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NATIONAL SECURITY AGENCY

MILITARY CRYPTANALYTICS
Part I

By

WILLIAM F. FRIEDMAN
and
LAMBROS D. CALLIMAHOS

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National Security Agency
Washington 25, D. C.

December 1952

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The Golden Guess
Is Morning-Star to the full round of Truth.
-- Tennyson.

Preface

This text represents an extensive expansion and revision, both in scope and content, of the earlier work entitled "Military Cryptanalysis, Part I" by William F. Friedman. This expansion and revision was necessitated by the considerable advancement made in the art since the publication of the previous text.

I wish to express grateful acknowledgment for Mr. Friedman's generous assistance and invaluable collaboration in the preparation of this edition. I also extend particular appreciation to my colleague Robert E. Cefail for his numerous valuable comments and assistance in writing the new material which is contained herein.

– L. D. C.

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SECTION I

INTRODUCTORY REMARKS

1. Scope of this text.--a. This text constitutes the first of a series of six basic texts[1] on the art of cryptanalysis. Although most of the information contained herein is applicable to cryptograms of various types and sources, special emphasis will be laid upon the principles and methods of solving military[2] cryptograms. Except for an introductory discussion of fundamental principles underlying the science of cryptanalytics, this first text in the series will deal solely with the principles and methods for the analysis of monoalphabetic substitution ciphers. Even with this limitation it will be possible to discuss only a few of the many variations of this one type that are met in practice; but with a firm grasp upon the general principles few difficulties should be experienced with any modifications or variations that may be encountered.

b. This and some of the succeeding texts will deal only with basic types of cryptosystems not because they may be encountered unmodified in military operations but because their study is essential to an understanding of the principles underlying the solution of the modern, very much more complex types of codes, ciphers, and certain encrypted transmission systems that are likely to be employed by the larger governments of today in the conduct of their military affairs in time of war.

c. It is presupposed that the student has no prior background in the field of cryptology; therefore cryptography is presented concurrently with cryptanalysis. Basic terminology and preliminary cryptologic considerations are treated in Section II; other terms are usually defined upon their first occurrence, or they may be found in the Glossary (Appendix 1).

d. The cryptograms presented in the examples embrace messages from hypothetical air, ground, and naval traffic; thus, the student will have the opportunity to familiarize himself with the language and phraseology of all three Services comprising the Armed Forces of the United States.

[1] Each text has its accompanying course in cryptanalysis, so that the student may test his learning and develop his skill in the solution of the types of cryptograms treated in the respective texts. The problems which pertain to this text constitute Appendix 13.

[2] The word "military" is here used in its broadest sense. In this connection see subpar. d, below.

2. Mental equipment necessary for cryptanalytic work.--a. Captain Parker Hitt, in the first United States Army manual[3] dealing with cryptology, opens the first chapter of his valuable treatise with the following sentence:

> "Success in dealing with unknown ciphers is measured by these four things in the order named: perseverance, careful methods of analysis, intuition, luck."

These words are as true today as they were then. There is no royal road to success in the solution of cryptograms. Hitt goes on to say:

> "Cipher work will have little permanent attraction for one who expects results at once, without labor, for there is a vast amount of purely routine labor in the preparation of frequency tables, the rearrangement of ciphers for examination, and the trial and fitting of letter to letter before the message begins to appear."

The present author deems it advisable to add that the kind of work involved in solving cryptograms is not at all similar to that involved in solving crossword puzzles, for example. The wide vogue the latter have had and continue to have is due to the appeal they make to the quite common interest in mysteries of one sort or another; but in solving a crossword puzzle there is usually no necessity for performing any preliminary labor, and palpable results become evident after the first minute or two of attention. This successful start spurs the crossword "addict" on to complete the solution, which rarely requires more than an hour's time. Furthermore, crossword puzzles are all alike in basic principles and once understood, there is no more to learn. Skill comes largely from the embellishment of one's vocabulary, though, to be sure, constant practice and exercise of the imagination contribute to the ease and rapidity with which solutions are generally reached. In solving cryptograms, however, many principles must be learned, for there are many different systems of varying degrees of complexity. Even some of the simpler varieties require the preparation of tabulations of one sort or another, which many people find irksome; moreover, it is only toward the very close of the solution that results in the form of intelligible text become evident. Often, indeed, the student will not even know whether he is on the right track until he has performed a large amount of preliminary "spade work" involving many hours of labor. Thus, without at least a willingness to pursue a fair amount of theoretical study, and a more than average amount of patience and perseverance, little skill and experience can be gained in the rather difficult art of cryptanalysis. General Givierge, the author of an excellent treatise on cryptanalysis, remarks in this connection:[4]

> "The cryptanalyst's attitude must be that of William the Silent: No need to hope in order to undertake, nor to succeed in order to persevere."

[3] Hitt, Capt. Parker, Manual for the Solution of Military Ciphers. Army Service Schools Press, Fort Leavenworth, Kansas, 1916. 2d Edition, 1918. (Both out of print.)

[4] Givierge, Général Marcel, Cours de Cryptographie, Paris, 1925, p. 301.

b. As regards Hitt's reference to careful methods of analysis, before one can be said to be a cryptanalyst worthy of the name it is necessary that one should have, firstly, a sound knowledge of the basic principles of cryptanalysis, and secondly, a long, varied, and active practical experience in the successful application of those principles. It is not sufficient to have read treatises on this subject. One month's actual practice in solution is worth a whole year's mere reading of theoretical principles. An exceedingly important element of success in solving the more intricate cryptosystems is the possession of the rather unusual mental faculty designated in general terms as the power of inductive and deductive reasoning. Probably this is an inherited rather than an acquired faculty; the best sort of training for its emergence, if latent in the individual, and for its development is the study of the natural sciences, such as chemistry, physics, biology, geology, and the like. Other sciences such as linguistics, archaeology, and philology are also excellent.

c. Aptitude in mathematics is quite important, more especially in the solution of ciphers and enciphered codes than in codebook reconstruction, which latter is purely and simply a linguistic problem. Although in the early days of the emergence of the science of cryptanalytics little thought was given to the applications of mathematics in this field, many branches of mathematics and, in particular, probability and statistics, have now found cryptologic applications. Those portions of mathematics and those mathematical methods which have cryptologic applications[5] are known collectively as cryptomathematics.

[5] It is quite important to stress at this point that in professional cryptologic work the science of cryptanalytics is subordinated to the art of cryptanalysis, just as in the world of music the technical virtuosity of a great violinist is adjuvant to the expression of music, that is, the virtuosity is a "tool" for the recovery of the complete musical "plain text" conceived by the composer. Since the practice of cryptanalysis is an art, mathematical approaches cannot always be expected to yield a solution in cryptology, because art can and must transcend the cold logic of scientific method. By way of example, an experienced Indian guide can usually find his way out of a dense forest more readily than a surveyor equipped with all the refined apparatus and techniques of his profession. Likewise, an experienced cryptanalyst can generally find his way through a cryptosystem more readily than a pure mathematician equipped merely with the techniques of his field no matter how abstruse or refined they may be. A cryptomathematician of repute once stated that "the only effect of /refined mathematical techniques/ is frequently to discourage one so much that one does nothing at all and some unmathematical ignoramus then gets the problem out in some very unethical way. This is intensely irritating." See also in this connection the remarks made in subpar. 27e in reference to the validity of statistical tests in cryptanalysis.

d. An active imagination, or perhaps what Hitt and other writers call intuition, is essential, but mere imagination uncontrolled by a judicious spirit will be more often a hindrance than a help. In practical cryptanalysis the imaginative or intuitive faculties must, in other words, be guided by good judgment, by practical experience, and by as thorough a knowledge of the general situation or extraneous circumstances that led to the sending of the cryptogram as is possible to obtain. In this respect the many cryptograms exchanged between correspondents whose identities and general affairs, commercial, social, or political, are known are far more readily solved[6] than are isolated cryptograms exchanged between unknown correspondents, dealing with unknown subjects. It is obvious that in the former case there are good data upon which the intuitive powers of the cryptanalyst can be brought to bear, whereas in the latter case no such data are available. Consequently, in the absence of such data, no matter how good the imagination and intuition of the cryptanalyst, these powers are of no particular service to him. Some writers, however, regard the intuitive spirit as valuable from still another viewpoint, as may be noted in the following:[7]

"Intuition, like a flash of lightning, lasts only for a second. It generally comes when one is tormented by a difficult decipherment and when one reviews in his mind the fruitless experiments already tried. Suddenly the light breaks through and one finds after a few minutes what previous days of labor were unable to reveal."

This, too, is true, but unfortunately there is no way in which the intuition may be summoned at will, when it is most needed.[8] There are certain authors who regard as indispensable the possession of a somewhat

[6] The application in practical, operational cryptanalysis of "probable words" or "cribs", i.e., plain text assumed or known to be present in a cryptogram, is developed in time of war into a refinement the extent and usefulness of which cannot be appreciated by the uninitiated. Even as great a thinker as Voltaire found the subject of cryptanalysis stretching his credulity to the point that he said:

"Those who boast that they can decipher a letter without knowing its subject matter, and without preliminary aid, are greater charlatans than those who would boast of understanding a language which they have never learned."--Dictionnaire Philosophique, under the article "Poste".

[7] Lange et Soudart, Traité de Cryptographie, Libraire Félix Alcan, Paris, 1925, p. 104.

[8] The following extracts are of interest in this connection:

"The fact that the scientific investigator works 50 per cent of his time by non-rational means is, it seems, quite insufficiently recognized. There is without the least doubt an instinct for research, and often the most successful investigators of nature are quite unable to give an account of their reasons for doing such and such an experiment, or for placing side by side two apparently unrelated facts Again, one of the most salient traits in the character of the successful scientific worker is the capacity for knowing that a point is proved when it would not appear to be proved to an outside intelligence functioning in a purely rational manner; thus the investigator feels that some proposition is true, and proceeds at once to the next set of experiments without waiting and wasting time in the elaboration of the formal proof of the point which heavier minds would need. Questionless such a scientific intuition may and does sometimes lead investigators astray, but it is quite certain that if they did not widely make use of it, they would not get a quarter as far as they do. Experiments confirm each other, and a rare, rather mysterious faculty that they designate by the word "flair", or by the expression "cipher brains". Even so excellent an authority as General Givierge,[9] in referring to this mental faculty, uses the following words:

> "Over and above perseverance and this aptitude of mind which some authors consider a special gift, and which they call intuition, or even, in its highest manifestation, clairvoyance, cryptographic studies will continue more and more to demand the qualities of orderliness and memory."

Although the present author believes a special aptitude for the work is essential to cryptanalytic success, he is sure there is nothing mysterious about the matter at all. Special aptitude is prerequisite to success in all fields of endeavor. There are, for example, thousands of physicists, hundreds of excellent ones, but only a handful of worldwide fame. Should it be said, then, that a physicist who has achieved very notable success in his field has done so because he is the fortunate possessor of a mysterious faculty? That he is fortunate in possessing a special aptitude for his subject is granted, but that there is anything mysterious about it, partaking of the nature of clairvoyance (if, indeed, the latter is a reality) is not granted. While the ultimate nature of any mental process seems to be as complete a mystery today as it has ever been, the present author would like to see the superficial veil of mystery removed from a subject that has been shrouded in mystery from even before the Middle Ages down to our own times. (The principal and readily understandable reason for this is that governments have always closely guarded cryptographic secrets and anything so guarded soon becomes "mysterious".) He would, rather, have the student approach the subject as he might approach any other science that can stand on its own merits with other sciences, because cryptanalytics, like other sciences, has a practical importance in human affairs. It presents to the inquiring mind an interest in its own right as a branch of knowledge; it, too, holds forth many difficulties and disappointments, and these are all the more

false step is usually soon discovered. And not only by this partial replacement of reason by intuition does the work of science go on, but also to the born scientific worker—and emphatically they cannot be made—the structure of the method of research is as it were given, he cannot explain it to you, though he may be brought to agree *a posteriori* to a formal logical presentation of the way the method works".—Excerpt from Needham, Joseph, *The Sceptical Biologist*, London, 1929, p. 79.

"The essence of scientific method, quite simply, is to try to see how data arrange themselves into causal configurations. Scientific problems are solved by collecting data and by "thinking about them all the time." We need to look at strange things until, by the appearance of known configurations, they seem familiar, and to look at familiar things until we see novel configurations which make them appear strange. We must look at events until they become luminous. That is scientific method . . . Insight is the touchstone . . . The application of insight as the touchstone of method enables us to evaluate properly the role of imagination in scientific method. The scientific process is akin to the artistic process: it is a process of selecting out those elements of experience which fit together and recombining them in the mind. Much of this kind of research is simply a ceaseless mulling over, and even the physical scientist has considerable need of an armchair . . . Our view of scientific method as a struggle to obtain insight forces the admission that science is half art . . . Insight is the unknown quantity which has eluded students of scientific method".—Excerpts from an article entitled *Insight and Scientific Method*, by Willard Waller, in *The American Journal of Sociology*, Vol. XL, 1934

[9] Op. cit., p. 302.

keenly felt when the nature of these difficulties is not understood by those unfamiliar with the special circumstances that very often are the real factors that led to success in other cases. Finally, just as in the other sciences wherein men labor long and earnestly for the true satisfaction and pleasure that comes from work well done, so the mental pleasure that the successful cryptanalyst derives from his accomplishments is very often the only reward for much of the drudgery that he must do in his daily work. General Givierge's words in this connection are well worth quoting:[10]

"Some studies will last for years before bearing fruit. In the case of others, cryptanalysts undertaking them never get any result. But, for a cryptanalyst who likes the work, the joy of discoveries effaces the memory of his hours of doubt and impatience."

e. With his usual deft touch, Hitt says of the element of luck, as regards the role it plays in analysis:

"As to luck, there is the old miners' proverb: 'Gold is where you find it.'"

The cryptanalyst is lucky when one of the correspondents whose cryptograms he is studying makes a blunder that gives the necessary clue; or when he finds two cryptograms identical in text but in different keys in the same system; or when he finds two cryptograms identical in text but in different systems, and so on. The element of luck is there, to be sure, but the cryptanalyst must be on the alert if he is to profit by these lucky "breaks".

f. If the present author were asked to state, in view of the progress in the field since 1916, what elements might be added to the four ingredients Hitt thought essential to cryptanalytic success, he would be inclined to mention the following:

(1) A broad, general education, embodying interests covering as many fields of practical knowledge as possible. This is useful because the cryptanalyst is often called upon to solve messages dealing with the most varied of human activities, and the more he knows about these activities, the easier his task.

(2) Access to a large library of current literature, and wide and direct contacts with sources of collateral information. These often afford clues as to the contents of specific messages. For example, to be able instantly to have at his disposal a newspaper report or a personal report of events described or referred to in a message under investigation goes a long way toward simplifying or facilitating solution. Government cryptanalysts are sometimes fortunately situated in this respect, especially where various agencies work in harmony.

(3) Proper coordination of effort. This includes the organization of cryptanalytic personnel into harmonious, efficient teams of cooperating individuals.

[10] Op. cit., p. 301.

(4) Under mental equipment he would also include the faculty of being able to concentrate on a problem for rather long periods of time, without distraction, nervous irritability, and impatience. The strain under which cryptanalytic studies are necessarily conducted is quite severe and too long-continued application has the effect of draining nervous energy to an unwholesome degree, so that a word or two of caution may not here be out of place. One should continue at work only so long as a peaceful, calm spirit prevails, whether the work is fruitful or not. But just as soon as the mind becomes wearied with the exertion, or just as soon as a feeling of hopelessness or mental fatigue intervenes, it is better to stop completely and turn to other activities, rest, or play. It is essential to remark that systematization and orderliness of work are aids in reducing nervous tension and irritability. On this account it is better to take the time to prepare the data carefully, rewrite the text if necessary, and so on, rather than work with slipshod, incomplete, or improperly arranged material.

(5) A retentive memory is an important asset to cryptanalytic skill, especially in the solution of codes. The ability to remember individual groups, their approximate locations in other messages, the associations they form with other groups, their peculiarities and similarities, saves much wear and tear of the mental machinery, as well as much time in looking up these groups in indexes.

(6) The assistance of machine aids in cryptanalysis. The importance and value of these aids cannct be overemphasized in their bearing on practical, operational cryptanalysis, especially in the large-scale effort that would be made in time of war on complex, high-grade cryptosystems at a theater headquarters or in the zone of the interior. These aids, under the general category of rapid analytical machines, comprise both punched-card tabulating machinery and certain other general- and special-purpose high-speed electrical and electronic devices. Some of the more compact equipment may be employed by lower echelons within a theater of operations to facilitate the cryptanalysis of medium-grade cryptosystems found in tactical communications.

g. It may be advisable to add a word or two at this point to prepare the student to expect slight mental jars and tensions which will almost inevitably come to him in the conscientious study of this and the subsequent texts. The present author is well aware of the complaint of students that authors of texts on cryptanalysis base much of their explanation upon their foreknowledge of the "answer"--which the student does not know while he is attempting to follow the solution with an unbiased mind. They complain, too, that these authors use such expressions as "it is obvious that", "naturally", "of course", "it is evident that", and so on, when the circumstances seem not at all to warrant their use. There is no question that this sort of treatment is apt to discourage the student, especially when the point elucidated becomes clear to <u>him</u> only after many hours' labor, whereas, according to the book, the author noted the weak spot at the first moment's inspection. The present author can only promise to try to avoid making the steps appear to be much more simple than they really are, and to suppress glaring instances of unjustifiable "jumping at conclusions". At the same time he must indicate that for pedagogical reasons in many cases a message has been consciously "manipulated" so as to allow certain principles to become more obvious in the illustrative examples than they ever are in practical work. During the course of some of the explanations attention will even be directed to cases of unjustified inferences. Furthermore, of the student who is quick in observation and deduction, the author will only ask that he bear in mind that if the elucidation of certain principles seems prolix and occupies more space than necessary, this is occasioned by the author's desire to carry the explanation forward in very short, easily-comprehended, and plainly-described steps, for the benefit of students who are perhaps a bit slower to grasp but who, once they understand, are able to retain and apply principles slowly learned just as well, if not better than the students who learn more quickly.[11]

3. Validity of results of cryptanalysis.--Valid or authentic cryptanalytic solutions cannot and do not represent "opinions" of the cryptanalyst. They are valid only so far as they are wholly objective, and are susceptible of demonstration and proof, employing authentic, objective methods. It should hardly be necessary (but an attitude frequently encountered among laymen makes it advisable) to indicate that the validity of the results achieved by any serious cryptanalytic studies on authentic material rests upon the same sure foundations and are reached by the same general steps as the results achieved by any other scientific studies; viz., observation, hypothesis, deduction and induction, and confirmatory experiment. Implied in the latter is the possibility that two or more qualified investigators, each working independently upon the same material, will achieve identical (or practically identical) results--there is one and only one (valid) solution to a cryptogram. Occasionally a "would-be" or pseudo-cryptanalyst offers "solutions" which cannot withstand such tests; a second, unbiased, investigator working independently either cannot consistently apply the methods alleged to have been applied by the pseudo-cryptanalyst, or else, if he can apply

[11] In connection with the use of the word "obvious", the following extract is of interest:

"Now the word 'obvious' is a rather dangerous one. There is an incident, which has become something of a legend in mathematical circles, that illustrates this danger. A certain famous mathematician was lecturing to a group of students and had occasion to use a formula which he wrote down with the remark, 'This statement is obvious.' Then he paused and looked rather hesitantly at the formula. 'Wait a moment,' he said. 'Is it obvious? I think it's obvious.' More hesitation, and then, 'Pardon me, gentlemen, I shall return.' Then he left the room. Thirty-five minutes later he returned; in his hands was a sheaf of papers covered with calculations, on his face a look of quiet satisfaction. 'I was right, gentlemen. It is obvious,' he said, and proceeded with his lecture."--Excerpt from The Anatomy of Mathematics by Kershner and Wilcox. New York, 1950.

them at all, the results (plaintext translations) are far different in the two cases. The reason for this is that in such cases it is generally found that the "methods" are not clear-cut, straightforward or mathematical in character. Instead, they often involve the making of judgments on matters too tenuous to measure, weigh, or otherwise subject to careful scrutiny. Often, too, they involve the "correction" of an inordinate number of "errors" which the pseudo-cryptanalyst assumes to be present and which he "corrects" in order to make his "solution" intelligible. And sometimes the pseudo-cryptanalyst offers as a "solution" plain text which is intelligible only to him or which he makes intelligible by expanding what he alleges to be abbreviations, and so on. In all such cases, the conclusion to which the unprejudiced observer is forced to come is that the alleged "solution" obtained by the pseudo-cryptanalyst is purely subjective.[12] In nearly all cases where this has happened (and they occur from time to time) there has been uncovered nothing which can in any way

[12] A mathematician is often unable to grasp the concept behind the expression "subjective solution" as used in the cryptanalytic field, since the idea is foreign to the basic philosophy of mathematics and thus the expression appears to him to represent a contradiction in terms. As an illustration, let us consider a situation in which a would-be cryptanalyst offers a solution to a cryptogram he alleges to be a simple monoalphabetic substitution cipher. His so-called solution, however, requires that he assume the presence of, let us say, approximately 50% garbles (which he claims to have been introduced by cipher clerks' errors, faulty radio reception because of adverse weather conditions, etc.). That is, the "plain text" he offers as the "solution" involves his making helter-skelter many "corrections and emendations", which, one may be sure, will be based on what his subconscious mind expects or desires to find in the cleartext message. Unfortunately, another would-be cryptanalyst working upon the same cryptogram and hypothesis independently might conceivably "degarble" the cryptogram in different spots and produce an entirely dissimilar "plain text" as his "solution". Both "solutions" would be invalid because they are based upon an erroneous hypothesis--the cryptogram actually happens to be a polyalphabetic substitution cipher which when correctly analyzed requires on the part of unbiased observers no assumption of garbles to a degree that strains their credulity. The last phrase is added here because in professional cryptanalytic work it is very often necessary to make a few corrections for errors but it is rarely the case that the garble rate exceeds more than a few percent of the characters of the cryptogram, say 5 to 10% at the outside. It is to be noted, however, that occasionally the solution to a cryptogram may involve the correction of more than this percentage of errors, but the solution would be regarded as valid only if the errors can be shown to be systematic in some significant respect, or can otherwise be explained by objective rationalization.

be used to impugn the integrity of the pseudo-cryptanalyst. The worst that can be said of him is that he has become a victim of a special or peculiar form of self-delusion, and that his desire to solve the problem, usually in accord with some previously-formed opinion, or notion, has over-balanced, or undermined, his judgment and good sense.[13]

[13] Specific reference can be made to the following typical "case histories":

Donnelly, Ignatius, The Great Cryptogram. Chicago, 1888.
Owen, Orville W., Sir Francis Bacon's Cipher Story. Detroit, 1895.
Gallup, Elizabeth Wells, Francis Bacon's Biliteral Cipher. Detroit, 1900.
Arensberg, Walter Conrad, The Cryptography of Shakespeare. Los Angeles, 1922.
The Shakespearean Mystery. Pittsburgh, 1928.
The Baconian Keys. Pittsburgh, 1928.
Margoliouth, D. S., The Homer of Aristotle. Oxford, 1923.
V Newbold, William Romaine, The Cipher of Roger Bacon. Philadelphia, 1928. (For a scholarly and complete demolition of Professor Newbold's work, see an article entitled Roger Bacon and the Voynich MS, by John M. Manly, in Speculum, Vol. VI, No. 3, July 1931.)
Feely, Joseph Martin, The Shakespearean Cypher. Rochester, N. Y., 1931.
Deciphering Shakespeare. Rochester, N. Y., 1934.
3 Roger Bacon's Cypher: the right key found. Rochester, N. Y., 1943.
Wolff, Werner, Déchiffrement de l'Ecriture Maya. Paris, 1938.
Strong, Leonell C., Anthony Askham, the author of the Voynich manuscript, in Science, Vol. 101, June 15, 1945, pp. 608-9.

SECTION II

BASIC CRYPTOLOGIC CONSIDERATIONS

4. Cryptology, communication intelligence, and communication security. The occasional or frequent need for secrecy in the conduct of important affairs has been recognized from time immemorial. In the case of diplomacy and organized warfare this need is especially important in regard to communications. However, when such communications are transmitted by electrical means, they can be heard and copied by unauthorized persons. The protection resulting from all measures designed to deny to unauthorized persons information of value which may be derived from such communications is called communication security. The evaluated information concerning the enemy, derived principally from a study of his electrical communications, is called communication intelligence. The collective term including all phases of communication intelligence and communication security is cryptology.[1] Or, stated in broad terms, cryptology is that branch of knowledge which treats of hidden, disguised, or secret[2] communications.

[1] From the Greek kryptos (hidden) + logos (learning). The prefix "crypto-" in compound words pertains to "cryptologic", "cryptographic", or "cryptanalytic", depending upon the use of the particular word as defined.

[2] In this text the term "secret" will be used in its ordinary sense as given in the dictionary. Whenever the designation is used in the more restricted sense of the security classification as defined in official regulations, it will be capitalized. There are in current use the four classifications Restricted, Confidential, Secret, and Top Secret, listed in ascending order of degree.

5. Secret communication.--a. Communication may be conducted by any means susceptible of ultimate interpretation by one of the five senses, but those most commonly used are sight and hearing. Aside from the use of simple visual and auditory signals for communication over relatively short distances, the usual method of communication between or among individuals separated from one another by relatively long distances involves, at one stage or another, the act of writing or of speaking over a telephone.

b. Privacy or secrecy in communication by telephone can be obtained by using equipment which affects the electrical currents involved in telephony so that the conversations can be understood only by persons provided with suitable equipment properly arranged for the purpose. The same thing is true in the case of electrical transmission of pictures, drawings, maps, and television images. However, this text will not treat of these aspects[3] of cryptology.

c. Writing may be either visible or invisible. In the former, the characters are inscribed with ordinary writing materials and can be seen with the naked eye; in the latter, the characters are inscribed by means or methods which make the writing invisible to the naked eye. Invisible writing can be prepared with certain chemicals called invisible, sympathetic, or secret inks, and in order to "develop" such writing, that is, make it visible, special processes must usually be applied. There are also methods of producing writing which is invisible to the naked eye because the characters are of microscopic size, thus requiring special photographic or microscopic apparatus to make such writing visible to the naked eye.

d. Invisible writing and unintelligible visible writing constitute secret writing.

6. Plain text and encrypted text.--a. Visible writing which is intelligible, that is, conveys a more or less understandable or sensible meaning (in the language in which written) and which is not intended to convey a hidden meaning, is said to be in plain text.[4] A message in plain text is termed a plaintext message, a cleartext message, or a message in clear.

[3] These aspects of cryptology are now known as ciphony (from cipher + telephony); cifax (from cipher + facsimile); and civision (from cipher + television).

[4] Visible writing may be intelligible but the meaning it obviously conveys may not be its real meaning, that is, the meaning intended to be conveyed. To quote a simple example of an apparently innocent message containing a secret or hidden meaning, prepared with the intention of escaping censorship, the sentence "Son born today" may mean "Three transports left today." Messages of this type are said to be in open code. Secret communication methods or artifices of this sort (concealment systems) are impractical for field military use but are often encountered in espionage and counter-espionage activities.

b. Visible writing which conveys no intelligible meaning in any recognized language[5] is said to be in encrypted text and such writing is termed a cryptogram.[6]

7. Cryptography, encrypting, and decrypting.--a. Cryptography is that branch of cryptology which treats of various means, methods, and apparatus for converting or transforming plaintext messages into cryptograms and for reconverting the cryptograms into their original plaintext forms by a simple reversal of the steps used in their transformation.

b. To encrypt is to convert or transform a plaintext message into a cryptogram by following certain rules, steps, or processes constituting the key or keys and agreed upon in advance by correspondents, or furnished them by higher authority.

c. To decrypt is to reconvert or to transform a cryptogram into the original equivalent plaintext message by a direct reversal of the encrypting process, that is, by applying to the cryptogram the key or keys (usually in a reverse order) used in producing the cryptogram.

d. A person skilled in the art of encrypting and decrypting, or one who has a part in devising a cryptographic system is called a cryptographer; a clerk who encrypts and decrypts, or who assists in such work, is called a cryptographic clerk.

8. Codes, ciphers, and enciphered code.--a. Encrypting and decrypting are accomplished by means collectively designated as codes and ciphers. Such means are used for either or both of two purposes: (1) secrecy, and (2) economy or brevity. Secrecy usually is far more important in military cryptography than economy or brevity. In ciphers or cipher systems, cryptograms are produced by applying the cryptographic treatment to individual letters of the plaintext messages, whereas, in codes or code systems, cryptograms are produced by applying the cryptographic treatment to entire words, phrases, and sentences of the plaintext messages. The specialized meanings of the terms code and cipher are explained in detail later.

b. A cryptogram produced by means of a cipher system is said to be in cipher and is called a cipher message, or sometimes simply a cipher. The act or operation of encrypting a cipher message is called enciphering,

[5] There is a certain type of writing which is considered by its authors to be intelligible, but which is either completely unintelligible to the wide variety of readers or else requires considerable mental struggle on their part to make it intelligible. Reference is here made to so-called "modern literature" and "modern verse", products of such writers as E. E. Cummings, Gertrude Stein, James Joyce, et al.

[6] From kryptos + gramma (that which is written). Analogous terminology would call a plaintext message a phanerogram (phaneros = visible, manifest, open).

and the enciphered version of the plain text, as well as the act or process itself, is often referred to as the *encipherment*. The cryptographic clerk who performs the process serves as *an encipherer*. The corresponding terms applicable to the decrypting of cipher messages are *deciphering*, *decipherment*, and *decipherer*. A clerk who serves as both an encipherer and decipherer of messages is called a *cipher clerk*.

c. A *cipher device* is a relatively simple mechanical contrivance for encipherment and decipherment, usually "hand-operated" or manipulated by the fingers, as for example a device with concentric rings of alphabets, manually powered; a *cipher machine* is a relatively complex apparatus or mechanism for encipherment and decipherment, usually equipped with a typewriter key board and often requiring an external power source.

d. A cryptogram produced by means of a code system is said to be *in code* and is called a *code message*. The text of the cryptogram is referred to as *code text*. This act or operation of encrypting is called *encoding*, and the encoded version of the plain text, as well as the act or process itself, is referred to as the *encodement*. The clerk who performs the process serves as an *encoder*. The corresponding terms applicable to the decrypting of code messages are *decoding*, *decodement*, and *decoder*. A cryptographic clerk who serves as both an encoder and decoder of messages is called a *code clerk*.

e. Sometimes, for special purposes (usually increased security), the code text of a cryptogram undergoes a further step in concealment involving *superencryption*, that is, encipherment of the characters comprising the code text, thus producing what is called an *enciphered-code message*, or *enciphered code*. *Encoded cipher*, that is, the case where the final cryptogram is produced by enciphering the plain text and then encoding the cipher text obtained from the first operation, is also possible, but rare.

9. General system, specific key, and cryptosystem.---*a*. There are a great many different methods of encrypting messages, so that correspondents must first of all be in complete agreement as to which of them will be used in their secret communications, or in different types or classes of such communications. Furthermore, it is to be understood that all the detailed rules, processes, or steps comprising the cryptography agreed upon will be *invariant*, that is, constant or unvarying in their use in a given set of communications. The totality of these basic, invariable rules, processes, or steps to be followed in encrypting a message according to the agreed method constitutes the general cryptographic system or, more briefly, the *general system*.

b. It is usually the case that the general system operates in connection with or under the control of a number, a group of letters, a word, a phrase, or sentence which is used as a *key*, that is, the element which specifically governs the manner in which the general system will be applied in a specific message, or the exact *setting* of a cipher device or a cipher machine at the initial point of encipherment or decipherment of a specific message. This element--usually of a variable nature or changeable at the will of the correspondents, or prearranged for them by higher authority--is called the specific key. The specific key may also involve the use of a set of specially prepared tables, a special document, or even a book.

c. The term cryptosystem[7] is used when it is desired to designate or refer to all the cryptomaterial (device, machine, instructions for use, key lists, etc.) as a unit to provide a single, complete system and means for secret communication.

10. Cryptanalytics and cryptanalysis.--a. In theory any cryptosystem (except one[8]) can be "broken", i.e., solved, if enough time, labor, and skill are devoted to it, and if the volume of traffic in that system is large enough. This can be done even if the general system and the specific key are unknown at the start. In military operations theoretical rules must usually give way to practical considerations. How the theoretical rule in this case is affected by practical considerations will be discussed in Appendix 11.

b. That branch of cryptology which deals with the principles, methods, and means employed in the solution or analysis of cryptosystems is called cryptanalytics.

c. The steps and operations performed in applying the principles of cryptanalytics constitute cryptanalysis. To cryptanalyze a cryptogram is to solve it by cryptanalysis.

d. A person skilled in the art of cryptanalysis is called a cryptanalyst, and a clerk who assists in such work is called a cryptanalytic clerk.

11. Transposition and substitution.--a. Technically there are only two distinct types of treatment which may be applied to written plain text to convert it into secret text, yielding two different classes of cryptograms. In the first, called transposition, the elements or units of the plain text retain their original identities and merely undergo some change in their relative positions, with the result that the original text becomes unintelligible. In the second, called substitution, the elements of the plain text retain their original relative positions but are replaced by other elements with different values or meanings, with the result that the original text becomes unintelligible. Thus, in the case of transposition ciphers, the unintelligibility is brought about merely by a change in the original sequence of the elements or units of

[7] The term cryptosystem is used in preference to cryptographic system so as to permit its use in designating secret communication systems involving means other than writing, such as ciphony and cifax.

[8] The exception is the "one-time" system in which the key is used only once and in itself must have no systematic construction, derivation, or meaning.

the plain text; in the case of substitution ciphers, the unintelligibility is brought about by a change in the elements or units themselves, without a change in their relative order.

b. It is possible to encrypt a message by a substitution method and then to apply a transposition method to the substitution text, or vice versa. Such combined transposition-substitution methods do not form a third class of methods. They are occasionally encountered in military cryptography, but the types of combinations that are sufficiently simple to be practicable for field use are very limited.[9]

c. Under each of the two principal classes of cryptograms as outlined above, a further classification can be made based upon the number of characters composing the textual elements or units undergoing cryptographic treatment. These textual units are composed of (1) individual letters, (2) combinations of letters in regular groupings, (3) combinations of letters in irregular, more or less euphonious groupings called syllables, and (4) complete words, phrases, and sentences. Methods which deal with the first type of units are called monographic methods; those which deal with the second type are called polygraphic (digraphic, trigraphic, etc.); those which deal with the third type, or syllables, are called syllabic; and, finally, those which deal with the fourth type are called lexical (of or pertaining to words).

d. It is necessary to indicate that the foregoing classification of cryptographic methods is more or less artificial in nature, and is established for purpose of convenience only. No sharp line of demarcation can be drawn in every case, for occasionally a given system may combine methods of treating single letters, regular or irregular-length groupings of letters, syllables, words, phrases, and complete sentences. When in a single system the cryptographic treatment is applied to textual units of regular length, usually monographic or digraphic (and seldom longer, or intermixed monographic and digraphic), the system is called a cipher system. Likewise, when in a single system the cryptographic treatment is applied to textual units of irregular length, usually syllables, whole words, phrases, and sentences, and is only exceptionally applied to single letters or regular groupings of letters, the system is called a code system and generally involves the use of a code book.[10]

12. Nature of alphabets.--a. One of the simplest kinds of substitution ciphers is that which is known in cryptologic literature as Julius Caesar's Cipher, but which, as a matter of fact, was a favorite long before his day. In this cipher each letter of the text of a message is replaced by the letter standing the third to the right of it in the

[9] One notable exception is the ADFGVX system, used extensively by the Germans in World War I. See in this connection the Cryptographic Supplement (Appendix 7).

[10] A list of single letters, frequent digraphs, trigraphs, syllables, and words is often called a syllabary; cryptographic treatment of the units of such syllabaries places them in the category of code systems.

[illegible] ordinary alphabet; the letter A is replaced by D, the letter B by E, and so on. The word cab becomes converted into FDE, which is cipher.

b. The English language is written by means of 26 simple characters called letters which, taken together and considered as a sequence of symbols, constitute the alphabet of the language. Not all systems of writing are of this nature. Chinese writing is composed of about 44,000 complex characters, each representing one sense of a word. Whereas English words are composite or polysyllabic and may consist of one to eight or more syllables, Chinese words are all monosyllables and each monosyllable is ɛ word. Written languages of the majority of other civilized peoples of today are, however, alphabetic and polysyllabic in construction, so that the principles discussed here apply to all of them.

c. The letters comprising the English alphabet used today are the results of a long period of evolution, the complete history of which may never fully be known.[11] They are conventional symbols representing elementary sounds, and any other simple symbols, so long as the sounds which they represent are agreed upon by those concerned, will serve the purpose equally well. If taught from early childhood that the symbols $, *, and @ represent the sounds "Ay", "Bee", and "See" respectively, the combination @$* would still be pronounced cab, and would, of course, have exactly the same meaning as before. Again, let us suppose that two persons have agreed to change the sound values of the letters F, G, and H, and after long practice have become accustomed to pronouncing them as we pronounce the letters A, B, and C, respectively; they would then write the "word" HFG, pronounce it cab, and see nothing strange whatever in the matter. But to others no party to their arrangements, HFG constitutes cipher. The combination of sounds called for by this combination of symbols is perfectly intelligible to the two who have adopted the new sound values for those symbols and therefore pronounce HFG as cab; but HFG is utterly unpronounceable and wholly unintelligible to others who are reading it according to their own long-established system of sound and symbol equivalents. It would be stated that there is no such word as HFG, which would mean merely that the particular combination of sounds represented by this combination of letters has not been adopted by convention to represent a thing or an idea in the English language. Thus, it is seen that, in order for the written words of a language to be pronounceable and intelligible to all who speak that language, it is necessary, first, that the sound values of the letters or symbols be universally understood and agreed upon and, secondly, that the particular combination of sounds denoted by the letters should have been adopted to represent a thing or an idea. Spoken plain language consists of vocables; that is, combinations and permutations of elementary speech-sounds which have by long usage come to be adopted and recognized as representing definite things and ideas. Written plain language consists of words; that is, combinations and permutations of simple symbols, called letters, which represent visually and call forth vocally the elementary speech-sounds of which the spoken language is composed.

[11] An excellent and most authoritative book on this subject is The Alphabet: a key to the history of Mankind by David Diringer. London, 1949.

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d. It is clear also that in order to write a polysyllabic language with facility it is necessary to establish and to maintain by common agreement or convention, equivalency between two sets of elements, first, a set of elementary sounds and, second, a set of elementary symbols to represent the sounds. When this is done the result is what is called an alphabet, a word derived from the names of the first two letters of the Greek alphabet, "alpha" and "beta".

e. Theoretically, in an ideal alphabet each symbol or letter would denote only one elementary sound, and each elementary sound would invariably be represented by the same symbol. But such an alphabet would be far too difficult for the average person to use. It has been conservatively estimated that a minimum of 100 characters would be necessary for English alone. Attempts toward producing and introducing into usage a practical, scientific alphabet have been made, one being that of the Simplified Spelling Board in 1928, which advocated a revised alphabet of 42 characters. Were such an alphabet adopted into current usage, in books, letters, telegrams, etc., the flexibility of cryptographic systems would be considerably extended and the difficulties set in the path of the enemy cryptanalysts greatly increased. The chances for its adoption in the near future are, however, quite small. Because of the continually changing nature of every living language, it is doubtful whether an initially "perfect alphabet" could, over any long period of time, remain so and serve to indicate with great precision the exact sounds which it was originally designed to represent.

13. Types of alphabets.--a. In the study of cryptography the dual nature of the alphabet becomes apparent. It consists of two parts or components, (1) an arbitrarily-arranged sequence of sounds, and (2) an arbitrarily-arranged sequence of symbols.

b. The normal alphabet for any language is one in which these two components are the ordinary sequences that have been definitely fixed by long usage or convention. The dual nature of our normal or everyday alphabet is often lost sight of. When we write A, B, C,... we really mean:

Sequence of sounds:	"Ay"	"Bee"	"See"	....
Sequence of symbols:	A	B	C	....

Normal alphabets of different languages vary considerably in the number of characters composing them and the arrangement or sequence of the characters. The English, Dutch, and German alphabets each have 26; the French, 25; the Italian, 21; the Spanish, 27 (including the digraphs CH and LL); and the Russian, 31.[12] The Japanese language has a syllabary consisting of 72 syllabic sounds which require 48 characters for their representation.

[12] In contrast to the foregoing alphabets, it is of interest to note that in the Hawaiian language the alphabet consists of only 12 letters, viz, the five vowels A, E, I, O, U, and the seven consonants H, K, L, M, N, P, W.

c. A cipher alphabet, or substitution alphabet as it is sometimes called, is one in which the elementary speech-sounds are represented by characters other than those representing them in the normal alphabet. These characters may be letters, figures, signs, symbols, or combinations of them.

d. When the plain text of a message is converted into encrypted text by the use of one or more cipher alphabets, the resultant cryptogram constitutes a substitution cipher. If only one cipher alphabet is involved, it is called a monoalphabetic substitution cipher; if two or more cipher alphabets are involved, it is called a polyalphabetic substitution cipher.

e. It is convenient to designate that component of a cipher alphabet constituting the sequence of speech-sounds as the plain component and the component constituting the sequence of symbols as the cipher component. If omitted in a cipher alphabet, the plain component is understood to be the normal sequence. For brevity and clarity, a letter of the plain text, or of the plain component of a cipher alphabet, is designated by suffixing a small letter "p" to it: A_p means A of the plain text, or of the plain component of a cipher alphabet. Similarly, a letter of the cipher text, or of the cipher component of a cipher alphabet, will be designated by suffixing a small letter "c" to it: X_c means X of the cipher text, or of the cipher component of a cipher alphabet. The expression $A_p = X_c$ means that A of the plain text, or A of the plain component of a cipher alphabet, is represented by X in the cipher text, or by X in the cipher component of a cipher alphabet.

f. With reference to the arrangement or sequence of letters forming their components, cipher alphabets are of two types:

(1) Standard cipher alphabets, in which the sequence of letters in the plain component is the normal, and in the cipher component is the same as the normal, but reversed in direction or shifted from its normal point of coincidence with the plain component.

(2) Mixed cipher alphabets, in which the sequence of letters or characters in one or both of the components is no longer the same as the normal in its entirety.

g. Although the basic considerations of the preceding paragraphs place the student in a position to undertake the study of certain fundamental principles of cryptanalysis, this may be a good point at which to pause and to make a few remarks with regard to the role that cryptanalysis plays in the whole chain of more or less complex operations involved in deriving communication intelligence, after which these fundamental cryptanalytic principles will be treated.

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SECTION III

FUNDAMENTAL CRYPTANALYTIC OPERATIONS

14. The role of cryptanalysis in communication intelligence operations.--a. Through the medium of communication intelligence an attempt is made to answer three questions concerning enemy communications: "Who?" "Where?" "What?"--Who are their originators and addressees? Where are these originators and addressees located? What do the messages say?

b. All of the foregoing questions are very important in the military application of communication intelligence. Hence, even though this text deals almost exclusively with the principles and operations involved in deriving the answer to the third question--"What do the messages say?"--a few words on the importance of the first and second questions may be useful. It is a serious mistake to think that one can necessarily and always correctly interpret the mere text of a message without identifying and locating the originator and the addressee or, on many occasions, without having a background against which to interpret the message in order to appreciate its real import or significance.

c. The very first step in the series of activities involved in deriving communication intelligence is the collection of the raw material, that is, the interception[1] and copying of the transmissions constituting the messages to be studied and analyzed.

d. Then, with the raw material in hand, studies are made in order to answer the first two questions--"Who?" and "Where?" The answers to these questions are not always obvious in modern military communications, especially in the case of messages exchanged by units in the combat zone, since messages of this sort rarely indicate in plain language who the

[1] To intercept means, in its cryptologic sense, to gain possession of communications which are intended for other recipients, without obtaining the consent of these addressees and without preventing or ordinarily delaying the transmission of the communications to them.

originator and the addressee are or where they are located. Consequently, certain apparatus and techniques specifically developed for finding the answers to these questions must be employed. These apparatus and techniques are embraced by that part of communication intelligence theory and practice which is known as traffic analysis. This latter subject and interception are treated briefly in Appendix 10, "Communication intelligence operations". (The serious student will derive much practical benefit from a careful reading of this appendix.)

e. The foregoing operations, interception and traffic analysis, along with cryptanalysis constitute the first three operations of communication intelligence. But generally there must follow at least one additional operation. If the plain texts recovered through cryptanalysis are in a foreign language, they must usually be translated, and translation constitutes this fourth operation. In the course of translating, it may be found that, because of errors in transmission or reception, corrections and emendations must be made in these plain texts; however, although this often requires skill and experience of a high order, it does not constitute another communication intelligence operation, since it is but an auxiliary step to the process of translation.

f. In a large-scale communication intelligence effort these four steps, interception, traffic analysis, cryptanalysis, and translation, must be properly organized and coordinated in order to gain the most benefit from the potentialities of communication intelligence, that is, the production of the maximum quantity of information from the raw traffic. This information must then be evaluated by properly trained intelligence specialists, collated with intelligence derived from other sources, and, finally, disseminated to the commanders who need the intelligence in time to be of operational use to them, rather than of mere historical interest. The foregoing operations and especially the first three--interception, traffic analysis, and cryptanalysis--usually complement one another. This, however, is not the place for elaboration on the interrelationships which exist and which when properly integrated make the operations as a whole an efficient, unified complex geared to the fulfillment of its principal goal, namely, the production of timely communication intelligence.

g. With the foregoing general background, the student is prepared to proceed to the technical considerations and principles of cryptanalysis.

15. The four basic operations in cryptanalysis.--a. The solution of practically every cryptogram involves four fundamental operations or steps:

(1) The determination of the language employed in the plaintext version.

(2) The determination of the general system of cryptography employed.

(3) The reconstruction of the specific key in the case of a cipher system, or the reconstruction, partial or complete, of the code book, in the case of a code system; or both, in the case of an enciphered code system.

(4) The reconstruction or establishment of the plain text.

b. These operations will be taken up in the order in which they are given above and in which they usually are performed in the solution of cryptograms, although occasionally the second step may precede the first.[1]

16. The determination of the language employed.--a. There is not much that need be said with respect to this operation except that the determination of the language employed seldom comes into question in the case of studies made of the cryptograms of an organized enemy. By this is meant that during wartime the enemy is of course known, and it follows, therefore, that the language he employs in his messages will almost certainly be his native or mother tongue. Only occasionally nowadays is this rule broken. Formerly it often happened, or it might have indeed been the general rule, that the language used in diplomatic correspondence was not the mother tongue, but French. In isolated instances during World War I the Germans used English when their own language could for one reason or another not be employed. For example, for a year or two before the entry of the United States into that war, during the time America was neutral and the German Government maintained its embassy in Washington, some of the messages exchanged between the Foreign Office in Berlin and the Embassy in Washington were encrypted in English, and a copy of the code used was deposited with the Department of State and our censor. Another instance is found in the case of certain Hindu conspirators who were associated with and partially financed by the German Government in 1915 and 1916; they employed English as the language of their cryptographic messages. Occasionally the cryptograms of enemy agents may be in a language different from that of the enemy. But in general these

[1] Although the foregoing four steps represent the classical or ideal approach to cryptanalysis, the art may be reduced to the following:

	Procedures in cryptanalysis	Requirements
1.	Arrangement and rearrangement of data to disclose non-random characteristics or manifestations (i.e., in frequency counts, repetitions, patterns, symmetrical phenomena, etc.).	Experience or ingenuity, and time (which latter may be appreciably lowered by the use of machine aids in cryptanalysis).
2.	Recognition of the non-random characteristics or manifestations when disclosed.	Experience or statistics.
3.	Explanation of the non-random characteristics when recognized.	Experience or imagination, and intelligence.

In all of the foregoing, the element of luck plays a very important part, as it is possible to side-step a large amount of labor and effort, in many cases, if "hunches" or intuition lead the analyst forthwith to the right path. Therefore, the phrase "or luck" should be added to each of the requirements above.

In fact, it all boils down to the simple statement: "Find something significant, and attach some significance thereto."

are, as has been said, isolated instances; as a rule, the language used in cryptograms exchanged between members of large organizations is the mother tongue of the correspondents. Where this is not the case, that is, when cryptograms of unknown origin must be studied, the cryptanalyst looks for any indications on the cryptograms themselves which may lead to a conclusion as to the language employed. Address, signature, and other data, if in plain text in the preamble, in the body, or at the end of the cryptogram, all come under careful scrutiny, as well as all extraneous circumstances connected with the manner in which the cryptograms were obtained, the person on whom they were found, or the locale of their origin and destination.

b. In special cases, or under special circumstances a clue to the language employed is found in the nature and composition of the cryptographic text itself. For example, if the letters K and W are entirely absent or appear very rarely in messages, it may indicate that the language is Spanish, for these letters are absent in the alphabet of that language and are used only to spell foreign words or names. The presence of accented letters or letters marked with special signs of one sort or another, peculiar to certain languages, will sometimes indicate the language used. The Japanese Morse telegraph alphabet and the Russian Morse telegraph alphabet contain combinations of dots and dashes which are peculiar to those alphabets and thus the interception of messages containing these special Morse combinations at once indicates the language involved. Finally, there are certain peculiarities of alphabetic languages which, in certain types of cryptograms, viz., pure transposition, give clues as to the language used. For example, the frequent digraph CH, in German, leads to the presence, in cryptograms of the type mentioned, of many isolated C's and H's; if this is noted, the cryptogram may be assumed to be in German.

c. In some cases it is perfectly possible to perform certain steps in cryptanalysis before the language of the cryptogram has been definitely determined. Frequency studies, for example, may be made and analytic processes performed without this knowledge, and by a cryptanalyst wholly unfamiliar with the language even if it has been identified, or who knows only enough about the language to enable him to recognize valid combinations of letters, syllables, or a few common words in that language. He may, after this, call to his assistance a translator who may not be a cryptanalyst but who can materially aid in making necessary assumptions based upon his special knowledge of the characteristics of the language in question. Thus, cooperation between cryptanalyst and translator results in solution.[2]

[2] The writer has seen in print statements that "during World War I . . decoded messages in Japanese and Russian without knowing a word of either language." The extent to which such statements are exaggerated will soon become obvious to the student. Of course, there are occasional instances in which a mere clerk with quite limited experience may be able to "solve" a message in an extremely simple system in a language of which he has no knowledge at all; but such a "solution" calls for nothing more arduous than the ability to recognize pronounceable combinations of vowels and consonants—an ability that hardly deserves to be rated as "cryptanalytic" in any real sense. To say that it is possible to solve a cryptogram in a foreign language "without knowing a word of that language" is not quite the same as to say that it is possible to do so with only a slight knowledge of the language; and it may be stated without cavil that the better the cryptanalyst's knowledge of the language, the greater are the chances for his success and, in any case, the easier is his work.

17. The determination of the general system.--a. Except in the case of the more simple types of cryptograms, the step referred to as diagnosis, that is, ascertaining the general system according to which a given cryptogram has been produced is usually a difficult, if not the most difficult, step in its solution. The reason for this is not hard to find.

b. As will become apparent to the student as he proceeds with his study, in the final analysis, the solution of every cryptogram involving a form of substitution depends upon its reduction to monoalphabetic terms, if it is not originally in those terms. This is true not only of ordinary substitution ciphers, but also of combined substitution-transposition ciphers, and of enciphered code. If the cryptogram must be reduced to monoalphabetic terms, the manner of its accomplishment is usually indicated by the cryptogram itself, by external or internal phenomena which become apparent to the cryptanalyst as he studies the cryptogram. If this is impossible, or too difficult, the cryptanalyst must, by one means or another, discover how to accomplish this reduction, by bringing to bear all the special or collateral information he can get from all the sources at his command. If both these possibilities fail him, there is little left but the long, tedious, and often fruitless process of elimination. In the case of transposition ciphers of the more complex type, the discovery of the basic method is often simply a matter of long and tedious elimination of possibilities. For cryptanalysis has unfortunately not yet attained, and may indeed never attain, the precision found today in qualitative analysis in chemistry, for example, where the analytic process is absolutely clear-cut and exact in its dichotomy. A few words in explanation of what is meant may not be amiss. When a chemist seeks to determine the identity of an unknown substance, he applies certain specific reagents to the substance and in a specific sequence. The first reagent tells him definitely into which of two primary classes the unknown substance falls. He then applies a second test with another specific reagent, which tells him again quite definitely into which of two secondary classes the unknown substance falls, and so on, until finally he has reduced the unknown substance to its simplest terms and has found out what it is. In striking contrast to this situation, cryptanalysis affords exceedingly few "reagents" or tests that may be applied to determine positively that a given cipher belongs to one or the other of two systems yielding externally similar results. And this is what makes the analysis of an isolated, complex cryptogram so difficult. Note the limiting adjective "isolated" in the foregoing sentence, for it is used advisedly. It is not often that the general system fails to disclose itself or cannot be discovered by painstaking investigation when there is a great volume of text accumulating from a regular traffic between numerous correspondents in a large organization. Sooner or later the system becomes known, either because of blunders and carelessness on the part of the personnel entrusted with the encrypting of the messages, or because the accumulation of text itself makes possible the determination of the general system by cryptanalytic, including statistical, studies. But in the case of a single or even a few isolated cryptograms concerning which little or no information can be gained by the cryptanalyst, he is often unable, without a knowledge of, or a shrewd guess as to the general system employed, to decompose the heterogeneous text of the cryptogram into homogeneous, monoalphabetic text, which is the ultimate and essential step in analysis. The only knowledge that the cryptanalyst can bring to his aid in this most difficult step is that gained by long experience and practice in the analysis of many different types of systems. In this respect the practice of cryptanalysis is analogous to the practice of medicine: correct diagnosis is the most important and often the most difficult first step toward success.

c. On account of the complexities surrounding this particular phase of cryptanalysis, and because in any scheme of analysis based upon successive eliminations of alternatives the cryptanalyst can only progress as far as the extent of his own knowledge of all the possible alternatives will permit, it is necessary that detailed discussion of the eliminative process be postponed until the student has covered most of the field. For example, the student will perhaps want to know at once how he can distinguish between a cryptogram that is in code or enciphered code from one that is in cipher. It is at this stage of his studies impracticable to give him any helpful indications on his question. In return it may be asked of him why he should expect to be able to do this in the early stages of his studies when often the experienced expert cryptanalyst is baffled on the same score!

d. Nevertheless, in lieu of more precise diagnostic tests not yet discovered, a general guide that may be useful in cryptanalysis will be built up, step by step as the student progresses, in the form of a series of charts comprising what may be designated An Analytical Key for Cryptanalysis. (See Section X.) It may be of assistance to the student if, as he proceeds, he will carefully study the charts and note the place which the particular cipher he is solving occupies in the general cryptanalytic panorama. These charts admittedly constitute only very brief outlines, and can therefore be of but little direct assistance to him in the analysis of the more complex types of cryptosystems he may encounter later on. So far as they go, however, they may be found to be quite useful in the study of elementary cryptanalysis. For the experienced cryptanalyst they can serve only as a means of assuring that no possible step or process is inadvertently overlooked in attempts to solve a difficult cryptosystem.

e. Much of the labor involved in cryptanalytic work, as referred to in par. 2, is connected with this determination of the general system. The preparation of the text, its rewriting in different forms, sometimes being rewritten in dozens of ways, the recording of letters, the establishment of frequencies of occurrences of letters, comparisons and experiments made with known material of similar character, and so on, constitute much labor that is most often indispensable, but which sometimes turns out to have been wholly unnecessary, or in vain. In one treatise[3] it is stated quite boldly that "this work once done, the determination of the system is often relatively easy." This statement can certainly apply only to the simpler types of cryptosystems; it is entirely misleading as regards the much more frequently encountered complex cryptograms of modern times.

18. The reconstruction of the specific key.--a. Nearly all practical cryptographic methods require the use of a specific key to guide, control, or modify the various steps under the general system. Once the latter has been disclosed, discovered, or has otherwise come into the possession of the cryptanalyst, the next step in solution is to determine, if necessary and if possible, the specific key that was employed to encrypt the message or messages under examination. This determination may not be in complete detail; it may go only so far as to lead to a knowledge of the number of alphabets involved in a substitution cipher, or the number of columns involved in a transposition cipher, or that a one-part code has been used, in the case of a code system. But it is often desirable to determine the specific key in as complete a form and with as much detail as possible, for this information will very frequently be useful in the solution of subsequent cryptograms exchanged between the same correspondents, since the nature or source of the specific key in a solved case may be expected to give clues to the specific key in an unsolved case.

b. Frequently, however, the reconstruction of the key is not a prerequisite to, and does not constitute an absolutely necessary preliminary step in, the fourth basic operation, viz., the reconstruction or establishment of the plain text. In many cases, indeed, the two processes are carried along simultaneously, the one assisting the other, until in the final stages both have been completed in their entireties. In still other cases the reconstruction of the specific key may follow the reconstruction of the plain text instead of preceding it and is accomplished purely as a matter of academic interest; or the specific key may, in unusual cases, never be reconstructed.

19. The reconstruction of the plain text.--a. Little need be said at this point on this phase of cryptanalysis. The process usually consists, in the case of substitution ciphers, in the establishment of equivalency between specific letters of the cipher text and the plain text, letter by letter, pair by pair, and so on, depending upon the particular type of substitution system involved. In the case of transposition ciphers, the process consists in rearranging the elements of the cipher text, letter by letter, pair by pair, or occasionally word by word, depending upon the particular type of transposition system involved, until the letters or words have been returned to their original plaintext order. In the case of code, the process consists in determining the meaning of each code group and inserting this meaning in the code text to reestablish the original plain text.

[3] Lange et Soudart, op. cit., p. 106.

b. The foregoing processes do not, as a rule, begin at the beginning of a message and continue letter by letter, or group by group in sequence up to the very end of the message. The establishment of values of cipher letters in substitution methods, or of the positions to which cipher letters should be transferred to form the plain text in the case of transposition methods, comes at very irregular intervals in the process. At first only one or two values scattered here and there throughout the text may appear; these then form the "skeletons" of words, upon which further work, by a continuation of the reconstruction process, is made possible; in the end the complete or nearly complete[4] text is established.

c. In the case of cryptograms in a foreign language, the translation of the solved messages is a final and necessary step, but is not to be considered as a cryptanalytic process. However, it is commonly the case that the translation process will be carried on simultaneously with the cryptanalytic, and will aid the latter, especially when there are lacunae which may be filled in from the context. (See also subpar. 16c in this connection.)

20. The utilization of traffic intercepts.[5]--a. There are, of course, other operations which are not as basic in nature as those just outlined but which must generally be performed as preliminary steps in practical cryptanalytic work (as distinguished from academic cryptanalysis). Before a military cryptanalyst can begin the analysis of an enemy cryptosystem, it is necessary for him to study the intercept material that is available to him, isolate the messages that hve been encrypted by means of the cryptosystem to be exploited, and to arrange the latter in a systematic order for analysis. This work, although apparently very simple, may require a great deal of time and effort.

b. Since, whenever practicable, two or more intercept stations are assigned to copy traffic emanating from the stations of one enemy radio net, it is natural that there should be a certain amount of duplication in the work of the several stations. This is desirable since it provides the cryptanalysts with two or more sets of the same messages, so that when one intercept station fails to receive all the messages completely and correctly, because of radio difficulties, local static, or poor operation, it is possible by studying the other sets to reconstruct accurately the entire traffic of the enemy net.

[4] Sometimes in the case of code, the meaning of a small percentage of the code groups occurring in the traffic may be lacking, because there is insufficient text to establish their meaning.

[5] A traffic intercept is a copy of a communication gained through interception.

c. In all intercept activities where operators are used for copying the traffic, one of the most likely errors to be found is caused by the human element in reception. For this reason cryptanalysts and their assistants should be familiar with the international Morse alphabet and the most common errors in wire and radio transmission methods so as to be able to correct garbled groups when they occur. In this connection, Chart 1, above, will be found useful.

Ltrs. and Figs.	Morse equi-valent	Frequent Errors	Ltrs. and Figs.	Morse equi-valent	Frequent Errors
A	•-	i, m, t, et	S	•••	h, d, i, r, u
B	-•••	d, ts	T	-	a, e, n
C	-•-•	f, k, r, nn	U	••-	a, s, v, it
D	-••	b, s, l, ti	V	•••-	h, u, x, st
E	•	t, i	W	•--	a, m, o, r, u, at
F	••-•	r, in	X	-••-	v, k, y, tu
G	--•	m, o, z, me	Y	-•--	x, c, nm
H	••••	s, v, b, ii, se	Z	--••	b, g, q, mi
I	••	a, n, s	1	•----	∅, 2
J	•---	w, o, am, eo	2	••---	1, 3
K	-•-	d, o, ta	3	•••--	2, 4
L	•-••	r, d, ed	4	••••-	3, 5
M	--	a, n, tt	5	•••••	4, 6
N	-•	i, m, t, te	6	-••••	5, 7
O	---	g, k, w, mt	7	--•••	6, 8
P	•--•	j, g, l, w, an	8	---••	7, 9
Q	--•-	o, x, z, ma	9	----•	8, ∅
R	•-•	a, f, g, l, n, s, w	∅	-----	9, 1

Chart 1. Most common errors in telegraphic transmission.

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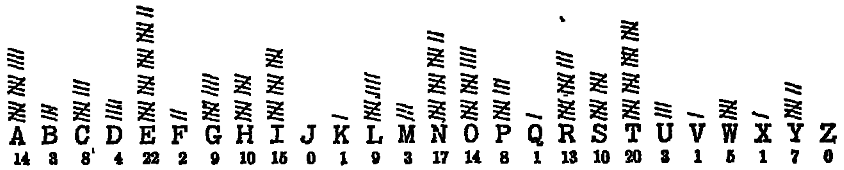
SECTION IV

FREQUENCY DISTRIBUTIONS AND THEIR FUNDAMENTAL USES

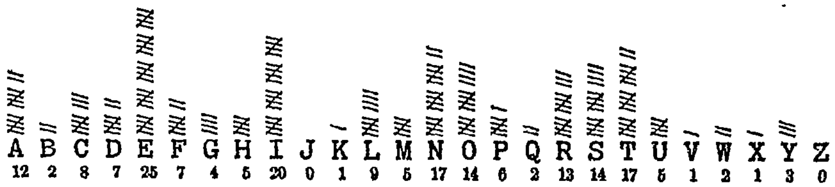
21. The simple or uniliteral frequency distribution.--a. It has long been known to cryptographers and typographers that the letters composing the words of any intelligible written text composed in any language which is alphabetic in construction are employed with greatly varying frequencies. For example, if on cross-section paper a simple tabulation, shown in Fig. 1, called a uniliteral frequency distribution, is made of the letters composing the words of the preceding sentence, the variation in frequency is strikingly demonstrated. It is seen that whereas certain letters, such as A, E, I, N, O, R, and T, are employed very frequently, other letters, such as C, G, H, L, P, and S are employed not nearly so frequently, while still other letters, such as F, J, K, Q, V, X, and Z are employed either seldom or not at all.



(Total=200 letters)

Figure 1.

b. If a similar tabulation is now made of the letters comprising the words of the second sentence in the preceding subparagraph, the distribution shown in Fig. 2 is obtained. Both sentences have exactly the same number of letters (200).



(Total=200 letters)

Figure 2.

c. Although each of these two distributions exhibits great variation in the relative frequencies with which different letters are employed in the respective sentences to which they apply, no marked differences are exhibited between the frequencies of the same letter in the two distributions. Compare, for example, the frequencies of A, B, C . . . Z in Fig. 1 with those of A, B, C . . . Z in Fig. 2. Aside from one or two exceptions, as in the case of the letter F, these two distributions agree rather strikingly.

d. This agreement, or similarity, would be practically complete if the two texts were much longer, for example, five times as long. In fact, when two texts of similar character, each containing more than 1,000 letters, are compared, it would be found that the respective frequencies of the 26 letters composing the two distributions show only very slight differences. This means, in other words, that in normal plain text each letter of the alphabet occurs with a rather constant or characteristic frequency which it tends to approximate, depending upon the length of the text analyzed. The longer the text (within certain limits), the closer will be the approximation to the characteristic frequencies of letters in the language involved. However, when the amount of text being analyzed has reached a substantial volume (roughly, 1,000 letters), the practical gain in accuracy does not warrant further increase in the amount of text.[1]

e. An experiment along these lines will be convincing. A series of 260 official telegrams[2] passing through the Department of the Army Message Center was examined statistically. The messages were divided into five sets, each totaling 10,000 letters, and the five distributions shown in Table 1-A, were obtained.

[1] See footnote 5, page 38.

[2] These comprised messages from several official sources in addition to the Department of the Army and were all of an administrative character.

TABLE 1-A.—*Absolute frequencies of letters appearing in five sets of Governmental plain-text telegrams, each set containing 10,000 letters, arranged alphabetically*

Set No. 1		Set No. 2		Set No. 3		Set No. 4		Set No. 5	
Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency
A	738	A	783	A	681	A	740	A	741
B	104	B	103	B	98	B	83	B	99
C	319	C	300	C	288	C	326	C	301
D	387	D	413	D	423	D	451	D	448
E	1,367	E	1,294	E	1,292	E	1,270	E	1,275
F	253	F	287	F	308	F	287	F	281
G	166	G	175	G	161	G	167	G	150
H	310	H	351	H	335	H	349	H	349
I	742	I	750	I	787	I	700	I	697
J	18	J	17	J	10	J	21	J	16
K	36	K	38	K	22	K	21	K	31
L	365	L	393	L	333	L	386	L	344
M	242	M	240	M	238	M	249	M	268
N	786	N	794	N	815	N	800	N	780
O	685	O	770	O	791	O	756	O	762
P	241	P	272	P	317	P	245	P	260
Q	40	Q	22	Q	45	Q	38	Q	30
R	760	R	745	R	762	R	735	R	786
S	658	S	583	S	585	S	628	S	604
T	936	T	879	T	894	T	958	T	928
U	270	U	233	U	312	U	247	U	238
V	163	V	173	V	142	V	133	V	155
W	166	W	163	W	136	W	133	W	182
X	43	X	50	X	44	X	53	X	41
Y	191	Y	155	Y	179	Y	213	Y	229
Z	14	Z	17	Z	2	Z	11	Z	5
Total	10,000		10,000		10,000		10,000		10,000

f. If the five distributions in Table 1-A are summed, the results are as shown in Table 2-A.

TABLE 2-A.—*Absolute frequencies of letters appearing in the combined five sets of messages totaling 50,000 letters, arranged alphabetically*

A	3,683	G	819	L	1,821	Q	175	V	766
B	487	H	1,694	M	1,237	R	3,788	W	780
C	1,534	I	3,676	N	3,975	S	3,058	X	231
D	2,122	J	82	O	3,764	T	4,595	Y	967
E	6,498	K	148	P	1,335	U	1,300	Z	49
F	1,416								

g. The frequencies noted in Table 2-A above, when reduced to the basis of 1,000 letters and then used as a basis for constructing a simple chart that will exhibit the variations in frequency in a striking manner, yield the following distribution which is hereafter designated as the normal or standard uniliteral frequency distribution for English telegraphic plain text:

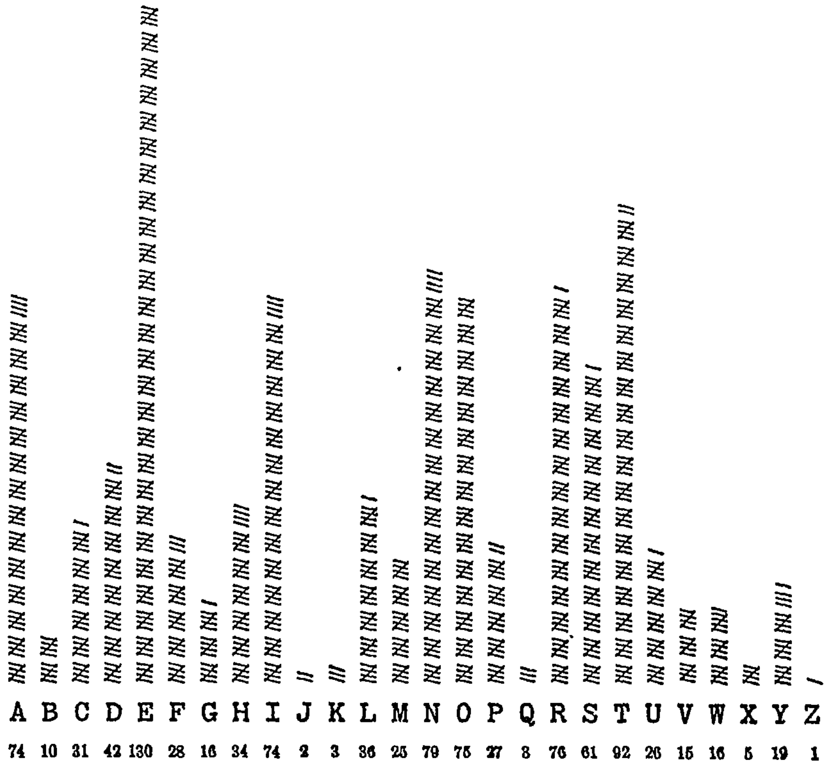


Figure 3.

22. Important features of the normal uniliteral frequency distribution.--a. When the distribution shown in Fig. 3 is studied in detail, the following features are apparent:

(1) It is quite irregular in appearance. This is because the letters are used with greatly varying frequencies, as discussed in the preceding paragraph. This irregular appearance is often described by saying that the distribution shows marked crests and troughs, that is, points of high frequency and low frequency.

(2) The relative positions in which the crests and troughs fall within the distribution, that is, the spatial relations of the crests and troughs, are rather definitely fixed and are determined by circumstances which have been explained in subpar. 13b.

(3) The relative heights and depths of the crests and troughs within the distribution, that is, the linear extensions of the lines marking the respective frequencies, are also rather definitely fixed, as would be found if an equal volume of similar text were analyzed.

(4) The most prominent crests are marked by the vowels A, E, I, O, and the consonants N, R, S, T; the most prominent troughs are marked by the consonants J, K, Q, X, and Z.

(5) The important data are summarized in tabular form in Table 3.

TABLE 3

	Frequency	Percent of total	Percent of total in round numbers
6 Vowels: A E I O U Y	398	39.8	40
20 Consonants:			
5 High Frequency (D N R S T)	350	35.0	35
10 Medium Frequency (B C F G H L M P V W)	238	23.8	24
5 Low Frequency (J K Q X Z)	14	1.4	1
Total	1,000	100.0	100

(6) The frequencies of the letters of the alphabet, reduced to a base of 1000, are as follows:

A	74	G	16	L	36	Q	3	V	15
B	10	H	34	M	25	R	76	W	16
C	31	I	74	N	79	S	61	X	5
D	42	J	2	O	75	T	92	Y	19
E	130	K	3	P	27	U	26	Z	1
F	28								

(7) The relative order of frequency of the letters is as follows:

E	130	I	74	C	31	Y	19	X	5
T	92	S	61	F	28	G	16	Q	3
N	79	D	42	P	27	W	16	K	3
R	76	L	36	U	26	V	15	J	2
O	75	H	34	M	25	B	10	Z	1
A	74								

(8) The four vowels A, E, I, O (combined frequency 353) and the four consonants N, R, S, T (combined frequency 308) form 661 out of every 1,000 letters of plain text; in other words, less than one-third of the alphabet is employed in writing two-thirds of normal plain text.

b. The data given in Fig. 3 and Table 3 represent the relative frequencies found in a large volume of English telegraphic text of a governmental, administrative character.[3] These frequencies will vary somewhat with the nature of the text analyzed. For example, if an equal number of telegrams dealing solely with commercial transactions in the leather industry were studied statistically, the frequencies would be slightly different because of the repeated occurrence of words peculiar to that industry. Again, if an equal number of telegrams dealing solely with military messages of a tactical character were studied statistically, the frequencies would differ slightly from those found above for general governmental messages of an administrative character.

c. If ordinary English literary text (such as may be found in any book, newspaper, or printed document) were analyzed, the frequencies of certain letters would be changed to an appreciable degree. This is because in telegraphic text words which are not strictly essential for intelligibility (such as the definite and indefinite articles, certain prepositions, conjunctions, and pronouns) are omitted. In addition, certain essential words, such as "stop", "period", "comma", and the like, which are usually indicated in written or printed matter by symbols not easy to transmit telegraphically and which must, therefore, be spelled out in telegrams, occur very frequently. Furthermore, telegraphic text often employs longer and more uncommon words than does ordinary newspaper or book text.

d. As a matter of fact, other tables compiled from Army sources gave slightly different results, depending upon the source of the text. For example, three tables based upon 75,000, 100,000, and 136,257 letters taken from various sources (telegrams, newspapers, magazine articles, books of fiction) gave as the relative order of frequency for the first 10 letters the following:

For 75,000 letters................	E T R N I O A S D L
For 100,000 letters...............	E T R I N O A S D L
For 136,257 letters...............	E T R N A O I S L D

[3] Just as the individual letters constituting a large volume of plain text have more or less characteristic or fixed frequencies, so it is found that digraphs and trigraphs (two- and three-letter combinations, respectively) have characteristic frequencies, when a large volume of text is studied statistically. In Table 6 of Appendix 2, "Letter frequency data - English", are shown the relative frequencies of all digraphs appearing in the 260 telegrams referred to in subpar. 21e. This appendix also includes several other kinds of tables and lists of frequency data which will be useful to the student in his work. It is suggested that the student refer to this appendix now, to gain an idea of the data available for his future reference.

Other languages, of course, each have their own individual characteristic plaintext frequencies of single letters, digraphs, trigraphs, etc. A brief summary of the letter frequency data for German, French, Italian, Spanish, Portuguese, and Russian constitute Appendix 5, "Letter frequency data - foreign languages".

e. Frequency data applicable purely to English military text were compiled by Hitt,[4] from a study of 10,000 letters taken from orders and reports. The frequencies found by him are given in Tables 4 and 5.

TABLE 4.—*Frequency table for 10,000 letters of literary English, as compiled by Hitt*

ALPHABETICALLY ARRANGED

A	778	G	174	L	372	Q	8	V	112
B	141	H	595	M	288	R	651	W	176
C	296	I	667	N	686	S	622	X	27
D	402	J	51	O	807	T	855	Y	196
E	1,277	K	74	P	223	U	308	Z	17
F	197								

ARRANGED ACCORDING TO FREQUENCY

E	1,277	R	651	U	308	Y	196	K	74
T	855	S	622	C	296	W	176	J	51
O	807	H	595	M	288	G	174	X	27
A	778	D	402	P	223	B	141	Z	17
N	686	L	372	F	197	V	112	Q	8
I	667								

TABLE 5.—*Frequency table for 10,000 letters of telegraphic English, as compiled by Hitt*

ALPHABETICALLY ARRANGED

A	813	G	201	L	392	Q	38	V	136
B	149	H	386	M	273	R	677	W	166
C	306	I	711	N	718	S	656	X	51
D	417	J	42	O	844	T	634	Y	208
E	1,319	K	88	P	243	U	321	Z	6
F	205								

ARRANGED ACCORDING TO FREQUENCY

E	1,319	S	656	U	321	F	205	K	88
O	844	T	634	C	306	G	201	X	51
A	813	D	417	M	273	W	166	J	42
N	718	L	392	P	243	B	149	Q	38
I	711	H	386	Y	208	V	136	Z	6
R	677								

23. Constancy of the standard or normal uniliteral frequency distribution.--a. The relative frequencies disclosed by the statistical study of large volumes of text may be considered to be the standard or normal frequencies of the letters of written English. Counts made of smaller volumes of text will tend to approximate these normal frequencies,

[4] Op. cit., pp. 6-7.

and, within certain limits,[5] the smaller the volume, the lower will be the degree of approximation to the normal, until, in the case of a very short message, the normal proportions may not manifest themselves at all. It is advisable that the student fix this fact firmly in mind, for the sooner he realizes the true nature of any data relative to the frequency of occurrence of letters in text, the less often will his labors toward the solution of specific ciphers be thwarted and retarded by too strict an adherence to these generalized principles of frequency. He should constantly bear in mind that such data are merely statistical generalizations, that they will be found to hold strictly true only in large volumes of text, and that they may not even be approximated in short messages.

b. Nevertheless the normal frequency distribution or the "normal expectation" for any alphabetic language is, in the last analysis, the best guide to, and the usual basis for, the solution of cryptograms of a certain type. It is useful, therefore, to reduce the normal, uniliteral frequency distribution to a basis that more or less closely approximates the volume of text which the cryptanalyst most often encounters in individual cryptograms. As regards length of messages, counting only the letters in the body, and excluding address and signature, a study of the 260 telegrams referred to in par. 21 shows that the arithmetical average is 217 letters; the statistical mean, or weighted average[6], however, is 191 letters. These two results are, however, close enough together to warrant the statement that the average length of telegrams is approximately 200 letters. The frequencies given in par. 21 have therefore been reduced to a basis of 200 letters, and the following uniliteral frequency distribution may be taken as showing the most typical distribution to be expected in 200 letters of English telegraphic text:

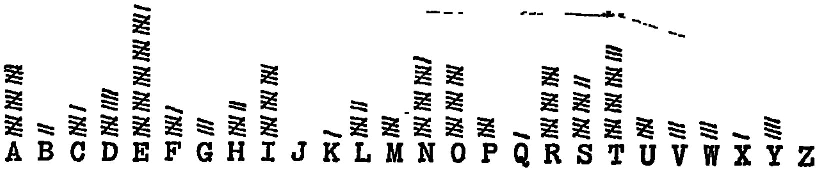


Figure 4.

[5] It is useless to go beyond a certain limit in establishing the normal-frequency distribution for a given language. As a striking instance of this fact, witness the frequency study made by an indefatigable German, Kaeding, who in 1898 made a count of the letters in about 11,000,000 words, totaling about 62,000,000 letters in German text. When reduced to a percentage basis, and when the relative order of frequency was determined, the results he obtained differed very little from the results obtained by Kasiski, a German cryptographer, from a count of only 1,000 letters. See Kaeding, *Haeufigkeitswoerterbuch*, Steglitz, 1898; Kasiski, *Die Geheimschriften und die Dechiffrir-Kunst*, Berlin, 1863.

[6] The arithmetical average is obtained by adding each different length and dividing by the number of different-length messages; the mean is obtained by multiplying each different length by the number of messages of that length, adding all products, and dividing by the total number of messages.

c. The student should take careful note of the appearance of the distribution[7] shown in Fig. 4, for it will be of much assistance to him in the early stages of his study. The manner of setting down the tallies should be followed by him in making his own distributions, indicating every fifth occurrence of a letter by an oblique tally. This procedure almost automatically shows the total number of occurrences for each letter, and yet does not destroy the graphical appearance of the distribution, especially if care is taken to use approximately the same amount of space for each set of five tallies. Cross-section paper is very useful for this purpose.

d. The word "uniliteral" in the designation "uniliteral frequency distribution" means "single letter", and it is to be inferred that other types of frequency distributions may be encountered. For example, a distribution of pairs of letters, constituting a biliteral frequency distribution, is very often used in the study of certain cryptograms in which it is desired that pairs made by combining successive letters be listed. A biliteral distribution of A B C D E F would take these pairs: AB, BC, CD, DE, EF. The distribution could be made in the form of a large square divided up into 676 cells. When distributions beyond biliteral are required (triliteral, quadriliteral, etc.) they can only be made by listing them in some order, for example, alphabetically based on the 1st, 2d, 3d, . . . letter.

[7] The use of the terms "distribution" and "frequency distribution", instead of "table" and "frequency table", respectively, is considered advisable from the point of view of consistency with the usual statistical nomenclature. When data are given in tabular form, with frequencies indicated by numbers, then they may properly be said to be set out in the form of a table. When, however, the same data are distributed in a chart which partakes of the nature of a graph, with the data indicated by horizontal or vertical linear extensions, or by a curve connecting points corresponding to quantities, then it is more proper to call such a graphic representation of the data a distribution.

24. The three facts which can be determined from a study of the unilitcral frequency distribution for a cryptogram.--a. The following three facts (to be explained subsequently) can usually be determined from an inspection of the unilitcral frequency distribution for a given cipher message of average length, composed of letters:

(1) Whether the cipher belongs to the substitution or the transposition class;

(2) If to the former, whether it is monoalphabetic[8] or non-monoalphabetic[9] in character;

(3) If monoalphabetic, whether the cipher alphabet is standard (direct or reversed) or mixed.

b. For immediate purposes the first two of the foregoing determinations are quite important and will be discussed in detail in the next two paragraphs; the other determination will be touched upon very briefly, leaving its detailed discussion for subsequent sections of the text.

25. Determining the class to which a cipher belongs.--a. The determination of the class to which a cipher belongs is usually a relatively easy matter because of the fundamental difference between transposition and substitution as cryptographic processes. In a transposition cipher the original letters of the plain text have merely been rearranged, without any change whatsoever in their identities, that is, in the conventional values they have in the normal alphabet. Hence, the numbers of vowels (A, E, I, O, U, Y), high-frequency consonants (D, N, R, S, T), medium-frequency consonants (B, C, F, G, H, L, M, P, V, W), and low-frequency consonants (J, K, Q, X, Z) are exactly the same in the cryptogram as they are in the plaintext message. Therefore, the percentages of vowels, high-, medium-, and low-frequency consonants are the same in the transposed text as in the equivalent plain text. In a

[8] In connection with uniliteral frequency distributions, the term monoalphabetic is considered to embrace the concept of monoalphabetic-monographic-uniliteral systems only, thus excluding polygraphic and multiliteral systems, both of which, however, usually fall into the monoalphabetic category.

[9] The term non-monoalphabetic as applied in this instance is considered to embrace all deviations from the characteristic appearance of monoalphabetic distributions. These deviations include the phenomena inherent in polyalphabetic, polygraphic, and multiliteral cryptograms, as well as in random text, i.e., text which appears to have been produced by chance or accident, having no discernible patterns or limitations.

substitution cipher, on the other hand, the identities of the original letters of the plain text have been changed, that is, the conventional values they have in the normal alphabet have been altered. Consequently, if a count is made of the various letters present in such a cryptogram, it will be found that the number of vowels, high-, medium-, and low-frequency consonants will usually be quite different in the cryptogram from what they are in the original plaintext message. Therefore, the percentages of vowels, high-, medium-, and low-frequency consonants are usually quite different in the substitution text from what they are in the equivalent plain text. From these considerations it follows that if in a specific cryptogram the percentages of vowels, high-, medium-, and low-frequency consonants are approximately the same as would be expected in normal plain text, the cryptogram probably belongs to the transposition class; if these percentages are quite different from those to be expected in normal plain text the cryptogram probably belongs to the substitution class.

b. In the preceding subparagraph the word "probably" was emphasized by italicizing it, for there can be no certainty in every case of this determination. Usually these percentages in a transposition cipher are close to the normal percentages for plain text; usually, in a substitution cipher, they are far different from the normal percentages for plain text. But occasionally a cipher message is encountered which is difficult to classify with a reasonable degree of certainty because the message is too short for the general principles of frequency to manifest themselves. It is clear that if in actual messages there were no variation whatever from the normal vowel and consonant percentages given in Table 3, the determination of the class to which a specific cryptogram belongs would be an extremely simple matter. But unfortunately there is always some variation or deviation from the normal. Intuition suggests that as messages decrease in length there may be a greater and greater departure from the normal proportions of vowels, high-, medium-, and low-frequency consonants, until in very short messages the normal proportions may not hold at all. Similarly, as messages increase in length there may be a lesser and lesser departure from the normal proportions, until in messages totalling a thousand or more letters there may be no difference at all between the actual and the theoretical proportions. But intuition is not enough, for in dealing with specific messages of the length of those commonly encountered in practical work the question sometimes arises as to exactly how much deviation (from the normal proportions) may be allowed for in a cryptogram which shows a considerable amount of deviation from the normal and which might still belong to the transposition rather than to the substitution class.

c. Statistical studies have been made on this matter and some graphs have been constructed thereon. These are shown in Charts 2 - 5 in the form of simple curves, the use of which will now be explained. Each chart contains two curves marking the lower and upper limits, respectively, of the theoretical amount of deviation (from the normal percentages) of vowels or consonants which may be allowable in a cipher believed to belong to the transposition class.

d. In Chart 2, curve V_1 marks the lower limit of the theoretical amount of deviation[10] from the number of vowels theoretically expected to appear[11] in a message of given length; curve V_2 marks the upper limit of the same statistic. Thus, for example, in a message of 100 letters in plain English there should be between 33 and 47 vowels (A E I O U Y). Likewise, in Chart 3 curves H_1 and H_2 mark the lower and upper limits as regards the high-frequency consonants. In a message of 100 letters there should be between 28 and 42 high-frequency consonants (D N R S T). In Chart 4 curves M_1 and M_2 mark the lower and upper limits as regards the medium-frequency consonants. In a message of 100 letters there should be between 17 and 31 medium-frequency consonants (B C F G H L M P V W). Finally, in Chart 5, curves L_1 and L_2 mark the lower and upper limits as regards the low-frequency consonants. In a message of 100 letters there should be between 0 and 3 low-frequency consonants (J K Q X Z). In using the charts, therefore, one finds the point of intersection of the vertical coordinate corresponding to the length of the message, with the horizontal coordinate corresponding to (1) the number of vowels, (2) the number of high-frequency consonants, (3) the number of medium-frequency consonants, and (4) the number of low-frequency consonants actually counted in the message. If all four points of intersection fall within the area delimited by the respective curves, then the numbers of vowels and high-, medium-, and low-frequency consonants correspond with the numbers theoretically expected in a normal plaintext message of the same length; since the message under investigation is not plain text, it follows that the cryptogram may certainly be classified as a transposition cipher. On the other hand, if one or more of these points of intersection fall outside the area delimited by the respective curves, it follows that the cryptogram is probably a substitution cipher. The distance that the point of intersection falls outside the area delimited by these curves is a more or less rough measure of the improbability of the cryptogram's being a transposition cipher.

e. Sometimes a cryptogram is encountered which is hard to classify with certainty even with the foregoing aids, because it has been consciously prepared with a view to making the classification difficult. This can be done either by selecting peculiar words (as in "trick cryptograms") or by employing a cipher alphabet in which letters of approximately similar normal frequencies have been interchanged. For example, E may be replaced by O, T by R, and so on, thus yielding a cryptogram giving external indications of being a transposition cipher but which is really a substitution cipher. If the cryptogram is not too short, a close study will usually disclose what has been done, as well as the futility of so simple a subterfuge.

[10] In Charts 2 - 5, inclusive, the limits of the upper and lower curves have been calculated to include approximately 70 percent of messages of the various lengths.

[11] The expression "the number of ... theoretically expected to appear" is often condensed to "the theoretical expectation of ..." or "the normal expectation of ..."

f. In the majority of cases, in practical work, the determination of the class to which a cipher of average length belongs can be made from a mere inspection of the message, after the cryptanalyst has acquired a familiarity with the normal appearance of transposition and of substitu-

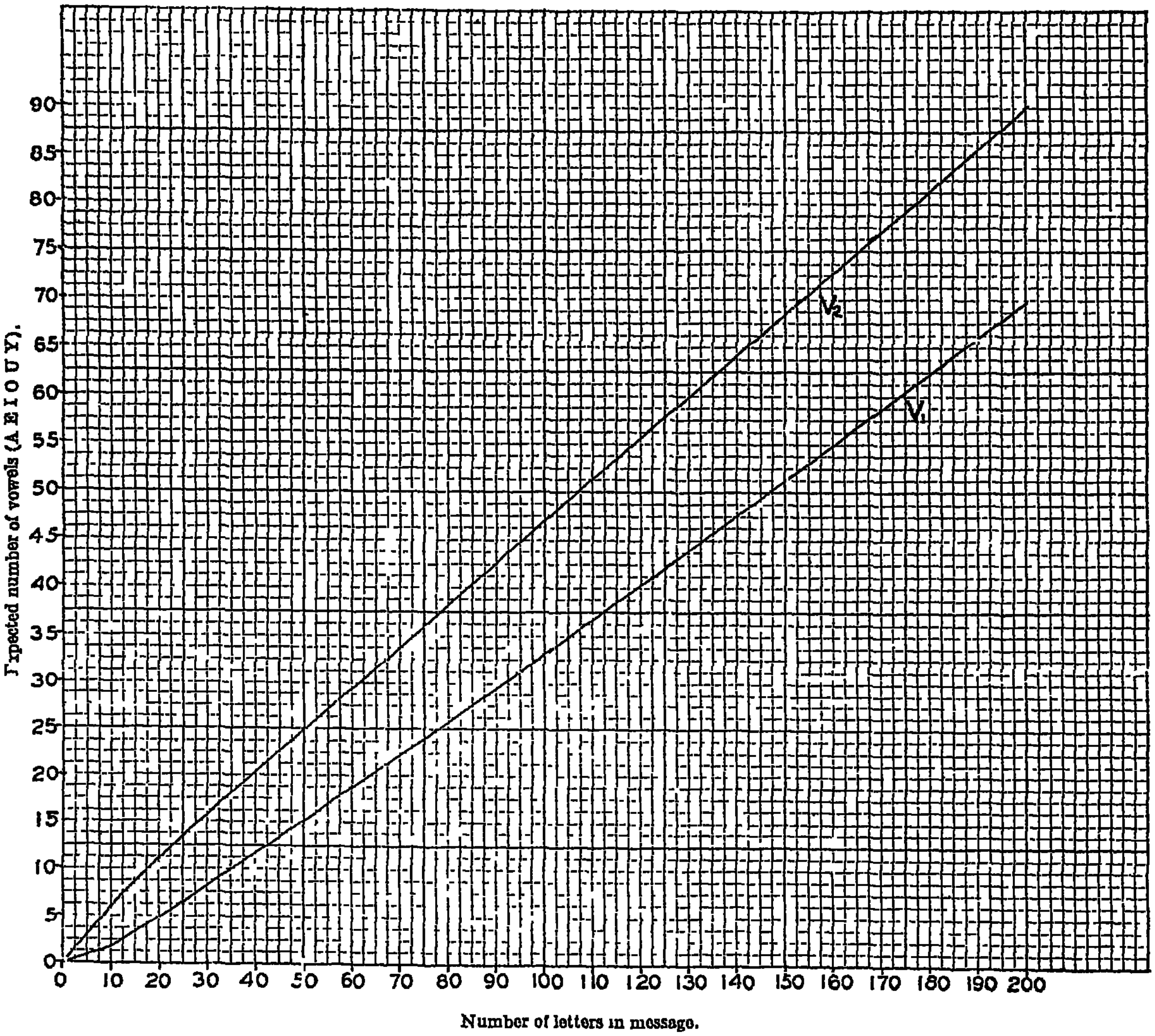


Chart 2. Curves marking the lower and upper limits of the theoretical amount of deviation from the number of vowels theoretically expected in messages of various lengths. (See subpar. 25d.)

tion ciphers. In the former case, his eyes very speedily note many high-frequency letters, such as E, T, N, R, O, and S, with the absence of low-frequency letters, such as J, K, Q, X, and Z; in the latter case, his eyes just as quickly note the presence of many low-frequency letters, and a corresponding absence of some of the high-frequency letters.

g. Another rather quickly completed test, in the case of the simpler varieties of ciphers, is to look for repetitions of groups of letters. As will become apparent very soon, recurrences of syllables, entire words and short phrases constitute a characteristic of all normal plain text. Since a transposition cipher involves a change in the sequence of the letters composing a plaintext message, such recurrences are broken up so that the cipher text no longer will show repetitions of more or less lengthy sequences of letters. But if a cipher message does show many repetitions and these are of several letters in length, say over four or five, the

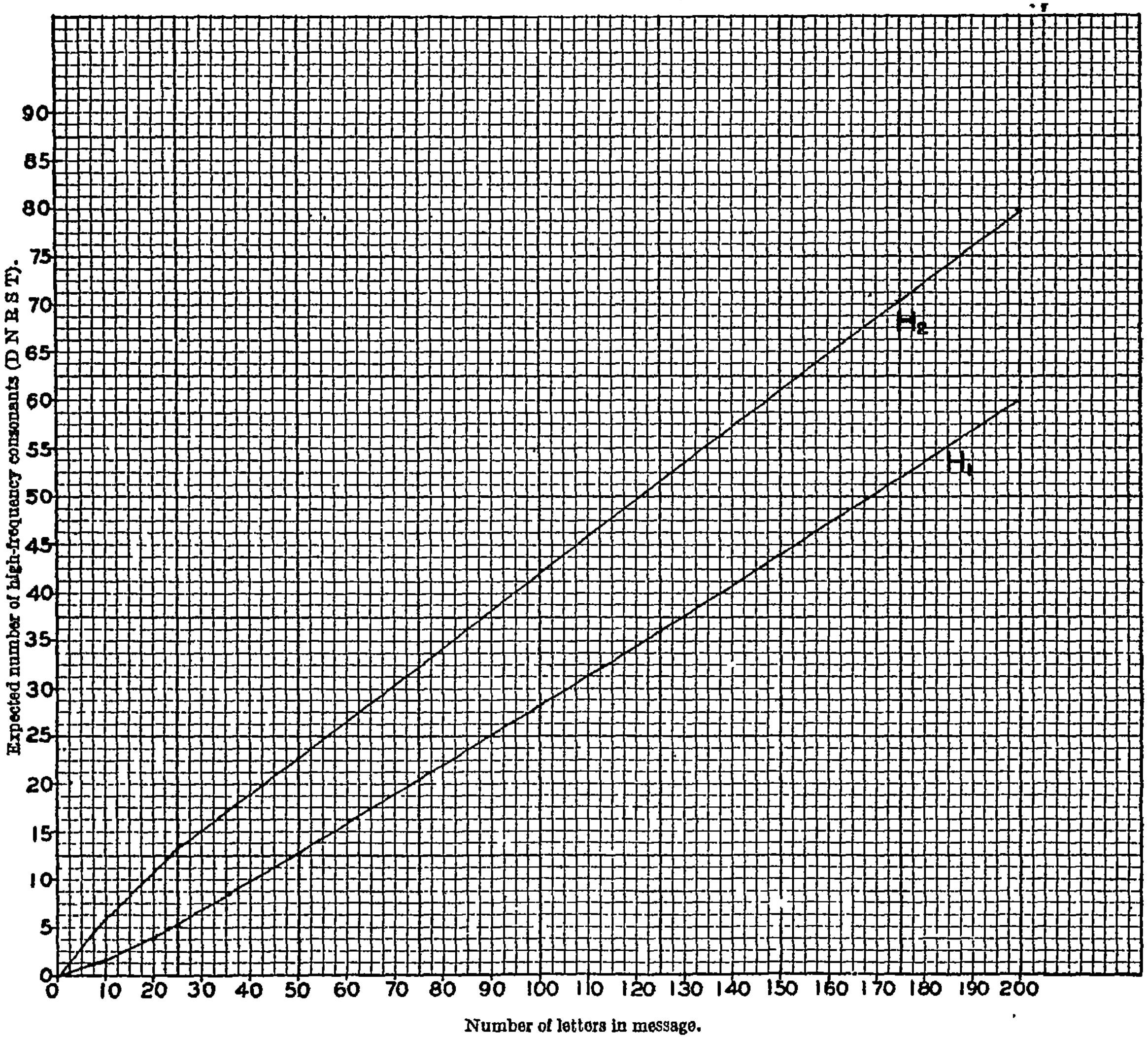


Chart 3. Curves marking the lower and upper limits of the theoretical amount of deviation from the number of high-frequency consonants theoretically expected in messages of various lengths. (See subpar. 25d.)

conclusion is at once warranted that the cryptogram is most probably a substitution and not a tranposition cipher. However, for the beginner in cryptanalysis, it will be advisable to make the uniliteral frequency distribution, and note the frequencies of the vowels and of the high-, medium-, and low-frequency consonants. Then, referring to Charts 2 to 5, he should carefully note whether or not the observed frequencies for these categories of letters fall within the limits of the theoretical frequencies for a normal plaintext message of the same length, and be guided accordingly.

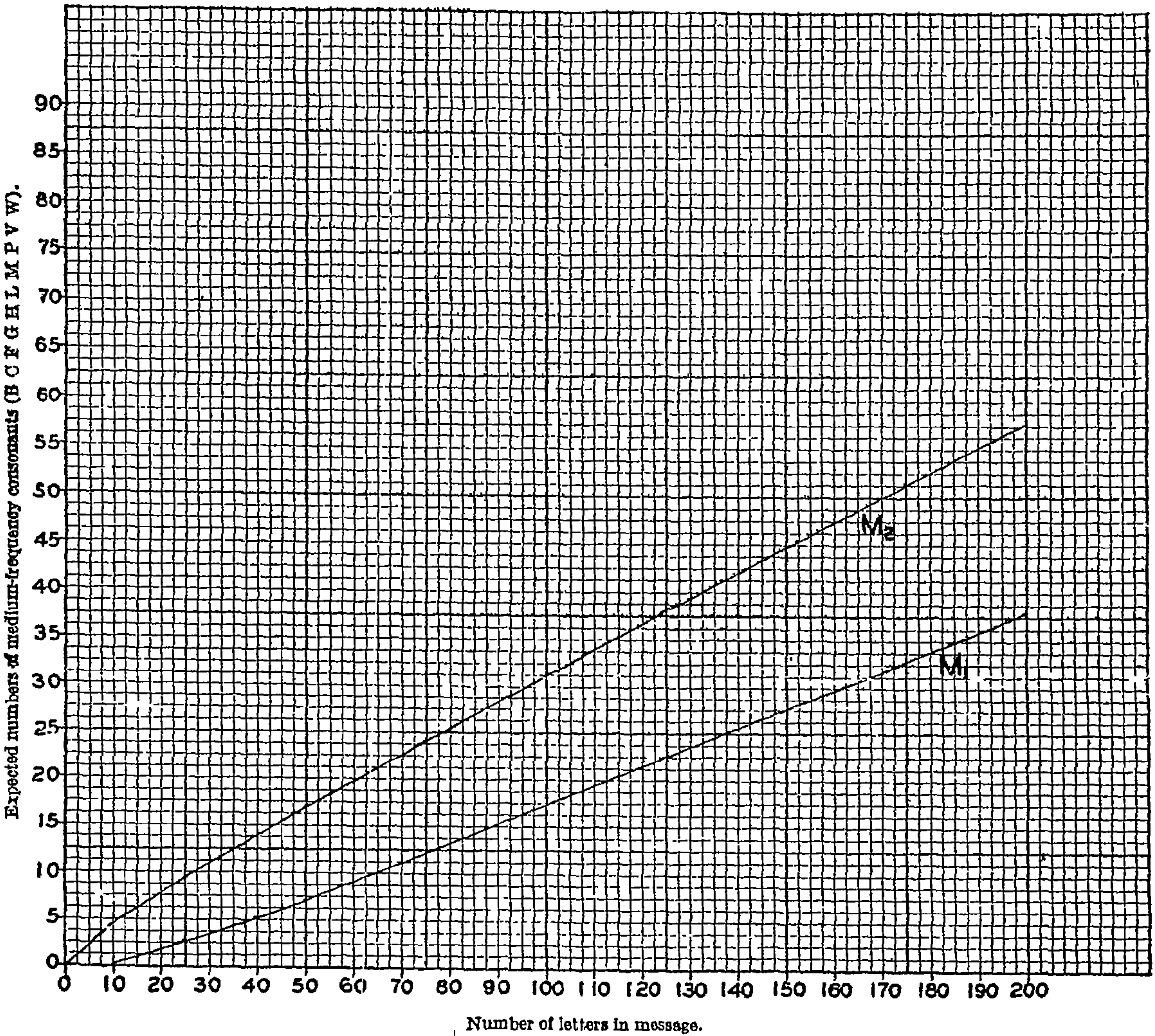


Chart 4. Curves marking the lower and upper limits of the theoretical amount of deviation from the number of medium-frequency consonants theoretically expected in messages of various lengths. (See subpar. 25d.)

h. It is obvious that the foregoing rule applies only to ciphers composed wholly of letters. If a message is composed entirely of figures, or of arbitrary signs and symbols, or of intermixtures of letters, figures and other symbols, it is immediately apparent that the cryptogram is a substitution cipher.

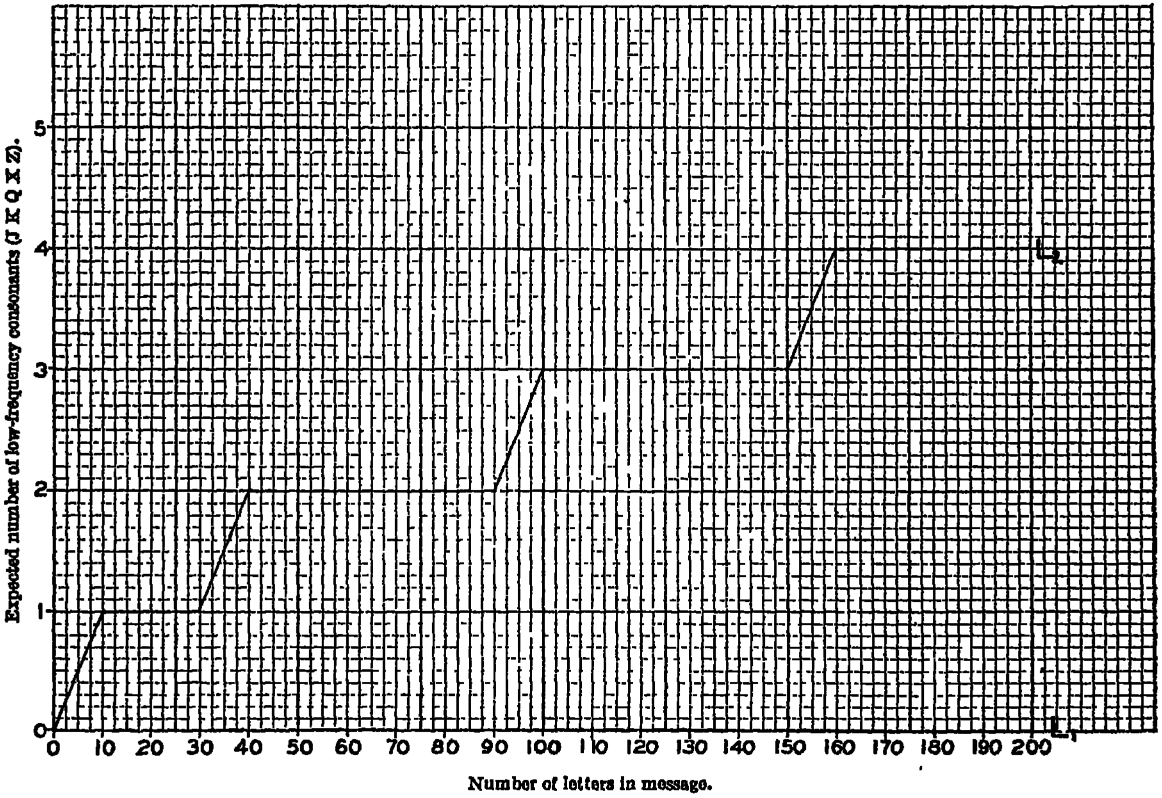


Chart 5. Curves marking the lower and upper limits of the theoretical amount of deviation from the number of low-frequency consonants theoretically expected in messages of various lengths. (See subpar. 25d.)

i. Finally, it should be mentioned that there are certain kinds of cryptograms whose class cannot be determined by the method set forth in subparagraph d above. These exceptions will be discussed in a subsequent section of this text.[12]

[12] Section X.

26. Determining whether a substitution cipher is monoalphabetic or non-monoalphabetic.--a. It will be remembered that a monoalphabetic substitution cipher is one in which a single cipher alphabet is employed throughout the whole message; that is, a given plaintext letter is invariably represented throughout the message by one and the same letter in the cipher text. On the other hand, a polyalphabetic substitution cipher is one in which two or more cipher alphabets are employed within the same message; that is, a given plaintext letter may be represented by two or more different letters in the cipher text, according to some rule governing the selection of the equivalent to be used in each case. From this it follows that a single cipher letter may represent two or more different plaintext letters. A similar situation prevails in the case of multiliteral substitution, in which a particular cipher letter may constitute a part of the equivalents for several plaintext letters, giving rise to phenomena resembling those of polyalphabeticity.

b. It is easy to see why and how the appearance of the uniliteral frequency distribution for a substitution cipher may be used to determine whether the cryptogram is monoalphabetic or non-monoalphabetic in character. The normal distribution presents marked crests and troughs by virtue of two circumstances. First, the elementary sounds which the symbols represent are used with greatly varying frequencies, it being one of the striking characteristics of every alphabetic language that its elementary sounds are used with greatly varying frequencies.[13] In the second place, except for orthographic aberrations peculiar to certain languages (conspicuously, English and French), each such sound is represented by the same symbol. It follows, therefore, that since in a monoalphabetic substitution cipher each different plaintext letter (=elementary sound) is represented by one and only one cipher letter (=elementary symbol), the uniliteral frequency distribution for such a cipher message must also exhibit the irregular crest-and-trough appearance of the normal distribution, but with this important modification--the absolute positions of the crests and troughs will not be the same as in the normal. That is, the letters accompanying the crests and the troughs in the distribution for the cryptogram will be different from those accompanying the crests and the troughs in the normal distribution. But the marked irregularity or "roughness" of the distribution, that is, the presence of accentuated crests and troughs, is in itself an indication that each symbol or cipher letter always represents the same plaintext letter in that cryptogram. Hence the general rule: A marked crest-and-trough appearance in the uniliteral frequency distribution for a given cryptogram indicates that a single cipher alphabet is involved and constitutes one of the tests for a monoalphabetic substitution cipher.

c. On the other hand, suppose that in a cryptogram each cipher letter represents several different plaintext letters. Some of them are of high frequency, others of low frequency. The net result of such a

[13] The student who is interested in this phase of the subject may find the following reference of value: Zipf G.K., Selected Studies of the Principle of Relative Frequency in Language, Cambridge, Mass., 1932.

situation, so far as the uniliteral frequency distribution for the cryptogram is concerned, is to prevent the appearance of any marked crests and troughs and to tend to reduce the elements of the distribution to a more or less common level. This imparts a "flattened out" appearance to the distribution. For example, in a certain cryptogram of polyalphabetic construction, K_c=E_p, G_p, and J_p; R_c=A_p, D_p, and B_p; X_c=O_p, L_p, and F_p. The frequencies of K_c, R_c, and X_c will be approximately equal because the summations of the frequencies of the several plaintext letters each of these cipher letters represents at different times will be about equal. If this same phenomenon were true of all the letters of the cryptogram, it is clear that the frequencies of the 26 letters, when shown by means of the ordinary uniliteral frequency distribution, would show no striking differences and the distribution would have the flat appearance of a typical polyalphabetic substitution cipher. Hence, the general rule: The absence of marked crests and troughs in the uniliteral frequency distribution indicates that a complex form of substitution is involved. The flattened-out appearance of the distribution, then, is one of the criteria for the rejection of a hypothesis of monoalphabetic[14] substitution.

d. The foregoing test based upon the appearance of the frequency distribution is only one of several means of determing whether a substitution cipher is monoalphabetic or non-monoalphabetic in composition. It can be employed in cases yielding frequency distributions from which definite conclusions can be drawn with more or less certainty by mere ocular examination. In those cases in which the frequency distributions contain insufficient data to permit drawing definite conclusions by such examination, certain statistical tests can be applied. One of these tests, called the ϕ (phi) test, warrants detailed treatment and is discussed in paragraph 27 below.

e. At this point, however, one additional test will be given because of its simplicity of application. This test, the Λ (lambda) or blank-expectation test, may be employed in testing messages up to 200 letters in length, it being assumed that in messages of greater length ocular examination of the frequency distribution offers little or no difficulty. This test concerns the number of blanks in the frequency distribution, that is, the number of letters of the alphabet which are entirely absent from the message. It has been found from statistical studies that rather definite "laws" govern the theoretically expected number of blanks in normal plaintext messages and in frequency distributions for cryptograms of different natures and of various sizes. The results of certain of these studies have been embodied in Chart 6.

f. This chart contains two curves. The one labeled P applies to the average number of blanks theoretically expected in frequency distributions based upon normal plaintext messages of the indicated lengths. The other curve, labeled R, applies to the average number of blanks theoretically expected in frequency distributions based upon perfectly random assortments of letters; that is, assortments such as would be found by random

[14] Cf., footnote 8 on page 40.

selection of letters out of a hat containing thousands of letters, all of the 26 letters of the alphabet being present in equal proportions, each letter being replaced after a record of its selection has been made. Such random assortments correspond to polyalphabetic cipher messages in which the number of cipher alphabets is so large that if uniliteral frequency distributions are made of the letters, the distributions are practically identical with those which are obtained by random selections of letters out of a hat.

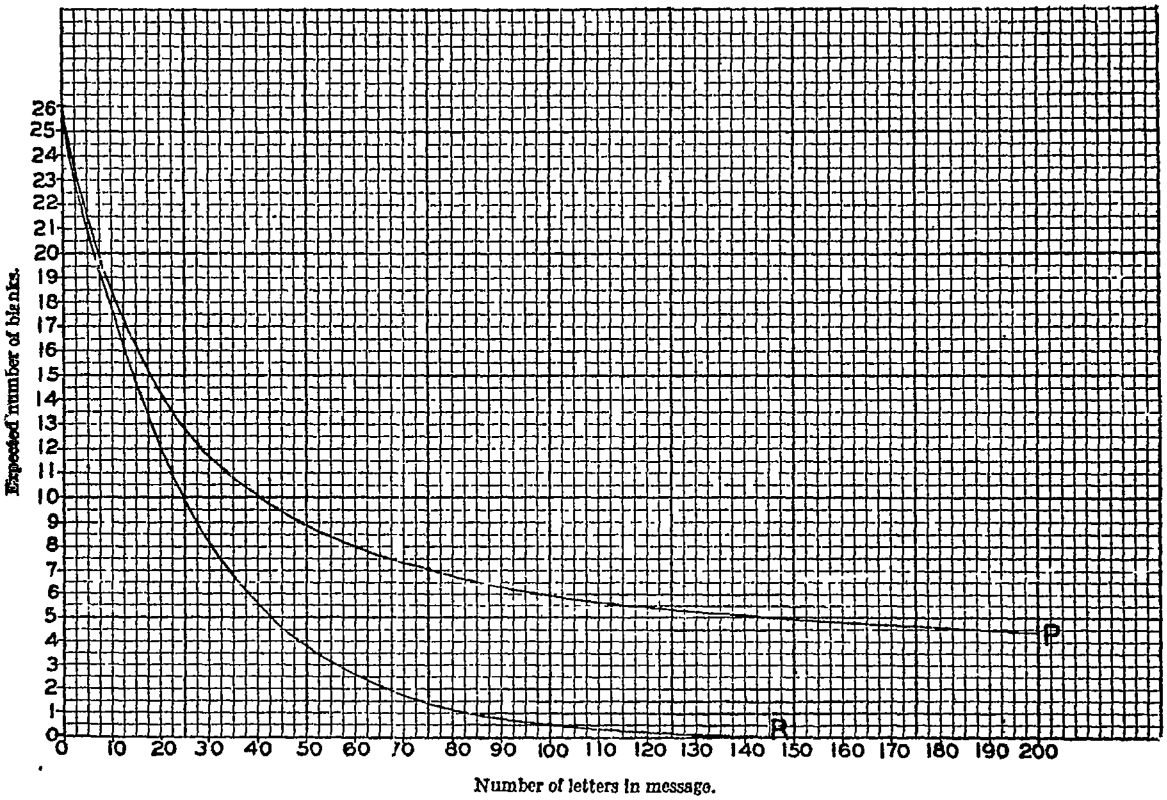


Chart 6. Curves showing the average number of blanks theoretically expected in distributions for plain text (P) and for random text (R) for messages of various lengths. (See subpar. 26f.)

g. In using this chart, one finds the point of intersection of the vertical coordinate corresponding to the length of the message, with the horizontal coordinate corresponding to the observed number of blanks in the distribution for the message. If this point of intersection falls closer to curve P than it does to curve R, the number of blanks in the message approximates or corresponds more closely to the number theoretically expected in a plaintext message than it does to a random (ciphertext) message of the same length; therefore, this is evidence that the cryptogram is monoalphabetic. Conversely, if this point of intersection falls closer to curve R than to curve P, the number of blanks in the message approximates or corresponds more closely to the number theoretically expected in a random text than it does to a plaintext message of the same length; therefore, this is evidence that the cryptogram is non-monoalphabetic.

27. The ϕ (phi) test for determining monoalphabeticity.--a. The student has seen in the preceding paragraph how it is possible to determine by ocular examination whether or not a substitution cipher is monoalphabetic. This tentative determination is based on the presence of a marked crest-and-trough appearance in the uniliteral frequency distribution, and also on the number of blanks in the distribution. However, when the distribution contains a small number of elements, ocular examination and evaluation becomes increasingly difficult and uncertain. In such cases, recourse may be had to a mathematical test, known as the ϕ test, to determine the relative monoalphabeticity or non-monoalphabeticity of a distribution.

b. Without going into the theory of probability at this time, or into the derivation of the formulas involved, let it suffice for the present to state that with this test the "observed value of ϕ" (symbolized by ϕ_o) is compared with the "expected value of ϕ random" (ϕ_r) and the "expected value of ϕ plain" (ϕ_p). The formulas are ϕ_r=.0385N(N-1) and, for English military text, ϕ_p=.0667N(N-1), where N is the total number of elements in the distribution.[15] The use of these formulas is best illustrated by an example.

c. The following short cryptogram with its accompanying uniliteral frequency distribution is at hand:

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QCYCH ADSKS YZZQE CYKYK QZYSK

LSZAC TKFCX LKLKC ESZMX KISZX
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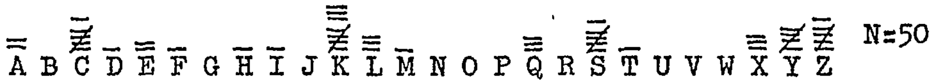

[15] The constant .0385 is the decimal equivalent of 1/26, i.e., the reciprocal of the number of elements in the alphabet. The constant .0667 is the sum of the squares of the probabilities of occurrence of the individual letters in English plain text. These constants are treated in detail in Military Cryptanalysis, Part II.

ϕ_o is calculated by applying the formula f(f-1) to the frequency (f) of each letter and totaling the result; or, expressed in mathematical notation,[16] $\phi_o = \Sigma f(f-1)$. Thus,

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
$\Sigma f =$	2		6	1	2	1		1	1		8	3	1				3		6	1				3	5	6	= 50
$\Sigma f(f-1) =$	2		30	0	2	0		0	0		56	6	0				6		30	0				6	20	30	= 188

For this distribution, $\phi_r = .0385N(N-1) = .0385 \times 50 \times 49 = 94$, and
$\phi_p = .0667N(N-1) = .0667 \times 50 \times 49 = 163$.

Now since ϕ_o, 188, is in fact greater than ϕ_p, we have a mathematical corroboration of the hypothesis that the cryptogram is a monoalphabetic substitution cipher. If ϕ_o were nearer to ϕ_r, then the assumption would be that the cryptogram is not a monoalphabetic cipher. If ϕ_o were just half way between ϕ_r and ϕ_p, then decision would have to be suspended, since no further statistical proof in the matter is possible with this particular test.[17]

d. Two further examples may be illustrated:

	$\bar{A}$	B	C	$\bar{D}$	$\bar{\bar{E}}$	$\bar{\bar{\bar{F}}}$	$\bar{\bar{\bar{\bar{G}}}}$	$\bar{\bar{H}}$	I	J	$\bar{K}$	L	M	N	$\bar{\bar{\bar{\bar{O}}}}$	$\bar{\bar{P}}$	Q	$\bar{R}$	S	T	U	V	W	$\bar{X}$	Y	$\bar{\bar{\bar{Z}}}$	N=25
(1)	0			0	2	6	12	2			0				12	2		0						0		6	$\Sigma f(f-1) = 42$

[16] The more usual mathematical notation for expressing ϕ_o would be $\sum_{i=A}^{Z} f_i(f_i-1)$, which is read as "the sum of all the terms for all integral values of f from A to Z inclusive. In turn, $\sum_{i=A}^{Z} f_i(f_i-1)$ would be expanded as $f_A(f_A-1) + f_B(f_B-1) + f_C(f_C-1) + \ldots + f_Z(f_Z-1)$. However, in the interest of simplicity the notation $\Sigma f(f-1)$ is employed; likewise, the notations ϕ_r and ϕ_p are employed in lieu of the more usual $E(\phi_r)$ and $E(\phi_p)$.

[17] Another method of determining the relative monoalphabeticity of a cryptogram is based upon comparing the <u>index of coincidence</u> (abbr. I.C.) of the cryptogram under examination with the theoretical I.C. of plain text. The I.C. of a message is defined as the ratio of ϕ_o to ϕ_r; thus, in the example above, the I.C. is $\frac{188}{94}$, which equals 2. The theoretical I.C. of English plain text is 1.73, which is the decimal equivalent of $\frac{.0667}{.0385}$, the ratio of the "plain constant" to the "random constant". The I.C. of random text is 1, i.e., $\frac{.0385}{.0385}$.

$$(2)\quad \begin{array}{cccccccccccccccccccccccccc} A & B & \overline{C} & D & E & F & \overline{G} & \overline{H} & \overset{=}{I} & \overline{J} & \overline{K} & \overline{L} & \overset{\equiv}{M} & \overline{N} & \overline{O} & P & \overline{Q} & \overset{=}{R} & S & \overline{T} & \overline{U} & V & \overline{W} & \overline{X} & \overset{=}{Y} & \overset{\equiv}{Z} \\ & & 0 & & & & 0 & 0 & 2 & 0 & 0 & 0 & 6 & 0 & 0 & & 0 & 2 & & 0 & 0 & & 0 & 0 & 2 & 6 \end{array} \begin{array}{l} N=25 \\ \Sigma f(f-1)=18 \end{array}$$

Since both distributions have 25 elements, then for both

$$\phi_r = .0385 \times 25 \times 24 = 21, \text{ and}$$

$$\phi_p = .0667 \times 25 \times 24 = 40.$$

Hence distribution (1) is monoalphabetic, while (2) is not.

e. The student must not assume that statistical tests in cryptanalysis are infallible or absolute in themselves[18]; statistical approaches serve only as a means to the end, in guiding the analyst to the most probably fruitful sources of attack. Since no one test in cryptanalysis gives definite proof of a hypothesis (in fact, not even a battery of tests gives absolute proof), all applicable statistical means at the disposal of the cryptanalyst should be used; thus, in examination for monoalphabeticity, the ϕ test, Λ test, and even other tests[19] could profitably be employed. To illustrate this point, if the ϕ test is taken on the distribution of the plaintext letters of the phrase

A QUICK BROWN FOX JUMPS OVER THE LAZY DOG

$$\begin{array}{cccccccccccccccccccccccccc} \overset{=}{A} & \overline{B} & \overline{C} & \overline{D} & \overset{=}{E} & \overline{F} & \overline{G} & \overline{H} & \overline{I} & \overline{J} & \overline{K} & \overline{L} & \overline{M} & \overline{N} & \overset{\equiv}{\overline{O}} & \overline{P} & \overline{Q} & \overset{=}{R} & \overline{S} & \overline{T} & \overset{=}{U} & \overline{V} & \overline{W} & \overline{X} & \overline{Y} & \overline{Z} \\ 2 & & & & 2 & & & & & & & & & & 12 & & & 2 & & & 2 & & & & & \end{array} \begin{array}{l} N=33 \\ \Sigma f(f-1)=20 \end{array}$$

$$\phi_r = 41; \ \phi_p = 70$$

it will be noticed that ϕ_o is less than half of ϕ_r, thus conclusively "proving" that the letters of this phrase could not possibly constitute plain text nor a monoalphabetic encipherment of plain text in any language! The student should be able to understand the cause of this cryptologic curiosity.

[18] The following quotation from the Indian mathematician P. C. Mahalanobis, concerning the fallibility of statistics, is particularly appropriate in this connection: "If statistical theory is right, predictions must sometimes come out wrong; on the other hand, if predictions are always right, then the statistical theory must be wrong."--Sankhyā, Vol. 10, Part 3, p. 203. Calcutta, 1950.

[19] One of these, the chi-square test, will be treated in a subsequent text.

28. *Determining whether a cipher alphabet is standard (direct or reversed) or mixed.*--*a*. Assuming that the uniliteral frequency distribution for a given cryptogram has been made, and that it shows clearly that the cryptogram is a substitution cipher and is monoalphabetic in character, a consideration of the nature of standard cipher alphabets[20] almost makes it obvious how an inspection of the distribution will disclose whether the cipher alphabet involved is a standard cipher alphabet or a mixed cipher alphabet. If the crests and troughs of the distribution occupy positions which correspond to the *relative* positions they occupy in the normal frequency distribution, then the cipher alphabet is a standard cipher alphabet. If this is not the case, then it is highly probable that the cryptogram has been prepared by the use of a mixed cipher alphabet. A mechanical test may be applied in doubtful cases arising from lack of material available for study; just what this test involves, and an illustration of its application will be given in the next section, using specific examples.

b. Of course, if it has been determined that a standard cipher alphabet is involved in a particular instance, it goes without saying that at the same time it must have been found whether the alphabet is a direct standard or reversed standard cipher alphabet. The difference between the distribution of a direct standard alphabet cipher and one of a reversed standard alphabet cipher is merely a matter of the *direction* in which the sequence of crests and troughs progresses--to the right, as is done in normally reading or writing the alphabet (A B C .→. Z), or to the left, that is, in the reversed direction (Z .←. C B A). With a direct standard cipher alphabet the direction in which the crests and troughs of the distribution progress is the normal direction, from left to right; with a reversed standard cipher alphabet this direction is reversed, from right to left.

[20] See par. 12.

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SECTION V

UNILITERAL SUBSTITUTION WITH STANDARD CIPHER ALPHABETS

29. Types of standard cipher alphabets.--a. Standard cipher alphabets are of two types:

(1) Direct standard, in which the cipher component is the normal sequence but shifted to the right or left of its point of coincidence in the normal alphabet. Example:

```
         ——→
Plain:   ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher:  QRSTUVWXYZABCDEFGHIJKLMNOP
                   ——→
```

It is obvious that the cipher component can be applied to the plain component at any one of 26 points of coincidence, but since the alphabet that results from one of these applications coincides exactly with the normal alphabet, a series of only 25 (direct standard) cipher alphabets results from the shifting of the cipher component.

(2) Reversed standard, in which the cipher component is also the normal sequence but runs in the opposite direction from the normal. Example:

```
         ——→
Plain:   ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher:  QPONMLKJIHGFEDCBAZYXWVUTSR
                   ←——
```

Here the cipher component can be applied to the plain component at any of 26 points of coincidence, each yielding a different cipher alphabet. There is in this case, therefore, a series of 26 (reversed standard) cipher alphabets.

b. It is often convenient to refer to or designate one of a series of cipher alphabets without ambiguity or circumlocution. The usual method is to indicate the particular alphabet to which reference is made by citing a pair of equivalents in that alphabet, such as, in the example above, $A_p=Q_c$. The key for the cipher alphabet just referred to, as well as that preceding it, is $A_p=Q_c$, and it is said that the key letter for the cipher alphabet is Q_c.

c. The cipher alphabet in subpar. a(2), above, is also a reciprocal alphabet; that is, the cipher alphabet contains 13 distinct pairs of equivalents which are reversible. For example, in the alphabet referred to, $A_p=Q_c$ and $Q_p=A_c$; $B_p=P_c$ and $P_p=B_c$, etc. The reciprocity exists throughout the alphabet and is a result of the method by which it was formed. (Reciprocal alphabets may be produced by juxtaposing any two components which are identical but progress in opposite directions.)

30. Procedure in encipherment and decipherment by means of uniliteral substitution.--a. When a message is enciphered by means of uniliteral substitution, or simple substitution (as it is often called), the individual letters of the message text are replaced by the single-letter equivalents taken from the cipher alphabet selected by prearrangement. Example:

Message: EIGHTEEN PRISONERS CAPTURED

Enciphering alphabet: Direct standard, $A_p=T_c$

```
Plain:   ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher:  TUVWXYZABCDEFGHIJKLMNOPQRS
```

Letter-for-letter encipherment:

```
                    EIGHTEEN PRISONERS CAPTURED
                    XBZAMXXG IKBLHGXKL VTIMNKXW
```

The cipher text is then regrouped, for transmission, into groups of five.

Cryptogram:

```
          XBZAM XXGIK BLHGX KLVTI MNKXW
```

b. The procedure in decipherment is merely the reverse of that in encipherment. The cipher alphabet selected by prearrangement is set up with the cipher component arranged in the normal sequence and placed above the plain component for ease in deciphering. The letters of the cryptogram are then replaced by their plaintext equivalents, as shown below.

```
Cipher:  ABCDEFGHIJKLMNOPQRSTUVWXYZ
Plain:   HIJKLMNOPQRSTUVWXYZABCDEFG
```

The message deciphers thus:

```
Cipher:  XBZAM XXGIK BLHGX KLVTI MNKXW
Plain:   EIGHT EENPR ISONE RSCAP TURED
```

The deciphering clerk rewrites the text in word lengths:

```
               EIGHTEEN PRISONERS CAPTURED
```

c. In subpar. a, above, the cryptogram was prepared in final form for transmission by dividing the cryptographic text into groups of five. This is generally the case in military communications involving cipher systems. It promotes accuracy in telegraphic transmission since an operator knows he must receive a definite number of characters in each group, no more and no less. Also, it usually makes solution of the messages by unauthorized persons more difficult because the length of the words, phrases, and sentences of the plain text is hidden. If the last group of the cipher text in subpar. 30a had not been a complete group of five letters, it might have been completed by adding a sufficient number of meaningless letters (called nulls).

31. Principles of solution by construction and analysis of the uniliteral frequency distribution.--a. The analysis of monoalphabetic cryptograms prepared by the use of standard cipher alphabets follows almost directly from a consideration of the nature of such alphabets. Since the cipher component of a standard cipher alphabet consists either of the normal sequence merely displaced 1, 2, 3, . . . intervals from the normal point of coincidence, or of the normal sequence proceeding in a reversed-normal direction, it is obvious that the uniliteral frequency distribution for a cryptogram prepared by means of such a cipher alphabet employed monoalphabetically will show crests and troughs whose relative positions and frequencies will be exactly the same as in the uniliteral frequency distribution for the plain text of that cryptogram. The only thing that has happened is that the whole set of crests and troughs of the distribution has been displaced to the right or left of the position it occupies in the distribution for the plain text; or else the successive elements of the whole set progress in the opposite direction. Hence, it follows that the correct determination of the plaintext value of the cipher letter marking any crest or trough of the uniliteral frequency distribution, coupled with the correct determination of the relative direction in which the plain component sequence progresses, will result at one stroke in the correct determination of the plaintext values of all the remaining 25 letters respectively marking the other crests and troughs in that distribution. The problem thus resolves itself into a matter of selecting that point of attack which will most quickly or most easily lead to the determination of the value of one cipher letter. The single word identification will hereafter be used for the phrase "determination of the value of a cipher letter"; to identify a cipher letter is to find its plaintext value.

b. It is obvious that the easiest point of attack is to assume that the letter marking the crest of greatest frequency in the frequency distribution for the cryptogram represents E_p. Proceeding from this initial point, the identifications of the remaining cipher letters marking the other crests and troughs are tentatively made on the basis that the letters of the cipher component proceed in accordance with the normal alphabetic sequence, either direct or reversed. If the actual frequency of each letter marking a crest or a trough approximates to a fairly close degree the normal or theoretical frequency of the assumed plaintext equivalent, then the initial identification $\Theta_c=E_p$ may be assumed to be correct and therefore the derived identifications of the other cipher letters also may be assumed to be correct.[1] If the original starting point for assignment of plaintext values is not correct, or if the direction of "reading" the successive crests and troughs of the distribution is not correct, then the frequencies of the other 25 cipher letters will not correspond to or even approximate the normal or theoretical frequencies of their hypothetical plaintext equivalents on the basis of the initial identification. A new initial point, that is, a different cipher equivalent, must then be selected to represent E_p; or else the direction of "reading" the crests and troughs must be reversed. This procedure, that is, the attempt to make the actual frequency relations exhibited by the uniliteral frequency distribution for a given cryptogram conform to the theoretical frequency relations of the normal frequency distribution in an effort to solve the cryptogram, is referred to technically as "fitting the actual uniliteral frequency distribution for a cryptogram to the theoretical uniliteral frequency distribution for normal plain text", or, more briefly, as "fitting the frequency distribution for the cryptogram to the normal frequency distribution", or, still more briefly, "fitting the distribution to the normal." In statistical work the expression commonly employed in connection with this process of fitting an actual distribution to a theoretical one is "testing the goodness of fit." The goodness of fit may be stated in various ways, mathematical in character.[2]

c. In fitting the actual distribution to the normal, it is necessary to regard the cipher component (that is, the letters A . . . Z marking the successive crests and troughs of the distribution) as partaking of the nature of a circle, that is, a sequence closing in upon itself, so that no matter with what crest or trough one starts, the spatial and frequency relations of the crests and troughs are constant. This manner of regarding the cipher component as being cyclic in nature is valid because it is obvious that the relative positions and frequencies of the crests and troughs of any uniliteral frequency distribution must remain the same regardless of what letter is employed as the initial point of the distribution. Fig. 5 gives a clear picture of what is meant in this connection, as applied to the normal frequency distribution.

[1] The Greek letter Θ (theta) is used to represent a character or letter without indicating its identity. Thus, instead of the circumlocution "any letter of the plain text", the symbol Θ_p is used; and for the expression "any letter of the cipher text", the symbol Θ_c is used.

[2] One of these tests for expressing the goodness of fit, the χ (chi) test, will be treated in Military Cryptanalysis, Part II.

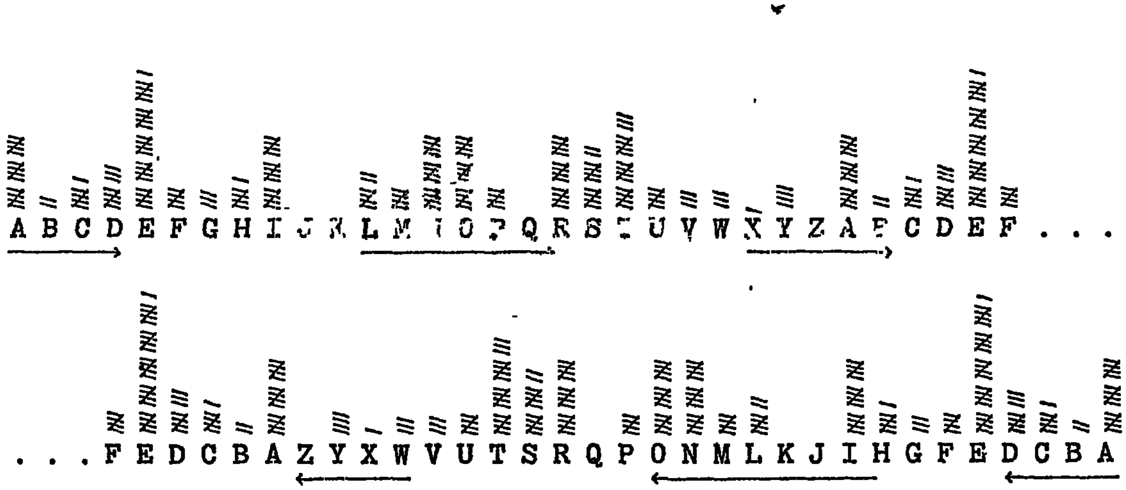


Figure 5.

d. In the third sentence of subparagraph b, the phrase "assumed to be correct" was advisedly employed in describing the results of the attempt to fit the distribution to the normal, because the final test of the goodness of fit in this connection (that is, of the correctness of the assignment of values to the crests and troughs of the distribution) is whether the consistent substitution of the plaintext values of the cipher characters in the cryptogram will yield intelligible plain text. If this is not the case, then no matter how close the approximation between actual and theoretical frequencies is, no matter how well the actual frequency distribution fits the normal, the only possible inferences are that (1) either the closeness of the fit is a pure coincidence in this case and that another equally good fit may be obtained from the same data, or else (2) the cryptogram involves something more than simple monoalphabetic substitution by means of a single standard cipher alphabet. For example, suppose a transposition has been applied in addition to the substitution. Then, although an excellent correspondence between the uniliteral frequency distribution and the normal frequency distribution has been obtained, the substitution of the cipher letters by their assumed equivalents will still not yield plain text. However, aside from such cases of double encipherment, instances in which the uniliteral frequency distribution may be easily fitted to the normal frequency distribution and in which at the same time an attempted simple substitution fails to yield intelligible text are rare. It may be said that, in practical operations whenever the uniliteral frequency distribution can be made to fit the normal frequency distribution, substitution of values will result in solution; and, as a corollary, whenever the uniliteral frequency distribution cannot be made to fit the normal frequency distribution, the cryptogram does not represent a case of simple, monoalphabetic substitution by means of a standard alphabet.

32. Theoretical example of solution.--a. The foregoing principles will become clearer by noting the encryption and solution of a theoretical example. The following message is to be encrypted.

HOSTILE FORCE ESTIMATED AT ONE REGIMENT INFANTRY AND TWO PLATOONS CAVALRY MOVING SOUTH ON QUINNIMONT PIKE STOP HEAD OF COLUMN NEARING ROAD JUNCTION SEVEN THREE SEVEN COMMA EAST OF GREENACRE SCHOOL FIRED UPON BY OUR PATROLS STOP HAVE DESTROYED BRIDGE OVER INDIAN CREEK.

b. First, solely for purposes of demonstrating certain principles, the uniliteral frequency distribution for this plaintext message is presented in Figure 6.

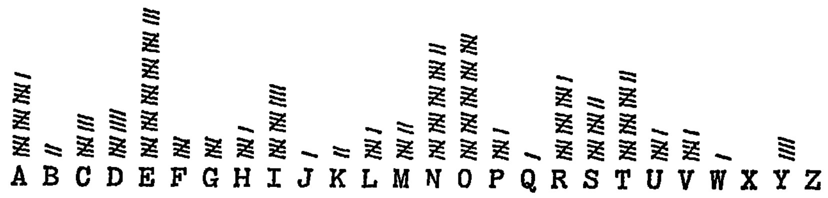


Figure 6.

c. Now let the foregoing message be encrypted monoalphabetically by the following standard cipher alphabet, yielding the cryptogram shown below and the frequency distribution shown in Figure 7.

```
    Plain - - - - A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
    Cipher  - - - G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
```

```
Plain - - - HOSTI LEFOR CEEST IMATE DATON EREGI MENTI NFANT RYAND
Cipher  - - NUYZO RKLUX IKKYZ OSGZK JGZUT KXKMO SKTZO TLGTZ XEGTJ

Plain - - - TWOPL ATOON SCAVA LRYMO VINGS OUTHO NQUIN NIMON TPIKE
Cipher  - - ZCUVR GZUUT YIGBG RXESU BOTMY UAZNU TWAOT TOSUT ZVOQK

Plain - - - STOPH EADOF COLUM NNEAR INGRO ADJUN CTION SEVEN THREE
Cipher  - - YZUVN KGJUL IURAS TTKGX OTMXU GJPAT IZOUT YKBKT ZNXKK

Plain - - - SEVEN COMMA EASTO FGREE NACRE SCHOO LFIRE DUPON BYOUR
Cipher  - - YKBKT IUSSG KGYZU LMXKK TGIXK YINUU RLOXK JAVUT HEUAX

Plain - - - PATRO LSSTO PHAVE DESTR OYEDB RIDGE OVERI NDIAN CREEK
Cipher  - - VGZXU RYYZU VNGBK JKYZX UEKJH XOJMK UBKXO TJOGT IXKKQ
```

Cryptogram

```
N U Y Z O   R K L U X   I K K Y Z   O S G Z K   J G Z U T   K X K M O
S K T Z O   T L G T Z   X E G T J   Z C U V R   G Z U U T   Y I G B G
R X E S U   B O T M Y   U A Z N U   T W A O T   T O S U T   Z V O Q K
Y Z U V N   K G J U L   I U R A S   T T K G X   O T M X U   G J P A T
I Z O U T   Y K B K T   Z N X K K   Y K B K T   I U S S G   K G Y Z U
L M X K K   T G I X K   Y I N U U   R L O X K   J A V U T   H E U A X
V G Z X U   R Y Y Z U   V N G B K   J K Y Z X   U E K J H   X O J M K
U B K X O   T J O G T   I X K K Q
```

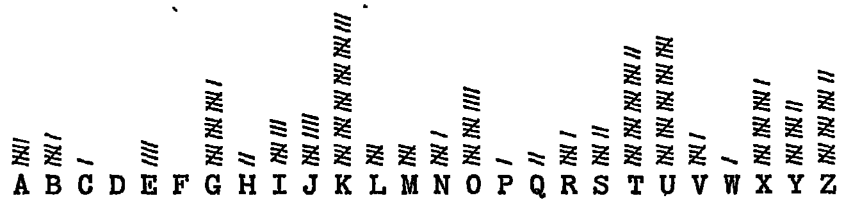


Figure 7.

d. Let the student now compare Figs. 6 and 7, which have been superimposed in Fig. 8 for convenience in examination. Crests and troughs are present in both distributions; moreover their relative positions and frequencies have not been changed in the slightest particular. Only the absolute position of the sequence as a whole has been displaced six places to the right in Fig. 7, as compared with the absolute position of the sequence in Fig. 6.

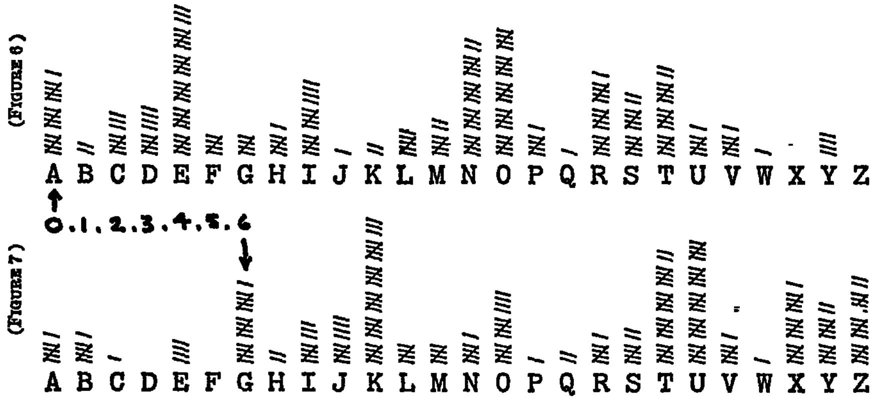


Figure 8.

e. If the two distributions are compared in detail the student will clearly understand how easy the solution of the cryptogram would be to one who knew nothing about how it was prepared. For example, the frequency of the highest crest, representing E_p in Fig. 6 is 28; at an interval of four letters before E_p there is another crest representing A_p with frequency 16. Between A and E there is a trough, representing the medium-frequency letters B, C, D. On the other side of E, at an interval of four letters, comes another crest, representing I with frequency 14. Between E and I there is another trough, representing the medium-frequency letters F, G, H. Compare these crests and troughs with their homologous crests and troughs in Fig. 7. In the latter, the letter K marks the highest crest in the distribution with a frequency of 28; four letters before K there is another crest, frequency 16, and four letters on the other side of K there is another crest, frequency 14. Troughs corresponding to B, C, D and F, G, H are seen at H, I, J and L, M, N in Fig. 7. In fact, the two distributions may be made to coincide exactly, by shifting the frequency distribution for the cryptogram six places to the left with respect to the distribution for the equivalent plaintext message, as shown herewith.

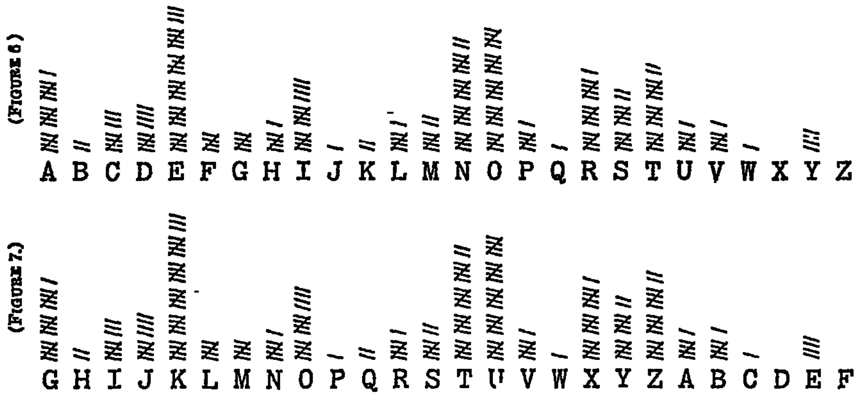


Figure 9.

f. Let us suppose now that nothing is known about the process of encryption, and that only the cryptogram and its uniliteral frequency distribution is at hand. It is clear that simply bearing in mind the spatial relations of the crests and troughs in a normal frequency distribution would enable the cryptanalyst to fit the distribution to the normal in this case. He would naturally first assume that $K_c=E_p$, from which it would follow that if a direct standard alphabet is involved, $L_c=F_p$, $M_c=G_p$, and so on, yielding the following (tentative) deciphering alphabet:

Cipher - - - A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Plain - - - U V W X Y Z A B C D E F G H I J K L M N O P Q R S T

g. Now comes the final test! If these assumed values are substituted in the cipher text, the plain text immediately appears. Thus:

NUYZO RKLUX IKKYZ OSGZK JGZUT etc.
HOSTI LEFOR CEEST IMATE DATON etc.

h. It should be clear, therefore, that the initial selection of G_c as the specific key (that is, to represent A_p) in the process of encryption has absolutely no effect upon the relative spatial and frequency relations of the crests and troughs of the frequency distribution for the cryptogram. If Q_c had been selected to represent A_p, these relations would still remain the same, the whole series of crests and troughs being merely displaced further to the right of the positions they occupy when $G_c=A_p$.

33. Practical example of solution by the frequency method.--a. The case of direct standard alphabet ciphers.--(1) The following cryptogram is to be solved by applying the foregoing principles:

NWNVH CAXXY BJCCJ LTRWP XDAYX BRCRX
WBNJB CXOWN FCXWB CXYYN CHABL XURWO

(2) From the presence of so many low-frequency letters such as B, W, and X it is at once suspected that this is a substitution cipher. But to illustrate the steps that must be taken in difficult cases in order to be certain in this respect, a uniliteral frequency distribution is constructed, and then reference is made to Charts 2 to 5 to note whether the actual numbers of vowels, high-, medium-, and low-frequency consonants fall inside or outside the areas delimited by the respective curves.

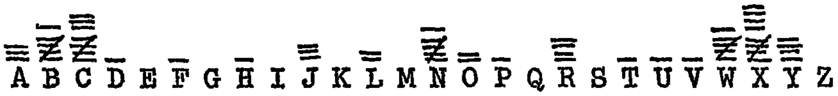


Figure 10 a.

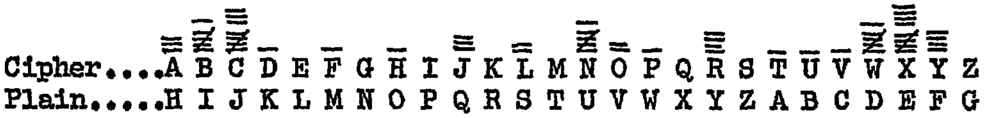
Letters	Frequency	Position with respect to areas delimited by curves
Vowels (A E I O U Y)	10	Outside, chart 1.
High-frequency Consonants (D N R S T)	12	Outside, chart 2.
Medium-frequency Consonants (B C F G H L M P V W)	26	Outside, chart 3.
Low-frequency Consonants (J K Q X Z)	12	Outside, chart 4.
Total	60	

(3) All four points falling completely outside the areas delimited by the curves applicable to these four classes of letters, the cryptogram is clearly a substitution cipher.

(4) The appearance of the frequency distribution, with marked crests and troughs, indicates that the cryptogram is probably monoalphabetic. At this point the ϕ test is applied to the distribution. The observed value of ϕ is found to be 258, while the expected value of ϕ plain and ϕ random are calculated to be 236 and 136, respectively. The fact that the observed value is not only closer to but greater than ϕ_p is taken as statistical evidence that the cryptogram is monoalphabetic. Furthermore, reference being made to Chart 6, the point of intersection of the message length (60 letters) and the number of blanks (8) falls directly on curve P; this is additional evidence that the message is probably monoalphabetic.

(5) The next step is to determine whether a standard or a mixed cipher alphabet is involved. This is done by studying the positions and the sequence of crests and troughs in the frequency distribution, and trying to fit the distribution to the normal.

(6) The first assumption to be made is that a direct standard cipher alphabet is involved. The highest crest in the distribution occurs over X_c. Let it be assumed that X_c=E_p. Then Y_c, Z_c, A_c, ... =F_p, G_p, H_p, ..., respectively; thus:



```
Cipher....A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Plain.....H I J K L M N O P Q R S T U V W X Y Z A B C D E F G
```

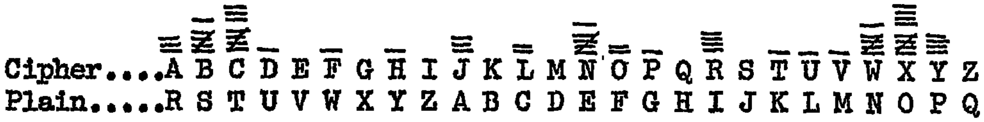
Figure 10b.

It may be seen quickly that the approximation to the expected frequencies is very poor. There are too many occurrences of J_p, Q_p, U_p and F_p and too few occurrences of N_p, O_p, R_p, S_p, T_p and A_p. Moreover, if a substitution is attempted on this basis, the following is obtained for the first two cipher groups:

```
Cipher.....N W N V H   C A X X Y
"Plain text"U D U C O   J H E E F
```

This is certainly not plain text and it seems clear that X_c is not E_p, if the hypothesis of a direct standard alphabet cipher is correct. A different assumption will have to be made.

(7) Suppose C_c=E_p. Going through the same steps as before, again no satisfactory results are obtained. Further trials[3] are made along the same lines, until the assumption N_c=E_p is tested:



```
Cipher....A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Plain.....R S T U V W X Y Z A B C D E F G H I J K L M N O P Q
```

Figure 10c.

(8) The fit in this case is quite good; possibly there are too few occurrences of A_p, D_p, and R_p. But the final test remains: trial of the substitution alphabet on the cryptogram itself. This is done and the results are as follows:

```
C: N W N V H   C A X X Y   B J C C J   L T R W P   X D A Y X   B R C R X
P: E N E M Y   T R O O P   S A T T A   C K I N G   O U R P O   S I T I O

C: W B N J B   C X O W N   F C X W B   C X Y Y N   C N A B L   X U R W O
P: N S E A S   T O F N E   W T O N S   T O P P E   T E R S C   O L I N F
```

ENEMY TROOPS ATTACKING OUR POSITIONS EAST OF NEWTON. PETERS COL INF.

[3] It is unnecessary, of course, to write out all the alphabets and pseudo-decipherments, as shown above, when testing assumptions. This is usually done mentally.

(9) It is always advisable to note the specific key. In this case the correspondence between any plaintext letter and its cipher equivalent will indicate the key. Although other conventions are possible, and equally valid, it is usual, however, to indicate the key by noting the cipher equivalent of A_p. In this case $A_p=J_c$.

b. The case of reversed standard alphabet ciphers.--(1) Let the following cryptogram and its frequency distribution be studied.

```
F W F X L   Q S V V U   R J Q Q J   H Z B W D   V P S U V   R B Q B V
W R F J R   Q V E W F   N Q V W R   Q V U U F   Q F S R H   V Y B W E
```

(2) The preliminary steps illustrated above, under subpar. a (1) to (4) inclusive, in connection with the test for class and monoalphabeticity, will here be omitted, since they are exactly the same in nature. The result is that the cryptogram is obviously a substitution cipher and is monoalphabetic.

(3) Assuming that it is not known whether a direct or a reversed standard alphabet is involved, attempts are at once made to fit the frequency distribution to the normal direct sequence. If the student will try them he will soon find out that these are unsuccessful. All this takes but a few minutes.

(4) The next logical assumption is now made, viz., that the cipher alphabet is a reversed standard alphabet. When on this basis F_c is assumed to be E_p, the distribution can readily be fitted to the normal, practically every crest and trough in the actual distribution corresponding to a crest or trough in the expected distribution.

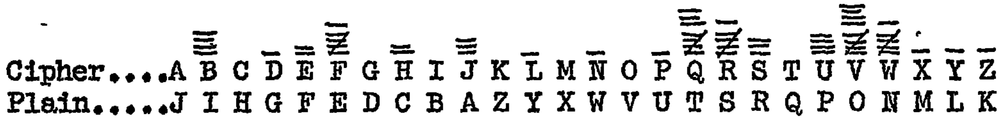


Figure 10d.

(5) When the substitution is made in the cryptogram, the following is obtained.

```
Cryptogram...F W F X L   Q S V V U   R J Q Q J
Plain text...E N E M Y   T R O O P   S A T T A
```

(6) The plaintext message is identical with that in subpar. a. The specific key in this case is also $A_p=J_c$. If the student will compare the frequency distributions in the two cases, he will note that the relative positions and extents of the crests and troughs are identical; they merely progress in opposite directions.

c. General note on solution by the frequency method.--In actual practice, the procedure of subpars. *a* and *b* are given a more rapid treatment than that just described, the practical treatment being based, not on the initial finding of some single crest or trough, but rather on locating the more readily-discernible *clusters* of crests which usually appear in a distribution, such as the distinctive crest-patterns representing "A...E...I" and "RST". These crest-patterns are searched for, with a quick scanning of the distribution, and then the relative placement with respect to each other is tested to see if it conforms to the expectation for a *direct* standard cipher alphabet, and, if not, then for a *reversed standard cipher* alphabet. During this latter step, which consists of little more than counting in one direction and then (when necessary) in the other, the blank (or nearly-blank) expectation of "JK" followed by the characteristic curve for "LMNOP" and the blank "Q" are considered, as a means of either substantiating or invalidating the original "identification" of the crests.

34. Solution by completing the plain-component sequence.--
a. The case of direct standard alphabet ciphers.--(1) The foregoing method of analysis, involving as it does the construction of a uniliteral frequency distribution, was termed a *solution by the frequency method* because it involves the construction of a frequency distribution and its study. There is, however, another method which is much more rapid, almost wholly mechanical, and which, moreover, does not necessitate the construction or study of any frequency distribution whatever. An understanding of the method follows from a consideration of the method of encipherment of a message by the use of a single, direct standard cipher alphabet.

(2) Note the following encipherment:

Message------ TWO CRUISERS SUNK

Enciphering Alphabet

```
Plain----- A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Cipher---- G H I J K L M N O P Q R S T U V W X Y Z A B C D E F
```

Encipherment

```
Plain text------ T W O   C R U I S E R S   S U N K
Cryptogram------ Z C U   I X A O Y K X Y   Y A T Q
```

Cryptogram

```
Z C U I X   A O Y K X   Y Y A T Q
```

(3) The enciphering alphabet shown above represents a case wherein the sequence of letters of both components of the cipher alphabet is the normal sequence, with the sequence forming the cipher component merely shifted six places to the left (or 20 positions to the right) of the position it occupies in the normal alphabet. If, therefore, two strips

of paper bearing the letters of the normal sequence, equally spaced, are regarded as the two components of the cipher alphabet and are juxtaposed at all of the 25 possible points of coincidence, it is obvious that one of these 25 juxtapositions must correspond to the actual juxtaposition shown in the enciphering alphabet directly above.[4] It is equally obvious that if a record were kept of the results obtained by applying the values given at each juxtaposition to the letters of the cryptogram, one of these results would yield the plain text of the cryptogram.

(4) Let the work be systematized and the results set down in an orderly manner for examination. It is obviously unnecessary to juxtapose the two components so that $A_c=A_p$, for on the assumption of a direct standard alphabet, juxtaposing two direct normal components at their normal point of coincidence merely yields plain text. The next possible juxtaposition, therefore, is $A_c=B_p$. Let the juxtaposition of the two sliding strips therefore be $A_c=B_p$, as shown here:

```
Plain------------                          ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher----------- ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJKLMNOPQRSTUVWXYZ
```

The values given by this juxtaposition are substituted for the letters of the cryptogram and the following results are obtained.

```
Cryptogram------------ Z C U I X   A O Y K X   Y Y A T Q
1st Test--"Plain text" A D V J Y   B P Z L Y   Z Z B U R
```

This certainly is not intelligible text; obviously, the two components were not in the position indicated in this first test. The plain component is therefore slid one interval to the left, making $A_c=C_p$, and a second test is made. Thus

```
Plain------------                         ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher----------- ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJKLMNOPQRSTUVWXYZ

Cryptogram------------ Z C U I X   A O Y K X   Y Y A T Q
2d Test---"Plain text" B E W K Z   C Q A M Z   A A C V S
```

Neither does the second test result in disclosing any plain text. But, if the results of the two tests are studied a phenomenon that at first seems quite puzzling comes to light. Thus, suppose the results of the two tests are superimposed in this fashion.

```
Cryptogram------------ Z C U I X   A O Y K X   Y Y A T Q
1st Test--"Plain text" A D V J Y   B P Z L Y   Z Z B U R
2d Test---"Plain text" B E W K Z   C Q A M Z   A A C V S
```

[4] One of the strips should bear the sequence repeated. This permits juxtaposing the two sequences at all 26 possible points of coincidence so as to have a complete cipher alphabet showing at all times.

(5) Note what has happened. The net result of the two experiments was merely to continue the normal sequence begun by the cipher letters at the heads of the columns of letters. It is obvious that if the normal sequence is completed in each column the results will be exactly the same as though the whole set of 25 possible tests had actually been performed. Let the columns therefore be completed, as shown in Fig. 11.

```
 Z C U I X A O Y K X Y Y A T Q
 A D V J Y B P Z L Y Z Z B U R
 B E W K Z C Q A M Z A A C V S
 C F X L A D R B N A B B D W T
 D G Y M B E S C O B C C E X U
 E H Z N C F T D P C D D F Y V
 F I A O D G U E Q D E E G Z W
 G J B P E H V F R E F F H A X
 H K C Q F I W G S F G G I B Y
 I L D R G J X H T G H H J C Z
 J M E S H K Y I U H I I K D A
 K N F T I L Z J V I J J L E B
 L O G U J M A K W J K K M F C
 M P H V K N B L X K L L N G D
 N Q I W L O C M Y L M M O H E
 O R J X M P D N Z M N N P I F
 P S K Y N Q E O A N O O Q J G
 Q T L Z O R F P B O P P R K H
 R U M A P S G Q C P Q Q S L I
 S V N B Q T H R D Q R R T M J
*T W O C R U I S E R S S U N K
 U X P D S V J T F S T T V O L
 V Y Q E T W K U G T U U W P M
 W Z R F U X L V H U V V X Q N
 X A S G V Y M W I V W W Y R O
 Y B T H W Z N X J W X X Z S P
```

Figure 11.

An examination of the successive horizontal lines of the diagram discloses one and only one line of plain text, that marked by the asterisk and reading TWOCRUISERSSUNK.

(6) Since each column in Fig. 11 is nothing but a normal sequence, it is obvious that instead of laboriously writing down these columns of letters every time a cryptogram is to be examined, it would be more convenient to prepare a set of strips each bearing the normal sequence doubled (to permit complete coincidence for an entire alphabet at any setting), and have them available for examining any future cryptograms. In using such a set of sliding strips in order to solve a cryptogram prepared by means of a single direct standard cipher alphabet, or to make a test to determine whether a cryptogram has been so prepared, it is only necessary to "set up" the letters of the cryptogram on the strips, that is, align them in a single row across the strips (by sliding the individual strips

up or down). The successive horizontal lines, called generatrices (singular, generatrix)[5], are then examined in a search for intelligible text. If the cryptogram really belongs to this simple type of cipher, one of the generatrices will exhibit intelligible text all the way across; this text will practically invariably be the plain text of the message. This method of analysis may be termed a solution by completing the plain-component sequence. Sometimes it is referred to as "running down" the sequence. The principle upon which the method is based constitutes one of the cryptanalyst's most valuable tools.[6]

b. The case of reversed standard alphabets.--(1) The method described under subpar. a may also be applied, in slightly modified form, in the case of a cryptogram enciphered by a single reversed standard alphabet. The basic principles are identical in the two cases, as will now be demonstrated.

(2) Let two sliding components be prepared as before, except that in this case one of the components must be a reversed normal sequence, the other, a direct normal sequence.

(3) Let the two components be juxtaposed A to A, as shown below, and then let the resultant values be substituted for the letters of the cryptogram. Thus:

CRYPTOGRAM

N K S E P   M Y O C P   O O M T W

```
Plain-----------                          ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher---------- ZYXWVUTSRQPONMLKJIHGFEDCBAZYXWVUTSRQPONMLKJIHGFEDCBA
   Cryptogram------------ N K S E P   M Y O C P   O O M T W
   1st Test--"Plain text" N Q I W L   O C M Y L   M M O H E
```

(4) This does not yield intelligible text, and therefore the reversed component is slid one space forward and a second test is made. Thus:

```
Plain-----------                         ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher---------- ZYXWVUTSRQPONMLKJIHGFEDCBAZYXWVUTSRQPONMLKJIHGFEDCBA
   Cryptogram------------ N K S E P   M Y O C P   O O M T W
   2d Test---"Plain text" O R J X M   P D N Z M   N N P I F
```

(5) Neither does the second test yield intelligible text. But let the results of the two tests be superimposed. Thus:

```
   Cryptogram------------ N K S E P   M Y O C P   O O M T W
   1st Test--"Plain text" N Q I W L   O C M Y L   M M O H E
   2d Test---"Plain text" O R J X M   P D N Z M   N N P I F
```

[5] Pronounced: jĕn′ẽr-ā-trī′sēz and jĕn′ẽr-ā′triks, respectively.

[6] A set of heavy paper strips, suitable for use in completing the plain-component sequence, has been prepared for use as a training aid in connection with the courses in Military Cryptanalysis.

(6) It is seen that the letters of the "plain text" given by the second trial are merely the continuants of the normal sequences initiated by the letters of the "plain text" given by the first trial. If these sequences are "run down"--that is, completed within the columns--the results must obviously be the same as though successive tests exactly similar to the first two were applied to the cryptogram, using one reversed normal and one direct normal component. If the cryptogram has really been prepared by means of a single reversed standard alphabet, one of the generatrices of the diagram that results from completing the sequences must yield intelligible text.

(7) Let the diagram be made, or better yet, if the student has already at hand the set of sliding strips referred to in footnote 6 to page 69, let him "set up" the letters given by the first trial. Fig. 12 shows the diagram and indicates the plaintext generatrix.

N	K	S	E	P	M	Y	O	C	P	O	O	M	T	W
N	Q	I	W	L	O	C	M	Y	L	M	M	O	H	E
O	R	J	X	M	P	D	N	Z	M	N	N	P	I	F
P	S	K	Y	N	Q	E	O	A	N	O	O	Q	J	G
Q	T	L	Z	O	R	F	P	B	O	P	P	R	K	H
R	U	M	A	P	S	G	Q	C	P	Q	Q	S	L	I
S	V	N	B	Q	T	H	R	D	Q	R	R	T	M	J
*T	W	O	C	R	U	I	S	E	R	S	S	U	N	K
U	X	P	D	S	V	J	T	F	S	T	T	V	O	L
V	Y	Q	E	T	W	K	U	G	T	U	U	W	P	M
W	Z	R	F	U	X	L	V	H	U	V	V	X	Q	N
X	A	S	G	V	Y	M	W	I	V	W	W	Y	R	O
Y	B	T	H	W	Z	N	X	J	W	X	X	Z	S	P
Z	C	U	I	X	A	O	Y	K	X	Y	Y	A	T	Q
A	D	V	J	Y	B	P	Z	L	Y	Z	Z	B	U	R
B	E	W	K	Z	C	Q	A	M	Z	A	A	C	V	S
C	F	X	L	A	D	R	B	N	A	B	B	D	W	T
D	G	Y	M	B	E	S	C	O	B	C	C	E	X	U
E	H	Z	N	C	F	T	D	P	C	D	D	F	Y	V
F	I	A	O	D	G	U	E	Q	D	E	E	G	Z	W
G	J	B	P	E	H	V	F	R	E	F	F	H	A	X
H	K	C	Q	F	I	W	G	S	F	G	G	I	B	Y
I	L	D	R	G	J	X	H	T	G	H	H	J	C	Z
J	M	E	S	H	K	Y	I	U	H	I	I	K	D	A
K	N	F	T	I	L	Z	J	V	I	J	J	L	E	B
L	O	G	U	J	M	A	K	W	J	K	K	M	F	C
M	P	H	V	K	N	B	L	X	K	L	L	N	G	D

Figure 12.

(8) The only difference in procedure between this case and the preceding one (where the cipher alphabet was a direct standard alphabet) is that the letters of the cipher text are first "deciphered" by means of any reversed standard alphabet and then the columns are "run down", according to the normal A B C . . . Z sequence. For reasons which will

become apparent very soon, the first step in this method is technically termed converting the cipher letters into their plain-component equivalents; the second step is the same as before, viz., completing the plain-component sequence.

35. Special remarks on the method of solution by completing the plain-component sequence.--a. The terms employed to designate the steps in the solution set forth in par. 34b(8), viz., "converting the cipher letters into their plain-component equivalents" and "completing the plain-component sequence", accurately describe the process. Their meaning will become more clear as the student progresses with the work. It may be said that whenever the components of a cipher alphabet are known sequences, no matter how they are composed, the difficulty and time required to solve any cryptogram involving the use of those components is considerably reduced. In some cases this knowledge facilitates, and in other cases is the only thing that makes possible, the solution of a very short cryptogram that might otherwise defy solution. Later on an example will be given to illustrate what is meant in this regard.

b. The student should take note, however, of two qualifying expressions that were employed in a preceding paragraph to describe the results of the application of the method. It was stated that "one of the generatrices will exhibit intelligible text all the way across; this text will practically invariably be the plain text." Will there ever be a case in which more than one generatrix will yield intelligible text through its extent? That obviously depends almost entirely on the number of letters that are aligned to form a generatrix. If a generatrix contains but a very few letters, only five, for example, it may happen as a result of pure chance that there will be two or more generatrices showing what might be "intelligible text." Note in Fig. 11, for example, that there are several cases in which 3-letter and 4-letter English words (LAD, COB, MESH, MAPS, etc.) appear on generatrices that are not correct, these words being formed by pure chance. But there is not a single case, in this diagram, of a 5-letter or longer word appearing fortuitously, because obviously the longer the word the smaller the probability of its appearance purely by chance; and the probability that two generatrices of 15 letters each will both yield intelligible text along their entire length is exceedingly remote, so remote, in fact, that in practical cryptology such a case may be considered nonexistent.[7]

c. The student should observe that in reality there is no difference whatsoever in principle between the two methods presented in subpars. a and b of par. 34. In the former the preliminary step of converting the cipher letters into their plain-component equivalents is apparently not present but in reality it is there. The reason for its apparent absence is that in that case the plain component of the cipher alphabet is identical in all respects with the cipher component, so that the cipher letters

[7] A person with patience and an inclination toward the curiosities of the science might construct a text of 15 or more letters which would yield two "intelligible" texts on the plain-component completion diagram.

require no conversion, or, rather, they are identical with the equivalents that would result if they were converted on the basis $A_c=A_p$. In fact, if the solution process had been arbitrarily initiated by converting the cipher letters into their plain-component equivalents at the setting $A_c=O_p$, for example, and the cipher component slid one interval to the right thereafter, the results of the first and second tests of par. 34a would be as follows:

Cryptogram---------------	Z	C	U	I	X	A	O	Y	K	X	Y	Y	A	T	Q
1st Test--"Plain text"---	N	Q	I	W	L	O	C	M	Y	L	M	M	O	H	E
2d Test---"Plain text"---	O	R	J	X	M	P	D	N	Z	M	N	N	P	I	F

Thus, the foregoing diagram duplicates in every particular the diagram resulting from the first two tests under par. 34b: a first line of cipher letters, a second line of letters derived from them but showing externally no relationship with the first line, and a third line derived immediately from the second line by continuing the direct normal sequence. This point is brought to attention only for the purpose of showing that a single, broad principle is the basis of the general method of solution by completing the plain-component sequence, and once the student has this firmly in mind he will have no difficulty whatsoever in realizing when the principle is applicable, what a powerful cryptanalytic tool it can be, and what results he may expect from its application in specific instances.

d. In the two foregoing examples of the application of the principle, the components were normal sequences; but it should be clear to the student, if he has grasped what has been said in the preceding subparagraph, that these components may be mixed sequences which, if known (that is, if the sequence of letters comprising the sequences is known to the cryptanalyst), can be handled just as readily as can components that are normal sequences.

e. It is entirely immaterial at what points the plain and the cipher components are juxtaposed in the preliminary step of converting the cipher letters into their plain-component equivalents. For example, in the case of the reversed alphabet cipher solved in par. 34b, the two components were arbitrarily juxtaposed to give the value $A_p=A_c$, but they might have been juxtaposed at any of the other 25 possible points of coincidence without in any way affecting the final result, viz., the production of one plaintext generatrix in the completion diagram.

36. Value of mechanical solution as a short cut.--a. It is evident that the very first step the student should take in his attempts to solve an unknown cryptogram that is obviously a substitution cipher is to try the mechanical method of solution by completing the plain-component sequence, using the normal alphabet, first direct, then reversed. This takes only a very few minutes and is conclusive in its results. It saves the labor and trouble of constructing a frequency distribution in case the cipher is of this simple type. Later on it will be seen how certain variations of this simple type may also be solved by the application of this method. Thus, a very easy short cut to solution is afforded, which even the experienced cryptanalyst never overlooks in his first attack on an unknown cipher.

b. It is important now to note that if neither of the two foregoing attempts is successful in bringing plain text to light and the cryptogram is quite obviously monoalphabetic in character, the cryptanalyst is warranted in assuming that the cryptogram involves a mixed cipher alphabet.[8]

37. Basic reason for the low degree of cryptosecurity afforded by monoalphabetic cryptograms involving standard cipher alphabets.--The student has seen that the solution of monoalphabetic cryptograms involving standard cipher alphabets is a very easy matter. Two methods of analysis were described, one involving the construction of a frequency distribution, the other not requiring this kind of tabulation, being almost mechanical in nature and correspondingly rapid. In the first of these two methods it was necessary to make a correct assumption as to the value of but one of the 26 letters of the cipher alphabet and the values of the remaining 25 letters at once became known; in the second method it was not necessary to assume a value for even a single cipher letter. The student should understand what constitutes the basis of this situation, viz., the fact that the two components of the cipher alphabet are composed of known sequences. What if one or both of these components are, for the cryptanalyst, unknown sequences? In other words, what difficulties will confront the cryptanalyst if the cipher component of the cipher alphabet is a mixed sequence? Will such an alphabet be solvable as a whole at one stroke, or will it be necessary to solve its values individually? Since the determination of the value of one cipher letter in this case gives no direct clues to the value of any other letter, it would seem that the solution of such a cipher should involve considerably more analysis and experiment than has the solution of either of the two types of ciphers so far examined. The steps to be taken in the cryptanalysis of a mixed-alphabet cipher will be discussed in the next section.

[8] There is but one other possibility, already referred to under subpar. 31d which involves the case where transposition and monoalphabetic substitution processes have been applied in successive steps. This is unusual, however, and will be discussed in its proper place.

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SECTION VI

UNILITERAL SUBSTITUTION WITH MIXED CIPHER ALPHABETS

38. Literal keys and numerical keys.--a. As has been previously mentioned, most cryptosystems involve the use of a specific key to control the steps followed in encrypting or decrypting a specific message (see subpar. 9b). Such a key may be in literal form or in numerical form.

b. It is convenient to designate a key which is composed of letters as a literal key. As already mentioned, a literal key may consist of a single letter, a single word, a phrase, a sentence, a whole paragraph, or even a book; and, of course, it may consist merely of a sequence of letters chosen at random.

c. Certain cryptosystems involve the use of a numerical key, which may consist of a relatively long sequence of numbers difficult or impossible for the average cipher clerk to memorize. Several simple methods for deriving such sequences from words, phrases, or sentences have been devised, and a numerical key produced by any of these methods is called a derived numerical key (as opposed to a key consisting of randomly-selected numbers). One of the commonly-used methods consists of assigning numerical values to the letters of a selected literal key in accordance with their relative positions in the ordinary alphabet, as exemplified in the following subparagraph.

d. Let the prearranged key word be the word LOGISTICS. Since C, the penultimate letter of the key word, appears in the normal alphabet before any other letter of the key word, it is assigned the number 1:

```
L O G I S T I C S
              1
```

The next letter of the normal alphabet that occurs in the key word is G, which is assigned the number 2. The letter I, which occurs twice in the key word, is assigned the number 3 for its first occurrence and the number 4 for its second occurrence; and so on. The final result is:

```
L O G I S T I C S
5 6 2 3 7 9 4 1 8
```

This method of assigning the numbers is very flexible and varies with different uses to which numerical keys are put. It may, of course, be applied to phrases or to sentences, so that a very long numerical key, ordinarly impossible to remember, may be thus derived at will from an easily-remembered key text.

e. As far as the cryptanalyst is concerned, the derivation of a numerical key from a specific literal key is of interest to him because this knowledge may assist in subsequent solutions of cryptograms prepared according to the same basic system, or in identifying the source from which the literal key was selected - perhaps an ordinary book, a magazine, etc. However, it should be pointed out that in some instances the cryptanalyst may be unaware that a literal key has in fact been used as the basis for deriving a numerical key.

39. Types of mixed cipher alphabets.--a. It will be recalled that in a mixed cipher alphabet the sequence of letters or characters in one of the components (usually the cipher component) does not correspond to the normal sequence. There are various methods of composing the sequence of letters or elements of this mixed component, and those which are based upon a scheme that is systematic in its nature are very useful because they make possible the derivation of one or more mixed sequences from any easily-remembered word or phrase, and thus do not necessitate the carrying of written memoranda. Alphabets involving a systematic method of mixing are called systematically-mixed cipher alphabets.

b. One of the simplest types of systematically-mixed cipher alphabets is the keyword-mixed alphabet. The cipher component consists of a key word or phrase (with repeated letters, if present, omitted after their first occurrence)[1], followed by the letters of the alphabet in their normal sequence (with letters already occurring in the key omitted of course). Example, with GOVERNMENT as the key word:

```
Plain:  ABCDEFGHIJKLMNOPQRSTUVWXYZ
Cipher: GOVERNMTABCDFHIJKLPQSUWXYZ
```

c. It is possible to disarrange the sequence constituting the cipher component even more thoroughly by applying a simple method of transposition to the keyword-mixed sequence. Two common methods are illustrated below, using the key word TELEPHONY.

(1) Simple columnar transposition:

```
T E L P H O N Y
A B C D F G I J
K M Q R S U V W
X Z
```

Mixed sequence (formed by transcribing the successive columns from left to right):

TAKXEBMZLCQPDRHFSOGUNIVYJW

(2) Numerically-keyed columnar transposition:

```
7-1-3-6-2-5-4-8
T E L P H O N Y
A B C D F G I J
K M Q R S U V W
X Z
```

Mixed sequence (formed by transcribing the columns in a sequence determined by the numerical key derived from the key word itself):

EBMZHFSLCQNIVOGUPDRTAKXYJW

[1] Mixed alphabets formed by including all repeated letters of the key word or key phrase in the cipher component were common in Edgar Allan Poe's day but are impractical because they are ambiguous, making decipherment difficult; an example:

```
                                      Plain:  ABCDEFGHIJKLMNOPQRSTUVWXYZ
(a) Alphabet for enciphering.--       Cipher: NOWISTHETIMEFORALLGOODMENT

                                      Cipher: ABCDEFGHIJKLMNOPQRSTUVWXYZ
(b) Inverse form of (a),              Plain:  P  VHMSGD  QKAB  OEF  C
      for deciphering.----------                  L   J  RWYN    I
                                                  X         T    Z
                                                            U
```

The average cipher clerk would have considerable difficulty in decrypting a cipher group such as TOOET, each letter of which has three or more equivalents, and from which the plaintext fragments (N)INTH., ..FT THI(S), IT THI..., etc. can be formed on decipherment.

d. The last two systematically-mixed sequences are examples of transposition-mixed sequences. Almost any method of transposition may be used to produce such sequences.

e. Another simple method of forming a mixed sequence is the decimation method. In this method, letters in the normal alphabet, or in a keyword-mixed sequence, are "counted off" according to any selected interval. As each letter is decimated--that is, eliminated from the basic sequence by counting off--it is entered in a separate list to form the new mixed sequence. For example, to form a mixed sequence by this method from a keyword-mixed sequence based on the key phrase SING A SONG OF SIXPENCE with 7 the interval selected, proceed as follows:

Keyword-mixed (or basic) sequence:

SINGAOFXPECBDHJKLMQRTUVWYZ

When the letters are counted off by 7's from left to right, F will be the first letter arrived at, H the second, T the third:

S I N G A O ~~F~~ X P E C B D ~~H~~ J K L M Q R ~~T~~ U V W Y Z

1 2 3 4 5 6 7 1 2 3 4 5 6 7 1 2 3 4 5 6 7

These letters are entered in a separate list (F first, H second, T third, and so on) and eliminated from the keyword-mixed sequence. When the end of the keyword-mixed sequence is reached, return to the beginning, skipping the letters already eliminated:

S ~~I~~ N G A O ~~F~~ X P ~~E~~ C B D ~~H~~ J K L ~~M~~ Q R ~~T~~ U V W Y Z

1 2 3 4 5

6 7 1 2 3 4 5 6 7 1 2 3 4 5 6 7

The decimation-mixed sequence:

FHTIEMZPQNDWCVBSLXAGOKYJRU

f. Practical considerations, of course, set a limit to the complexities that may be introduced in constructing systematically-mixed alphabets. Beyond a certain point there is no object in further mixing. The greatest amount of mixing by systematic processes will give no more security than that resulting from mixing the alphabet by random selection, such as by putting the 26 letters in a box, thoroughly shaking them up, and then drawing the letters out one at a time. Whenever the laws of chance operate in the construction of a mixed alphabet, the probability of producing a thorough disarrangement of letters is very great. Random-mixed alphabets give more cryptographic security than do the less complicated systematically-mixed alphabets, because they afford no clues to positions of letters, given the position of a few of them. Their chief disadvantage is that they must be reduced to writing, since they cannot readily be remembered, nor can they be reproduced at will from an easily-remembered key word.

40. Additional remarks on cipher alphabets.--a. All cipher alphabets may be classified on the basis of their arrangement as enciphering or deciphering alphabets. An enciphering alphabet is one in which the sequence of letters in the plain component coincides with the normal sequence and is arranged in that manner for convenience in encipherment. In a deciphering alphabet the sequence of letters in the cipher component coincides with the normal, for convenience in deciphering. For example, (1), below, shows a mixed cipher alphabet arranged as an enciphering alphabet; (2) shows the corresponding deciphering alphabet. An enciphering alphabet and its corresponding deciphering alphabet present an inverse relationship to each other. To invert a deciphering alphabet is to write the corresponding enciphering alphabet; to invert an enciphering alphabet is to write the corresponding deciphering alphabet.

Enciphering Alphabet

```
(1) Plain:  ABCDEFGHIJKLMNOPQRSTUVWXYZ
    Cipher: JKQVXZWESTRNUIOLGAPHCMYBDF
```

Deciphering Alphabet

```
(2) Cipher: ABCDEFGHIJKLMNOPQRSTUVWXYZ
    Plain:  RXUYHZQTNABPVLOSCKIJMDGEWF
```

b. A series of related reciprocal alphabets may be produced by juxtaposing at all possible points of coincidence two components which are identical but progress in opposite directions. This holds regardless of whether the components are composed of an even or an odd number of elements. The following reciprocal alphabet is one of such a series of 26 alphabets:

```
Plain:  HYDRAULICBEFGJKMNOPQSTVWXZ
Cipher: GFEBCILUARDYHZXWVTSQPONMKJ
```

A single or isolated reciprocal alphabet may be produced in one of two ways:

(1) By constructing a complete reciprocal alphabet by arbitrary or random assignments of values in pairs. That is, if A_p is made the equivalent of K_c, then K_p is made the equivalent of A_c; if B_p is made R_c, then R_p is made B_c, and so on. If the two components thus constructed are slid against each other no additional reciprocal alphabets will be produced.

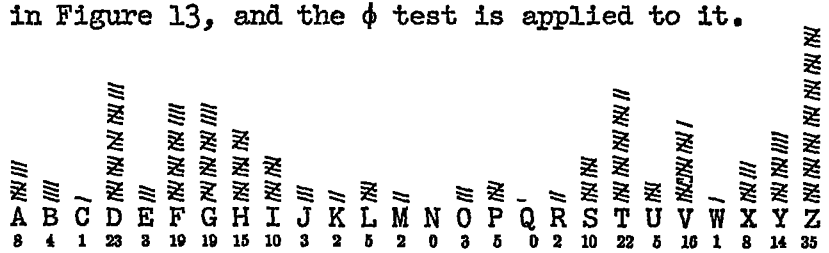
(2) By juxtaposing a sequence comprising an even number of elements against the same sequence shifted exactly half way to the right (or left), as seen below:

```
             ABCDEFGHIJKLMNOPQRSTUVWXYZ
ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJKLMNOPQRSTUVWXYZ
```

41. Preliminary steps in the analysis of a monoalphabetic, mixed-alphabet cryptogram.--a. The student is now ready to resume his cryptanalytic studies. Note the following cryptogram:

SFDZF IOGHL PZFGZ DYSFF HBZDS GVHTF UPLVD FGYVJ VFVHT GADZZ AITYD ZYFZJ
ZTGPT VTZBD VFHTZ DFXSB GIDZY VTXOI YVTEF VMGZZ THLLV XZDFM HTZAI TYDZY
BDVFH TZDFK ZDZZJ SXISG ZYGAV FSLGZ DTHHT CDZRS VTYZD OZFFH TZAIT YDZYG
AVDGZ ZTKHI TYZYS DZGHU ZFZTG UPGDI XWGHX ASRUZ DFUID EGHTV EAGXX

b. A casual inspection of the text discloses the presence of several long repetitions as well as of many letters of normally low frequency, such as F, G, V, X, and Z; on the other hand, letters of normally high frequency, such as the vowels, and the consonants N and R, are relatively scarce. The cryptogram is obviously a substitution cipher and the usual mechanical tests for determining whether it is possibly of the monoalphabetic, standard-alphabet type are applied. The results being negative, a uniliteral frequency distribution is immediately constructed, as shown in Figure 13, and the ϕ test is applied to it.



$\phi_p = 3668$ $\phi_r = 2117$ $\phi_o = 3862$

Figure 13.

c. The fact that the frequency distribution shows very marked crests and troughs indicates that the cryptogram is very probably monoalphabetic, and the results of the ϕ test further support this hypothesis. The fact that the cryptogram has already been tested by the method of completing the plain-component sequence and found not to be of the monoalphabetic, standard-alphabet type, indicates with a high degree of probability that it involves a mixed cipher alphabet. A few moments might be devoted to making a careful inspection of the distribution to insure that it cannot be made to fit the normal; the object of this would be to rule out the possibility that the text resulting from substitution by a standard cipher alphabet had not subsequently been transposed. But this inspection in this case is hardly necessary, in view of the presence of long repetitions in the message.[2] (See subpar. 25g.)

[2] This possible step is mentioned here for the purpose of making it clear that the plain-component sequence completion method cannot solve a case in which transposition has followed or preceded monoalphabetic substitution with standard alphabets. Cases of this kind will be discussed in a later text. It is sufficient to indicate at this point that the frequency distribution for such a combined substitution-transposition cipher would present the characteristics of a standard alphabet cipher and yet the method of completing the plain-component sequence would fail to bring out any plain text.

d. One might, of course, attempt to solve the cryptogram by applying the simple principles of frequency. One might, in other words, assume that Z_c (the letter of greatest frequency) represents E_p, D_c (the letter of next greatest frequency) represents T_p, and so on. If the message were long enough this simple procedure might more or less quickly give the solution. But the message is relatively short and many difficulties would be encountered. Much time and effort would be expended unnecessarily, because it is hardly to be expected that in a message of only 235 letters the relative order of frequency of the various cipher letters should exactly coincide with, or even closely approximate the relative order of frequency of letters of normal plain text found in a count of 50,000 letters. It is to be emphasized that the beginner must repress the natural tendency to place too much confidence in the generalized principles of frequency and to rely too much upon them. It is far better to bring into effective use certain other data concerning normal plain text, such as digraphic and trigraphic frequencies.

42. Preparation of the work sheet.--a. The details to be considered in this paragraph may at first appear to be superfluous, but long experience has proved that systematization of the work and preparation of the data in the most utilizable, condensed form is most advisable, even if this seems to take considerable time. In the first place, if it merely serves to avoid interruptions and irritations occasioned by failure to have the data in an instantly available form, it will pay by saving mental wear and tear. In the second place, especially in the case of complicated cryptograms, painstaking care in these details, while it may not always bring about success, is often the factor that is of greatest assistance in ultimate solution. The detailed preparation of the data may be irksome to the student, and he may be tempted to avoid as much of it as possible, but, unfortunately, in the early stages of solving a cryptogram he does not know (nor, for that matter, does the expert always know) just which data are essential and which may be neglected. Even though not all of the data may turn out to have been necessary, as a general rule, time is saved in the end if all the usual data are prepared as a regular preliminary to the solution of most cryptograms.

b. First, the cryptogram is recopied in the form of a work sheet. This sheet should be of a good quality of paper so as to withstand considerable erasure. If the cryptogram is to be copied by hand, cross-section paper of $\frac{1}{4}$-inch squares is extremely useful. The writing should be in ink, and plain, carefully-made roman capital letters should be used in all cases.[3] If the cryptogram is to be copied on a typewriter, the ribbon employed should be impregnated with an ink that will not smear or smudge under the hand.

[3] It is advisable to use, for this purpose, the system of standardized manual printing adopted by Service communications personnel. The use of this system, which is included in Appendix 7, assures that work sheets are completely legible, not only to the person preparing them, but to others as well.

c. The arrangement of the characters of the cryptogram on the work sheet is a matter of considerable importance. If the cryptogram as first obtained is in groups of regular length (usually five characters to a group) and if the uniliteral frequency distribution shows the cryptogram to be monoalphabetic, the characters should be copied without regard to this grouping. It is advisable to allow one space between letters (this is especially true for work sheets prepared on the typewriter), and to write a constant number of letters per line, approximately 25. At least two spaces, preferably three spaces, should be left between horizontal lines, to allow room for multiple assumptions. Care should be taken to avoid crowding the letters in any case, for this is not only confusing to the eye but also mentally irritating when later it is found that not enough space has been left for making various sorts of marks or indications. If the cryptogram is originally in what appears to be word lengths (and this is the case, as a rule, only with the cryptograms of amateurs), naturally it should be copied on the work sheet in the original groupings.[4] If further study of a cryptogram shows that some special grouping is required, it is often best to recopy it on a fresh work sheet rather than to attempt to indicate the new grouping on the old work sheet.

d. In order to be able to locate or refer to specific letters or groups of letters with speed, certainty, and without possibility of confusion, it is advisable to use coordinates applied to the lines and columns of the text as it appears on the work sheet. To minimize possibility of confusion, it is best to apply letters to the horizontal lines of the text, numbers to the vertical columns. In referring to a letter, the horizontal line in which the letter is located is usually given first. Thus, referring to the work sheet shown below, coordinates A17 designate the letter Y, the 17th letter in the first line. The letter I is usually omitted from the series of line indicators so as to avoid confusion with the figure 1. If lines are limited to 25 letters each, then each set of 100 letters of the text is automatically blocked off by remembering that 4 lines constitute 100 letters.

e. Above each character of the cipher text may be some indication of the frequency of that character in the whole cryptogram. This indication may be the actual number of times the character occurs, or, if colored pencils are used, the cipher letters may be divided up into three categories or groups--high-frequency, medium-frequency, and low-frequency. It is perhaps simpler, if clerical help is available, to indicate the actual frequencies. This saves constant reference to the frequency tables, which interrupts the train of thought, and saves considerable time in the end, since it enables the student better to visualize frequency-patterns of words. In any case, it is recommended that the frequencies of the letters comprising the repetitions be inscribed over their

[4] In some cryptosystems, certain low-frequency letters are employed as word separators to indicate the end of a word; if the meaning of these letters is discovered, it is tantamount to having the cryptogram in word lengths and thus the work sheet is made accordingly. See also in this connection the treatment on word separators in Section VII.

respective letters; likewise, the frequencies of the first 10 and last 10 letters should also be inscribed, as these positions often lend themselves readily to attack.[5]

f. After the special frequency distribution, explained in Par. 43 below, has been constructed, repetitions of digraphs and trigraphs should be underscored. In so doing, the student should be particularly watchful for trigraphic repetitions which can be further extended into tetragraphs and polygraphs of greater length. Repetitions of more than ten characters should be set off by heavy vertical lines, as they indicate repeated phrases and are of considerable assistance in solution. If a repetition continues from one line to the next, put an arrow at the end of the underscore to signal this fact. Reversible digraphs and trigraphs should also be indicated by an underscore with an arrow pointing in both directions. Anything which strikes the eye as being peculiar, unusual, or significant as regards the distribution or recurrence of the characters should be noted. All these marks should, if convenient, be made with ink so as not to cause smudging. The work sheet will now appear as shown below (not all the repetitions are underscored):

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	10	19	23	35	19	10	3	19	15	5	5	35	19	19	35	23	14	10	5	19	15	4	35	23	10
	S	F	D	Z	F	I	O	G	H	L	P	Z	F	G	Z	D	Y	S	P	F	H	B	Z	D	S
B	19	16	15	22	19	5	5	5	16	23	19	19	14	16	3	16	19	16	15	22	19	8	23	35	35
	G	V	H	T	F	U	P	L	V	D	F	G	Y	V	J	V	F	V	H	T	G	A	D	Z	Z
C	8	10	22	14	23	35	14	19	35	3	35	22	19	5	22	16	22	35	4	23	16	19	15	22	35
	A	I	T	Y	D	Z	Y	F	Z	J	Z	T	G	P	T	V	T	Z	B	D	V	F	H	T	Z
D	23	19	8	10	4	19	10	23	35	14	16	22	8	3	10	14	16	22	3	19	16	2	19	35	35
	D	F	X	S	B	G	I	D	Z	Y	V	T	X	O	I	Y	V	T	E	F	V	M	G	Z	Z
E	22	15	5	5	16	8	35	23	19	2	15	22	35	8	10	22	14	23	35	14	4	23	16	19	15
	T	H	L	L	V	X	Z	D	F	M	H	T	Z	A	I	T	Y	D	Z	Y	B	D	V	F	H
F	22	35	23	19	2	35	23	35	35	3	10	8	10	10	19	35	14	19	8	16	19	10	5	19	35
	T	Z	D	F	K	Z	D	Z	Z	J	S	X	I	S	G	Z	Y	G	A	V	F	S	L	G	Z
G	23	22	15	15	22	1	23	35	2	10	16	22	14	35	23	8	35	19	19	15	22	35	8	10	22
	D	T	H	H	T	C	D	Z	R	S	V	T	Y	Z	D	O	Z	F	F	H	T	Z	A	I	T
H	14	23	35	14	19	8	16	23	19	35	35	22	2	15	10	22	14	35	14	10	23	35	19	15	5
	Y	D	Z	Y	G	A	V	D	G	Z	Z	T	K	H	I	T	Y	Z	Y	S	D	Z	G	H	U
J	35	19	35	22	19	5	5	19	23	10	8	1	19	15	8	8	10	2	5	35	23	19	5	10	23
	Z	F	Z	T	G	U	P	G	D	I	X	W	G	H	X	A	S	R	U	Z	D	F	U	I	D
K	3	19	15	22	16	3	8	19	8	8															
	E	G	H	T	V	E	A	G	X	X															

[5] See Appendix 4 in this connection.

43. Triliteral frequency distributions.--a. In what has gone before, a type of frequency distribution known as a uniliteral frequency distribution was used. This, of course, shows only the number of times each individual letter occurs. In order to apply the normal digraphic and trigraphic frequency data (given in Appendix 2) to the solution of a cryptogram of the type now being studied, it is obvious that the data with respect to digraphs and trigraphs occurring in the cryptogram should be compiled and should be compared with the data for normal plain text. In order to accomplish this in suitable manner, it is advisable to construct a more comprehensive form of distribution termed a triliteral frequency distribution.[6]

b. Given a cryptogram of 50 or more letters and the task of determining what trigraphs are present in the cryptogram, there are three ways in which the data may be arranged or assembled. One may require that the data show (1) each letter with its two succeeding letters; (2) each letter with its two preceding letters; (3) each letter with one preceding letter and one succeeding letter.

c. A distribution of the first of the three foregoing types may be designated as a "triliteral frequency distribution showing two suffixes"; the second type may be designated as a "triliteral frequency distribution showing two prefixes"; the third type may be designated as a "triliteral frequency distribution showing one prefix and one suffix." Quadriliteral and pentaliteral frequency distributions may occasionally be found useful.

d. Which of these three arrangements is to be employed at a specific time depends largely upon what the data are intended to show. For present purposes, in connection with the solution of a monoalphabetic substitution cipher employing a mixed alphabet, possibly the third arrangement, that showing one prefix and one suffix, is most satisfactory.

e. It is convenient to use $\frac{1}{4}$-inch cross-section paper for the construction of a triliteral frequency distribution in the form of a distribution showing crests and troughs, such as that in Figure 14. In that figure the prefix to each letter to be recorded is inserted in the left half of the cell directly above the cipher letter being recorded; the suffix to each letter is inserted in the right half of the cell directly above the letter being recorded; and in each case the prefix and the suffix to the letter being recorded occupy the same cell, the prefix being directly to the left of the suffix. The number in parentheses gives the total frequency for each letter.

[6] It is felt advisable here to distinguish between two closely related terms. A triliteral distribution of A B C D E F would consider the groups A B C, B C D, C D E, D E F; a trigraphic distribution would consider only the trigraphs A B C and D E F. (See also subpar. 23d.)

CONDENSED TABLE OF REPETITIONS

Digraphs			*Trigraphs*		*Longer Polygraphs*
DZ–9	TZ–5	VF–4	DZY–4	FHT–3	HTZAITYDZY–2
ZD–9	TY–5	VT–4	HTZ–4	TYD–3	BDVFHTZDF–2
HT–8	FH–4	ZF–4	ITY–4	YDZ–3	ZAITYDZY–3
ZY–6	GH–4	ZT–4	ZDF–4	ZAI–3	FHTZ–3
DF–5	IT–4	ZZ–4	AIT–3		
GZ–5					

																									UD
																									FT
																									UF
																									DG
																									YY
																									ZT
																									GZ
																									DY
																									TA
																									OF
																									YD
																									DR
			IE																						GD
			ZF																HV						GY
			GI																ZG						ZJ
			SZ																IY						DZ
			VG		DU	AX													ZK						KD
			YZ		ZZ	EH													IY						TD
			ZO		FH	WH													HZ						DY
			CZ		ZF	PD													VY		TE				TA
			ZT		VS	TU	GT												HC		AD				XD
			ZZ		DK	ZH	GX												DH		ST			ZS	ZT
			ZF		VH	DZ	GU												HZ		AF			TZ	GZ
			BV		DM	YA	KI												IY		DF			ZG	DY
			YZ		EV	LZ	FT												HZ		LX			TD	TD
			ZF		DX	YA	HT	UD										AR	ZH		FM			TZ	TB
			IZ		VH	SZ	TH	DX										YD	VE		YT			ZG	JT
EG			ZF		YZ	MZ	FT	HT										RV	VX		YT		X–	ZB	FJ
XS			BV		VV	BI	MT	AT										FL	HZ		DF		GX	TD	DY
GV			YZ		DG	TP	TL	XS										IG	VZ		TT		HA	IV	ZA
ZI			AZ		TU	TA	FT	AT			SG				UG			JX	PV	FI	FH		IW	ZV	DZ
GV	YD		VF		PH	FY	VT	OY			LV				GT			XB	ZG	RZ	JF		SI	ZF	BD
ZI	SG		ZS	VA	ZG	SV	VT	GD	ZS		HL			DZ	UL			DG	IY	GP	YJ		VZ	TD	GD
ZI	ZD		ZY	DG	ZI	FZ	FB	AT	ZZ	TH	PV	FH		XI	SF		SU	YP	HG	HZ	LD		TO	GV	PF
GD	HZ	TD	FZ	TF	SD	OH	GL	FO	VV	FZ	HP	VG		IG	LZ		ZS	–F	HF	FP	GH	XG	FS	DS	DF
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
(8)	(4)	(1)	(23)	(3)	(19)	(19)	(15)	(10)	(3)	(2)	(5)	(2)	(0)	(3)	(5)	(0)	(2)	(10)	(22)	(5)	(16)	(1)	(8)	(14)	(35)

FIGURE 14.

f. The triliteral frequency distribution is now to be examined with a view to ascertaining what digraphs and trigraphs occur two or more times in the cryptogram. Consider the pair of columns containing the prefixes and suffixes to D_c in the distribution, as shown in Fig. 14. This pair of columns shows that the following digraphs appear in the cryptogram:

Digraphs based on prefixes (arranged as one reads up the column)

FD, ZD, ZD, VD, AD, YD, BD,
ZD, ID, ZD, YD, BD, ZD, ZD,
ZD, CD, ZD, YD, VD, SD, GD,
ZD, ID

Digraphs based on suffixes (arranged as one reads up the column)

DZ, DY, DS, DF, DZ, DZ, DV,
DF, DZ, DF, DZ, DV, DF, DZ,
DT, DZ, DO, DZ, DG, DZ, DI,
DF, DE

The nature of the triliteral frequency distribution is such that in finding what digraphs are present in the cryptogram it is immaterial whether the prefixes or the suffixes to the cipher letters are studied, so long as one is consistent in the study. For example, in the foregoing list of digraphs based on the prefixes to D_c, the digraphs FD, ZD, ZD, VD, etc., are found; if now, the student will refer to the suffixes of F_c, Z_c, V_c, etc., he will find the very same digraphs indicated. This being the case, the question may be raised as to what value there is in listing both the prefixes and the suffixes to the cipher letters. The answer is that by so doing the trigraphs are indicated at the same time. For example, in the case of D_c, the following trigraphs are indicated:

FDZ, ZDY, ZDS, VDF, ADZ, YDZ, BDV, ZDF, IDZ, ZDF, YDZ, BDV, ZDF,
ZDZ, ZDT, CDZ, ZDO, YDZ, VDG, SDZ, GDI, ZDF, IDE.

g. The repeated digraphs and trigraphs can now be found quite readily. Thus, in the case of D_c, examining the list of digraphs based on suffixes, the following repetitions are noted:

DZ appears 9 times; DF appears 5 times; DV appears 2 times

Examining the trigraphs with D_c as central letter, the following repetitions are noted:

ZDF appears 4 times; YDZ appears 3 times; BDV appears 2 times

h. It is unnecessary, of course, to go through the detailed procedure set forth in the preceding subparagraphs in order to find all the repeated digraphs and trigraphs. The repeated trigraphs with D_c as central letter can be found merely from an inspection of the prefixes and suffixes opposite D_c in the distribution. It is necessary only to find those cases in which two or more prefixes are identical at the same time that the suffixes are identical. For example, the distribution shows at once that in four cases the prefix to D_c is Z_c at the same time that the suffix to this letter is F_c. Hence, the trigraph ZDF appears four times. The repeated trigraphs may all be found in this manner.

CONDENSED TABLE OF REPETITIONS

Digraphs			*Trigraphs*		*Longer Polygraphs*
DZ–9	TZ–5	VF–4	DZY–4	FHT–3	HTZAITYDZY–2
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HT–8	FH–4	ZF–4	ITY–4	YDZ–3	ZAITYDZY–3
ZY–6	GH–4	ZT–4	ZDF–4	ZAI–3	FHTZ–3
DF–5	IT–4	ZZ–4	AIT–3		
GZ–5					

																									UD
																									FT
																									UF
																									DG
																									YY
																									ZT
																									GZ
																									DY
																									TA
																									OF
																									YD
																									DR
			IE																						GD
			ZF																HV						GY
			GI																ZG						ZJ
			SZ																IY						DZ
			VG		DU	AX													ZK						KD
			YZ		ZZ	EH													IY						TD
			ZO		FH	WH													HZ						DY
			CZ		ZF	PD													VY		TE				TA
			ZT		VS	TU	GT												HC		AD				XD
			ZZ		DK	ZH	GX												DH		ST			ZS	ZT
			ZF		VH	DZ	GU												HZ		AF			TZ	GZ
			BV		DM	YA	KI												IY		DF			ZG	DY
			YZ		EV	LZ	FT												HZ		LX			TD	TD
			ZF		DX	YA	HT	UD										AR	ZH		FM			TZ	TB
			IZ		VH	SZ	TH	DX										YD	VE		YT			ZG	JT
EG			ZF		YZ	MZ	FT	HT										RV	VX		YT		X–	ZB	FJ
XS			BV		VV	BI	MT	AT										FL	HZ		DF		GX	TD	DY
GV			YZ		DG	TP	TL	XS										IG	VZ		TT		HA	IV	ZA
ZI			AZ		TU	TA	FT	AT			SG				UG			JX	PV	FI	FH		IW	ZV	DZ
GV	YD		VF		PH	FY	VT	OY			LV				GT			XB	ZG	RZ	JF		SI	ZF	BD
ZI	SG		ZS	VA	ZG	SV	VT	GD	ZS		HL			DZ	UL			DG	IY	GP	YJ		VZ	TD	GD
ZI	ZD		ZY	DG	ZI	FZ	FB	AT	ZZ	TH	PV	FH		XI	SF		SU	YP	HG	HZ	LD		TO	GV	PF
GD	HZ	TD	FZ	TF	SD	OH	GL	FO	VV	FZ	HP	VG		IG	LZ		ZS	–F	HF	FP	GH	XG	FS	DS	DF
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
(8)	(4)	(1)	(23)	(3)	(19)	(19)	(15)	(10)	(3)	(2)	(5)	(2)	(0)	(3)	(5)	(0)	(2)	(10)	(22)	(5)	(16)	(1)	(8)	(14)	(35)

Figure 14.

f. The triliteral frequency distribution is now to be examined with a view to ascertaining what digraphs and trigraphs occur two or more times in the cryptogram. Consider the pair of columns containing the prefixes and suffixes to D_c in the distribution, as shown in Fig. 14. This pair of columns shows that the following digraphs appear in the cryptogram:

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ZD, ID, ZD, YD, BD, ZD, ZD,
ZD, CD, ZD, YD, VD, SD, GD,
ZD, ID

Digraphs based on suffixes (arranged as one reads up the column)

DZ, DY, DS, DF, DZ, DZ, DV,
DF, DZ, DF, DZ, DV, DF, DZ,
DT, DZ, DO, DZ, DG, DZ, DI,
DF, DE

The nature of the triliteral frequency distribution is such that in finding what digraphs are present in the cryptogram it is immaterial whether the prefixes or the suffixes to the cipher letters are studied, so long as one is consistent in the study. For example, in the foregoing list of digraphs based on the prefixes to D_c, the digraphs FD, ZD, ZD, VD, etc., are found; if now, the student will refer to the suffixes of F_c, Z_c, V_c, etc., he will find the very same digraphs indicated. This being the case, the question may be raised as to what value there is in listing both the prefixes and the suffixes to the cipher letters. The answer is that by so doing the trigraphs are indicated at the same time. For example, in the case of D_c, the following trigraphs are indicated:

FDZ, ZDY, ZDS, VDF, ADZ, YDZ, BDV, ZDF, IDZ, ZDF, YDZ, BDV, ZDF,
ZDZ, ZDT, CDZ, ZDO, YDZ, VDG, SDZ, GDI, ZDF, IDE.

g. The repeated digraphs and trigraphs can now be found quite readily. Thus, in the case of D_c, examining the list of digraphs based on suffixes, the following repetitions are noted:

DZ appears 9 times; DF appears 5 times; DV appears 2 times

Examining the trigraphs with D_c as central letter, the following repetitions are noted:

ZDF appears 4 times; YDZ appears 3 times; BDV appears 2 times

h. It is unnecessary, of course, to go through the detailed procedure set forth in the preceding subparagraphs in order to find all the repeated digraphs and trigraphs. The repeated trigraphs with D_c as central letter can be found merely from an inspection of the prefixes and suffixes opposite D_c in the distribution. It is necessary only to find those cases in which two or more prefixes are identical at the same time that the suffixes are identical. For example, the distribution shows at once that in four cases the prefix to D_c is Z_c at the same time that the suffix to this letter is F_c. Hence, the trigraph ZDF appears four times. The repeated trigraphs may all be found in this manner.

i. The most frequently repeated digraphs and trigraphs are then assembled in what is termed a condensed table of repetitions, so as to bring this information prominently before the eye. As a rule, in messages of average length, digraphs which occur less than four or five times, and trigraphs which occur less than three or four times may be omitted from the condensed table as being relatively of no importance in the study of repetitions. In the condensed table the frequencies of the individual letters forming the most important digraphs, trigraphs, etc., should be indicated.

44. Classifying the cipher letters into vowels and consonants.--a. Before proceeding to a detailed analysis of the repeated digraphs and trigraphs, a very important step can be taken which will be of assistance not only in the analysis of the repetitions but also in the final solution of the cryptogram. This step concerns the classification of the high-frequency cipher letters into two groups--(1) those which most probably represent vowels, and (2) those which most probably represent consonants. For if the cryptanalyst can quickly ascertain the equivalents of the four vowels, A, E, I, and O, and of only the four consonants, N, R, S, and T, he will then have the values of approximately two-thirds of all the cipher letters that occur in the cryptogram; the values of the remaining letters can almost be filled in automatically.

b. The basis for the classification will be found to rest upon a comparatively simple phenomenon: the associational or combinatory behavior of vowels is, in general, quite different from that of consonants. If an examination be made of Table 7-B in Appendix 2, showing the relative order of frequency of the 18 digraphs composing 25 percent of English telegraphic text, it will be seen that the letter E enters into the composition of 9 of the 18 digraphs; that is, in exactly half of all the cases the letter E is one of the two letters forming the digraph. The digraphs containing E are as follows:

ED EN ER ES
NE RE SE TE VE

The remaining nine digraphs are as follows:

AN ND OR ST
IN NT TH
ON TO

c. None of the 18 digraphs is a combination of vowels. Note now that of the 9 combinations with E, 7 are with the consonants N, R, S, and T, one is with D, one is with V, and none is with any vowel. In other words, E_p combines most readily with consonants but not with other vowels, or even with itself. Using the terms often employed in the chemical analogy, E shows a great "affinity" for the consonants N, R, S, T, but not for the vowels. Therefore, if the letters of highest frequency occurring in a given cryptogram are listed, together with the number of times each of them combines with the assumed cipher equivalent of E_p, those which show considerable combining power or affinity for the cipher equivalent of E_p may be assumed to be the cipher equivalents of N, R, S, T_p; those which do not show any affinity for the cipher equivalent of E_p may be assumed to be the cipher equivalents of A, I, O, U_p. Applying these principles to the problem in hand, and examining the triliteral frequency distribution, it is quite certain that Z_c=E_p, not only because Z_c is the letter of highest frequency, but also because it combines with several other high-frequency letters, such as D_c, F_c, G_c, etc. The nine letters of next highest frequency are:

23	22	19	19	16	15	14	10	10
D	T	F	G	V	H	Y	S	I

Let the combinations these letters form with Z_c be indicated in the following manner:

Number of times Z_c occurs as prefix---	≣ ≢	≣	≣	—			— ≢		
Cipher Letter------	D(23)	T(22)	F(19)	G(19)	V(16)	H(15)	Y(14)	S(10)	I(10)
Number of times Z_c occurs as suffix---	≢ ≣	≢	=	≢			=		

d. Consider D_c. It occurs 23 times in the message and 18 of those times it is combined with Z_c, 9 times in the form Z_cD_c (=$E\theta_p$), and 9 times in the form D_cZ_c (=θE_p). It is clear that D_c must be a consonant. In the same way, consider T_c, which shows 9 combinations with Z_c, 4 in the form Z_cT_c (=$E\theta_p$) and 5 in the form T_cZ_c (=θE_p). The letter T_c appears to represent a consonant, as do also the letters F_c, G_c, and Y_c. On the other hand, consider V_c, occurring in all 16 times but never in combination with Z_c; it appears to represent a vowel, as do also the letters H_c, S_c, and I_c. So far, then, the following classification would seem logical:

Vowels	Consonants
Z_c(=E_p), V_c, H_c, S_c, I_c	D_c, T_c, F_c, G_c, Y_c

45. Further analysis of the letters representing vowels and consonants.--a. O_p is usually the vowel of second highest frequency. Is it possible to determine which of the letters V, H, S, I_c is the cipher equivalent of O_p? Let reference be made again to Table 6 in Appendix 2, where it is seen that the 10 most frequently occurring diphthongs are:

Diphthong-----	IO	OU	EA	EI	AI	IE	AU	EO	AY	UE
Frequency-----	41	37	35	27	17	13	13	12	12	11

If V, H, S, I_c are really the cipher equivalents of A, I, O, U_p (not respectively), perhaps it is possible to determine which is which by examining the combinations they make among themselves and with Z_c (=E_p). Let the combinations of V, H, S, I, and Z that occur in the message be listed. There are only the following:

ZZ_c--4	VH_c--2	HH_c--1	HI_c--1	IS_c--1	SV_c--1

ZZ_c is of course EE_p. Note the doublet HH_c; if H_c is a vowel, then the chances are excellent that H_c=O_p because the doublets AA_p, II_p, UU_p, are practically non-existent, whereas the double vowel combination OO_p is of next highest frequency to the double vowel combination EE_p. If $H_c=O_p$, then V_c must be I_p because the digraph VH_c occurring two times in the message could hardly be AO_p, or UO_p, whereas the dipthong IO_p is the one of high frequency in English. So far then, the tentative (because so far unverified) results of the analysis are as follows:

$$Z_c=E_p \quad H_c=O_p \quad V_c=I_p$$

This leaves only two letters, I_c and S_c (already classified as vowels) to be separated into A_p and U_p. Note the digraphs:

$$HI_c=O\theta_p \quad IS_c=\theta\theta_p \quad SV_c=\theta I_p$$

Only two alternatives are open:

(1) Either $I_c=A_p$ and $S_c=U_p$,
(2) Or $I_c=U_p$ and $S_c=A_p$.

If the first alternative is selected, then

$$HI_c=OA_p \quad IS_c=AU_p \quad SV_c=UI_p$$

If the second alternative is selected, then

$$HI_c=OU_p \quad IS_c=UA_p \quad SV_c=AI_p$$

The eye finds it difficult to choose between these alternatives; but suppose the frequency values of the plaintext diphthongs as given in Table 6 of Appendix 2 are added for each of these alternatives, giving the following:

$HI_c=OA_p$, frequency value=	7	$HI_c=OU_p$, frequency value=	37
$SV_c=UI_p$, frequency value=	5	$SV_c=AI_p$, frequency value=	17
$IS_c=AU_p$, frequency value=	13	$IS_c=UA_p$, frequency value=	5
Total--------	25	Total--------	59

Mathematically, the second alternative appears to be more probable than the first.[7] Let it be assumed to be correct and the following (still tentative) values are now at hand:

$$Z_c=E_p \quad H_c=O_p \quad V_c=I_p \quad S_c=A_p \quad I_c=U_p$$

b. Attention is now directed to the letters classified as consonants: How far is it possible to ascertain their values? The letter D_c, from considerations of frequency alone, would seem to be T_p, but its frequency, 23, is not considerably greater than that for T_c. It is not

[7] A more accurate guide for choosing between the alternative groups of digraphs could be obtained through a consideration of the logarithmic weights of their assigned probabilities, rather than their plaintext frequency values. These weights are given in Appendix 2, along with an explanation of the method for their derivation; a detailed treatment of their application is presented in Military Cryptanalysis, Part II.

much greater than that for F_c or G_c, with a frequency of 19 each. But perhaps it is possible to ascertain not the value of one letter alone but of two letters at one stroke. To do this one may make use of a tetragraph of considerable importance in English, viz., $TION_p$. For if the analysis pertaining to the vowels is correct, and if VH_c=IO_p, then an examination of the letters immediately before and after the digraph VH_c in the cipher text might disclose both T_p and N_p. Reference to the text gives the following:

$$\begin{array}{cc} GVHT_c & FVHT_c \\ \theta IO\theta_p & \theta IO\theta_p \end{array}$$

The letter T_c follows VH_c in both cases and very probably indicates that T_c=N_p; but as to whether G_c or F_c equals T_p cannot be decided. However, two conclusions are clear: first, the letter D_c is neither T_p nor N_p, from which it follows that it must be either R_p or S_p; second, the letters G_c and F_c must be either T_p and S_p, respectively, or S_p and T_p, respectively, because the only tetragraphs usually found (in English) containing the diphthong IO_p as central letters are $SION_p$ and $TION_p$. This in turn means that as regards D_c, the latter cannot be <u>either</u> R_p or S_p; it <u>must</u> be R_p, a conclusion which is corroborated by the fact that ZD_c (=ER_p) and DZ_c (=RE_p) occur 9 times each. Thus far, then, the identifications, when inserted in an <u>enciphering</u> alphabet, are as follows:

Plain------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher-----	S				Z				V					T	H			D	G	F	I					
																			F	G						

<u>46. Substituting deduced values in the cryptogram</u>.--<u>a</u>. Thus far the analysis has been almost purely hypothetical, for as yet not a single one of the values deduced from the foregoing analysis has been tried out in the cryptogram. It is high time that this be done, because the final test of the validity of the hypotheses, assumptions, and identifications made in any cryptographic study is, after all, only this: do these hypotheses, assumptions, and identifications ultimately yield verifiable, intelligible plain text when <u>consistently</u> applied to the cipher text?

<u>b</u>. At the present stage in the process, since there are at hand the assumed values of but 9 out of the 25 letters that appear, it is obvious that a continuous "reading" of the cryptogram can certainly not be expected from a mere insertion of the values of the 9 letters. However, the substitution of these values should do two things. First, it should immediately disclose the fragments, outlines, or "skeletons" of "good" words in the text; and second, it should disclose no places in the text where "impossible" sequences of letters are established. By the first is meant that the partially deciphered text should show the outlines or skeletons of words such as may be expected to be found in the communication; this will become quite clear in the next subparagraph. By the second is meant that sequences, such as "AOOEN" or "TNRSENO" or the like, obviously not possible or extremely unusual in normal English text, must not result from the substitution of the tentative identifications resulting from the analysis. The appearance of several such extremely unusual or impossible sequences would at once signify that one or more of the assumed values is incorrect.

c. Here are the results of substituting the nine values which have been deduced by the reasoning based on a classification of the high-frequency letters into vowels and consonants and the study of the members of the two groups:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	10 S A	19 F T S	23 L R	35 Z E	19 F T S	10 I	3 O	19 G S T	15 H O	5 L	5 P	35 Z E	19 F T S	19 G S T	35 Z E	23 D R	14 Y	10 S A	5 P	19 F T S	15 H O	4 B	35 Z E	23 D R	10 S A
B	19 G S T	16 V I	15 H O	22 T N	19 F T S	5 U	5 P	5 L	16 V I	23 D R	19 F T S	19 G S T	14 Y	16 V I	3 J	16 V I	19 F T S	16 V I	15 H O	22 T N	19 G S T	8 A	23 D R	35 Z E	35 Z E
C	8 A	10 I	22 T N	14 Y	23 D R	35 Z E	14 Y	19 F T S	35 Z E	3 J	35 Z E	22 T N	19 G S T	5 P	22 T N	16 V I	22 T N	35 Z E	4 B	23 D R	16 V I	19 F T S	15 H O	22 T N	35 Z E
D	23 D R	19 F T S	8 X	10 S A	4 B	19 G S T	10 I	23 D R	35 Z E	14 Y	16 V I	22 T N	8 X	3 O	10 I	14 Y	16 V I	22 T N	3 E	19 F T S	16 V I	2 M	19 G S T	35 Z E	35 Z E
E	22 T N	15 H O	5 L	5 L	16 V I	8 X	35 Z E	23 D R	19 F T S	2 M	15 H O	22 T N	35 Z E	8 A	10 I	22 T N	14 Y	23 D R	35 Z E	14 Y	4 B	23 D R	16 V I	19 F T S	15 H O
F	22 T N	35 Z E	23 D R	19 F T S	2 K	35 Z E	23 D R	35 Z E	35 Z E	3 J	10 S A	8 X	10 I	10 S A	19 G S T	35 Z E	14 Y	19 G S T	8 A	16 V I	19 F T S	10 S A	5 L	19 G S T	35 Z E
G	23 D R	22 T N	15 H O	15 H O	22 T N	1 C	23 D R	35 Z E	2 R	10 S A	16 V I	22 T N	14 Y	35 Z E	23 D R	3 O	35 Z E	19 F T S	19 F T S	15 H O	22 T N	35 Z E	8 A	10 I	22 T N
H	14 Y	23 D R	35 Z E	14 Y	19 G S T	8 A	16 V I	23 D R	19 G S T	35 Z E	35 Z E	22 T N	2 K	15 H O	10 I	22 T N	14 Y	35 Z E	14 Y	10 S A	23 D R	35 Z E	19 G S T	15 H O	5 U
J	35 Z E	19 F T S	35 Z E	22 T N	19 G S T	5 U	5 P	19 G S T	23 D R	10 I	8 X	1 W	24 G S T	15 H O	8 X	8 A	10 S A	2 R	5 U	35 Z E	23 D R	19 F T S	5 U	10 I	23 D R
K	3 E	19 G S T	15 H O	22 T N	16 V I	3 E	8 A	19 G S T	8 X	8 X															

d. No impossible sequences are brought to light, and, moreover, several long words, nearly compleτe, stand out in the text. Note the following portions:

```
         A21
         H B Z D S G V H T F
    (1)  O ? E R A S I O N T
                   T       S

         C15
         T V T Z B D V F H T Z D F
    (2)  N I N E ? R I T O N E R T
                       S         S

         F22
         S L G Z D T H H T
    (3)  A ? S E R N O O N
             T
```

The words are obviously OPERATIONS, NINE PRISONERS, and AFTERNOON. The value G_c is clearly T_p; that of F_c is S_p; and the following additional values are certain:

$$B_c{=}F_p \qquad L_c{=}F_p$$

47. Completing the solution.--a. Each time an additional value is obtained, substitution is at once made throughout the cryptogram. This leads to the determination of further values, in an ever-widening circle, until all the identifications are firmly and finally established, and the message is completely solved. In this case the decipherment is as follows:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	S A	F S	D R	Z E	F S	I U	O L	G T	H O	L F	P Y	Z E	F S	G T	Z E	D R	Y D	S A	P Y	F S	H O	B P	Z E	D R	S A
B	G T	V I	H O	T N	F S	U B	P Y	L F	V I	D R	F S	G T	Y D	V I	J V	V I	F S	V I	H O	T N	G T	A H	D R	Z E	Z E
C	A H	I U	T N	Y D	D R	Z E	Y D	F S	Z E	J V	Z E	T N	G T	P Y	T N	V I	T N	Z E	B P	D R	V I	F S	H O	T N	Z E
D	D R	F S	X C	S A	B P	G T	I U	D R	Z E	Y D	V I	T N	X C	O L	I U	Y D	V I	T N	E G	F S	V I	M X	G T	Z E	Z E
E	T N	H O	L F	L F	V I	X C	Z E	D R	F S	M X	H O	T N	Z E	A H	I U	T N	Y D	D R	Z E	Y D	B P	D R	V I	F S	H O
F	T N	Z E	D R	F S	K W	Z E	D R	Z E	Z E	J V	S A	X C	I U	S A	G T	Z E	Y D	G T	A H	V I	F S	S A	L F	G T	Z E
G	D R	T N	H O	H O	T N	C Q	D R	Z E	R M	S A	V I	T N	Y D	Z E	D R	O L	Z E	F S	F S	H O	T N	Z E	A H	I U	T N
H	Y D	D R	Z E	Y D	G T	A H	V I	D R	G T	Z E	Z E	T N	K W	H O	I U	T N	Y D	Z E	Y D	S A	D R	Z E	G T	H O	U B
J	Z E	F S	Z E	T N	G T	U B	P Y	G T	D R	I U	X C	W K	G T	H O	X C	A H	S A	R M	U B	Z E	D R	F S	U B	I U	D R
K	E G	G T	H O	T N	V I	E G	A H	G T	X X	X X															

Message: AS RESULT OF YESTERDAYS OPERATIONS BY FIRST DIVISION THREE HUNDRED SEVENTY NINE PRISONERS CAPTURED INCLUDING SIXTEEN OFFICERS ONE HUNDRED PRISONERS WERE EVACUATED THIS AFTERNOON REMAINDER LESS ONE HUNDRED THIRTEEN WOUNDED ARE TO BE SENT BY TRUCK TO CHAMBERSBURG TONIGHT

b. The solution should, as a rule, not be considered complete until an attempt has been made to discover all the elements underlying the general system and the specific key to a message. In this case, there is no need to delve further into the general system, for it is merely one of unilateral substitution with a mixed cipher alphabet. It is necessary or advisable, however, to reconstruct the cipher alphabet because this may give clues that later may become valuable.

c. Cipher alphabets should, as a rule, be reconstructed by the cryptanalyst in the form of enciphering alphabets because they will then usually be in the form in which the encipherer used them. This is important for two reasons. First, if the sequence in the cipher component gives evidence of system in its construction or if it yields clues pointing toward its derivation from a key word or a key phrase, this may often corroborate the identifications already made and may lead directly to additional identifications. A word or two of explanation is advisable here. For example, refer to the skeletonized enciphering alphabet given at the end of subpar. 45b:

Plain--------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher-------	S				Z				V					T	H			D	G	F	I					
																			F	G						

Suppose the cryptanalyst, looking at the sequence DGFI or DFGI in the cipher component, suspects the presence of a keyword-mixed alphabet. Then DFGI is certainly a more plausible sequence than DGFI. Examining the skeleton cipher component more carefully, he notes that S . . . Z would allow for insertion of three of the missing letters UWXY, since the letters T and V occur later, probably in the keyword itself; further, he notes that the key word probably begins under F_p and ends in TH, making it probable that the TH is followed by AB or BC. This would mean that either P, Q_p=A, B_c or B, C_c. Assuming that P, Q_p=A, B_c, he refers to the frequency distribution and finds that the assumptions P_p=A_c and Q_p=B_c are not good; on the other hand, assuming that F, Q_p=B, Cc, the frequency distribution gives excellent corroboration. A trial of these values would materially hasten solution because it is often the case in cryptanalysis that if the value of a very low-frequency letter can be surely established it will yield clues to other values very quickly. Thus, if Q_p is definitely identified it almost invariably will identify U_p, and will give clues to the letter following the U_p, since it must be a vowel. In the case under discussion the identification P, Q_p=B, C_c would have turned out to be correct. For the foregoing reason an attempt should always be made in the early stages of the analysis to determine, if possible, the basis of construction or derivation of the cipher alphabet; as a rule this can be done only by means of the enciphering alphabet, and not the deciphering alphabet. For example, the skeletonized deciphering alphabet corresponding to the enciphering alphabet directly above is as follows:

Cipher--------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Plain---------				R		T S	S T	O	U										A	N		I				E

Here no evidences of a keyword-mixed alphabet are seen at all. However, if the enciphering alphabet has been examined and shows no evidences of systematic construction, the deciphering alphabet should then be examined with this in view, because occasionally it is the deciphering alphabet which shows the presence of a key or keying element, or which has been systematically derived from a word or phrase. The second reason why it is important to try to discover the basis of construction or derivation of the cipher alphabet is that it affords clues to the general type of key words or keying elements employed by the enemy. This is a psychological factor, of course, and may be of assistance in subsequent studies of his traffic. It merely gives a clue to the general type of thinking indulged in by certain of his cryptographers.

d. In the case of the foregoing solution, the complete enciphering alphabet is found to be as follows:

Plain---------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher--------	S	U	X	Y	Z	L	E	A	V	N	W	O	R	T	H	B	C	D	F	G	I	J	K	M	P	

Obviously, the letter Q, which is the only letter not appearing in the cryptogram, should follow P in the cipher component. Note now that the latter is based upon the keyword LEAVENWORTH, and that this particular cipher alphabet has been composed by shifting the mixed sequence based upon this keyword five intervals to the right so that the key for the message is $A_p=S_c$.[8] Note also that the deciphering alphabet fails to give any evidence of keyword construction based upon the word LEAVENWORTH.

Cipher--------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Plain---------	H	P	Q	R	G	S	T	O	U	V	W	F	X	J	L	Y	Z	M	A	N	B	I	K	C	D	E

e. If neither the enciphering nor the deciphering alphabet exhibits characteristics which give indication of derivation from a key word by some form of mixing or disarrangement, the use of such a key word for this purpose is nevertheless not finally excluded as a possibility. For the reconstruction of such mixed alphabets the cryptanalyst must use ingenuity and a knowledge of the more common methods of suppressing the appearance of key words in the mixed alphabets. Several of these methods are given detailed treatment in par. 51 below.

f. It is very important in practical cryptanalytic work to prepare a technical summary of the solution of a system. Step-by-step

[8] It is usual practice to employ as the specific key the equivalent of either A_p, or the equivalent of the first letter of the plain component when this component is a mixed sequence.

commentaries should accompany an initial solution; the steps taken should be jotted down as they are made, and at the end they should be combined into a complete résumé of the analysis. The résumé should be brief and concise, yet comprehensive enough that at any future time the solution may be reconstructed following the exact manner in which it was originally accomplished. Assumptions of words, etc., should be referred to with work sheet line- and column-indicators, and should be couched in the proper cryptologic language or symbols. A short exposition of the mechanics of the general system, enciphering alphabets, enciphering diagrams, etc., as well as all key words (together with their derivation) and specific keys should be included. On the work sheet there should be a letter-for-letter decryptment under the cipher text; the final plaintext version should be in word lengths, with any errors or garbles corrected. Nulls or indicators showing sentence separation, change of key, etc., may be enclosed in parentheses. All work sheets and notes should be kept together with the solution.

48. General remarks on the foregoing solution.--a. The example solved above is admittedly a more or less artificial illustration of the steps in analysis, made so in order to demonstrate general principles. It was easy to solve because the frequencies of the various cipher letters corresponded quite well with the normal or expected frequencies. However, all cryptograms of the same monoalphabetical nature can be solved along the same general lines, after a certain amount of experimentation, depending upon the length of the cryptogram, and the skill and experience of the cryptanalyst.[9]

b. It is no cause for discouragement if the student's initial attempts to solve a cryptogram of this type require much more time and effort than were apparently required in solving the foregoing purely illustrative example. It is indeed rarely the case that every assumption made by the cryptanalyst proves in the end to have been correct; more often it is the case that a good many of his initial assumptions are incorrect, and that he loses much time in casting out the erroneous ones. The speed and facility with which this elimination process is conducted is in many cases all that distinguishes the expert from the novice.

[9] The use of monoalphabetic substitution in modern military operations is exceedingly rare because of the simplicity of solution. However, such cases have occurred, and one rather illuminating instance may be cited. In an important communication on 5 August 1918, General Kress von Kressenstein used a single mixed alphabet, and the intercepted radio message was solved at American GHQ very speedily. A day later another message, but in a very much more difficult cipher system, was intercepted and solved. When translated, it read as follows:

"GHQ Kress:

The cipher prepared by General von Kress was at once solved here. Its further use and employment is forbidden.

Chief Signal Officer, Berlin."

c. Nor will the student always find that the initial classification into vowels and consonants can be accomplished as easily and quickly as was apparently the case in the illustrative example. The principles indicated are very general in their nature and applicability, and there are, in addition, some other principles that may be brought to bear in case of difficulty. Of these, perhaps the most useful are the following:

(1) In normal English it is unusual to find more than two consonants in succession, each of high frequency. If in a cryptogram a succession of three or four letters of high-frequency appear in succession, it is practically certain that at least one of these represents a vowel.[10]

(2) Successions of three vowels are rather unusual in English.[11] Practically the only time this happens is when a word ends in two vowels and the next word begins with a vowel.[12]

(3) When two letters already classified as vowel-equivalents are separated by a sequence of six or more letters, it is either the case that one of the supposed vowel-equivalents is incorrect, or else that one or more of the intermediate letters is a vowel-equivalent.[13]

(4) Reference to Table 7-B of Appendix 2 discloses the following:

Distribution of first 18 digraphs forming 25 percent of English text

Number of consonant-consonant digraphs	4
Number of consonant-vowel digraphs	6
Number of vowel-consonant digraphs	8
Number of vowel-vowel digraphs	0

Distribution of first 53 digraphs forming 50 percent of English text

Number of consonant-consonant digraphs	8
Number of consonant-vowel digraphs	23
Number of vowel-consonant digraphs	18
Number of vowel-vowel digraphs	4

[10] Sequences of seven consonants are not impossible, however, as in STRENGTH THROUGH.

[11] Note that the word RADIOED, past tense of the verb RADIO, is coming into usage.

[12] A sequence of seven vowels is not impossible, however, as in THE WAY YOU EARN.

[13] Some cryptanalysts place a good deal of emphasis upon this principle as a method of locating the remaining vowels after the first two or three have been located. They recommend that the latter be underlined throughout the text and then all sequences of five or more letters showing no underlines be studied attentively. Certain letters which occur in several such sequences are sure to be vowels. An arithmetical aid in the study is as follows: Take a letter thought to be a good possibility as the cipher equivalent of a vowel (hereafter termed a *possible vowel-equivalent*) and find the length of each interval from the possible vowel-equivalent to the next *known* (fairly surely determined) vowel-equivalent. Multiply the interval by the number of times this interval is found. Add the products and divide by the total number of intervals considered. This will give the *mean* interval for that possible vowel-equivalent. Do the same for all the other possible vowel-equivalents. The one for which the mean is the greatest is most probably a vowel-equivalent. Underline this letter throughout the text and repeat the process for locating additional vowel-equivalents, if any remain to be located.

The latter tabulation shows that of the first 53 digraphs which form 50 percent of English text, 41 of them, that is, over 75 percent, are combinations of a vowel with a consonant. In short, in normal English the vowels and the high-frequency consonants are in the long run distributed fairly evenly and regularly throughout the text.

(5) As a rule, repetitions of trigraphs in the cipher text are composed of high-frequency letters forming high-frequency combinations. The latter practically always contain at least one vowel; in fact, if reference is made to Table 10-A of Appendix 2 it will be noted that 36 of the 56 trigraphs having a frequency of 100 or more contain one vowel, 17 of them contain two vowels, and only three of them contain no vowel. In the case of tetragraph repetitions, Table 11-A of Appendix 2 shows that no tetragraph listed therein fails to contain at least one vowel; 27 of them contain one vowel, 25 contain two vowels, and 2 contain three vowels.

(6) Quite frequently when two known vowel-equivalents are separated by six or more letters none of which seems to be of sufficiently high frequency to represent one of the vowels A E I O, the chances are good that the cipher-equivalent of the vowel U or Y is present.

d. To recapitulate the general principles, vowels may then be distinguished from consonants in that they are usually represented by:

(1) high-frequency letters;

(2) high-frequency letters which do not readily contact each other;

(3) high-frequency letters which have a great variety of contact;

(4) high-frequency letters which have an affinity for low-frequency letters (i.e., low-frequency plaintext consonants).

e. In the foregoing example the amount of experimentation or "cutting and fitting" was practically nil. (This is not true of real cases as a rule.) Where such experimentation is necessary, the underscoring of all repetitions of several letters is very essential, as it calls attention to peculiarities of structure that often yield clues.

f. After a few basic assumptions of values have been made, if short words or skeletons of words do not become manifest, it is necessary to make further assumptions for unidentified letters. This is accomplished most often by assuming a word.[14] Now there are two places in every message which lend themselves more readily to successful attack by the assumption of words than do any other places--the very beginning and the very end of the message. The reason is quite obvious, for although words may begin or end with almost any letter of the alphabet, they usually begin

[14] This process does not involve anything more mysterious than ordinary, logical reasoning; there is nothing of the subnormal or supernormal about it. If cryptanalytic success seems to require processes akin to those of medieval magic, if "hocus-pocus" is much to the fore, the student should begin to look for items that the claimant of such success has carefully hidden from view, for the mystification of the uninitiated. If the student were to adopt as his personal motto for all his cryptanalytic ventures the quotation (from Tennyson's poem *Columbus*) appearing on the back of the title page of this text, he will frequently find "short cuts" to his destination and will not too often be led astray!

and end with but a few very common digraphs and trigraphs. Very often the association of letters in peculiar combinations will enable the student to note where one word ends and the next begins. For example suppose, E, N, S, and T have been definitely identified, and a sequence like the following is found in a cryptogram:

. . . E N T S N E . . .

Obviously the break between two words should fall either after the S of E N T S or after the T of E N T, so that two possibilities are offered: . . . E N T S / N E . . ., or . . . E N T / S N E . . .. Since in English there are very few words with the initial trigraph S N E, it is most likely that the proper division is . . . E N T S / N E . . .. Of course, when several word divisions have been found, the solution is more readily achieved because of the greater ease with which assumptions of additional new values may be made.

g. Although a considerable amount of detailed treatment has been devoted to vowel-consonant analysis, it is felt advisable again to caution the student against the natural tendency to accept without question the results of any one cryptanalytic technique exclusively, even one such as vowel-consonant analysis which seems quite scientific in character.

49. The "probable-word" method; its value and applicability.--a. In practically all cryptanalytic studies, short cuts can often be made by assuming the presence of certain words in the message under study. Some writers attach so much value to this kind of an "attack from the rear" that they practically elevate it to the position of a method and call it the "intuitive method" or the "probable-word method." It is, of course, merely a refinement of what in everyday language is called "assuming" or "guessing" a word in the message. The value of making a "good guess" can hardly be overestimated, and the cryptanalyst should never feel that he is accomplishing a solution by an illegitimate subterfuge when he has made a fortunate guess leading to solution. A correct assumption as to plain text will often save hours or days of labor, and sometimes there is no alternative but to try to "guess a word", for occasionally a system is encountered the solution of which is absolutely dependent upon this artifice.

b. The expression "good guess" is used advisedly. For it is "good" in two respects. First, the cryptanalyst must use care in making his assumptions as to plaintext words. In this he must be guided by extraneous circumstances leading to the assumption of *probable* words--not just any words that come to his mind. Therefore he must use his imagination but he must nevertheless carefully control it by the exercise of *good* judgement. Second, only if the "guess" is correct and leads to solution, or at least puts him on the road to solution, it is a good guess. But, while realizing the usefulness and the time and labor-saving features of a solution by assuming a probable word, the cryptanalyst should exercise discretion in regard to how long he may continue in his efforts with this method. Sometimes he may actually waste time by adhering to the method too long, if straightforward, methodical analysis will yield results more quickly.

c. Obviously, the "probable-word" method has much more applicability when working upon material the general nature of which is known, than when working upon more or less isolated communications exchanged between correspondents concerning whom or whose activities nothing is known. For in the latter case there is little or nothing that the imagination can seize upon as a background or basis for the assumptions.[15] However, in the case of military cryptanalysis in time of active operations there is, indeed, so great a probability that certain words and expressions are present in certain cryptograms that those words and expressions ("cliches") are often referred to as "cribs" (as defined in Webster's New Collegiate Dictionary: "...a plagiarism; hence, a translation, etc., to aid a student in reciting."). The cryptanalyst is quite sure they are present in the cryptogram under examination--what he must do is to "fit the crib to the text", that is, locate it in the cipher text.

d. Very frequently, the choice of probable words is aided or limited by the number and positions of repeated letters. These repetitions may be patent--that is, externally visible in the cryptographic text as it originally stands--or they may be latent--that is, externally invisible but susceptible of being made patent as a result of the analysis. For example, in a monoalphabetic substitution cipher, such as that discussed in the preceding paragraph, the repeated letters are directly exhibited in the cryptogram; later the student will encounter many cases in which the repetitions are latent, but are made patent by the analytical process. When the repetitions are patent, then the pattern or formula to which the repeated letters conform is of direct use in assuming plaintext words; and when the text is in word-lengths, the pattern is obviously of even greater assistance. Suppose the cryptanalyst is dealing with military text, in which case he may expect such words as DIVISION, BATTALION, etc., to be present in the text. The positions of the repeated letter I in DIVISION, of the reversible digraph AT, TA in BATTALION, and so on, constitute for the experienced cryptanalyst tell-tale indications of the presence of these words, even when the text is not divided up into its original word lengths.

e. The important aid that a study of word patterns can afford in cryptanalysis warrants the use of definite terminology and the establishment of certain data having a bearing thereon. The phenomenon herein under discussion, namely, that many words are of such construction as regards the number and positions of repeated letters as to make them readily identifiable, will be termed idiomorphism (from the Greek "idios"= one's own, individual, peculiar + "morphe"=form). Words which show this phenomenon will be termed idiomorphic. It will be useful to deal with the idiomorphisms symbolically and systematically as described below.

[15] General Givierge in his *Cours de Cryptographie* (p 121) says. "However, expert cryptanalysts often employ such details as are cited above [in connection with assuming the presence of 'probable words'], and the experience of the years 1914 to 1918, to cite only those, prove that in practice one often has at his disposal elements of this nature, permitting assumptions much more audacious than those which served for the analysis of the last example. The reader would therefore be wrong in imagining that such fortuitous elements are encountered only in cryptographic works where the author deciphers a document that he himself enciphered. Cryptographic correspondence, if it is extensive, and if sufficiently numerous working data are at hand, often furnishes elements so complete that an author would not dare use all of them in solving a problem for fear of being accused of obvious exaggeration."

f. When dealing with cryptograms in which the word lengths are determined or specifically shown, it is convenient to indicate their lengths and their repeated letters in some easily recognized manner or by formulas. This is exemplified, in the case of the word DIVISION, by the formula ABCBDBEF; in the case of the word BATTALION, by the formula ABCCBDEFG. If the cryptanalyst, during the course of his studies, makes note of striking formulas he has encountered, with the words which fit them, after some time he will have assembled a quite valuable body of data. And after more or less complete lists of such formulas have been established in some systematic arrangement, a rapid comparison of the idiomorphs in a specific cryptogram with those in his lists will be feasible and will often lead to the assumption of the current word. Such lists can be arranged according to word length, as shown herewith:

3/aba	:	DID, EVE, EYE, etc.
abb	:	ADD, ALL, ILL, OFF, etc.
4/abac	:	ARAB, AWAY, etc.
abbc	:	ALLY, BEEN, etc.
abca	:	AREA, BOMB, DEAD, etc.
abcb	:	ANON, CEDE, etc.
etc.		etc.

g. When dealing with cryptographic text in which the lengths of the words are not indicated or otherwise determinable, lists of the foregoing nature are not so useful as lists in which the words (or parts of words) are arranged according to the intervals between identical letters, in the following manner:

1 Interval	2 Intervals	3 Intervals	Repeated digraphs
-DiD-	AbbAcy	AbeyAnce	COCOa
-EvE-	ArAbiA	hAbitAble	-dERER
-EyE-	AblAtive	lAborAtory	ICICle
dIvIsion	AboArd	AbreAst	-ININg
revIsIon	-AciA-	AbroAd	bAGgAGe
etc.	etc.	etc.	etc.

h. The most usual practice, however, in designating idiomorphic patterns and classifying them into systematic lists is to assign a literal nomenclature to that portion of a word (or sequence of plaintext letters) which contains the distinctive pattern, beginning with the first letter which is repeated in the pattern and ending with the last letter which is repeated in the pattern. Thus, the word DIVISION would be termed as an idiomorph of the *abaca* class (based on the sequence $\overline{\text{IVISI}}$ contained therein), and the word BATTALION as an idiomorph of the *abba* class (based on the sequence $\overline{\text{ATTA}}$). In Appendix 3 will be found a compendium of the more frequent military words in English, arranged according to word-lengths in alphabetical order and in rhyming order; in addition, there will be found in this appendix a listing of idiomorphs arranged first according to pattern and then according to the first letter of the idiomorphic sequence.

50. Solution of additional cryptograms produced by the same components.--a. To return, after a rather long digression, to the cryptogram solved in pars. 44 - 47, once the components of a cipher alphabet have been reconstructed, subsequent messages which have been enciphered by means of the same components may be solved very readily, and without recourse to the principles of frequency, or application of the probable-word method. It has been seen that the illustrative cryptogram treated in paragraphs 41 - 47 was enciphered by juxtaposing the cipher component against the normal sequence so that $A_p=S_c$. It is obvious that the cipher component may be set against the plain component at any one of 26 different points of coincidence, each yielding a different cipher alphabet. After the components have been reconstructed, however, they become known sequences and the method of converting the cipher letters into their plain-component equivalents and then completing the plain-component sequence[16] begun by each equivalent can be applied to solve any cryptogram which has been enciphered by these components.

b. An example will serve to make the process clear. Suppose the following message, passing between the same two stations as before, was intercepted shortly after the first message had been solved:

IYEWK CERNW OFOSE LFOOH EAZXX

It is assumed that the same components were used, but with a different key letter. First the initial two groups are converted into their plain-component equivalents by setting the cipher component against the plain component at any arbitrary point of coincidence. The initial letter of the former may as well be set against A of the latter, with the following result:

Plain----------	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher---------	L	E	A	V	N	W	O	R	T	H	B	C	D	F	G	I	J	K	M	P	Q	S	U	X	Y	Z

Cryptogram----	I	Y	E	W	K	C	E	R	N	W	. . .
Equivalents---	P	Y	B	F	R	L	B	H	E	F	. . .

The plain component sequence initiated by each of these conversion equivalents is now completed, with the results shown in Fig. 15. Note the plaintext generatrix, CLOSEYOURS, which manifests itself without further analysis. The rest of the message may be read either by continuing the same process, or, what is even more simple, the key letter of the message may now be determined quite readily and the message deciphered by its means.

[16] It must be noted that if the plain component is a mixed sequence, then it is this mixed sequence which must be used to complete the columns.

I	Y	E	W	K	C	E	R	N	W
P	Y	B	F	R	L	B	H	E	F
Q	Z	C	G	S	M	C	I	F	G
R	A	D	H	T	N	D	J	G	H
S	B	E	I	U	O	E	K	H	I
T	C	F	J	V	P	F	L	I	J
U	D	G	K	W	Q	G	M	J	K
V	E	H	L	X	R	H	N	K	L
W	F	I	M	Y	S	I	O	L	M
X	G	J	N	Z	T	J	P	M	N
Y	H	K	O	A	U	K	Q	N	O
Z	I	L	P	B	V	L	R	O	P
A	J	M	Q	C	W	M	S	P	Q
B	K	N	R	D	X	N	T	Q	R
*C	L	O	S	E	Y	O	U	R	S
D	M	P	T	F	Z	P	V	S	T
E	N	Q	U	G	A	Q	W	T	U
F	O	R	V	H	B	R	X	U	V
G	P	S	W	I	C	S	Y	V	W
H	Q	T	X	J	D	T	Z	W	X
I	R	U	Y	K	E	U	A	X	Y
J	S	V	Z	L	F	V	B	Y	Z
K	T	W	A	M	G	W	C	Z	A
L	U	X	B	N	H	X	D	A	B
M	V	Y	C	O	I	Y	E	B	C
N	W	Z	D	P	J	Z	F	C	D
O	X	A	E	Q	K	A	G	D	E

Figure 15.

c. In order that the student may understand without question just what is involved in the latter step, that is, discovering the key letter after the first two or three groups have been deciphered by the conversion-completion process, the foregoing example will be used. It was noted that the first cipher group was finally deciphered as follows:

Cipher-------- I Y E W K
Plain--------- C L O S E

Now set the cipher component against the normal sequence so that $C_p=I_c$. Thus:

Plain--------- A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Cipher-------- F G I J K M P Q S U X Y Z L E A V N W O R T H B C D

It is seen here that when $C_p=I_c$ then $A_p=F_c$. This is the key for the entire message. The decipherment may be completed by direct reference to the cipher alphabet. Thus:

Cipher-- I Y E W K   C E R N W   O F O S E   L F O O H   E A Z X X
Plain--- C L O S E   Y O U R S   T A T I O   N A T T W   O P M X X

Message: CLOSE YOUR STATION AT TWO PM

d. The student should make sure that he understands the fundamental principles involved in this quick solution, for they are among the most important principles in cryptanalytics. How useful they are will become clear as he progresses into more and more complex cryptanalytic studies.

e. It must be kept in mind that there are four ways that two basic sequences may be used to form a cipher alphabet, subject to the instructions guiding the cryptographer in the use of his cryptosystem; this fact must be considered when additional cryptograms appear in a particular cryptosystem for which the primary components have been recovered. Assuming that the sequences just recovered are labelled "A" and "B", then the following contingencies might arise in the encryption of subsequent messages:

(1) "A" direct for the plain component, and "B" direct for the cipher component (as in the original recovery);

(2) "A" direct for the plain, and "B" reversed for the cipher;

(3) "B" direct for the plain, and "A" direct for the cipher; and

(4) "B" direct for the plain, and "A" reversed for the cipher.

51. Derivation of key words.--a. Concurrent with the solution of a cryptogram, there should be a simultaneous effort in the reconstruction of cipher alphabets and recovery of key words. Much labor can thus be saved as recovery of the keys early in the stages of solution may transform the process of cryptanalysis into one of decipherment.

b. A mixed cipher alphabet falls into one of five categories, according to the composition of its components, viz.,

(1) the plain component is the normal sequence and the cipher component is mixed;

(2) the cipher component is the normal sequence and the plain component is mixed;

(3) both components are the same mixed sequence;

(4) both components are the same mixed sequence, but running in reverse; or

(5) the components are different mixed sequences.

c. Let us examine several types of mixed sequences, using the key word HYDRAULIC as an example. The ordinary keyword-mixed sequence produced from this key word is:

(1) H Y D R A U L I C B E F G J K M N O P Q S T V W X Z

The two principal transposition-mixed types based on this key word are derived from the diagram:

H	Y	D	R	A	U	L	I	C
B	E	F	G	J	K	M	N	O
P	Q	S	T	V	W	X	Z	

and read:

(2) H B P Y E Q D F S R G T A J V U K W L M X I N Z C O and

(3) A J V C O D F S H B P I N Z L M X R G T U K W Y E Q

Other types may arise from various types of route transpositions such as the following, using the foregoing diagram:

(4) H B P Q E Y D F S T G R A J V W K U L M X Z N I C O

(5) H Y B P E D R F Q S G A U J T V K L I M W X N C O Z

(6) P B Q H E S Y F T D G V R J W A K X U M Z L N I O C

(7) H Y D R A U L I C O N M K J G F E B P Q S T V W X Z

(8) O C I L U A R D Y H B P Q S T V W X Z N M K J G F E

(9) H Y E B P Q S T G F D R A U K J V W X Z N M L I C O

(10) C P I O Q B L N S E H U M Z T F Y A K X V G D R J W

Any transposition system may be employed to produce a systematically-mixed sequence; practicability of method is the only determining factor. It must be remembered that the greatest amount of systematic mixing will produce a sequence inherently no more secure than a random-mixed alphabet.

d. The student would do well to construct both enciphering and deciphering versions of cipher alphabets recovered, as has been previously mentioned. For example, in the following case

Plain: J Q N M F H L E B R S K G Y Z O T I C D U V A W P X
Cipher: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

no semblance of a key is apparent; but in the inverse form

Plain: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Cipher: W I S T H E M F R A L G D C P Y B J K Q U V X Z N O

the key-phrase "NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THEIR PARTY" is quite clear. In other types of mixed sequences, first the one form is attacked, and then if negative results are obtained the inverse form is treated.

e. Let us consider the following cipher alphabet:

P: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
C: D W Z M S O C R Y A T X B E F U G Q H I V J K L N P

The section V W X seems to comprise superimposed parts of the non-keyword
J K L
portions of mixed sequences. Adding Y Z to the plain component, we get

V W X Y Z which is certainly consistent as far as alphabetical progres-
J K L N P
sion goes, and indicates that the letters M and O are present in the key word of the cipher component. Continuing in this vein, the section
M N O Q S T V W X Y Z is rapidly established by correlating both se-
B E F G H I J K L N P
quences. It is obvious that the plain component key word begins right after the Z, and that the cipher component key word probably just pre-
cedes the B. Going to the right, Z R H suggests key words like RHOMBOID,
P Q R
RHEUMATISM, etc. These trials are quickly repudiated; therefore we go on
to Z R E which is acceptable. Z R E K is found wanting, but Z R E P is
P Q S P Q S T P Q S U
very satisfactory, and this is soon expanded to Z R E P U B L I C, and in
P Q S U V W X Y Z
a moment or two we recover the complete cipher alphabet:

P: R E P U B L I C A N D F G H J K M O Q S T V W X Y Z
C: Q S U V W X Y Z D E M O C R A T B F G H I J K L N P

f. In the example below the student will observe that the alphabets are reciprocal: this is an indication of identical sequences at a shift of 13, or that a mixed sequence running against itself in reverse has
been employed. In this case the W X Y Z points to the latter hypothesis.
Z Y X W

P: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
C: H O J F T D N A K C I M L G B S U V P E Q R Z Y X W

Starting with the V W X Y Z R cluster, we see that the key word begins
R Z Y X W V
with the letter R; therefore the next letter should be a vowel. Z R A
W V H
is not acceptable, but Z R E is fine, showing that the letter U appears
W V T
in the key word. Continuing the same line of reasoning as in the preceding example, and with a little further experimentation, the final alphabet is discovered to be

P: R E P U B L I C A N D F G H J K M O Q S T V W X Y Z
C: V T S Q O M K J H G F D N A C I L B U P E R Z Y X W

g. In the next example, all efforts to derive key words on the basis of keyword-mixed sequences are fruitless: the conclusion is therefore drawn that this is a case of a transposition.

P: A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
C: A C S E J Y I G W L F V M H X N K Z P B Q R D U T O

Considering the mechanics of the cryptography involved, and assuming for the time being that Z is at the bottom of the matrix and not in the key word, we start with the letters to the left, or if this fails, to the
right of Z in the cipher component, obtaining the column N which is not
K
Z
incompatible if N is in the key word on the top row. If we place Y to

the left of Z and build up its column, we get E N which is excellent.

```
E N
J K
Y Z
```

This is expanded into I M E N which quickly becomes

```
I M E N          7 1 8 4 3 5 2 6 9
G H J K          P A R L I M E N T
W X Y Z          B C D F G H J K O
                 Q S U V W X Y Z
```

This last example was very easy because none of the letters V W X Y Z appeared in the key word; but other cases should hardly prove more difficult.

h. Two additional methods that have been encountered for deriving mixed sequences may be mentioned. One is a slight modification of the preceding paragraph, when the key word contains repeated letters:

```
1 8 7 3 4 9 5 2 6
C O M . I T . E .
A B D F G H J K L
N P Q R S U V W X
Y Z                  which produces the mixed sequence:

C A N Y E K W F R I G S J V L X M D Q O B P Z T H U
```

The other method is an interrupted-key columnar transposition system:[17]

```
5 1 3 4 2 6
V A L . E Y
B C)
D F G H I)
J K M)
N O P Q)
R)
S T U W X Z)  which produces the mixed sequence:

A C F K O T E I X L G M P U H Q W V B D J N R S Y Z
```

The first example will succumb to the treatment outlined in subpar. g, whereas the second method is vulnerable owing to the presence of the fragments D J N, F K O, and G M P in the sequence which may be anagrammed. Note the fair-sized fragment B D J N R S, composed of an ascending sequence of letters; this is an outward manifestation of the interrupted-key columnar method.

i. There are still other methods used for the production of mixed sequences, but space does not permit giving further examples. However, the student should by this time be able to devise methods of attack for any special cases that may present themselves, based upon the cryptanalytically exploitable weaknesses or peculiarities inherent in the system of cryptography involved.

[17] It is to be noted that in this particular case the numerical key serves two purposes: (1) determining the cut-off point (and therefore the number of letters) in each row of the diagram, after the appearance of the keyword; and (2) determining the order of transcription of the columns.

SECTION VII

MULTILITERAL SUBSTITUTION WITH SINGLE-EQUIVALENT CIPHER ALPHABETS

52. General types of multiliteral cipher alphabets.--a. Monoalphabetic substitution methods in general may be classified into uniliteral and multiliteral systems. In the former there is a strict "one-to-one" correspondence between the length of the units of the plain and those of the cipher text; that is, each letter of the plain text is replaced by a single character in the cipher text. In the latter this correspondence is no longer $1_p:1_c$ but may be $1_p:2_c$, where each letter of the plain text is replaced by a combination of two characters in the cipher text; or $1_p:3_c$, where a three-character combination in the cipher text represents a single letter of the plain text, and so on. A cipher in which the correspondence is of the $1_p:1_c$ type is termed uniliteral in character; one in which it is of the $1_p:2_c$ type, biliteral; $1_p:3_c$, triliteral, and so on. Ciphers in which one plaintext letter is represented by cipher characters of two or more elements are classed as multiliteral.[1]

b. Biliteral alphabets are usually composed of a set of 25 or 26 combinations of a limited number of characters taken in pairs. An example of such an alphabet is the following:

Plain--------	A	B	C	D	E	F	G	H	I	J	K	L	M
Cipher-------	WW	WH	WI	WT	WE	HW	HH	HI	HT	HT	HE	IW	IH
Plain--------	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher-------	II	IT	IE	TW	TH	TI	TT	TE	EW	EH	EI	ET	EE

This alphabet is derived from the cipher square or matrix shown in Fig. 16. The cipher equivalent of each plaintext element is made up of two coordinate letters from outside the cipher matrix, one letter being the coordinate of the row, the other being the coordinate of the column

[1] The terms uniliteral and multiliteral, although originally applied only to cipher text composed of letters, are used here in their broader sense to embrace cipher text in letters, digits, and even other symbols. In more precise terminology, these terms would probably be monosymbolic and polysymbolic, respectively, but the terms uniliteral and multiliteral are too well established in literature to be changed at this late time.

in which the plaintext letter is located. In other words, the letters at the side and top of the matrix have been used to designate, according to

(2)

		W	H	I	T	E
	W	A	B	C	D	E
	H	F	G	H	I-J	K
(1)	I	L	M	N	O	P
	T	Q	R	S	T	U
	E	V	W	X	Y	Z

Figure 16.

a coordinate system, the cell occupied by each letter within the matrix. The letters (or figures) constituting the coordinate elements of such matrices are termed row and column indicators.

c. If a message is enciphered by means of the foregoing biliteral alphabet, the cryptogram is still monoalphabetic in character. A frequency distribution based upon pairs of letters will obviously have all the characteristics of a simple, uniliteral distribution for a monoalphabetic substitution cipher.

d. The cipher alphabets shown thus far in this text have involved only letters, but alphabets in which the cipher component consists of figures, or groups of figures, are not uncommon in military cryptography.[2] Since there are but 10 digits it is obvious that, in order to represent an alphabet of more than 10 characters by means of figure ciphers, combinations of at least two digits are necessary. The simplest kind of such an alphabet is that in which A_p=01, B_p=02, . . . Z_p=26; that is, one in which the plaintext letters have as their equivalents two-digit numbers indicating their positions in the normal alphabet.

e. Instead of a simple alphabet of the preceding type, it is possible to use a diagram of the type shown in Fig. 17. In this cipher

	1	2	3	4	5	6	7	8	9	Ø
1	A	B	C	D	E	F	G	H	I	J
2	K	L	M	N	O	P	Q	R	S	T
3	U	V	W	X	Y	Z	.	,	:	;

Figure 17.

[2] Although, as an extension of this idea, cipher alphabets employing signs and symbols are possible, such alphabets are not suitable for modern cryptography because they can be neither telegraphed nor telephoned with any degree of accuracy, speed, or facility.

the letter A_p is represented by the dinome[3] 11, B_p by the dinome 12, etc. Furthermore, this matrix includes provision for the encipherment of some of the frequently-used punctuation marks in addition to the 26 letters.

f. Other types of biliteral cipher alphabets are illustrated in the examples below:

	5	6	7	8	9	Ø
1	A	B	C	D	E	F
2	G	H	I-J	K	L	M
3	N	O	P	Q	R	S
4	T	U-V	W	X	Y	Z

Figure 18.

	1	2	3	4	5	6	7	8	9
1	A	B	C	D	E	F	G	H	I
2	J	K	L	M	N	O	P	Q	R
3	S	T	U	V	W	X	Y	Z	*

Figure 19.

	M	U	N	I	C	H
B	G	7	E	5	R	M
E	A	1	N	Y	B	2
R	C	3	D	4	F	6
L	H	8	I	9	J	Ø
I	K	L	O	P	Q	S
N	T	U	V	W	X	Z

Figure 20.

	A	B	C	D	E	F	G	H	I
A	A	D	G	J	M	P	S	V	Y
B	B	E	H	K	N	Q	T	W	Z
C	C	F	I	L	O	R	U	X	1
D	2	3	4	5	6	7	8	9	Ø

Figure 21.

g. It is to be noted that in alphabets of the foregoing types, the row indicators may be distinct from the column indicators (e.g., Fig. 18), or they may not (e.g., Fig. 19); of course, when there is any duplication between the row and column indicators, it is necessary to agree beforehand upon which indicator will be given as the first half of the equivalent for a letter, in order to avoid ambiguity. (In all of the systems described in this and subsequent sections of this text, the row indicator will always form the first part of an equivalent). When letters are used as row and column indicators they may form a key word (e.g., Fig. 20), or they may not (e.g., Fig. 21); the key words, if formed, may be identical (e.g., Fig. 16) or different (e.g., Fig. 20). Furthermore, the plaintext letters may be arranged within the matrix as a mixed sequence (e.g., Fig. 20), either systematically- or random-mixed; and the matrix may contain, in addition to the letters of the alphabet, punctuation symbols (Fig. 17), numbers (Figs. 20, 21), etc., permitting their encipherment as such, instead of having to be spelled out.

[3] A pair of digits is called a dinome; similarly, a trinome is a set of three digits; a tetranome, a set of four digits; etc. Although a single digit would properly be termed a mononome, for the sake of euphony it is shortened into the term monome.

h. When letters are used as row and column indicators, they may be selected so as to result in producing cipher text that resembles artificial words; that is, words composed of alternate vowels and consonants. For example, if in Figure 16 the row indicators consisted of the vowels A E I O U in this sequence from the top down, and the column indicators consisted of the consonants B C D F G in this sequence from left to right, the word RAIDS would be enciphered as OCABE FAFOD, which very closely resembles code of the type formerly called artificial code language. Such a system may be called a false, or pseudo-code system.[4]

i. As a weak type of subterfuge, biliteral ciphers may involve a third character appended to the basic two-character cipher unit; this is done to "camouflage" the biliteral nature of the cipher text. This third character may be produced through the use of a cipher matrix of the type illustrated in Fig. 22 (wherein A_p=611, B_p=612, etc.); or the third character may be a "sum-checking" digit which is the non-carrying sum (i.e., the sum modulo 10)[5] of the preceding two digits, such as in the trinomes 257, 831, and 662; or it may merely be a randomly-selected character (inserted solely for the purpose of leading the cryptanalyst astray).

	1	2	3	4	5
61	A	B	C	D	E
72	F	G	H	I-J	K
83	L	M	N	O	P
94	Q	R	S	T	U
05	V	W	X	Y	Z

Figure 22.

j. Another possibility that lends itself to certain multiliteral ciphers is the use of a word spacer or word separator. This word separator might be represented by a value in the matrix; i.e., the separator is enciphered (for instance, the dinome "39" in Fig. 19 might stand for a word separator). The word separator might instead be a single element not otherwise used in the cryptosystem; i.e., unenciphered, and thus not giving rise to any possible ambiguity. Thus, in Fig. 19 the digit Ø and in Fig. 21 the letter J might be used as word separators, since no confusion would arise in decrypting.

[4] Prior to 1934, international telegraph regulations required code words of five letters to contain at least one vowel and code words of ten letters to contain at least three vowels. The International Telegraph Conference held in Madrid in 1932 amended these regulations to permit the use of 5-letter code groups containing any combination of letters. These unrestricted code groups were authorized for use after 1 January 1934.

[5] The term modulo (abbreviated mod) pertains to a cyclic scale or basis of arithmetic; thus, in the modulus of 7, the numbers 8 and 15 are equivalent to 1, and 9 and 16 are equivalent to 2, etc.; or expressed differently, 8 mod 7 is 1, 9 mod 7 is 2. In cryptology, many operations are expressed mod 10 and mod 26.

k. The biliteral alphabets yielded by the matrices of Figs. 16-21 may also be termed bipartite, because the cipher units of these alphabets may be divided into two separate parts whose functions are clearly defined, viz., row indicators and column indicators. As will be discussed later, this bipartite nature of most biliteral alphabets produced from cipher matrices constitute one of the weaknesses of these alphabets which make them recognizable as such to a cryptanalyst. However, it is possible to employ a cipher matrix in a manner which will produce a biliteral alphabet not bipartite in character. For example, using the matrix of Fig. 23 one could produce the following biliteral cipher alphabet in which the equivalent for any letter in the matrix is the sum of the two coordinates which indicate its cell in the matrix:

Plain--------	A	B	C	D	E	F	G	H	I	J	K	L	M
Cipher-------	14	20	19	12	22	23	24	10	18	18	25	17	26

Plain--------	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Cipher-------	28	29	30	31	13	32	34	16	35	36	37	11	38

	1	2	3	4	5
09	H	Y	D	R	A
15	U	L	I-J	C	B
21	E	F	G	K	M
27	N	O	P	Q	S
33	T	V	W	X	Z

Figure 23.

The cipher units of this alphabet are, of course, biliteral; but they are not bipartite. Note the equivalent of A_p, that is 14--if divided, it yields the digits 1 and 4 which have no meaning per se: plaintext letters whose cipher equivalents begin with 1 may be found in two different rows of the matrix, and those whose equivalents end in 4 appear in three different columns.

53. The Baconian and Trithemian ciphers.--a. An interesting example in which the cipher equivalents are five-letter groups and yet the resulting cipher is strictly monoalphabetic in character is found in the cipher system invented by Sir Francis Bacon (1561-1626) over 300 years ago. Despite its antiquity the system possesses certain features of

merit which are well worth noting.[6] Bacon proposes the following 24-element cipher alphabet, composed of permutations of two elements taken five at a time:[7]

A=aaaaa	I-J=abaaa	R=baaaa
B=aaaab	K=abaab	S=baaab
C=aaaba	L=ababa	T=baaba
D=aaabb	M=ababb	U-V=baabb
E=aabaa	N=abbaa	W=babaa
F=aabab	O=abbab	X=babab
G=aabba	P=abbba	Y=babba
H=aabbb	Q=abbbb	Z=babbb

If this were all there were to Bacon's invention it would be hardly worth bringing to attention. But what he pointed out, with great clarity and simple examples, was how such an alphabet might be used to convey a secret message by enfolding it in an innocent, external message which might easily evade the strictest kind of censorship. As a very crude example, suppose that a message is written in capital and lower-case letters, any capital letter standing for an "a" element of the cipher alphabet, and any small letter, for a "b" element. Then the external sentence "All is well with me today" can be made to contain the secret message "Help." Thus:

$$\underbrace{\overset{A}{a}\;\overset{L}{a}\;\overset{l}{b}\quad\overset{i}{b}\;\overset{s}{b}}_{H}\quad\underbrace{\overset{W}{a}\;\overset{E}{a}\;\overset{l}{b}\;\overset{L}{a}\quad\overset{W}{a}}_{E}\;\underbrace{\overset{I}{a}\;\overset{t}{b}\;\overset{H}{a}\quad\overset{m}{b}\;\overset{E}{a}}_{L}\quad\underbrace{\overset{T}{a}\;\overset{o}{b}\;\overset{d}{b}\;\overset{a}{b}\;\overset{Y}{a}}_{P}$$

Instead of employing a device so obvious as capital and small letters, suppose that an "a" element be indicated by a very slight shading, or a

[6] For a true picture of this cipher, the explanation of which is often distorted beyond recognition even by cryptographers, see Bacon's own description of it as contained in his De Augmentis Scientiarum (The Advancement of Learning), as translated by any first class editor, such as Gilbert Watts (1640) or Ellis, Spedding, and Heath (1857, 1870). The student is cautioned, however, not to accept as true any alleged "decipherments" obtained by the application of Bacon's cipher to literary works of the 16th century. These readings are purely subjective.

[7] Bacon's alphabet was called by him a "biliteral alphabet" because it employs permutations of two letters. But from the cryptanalytic standpoint the significant point is that each plaintext letter is represented by a 5-character equivalent. Hence, present terminology requires that this alphabet be referred to as a quinqueliteral alphabet. Although the quinqueliteral alphabet affords 32 permutations, Bacon used only 24 of them, because in the 16th century the letters I and J, U and V were used interchangeably. Note the regularity of construction of Bacon's biliteral alphabet, a feature which easily permits its reconstruction from memory.

very slightly heavier stroke. Then a secret message might easily be thus enfolded within an external message of exactly opposite meaning. The number of possible variations of this basic scheme is very high. The fact that the characters of the cryptographic text are hidden in some manner or other has, however, no effect upon the strict monoalphabeticity of the scheme.

b. Almost 100 years before Bacon's time, the abbot Trithemius, born Johann von Heydenberg (1462-1516), invented a triliteral alphabet which he evidently intended to use in a fashion similar to Bacon's alphabet; i.e., as a means of disguise or cover for a secret text. This alphabet, modified to include the 26 letters of the present-day English alphabet, is shown in Fig. 23 below; it consists of all the permutations of three things taken three at a time, i.e., 3^3 or 27 in all.

A=111	D=121	G=131	J=211	M=221	P=231	S=311	V=321	Y=331
B=112	E=122	H=132	K=212	N=222	Q=232	T=312	W=322	Z=332
C=113	F=123	I=133	L=213	O=223	R=233	U=313	X=323	*=333

Figure 23.

The cipher text of course does not have to be restricted to digits; any groupings of three things taken three at a time will do.

54. Analysis of multiliteral, monoalphabetic substitution ciphers.-- a. Biliteral ciphers and those of the other multiliteral (triliteral, quadriliteral, . . .) types are often readily detected externally by the fact that the cryptographic text is usually composed of but a very limited number of different characters. They are handled in exactly the same manner as are uniliteral, monoalphabetic substitution ciphers. So long as the same character, or combination of characters, is always used to represent the same plaintext letter, and so long as a given letter of the plain text is always represented by the same character or combination of characters, the substitution is strictly monoalphabetic and can be handled in the simple manner described in the preceding section of this text.

b. In the case of biliteral ciphers in which the row and column indicators are not identical, and the direction of reading the cipher pairs is chosen at will for each succeeding cipher pair, an analysis of the contacts of the letters comprising the cipher pairs will disclose that there are two distinct families of letters, and a cipher pair will never consist of two letters of the same family. With this fact discovered, the cipher may be quickly reduced to uniliteral terms and solved in the manner previously mentioned.

c. If a multiliteral cipher includes provision for the encipherment of a word separator, the cipher equivalent of this word separator may be readily identified because it will have the highest frequency of any cipher unit. On the other hand, if the word separator is a single character (see subpar. 52j. on the use of the digit Ø and the letter J), this character may be identified throughout the encrypted text by its positional appearance spaced "wordlength-wise" in the cipher text, and by the fact that it never contacts itself. If this single character is used as a null indiscriminately throughout the cipher text, instead of as a word separator, the analysis is a bit more complicated but not as great as might be thought.

d. As a general rule, it is advisable to reduce multiliteral cipher text to uniliteral equivalents, especially if a triliteral frequency distribution is to be made. If not more than 36 different combinations are present in a cryptogram, the extra values over 26 may be represented by digits for the purpose of this reduction. If, however, more than 36 different combinations are found in the encrypted text, it is usually not worth the trouble to attempt any uniliteral reduction, and the cipher text can be attacked in its multiliteral groupings.

e. As one of the first steps in the solution of any multiliteral cipher in letters which appears to involve the use of a cipher matrix, it is generally advisable to anagram the letters comprising the row and column indicators in an attempt to disclose any key words for these indicators. When the anagramming process does disclose such a key word or words, the next step is to make a skeleton reconstruction matrix which is a duplicate of the original enciphering matrix in that the indicators are arranged in the same order as on the original. Then, as plain text is recovered in the cryptogram by any of the methods outlined in the previous section of this text, the recovered plaintext letters should be inserted in the proper cells of the reconstruction matrix, so that any systematic arrangement of the plaintext letters, if present in the original, may be disclosed prior to recovery of the complete plain text. Furthermore, it may in some instances be found worthwhile, immediately after successfully uncovering the key words used as indicators, to make a frequency distribution of the particular cryptogram in the form of tally marks within the properly arranged frame of the reconstruction matrix, because it may be that a few moments' study of the locations of the crests and troughs in the distribution made in that form may, if the plaintext letters are arranged in the normal sequence or in a keyword-mixed sequence (especially if it is related to the key words for the indicators), provide a basis for the derivation of this sequence at one stroke, without recourse to analysis of the cipher text.

55. Historically interesting examples.--a. Two examples of multiliteral ciphers of historical interest will be cited as illustrations. During the campaign for the presidential election of 1876 (Hayes vs. Tilden) many cipher messages were exchanged between the Tilden managers and their agents in several states where the voting was hotly contested. Two years later the New York Tribune[8] exposed many irregularities in the

[8] New York Tribune, Extra No. 44, The Cipher Dispatches, New York, 1879.

campaign by publishing the decipherments of many of these messages. These decipherments were achieved by two investigators employed by the Tribune, and the plain text of the messages seems to show that illegal attempts and measures to carry the election for Tilden were made by his managers. Here is one of the messages:

JACKSONVILLE, Nov. 16 (1876).

GEO. F. RANEY, Tallahassee.

```
    P p y y e m n s n y y y p i m a s h n s y y s s i t e p a a e n s h n s
p e n s s h n s m m p i y y s n p p y e a a p i e i s s y e s h a i n s s s p
e e i y y s h n y n s s s y e p i a a n y i t n s s h y y s p y y p i n s y y
s s i t e m e i p i m m e i s s e i y y e i s s i t e i e p y y p e e i a a s s
i m a a y e s p n s y y i a n s s s e i s s m m p p n s p i n s s n p i n s i m
i m y y i t e m y y s s p e y y m m n s y y s s i t s p y y p e e p p p m a
a a y y p i i t
```

L'Engle goes up tomorrow.

DANIEL.

Examination of the message discloses that only ten different letters are used. It is probable, therefore, that what one has here is a cipher which employs a multiliteral alphabet. First assuming that the alphabet is one in which combinations of two letters represent single letters of the plain text, the message is rewritten in pairs and substitution of arbitrary letters for the pairs is made, as seen below:

PP	YY	EM	NS	NY	YY	PI	MA	SH	NS	YY	SS	etc.
A	B	C	D	E	B	F	G	H	D	B	I	etc.

A triliteral frequency distribution is then made and analysis of the message along the lines illustrated in the preceding section of this text yields solution, as follows:

Jacksonville, Nov. 16.

GEO. F. RANEY, Tallahassee:

Have Marble and Coyle telegraph for influential men from Delaware and Virginia. Indications of weakening here. Press advantage and watch Board. L'Engle goes up tomorrow.

DANIEL.

b. The other example, using numbers, is as follows:

Jacksonville, Nov. 17.

S. PASCO and E. M. L'ENGLE:

```
84 55 84 25 93 34 82 31 31 75 93 82 77 33 55 42
93 20 93 66 77 66 33 84 66 31 31 93 20 82 33 66
52 48 44 55 42 82 48 89 42 93 31 82 66 75 31 93
```

DANIEL.

There were, of course, several messages of like nature, and examination disclosed that only 26 different numbers in all were used. Solution of these ciphers followed very easily, the decipherment of the one given above being as follows:

Jacksonville, Nov. 17.

S. PASCO and E. M. L'ENGLE:

Cocke will be ignored, Eagan called in. Authority reliable.

DANIEL.

c. The Tribune experts gave the following alphabets as the result of their decipherments:

AA=O	EN=Y	IT=D	NS=E	PP=H	SS=N
AI=U	EP=C	MA=B	NY=M	SH=L	YE=F
EI=I	IA=K	MM=G	PE=T	SN=P	YI=X
EM=V	IM=S	NN=J	PI=R	SP=W	YY=A
20=D	33=N	44=H	62=X	77=G	89=Y
25=K	34=W	48=T	66=A	82=I	93=E
27=S	39=P	52=U	68=F	84=C	96=M
31=L	42=R	55=O	75=B	87=V	99=J

They did not attempt to correlate these alphabets, or at least they say nothing about a possible relationship. The present author has, however, reconstructed the rectangle upon which these alphabets are based, and it is given below (Fig. 24).

2d Letter or Number

1st Letter or Number	H 1	I 2	S 3	P 4	A 5	Y 6	M 7	E 8	N 9	T 0
H 1										
I 2					K		S			D
S 3	L		N	W					P	
P 4		R		H				T		
A 5		U			O					
Y 6		X				A		F		
M 7					B		G			
E 8		I		C			V		Y	
N 9			E			M			J	
T 0										

Figure 24.

It is amusing to note that the conspirators selected as their key a phrase quite in keeping with their attempted illegalities - HIS PAYMENT - for bribery seems to have played a considerable part in that campaign. The blank cells in the matrix probably contained proper names, numbers, etc.[9]

56. The international (Baudot) teleprinter code.--a. Modern printing telegraph systems,[10] or teleprinter systems as they are more often called, make use of a five-unit code[11] or alphabet which is similar to the Baconian alphabet treated in par. 53. Like the Baconian alphabet, the teleprinter alphabet is composed of permutations of two elements taken five at a time, making it possible to obtain 32 different permutations, 26 of which are assigned to the letters of the alphabet, leaving 1 for an "idle condition" and 5 for certain printer operations called functions, such as "space", "figure shift", "letter shift," etc.

b. During electrical transmission, the two distinct elements of which each character is composed take the form of (1) a timed interval of electrical current and (2) a timed interval of no current, which are commonly referred to as "mark" impulses and "space" impulses, respectively. In certain operations, a paper tape is prepared of the traffic to be transmitted, or a paper tape may be prepared of the incoming traffic at the receiving end; in such tapes, the elements of the Baudot characters take the form of punched holes ("mark" impulses) and imperforate positions ("space" impulses).

[9] As was mentioned in a previous footnote, a matrix containing such items would be termed a syllabary square; for example of such matrices see the treatment of syllabary squares and code charts in Section X.

[10] Such systems are characterized by the transmission and reception-printing of messages by electrical means, incorporating two electrically-connected instruments, resembling typewriters. When a key of the keyboard on the transmitting instrument is depressed, an electrical signal is transmitted to the receiving instrument, causing the corresponding character to be printed therein. Usually the message is printed at the local as well as the distant station. The system has been adapted to radio as well as wire and overseas cable transmission.

[11] The five-unit code was first applied to teleprinter systems by Jean Maurice Emile Baudot (1845-1903), and is commonly known as the Baudot code. It is worthwhile to point out that Baudot apparently constructed his alphabet to correspond with normal frequencies of characters (with certain exceptions), since the most frequent ones are represented by permutations requiring the least electrical energy on the basis of "marking" and "spacing." In this respect Baudot "took a leaf out of Morse's notebook."

c. The teleprinter code in international use is given in Chart 7, below, wherein the mark and space impulses (known collectively as bauds) are illustrated as the holes (shown as black dots) and "no-holes" of a teleprinter tape. The letter equivalents ("lower case") are self-explanatory. The figure shift is used to change the meaning of a particular character to an "upper case" equivalent, and when it is desired to return to lower case, the letter shift is used; in regular teleprinter usage, the "communications" set of upper-case equivalents are the ones recorded on the typed copy by the teleprinter, whereas the "weather symbols" are the upper-case equivalents which are printed in teleprinter systems designed for the sending and receiving of weather information. The space is used to separate words; the carriage return (C.R.) effects the return of the teleprinter carriage to the right and the line feed (L.F.) rolls the platen to the next line for printing (cf. the corresponding functions of an ordinary typewriter). In addition, when the upper-case equivalent of "S" is used, a bell rings in the receiving teleprinter as a signal to call the operator to his machine, or to indicate that traffic is about to be sent.

UPPER CASE	WEATHER SYMBOLS	↑	⊕	○	↗	3	→	↘	↓	8	↙	←	↖		⦶	9	Ø	1	4	Δ	5	7	Ⓘ	2	/	6	+	−	<	≡			
	COMMUNICATIONS	−	?		$	3	!	&	£	8		(	)		,	9	Ø	1	4	Δ	5	7	;	2	/	6	'	≈	<	≡			
LOWER CASE		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	BLANK	C R	L F	SPACE	LTR SHIFT	FIG SHIFT
	1	●	●		●	●	●				●	●						●		●		●		●	●	●	●					●	●
	2	●		●				●		●	●	●	●				●	●	●			●	●	●						●		●	●
	FEED HOLES	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	3			●			●		●	●		●		●	●		●	●		●		●	●		●	●					●	●	
	4		●	●	●		●	●			●	●		●	●	●			●				●		●				●			●	●
	5		●					●	●				●	●		●	●	●			●		●	●	●	●	●					●	●

Chart 7. International teleprinter code.

d. In Fig. 25 is shown a portion of a teleprinter tape containing the beginning of the phrase "Now is the time for all good men . . ."

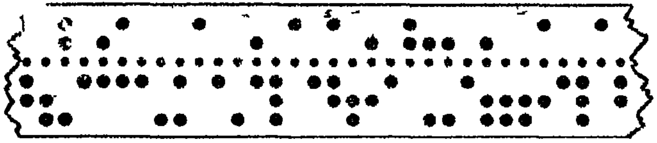

Figure 25.

The small holes, one of which appears in every position of the tape between the second and third levels, are sprocket holes used for advancing the tape through the transmitter unit.

e. It is to be emphasized that messages are not made secure from unauthorized reading merely by sending them by means of an ordinary teleprinter system--the teleprinter alphabet is internationally known, just as the English, Russian, etc. alphabets are. In order to provide security for a teleprinter message, it is just as necessary to apply thereto some sort of cryptographic treatment as it is to any other kind of message. The cryptosystems used for teleprinter encryption may involve either, or both, of the two classes of cryptographic treatment, viz., substitution and transposition. A substitution treatment might involve changing certain of the mark impulses of the characters comprising a message to space impulses, and vice versa, according to a prearranged system, a transposition treatment might involve changing the order of the 5 impulses in the Baudot equivalents for the characters comprising a message; and so on. The cryptographic treatment can be accomplished by a special cipher attachment (called an "appliqué unit") to a teleprinter; thus no modification of the teleprinter itself would be necessary. There are, of course, self-contained cipher teleprinters designed as such for engineering or cryptographic reasons, or both.

f. In the analysis of encrypted teleprinter systems, recourse is had to special tables[12] of the frequencies of single Baudot characters, digraphs, trigraphs, etc., as they appear in teleprinter traffic. It is important to note that in teleprinter traffic, as in any other type of traffic involving the use of a word separator, this character has the highest frequency of any plaintext element! Furthermore, one of the highest-frequency plaintext digraphs, in addition to those wherein the word separator constitutes one of the elements, will be the combination "carriage-return/line-feed", since this combination of characters is used in the normal procedure of typing each line of text on the teleprinter.

[12] In such tables, as is common in cryptanalytic practice, the mark impulses are designated by a plus symbol (+), and the space impulses are designated by a minus symbol (-). In addition, it is usual in such tables to denote the character representing the figure shift by the digit "2", the space by "3", the letter shift by "4", the line feed by "5", the blank by "6", and the carriage return by "7".

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SECTION VIII

MULTILITERAL SUBSTITUTION WITH VARIANTS

Paragraph

57. Purpose of providing variants in monoalphabetic substitution.--a It has been seen that the individual letters composing ordinary intelligible plain text are used with varying frequencies, some, such as (in English) E, T, R, I, and N, are used much more often than others, such as J, K, Q, X, and Z. In fact, each letter has a characteristic frequency which affords definite clues in the solution of simple monoalphabetic ciphers, such as those discussed in the preceding sections of this text. In addition, the associations which individual letters form in combining to make up words, and the peculiarities which certain of them manifest in plain text, afford further direct clues by means of which ordinary monoalphabetic substitution encipherments of such plain text may be more or less speedily solved. This has led cryptographers to devise methods for disguising, suppressing, or eliminating the foregoing characteristics manifested in cryptograms produced by the simpler methods of monoalphabetic substitution One category of such methods, the one to be discussed in this section, is that in which the letters of the plain component of a cipher alphabet are assigned two or more cipher equivalents, which are called variant values (or, more simply, variants).

b. Basically, systems involving variants are multiliteral[1] and, in such systems, because of the large number of equivalents made available

[1] Uniliteral substitution with variants is also possible. Note the following cipher alphabet, illustrated by Captain Roger Baudouin in his excellent treatise, Eléments de Cryptographie, p. 101 (Paris, 1939)

Plain	A	B	C	D	E	F	G	H	I	L	M	N	O	P	Q	R	S	T	U	V	X	Z
Cipher	L	G	O	R	F	Q	A	H	C	M	B	T	I	D	N	P	U	S	Y	E	W	J
					K							X					Z					
					V																	

Baudouin proposed that J_p and Y_p be replaced by I_p, K_p by C_p or Q_p, and W_p by VV_p--thus four cipher letters would be available as variants for the high-frequency plaintext letters in French.

by the combinations and permutations of a limited number of elements, each letter of the plain text may be represented by several multiliteral cipher equivalents which may be selected at random. For example, if 3-letter combinations are employed as the multiliteral equivalents, there are available 26^3 or 17,576 such equivalents for the 26 letters of the plain text, they may be assigned in equal numbers of different equivalents for the 26 letters, in which case each letter would be representable by 676 different 3-letter equivalents, or they may be assigned on some other basis, for example, proportionately to the relative frequencies of plaintext letters. For this reason this type of system may be more completely described as a monoalphabetic, multiliteral substitution with a multiple-equivalent cipher alphabet.[2] Some authors term such a system "simple substitution with multiple equivalents", others term it "monoalphabetic substitution with variants", or multiliteral substitution with variants. For sake of brevity and precise terminology, the latter designation will be employed in this text, it being understood without further restatement that only such systems as are monoalphabetic will be discussed.

c. The primary object of monoalphabetic substitution with variants is, as has been mentioned above, to provide several values which may be employed at random in a simple substitution of cipher equivalents for the plaintext letters

d. A word or two concerning the underlying theory of (monoalphabetic) multiliteral substitution with variants may not be amiss. Whereas in simple or single-equivalent substitution it has been seen that

(1) the same letter of the plain text is invariably represented by but one and always the same character of the cryptogram, and
(2) the same character of the cryptogram invariably represents one and always the same letter of the plain text,

in multiliteral substitution with variants it will be seen that

(1) the same letter of the plain text may be represented by one or more different characters of the cryptogram, but
(2) the same character of the cryptogram nevertheless invariably represents one and always the same letter of the plain text.

58. Simple types of cipher alphabets with variants.--a. The matrices shown on the next page provide some of the simpler means for accomplishing monoalphabetic substitution with variants. The systems incorporating these matrices are extensions of the basic ideas of multiliteral substitution treated in par 52 The variant equivalents for any plaintext letter may be chosen at will, thus, in Fig. 26, E_p=10, 15, 60, or 65, in Fig. 27, F_p=AU_c, AZ_c, FU_c, FZ_c, LU_c, or LZ_c, etc

[2] Cf. the title of the preceding section, "Multiliteral substitution with single-equivalent cipher alphabets."

		6	7	8	9	Ø
		1	2	3	4	5
6	1	A	B	C	D	E
7	2	F	G	H	I-J	K
8	3	L	M	N	O	P
9	4	Q	R	S	T	U
Ø	5	V	W	X	Y	Z

Figure 26

			V	W	X	Y	Z
			Q	R	S	T	U
L	F	A	A	B	C	D	L
M	G	B	F	G	H	I-J	K
N	H	C	L	M	N	O	P
O	I	D	Q	R	S	T	U
P	K	E	V	W	X	Y	Z

Figure 27

				A	E	I	O	U
T	N	H	B	A	B	C	D	L
V	P	J	C	F	G	H	I-J	K
W	Q	K	D	L	M	N	O	P
X	R	L	F	Q	R	S	T	U
Z	S	M	G	V	W	X	Y	Z

Figure 28

					V	W	X	Y	Z
					Q	R	S	T	U
					L	M	N	O	P
					F	G	H	I	K
					A	B	C	D	E
V	Q	L	F	A	A	B	C	D	E
W	R	M	G	B	F	G	H	I-J	K
X	S	N	H	C	L	M	N	O	P
Y	T	O	I	D	Q	R	S	T	U
Z	U	P	K	E	V	W	X	Y	Z

Figure 29

					O				
					M	N			
					J	K	L		
					F	G	H	I	
					A	B	C	D	E
O	M	J	F	A	E	N	A	L	U
	N	K	G	B	T	R	S	F	W
		L	H	C	O	I-J	H	Y	X
			I	D	D	C	M	V	K
				E	P	G	B	Q	Z

Figure 30

				Z				
				W	X	Y		
				S	T	U	V	
				N	O	P	Q	R
M	J	F	A	E	N	A	L	U
	K	G	B	T	R	S	F	W
	L	H	C	O	I-J	H	Y	X
		I	D	D	C	M	V	K
			E	P	G	B	Q	Z

Figure 31

			1	2	3	4	5	6	7	8	9	Ø
7	4	1	A	B	C	D	E	F	G	H	I	J
8	5	2	K	L	M	N	O	P	Q	R	S	T
9	6	3	U	V	W	X	Y	Z	.	,		,

Figure 32

			1	2	3	4	5	6	7	8	9
7	4	1	A	B	C	D	E	F	G	H	I
8	5	2	J	K	L	M	N	O	P	Q	R
9	6	3	S	T	U	V	W	X	Y	Z	*

Figure 33

		1	2	3	4	5	6	7	8	9
5	1	A	B	C	D	E	F	G	H	I
6	2	J	K	L	M	N	O	P	Q	R
7	3	S	T	U	V	W	X	Y	Z	1
8	4	2	3	4	5	6	7	8	9	Ø

Figure 34

				1	2	3	4	5	6	7	8	9
Ø	8	5	1	T	E	R	M	I	N	A	L	S
	9	6	2	B	C	D	F	G	H	J	K	O
		7	3	P	Q	U	V	W	X	Y	Z	1
			4	2	3	4	5	6	7	8	9	Ø

Figure 35

b. It is to be noted that encipherment by means of the matrices in Figures 27, 28, and 31 is commutative, i.e., the coordinates may be read in either row-column or column-row order without cryptographic ambiguity, since there is no duplication between the row and column coordinates. The remaining matrices above are non-commutative, therefore a convention must be agreed upon as to the order of reading the coordinates. It should also be noted that in Figs. 30 and 31 the letters in the square have been inscribed in such a manner that, coupled with the particular arrangement of the row and column coordinates, the number of variants available for each plaintext letter is roughly proportional to the frequencies of the letters in plain text A similar idea is found in Fig. 35, wherein the top row of the rectangle contains a word composed of high-frequency letters, and the coordinates are arranged in a manner roughly corresponding to the frequencies of plaintext letters. The matrix in Fig. 28 is a modification of the pseudo-code system described in par. 52h, with the added feature of variants.

c. Other simple ideas for producing variant systems are matrices such as the following

A	B	C	D	E	F	G	H	I-J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	01	02	03	04	05	06	07
35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	26	27	28	29	30	31	32	33	34
68	69	70	71	72	73	74	75	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
87	88	89	90	91	92	93	94	95	96	97	98	99	00	76	77	78	79	80	81	82	83	84	85	86

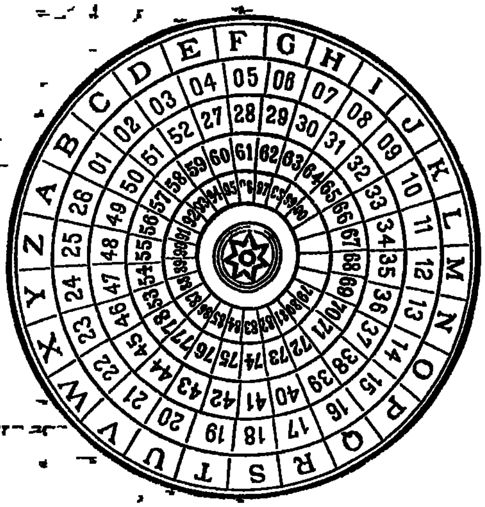
Figure 36

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
14	15	16	17	18	19	20	21	22	23	24	25	26	01	02	03	04	05	06	07	08	09	10	11	12	13
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	53	54	55	56	57
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	▨	▨	▨	▨	79	80

Figure 37

In these two matrices there has been a regular inscription of the dinomes in the rows. Furthermore, in Fig 36 the dinomes 01, 26, 51, and 76 (i e., the lowest number in each of the four sequences) give the key word (TRIP) for that matrix, and in Fig 37, the dinomes 01, 27, 53, and 79 denote the key word (NAVY) for that matrix The security of systems involving such matrices would of course be greatly improved if the dinomes were assigned in a random manner but then the easy mnemonic feature of the four sequences and the key word would be lost.

a. An interesting adaptation in a disc form of the type of matrix illustrated in Fig. 37 is the following device reputedly once used by the Mexican Army



The device consisted of five-concentric discs, the outer disc bearing the 26 letters of the alphabet, and the other four bearing the sequences 01-26, 27-52, 53-78, and 79-00. The rotatable discs made it possible to change the keys at frequent intervals, without the necessity of writing out a new matrix each time

59 <u>More complicated types of cipher alphabets with variants</u>.--
a. Matrices such as those in Figs. 38, 39, and 40 below are termed frequential matrices, since the number of cipher values available for any given plaintext letter closely approximates its relative plaintext frequency.

	A	B	C	D	E		V	W	X	Y	Z
A	T	G	A	U	R		I	E	C	A	P
B	S	L	I	E	Y		F	R	N	S	T
C	C	N	D	O	M		E	L	T	I	H
D	R	A	P	T	F		O	Y	S	O	V
E	N	T	X	N	E		C	E	R	E	D
									⋮		
V	N	O	A	T	L		A	L	E	Z	H
W	I	H	R	O	Q		E	T	R	B	T
X	O	I	E	T	A	. .	C	N	P	E	S
Y	F	T	L	O	S	- -	A	M	T	I	U
Z	I	S	N	D	R		I	E	D	O	N

(676 - cell matrix)

Figure 38

	6	8	9	1	5	4	3	7	2	Ø
7	A	A	A	C	D	E	E	I	L	N
1	A	A	C	D	E	E	H	K	N	O
3	A	B	D	E	E	H	J	N	O	R
8	A	D	E	E	H	I	N	O	R	S
9	C	E	E	G	I	N	O	R	S	T
2	E	E	F	I	M	O	Q	S	T	T
Ø	E	F	I	M	O	P	R	T	T	U
5	F	I	L	N	P	R	S	T	U	X
6	I	L	N	P	R	S	T	U	W	Y
4	L	N	O	R	S	T	T	V	Y	Z

Figure 39

	Ø	1	2	3	4	5	6	7	8	9
Ø	E	N	T	R	U	C	K	I	N	G
1	Q	U	A	R	A	N	T	I	N	E
2	U	N	E	X	P	E	N	D	E	D
3	I	M	P	O	S	S	I	B	L	E
4	V	I	C	T	O	R	I	O	U	S
5	A	D	J	U	D	I	C	A	T	E
6	L	A	B	O	R	A	T	O	R	Y
7	E	I	G	H	T	E	E	N	T	H
8	N	A	T	U	R	A	L	I	Z	E
9	T	W	E	N	T	Y	F	I	V	E

Figure 40

b. In the fragmentary matrix illustrated in Fig. 38, the number of occurrences of a particular letter within the matrix is proportional to its frequency in plain text, the letters are inscribed in a random manner, in order to enhance further the security of the system. In Fig. 39, we have a modification of the idea set forth in Fig. 38, except that the size of the matrix has been reduced from 26x26 to 10x10, in this case, the letters (with appropriate number of repetitions) have been inscribed in a simple diagonal route (lower left to upper right) within the square, and the coordinates have been scrambled, for greater security. In Fig. 40, there is illustrated a type of cipher square which is known in cryptologic literature as the Grandpré cipher, in this square there are inscribed ten 10-letter words containing all the letters of the alphabet in their approximate plaintext frequencies These ten words are further linked together by a 10-letter word which appears vertically in the first column, as a mnemonic feature for the inscription of the words in the rows.

c. The frequential-type system represented in Fig. 41a (enciphering matrix) and 41b (deciphering matrix) was described by Sacco[3], who proposed that the dinomes inscribed in the enciphering matrix be thoroughly disarranged by applying a double transposition to the dinomes 00-99 as a means of suppressing any patent relationships among the variant values for the various plaintext letters, furthermore, the nulls incorporated in the matrix were to be used occasionally during the encryption of a message, in order to throw a cryptanalyst off the track In this example the number of variant values for each plaintext letter has been established, of course, from the standpoint of Italian letter frequencies.

[3] Sacco, Generale Luigi, Manuale di Crittografia, 3d Ed., Rome, 1947, p. 22.

Nulls 48-56 21-09 76-54 42-12 64-74 55-14 83-90 63-06 47-45	A 03-25 52-62 79-69	E 18-35 37-65 71-78	I 10-23 53-75 82-87	M 39 68	Q 20 77	V 02-86	one 44 66	seven 46
	B 40 93	F 24 57	J 81	N 13-73	R 26-94	W 95	two 84	eight 29 nine 31
	C 28 70	G 38 97	K 96	O 07-30 51-67 72-89	S 11-58 T 33-88	X 85 Y 22	three 50 four 27	zero 19 92
	D 08 80	H 17 43	L 05 49	P 41 98	U 00-15 36-99 01	Z 34 59	five 60-91 six 04	period 16-61 comma 32

Figure 41a

	1	2	3	4	5	6	7	8	9	Ø
1	S	-	N	-	U	period	H	E	zero	I
2	-	Y	I	F	A	R	four	C	eight	Q
3	nine	comma	T	Z	E	U	E	G	M	O
4	P	-	H	one	-	seven	-	-	L	B
5	O	A	I	-	-	-	F	S	Z	three
6	period	A	-	-	E	one	O	M	A	five
7	E	O	N	-	I	-	Q	E	A	C
8	J	I	-	two	X	V	I	T	O	D
9	five	zero	B	R	W	K	G	P	U	-
Ø	U	V	A	six	L	-	O	D	-	U

Figure 41b.

d. The Baconian cipher described in par. 53a may be used as a basis for superimposing additional complexities. For instance, the "a" elements may be represented by any one of the 20 consonants as variants, while the "b" elements may be represented by any one of the six vowels, or the letters A-M may be used to represent the "a" elements and the letters N-Z for the "b" elements, digits may be used for the "a" and "b" elements, either on the basis of the first five and last five digits, or on the basis of the odd and even digits, or the first 10 consonants (B-M) and the last 10 consonants (N-Z) may be used for the "a" and "b" elements, with the vowels used occasionally as nulls--thus the resultant cryptograms will resemble those of a fairly complex cryptosystem. However, once the cryptanalyst assumes the possibility of such a system, its complexity is more apparent than real. Similarly, variations of this genre may be superimposed on triliteral systems such as the Trithemian cipher illustrated in par. 53b; variants for the "1", "2", and "3" elements may be chosen in such a way as to provide a large number of equivalents for each basic triliteral combination.

e. Another scheme for a complex variant system is a summing-trinome system. In this cryptosystem, each plaintext letter is assigned a unique value of 1 to 26, this value is then expressed as a trinome, the digits of which sum to the designated value of the letter. For example, if a letter has been assigned the value "4", it may be represented by any one of the following permutations and combinations[4]

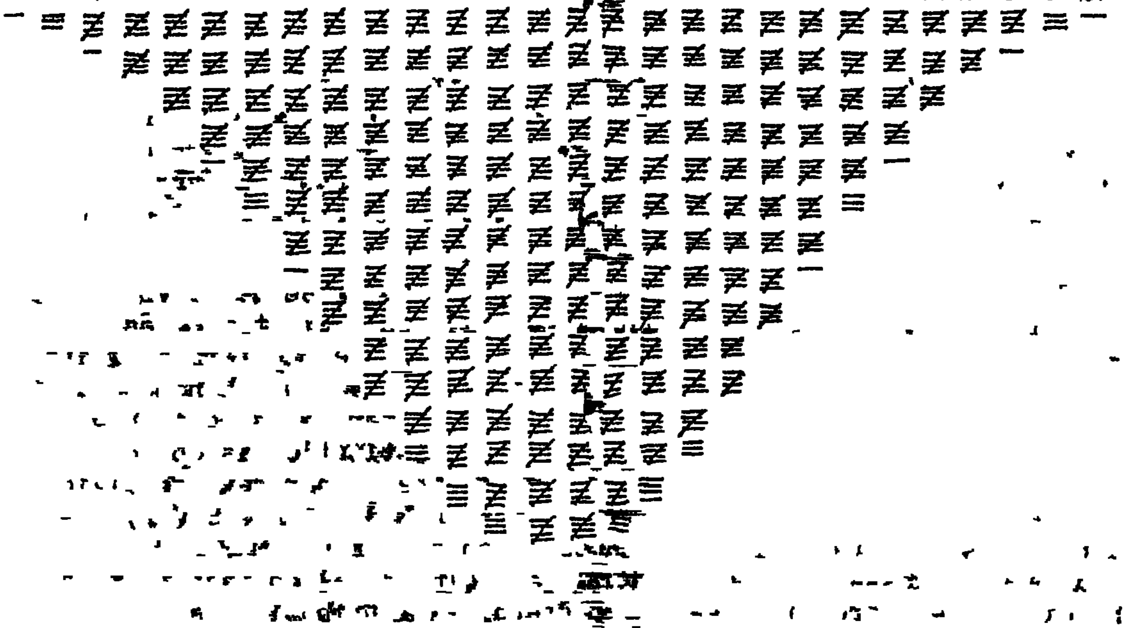
004	031	112	202	301
013	040	121	211	310
022	103	130	220	400

Since the values toward the middle of the range 1-26 may be represented by a very considerable number of summing-trinomes (e.g., for the values 13 and 14 there are 75 variants each), such a system would offer a cryptographer wide latitude in the choice of cipher equivalents in enciphering,

[4] The representations of an integer (i.e., a whole number) as the sum of integers in all possible ways are termed the partitions of that number. The partitions in this subparagraph are mod 10 and also include the digit Ø in order to form trinome equivalents out of all the possible permutations.

especially if the basic values of the plaintext letters were chosen to correspond with the scale of their relative frequencies, such as the following

	J	Q	B	W	Y	U	F	H	D	I	O	N	E	T	R	A	S	L	C	P	M	G	V	X	K	Z	
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27



The tallies beneath each value represent the number of variants possible for the particular value The unused values for Ø and 27 (uniquely represented by 000 and 999, respectively) may be used for punctuation marks, nulls, or other special-purpose symbols. Since such a system, once suspected, would offer little difficulty[5] to a cryptanalyst, certain modifications would be necessary in order to pose any real obstacles in the way of solution. For instance, if the numerical value of a letter is expressed by permutations of 3 letters (intead of digits) out of a set of the 10 letters A-J wherein the sequence of the letters A-J represents a disarranged sequence of the digits Ø-9, such a system may be among the most complex types of ciphers in the realm of monoalphabetic substitution, requiring the solution of many simultaneous equations. A further refinement would involve the use of all 26 letters as variants, in predetermined groups, to represent the digits 1-9 Fortunately for the cryptanalyst, such systems are impracticable for field military use, but if they were encountered, a sufficiently large volume of text, coupled with Hitt's four essentials quoted in Section I, would eventually make a solution possible. The actual cryptanalytic complexity of certain apparently exceedingly complex cryptosystems is dependent on their being correctly used at all times, which is not invariably the case with military ciphers.

[5] The solution would involve simply dividing the cipher text into groups of 3 digits, summing the trinomes thus produced to yield 28 possible basic values, and solving these basic values as in any simple monoalphabetic substitution cipher.

60. Analysis of simple examples.--a. The following cryptogram is available for study

```
Q M D C V   P L F N F   D H N W J   W L K D K   N H B P V   R L T V M
B K L W D   W V H V K   S H B C L   P Q K J R   V W S M L   K G C N R
L R N K V   M G F X W   J R G M V   W G T J H   Q K X F N   Z V F D M
L T B P L   P V F L M   D C N W N   H B C V Z   N M L W Q   F D H D W
V Z B R V   K L C V C   V R D H L   R V T L F   N C D K G   M X W X M
D T S C B   C L Z L R   L M V T S   Z N K B W   V P B R N   C L R X R
D C N K V   P B T N T   G H J Z L   F Q F V K   B W D Z X   P N H S P
G H L K L   F V Z L T   V M L K D   P Q R N Z   L Z D T B   M N T G M
N Z V F X   K S F D C   L Z V T V   F D F V R   G C L P Q   P N C D W
V R J T N   H L Z L M   V W N P V   P D Z D W   J P N W L   R J K V M
X M D T S   M G F D R   D K L W J   F L P J M   S F Q W B   F N C B Z
D K V W G   Z S H B H   D H J C X
```

The first thing that strikes the eye is the total absence of vowels, remarkable not only because six letters are missing (cf. the Λ test) in a text of this size, but also because all six of these letters fall into an identical limited category--a significant non-random phenomenon. Since a unilateral substitution alphabet with six letters missing is highly improbable, the conclusion of multiliteral substitution is obvious. Upon closer inspection it is found that, if the cipher text is divided into pairs of letters, only ten consonants (B D G J L N Q S V X) are used as prefixes, and the remaining ten consonants (C F H K M P R T W Z) are used as suffixes--thus the biliteral (and bipartite) characteristics of the cipher text are disclosed. A digraphic[6] distribution is therefore constructed

	C	F	H	K	M	P	R	T	W	Z
B	3	1	1	1	1	2	2	1	2	1
D	4	1	4	4	1	1	1	3	4	2
G	2	2	2		3			1		1
J	1	1	1	1	1	1	2	1	1	1
L	1	4		4	3	4	5	3	3	4
N	4	1	4	3	1	1	1	2	3	3
Q		2		2	1	1	1		1	
S	1	2	2		2	1				1
V	1	4	1	3	4	4	4	3	4	3
X		1		1	2	1	1		2	

[6] If it had not been noticed that the cryptogram should be divided into pairs for analysis, a biliteral distribution (see par. 23d) might have been made, in order to reveal contact affinities of the cipher letters.

b. It is possible that the cryptogram under study may involve the use of a small enciphering matrix with variants for the rows and columns. Since there is available an easily-applied special solution which permits the determination of the row indicators which are equivalent (i.e., interchangeable variants) and the column indicators which are equivalent, merely from a study of the digraphic distribution, this possibility is examined. The special solution is based on the following considerations. In a message of moderate length for such a cryptosystem, it may be assumed that the various possible cipher pairs for a given plaintext letter will be used with approximately equal frequency, for this reason, the cipher letters which pair with one of the letters used to indicate any particular row of the enciphering matrix may be expected to pair equally often with any other cipher letter which has been used to indicate the same row (and, of course, the same is true concerning the column-indicator letters). Thus, in the digraphic distribution of such a cryptogram, sets of rows appear which have similar "profiles" and, likewise, sets of similar columns.[7] First a study will be made of the rows of the distribution just compiled, in an attempt to locate and isolate those which match with each other, then, the same will be done with the columns of the distribution.

c. It is noted that the "L" and "V" distributions have pronounced similarities (Fig. 42a)--these rows came under consideration first because of their unique "heaviness" of their frequency characteristics. Likewise, the "D" and "N" rows have homologous attributes in their appearance (Fig. 42b). However, the further grouping of the rows by ocular inspection may present difficulties to the student, since he may not yet trust his eye in matching distributions, and he may feel the need for some kind of statistical assurance. In the following subparagraphs there is given the technique of a more precise method for matching, mathematical in nature.

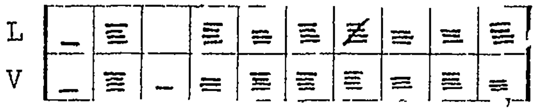


Figure 42a

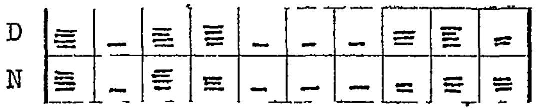


Figure 42b.

[7] These similarities are especially pronounced when the encipherer uses a "check-off" procedure for choosing his variants for each letter, that is, when he systematically "checks off" the variants used during encryption to insure that all possible variants are used in approximately equal proportions.

d. This method of matching in an attempt to "equate" interchangeable variants involves computing a separate value for each trial matching of a particular row (or column) against each of a series of other rows (or columns, as appropriate)--such a value is taken as an indication of the "goodness of match" exhibited by the particular trial, the theory being that the correct match will produce the highest value.[8] The value for a particular trial match is computed by multiplying the number of tallies in each cell of one row (or column) by the number of tallies in each corresponding cell in the other row (or column) and then totaling the products thus obtained. Because of the way in which it is produced, such a value is termed a "cross-products sum".

e. In subparagraph c above, it was determined that the "L" and "V" rows were equivalent, and that the "D" and "N" rows also formed an equivalent pair. The next "heavy" row is the "G" row, this is to be tested for match with the five remaining unmatched rows. Let the "G" row be tested first against the "B" row These two rows are given below, with their cross-products sum. For convenience, the cross-products sum is symbolized by $\chi(\theta^1,\theta^2)$, where θ^1 and θ^2 represent the designators of the distributions to be matched[9]

"G"	2	2	2	-	3	-	-	1	-	1	
"B"	3	1	1	1	1	2	2	1	2	1	
χ(G,B)	6	2	2	-	3	-	-	1	-	1	= 15

The complete table of the comparisons of the "G" row with the five available rows is as follows

χ(G,B)	6	2	2	-	3	-	-	1	-	1	= 15
χ(G,J)	2	2	2	-	3	-	-	1	-	1	= 11
χ(G,Q)	-	4	-	-	3	-	-	-	-	-	= 7
χ(G,S)	2	4	4	-	6	-	-	-	-	1	= 17
χ(G,X)	-	2	-	-	6	-	-	-	-	-	= 8

The results indicate that the most probable match with the "G" row is the "S" row.

f. Since the next "heaviest" row to be tested is the "B" row, its matchings with the three remaining rows are made, and are given below

χ(B,J)	3	1	1	1	1	2	4	1	2	1	= 17
χ(B,Q)	-	2	-	2	1	2	2	-	2	1	= 12
χ(B,X)	-	1	-	1	2	2	2	-	4	-	= 12

[8] In this connection, note the considerations treated in subpar. 60j.

[9] The Greek letter χ (chi) is often used in cryptology to symbolize matching operations

The correct matching of the "B" and "J" rows is indicated by the results. This leaves only the "Q" and "X" rows, which are presumed to go together, since not only is their cross-products sum satisfactory (when compared to the χ values for some of the other rows which have been matched), but, equally important, their patterns of crests and troughs are similar. Since we have not found more than two rows for any one set of interchangeable values, it appears that the original matrix had only five rows, with two variants for each row. The rows of the distribution diagram are therefore combined in the following diagram

	C	F	H	K	M	P	R	T	W	Z
BJ	4	2	2	2	2	3	4	2	3	2
DN	8	2	8	7	2	2	2	5	7	5
GS	3	4	4	-	5	1	-	1	-	2
LV	2	8	1	7	7	8	9	6	7	7
QX	-	3	-	3	3	2	2	-	3	-

Figure 43

g. Analysis of the distributions of the columns of Fig. 43 quickly reveals that columns "C" and "H" may be matched as a pair, and likewise columns "F" and "M", and columns "P" and "R". In order to decide the groupings of the remaining columns, the six possible χ values are derived.

χ(K,T)·	4	35	-	42	-	=	81
χ(K,W)·	4	49	-	49	9	=	113
χ(K,Z)	4	35	-	49	-	=	88
χ(T,W)	6	35	-	42	-	=	83
χ(T,Z)	4	25	2	42	-	=	73
χ(W,Z)	6	35	-	49	-	=	90

Combinations

KT, WZ	81 + 90 = 171
KW, TZ·	113 + 73 = 186
KZ, TW	88 + 83 = 171

It appears that the proper pairings of the columns are "K" and "W", "T" and "Z".

h. The groupings of the columns having been determined, the frequency diagram is reduced to its basic 5x5 square, and the ϕ test is taken as further statistical assurance of the matchings. Although ϕ_o in this case does not come up to the best expectations, we feel nevertheless that the matching has been carefully and correctly accomplished, and so

	C	F	K	P	T
	H	M	W	R	Z
BJ	6	4	5	7	4
DN	16	4	14	4	10
GS	7	9	-	1	3
LV	3	15	14	17	13
QX	-	6	6	4	-

ϕ_p=1962
ϕ_r=1132
ϕ_o=1670

the next step is continued with a conversion of the multiliteral text into uniliteral equivalents, using the following reduction square containing an arbitrary sequence

	C	F	K	P	T
	H	M	W	R	Z
BJ	A	B	C	D	E
DN	F	G	H	I	K
GS	L	M	N	O	P
LV	Q	R	S	T	U
QX	V	W	X	Y	Z

The converted cryptogram is now easily solved, using the principles set forth in Section VI. The first fifteen letters of the plaintext message are found to read "WEATHER FORECAST . .", and the original enciphering matrix is recovered, based on the key word ATMOSPHERIC, as follows

	P	F	C	K	T
	R	M	H	W	Z
LV	A	T	M	O	S
DN	P	H	E	R	I
BJ	C	B	D	F	G
GS	K	L	N	Q	U
QX	V	W	X	Y	Z

i. The method of matching rows and columns just described in the preceding subparagraphs applies equally well to all the matrices in Figs. 26-35, and similar variations If in the process of equating indicators the cryptanalyst sees that the row indicators are falling into the same groupings as the column indicators, he might be able to accelerate the equating process by taking advantage of this feature alone, as would be the case if he had encountered a cryptogram involving a matrix with indicators arranged in a manner similar to that shown in Figs 29 and 30. Furthermore, a cryptogram enciphered in a commutative system, wherein the equivalents have been taken in row-column and column-row order indiscriminately, may be recognized as such through a study of the digraphic distribution of the cryptogram since the " α " row of the distribution will have an appearance similar to the " α " column, the " β " row will be similar to the " β " column, etc,[10] this matter is discussed further in subpar 61d.

[10] It is often convenient to use arbitrary symbols in cryptanalytic work, to prevent confusion with designations of actual elements of plain text, cipher text, or key (see footnote 1 on page 58). For this purpose Greek letters are often used, for reference, the 24 letters of the Greek alphabet and their names are appended in the chart below

Α	α	alpha	Ε	ε	epsilon	Ι	ι	iota	Ν	ν	nu	Ρ	ρ	ro	Φ	φ	phi
Β	β	beta	Ζ	ζ	zeta	Κ	κ	kappa	Ξ	ξ	xi	Σ	σ	sigma	Χ	χ	chi
Γ	γ	gamma	Η	η	eta	Λ	λ	lambda	Ο	ο	omicron	Τ	τ	tau	Ψ	ψ	psi
Δ	δ	delta	Θ	θ	theta	Μ	μ	mu	Π	π	pi	Υ	υ	upsilon	Ω	ω	omega

j. It is important to point out that in matching, the cryptanalyst should begin with the "best" rows or columns--best not only from the standpoint of "heaviness" of the distribution, but also best from the point of view of a distinctive pattern of crests and troughs. If insufficient text is available to allow equating all the interchangeable coordinates of a particular enciphering matrix, it may still be possible that a conversion of the cipher text by means of a partially-reduced reconstruction matrix may yield enough idiomorphic patterns and other data to make possible an entry into the text. If the cryptographer has not used a "check-off" process in enciphering, but instead has favored certain equivalents for the various plaintext letters, matching may not be possible, nevertheless, an entry into the text may be facilitated in this case, because some of the resultant peaks in the cipher text may be correctly identified Furthermore, since no variant system can possibly disguise the letters of low frequency in plain text, their low-frequency equivalents in the cipher text may provide possible approaches to solution (See also subpar. 61e).

k. In addition to the method of solution by matching and combining rows and columns of a digraphic distribution of a multiliteral cipher, there is also the general approach applicable without exception to any variant system. This method, involving the correlation of cipher elements suspected to be the equivalents of specific but unknown plaintext letters, is treated in detail in paragraphs 61 and 62.

l. Systems such as the 4-level dinome cipher illustrated in Fig. 36 are susceptible to a very easy solution, if the dinomes have been inscribed in numerical order as indicated. Assuming such a case in a specific cryptogram, the first six groups of which are

68321 09022 48057 65111 88648 42036 . .

a four-part frequency distribution of the entire message, is taken as illustrated in Fig. 44 below

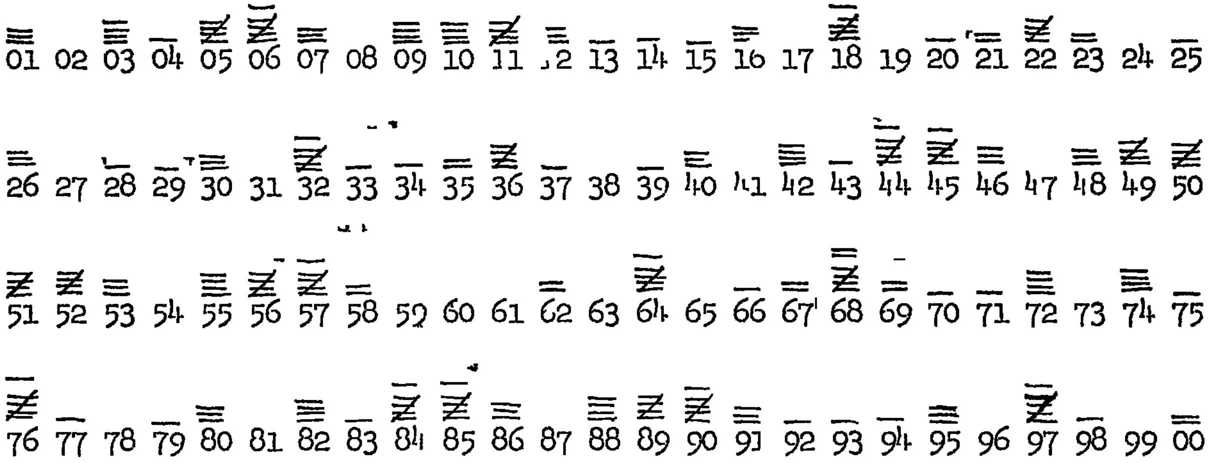


Figure 44.

If the student will bring to bear upon this problem the principles he learned in Section V of this text, he will soon realize that what he now has before him are four simple, monoalphabetic frequency distributions similar to those involved in a monoalphabetic substitution cipher using standard alphabets. The realization of this fact immediately provides the clue to the next step: "fitting each of the distributions to the normal". (See par. 31). This can be done without difficulty in this case (remembering that a 25-letter alphabet is involved and assuming that I and J are combined) and the following alphabets result

01—I-J	26—U	51—N	76—E
02—K	27—V	52—O	77—F
03—L	28—W	53—P	78—G
04—M	29—X	54—Q	79—H
05—N	30—Y	55—R	80—I-J
06—O	31—Z	56—S	81—K
07—P	32—A	57—T	82—L
08—Q	33—B	58—U	83—M
09—R	34—C	59—V	84—N
10—S	35—D	60—W	85—O
11—T	36—E	61—X	86—P
12—U	37—F	62—Y	87—Q
13—V	38—G	63—Z	88—R
14—W	39—H	64—A	89—S
15—X	40—I-J	65—B	90—T
16—Y	41—K	66—C	91—U
17—Z	42—L	67—D	92—V
18—A	43—M	68—E	93—W
19—B	44—N	69—F	94—X
20—C	45—O	70—G	95—Y
21—D	46—P	71—H	96—Z
22—E	47—Q	72—I-J	97—A
23—F	48—R	73—K	98—B
24—G	49—S	74—L	99—C
25—H	50—T	75—M	00—D

The key word is seen to be JUNE and the beginning of the cryptogram is deciphered as "EASTERN ENTRANCE....."

m. If instead of 25-element alphabets, a system such as that in Fig. 37 has been used, only a slight modification of the procedure in subparagraph j would have been necessary, i.e., the distributions would have had to be considered on a basis of 26, and the process of fitting the distributions to the normal would have gone on as in the previous example.

n. One further application of principles learned in Section V deserves to be mentioned here, in connection with the solution of systems such as those of Fig. 36. Let the following short message be considered

```
48226  88423  52099  93604  76059  05651
36683  52267  97114  54466  76
```

If it is known that the correspondents have been using a variant system such as that in Fig. 36, a special solution may be employed in those cases wherein there is insufficient cipher text to permit analysis by the method of fitting the frequency distribution to the normal. Thus, a short cryptogram may be solved by a variation of the plain-component completion method described in par. 34.[11] First, let the cryptogram be copied in dinomes, with an indication of the level (i.e., the "alphabet") the dinome would occupy in the 4-level matrix, thus

48	22	68	84	23	52	09	99	36	04	76	05	90	56	51	36	68	35	22	67	97	11	45	44	66	76
2	1	3	4	1	3	1	4	2	1	4	1	4	3	3	2	3	2	1	3	4	1	2	2	3	4

The dinomes belonging to the four levels are as follows

(1) 22 23 09 04 05 22 11
(2) 48 36 36 35 45 44
(3) 68 52 56 51 68 67 66
(4) 84 99 76 90 97 76

These dinomes are converted into terms of the plain component by setting each of the cipher sequences against the plain component at an arbitrary point of coincidence, such as in the following example

A	B	C	D	E	F	G	H	I-J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00

(1) 22=W, 23=X, 09=I, 04=D, 05=E, 22=W, 11=L
(2) 48=X, 36=L, 36=L, 35=K, 45=U, 44=T
(3) 68=S, 52=B, 56=F, 51=A, 68=S, 67=R, 66=Q
(4) 84=I, 99=Y, 76=A, 90=P, 97=W, 76=A

[11] It should be clear to the student that the reason this method can be applied in this instance is that both the plain component (ABC.... Z) and the cipher component (01, 02, 03 ..... 25, 26-50, 51-75, 76-00) are known sequences (or thus assumed).

o. The plain component sequence is now completed on the letters of the four levels, as follows:

1st level	2d level	3d level	4th level
W X I D E W L	X L L K U T	S B F A S R Q	I Y A P W A
X Y K E F X M	Y M M L V U	T C G B T S R	K Z B Q X B
Y Z L F G Y N	Z N N M W V	U D H C U T S	L A C R Y C
Z A M G H Z O	A O O N X W	V E I D V U T	M B D S Z D
A B N H I A P	B P P O Y X	W F K E W V U	N C E T A E
B C O I K B Q	C Q Q P Z Y	X G L F X W V	O D F U B F
C D P K L C R	D R R Q A Z	Y H M G Y X W	P E G V C G
D E Q L M D S	E S S R B A	Z I N H Z Y X	Q F H W D H
E F R M N E T	F T T S C B	A K O I A Z Y	R G I X E I
F G S N O F U	G U U T D C	B L P K B A Z	S H K Y F K
G H T O P G V	H V V U E D	C M Q L C B A	T I L Z G L
H I U P Q H W	I W W V F E	D N R M D C B	U K M A H M
I K V Q R I X	K X X W G F	E O S N E D C	V L N B I N
K L W R S K Y	L Y Y X H G	F P T O F E D	W M O C K O
L M X S T L Z	M Z Z Y I H	G Q U P G F E	Y N P D L P
M N Y T U M A	N A A Z K I	H R V Q H G F	Y O Q E M Q
N O Z U V N B	O B B A L K	I S W R I H G	Z P R F N R
O P A V W O C	P C C B M L	K T X S K I H	A Q S G O S
P Q B W X P D	Q D D C N M	L U Y T L K I	B R T H P T
Q R C X Y Q E	R E E D O N	M V Z U M L K	C S U I Q U
R S D Y Z R F	S F F E P O	N W A V N M L	D T V K R V
S T E Z A S G	T G G F Q P	O X B W O N M	E U W L S W
T U F A B T H	U H H G R Q	P Y C X P O N	F V X M T X
U V G B C U I	V I I H S R	Q Z D Y Q P O	G W Y N U Y
V W H C D V K	W K K I T S	R A E Z R Q P	H X Z O V Z

It is seen that the generatrices with the best assortment[12] of high-frequency letters for the four levels are

1st level	2d level	3d level	4th level
E F R M N E T	R E E D O N	E O S N E D C	N C E T A E

[12] In evaluating generatrices, the sum of the arithmetical frequencies of the letters in each row may be used as an indication of their relative "goodness". A statistically much more accurate method of evaluating generatrices involves the use of logarithms of the probabilities of the plaintext letters forming the generatrices. (See also footnote 7 on page 89.)

If the letters of these generatrices are arranged in the order of appearance of their dinome equivalents, according to the way they fall into the various levels,

48	22	68	84	23	52	09	99	36	04	76	05	90	56	51	36	68	35	22	67	97	11	45	44	66	76
	E			F		R			M		N							E			T				
R								E							E		D					O	N		
		E			O								S	N		E			D					C	
			N				C			E		T								A					E

the plain text "REENFORCEMENTS NEEDED AT ONCE" is clearly seen. Or, more simply, if we examine the equivalents of 01, 26, 51, and 76 after the generatrix determination has been made, the key word JUNE is revealed. If an error had been made in the selection of a generatrix, the error could be resolved by hypothesizing the probable key word, or by deciphering the text on the basis of the assumed diagram and then noting and degarbling the systematic errors (which, it would be noticed, all come from one level)

p. The student should note that no one generatrix will yield plain text all the way across as in the example in par. 34 Instead, the generatrices must be considered separately for the four levels, since it is within each of the four levels that there is a homogeneous relationship of dinomes Obviously if dinomes from more than one level were used to complete the plain component sequence, the generatrices would not consist of a homogeneous group of letters but instead would represent an assortment of letters from two or more "alphabets"

61. Analysis of more complicated examples.--a As soon as a beginner in cryptography realizes the consequences of the fact that letters are used with greatly varying frequencies in normal plain text, a brilliant idea very speedily comes to him Why not disguise the natural frequencies of letters by a system of substitution using many equivalents, and let the numbers of equivalents assigned to the various letters be more or less in direct proportion to the normal frequencies of the letters? Let E, for example, have 13 equivalents, T, 9, N, 8, etc., and thus (he thinks) the enemy cryptanalyst can have nothing in the way of telltale or characteristic frequencies to use as an entering wedge

b. If the text available for study is small in amount and if the variant values are wholly independent of one another, the problem can become exceedingly difficult. But in practical military communications such methods are rarely encountered, because the volume of text is usually great enough to permit of the establishment of equivalent values. To illustrate what is meant, suppose a number of cryptograms produced by the monoalphabetic-variant method described above show the following two sets of groupings[13] of cipher elements in the text, Set "A" being assumed to be different representations of one particular underlying plain text, and Set "B" assumed to be representations of another underlying plain text

Set "A"	Set "B"
(12-37-02-79-68-13-03-37-77)	(71-12-02-51-23-05-77)
(82-69-02-79-13-68-23-37-35)	(11-82-51-02-03-05-35)
(82-69-51-16-13-13-78 05-35)	(11-91-02-02-23-37-35)
(91-05-02-01-68-42-78-37-77)	(97-12-51-02-78-69-77)

An examination of these groupings would lead to the following tentative conclusions with regard to probable equivalents

(12, 82, 91)	(02, 51)	(13, 42, 68)	(35, 77)
(05, 37, 69)	(01, 16, 79)	(03, 23, 78)	(11, 71, 97)

The establishment of these equivalencies would sooner or later lead to the finding of additional sets of equal values. The completeness with which this can be accomplished will determine the ease or difficulty of solution Of course, if many equivalencies can be established the problem can then be reduced practically to monoalphabetic terms and a speedy solution can be attained

c. Theoretically, the determination of equivalencies may seem to be quite an easy matter, but practically it may be very difficult, because the cryptanalyst can never be certain that a combination showing what may appear to be a variant value is really such and does not represent a part of a different plaintext sequence. For example, take the groups --

17-82-31-82-14-63, and
27-82-40-82-14-63

Here one might suspect that 17 and 27 represent the same letter, 31 and 40 another letter. But it happens that one group represents the word MANAGE, the other DAMAGE. There are hundreds of such cases in English and in other languages

d. When reversible combinations are used as variants, the problem is perhaps a bit more simple For example, using the accompanying Fig. 45

	K,Z	Q,V	B,H	M,R	D,L
W,S	N	H	A	O	E
M,Y	D	T	M	F	P
G,J	Q	B	U	I	V
C,N	G	X	R	C	S
P,T	Z	L	Y	W	K

Figure 45

[13] The alert student might be able to determine the underlying plain text of the two sets of ciphertext groupings.

for encipherment, two messages with the same initial words, REFERENCE YOUR, may be enciphered as follows

```
      R   E   F   E   R   E   N   C   E   Y   O   U   R
(1)  N H W D R  X L S H C  D W W Z N  R S L H P  S R B J C  H
(2)  C H D W R  X S L H N  D W Z W N  R L S H P  R W J B N  H
```

The experienced cryptanalyst, noting the appearance of the very first few cipher groups, assumes that not only have the messages identical beginnings in their plain texts, but also that he is here confronted with a variant system involving biliteral reversible equivalents One of the manifestations of such a cryptosystem is that in the digraphic distribution of the cipher text the "B" row will have an appearance similar to the "B" column, the "C" row will resemble the "C" column, etc., thus, the cryptanalyst will almost immediately realize that he has encountered a commutative system involving a matrix smaller than that indicated by the size of matrix necessary for making the digraphic distribution.

e The probable-word method of solution may be used, but with a slight variation introduced because of the fact that, regardless of the system, letters of low frequency in plain text remain infrequent in the cryptogram. Hence, suppose a word containing low-frequency letters, but in itself a rather common word strikingly idiomorphic in character is sought as a "probable word", for example, words such as CAVALRY, ATTACK, and PREPARE. Such a word may be written on a slip of paper and slid one interval at a time under the text, which has been marked so that the high- and low-frequency characters are indicated. Each coincidence of a low-frequency letter of the text with a low-frequency letter of the assumed word is examined carefully to see whether the adjacent text letters correspond in frequency with the other letters of the assumed word; or, if the latter presents repetitions, whether there are correspondences between repetitions in the cipher text and those in the word. Many trials are necessary but this method will produce results when the difficulties are otherwise too much for the cryptanalyst to overcome.

62. Analysis involving the use of isologs.--a. In military communications it is not unusual that cryptograms are produced containing identical plain text but which have been subjected to different cryptographic treatment, thus yielding different cipher texts. This difference in cryptographic treatment may be caused by the use of an entirely different general system, or by the use of a different specific key, or merely by the choice of equivalents in a variant system. Messages which present different encrypted texts but which contain identical plain text are called isologs (from the Greek iso = "equal" and logos = "word"). One of the easily-noted indications of the possible presence of isologs is equality or near-equality in the lengths of two (or more) cryptograms. Isologs, no matter how the cryptographic treatment varies, are among the most powerful media available to the cryptanalyst for the successful solution of a difficult cryptosystem--and, in some cases, may provide the

only possible entries into a complex cryptosystem. An inkling of the help afforded by isologs was revealed by the example contained in subpar. 61d above; however, a much more striking illustration is given in the next few subparagraphs.

b. The following two cryptograms, suspected to be isologs, are available for study

Message "A"

```
82265  63103  74839  69842  32529  70115
80277  89106  94000  13828  54082  40065
63629  33918  43158  81048  26458  45039
81713  52538  73309  20749  61752  16476
38728  91147  99926  41468  13365  33881
89697  93816  51750  57074  11804  43255
28120  27730  31199  79962  27865  60653
90870  40867  46594  19855  10822  22987
46729  36245
```

Message "B"

```
30150  87497  14511  97360  49676  50106
45647  99181  69672  53889  41563  25203
90628  77536  20351  10570  89277  75011
35199  90138  99974  50232  04115  89216
38463  17547  14648  00646  85864  53898
26121  83878  94889  33728  11272  20504
06484  32103  98715  42662  80760  89880
44105  52900  59728  22855  87300  70893
59682  46253
```

On the possibility that some dinome system (or systems) is involved, the messages are written under each other in dinomes to facilitate the examination of the similarities and differences of such a grouping of the cipher texts, as shown on the next page

~~RESTRICTED~~

					5					10					15
A	82	26	56	31	03	74	83	96	98	42	32	52	97	01	15
A'	30	15	08	74	97	14	51	19	73	60	49	67	65	01	06
B	80	27	78	91	06	94	00	01	38	28	54	08	24	00	65
B'	45	64	79	91	81	69	67	25	38	89	41	56	32	52	03
C	63	62	93	39	18	43	15	88	10	48	26	45	84	50	39
C'	90	62	87	75	36	20	35	11	05	70	89	27	77	50	11
D	81	71	35	25	38	73	30	92	07	49	61	75	21	64	76
D'	35	19	99	01	38	99	97	45	02	32	04	11	58	92	16
E	38	72	89	11	47	99	92	64	14	68	13	36	53	38	81
E'	38	46	31	75	47	14	64	80	06	46	85	86	45	38	98
F	89	69	79	38	16	51	75	05	70	74	11	80	44	32	55
F'	26	12	18	38	78	94	88	93	37	28	11	27	22	05	04
G	28	12	02	77	30	31	19	97	99	62	27	86	56	06	53
G'	06	48	43	21	03	98	71	54	26	62	80	76	08	98	80
H	90	87	04	08	67	46	59	41	98	55	10	82	22	29	87
H'	44	10	55	29	00	59	72	82	28	55	87	30	07	08	93
J	46	72	93	62	45										
J'	59	68	24	62	53										

The dinome distributions for the two messages are as follows:

	Ø	1	2	3	4	5	6	7	8	9
Ø	2	2	1	1	1	1	2	1	2	-
1	2	2	1	1	1	2	1	-	1	1
2	-	1	1	-	1	1	2	2	2	1
3	2	2	2	-	-	1	1	-	5	2
4	-	1	1	1	1	2	2	1	1	1
5	1	1	1	2	1	2	2	-	-	1
6	-	1	3	1	2	1	-	1	1	1
7	1	1	2	1	2	2	1	1	1	1
8	2	2	2	1	1	-	1	2	1	2
9	1	1	2	2	1	-	1	2	2	2

Distribution for
Message "A"

	Ø	1	2	3	4	5	6	7	8	9
Ø	1	2	1	2	2	2	3	1	3	-
1	1	4	1	-	2	1	1	-	1	2
2	1	1	1	-	1	1	2	2	2	1
3	2	1	2	-	-	2	1	1	5	-
4	-	1	-	1	1	3	2	1	1	1
5	1	1	1	1	1	2	1	-	1	2
6	1	-	3	-	2	1	-	2	1	1
7	1	1	1	1	1	2	1	1	1	1
8	3	1	1	-	-	1	1	2	1	2
9	1	1	1	2	1	-	-	2	3	2

Distribution for
Message "B"

~~RESTRICTED~~

c. Since a general absence of marked crests and troughs is noted in both distributions, if the division of these cryptograms into dinomes is correct, and if they are both monoalphabetic, it is quite probable that some type of variant system (or systems) has been used. With this in mind, the encrypted texts and their distributions are scrutinized further for some indication of the kind of relationship which exists between the methods of encipherment of the two messages. The distributions are seen to be strikingly similar, not only with respect to the location of the one predominant peak in each, but also in the close correlation of the locations of the blanks in each.[14] Furthermore, upon examination of the superimposed messages themselves, it is observed that there are several instances wherein a value in message "A" coincides with the same value in message "B" (e.g., see positions A/A' 14, B/B' 9). This observation, taken in conjunction with the marked similarity of the distributions, strongly indicates that not only has the same general cryptosystem been used for the encryption of both messages, but that the same enciphering matrix has been used for both. Also, in the case of the values 38 and 62, it is noted that wherever either occurs in one message the same value

[14] For the benefit of the student with a mathematical background, it might be interesting to point out certain applications of cryptomathematics in connection with these two distributions. First of all, each of the two distributions is much flatter than that which would be expected for a sample of 125 dinomes of random text, i.e., a drawing (with replacement) and recording from an urn containing equal numbers of counters in each of 100 categories labeled 00-99 consecutively. In other words, whereas "random" follows a characteristic distributional appearance, approximated by the normal or binomial distributions, the samples at hand exhibit phenomena even flatter (or "worse") than that expected for random, approaching the theoretical (and fantastically non-random) "equilibrium" of exactly the same number of tallies in each cell of a distribution. The following table gives the observed number of x-fold repetitions in the two distributions, together with the expected number of x-fold repetitions in a sample of like size of random text, which expected number has been computed from tables of the Poisson exponential distribution (see Military Cryptanalysis, Part III).

x	Observed Msg. "A"	Observed Msg. "B"	Expected
Ø	14	17	29
1	51	52	36
2	33	23	22
3	1	6	9
4	-	1	3
5	1	1	1

It is to be noted that in the distribution for Message "A" the observed number of blanks (14) against the expected number of blanks from random text (29) represents a sigmage or standard deviation of 2.78 σ, which occurs in the other message, a phenomenon explainable on the assumption that the plaintext equivalents of these values are of such low frequency that no variant values have been provided for these plaintext letters in the cryptosystem.

d. With the foregoing details determined, it is now realized that it should be possible to form, between the two messages, "chains" of those cipher values which represent identical plaintext letters, as exemplified below. Beginning with the first value in each message, 82 and 30, a partial chain of equivalent variants is started, now locating some other occurrence of either value elsewhere (e g., 82 at position H'8), and noting the cipher value coinciding with it (in this case, 41), the partial chain may be extended (including now 82, 30, and 41). After this particular chain is extended to include as many values as possible, another chain is formed by starting with any value which has not already been included in the preceding chain, this procedure being repeated until

can be translated as odds of 368 to 1 against its occurrence by pure chance. Likewise the other entries besides ∅ (in particular, the x-values of 1 and 2, and the cumulative values of 3-and-better) may be evaluated in terms of sigmages, and the conclusion would be reached that the two distributions have a most remote chance of being as flat as they are through mere chance; for instance, it is 3.05 σ or 877 to 1 against distribution "A" having only two tallies occurring three or more times when 13 such tallies are expected by random--and this sigmage when taken into consideration with that of the number of blanks yields a sigmage of 4 σ or approximately 31,000 to 1 of occurring through sheer chance. The sum total of all the deviations could be collectively evaluated, but this would involve the laborious computation of a multinomial distribution. Since the distributions of the two messages are much worse than would even be expected for random chance, the conclusion is drawn that the dinome grouping is highly significant and therefore must be correct, and furthermore that the cryptosystem involves variants in sufficient numbers for the plaintext letters to permit the encipherer to select the cipher equivalents with a view to suppressing as much of the phenomena of repetition as possible Secondly, the χ test of the two distributions gives a χ value of 206, as against the χ value of 156 for random samples of this size, this represents a sigmage of 4.02 σ , or a ratio of 33,000 to 1 against its happening by pure chance, i.e., if the cryptograms were not in the same general system and specific keys. Therefore it is a foregone conclusion statistically that not only do the cryptosystems involve dinomes as the ciphertext grouping, but that the identical cryptosystem is involved in the two messages, and that because of the close correlation of the patterns of the two distributions, there is a good probability that the cryptograms contain identical plain text and therefore are isologs This specific illustration of the potentialities of cryptomathematics indicates the important role that this branch of science may play in the art of cryptanalysis.

all possible chains are completed. It is found that the following chains, arbitrarily arranged here according to length, may be derived from the two messages

(06 14 15 26 28 31 35 73 74 81 89 98 99)
(02 07 20 22 43 44 63 90)
(12 37 48 51 69 70 83 94)
(03 30 41 54 65 82 97)
(05 10 24 32 49 87 93)
(16 18 36 76 78 79 86)
(27 45 53 64 80 92)
(11 39 75 88)
(21 58 77 84)
(46 59 68 72)
(00 52 67)
(04 55 61)
(08 29 56)
(19 71 96)
(01 25)
(13 85)
(42 60)

Single dinomes

(38) (47) (50) (62) (91)

If we now make an arbitrary assignment of a different letter to represent each chain (and each single dinome) and convert either of the messages to uniliteral terms by means of these arbitrarily-assigned values, we note the pattern of the opening stereotype "REFERENCE YOUR MESSAGE.....", and quickly recover the plain text.

e. The plaintext values when inserted into a 10x10 matrix having arbitrarily-arranged coordinates yield the following.

	Ø	1	2	3	4	5	6	7	8	9
Ø	U	N	T	R	P	O	E	T	F	-
1	O	D	N	H	E	E	A	-	A	C
2	T	I	T	-	O	M	E	S	E	F
3	R	E	O	-	-	E	A	N	B	D
4	-	R	Y	T	T	S	L	V	N	O
5	X	N	U	S	R	P	F	-	I	L
6	Y	P	W	T	S	R	-	U	L	N
7	N	C	L	E	E	D	A	I	A	A
8	S	E	R	N	I	H	A	O	D	E
9	T	G	S	O	N	-	C	R	E	E

Manipulating the rows and columns with a view to uncovering some symmetry or systematic phenomena, the latent diagonal pattern of the equivalents for certain of the letters (such as E_p, N_p, O_p, R_p, and S_p) is revealed, and the rows and columns of the reconstruction diagram are permuted to yield the following original enciphering matrix

	6	8	9	1	5	4	3	7	2	Ø
7	A	A	A	C	D	E	E	I	L	N
1	A	A	C	D	E	E	H	K	N	O
3	A	B	D	E	E	H	J	N	O	R
8	A	D	E	E	H	I	N	O	R	S
9	C	D	E	G	I	N	O	R	S	T
2	E	E	F	I	M	O	Q	S	T	T
Ø	E	F	I	M	O	P	R	T	T	U
5	F	I	L	N	P	R	S	T	U	X
6	I	L	N	P	R	S	T	U	W	Y
4	L	N	O	R	S	T	T	V	Y	Z

There are no observable relationships in or between the sequences of digits in the row and column coordinates, therefore for want of any visible phenomena or further information on the derivation (if any) of these digits, it is assumed that they must have been assigned at random. The student will note that the final matrix is identical to that of Figure 39 in paragraph 59.

f. It should be emphasized that in the example of the preceding subparagraphs it was only possible to form chains of values from both messages reciprocally because the same enciphering matrix had been used for both. A non-reciprocal chaining procedure would have been required if only the general system had been the same for both but the enciphering matrices had differed in some respect, or if two completely different variant systems had been used (e g , one using a frequential matrix and the other involving a less complex type of variant matrix, such as Fig. 29). Specifically, it would have been necessary to maintain two separate groups of chains, one group for each message, otherwise heterogeneous values would have become intermingled.

g. Although an analysis of but one isolated example by means of isologs was presented, the student should be able to appreciate the significance and potentially enormous value of isologs to a cryptanalyst. This value goes far beyond the simple variant encryption in a monoalphabetic substitution system, isologs produced by the use of two different code books, or two different enciphered code versions of the same underlying plain text, or two encryptions of identical plain text by two different "settings" of a cipher machine, may all prove of inestimable value in the attack on a difficult cryptosystem

63. Further remarks on variant systems.--a. A few words should be added with regard to certain subterfuges which are sometimes encountered in monoalphabetic substitution with variants, and which, if not recognized in time, cause considerable delays The considerations treated before in subpars. 52i and j on the disguise of the length of the basic multiliteral group apply equally here to multiliteral substitution with variants, thus, in dinome systems, a sum-checking digit or a null might be added in specified positions of the group to form a trinome. In complex variant systems, the presence of a null as one of the digits of a trinome would add greatly to the complexities of cryptanalysis of that system. The most important of the subterfuges have to deal with the use of nulls which are of a different size than the real cryptographic units, inserted occasionally to prevent the cryptanalyst from breaking up the text into its proper units The student should take careful note of the last phrase, the mere insertion of symbols having the same characteristics as the symbols of the cryptographic text, except that they have no meaning, is not what is meant This class of nulls rarely achieves the purpose intended. What is really meant can best be explained by an example. Suppose that a 5x5 variant matrix with the row and column indicators shown in Fig. 46 is adopted for encipherment. Normally, the cipher units would consist of 2-letter combinations of the indicators, invariably giving the row indicator first (by agreement).

	V	G	I	W	D
	A	H	P	S	M
	T	O	E	B	N
	F	U	R	L	C
V,A,T,F	A	B	C	D	E
G,H,O,U	F	G	H	I-J	K
I,P,E,R	L	M	N	O	P
W,S,B,L	Q	R	S	T	U
D,M,N,C	V	W	X	Y	Z

Figure 46

The phrase COMMANDER OF SPECIAL TROOPS might be enciphered thus·

```
 C   O   M   M   A   N   D   E   R   O   F   . . .
VI  EB  PH  IU  FT  IP  AB  TN  WO  PW  GT   . . .
```

These would normally then be arranged in 5-letter groups, thus

```
VIEBP  HIUFT  IPABT  NWOPW  GT...
```

b. It will be noted, however, that only 20 of the 26 letters of the alphabet have been employed as row and column indicators, leaving J, K, Q, X, Y, and Z unused. Now, suppose these 6 letters are used as nulls, not in pairs, but as individual letters inserted at random just before the real text is arranged in 5-letter groups. Occasionally, a pair of letters might be inserted, in order to mask the characteristics of "avoidance" of these letters for each other. Thus, for example.

V I E X B P H K I U F J X T I E A J B T M W O Q P W G K T Y

The cryptanalyst, after some study suspecting a bilateral cipher, proceeds to break up the text into pairs

VI EX BP HK IU FJ XT IE AJ BT MW OQ PW GK TY

Compare this set of 2-letter combinations with the correct set. Only 4 of the 15 pairs are "proper" units. It is easy to see that without a knowledge of the existence of the nulls--and even with a knowledge, if he does not know which letters are nulls--the cryptanalyst would be confronted with a problem for the solution of which a fairly large amount of text might be necessary. The careful employment of the variants also very materially adds to the security of the method because repetitions can be rather effectively suppressed.

c. Similarly in the examples under paragraph 58, the letter J in Figs. 27 and 29 may be used as a null, the letter Y in Fig. 28, and the digit Ø in Figs. 33 and 34. In Fig. 30, any letters in the range of P - Z might be used as nulls, but this usage might be weak because of the extremely low frequency of these letters as compared with the letters A - O, this is an important point to consider in the examination of encrypted text for possible poor usages of nulls.

d. From the cryptographic standpoint, usage of nulls in the manner outlined above results in cryptographic text even more than twice as long as the plain text, thus constituting a serious disadvantage. From the cryptanalytic standpoint, the [illegible] of the cipher units in the system described in subpar. b above constitutes the most important obstacle to solution, this, coupled with the use of variants, makes this system considerably more difficult to solve, despite its monoalphabeticity.

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SECTION IX

POLYGRAPHIC SUBSTITUTION SYSTEMS

64. General remarks on polygraphic substitution.--a. The substitution systems dealt with thus far have involved plaintext units consisting of single elements (usually single letters). The major distinction between them has been made simply on the basis of the number of elements constituting the ciphertext units of each, i.e., those involving single-element ciphertext units were termed uniliteral, and those involving ciphertext units composed of two or more elements were termed multiliteral.[1] That is to say, when the terms "uniliteral", "biliteral", "triliteral", etc., were used, it was to have been automatically inferred that the plaintext units were composed of single elements.

b. This section of the text will deal with substitution systems involving plaintext units composed of more than one element; such systems are termed polygraphic.[2] (By comparing this new term with the terms "uniliteral" and "multiliteral" it may then be deduced--and correctly so--that a term involving the suffix "-literal" is descriptive of the composition of the cipher text units of a cryptosystem, and that a term containing the suffix "-graphic" describes the composition of the

[1] See also subpar. 52a.

[2] Systems involving plaintext units composed of single elements may, on this basis, be termed monographic; however, as has been stated in connection with the terms "uniliteral" and "multiliteral", the plaintext units of a system are understood (without restatement) to be monographic unless otherwise specified.

plaintext units.[3]) Polygraphic systems in which the plaintext units are composed of two elements are called digraphic, those in which the plaintext units are composed of three elements are trigraphic, etc. The ciphertext units of polygraphic systems usually consist of the same number of elements as the plaintext units.[4] Thus, if a system is called "digraphic", it may be assumed that the ciphertext units of the system consist of two elements, as do the plaintext units; if this were not the case, the term "digraphic" by itself would not be adequate to describe the system completely, and an additional modifying word or phrase would have to be used to indicate this fact.[5]

c. In polygraphic substitution, the combinations of elements which constitute the plaintext units are considered as indivisible compounds. The units are composite in character and the individual elements composing the units affect the equivalent cipher units jointly, rather than separately. The basic important factor in true polygraphic substitution is that all the letters of each plaintext unit participate in the determination of its cipher equivalent, the identity of each element of the plaintext unit affects the composition of the whole cipher unit.[6] Thus, in a certain digraphic system, $\overline{AB}_p$ may be enciphered as $\overline{XP}_c$, and $\overline{AC}_p$, on the other hand, may be enciphered as $\overline{NK}_c$; a difference in the identity of but one of the letters of the plaintext pair here produces a difference in the identity of both letters of the cipher pair.[7]

[3] In this connection, it is further pointed out that since the root "literal" derives from the Latin "litera", it is conventionally prefixed by modifiers of Latin origin, such as "uni-", "bi-", and "multi-"; similarly, "graphic", deriving from the Greek "graphikos", is prefixed by modifiers of Greek origin, such as "mono-", "di-", and "poly-".

[4] The qualifying adverb "usually" is employed because this correspondence is not essential. For example, if one should draw up a set of 676 arbitrary single signs, it would be possible to represent the 2-letter pairs from AA to ZZ by single symbols. This would still be a digraphic system.

[5] See subpars. 65e and 66f for examples of two such systems and their names.

[6] An analogy is found in chemistry, when two elements combine to form a molecule, the latter usually having properties quite different from those of either of the constituent elements. For example, sodium, a metal, and chlorine, a gas, combine to form sodium chloride, common table salt. However, sodium and fluorine, also a gas similar in many respects to chlorine, combine to form sodium fluoride, which is much different from table salt.

[7] For this reason the two letters are marked by a ligature, that is, by a bar across their tops. In cryptologic notation, the symbol $\overline{\theta\theta}_p$ means "any plaintext digraph", the symbol $\overline{\theta\theta}_c$, "any ciphertext digraph". To refer specifically to the 1st, 2d, 3d,. . member of a ligature, the exponent 1, 2, 3,... will be used. Thus θ_p^2 of $\overline{REM}_p$ is the letter E, θ_c^3 of $\overline{XRZ}_c$ is Z. See also footnote 1 on page 18

d. The fundamental purpose of polygraphic substitution is again the suppression or the elimination of the frequency characteristics of single letters of plain text, just as is the case in monoalphabetic substitution with variants; but here this is accomplished by a different method, the latter arising from a somewhat different approach to the problem involved in producing cryptographic security. When the substitution involves replacement of *single* letters in a monoalphabetic system, even a single cryptogram can be solved rather readily; basically the reason for this is that the principles of frequency and the laws of probability, applied to individual units (single letters) of the plain text, have a very good opportunity to manifest themselves. However, when the substitution involves replacement of plaintext units composed of two or more letters--that is, when the substitution is polygraphic in nature--the principles of frequency and laws of probability have a much lesser opportunity to manifest themselves. If the substitution is digraphic, then the units are pairs of letters and the normal frequencies of plaintext *digraphs* become of first consideration; if the substitution is trigraphic, the units are sets of three letters and the normal frequencies of plaintext trigraphs are involved. In these cases the data that can be employed in the solution are meager; that is why, generally speaking, the solution of polygraphic substitution ciphers is often extremely difficult.

e. By way of example, a given plaintext message of say *n* letters, enciphered by means of a uniliteral substitution system, affords *n* cipher characters, and the same number of cipher units. The same message, enciphered digraphically, still affords *n* cipher characters but only $\frac{n}{2}$ cipher units. Statistically speaking, the sample to which the laws of probability now are to be applied has been cut in half. Furthermore, from the point of view of frequency; (the very noticeable diversity in the frequencies of individual letters) leading to the marked crests and troughs of the uniliteral frequency distribution, is no longer so strikingly in evidence in the frequencies of digraphs. Therefore, although digraphic encipherment, for example, simply cuts the cryptographic textual units in half, the number of cipher units which must be identified has been *squared*, and the difficulty of solution is not merely doubled but, if a matter of judgment arising from practical experience can be expressed or approximated mathematically, squared or cubed.

f. The following two paragraphs will treat various polygraphic substitution methods. The most practical of these methods are digraphic in character and for this reason their treatment herein will be more detailed than that of trigraphic methods.

65. Polygraphic substitution methods employing large tables.--

a. The simplest method of effecting polygraphic substitution involves the use of tables similar to that shown in Figure 47*a*. This table merely provides equivalents for digraphs, by means of the coordinate system. Specifically, in obtaining the cipher equivalent of any

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	WG	EE	SN	TR	IA	NL	GC	HT	OI	UO	AM	RP	BY	KB	CD	DF	FH	JJ	LK	MQ	PS	QU	VV	XW	YX	ZZ
B	EG	SE	TN	IR	NA	GL	HC	OT	UI	AO	RM	BP	KY	CB	DD	FF	JH	LJ	MK	PQ	QS	VU	XV	YW	ZX	WZ
C	SG	TE	IN	NR	GA	HL	OC	UT	AI	RO	BM	KP	CY	DB	FD	JF	LH	MJ	PK	QQ	VS	XU	YV	ZW	WX	EZ
D	TG	IE	NN	GR	HA	OL	UC	AT	RI	BO	KM	CP	DY	FB	JD	LF	MH	PJ	QK	VQ	XS	YU	ZV	WW	EX	SZ
E	IG	NE	GN	HR	OA	UL	AC	RT	BI	KO	CM	DP	FY	JB	LD	MF	PH	QJ	VK	XQ	YS	ZU	WV	EW	SX	TZ
F	NG	GE	HN	OR	UA	AL	RC	BT	KI	CO	DM	FP	JY	LB	MD	PF	QH	VJ	XK	YQ	ZS	WU	EV	SW	TX	IZ
G	GG	HE	ON	UR	AA	RL	BC	KT	CI	DO	FM	JP	LY	MB	PD	QF	VH	XJ	YK	ZQ	WS	EU	SV	TW	IX	NZ
H	HG	OE	UN	AR	RA	BL	KC	CT	DI	FO	JM	LP	MY	PB	QD	VF	XH	YJ	ZK	WQ	ES	SU	TV	IW	NX	GZ
I	OG	UE	AN	RR	BA	KL	CC	DT	FI	JO	LM	MP	PY	QB	VD	XF	YH	ZJ	WK	EQ	SS	TU	IV	NW	GX	HZ
J	UG	AE	RN	BR	KA	CL	DC	FT	JI	LO	MM	PP	QY	VB	XD	YF	ZH	WJ	EK	SQ	TS	IU	NV	GW	HX	OZ
K	AG	RE	BN	KR	CA	DL	FC	JT	LI	MO	PM	QP	VY	XB	YD	ZF	WH	EJ	SK	TQ	IS	NU	GV	HW	OX	UZ
L	RG	BE	KN	CR	DA	FL	JC	LT	MI	PO	QM	VP	XY	YB	ZD	WF	EH	SJ	TK	IQ	NS	GU	HV	OW	UX	AZ
M	BG	KE	CN	DR	FA	JL	LC	MT	PI	QO	VM	XP	YY	ZB	WD	EF	SH	TJ	IK	NQ	GS	HU	OV	UW	AX	RZ
N	KG	CE	DN	FR	JA	LL	MC	PT	QI	VO	XM	YP	ZY	WB	ED	SF	TH	IJ	NK	GQ	HS	OU	UV	AW	RX	BZ
O	CG	DE	FN	JR	LA	ML	PC	QT	VI	XO	YM	ZP	WY	EB	SD	TF	IH	NJ	GK	HQ	OS	UU	AV	RW	BX	KZ
P	DG	FE	JN	LR	MA	PL	QC	VT	XI	YO	ZM	WP	EY	SB	TD	IF	NH	GJ	HK	OQ	US	AU	RV	BW	KX	CZ
Q	FG	JE	LN	MR	PA	QL	VC	XT	YI	ZO	WM	EP	SY	TB	ID	NF	GH	HJ	OK	UQ	AS	RU	BV	KW	CX	DZ
R	JG	LE	MN	PR	QA	VL	XC	YT	ZI	WO	EM	SP	TY	IB	ND	GF	HH	OJ	UK	AQ	RS	BU	KV	CW	DX	FZ
S	LG	ME	PN	QR	VA	XL	YC	ZT	WI	EO	SM	TP	IY	NB	GD	HF	OH	UJ	AK	RQ	BS	KU	CV	DW	FX	JZ
T	MG	PE	QN	VR	XA	YL	ZC	WT	EI	SO	TM	IP	NY	GB	HD	OF	UH	AJ	RK	BQ	KS	CU	DV	FW	JX	LZ
U	PG	QE	VN	XR	YA	ZL	WC	ET	SI	TO	IM	NP	GY	HB	OD	UF	AH	RJ	BK	KQ	CS	DU	FV	JW	LX	MZ
V	QG	VE	XN	YR	ZA	WL	EC	ST	TI	IO	NM	GP	HY	OB	UD	AF	RH	BJ	KK	CQ	DS	FU	JV	LW	MX	PZ
W	VG	XE	YN	ZR	WA	EL	SC	TT	II	NO	GM	HP	OY	UB	AD	RF	BH	KJ	CK	DQ	FS	JU	LV	MW	PX	QZ
X	XG	YE	ZN	WR	EA	SL	TC	IT	NI	GO	HM	OP	UY	AB	RD	BF	KH	CJ	DK	FQ	JS	LU	MV	PW	QX	VZ
Y	YG	ZE	WN	ER	SA	TL	IC	NT	GI	HO	OM	UP	AY	RB	BD	KF	CH	DJ	FK	JQ	LS	MU	PV	QW	VX	XZ
Z	ZG	WE	EN	SR	TA	IL	NC	GT	HI	OO	UM	AP	RY	BB	KD	CF	DH	FJ	JK	LQ	MS	PU	QV	VW	XX	YZ

Figure 47a.

plaintext digraph, the initial letter of the plaintext digraph is used to indicate the row in which the equivalent is found, and the final letter of the plaintext digraph indicates the column, the cipher digraph is then found at the intersection of the row and column thus indicated. For example, $\overline{KG}_p=\overline{FC}_c$, $\overline{WM}_p=\overline{OY}_c$, etc.

b. In the preceding table two mixed sequences were employed to form the cipher equivalents, one sequence being based on the key phrase WESTINGHOUSE AIR BRAKE and the other on GENERAL ELECTRIC COMPANY. The table in Figure 47a could have been drawn up in a slightly different manner, as shown in Figure 47b, and still yield the same cipher equivalents as before. Using this latter table, θ_c^1 for any plaintext digraph is found at the intersection of the row and column identified by θ_p^1 and θ_p^2, respectively, θ_c^2 is found in the sequence below the table and is

θ^2_p

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z
B	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W
C	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E
D	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S
E	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T
F	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I
G	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N
H	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G
I	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H
J	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O
K	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U
L	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A
M	B	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R
N	K	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B
O	C	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K
P	D	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C
Q	F	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D
R	J	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F
S	L	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J
T	M	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L
U	P	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M
V	Q	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P
W	V	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q
X	X	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V
Y	Y	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X
Z	Z	W	E	S	T	I	N	G	H	O	U	A	R	B	K	C	D	F	J	L	M	P	Q	V	X	Y
θ^2_c	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z

Figure 47b.

taken from the position directly under the column identified by θ^2_p. A few sample enciphements will illustrate that this table is cryptographically equivalent to that of Fig. 47a.

c. Figures 48 and 49, below, contain other possible types of tables for digraphic substitution. In Fig. 48, it will be seen that there are two vertical sequences to the left of this table and no horizontal sequence below it. θ^1_p is located in the leftmost sequence, θ^1_c being found directly to its side in the right-hand sequence, θ^2_c is then found at the intersection of the row and column identified by θ^1_p and θ^2_p,

θ_p^2

θ_p^1	θ^1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	W	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z
B	E	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G
C	S	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E
D	T	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N
E	I	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R
F	N	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A
G	G	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L
H	H	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C
I	O	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T
J	U	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I
K	A	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O
L	R	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M
M	B	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P
N	K	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y
O	C	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B
P	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D
Q	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F
R	J	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H
S	L	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J
T	M	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K
U	P	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q
V	Q	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S
W	V	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U
X	X	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V
Y	Y	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W
Z	Z	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X

Figure 48.

respectively. The table in Fig. 49 provides digraphic equivalents by means of the coordinate system (e.g., $\overline{RE}_p=\overline{JZ}_c$), in the same manner as in Fig. 47<u>a</u>, and a cursory examination of the inside of the table might disclose nothing new about this table at all. But, if one were to scan closely the diagonals formed by each θ_c^1 from upper right to lower left, he would see that each such diagonal changes below the "M_p row", similarly, if the diagonals formed by θ_c^2 are scanned from upper left to lower right, it will be seen that each of them also changes after the "M_p row". In effect, the inside of the table is divided into two separate portions by an imaginary line extending horizontally between the M and N rows, but within each portion a straightforward type of symmetry is exhibited and the same two mixed sequences have been employed in each. Actually, in a 26x26 table, it is not possible to maintain the diagonals formed thus by θ_c^1 and θ_c^2 in a completely "unbroken" sequence without producing repeated digraphs within the table and without consequent cryptographic ambiguity, thus, Fig. 49 illustrates one type of limited diagonal symmetry which must be resorted to in the systematic construction of such a table.

θ^{2}_{p}

θ^{1}_{p}	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	W Z	E X	S W	T V	I U	N S	G Q	H K	O J	U H	A F	R D	B B	K Y	C P	D M	F O	J I	I T	M C	P L	Q A	V R	X N	Y E	Z G
B	E G	S Z	T X	I W	N V	G U	H S	O Q	U K	A J	R H	B F	K D	C B	D Y	F P	J M	L O	M I	P T	Q C	V L	X A	Y R	Z N	W E
C	S E	T G	I Z	N X	G W	H V	O U	U S	A Q	R K	B J	K H	C F	D D	F B	J Y	L P	M M	P O	Q I	V T	X C	Y L	Z A	W R	E N
D	T N	I E	N G	G Z	H X	O W	U V	A U	R S	B Q	K K	C J	D H	F F	J D	L D	M Y	P P	Q M	V O	X I	Y T	Z C	W L	E A	S R
E	I R	N N	G E	H G	O Z	U X	A W	R V	B U	K S	C Q	D K	F J	J H	L F	M D	P B	Q Y	V P	X M	Y O	Z I	W T	E C	S L	T A
F	N A	G R	H N	O E	U G	A Z	R X	B W	K V	C U	D S	F Q	J K	L J	M H	P F	Q D	V B	X Y	Y P	Z M	W O	E I	S T	T C	I L
G	G L	H A	O R	U N	A E	R G	B Z	K X	C W	D V	F U	J S	L Q	M K	P J	Q H	V F	X D	Y B	Z Y	W P	E M	S O	T I	I T	N C
H	H C	O L	U A	A R	R N	B E	K G	C Z	D X	F W	J V	L U	M S	P Q	Q K	V J	X H	Y F	Z D	W B	E Y	S P	T M	I O	J I	G T
I	O T	U C	A L	R A	B R	K N	C E	D G	F Z	J X	L W	M V	P U	Q S	V Q	X K	Y J	Z H	W F	E D	S B	T Y	I P	N M	G O	H I
J	U I	A T	R C	B L	K A	C R	D N	F E	J G	L Z	M X	P W	Q V	V U	X S	Y Q	Z K	W J	E H	S F	T D	I B	N Y	G P	H M	O O
K	A O	R I	B T	K C	C L	D A	F R	J N	L E	M G	P Z	Q X	V W	X V	Y U	Z S	W Q	E K	S J	T H	I F	N D	G B	H Y	O P	U M
L	R M	B O	K I	C T	D C	F L	J A	L R	M N	P E	Q G	V Z	X X	Y W	Z V	W U	E S	S Q	T K	I J	N H	G F	H D	O B	U Y	A P
M	B P	K M	C O	D I	F T	J C	L L	M A	P R	Q N	V E	X G	Y Z	Z X	W W	E V	S U	T S	I Q	N K	G J	H H	O F	U D	A B	R Y
N	Z Z	Y G	X E	V N	Q R	P A	M L	L C	J T	F I	D O	C M	K P	B Y	R B	A D	U F	O H	H J	G K	N Q	I S	T U	S V	E W	W X
O	Y X	X Z	V G	Q E	P N	M R	L A	J L	F C	D T	C I	K O	B M	R P	A Y	U B	O D	H F	G H	N J	I K	T Q	S S	E U	W V	Z W
P	X W	V X	Q Z	P G	M E	L N	J R	F A	D L	C C	K T	B I	R O	A M	U P	O Y	H B	G D	N F	I H	T J	S K	E Q	W S	Z U	Y V
Q	V V	Q W	P X	M Z	L G	J E	F N	D R	C A	K L	B C	R T	A I	U O	O M	H P	G Y	N B	I D	T F	S H	E J	W E	Z Q	Y S	X U
R	Q U	P V	M W	L X	J Z	F G	D E	C N	K R	B A	R L	A C	U T	O I	H O	G M	N P	I Y	T B	S D	E F	W H	Z J	Y K	X Q	V S
S	P S	M U	L V	J W	F X	D Z	C G	K E	B N	R P	A A	U L	O C	H T	G I	N O	I M	T P	S Y	E B	W D	Z F	Y H	X J	V K	Q Q
T	M Q	L S	J U	F V	D W	C X	K Z	B G	R E	A N	U R	O A	H L	G C	N T	I I	T O	S M	E P	W Y	Z B	Y D	X F	V H	Q J	P K
U	L K	J Q	F S	D U	C V	K W	B X	R Z	A G	U E	O N	H R	G A	N L	 C	T T	S I	E O	W M	Z P	Y Y	X B	V D	Q F	P H	M J
V	J J	F K	D Q	C S	K U	B V	R W	A X	U Z	O G	H E	G N	N R	I A	T L	S C	E T	W I	Z O	Y M	X P	V Y	Q B	P D	M F	L H
W	F H	D J	C K	K Q	B S	R U	A V	U W	O X	H Z	G G	N E	I N	T R	S A	E L	W C	Z T	Y I	X O	V M	Q P	P Y	M B	L D	J F
X	D F	C H	K J	B K	R Q	A S	U U	O V	H W	G X	N Z	I G	T E	S N	E R	W A	Z L	Y C	X T	V I	Q O	P M	M P	L Y	J B	F D
Y	C D	K F	B H	R J	A K	U Q	O S	H U	G V	N W	I X	T Z	S G	E E	W N	Z R	Y A	X L	V C	Q T	P I	M O	L M	J P	F Y	D B
Z	X B	B D	R F	A H	U J	O K	H Q	G S	N U	I V	T W	S X	E Z	W G	Z E	Y N	X R	V A	Q L	P C	M T	L I	J O	F M	D P	C Y

Figure 49.

d. All of the foregoing tables have exhibited a symmetry in the arrangement of their contents, which is undesirable from the standpoint of cryptographic security. This systematic internal arrangement could be detected by a cryptanalyst early in his attack on cryptograms produced through their use, permitting rapid reconstruction of the particular table involved, this subject will be given a more detailed treatment in par. 72. The table in Figure 50 is an example of one type of table which would provide more security than the foregoing. This table is constructed by random assignment of values and shows no symmetry whatsoever in its arrangement of contents. It will be noted that this table is

(Showing only a partially filled table)

Final Letter (θ^2_p)

Initial letter (θ^1_p)

	A	B	C	D	E	F	G	H	I	J	K	X	Y	Z
A	FX	CH	XE	YY	ZA	YG	FB	CD	EF	XJ	ZX	EA	DJ	FH
B	NY	DC	NB	ZI	XX	DX								
C				AH				AB					ND	
D			BB		YA					AY		BF		
E	AX					AI								
F		AG			NZ			AZ				AA		
N		BC		CY									BA	FE
X					AC					AJ		BE		
Y	DE						AΓ						AD	
Z	AE								BD			AK		

Figure 50.

reciprocal in nature, that is $\overline{AF}_p=\overline{YG}_c$ and $\overline{YG}_p=\overline{AF}_c$. Thus, this single table serves for deciphering as well as for enciphering. Reciprocity is, however, not an essential factor, in fact, greater security is provided by non-reciprocal tables. But, in the case of such non-reciprocal, randomly constructed tables, each enciphering table must have its complementary deciphering table.

e. Digraphic tables employing numerical equivalents instead of letter equivalents may be encountered. However, since 676 equivalents are required (there being 676, or 26x26, different pairs of letters), this means that combinations of three figures must be used, such systems are termed trinome-digraphic systems, indicating clearly the number of elements which comprise the cipher units. By way of an example, the following figure contains a fragment of a table[8] which provides trinome equivalents for the plaintext digraphs:

	A	B	C	D	E				Y	Z
A	001	002	003	004	005	...	...	...	025	026
B	027	028	029	030	031				051	052
C	053	054								
	...									
	...									
	...									
Y	625	626							649	650
Z	651	652							675	676

Figure 51.

f. All of the foregoing tables have been digraphic in nature, but a kind of false trigraphic substitution may also be accomplished by means of similar tables, as illustrated in Figure 52, wherein the table is the same as that in Figure 49 with the addition of one more sequence at the top of the table. In using this table, θ_p^1 is located in sequence I, and

[8] It is interesting to note that this comparatively bulky and unwieldy table can be reduced to the following two alphabets with numerical equivalents for the letters:

	A	B	C	D	E	F	.	.	.	.	.	X	Y	Z
(1)	000	026	052	078	104	130	...	...	...	...	...	598	624	650

	A	B	C	D	E	F	.	.	.	.	.	X	Y	Z
(2)	1	2	3	4	5	6	.	.	.	.	.	24	25	26

In enciphering, the first letter of the plaintext digraph is converted into its numerical value from alphabet (1), and the second plaintext letter is converted by means of alphabet (2), the two numerical values thus derived are added together, and their sum is taken as the cipher equivalent of the particular plaintext digraph. Of course, this simple reduction would not be possible if the trinomes, in ascending order, had been arranged in the table in, say, a diagonal manner.

	III	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
	IV	R	A	D	I	O	C	P	T	N	F	M	E	B	G	H	J	K	L	Q	S	U	V	W	X	Y	Z
I	II																										
A	W	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z
B	E	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G
C	S	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E
D	T	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N
E	I	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R
F	N	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A
G	G	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L
H	H	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C
I	O	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T
J	U	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I
K	A	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O
L	R	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M
M	B	Y	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P
N	K	B	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y
O	C	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B
P	D	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D
Q	F	H	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F
R	J	J	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H
S	L	K	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J
T	M	Q	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K
U	P	S	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q
V	Q	U	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S
W	V	V	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U
X	X	W	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V
Y	Y	X	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W
Z	Z	Z	G	E	N	R	A	L	C	T	I	O	M	P	Y	B	D	F	H	J	K	Q	S	U	V	W	X

Figure 52.

its equivalent, θ_c^1, taken from sequence II; θ_p^2 is located in sequence III, and its equivalent, θ_c^2, taken from sequence IV; θ_c^3 is the letter lying at the intersection of the row indicated by θ_p^3 in sequence I and the column determined by θ_p^2. Thus, FIRE LINES would be enciphered $\overline{\mathrm{NNZ}}$ $\overline{\mathrm{IEQ}}$ $\overline{\mathrm{KOV}}$. Various other agreements may be made with respect to the alphabets in which each plaintext letter will be sought in such a table, but the basic cryptographic principles are the same as in the case described.

g. Tables such as those illustrated in Figs. 47-52, above, have been encountered in operational systems, but their use has not been very widespread because of their relatively large size and the inconvenience in their production and handling. In lieu of these large tables it is possible to employ much smaller matrices or geometrical designs to accomplish digraphic substitution, methods ınvolving their use will be discussed in the following paragraph.

66 Polygraphic substitution methods employing small matrices.[9]--

a. A simple method for accomplishing digraphic substitution involves the use of the four-square matrix, a matrix consisting of four 5x5 squares in which the letters of a 25-element alphabet (combining I and J) are inserted in any prearranged order. When four such squares are arranged in a matrix as shown in Figure 53, the latter may be employed for digraphic substitution to yield the same cipher results as does a much larger table of the type treated in the preceding paragraph. In a four-square matrix, θ_p^1 of $\overline{\theta\theta}_p$ is sought in section 1, θ_p^2, in section 2. Thus, θ_p^1 and θ_p^2 will always form the northwest-southeast corners of an imaginary rectangle delimited by these two letters as located in these two sections of the square. Then θ_c^1 and θ_c^2 are, respectively, the letters at the northeast-southwest corners of this same rectangle. Thus, $\overline{TG}_p=\overline{XS}_c$, $\overline{UD}_p=\overline{CH}_c$, $\overline{OR}_p=\overline{YW}_c$; $\overline{UR}_p=\overline{XB}_c$; etc. In decrypting, θ_c^1 and θ_c^2 are sought in sections 3 and 4, respectively, and their equivalents, θ_p^1 and θ_p^2, noted in sections 1 and 2, respectively.

	A	B	C	D	E	F	O	U	R	T	
	F	G	H	I	K	L	M	P	Q	E	
Sec. 1 (θ_p^1)	L	M	N	O	P	K	Y	Z	S	N	Sec. 3 (θ_c^1)
	Q	R	S	T	U	I	X	W	V	A	
	V	W	X	Y	Z	H	G	D	C	B	
	T	H	I	R	E	A	B	C	D	E	
	O	P	Q	S	N	F	G	H	I	K	
Sec. 4 (θ_c^2)	M	Y	Z	U	A	L	M	N	O	P	Sec. 2 (θ_p^2)
	L	X	W	V	B	Q	R	S	T	U	
	K	G	F	D	C	V	W	X	Y	Z	

Figure 53.

b. It is possible to effect digraphic substitution with a matrix consisting of but two sections by a modification in the method of finding equivalents. In a horizontal two-square matrix, such as that shown in Figure 54, θ_p^1 of $\overline{\theta\theta}_p$ is located in the square at the left, θ_p^2, in the square at the right.

[9] The word matrix as employed in this paragraph refers to checkerboard-type diagrams smaller than the tables illustrated in the preceding paragraph. These matrices are usually composed of sections containing 25 cells each.

	M	A	N	U	F	A	U	T	O	M	
	C	T	R	I	G	B	I	L	E	S	
$\theta_p^1\theta_c^2$	B	D	E	H	K	C	D	F	G	H	$\theta_p^2\theta_c^1$
	L	O	P	Q	S	K	N	P	Q	R	
	V	W	X	Y	Z	V	W	X	Y	Z	

Figure 54

When θ_p^1 and θ_p^2 are at the opposite ends of the diagonal of an imaginary rectangle defined by these letters, the ciphertext equivalent comprises the two letters appearing at the opposite ends of the other diagonal of the same rectangle, θ_c^1 is the particular one which is in the same row as θ_p^1, and θ_c^2 is the one in the same row as θ_p^2. For example, $\overline{AL}_p=\overline{TT}_c$, $\overline{DO}_p=\overline{GA}_c$. When θ_p^1 and θ_p^2 happen to be in the same row, the ciphertext equivalent is merely the reverse of the plaintext digraph, for example, $\overline{AT}_p=\overline{TA}_c$ and $\overline{EH}_p=\overline{HE}_c$.

c. Digraphic substitution may also be effected by means of vertical two-square matrices, in which one section is directly above the other, as in Figure 55, it will be noted that matrices of this type have a feature of reciprocity when employed according to the usual rules, which follow.

M	A	N	U	F
C	T	R	I	G
B	D	E	H	K
L	O	P	Q	S
V	W	X	Y	Z
A	U	T	O	M
B	I	L	E	S
C	D	F	G	H
K	N	P	Q	R
V	W	X	Y	Z

Figure 55.

When θ_p^1 and θ_p^2 are at the opposite ends of a diagonal, the rule for encipherment is the same as that for horizontal two-square encipherment (e.g., $\overline{MO}_p=\overline{UA}_c$ and $\overline{UA}_p=\overline{MO}_c$); when both θ_p^1 and θ_p^2 happen to be in the same column, the plaintext digraphs are self-enciphered, (e.g., $\overline{MA}_p=\overline{MA}_c$ and $\overline{EL}_p=\overline{EL}_c$), a fact which constitutes an important weakness of this method.[10] This disadvantage is only slightly less obvious in the preceding case of horizontal two-square methods wherein the cipher equivalent of $\overline{\theta\theta}_p$ consists merely of the plaintext letters in reversed order.

d. One-square digraphic methods, with a necessary modification of the method for finding equivalents, are also possible. The first of this type to appear as a practical military system was that known as the Playfair cipher.[11] It was used for a number of years as a field cipher by the British Army, before and during World War I, and for a short time, also during that war, by certain units of the American Expeditionary Forces. Figure 56 shows a typical Playfair square. The modification in the method of finding cipher equivalents has been found useful in imparting a greater degree of security than that afforded in the preceding small matrix methods. The usual method of encipherment can be best explained by examples given under four categories:

M	A	N	U	F
C	T	R	I	G
B	D	E	H	K
L	O	P	Q	S
V	W	X	Y	Z

Figure 56.

[10] See subpar. 73b on other enciphering conventions which remove this weakness.

[11] This cipher was really invented by Sir Charles Wheatstone but receives its name from Lord Playfair, who apparently was its sponsor before the British Foreign Office. See Wemyss Reid, Memoirs of Lyon Playfair, London, 1899. It is of interest to note that, to students of electrical engineering, Wheatstone is generally not known for his contributions to cryptography but is famed for something he did not invent--the so-called Wheatstone bridge", really invented by Samuel H. Christie.

(1) Members of the plaintext pair, θ_p^1 and θ_p^2, are at opposite ends of the diagonal of an imaginary rectangle defined by the two letters, the members of the ciphertext pair, θ_c^1 and θ_c^2, are at the opposite ends of the other diagonal of this imaginary rectangle. Examples: $\overline{MO}_p=\overline{AL}_c$, $\overline{MI}_p=\overline{UC}_c$, $\overline{LU}_p=\overline{QM}_c$, $\overline{VI}_p=\overline{YC}_c$.

(2) θ_p^1 and θ_p^2 are in the same row, the letter immediately to the right of θ_p^1 forms θ_c^1, the letter immediately to the right of θ_p^2 forms θ_c^2. When either θ_p^1 or θ_p^2 is at the extreme right of the row, the first letter in the row becomes its cipher equivalent. Examples: $\overline{MA}_p=\overline{AN}_c$, $\overline{MU}_p=\overline{AF}_c$; $\overline{AF}_p=\overline{NM}_c$; $\overline{FA}_p=\overline{MN}_c$.

(3) θ_p^1 and θ_p^2 are in the same column, the letter immediately below θ_p^1 forms θ_c^1, the letter immediately below θ_p^2 forms θ_c^2. When either θ_p^1 or θ_p^2 is at the bottom of the column, the top letter in that column becomes its cipher equivalent. Examples $\overline{MC}_p=\overline{CB}_c$, $\overline{AW}_p=\overline{TA}_c$, $\overline{WA}_p=\overline{AT}_c$, $\overline{QU}_p=\overline{YI}_c$.

(4) θ_p^1 and θ_p^2 are identical, they are to be separated by inserting a null, usually the letter X or Q, and subsequently enciphered by the pertinent rule from above. For example, the word BATTLES would be enciphered thus:

BA TX TL ES
DM RW CO KP

The Playfair square is automatically reciprocal so far as encipherments of type (1) above are concerned, but this is not true of encipherments of type (2) and (3).

e. It is not essential that the small matrices used for digraphic substitution be in the shape of perfect squares, rectangular designs will serve equally well, with little or no modification in procedure.[12] For example, each section of, say, a four-square matrix could be constructed with four rows containing six letters each by having U_p serve for V_p, as well as I_p for J_p. Furthermore, it is possible to expand the sections of a digraphic matrix to 28, 30, or more characters by the following subterfuge, without introducing digits or symbols into the cipher text.[13] One

[12] However, because the terms "four-square matrix", "two-square matrix", and "Playfair square" have become firmly fixed in cryptologic literature and practice, they continue to be applied to all such matrices, even when the "squares" of such matrices do not contain an equal number of rows and columns (that is, even when they are not square).

[13] The addition of any symbols such as the digits 1, 2, 3,... into a matrix solely to augment the number of elements to 27, 28, 30, 32, or 36 characters would not be considered practicable, since such a procedure would result in producing cryptograms containing intermixtures of letters and figures.

of the letters of the alphabet may be omitted from the set of 26 letters, and this letter may then be replaced by 2, 3, or more pairs of letters, each pair having as one of its members the omitted single letter. The 5x6 Playfair square of Figure 57a has been derived thus, the letter K has been omitted as a single letter, and the number of characters in the rectangle has been made a total of 30 by the addition of five combinations of K with other letters. An interesting consequence of this modification is that certain irregularities are introduced in any cryptogram produced through its use, for example, (1) occasionally a plaintext digraph is replaced by ciphertext trigraph or tetragraph, such as $\overline{AM}_p=\overline{HKU}_c$ and $\overline{EP}_p=\overline{KEKO}_c$; and (2) variant values may appear--$\overline{BKE}_c$, $\overline{DKE}_c$, $\overline{KEP}_c$, $\overline{GP}_c$, and $\overline{TP}_c$ all may be used to represent $\overline{CK}_p$. As far as the deciphering is concerned, there is no difficulty because any K occurring in the cipher text is considered as invariably forming a ligature with the succeeding letter, taking the pair of letters as a unit; and, when a plaintext unit is obtained containing one of the K-pairs, the letter after the K is disregarded, for example, $\overline{CKO}_p$ is read as CK. The four-square matrix in Fig. 57b has also been constructed using the foregoing

W	A	S	H	I	N
G	T	O	B	C	D
E	F	J	KA	KE	KI
KO	KU	L	M	P	Q
R	U	V	X	Y	Z

Figure 57a.

	B	2	E	5	R	L	A	B	C	D	E	F	
	I	9	N	A	1	C	G	H	I	J	KA	KE	
θ_p^1	3	D	4	F	6	G	KI	KO	KU	KY	L	M	θ_c^1
	7	H	8	J	Ø	K	N	O	P	QA	QE	QI	
	M	O	P	Q	S	T	QO	QU	QY	R	S	T	
	U	V	W	X	Y	Z	U	V	W	X	Y	Z	
	A	B	C	D	E	F	M	U	N	I	9	C	
	G	H	I	J	KA	KE	3	H	8	A	1	B	
θ_c^2	KI	KO	KU	KY	L	M	2	D	4	E	5	F	θ_p^2
	N	O	P	QA	QE	QI	6	G	7	J	Ø	K	
	QO	QU	QY	R	S	T	L	O	P	Q	R	S	
	U	V	W	X	Y	Z	T	V	W	X	Y	Z	

Figure 57b.

subterfuge. With this latter matrix, numbers in the plain text may be enciphered, still without producing cipher text containing numbers, for example, the plain text "HILL 3406" would be represented by the cipher QAB AT KUKI NQE, which would be regrouped into groups of five letters and sent as QABAT KUKIN QE...

f. Figure 58 shows a numerical four-square matrix which presents a rather interesting feature in that it makes possible the substitution of 3-figure combinations for digraphs in a unique manner. To encipher a message one proceeds as usual to find the numerical equivalents of a pair, and then these numbers are added together Thus

Plain text.	PR	OC	EE	DI	NG
	275	350	100	075	325
	9	13	24	18	7
Cipher text·	284	363	124	093	332

	A	B	C	D	E	000	025	050	075	100	
	F	G	H	I	K	125	150	175	200	225	
Sec 1 (θ^1_p)	L	M	N	O	P	250	275	300	325	350	Sec 3 (θ^1_c)
	Q	R	S	T	U	375	400	425	450	475	
	V	W	X	Y	Z	500	525	550	575	600	
	0	1	2	3	4	V	Q	L	F	A	
	5	6	7	8	9	W	R	M	G	B	
Sec 4 (θ^2_c)	10	11	12	13	14	X	S	N	H	C	Sec 2 (θ^2_p)
	15	16	17	18	19	Y	T	O	I	D	
	20	21	22	23	24	Z	U	P	K	E	

Figure 58.

In deciphering, the greatest multiple of 25 contained in the group of three digits is determined, then this multiple and its remainder are used to form the elements for determining the plaintext pair in the usual manner. Thus, 284=275+9=PR.

g. Thus far all the small-matrix methods have involved only digraphic substitution. The two matrices together illustrated in Figures 59a and b may be used to provide a system for encipherment which is partly trigraphic, the adverb "partly" has been used because this particular system will yield trigraphic encipherment approximately 88.5% of the time in ordinary text and digraphic encipherment approximately 11.5% of the time.[14] In this case the cipher equivalents of the trigraphs

[14] These figures are based on the number of trigraphs ending in one of the 15 highest-frequency letters (ETNROAISDLHCFPU), and on the number of trigraphs ending with other letters.

H_1	H_2	H_3	H_4	Y_1	Y_2	Y_3	Y_4	D_1	D_2	00	01	02	03	04	05	06	07	08	09
D_3	D_4	R_1	R_2	R_3	R_4	A_1	A_2	A_3	A_4	10	11	12	13	14	15	16	17	18	19
U_1	U_2	U_3	U_4	L_1	L_2	L_3	L_4	I_1	I_2	20	21	22	23	24	25	26	27	28	29
I_3	I_4	C_1	C_2	C_3	C_4	B_1	B_2	B_3	B_4	30	31	32	33	34	35	36	37	38	39
E_1	E_2	E_3	E_4	F_1	F_2	F_3	F_4	G_1	G_2	40	41	42	43	44	45	46	47	48	49
G_3	G_4	K_1	K_2	K_3	K_4	M_1	M_2	M_3	M_4	50	51	52	53	54	55	56	57	58	59
N_1	N_2	N_3	N_4	O_1	O_2	O_3	O_4	P_1	P_2	60	61	62	63	64	65	66	67	68	69
P_3	P_4	Q_1	Q_2	Q_3	Q_4	S_1	S_2	S_3	S_4	70	71	72	73	74	75	76	77	78	79
T_1	T_2	T_3	T_4	V_1	V_2	V_3	V_4	W_1	W_2	80	81	82	83	84	85	86	87	88	89
W_3	W_4	X_1	X_2	X_3	X_4	Z_1	Z_2	Z_3	Z_4	90	91	92	93	94	95	96	97	98	99
00	01	02	03	04	05	06	07	08	09	Q_1	Q_2	Q_3	Q_4	U_1	U_2	U_3	U_4	E_1	E_2
10	11	12	13	14	15	16	17	18	19	E_3	E_4	S_1	S_2	S_3	S_4	T_1	T_2	T_3	T_4
20	21	22	23	24	25	26	27	28	29	I_1	I_2	I_3	I_4	O_1	O_2	O_3	O_4	N_1	N_2
30	31	32	33	34	35	36	37	38	39	N_3	N_4	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4
40	41	42	43	44	45	46	47	48	49	L_1	L_2	L_3	L_4	Y_1	Y_2	Y_3	Y_4	C_1	C_2
50	51	52	53	54	55	56	57	58	59	C_3	C_4	D_1	D_2	D_3	D_4	F_1	F_2	F_3	F_4
60	61	62	63	64	65	66	67	68	69	G_1	G_2	G_3	G_4	H_1	H_2	H_3	H_4	K_1	K_2
70	71	72	73	74	75	76	77	78	79	K_3	K_4	M_1	M_2	M_3	M_4	P_1	P_2	P_3	P_4
80	81	82	83	84	85	86	87	88	89	R_1	R_2	R_3	R_4	V_1	V_2	V_3	V_4	W_1	W_2
90	91	92	93	94	95	96	97	98	99	W_3	W_4	X_1	X_2	X_3	X_4	Z_1	Z_2	Z_3	Z_4

Figure 59a.

	1	2	3	4
1	-	E	T	N
2	R	O	A	I
3	S	D	L	H
4	C	F	P	U

Fig. 59b.

(or digraphs, as the case may be) are tetranomes. Encipherment is best illustrated by an example, this is given in the next subparagraph.

h. Let the text to be enciphered be a message beginning with the words "REFERRING TO YOUR MESSAGE NUMBER FIVE STOP ..." This is rewritten into trigraphs, with the proviso that the third letter of the trigraph be one of the letters contained in the small square in Fig. 59b, if the third letter is not one of these 15 letters, the plaintext grouping is left as a digraph, then the grouping into trigraphs (or digraphs) continues. Thus, the foregoing plain text would be written as follows·

REF ERR IN- GTO YOU RME SSA GEN UM- BER FI- VES TOP ...

In encipherment, it is to be noticed that R_p occurs four times in section 1 (as do all the letters) and E_p occurs four times in section 2; the proper combination of the 16 possibilities is determined by the coordinates of the third letter of the trigraph as indicated in the small square, Fig. 59b. Since the coordinates of F_p in this square are 42, then it is the 4th occurrence of R_p in section 1 and the 2d occurrence of E_p in section 2 which are used to obtain the equivalent for the trigraph $\overline{REF}_p$, this equivalent is 1905. When the plaintext unit as obtained above is only a digraph, it is the 1st occurrence of θ_p^1 which is used in section 1 and the 1st occurrence of θ_p^2 which is used in section 2; thus, "IN-" from the sample message beginning, above, would be enciphered 2828. The encipherment of the plaintext example above is then

REF	ERR	IN-	GTO	YOU	RME	SSA	GEN	UM-	BER	FI-	VES	TOP
1905	4081	2828	4719	0727	1372	7417	4118	2270	3807	4024	8806	8623

The cipher text could then be transmitted in groups of four digits, or, as a subterfuge to conceal the basic group length, the transmission could be in five-digit groups. In decipherment, the ciphertext tetranome is deciphered in the manner of the usual four-square matrix, and the location of the particular values for θ_p^1 and θ_p^2 will indicate the identity of the third plaintext letter, if any.

i. Now that the student has become familiar with the details of typical polygraphic substitution systems, he is ready to continue his cryptanalytic study with the treatment of methods for recognizing polygraphic substitution, these methods are described in the next paragraph.

67. Methods for recognizing polygraphic substitution.--a. The methods used to determine whether a given cryptogram is digraphic in character are usually rather simple. If there are many repetitions in a cryptogram or a set of cryptograms and yet the uniliteral frequency distribution gives no clear-cut indications of monoalphabeticity, if most of the repetitions contain an even number of letters and these repetitions for the most part begin on he odd letters and end on the even letters of the message, yet the cipher text does not yield to solution as a biliteral cipher when the procedures outlined in Sections VII and VIII are applied to it, if the cryptograms usually contain an even number of letters (exclusive of nulls), and if the cipher text is in letters and all 26 letters are not present and J or U are among the absent letters (or if the cipher is in digits and there is a limitation in the range of the text when divided into trinomes, this range usually being not greater than 001-676), then the encipherment may be assumed to be digraphic in nature.

b. Although the foregoing general remarks are true as far as they go, occasionally they may be difficult to apply with any clear-cut results unless a large volume of cipher text is available for study. To supplement them there are statistical tests which may be applied for the recognition of digraphic substitution. Just as the ϕ test and the Λ test may be applied to the uniliteral distribution of a cryptogram to help determine whether it is monoalphabetic with respect to single-letter plaintext units, so may these same tests be applied to the digraphic distribution of a cryptogram for the purpose of determining whether the cryptogram in question is monoalphabetic when considered as a digraphic cipher.

c The basic form of the ϕ test is the same when applied to digraphic distributions as when applied to monographic--that is, uniliteral--distributions (see par. 27). It is only the plain and random constants that change, and "N" in the formulas now pertains to the number of digraphs under consideration, instead of the number of single letters.

To illustrate this, the formulas for computing the "digraphic phi plain (ϕ^2_p)" and the "digraphic phi random (ϕ^2_r)" are shown below:[15]

$$\phi^2_p = .0069\ N(N-1)$$

$$\phi^2_r = .0015\ N(N-1)$$

The "digraphic phi observed (ϕ^2_o)" is calculated in the usual manner, that is, by multiplying each f (which in this case is found in one of the cells of a digraphic distribution) by f-1, and then totalling all the values thus derived.

d. The Λ^2 test (or the "digraphic blank-expectation test") may be applied to a digraphic distribution just as easily as its monographic counterpart is applied to a uniliteral frequency distribution. For this purpose, Chart 8 is given below, showing the average number of blanks theoretically expected in digraphic distributions for plain text and for random text containing various numbers of digraphs (up to 200 digraphs). As can be seen, the chart contains two curves. The one labeled P applies to the average number of blanks theoretically expected in digraphic distributions based upon normal plaintext messages containing the indicated number of digraphs. The other curve, labeled R, applies to the average number of blanks theoretically expected in digraphic distri-

[15] The digraphic plain constant, .0069, was obtained by summing the squares of the probabilities of digraphs in English plain text; the digraphic random constant, .0015, is merely the decimal equivalent of 1/676. Further elaboration on the use of these constants, among others, will be given in Military Cryptanalysis, Part II.

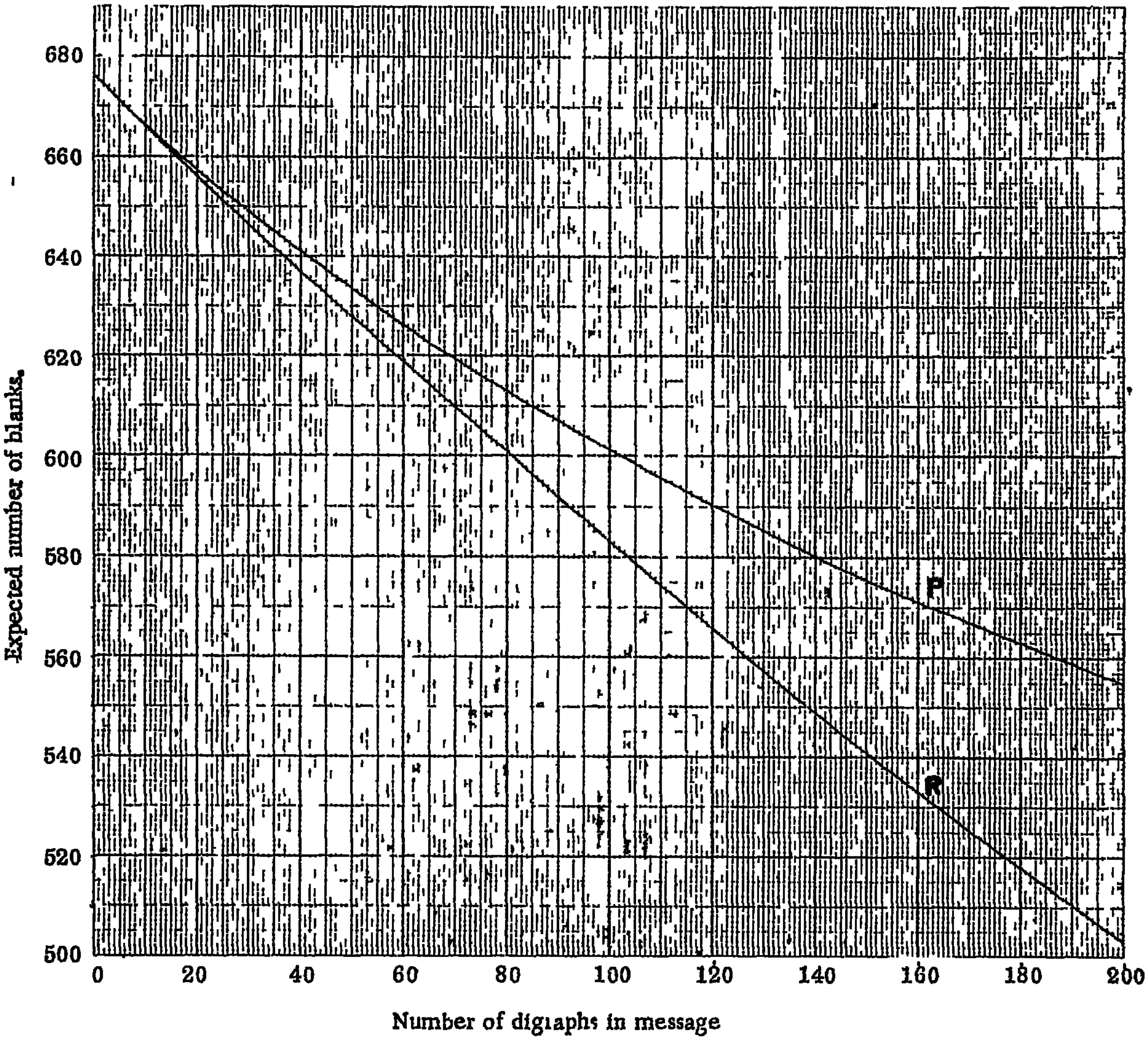


Chart 8.

butions based upon perfectly random assortments of digraphs. In using this chart one finds the point of intersection of the vertical coordinate corresponding to the number of digiaphs in the message, with the horizontal coordinate corresponding to the observed number of blanks in the digraphic distribution for the message. If this point of intersection falls closer to curve P than it does to curve R, this is evidence that the cryptogram is digraphic in nature[16]; if it falls closer to curve R than to curve P, this is evidence that the cryptogram is not digraphic in character.

e. Although it may not be necessary to resort to the use of the ϕ^2 and Λ^2 test to determine whether or not a particular cryptogram has been digraphically enciphered, it is well to know the application of these tests, since use has been made of them in difficult cases in operational practice. They may be helpfully employed in cases where the cryptanalyst is uncertain as to whether or not a single null has been added at the beginning of a cryptogram suspected to be a digraphic cipher; and these tests may also be found useful in the analysis of complex cases where the digraphic encipherment has been applied, not to adjacent letters of the plaintext message, but to digraphs composed of more-or-less separated letters in the message. Elaborations of these ideas will be treated in Military Cryptanalysis, Part II.

f. As for the recognition of trigraphic substitution ciphers--if most of the repetitions are a multiple of three letters in length, if these repetitions for the most part begin (when the cipher text is divided into trigraphs) with the first letters and end with the third letters of the trigraphs, and if the length of the cryptograms is for the most part a multiple of three letters, yet the cipher text does not yield to solution as a triliteral cipher, then the encipherment may be assumed to be trigraphic in nature.

g. Just as the ϕ test may be used as an aid in the recognition of digraphicity, it may theoretically be used for recognizing the trigraphic, tetragraphic, etc., nature of cryptograms, but its use for these latter purposes is much more limited because of the large amount of text which would be required to permit a valid application of the pertinent polygraphic ϕ test.

68. General procedure in the identification and analysis of polygraphic substitution ciphers.--a. Certain systems which at first glance seem to be polygraphic, in that groupings of plaintext letters are treated as units, are on closer inspection seen to be only partly polygraphic in character. Such is true of systems involving large tables of the type illustrated in Figs. 47a and b, and 48 (in par. 65, above),

[16] Unfortunately, such would also be the case if the cryptogram under consideration were a polyalphabetic cipher involving two alphabets. However, to distinguish between a digraphic cipher and a polyalphabetic cipher with two alphabets, a digraphic distribution could be made "off the cut", that is, made of those ciphertext digraphs which are formed by omitting the first letter of text and then dividing the remaining text into groups of two letters. If the system were digraphic, such a distribution would exhibit a poor ϕ_o^2; if the system were a two-alphabet substitution system, the ϕ_o^2 would be as satisfactory as that of the regular distribution, taken "on the cut".

wherein encipherment is by pairs but one of the letters in each pair is enciphered monoalphabetically, making these systems only pseudo-polygraphic. For example, using the table in Figure 48, any plaintext digraph beginning with "A" must be enciphered by a ciphertext digraph beginning with "W"; any plaintext digraph beginning with "B" must be enciphered by a ciphertext digraph beginning with "E"; etc. A cryptogram involving the use of this table may then be identified as such merely from a study of the uniliteral frequency distribution made on the initial letters of the cipher digraphs, since such a distribution would perforce be monoalphabetic.[17]

b. In certain other systems--namely, the four-square, two-square, and Playfair square systems of par. 66, above--the method of encipherment is by pairs, but the encipherments of the left-hand and right-hand members of the pairs show group relationships; this is not pseudo-polygraphic but, rather, partially-polygraphic. Cryptograms enciphered by means of systems of this latter type may not be readily identified as such merely through an examination of their cipher text, but their solution may be effected rather rapidly as soon as a few correct plaintext assumptions have been made therein. A more detailed treatment of this matter will be given in succeeding paragraphs of this section.

c. The analysis of cryptograms which have been produced by digraphic substitution is accomplished largely by the application of the simple principles of frequency of digraphs,[18] with the additional aid of digraphic idiomorphs and such special circumstances as may be known to or suspected by the cryptanalyst. The latter refer to peculiarities which may be the result of the particular method employed in obtaining the equivalents of the plaintext digraphs in the encrypting process, such as those mentioned in subpars. a and b, above. In general, if there is sufficient text to disclose the normal phenomena of repetition and idiomorphism, or if cribs are available to be used as an entering wedge, solution will be feasible. The foregoing general statements will be expanded upon in the following two subparagraphs, d and e.

d. When a digraphic system is employed in regular service, there is little doubt that traffic will rapidly accumulate to an amount more than sufficient to permit of solution by simple principles of frequency. Sometimes only two or three long messages, or a half-dozen of average length, are sufficient. For with the identification of only a few cipher

[17] For this purpose, the simplest and most economical way to obtain the uniliteral distributions for the initial and final letters of digraphs is to make a digraphic distribution and then add the tallies in each row to yield the distribution for the initial letters, and add the tallies in each column to obtain the distribution for the final letters.

[18] In this connection, it would be well for the student to familiarize himself with that portion of Appendix 2 which contains digraphic frequency data.

digraphs, larger portions of messages may be read because the skeletons of words formed from the few high-frequency digraphs very definitely limit the values that can be inserted for the intervening unidentified digraphs. For example, suppose that the plaintext digraphs RE, IN, ON, ND, NO, SI, NT, and TO are among those that have been identified by frequency considerations, corroborated by a tentatively identified long repetition; and suppose also that the enemy is known to be using a large table of 676 cells containing digraphs showing reciprocal equivalence between plaintext and ciphertext digraphs. Suppose the message begins as follows (in which the assumed values have been inserted).

```
XQ  VO  ZI  LK  AP  OL  ZX  PV  CK  IK  OL  UK  AT  HN  LK
        ND  IN      NT      RE          NT  NO          IN

VL  BN  OZ  BZ  DY  TY  LE  GI
    SI      ON  TO
```

The initial words SECOND INFANTRY REGIMENT are readily recognized. Furthermore, if $\overline{CK}_c=\overline{GI}_p$, then $\overline{GI}_c=\overline{CK}_p$, which suggests ATTACK as the last word in the message beginning. This fragment of the message may now be completely recovered. SECOND INFANTRY REGIMENT NOT YET IN POSITION TO ATTACK.....

e. Just as the choice of probable words in the solution of uniliteral systems is aided or limited by the positions of repeated letters (see subpar. 49d), so, in digraphic ciphers, is the placing of cribs aided or limited by the positions of repeated digraphs. In this connection, several frequent words and phrases containing repeated digraphs have been tabulated for the student's aid, and this list of digraphic idiomorphs is presented as Section D in Appendix 3 (q.v.). Thus, if one is confronted by a ciphertext message containing the following repeated sequence (therefore likely to represent an entire word).

VI FW HM AZ FF FW RO

he may refer to the appropriate section of Appendix 3 which will disclose, on the basis of the idiomorphic pattern "AB -- -- -- AB" starting with the second cipher digraph, that the underlying plaintext word may be RE EN FO RC EM EN T, among others. Once a good start has been made and a few words have been solved, subsequent work is quite simple and straightforward. A knowledge of enemy correspondence, including data regarding its most common words and phrases, is of as much assistance in breaking down digraphic systems as it is in the solution of any other cryptosystems.

f. In the case of trigraphic substitution, analysis is made considerably more complex by the large amount of traffic required, not only for the initial entries, but also for further exploitation of the entering wedges. In effect, the solution of a trigraphic system closely parallels the solution of the syllabary portion of a large two-part code, these techniques will be discussed in Military Cryptanalysis, Part V.

69. Analysis of four-square matrix systems.--a. In all the small-matrix methods illustrated in paragraph 66, the encipherment is only partially digraphic because there are certain relationships between those plaintext digraphs which have common elements and their corresponding ciphertext digraphs, which will also have common elements. For example, in the four-square matrix given in Fig. 53, it will be noted that $\overline{AA}_p=\overline{FT}_c$, $\overline{AF}_p=\overline{FO}_c$, $\overline{AL}_p=\overline{FM}_c$, $\overline{AQ}_p=\overline{FL}_c$, and $\overline{AV}_p=\overline{FK}_c$. In each of these cases when A_p is the initial letter of the plaintext pair, the initial letter of the ciphertext equivalent is F_c. This, of course, is the direct result of the method, it means that the encipherment is monoalphabetic for the first half of each of these five plaintext pairs. This relationship holds true for four other groups of five pairs beginning with A_p, in effect, there are five cipher alphabets employed, not 25. Thus, this case differs from the case discussed under subpar. 68a only in that the monoalphabeticity is complete, not for half of all the pairs but only among the members of certain groups of pairs. In a true digraphic system, such as a system making use of a 676-cell randomized table, relationships of the foregoing type are entirely absent, and for this reason such a system is cryptographically more secure than small-matrix systems.

b. From the foregoing it is clear that when solution has progressed sufficiently to disclose a few values, the insertion of letters within the cells of the matrix to give the plaintext-ciphertext relationships indicated by the solved values immediately leads to the disclosure of additional values. Thus, the solution of only a few values soon leads to the breakdown of the entire matrix.

c. The following example will serve to illustrate the procedure. (1) Let the message be as follows.

```
     1 2 3 4 5   6 7 8 9 10  11 12 13 14 15  16 17 18 19 20  21 22 23 24 25  26 27 28 29 30
A.   H F C A P   G O Q I L   B  S  P  K  M   N  D  U  K  E   O  H  Q  N  F   B  O  R  U  N
B.   Q C L C H   Q B Q B F   H  M  A  F  X   S  I  O  K  O   Q  Y  F  N  S   X  M  C  G  Y
C    X I F B E   X A F D X   L  P  M  X  H   H  R  G  K  G   Q  K  Q  M  L   F  E  Q  Q  I
D.   G O I H M   U E O R D   C  L  T  U  F   E  Q  Q  C  G   Q  N  H  F  X   I  F  B  E  X
E.   F L B U Q   F C H Q O   Q  M  A  F  T   X  S  Y  C  B   E  P  F  N  B   S  P  K  N  U
F.   Q I T X E   U Q M L F   E  Q  Q  I  G   O  I  E  U  E   H  P  I  A  N   Y  T  F  L  B
G.   F E E P I   D H P C G   N  Q  I  H  B   F  H  M  H  F   X  C  K  U  P   D  G  Q  P  N
H.   C B C Q L   Q P N F N   F  N  I  T  O   R  T  E  N  C   O  B  C  N  T   F  H  H  A  Y
J.   Z L Q C I   A A I Q U   C  H  T  P  C   B  I  F  G  W   K  F  C  Q  S   L  Q  M  C  B
K.   O Y C R Q   Q D P R X   F  N  Q  M  L   F  I  D  G  C   C  G  I  O  G   O  I  H  H  F
L.   I R C G G   G N D L N   O  Z  T  F  G   E  E  R  R  P   I  F  H  O  T   F  H  H  A  Y
M.   Z L Q C I   A A I Q U   C  H  T  P
```

(2) The cipher having been tested for standard alphabets (by the method of completing the plain-component sequence) and found to give negative results, a uniliteral frequency distribution is made. It is as follows:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
11	15	26	8	16	30	17	22	24	0	8	14	11	18	15	16	33	9	6	11	11	0	1	12	7	3

(3) At first glance this may appear to the untrained eye to be a monoalphabetic frequency distribution, but upon closer inspection it is noted that, aside from the frequencies of four or five letters, the frequencies for the remaining letters are not very dissimilar. There are, in reality, no very marked crests and troughs--certainly not as many as would be expected in a monoalphabetic substitution cipher of equal length. The ϕ test, if taken (this test, as a rule, is not necessary with samples of text of sizes such as this), would show unsatisfactory results (ϕ_o=6084, as against ϕ_p=7870 and ϕ_r=4543).

(4) The message is carefully examined for repetitions of 4 or more letters, and all of them are listed.

	Frequency	Located in lines
TFHHAYZLQCIAAIQUCHTP (20 letters)........	2	H and L.
QMLFEQQIGOI (11 letters).................	2	C and F.
XIFBEX (6 letters).......................	2	C and D.
FEQQ.....................................	3	C, D, F.
QMLF.....................................	3	C, F, K.
BFHM.....................................	2	B and G.
BSPK.....................................	2	A and E.
GOIH.....................................	2	D and K.

Since there are quite a few repetitions, two of considerable length, since all but one of them contain an even number of letters, since these repetitions with but two exceptions begin on odd letters and end on even letters, and since the message also contains an even number of letters (344), the cryptogram is retranscribed into 2-letter groups for further study. It is as follows:

Message transcribed in pairs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	HF	CA	PG	OQ	IL	BS	PK	MN	DU	KE	OH	QN	FB	OR	UN
B	QC	LC	HQ	BQ	BF	HM	AF	XS	IO	KO	QY	FN	SX	MC	GY
C	XI	FB	EX	AF	DX	LP	MX	HH	RG	KG	QK	QM	LF	EQ	QI
D	GO	IH	MU	EO	RD	CL	TU	FE	QQ	CG	QN	HF	XI	FB	EX
E	FL	BU	QF	CH	QO	QM	AF	TX	SY	CB	EP	FN	BS	PK	NU
F	QI	TX	EU	QM	LF	EQ	QI	GO	IE	UE	HP	IA	NY	TF	LB
G	FE	EP	ID	HP	CG	NQ	IH	BF	HM	HF	XC	KU	PD	GQ	PN
H	CB	CQ	LQ	PN	FN	PN	IT	OR	TE	NC	CB	CN	TF	HH	AY
J	ZL	QC	IA	AI	QU	CH	TP	CB	IF	GW	KF	CQ	SL	QM	CE
K	OY	CR	QQ	DP	RX	FN	QM	LF	ID	GC	CG	IO	GO	IH	HF
L	IR	CG	GG	ND	LN	OZ	TF	GE	ER	RP	IF	HO	TF	HH	AY
M	ZL	QC	IA	AI	QU	CH	TP								

It is noted that all the repetitions listed above break up properly into digraphs except in one case, viz., FEQQ in lines C, D, and F. This latter seems rather strange, and at first thought one might suppose that a letter was dropped out or was added in the vicinity of the FEQQ in line D. But it may be assumed that the FE QQ in line D has no relation at all to the .F EQ Q. in lines C and F and is merely an accidental repetition.

(5) A digraphic distribution is made as follows·

~~RESTRICTED~~

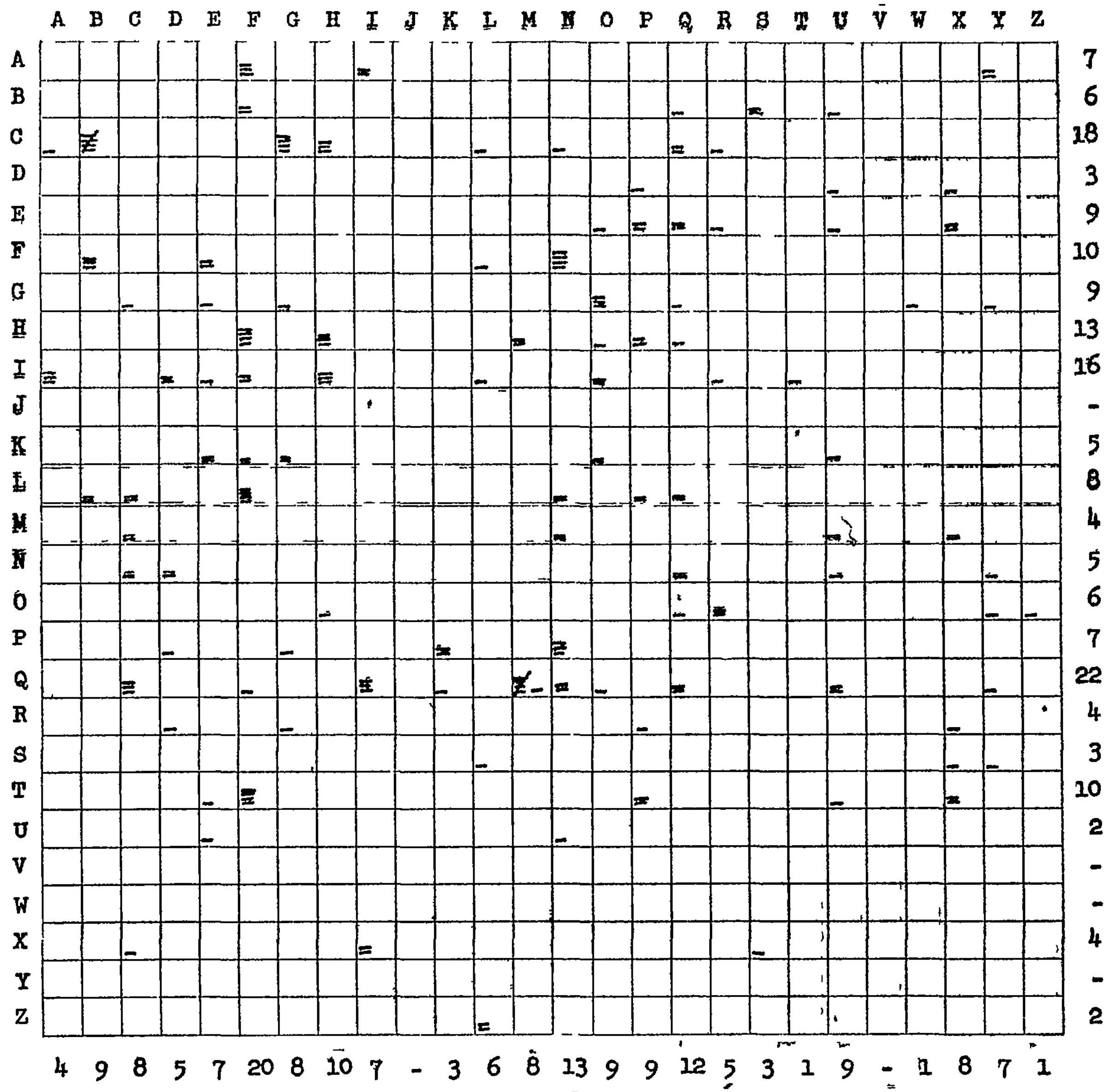

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
A 7
B 6
C 18
D 3
E 9
F 10
G 9
H 13
I 16
J -
K 5
L 8
M 4
N 5
O 6
P 7
Q 22
R 4
S 3
T 10
U 2
V -
W -
X 4
Y -
Z 2
4 9 8 5 7 20 8 10 7 - 3 6 8 13 9 9 12 5 3 1 9 - 1 8 7 1

Figure 60.

(6) The appearance of the foregoing distribution for this message is quite characteristic of that for a digraphic substitution cipher. Although there are 676 possible digraphs, only 107 are present in the distribution, this parallels what is expected of normal plain text, since out of the 676 possible two-letter combinations (including "impossible plaintext digraphs" such as QQ, JK, etc., which might have been used for special indicators, punctuation marks, etc.) only about 300 are usually used in the construction of plain text.[19] The number of blank cells,

[19] The 300 most frequent digraphs comprise 95% of normal English plain text (Appendix 2, Table 7-A).

~~RESTRICTED~~

569, closely approximates the 565 which would be expected in a distribution made on a sample of plain text of this size, as shown by Chart 8. Furthermore, although there are many cases in which a digraph appears only once, there are quite a few in which a digraph appears two or three times, four cases in which a digraph appears four times, one case in which a digraph appears five times, and one in which a digraph appears six times. All of the foregoing observations concerning the distribution are reflected by the ϕ test: the observed digraphic phi value, 210, compares very favorably with the expected plain value (=.0069 x 172 x 171 = 203) as against the expected random value (=.0015 x 172 x 171 = 44). Thus all indications point to a *digraphic* substitution system.

(7) Since neither the ϕ_o (1780) and Λ_o (4) for the initial letters of the cipher digraphs nor the ϕ_o (1496) and Λ_o (2) for the final letters are too satisfactory in their approximation to the values expected for monoalphabetic distiibutions (ϕ_p=1962 and ϕ_r=1133; Λ_p=5 and Λ_r=0), the possibility of a *pseudo*-digraphic system is ruled out. There remain the possibilities of a *partially*-digraphic system employing a small matrix, or a *true* digraphic system employing a large, randomized table. In one common type of small-matrix system, the Playfair cipher, one of the telltale indications besides the absence of (usually) the letter J is the absence of cipher doublets, that is, two successive identical cipher letters. The occurrence of the double letters GG, HH, and QQ in the message under investigation eliminates the possibility of its being a normal Playfair cipher. For want of more accurate diagnostic criteria [20] *at this stage*,[21] the simplest thing to assume, from among the various hypotheses that remain to be considered, is that a four-square matrix is involved. One with normal alphabets (as being the simplest case) in Sections 1 and 2 is therefore set down (Figure 61*a*).

[20] Even a medical practitioner often cannot successfully diagnose a condition on the first visit. Cryptanalytically speaking, we are still on our "first visit". Subsequent probing will, we hope, reject or substantiate this or that hypothesis or assumption, until the patient (the cipher text) is recovered (i.e., brought back to plain text).

[21] However, see the treatment on the diagnosis of various types of digraphic systems in subpar 73*j*.

	A	B	C	D	E						
	F	G	H	I–J	K						
1	L	M	N	O	P						3
	Q	R	S	T	U						
	V	W	X	Y	Z						
						A	B	C	D	E	
						F	G	H	I–J	K	
4						L	M	N	O	P	2
						Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61a.

(8) The recurrence of the group QMLF, three times, and at intervals suggesting that it might be a sentence separator, leads to the assumption that it represents the word STOP. The letters Q, M, L, and F are therefore inserted in the appropriate cells in Sections 3 and 4 of the diagram. Thus (Fig. 61b)·

	A	B	C	D	E						
	F	G	H	I–J	K						
1	L	M	N	O	P					L	3
	Q	R	S	T	U				Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
						F	G	H	I–J	K	
4				F		L	M	N	O	P	2
			M			Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61b.

These placements seem rather good from the standpoint that keyword-mixed sequences may have been used in these two sections. Moreover, in Section 3 the number of cells between L and Q is just one less than enough to contain all the letters M to P, inclusive, this suggests that one of these letters, probably N or O, is in the keyword portion of the sequence, that is, near the top of Section 3. Without making a commitment in the matter, let us suppose that M follows L and that P precedes Q; then let both N and O, for the present, be inserted in the cell between M and P. Thus (Fig. 61c)·

	A	B	C	D	E						
	F	G	H	I–J	K						
1	L	M	N	O	P					L	3
	Q	R	S	T	U	M	N O	P	Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
						F	G	H	I–J	K	
				F		L	M	N	O	P	
4			M			Q	R	S	T	U	2
						V	W	X	Y	Z	

Figure 61c.

(9) Now, if the placement of P in Section 3 is correct, the cipher equivalent of $\overline{TH}_p$ will be $\overline{P\theta}_c$, and there should be a group of adequate frequency to correspond. Noting that $\overline{PN}_c$ occurs three times, it is assumed to represent $\overline{TH}_p$ and the letter N is inserted in the appropriate cell in Section 4. Thus (Fig. 61d)·

	A	B	C	D	E						
	F	G	H	I–J	K						
1	L	M	N	O	P					L	3
	Q	R	S	T	U	M	N O	P	Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
				N		F	G	H	I–J	K	
4				F		L	M	N	O	P	2
			M			Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61d.

(10) It is about time to try out these assumed values in the message. The proper insertions are made, with the following results.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	HF	CA	PG	OQ	IL	BS	PK	MN	DU	KE	OH	QN	FB	OR	UN
B	QC	LC	HQ	BQ	BF	HM	AF	XS	IO	KO	QY	FN	SX	MC	GY
C	XI	FB	EX	AF	DX	LP	MX	HH	RG	KG	QK	QM ST	LF OP	EQ	QI →
D	← GO	IH	MU	EO	RD	CL	TU	FE	QQ	CG	QN	HF	XI	FB	EX
E	FL	BU	QF	CH	QO	QM ST	AF	TX	SY	CB	EP	FN	BS	PK	NU
F	QI	TX	EU	QM ST	LF OP	EQ	QI	GO	IE	UE	HP	IA	NY	TF	LB
G	FE	EP	ID	HP	CG	NQ	IH	BF	HM	HF	XC	KU	PD	GQ	PN TH
H	CB	CQ	LQ	PN TH	FN	PN TH	IT	OR	TE	NC	CB	CN	TF	HH	AY →
J	← ZL	QC	IA	AI	QU	CH	TP	CB	IF	GW	KF	CQ	SL	QM ST	CB
K	OY	CR	QQ	DP	RX	FN	QM ST	LF OP	ID	GC	CG	IO	GO	IH	HF
L	IR	CG	GG	ND	LN	OZ	TF	GE	ER	RP	IF	HO	TF	HH	AY →
M	← ZL	QC	IA	AI	QU	CH	TP								

(11) So far no impossible combinations are in evidence. Beginning with group H4 in the message is seen the following sequence.

P N F N P N
T H . . T H

Assume it to be THAT THE. Then $\overline{AT}_p=\overline{FN}_c$, and the letter N is to be inserted in row 4 column 1 of Section 4. But this is inconsistent with previous assumptions, since N in Section 4 has already been tentatively placed in row 2 column 4. Other assumptions for $\overline{FN}_c$ are made: that it is, $\overline{IS}_p$ (THIS TH...), that it is $\overline{EN}_p$ (THEN TH...), but the same inconsistency is apparent. In fact the student will see that $\overline{FN}_c$ must represent a digraph ending in F, G, H, I-J, or K, since N_c is tentatively located on the same line as these letters in Section 2. Now $\overline{FN}_c$ occurs 4 times in the message. The digraph it represents must be one of the following:

DF, DG, DH, DI, DJ, DK   OF, OG, OH, OI, OJ,
IF, IG, IH, II, IJ, IK   TK,
JF, JG, JH, JI, JJ, JK   YF, YG, YH, YI, YJ, YK

Of these the only one likely to be repeated 4 times is OF, yielding

```
P N F N P N
T H O F T H which may be a part of
```

```
C Q L Q P N F N P N I T        C Q L Q P N F N P N I T
  N O R T H O F T H E .   or   . S O U T H O F T H E
```

In either case, the position of the F in Section 3 is excellent F . L in row 3 There are 3 cells intervening between F and L, into which G, H, I-J, and K may be inserted. It is not nearly so likely that G, H, and K are in the keyword as that I should be in it Let it be assumed that this is the case, and let the letters G, H, and K be placed in the appropriate cells in Section 3 Thus (Fig 61e)

	A	B	C	D	E						
	F	G	H	I–J	K						
1	L	M	N	O	P	F	G	H	K	L	3
	Q	R	S	T	U	M	N O	P	Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
				N		F	G	H	I–J	K	
4				F		L	M	N	O	P	2
			M	Q		Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61e.

Let the resultant derived values be checked against the frequency distribution. If the position of H in Section 3 is correct, then the digraph $\overline{ON}_p$, normally of high frequency, should be represented several times by $\overline{HF}_c$. Reference to Fig. 60 shows $\overline{HF}_c$ to have a frequency of 4. And $\overline{HM}_c$, with 2 occurrences, represents $\overline{NS}_p$. There is no need to go through all the possible corroborations.

```
                                       P N F N P N
```
(12) Going back to the assumption that T H . . T H is part of the expression

```
C Q L Q P N F N P N I T        C Q L Q P N F N P N I T
. N O R T H O F T H E .   or   . S O U T H O F T H E .,
```

it is seen at once from Fig 61e that the latter is apparently correct and not the former, because $\overline{LQ}_c$ equals $\overline{OU}_p$ and not $\overline{OR}_p$. If $\overline{OS}_p$=$\overline{CQ}_c$, this means that the letter C of the digraph $\overline{CQ}_c$ must be placed in row 1 column 3 or row 2 column 3 of Section 3. Now the digraph $\overline{CB}_c$ occurs 5 times, $\overline{CG}_c$, 4 times, $\overline{CH}_c$, 3 times, $\overline{CQ}_c$, 2 times. Let an attempt be made to deduce the exact position of C in Section 3 and the positions of B, G, and H in Section 4. Since F is already placed in Section 4, assume G and H directly follow it, and that B comes before it. How much before? Suppose a trial be made. Thus (Fig. 61f)

	A	B	C	D	E			C?			
	F	G	H	I-J	K			C?			
1	L	M	N	O	P	F	G	H	K	L	3
	Q	R	S	T	U	M	N O	P	Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
				N		F	G	H	I-J	K	
4	B?	B?	B?	F	G	L	M	N	O	P	2
	H		M	Q		Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61f

By referring now to the frequency distribution, Fig. 60, after a very few minutes of experimentation it becomes apparent that the following is correct:

	A	B	C	D	E			C			
	F	G	H	I-J	K						
1	L	M	N	O	P	F	G	H	K	L	3
	Q	R	S	T	U	M	N O	P	Q		
	V	W	X	Y	Z						
						A	B	C	D	E	
				N		F	G	H	I-J	K	
4	B			F	G	L	M	N	O	P	2
	H		M	Q		Q	R	S	T	U	
						V	W	X	Y	Z	

Figure 61g.

(13) The identifications given by these placements are inserted in the text, and solution is very rapidly completed The final matrix and deciphered text are given below.

	A	B	C	D	E	S	O	C	I	E	
	F	G	H	I-J	K	T	Y	A	B	D	
1	L	M	N	O	P	F	G	H	K	L	3
	Q	R	S	T	U	M	N	P	Q	R	
	V	W	X	Y	Z	U	V	W	X	Z	
	E	X	P	U	L	A	B	C	D	E	
	S	I	O	N	A	F	G	H	I-J	K	
4	B	C	D	F	G	L	M	N	O	P	2
	H	K	M	Q	R	Q	R	S	T	U	
	T	V	W	Y	Z	V	W	X	Y	Z	

Figure 61h.

```
A  H F C A P   G O Q I L   B S P K M   N D U K E   O H Q N F   B O R U N
   O N E H U   N D R E D   F I R S T   F I E L D   A R T I L   L E R Y F

B  Q C L C H   Q B Q B F   H M A F X   S I O K O   Q Y F N S   X M C G Y
   R O M P O   S I T I O   N S I N V   1 C I N I   T Y O F B   A R L O W

C  X I F B E   X A F D X   L P M X H   H R G K G   Q K Q M L   F E Q Q I
   W I L L B   E I N G E   N E R A L   S U P P O   R T S T O   P D U R I

D  G O I H M   U E O R D   C L T U F   E Q Q C G   Q N H F X   I F B E X
   N G A T T   A C K S P   E C I A L   A T T E N   T I O N W   I L L B E

E  F L B U Q   F C H Q O   Q M A F T   X S Y C B   E P F N B   S P K N U
   P A I D T   O A S S I   S T I N G   A D V A N   C E O F F   I R S T B

F  Q I T X E   U Q M L F   E Q Q I G   O I E U E   H P I A N   Y T F L B
   R I G A D   E S T O P   D U R I N   G A D V A   N C E I T   W I L L P

G  F E E P I   D H P C G   N Q I H B   F H M H F   X C K U P   D G Q P N
   L A C E C   O N C E N   T R A T I   O N S O N   W O O D S   N O R T H

H  C B C Q L   Q P N F N   P N I T O   R T E N C   C B C N T   F H H A Y
   A N D S O   U T H O F   T H A Y E   R F A R M   A N D H I   L L S I X

J  Z L Q C I   A A I Q U   C H T P C   B I F G W   K F C Q S   L Q M C B
   Z E R O E   I G H T D   A S H A A   N D O N W   O O D S E   A S T A N

K  O Y C R Q   Q D P R X   F N Q M L   F I D G C   C G I O G   O I H H F
   D W E S T   T H E R E   O F S T O   P C O M M   E N C I N   G A T O N

L  I R C G G   G N D L N   O Z T F G   E E R R P   I F H O T   F H H A Y
   E T E N P   M S M O K   E W I L L   B E U S E   D O N H I   L L S I X

M  Z L Q C I   A A I Q U   C H T P
   Z E R O E   I G H T D   A S H A
```

d. In the solution of four-square cryptograms, advantage may be taken not only of the general type of digraphic idiomorphs mentioned in subpar. 68e, above, but also of a special type of partial idiomorphism present in any four-square cryptograms involving the use of a matrix in which the plain components consist of normal alphabets normally inscribed.[22] As an illustration, let the digraphs $\overline{SO}$ $\overline{UT}$ (H.) be enciphered by means of any four-square having normal alphabets in Sections 1 and 2, and it will be found that in the encipherment the initial letter of the cipher digraph representing $\overline{SO}_p$ will be identical to the initial letter of the cipher digraph representing $\overline{UT}_p$, regardless of how the cipher components are constructed. On this basis, a brief list of specialized single-letter patterns have been compiled for use in the solution of such a digraphic system, this list of "four-square digraphic idiomorphs" constitutes Section F of Appendix 3.

e. It is interesting to note how much simpler the technique of analysis is in the case of so-called inverse four-square ciphers, which involve the use of a matrix wherein the ciphertext sections contain normal alphabets, the plain components being mixed. For example, referring to Fig. 53, suppose that Sections 3 and 4 are used as the source of the plaintext pairs, and Sections 1 and 2 as the source of the ciphertext pairs, then $ON_p=ET_c$, $EH_p=GE_c$, etc. The simplicity of the analytic procedure will be made clear by the following exposition.

(1) To solve a message enciphered with an inverse four-square matrix, it is necessary to perform two steps. First, convert the ciphertext pairs into their plain-component equivalents by "deciphering" the message with a matrix in which all four sections contain normal alphabets, this operation yields two uniliteral substitution "ciphers", one composed of the odd letters, the other of the even letters. The second step is to solve these two monoalphabetic portions

(2) As an example, let us consider the following cipher text, known (or assumed) to have been encrypted with a trinome-digraphic[23] system

[22] If any other known plain components were involved, the procedure of deriving a list of idiomorphic patterns would be modified to fit the particular case.

[23] If the cipher text were being examined "from cryptanalytic scratch", the limitations (003-595) of the cipher text when the latter is divided into trinomes for examination would have at once indicated that this grouping is the one which merits detailed analysis. The ϕ^2 test would then give an indication of the digraphic nature of the underlying cryptographic treatment.

incorporating a four-square matrix similar to that illustrated in Fig. 58, except that the plain-component sections have been changed

```
20323  85081  83450  27934  11503  09168
27835  41804  50413  27416  33091  01092
20805  74135  35473  32626  91160  03218
46818  33930  91393  41104  41331  17296
24302  83832  28359  38022  61043  69130
15313  61041  00144  10101  82403  36168
46536  62663  44007  18345  01402  88152
47821  73933  81193  47924  04032  41306
08703  70914  19391  11607  71371  53595
00741  33381  33593  39340  63531  88133
```

(3) The first thing to be done is to construct a four-square matrix with the known ciphertext sections, and inscribe arbitrary alphabets in the pl ext sections, as follows·

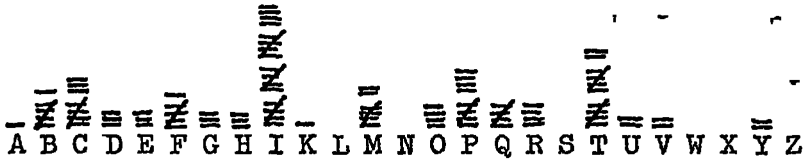
A	B	C	D	E	000	025	050	075	100
F	G	H	I	K	125	150	175	200	225
L	M	N	O	P	250	275	300	325	350
Q	R	S	T	U	375	400	425	450	475
V	W	X	Y	Z	500	525	550	575	600
Ø	1	2	3	4	A	B	C	D	E
5	6	7	8	9	F	G	H	I	K
10	11	12	13	14	L	M	N	O	P
15	16	17	18	19	Q	R	S	T	U
20	21	22	23	24	V	W	X	Y	Z

(4) The cipher text is then written in trinomes, and these trinomes are "deciphered" by means of the foregoing matrix, yielding the converted cipher text as follows:

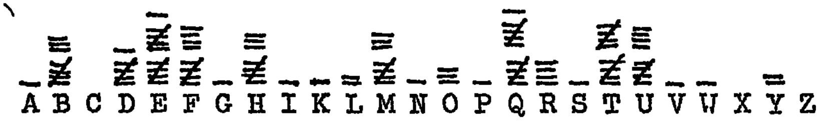
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	203 ID	238 IP	508 YF	183 IH	450 QD	279 PB	341 MT	150 FB	309 PH	168 IR	278 OB	354 PT	180 FH	450 QD	413 TM
B	274 PV	163 IM	309 PH	101 BE	092 CT	208 II	057 CH	413 TM	535 VM	473 TY	326 MD	269 PQ	116 BU	003 DA	218 IT
C	468 TT	183 IH	393 TQ	091 BT	393 TQ	411 RM	044 ER	133 IF	117 CU	296 MW	243 IU	028 DB	383 TF	228 IE	359 PK
D	380 QF	226 GE	104 EE	369 PU	130 FF	153 IB	136 GL	104 EE	100 AE	144 KQ	101 BE	018 DQ	240 FU	336 MO	168 IR
E	465 QT	366 MU	266 MQ	344 PT	007 CF	183 IH	450 QD	140 FQ	288 OM	152 HB	478 TE	217 HT	393 TQ	381 RF	193 IS
F	479 UE	240 FU	403 TB	241 GU	306 MH	087 CO	037 CM	091 BT	419 UR	391 RQ	116 BU	077 CD	137 HL	153 IB	595 VY
G	007 CF	413 TM	338 OO	133 IF	593 YT	393 TQ	406 RG	353 OE	188 IN	133 IF					

The distributions of the letters constituting the initial letters and final letters of the converted digraphs are as follows

(Initial Letters)



(Final Letters)



(5) Using straightforward principles of frequency and partial idiomorphs,[24] the plain text (beginning with the opening words ENEMY RECONNAISSANCE...) is recovered, and the following equivalents are obtained for the converted cipher letters of the two alphabets

(Initial Letters)

C	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
P	B	R	A	H	M	S	C	D	E	F		I		L	N	O	P		T	U	V			Y	

(Final Letters)

C	A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
P·	W	A		N	E	R	B	C	D	F	H	I	K	L	M	O	P	Q	S	T	U	V		Y	

[24] Note the ABA pattern of the first word in the message (ENEMY), made patent by the two-alphabet conversion process. Also note the 3-fold repetition (representing the plaintext word STOP) which, although hidden in the original cipher text, now comes to light.

Keyword-mixed sequences directly manifest themselves because the original enciphering matrix contained such sequences in Sections 1 and 2, inscribed in the same manner as were the arbitrary A-Z sequences which were used for the conversion. In fact, the key words of the two distributions might have been recovered from an analysis of the "profiles" of the distributions above, as described in subpar 54e

(6) The original enciphering matrix is then reconstructed, thus

B	R	A	H	M	000	025	050	075	100
S	C	D	E	F	125	150	175	200	225
G	I	K	L	N	250	275	300	325	350
O	P	Q	T	U	375	400	425	450	475
V	W	X	Y	Z	500	525	550	575	600
Ø	1	2	3	4	W	A	G	N	E
5	6	7	8	9	R	B	C	D	F
10	11	12	13	14	H	I	K	L	M
15	16	17	18	19	O	P	Q	S	T
20	21	22	23	24	U	V	X	Y	Z

(7) Although the example illustrated was that of a numerical digraphic system, it is obvious that this technique of solution also applies to literal four-square systems in which the cipher components are known sequences. It should be clear to the student the tremendous difference it makes when it is possible to convert a digraphic system into a two-alphabet system, in a digraphic system, we are plagued by a potential 676 different elements in the cipher, whereas in a two-alphabet system we still have only 26 elements (in each of two sets, it is true) in the cipher text to be solved This principle of conversion of cipher text into a secondary cipher text has application in some of the most complex types of cryptosystems, the student would do well to keep this in mind

(8) As a further observation on inverse four-square systems, it is pointed out that where the same mixed alphabet is present in Sections 3 and 4, the problem is still easier, since the letters resulting from the conversion into plain-component equivalents all belong to the same, single mixed alphabet, thus such a digraphic system is reduced to an ordinary simple substitution cipher.

f. The solution of cryptograms enciphered by other types of small matrices is accomplished along lines very similar to those set forth in subparagraph c on the solution of a four-square cipher, this will be illustrated in subsequent paragraphs There are, unfortunately, few means or tests which can be applied to determine in the early stages of the analysis exactly what type of digraphic system is involved in the first case under study The author freely admits that the solution outlined in subparagraph c is quite artificial in that nothing is demonstrated in step (7) that obviously leads to or warrants the assumption that a four-square matrix is involved. The point was passed over with the quite bald statement that this was "from among the various hypotheses that remain to be considered"--and then the solution proceeded exactly as though this were hypothesis had been definitely established For example, the very first results obtained were based upon assuming that a certain 4-letter repetition represented the word STOP and immediately inserting certain letters in appropriate cells in a four-square matrix with normal sequences in Sections 1 and 2. Several more assumptions were built on top of that, and very rapid strides were made What if it had not been a four-square matrix at all? What if it had been some other type of not readily identifiable digraphic system? The only defense that can be made of what may seem to the student to be purely arbitrary procedure based upon the author's advance information or knowledge is the following. In the first place, in order to avoid making the explanation a too-long-drawn-out affair, it is necessary (and pedagogical experience warrants) that certain alternative hypotheses be passed over in silence. In the second place, it may now be added, after the principles and procedure have been elucidated (which at this stage is the primary object of this text) that if good results do not follow from a first hypothesis, the only thing the cryptanalyst can do is to reject that hypothesis and formulate a second hypothesis In actual practice he may have to reject a second, third, fourth, ...nth hypothesis. In the end he may strike the right one--or he may not. There is no assurance of success in the matter In the third place, one of the objects of this text is to show how certain cryptosystems, if employed for military purposes, can readily be broken down Assuming that some type of digraphic system is in use, and that daily changes in key words are made, it is possible that the traffic of the first day might give considerable difficulty in solution if the specific type of digraphic system were not known to the cryptanalyst But by the time two or three days' traffic had accumulated it would be easy to solve, because probably by that time the cryptanalytic personnel would have successfully analyzed the cryptosystem and thus learned what type of matrix or table the enemy is using

70 Analysis of two-square matrix systems --a Cryptosystems involving either vertical two-square or horizontal two-square matrices may be identified as such and solved by capitalizing on the cryptographic peculiarities and idiosyncracies of these systems It will be noted that, considering the mechanics of the cryptosystems, in vertical two-square matrices employing the normal enciphering conventions,[25] exactly 20% of the 625 "possible" plaintext digraphs will be "transparent" (i.e , self-enciphered) in cipher text, in horizontal two-square systems, exactly 20% of the 625 digraphs will be characterized by an "inverse transparency"

[25] That is, for vertical two-square systems, digraphs are self-enciphered if θ_p^1 and θ_p^2 fall in the same column in the matrix, and, for horizontal two-square systems, if θ_p^1 and θ_p^2 are in the same row, the ciphertext digraphs are the reversed plaintext digraphs

(i.e., enciphered by the same digraphs reversed).[26] Therefore, if an examination of a cryptogram or a set of cryptograms discloses a goodly portion of what appear to be direct transparencies (cipher digraphs which could well be plaintext digraphs), it may then be assumed that a vertical two-square matrix has been used for the encryption. On the other hand, if a large number of cipher digraphs could be "good" plaintext digraphs if the positions of the letters were reversed, then it may be assumed that the cryptosystem involved a horizontal two-square matrix Sometimes skeletons of words or even of whole phrases are self-evident in such cipher text, thus affording an easy entering wedge into the cryptosystem

b An example will best serve to illustrate the techniques of identification and subsequent solution of a two-square matrix cipher. The following naval message is to be studied

```
U O D L C   E N O A N   S I G L B   B E I R I   R C R G L   N M O L C
P T E R G   R B B O E   G P A B Q   W N N K S   I P C R M   O O R A P
D E A [illegible] H   A N X R A   I E D A I   R M A G B   E K H S L   C D D L C
T Q O R E   N D T M D   T I A Q F   I E Q T A   N N B F N   O U O O S
S N N N R   K T A S E   S N H L P   O N N K S   I P C R C   E N O I S
H L I R K   P L O N O   N Z U C T   A L T O I   I H O C N   O C E R A
O S D I N   O E E K R   L C U B R   A O S D I   I P D A R   C O G G R
O L N O C   W D I L P   O I L N Q   X D I G L   R B B Q Y   F S S R A
V Y O I G   R S L X X
```

Preliminary steps in analysis are made according to the procedures already described in this text, and the hypothesis of monographic, uniliteral encipherment (with either standard or mixed cipher alphabets) has been rejected Multiliteral substitution, or digraphic substitution, comes next

[26] Although 625 "possible" plaintext digraphs are involved, the identity of digraphs actually used in plain text limit this figure considerably Furthermore, the frequencies of the plaintext digraphs actually used come into consideration, in conjunction with the location of the letters of these digraphs in any particular two-square matrix Thus, from the cryptanalyst's standpoint, there are "excellent" two-square matrices giving a high self-encipherment rate for high frequency plaintext digraphs, and there are "poor" two-square matrices which have a potentially high self-encipherment rate only for those low frequency plaintext digraphs which may not occur at all in a given cryptogram

into consideration The cipher text is written in digraphs, as follows

					5					10					15
A	UO	DL	CE	NO	AN	SI	GL	BB	EI	RI	RC	RG	LN	MO	LC
B	PT	ER	GR	BB	OE	GP	AB	QW	NN	KS	IP	CR	MO	OR	AP
C	DE	AM	HA	NX	RA	IE	DA	IR	MA	GB	EK	HS	LC	DD	LC
D	TQ	OR	EN	DT	MD	TI	AQ	FI	EQ	TA	NN	BF	NO	UO	OS
E	SN	NN	RK	TA	SE	SN	HL	PO	NN	KS	IP	CR	CE	NO	IS
F	HL	IR	KP	LO	NO	NZ	UC	TA	LT	OI	IH	OC	NO	CE	RA
G	OS	DI	NO	EE	KR	LC	UB	RA	OS	DI	IP	DA	RC	OG	GR
H	OL	NO	CW	DI	LP	OI	LN	QX	DI	GL	RB	BQ	YF	SS	RA
J	VY	OI	GR	SL	XX										

Figure 62

Noting the 8-letter repetition 90 letters apart, the 6-letter repetition 16 letters apart, and the 4-letter repetition at an interval of 220 letters, and that those repetitions begin on odd letters and end on even letters, credence is given to the grouping of the cipher text into pairs of letters. A digraphic distribution is then made, illustrated in Fig. 63

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
A		1											1	1		1	1										5
B		2				1											1										4
C					3													2					1				6
D	2			1	1				4			1								1							10
E					1				1		1			1			1	1									6
F									1																		1
G		1										2				1		3									7
H	1											2							1								4
I					1			1								3		2	1								8
J																											-
K																1		1	2								4
L			4											2	1	1				1							9
M	1			1											2												4
N														4	7									1		1	13
O			1		1		1		3			1						2	3								12
P															1					1							2
Q																							1	1			2
R	4	1	2				1		1		1																10
S					1				1			1		2					1								6
T	3								1								1										5
U		1	1												2												4
V																									1		1
W																											-
X																								1			1
Y						1																					1
Z																											-
	11	6	8	2	8	2	2	1	12	-	2	7	1	10	13	7	4	11	8	3	-	-	2	3	1	1	

Figure 63

<u>c</u> The ϕ_o^2, 152, is most satisfactory when compared with ϕ_p^2 (107) and ϕ_r^2 (23) Since the cryptogram has all the earmarks of a digraphic cipher, and no manifestations are found to support the hypothesis of a multiliteral system, the next problem is the specific determination of the particular kind of digraphic system involved It may be noted that there are quite a few digraphs in the cipher text which resemble good plaintext digraphs, proportionally more so than, for instance, in the cryptogram in subpar 69<u>c</u>, the cryptologic finger points to the possibility of a two-square system However, since the words "good digraphs" are semantically

elusive, let us attempt to determine statistically whether or not a two-square system might be involved and, if a two-square, whether it is more probably a vertical or a horizontal two-square [27]

d First, for the purpose of determining whether "direct transparencies" or "inverse transparencies" predominate in this cryptogram, the digraphs of the distribution in Fig 63 will be set down in tabular form, with an indication of their frequency in the cryptogram, and with data relative to the probability of these digraphs as plaintext digraphs, and as plaintext digraphs when reversed. In the table on page 194, col (1) is a listing of the ciphertext digraphs; col (2) is the frequency of the ciphertext digraph as it occurs in the cryptogram, col (3) is the logarithm of the theoretical plaintext frequency of the particular digraph (from Table 15, Appendix 2), col (4) represents the products of the entries in cols (2) and (3); col. (5) is the logarithm of the theoretical plaintext frequency of the reversed digraph (from Table 15, Appendix 2), and col. (6) represents the products of the entries in cols. (2) and (5). From this, the sum of the values in col. (4), 58.34, is taken to be the "direct transparency" value, and the sum of the values in col. (6), 63.02, is taken to be the "inverse transparency" value. Thus, since this particular cryptogram has an "inverse transparency" value which is higher

[27] The test to be described in the following subparagraphs is based on an evaluation of those instances wherein the observed frequency of any particular ciphertext digraph approximates the frequency with which the particular digraph, or its reversal, would be expected to occur if considered as a plaintext digraph Any such correlation which occurs in a four-square or Playfair cipher, or in a cryptogram produced by a large randomized digraphic table, is purely accidental because it is not a result of the mechanics of the system However, in two-square cryptograms such correlation is caused by the mechanics of the system in the encipherment of 20% of the possible plaintext digraphs, and these causal instances of correlation occur in addition to any accidental instances which may arise in the encipherment of the remaining 80% Thus, if a digraphic cipher exhibits merely the random expectation of correlation both when the particular ciphertext digraphs are considered as they are and when their reversals are considered, the cryptogram may be assumed to involve a system other than two-square If a digraphic cipher exhibits more than the random expectation of correlation, either when the particular digraphs are considered direct or when considered reversed, it may be assumed to involve two-square encipherment, and the particular consideration--that of the digraphs direct or that of the digraphs reversed--which gives rise to the greater degree of correlation indicates whether the cryptogram involves a vertical two-square or a horizontal two-square, respectively

(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
AB	1	45	0.45	.38	0.38	HA	1	.67	0.67	.25	0.25	OR	2	.89	1.78	.74	1.48
AM	1	.61	0.61	.78	0.78	HL	2	.13	0.26	.13	0.26	OS	3	.61	1.83	.62	1.86
AN	1	.89	0.89	.72	0.72	HS	1	.38	0.38	.72	0.72	PO	1	.64	0.64	.72	0.72
AP	1	.58	0.58	.61	0.61	IE	1	.59	0.59	.73	0.73	PT	1	.51	0.51	.25	0.25
AQ	1	.00	0.00	.00	0.00	IH	1	.00	0.00	.77	0.77	QW	1	.00	0.00	.00	0.00
BB	2	.00	0.00	.00	0.00	IP	3	.48	1.44	.45	1.35	QX	1	.00	0.00	.00	0.00
BF	1	.00	0.00	.00	0.00	IR	2	.73	1.46	.75	1.50	RA	4	.80	3.20	.82	3.28
BQ	1	)	0.00	.00	0.00	IS	1	.78	0.78	.77	0.77	RB	1	.25	0.25	.25	0.25
CE	3	/6	2.28	.76	2.28	KP	1	.00	0.00	.00	0.00	RC	2	.53	1.06	.38	0.76
CR	2	.38	0.76	.53	1.06	KR	1	.00	0.00	.13	0.13	RG	1	.48	0.48	.42	0.42
CW	1	.13	0.13	.00	0.00	KS	2	.13	0.26	.13	0.26	RI	1	.75	0.75	.73	0.73
DA	2	.76	1 52	.73	1.46	LC	4	.33	1.32	.42	1.68	RK	1	.13	0.13	.00	0.00
DD	1	.51	0.51	.51	0.51	LN	2	.13	0.26	.42	0.84	SE	1	.84	0.84	.86	0.86
DE	1	.77	0.77	.88	0.88	LO	1	.59	0.59	.67	0.67	SI	1	.77	0.77	.78	0.78
DI	4	.73	2 92	45	1.80	LP	1	.33	0.33	.59	0.59	SL	1	.25	0.25	.45	0.45
DL	1	.33	0.33	.53	0.53	LT	1	.51	0.51	.42	0.42	SN	2	.38	0.76	.71	1.42
DT	1	.62	0.62	.45	0.45	MA	1	.78	0.78	.61	0.61	SS	1	.67	0.67	.67	0.67
EE	1	.81	0.81	.81	0.81	MD	1	.13	0.13	.42	0.42	TA	3	.74	2.22	.83	2.49
EI	1	.73	0.73	.59	0.59	MO	2	55	1.10	.72	1.44	TI	1	.82	0.82	73	0 /3
EK	1	.00	0.00	.45	0.45	NN	4	.51	2.04	.51	2.04	TQ	1	.13	0.13	.00	0.00
EN	1	.99	0.99	.87	0.87	NO	7	.66	4.62	.92	5.74	UB	1	.33	0.33	.25	0.25
EQ	1	.58	0.58	.00	0.00	NX	1	.00	0.00	.13	0.13	UC	1	.33	0.33	.38	0 38
ER	1	.94	0.94	.96	0.96	NZ	1	.00	0.00	.00	0.00	UO	2	.13	0.26	.79	1.58
FI	1	.80	0.80	.55	0.55	OC	1	.51	0.51	.80	0.80	VY	1	.00	0.00	.00	0.00
GB	1	.00	0.00	.00	0.00	OE	1	33	0.33	.58	0.58	XX	1	.00	0.00	.00	0.00
GL	2	.25	0.50	.13	0.26	OG	1	.25	0.25	.45	0.45	YF	1	.56	0.56	.13	0.13
GP	1	.25	0.25	.00	0.00	OI	3	.42	1.26	.80	2.40		125		58.34		63.02
GR	3	.42	1.26	48	1.44	OL	1	67	0 67	.59	0.59						

(1) Identity of cipher digraph appearing in the cryptogram.

(2) Frequency of the particular digraph as it occurs in the cryptogram

(3) Logarithm of theoretical plaintext frequency of the particular digraph (from Table 15, Appendix 2).

(4) Product of entries in columns (2) and (3).

(5) Logarithm of theoretical plaintext frequency of the digraph's reversal (from Table 15, Appendix 2).

(6) Product of entries in columns (2) and (5).

than the "direct transparency" value, it may be assumed[28] to involve a *horizontal* two-square--if, indeed, two-square encipherment has been employed. It is now for us to establish whether or not this latter *is* the case, and this will be done by determining whether or not the foregoing observed value, 63.02, is representative of the degree of transparency which may be expected in a horizontal two-square cipher. (If the "*direct* transparency" value had been the higher of the two, then it would have been more probable that a *vertical* two-square were involved, and it would be necessary to determine whether or not *this* observed value was representative of the degree of transparency expected in a *vertical* two-square cipher.)

e. The observed "inverse transparency" value (selected in this case because it is the higher observed value) will be compared with the value *expected* from a horizontal two-square cryptogram of the same size, and if this observed value is *as great as or greater than* the transparency value expected for horizontal two-squares, the cryptogram may be considered to be a horizontal two-square cipher; if the observed value is lower than the expected two-square value, decision will have to be suspended.[29] The transparency value expected in a horizontal two-square cipher containing N digraphs is computed by multiplying N by .3388, which in this case

[28] Actually, if the two-square hypothesis is made, the difference between the horizontal two-square value and the vertical two-square value will indicate the degree of probability of the higher score over the lower. In this case, the difference of 4.68 (= 63.02 - 58.34), which represents a difference of *log scores*, is equivalent to an overwhelming ratio of 100 *billion* to 1 (i.e., $224^{4.68}$ to 1) in favor of the hypothesis of a horizontal two-square. The foregoing computation involves an aspect of mathematics which will be given detailed treatment in Military Cryptanalysis, Part III.

[29] For the benefit of the student with a background in statistics, it is pointed out that by abiding by the stipulation "as great or greater", some cryptograms which actually *are* the result of two-square encipherment may be rejected by this stipulation, but it will insure that only a relatively few non-two-square cryptograms will be accepted. A better approach of a statistical nature would involve, first, computing the expected value for *non*-two-squares as well as that for two-squares. Then, any observed value falling below the expected two-square value could be expressed in terms of the number of standard deviations (i.e., the sigmage) from this expected two-square value and from the expected *non*-two-square value. Finally, the particular expected value which would be considered as significant would be the one from which the observed value differed by the smaller number of standard deviations. The concept of standard deviation will be treated in Military Cryptanalysis, Part III.

yields 42 35 (= 3388 x 125).[30] The observed value for the cryptogram, 63 02, is much higher than the expected value, 42 35. Thus, it has been proven statistically that the cryptogram at hand involves two-square encipherment, particularly, *horizontal* two-square encipherment

f Having now proved that the cryptogram at hand is a horizontal two-square cipher, the next step is to assume some plain text in the message, guided by probable inverse transparencies (*inverse* because the system has been identified as a horizontal two-square) in the cipher text. Referring to the work sheet in Fig 62, the repeated sequence at B9 and E9 *is* assumed to represent the plain text TA SK FO RC (E-), on the basis of $\overline{KS}_c = \overline{SK}_p$, and $\overline{CR}_c = \overline{RC}_p$ The plaintext-ciphertext values are now

[30] In the case of *vertical* two-squares, N would be multiplied by the constant 3610 The mathematical considerations underlying this test and their proofs (involving Bayes' theorem and Bayes' factors) are beyond the scope this text, however, for the benefit of the mathematician, the derivation of the foregoing constants is explained below, along with the derivation of the constant used for computing the expected transparency value for *non*-two-squares In the formulas, below,

$\sum_{AB}$ = the summation over all digraphs AA-ZZ

F_{AB} = the frequency of a given digraph AB as found in Table 6A, Appendix 2

α_{AB} = the logarithm (to the base 224) of the frequency of a given digraph AB as found in Table 15, Appendix 2

For vertical two-squares,

$$k = \sum_{AB} \alpha_{AB} \left[.80(.0015) + \frac{20\ F_{AB}}{5000} \right] = 3610$$

For horizontal two-squares,

$$k = \sum_{AB} \alpha_{BA} \left[80(\ 0015) + \frac{20\ F_{AB}}{5000} \right] = 3388$$

For *non*-two square digraphic systems,

$$k = \frac{\alpha_{AB}}{676} = 2737$$

recorded[31] in a skeleton reconstructibn diagram as illustrated in Fig. 64a. At A3, the assumption of (-R) EC ON NA IS SA NC (E-) is tossed off without much ado, since four of the six digraphs concerned are transparent. The plain-cipher relationships from this assumption are added to the reconstruction diagram, as shown in Fig. 64b. Continuing in this vein, the plain text (-A) IR CR AF (T-) is inserted at A1Ø, and the plain text (-B) AT TL ES HI (P-) is inserted at J3, the successive cumulative reconstruction diagrams for these two assumptions are shown in Figs. 64c

			T	N			
			N	A			
		S			K		
	F					I	
	P					O	
R							C

Figure 64a.

	O					T	N				
					L	N	A			B	
					S		G	K			
				F					I		
				P					O		
		E	R			B				C	
I											S

Figure 64b.

		O					T	N					
A	C		I			L	N	A			B	S	R
						S		G	K				
					F					I			
					P					O			
			E	R			B	E			C		
G													F

Figure 64c.

[31] During the reconstruction of the squares of the matrix, the student should keep clear in his skeleton diagram which letters are in the same row, and which are in the same column. It will be found expeditious to draw a dividing line (either horizontal or vertical, depending on the type of two-square matrix involved) on the page to keep the elements of the two squares independent, recording the values which are in the same row or column and writing down the letters as they are assumed. In the early stages of this process the student must exercise care in recording the letters so that no false relationships are formed, in other words, the values should be written down so that they are not in the same row or column with any letters other than those with which they are known to be related. This will entail spreading the work rather widely over the page initially, then gradually telescoping and reducing the size of the reconstruction diagram as the work progresses, until in the end it will be reduced to a concise matrix of two 5x5 squares.

			O					T	N						L
	A	C		I			L	N	A		S	B	R	T	
							S		G	K					
H						F					I				
				E	R	P		B	E		O	C			
	G												F		

Figure 64d.

and 64d below. It is to be noted that at J7, $\overline{OC}_c=\overline{P\Theta}_p$; but since in Fig. 64d it has already been determined that $OC_c=\Theta S_p$, then $\overline{OC}_c$ must equal $\overline{PS}_I$ aking the word BATTLESHIPS rather than in the singular.

g. At this point the partially filled-in work sheet will look as follows:

					5					10					15
A	UO	DL -R	CE EC	NO ON	AN NA	SI IS	GL SA	BB NC	EI EA	RI IR	RC CR	RG AF	LN T-	MO E-	LC
B	PT	ER RE	GR -E	BB NC	OE EO	GP -E	AB NE	QW	NN TA	KS SK	IP FO	CR RC	MO E-	OR RO	AP -E
C	DE	AM	HA	NX	RA AR	IE -O	DA	IR -O	MA	GB -E	EK	HS	LC	DD	LC
D	TQ	OR RO	EN BA	DT	MD	TI IT	AQ	FI -R	EQ	TA AT	NN TA	BF	NO ON	UO	OS
E	SN NS	NN TA	RK	TA AT	SE TO	SN NS	HL	PO	NN TA	KS SK	IP FO	CR RC	CE EC	NO ON	IS
F	HL	IR -O	KP	LO OL	NO ON	NZ	UC -B	TA AT	LT TL	OI ES	IH HI	OC PS	NO ON	CE EC	RA AR →
G	← OS	DI	NO ON	EE EE	KR	LC	UB	RA AR	OS	DI	IP FO	DA	RC CR	OG	GR -E
H	OL -S	NO ON	CW	DI	LP	OI ES	LN T-	QX	DI	GL SA	RB N-	BQ	YF	SS L-	RA AR
J	VY	OI ES	GR -E	SL LS	XX										

Skeletons of additional plain text, such as the word OUR at A1, PRESENCE OF ENEMY at B1, PROBABLE at D1, ATTACK ON OUR INSTALLATIONS at D10, CARRIER at F14, and VESSELS at J1, may now clearly be seen The complete recovery of the plain text follows, and the reconstruction diagram is completed and telescoped into the form shown in Fig 64c Since phenomena of keyword-mixed sequences are observed, the rows and columns of

Q	M	O	K	T	N	-	Q	L	P
A	I	C	L	N	A	B	S	R	T
G	D	F	S	H	G	K	I	F	H
U	E	P	R	B	E	C	O	D	M
Y	-	X	V	-	W	Z	Y	-	X

Figure 64c

R	E	P	U	B	D	E	M	O	C
L	I	C	A	N	R	A	T	S	B
S	D	F	G	H	F	G	H	I	K
K	M	O	Q	T	L	N	P	Q	U
V	W	X	Y	Z	V	W	X	Y	Z

Figure 64f

Fig 64e are permuted to yield the original two-square matrix as shown in Fig 64f

h The solution of vertical two-square systems follows analogous lines, with the necessary modifications of the reconstruction diagram in consonance with the difference in mechanics between horizontal and vertical two-square systems

i A few additional remarks concerning the test applied in subpars d and e, above, are in order First, the exceptionally high transparency value observed in this cryptogram is a direct result of the very favorable manner in which the keyword-mixed sequences in the two squares interact, in the foregoing cryptogram, 47 of the 125 digraphs present (approx 38%) were inverse transparencies It is also pointed out that, although some actual two-square cryptograms may be rejected by that portion of the test which was described in subpar e, the other phase of the test (described in subpar d)--by which one may determine whether a cryptogram is more probably a vertical two-square encipherment or more probably a horizontal two-square encipherment--is extremely sensitive and highly accurate The foregoing statistical method is not merely valuable per se as an application of cryptomathematics in the analysis of two-square matrix systems, but is included as being illustrative of the general principles of special techniques that may be developed in the attack on any particular cryptosystem, the mechanics of which are known to the cryptanalyst The field of actual operational cryptanalysis is replete with special methods of attack of this nature

71 Analysis of Playfair cipher systems --a Of all digraphic cryptosystems employing small matrices, the one which has been most frequently encountered is the Playfair cipher Certain variations of this cipher have been incorporated in several complex manual ciphers used in actual operational practice, because of this it is important that the student gain familiarity with the methods of solution of the classic Playfair system

b The first published solutions[32] for this cipher are quite similar basically and vary only in minor details The earliest, that by Lieut. Mauborgne (later to become Chief Signal Officer of the U.S. Army), used straightforward principles of frequency to establish the values of three or four of the most frequent digraphs Then, on the assumption that in most cases in which a keyword appears on the first and second rows the last five letters of the normal alphabet, VWXYZ, will rarely be disturbed in sequence and will occupy the last row of the square, he "juggles" the letters given by the values tentatively established from frequency considerations, placing them in various positions in the square, together with VWXYZ, to correspond to the plaintext-ciphertext relationships tentatively established A later solution by Lieut Frank Moorman, as described in Hitt's manual, assumes that in a Playfair cipher prepared by means of a square in which the key word occupies the first and second rows, if a digraphic frequency distribution is made, it will be found that the letters having the greatest combining power are very probably letters of the key A still later solution, by Lieut Commander Smith, is perhaps the most lucid and systematized of the three He sets forth in definite language certain considerations which the other two writers certainly entertained but failed to indicate

c The following details have been summarized from Smith's solution

(1) The Playfair cipher may be recognized by virtue of the fact that it always contains an even number of letters, and that when divided into groups of two letters each, no group contains a repetition of the same letter, as NN or EE Repetitions of digraphs, trigraphs, and polygraphs will be evident in fairly long messages

(2) Using the square[33] shown in Fig 65, there are two general cases to be considered, as regards the results of encipherment

B	A	N	K	R
D	E	F	G	H
I-J	L	M	O	Q
U	P	T	C	Y
S	V	W	X	Z

Figure 65

[32] Mauborgne, Lieut J. O., U S.A An advanced problem in cryptography and its solution, Leavenworth, 1914

Hitt, Captain Parker, U.S.A Manual for the solution of military ciphers, Leavenworth, 1918

Smith, Lieut Commander W. W., U.S.N. In Cryotography by André Langie, translated by J.C.H. Macbeth, New York, 1922

[33] The Playfair square accompanying Smith's solution is based upon the key word BANKRUPTCY, "to be distributed between the first and fourth lines of the square" This is a simple departure from the original Playfair scheme in which the letters of the key word are written from left to right and in consecutive lines from the top downward

Case 1 Letters at opposite corners of a rectangle The following illustrative relationships are found

$$\overline{TH}_p=\overline{YF}_c$$
$$\overline{HT}_p=\overline{FY}_c$$
$$\overline{YF}_p=\overline{TH}_c$$
$$\overline{FY}_p=\overline{HT}_c$$

Reciprocity and reversibility [34]

Case 2 Two letters in the same row or column. The following illustrative relationships are found

$$\overline{AN}_p=\overline{NK}_c$$
$$\overline{NA}_p=\overline{KN}_c$$

But $\overline{NK}_p$ does not = $\overline{AN}_c$, nor does $\overline{KN}_p=\overline{NA}_c$.

Reversibility only

(3) The foregoing gives rise to the following

Rule I (a) Regardless of the position of the letters in the square, if

1 2=3 4, then
2 1=4 3

This rule is of particular aid in selecting probable words in the solution of Playfair ciphers, as will be shown shortly [35]

(b) If 1 and 2 form opposite corners of a rectangle, the following equations obtain

1 2=3 4
2 1=4 3
3 4=1 2
4 3=2 1

[34] By way of explaining what is meant by reciprocity and by reversibility, in the case of digraphic systems, the following examples are given $\overline{TH}_p=\overline{YF}_c$ and $\overline{YF}_p=\overline{TH}_c$ constitute a reciprocal relationship, $\overline{TH}_p=\overline{YF}_c$ and $\overline{HT}_p=\overline{FY}_c$ constitute a reversible relationship

[35] In this connection, a list of frequently-encountered words and phrases which contain reversed digraphs (so-called "ABBA patterns") has been compiled and is included as Section E, "Digraphic idiomorphs. Playfair", in Appendix 3

(4) A letter considered as occupying a position in a row can be combined with but four other letters in the same row, the same letter considered as occupying a position in a column can be combined with but four other letters in the same column. Thus, this letter can be combined with only 8 other letters all told, under Case 2, above But the same letter considered as occupying a corner of a rectangle can be combined with 16 other letters, under Case 1, above Smith derives from these facts the conclusion that "it would appear that Case 1 is twice as probable as Case 2". He continues thus (notation my own)·

"Now in the square, note that

$$\begin{array}{lcl} \overline{AN}_p=\overline{NK}_c & & \overline{EN}_p=\overline{FA}_c \\ \overline{GN}_p=\overline{FK}_c & & \overline{EM}_p=\overline{FL}_c \\ \overline{ON}_p=\overline{MK}_c & \text{also} & \overline{ET}_p=\overline{FP}_c \\ \overline{CN}_p=\overline{TK}_c & & \overline{EW}_p=\overline{FV}_c \\ \overline{XN}_p=\overline{WK}_c & & \overline{EF}_p=\overline{FG}_c \end{array}$$

"From this it is seen that of the 24 equations that can be formed when each letter of the square is employed either as the initial or final letter of the group, five will indicate a repetition of a corresponding letter of plain text

"Hence, Rule II After it has been determined, in the equation 1 2=3 4, that, say, $\overline{EN}_p=\overline{FA}_c$, there is a probability of one in five that any other group beginning with F_c indicates $\overline{E\theta}_p$, and that any group ending in A_c indicates $\overline{\theta N}_p$ [36]

"After such combinations as $\overline{ER}_p$, $\overline{OR}_p$, and $\overline{EN}_p$ have been assumed or determined, the above rule may be of use in discovering additional digraphs and partial words"

[36] There is an error in this reasoning Take, for example, the 24 equations having F as an initial letter

Case		Case		Case		Case	
1	$FB_c=DN_p$	2	FE=ED	2	FT=NM	1	FX=GW
2	FD =EH	1	FL=EM	2	FW=NT	1	FR=HN
1	FI =DM	1	FP=ET	1	FK=GN	2	FH=EG
1	FU =DT	1	FV=EW	2	FG=EF	1	FQ=HM
1	FS =DW	2	FN=NW	1	FO=GM	1	FY=HT
1	FA =EN	2	FM=NF	1	FC=GT	1	FZ=HW

Here, the initial letter F_c represents the following initial letters of plain-text digraphs

$D\theta_p$, $E\theta_p$ $N\theta_p$, $G\theta_p$, and $H\theta_p$

It is seen that F_c represents D_p, N_p G_p, H_p 4 times each, and E_p, 8 times Consequently, supposing that it has been determined that $FA_c=EN_p$, the probability that F_c will represent E_p is not 1 in 5 but 8 in 24, or 1 in 3, but supposing that it has been determined that $FW_c=NT_p$, the probability that F_c will represent N_p is 4 in 24 or 1 in 6 The difference in these probabilities is occasioned by the fact that the first instance, $FA_c=EN_p$ corresponds to a Case 1 encipherment, the second instance $FW_c=NT_p$, to a Case 2 encipherment But there is no way of knowing initially, and without other data, whether one is dealing with a Case 1 or Case 2 encipherment Only as an approximation therefore, may one say that the probability of F_c representing a given θ_p is 1 in 5 A probability of 1 in 5 is of almost trivial importance in this situation since it represents such a long shot ' for success The following rule might be preferable If the equation 1 2=3 4 has been established where all the letters represented

Rule III In the equatioh $1\ 2=3.4$, 1 and 3 can never be identical, nor can 2 and 4 ever be identical Thus, $\overline{AN}_p$ could not possibly be represented by $\overline{AY}_c$, nor could $\overline{ER}_p$ be represented by $\overline{KR}_c$ This rule is useful in elimination of certain possibilities when a specific message is being studied

Rule IV In the equation $1.2_p=3.4_c$, if 2 and 3 are identical, the letters are all in the same row or column, and in the relative order 1-2-4 from left to right or top to bottom, respectively In the square shown, $\overline{AN}_p=\overline{NK}_c$ and the absolute order is ANK The relative order 1-2-4 includes five absolute orders which are cyclic permutations of one another Thus: ANK.., NK..A, K..AN, ..ANK, and .ANK

Rule V In the equation $1\ 2_p=3.4_c$, if 1 and 4 are identical, the letters are all in the same row or column, and in the relative order 2-4-3 from left to right or top to bottom In the square shown, $\overline{KN}_p=\overline{RK}_c$ and the absolute order is NKR The relative order 2-4-3 includes five absolute orders which are cyclic permutations of one another Thus NKR.., KR .N, R..NK, ..NKR, and .NKR..

Rule VI "Analyze the message for group recurrences. Select the groups of greatest recurrence and assume them to be high-frequency digraphs.[37] Substitute the assumed digraphs throughout the message, testing the assumptions in their relation to other groups of the cipher The reconstruction of the square proceeds simultaneously with the solution of the message and aids in hastening the translation of the cipher".

by 1, 2, 3, and 4 are different, then there is a probability of 4/5 that a Case 1 encipherment is involved Consequently, if at the same time another equation, 3 6=5 2, has been established, where 2 and 3 represent the same letters as in the first equation, and 5 and 6 are different letters, also different from 2 and 3 there is a probability of 16/25 that the equation 1 6=5 4 is valid or if at the same time that the equation 1 2=3 4 has been determined, the equation 1 6=5 4 has also been established, then there is a probability of 16/25 that the equation 3 6=5 2 is valid (Check this by noting the following equations based upon Fig 25*a* $\overset{1\ 2}{\text{CE}}=\overset{3\ 4}{\text{PG}}$, $\overset{3\ 6}{\text{PH}}=\overset{5\ 2}{\text{YE}}$, $\overset{1\ 6}{\text{CH}}=\overset{5\ 4}{\text{YG}}$ Note the positions occupied in Fig 25*a* by the letters involved) Likewise, if the equations 1 2=3 4 and 1 6=3 5 have been simultaneously established, then there is a probability that the equation 2 5=4 6 is valid, or if the equations 1 2=3 4 and 2 5=4 6 have been simultaneously established, then there is a probability that the equation 2 5=4 6 is valid (Check this by noting the following equations $\overset{1\ 2}{\text{CE}}=\overset{3\ 4}{\text{PG}}$, $\overset{1\ 6}{\text{CA}}=\overset{3\ 5}{\text{PK}}$, $\overset{2\ 5}{\text{EK}}=\overset{4\ 6}{\text{GA}}$, note the positions occupied in Fig 25*a* by the letters involved) However, it must be added that these probabilities are based upon assumptions which fail to take into account any considerations whatever as to frequency of letters or specificity of composition of the matrix For instance, suppose the 5 high-frequency letters E, T, R, I N all happen to fall in the same row or column in the matrix, the number of Case 2 encipherments would be much greater than expectancy and the probability that the equation 1 2=3 4 represents a Case 1 encipherment falls much below 4/5

[37] A more accurate guide to the determination of the plaintext equivalents of high-frequency cipher digraphs would involve the consideration of the difference in frequency of a particular digrapn and its reversal Thus, an example of a high-frequency $\overline{\theta\theta}_p$ which is also high-frequency in its reversal, is $\overline{RE}_p$, an example of a high-frequency $\overline{\theta\theta}_p$ which is rarely found in its reversed form, is $\overline{TH}_p$

d (1) When solutions for the Playfair cipher system were first developed, based upon the fact that the letters were inserted in the cells in keyword-mixed order, cryptographers thought it desirable to place stumbling blocks in the path of such solution by departing from strict, keyword-mixed order One of the simplest methods is illustrated in Fig 65, wherein it will be noted that the last five letters of the keyword proper are inserted in the fourth row of the square instead of the second, where they would naturally fall. Another method involves inserting the letters within the cells from left to right and top downward but using a sequence that is derived from a columnar transposition instead of a keyword-mixed sequence Thus, using the keyword BANKRUPTCY.

2	1	5	4	7	9	6	8	3	10
B	A	N	K	R	U	P	T	C	Y
D	E	F	G	H	I	L	M	O	Q
S	V	W	X	Z					

Sequence A E V B D S C O K G X N F W P L R H Z T M U I Y Q

The Playfair square is as follows

A	E	V	B	D
S	C	O	K	G
X	N	F	W	P
L	R	H	Z	T
M	U	I	Y	Q

Figure 66a

(2) Note the following three squares

Z	T	L	R	H
Y	Q	M	U	I
B	D	A	E	V
K	G	S	C	O
W	P	X	N	F

Figure 66b

O	K	G	S	C
F	W	P	X	N
H	Z	T	L	R
I	Y	Q	M	U
V	B	D	A	E

Figure 66c

N	F	W	P	X
R	H	Z	T	L
U	I	Y	Q	M
E	V	B	D	A
C	O	K	G	S

Figure 66d

At first glance they all appear to be different, but closer examination shows them to be cyclic permutations of one another and of the square in Fig. 66a. They yield identical cryptographic equivalents in all cases However, if an attempt be made to reconstruct the original key word, it would be much easier to do so from Fig 66a than from any of the others, because in Fig 66a the original keyword-mixed sequence has not been disturbed as much as in Figs 66b, c, and d In working with Playfair ciphers, the student should be on the lookout for such instances of cyclic permutation of the original Playfair square, for during the course of solution he will not know whether he is building up the original or an equivalent cyclic permutation of the original matrix, usually only after he has completely reconstructed the matrix will he be able to determine this point

e (1) The steps in the solution of a typical example of this cipher will now be illustrated Let the message be as follows

```
    1 2 3 4 5   6 7 8 9 10   11 12 13 14 15   16 17 18 19 20   21 22 23 24 25   26 27 28 29 30
A   V T Q E U   H I O F T    C  H  X  S  C    A  K  T  V  T    R  A  Z  E  V    T  A  G  A  E
B   O X T Y M   H C R L Z    Z  T  Q  T  D    U  M  C  Y  C    X  C  T  G  M    T  Y  C  Z  U
C   S N O P D   G X V X S    C  A  K  T  V    T  P  K  P  U    T  Z  P  T  W    Z  F  N  B  G
D   P T R K X   I X B P R    Z  O  E  P  U    T  O  L  Z  E    K  T  T  C  S    N  H  C  Q  M
E   V T R K M   W C F Z U    B  H  T  V  Y    A  B  G  I  P    R  Z  K  P  C    Q  F  N  L  V
F   O X O T U   Z F A C X    X  C  P  Z  X    H  C  Y  N  O    T  Y  O  L  G    X  X  I  I  H
G   T M S M X   C P T O T    C  X  O  T  T    C  Y  A  T  E    X  H  F  A  C    X  X  C  P  Z
H   X H Y C T   X W L Z T    S  G  P  Z  T    V  Y  W  C  E    T  W  G  C  C    M  B  H  M  Q
J   Y X Z P W   G R T I V    U  X  P  U  M    Q  R  K  M  W    C  X  T  M  R    S  W  G  H  B
K   X C P T O   T C X O T    M  I  P  Y  D    N  F  G  K  I    T  C  O  L  X    U  E  T  P  X
L   X F S R S   U Z T D B    H  O  Z  I  G    X  R  K  I  X    Z  P  P  V  Z    I  D  U  H  Q
M   O T K T K   C C H X X
```

(2) Without going through the preliminary tests in detail, with which it will be assumed that the student is now familiar,[38] the conclusion is reached that the cryptogram is digraphic in nature, and a digraphic frequency distribution is made (Fig 67)

[38] See par 69c

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A					−		−																			
B							=	=																		
C	=				−	−		=					−				−	−						≢	−	
D		−					−							−							=					
E																−				−						
F	=						−							=						−						
G			−																					=		
H		=	−												−		−									
I								−							−	−						−		−		
J																										
K									−							−				≣						
L																						−				−
M			−					−	−								=			−			=			
N															−											
O												=				−				≢ −				=		
P											−							−		≣	=	−		−	−	≡
Q					−								−							−						
R	−										≣								−	−						−
S							−						−	=				−			−					
T			≡		−		−						=									=	−	−	=	−
U								−												−				−		−
V																				≢ −						
W							=					−														−
X		−	≢ −			−		≡	=										=		−	−				
Y	=		≡																				−	−		
Z					=				=						−	=				≡	=					

Figure 67

Since there are no double-letter groups (termed "doublets"), the conclusion is reached that a Playfair cipher is involved and the message is rewritten in digraphs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	VT	QE	UH	IO	FT	CH	XS	CA	KT	VT	RA	ZE	VT	AG	AE
B	OX	TY	MH	CR	LZ	ZT	QT	DU	MC	YC	XC	TG	MT	YC	ZU
C	SN	OP	DG	XV	XS	CA	KT	VT	PK	PU	TZ	PT	WZ	FN	BG
D	PT	RK	XI	XB	PR	ZO	EP	UT	OL	ZE	KT	TC	SN	HC	QM
E	VT	RK	MW	CF	ZU	BH	TV	YA	BG	IP	RZ	KP	CQ	FN	LV
F	OX	OT	UZ	FA	CX	XC	PZ	XH	CY	NO	TY	OL	GX	XI	IH
G	TM	SM	XC	PT	OT	CX	OT	TC	YA	TE	XH	FA	CX	XC	PZ →
H	← XH	YC	TX	WL	ZT	SG	PZ	TV	YW	CE	TW	GC	CM	BH	MQ
J	YX	ZP	WG	RT	IV	UX	PU	MQ	RK	MW	CX	TM	RS	WG	HB
K	XC	PT	OT	CX	OT	MI	PY	DN	FG	KI	TC	OL	XU	ET	PX
L	XF	SR	SU	ZT	DB	HO	ZI	GX	RK	IX	ZP	PV	ZI	DU	HQ
M	OT	KT	KC	CH	XX										

(3) The following three fairly lengthy repetitions are noted:

Lines									
F	OT	UZ	FA	CX →	← XC	PZ	XH	CY	NO
G	TE	XH	FA	CX	XC	PZ	XH	YC	TX
A	FT	CH	XS	CA	KT	VT	RA	ZE	
C	DG	XV	XS	CA	KT	VT	PK	PU	
G	TM	SM	XC	PT	OT	CX	OT	TC	
K	WG	HB	XC	PT	OT ↖	CX	↗ OT	MI	

The first long repetition, with the sequent reversed digraphs $\overline{CX}$ and $\overline{XC}$ immediately suggests the word BATTALION (see Section E, Appendix 3), split up into -B AT TA LI ON and the sequence containing this repetition in lines F and G becomes as follows

Line F	OX	OT	UZ	FA	CX	XC	PZ	XH	CY	NO	TY
				-B	AT	TA	LI	ON			
Line G	YA	TE	XH	FA	CX	XC	PZ	XH	YC	TX	WL
				B	AT	TA	LI	ON			

(4) Because of the frequent use of numerals before the word BATTALION (as mentioned in Section B of Appendix 4) and because of the appearance of ON_p before this word in line G, the possibility suggests itself that the word before BATTALION in line G is either ONE or SECOND. The identical cipher digraph $\overline{FA}$ in both cases gives a hint that the word BATTALION in line F may also be preceded by a numeral, if ONE is correct

in line G, then THREE is possible in line F On the other hand, if SECOND is correct in line G, then THIRD is possible in line F Thus

Line F . .	OX	OT	UZ	FA	CX	XC	PZ	XH	CY	NO	TY
1st hypothesis	--	TH	RE	EB	AT	TA	LI	ON			
2nd hypothesis .	--	TH	IR	DB	AT	TA	LI	ON			
Line G	YA	TE	XH	FA	CX	XC	PZ	XH	YC	TX	WL
1st hypothesis	--	--	ON	EB	AT	TA	LI	ON			
2nd hypothesis .	-S	EC	ON	DB	AT	TA	LI	ON			

First, note that if either hypothesis is true, then $\overline{OT}_c=\overline{TH}_p$ The frequency distribution shows that $\overline{OT}$ occurs 6 times and is in fact the most frequent digraph in the message Moreover, by Rule I of subparagraph b, if $\overline{OT}_c=\overline{TH}_p$ then $\overline{TO}_c=\overline{HT}_p$ Since $\overline{HT}_p$ is a very rare digraph in normal plain text, $\overline{TO}_c$ should either not occur at all in so short a message or else it should be very infrequent The frequency distribution shows that it does not occur Hence, there is nothing inconsistent with the supposition that the word in front of BATTALION in line F is THREE or THIRD, and there is some evidence that it is actually one or the other

(5) But can evidence be found for the support of one hypothesis against the other? Let the frequency distribution be examined with a view to throwing light upon this point If the first hypothesis is true, then $\overline{UZ}_c=\overline{RE}_p$, and, by Rule I, $\overline{ZU}_c=\overline{ER}_p$ The frequency distribution shows but one occurrence of $\overline{UZ}_c$ and but two occurrences of $\overline{ZU}_c$ These do not look very good for $\overline{RE}$ and $\overline{ER}$ On the other hand, if the second hypothesis is true, then $\overline{UZ}_c=\overline{IR}_p$ and by Rule I, $\overline{ZU}_c=\overline{RI}_p$ The frequencies are much more favorable in this case Is there anything inconsistent with the assumption, on the basis of the second hypothesis, that $\overline{TE}_c=\overline{EC}_p$? The frequency distribution shows no inconsistency, for $\overline{TE}_c$ occurs once and $\overline{ET}_c$($=\overline{CE}_p$, by Rule I) occurs once As regards whether $\overline{FA}_c=\overline{EB}_p$ or $=\overline{DB}_p$, both hypotheses are tenable, possibly the second hypothesis is a shade better than the first, on the following reasoning By Rule I, if $\overline{FA}_c=\overline{EB}_p$ then $\overline{AF}_c=\overline{BE}_p$, or if $\overline{FA}_c=\overline{DB}_p$ then $\overline{AF}_c=\overline{BD}_p$ The fact that no $\overline{AF}_c$ occurs, whereas at least one $\overline{BE}_p$ may be expected in this message, inclines one to the second hypothesis, since $\overline{BD}_p$ is very rare

(6) Let the 2nd hypothesis be assumed to be correct The additional values are tentatively inserted in the text, and in lines G and K two interesting repetitions are noted

Line G	TM	SM	XC	PT	OX	CX	OT	TC	YA	TE	XH	FA	CX	YC	PZ	XH
			TA		TH	AT	TH		-S	EC	ON	DB	AT	TA	LI	ON
Line K	VG	HB	XC	PT	OT	CX	OT	HI	PY	DI	FG	KI	TC	OL	XU	LT
			TA		TH	AT	TH									

This certainly looks like STATE THAT THE . . , which would make $\overline{TE}_p=\overline{PT}_c$ Furthermore, in line G the sequence STATETHATTHE .SECONDBATTALION can hardly be anything else than STATE THAT THEIR SECOND BATTALION, which would make $\overline{TC}_c=\overline{EI}_p$ and $\overline{YA}_c=\overline{RS}_p$ Also $\overline{SM}_c=\overline{-S}_p$

(7) It is perhaps high time that the whole list of tentative equivalent values be studied in relation to their consistency with the positions of letters in the Playfair square, moreover, by so doing, additional values may be obtained in the process The complete list of values is as follows

Assumed values	Derived by Rule I
$\overline{AT}_p=\overline{CX}_c$	$\overline{TA}_p=\overline{XC}_c$
$\overline{LI}_p=\overline{PZ}_c$	$\overline{IL}_p=\overline{ZP}_c$
$\overline{ON}_p=\overline{XH}_c$	$\overline{NO}_p=\overline{HX}_c$
$\overline{TH}_p=\overline{OT}_c$	$\overline{HT}_p=\overline{TO}_c$
$\overline{IR}_p=\overline{UZ}_c$	$\overline{RI}_p=\overline{ZU}_c$
$\overline{DB}_p=\overline{FA}_c$	$\overline{BD}_p=\overline{AF}_c$
$\overline{FC}_p=\overline{IE}_c$	$\overline{CF}_p=\overline{EI}_c$
$\overline{TE}_p=\overline{PT}_c$	$\overline{ET}_p=\overline{TP}_c$
$\overline{EI}_p=\overline{TC}_c$	$\overline{IE}_p=\overline{CT}_c$
$\overline{RS}_p=\overline{YA}_c$	$\overline{SR}_p=\overline{AY}_c$
$\text{-S}_p=\overline{SM}_c$	$\overline{S-}_p=\overline{MS}_c$

(8) By Rule V, the equation $\overline{TH}_p=\overline{OT}_c$ means that H, O, and T are all in the same row or column and in the absolute order HTO similarly, C, E, and T are in the same row or column and in the absolute order CET Further, E, P, and T are in the same row and column, and their absolute order is ETP That is, these sequences must occur someplace in the square, in either rows or columns, taking into consideration of course the probability of cyclic displacements of these sequences within the square

(a) H T O (b) C E T (c) E T P

(9) Noting the common letters E and T in the second and third sequences, these two sequences may be combined into one sequence of four letters, viz , C E T P Since only one position remains to be filled in this row (or column) of the square, and noting in the list of equivalents that $\overline{EI}_p=\overline{TC}_c$, it is obvious that the letter I belongs to the C E T P sequence, the complete sequence is therefore C E T P I

(10) Since the sequence HTO has a common letter (T) with the sequence CETPI, it follows that if the HTO sequence occupies a row, then the CETPI sequence must occupy a column, or, if the HTO sequence occupies a column, then the CETPI sequence must occupy a row, and they may be combined by means of their common letter, T, viz

```
                      C
        H             E
    C E T P I   or  H T O
        O             P
                      I
```

The pioof of whether the CETPI sequence, foı example, properly belongs as a row or a column of the Playfair square lies in the establishment of a rectangular relationship, instead of the linear relationships constructed thus far.

(11) We note that, from the assumptions in subpar d(6), $\overline{AT}_p = \overline{CX}_c$ and $\overline{ON}_p = \overline{XH}_c$ The relationship $\overline{ON}_p = \overline{XH}_c$ might be either a rectangular one, such as

$$\begin{tikzcd} O \arrow[dr] & X \arrow[dl] \\ H & N \end{tikzcd}$$

or it might be linear, viz , HTOXN or

```
H
T
O
X
N
```

Since however $\overline{AT}_p = \overline{CX}_c$ must be a rectangular relationship, then only the configuration

```
  C   A
  E
H T O X N
  P
  I
```

will be valid, since the alternative form

```
    H
C E T P I
    O
A   X
    N
```

will not satisfy the equation $\overline{AT}_p = \overline{CX}_c$

(12) The fragmentary Playfair square[39] has been established, in one of its 25 possible cyclic permutations, as

```
  C   A
  E
H T O X N
  P
  I
```

Scanning the list of plain-cipher equivalents given in subpar d(7) in order to insert possible additional letters, none is found But seeing that several high-frequency letters have already been inserted in the matrix, perhaps reference to the cıyptogram itself in connection with values derived from these inserted letters may yield further clues For example, the vowels A, E, I, and O are all in position, as are the very frequent consonants N and T The following combinations may be studied

$\overline{AN}_p = \overline{\theta X}_c$	$\overline{AT}_p = \overline{CX}_c$	$\overline{NA}_p = \overline{X\theta}_c$	$\overline{TA}_p = \overline{XC}_c$
$\overline{EN}_p = \overline{\theta T}_c$	$\overline{ET}_p = \overline{TP}_c$	$\overline{NE}_p = \overline{T\theta}_c$	$\overline{TE}_p = \overline{PT}_c$
$\overline{IN}_p = \overline{\theta T}_c$	$\overline{IT}_p = \overline{CP}_c$	$\overline{NI}_p = \overline{T\theta}_c$	$\overline{TI}_p = \overline{PC}_c$
$\overline{ON}_p = \overline{XH}_c$	$\overline{OT}_p = \overline{XO}_c$	$\overline{NO}_p = \overline{HX}_c$	$\overline{TO}_p = \overline{OX}_c$

[39] In actual practice, it is more usual to start witr a much laıgeı diagram than a simple 5x5 square, as relationships develop, the diagram is gıadually condensed, until finally a 5x5 square emerges This pıocedure is quite similar to that employed in the reconstıuction diagrams for two-square matrices

$\overline{AT}_p(=\overline{CX}_c)$, $\overline{TA}_p(=\overline{XC}_c)$, $\overline{ON}_p(=\overline{XH}_c)$, $\overline{TE}_p(=\overline{PT}_c)$ and $\overline{ET}_p(=\overline{TP}_c)$ have already been inserted in the text Of the others, only $\overline{OX}_c(=\overline{TO}_p)$ occurs two times, and this value can be at once inserted in the text But can the equivalents of $\overline{AN}$, $\overline{EN}$, or $\overline{IN}$ be found from frequency considerations? Take $\overline{EN}_p$, for example, it is represented by $\overline{\theta T}_c$ What combination of $\overline{\theta T}$ is most likely to represent $\overline{EN}_p$ among the following candidates

$\overline{KT}_c$ (4 times), by Rule I, $\overline{NE}_p$ would = $\overline{TK}_c$ (no occurrences)

$\overline{VT}_c$ (5 times), by Rule I, $\overline{NE}_p$ would = $\overline{TV}_c$ (2 times)

$\overline{ZT}_c$ (3 times), by Rule I, $\overline{NE}_p$ would = $\overline{TZ}_c$ (1 time)

$\overline{VT}_c$ certainly looks good it begins the message, suggesting the word ENEMY, and the sequence $PZTV_c$, in line H, would become the plaintext sequence LINE. Let this be assumed to be correct, and let the word ENEMY also be assumed to be correct Then $\overline{EM}_p=\overline{QE}_c$ and the partial square then becomes as shown herewith·

		P		
		I		
		C		A
V	M	E	Q	
N	H	T	O	X

Figure 68a

(13) In line E is seen the following sequence

Line E	.	VT	RK	MW	CF	ZU	BH	TV	YA	BG	IP	RZ	KP	CQ	FN	LV
		EN				RI		NE	RS		PT			-E		

The plaintext sequence RI..NERS..PT... suggests PRISONERS CAPTURED, as follows

MW	CF	ZU	BH	TV	YA	BG	IP	RZ	KP
	P	RI	SO	NE	RS	CA	PT	UR	ED

This gives the following new values· $\overline{\theta P}_p=\overline{CF}_c$, $\overline{SO}_p=\overline{BH}_c$, $\overline{CA}_p=\overline{BG}_c$, $\overline{UR}_p=\overline{RZ}_c$, and $\overline{ED}_p=\overline{KP}_c$ The letters B and G can be placed in position in the partial square at once, since the positions of C and A are already known The insertion of the letter B immediately permits the placement of the letter S, from the equation $\overline{SO}_p=\overline{BH}_c$ Of the remaining equations only $\overline{ED}_p=\overline{KP}_c$ can be used Since E and P are fixed and are in the same column, D and K must be in the same column, and moreover the K must be in the same row as E There is only one possible position for K, viz , immediately after Q This automatically fixes the position of D The square is now as shown herewith.

		P		D
		I		
G	S	C	B	A
V	M	E	Q	K
N	H	T	O	X

Figure 68*b*

(14) A review of all equations, including the very first ones established, gives the following which may now be used $\overline{DB}_p=\overline{FA}_c$, $\overline{RS}_p=\overline{YA}_c$ The first permits the immediate placement of F, the second, by elimination of possible positions, permits the placement of both R and Y The square is now as shown herewith

		P	F	D
	Y	I		R
G	S	C	B	A
V	M	E	Q	K
N	H	T	O	X

Figure 68*c*

Once more a review is made of all remaining unused equations $\overline{LI}_p=\overline{PZ}_c$ now permits the placement of L and Z $\overline{IR}_p=\overline{UZ}_c$ now permits the placement of U, which is confirmed by the equation $\overline{UR}_p=\overline{RZ}_c$ from the word CAPTURED. There is then only one cell vacant, and it must be occupied by the only letter left unplaced, viz , W Thus the whole square has been reconstructed, and the message can now be deciphered.

L	(W)	P	F	D
Z	Y	I	U	R
G	S	C	B	A
V	M	E	Q	K
N	H	T	O	X

Figure 68*d*

f Reconstruction of the square in Playfair ciphers is normally carried on concurrently with the synthesis of the plain text, once a few correct assumptions have been made. Now, having just reconstructed the square as shown in Fig 68*d*, the question to be answered is whether this square is identical with the original enciphering matrix or whether it is a cyclic permutation of the original square (which may have contained, say, a transposition-mixed sequence) Even though the cryptogram in subpar 71*e* has been solved, this point is still of interest

(1) The square that is derived may not necessarily be the original enciphering square, more than likely it will be one of the 24 possible cyclic permutations of the original square If the Playfair square consisted of a keyword-mixed sequence, a permutation of the square will cause no difficulty in recovering the original matrix and hence the key word For example, if the square derived in some other instance is

```
Q T L N O  then the square  P Y R A M  is easily recovered because of the
X Z U V W                   I D S B C
A M P Y R                   E F G H K
B C I D S                   L N O Q T
H K E F G                   U V W X Z
```

tell-tale letters UVWXZ occurring in a row of the derivative square But when the Playfair square consists of a transposition-mixed sequence, then a different procedure must be adopted

(2) As an example, let us take the transposition matrix

```
5 8 6 1 4 3 2 7  from which  A F T D K  is the original square  Using the
P Y R A M I D S              W I H V M
B C E F G H K L              G U P B N
N O Q T U V W X              Z R E Q S
Z                            L X Y C O
```

methods illustrated in par. 51g, scanning successive rows of the square will disclose sequences of letters which could have appeared as columns in the transposition matrix For example, discovery of the columns

```
I|D|S
H|K|L
V|W|X
```

will afford rapid recovery of the key word. But if instead of the original square we had one of its permutations such as

```
Q S Z R E
C O L X Y
D K A F T
V M W I H
B N G U P
```

then treatment of the "columns", e.g ,

```
F|V|O|L|Q
T|M|L|X|S
V|W|X|Y|Z
```

of the tentative transposition matrix (assuming that some or all of the letters V, W, X, Y, Z are in the last row of the transposition matrix) will be without significance, therefore the procedure above is inapplicable without a slight modification.

(3) Since it will be noted that a permutation of the rows will not affect the procedure of keyword recovery, then we construct a 9x5 rectangle

```
Q S Z R E Q S Z P
C O L X Y C O L X
D K A F T D K A F
V M W I H V M W I
B N G U P B N G U
```

which contains the five squares which result simply from successive permutations of the columns. A 5x5 cut-out square will be found convenient in testing each permutation in turn Affirmative results will be obtained when the correct permutation is reached,

which in this case is the third square in the rectangle, namely,
Z R E Q S. After recovery of the key word from this permuted square it
L X Y C O
A F T D K
W I H V M
G U P B N

is probable then that the original enciphering square must have been

A F T D K.
W I H V M
G U P B N
Z R E Q S
L X Y C O

(4) In the case of the square recovered in Fig 68d, it is found that, following the procedure outlined in subpars (1), (2), and (3) above he key word is based on COMPANY, recoverable from the following diagram:

2	5	3	6	1	4	7
C	O	M	P	A	N	Y
B	D	E	F	G	H	I
K	L	Q	R	S	T	U
V	W	X	Z			

The original square must have been this

A	G	S	C	B
K	V	M	E	Q
X	N	H	T	O
D	L	W	P	F
R	Z	Y	I	U

Figure 68e

g Continued practice in the solution of Playfair ciphers will make the student quite expert in the matter and will enable him to solve shorter and shorter messages[40] Also, with practice it will become a matter of indifference to him as to whether the letters are inserted in the square with any sort of regularity, such as simple keyword-mixed order, transposition-mixed order, or in a purely random order

h It may perhaps seem to the student that the foregoing steps are somewhat too artificial, a bit too "cut and dried" in their accuracy to portray the process of analysis as it is applied in practice For example, the critical student may well object to some of the assumptions and the reasoning in subpar e(5), above, in which the words THREE and

[40] The author once had a student who "specialized" in Playfair ciphers and became so adept that he could solve messages containing as few as 50-60 letters within 30 minutes

ONE (1st hypothesis) were rejected in favor of the words THIRD and SECOND (2nd hypothesis) This rested largely upon the rejection of $\overline{RE}_p$ and $\overline{ER}_p$ as the equivalents of $\overline{UZ}_c$ and $\overline{ZU}_c$, and the adoption of $\overline{IR}_p$ and $\overline{RI}_p$ as their equivalents Indeed if the student will examine the final message with a critical eye, he will find that while the bit of reasoning in step (5) is perfectly logical, the assumption upon which it is based is in fact wrong, for it happens that in this case $\overline{ER}_p$ occurs only once and $\overline{RE}_p$ does not occur at all Consequently, although most of the reasoning which led to the rejection of the first hypothesis and the adoption of the second was logical, it was in fact based upon erroneous assumption In other words, despite the fact that the assumption was incorrect, a correct deduction was made The student should take note that in cryptanalysis situations of this sort are not at all unusual Indeed they are to be expected, and a few words of explanation at this point may be useful

i Cryptanalysis is a science in which deduction, based upon observational data, plays a very large role But it is also true that in this science most of the deductions usually rest upon assumptions It is most often the case that the cryptanalyst is forced to make his assumptions based upon a quite limited amount of text. It cannot be expected that assumptions based upon statistical generalizations will always hold true when applied to data comparatively very much smaller in quantity than the total data used to derive the generalized rules Consequently, as regards assumptions made in specific messages, most of the time they will be correct, but occasionally they will be incorrect[41] In cryptanalysis it is often found that among the correct deductions there will be cases in which subsequently discovered facts do not bear out the assumptions on which the deduction was based Indeed, it is sometimes true that if the facts had been known before the deduction was made, this knowledge would have prevented making the correct deduction For example, suppose the cryptanalyst had somehow or other divined that the message under consideration contained no RE, only one ER, one IR, and two RI's (as is actually the case) He would certainly not have been able to choose between the words THREE and ONE (1st hypothesis) as against THIRD and SECOND (2d hypothesis) But because he assumes that there should be more $\overline{ER}_p$'s and $\overline{RE}_p$'s than $\overline{IR}_p$'s and $\overline{RI}_p$'s in the message, he deduces that $\overline{UZ}_c$ cannot be $\overline{RE}_p$, rejects the first hypothesis and takes the second It later turns out, after the problem has been solved, that the deduction was correct, although the assumption on which it was based (expectation of more frequent appearance of $\overline{RE}_p$ and $\overline{ER}_p$) was, in fact, not true in this particular case The cryptanalyst can only hope that the number of times when his deductions are correct, even though based upon assumptions which later turn out to be erroneous, will abundantly exceed the number of times when his deductions are wrong, even though based upon assumptions which later prove to be correct If he is lucky,

[41] See footnote 19 on page 52

the making of an assumption which is really not true will make no difference in the end and will not delay solution, but if he is specially favored with luck, it may actually help him solve the message--as was the case in this particular example

j Another comment of a general nature may be made in connection with this specific example. The student may ask what would have been the procedure in this case if the message had not contained such a tell-tale repetition as the word BATTALION, which formed the point of departure for the solution, or, as it is often said, permitted an "entering wedge" to be driven into the message The answer to his query is that if the word BATTALION had not been repeated, there would probably have been some other repetition which would have permitted the same sort of attack If the student is looking for cut and dried, straightforward, unvarying methods of attack, he should remember that cryptanalysis, while considered a branch of mathematics by some, is not a science which has many "general solutions" such as are found and expected in mathematics proper It is inherent in the very nature of cryptanalytics that, as a rule, only general principles can be established, their practical application must take advantage of peculiarities and particular situations which are noted in specific messages This is especially true in a text on the subject The illustration of a general principle requires a specific example, and the latter must of necessity manifest characteristics which make it different from any other example The word BATTALION was not purposely repeated in this example in order to make the demonstration of solution easy, "it just happened that way" In another example, some other entering wedge would have been found The student can be expected to learn only the general principles which will enable him to take advantage of the specific characteristics manifested in specific cases Here it is desired to illustrate the general principles of solving Playfair ciphers and to point out the fact that entering wedges must and can be found. The specific nature of the entering wedge varies with specific examples

72 Analysis of polygraphic systems involving large tables --a The analysis of systems incorporating large digraphic tables is accomplished by entering, within the appropriate cells of a 26x26 chart, data corresponding to the plain-cipher relationships of assumed cribs on 26x26 charts, and examining the charts for evidences of symmetry or systematic construction in their compilation The initial plaintext entries may, in the absence of cribs, be made on the basis of digraphic frequency considerations, aided by idiomorphisms and repetitions

b. In pseudo-digraphic systems, such as those incorporating tables similar to Figs 47a and b, and 48, the identification of the monoalphabetically-enciphered component of cipher digraphs will greatly accelerate plaintext entries, since advantage may be taken of this monoalphabeticity. Tables with a feature of reciprocity, such as the example in Fig 50, may be exploited on the basis of this weakness, even if the reciprocal pairs are assigned at random Tables such as that in Fig 49 and the one for trinome digraphic encipherment shown in Fig 51 may also be exploited with facility, once enough plain text has been correctly assumed and inserted to disclose their systematic construction A word of warning is inserted here against making incautious assumptions concerning the exact internal composition of tables such as that in Fig 49, since their unusual construction could easily mislead the analyst who jumps to premature conclusions. In the case of a table such as Fig 53 wherein the trinomes have been inscribed in straight horizontals (or for that matter, any other known inscription), if the dimensions of the table have been correctly assumed the simplest solution involves a reduction to two alphabets, reflecting the sequences of letters for the side and top of the matrix, this solution closely parallels that of the numerical four-square system described in subpar 69e

c Because the foregoing principles are rather straightforward, it is not considered necessary to illustrate their application with examples Of course, when digraphic tables of random construction have been used, no refinements in solution are possible However, the recording of as few as 225 different plaintext digraphs and their ciphertext equivalents will theoretically enable the automatic decryption of approximately 92% of the cipher digraphs of messages, and the recording of 335 plaintext-ciphertext values will enable the automatic decryption of 98% of the cipher digraphs, thus almost every message may be read in its entirety without recourse to further assumptions Actually, it should be pointed out that having only 122 matched plaintext-ciphertext equivalencies will theoretically enable the decryption of 75% of the cipher digraphs, and enough skeletons of plain text may then be manifest to permit the decryption of the complete message texts

d It might be well to point out in connection with large digraphic tables that there exist literal types which give rise to monoalphabetic distributions for both the initial letters and final letters of pairs Such a table is illustrated in Fig 69 below

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	HQ	YQ	DQ	RQ	AQ	UQ	LQ	IQ	CQ	BQ	EQ	FQ	GQ	JQ	KQ	MQ	NQ	OQ	PQ	QQ	SQ	TQ	VQ	WQ	XQ	ZQ
B	HU	YU	DU	RU	AU	UU	LU	IU	CU	BU	EU	FU	GU	JU	KU	MU	NU	OU	PU	QU	SU	TU	VU	WU	XU	ZU
C	HE	YE	DE	RE	AE	UE	LE	IE	CE	BE	EE	FE	GE	JE	KE	ME	NE	OE	PE	QE	SE	TE	VE	WE	XE	ZE
D	HS	YS	DS	RS	AS	US	LS	IS	CS	BS	ES	FS	GS	JS	KS	MS	NS	OS	PS	QS	SS	TS	VS	WS	XS	ZS
E	HT	YT	DT	RT	AT	UT	LT	IT	CT	BT	ET	FT	GT	JT	KT	MT	NT	OT	PT	QT	ST	TT	VT	WT	XT	ZT
F	HI	YI	DI	RI	AI	UI	LI	II	CI	BI	EI	FI	GI	JI	KI	MI	NI	OI	PI	QI	SI	TI	VI	WI	XI	ZI
G	HO	YO	DO	RO	AO	UO	LO	IO	CO	BO	EO	FO	GO	JO	KO	MO	NO	OO	PO	QO	SO	TO	VO	WO	XO	ZO
H	HN	YN	DN	RN	AN	UN	LN	IN	CN	BN	EN	FN	GN	JN	KN	MN	NN	ON	PN	QN	SN	TN	VN	WN	XN	ZN
I	HA	YA	DA	RA	AA	UA	LA	IA	CA	BA	EA	FA	GA	JA	KA	MA	NA	OA	PA	QA	SA	TA	VA	WA	XA	ZA
J	HB	YB	DB	RB	AB	UB	LB	IB	CB	BB	EB	FB	GB	JB	KB	MB	NB	OB	PB	QB	SB	TB	VB	WB	XB	ZB
K	HL	YL	DL	RL	AL	UL	LL	IL	CL	BL	EL	FL	GL	JL	KL	ML	NL	OL	PL	QL	SL	TL	VL	WL	XL	ZL
L	HY	YY	DY	RY	AY	UY	LY	IY	CY	BY	EY	FY	GY	JY	KY	MY	NY	OY	PY	QY	SY	TY	VY	WY	XY	ZY
M	HC	YC	DC	RC	AC	UC	LC	IC	CC	BC	EC	FC	GC	JC	KC	MC	NC	OC	PC	QC	SC	TC	VC	WC	XC	ZC
N	HD	YD	DD	RD	AD	UD	LD	ID	CD	BD	ED	FD	GD	JD	KD	MD	ND	OD	PD	QD	SD	TD	VD	WD	XD	ZD
O	HF	YF	DF	RF	AF	UF	LF	IF	CF	BF	EF	FF	GF	JF	KF	MF	NF	OF	PF	QF	SF	TF	VF	WF	XF	ZF
P	HG	YG	DG	RG	AG	UG	LG	IG	CG	BG	EG	FG	GG	JG	KG	MG	NG	OG	PG	QG	SG	TG	VG	WG	XG	ZG
Q	HH	YH	DH	RH	AH	UH	LH	IH	CH	BH	EH	FH	GH	JH	KH	MH	NH	OH	PH	QH	SH	TH	VH	WH	XH	ZH
R	HJ	YJ	DJ	RJ	AJ	UJ	LJ	IJ	CJ	BJ	EJ	FJ	GJ	JJ	KJ	MJ	NJ	OJ	PJ	QJ	SJ	TJ	VJ	WJ	XJ	ZJ
S	HK	YK	DK	RK	AK	UK	LK	IK	CK	BK	EK	FK	GK	JK	KK	MK	NK	OK	PK	QK	SK	TK	VK	WK	XK	ZK
T	HM	YM	DM	RM	AM	UM	LM	IM	CM	BM	EM	FM	GM	JM	KM	MM	NM	OM	PM	QM	SM	TM	VM	WM	XM	ZM
U	HP	YP	DP	RP	AP	UP	LP	IP	CP	BP	EP	FP	GP	JP	KP	MP	NP	OP	PP	QP	SP	TP	VP	WP	XP	ZP
V	HR	YR	DR	RR	AR	UR	LR	IR	CR	BR	ER	FR	GR	JR	KR	MR	NR	OR	PR	QR	SR	TR	VR	WR	XR	ZR
W	HV	YV	DV	RV	AV	UV	LV	IV	CV	BV	EV	FV	GV	JV	KV	MV	NV	OV	PV	QV	SV	TV	VV	WV	XV	ZV
X	HW	YW	DW	RW	AW	UW	LW	IW	CW	BW	EW	FW	GW	JW	KW	MW	NW	OW	PW	QW	SW	TW	VW	WW	XW	ZW
Y	HX	YX	DX	RX	AX	UX	LX	IX	CX	BX	EX	FX	GX	JX	KX	MX	NX	OX	PX	QX	SX	TX	VX	WX	XX	ZX
Z	HZ	YZ	DZ	RZ	AZ	UZ	LZ	IZ	CZ	BZ	EZ	FZ	GZ	JZ	KZ	MZ	NZ	OZ	PZ	QZ	SZ	TZ	VZ	WZ	XZ	ZZ

Figure 69.

In effect, encipherment by means of such a system yields the equivalent of a two-alphabet cipher, with a transposition within each of the pairs of letters. The cipher text produced by such a system may be characterized by a large number of repetitions which begin with the initial letter of digraphs and end on the final letter of digraphs and which are preceded by digraphs having repeated initial letters or which are followed by digraphs having repeated final letters; for example, ciphertext passages of the following type might often arise: SF BD GB HK and SQ BD GB WK (wherein the repeated plain text is actually represented by SDBBGK, affected by the transposition). This system is included here as being illustrative of many simple systems which are capable of leading the student very much astray in this instance, if one were unaware of the transposition feature involved and were to attempt what appears to be the simple task of fitting plain text into the two monoalphabetic portions on the basis of single-letter frequency considerations, he could spend a great deal of time without success--probably without any idea of what was causing his difficulties.

e. A pseudo-trigraphic cipher involving a table such as that in Fig. 52 may be readily recognized as such, since two letters of each trigraph enciphered by means of such a table are treated monoalphabetically. If three separate uniliteral frequency distributions are made--one for each of the three letters of the cipher trigraphs--two of the distributions should be monoalphabetic. Then, exploiting the monoalphabeticity (i.e., the *positional* monoalphabeticity) thus disclosed in the cipher text, plain text can be fitted to the cipher on the basis of single-letter frequency considerations; in addition, advantage may be taken of *partial* idiomorphisms, if these idiomorphisms involve the particular positions of the trigraphs which have been treated monoalphabetically.

f. Fortunately, it is unlikely that trigraphic systems other than the foregoing pseudo-trigraphic type will be encountered, because they are difficult to manipulate without extensive tables or complicated rules for encryption.[41] The subject can be passed over with the simple statement that their analysis requires much text to permit of solution by the frequency method,--and blood, sweat, and tears.[42]

73. Further remarks on polygraphic substitution systems.--*a*. In the treatment of the cryptography of the various digraphic systems in this Section, the rules for encryption and decryption which have been illustrated are the "standard" rules (i.e., the rules extant in cryptologic literature, or the rules most commonly encountered in operational practice). Needless to say, however, there is no cryptologic counterpart of the Geneva Convention making these rules sacrosanct, nor forbidding the use of other rules for enciphering and deciphering.

b. In two-square systems and Playfair systems there are possible (and, in fact, there have been encountered in operational practice) modifications of the usual enciphering and deciphering rules which, if not suspected, may pose difficulties in the identification of such systems and in their cryptanalysis. For example, in a vertical two-square system, when two plaintext letters fall in the same column, their cipher equivalents might be taken as the letters immediately to the right of or immediately below these plaintext letters. Similarly, in a horizontal two-square system, if two plaintext letters are in the same row, their cipher equivalents might be taken as those immediately below, or to the right of these letters. In Playfair cipher systems, two plaintext letters in the same row might be represented by the letters immediately below, two plaintext letters in the same column might be represented by the letters immediately to the right; a plaintext doublet might be represented by a ciphertext *doublet* formed by doubling the letter immediately to the right, or below, or diagonally to the right and below, thus removing one of the identifying ciphertext characteristics of the *normal* Playfair system. In *one case* encountered, instead of the *normal* Playfair linear relationship $\overline{AB}_p{=}\overline{BC}_c$, the rule was changed to $\overline{AB}_p{=}\overline{CB}_c$ (thus allowing a

[41] However, see in this connection Appendix 8, "Lester S. Hill algebraic encipherment", which gives a mathematical treatment of *true* polygraphic encipherment for polygraphs of *any* size. (See also subpar. 73*h*).

[42] If a trigraphic system is encountered in operational cryptanalysis, special solutions would be made possible by the application of cribs, the aid furnished by isologs (not only in the same system, but also *between* systems), etc.

letter to "represent itself"--an "impossibility" in Playfair encipherment), even this simple modification caused difficulties in cryptanalysis because variant rules for encryption had not been considered

c The placing of cribs in small-matrix digraphic systems may be guided by the cryptographic peculiarities of these systems, when the general system is known to, or suspected by the cryptanalyst, conversely, the placing of a known crib may assist in the determination of the type of cryptosystem, or in the rejection of other types of systems For example, cribs may be placed in Playfair ciphers on the basis of the "non-crashing" feature of the normal Playfair, that is, on the basis that in the equation 1 2=3 4 neither 1 and 3 nor 2 and 4 can be identical In horizontal two-square systems, if $\alpha\beta_c = \_\alpha_p$, then $\alpha\beta_c$ must equal $\beta\alpha_p$, and if $\alpha\beta_c = \beta\_\ p$, then $\alpha\beta_c$ must equal $\beta\alpha_p$ If, by placing a known crib in a cryptogram, evidence of non-reciprocity is disclosed (e g , if $\overline{AB}_p = CD_c$, but $\overline{CD}_p = XY_c$), the cryptogram may be assumed to be other than a vertical two-square cipher, since vertical two-square encipherment yields complete reciprocity In either type of two-square system, if one of the two squares is known (for example, a vertical two-square might be employed in which the upper square is always a normal alphabet), the placement of cribs is materially facilitated

d The ϕ test performed separately on the initial letter and final letter of ciphertext pairs from cryptograms produced by small-matrix digraphic systems will give results neither close to that expected for plain text, nor close to that for random text The reason for the comparative "roughness" or pronounced differences among the relative frequencies in these distributions, as contrasted with the "smoothness" expected of random, is that small-matrix digraphic systems are only partially digraphic in nature and that the encryption involves characteristics similar to those of monoalphabetic substitution with variants This roughness of the uniliteral frequency distributions for the prefixes and suffixes, and, for that matter, for the over-all cipher text, reflects the partially digraphic nature of the encipherment

e If the cipher letters V, W, X, Y, and Z are of very low frequency in the over-all uniliteral frequency distribution of a digraphic cryptogram or set of cryptograms, this may be taken as evidence that the cryptosystem is a small-matrix digraphic system employing keyword-mixed sequences in the matrix or matrices Furthermore, in small-matrix systems involving keyword-mixed squares, if θ_c^1 of $\overline{\theta\theta}_c$ is one of the letters VWXYZ, the θ_p^1 of the corresponding $\overline{\theta\theta}_p$ is likely to be one of these same letters Similarly, if θ_c^2 is one of the letters VWXYZ, then θ_p^2 of the corresponding $\overline{\theta\theta}_p$ is likely to be one of these letters

f In trinome-digraphic systems employing large tables, the trinomes may run from 001 to 676, as in Fig 51, or any consecutive set of 676 trinomes in the scale of 1000 possible trinomes may be used For that matter, the entire span of trinomes 000-999 might be used in such a table, with occasional gaps, to hide the limitations of this system As another means of disguising the limitation of 676 trinomes in such a system, three of the initial digits of the trinomes might have one variant each--thus no limitation would exist in the first position of trinomes The 001, or other starting point in the cyclic scale, need not be at the upper left-hand corner of the table The 676 trinomes in such tables may be inscribed in straight horizontals (i e., in the normal manner of writing) as in Fig 51, or they might be inscribed according to some other route, they probably would *not* be inscribed in a random manner because clumsy "deciphering tables" would then be necessary It is also possible that the trinomes in a trinome-digraphic system might be converted into tetranomes by the addition of a sum-check (to assist in error-correction)

g The cryptanalysis of tetranome-trigraphic systems with matrices similar to that illustrated in Fig 59 involves a modification of the technique used in solving inverse four-square systems If the plain-component and cipher-component sections of the large square have been inscribed according to the normal manner of writing (or any other manner, *if known*), the first two elements of the trigraphs may be reduced to a pair of cipher alphabets, and these two monoalphabetic substitutions may be solved as indicated in subpar *69e* The applicability of inverse four-square solution principles to this tetranome-trigraphic system of course rests on the fact that the ciphertext sections are known or assumed to contain the dinomes 00-99 in numerical order, inscribed in the normal manner of writing, the conversion of the first two elements of the trigraphs depends upon the knowledge of the manner of inscription of the letters of the plain component sections, in order that the *four occurrences of the initial letters* and the *four occurrences of the final letters* may be correctly combined into two monoalphabetic distributions Of course, if the composition of the small square (for the third element of trigraphs) is known, the third letter of trigraphs may be automatically deciphered If the composition of the small square is not known, a consideration of the frequencies of the converted dinomes for the small square (i e , the coordinates of the square to indicate the third member of trigraphs) may be used to obtain an entering wedge into this *third* monoalphabetic substitution

h There are but a very limited number of known cipher mechanisms which employ the polygraphic encipherment principle in any form U.S Patent No 1515680 issued to A Henkels in 1924 and U S Patent No 1845947 issued to Weisner and Hill in 1932 describe two such mechanisms which produce polygraphic substitution The latter, that of Weisner and Hill, is of particular interest because it is based on a rather simple mathematical process which can yield *true* polygraphic encipherment for polygraphs of any size The underlying mathematical process, invented by Prof Lester S Hill of Hunter College and described in the "American Mathematical Monthly" in 1929 (Vol XXXVI, p 306) and 1931 (Vol XXXVIII, p 135), is treated briefly, below, a more detailed treatment is contained in Appendix 8, "Lester S Hill algebraic encipherment", which also includes remarks on the cryptanalysis of this method of encipherment

(1) Since Professor Hill's system is mathematical in nature, the first step in its use involves the conversion of the plaintext letters into numbers by means of a conversion alphabet which shows a correspondence between the 26 letters of the alphabet and the 26 numbers from 0 to 25, such as the following·

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
0	9	3	5	24	6	18	8	11	1	21	14	15	12	4	10	25	17	7	19	20	2	22	16	23	13

(2) The numbers obtained through the conversion of the plaintext letters are next treated arithmetically through the application of algebraic linear functions, this treatment being performed by means of mod 26 arithmetic[43] The numerical results yielded by the algebraic treatment are then converted back into letters by means of the conversion alphabet, to yield the cipher equivalent of the original plain text

(3) For example, suppose that the message "NOTHING TO REPORT" is to be enciphered by trigraphs, and that, for this purpose, the enciphering keys[44] are 1, 2, 1, 5, 11, 3, 2, 4, 13 The message would be divided into trigraphs NOT-HIN-GTO-REP-ORT and the letters which result from the following operation would be taken as the cipher equivalent of the first trigraph.

Using the conversion alphabet in (1), above, (N O T) is converted into (12 4 19), then the foregoing keys are applied--

$$1 \times 12 + 2 \times 4 + 1 \times 19 = 12 + 8 + 19 = 13 + 1(26) = Z$$

$$5 \times 12 + 11 \times 4 + 3 \times 19 = 8 + 18 + 5 = 5 + 1(26) = D$$

$$2 \times 12 + 4 \times 4 + 13 \times 19 = 24 + 16 + 13 = 1 + 2(26) = J$$

Thus, $\overline{\text{NOT}}_p$ is enciphered as $\overline{\text{ZDJ}}_c$

(4) A large number of sets of enciphering and deciphering keys can be constructed It is even possible to construct keys which yield reciprocal encipherment, and it is this possibility which makes practicable the construction of a machine or device to accomplish the enciphering and deciphering

[43] Using "mod 26 arithmetic", one considers as the sum or product of two numbers, the number from 0-25 which is obtained by subtracting 26 (or a multiple of 26) from the ordinary arithmetical sum or product of the numbers

[44] Encipherment of polygraphs containing $\underline{n}$ letters requires the use of $\underline{n}^2$ keys Thus, 9 keys are necessary for trigraphic encipherment, digraphic encipherment requires only 4 keys, whereas tetragraphic and pentagraphic encipherment necessitate the use of 16 and 25 keys, respectively The numbers selected for use as keys must be chosen according to rather definite rules based on the "theory of determinants", otherwise, cryptographic ambiguity may result when decipherment is attempted Appendix 8 contains more on this matter

i. Attention is called here to the applications of Table 13 ("Four-square individual frequencies") of Appendix 2; this table has been reproduced here for convenience. If the cryptanalyst has at hand a fairly large volume of cipher digraphs produced by encipherment with a normal four-square, he may use Table 13 as an aid in placing the initial letters and final letters of the cipher digraphs into the appropriate cells of the cipher component sections on the basis of their uniliteral frequencies. Thus, if a distribution made of the initial letters of cipher pairs in a particular example shows Q_c, I_c, and C_c to be the letters of predominantly high frequency (listed in descending order of frequency), and if the distribution of the final letters shows F_c, Q_c, and P_c as the letters of predominantly high frequency (in descending order of frequency), these letters may be tentatively placed into a skeleton four-square matrix as follows (Fig 70), based on the locations of the highest frequencies as given in Table 13

(Table 13, Appendix 2)

[Based on a count of 6,000 digraphs]

P₁					C₁				
A	B	C	D	E	244	225	375	394	197
F	G	H	I J	K	125	98	193	271	95
L	M	N	O	P	229	199	188	350	251
Q	R	S	T	U	148	162	258	427	295
V	W	X	Y	Z	42	12	34	91	97
212	317	358	308	249	A	B	C	D	E
120	108	216	256	85	F	G	H	I J	K
216	140	152	435	269	L	M	N	O	P
206	121	306	364	284	Q	R	S	T	U
38	29	21	147	43	V	W	X	Y	Z
C₂					P₂				

A	B	C	D	E			C	I	
F	G	H	I	K					
L	M	N	O	P					
Q	R	S	T	U				Q	
V	W	X	Y	Z					
		P			A	B	C	D	E
					F	G	H	I	K
			F		L	M	N	O	P
			Q		Q	R	S	T	U
					V	W	X	Y	Z

Figure 70

j In attempting to diagnose the underlying cryptosystem in any particular polygraphic cipher, the student may gain some assistance from the following recapitulation

(1) In digraphic ciphers the majority of repetitions will be an even number of letters apart and these repetitions should for the most part begin on the first letters of pairs and end on the last letters of pairs The majority of repetitions in trigraphic ciphers will be some multiple of three letters apart and these repetitions should for the most part begin on the first letters of trigraphs and end on the last letters of trigraphs.

(2) Digraphic ciphers may be revealed as such by the digraphic phi test, with additional support being given by the digraphic blank-expectation test, the presence of a null letter at the beginning of the cipher text might be disclosed by applying the two foregoing tests to a distribution of the digraphs which are formed when the first letter of the text is omitted

(3) If either the uniliteral frequency distribution for the initial letters or for the final letters of the digraphs in a cryptogram exhibits monoalphabeticity, the cryptogram is probably a pseudo-digraphic cipher involving a large table of the type in Fig 47 or 48 If both of the foregoing uniliteral frequency distributions reflect monoalphabeticity, the cryptogram may involve the use of a table of the type in Fig 69

(4) If the "decipherment" of a cryptogram by means of a four-square matrix containing four normal alphabets yields two monoalphabetic substitutions--one for the initial letters and one for the final letters of the pseudo-decipherment--the cryptogram may be assumed to be an inverse four-square cipher.

(5) If an ocular inspection or statistical evaluation of the cipher text of a cryptogram reveals a large number of "transparencies", the cryptogram probably involves a two-square system

(6) If a cryptogram contains several cipher doublets, all of which are broken up when the cipher text is divided into digraphs, the cryptogram may well involve normal Playfair encipherment

(7) If the cipher text of a cryptogram exhibits any invariable affinity of one of the letters J, K, Q, X, or Z for vowels (or, for that matter, another cluster of 5 or 6 letters), the cryptogram probably is in a small-matrix system employing sections consisting of more than 25 letters

k If a particular four-square cryptogram involves the use of a matrix in which either the plain component sections or the cipher component sections are normal alphabets, the matrix will be recovered through cryptanalysis in its original form, even when the components which are mixed have been derived by a transposition method or by no method at all In Playfair cipher solution, the matrix can be recovered in its original form as long as the original matrix has been mixed in some systematic manner However, in the case of two-square solution, there is no guarantee that the matrix can be recovered in its original form unless the original matrix has been keyword-mixed, if the original has been transposition-mixed, for example, the matrix which has been recovered through cryptanalysis--while being cryptographically equivalent to the original--will undoubtedly involve a permutation of the rows and columns of the original

l When four-square systems are encountered in which the matrix consists of four differently-mixed sections, reconstruction of the matrix is accomplished in a manner similar to that used in the analysis of two-square ciphers If the sections are composed of keyword-mixed sequences, the original matrix may be recovered Otherwise, the reconstructed matrix will in all probability be a permutation of both the rows and the columns of the original matrix, and there may be no way of recovering or or proving the original matrix

m In passing, it might be well to mention that any two-square system can be solved as a four-square system in which the matrix is composed of four mixed sections, upon the realization, from phenomena in the matrix reconstruction, that a two-square matrix is involved, the proper conversion can then easily be made

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SECTION X

CRYPTOSYSTEMS EMPLOYING IRREGULAR-LENGTH CIPHERTEXT UNITS

74. Preliminary observations.--a. The cipher alphabets of nearly all of the various cryptosystems treated thus far in this text have involved cipher units of a constant length.[1] That is, the ciphertext units have been (prior to regrouping into fives for transmission) either single characters, or pairs of characters, or three-character groupings, or, in the case of the Baconian and Baudot alphabets, 5-element ciphertext units; however, within a given cryptosystem the lengths of the ciphertext units have been consistent, and it is this consistency that has been of most importance to the cryptanalyst.

b. There is no reason why a cryptographer could not vary the size of the cipher units in a particular cryptosystem, as long as no cryptographic ambiguity in deciphering would result thereby. Furthermore, if the size of the cryptographic units *is* varied within a particular cryptosystem, obstacles are put in the way of cryptanalytic attack on the system--varying the length of the ciphertext groupings complicates the cryptanalyst's preliminary task of dividing the cipher text into the proper units for study. In this connection, the student should refer back to par. 63 and read again the remarks on the use of nulls which differ in size from the real cryptographic units. The example contained therein makes it clear that, until such nulls are identified and isolated by the cryptanalyst, he is unable to divide the cipher text properly and make appropriate frequency distributions. However, nulls may sometimes be recognized as such because they do not behave like units which represent actual plaintext elements. For example, in the three almost-identical ciphertext passages below,

```
(a) ...181Ø5  11343  71129  3219Ø  23231  52937...
(b) ...18151  Ø1343  71129  32192  32Ø31  52937...
(c) ...18151  13437  1Ø129  32192  3Ø231  52937...
```

[1] The only exceptions have been in the digraphic systems using the matrices illustrated in Figs. 57a and 57b, in which a plaintext digraph may be represented by a ciphertext digraph, trigraph, or tetragraph, depending upon the identity of the plaintext digraph.

the behavior of the digit Ø is characteristic of a null, and when this is recognized and eliminated, the remaining cryptographic text may be broken up into its real units and solved quite readily.

c. Since it has been indicated above that there are weaknesses in a scheme in which all cipher elements do not behave like equivalents for plaintext elements, it would be logical then to devise a system in which different-sized ciphertext units all represent actual plaintext elements and thus do behave more or less alike. It is easy to draw up cipher alphabets in which, for example, some of the letters are represented by single digits, others by pairs of digits. Such a system, called a monome-dinome system[2], would produce cipher text which is an irregular intermixture of uniliteral and multiliteral equivalents. From the cryptanalytic standpoint, the decomposition of such cipher text could be very difficult for the analyst who does not know which digits to treat separately, which in pairs. Such systems, and similar variations, are given detailed treatment in the following paragraph.

75. Types of alphabets with irregular-length ciphertext units.--a. One simple scheme for yielding single-digit equivalents for some letters and two-digit equivalents for others makes use of a rectangular matrix which is similar to some of the biliteral matrices of Sections VII and VIII, but which differs in that the top row of the matrix has no indicator (or coordinate). For examples, see Figs. 71-74, below. Each plaintext character appearing in the top row in the matrix has as its cipher equivalent merely the monome which appears above it, among the column coordinates; thus, in Fig. 71, $E_p = Ø_c$, $T_p = 1_c$, $N_p = 8_c$, etc. Each plaintext character

	Ø	1	8	3	4	5	2	9	7	6
-	E	T	N	R	O	A	I	S	▨	▨
7	B	C	D	F	G	H	J	K	L	M
6	P	Q	U	V	W	X	Y	Z	.	*

Figure 71.

	Ø	1	8	3	4	5	2	9	7	6
-	▨	▨	▨	T	R	E	A	S	O	N
Ø	B	C	D	F	G	H	I	J	K	L
1	M	P	Q	U	V	W	X	Y	Z	.
8	Ø	1	2	3	4	5	6	7	8	9

Figure 72.

	Ø	1	2	3	4	5	6
-	R	A	T	I	O	N	S
7	B	C	D	E	F	G	H
8	J	K	L	M	P	Q	U
9	V	W	X	Y	Z	.	*

Figure 73.

	Ø	1	8	3	4
-	A	E	I	O	U
5	B	C	D	F	G
2	H	K	L	M	N
9	P	Q	R	S	T
7	V	W	X	Y	Z

Figure 74.

[2] See in this connection Foote, Alexander, Handbook for Spies, New York, 1949, pp. 250-256, wherein is described such a cryptosystem reputedly typical of those used by secret agents in World War II.

appearing in one of the remaining rows has as its cipher equivalent the dinome formed by its row coordinate and column coordinate, respectively; thus in Fig. 71, $G_p = 74_c$, $Q_p = 61_c$, etc.

b. It should be noted that the external construction of all of the foregoing matrices is such that any digit which appears as a row coordinate does not occur as the monome equivalent for any letter; this limitation, accomplished by blanking out appropriate cells in the top row, is necessary in all monome-dinome systems in order that cryptographic ambiguity will not arise. In Fig. 71, the internal composition is such that the plaintext letters which are most frequent in English are the ones which are provided with monome equivalents. This type of arrangement theoretically provides the most economical encryption for any given message--that is, theoretically yields the shortest possible cipher text for a given plain text--but, of course, greatly limits the number of internal arrangements which may be used. Fig. 75, below, which is split into two separate parts--one providing the monome equivalents and the other providing the dinome equivalents--illustrates another scheme for drawing up a monome-dinome cipher alphabet. In this alphabet, the digits which are used for the initial and final elements of dinomes are completely distinct from the digits used as monomes.

	5	2	9	7	6
5	A	B	C	D	F
2	G	H	I	J	K
9	L	M	P	Q	S
7	U	V	W	X	Y
6	Z	.	(	)	*

Figure 75a.

Ø	1	8	3	4
E	T	N	R	O

Figure 75b.

c. Most of the foregoing matrices contain a period for punctuation, and the matrix in Fig. 72, containing the single digits Ø-9, provides a means for encrypting numbers without first spelling them out. The matrices in Figs. 71, 73, and 75 contain another character, symbolized by an asterisk, which may be used for punctuation or as a special indicator[3]. The matrix in Fig. 74 uses only nine of the single digits as coordinates, the digit 6 being omitted; this single digit might be employed as a word separator, a stop, or a null. The matrix in Fig. 76, below, illustrates

[3] For example, this special character may be put to use as an indicator to show that plaintext numbers begin or end, thus obviating the necessity of including digits within the cipher matrix. In this usage digits in the plain text might be tripled and inserted in the cipher text with the appropriate indicator before and after the plaintext digits. Thus, using the matrix in Fig. 71, the plaintext fragment"..HILL 865.." would be encrypted as the cipher sequence 75 2 77 77 66 888 666 555 66 (prior to regrouping into five-character groups).

a scheme by which certain high-frequency plaintext digraphs and trigraphs may be represented in the matrix, as well as the single letters and digits. The symbol # in this latter matrix could be used as a "repetition indicator" for checking numbers, as in the ciphertext passage 69 65 68 76 69 65 68, meaning the number 752, the symbol * might be used as an indicator meaning "the immediately-preceding plaintext letter is repeated" (thus AA patterns would be suppressed in the cipher text). In all of the foregoing matrices the order of inscription of the letters within the matrix, and the particular arrangement of the row- and column-coordinates are both subject to variation.

	∅	1	8	3	4	5	2	9	7	6
-	R	E	T	A	I	N	▨	▨	▨	▨
2	B	C	D	F	G	H	J	K	L	M
9	O	P	Q	S	U	V	W	X	Y	Z
7	.	,	TH	IN	ST	ED	ION	ING	*	#
6	∅	1	2	3	4	5	6	7	8	9

Figure 76.

d. By prearranged convention it is possible to employ ordinary commutative bipartite matrices (such as those already described in Sections VII and VIII) in a manner which yields monome-dinome encipherment. For example, using the matrix illustrated in Fig. 77, the plaintext word EIGHT could be encrypted as 10 29 7 8 49. That is, the normal bipartite enciphering conventions would be used, with the exception that the row indicator in the cipher equivalent for a particular plaintext letter would not be employed when this row indicator is the same as that for the immediately preceding letter of the plain text.[4] As may be noted, no cryptographic ambiguity in decipherment may arise.

	6	7	8	9	∅
1	A	B	C	D	E
2	F	G	H	I	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

Figure 77.

e. Of course, as an extension of the foregoing ideas, there could also be monome-dinome-trinome systems, incorporating matrices of the types illustrated in Figs. 78-82, below. In Fig. 83 there is a matrix which may

[4] A variation of this method could make use of a convention by which the column indicator is dropped if it is the same as that for the preceding plaintext letter.

	∅	1	8	3	4
-	S	T	O	N	E
5	A	B	C	D	F
2	G	H	I	K	L
9	M	P	Q	R	U
7	V	W	X	Y	Z
6∅	∅	1	2	3	4
61	5	6	7	8	9

Figure 78.

	∅	1	8	3	4
∅	A	B	C	D	F
1	G	H	I	K	L
8	M	P	Q	S	U
3	V	W	X	Y	Z
45	∅	1	2	3	4
42	5	6	7	8	9

Figure 79a.

5	2	9	7	6
T	E	N	O	R

Figure 79b.

	∅	1	8	3	4	5
-	B	R	A	N	C	H
2	D	E	F	G	I	J
9	K	L	M	O	P	Q
7	S	T	U	V	W	X
29	Y	Z	∅	1	2	3
27	4	5	6	7	8	9

Figure 80.

	∅	1	8	3	4	5	2	9	7	6
-	R	E	L	A	T	I	O	N	▨	▨
7	B	C	D	F	G	H	J	K	M	▨
6	P	Q	S	U	V	W	X	Y	Z	.
76	∅	1	2	3	4	5	6	7	8	9

Figure 81.

	∅	1	8	3	4	5	2	9
-	E	T	N	R	O	A	I	S
7	B	C	D	F	G	H	J	K
6	L	M	P	Q	U	V		
62	W	X	Y	Z	∅	1	2	3
69	4	5	6	7	8	9	.	,

Figure 82.

	∅	1	8	3	4	5
2	A	B	C	D	E	F
9	G	H	I	J	K	L
7	M	N	O	P	Q	R
62	S	T	U	V	W	X
69	Y	Z	∅	1	2	3
67	4	5	6	7	8	9

Figure 83.

be used for dinome-trinome encipherment. Encipherment with this latter matrix is commutative; for example, E_p = 24 or 42, and T_p = 621 or 162.

f. Literal versions of the preceding types of alphabets with irregular-length cipher units are also possible. Several types are illustrated in Figs, 84-88, including among them matrices permitting the use

	B	L	A	C	K
-	A	L	I	G	N
W	B	C	D	E	F
H	H	J	K	M	O
I	P	Q	R	S	T
T	U	V	W	X	Y
E	Z	.	,	(	)

Figure 84.

			V	W	X	Y	Z
			Q	R	S	T	U
		-	E	T	N	R	O
L	F	A	A	B	C	D	F
M	G	B	G	H	I	J	K
N	H	C	L	M	P	Q	S
O	J	D	U	V	W	X	Y
P	K	E	Z	.	,	(	)

Figure 85.

		L	M	N	O	P
		F	G	H	I	K
F	A	B	D	E	F	G
G	B	I	J	K	L	N
H	C	O	P	Q	S	T
I	D	U	V	W	X	Y
K	E	Z	.	,	(	)

Figure 86a.

M	A	R	C	H_p
Q	R	S	T	U
V	W	X	Y	Z

Figure 87b.

		N	O	P	Q	R
		I	J	K	L	M
E	A	A	B	C	D	E
F	B	F	H	I	K	L
G	C	M	N	Q	S	T
H	D	V	W	X	Y	Z

Figure 87a.

G	R	O	U	P_p
S	T	U	V	W
X	Y	Z		

Figure 87b.

		Q	R	S	T	U	V	W	X	Y	Z
		G	H	I	J	K	L	M	N	O	P
	-	E	T	N	R	O	A	I	S	D	L
D	A	B	G	K	Q	W	Z	2	5	8	.
E	B	C	H	M	U	X	∅	3	6	9	,
F	C	F	J	P	V	Y	1	4	7	(	)

Figure 88.

of variants in encryption. Furthermore, any of the commutative variant matrices treated in par. 58a (i.e., Figs. 27, 28, and 31) may be used in connection with the convention described in subpar. d, above, to provide cipher alphabets with irregular-length ciphertext units.

76. General remarks on analysis.--a. The first step in the analysis of any cryptogram encrypted in a system with irregular-length cipher groupings involves dividing the cryptogram into the proper, vari-sized cipher units--that is, reducing the cryptogram to monoalphabetic terms. After this has been done, solution proceeds along the straightforward lines which have been described in earlier sections of the text. Thus, in this section, attention will be focused on this first step of dividing the text into its proper monoalphabetic units. In order to simplify somewhat the general treatment contained in this paragraph, all remarks will be directed at monome-dinome systems, most of the principles and methods outlined herein are general enough that they may be modified and applied in the solution of other types of systems with irregular-length ciphertext units.

b. A cryptographer, in his process of deciphering a particular monome-dinome cryptogram, would begin by considering whether or not the first digit of the cipher text were among those digits which can start a dinome--that is, whether it were a row coordinate or not. If it were, he would treat it along with the next digit of the text as a dinome, and then proceed to consider whether or not the following digit were a row coordinate, etc. If the first digit of the message were not a row coordinate, he would treat it as a monome, and then proceed to consider whether or not the next digit were a row coordinate, etc. One may now see that the cryptographic process of dividing the cipher text into its proper units is based solely on a knowledge of the digits which are the row coordinates of the pertinent matrix. Thus, it may further be seen that the cryptanalytic attack on a monome-dinome cipher would first involve an attempt to determine the identity of the row coordinates.

c. If a given cryptogram involves a matrix in which the high-frequency plaintext elements are evenly distributed throughout the various rows, it may be expected that the particular digits occurring with the greatest frequency in a uniliteral frequency distribution made on the cipher text are those which are row coordinates of the pertinent matrix. This may be explained by the fact that the digits used as row coordinates occur in the cipher equivalents for more plaintext letters than do those digits which are used as monomes. However, one must remember that a monome-dinome matrix may involve two, three, four, or more row coordinates and, although in a particular instance it may be that the most frequent cipher digits are those digits which have been used as row coordinates, a study of the uniliteral frequency distribution may not make it obvious as to just how many coordinates are involved, it may be necessary to make several trials, one considering only the two most frequent cipher digits as row coordinates, one considering the three most frequent, etc.

d. If trials of the type just mentioned do not yield reduced, monoalphabetic text which will succumb to the principles of plaintext recovery treated in the earlier sections of this text, it may then be assumed that the cryptogram involves a matrix in which several of the high-frequency letters are arranged together in the top row or in which one or more columns are composed solely of high-frequency letters. Such matrices are likely to produce cipher text in which some of the digits which have been used as monomes occur more frequently than some of those used as row coordinates. Thus, the easy mode of entry via the uniliteral frequency distribution may not be used, and other approaches of a less clear-cut nature must be taken.

e. In an attempt to identify at least one or two probable coordinates, the analyst should carefully scrutinize the cryptogram itself in order to find passages exhibiting bipartite characteristics, such as appear in the sequence 8043818741, wherein the digits 8 and 4 "act" like digits which have been used as row coordinates, being spaced off at intervals of two. A slightly more objective approach involves first making a biliteral[5] distribution of the cipher text, and then considering as a probable row coordinate the initial digit of the particular dinome which the distribution shows to be the most frequent. Of course, this approach is most likely to be valid when the particular dinome occurs with a much greater frequency than the remaining dinomes. While still on the subject of distributions, it is pointed out that the previously-mentioned "bipartite characteristics" manifested in a cryptogram might be disclosed by making a biliteral distribution of alternate digits of the cipher text[6], that is, in the sequence 123456 one would consider the dinomes 13, 24, 35, 46. In such a distribution, one may expect that the most frequent dinomes will be those comprising two digits which were both row coordinates of the pertinent enciphering matrix.

f. If the cipher text of a given monome-dinome cryptogram begins with a doubled digit, this digit is most probably one of the row coordinates of the pertinent matrix; otherwise, the doublet would have to be considered as comprising two monomes and the first word of the underlying plain text would have to begin with a doublet (a very rare contingency in the English language). Similarly, if the cipher text is seen to contain any digit repeated consecutively four or more times, the particular digit may be assumed to be a row coordinate; otherwise, such a sequence of repeated digits would have to represent at least a threefold repetition of some one plaintext letter (another rare event in English, although not as rare as that mentioned in the preceding sentence).

[5] The use of the term "biliteral" in connection with digit cipher text may not be in conformance with the strictest rules of semantics, but the author feels that it is unnecessary to give a new name to an already-familiar type of distribution merely because it is being applied to a different kind of text. However, some who prefer to be purists in this matter term a digraphic distribution which is made on digit text as a "dinome distribution" or "dinomic distribution", and a biliteral distribution made on digit text, a "running dinome distribution".

[6] In the vernacular such a distribution is termed an "A-A" (pronounced "ay-dit-ay") distribution.

g. On occasion it may be found that much time has been spent in the attempt to identify the row coordinates, yet apparently with not all of the coordinates being identified. In such a case, it may be found useful to consider those digits which are least likely to be row coordinates, specifically, those which occur least frequently in the cryptogram. The analyst may go through the troublesome cryptogram and place a slant bar (virgule) directly after each such digit as it occurs in the message. These marks may then be taken as an indication of places in the cryptogram where one bona fide cipher unit ends and the next begins. The analyst must then study the digits which directly follow these slant bars with a view to discovering new possibilities for row coordinates--possibilities which, although previously latent, have been made patent by this latest step.

h. In the foregoing subparagraphs, a to g, the secondary step of testing for the corroboration or invalidation of any particular trial decomposition has been passed over quite briefly. Actually, this step is best described with specific examples of solution, and for this reason is treated in two subsequent paragraphs, 77 and 78, with such examples. However, a few methods which can be applied for the rejection of incorrect hypotheses will be mentioned here, because they are rather basic and simple. If the cryptanalyst finds, after having divided a monome-dinome cipher on the basis of a particular hypothesis, that a long repetition in the cryptogram is not broken up in the same way on each of its occurrences, he may well reject as incorrect the hypothesis on which the division is based. Likewise, the analyst may reject any hypothesis which requires him to make the last digit of a cryptogram a monome when this particular digit has to be considered as a row coordinate as part of the basic assumption.[7] The presence of an inordinate number of consecutive monomes may cause one to suspect that a particular decomposition is incorrect; however, probably only continued exposure to traffic of a certain type or involving one kind of enciphering matrix would provide one with a sound basis for knowing just how many are too many.

i. There is one practical, straightforward measure for determining the relative goodness of an assumed decomposition which deserves particular mention. It involves considering the ratio of the number of monomes produced in a particular decomposition to the number of remaining cipher units. In the case of monome-dinome ciphers, for example, in which an assumption of only two row coordinates is made, there can be no more than eight different plaintext letters represented by monomes and the total frequency of those monomes can not exceed the frequency expected of the eight most frequent letters in the language.[8] Since in English the eight most frequent letters occur with a total relative frequency of 66%, any trial decomposition giving rise to a ratio of monomes to dinomes which is

[7] However, the possibility of a final null or nulls must not be ignored; the presence of nulls at the end of the cipher text would invalidate this reasoning.

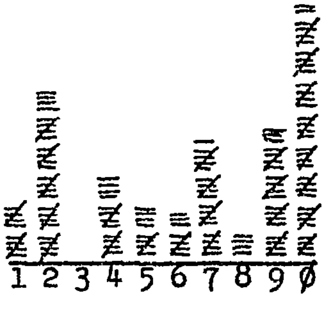
[8] The only exception to this statement would be a case wherein a word separator is included as part of the cryptosystem, and that this separator is represented by a monome. This usage, however, seems rather unlikely.

considerably more than 66 to 34 (= 1.9) may be considered incorrect. Likewise, since an assumption of three row coordinates limits to seven the number of different plaintext letters which may have monome equivalents and since the seven most frequent letters in English occur with a total relative frequency of 60%, any such assumption giving rise to a ratio of monomes to dinomes which is considerably more than 60 to 40 (= 1.5) may be considered invalid. The author does, however, hasten to point out that a ratio which is smaller in any instance than the pertinent ratio, above, does not disprove the particular trial decomposition since the plaintext letters represented by monomes may not necessarily be the letters of highest frequency. The examples in the next two paragraphs will serve to clarify the foregoing considerations.

77. Analysis of simple examples.--a. The following cryptogram, suspected to be a monome-dinome cipher, is available for study:

	5	10	15	20	25	30
A	24090	15709	08121	02092	92405	56001
B	27072	90482	47607	09022	10209	29724
C	07292	91257	52961	09042	72002	07247
D	50570	96081	72409	29040	40971	24097
E	29128	76090	40750	65297	09067	20902
F	09040	74076				

Cursory examination of the cipher text reveals nothing more significant than the fact that the digit 3 is absent; however, the significance of this escapes us for the moment. A uniliteral frequency distribution of the text is then made, as is illustrated below:



b. The uniliteral frequency distribution shows four marked peaks (2,7,9, and ∅) and one pronounced trough (8). A biliteral frequency distribution is made, as shown below, to assist in further evaluation of the properties of the cipher text. It is noted that the 2 and ∅ rows,

	1	2	3	4	5	6	7	8	9	∅
1	-	5	-	-	1	-	1	-	-	3
2	2	1	-	7	1	-	2	1	9	6
3	-	-	-	-	-	-	-	-	-	-
4	-	1	-	-	-	-	2	1	-	10
5	-	2	-	-	1	1	3	-	-	2
6	1	-	-	-	1	-	1	-	-	4
7	1	8	-	1	3	3	-	-	-	5
8	2	1	-	-	-	-	1	-	-	-
9	2	5	-	-	-	2	4	-	-	10
0	2	5	-	6	2	2	7	2	14	2

representing the two highest-frequency digits in the cipher text, have the most liberal combinations with the remaining digits; this would indicate that 2 and ∅ are likely row coordinates of the cipher matrix. Since the 7 and 9 rows show less affinity of these digits for other digits, 7 and 9 are less likely to represent row coordinates of the matrix; consequently the assumption is made that the matrix involved only two numbered row coordinates, 2 and ∅.

c. The cryptogram is now divided accordingly, and the assumption of 2 and ∅ as row coordinates is borne out by the bipartite character of the following passages in the cipher text:

(1) .../21/02/09/29/24/05/... (at A14)
(2) .../07/09/02/21/02/09/29/... (at B14)
(3) .../09/04/27/20/02/07/24/... (at C16)
(4) .../24/09/29/04/04/09/... (at D12)

A frequency distribution of the decomposed text is made, as illustrated below:

	1	2	3	4	5	6	7	8	9	∅
-	7	□	-	1	6	6	12	1	1	□
2	2	-	-	7	1	-	2	1	9	2
∅	1	5	-	6	2	2	7	2	13	1

The percentage of monomes, 35%, does not exceed the threshold for the sum of the frequencies of the eight highest-frequency plaintext letters; furthermore, since the eight monomes have a much lower frequency than the sum of the eight highest-frequency letters in English, this is an indication that some of the monomes represent plaintext letters of lower frequency.

d. The decomposed text may now be solved, and the message is found to begin with the words "SABOTAGE PLANS..." The original matrix is reconstructed, and is discovered to be based upon the key word VERMOUTH, as follows:

	9	1	6	4	5	8	7	3	∅	2
-	V	E	R	M	O	U	T	H		
∅	A	B	C	D	F	G	I	J	K	L
2	N	P	Q	S	W	X	Y	Z	.	

The reason for the absence of the digit 3 in the cipher text may now be seen: the digit 3 forms a part of only the letters H, J, and Z, and these letters did not occur in the plaintext message.

e. Solution of certain other cases of mixed-length systems progresses as easily as did the solution of the foregoing example.

(1) For instance, in the case of a cryptogram produced by a matrix with which the digits used for both the initial and final digits of dinomes are completely distinct from the monome digits (e.g., Fig. 75), it may be seen that "eliminating" from the cipher text those particular digits which were used as monomes in the original enciphering alpnabet will leave the remainder of the cryptogram broken up into units all of which contain an even number of digits. (This would not be true in the case of other types of matrices, such as Figs. 71-74, since eliminating the digits which were used as monomes in the pertinent alphabet would remove not only actual cipher monomes but also the final digits of many cipher dinomes.) Based on this fact, if one is confronted with a cryptogram which he assumes to have been produced by a matrix such as that in Fig. 75, he may use a mechanical method by means of which he will quickly be able to determine which digits are row coordinates and which are not, or, if his basic assumption concerning the type of matrix involved is incorrect, the error will quickly become known to him. He need only make successive trials each of which involves considering a different one of the 10 digits as being one of those which is a monome in the pertinent alphabet, "eliminating" the particular digit from the cryptogram in each trial will inevitably lead to other digits which must also be eliminated throughout the cryptogram in order to maintain the stipulation that all the cipher units which remain must contain an even number of digits. For example, if one assumes that "∅" is a digit which was a monome, then he must further assume from a sequence of cipher digits such as ∅5∅35∅ that "5" is also a digit which was a monome; and then likewise "3". Any particular one of the ten trials which is based on an incorrect initial assumption may be expected to end up with all ten digits being considered as digits which were monomes.

(2) In the case of a monome-dinome system in which the row coordinates of the enciphering matrix are distinct from the column coordinates (as in Figs. 73 and 74), solution is expedited by capitalizing on the fact that the digits within the family comprising the row coordinates do not (and cannot) contact themselves or any other digits within the family; using Fig. 73 as an example, it is obvious that the digits 7, 8, and 9 can never be followed by a 7, 8, or 9. A cryptogram enciphered by such a system may be expected to contain much fewer cipher doublets than would a cryptogram produced by a matrix without the foregoing limitation, and the doublets which do occur will themselves involve but a limited number

of the 10 different digits. When solving such a cryptogram, the cryptanalyst need only consider as possible candidates for row coordinates those particular digits which do not appear in cipher doublets. Furthermore, he may with certainty go through the cryptogram placing a slant bar (to indicate the end of a valid cipher unit) after every occurrence of any digit which has appeared in a cipher doublet.

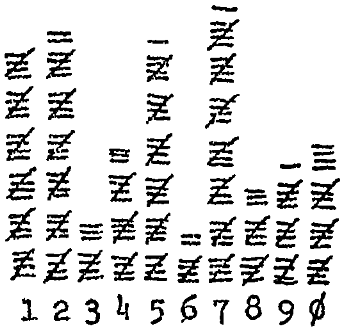
(3) If the cryptanalyst is confronted with a monome-dinome cipher which is the result of encipherment by means of a commutative bipartite matrix (see subpar. 75<u>d</u> and the accompanying Fig. 77), he knows that the first digit of the cryptogram must be a row coordinate. The analyst then has only to go through the cryptogram noting the digits which follow this row coordinate digit wherever it occurs in the cryptogram and, in this way, he may be able to identify all the column coordinate digits. Of course, by the process of elimination, he will then know which digits are row coordinates besides the initial digit of the cryptogram, and it will then be possible for him to divide the text into its proper irregular-length ciphertext units.

<u>78. Analysis of more complicated examples</u>.--<u>a</u>. In some cases, the rather simple methods of analysis applied in the preceding paragraph will not bear fruit, either because of the complexity inherent in the number of plaintext elements in the cipher matrix, or because of certain unpredictable abberrations caused by the particular designations of the row and column coordinates. For instance, if a specific matrix contained only the highest-frequency letters in the top row, and if the matrix contained a fairly large number of plaintext elements (and therefore embodied 3 or 4, or more, row coordinates), and if the elements in the dinome rows were balanced from the frequency standpoint, so that the rows would be used with approximately equal frequency, and if furthermore certain of the columns were composed of heavier elements than others (thus producing peaks that might incorrectly be identified as row coordinates)--all these conditions would yield a cryptosystem that might pose considerable difficulties in the way of straightforward analysis. A case will now be studied that will illustrate typical techniques that would be necessary in more difficult circumstances.

<u>b</u>. The following cryptogram has been intercepted on an enemy net known to be passing monome-dinome traffic:

```
62719 44081 21204 71270 55042 12627

09637 06212 24712 91724 21058 12727

07055 58719 55721 04109 52847 71297

23571 82123 94578 77571 80581 97654

74572 05191 77194 52958 70012 12251

69051 15724 71389 47316 79035 47359

54742 78271 72327 05504 58255 55918
```

The uniliteral frequency distribution for the cryptogram is shown below:



c. From the appearance of the uniliteral frequency distribution, it is to be expected that from among the four peaks (1, 2, 5, and 7) some row coordinates must be represented, and since there is not much variance in frequency among these peaks, perhaps all four represent row coordinates. In an attempt to obtain as much information as possible from a study of the frequency characteristics of the cipher text, a biliteral distribution is made and is shown below.

	1	2	3	4	5	6	7	8	9	0
1	1	11	1	-	1	2	3	3	5	3
2	7	2	3	3	2	1	9	1	3	2
3	1	1	-	-	3	-	1	1	1	-
4	1	3	-	1	9	-	6	5	2	1
5	3	2	-	3	9	-	6	5	2	2
6	-	3	1	-	1	-	1	-	1	-
7	10	7	2	2	1	1	3	2	1	7
8	3	3	-	1	-	-	3	-	1	1
9	3	-	-	4	4	1	2	-	-	2
0	1	-	1	4	7	1	1	1	2	1

Examination of this latter distribution adds support to the impressions gained from the uniliteral frequency distribution, namely, that the row coordinates for the cipher matrix are very likely to be found among the digits 1, 2, 5, and 7. Furthermore the digit 7, because of its high frequency and because of satisfactory combinative qualities in the biliteral distribution, is selected as a definite row coordinate--this will reduce the number of trials that must subsequently be considered.

d. If all of the row coordinates of the cipher matrix are found among the various combinations of 7 with 1, 2, and 5, then it is clear that:

(1) if there are but two coordinates of the matrix, these must be either 7 and 1, 7 and 2, or 7 and 5, (three cases);

(2) if there are three coordinates of the matrix, these must be either 7-1-2, 7-1-5, or 7-2-5 (three cases); or

(3) if the matrix has four numbered coordinates, this must entail the combination of 7-1-2-5 (only one case).

e. On the basis of each of the foregoing seven hypotheses, the cipher text is divided and the resulting frequency distributions are shown below:

	1	2	3	4	5	6	7	8	9	Ø
-	▨	17	6	16	31	4	▨	10	13	9
1	1	8	-	-	-	2	2	1	2	3
7	9	7	2	2	-	1	2	2	1	7

Case I

	1	2	3	4	5	6	7	8	9	Ø
-	18	▨	5	16	30	5	▨	11	12	15
2	6	2	1	-	1	1	8	1	3	1
7	6	6	2	2	-	1	3	1	1	3

Case II

	1	2	3	4	5	6	7	8	9	Ø
-	21	25	6	13	▨	6	▨	7	14	12
5	3	2	-	3	6	-	5	5	1	-
7	6	5	2	2	-	1	3	1	1	7

Case III

	1	2	3	4	5	6	7	8	9	Ø
-	▨	▨	4	15	29	3	▨	10	10	13
1	1	6	-	-	-	2	3	1	3	2
2	4	1	2	1	2	1	6	1	2	-
7	7	5	2	2	-	1	2	1	1	4

Case IV

	1	2	3	4	5	6	7	8	9	Ø
-	▨	16	6	13	▨	5	▨	4	13	9
1	-	9	-	-	1	1	2	3	1	3
5	3	2	-	3	6	-	4	5	1	-
7	7	5	2	2	-	1	2	1	1	7

Case V

	1	2	3	4	5	6	7	8	9	Ø
-	17	▨	5	12	▨	5	▨	8	11	14
2	6	2	1	1	1	1	8	-	2	2
5	3	2	-	3	5	-	5	5	2	-
7	4	4	2	2	-	1	3	-	1	3

Case VI

	1	2	3	4	5	6	7	8	9	Ø
-	▨	▨	4	12	▨	3	▨	5	10	12
1	-	7	-	-	1	2	3	3	2	2
2	4	1	2	1	2	1	6	-	1	1
5	2	2	-	3	5	-	4	5	2	-
7	5	4	2	2	-	1	2	-	1	4

Case VII

f. In order to be able to evaluate the relative merits of the seven hypotheses and choose the case which is most likely to be correct, it is possible to resort to a method wherein group frequencies of the high-frequency elements from each of the decompositions are studied. In the following table drawn up for this purpose, the column of figures under "x" denotes the cumulative twelve highest-frequency ciphertext units; under "N", we have the actual frequencies of the first, the first two, the first three..., the first 12 highest-frequency ciphertext units for each hypothesis (compare with the distributions in subpar. e); in the adjoining column to the right of each "N" column, the various cumulative frequency values are expressed as percentages of the total number of ciphertext

	I		II		III		IV		V		VI		VII		P
x	N	$\frac{N}{158}$	N	$\frac{N}{161}$	N	$\frac{N}{157}$	N	$\frac{N}{147}$	N	$\frac{N}{138}$	N	$\frac{N}{139}$	N	$\frac{N}{129}$	
1	31	19.6	30	18.6	25	15.9	29	19.7	16	11.6	17	12.2	12	9.3	13.0
2	48	30.4	48	29.8	46	29.3	44	29.9	29	21.0	31	22.3	24	18.6	22.2
3	64	45.0	64	39.8	60	38.2	57	38.8	42	30.4	43	30.9	34	26.6	30.2
4	77	48.7	79	49.1	73	46.5	67	45.6	51	37.0	54	38.8	41	31.8	37.8
5	87	55.1	91	56.5	85	54.1	77	52.4	60	43.5	62	44.6	47	36.4	45.3
6	96	60.8	102	63.4	92	58.6	84	57.1	67	48.6	70	50.4	52	40.3	52.7
7	105	66.5	110	68.3	99	63.1	90	61.2	74	53.6	76	54.7	57	44.2	60.1
8	113	71.5	116	72.0	105	66.9	96	65.3	80	58.0	81	58.3	62	48.1	66.2
9	120	75.9	122	75.8	111	70.7	101	68.7	86	62.3	86	61.9	67	51.9	70.4
10	127	80.4	128	79.5	117	74.5	105	71.4	91	65.9	91	65.5	71	55.0	74.0
11	133	84.2	133	82.6	122	77.7	109	74.1	96	69.6	96	69.1	75	58.1	77.4
12	137	86.7	138	85.7	127	80.9	113	76.9	101	73.2	101	72.7	79	61.2	80.5

units which remain after the particular trial decomposition. The column labelled "P" gives the cumulative theoretical frequencies of the first 12 letters in English plain text.

g. It is noted that in Case I, the most frequent ciphertext unit has a percentile frequency of 19.6%, the highest two units, a percentile frequency of 30.4%; the highest three, a percentile frequency of 45.0%. When these percentages are compared with the percentile frequency of the highest-frequency letter in English plain text (13.0%), of the highest two letters (22.2%), and of the highest three letters (30.2%), it is clear that Case I does not conform to the characteristics expected of a simple monoalphabetic substitution, therefore Case I is not the correct division of the cipher text. Similarly, Cases II, III, and IV can also be rejected because the cumulative values are much higher than the corresponding expectations for plain text. Case VII, on the other hand, demonstrates values much lower than the corresponding expectations for plain text; therefore this case too is rejected. This leaves only Cases V and VI, both of which show a close correspondence with plaintext expectations.

h. If there were nothing else in the manifestations of the decomposed cipher text in Case V and Case VI, these two cases would have to be tried in turn, making some tentative plaintext assumptions; of course, only the correct case would consistently yield plain text. However, there is an additional bit of reasoning which may be applied here as a means of deciding which of these two remaining cases is more likely to be correct and ought to be worked on first--namely, it may be reasoned that cipher text which has been decomposed according to an incorrect hypothesis will be likely to contain a larger ratio of monomes to dinomes than would the same text if it had been decomposed according to the correct hypothesis.[9]

[9] This intuitive reasoning has been borne out by empirical observation. 30 monome-dinome ciphers of an average length of 100 digits were decomposed in all possible ways based on the hypotheses of two, three, and four row coordinates. In the case of ____ of these ciphers, the correct decomposition yielded a monome-to-dinome ratio which was lower than the monome-to-dinome ratio yielded by any of the incorrect decompositions.

Case V has a monome-dinome ratio of .916 whereas Case VI has a corresponding ratio of 1.043; thus Case V is indicated as the case which is more likely to be correct.

i. The cipher text is now divided according to the hypothesis of row coordinates of 1, 5, and 7, and the plain text is quickly recovered, facilitated by the pattern of the first word, RECONNAISSANCE. The cipher matrix is reconstructed as follows:

	1	7	5	Ø	2	8	4	9	6	3
-	▨	▨	▨	A	E	I	N	O	R	T
1	B	F	J	M	S	W	Z	1	4	7
7	C	G	K	P	U	X	.	2	5	8
5	D	H	L	Q	V	Y	Ø	3	6	9

The reason for the high frequency of the cipher digit 2 is now seen: the combined frequencies of E_p, S_p, and U_p contribute to an inordinate peak for that column coordinate.

j. In retrospect, several important points may be noted in the solution of this particular cryptogram. First of all, the four consecutive 5's in the last two groups of the cryptogram make it a very strong probability that 5 is a row coordinate, otherwise the four 5's would mean a threefold (or even fourfold) repetition of a monome letter, a comparatively rare contingency. Secondly, the digit 1 could have been selected as a row coordinate with considerable certainty, based on the fact that, since the dinome 12 was the highest-frequency element in the biliteral distribution, it may be assumed that at least a number of 12's were causal and therefore 1 must be a row coordinate. In other words, the correct set of coordinates might have been established at the very beginning of the analysis, but for pedagogical reasons it was felt necessary to proceed along the general lines of the solution as given. It is to be noted that, since at the start of solution we did not know exactly how many numbered row coordinates there were in this particular case, we could not apply the ratio of monomes to dinomes at once as the deciding criterion.

k. If mixed-length systems were encountered in actual practice, after the type of matrix became known through solution of several days' traffic, solution of subsequent days' messages would be facilitated because by this time the analyst would be familiar with the general type of matrix used. This knowledge would be of great assistance in making assumptions as to the nature of subsequent matrices. In some cases, the internal arrangement of the matrix might remain fixed, with only the coordinates being changed periodically, in other cases, the internal arrangement and the coordinates of the matrix might change, with only the size of the matrix remaining fixed. If it were known, for instance, that the enemy were using a monome-dinome system with only two numbered row coordinates, then there would only be $\frac{10 \times 9}{1 \times 2}$ or 45 exhaustive trials (if these had to be made) which would be necessary to guarantee reaching the correct decomposition of the cipher text; if there were three numbered coordinates, then there would be a maximum of $\frac{10 \times 9 \times 8}{1 \times 2 \times 3}$ or 120 trials necessary to insure reaching the proper scheme for the decomposition of the cipher text.[10] Such trials, although laborious (and ordinarily unnecessary) when made by manual methods, would be by no means prohibitive if there were available machine processes for assistance. Exhaustive trials would rarely be necessary, except in very difficult cases; in the majority of instances, straightforward methods of cryptanalysis would reduce the large number of theoretical trials to but a few, from which the correct selection could be made.

l. If the exact composition of the internal arrangement of the matrix were known, this knowledge would be useful in determining how the letters of assumed cribs would be enciphered as monomes or dinomes. In any case, if a word of pronounced idiomorphic pattern is assumed, no matter how the letters of the word are encrypted as monomes or dinomes, the idiomorphism must be patent in the cipher text; for example, the word ARTILLERY in a monome-dinome system must have a consecutively repeated monome or dinome representing L_p, closely flanked on both sides by some particular monome or dinome representing R_p. If unenciphered numbers were to appear in the encrypted text, bracketed by an indicator to signal that numbers begin and end, the recognition of these plaintext numbers would enable the analyst to identify the indicator, and thus, lead to the establishment of one row coordinate.

m. It must be pointed out that mixed-length systems, even more so than other types of systems treated in this text, often present unusual problems for the cryptanalyst. Each case is a distinctly special case,[11] but continued practice in the solution of these types of systems should, as in other situations, cultivate skill and develop abilities in this field.

n. The student may have noted that no mention has been made concerning the possible use of the ϕ test as a means for determining whether or not a particular trial decomposition represents the proper reduction of a cryptogram to monoalphabetic terms. The ϕ test has been ignored throughout this Section because, when dealing with cipher alphabets which include plaintext elements other than single letters (e.g., such elements as syllables, numbers, indicators, etc.), the value of ϕ_p can only be loosely approximated, furthermore, computation of the value of ϕ_r in a mixed-length cipher is also a rather tenuous matter. For this reason, it has been considered best to describe only methods of solution which do not depend at all on the use of the ϕ test, and thus keep from establishing in the mind of the student any doubt as to the usefulness of this test when applied in other instances, such as those described in earlier sections of this text.

[10] The number of combinations of N things taken r at a time is given by the formula $_NC_r = \frac{N!}{r!(N-r)!}$; thus for the assumption of 3 numbered rows in a monome-dinome matrix, $_{10}C_3 = \frac{10\cdot9\ 8\ 7\ 6\ 5\cdot4\ 3\cdot2\cdot1}{3\cdot2\cdot1\ (7\ 6\cdot5\ 4\cdot3\cdot2\cdot1)} = \frac{10\cdot9\cdot8}{3\cdot2\cdot1} = 120.$ The notation N! is read as "factorial N."

[11] And, as one cryptowag has pointed out, some cases are more special than others.

79. Further remarks on cryptosystems employing irregular-length ciphertext units.--*a*. The subject of the diagnosis or identification of mixed-length cipher systems has not been discussed. This problem can sometimes be extremely difficult in complex cases; however, the general statement can be made that one takes advantage of any phenomena of repetitions that are present in a cryptogram to arrive at the conclusion that a mixed-length system has been encountered. If the repetitions present are separated by numbers of letters without a constant factor, or if the interval between repetitions is a prime number, and if the possibility of a null or nulls (of a different size than the real cryptographic units) has been considered and ruled out, then in all probability the cryptogram involves some sort of mixed-length cipher units. As to exactly *which* kind of mixed-length system is involved, this question can be answered only by detailed analysis, sometimes to the point of actual plaintext recoveries in order to be certain about one's conclusions.[12]

b. It is not imperative that a mixed-length cipher system be produced through the medium of a matrix with row and column coordinates. For example, in one cryptogram that was submitted for solution, the cipher text began as follows:

QKT2Q 3KB3K QKTQK T3QKT 2KB3Q KTQR2

KKT2K KT2KB 3QKTQ BQRK3 KQ2QK T2QR2....

The entire cryptogram, containing 490 characters, consisted only of the seven symbols B, K, Q, R, T, 2, and 3. When this cryptogram was solved, the following alphabet was recovered:

A = K3	G = KR2	N = Q2	U = Q
B = KR3	H = Q3	O = QR2	V = QB2
C = QB3	IJ = QKT3	P = QR	W = K
D = KB2	KQ = K2	R = QKT	X = KB
E = KB3	L = KKT3	S = QB	Y = KKT
F = KKT2	M = QR3	T = QKT2	Z = KR

To the reader who is a devotee of the royal game, it will be apparent that the foregoing alphabet is based upon chess notation.[13] If however the digits 1-7 had been used in lieu of the symbols above, the cryptogram could still have been correctly divided into its component ciphertext groupings of 1, 2, 3, and 4 digits, based upon an interpretation of the characteristics present in the cipher text, and of the phenomena in a triliteral distribution showing one prefix and one suffix.[14]

[12] Cf. the discussion of diagnosis in subpar. 69*f*.

[13] The chess-playing reader might be interested in recovering the key word for this alphabet.

[14] The interested student could make up a cryptogram using seven characters in this fashion, so he could see for himself the methods of attack on such a system.

c. The concept of irregular-length cryptographic units can be applied to many varieties of systems, both code and cipher. For example, in Fig. 89, below, there is illustrated a four-square matrix in which plaintext digraphs are represented by ciphertext dinomes, trinomes, or tetranomes. The positioning of the monomes in the ciphertext portions of the matrix was governed by the frequencies of individual components of four-square cipher digraphs,[15] thus permitting optimum compression of the cipher text, i.e., allowing the most liberal use of ciphertext dinomes and trinomes rather than the maximum cipher length of tetranomes; for example, the word REGIMENTAL would be encrypted RE GI ME NT AL.
76 814 06 68 1018

A	B	C	D	E	10	12	5	3	13
F	G	H	I	K	14	15	16	8	17
L	M	N	O	P	18	19	40	6	Ø
Q	R	S	T	U	42	43	9	2	7
V	W	X	Y	Z	45	46	47	48	49
10	6	5	7	12	A	B	C	D	E
13	14	15	16	17	F	G	H	I	K
18	19	40	2	Ø	L	M	N	O	P
42	43	8	3	9	Q	R	S	T	U
45	46	47	48	49	V	W	X	Y	Z

Figure 89

d. The matrix for another mixed-length cipher system, employing dinomes and trinomes for the encryption of plaintext digraphs, is shown

[15] See Appendix 2, Table 13, "Four-square individual frequencies."

in Figs. 90a and b. Using this matrix, the word DIVISION is encrypted as 07 883 3$\overline{2}$ 746. It is noted that consonant-vowel digraphs involving

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425
B	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451
C	▨	452	453	454	▨	455	456	457	▨	458	459	460	461	462	▨	463	464	465	466	467	▨	468	469	470	471	472
D	▨	473	474	475	▨	476	477	478	▨	479	480	481	482	483	▨	484	485	486	487	488	▨	489	490	491	492	493
E	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519
F	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545
G	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571
H	▨	572	573	574	▨	575	576	577	▨	578	579	580	581	582	▨	583	584	585	586	587	▨	588	589	590	591	592
I	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618
J	619	620	621	622	623	624	625	626	627	▨	628	629	630	631	632	633	634	635	636	637	638	▨	▨	▨	▨	▨
K	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664
L	▨	665	666	667	▨	668	669	670	▨	671	672	673	674	675	▨	676	677	678	679	680	▨	681	682	683	684	685
M	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711
N	▨	712	713	714	▨	715	716	717	▨	718	719	720	721	722	▨	723	724	725	726	727	▨	728	729	730	731	732
O	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758
P	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784
Q	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	785	▨	▨	▨	▨	▨
R	▨	786	787	788	▨	789	790	791	▨	792	793	794	795	796	▨	797	798	799	800	801	▨	802	803	804	805	806
S	▨	807	808	809	▨	810	811	812	▨	813	814	815	816	817	▨	818	819	820	821	822	▨	823	824	825	826	827
T	▨	828	829	830	▨	831	832	833	▨	834	835	836	837	838	▨	839	840	841	842	843	▨	844	845	846	847	848
U	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874
V	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900
W	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926
X	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952
Y	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978
Z	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	▨	▨	▨	▨	▨

Figure 90a.

	A	E	I	O	U
C	00	01	02	03	04
D	05	06	07	08	09
H	10	11	12	13	14
L	15	16	17	18	19
N	20	21	22	23	24
R	25	26	27	28	29
S	30	31	32	33	34
T	35	36	37	38	39

Figure 90b.

eight high-frequency consonants with five vowels are represented by dinomes, and all other plaintext digraphs are represented by trinomes. In those rare cases where, as in the example MU ZZ LE, an "impossible" digraph appears in the plain text, the insertion of the letter K_p in the plain text at that point in question, similar to the normal Playfair doublet convention, enables the encryption of the word, as MU ZK ZL E. A better variation of the foregoing system might incorporate a dinome matrix for the 40 highest-frequency digraphs (comprising 42% of English plain text) such as that illustrated in Fig. 91, and a trinome matrix modified

	Ø	1	2	3	4	5	6	7	8	9
Ø	AN	AR	AS	AT	CO	DE	EA	ED	EE	EN
1	ER	ES	ET	FI	FO	HI	IN	IO	IS	LE
2	MA	ND	NE	NT	ON	OR	OU	RA	RE	RT
3	SE	SI	ST	TE	TH	TI	TO	TW	TY	VE

Figure 91.

in suitable fashion for the remaining digraphs. Such a scheme would yield a greater condensing property for the cipher text, but would not be as easy to use as the system described above since the easy mnemonic feature of the matrix in Fig. 90b would be lost.

e. Another idea for a cryptosystem having irregular-length cipher-text groupings employs the diagram in Figs. 92a and b. This scheme incorporates Playfair digraphic encipherment (with biliteral cipher equivalents) and monographic encipherment (with uniliteral cipher equivalents). In order to disturb the regularity of usual digraphic encipherment (produced by the Playfair-type matrix in Fig. 92a), certain selected medium-frequency consonants are enciphered monographically and uniliterally by the reciprocal alphabet shown in Fig. 92b. Using Fig. 92, as an example, the phrase BRIGADE OF ENEMY INFANTRY MOVING...would be broken up and enciphered as follows:

A	C	D	E	F
H	I	K	L	N
O	P	Q	R	S
T	U	X	Y	Z

Figure 92a

B	G	M	V	W
W	V	M	G	B

Figure 92b

```
B RI G AD EO FE NE M YI NF AN TR YX M OX V IN G
W PL V CE AR AF LF M UL SN FH YO ZY M QT G KH V
```

The cipher text, regrouped into fives, WPLVC EARAF LFMUL SNFHY OZYMQ TGKHV, reveals no indication of the uniliteral-biliteral encipherment involved. Since the letters BGMVW represent 8.2% of normal plain text, there is approximately 8% interruption of the regularity of normal digraphic text. Furthermore, since it is expected that about half the time these letters will occur as singles in the plain text, and about half the time as interruptor letter (such as X_p in the example above) will have to be used, this scheme is accomplished by adding only about 4% to the length of the original plain text. Other variations of the basic idea are found in Figs. 93 and 94; in Fig. 93, the Playfair matrix is a 6 x 4 rectangle omitting S and Y, and these two letters form a reciprocal monographic encipherment convention; in Fig. 94, the Playfair matrix is the normal 5 x 5, but with the convention that, unless E_p is the second member of a digraph in the process of encryption, E_p is represented monographically

A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
T	U	V	W	X	Z

S	Y
Y	S

Figure 93

A	B	C	D	E
F	G	H	I	K
L	M	N	O	P
Q	R	S	T	U
V	W	X	Y	Z

E_p
J_c

Figure 94

by J_c. In the foregoing two figures, the SY of Fig. 93 could be replaced of course by any other two letters whose combined frequency is in the neighborhood of 6-10%, and the monographic E_p of Fig. 94 could be replaced by any other high- or medium-frequency letter. Instead of Playfair matrices, the digraphic portions of the enciphering schemes of this subparagraph could be accomplished by the use of any other small-matrix digraphic methods.

f. The Morse code, consisting as it does of irregular-length units composed of dots and dashes, lends itself to interesting cryptographic treatments. For example, the dots and dashes (and, of necessity, the spaces between Morse characters) might be encrypted by means of the table illustrated in Fig. 95, wherein each of the three elements has approximately the same number of variants. A better idea, however, is to employ variants in the proportions of dots (42.4%), dashes (29.1%), and spaces (28.4%) of the letters comprising normal English plain text; such a scheme for variants is shown in Fig. 96. Thus, using the example of Fig. 96, the word ENEMY (which in Morse code is · -·   -- -·--) might be encrypted as RS MDW CQ NFV PIKGZ, which would then be regrouped in fives for transmission. Other ideas for the encryption in digit form of Morse code systems might incorporate alphabets such as those illustrated in Figs. 97 and 98 below:[16]

dot:	A B C D E F G H I
dash:	J K L M N O P Q R
space:	S T U V W X Y Z

Figure 95

dot:	H Y D R A U L I C B E
dash:	F G J K M N O P
space.	Q S T V W X Z

Figure 96

dot:	1 2 3 4
dash:	5 6 7
space:	8 9 0

Figure 97

dot:	1 3 5 7 9
dash:	2 4 6 8
space:	0

Figure 98

g. Space does not permit detailed examples of analysis of some of the foregoing systems. Admittedly, some of them would pose considerable difficulty in the way of solution, however, if these systems were used in actual practice, then operational cryptanalytic methods and entries would make possible successful solution.

[16] Further ideas of cryptosystems based on the Morse code will be treated in Military Cryptanalysis, Part IV.

SECTION XI

MISCELLANEOUS MONOALPHABETIC SYSTEMS, CONCLUDING REMARKS

80. Cryptosystems employing syllabary squares and code charts.--a. The various cryptosystems treated in the preceding sections of this text have in the main fallen into *either* the multiliteral category *or* the polygraphic category This and the next few subparagraphs will treat of systems which represent a merger of these two categories--namely, biliteral systems which have as plaintext elements not only single letters and digits, but also certain polygraphs selected for the condensation in cipher text that their usage may permit In addition, treatment will be made of biliteral systems which involve, as plaintext units, a selection of frequent words (that is, which occur frequently in the type of traffic for which the particular cryptosystem is intended) and perhaps some common phrases, such as "reference your message number", "request acknowledgment", "nothing to report", etc. Systems which embrace digraphs, trigraphs and other polygraphs as plaintext elements in addition to single letters and digits are called *syllabary systems* because the additional inclusion of these polygraphs permits the encryption of plain text in a syllabic or quasi-syllabic fashion, most systems of this type involve bipartite matrices in the cryptographic scheme, and these matrices are called *syllabary squares*. When the matrix in this general type of system *also* incorporates words among the plaintext elements, the matrix is termed a *code chart*.

b. The category of systems embodying syllabary squares and code charts as the cryptographic vehicle actually constitutes a transition between *cipher* and *code* systems,[1] since a syllabary square or a code chart may be regarded equally properly as either a special type of cipher or a primitive code. However, because syllabary systems follow very closely on the ideas of bipartite matrices, these systems are included in this particular text instead of being reserved for treatment in a subsequent text.

[1] See definitions of the terms *cipher* and *code* in the glossary.

c A sample syllabary square is illustrated in Fig 99, below:

	1	2	3	4	5	6	7	8	9	Ø
1	A	1	AL	AN	AND	AR	ARE	AS	AT	ATE
2	ATI	B	2	BE	C	3	CA	CE	CO	COM
3	D	4	DA	DE	E	5	EA	ED	EN	ENT
4	ER	ERE	ERS	ES	EST	F	6	G	7	H
5	8	HAS	HE	I	9	IN	ING	ION	IS	IT
6	IVE	J	Ø	K	L	LA	LE	M	ME	N
7	ND	NE	NT	O	OF	ON	OR	OU	P	Q
8	R	RA	RE	RED	RES	RI	RO	S	SE	SH
9	ST	STO	T	TE	TED	TER	TH	THE	THI	THR
Ø	TI	TO	U	V	VE	W	WE	X	Y	Z

Figure 99.

It will be noted that the square contains the 26 letters, the 10 digits, and 64 digraphs and trigraphs chosen both on the basis of frequency considerations and the combinative potentialities of the particular polygraphs; the internal arrangement of the square is such as to permit the easy finding of the plaintext elements to be enciphered. Other matrices, of larger dimensions, may contain not only a larger number of different plaintext elements within the matrix, but may also duplicate some of the more frequent plaintext elements and thus incorporate plaintext variants within the matrix. Furthermore, when letters are used as coordinates, variant cipher equivalents may be incorporated into the scheme

d. Typical of the many ideas that have been employed in the past for code charts is the chart which is shown in Fig. 100, below, and which

	C,D	E,H	F,I	J,K	T,L	M,O	U,V	Y,G	Z,N	P,Q	X,R	W,S	B,A
M,H	ØØØ Act n i e i ity s	Ø2 Adddio i	15 Ad ce d i q s	45 Afte	A Agg es ive (ly)	AD Ar	Spell/fig B g s	AL A ib ne	AM A rq fi/ Anpl c s	AN Amn t on	AND A t c ft	AR A t tank	ARE Area (of)
T,Q	ØØ A mo d	Ø3 Arri e l d l g	16 A till y	5Ø Assemble d ing s	AS Atta k ed g	AT Attempt d g s	B Ar m th (deg)	BA Batt lion	E B tt y i	BY B g n/start d g s	C Bomb ed e i g	CA B idge d i g	CAN Captu d i g s
K,Z	Ø Cas alty ies	Ø4 Command r i g s	17 Comm icate, d ing i	55 Company i s	CE C mplete d g i s	CH Co c trate d i g io	CO C tact d g	D C o d at d q i	DA C rp	DAY Cou t ck, d g	DE C q s ed g	DI D fe d/d f s (of)	DO D l y d i g s
O,L	1 Destroy ed g s	Ø5 Det ch d m t (of)	18 D spose al d ti	E D l	FA D mp	ED E st (l)	EE Encou t r d i g	EN E my s	ENT Eng eer s	ER E i sted M /M	ERS Equ p me t, p d p g	ES E cap d g s	EST Est mat , d ing s (l)
R,X	2 E pect ed i g (t)	Ø6 F ght e g	19 Fi d i g	ET Fl k	F Force d g	FO Forw rd	FOR F d ly	G F m	H F nt l	HA F l	HE Gu s	I H /h e	IL H dqu t s
S,P	3 He y ly	Ø7 H ll (N)	2Ø H ld i g s'h ld	IN H tle ty t	ING H	ION H w	IS Id t fy d g at o	IT I med t ly	IVE I I ury	J I f rm t d g	K I st ll t d g s	L J ctl s (l)	LA L d d i g
W,N	4 La ge	Ø8 L ft (of)	21 L e s (of)	LE Local d g lo s	LI Mach ne gun, s (t)	LO Ma	LY M p ped p g s	M Me ha ze d	MA M sag ng s	ME Mil (f om) (to)	MENT M d i g s	MI M ss on s	MY Mo ning
A,B	5 Mo t	Ø9 M d i g m t	22 N ar	N Night	NA N t, th g g t	ND N tl (f)	NE N mb (f)	NI Obj t	NO Ob rve t d i g	NOT Oc py d i g	NT Off	O Ope ate d i g i	OF O de ed i g
C,E	6 O c	1Ø Pat l led ling s	23 F elr te d i g l s	ON Pl ed, n g s (t)	OR Plat n s	OU P int ed s	OUR P t s	P Post ed g s	PE P cpa e, d t c g s	Q P s e s	QU P ceed ed g	R Rad o ed	RA Railway/ R l o d s
1,G	7 R dy (fo) (to)	11 Rea	25 R ve d g, c pt	RE R s c	RED R f e ed g (t)	RES R g m t l s	PI R f c d g m t s	RO R pl ce d g m s	RS R po t ed g	RT Request ed, g	S Requ e d g t o	SA Reserve d g	SE R dg
D,J	8 Right (of)	12 R / St e m	3Ø R d / Rout s	SH Sc t i g s	SI S t s Se t s	SO Send ng sh t (t)	ST Sh ll d i g s	T Sm ll/ Sm ll m	TA S th (of)	TE Sq d s	TED St e gth s (l)/ tr g	TER St p ped p g s	TH Supply s (l)
F,V	9 ppo t, d i g s	13 Ta k	35 T get s	TI Tod y	TION Tomorrow	TO Tonight	TR T op s	U T ck s/ V h le s	UN U t (l)	US U i t	V U ge t cy ly	W V n ly (l)	WE Wate
U,Y	Ø1 West (of)	14 What/who	4Ø Whe	X Whe e	Y W ll	Z W th	Spell/f'g Ends	Per d W thd w l g	Comma W d	Colon Ya d s (f m) (o)	Smcl , Y t d y	D th — Y	Pa n ( ) Z (l)

Figure 100

has been used as a standard tactical cryptosystem for ground forces by AGGRESSOR, the maneuver enemy in U.S. joint maneuvers and training exercises. This chart provides 2-letter equivalents for letters, numbers, syllables, and a selection of words which occur frequently in low-echelon[2] messages. A particular plaintext value may be designated by a combination of one of the two row coordinates and one of the two column coordinates of the cell containing the plaintext value; thus each plaintext element has four variant equivalents and, for example, the word ARTILLERY contained in the chart may be encrypted in toto as TF, TI, QF, or QI When a complete word contained in the chart is to be encrypted in a message, no designator is necessary to indicate this lowercase meaning However, when upper-case meanings (i.e., letters, numbers, and syllables) are to be encrypted, it is necessary first to encrypt the designator "Spell/fig Begins", followed by the cipher equivalents of the particular upper-case meanings; when the spelling is completed, the designator "Spell/fig Ends" is encrypted, to show the return to lower-case meanings. The coordinates of the chart, as used by AGGRESSOR, were random sequences and were changed daily, the inside of the chart remained unchanged

e For the most part, the steps used in the recovery of plain text from messages involving syllabary squares differ from those used in the solution of previously-discussed multiliteral and polygraphic systems only in that a larger number of plaintext elements may have to be considered. The cryptanalyst must accordingly modify his interpretation of the frequency characteristics and idiomorphic patterns occurring in such messages. By a careful study of the behavior of frequently recurring cipher units, the analyst is led to conclude that certain units, because of the general characteristics they exhibit, must be representative of numbers, others of punctuation, others of single letters, and so on. This classification is based upon a knowledge of the general behavior of the various classes of plaintext elements For example, cipher units representing digits may be expected to appear in clusters (as in dates and time, and the designations of topographical features, such as hills, road junctions, etc.); whereas those which represent punctuation may be expected to appear at varying intervals throughout the message text (the particular intervals being dependent upon the particular punctuation mark) When this classification has proceeded upon a solid foundation far enough, each set of cipher units is underlined throughout the text in some distinctive manner by means of colored pencils. Subsequent to this, the individual members of each class of cipher units are subjected to closer scrutiny, and based upon a knowledge of the specific behavior of the various elements in each class, specific units are identified as having specific plaintext meanings. For example, among those cipher units which the analyst has decided constitute the class which represents plaintext digits, the particular cipher unit

[2] The term low-echelon as applied to a cryptographic system means that the system is designed for use at the lower organizational levels such as (in the army) at the regimental level and below. The term low-grade as applied to cryptosystems means that the inherent security afforded by the system is low. Cf. the terms medium-echelon and -grade, and high-echelon and -grade.

representing plaintext "Ø" may be expected to be readily recognizable on the basis that (1) it is one of the three units which appear as the first unit in those clusters which are suspected of representing four-digit time designations and (2) it is one of the two cipher units which, with any noteworthy frequency, occur doubled at the end of the same four-unit clusters.

f When working on messages involving code charts, the cryptanalyst usually starts by attempting to isolate sequences of cipher units which represent plaintext letters, syllables, numbers and punctuation Subsequent to this he proceeds to classify and identify these particular cipher units in the manner described in the foregoing subparagraph; the recovery of word meanings is usually accomplished much later. The isolating of the ciphertext units which represent syllabary portions may be readily accomplished in those cases wherein the underlying code chart has only one "Spell/fig. Begins" group and one "Spell/fig Ends" group, since the recognition of these designators automatically permits one to divide the cipher text into word values and non-word values, the recognition of these designators is made on the basis of their high frequency and their alternating placements throughout the cipher text

g. As plaintext meanings are recovered in a syllabary square system or code chart system, these meanings should be entered into a skeleton matrix in a manner similar to that used in the solution of the bipartite systems previously described (Sections VII and VIII). This is done in order to uncover and exploit as early as possible any evidences of systematic construction arising from the arrangement which was used in the underlying matrix. It may be assumed that each syllabary square and code chart will normally have had its internal elements arranged in some type of systematic fashion in order to permit the ready finding of plaintext elements during the encryption of a message

h. When there are special circumstances involved, for instance, when the contents or the exact internal construction of the matrix is known, or when the arrangement of the outside coordinates is known, or when messages with isologous syllabary portions (i.e., spelled-out portions encrypted "off-the-cut", such as IN TER CE P TO R and I NT ER CE P T OR) are present in the cipher text, solution is naturally considerably facilitated. Even when only a single message is available, if the matrix is known there may be special approaches to solution, based on the nature of the plaintext elements constituting each row and each column of the particular matrix. For instance, if the words REFERENCE and YOUR and MESSAGE are known to be in the same row of a particular code chart, then it would be quite possible that the ciphertext sequence LA LH LT at the beginning of a message represents the stereotype REFERENCE YOUR MESSAGE, if but a few other similarly identifiable sequences were also available to the cryptanalyst, he could possibly recover the arrangement of the outside coordinates after a relatively few steps.

81 Cryptosystems employing characters other than letters or figures.--
a In practical cryptography today, the use of characters other than the letters of bona fide alphabets (including recognized Morse and Baudot

alphabets) or the 10 digits is comparatively rare. When so-called symbol ciphers, that is, ciphers employing peculiar symbols, signs of punctuation, diacritical marks, figures of "dancing men", and so on are encountered in practical work nowadays, they are almost certain to be simple monoalphabetic ciphers. They are adequately described in romantic tales,[3] in popular books on cryptography, and in the more common types of magazine articles. No further space need be given ciphers of this type in this text, not only because of their simplicity but also because they are encountered in military cryptography only in sporadic instances, principally in censorship activities. Even in the latter cases, it is usually found that such ciphers are employed in "intimate" correspondence for the exchange of sentiments that appear less decorous when set forth in plain language. They are very seldom used by authentic enemy agents When such a cipher is encountered nowadays it may practically always be regarded as the work of the veriest tyro, when it is not that of a crank or a mentally-deranged person.

b. The usual preliminary procedure in handling such cases, where the symbols may be somewhat confusing to the mind because of their unfamiliar appearance to the eye, is to substitute letters for them consistently throughout the message and then treat the resulting text in the manner in which an ordinary cryptogram composed of letters is treated. This procedure also facilitates the construction of the necessary frequency distributions, which would be tedious to construct by using symbols.

c. A final word must be said on the subject of symbol ciphers by way of caution When symbols are used to replace letters, syllables, and entire words, then the systems approach code methods in principle, and can become difficult of solution[4] The logical extension of the use of symbols in such a form of writing is the employment of arbitrary characters for a specially developed "shorthand" system bearing little or no resemblance to well-known and therefore nonsecret, systems of shorthand, such as Gregg, Pitman, etc. Unless a considerable amount of text is available for analysis, a privately-devised shorthand may be very difficult to solve. Fortunately, such systems are rarely encountered in military cryptography. They fall under the heading

[3] The most famous: Edgar Allan Poe's The Gold Bug; Sir Arthur Conan Doyle's The Adventure of the Dancing Men, Jules Verne's A Journey to the Center of the Earth.

[4] The use of symbols for abbreviation and speed in writing goes back to the days of antiquity. Cicero's freedman and amanuensis, Tiro, is reported to have drawn up "a book like a dictionary, in which he placed before each word the notation (symbol) which should represent it, and so great was the number of notations and words that whatever could be written in Latin could be expressed in his notation." The designation "Tironian notes" is applied to this type of shorthand.

of cryptographic curiosities, of interest to the cryptanalyst in his leisure moments.[5]

82 Special remarks concerning the initial classification of cryptograms.--a The student should by this time have a good conception of the basic nature of monoalphabetic substitution and of the many variations which may be played upon this simple tune The first step of all, naturally, is to be able to classify a cryptogram properly and place it in either the transposition or the substitution class. The tests for this classification have been given and as a rule the student will encounter no difficulty in this respect.

b. There are, however, certain kinds of cryptograms whose class cannot be determined in the usual manner, as outlined in par. 25 of this text. First of all there is the type of code message which employs bona fide dictionary words as code groups. Naturally, a frequency distribution of such a message will approximate that for normal plain text. The appearance of the message, however, gives clear indications of what is involved The study of such cases will be taken up in its proper place. At the moment it is only necessary to point out that these are code messages and not cipher, and it is for this reason that in pars. 24 and 25 the words "cipher" and "cipher messages" are used, the word "cryptogram" being used only where technically correct.

c. Secondly, there come the unusual and borderline cases, including cryptograms whose nature and type can not be ascertained from frequency distributions. Here, the cryptograms are technically not ciphers but special forms of disguised secret writings which are rarely susceptible of being classed as transposition or substitution. These include a large share of the cases wherein the cryptographic messages are disguised and carried under an external, innocuous text which is innocent and seemingly without cryptographic content--for instance, in a message wherein specific letters are indicated in a way not open to suspicion under censorship, these letters being intended to constitute the letters of the cryptographic messages and the other letters constituting "dummies." Obviously, no amount of frequency tabulations will avail a competent, expert cryptanalyst in demonstrating or disclosing the presence of a cryptographic message, written and secreted within the "open" message, which serves but as an envelop and disguise for its authentic or real import. Certainly, such frequency tabulations can disclose the existence neither of substitution nor transposition in these cases, since both forms are absent. The next paragraph contains more about these latter cases.[6]

[5] An example is found in the famous Pepys Diary, which was written in shorthand, purely for his own eyes by Samuel Pepys (1633-1703) "He wrote it in Shelton's system of tachygraphy (1641), which he complicated by using foreign languages or by varieties of his own invention whenever he had to record passages least fit to be seen by his servants, or by 'all the world.'"

[6] The subparagraph which the student has just read (82c) contains a hidden cryptographic message. With the hints given in par. 83 let the student see if he can uncover it

83. Disguised secret communications --a As was mentioned above, there is a general class of methods of secret writing in which a secret message is concealed within the text of an apparently innocuous plaintext message, also, by extension, a secret message may be concealed within otherwise bona fide media such as maps, drawings, charts, music manuscripts, bridge hands, chess problems, shopping lists, stock quotations, and so on The addressee of such a communication, knowing where to look for the secret elements, does so and from them is able to read the message contained within its covering disguise. When the plaintext elements of the secret message are concealed by surrounding them with the plaintext elements of an innocent cover text, such a system is known as a concealment system When, however, the actual plaintext elements of the secret message are not themselves concealed within a cover text, but instead have code equivalents which are themselves actual plaintext words or phrases and which are used to form an apparently innocent message, such systems are called open code systems.

b. An example of a concealment system message is the communication "HAVE ESTABLISHED LOW PRIORITY", in which the secret message "help" has been concealed as the first letter of each word of the covering text As an example of an open code, in the message "AUNT MARY LEFT FOR DETROIT ON FRIDAY", the words AUNT MARY might stand for "five troop ships", DETROIT might mean "Southampton", and FRIDAY might stand for "Monday." An often-cited case of open code is the message "A SON IS BORN", which allegedly was sent out by German-controlled radio stations all over the world in August, 1914, meaning that war was about to be declared

c. The solution of concealment systems may pose considerable difficulties for the cryptanalyst, who is placed in the rather odd situation where he might have before him a simple system, if he can but find the system. Most of the statistical and other tools at the disposal of the cryptanalyst are of no avail to him in the attack on concealment systems. First of all, he might not even know whether or not a given letter does contain a secret message, often the only reason for an examination of a particular message, other than a random sampling case, is that the originator or the addressee is on a suspect list and therefore the communication is considered for possible secret writing. The difficulty in analysis is usually not brought about by the complexity of the system, for concealment systems are almost always cryptographically simple. The difficulty of the problem arises from the lack, at the outset, of tangible cryptographic elements into which the cryptanalyst can "get his teeth" There is primarily the question of whether or not a secret text actually exists,[7] and, if it does, where are the elements constituting the secret text As a consequence, locating the elements of the secret text and deriving the meaning of the secret text are practically synonymous. Success in this type of analytic work requires extraordinary patience and perseverance, keen powers of observation nurtured by unrelenting suspicion, a lively imagination, exceptional ingenuity, and organized methods of analysis--plus a firm foundation and considerable experience in the methods and practices of concealment systems

d The number of different concealment systems possible is enormous. The letters of the secret message might be concealed as the first, second, or third letters of the cover text, or they might be concealed as the final penultimate, or antepenultimate letters of the words, or they might be concealed by means of a specific key into prearranged variable placements within the words of the innocent text. The secret text might be read by considering the letters which follow or precede all unnecessary breaks in cursive handwriting; or the secret text might be indicated by shaded letters or by pin pricks over significant letters, or even by elongated tails on words pointing to significant letters in the line above. In the analysis of such concealed-letter systems, it is advisable to write the successive words of the cover text one below the other, in a column, aligned by their beginnings and subsequently to rewrite them columnwise aligned by their endings, this will assist in disclosing a secret text hidden in a fixed position relative to the beginnings or endings, or in diagonal routes near those locations (see Fig 101). It is also advisable to write out the

[7] In this connection, it is worthwhile to cite an extract from an official report prepared in 1946 by the wartime Office of Censorship:

> "Detection of concealed messages is based on the principle that there is no absolutely safe disguise for duplicity. Espionage letters have weaknesses and identifying characteristics, which modern techniques can minimize but never completely eliminate. Seasoned examiners develop an ability to relate facts and think clearly about possibilities They develop a keen perception of, or alertness to, certain peculiarities, an attitude of suspicion toward certain indicators, and experience or training in handling certain types of materials.
>
> "The texts of letters containing concealed messages do not ring true; they lack spontaneity, and the normal emphasis which people give to certain thoughts or ideas is absent Something comparable in social life is the stilted behavior and speech of a person who is obliged to entertain a stranger with whom he feels nothing in common, he behaves unnaturally, he desires to be polite, but in order to do so he must hide his boredom and pretend an interest he does not feel. Exactly the same is true in the writing of cover texts or open code letters--the attempt to pursue two aims simultaneously results in strain. Skill and experience may overcome the strained-text hazard to a high degree, but they can never completely dispel the distortion and dislocation of a normal emphasis inevitable in a cover letter."

cover text in rectangular arrangements of various widths, in order to disclose secret text which might have been concealed in every nth letter of the entire cover text (see Fig. 102). In cases where physical indicators are employed, such as breaks in handwriting or as shaded letters, an examination of the letters in the immediate vicinity of such indicators would disclose the secret text

Cover text:

UNCLE EZRA SEEMS DESPONDENT.
HAVE YOU HEARD THE LAST REPORT?

```
          U N C L E
            E Z R A
          S E E M S
D E S P O N D E N T
            H A V E
              Y O U
          H E A R D
              T H E
            L A S T
        R E P O R T
```

Secret text: NEED HELP

Figure 101.

Cover text:

WHEN YOU SEE CHESTER AT
MADISON'S HOUSE TELL HIM
LOIS DEPARTED.

```
W H E N Y O
U S E E C H
E S T E R A
T M A D I S
O N S H O U
S E T E L L
H I M L O I
S D E P A R
T E D
```

Secret text: NEED HELP

Figure 102.

e. Some systems involve the concealment of entire words, instead of just individual letters, in the cover text Thus, for example, the secret text might consist of (1) every nth word of the cover text, (2) the first and last words of every line, (3) words preceding or following punctuation marks, (4) words bisected by an imaginary line running diagonally from the upper left to the lower right of the sheet of paper; or countless varieties of similar schemes. Grilles have also been used, the secret text being written through the apertures of the grille on placed positions on the sheet of paper, and then a covering letter written to surround and camouflage the secret text. In the solution of concealed-word systems, examining the text produced by counting off every nth word may bear fruit; if the secret text is long enough, the validity of the assumed secret text may be proved by the consistency of the decimation. In cases wherein a variable key has been used to indicate which words constitute the secret text, proof of the assumed secret text may be impossible, unless the key is short compared to the message lengths, or unless additional messages in exactly the same key are available for comparison to test an assumed key.

f. There have been many cases in which a secret text has first been converted into the dots, dashes, and spaces of the Morse code, or encrypted in a Baconian or a tripartite cipher; then this converted text was concealed within an innocent text in any one of the almost infinite number of possible ways Some of these ways in which the multiliteral elements of the preliminary conversion may be represented are by (1) the lengths of words,

(2) the number of vowels or consonants in the words; (3) the number of syllables in the words; or (4) by the ways in which t's are crossed or i's are dotted. The solution of such systems involves experimentation with basic hypotheses concerning the manner in which multiliteral elements are denoted, followed by a recombination into monoalphabetic terms (under the assumption of a Morse, tripartite, or Baconian system) and solving the reduced monoalphabetic text Another method for a concealment system involves the use of a bipartite matrix employing coordinates consisting of vowels (or, for that matter, any other set of five or six letters), the secret text is first enciphered in this biliteral system, and then the vowels are surrounded by consonants to form the plain text of an innocent cover message. As in most concealment systems, once such a subterfuge is suspected or assumed, then and only then is solution possible

g The detailed discussion thus far has been limited to concealment systems [8] In cases of open code, unfortunately there are no clear-cut methods of analysis or even of recognition, there is simply no rational way of proving that a message such as "AUNT MARY LEFT FOR DETROIT TODAY" contains a secret meaning, unless it is known for a fact that the sender has no aunt named Mary, and even then there still might exist a friend of the sender's who is affectionately called "Aunt Mary"--or, for that matter, she might be someone else's aunt [9] And once having suspected or even proved that there is something rotten in Denmark, proof of the content of the hidden meaning is simply out of the question unless the sender is somehow convinced to mend his ways and thereupon volunteers the information In many wartime instances where open codes have been used, a legal case could not be proved against a suspect without his cooperation.

h. A prominent case of the use of open code in espionage communications is that of an Axis spy, Mrs. Velvalee Dickinson, who in August, 1944, was sentenced in New York to ten years' imprisonment and was fined $10,000 after pleading guilty to the charge that a series of letters she had written to an agent in Buenos Aires in the early part of 1942 contained secret messages hidden in the plain text. These messages gave information regarding the location and condition of allied warships in Pacific ports These two agents professed to be dealers in antique dolls and used a prearranged code giving secondary meaning to words pertaining to the sale of dolls Mrs. Dickinson would send out letters advertising or offering to sell certain of her antique dolls to the addressee. She would write the doll's name and after the name a brief description, then she would write, as in an ordinary business letter, the price of each

[8] Further discussion of this subject will be found in Appendix 9, "Concealment Systems."

[9] In one instance, it has been related that a censor reviewed a telegram transmitted by a person on a suspect list The telegram read "FATHER IS DECEASED." The censor, smelling a rat, changed the text to read "FATHER IS DEAD", and waited. Sure enough, several hours later came a query: "IS FATHER DEAD OR DECEASED?"

doll The original cause for suspicion was the extreme variation in prices over a range of three or four letters of what was apparently the same doll or the same type of doll A great many letters were necessary in order to build up a case sufficient to prove the use of open code. It is doubtful even then that the use of open code could have been legally proven except for the fact that, faced with so much evidence against her, she chose to confess this use.

i. In addition to concealment systems and open codes, there are three other methods for hiding the existence of secret text. These methods embrace the following:

(1) secret inks;
(2) microscopic writing, involving use of micropantographs; and
(3) photographic methods, including "microdots" (i.e., the reduction of a page of copy to a negative the size of a miniature dot, which is then affixed on a period or on the dot of an "i"), double printing, double exposure, or concealment within photographs.

The methods of use and analysis of these systems, however, are beyond the scope of this text.

84 Concluding remarks --a The student will have by this time appreciated that monoalphabetic substitution ciphers are for the most part quite easy to solve, once the underlying principles are thoroughly understood. As in other arts, continued practice with many examples leads to facility and skill in solution, especially where the student concentrates his attention upon traffic all of the same general nature, so that the type of text which he is continually encountering becomes familiar to him and its peculiarities or characteristics of construction give clues for short cuts to solution It is true that a knowledge of the general phraseology of messages, the kind of words used, their sequences, and so on, is of very great assistance in practical work in all fields of cryptanalysis In operational cryptanalysis, it is of vital importance to gain a knowledge of the language habits of a particular group of correspondents, to permit the rapid exploitation of the cryptosystem involved. Thus, at least initially, all possible traffic is cryptanalyzed, even that in simple systems and that of comparatively little intelligence value Word lists obtained empirically are of more value than "intuitive" or academic compilations, however, at the outset, reference may of course be made to these latter compilations [10]

b. Some of the simpler subterfuges which the student should be on the lookout for in monoalphabetic substitution are the following:

(1) There may be employed in the cryptographic scheme the consecutive use of several different mixed cipher alphabets in a single long message Obviously, a single, composite frequency distribution for the whole message will not show the characteristic crest and trough appear-

[10] See in this connection the word and idiomorph lists comprising Appendix 3.

ance of a simple monoalphabetic cipher, since a given cipher unit will represent different plaintext letters in different parts of the message. But if the cryptanalyst will carefully observe the distribution as it is being compiled, he will note that at first it presents the characteristic crest and trough appearance of monoalphabeticity, and that after a time it begins to lose this appearance If possible he should be on the lookout for some peculiarity of grouping of letters which serves as an indicator for the shift from one cipher alphabet to the next. If he finds such an indicator he should begin a second distribution from that point on, and proceed until another shift is encountered. By thus isolating the different portions of the text, and restricting the frequency distributions to the separate monoalphabets, the problem may be treated then as an ordinary simple monoalphabetic substitution.[11] Consideration of these remarks in connection with instances of this kind leads to the comment that it is often more advisable for the cryptanalyst to compile his own data, than to have the latter prepared by clerks, especially when studying a system ab initio. For observations which will certainly escape an untrained clerk can be most useful and may indeed facilitate solution. For example, in the case under consideration, if a clerk should merely hand the completed over-all uniliteral distribution to the cryptanalyst, the latter may be led astray, the appearance of the composite distribution might convince him that the cryptogram is much more complicated than it really is. While still on the subject of frequency distributions, it is pointed out that, although earlier (par 43) the triliteral frequency distribution was cited primarily for its usefulness in extracting frequency data relative to the digraphs and trigraphs occurring in a simple substitution cipher, this particular type of distribution is used extensively in the manual attack on many other types of cryptograms because it provides one of the best means for systematically locating all of the repetitions which appear in a message.

(2) There have been cases where direct and reversed standard alphabets have been used alternately in a single cryptogram, the change of alphabets being made at irregular intervals, or changed at the end of every word or with each group of five letters. If the interruption takes place at too short an interval, not only will a frequency distribution be of no avail, but also it would be almost impossible for the cryptanalyst to determine when and how the change of alphabets occurs from a mere examination of the cipher text However, if the cryptanalyst is on the alert to try the simplest thing first, completing the plain-component sequence on the assumption of standard alphabets will yield a solution where otherwise a solution might be out of the question

(3) Another subterfuge that has been encountered is the encryption by means of a monoalphabetic uniliteral substitution of a message whose

[11] The cryptanalyst should be on the alert for the possibility of related alphabets in such a system, if this is the case, the reconstruction of the primary components from the solution of one portion of the message would enable the reading of other portions of the message by means of the generatrix method treated in par 50

plain text has first been written backwards (or for that matter, an ordinary simple substitution cipher sent backwards) Ciphers of this type may successfully resist the unsystematic attempts of solution which a tyro might make, however, the experienced analyst would probably quickly recognize the weak subterfuge if he were to examine the frequencies of cipher digraphs, trigraphs, and tetragraphs, in relation to the uniliteral frequencies of their component letters

c. Monoalphabetic substitution with variants represents an extension of the basic principle, with the intention of masking the characteristic frequencies resulting from a strict monoalphabeticity, by means of which solutions are rather readily obtained Some of the subterfuges applied on the establishment of variant or multiple values are simple and more or less fail to serve the purpose for which they are intended; others, on the contrary, may interpose serious difficulties to a straightforward solution. But in no case may the problem be considered of more than ordinary difficulty; however, it should be recognized that where these subterfuges are really adequate to the purpose, the complications introduced are such that the practical manipulation of the system becomes as difficult for the cryptographer as for the cryptanalyst

(1) A few words may be added here in regard to a method which often suggests itself to laymen, but which is very old indeed in the art. This consists in using a book possessed by all the correspondents and indicating the letters of the message by means of numbers referring to specific letters in the book One way consists in selecting a certain page and then giving the line number and position of the letter in the line, the page number being shown by a single initial indicator Another way is to use the entire book, giving the cipher equivalents in groups of three numbers representing page, line, and number of letter (for example, 75-8-10 means page 75, 8th line, 10th letter in the line) Such systems are, however, extremely cumbersome to use and, when the enciphering is done carelessly, can be solved The basis for solution in such cases rests upon the use of adjacent letters on the same line, the accidental repetitions of certain letters, and the occurrence of unenciphered words in the messages, when laziness or fatigue intervenes in the enciphering [12]

(2) It may also be indicated that human nature and the fallibility of cipher clerks is such that it is rather rare for an encipherer

[12] In 1915 the German Government conspired with a group of Hindu revolutionaries to stir up a rebellion in India, the purpose being to cause the withdrawal of British troops from the Western Front Hindu conspirators in the United States were given money to purchase arms and ammunition and to transport them to India For communication with their superiors in Berlin the conspirators used, among others the system described in this paragraph A 7-page typewritten letter built up from page, line, and letter-number references to a book known only to the communicants, was intercepted by the British and turned over to the United States Government for use in connection with the prosecution of the Hindus for violating our neutrality . The author /W.F.F./ solved this message without the book in question, by taking full advantage of the clues referred to

to make full use of the complement of variants placed at his disposal. The result is that in most cases certain of the equivalents will be used so much more often than others that diversities in frequencies will soon manifest themselves, affording important data for attack by the cryptanalyst

d There is one aspect of cryptography within the realm of monoalphabetic substitution ciphers that should be discussed at this point--the aspect involving repetitive monoalphabetic substitution.

(1) Suppose a message undergoes a primary encipherment by means of a single mixed, non-reciprocal cipher alphabet, and this primary cipher text then undergoes a secondary encipherment by means of the same or a different mixed alphabet The resulting cryptogram is still monoalphabetic in character, and presents very little, if any, augmentation in the degree of security (depending upon the type of alphabet employed).[13] Here an entirely illusory increase in security is involved and an ineffectual complexity is introduced, the process may indeed be repeated indefinitely without producing the desirable result of added security Similarly, the same illusory increase in security is present in the case of repetitive multiliteral encipherments involving regular-length ciphertext units, as long as the repetitive encipherments are made "on the cut".

(2) In the case of repetitive polygraphic encipherment made on the cut, a moderate increase in security is achieved over the degree of security normally provided by a single polygraphic encipherment. For instance, in the case of repetitive digraphic encipherment using, let us say, a four-square system for the first encipherment and modified Playfair system for the second step, the final encipherment is still monoalphabetic digraphic in character, except that the cryptosystem might have to be resolved as involving a more-or-less random square table, instead of being recovered in its primary and secondary steps, all the repetitive encipherment has accomplished is that it has added to the difficulty of reconstruction of the matrices used--but this, in the case of a digraphic system, is a reasonably fair increase in security, since we expect solution to be expedited through an early recovery of the matrix

(3) When, however, successive multiliteral or polygraphic encipherments are made "off the cut" for the second step, the increase in security can be considerable, since the end result no longer exhibits the phenomena of monoalphabeticity and the cryptanalytic complexity of the

[13] The only possible slight increase in security lies in the fact that the key words for the primary and secondary encipherments might be made more difficult to recover or even impossible to recover

system has been thereby materially enhanced [14] For example, using the two-square matrix illustrated in Fig 55 on page 162, the message REENFORCEMENTS NEEDFD undergoes the following encipherments·

```
                RE  FN  FO  RC  EM  EN  TS  NE  ED  ED

     Cipher I   IL  DP  UM  CF  KT  DP  GI  UL  DF  DF

     Cipher II    OC  OT  MC  MR  TD  QF  TO  OC  AH
```

The first encipherment, IL DP UM. , is subjected to a second encipherment by considering the digraphs "off the cut", resulting in the encryptment OC OT MC In the final cryptogram, the first and last letters of the primary encipherment may be retained as is, or they may be combined for the second encryption, for added security, thus the final cryptogram may read either IOCOT OCAHF, or ROCOT . OCAHG When this sort of secondary encipherment is applied in a repetitive multiliteral cipher, the systen is called a fractionating system [15] The cryptanalysis of these systems, which is often quite complex, will be treated in subsequent texts.

c. If the cryptanalyst is fortunate enough to have a pair of isologs, one message of which is in a monoalphabetic substitution system and the other in a transposition system, it may be possible for him to make exact identifications of the elements in the substitution cipher based on the plaintext letter frequencies present in the transposition cipher. Then, having the plain text, the solution of the transposition is greatly facilitated

[14] A rather ingenious idea proposed by Charles Eyraud in his excellent work, Precis de Cryptographie Moderne, Paris, 1953, pp 224-225, involves a repetitive encipherment using two different monome-dinome matrices. In Eyraud's example, using the two matrices illustrated, the plain text

	1	2	3	4	5	6	7	8	9
-	▨	▨	E	S	A	N	T	I	R
1	U	D	L	F	V	Q	M	P	C
2	H	G	O	B	X	W	J	Z	K

Matrix I

	1	2	3	4	5	6	7	8	9
-	▨	P	▨	B	G	M	U	Z	A
1	C	H	N	V	R	D	J	O	W
3	I	F	K	Q	X	S	F	L	T
	Y		Y						

Matrix II

```
 E  C R I T  U R  E S  S E  C  R  E T E S
 ----------------------------------------
 3 19 9 8 7 11 9  3 4  4 3 19  9  3 7 3 4
31  9 9 8 7 11 9 34 4 31 9  9 37 34
 ----------------------------------------
 I  A A Z U  C A  Q B  I A  A  F  Q
```

"ECRITURES SECRETES" is first enciphered with Matrix I, then the digits are recombined into letters using Matrix II with the resulting cipher text IAAZU (It is interesting to note that the 17 letters of the plain text are encrypted by only 14 letters in the final cipher') The letter Y_p is eliminated from Matrix I, and is included in Matrix II to take care of a final 1 or 3 in the first encipherment which otherwise could not have been encrypted as a single element.

[15] See Appendix 7 for other examples

f As has already been stated in subpar 2c, mathematics and mathematical methods have an important place in the art of cryptanalysis. This text has included only those introductory statistical and mathematical applications which apply to monoalphabetic systems If it appears to the student that there has been a rather extensive treatment of too-specialized techniques, let him be reassured that these have been included as being in the nature of collateral information, rather than being an absolute necessity in the solution of the particular problems to which they were applied As a final woid of caution to the student the following extract from a repoit by C. H. O'D. Alexander is included:

"There is a considerable danger that a learner, when he realizes that statistical methods can be of some use, will attempt to use them where they are quite inappropriate If he does this a few times and finds it gets him nowhere, he then gives the whole thing up as a waste of time and does not use such methods where he might There is also the worse danger of doing statistical tests for their own sake so that they are used as a method of passing the time and avoiding real thought about the problem to be solved "

g. The general problem of cryptanalytic diagnosis has been discussed briefly in various Sections of this text The problem is far from simple, since many variations and conventions may be encountered in the various systems treated in this text, furthermore, the problem is made even harder by the fact that certain systems, themselves quite simple, may be combined to produce a system much more difficult to diagnose The lack of precise diagnostic tests, such as those available in the natural sciences,[16] is brought about by the fact that variations and conventions introduced into otherwise conventional systems may change radically the appearance and manifestations expected in the cipher text produced by the known systems, yielding "hitherto-unencountered phenomena." Each cryptosystem is then actually an individual and unique case in diagnosis [17]

(1) For example, four-letter cipher groups of the pattern consonant-vowel-consonant-consonant do not necessarily prove a code system, even though this grouping is a frequent one in four-letter code systems, the basic system might still be a cipher system, with the apparent

[16] The author feels that it is of value to pursue further a discussion of how the science of cryptanalytics compares with some branch of one of the natural sciences, when the diagnostic procedures involved in each are considered. In that branch of biology called taxonomic botany, for example, the first steps in the classificatory process are based upon observation of externally quite marked differences; as the process continues, the observational details become finer and finer, involving more and more difficulties as the work progresses Towards the end of the work the botanical taxonimist may have to dissect the specimen and study internal characteristics. The whole process is largely a matter of painstaking, accurate observation of data and drawing proper conclusions therefrom Except for the fact that the botanical taxonomist depends almost entirely upon ocular observation of characteristics while the cryptanalyst in addition to observation must use some statistics, the steps taken by the former are quite similar to those taken by the latter It is only at the very end of the work that a significant dissimilarity between the two sciences arises. If the botanist makes a mistake in observation or deduction, he merely fails to identify the specimen correctly, he has an "answer"--but the answer is wrong He may not be cognizant of the error, however, other more skillful botanists will find him out But if the cryptanalyst makes a mistake in observation or deduction, he fails to get any "answer" at all, he needs nobody to tell him he has failed. Further, there is one additional important point of difference The botanist is studying a bit of Nature--and she does not consciously interpose obstacles, pitfalls, and dissimulations in the path of those trying to solve her mysteries. The cryptanalyst, on the other hand, is studying a piece of writing prepared with the express purpose of preventing its being read by any persons for whom it is not intended. The obstacles, pitfalls, and dissimulations are here consciously interposed by the one who encrypted the message. These, of course, are what make cryptanalytics different and difficult.

[17] Baudouin (op cit., Chapter XIV) drew up a sort of check list of the classificatory procedures which an analyst might follow when attempting to diagnose the cryptosystem underlying a particular cryptogram or cryptograms. However, the science of cryptanalytics being as it is does not lend itself to successful completion of such diagnostic "check lists." Thus, the one compiled by Baudouin is far from satisfactory and is of no more than academic interest to the present-day practicing cryptanalyst

characteristics of a code system. Upon closer examination, it might be possible to disprove a code system, based on the non-appearance of certain other characteristics that should be present in a code system

(2) If a cryptogram or a set of cryptograms contain only the letters A through O in the cipher text, all that can be said initially is that only 15 letters are present in the encrypted text, and that the system must be one of substitution, either cipher or code. If a cipher, then the system must of course be a multiliteral system (including perhaps a mixed-length system), not excluding, for example, a digraphic system or a code chart For instance, in the biliteral matrix below, the ciphertext units consist only of pairs of consonants, and the plaintext elements include the 26 letters and the 374 most frequent digraphs; thus the system is essentially a digraphic system Such a system would not be at once recognized as a digraphic system, and if the vowels were used as nulls, the diagnosis of the cryptosystem would be considerably impeded

h. The often extensive and elaborate treatment of the many varieties of cryptosystems within the scope of this text has not been given solely for the sake of the analysis of the particular systems involved, but rather to illustrate the general cryptanalytic techniques which are applied to various problems. In being guided along the lines of "thinking cryptanalytically", the student has been put in a position to analyze successfully many possible variations and modifications of the cryptosystems treated in this text and in the accompanying course. The cryptosystems in this text and accompanying course have been solved for the most part from one or two messages Naturally, there is a certain amount of artificiality in the

	B	C	D	F	G	H	J	K	L	M	N	P	Q	R	S	T	V	W	X	Z
B	A	AA	AB	AC	AD	AE	AF	AG	AH	AI	AK	AL	AM	AN	AO	AP	AR	AS	AT	AU
C	AV	AW	AY	B	BA	BE	BI	BL	BO	BR	BT	BU	BY	C	CA	CC	CE	CH	CI	CK
D	CL	CO	CR	CT	CU	CY	D	DA	DB	DC	DD	DE	DF	DG	DH	DI	DL	DM	DN	DO
F	DP	DQ	DR	DS	DT	DU	DV	DW	DY	E	EA	EB	EC	ED	EE	EF	EG	EH	EI	EJ
G	EL	EM	EN	EO	EP	EQ	ER	ES	ET	EU	EV	EW	EX	EY	EZ	F	FA	FC	FE	FF
H	FI	FL	FO	FR	FS	FT	FU	FY	G	GA	GC	GE	GF	GG	GH	GI	GL	GN	GO	GP
J	GR	GS	GT	GU	GW	H	HA	HB	HC	HD	HE	HF	HI	HL	HM	HN	HO	HR	HS	HT
K	HU	HY	I	IA	IB	IC	ID	IE	IF	IG	IK	IL	IM	IN	IO	IP	IR	IS	IT	IV
L	IX	IZ	J	JA	JE	JO	JU	K	KA	KE	KI	KS	L	LA	LB	LC	LD	LE	LF	LG
M	LI	LL	LM	LN	LO	LP	LR	LS	LT	LU	LV	LW	LY	M	MA	MB	MC	ME	MI	MM
N	MO	MP	MR	MS	MT	MU	MY	N	NA	NB	NC	ND	NE	NF	NG	NH	NI	NK	NL	NM
P	NN	NO	NP	NR	NS	NT	NU	NV	NW	NY	O	OA	OB	OC	OD	OE	OF	OG	OH	OI
Q	OK	OL	OM	ON	OO	OP	OR	OS	OT	OU	OV	OW	OX	OY	P	PA	PE	PF	PH	PI
R	PL	PM	PN	PO	PP	PR	PS	PT	PU	PY	Q	QU	R	RA	RB	RC	RD	RE	RF	RG
S	RH	RI	RL	RM	RN	RO	RP	RR	RS	RT	RU	RV	RW	RY	S	SA	SB	SC	SD	SE
T	SF	SG	SH	SI	SK	SL	SM	SN	SO	SP	SR	SS	ST	SU	SW	SY	T	TA	TB	TC
V	TD	TE	TF	TG	TH	TI	TL	TM	TN	TO	TP	TR	TS	TT	TU	TW	TY	TZ	U	UA
W	UB	UC	UD	UE	UG	UI	UL	UM	UN	UP	UR	US	UT	V	VA	VE	VI	VO	W	WA
X	WE	WH	WI	WL	WN	WO	WR	WY	X	XA	XC	XE	XF	XI	XN	XP	XT	Y	YA	YB
Z	YC	YD	YE	YF	YG	YH	YI	YL	YM	YN	YO	YP	YR	YS	YT	YW	Z	ZA	ZE	ZI

Figure 103

examples and messages employed herein The texts of messages have been manipulated, especially in connection with the accompanying problems, in order to illustrate pedagogical principles and the application of cryptanalytic techniques In actual practice, instead of the one or two messages, five might be required, or for that matter, fifty or more might be required in order to effect a solution In operational practice, there is frequently a high incidence of garbles which would have a pronounced impact on not only a facile identification of the cryptosystem but also on its subsequent solution <u>Speed</u> is an essential criterion in operational practice, a cryptosystem must be broken and messages read as soon as possible, to be of maximum use to a field commander--messages read six or twelve months after they were sent are hardly of more than historical importance Nevertheless, when a system is cryptanalyzed for the first time, no matter when it is broken it helps maintain cryptologic continuity which is of extreme importance in successful operational practice.

<u>i</u> The student should now study, if he has not already done so, the various appendices to this text Through them, he may gain an insight into further aspects of cryptography and topics related to the art of cryptanalysis Practice on many different ciphers of the types covered in this text will tend to sharpen the wits and give to the student confidence and facility in the cryptanalysis of unknown examples It is for this reason that a course of problems is a necessary adjunct to the study of this text; as was previously mentioned, one month's actual practice in solution is worth a whole year's mere reading of theoretical principles

<u>j</u>. It may be of assistance to indicate, by means of a graphic outline, the relationship existing among the various cryptographic systems thus far considered The outline will be augmented with each succeeding text as the different cryptosystems are encountered, and will constitute what has already been alluded to in par 6d and there termed a "synoptic chart of cryptography" The synoptic chart for this text (Chart 9) forms an insert following this Section. Looking at this chart the student may see that, although it is essentially dichotomous in form, at several levels there appears a sort of cryptographic tertium quid--some category (or categories) of cryptosystems which properly belongs at the particular level shown, but which does not directly fit into either of the two <u>primary</u> subdivisions already appearing at that level However, if the student will study the synoptic chart attentively, it will assist him in fixing in mind the manner in which the various systems covered thus far are related to one another, and this will be of benefit in clearing away some of the mental fog or haziness from which he is at first apt to suffer.

<u>k</u>. There remain five more volumes to this series of basic texts on the art of cryptanalysis Military Cryptanalytics, Part II, will treat mainly periodic polyalphabetic substitution ciphers, including periodic numerical systems, Part III will treat varieties of aperiodic substitution systems, including an introduction to elementary cipher devices and cryptomechanisms, Part IV will treat transposition and fractionating systems, and combined substitution-transposition systems, Part V will treat the reconstruction of codes, and the solution of enciphered code systems, and Part VI will treat the solution of representative machine cipher systems. In addition,

throughout the five remaining texts there will be interpolated statistical techniques applicable to the systems treated, and information on the application of analytical machines in cryptanalytic problems. The security classification of each succeeding text will vary according to the information contained therein. It is not intended that the student study all six texts; life is too short to become an expert cryptanalyst in all fields of the art. Parts I and II embrace most of the necessary fundamentals of cryptanalysis; the succeeding four volumes will impart knowledge on more specific categories of systems with which the cryptanalyst may be faced.

* * * * *

ETSAW SEKAM ETSAH

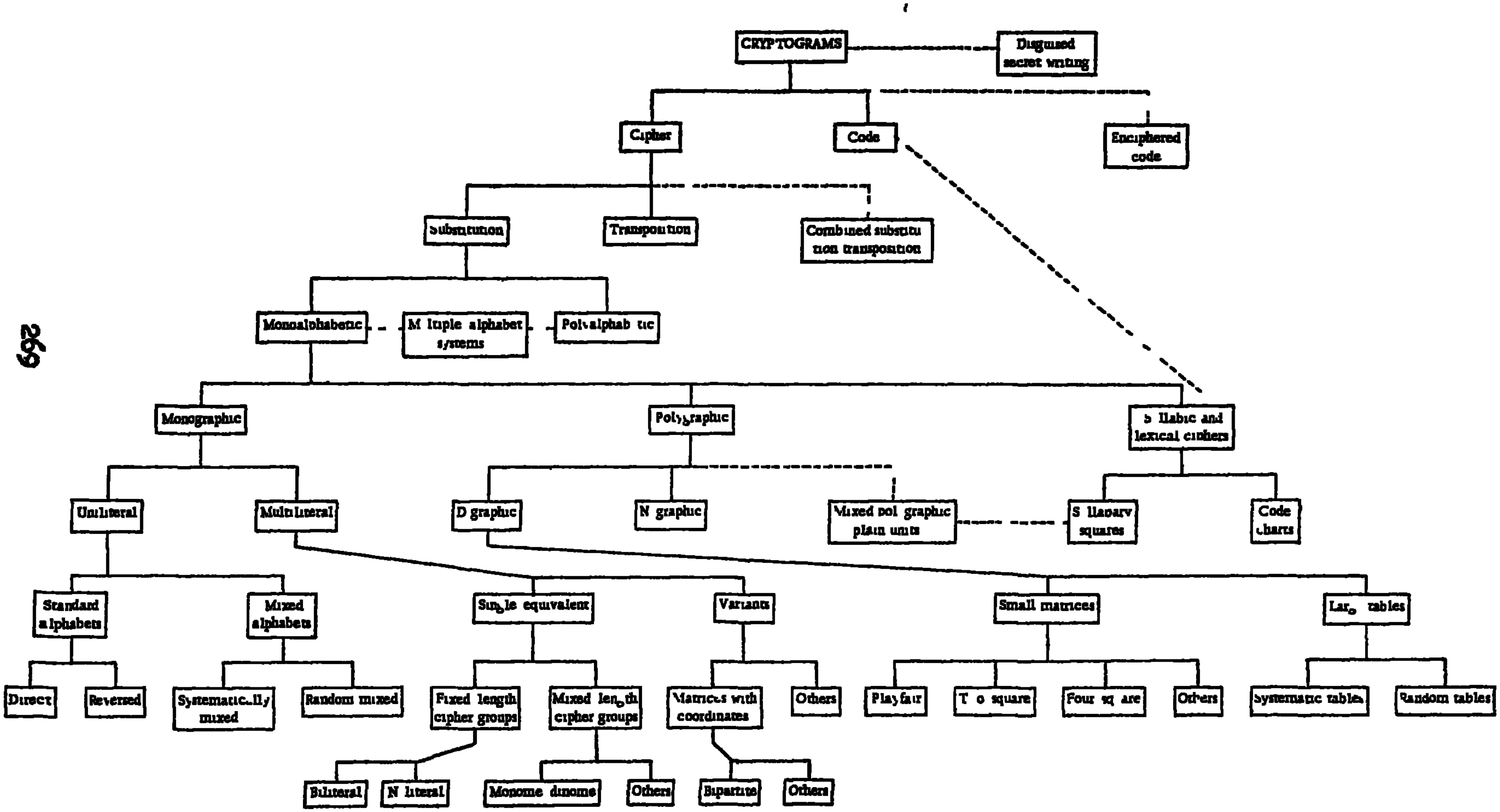


Chart 7. Synoptic chart of cryptography for Military Cryptanalytics, Part I.

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APPENDICES

APPENDIX 1

GLOSSARY FOR MILITARY CRYPTANALYSIS, PART I

Explanatory Notes

1. This glossary is designed primarily to be used in connection with the text Military Cryptanalysis, Part I. It is limited in scope to cryptologic terms actually appearing in the text, terms likely to be encountered in other cryptologic literature of approximately the same level as the text, and a few other terms considered necessary to complement or to clarify certain definitions.

2. The terms in this glossary are arranged in strictly alphabetical order, disregarding word spaces and hyphens. Single words and certain hyphenated words are followed directly by an abbreviation of the part of speech. Run-on entries, indicating a part of speech different from that of the main entry, are shown simply by means of a series of dashes followed by the abbreviation of the part of speech, and the appropriate definition. Abbreviations used for parts of speech, as well as those used to indicate examples, cross-references, etc., are those listed in Webster's New International Dictionary, Second Edition.

GLOSSARY FOR MILITARY CRYPTANALYSIS, PART I

accidental repetition. A repetition produced fortuitously, and not by the encipherment of identical plaintext letters by identical keying elements. (Cf. causal repetition.)

additive, n. A single digit, a series of digits, or a numerical group which, for the purpose of encipherment, is added to a numerical code group or to numerical cipher or plain text.

additive book. A book comprising a group of additive tables.

additive system. A cryptosystem in which encipherment is accomplished through the application of additives.

additive table. A tabular arrangement of additives.

addressee, n. The office, headquarters, activity or individual to whom a message is directed by the originator.

ADFGVX system. A German high-command cipher system used in World War I. Essentially, a biliteral substitution system employing a 6 x 6 square, to which a columnar transposition was subsequently applied.

appliqué unit, teleprinter. A special cipher attachment used in connection with a teleprinter to provide cryptographic treatment for teleprinter messages.

artificial word. A group of letters having no real meaning, constructed by the systematic arrangement of vowels and consonants so as to give the appearance and pronounceability of a bona fide word.

Baconian cipher. A cipher system invented by Sir Francis Bacon (1561-1626). It is basically a monoalphabetic substitution system in which single plaintext letters are represented by five-letter cipher equivalents formed by permutations of two letters taken five at a time.

baud, n. A mark or space impulse in the international (Baudot) teleprinter code.

Baudot code. A five-unit code applied to teleprinter systems by Jean Maurice Emile Baudot (1845-1903). It employs a 32-element alphabet composed of permutations of two elements taken five at a time. Also called the international teleprinter code.

biliteral, adj. Of or pertaining only to cryptosystems, cipher alphabets, and frequency distributions which involve cipher units of two letters or characters. See the more inclusive term digraphic; see also biliteral frequency distribution.

biliteral alphabet. A cipher alphabet involving a cipher component composed of two-character units.

biliteral frequency distribution. A frequency distribution of pairs formed by combining successive letters or characters. Thus, a biliteral distribution of ABCDEF would list the following pairs: AB, BC, CD, DE, EF. (Cf. digraphic frequency distribution.)

bipartite alphabet. A biliteral alphabet in which the cipher units may be divided into two separate parts whose functions are clearly defined, viz., row indicators and column indicators of a matrix.

bipartite system. A substitution system involving the use of a bipartite alphabet.

blank-expectation test. See lambda test.

bust message. A message containing an error in encipherment which jeopardizes the cryptographic security of the message, and thus is potentially valuable to the cryptanalyst.

Caesar's cipher. An ancient form of simple substitution cipher in which each plaintext letter was replaced by the letter three places to the right of it in the normal alphabet; attributed to Julius Caesar.

call sign. A group of letters or numbers, or a combination of both, used as the identification for a telecommunication station (or stations), when stations are establishing contact with each other.

causal repetition. A repetition produced by the encipherment of identical plaintext letters by identical keying elements.

cell, n. An individual small square on cross-section paper, grilles, etc.

characteristic frequency. See normal frequency.

chi-square (χ) table. A mathematical table listing the probabilities of occurrence by chance of a chi-square value higher than that observed in a given case; an adjunct to the chi-square test.

chi-square (χ) test. A mathematical means for determining the relative likelihood that two distributions derive from the same source. For example, the test can be used to aid in the determination of whether a distribution is more likely to be random or not; in this usage, the observed distribution is compared with a theoretical distribution representing that which is expected for random. The end result of the test is a value representing the discrepancy between the two distributions which have been compared. This value, called a "chi-square value" may be interpreted as it is, or it may be interpreted through the use of a chi-square table.

chi (χ) test. A test applied to the distributions of the elements of two cipher texts either to determine whether the distributions are the result of encipherment by identical cipher alphabets, or to determine whether the underlying cipher alphabets are related. Also called the cross-product test.

cifax, n. Enciphered facsimile. The process of converting a plane image into an unintelligible image or series of electrical impulses and of reconverting it or them into intelligibility through the use of a key.--adj. Using or pertaining to cifax.

cipher, n. 1. A cipher system. 2. A cryptogram produced by means of a cipher system.---adj. Pertaining to that which enciphers or is enciphered.

cipher alphabet. An ordered arrangement of the letters (or other conventional signs, or both) of a written language and of the characters which replace them in a cryptographic process of substitution.

cipher clerk. A clerk who enciphers and deciphers messages.

cipher component. The sequence of a cipher alphabet containing the symbols which replace the plain symbols in the process of substitution.

cipher device. A nonmechanical and nonelectrical apparatus used for enciphering and deciphering.

cipher disk. A cipher device consisting of two or more concentric disks, each bearing on its periphery one component of a cipher alphabet.

cipher machine. A mechanical or electrical apparatus for enciphering and deciphering.

cipher square. An orderly arrangement or collection of sequences set forth in a rectangular form, commonly a square (e.g., a Vigenère square)

cipher system. Any cryptosystem in which cryptographic treatment is applied to textual units of regular length, usually monographic or digraphic. (Cf. code system.)

cipher text. The text of a cryptogram which has been produced by means of a cipher system.

ciphony, n. Enciphered telephony. The process of converting vocal communications into unintelligibility and of reconverting them into intelligibility through cryptographic treatment.---adj. Using or pertaining to ciphony.

citrol, n. The process of converting control and telemetering signals, such as those used in missile guidance, into unintelligibility and reconverting them into intelligibility through cryptographic treatment.---adj. Using or pertaining to citrol.

civision, n. Enciphered television. A system of converting television signals into unintelligible signals and vice versa, in accordance with certain predetermined procedures.---adj. Using or pertaining to civision.

clear text. Plain text.

code, n. 1. A code system. 2. A code book.---adj. Pertaining to that which encodes or is encoded.

code book. A book or document used in a code system, arranged in systematic form, containing units of plain text of varying length (letters, syllables, words, phrases, or sentences) each accompanied by one or more arbitrary groups of symbols used as equivalents in messages.

code chart. A chart in the form of a matrix containing letters, syllables, numbers, words and, occasionally, phrases. The matrix has row and column coordinates for the purpose of designating the plaintext elements within.

code clerk. A clerk who encodes and decodes messages.

code group. A group of letters or numbers, or a combination of both, assigned (in a code system) to represent a plaintext element.

code message. A cryptogram produced by encodement.

code system. A cryptosystem in which arbitrary groups of symbols represent plaintext units of irregular length, usually syllables, whole words, phrases and sentences.

code text. The text of a cryptogram which has been produced by means of a code system.

coincidence test. The kappa test. A statistical test applied to two ciphertext messages to determine whether they both involve encipherment by the same sequence of cipher alphabets.

columnar transposition. A method of transposition in which the ciphertext equivalent of a message is obtained by transcribing the columns of a matrix into which the message was inscribed earlier according to some scheme other than this vertical one.

column coordinate. A symbol normally at the top of a matrix or cryptographic table, identifying a specific column of cells, used in conjunction with a row coordinate to specify an individual cell in the matrix or table. Also called column indicator.

column indicator. See column coordinate.

communication intelligence (COMINT). Evaluated and interpreted information derived from the study of intercepted communications.

communication security (COMSEC). The protection resulting from all measures designed to deny to unauthorized persons information of value which might be derived from communications. Cryptosecurity, transmission security, and physical security are the components of communication security.

commutative, adj. As applied to cipher matrices, so constructed as to permit coordinates to be read in either row-column or column-row order without cryptographic ambiguity.

component, n. One of the two sequences (plain and cipher) which compose a cipher alphabet.

compromise, n. The loss of security of a classified document, information, or material, which results from the possibility of an unauthorized person or persons having knowledge thereof.

concealment system. A method of secret communication so designed as to convey a secret message without its presence being suspected by others than the addressee. In its most usual form, the plaintext elements are concealed by combining them with extraneous plaintext elements in such a way that the end result is an intelligible and apparently innocent message. (Cf. open code.)

crest, n. In its cryptologic application, a point of high relative frequency in a frequency distribution.

crib, n. 1. Plain text assumed or known to be present in a cryptogram. 2. Keys assumed or known to have been used in a cryptogram.---v.t. To fit assumed or known plain text or keys into the proper position in an encrypted message.

cross-product test. See chi test.

cryptanalysis, n. The steps and operations performed in applying the principles of cryptanalytics.

cryptanalyst, n. A person versed in the art of cryptanalysis.

cryptanalytic, adj. Of, pertaining to, or used in cryptanalytics.

cryptanalytics, n. That branch of cryptology which deals with the principles, methods, and means employed in the solution or analysis of cryptosystems.

cryptanalyze, v.t. To solve by cryptanalysis.

cryptogram, n. A communication in visible writing which conveys no intelligible meaning in any known language, or which conveys some meaning other than the real meaning.

cryptographer, n. One who encrypts or decrypts messages or has a part in making a cryptographic system.

cryptographic, adj. Of, pertaining to, or concerned with cryptography.

cryptographic ambiguity. Uncertainty as to the method of decryption or as to the meaning intended after decryption; created by a fault in the structure of a cryptosystem.

cryptographic arithmetic. The method of modular arithmetic used in cryptographic procedures which involves no carrying in addition and no borrowing in subtraction.

cryptographic security. See cryptosecurity.

cryptographic system. See cryptosystem.

cryptographic text. Encrypted text; the text of a cryptogram.

cryptography, n. That branch of cryptology which treats of the means, methods, and apparatus for converting or transforming plaintext messages into cryptograms, and for reconverting the cryptograms into their original plaintext form by a simple reversal of the steps used in their transformation.

cryptologic, adj. Of, pertaining to, or concerned with cryptology.

cryptology, n. That branch of knowledge which treats of hidden, disguised, or encrypted communications. It embraces all the means and methods of producing communication intelligence and maintaining communication security; for example, cryptology includes cryptography, cryptanalytics, traffic analysis, etc.

cryptomaterial, n. All documents, devices and machines employed in encrypting and decrypting messages.

cryptomathematician, n. One versed in cryptomathematics.

cryptomathematics, n. Those portions of mathematics and those mathematical methods which have cryptologic applications.

cryptosecurity, n. That component of communication security which results from the provision of technically sound cryptographic systems and from their proper use.

cryptosystem, n. The associated items of cryptomaterial and the methods and rules by which these items are used as a unit to provide a single means of encryption and decryption. A cryptosystem embraces the general cryptosystem and the specific keys essential to the employment of the general cryptosystem.

cyclic, adj. Periodic; continuing or repeating so that the first term of a series follows the last; characterized by a ring or closed-chain formation.

cyclic permutation. Any rearrangement of a sequence of elements which rearrangement merely involves shifting all the elements a common distance to the right or left of their initial positions in the sequence, the relative order remaining undisturbed; such a rearrangement requires that one consider the basic sequence as being circular in nature so that, for example, shifting that element which occupies the left-most position in the sequence one place to the left places this element in the right-most position.

daily keying element. That part of the specific key which changes at predetermined intervals, usually daily.

decimated alphabet. An alphabet produced by decimation.

decimation, n. The process of selecting members of a series by counting off at a chosen interval, the original series being treated as cyclic; or the result of the foregoing process.

decimation-mixed sequence. A mixed sequence produced by decimation.

decipher, v.t. To convert an enciphered message into its equivalent plain text by a reversal of the cryptographic process used in encipherment. (This does not include solution by cryptanalysis.)

deciphering alphabet. A cipher alphabet in which the sequence of symbols in the cipher component is arranged in normal order for convenience in decipherment.

decipherment, n. 1. The process of deciphering. 2. The plain text of a deciphered cryptogram. 3. In an enciphered code system, the code text resulting from the removal of the encipherment.

decode, v.t. To convert an encoded message into its plain text by means of a code book. (This does not include solution by cryptanalysis.) ---n. 1. That section of a code book in which the code groups are in alphabetical, numerical, or other systematic order. 2. The decoded, but not translated, version of a code message.

decodement, n. 1. The process of decoding. 2. The decoded, but not translated, version of a cryptogram.

decrypt, v.t. To transform an unintelligible or cryptic communication into an intelligible one by a reversal of the cryptographic process used in encryptment. (This does not include solution by cryptanalysis.)--n. A decrypted, but not translated, message.

decryption, n. The act of decrypting.

degarble, v.t. To make emendations in a garbled text.

derived numerical key. A key produced by assigning numerical values to a selected literal key.

diagnosis, cryptanalytic. A systematic examination of cryptograms with a view to discovering the general system underlying these cryptograms.

digraph, n. A pair of letters.

digraphic, adj. Of or pertaining to any combination of two characters.

digraphic frequency distribution. A frequency distribution of successive pairs of letters or characters. A digraphic distribution of ABCDEF would list the pairs: AB, CD, EF. (Cf. biliteral frequency distribution.)

digraphic idiomorph. A plaintext or cipher sequence which contains or shows a pattern in its construction as regards the number and position of repeated digraphs.

digraphic substitution. Encipherment by substitution methods in which the plaintext units are pairs of characters and their cipher equivalents usually consist of two characters.

dinome, n. A pair of digits.

direct standard cipher alphabet. A cipher alphabet in which both the plain and cipher components are the normal sequence, the two components being juxtaposed in any of the non-crashing placements.

discriminant, n. A group of symbols indicating the specific cryptosystem used in encrypting a given message. Also called system indicator.

distribution, n. See frequency distribution.

doublet, n. A double-letter digraph, such as, LL, EE, etc.

double transposition. A cryptosystem in which the characters of a first or primary transposition are subjected to a second transposition.

encicode, n. A portmanteau word for enciphered code.

encipher, v.t. To convert a plaintext message into unintelligible language by means of a cipher system.

enciphered code. A cryptographic system in which a cipher system is applied to encoded text.

enciphering alphabet. A cipher alphabet in which the sequence of letters in the plain component is arranged in normal order for convenience in encipherment.

encipherment, n. 1. The process of enciphering. 2. Text which has been enciphered.

encoded cipher. The final text produced by enciphering the plain text and then encoding the enciphered text.

encode, v.t. To convert a plaintext message into unintelligible language by means of a code book.---n. That section of a code book in which the plaintext equivalents of the code groups are in alphabetical, numerical, or other systematic order.

encodement, n. 1. The act or process of encrypting plain text with a code system. 2. The text produced by encoding plain text.

encrypt, v.t. To convert a plaintext message into unintelligible language by means of a cryptosystem.

encrypted text. The text produced by the application of a cryptosystem to a plaintext message.

encryption, n. 1. The act of encrypting. 2. Encrypted text.

external text. In concealment systems, the apparently innocent enveloping text within which a secret message is hidden.

four-level dinome cipher. A biliteral substitution cipher system employing four cipher sequences composed of two-digit numbers, by means of which all or nearly all of the plaintext letters are provided with four two-digit variant equivalents.

four-square matrix system. A digraphic substitution system employing a matrix which usually consists of four 5 x 5 squares in which the letters of 25-element alphabets (usually combining I and J) are inserted according to any prearranged order.

fractionating system. A cipher system in which plaintext units are represented by two or more cipher symbols which in turn are dissociated and subjected to further encipherment by substitution or transposition or both.

fractionation, n. A cryptographic process wherein the cipher symbols, which combined represent a plaintext unit, are dissociated and subjected to further encipherment.

frequency distribution. A tabulation of the frequency of occurrence of plaintext or ciphertext units in a message or a group of messages. A frequency count.

frequential matrix. A type of cipher matrix providing variants. A matrix in which the number of different cipher values available to represent any given plaintext letter closely approximates its relative plaintext frequency.

garble, n. An error in transmission, reception, encryption, or decryption which renders incorrect or undecryptable a message or transmission or a portion thereof.---v.t. To make an error in transmission, reception, encryption, or decryption of a message.

general cryptosystem. The basic invariable method of encryption included in a cryptosystem, excluding the specific keys essential to its employment.

generatrix, n. In connection with the method of completing the plain component sequence, any one of the rows, each of which represents a trial "decipherment" of the original cryptogram.

Grandpré cipher. A type of substitution system providing variants. This system employs a cipher square in which are inscribed ten 10-letter words containing all the letters of the alphabet in their approximate plaintext frequencies. These ten words are further linked together by a 10-letter word which appears vertically in the first column as a mnemonic feature for the inscription of the words in the rows.

grid, n. In a transposition system, a form or matrix over which a grille is placed for the purpose of enciphering or deciphering.

grille, n. 1. A sheet of paper, cardboard, thin metal, plastic, or like material in which perforations have been made for the uncovering of spaces in which textual units may be written or read on the grid. 2. A matrix in which certain squares are blocked out or otherwise marked so as not to be used.

group, n. A number of digits, letters or characters forming a unit for transmission or for cryptographic treatment.

high-echelon, adj. Pertaining to organizational units at the army divisional level or higher, or their equivalents.

high-grade, adj. Pertaining to a cryptosystem which offers a maximum of resistance to cryptanalysis; for example: (1) complex cipher machines, (2) one-time systems, (3) two-part codes enciphered with an additive book. (Cf. low-grade and medium-grade.)

Hill's algebraic encipherment. A true polygraphic system for the encipherment of polygraphs of any order, involving algebraic treatment by means of coefficients for the transformation of a plaintext polygraph into its ciphertext polygraphic equivalent, and vice versa. Invented by Professor Lester S. Hill of Hunter College.

hit, n. A coincidence or identity.

horizontal two-square matrix system. A digraphic substitution system employing a matrix which normally consists of two 5 x 5 squares placed side by side.

identification, n. Determination of the plaintext meaning of a cipher element or code group.

identify, v.t. To determine the plaintext meaning of a cipher element or code group.

idiomorph, n. A plaintext or cipher sequence which contains or shows a pattern in its construction as regards the number and positions of repeated letters.

idiomorphism, n. In a plaintext or cipher sequence, the phenomenon of showing a pattern as regards the number and positions of repeated letters.

index of coincidence. The ratio of the observed number of coincidences in a given cryptogram to the number of coincidences expected in a sample of random text of the same size as the cryptogram.

indicator, n. In cryptography, an element inserted within the text or heading of a message which serves as a guide to the selection or derivation and application of the correct system and key for the prompt decryption of the message. See also the more precise terms discriminant and message indicator.

inscription, n. In a transposition system, the process of writing a message into a matrix.

integer, n. A whole number.

intercept, v.t. In its cryptologic application, to gain possession of communications which are intended for other recipients, without obtaining the consent of the addressees and without preventing or ordinarily delaying the transmission of the communications to those addressees.--n. A copy of a message obtained by interception.

interception, n. The process of gaining possession of communications intended for others without obtaining the consent of the addressees and without preventing or ordinarily delaying the transmission of the communications to those addressees.

internal text. In concealment systems, the secret text which is enveloped by open or apparently innocent text.

international teleprinter code. See Baudot code.

interrupted-key columnar transposition. A columnar transposition system in which the plaintext elements are inscribed in a matrix in rows of irregular length as determined by a numerical key.

inverse four-square matrix system. A four-square matrix system in which the cipher sections contain normal alphabets while the plain component sections contain mixed alphabets.

invisible writing. Writing not visible to the naked eye; the characters composing such writing may be microscopic or inscribed with invisible ink.

isolog, n. A cryptogram of which the plain text is identical with that of another message encrypted in another system, key, code, etc.

isologous, adj. Pertaining to or having the nature of an isolog.

Jefferson cipher. A polyalphabetic substitution system invented by Thomas Jefferson and independently at a later date by the French cryptographer Bazeries. It provided for encipherment by means of a manually operated device involving a number of revolvable disks, each bearing a mixed alphabet on its periphery.

kappa plain constant. A constant employed in coincidence tests to denote the probability of coincidence of a given textual element or unit in plain text. It is the sum of the squares of the probabilities of occurrence of the different textual elements or units as they are employed in writing plain text; for example, in English telegraphic plain text, the monographic and digraphic kappa plain constants are .0667 and .0069 respectively.

kappa random constant. A constant employed in coincidence tests to denote the probability of coincidence of a given textual element or unit in random text. It is merely the reciprocal of the number of different elements or units of which the cipher text may have been composed; if a 26-letter alphabet were employed, for instance, the constant denoting the probability of coincidence of various textual elements would be derived as follows:

a.	single letters	1/26	=	.0385
b.	digraphs	1/676	=	.00148
c.	trigraphs	1/17576	=	.000057

kappa test. See coincidence test.

key, n. 1. In cryptography, a symbol or sequence of symbols applied to successive textual elements of a message to accomplish their encryption or decryption. 2. A specific key.

key book. A book containing key text, or plain text forming specific keys.

keyed columnar transposition. A transposition system in which the columns of a matrix are taken off in the order determined by the specific key, which is often a derived numerical key.

key phrase. An arbitrarily selected phrase from which a key is derived.

key recovery. The cryptanalytic reconstruction of a key.

key text. Text from which key is derived.

key word. An arbitrarily selected word used as a key per se, or from which a key is derived.

keyword-mixed alphabet. An alphabet constructed by writing the prearranged key word or key phrase (repeated letters, if present, usually being omitted after their first occurrence), and then completing the sequence from the unused letters of the alphabet in their normal sequence.

lambda (Λ) test. A test for monoalphabeticity in a message, based on a comparison of the observed number of blanks in its frequency distribution with the theoretically expected number of blanks both in (a) a normal plaintext message of equal length and (b) a random assortment of an equal number of letters. Also called the blank-expectation test.

latent repetition. A plaintext repetition not apparent in cipher text but susceptible of being made patent as a result of analysis.

Latin square. A cipher square in which no row nor column contains a repeated symbol.

lexical, adj. Of, pertaining to, or connected with words. In its cryptologic sense, the word is used to characterize those cryptographic methods (chiefly codes) which deal with plaintext elements comprising complete words, phrases and sentences.

literal key. A key composed of a sequence of letters.

logarithmic weights. Numerical weights assigned to units of plain text, which weights are actually logarithms of the probabilities of the plaintext units, and which are used to evaluate the results of certain cryptanalytic operations.

low-echelon, adj. Pertaining to organizational units below the level of the army division or its equivalent.

low-grade, adj. Pertaining to a cryptosystem which offers only slight resistance to cryptanalysis; for example: (1) Playfair ciphers, (2) single transposition, (3) unenciphered one-part codes. (Cf. medium-grade and high-grade).

matrix, n. A geometric form or pattern. In transposition systems, the figure or diagram in which the various steps of the transposition are effected; in substitution systems, the figure or diagram containing the sequence or sequences of plaintext or cipher symbols.

medium-grade, adj. Pertaining to a cryptosystem which offers considerable resistance to cryptanalysis; for example: (1) strip ciphers, (2) polyphase transposition, (3) unenciphered two-part codes. (Cf. low-grade and high-grade).

message, n. Any thought or idea expressed in plain or secret language, prepared in a form suitable for transmission by any means of communication.

message indicator. That part of the specific key which changes with every message.

message keying element. See message indicator.

mixed cipher alphabet. A cipher alphabet in which the sequence of letters or characters in one or both of the components is not the normal sequence.

mixed-length system. A cryptosystem in which the units of cipher text or code text are of irregular or non-constant length, as for example, a monome-dinome system, or a code system employing both 4-letter and 5-letter groups.

mnemonic key. A key so constructed as to be easily remembered.

modulo, adj. Pertaining to a cyclic scale or basis of arithmetic. (Abbreviated as mod; e.g., mod 10, mod 26, etc.)

modulus, n. Scale or basis of arithmetic; the number n is called the modulus when all numbers which differ from each other by n or a multiple of n are considered equivalent.

monitor, v.t. To intercept and copy one's own or friendly radio and wire transmissions for the purpose of detecting and correcting violations of regulations.

monoalphabeticity, n. A characteristic of encrypted text which indicates that it has been produced by methods involving a single cipher alphabet or single code book, unenciphered. It is normally disclosed by frequency distributions which display "roughness", or pronounced variation in relative frequencies.

monoalphabetic substitution. A type of substitution employing a single cipher alphabet by means of which each cipher equivalent, composed of one or more elements, invariably represents one particular plaintext unit, wherever it occurs throughout any given message.

monographic, adj. Of or pertaining to any units comprising single characters.

monographic substitution. Encipherment by substitution methods in which the plaintext units are single characters and their cipher equivalents usually consist of single characters.

monome, n. A single digit.

monome-dinome system. A substitution system in which certain plaintext elements have single-digit cipher equivalents, while others are represented by pairs of digits.

multiliteral, adj. Of or pertaining only to cryptosystems, cipher alphabets, and frequency distributions which involve cipher units of two or more letters or characters. See the more inclusive term polygraphic.

multiliteral cipher alphabet. A cipher alphabet in which one plaintext letter is represented by cipher units comprising two or more elements.

multiliteral system. A substitution system involving one or more multiliteral cipher alphabets.

multiple alphabet system. A type of substitution in which successive lengthy portions of a message are each monoalphabetically enciphered by a different alphabet; monoalphabetic encipherment by sections.

non-carrying sum. A sum produced in cryptographic (mod 10) arithmetic.

non-crashing, adj. A term used to describe that feature of the structure of certain cryptosystems which does not permit a plaintext unit to be self-enciphered.

non-commutative, adj. As applied to bipartite cipher matrices, so constructed that row and column coordinates must be read in a certain prescribed order (for example, in a row-column order).

normal frequency. The standard frequency of a plaintext unit or letter relative to other such units or letters, as disclosed by the statistical study of a large volume of text.

normal sequence. The normal alphabetical sequence of those letters which are used in the written text of any particular language, or any cyclic permutation thereof.

normal uniliteral frequency distribution. A distribution showing the standard relative frequency of single plaintext symbols as disclosed by statistical study of a large volume of text.

null, n. In cryptography, a symbol or unit of encrypted text having no plaintext significance.

numerical key. A key composed of a sequence of numbers.

numerically-keyed columnar transposition. A transposition system in which the columns of a matrix are taken off in the order determined by a numerical key.

off the cut. As applied to the division of cipher text into polygraphs, beginning elsewhere than with the initial character of a bona fide polygraph.

one-part code. A code in which the plaintext elements are arranged in alphabetical or numerical order accompanied by their code groups also arranged in alphabetical or numerical order.

one-time pad. A form of key book used in a one-time system so designed as to permit the destruction of each page of key as soon as it has been used.

one-time system. A cryptosystem in which the key, normally of a random nature, is used only once.

on the cut. As applied to the division of text into polygraphs, beginning with the first textual character.

open code. A cryptosystem in which units of plain text are used as the code equivalents for letters, numbers, words, phrases or sentences. The code equivalents themselves, usually words or phrases, can be combined to form the intelligible text of apparently innocent messages. (Cf. concealment system.)

originator, n. The individual (a commander or his officially designated representative) by whose authority a message is sent.

padding, n. Extraneous text added to a message for the purpose of concealing its length and beginning or ending or both.

paraphrase, v.t. To change the phraseology of a message without changing its meaning.

partially-polygraphic system. Any polygraphic substitution system in which the encipherment of certain members of the polygraphs shows group relationships; small matrix systems, such as the four-square, two-square and Playfair systems involve such group relationships and are considered to be partially-digraphic systems.

partition, n. Resolution of an integer into a set of integers (e.g., representation of the integer 6 as 1 and 5, 2 and 4, 3 and 3).

patent repetition. A repetition which is externally visible in the original cryptographic text.

pentagraph, n. A set of five letters.

pentanome, n. A set of five digits.

periodic substitution. Periodic polyalphabetic substitution. A method of encipherment involving the cyclic use of a plurality of alphabets.

permutation table. A table designed for the systematic construction of code groups. It may also be used to correct garbles in groups of code text.

phi (φ) test. A test applied to a frequency distribution to determine its relative monoalphabeticity. See also kappa plain constant and kappa random constant.

physical security. That component of communication security which results from all physical measures necessary to safeguard classified communication equipment and material from access thereto by unauthorized persons.

placode, n. A portmanteau word used to designate plain or unenciphered code.

plain code. Unenciphered code.

plain component. That component of a cipher alphabet which comprises the sequence of plaintext symbols.

plain component equivalents. In connection with the method of completing the plain component sequence, the plaintext equivalents for cipher units derived from an arbitrary juxtaposition of the components of a cipher alphabet.

plain language. Plain text.

plain text (clear text). 1. Text or language which conveys an intelligible meaning in the language in which it is written, with no hidden meaning. 2. The intelligible text underlying a cryptogram.

Playfair system. A type of digraphic substitution using a single matrix normally of 25 cells.

Poisson table. Table of the Poisson distribution. A type of mathematical table containing probability data applicable to the phenomena of repetitions expected to obtain in samples of random text; used in cryptanalysis to determine whether or not the repetitions observed in a given sample of cryptographic text are causal repetitions or accidental (random) repetitions.

polyalphabetic substitution. A type of substitution in which the successive plaintext elements of a message, usually single letters, are enciphered by a succession of different alphabets which may be used more than once and which are used in a predetermined order.

polygraphic, adj. Of, pertaining to, or connected with any groupings comprising two or more letters or characters.

polygraphic substitution. Encipherment by substitution methods in which the plaintext units are regular length groupings of more than one element.

polyphase encipherment. Any system of encryption involving two or more successive operations of encipherment.

probable word. Plain text assumed or known to be present in a cryptogram. A crib.

probable-word method. The method of solution involving the trial of plain text assumed to be present in a cryptogram.

proforma message. A message in standardized form, designed to convey intelligence by conventions of arrangement and abbreviation.

pseudo-code system. A cipher system which produces a cryptogram whose groups resemble those produced by a code system.

pseudo-polygraphic system. A polygraphic substitution system in which at least one of the letters in each polygraph is enciphered monoalphabetically.

quinqueliteral alphabet. A cipher alphabet in which each plaintext letter is represented by a 5-character equivalent.

random-mixed cipher alphabet. A cipher alphabet in which the letters comprising the plain or cipher component have been mixed at random. (Cf. systematically-mixed cipher alphabet).

random text. Text which appears to have been produced by chance or accident, having no discernible patterns or limitations.

rapid analytical machinery. Any high-speed cryptanalytic machinery, usually electronic or photoelectric in nature.

raw traffic. Intercepted traffic showing no evidence of processing for communication intelligence purposes beyond sorting by clear address elements, elimination of unwanted messages, and the inclusion of a case number and/or an arbitrary traffic designator.

reciprocal cipher alphabet. A cipher alphabet in which either of the two sequences may serve as plain or cipher since the equivalents exhibit reciprocity.

reciprocity, n. As used in cryptology, interchangeability of plain-cipher relationships (e.g., $A_p = B_c$ and $B_p = A_c$).

related alphabets. Any of the several secondary cipher alphabets which are produced by sliding any given pair of primary components against each other.

relative code. Code text from which an encipherment has been removed in relative terms but not reduced to plain-code text, so that the groups differ from the actual, original plain code by an interval constant for every group; thus the difference between two relative code groups is the same as that between their plain-code equivalents.

repeating-key method. See periodic substitution.

repetitive encipherment. A type of encipherment in which the primary cipher text of a cryptogram is subjected to further encipherment with either the same or a different system. Double transposition is a frequently-encountered example of repetitive encipherment.

reversed standard cipher alphabet. A cipher alphabet in which both the plain and cipher components are the normal sequence, the cipher component being reversed in direction from the plain component.

reversibility, n. That characteristic of the relationship between a plain-text digraph and its cipher digraph equivalent which permits the elements of each to be reversed (e.g., $AB_p = CD_c$ and $BA_p = DC_c$).

revolving grille. A type of grille in which the apertures are so distributed that when the grille is turned successively through four angles of 90 degrees and set in position on the grid, all the cells on the grid are disclosed only once. Also called rotating grille.

rotating grille. See revolving grille.

rotor, n. A disk which is designed to rotate within a cipher machine and which controls the action of some other machine component or produces a variation in some textual or keying element.

roughness, n. That characteristic of a frequency distribution where there is displayed in the distribution a pronounced variation in relative frequencies of the elements considered.(Cf. smoothness.)

route transposition. A method of transposition in which the cipher-text equivalent of a message is obtained by transcribing, according to any prearranged route, the cells of a matrix into which the message was inscribed earlier according to some other prearranged route.

row coordinate. A symbol normally at the side of a matrix or cryptographic table, identifying a specific row of cells, used in conjunction with a column coordinate to specify an individual cell in the matrix or table. Also called row indicator.

row indicator. See row coordinate.

running dinome distribution. A biliteral distribution made on digit text.

secret ink. Any of several chemicals used for writing or printing which have the property of being initially invisible to the naked eye or of becoming so after a short time. Also called invisible ink or sympathetic ink.

secret language. Text which conveys no intelligible meaning in any language or which conveys an intelligible meaning that is not the real, hidden meaning.

secret writing. 1. Visible writing in secret language. 2. Invisible writing.

separator, n. See word separator.

sequence, n. An ordered arrangement of symbols (letters, digits, etc.) having continuity. Specifically, the members of a component of a cipher alphabet in order; the symbols in a row, column, or diagonal of a cipher square in order; key letters or key figures in order.

setting, n. The arrangement and alignment of the variable elements of a cryptographic device or machine at any moment during its operation.

sigmage, n. As used in cryptomathematics, a measure of the standard deviation from normal, expressed in terms of sigma (σ).

simple substitution. Monoalphabetic uniliteral substitution.

simple transposition. See single transposition.

single transposition. A transposition in which only one inscription and one transcription are effected.

smoothness, n. That characteristic of a frequency distribution where there is displayed in the distribution no pronounced variation in relative frequencies of the elements considered. (Cf. roughness)

solution, n. In its cryptanalytic application, the process or result of solving a cryptogram or cryptosystem by cryptanalysis.

solve, v.t. To cryptanalyze. To find the plain text of encrypted communications by cryptanalytic processes, or to recover by analysis the keys and the principles of their application.

specific key. An element which is used with a specific cryptosystem to determine the encipherment of a message and which includes both the message keying element and the daily keying element. It may consist of a letter, number, word, phrase, sentence, a special document, book, or table, etc., usually of a variable nature and easily changeable at the will of the correspondents, or prearranged for them or for their agents by higher authority.

square, n. See matrix.

standard cipher alphabet. A cipher alphabet in which the sequence of letters in the plain component is the normal, and in the cipher component is the same as the normal, but either reversed in direction or shifted from its normal point of coincidence with the plain component.

standard uniliteral frequency distribution. See normal uniliteral frequency distribution.

stereotype, n. A word, number, phrase, abbreviation, etc., which as a result of language habits, has a high probability of occurrence, especially at the beginning or ending of a message.

stereotyped messages. Related encrypted messages which are recognizable as such because of distinctive characteristics of the underlying plain text.

strip cipher device. A cipher device employing sliding alphabet strips.

substitution alphabet. See cipher alphabet.

substitution cipher. 1. A cipher system in which the elements of the plain text are replaced by other elements. 2. A cryptogram produced by enciphering a plaintext message with a substitution system.

substitution system. A system in which the elements of the plain or code text are replaced by other elements.

sum-checking digit. A preselected digit (normally the final digit) in a code or cipher group which is the non-carrying sum of the other digits in the group.

summing-trinome system. A substitution system in which each plain-text letter is assigned a unique numerical value of 0 to 27. This value is then expressed as a trinome, the digits of which sum to the designated value of the letter.

superencipherment, n. A form of superencryption in which the final step involves encipherment.---v.t. Superencipher.

superencryption, n. A further encryption of the text of a cryptogram for increased security. Enciphered code is a frequently-encountered example of superencryption.---v.t. Superencrypt.

switch group. A group used within a message to indicate that the following textual elements are encrypted with a different key or code book.

syllabary, n. In a code book, a list of individual letters, combinations of letters, or syllables, accompanied by their equivalent code groups, usually provided for spelling out words or proper names not present in the vocabulary of a code; a spelling table.

syllabary square. A cipher matrix containing individual letters, digits, syllables, frequent digraphs, trigraphs, etc., which are encrypted by the row and column coordinates of the matrix.

syllabic, adj. Of, pertaining to, or denoting syllables.

system, n. See cryptosystem.

systematically-mixed cipher alphabet. A cipher alphabet in which the component that is mixed has been disarranged by systematic procedure. (Cf. random-mixed cipher alphabet)

system indicator. See discriminant.

teleprinter, n. An electrically-operated instrument resembling a typewriter, used for the transmission and reception-printing of messages by electrical means. Also called teletypewriter.

teletypewriter, n. A teleprinter.

tetragraph, n. A set of four letters.

tetranome, n. A set of four digits.

text, n. The part of a message containing the basic information which the originator desires to be communicated.

traffic, n. All transmitted communications.

traffic analysis. That branch of cryptology which, through a study of signal transmissions by all means short of cryptanalysis of message texts, assembles information concerning communication networks. This information is used (1) as a guide to further interception; (2) as an aid to cryptanalysis; (3) as a source of intelligence even in the absence of decrypted message texts; and (4) to strengthen our own security by discovering weaknesses in our communications and by avoiding weaknesses discovered in the communications of others.

traffic intercept. A copy of a communication obtained through interception.

transcription, n. In a transposition system, the process of removing the text from a matrix or grid by a method or route different from that used in the inscription.

transmission security. That component of communication security which results from all measures designed to protect transmissions from interception and traffic analysis.

transparency, direct. That characteristic of cipher text which indicates that certain plaintext elements may have been self-enciphered.

transparency, inverse. That characteristic of cipher text which indicates that certain cipher digraphs may be merely reversals of the corresponding plaintext digraphs.

transposition cipher. 1. A transposition system. 2. A cryptogram produced by enciphering a message with a transposition system.

transposition-mixed cipher alphabet. A cipher alphabet in which at least one component (plain or cipher) has been constructed by applying a form of transposition to either a standard or a mixed sequence.

transposition system. A cryptosystem in which the elements of plain text, whether individual letters, groups of letters, syllables, words, phrases, sentences, or code groups or their components undergo some change in their relative positions without a change in their identities.

trigraph, n. A set of three letters.

trigraphic, adj. Of or pertaining to any three-character group.

trigraphic frequency distribution. A frequency distribution of successive trigraphs. A trigraphic frequency distribution of ABCDEF would consider only the trigraphs ABC and DEF. (Cf. triliteral frequency distribution) trigraphic substitution system. A substitution system in which the plaintext units are composed of three elements.

triliteral, adj. Of, or pertaining only to cryptosystems, cipher alphabets, and frequency distributions which involve cipher units of three letters or characters. See the more inclusive term trigraphic; see also triliteral frequency distribution.

triliteral frequency distribution. A distribution of the characters in the text of a message in sets of three, which will show: (a) each character with its two preceding characters or (b) each character with its two succeeding characters, or, in its most usual form, (c) each character with one preceding and one succeeding character. A triliteral frequency distribution of ABCDEF would consider the groups ABC, BCD, CDE, DEF.

trinome, n. A set of three digits.

trinome-digraphic system. A substitution system in which plaintext digraphs are represented by 3-digit cipher elements.

trough, n. In its cryptologic application, a point of low relative frequency in a frequency distribution.

true polygraphic system. Any polygraphic substitution system in which the individual elements of the polygraphs display no evidence of monoalphabeticity, nor evidence of relationships within any group of polygraphs; that is, in a true polygraphic system, changing one letter in any plaintext polygraph affects the equivalent ciphertext polygraph in its entirety. (Cf. partially-polygraphic system and pseudo-polygraphic system.)

two-element differential. The characteristic incorporated in certain codes in which the groups differ from one another by a minimum of two elements, either in identity or the positions occupied. When the elements are letters, the characteristic is called a two-letter differential; when the elements are digits, it is called a two-digit differential.

two-part code. A randomized code, consisting of an encoding section in which the plaintext groups are arranged in alphabetical or other significant order accompanied by their code groups arranged in a non-alphabetical or random order; and a decoding section, in which the code groups are arranged in alphabetical or numerical order and are accompanied by their meanings as given in the encoding section.

two-square matrix system. A digraphic substitution system which normally employs a matrix consisting of two 5 x 5 squares arranged either horizontally or vertically.

uniliteral, adj. Of, or pertaining only to cryptosystems, cipher alphabets, and frequency distributions which involve cipher units of single letters or characters. See the more inclusive term monographic; see also uniliteral frequency distribution.

uniliteral frequency distribution. A simple tabulation showing the frequency of individual characters of a text.

uniliteral substitution. A cryptographic process in which the individual letters of a message text are replaced by single-letter cipher equivalents.

variant, n. 1. One of two or more cipher or code symbols which have the same plain equivalent; also called variant value. 2. One of several plaintext meanings which may be represented by a single code group.

variant system. A substitution system in which some or all plaintext letters may be represented by more than one cipher equivalent.

variant value. See variant.

vertical two-square matrix system. A digraphic substitution system employing a matrix which normally consists of two 5 x 5 squares arranged vertically.

Vigenère square. The cipher square commonly attributed in cryptographic literature to the French cryptographer Vigenère, having the normal sequence at the top (or bottom) and at the left (or right), with cyclic permutations of the normal or other sequence forming the successive rows (or columns) within the square.

visible writing. Writing in which the characters are inscribed with ordinary writing materials and can be seen with the naked eye. (Cf. invisible writing.)

Wheatstone cipher device. A cipher device consisting essentially of two rings mounted concentrically in a single plane, the outer (and larger) ring being the plain component of the device and comprising 27 equisized divisions, the inner (and smaller) ring being the cipher component, comprising 26 similar divisions. The device incorporates two hands (similar to those on a clock) pivoted at the center of the device--the larger hand serving the outer ring and the smaller hand, the inner--so geared together that for each complete revolution of the larger, the smaller turns through one complete revolution plus one twenty-sixth.

word pattern. The characteristic arrangement of repeated letters in a word which tends to make it readily identifiable when enciphered monoalphabetically.

word separator. A unit of one or more characters employed in certain cryptosystems to indicate the space between words. It may be enciphered or unenciphered. Also called a word spacer.

word transposition. A cryptosystem in which whole words are transposed according to a certain prearranged route or pattern.

APPENDIX 2

LETTER FREQUENCY DATA - ENGLISH

ENGLISH CRYPTANALYTIC DATA
FREQUENCY TABLES

* * * * *

SPECIAL-PURPOSE DATA

Table 1-A.—*Absolute frequencies of letters appearing in five sets of Governmental plain-text telegrams, each set containing 10,000 letters, arranged alphabetically*

Set No 1		Set No 2		Set No 3		Set No 4		Set No. 5	
Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency
A	738	A	783	A	681	A	740	A	741
B	104	B	103	B	98	B	83	B	99
C	319	C	300	C	288	C	326	C	301
D	387	D	413	D	423	D	451	D	448
E	1,367	E	1,294	E	1,292	E	1,270	E	1,275
F	253	F	287	F	308	F	287	F	281
G	166	G	175	G	161	G	167	G	150
H	310	H	351	H	335	H	349	H	349
I	742	I	750	I	787	I	700	I	697
J	18	J	17	J	10	J	21	J	16
K	36	K	38	K	22	K	21	K	31
L	365	L	393	L	333	L	386	L	344
M	242	M	240	M	238	M	249	M	268
N	786	N	794	N	815	N	800	N	780
O	685	O	770	O	791	O	756	O	762
P	241	P	272	P	317	P	245	P	260
Q	40	Q	22	Q	45	Q	38	Q	30
R	760	R	745	R	762	R	735	R	786
S	658	S	583	S	585	S	628	S	604
T	936	T	879	T	894	T	958	T	928
U	270	U	233	U	312	U	247	U	238
V	163	V	173	V	142	V	133	V	155
W	166	W	163	W	136	W	133	W	182
X	43	X	50	X	44	X	53	X	41
Y	191	Y	155	Y	179	Y	213	Y	229
Z	14	Z	17	Z	2	Z	11	Z	5
Total	10,000		10,000		10,000		10,000		10,000

TABLE 1-B.—*Absolute frequencies of letters appearing in five sets of Governmental plain-text telegrams, each set containing 10,000 letters, arranged according to frequency*

Set No 1		Set No 2		Set No 3		Set No 4		Set No 5	
Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency	Letter	Absolute Frequency
E	1,367	E	1,294	E	1,292	E	1,270	E	1,275
T	936	T	879	T	894	T	958	T	928
N	786	N	794	N	815	N	800	R	786
R	760	A	783	O	791	O	756	N	780
I	742	O	770	I	787	A	740	O	762
A	738	I	750	R	762	R	735	A	741
O	685	R	745	A	681	I	700	I	697
S	658	S	583	S	585	S	628	S	604
D	387	D	413	D	423	D	451	D	448
L	365	L	393	H	335	L	386	H	349
C	319	H	351	L	333	H	349	L	344
H	310	C	300	P	317	C	326	C	301
U	270	F	287	U	312	F	287	F	281
F	253	P	272	F	308	M	249	M	268
M	242	M	240	C	288	U	247	P	260
P	241	U	238	M	238	P	245	U	238
Y	191	G	175	Y	179	Y	213	Y	229
G	166	V	173	G	161	G	167	W	182
W	166	W	163	V	142	V	133	V	155
V	163	Y	155	W	136	W	138	G	150
B	104	B	103	B	98	B	83	B	99
X	43	X	50	Q	45	X	58	X	41
Q	40	K	38	X	44	Q	38	K	31
K	36	Q	22	K	22	K	21	Q	30
J	18	J	17	J	10	J	21	J	16
Z	14	Z	17	Z	2	Z	11	Z	5
Total	10,000		10,000		10,000		10,000		10,000

TABLE 1-C.—*Absolute frequencies of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants appearing in five sets of Governmental plain-text telegrams, each set containing 10,000 letters*

Set No	Vowels	High Frequency Consonants	Medium-Frequency Consonants	Low-Frequency Consonants
1	3,993	3,527	2,329	151
2	3,985	3,414	2,457	144
3	4,042	3,479	2,356	123
4	3,926	3,572	2,358	144
5	3,942	3,546	2,389	123
Total [1]	19,888	17,538	11,889	685

[1] Grand total, 50 000

Table 2-A.—*Absolute frequencies of letters appearing in the combined five sets of messages totalling 50,000 letters, arranged alphabetically*

A	3,683	G	819	L	1,821	Q	175	V	766
B	487	H	1,694	M	1,237	R	3,788	W	780
C	1,534	I	3,676	N	3,975	S	3,058	X	231
D	2,122	J	82	O	3,764	T	4,595	Y	967
E	6,498	K	148	P	1,335	U	1,300	Z	49
F	1,416								

Table 2-B.—*Absolute frequencies of letters appearing in the combined five sets of messages totalling 50,000 letters, arranged according to frequency*

E	6,498	I	3,676	C	1,534	Y	967	X	231
T	4,595	S	3,058	F	1,416	G	819	Q	175
N	3,975	D	2,122	P	1,335	W	780	K	148
R	3,788	L	1,821	U	1,300	V	766	J	82
O	3,764	H	1,694	M	1,237	B	487	Z	49
A	3,683								

Table 2-C.—*Absolute frequencies of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants appearing in the combined five sets of messages totalling 50,000 letters*

Vowels	19,888
High-frequency consonants (D, N, R, S, and T)	17,538
Medium-frequency consonants (B, C, F, G, H, L, M, P, V, and W)	11,889
Low-frequency consonants (J, K, Q, X, and Z)	685
Total	50,000

Table 2-D.—*Absolute frequencies of letters as initial letters of 10,000 words found in Governmental plain-text telegrams*

(1) ARRANGED ALPHABETICALLY

A	905	G	109	L	196	Q	30	V	77
B	287	H	272	M	384	R	611	W	320
C	664	I	344	N	441	S	965	X	4
D	525	J	44	O	646	T	1,253	Y	88
E	390	K	23	P	433	U	122	Z	12
F	855								
								Total	10,000

(2) ARRANGED ACCORDING TO FREQUENCY

T	1,253	R	611	M	384	L	196	J	44
S	965	D	525	I	344	U	122	Q	30
A	905	N	441	W	320	G	109	K	23
F	855	P	433	B	287	Y	88	Z	12
C	664	E	390	H	272	V	77	X	4
O	646								
								Total	10,000

~~RESTRICTED~~

TABLE 2–E — *Absolute frequencies of letters as final letters of 10,000 words found in Governmental plain-text telegrams*

(1) ARRANGED ALPHABETICALLY

A	269	G	225	L	354	Q	8	V	4
B	22	H	450	M	154	R	769	W	45
C	86	I	22	N	872	S	962	X	116
D	1,002	J	6	O	575	T	1,007	Y	866
E	1,628	K	53	P	213	U	31	Z	9
F	252								
								Total	10,000

(2) ARRANGED ACCORDING TO FREQUENCY

E	1,628	R	769	F	252	C	86	I	22
T	1,007	O	575	G	225	K	53	Z	9
D	1,002	H	450	P	213	W	45	Q	8
S	962	L	354	M	154	U	31	J	6
N	872	A	269	X	116	B	22	V	4
Y	866								
								Total	10,000

TABLE 3 —*Relative frequencies of letters appearing in 1,000 letters based upon Table 2–B*

(1) ARRANGED ALPHABETICALLY

A	73 66	G	16 38	L	36 42	Q	3 50	V	15 32
B	9 74	H	33 88	M	24 74	R	75 76	W	15 60
C	30 68	I	73 52	N	79 50	S	61 16	X	4 62
D	42 44	J	1 64	O	75 28	T	91 90	Y	19 34
E	129 96	K	2 96	P	26 70	U	26 00	Z	98
F	28 32								
								Total	1,000 00

(2) ARRANGED ACCORDING TO FREQUENCY

E	129 96	I	73 52	C	30 68	Y	19 34	X	4 62
T	91 90	S	61 16	F	28 32	G	16 38	Q	3 50
N	79 50	D	42 44	P	26 70	W	15 60	K	2 96
R	75 76	L	36 42	U	26 00	V	15 32	J	1 64
O	75 28	H	33 88	M	24 74	B	9 74	Z	98
A	73 66								
								Total	1,000 00

(3) VOWELS

A	73 66
E	129 96
I	73 52
O	75 28
U	26 00
Y	19 34
Total	397 76

(4) HIGH-FREQUENCY CONSONANTS

D	42 44
N	79 50
R	75 76
S	61 16
T	91 90
Total	350 76

TABLE 3, Contd —*Relative frequencies of letters appearing in 1,000 letters based upon Table 2–B*

(5) MEDIUM-FREQUENCY CONSONANTS

B	9 74
C	30 68
F	28 32
G	16 38
H	33 88
L	36 42
M	24 74
P	26 70
V	15 32
W	15 60
Total	237 78

(6) LOW-FREQUENCY CONSONANTS

X	4.62
Q	3 50
K	2 96
J	1 64
Z	98
Total	13 70

Total (3), (4), (5), (6) 1,000 00

TABLE 4 —*Frequency distribution for 10,000 letters of literary English, as compiled by Hitt* [1]

(1) ARRANGED ALPHABETICALLY

A	778	G	174	L	372	Q	8	V	112
B	141	H	595	M	288	R	651	W	176
C	296	I	667	N	686	S	622	X	27
D	402	J	51	O	807	T	855	Y	196
E	1,277	K	74	P	223	U	308	Z	17
F	197								

(2) ARRANGED ACCORDING TO FREQUENCY

E	1,277	R	651	U	308	Y	196	K	74
T	855	S	622	C	296	W	176	J	51
O	807	H	595	M	288	G	174	X	27
A	778	D	402	P	223	B	141	Z	17
N	686	L	372	F	197	V	112	Q	8
I	667								

TABLE 5 —*Frequency distribution for 10,000 letters of telegraphic English, as compiled by Hitt* [1]

(1) ARRANGED ALPHABETICALLY

A	813	G	201	L	392	Q	38	V	136
B	149	H	386	M	273	R	677	W	166
C	306	I	711	N	718	S	656	X	51
D	417	J	42	O	844	T	634	Y	208
E	1,319	K	88	P	243	U	321	Z	6
F	205								

(2) ARRANGED ACCORDING TO FREQUENCY

E	1,319	S	656	U	321	F	205	K	88
O	844	T	634	C	306	G	201	X	51
A	813	D	417	M	273	W	166	J	42
N	718	L	392	P	243	B	149	Q	38
I	711	H	386	Y	208	V	136	Z	6
R	677								

[1] Hitt, Capt Parker *Manual for the Solution of Military Ciphers* Army Service Schools Press, Fort Leavenworth, Kansas, 1916

Table 6–A.—*Frequency distribution of digraphs, based on 50,000 letters of Governmental plain-text telegrams, reduced to 5,000 digraphs*

	Second Letter																										Total	Blanks
First Letter	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z		
A	3	6	14	27	1	4	6	2	17	1	2	32	14	64	2	12		44	41	47	13	7	3		12		374	3
B	4				18				2	1		6	1		4			2	1	1	2				7		49	14
C	20		3	1	32	1		14	7		4	5	1	1	41			4	1	14	4		1		1		155	8
D	32	4	4	8	33	8	2	2	27	1		3	5	4	16	5	2	12	13	15	5	3	4		1		209	3
E	35	4	32	60	42	18	4	7	27	1		29	14	111	12	20	12	87	54	37	3	20	7	7	4	1	648	1
F	5		2	1	10	11	1		39			2	1		40	1		9	3	11	3		1		1		141	9
G	7		2	1	14	2	1	20	5	1		2	1	3	6	2		5	3	4	2		1				82	7
H	20	1	3	2	20	5			33			1	2	3	20	1	1	17	4	28	8		1		1		171	7
I	8	2	22	6	13	10	19				2	23	9	75	41	7		27	35	27		25		15		2	368	7
J	1				2										2						2						7	22
K	1		1		6				2			1		1					1								13	19
L	28	3	3	9	37	3	1	1	20			27	2	1	13	3		2	6	8	2	2	2		10		183	5
M	36	6	3	1	26	1		1	9				13		10	8		2	4	2	2				2		126	10
N	26	2	19	52	57	9	27	4	30	1	2	5	5	8	18	3	1	4	24	82	7	3	3		5		397	2
O	7	4	8	12	3	25	2	3	5	1	2	19	25	77	6	25		64	14	19	37	7	8	1	2		376	2
P	14	1	1	1	23	2		3	6			13	4	1	17	11		18	6	8	3	1	1		1		135	6
Q													1					1			15						17	23
R	39	2	9	17	98	6	7	3	30	1	1	5	9	7	28	13		11	31	42	5	5	4		9		382	3
S	24	3	13	5	49	12	2	26	34		1	2	3	4	15	10		5	19	63	11	1	4		1		307	4
T	28	3	6	6	71	7	1	78	45			5	6	7	50	2	1	17	19	19	5		36		41	1	454	4
U	5	3	3	3	11	1	8		5			6	5	21	1	2		31	12	12		1					130	9
V	6				57				12						1					1							77	21
W	12				22			4	13			1		2	19			1	1						1		76	16
X	2		2	1	1	1		1	2					1	1	2		1	1	7							23	13
Y	6	2	4	4	9	11	1	1	3			2	2	6	10	3		4	11	15	1		1				96	7
Z	1				2				1																		4	23
Total	370	46	154	217	657	137	82	170	374	8	14	189	123	397	373	130	17	368	304	462	130	75	77	23	99	4	5,000	
Blanks	1	11	6	7	1	7	12	10	3	18	19	6	6	7	3	8	21	4	4	5	7	15	11	23	10	23		248

TABLE 6-B —*Frequency distribution of digraphs (naval text), based on 20,000 letters of naval text, reduced to 2,000 digraphs*[1]

SECOND LETTER

FIRST LETTER	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	Total	Blanks
A	1	4	9	5		2	3	1	8		3	7	2	29		4		16	11	31	1	3		1	5		146	6
B	4			1	8				1			6	2		4						1				2		29	17
C	7		1		10		2	5	1		4				22	1		4	1	4							62	14
D	10	2	2	2	15	3	1	1	12			2	2		4	3		8	6	6	2	1	1		3		86	6
E	9	3	8	24	25	7	1	2	7	1	1	6	6	34	6	10	1	43	23	18	1	7	2	4	1	4	254	0
F	2		1		2	1			13			5	1		12	1		2	1	5	1				1		48	12
G	4		1	1	8	1	1	11	2			2		1	2	1		2	2	6	3					1	49	9
H	6				7	1			6				1		3	1		7	1	11	6		1				51	14
I	2	1	6	2	2	5	11					8	2	42	21	2		10	10	11		9		5			149	9
J															2												2	25
K	1	1	1		8	1			2			1		1													11	18
L	14	1	1		15	1			8			6			7	2		1	2	1	1	2			2		64	11
M	11	1			5				4			1	2		4	2			1						3		34	16
N	10	8	8	22	22	5	22	2	6		2	2	2	3	10	2		2	9	27	3		1				163	6
O	3	3	3	11	4	9	2		6		1	4	9	38	2	8		20	9	7	20	1	4	1	1	1	167	3
P	4				18			1	1			5			7	3		8	3	2	1						53	15
Q																					3						3	25
R	14	2	6	9	34	2	8		19		1	1	3	3	24	2		2	8	10	4		1				148	7
S	8	2	8	1	15	2		4	13			2	1	1	5	6	1	1	6	23	6		3				108	7
T	16	1	4	8	27	4	1	21	23			3	1	2	22	3		10	8	8	4		12		8	4	185	5
U	4	8	1	2	8		1		4			2	2	9		1		1	4	10							47	12
V	8				17				4						1												25	22
W	4				10			1	5						6			1									27	20
X			1			1		1	4			1								2							10	20
Y	8	1	2	1	2	8			1			3	2		2	2		1	2	2			1				28	11
Z					10																	1					11	24
Total	140	28	63	84	262	48	48	50	150	1	12	67	38	163	166	54	2	139	107	184	57	24	26	11	26	10	1,960	
Blanks	4	12	9	13	4	10	15	15	4	25	20	7	11	15	6	8	24	8	8	8	11	19	17	22	17	22		334

[1] Fractional values have been discarded This accounts for the discrepancy between the indicated total (1,960) and the stated total (2,000)

TABLES 7–11, Inclusive

Absolute frequencies of digraphs, trigraphs, and tetragraphs and the logarithms of their assigned probabilities [1]

1 For each of the following 18 tables, the basic data were first arranged according to their absolute frequencies (F), and then the logarithms—L_{10}(F) of the frequencies found

2 The tables are designed to facilitate determination of the relative weights or probability of occurrence of sets of digraphs, trigraphs, or tetragraphs, particularly with respect to various "matching" operations For example, are the matched digraphs RE and ET more probable than the matched digraphs RT and EF? Table 7–A shows the frequencies (F) of the digraphs to be as follows RE=98, ET=37, RT=42, EF=18 Therefore, 98 times 37 is compared with 42 times 18, or 3,626 with 756 This arithmetic method of approach is extremely cumbersome for a large number of comparisons By using the logarithms of the individual frequencies, the operation is greatly simplified, since the addition of the logarithms of two numbers is equivalent to the multiplication of their equivalent arithmetic values Thus, the foregoing computation may be expressed as Log 98+Log 37, compared with Log 42+Log 18, or 0 96+0 79 versus 0 81+0 66 (see Table 7–A and explanation below) If more than one occurrence of a particular digraph is involved, it is merely necessary to multiply the logarithmic value by the number of the occurrences, viz , Log X+2(Log Y)+3(Log Z), as compared with Log A+3(Log B)+2(Log C)

3 The logarithm of any given number is the power to which 10 must be raised to equal the given number Thus, 10^2=100, or the logarithm of 100=2 Similarly, 10^3=1,000, or the logarithm of 1,000=3 The sum of logaithms is equal to the logarithm of the product of their antilogs (arithmetic numbers they represent) For example, 10^2=100, 10^3=1000, 10^{2+3}=100×1000, Log 100,000=5 Also, 10^0=1, or Log 1=0 The Log of 0 is minus infinity (−∞)

4 In the compilation of the logarithms of the elements constituting these tables, frequencies of 1, of course, had a logarithmic value of 0 00 Digraphs which did not occur,[2] i e., those with 0 occurrences, had a logarithmic value of minus infinity (−∞) For practical use, each of the original frequency occurrences in these tables was doubled, i e , EN was given a frequency of 222 instead of 111, the frequency of RE became 196 instead of 98, etc Thus, single occurrences were doubled (2×1=2), and the logarithms of those elements became 0 30 instead of 0 This is equivalent to saying Log 1+Log 2=0 00+0 30=0 30 Those elements which occurred 0 times, now were assumed to have an occurrence of 1, with an equivalent logarithmic value of 0 00

5 In order to place all the logarithms of the initial frequencies on a comparable logarithmic basis, it was merely necessary to add 0 30 to each of them While EN had a frequency of 111 in the original compilation, it now had a frequency of 222, or 2(111) The logarithm of 222 is 2 35 This is equivalent to saying Log 111+Log 2=2 05+0 30=2 35

6 The frequencies as stated in terms of their actual logarithms do not readily indicate their relative size for each distribution Therefore, the highest frequency in each group was given a value of 0 99, and the lowest a value of 0, frequencies intermediate between these extremes were

[1] These frequency distributions are based upon data derived from 50,000 letters of U S Governmental plain-text telegrams, reduced to 5 000 digraphs

[2] While in general it is possible to assign probability values to digraphs in accordance with their observed frequencies, it is not strictly correct to associate the probability "0 with a frequency of zero This would be equivalent to saying Because a specified digraph has not occurred, it cannot occur and would be reflected in the mathematics Log probability zero equals minus infinity " What may be said is 'Since a specified digraph has not occurred in the data its true probability value is unknown except that it must be below the probability value assigned to a frequency of one " The proper way to assign a probability value to digraphs with frequencies of zero is to continue counting until they have at least one occurrence then the true relative probability can be found

A simple practical method of taking this difficulty into account is merely to assume that in twice the amount of data the digraph probably would have occurred at least once that is it has a frequency of one-half

It should be pointed out however, that *since probabilities are multiplied* (by summing logarithms) a 10% *error in evaluating the digraph* ZZ *for example*, makes the product, wherever ZZ occurs 10% wrong and is just as serious as a 10% error in evaluating the high frequency digraph EN

In practice however results obtained from the logarithmic method are so satisfactory that refinements are not needed evaluated in proportion to their respective frequencies This is equivalent to expressing the frequencies in logarithms with a base other than 10 In other words, this procedure of converting the logarithms to the range from 00 to 99 consists in dividing up the original range of logarithms into 100 equal parts and assigning each one to the proper rank in the range

7 The new base (C) used to convert each of the digraphic frequencies to the logarithmic range 0 to 0 99 is derived as follows, when 222 is the highest frequency (F)

$$\text{Let } 222 = C^{0\ 99}$$

$$\mathrm{Log}_{10}\ 222 = \mathrm{Log}_{10}\ C^{0\ 99}$$

$$\mathrm{Log}_{10}\ 222 = (0\ 99)\ (\mathrm{Log}_{10}\ C)$$

$$C = \text{Antilog}\ \frac{\mathrm{Log}_{10}\ 222}{0\ 99} = \text{Antilog}\ \frac{2\ 35}{0\ 99}$$

$$C = 224$$

8 The formula for the computation of the logarithm to the new base (C) of any actual frequency (Y) of a series is

$$\mathrm{Log}_c\ Y = \frac{\mathrm{Log}_{10}\ Y}{\mathrm{Log}_{10}\ C}$$

It is more expeditious to use reciprocals in the conversion of a whole series of logarithmic values, as in this instance The formula is $(\mathrm{Log}_{10}\ C)^{-1}\ \ (\mathrm{Log}_{10}\ Y) = \mathrm{Log}_c\ Y$

9 The digraphic index chart, Table 15, on page 37, summarizes the logarithmic frequencies of all English plain-text digraphs, computed to a base of 224 so that the logarithm of the highest frequency (EN) is 0 99

Example

$$\mathrm{EN} = 222$$

$$\mathrm{Log}_{10}\ 222 = 2\ 35$$

$$(\mathrm{Log}_{10}\ C)^{-1} = (\mathrm{Log}_{10}\ 224)^{-1} = 0\ 421$$

$$\mathrm{Log}_c\ 222 = 0\ 421 \times 2\ 35 = 0\ 99$$

10. Likewise, the trigraphs and tetragraphs have been computed to the bases L586 and L244, respectively, so that the logarithms of the highest-frequency trigraph (ENT) and tetragraph (TION) are 0.99. Since no use is being made of the trigraphs appearing less than 100 times and tetragraphs appearing less than 50 times, the basic frequencies of the trigraphs and tetragraphs have not been doubled in computing the new bases of the logarithms.

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TABLE 7-A —*The 428 different digraphs of Table 6-A, arranged according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
EN	111	2 05	99	DA	32	1 51	76	OL	19	1 28	67	EQ	12	1 08	58
RE	98	1 99	96	EC	32	1 51	76	OT	19	1 28	67	OD	12	1 08	58
ER	87	1 94	94	RS	31	1 49	75	SS	19	1 28	67	SF	12	1 08	58
NT	82	1 91	93	UR	31	1 49	75	TS	19	1 28	67	US	12	1 08	58
TH	78	1 89	92	NI	30	1 48	75	TT	19	1 28	67	UT	12	1 08	58
ON	77	1 89	92	RI	30	1 48	75	WO	19	1 28	67	VI	12	1 08	58
IN	75	1 88	92	EL	29	1 46	74	BE	18	1 26	66	WA	12	1 08	58
TE	71	1 85	91	HT	28	1 45	74	EF	18	1 26	66	FF	11	1 04	56
AN	64	1 81	89	LA	28	1 45	74	NO	18	1 26	66	FT	11	1 04	56
OR	64	1 81	89	RO	28	1 45	74	PR	18	1 26	66	PP	11	1 04	56
ST	63	1 80	88	TA	28	1 45	74	AI	17	1 23	64	RR	11	1 04	56
ED	60	1 78	88		[2]2,495			HR	17	1 23	64	SU	11	1 04	56
NE	57	1 76	87					PO	17	1 23	64	UE	11	1 04	56
VE	57	1 76	87	AD	27	1 43	73	RD	17	1 23	64	YF	11	1 04	56
ES	54	1 73	86	DI	27	1 43	73	TR	17	1 23	64	YS	11	1 04	56
ND	52	1 72	85	EI	27	1 43	73	DO	16	1 20	63	FE	10	1 00	55
TO	50	1 70	84	IR	27	1 43	73	DT	15	1 18	62	IF	10	1 00	55
SE	49	1 69	84	IT	27	1 43	73	IX	15	1 18	62	LY	10	1 00	55
	[1]1,249			LL	27	1 43	73	QU	15	1 18	62	MO	10	1 00	55
				NG	27	1 43	73	SO	15	1 18	62	SP	10	1 00	55
AT	47	1 67	83	ME	26	1 41	72	YT	15	1 18	62	YO	10	1 00	55
TI	45	1 65	82	NA	26	1 41	72	AC	14	1 15	61	FR	9	0 95	53
AR	44	1 64	82	SH	26	1 41	72	AM	14	1 15	61	IM	9	0 95	53
EE	42	1 62	81	IV	25	1 40	72	CH	14	1 15	61	LD	9	0 95	53
RT	42	1 62	81	OF	25	1 40	72	CT	14	1 15	61	MI	9	0 95	53
AS	41	1 61	80	OM	25	1 40	72	EM	14	1 15	61	NF	9	0 95	53
CO	41	1 61	80	OP	25	1 40	72	GE	14	1 15	61	RC	9	0 95	53
IO	41	1 61	80	NS	24	1 38	71	OS	14	1 15	61	RM	9	0 95	53
TY	41	1 61	80	SA	24	1 38	71	PA	14	1 15	61	RY	9	0 95	53
FO	40	1 60	80	IL	23	1 36	70	AU	13	1 11	59	YE	9	0 95	53
FI	39	1 59	80	PE	23	1 36	70	DS	13	1 11	59	DD	8	0 90	51
RA	39	1 59	80	IC	22	1 34	69	IE	13	1 11	59	DF	8	0 90	51
ET	37	1 57	79	WE	22	1 34	69	LO	13	1 11	59	HU	8	0 90	51
LE	37	1 57	79	UN	21	1 32	68	MM	13	1 11	59	IA	8	0 90	51
OU	37	1 57	79	CA	20	1 30	67	PL	13	1 11	59	LT	8	0 90	51
MA	36	1 56	78	EP	20	1 30	67	RP	13	1 11	59	MP	8	0 90	51
TW	36	1 56	78	EV	20	1 30	67	SC	13	1 11	59	NN	8	0 90	51
EA	35	1 54	78	GH	20	1 30	67	WI	13	1 11	59	OC	8	0 90	51
IS	35	1 54	78	HA	20	1 30	67		[3]3,745			OW	8	0 90	51
SI	34	1 53	77	HE	20	1 30	67					PT	8	0 90	51
DE	33	1 52	77	HO	20	1 30	67	AP	12	1 08	58	UG	8	0 90	51
HI	33	1 52	77	LI	20	1 30	67	AY	12	1 08	58	AV	7	0 85	48
AL	32	1 51	76	IG	19	1 28	67	DR	12	1 08	58	BY	7	0 85	48
CE	32	1 51	76	NC	19	1 28	67	EO	12	1 08	58	CI	7	0 85	48

[1] The 18 digraphs above this line compose 25% of the total

[2] The 53 digraphs above this line compose 50% of the total

[3] The 122 digraphs above this line compose 75% of the total

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Table 7-A, Contd —*The 428 different digraphs of Table 6-A, arranged according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
EH	7	0 85	48	RU	5	0 70	42	GS	3	0 48	33	JE	2	0 30	25
EW	7	0 85	48	RV	5	0 70	42	HC	3	0 48	33	JO	2	0 30	25
EX	7	0 85	48	SD	5	0 70	42	HN	3	0 48	33	JU	2	0 30	25
GA	7	0 85	48	SR	5	0 70	42	LB	3	0 48	33	KI	2	0 30	25
IP	7	0 85	48	TL	5	0 70	42	LC	3	0 48	33	LM	2	0 30	25
NU	7	0 85	48	TU	5	0 70	42	LF	3	0 48	33	LR	2	0 30	25
OA	7	0 85	48	UA	5	0 70	42	LP	3	0 48	33	LU	2	0 30	25
OV	7	0 85	48	UI	5	0 70	42	MC	3	0 48	33	LV	2	0 30	25
RG	7	0 85	48	UM	5	0 70	42	NP	3	0 48	33	LW	2	0 30	25
RN	7	0 85	48	AF	4	0 60	38	NV	3	0 48	33	MR	2	0 30	25
TF	7	0 85	48	BA	4	0 60	38	NW	3	0 48	33	MT	2	0 30	25
TN	7	0 85	48	BO	4	0 60	38	OE	3	0 48	33	MU	2	0 30	25
XT	7	0 85	48	CK	4	0 60	38	OH	3	0 48	33	MY	2	0 30	25
AB	6	0 78	45	CR	4	0 60	38	PH	3	0 48	33	NB	2	0 30	25
AG	6	0 78	45	CU	4	0 60	38	PU	3	0 48	33	NK	2	0 30	25
BL	6	0 78	45	DB	4	0 60	38	RH	3	0 48	33	OG	2	0 30	25
GO	6	0 78	45	DC	4	0 60	38	SB	3	0 48	33	OK	2	0 30	25
ID	6	0 78	45	DN	4	0 60	38	SM	3	0 48	33	OY	2	0 30	25
KE	6	0 78	45	DW	4	0 60	38	TB	3	0 48	33	PF	2	0 30	25
LS	6	0 78	45	EB	4	0 60	38	UB	3	0 48	33	RB	2	0 30	25
MB	6	0 78	45	EG	4	0 60	38	UC	3	0 48	33	SG	2	0 30	25
OO	6	0 78	45	EY	4	0 60	38	UD	3	0 48	33	SL	2	0 30	25
PI	6	0 78	45	GT	4	0 60	38	YI	3	0 48	33	TP	2	0 30	25
PS	6	0 78	45	HS	4	0 60	38	YP	3	0 48	33	UP	2	0 30	25
RF	6	0 78	45	MS	4	0 60	38	AH	2	0 30	25	WN	2	0 30	25
TC	6	0 78	45	NH	4	0 60	38	AK	2	0 30	25	XA	2	0 30	25
TD	6	0 78	45	NR	4	0 60	38	AO	2	0 30	25	XC	2	0 30	25
TM	6	0 78	45	OB	4	0 60	38	BI	2	0 30	25	XI	2	0 30	25
UL	6	0 78	45	PM	4	0 60	38	BR	2	0 30	25	XP	2	0 30	25
VA	6	0 78	45	RW	4	0 60	38	BU	2	0 30	25	YB	2	0 30	25
YA	6	0 78	45	SN	4	0 60	38	DG	2	0 30	25	YL	2	0 30	25
YN	6	0 78	45	SW	4	0 60	38	DH	2	0 30	25	YM	2	0 30	25
CL	5	0 70	42	WH	4	0 60	38	DQ	2	0 30	25	ZE	2	0 30	25
DM	5	0 70	42	YC	4	0 60	38	FC	2	0 30	25	AE	1	0 00	13
DP	5	0 70	42	YD	4	0 60	33	FL	2	0 30	25	AJ	1	0 00	13
DU	5	0 70	42	YR	4	0 60	38	GC	2	0 30	25	BJ	1	0 00	13
FA	5	0 70	42	AA	3	0 48	33	GF	2	0 30	25	BM	1	0 00	13
GI	5	0 70	42	AW	3	0 48	33	GL	2	0 30	25	BS	1	0 00	13
GR	5	0 70	42	CC	3	0 48	33	GP	2	0 30	25	BT	1	0 00	13
HF	5	0 70	42	DL	3	0 48	33	GU	2	0 30	25	CD	1	0 00	13
NL	5	0 70	42	DV	3	0 48	33	HD	2	0 30	25	CF	1	0 00	13
NM	5	0 70	42	EU	3	0 48	33	HM	2	0 30	25	CM	1	0 00	13
NY	5	0 70	42	FS	3	0 48	33	IB	2	0 30	25	CN	1	0 00	13
OI	5	0 70	42	FU	3	0 48	33	IK	2	0 30	25	CS	1	0 00	13
RL	5	0 70	42	GN	3	0 48	33	IZ	2	0 30	25	CW	1	0 00	13

TABLE 7-A, Concluded —*The 428 different digraphs of Table 6-A, arranged according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$
CY	1	0 00	13	HW	1	0 00	13	PD	1	0 00	13	WL	1	0 00	13
DJ	1	0 00	13	HY	1	0 00	13	PN	1	0 00	13	WR	1	0 00	13
DY	1	0 00	13	JA	1	0 00	13	PV	1	0 00	13	WS	1	0 00	13
EJ	1	0 00	13	KA	1	0 00	13	PW	1	0 00	13	WY	1	0 00	13
EZ	1	0 00	13	KC	1	0 00	13	PY	1	0 00	13	XD	1	0 00	13
FD	1	0 00	13	KL	1	0 00	13	QM	1	0 00	13	XE	1	0 00	13
FG	1	0 00	13	KN	1	0 00	13	QR	1	0 00	13	XF	1	0 00	13
FM	1	0 00	13	KS	1	0 00	13	RJ	1	0 00	13	XH	1	0 00	13
FP	1	0 00	13	LG	1	0 00	13	RK	1	0 00	13	XN	1	0 00	13
FW	1	0 00	13	LH	1	0 00	13	SK	1	0 00	13	XO	1	0 00	13
FY	1	0 00	13	LN	1	0 00	13	SV	1	0 00	13	XR	1	0 00	13
GD	1	0 00	13	MD	1	0 00	13	SY	1	0 00	13	XS	1	0 00	13
GG	1	0 00	13	MF	1	0 00	13	TG	1	0 00	13	YG	1	0 00	13
GJ	1	0 00	13	MH	1	0 00	13	TQ	1	0 00	13	YH	1	0 00	13
GM	1	0 00	13	NJ	1	0 00	13	TZ	1	0 00	13	YU	1	0 00	13
GW	1	0 00	13	NQ	1	0 00	13	UF	1	0 00	13	YW	1	0 00	13
HB	1	0 00	13	OJ	1	0 00	13	UO	1	0 00	13	ZA	1	0 00	13
HL	1	0 00	13	OX	1	0 00	13	UV	1	0 00	13	ZI	1	0 00	.13
HP	1	0 00	13	PB	1	0 00	13	VO	1	0 00	13		5,000		
HQ	1	0 00	13	PC	1	0 00	13	VT	1	0 00	13				

TABLE 7-B —*The 18 digraphs composing 25% of the digraphs in Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their initial letters*

(1) AND ACCORDING TO THEIR FINAL LETTERS

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES

	F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$
AN	64	1 81	89	ON	77	1 89	92	AN	64	1 81	89	ON	77	1 89	92
				OR	64	1 81	89					OR	64	1 81	.89
ED	60	1 78	88	RE	98	1 99	96	EN	111	2 05	99	RE	98	1 99	96
EN	111	2 05	99					ER	87	1 94	94				
ER	87	1 94	94	SE	49	1 69	84	ED	60	1 78	88	ST	63	1 80	88
ES	54	1 73	86	ST	63	1 80	88	ES	54	1 73	86	SE	49	1 69	84
				TE	71	1 85	91					TH	78	1 89	92
IN	75	1 88	92	TH	78	1 89	92	IN	75	1 88	92	TE	71	1 85	91
				TO	50	1 70	84					TO	50	1 70	84
ND	52	1 72	85	VE	57	1 76	87	NT	82	1 91	93	VE	57	1 76	87
NE	57	1 76	87		1,249			NE	57	1 76	87		1,249		
NT	82	1 91	93					ND	52	1 72	85				

TABLE 7-C.—*The 53 digraphs composing 50% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their initial letters*

(1) AND ACCORDING TO THEIR FINAL LETTERS								(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES							
	F	$L_{10}(F)$	$L_{224}(2\Gamma)$		F	$L_{10}(\Gamma)$	$L_{224}(2\Gamma)$		Γ	$L_{10}(\Gamma)$	$L_{224}(2F)$		Γ	$L_{10}(\Gamma)$	$L_{224}(2F)$
AL	32	1 51	76	MA	36	1 56	78	AN	64	1 81	89	MA	36	1 56	78
AN	64	1 81	89					AT	47	1 67	83				
AR	44	1 64	82	ND	52	1 72	85	AR	44	1 64	82	NT	82	1 91	93
AS	41	1.61	80	NE	57	1 76	87	AS	41	1 61	80	NE	57	1 76	87
AT	47	1 67	83	NI	30	1 48	75	AL	32	1 51	76	ND	52	1 72	85
				NT	82	1 91	93					NI	30	1 48	75
CE	32	1 51	76					CO	41	1 61	80				
CO	41	1 61	80	ON	77	1 89	92	CE	32	1 51	76	ON	77	1 89	92
				OR	64	1 81	89					OR	64	1 81	89
DA	32	1 51	76	OU	37	1 57	79	DE	33	1 52	77	OU	37	1 57	79
DE	33	1 52	77					DA	32	1 51	76				
				RA	39	1 59	80					RE	98	1 99	96
EA	35	1 54	78	RE	98	1 99	96	EN	111	2 05	99	RT	42	1 62	81
EC	32	1 51	76	RI	30	1 48	75	ER	87	1 94	94	RA	39	1 59	.80
ED	60	1 78	88	RO	28	1 45	74	ED	60	1 78	88	RS	31	1 49	75
EE	42	1 62	81	RS	31	1 49	75	ES	54	1 73	86	RI	30	1 48	75
EL	29	1 46	74	RT	42	1 62	81	EE	42	1 62	81	RO	28	1 45	74
EN	111	2 05	99					ET	37	1 57	79				
ER	87	1 94	94	SE	49	1 69	84	EA	35	1 54	78	ST	63	1 80	88
ES	54	1 73	86	SI	34	1 53	77	EC	32	1 51	76	SE	49	1 69	84
ET	37	1 57	79	ST	63	1 80	88	EL	29	1 46	74	SI	34	1 53	77
FI	39	1 59	80	TA	28	1 45	74	FO	40	1 60	80	TH	78	1 89	92
FO	40	1 60	.80	TE	71	1 85	91	FI	39	1 59	80	TE	71	1 85	91
				TH	78	1 89	92					TO	50	1 70	84
HI	33	1 52	77	TI	45	1 65	82	HI	33	1 52	77	TI	45	1 65	82
HT	28	1 45	74	TO	50	1 70	84	HT	28	1 45	74	TY	41	1 61	80
				TW	36	1 56	78					TW	36	1 56	78
IN	75	1 88	92	TY	41	1 61	80	IN	75	1 88	92	TA	28	1 45	74
IO	41	1 61	80					IO	41	1 61	80				
IS	35	1 54	78	UR	31	1 49	75	IS	35	1 54	78	UR	31	1 49	75
LA	28	1 45	74	VE	57	1 76	87	LE	37	1 57	79	VE	57	1 76	87
LE	37	1 57	79		2,495			LA	28	1 45	74		2,495		

TABLE 7–D.—*The 122 digraphs composing 75% of the 5,000 digraphs of Table 6–A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their initial letters*

(1) AND ACCORDING TO THEIR FINAL LETTERS

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
AC	14	1 15	61	ER	87	1 94	94	MA	36	1 56	78	RS	31	1 49	75
AD	27	1 43	73	ES	54	1 73	86	ME	26	1 41	72	RT	42	1 62	81
AI	17	1 23	64	ET	37	1 57	79								
AL	32	1 51	76	EV	20	1 30	67	NA	26	1 41	72	SA	24	1 38	71
AM	14	1 15	61					NC	19	1 28	67	SE	49	1 69	84
AN	64	1 81	89	FI	39	1 59	80	ND	52	1 72	85	SH	26	1 41	72
AR	44	1 64	82	FO	40	1 60	80	NE	57	1 76	87	SI	34	1 53	77
AS	41	1 61	80					NG	27	1 43	73	SO	15	1 18	62
AT	47	1 67	83	GE	14	1 15	61	NI	30	1 48	75	SS	19	1 28	67
AU	13	1 11	59	GH	20	1 30	67	NO	18	1 26	66	ST	63	1 80	88
								NS	24	1 38	71				
BE	18	1 26	66	HA	20	1 30	67	NT	82	1 91	93	TA	28	1 45	.74
				HE	20	1 30	67					TE	71	1 85	91
CA	20	1 30	67	HI	33	1 52	77	OF	25	1 40	72	TH	78	1 89	92
CE	32	1 51	76	HO	20	1 30	67	OL	19	1 28	67	TI	45	1 65	82
CH	14	1 15	61	HR	17	1 23	64	OM	25	1 40	72	TO	50	1 70	84
CO	41	1 61	80	HT	28	1 45	74	ON	77	1 89	92	TR	17	1 23	64
CT	14	1 15	61					OP	25	1 40	72	TS	19	1 28	67
DA	32	1 51	76	IC	22	1 34	69	OR	64	1 81	89	TT	19	1 28	67
DE	33	1 52	77	IE	13	1 11	59	OS	14	1 15	61	TW	36	1 56	78
DI	27	1 43	73	IG	19	1 28	67	OT	19	1 28	67	TY	41	1 61	80
DO	16	1 20	63	IL	23	1 36	70	OU	37	1 57	79				
DS	13	1 11	59	IN	75	1 88	92					UN	21	1 32	68
DT	15	1 18	62	IO	41	1 61	80	PA	14	1 15	61	UR	31	1 49	75
				IR	27	1 43	73	PE	23	1 36	70				
EA	35	1 54	78	IS	35	1 54	78	PO	17	1 23	64	VE	57	1 76	87
EC	32	1 51	76	IT	27	1 43	73	PR	18	1 26	66				
ED	60	1 78	88	IV	25	1 40	72					WE	22	1 34	69
EE	42	1 62	81	IX	15	1 18	62	QU	15	1 18	62	WO	19	1 28	67
EF	18	1 26	66												
EI	27	1 43	73	LA	28	1 45	74	RA	39	1 59	80	YT	15	1 18	62
EL	29	1 46	74	LE	37	1 57	79	RD	17	1 23	64		3,745		
EM	14	1 15	61	LI	20	1 30	67	RE	98	1 99	96				
EN	111	2 05	99	LL	27	1 43	73	RI	30	1 48	75				
EP	20	1 30	67	LO	13	1 11	59	RO	28	1 45	74				

TABLE 7-D, Concluded —*The 122 digraphs composing 75% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their initial letters*

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES

	F	$L_{10}(F)$	L_{24} (2F)
AN	64	1 81	89
AT	47	1 67	83
AR	44	1 64	82
AS	41	1 61	80
AL	32	1 51	76
AD	27	1 43	73
AI	17	1 23	64
AC	14	1 15	61
AM	14	1 15	61
AU	13	1 11	59
BE	18	1 26	66
CO	41	1 61	80
CE	32	1 51	76
CA	20	1 30	67
CH	14	1 15	61
CT	14	1 15	61
DE	33	1 52	77
DA	32	1 51	76
DI	27	1 43	73
DO	16	1 20	63
DT	15	1 18	62
DS	13	1 11	59
EN	111	2 05	99
ER	87	1 94	94
ED	60	1 78	88
ES	54	1 73	86
EE	42	1 62	81
ET	37	1 57	79
EA	35	1 54	78
EC	32	1 51	76
EL	29	1 46	74

	Γ	$L_{10}(F)$	L_{24} (2Γ)
EI	27	1 43	73
EP	20	1 30	67
EV	20	1 30	67
EF	18	1 26	66
EM	14	1 15	61
FO	40	1 60	80
FI	39	1 59	80
GH	20	1 30	67
GE	14	1 15	61
HI	33	1 52	77
HT	28	1 45	74
HA	20	1 30	67
HE	20	1 30	67
HO	20	1 30	67
HR	17	1 23	64
IN	75	1 88	92
IO	41	1 61	80
IS	35	1 54	78
IR	27	1 43	73
IT	27	1 43	73
IV	25	1 40	72
IL	23	1 36	70
IC	22	1 34	69
IG	19	1 28	67
IX	15	1 18	62
IE	13	1 11	59
LE	37	1 57	79
LA	28	1 45	74
LL	27	1 43	73
LI	20	1 30	67
LO	13	1 11	59

	F	$L_{10}(F)$	L_{24} (2Γ)
MA	36	1 56	78
ME	26	1 41	72
NT	82	1 91	93
NE	57	1 76	87
ND	52	1 72	85
NI	30	1 48	75
NG	27	1 43	73
NA	26	1 41	72
NS	24	1 38	71
NC	19	1 28	67
NO	18	1 26	66
ON	77	1 89	92
OR	64	1 81	89
OU	37	1 57	79
OF	25	1 40	72
OM	25	1 40	72
OP	25	1 40	72
OL	19	1 28	67
OT	19	1 28	67
OS	14	1 15	61
PE	23	1 36	70
PR	18	1 26	66
PO	17	1 23	64
PA	14	1 15	61
QU	15	1 18	62
RE	98	1 99	96
RT	42	1 62	81
RA	39	1 59	80
RS	31	1 49	75

	Γ	$L_{10}(\Gamma)$	L_{24} (2F)
RI	30	1 48	75
RO	28	1 45	74
RD	17	1 23	64
ST	63	1 80	88
SE	49	1 69	84
SI	34	1 53	77
SH	26	1 41	72
SA	24	1 38	71
SS	19	1 28	67
SO	15	1 18	62
TH	78	1 89	92
TE	71	1 85	91
TO	50	1 70	84
TI	45	1 65	82
TY	41	1 61	80
TW	36	1 56	78
TA	28	1 45	74
TS	19	1 28	67
TT	19	1 28	67
TR	17	1 23	64
UR	31	1 49	75
UN	21	1 32	68
VE	57	1 76	87
WE	22	1 34	69
WO	19	1 28	67
YT	15	1 18	62
	3,745		

TABLE 7-E —*All the 428 digraphs of Table 6-A, arranged first alphabetically according to their initial letters and then alphabetically according to their final letters*

(SEE TABLE 6-A—READ ACROSS THE ROWS)

TABLE 8 —*The 428 different digraphs of Table 6–A, arranged first alphabetically according to their initial letters and then according to their absolute frequencies under each initial letter,*[1] *accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{24}(2F)$		F	$L_{10}(F)$	$L_{24}(2F)$		F	$L_{10}(F)$	$L_{24}(2F)$		F	$L_{10}(F)$	$L_{24}(2F)$
AN	64	1 81	89	CT	14	1 15	61	ED	60	1 78	88	GH	20	1 30	67
AT	47	1 67	83	CI	7	0 85	48	ES	54	1 73	86	GE	14	1 15	61
AR	44	1 64	82	CL	5	0 70	42	EE	42	1 62	81	GA	7	0 85	48
AS	41	1 61	80	CK	4	0 60	38	ET	37	1 57	79	GO	6	0 78	45
AL	32	1 51	76	CR	4	0 60	38	EA	35	1 54	78	GI	5	0 70	42
AD	27	1 43	73	CU	4	0 60	38	EC	32	1 51	76	GR	5	0 70	42
AI	17	1 23	64	CC	3	0 48	33	EL	29	1 46	74	GT	4	0 60	38
AC	14	1 15	61	CD	1	0 00	13	EI	27	1 43	73	GN	3	0 48	33
AM	14	1 15	61	CF	1	0 00	13	EP	20	1 30	67	GS	3	0 48	33
AU	13	1 11	59	CM	1	0 00	13	EV	20	1 30	67	GC	2	0 30	25
AP	12	1 08	58	CN	1	0 00	13	EF	18	1 26	66	GF	2	0 30	25
AY	12	1 08	58	CS	1	0 00	13	EM	14	1 15	61	GL	2	0 30	25
AV	7	0 85	48	CW	1	0 00	13	EO	12	1 08	58	GP	2	0 30	25
AB	6	0 78	45	CY	1	0 00	13	EQ	12	1 08	58	GU	2	0 30	25
AG	6	0 78	45					EH	7	0 85	48	GD	1	0 00	13
AF	4	0 60	38	DE	33	1 52	77	EW	7	0 85	48	GG	1	0 00	13
AA	3	0 48	33	DA	32	1 51	76	EX	7	0 85	48	GJ	1	0 00	13
AW	3	0 48	33	DI	27	1 43	73	EB	4	0 60	38	GM	1	0 00	13
AH	2	0 30	25	DO	16	1 20	63	EG	4	0 60	38	GW	1	0 00	13
AK	2	0 30	25	DT	15	1 18	62	EY	4	0 60	38				
AO	2	0 30	25	DS	13	1 11	59	EU	3	0 48	33				
AE	1	0 00	13	DR	12	1 08	58	EJ	1	0 00	13				
AJ	1	0 00	13	DD	8	0 90	51	EZ	1	0 00	13	HI	33	1 52	77
				DF	8	0 90	51					HT	28	1 45	74
BE	18	1 26	66	DM	5	0 70	42	FO	40	1 60	80	HA	20	1 30	67
BY	7	0 85	48	DP	5	0 70	42	FI	39	1 59	80	HE	20	1 30	67
BL	6	0 78	45	DU	5	0 70	42	FF	11	1 04	56	HO	20	1 30	67
BA	4	0 60	38	DB	4	0 60	38	FT	11	1 04	56	HR	17	1 23	64
BO	4	0 60	38	DC	4	0 60	38	FE	10	1 00	55	HU	8	0 90	51
BI	2	0 30	25	DN	4	0 60	38	FR	9	0 95	53	HF	5	0 70	42
BR	2	0 30	25	DW	4	0 60	38	FA	5	0 70	42	HS	4	0 60	38
BU	2	0 30	25	DL	3	0 48	33	FS	3	0 48	33	HC	3	0 48	33
BJ	1	0 00	13	DV	3	0 48	33	FU	3	0 48	33	HN	3	0 48	33
BM	1	0 00	13	DG	2	0 30	25	FC	2	0 30	25	HD	2	0 30	25
BS	1	0 00	13	DH	2	0 30	25	FL	2	0 30	25	HM	2	0 30	25
BT	1	0 00	13	DQ	2	0 30	25	FD	1	0 00	13	HB	1	0 00	13
				DJ	1	0 00	13	FG	1	0 00	13	HL	1	0 00	13
CO	41	1 61	80	DY	1	0 00	13	FM	1	0 00	13	HP	1	0 00	13
CE	32	1 51	76					FP	1	0 00	13	HQ	1	0 00	13
CA	20	1 30	67	EN	111	2 05	99	FW	1	0 00	13	HW	1	0 00	13
CH	14	1 15	61	ER	87	1 94	94	FY	1	0 00	13	HY	1	0 00	13

[1] For arrangement alphabetically first under initial letters and then under final letters, see Table 6–A

Table 8, Contd —*The 428 different digraphs of Table 6-A, arranged first alphabetically according to their initial letters and then according to their absolute frequencies under each initial letter,*[1] *accompanied by the logarithms of their assigned probabilities*

	F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)
IN	75	1 88	92	LO	13	1 11	59	ND	52	1 72	85	OV	7	0 85	48
IO	41	1 61	80	LY	10	1 00	55	NI	30	1 48	75	OO	6	0 78	45
IS	35	1 54	78	LD	9	0 95	53	NG	27	1 43	73	OI	5	0 70	42
IR	27	1 43	73	LT	8	0 90	51	NA	26	1 41	72	OB	4	0 60	38
IT	27	1 43	73	LS	6	0 78	45	NS	24	1 38	71	OE	3	0 48	33
IV	25	1 40	72	LB	3	0 48	33	NC	19	1 28	67	OH	3	0 48	33
IL	23	1 36	70	LC	3	0 48	33	NO	18	1 26	66	OG	2	0 30	25
IC	22	1 34	69	LF	3	0 48	33	NF	9	0 95	53	OK	2	0 30	25
IG	19	1 28	67	LP	3	0 48	33	NN	8	0 90	51	OY	2	0 30	25
IX	15	1 18	62	LM	2	0 30	25	NU	7	0 85	48	OJ	1	0 00	13
IE	13	1 11	59	LR	2	0 30	25	NL	5	0 70	42	OX	1	0 00	13
IF	10	1 00	55	LU	2	0 30	25	NM	5	0 70	42				
IM	9	0 95	53	LV	2	0 30	25	NY	5	0 70	42	PE	23	1 36	70
IA	8	0 90	51	LW	2	0 30	25	NH	4	0 60	38	PR	18	1 26	66
IP	7	0 85	48	LG	1	0 00	13	NR	4	0 60	38	PO	17	1 23	64
ID	6	0 78	45	LH	1	0 00	13	NP	3	0 48	33	PA	14	1 15	61
IB	2	0 30	25	LN	1	0 00	13	NV	3	0 48	33	PL	13	1 11	59
IK	2	0 30	25					NW	3	0 48	33	PP	11	1 04	56
IZ	2	0 30	25	MA	36	1 56	78	NB	2	0 30	25	PT	8	0 90	51
				ME	26	1 41	72	NK	2	0 30	25	PI	6	0 78	45
JE	2	0 30	25	MM	13	1 11	59	NJ	1	0 00	13	PS	6	0 78	45
JO	2	0 30	25	MO	10	1 00	55	NQ	1	0 00	13	PM	4	0 60	38
JU	2	0 30	25	MI	9	0 95	53					PH	3	0 48	33
JA	1	0 00	13	MP	8	0 90	51					PU	3	0 48	33
				MB	6	0 78	45	ON	77	1 89	92	PF	2	0 30	25
KE	6	0 78	45	MS	4	0 60	38	OR	64	1 81	89	PB	1	0 00	13
KI	2	0 30	25	MC	3	0 48	33	OU	37	1 57	79	PC	1	0 00	13
KA	1	0 00	13	MR	2	0 30	25	OF	25	1 40	72	PD	1	0 00	13
KC	1	0 00	13	MT	2	0 30	25	OM	25	1 40	72	PN	1	0 00	13
KL	1	0 00	13	MU	2	0 30	25	OP	25	1 40	72	PV	1	0 00	13
KN	1	0 00	13	MY	2	0 30	25	OL	19	1 28	67	PW	1	0 00	13
KS	1	0 00	13	MD	1	0 00	13	OT	19	1 28	67	PY	1	0 00	13
				MF	1	0 00	13	OS	14	1 15	61				
LE	37	1 57	79	MH,	1	0 00	13	OD	12	1 08	58				
LA	28	1 45	74					OC	8	0 90	51	QU	15	1 18	62
LL	27	1 43	73	NT	82	1 91	93	OW	8	0 90	51	QM	1	0 00	13
LI	20	1 30	67	NE	57	1 76	87	OA	7	0 85	48	QR	1	0 00	13

[1] For arrangement alphabetically first under initial letters and then under final letters, see Table 6-A

TABLE 8, Concluded —*The 428 different digraphs of Table 6–A, arranged first alphabetically according to their initial letters and then according to their absolute frequencies under each initial letter,*[1] *accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$		F	$L_{10}(F)$	$L_{424}(2F)$
RE	98	1 99	96	SR	5	0 70	42	US	12	1 08	58	XI	2	0 30	25
RT	42	1 62	81	SN	4	0 60	38	UT	12	1 08	58	XP	2	0 30	25
RA	39	1 59	80	SW	4	0 60	38	UE	11	1 04	56	XD	1	0 00	13
RS	31	1 49	75	SB	3	0 48	33	UG	8	0 90	51	XE	1	0 00	13
RI	30	1 48	75	SM	3	0 48	33	UL	6	0 78	45	XF	1	0 00	13
RO	28	1 45	74	SG	2	0 30	25	UA	5	0 70	42	XH	1	0 00	13
RD	17	1 23	64	SL	2	0 30	25	UI	5	0 70	42	XN	1	0 00	13
RP	13	1 11	59	SK	1	0 00	13	UM	5	0 70	42	XO	1	0 00	13
RR	11	1 04	56	SV	1	0 00	13	UB	3	0 48	33	XR	1	0 00	13
RC	9	0 95	53	SY	1	0 00	13	UC	3	0 48	33	XS	1	0 00	13
RM	9	0 95	53					UD	3	0 48	33				
RY	9	0 95	53	TH	78	1 89	92	UP	2	0 30	25	YT	15	1 18	62
RG	7	0 85	48	TE	71	1 85	91	UF	1	0 00	13	YF	11	1 04	56
RN	7	0 85	48	TO	50	1 70	84	UO	1	0 00	13	YS	11	1 04	56
RF	6	0 78	45	TI	45	1 65	82	UV	1	0 00	13	YO	10	1 00	55
RL	5	0 70	42	TY	41	1 61	80					YE	9	0 95	53
RU	5	0 70	42	TW	36	1 56	78	VE	57	1 76	87	YA	6	0 78	45
RV	5	0 70	42	TA	28	1 45	,74	VI	12	1 08	58	YN	6	0 78	45
RW	4	0 60	38	TS	19	1 28	67	VA	6	0 78	45	YC	4	0 60	38
RH	3	0 48	33	TT	19	1 28	67	VO	1	0 00	13	YD	4	0 60	38
RB	2	0 30	25	TR	17	1 23	64	VT	1	0 00	13	YR	4	0,60	38
RJ	1	0 00	13	TF	7	0 85	48					YI	3	0 48	33
RK	1	0 00	13	TN	7	0 85	48	WE	22	1 34	69	YP	3	0 48	33
				TC	6	0 78	45	WO	19	1 28	67	YB	2	0 30	25
ST	63	1 80	88	TD	6	0 78	45	WI	13	1 11	59	YL	2	0 30	25
SE	49	1 69	84	TM	6	0 78	45	WA	12	1 08	58	YM	2	0 30	25
SI	34	1 53	77	TL	5	0 70	42	WH	4	0 60	38	YG	1	0 00	13
SH	26	1 41	72	TU	5	0 70	42	WN	2	0 30	25	YH	1	0 00	13
SA	24	1 38	71	TB	3	0 48	33	WL	1	0 00	13	YU	1	0 00	13
SS	19	1 28	67	TP	2	0 30	25	WR	1	0 00	13	YW	1	0 00	13
SO	15	1 18	62	TG	1	0 00	13	WS	1	0 00	13				
SC	13	1 11	59	TQ	1	0 00	13	WY	1	0 00	13	ZE	2	0 30	25
SF	12	1 08	58	TZ	1	0 00	13					ZA	1	0 00	13
SU	11	1 04	56					XT	7	0 85	48	ZI	1	0 00	13
SP	10	1 00	55	UR	31	1 49	75	XA	2	0 30	25		5,000		
SD	5	0 70	42	UN	21	1 32	68	XC	2	0 30	25				

[1] For arrangement alphabetically first under initial letters and then under final letters, see Table 6–A

TABLE 9-A.—*The 428 different digraphs of Table 6-A, arranged first alphabetically according to their final letters and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
RA	39	1 59	80	EC	32	1 51	76	RE	98	1 99	96	GF	2	0 30	25
MA	36	1 56	78	IC	22	1 34	69	TE	71	1 85	91	PF	2	0 30	25
EA	35	1 54	78	NC	19	1 28	67	NE	57	1 76	87	CF	1	0 00	13
DA	32	1 51	76	AC	14	1 15	61	VE	57	1 76	87	MF	1	0 00	13
LA	28	1 45	74	SC	13	1 11	59	SE	49	1 69	84	UF	1	0 00	13
TA	28	1 45	74	RC	9	0 95	53	EE	42	1 62	81	XF	1	0 00	13
NA	26	1 41	72	OC	8	0 90	51	LE	37	1 57	79				
SA	24	1 38	71	TC	6	0 78	45	DE	33	1 52	77				
CA	20	1 30	67	DC	4	0 60	38	CE	32	1 51	76	NG	27	1 43	73
HA	20	1 30	67	YC	4	0 60	38	ME	26	1 41	72	IG	19	1 28	67
PA	14	1 15	61	CC	3	0 48	33	PE	23	1 36	70	UG	8	0 90	51
WA	12	1 08	58	HC	3	0 48	33	WE	22	1 34	69	RG	7	0 85	48
IA	8	0 90	51	LC	3	0 48	33	HE	20	1 30	67	AG	6	0 78	45
GA	7	0 85	48	MC	3	0 48	33	BE	18	1 26	66	EG	4	0 60	38
OA	7	0 85	48	UC	3	0 48	33	GE	14	1 15	61	DG	2	0 30	25
VA	6	0 78	45	FC	2	0 30	25	IE	13	1 11	59	OG	2	0 30	25
YA	6	0 78	45	GC	2	0 30	25	UE	11	1 04	56	SG	2	0 30	25
FA	5	0 70	42	XC	2	0 30	25	FE	10	1 00	55	FG	1	0 00	13
UA	5	0 70	42	KC	1	0 00	13	YE	9	0 95	53	GG	1	0 00	13
BA	4	0 60	38	PC	1	0 00	13	KE	6	0 78	45	LG	1	0 00	13
AA	3	0 48	33					OE	3	0 48	33	TG	1	0 00	13
XA	2	0 30	25					JE	2	0 30	25	YG	1	0 00	13
JA	1	0 00	13	ED	60	1 78	88	ZE	2	0 30	25				
KA	1	0 00	13	ND	52	1 72	85	AE	1	0 00	13				
ZA	1	0 00	13	AD	27	1 43	73	XE	1	0 00	13				
				RD	17	1 23	64					TH	78	1 89	92
AB	6	0 78	45	OD	12	1 08	58					SH	26	1 41	72
MB	6	0 78	45	LD	9	0 95	53					GH	20	1 30	67
DB	4	0 60	38	DD	8	0 90	51	OF	25	1 40	72	CH	14	1 15	61
EB	4	0 60	38	ID	6	0 78	45	EF	18	1 26	66	EH	7	0 85	48
OB	4	0 60	38	TD	6	0 78	45	SF	12	1 08	58	NH	4	0 60	38
LB	3	0 48	33	SD	5	0 70	42	FF	11	1 04	56	WH	4	0 60	38
SB	3	0 48	33	YD	4	0 60	38	YF	11	1 04	56	OH	3	0 48	33
TB	3	0 48	33	UD	3	0 48	33	IF	10	1 00	55	PH	3	0 48	33
UB	3	0 48	33	HD	2	0 30	25	NF	9	0 95	53	RH	3	0 48	33
IB	2	0 30	25	CD	1	0 00	13	DF	8	0 90	51	AH	2	0 30	25
NB	2	0 30	25	FD	1	0 00	13	TF	7	0 85	48	DH	2	0 30	25
RB	2	0 30	25	GD	1	0 00	13	RF	6	0 78	45	LH	1	0 00	13
YB	2	0 30	25	MD	1	0 00	13	HF	5	0 70	42	MH	1	0 00	13
HB	1	0 00	13	PD	1	0 00	13	AF	4	0 60	38	XH	1	0 00	13
PB	1	0 00	13	XD	1	0 00	13	LF	3	0 48	33	YH	1	0 00	13

Table 9–A, Contd —*The 428 different digraphs of Table 6–A, arranged first alphabetically according to their final letters and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(1)$	L_{224} (2F)		Γ	$L_{10}(F)$	L_{224} (2F)		Γ	$L_{10}(\Gamma)$	$L_{2\ 4}$ (2F)		F	$L_{10}(F)$	L_{224} (2Γ)
TI	45	1 65	82	LL	27	1 43	73	AN	64	1 81	89	RP	13	1 11	59
FI	39	1 59	80	IL	23	1 36	70	UN	21	1 32	68	AP	12	1.08	58
SI	34	1 53	77	OL	19	1 28	67	NN	8	0 90	51	PP	11	1 04	56
HI	33	1 52	77	PL	13	1 11	59	RN	7	0 85	48	SP	10	1 00	55
NI	30	1.48	75	BL	6	0 78	45	TN	7	0 85	48	MP	8	0 90	51
RI	30	1 48	75	UL	6	0 78	45	YN	6	0 78	45	IP	7	0 85	48
DI	27	1 43	73	CL	5	0 70	42	DN	4	0 60	38	DP	5	0 70	42
EI	27	1 43	73	NL	5	0 70	42	SN	4	0 60	38	LP	3	0 48	33
LI	20	1 30	67	RL	5	0 70	42	GN	3	0 48	33	NP	3	0 48	33
AI	17	1 23	64	TL	5	0 70	42	HN	3	0 48	33	YP	3	0 48	33
WI	13	1 11	59	DL	3	0 48	33	WN	2	0 30	25	GP	2	0 30	.25
VI	12	1 08	58	FL	2	0 30	25	CN	1	0 00	13	TP	2	0 30	25
MI	9	0 95	53	GL	2	0 30	25	KN	1	0 00	13	UP	2	0 30	25
CI	7	0 85	48	SL	2	0 30	25	LN	1	0 00	13	XP	2	0 30	25
PI	6	0 78	45	YL	2	0 30	25	PN	1	0 00	13	FP	1	0 00	.13
GI	5	0 70	42	HL	1	0 00	13	XN	1	0 00	13	HP	1	0 00	13
OI	5	0 70	42	KL	1	0 00	13					EQ	12	1 08	58
UI	5	0 70	42	WL	1	0 00	13	TO	50	1 70	84	DQ	2	0 30	25
YI	3	0 48	33					CO	41	1 61	80	HQ	1	0 00	13
BI	2	0 30	25	OM	25	1 40	72	IO	41	1 61	80	NQ	1	0 00	13
KI	2	0 30	25	AM	14	1 15	61	FO	40	1 60	80	TQ	1	0 00	13
XI	2	0 30	25	EM	14	1 15	61	RO	28	1 45	74	ER	87	1 94	94
ZI	1	0 00	13	MM	13	1 11	59	HO	20	1 30	67	OR	64	1 81	89
				IM	9	0 95	53	WO	19	1 28	67	AR	44	1 64	82
AJ	1	0 00	13	RM	9	0 95	53	NO	18	1 26	66	UR	31	1 49	75
BJ	1	0 00	13	TM	6	0 78	45	PO	17	1 23	64	IR	27	1 43	73
DJ	1	0 00	13	DM	5	0 70	42	DO	16	1 20	63	PR	18	1 26	66
EJ	1	0 00	13	NM	5	0 70	42	SO	15	1 18	62	HR	17	1 23	64
GJ	1	0 00	13	UM	5	0 70	42	LO	13	1 11	59	TR	17	1 23	64
NJ	1	0 00	13	PM	4	0 60	38	EO	12	1 08	58	DR	12	1 08	58
OJ	1	0 00	13	SM	3	0 48	33	MO	10	1 00	55	RR	11	1 04	56
RJ	1	0 00	13	HM	2	0 30	25	YO	10	1 00	55	FR	9	0 95	53
				LM	2	0 30	25	GO	6	0 78	45	GR	5	0 70	42
CK	4	0 60	38	YM	2	0 30	25	OO	6	0 78	45	SR	5	0 70	42
AK	2	0 30	25	BM	1	0 00	13	BO	4	0 60	38	CR	4	0 60	38
IK	2	0 30	25	CM	1	0 00	13	AO	2	0 30	25	NR	4	0 60	38
NK	2	0 30	25	FM	1	0 00	13	JO	2	0 30	25	YR	4	0 60	38
OK	2	0 30	25	GM	1	0 00	13	UO	1	0 00	13	BR	2	0 30	25
RK	1	0 00	13	QM	1	0 00	13	VO	1	0 00	13	LR	2	0 30	25
SK	1	0 00	13					XO	1	0 00	13	MR	2	0 30	25
				EN	111	2 05	99					QR	1	0 00	13
AL	32	1 51	76	ON	77	1 89	92	OP	25	1 40	72	WR	1	0 00	13
EL	29	1 46	74	IN	75	1 88	92	EP	20	1 30	67	XR	1	0 00	13

TABLE 9-A, Concluded.—*The 428 different digraphs of Table 6-A, arranged first alphabetically according to their final letters and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
ES	54	1 73	86	OT	19	1 28	67	JU	2	0 30	25	PW	1	0 00	13
AS	41	1 61	80	TT	19	1 28	67	LU	2	0 30	25	YW	1	0 00	13
IS	35	1 54	78	DT	15	1 18	62	MU	2	0 30	25				
RS	31	1 49	75	YT	15	1 18	62	YU	1	0 00	13				
NS	24	1 38	71	CT	14	1 15	61					IX	15	1 18	62
SS	19	1 28	67	UT	12	1 08	58	IV	25	1 40	72	EX	7	0 85	48
TS	19	1 28	67	FT	11	1 04	56	EV	20	1 30	67	OX	1	0 00	13
OS	14	1 15	61	LT	8	0 90	51	AV	7	0 85	48				
DS	13	1 11	59	PT	8	0 90	51	OV	7	0 85	48	TY	41	1 61	80
US	12	1 08	58	XT	7	0 85	48	RV	5	0 70	42	AY	12	1 08	58
YS	11	1 04	56	GT	4	0 60	38	DV	3	0 48	33	LY	10	1 00	55
LS	6	0 78	45	MT	2	0 30	25	NV	3	0 48	33	RY	9	0 95	53
PS	6	0 78	45	BT	1	0 00	13	LV	2	0 30	25	BY	7	0 85	48
HS	4	0 60	38	VT	1	0 00	13	PV	1	0 00	13	NY	5	0 70	42
MS	4	0 60	38					SV	1	0 00	13	EY	4	0 60	38
FS	3	0 48	33	OU	37	1 57	79	UV	1	0 00	13	MY	2	0 30	25
GS	3	0 48	33	QU	15	1 18	62					OY	2	0 30	25
BS	1	0 00	13	AU	13	1 11	59	TW	36	1 56	78	CY	1	0 00	13
CS	1	0 00	13	SU	11	1 04	56	OW	8	0 90	51	DY	1	0 00	13
KS	1	0 00	13	HU	8	0 90	51	EW	7	0 85	48	FY	1	0 00	13
WS	1	0 00	13	NU	7	0 85	48	DW	4	0 60	38	HY	1	0 00	13
XS	1	0 00	13	DU	5	0 70	42	RW	4	0 60	38	PY	1	0 00	13
				RU	5	0 70	42	SW	4	0 60	38	SY	1	0 00	13
NT	82	1 91	93	TU	5	0 70	42	AW	3	0 48	33	WY	1	0 00	13
ST	63	1 80	88	CU	4	0 60	38	NW	3	0 48	33				
AT	47	1 67	83	EU	3	0 48	33	LW	2	0 30	25	IZ	2	0 30	25
RT	42	1 62	81	FU	3	0 48	33	CW	1	0 00	13	EZ	1	0 00	.13
ET	37	1 57	79	PU	3	0 48	33	FW	1	0 00	13	TZ	1	0 00	13
HT	28	1 45	74	BU	2	0 30	25	GW	1	0 00	13				
IT	27	1 43	73	GU	2	0 30	25	HW	1	0 00	13		5,000		

TABLE 9-B.—*The 18 digraphs composing 25% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(1) AND ACCORDING TO THEIR INITIAL LETTERS

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
ED	60	1 78	88	IN	75	1 88	92
ND	52	1 72	85	ON	77	1 89	92
NE	57	1 76	87	TO	50	1 70	84
RE	98	1 99	96				
SE	49	1 69	84	ER	87	1 94	94
TE	71	1 85	91	OR	64	1 81	89
VE	57	1 76	87				
				ES	54	1 73	86
TH	78	1 89	92	NT	82	1 91	93
				ST	63	1 80	88
AN	64	1 81	89		1,249		
EN	111	2 05	99				

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
ED	60	1 78	88	IN	75	1 88	92
ND	52	1 72	85	AN	64	1 81	89
RE	98	1 99	96	TO	50	1 70	84
TE	71	1 85	91				
NE	57	1 76	87	ER	87	1 94	94
VE	57	1.76	87	OR	64	1 81	89
SE	49	1 69	.84				
				ES	54	1 73	86
TH	78	1 89	92	NT	82	1 91	93
				ST	63	1 80	88
EN	111	2 05	99		1,249		
ON	77	1 89	92				

TABLE 9-C.—*The 53 digraphs composing 50% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(1) AND ACCORDING TO THEIR INITIAL LETTERS

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
DA	32	1 51	76	NE	57	1 76	87	AN	64	1 81	89	AS	41	1 61	.80
EA	35	1.54	78	RE	98	1 99	96	EN	111	2 05	99	ES	54	1 73	86
LA	28	1 45	74	SE	49	1 69	84	IN	75	1 88	92	IS	35	1 54	.78
MA	36	1 56	78	TE	71	1 85	91	ON	77	1 89	92	RS	31	1 49	75
RA	39	1 59	80	VE	57	1 76	87								
TA	28	1 45	74									AT	47	1 67	83
												ET	37	1 57	79
				TH	78	1 89	92	CO	41	1 61	80				
												HT	28	1 45	74
EC	32	1 51	76					FO	40	1 60	80				
												NT	82	1 91	93
				FI	39	1 59	80	IO	41	1 61	80				
												RT	42	1 62	81
				HI	33	1 52	77	RO	28	1 45	74				
												ST	63	1 80	88
ED	60	1 78	88	NI	30	1 48	75	TO	50	1 70	84				
ND	52	1 72	85	RI	30	1 48	75								
												OU	37	1 57	79
				SI	34	1.53	.77								
				TI	45	1 65	82								
CE	32	1 51	76					AR	44	1 64	82	TW	36	1 56	78
DE	33	1 52	77					ER	87	1 94	94				
EE	42	1 62	81	AL	32	1 51	76	OR	64	1 81	89	TY	41	1 61	80
LE	37	1 57	79	EL	29	1 46	74	UR	31	1 49	75		2,495		

Table 9-C, Concluded —*The 53 digraphs composing 50% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES

	F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)
RA	39	1 59	80	EE	42	1 62	81	EN	111	2 05	99	ES	54	1.73	.86
MA	36	1 56	78	LE	37	1 57	79	ON	77	1 89	92	AS	41	1 61	80
EA	35	1 54	78	DE	33	1 52	77	IN	75	1 88	92	IS	35	1 54	78
DA	32	1 51	76	CE	32	1 51	76	AN	64	1.81	.89	RS	31	1 49	75
LA	28	1 45	.74												
TA	28	1 45	74	TH	78	1 89	92					NT	82	1.91	93
								TO	50	1 70	84	ST	63	1 80	88
EC	32	1 51	76					CO	41	1 61	.80	AT	47	1 67	83
				TI	45	1 65	82	IO	41	1 61	80	RT	42	1.62	81
ED	60	1 78	88	FI	39	1 59	80	FO	40	1 60	80	ET	37	1 57	79
ND	52	1 72	.85	SI	34	1 53	77	RO	28	1 45	74	HT	28	1 45	74
				HI	33	1 52	77								
RE	98	1 99	96	NI	30	1 48	75					OU	37	1 57	79
TE	71	1 85	.91	RI	30	1 48	75	ER	87	1 94	94	TW	36	1.56	78
NE	57	1 76	87					OR	64	1 81	89				
VE	57	1 76	87	AL	32	1 51	76	AR	44	1 64	.82	TY	41	1 61	.80
SE	49	1.69	84	EL	29	1 46	74	UR	31	1 49	75		2,495		

Table 9-D —*The 122 digraphs composing 75% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(1) AND ACCORDING TO THEIR INITIAL LETTERS

	F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)		F	$L_{10}(F)$	L_{234} (2F)
CA	20	1 30	.67	ND	52	1 72	85	EF	18	1 26	66	SI	34	1 53	77
DA	32	1 51	76	RD	17	1 23	64	OF	25	1 40	72	TI	45	1 65	82
EA	35	1 54	78												
HA	20	1 30	67	BE	18	1 26	66	IG	19	1 28	67	AL	32	1 51	76
LA	28	1 45	74	CE	32	1 51	76	NG	27	1 43	73	EL	29	1 46	.74
MA	36	1 56	78	DE	33	1 52	77					IL	23	1 36	70
NA	26	1 41	72	EE	42	1 62	81	CH	14	1 15	61	LL	27	1 43	73
PA	14	1 15	61	GE	14	1 15	61	GH	20	1 30	67	OL	19	1 28	67
RA	39	1 59	80	HE	20	1 30	67	SH	26	1 41	72				
SA	21	1 38	71	IE	13	1 11	59	TH	78	1 89	.92				
TA	28	1 45	74	LE	37	1 57	79					AM	14	1 15	61
				ME	26	1 41	72	AI	17	1 23	64	EM	14	1 15	.61
AC	14	1 15	61	NE	57	1 76	87	DI	27	1 43	73	OM	25	1 40	72
EC	32	1 51	76	PE	23	1 36	70	EI	27	1 43	73				
IC	22	1 31	69	RE	98	1 99	96	FI	39	1 59	80	AN	64	1 81	89
NC	19	1 28	67	SE	49	1 69	84	HI	33	1 52	77	EN	111	2 05	99
				TE	71	1 85	91	LI	20	1 30	67	IN	75	1 88	92
AD	27	1 43	73	VE	57	1 76	87	NI	30	1 48	75	ON	77	1 89	92
ED	60	1 78	88	WE	22	1 34	69	RI	30	1 48	75	UN	21	1 32	68

TABLE 9-D, Contd —*The 122 digraphs composing 75% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(1) AND ACCORDING TO THEIR INITIAL LETTERS—Concluded

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
CO	41	1 61	80	AR	44	1 64	82	RS	31	1 49	75	TT	19	1 28	67
DO	16	1 20	63	ER	87	1 94	94	SS	19	1 28	67	YT	15	1 18	62
FO	40	1 60	80	HR	17	1 23	64	TS	19	1 28	67				
HO	20	1 30	67	IR	27	1 43	73					AU	13	1 11	59
IO	41	1 61	80	OR	64	1 81	89					OU	37	1 57	79
LO	13	1 11	59	PR	18	1 26	66	AT	47	1 67	83	QU	15	1 18	62
NO	18	1 26	66	TR	17	1 23	64	CT	14	1 15	61				
PO	17	1 23	64	UR	31	1 49	75	DT	15	1 18	62	EV	20	1 30	67
RO	28	1 45	74					ET	37	1 57	79	IV	25	1 40	72
SO	15	1 18	62	AS	41	1 61	80	HT	28	1 45	74	TW	36	1 56	78
TO	50	1 70	84	DS	13	1 11	59	IT	27	1 43	73				
WO	19	1 28	67	ES	54	1 73	86	NT	82	1 91	93	IX	15	1 18	62
				IS	35	1 54	78	OT	19	1 28	67				
EP	20	1 30	67	NS	24	1 38	71	RT	42	1 62	81	TY	41	1 61	80
OP	25	1 40	72	OS	14	1 15	61	ST	63	1 80	88		3,745		

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
RA	39	1 59	80	RE	98	1 99	96	TH	78	1 89	92	OM	25	1 40	72
MA	36	1 56	78	TE	71	1 85	91	SH	26	1 41	72	AM	14	1 15	61
EA	35	1 54	78	NE	57	1 76	87	GH	20	1 30	67	EM	14	1 15	61
DA	32	1 51	76	VE	57	1 76	87	CH	14	1 15	61				
LA	28	1 45	74	SE	49	1 69	84					EN	111	2 05	99
TA	28	1 45	74	EE	42	1 62	81					ON	77	1 89	92
NA	26	1 41	72	LE	37	1 57	79	TI	45	1 65	82	IN	75	1 88	92
SA	24	1 38	71	DE	33	1 52	77	FI	39	1 59	80	AN	64	1 81	89
CA	20	1 30	67	CE	32	1 51	76	SI	34	1 53	77	UN	21	1 32	68
HA	20	1 30	67	ME	26	1 41	72	HI	33	1 52	77				
PA	14	1 15	61	PE	23	1 36	70	NI	30	1 48	75	TO	50	1 70	84
				WE	22	1 34	69	RI	30	1 48	75	CO	41	1 61	80
EC	32	1 51	76	HE	20	1 30	67	DI	27	1 43	73	IO	41	1 61	80
IC	22	1 34	69	BE	18	1 26	66	EI	27	1 43	73	FO	40	1 60	80
NC	19	1 28	67	GE	14	1 15	61	LI	20	1 30	67	RO	28	1 45	74
AC	14	1 15	61	IE	13	1 11	59	AI	17	1 23	64	HO	20	1 30	67
												WO	19	1 28	67
				OF	25	1 40	72	AL	32	1 51	76	NO	18	1 26	66
ED	60	1 78	88	EF	18	1 26	66	EL	29	1 46	74	PO	17	1 23	64
ND	52	1 72	85					LL	27	1 43	73	DO	16	1 20	63
AD	27	1 43	73	NG	27	1 43	73	IL	23	1 36	70	SO	15	1 18	62
RD	17	1 23	64	IG	19	1 28	67	OL	19	1 28	67	LO	13	1 11	59

TABLE 9-D, Concluded —*The 122 digraphs composing 75% of the 5,000 digraphs of Table 6-A, accompanied by the logarithms of their assigned probabilities, arranged alphabetically according to their final letters*

(2) AND ACCORDING TO THEIR ABSOLUTE FREQUENCIES—Concluded

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
OP	25	1 40	72	ES	54	1 73	86	NT	82	1 91	93	OU	37	1 57	79
EP	20	1 30	67	AS	41	1 61	80	ST	63	1 80	88	QU	15	1 18	62
				IS	35	1 54	78	AT	47	1 67	83	AU	13	1 11	59
				RS	31	1 49	75	RT	42	1 62	81	IV	25	1 40	72
ER	87	1 94	94	NS	24	1 38	71	ET	37	1 57	79	EV	20	1 30	67
OR	64	1 81	89	SS	19	1 28	67	HT	28	1 45	74	TW	36	1 56	.78
AR	44	1 64	82	TS	19	1 28	67	IT	27	1 43	73	IX	15	1 18	62
UR	31	1 49	75	OS	14	1 15	61.	OT	19	1 28	67	TY	41	1 61	80
IR	27	1 43	73	DS	13	1 11	59	TT	19	1 28	67		3,745		
PR	18	1 26	66					DT	15	1 18	62				
HR	17	1 23	64					YT	15	1 18	62				
TR	17	1 23	64					CT	14	1 15	61				

TABLE 9-E —*All the 428 different digraphs of Table 6-A, arranged alphabetically first according to their final letters and then according to their initial letters*

(SEE TABLE 6-A —READ DOWN THE COLUMNS)

TABLE 10-A —*The 56 trigraphs appearing 100 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)		F	$L_{10}(F)$	L_{224} (2F)
ENT	569	2 76	99	TOP	174	2 24	82	EIG	135	2 13	79
ION	260	2 41	88	NTH	171	2 23	82	FIV	135	2 13	79
AND	228	2 36	86	TWE	170	2 23	82	MEN	131	2 12	78
ING	226	2 35	86	TWO	163	2 21	81	SEV	131	2 12	78
IVE	225	2 35	86	ATI	160	2 20	81	ERS	126	2 10	78
TIO	221	2 34	85	THR	158	2 20	81	UND	125	2 10	78
FOR	218	2 34	85	NTY	157	2 20	81	NET	118	2 07	77
OUR	211	2 32	85	HRE	153	2 18	80	PER	115	2 06	76
THI	211	2 32	85	WEN	153	2 18	80	STA	115	2 06	76
ONE	210	2 32	85	FOU	152	2 18	80	TER	115	2 06	76
NIN	207	2 32	85	ORT	146	2 16	80	EQU	111	2 06	76
STO	202	2 31	84	REE	146	2 16	80	RED	113	2 05	76
EEN	196	2 29	84	SIX	146	2 16	80	TED	112	2 05	76
GHT	196	2 29	84	ASH	143	2 16	80	ERI	109	2 04	76
INE	192	2 28	83	DAS	140	2 15	79	HIR	106	2 03	75
VEN	190	2 28	83	IGH	140	2 15	79	IRT	105	2 02	75
EVE	177	2 25	82	ERE	138	2 14	79	DER	101	2 00	74
EST	176	2 25	82	COM	136	2 13	79	DRE	100	2 00	74
TEE	174	2 24	82	ATE	135	2 13	79				

TABLE 10-B.—*The 56 trigraphs appearing 100 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their initial letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
AND	228	2 36	86	GHT	196	2 29	84	REE	146	2 16	80
ATI	160	2 20	81					RED	113	2 05	76
ASH	143	2 16	80	HRE	153	2 18	80				
ATE	135	2 13	79	HIR	106	2 03	75				
								STO	202	2 31	84
COM	136	2 13	79	ION	260	2 41	88	SIX	146	2 16	80
				ING	226	2 35	86	SEV	131	2 12	78
DAS	140	2 15	79	IVE	225	2 35	86	STA	115	2 06	76
DER	101	2 00	74	INE	192	2 28	83				
DRE	100	2 00	74	IGH	140	2 15	79	TIO	221	2 34	85
				IRT	105	2 02	75	THI	211	2 32	85
ENT	569	2 76	99					TEE	174	2 24	82
EEN	196	2 29	84	MEN	131	2 12	78	TOP	174	2 24	82
EVE	177	2 25	82					TWE	170	2 23	82
EST	176	2 25	82	NIN	207	2 32	85	TWO	163	2 21	81
ERE	138	2 14	79	NTH	171	2 23	82	THR	158	2 20	81
EIG	135	2 13	79	NTY	157	2 20	81	TER	115	2 06	.76
ERS	126	2 10	78	NET	118	2 07	77	TED	112	2 05	76
EQU	114	2 06	76								
ERI	109	2 04	76	OUR	211	2 32	85	UND	125	2 10	78
				ONE	210	2 32	85				
FOR	218	2 34	85	ORT	146	2 16	80	VEN	190	2 28	83
FOU	152	2 18	80								
FIV	135	2 13	.79	PER	115	2 06	76	WEN	153	2 18	80

TABLE 10-C.—*The 56 trigraphs appearing 100 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their central letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
DAS	140	2 15	79	IGH	140	2 15	79	ENT	569	2 76	99
								AND	228	2 36	86
EEN	196	2 29	84					ING	226	2 35	86
VEN	190	2 28	83					ONE	210	2 32	85
TEE	174	2 24	82	THI	211	2 32	85	INE	192	2 28	.83
WEN	153	2 18	80	GHT	196	2 29	84	UND	125	2 10	78
REE	146	2 16	80	THR	158	2 20	81				
MEN	131	2 12	78								
SEV	131	2 12	78								
NET	118	2 07	77	TIO	221	2 34	85				
PER	115	2 06	76	NIN	207	2 32	85	ION	260	2 41	88
TER	115	2 06	76	SIX	146	2 16	80	FOR	218	2 34	85
RED	113	2 05	76	EIG	135	2 13	79	TOP	174	2 24	82
TED	112	2 05	76	FIV	135	2 13	79	FOU	152	2 18	80
DER	101	2 00	74	HIR	106	2 03	75	COM	136	2 13	79

TABLE 10-C, Concluded —*The 56 trigraphs appearing 100 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their central letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
EQU	114	2 06	76	EST	176	2 25	82	OUR	211	2 32	85
				ASH	143	2 16	80				
HRE	153	2 18	80								
ORT	146	2 16	80	STO	202	2 31	84	IVE	225	2 35	86
ERE	138	2 14	79	NTH	171	2 23	82	EVE	177	2 25	82
ERS	126	2 10	78	ATI	160	2 20	81				
ERI	109	2 04	76	NTY	157	2 20	81				
IRT	105	2 02	75	ATE	135	2 13	79	TWE	170	2 23	82
DRE	100	2 00	74	STA	115	2 06	76	TWO	163	2 21	81

TABLE 10-D —*The 56 trigraphs appearing 100 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their final letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$		F	$L_{10}(F)$	$L_{224}(2F)$
STA	115	2 06	76	THI	211	2 32	85	TER	115	2 06	76
				ATI	160	2 20	81	HIR	106	2 03	75
AND	228	2 36	86	ERI	109	2 04	76	DER	101	2 00	74
UND	125	2 10	78								
RED	113	2 05	76	COM	136	2 13	79	DAS	140	2 15	79
TED	112	2 05	76					ERS	126	2 10	78
IVE	225	2 35	86	ION	260	2 41	88				
ONE	210	2 32	85	NIN	207	2 32	85	ENT	569	2 76	99
INE	192	2 28	83	EEN	196	2 29	84	GHT	196	2 29	84
EVE	177	2 25	82	VEN	190	2 28	83	EST	176	2 25	82
TEE	174	2 24	82	WEN	153	2 18	80	ORT	146	2 16	80
TWE	170	2 23	82	MEN	131	2 12	78	NET	118	2 07	77
HRE	153	2 18	80					IRT	105	2 02	75
REE	146	2 16	80	TIO	221	2 34	85				
ERE	138	2 14	79	STO	202	2 31	84	FOU	152	2 18	80
ATE	135	2 13	79	TWO	163	2 21	81	EQU	114	2 06	.76
DRE	100	2 00	74								
ING	226	2 35	86	TOP	174	2 24	82	FIV	135	2 13	79
EIG	135	2 13	79					SEV	131	2 12	78
				FOR	218	2 34	85				
NTH	171	2 23	82	OUR	211	2 32	85	SIX	146	2 16	80
ASH	143	2 16	80	THR	158	2 20	81				
IGH	140	2 15	79	PER	115	2 06	76	NTY	157	2 20	81

TABLE 11-A —*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	L_{10}(F)	L_{436} (2F)		F	L_{10}(F)	L_{436} (2F)		F	L_{10}(F)	L_{436} (2F)
TION	218	2 34	99	THIR	104	2 02	87	ASHT	64	1 81	.79
EVEN	168	2 23	95	EENT	102	2 01	87	HUND	64	1 81	79
TEEN	163	2 21	94	REQU	98	1 99	86	DRED	63	1 80	79
ENTY	161	2 21	94	HIRT	97	1 99	86	RIOD	63	1 80	.79
STOP	154	2 19	93	COMM	93	1 97	85	IVED	62	1 79	78
WENT	153	2 18	93	QUES	87	1 94	84	ENTS	62	1 79	78
NINE	153	2 18	93	UEST	87	1 94	84	FFIC	62	1 79	78
TWEN	152	2 18	93	EQUE	86	1 93	84	FROM	59	1 77	78
THRE	149	2 17	93	NDRE	77	1 89	82	IRTY	59	1 77	78
FOUR	144	2 16	92	OMMA	71	1 85	81	RTEE	59	1 77	78
IGHT	140	2 15	92	LLAR	71	1 85	81	UNDR	59	1 77	78
FIVE	135	2 13	91	OLLA	70	1 85	81	NAUG	56	1 75	77
HREE	134	2 13	91	VENT	70	1 85	81	OURT	56	1 75	.77
DASH	132	2 12	91	DOLL	68	1 83	80	UGHT	56	1 75	77
EIGH	132	2 12	91	LARS	68	1 83	80	STAT	54	1 73	76
SEVE	121	2 08	89	THIS	68	1 83	80	AUGH	52	1 72	76
ENTH	114	2 06	89	PERI	67	1 83	80	CENT	52	1 72	76
MENT	111	2 05	88	ERIO	66	1 82	80	FICE	50	1 70	75

TABLE 11-B —*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their initial letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	L_{10}(F)	L_{436} (2F)		F	L_{10}(F)	L_{436} (2F)		F	L_{10}(F)	L_{436} (2F)
ASHT	64	1 81	79	HREE	134	2 13	91	REQU	98	1 99	86
AUGH	52	1 72	76	HIRT	97	1 99	86	RIOD	63	1 80	.79
COMM	93	1 97	85	HUND	64	1 81	79	RTEE	59	1 77	78
CENT	52	1 72	76	IGHT	140	2 15	92	STOP	154	2 19	93
DASH	132	2 12	91	IVED	62	1 79	78	SEVE	121	2 08	89
DOLL	68	1 83	80	IRTY	59	1 77	78	STAT	54	1 73	76
DRED	63	1 80	79	LLAR	71	1 85	81	TION	218	2 34	99
EVEN	168	2 23	95	LARS	68	1 83	.80	TEEN	163	2 21	94
ENTY	161	2 21	94	MENT	111	2 05	88	TWEN	152	2 18	93
EIGH	132	2 12	91	NINE	153	2 18	93	THRE	149	2 17	93
ENTH	114	2 06	89	NDRE	77	1 89	82	THIR	104	2 02	87
EENT	102	2 01	87	NAUG	56	1 75	77	THIS	68	1 83	80
EQUE	86	1 93	84	OMMA	71	1 85	81	UEST	87	1 94	84
ERIO	66	1 82	80	OLLA	70	1 85	81	UNDR	59	1 77	78
ENTS	62	1 79	78	OURT	56	1 75	77	UGHT	56	1 75	77
FOUR	144	2 16	92	PERI	67	1 83	80	VENT	70	1 85	81
FIVE	135	2 13	91	QUES	87	1 94	84	WENT	153	2 18	93
FFIC	62	1 79	78								
FROM	59	1 77	78								
FICE	50	1 70	75								

TABLE 11-C —*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their second letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{464}(2F)$		F	$L_{10}(F)$	$L_{464}(2F)$		F	$L_{10}(F)$	$L_{464}(2F)$
DASH	132	2 12	91	TION	218	2 34	99	HREE	134	2 13	91
LARS	68	1 83	80	NINE	153	2 18	93	ERIO	66	1 82	80
NAUG	56	1 75	77	FIVE	135	2 13	91	DRED	63	1 80	79
NDRE	77	1 89	82	EIGH	132	2 12	91	FROM	59	1 77	78
TEEN	163	2 21	94	HIRT	97	1 99	86	IRTY	59	1 77	78
WENT	153	2 18	93	RIOD	63	1 80	79	ASHT	64	1.81	79
SEVE	121	2 08	89	FICE	50	1 70	75	STOP	154	2 19	93
MENT	111	2 05	88	LLAR	71	1 85	81	RTEE	59	1 77	78
EENT	102	2 01	87	OLLA	70	1 85	81	STAT	54	1 73	76
REQU	98	1 99	86	OMMA	71	1 85	81	QUES	87	1 94	84
UEST	87	1 94	84	ENTY	161	2 21	94	HUND	64	1 81	79
VENT	70	1 85	81	ENTH	114	2 06	89	OURT	56	1 75	77
PERI	67	1 83	80	ENTS	62	1 79	78	AUGH	52	1 72	76
CENT	52	1 72	76	UNDR	59	1 77	78	EVEN	168	2 23	95
FFIC	62	1 79	78	FOUR	144	2 16	92	IVED	62	1 79	78
IGHT	140	2 15	92	COMM	93	1 97	85	TWEN	152	2 18	93
UGHT	56	1 75	77	DOLL	68	1 83	80				
THRE	149	2 17	93	EQUE	86	1 93	84				
THIR	104	2 02	87								
THIS	68	1 83	80								

TABLE 11-D —*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their third letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	$L_{10}(F)$	$L_{464}(2F)$		F	$L_{10}(F)$	$L_{464}(2F)$		F	$L_{10}(F)$	$L_{464}(2F)$
LLAR	71	1 85	81	EIGH	132	2 12	91	COMM	93	1 97	85
STAT	54	1 73	76	AUGH	52	1 72	76	OMMA	71	1 85	81
FICE	50	1 70	.75	IGHT	140	2 15	92	WENT	153	2 18	93
UNDR	59	1 77	78	ASHT	64	1 81	79	NINE	153	2 18	93
EVEN	168	2 23	95	UGHT	56	1 75	77	MENT	111	2 05	88
TEEN	163	2 21	94	THIR	104	2 02	87	EENT	102	2 01	87
TWEN	152	2 18	93	THIS	68	1 83	80	VENT	70	1 85	81
HREE	134	2 13	91	ERIO	66	1 82	80	HUND	64	1 81	79
QUES	87	1 94	84	FFIC	62	1 79	78	CENT	52	1 72	76
DRED	63	1 80	79	OLLA	70	1 85	81	TION	218	2 34	99
IVED	62	1 79	78	DOLL	68	1 83	80	STOP	154	2 19	93
RTEE	59	1 77	78					RIOD	63	1 80	79
								FROM	59	1 77	78

TABLE 11-D, Concluded.—*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their third letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)
REQU	98	1 99	86	DASH	132	2 12	91	FOUR	144	2 16	92
				UEST	87	1 94	84	EQUE	86	1.93	84
THRE	149	2 17	93					NAUG	56	1 75	77
HIRT	97	1 99	86								
NDRE	77	1 89	82	ENTY	161	2 21	94				
LARS	68	1 83	80	ENTH	114	2 06	89				
PERI	67	1 83	80	ENTS	62	1 79	78	FIVE	135	2 13	91
OURT	56	1 75	77	IRTY	59	1 77	78	SEVE	121	2 08	89

TABLE 11-E.—*The 54 tetragraphs appearing 50 or more times in the 50,000 letters of Governmental plain-text telegrams, arranged first alphabetically according to their final letters, and then according to their absolute frequencies, accompanied by the logarithms of their assigned probabilities*

	F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)		F	L_{10}(F)	L_{224} (2F)
OMMA	71	1 85	81	DASH	132	2 12	91	QUES	87	1 94	84
OLLA	70	1 85	81	EIGH	132	2 12	91	THIS	68	1 83	80
				ENTH	114	2 06	89	LARS	68	1 83	80
				AUGH	52	1 72	76	ENTS	62	1 79	78
FFIC	62	1 79	78								
				PERI	67	1 83	80				
								WENT	153	2 18	93
HUND	64	1 81	79					IGHT	140	2 15	92
DRED	63	1 80	79	DOLL	68	1 83	80	MENT	111	2 05	88
RIOD	63	1 80	79	COMM	93	1 97	85	EENT	102	2 01	87
IVED	62	1 79	78	FROM	59	1 77	78	HIRT	97	1 99	86
								UEST	87	1 94	84
				TION	218	2 34	99	VENT	70	1 85	81
NINE	153	2 18	93	EVEN	168	2 23	95	ASHT	64	1 81	79
THRE	149	2 17	93	TEEN	163	2 21	94	OURT	56	1 75	77
FIVE	135	2 13	91	TWEN	152	2 18	93	UGHT	56	1 75	77
HREE	134	2 13	91					STAT	54	1 73	76
SEVE	121	2 08	89	ERIO	66	1 82	80	CENT	52	1 72	76
EQUE	86	1 93	84								
NDRE	77	1 89	82	STOP	154	2 19	93				
RTEE	59	1 77	78					REQU	98	1 99	86
FICE	50	1 70	75	FOUR	144	2 16	92				
				THIR	104	2 02	87				
				LLAR	71	1 85	81	ENTY	161	2 21	94
NAUG	56	1 75	77	UNDR	59	1 77	78	IRTY	59	1 77	78

TABLE 12.—*Average length of words and messages*

Number of letters in word x	Number of times x-letter word appears	Number of letters
1	378	378
2	973	1,946
3	1,307	3,921
4	1,635	6,540
5	1,410	7,050
6	1,143	6,858
7	1,009	7,063
8	717	5,736
9	476	4,284
10	274	2,740
11	161	1,771
12	86	1,032
13	23	299
14	23	322
15	4	60
	9,619	50,000

(1) Average length of words .... 5 2 letters
(2) Average length of messages .... 217 letters
(3) Modal (most frequent) length .... 105–114 letters
(4) It is extremely unusual to find five consecutive letters without at least one vowel
(5) The average number of letters between vowels is two

TABLE 13 —*Checkerboard individual frequencies*[1]

[Based on a count of 5 000 digraphs]

P1					C1				
A	B	C	D	E	244	225	375	394	197
F	G	H	I J	K	125	98	193	271	95
L	M	N	O	P	229	199	188	350	251
Q	R	S	T	U	148	162	258	427	295
V	W	X	Y	Z	42	12	34	91	97
212	317	358	308	249	A	B	C	D	E
120	108	216	256	85	F	G	H	I J	K
216	140	152	435	269	L	M	N	O	P
206	121	306	364	284	Q	R	S	T	U
38	29	21	147	43	V	W	X	Y	Z
C2					P2				

[1] The numbers in the C_1 C_2 squares represent the frequency of the individual components of the cipher digraph used to replace a given P_1 P_2 digraph in accordance with a digraphic checkerboard system where P_1 and P_2 are the plain-text squares

TABLE 14 —*Relative logarithmic values of frequencies of English digraphs*

[Based on a count of 5,000 digraphs. To obtain logarithm to base 10 (Log 10) divide by 100]

FIRST LETTER	SECOND LETTER																									
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	48	78	115	143	00	60	78	30	123	00	30	151	115	181	30	108	*	164	161	167	111	85	48	*	108	*
B	60	*	*	*	126	*	*	*	30	00	*	78	00	*	60	*	*	30	00	00	30	*	*	*	85	*
C	130	*	48	00	151	00	*	115	85	*	60	70	00	00	161	*	*	60	00	115	60	*	00	*	00	*
D	151	60	60	90	152	90	30	30	143	00	*	48	70	60	120	70	30	108	111	118	70	48	60	*	00	*
E	154	60	151	178	162	126	60	85	143	00	*	146	115	205	108	130	108	194	173	157	48	130	85	85	60	00
F	70	*	30	00	100	104	00	*	159	*	*	30	00	*	160	00	*	95	48	104	48	*	00	*	00	*
G	85	*	30	00	115	30	00	130	70	00	*	30	00	48	78	30	*	70	48	60	30	*	00	*	*	*
H	130	00	48	30	130	70	*	*	152	*	*	00	30	48	130	00	00	123	60	145	90	*	00	*	00	*
I	90	30	135	78	111	100	128	*	*	*	30	136	95	188	161	85	*	143	154	143	*	140	*	118	*	30
J	00	*	*	*	30	*	*	*	*	*	*	*	*	*	30	*	*	*	*	*	30	*	*	*	*	*
K	00	*	00	*	78	*	*	*	30	*	*	00	*	00	*	*	*	*	00	*	*	*	*	*	*	*
L	145	48	48	95	157	48	00	00	130	*	*	143	30	00	111	48	*	30	78	90	30	30	30	*	100	*
M	156	78	48	00	141	00	*	00	95	*	*	*	111	*	100	90	*	30	60	30	30	*	*	*	30	*
N	141	30	128	172	176	95	43	60	148	00	30	70	70	90	126	48	00	60	138	191	85	48	48	*	70	*
O	85	60	90	108	48	140	30	48	70	00	30	128	140	189	78	140	*	181	115	128	157	85	90	00	30	*
P	115	00	00	00	136	30	*	48	78	*	*	111	60	00	123	104	*	126	78	90	48	00	00	*	00	*
Q	*	*	*	*	*	*	*	*	*	*	*	*	00	*	*	*	*	00	*	*	118	*	*	*	*	*
R	159	30	95	123	199	78	85	48	148	00	00	70	95	85	145	111	*	104	149	162	70	70	60	*	95	*
S	138	48	111	70	169	108	30	142	153	*	00	30	48	60	118	100	*	70	128	180	104	00	60	*	00	*
T	145	48	78	78	185	85	00	189	165	*	*	70	78	85	170	30	00	123	128	128	70	*	156	*	161	00
U	70	48	48	48	104	00	90	*	70	*	*	78	70	182	00	30	*	149	108	108	*	00	*	*	*	*
V	78	*	*	*	176	*	*	*	108	*	*	*	*	*	00	*	*	*	*	00	*	*	*	*	*	*
W	108	*	*	*	134	*	*	60	111	*	*	00	*	30	128	*	*	00	00	*	*	*	*	*	00	*
X	30	*	30	00	00	00	*	00	30	*	*	*	*	00	00	30	*	00	00	85	*	*	*	*	*	*
Y	78	30	60	60	95	104	00	00	48	*	*	30	30	78	100	48	*	60	104	118	00	*	00	*	*	*
Z	00	*	*	*	30	*	*	*	00	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

*In computations, assign a value of -100 as the log for these digraphs These combinations do not usually occur in 5,000 digraphs Do not assign "0" to these combinations as that is the logarithmic value for a frequency of one, and these combinations have a frequency of less than one

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Table 15 —*Relative logarithmic values (Log$_e$ 222) of frequencies of English digraphs* *

[Based on a count of 5,000 digraphs]

Second Letter

First Letter

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	33	45	61	73	13	38	45	25	64	13	25	76	61	89	25	58	0	82	80	83	59	48	33	0	58	0
B	38	0	0	0	66	0	0	0	25	13	0	45	13	0	38	0	0	25	13	13	25	0	0	0	48	0
C	67	0	33	13	76	13	0	61	48	0	38	42	13	13	80	0	0	38	13	61	38	0	13	0	13	0
D	76	38	38	51	77	51	25	25	73	13	0	33	42	38	63	42	0	58	59	62	42	33	38	0	13	0
E	78	38	76	88	81	66	38	48	73	13	0	74	61	99	58	67	58	94	86	79	33	67	48	48	38	13
F	42	0	25	13	55	56	13	0	80	0	0	25	13	0	80	13	0	53	33	56	33	0	13	0	13	0
G	48	0	25	13	61	25	13	67	42	13	0	25	13	33	45	25	0	42	33	38	25	0	13	0	0	0
H	67	13	33	25	67	42	0	0	77	0	0	13	25	33	67	13	13	64	38	74	51	0	13	0	13	0
I	51	25	69	45	59	55	67	0	0	0	25	70	53	92	80	48	0	73	78	73	0	72	0	62	0	25
J	13	0	0	0	25	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	0
K	13	0	13	0	45	0	0	0	25	0	0	13	0	13	,0	0	0	0	13	0	0	0	0	0	0	0
L	74	33	33	58	79	33	13	13	67	0	0	73	25	13	59	33	0	25	45	51	25	25	25	0	55	0
M	78	45	33	13	72	13	0	13	53	0	0	0	59	0	55	51	0	25	38	25	25	0	0	0	25	0
N	72	25	67	85	87	53	73	38	75	13	25	42	42	51	66	33	13	38	71	93	48	33	38	0	42	0
O	48	38	51	58	33	72	25	33	42	13	25	67	72	92	45	72	0	89	61	67	79	48	51	13	25	0
P	61	13	13	13	70	25	0	33	45	0	0	59	38	13	64	56	0	66	45	51	33	13	13	0	13	0
Q	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	13	0	0	62	0	0	0	0	0
R	80	25	53	64	96	45	48	33	75	13	13	42	53	48	74	59	0	56	75	81	42	42	38	0	53	0
S	71	33	59	42	84	58	25	72	77	0	13	25	33	38	62	55	0	42	67	88	56	13	38	0	13	0
T	74	33	45	45	91	48	13	92	82	0	0	42	45	48	84	25	13	64	67	67	42	0	78	0	80	13
U	42	33	33	33	56	13	51	0	42	0	0	45	42	68	13	25	0	75	58	58	0	13	0	0	0	0
V	45	0	0	0	87	0	0	0	58	0	0	0	0	0	13	0	0	0	0	13	0	0	0	0	0	0
W	58	0	0	0	69	0	0	38	59	0	0	13	0	25	67	0	0	13	13	0	0	0	0	0	13	0
X	25	0	25	13	13	13	0	13	25	0	0	0	0	13	13	25	0	13	13	48	0	0	0	0	0	0
Y	45	25	38	38	53	56	13	13	33	0	0	25	25	45	55	33	0	38	56	62	13	0	13	0	0	0
Z	13	0	0	0	25	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* See pages 11–12 for details

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Table 16-A.--Frequency distribution of digraphs, based on 64,365 letters of decrypted U. S. Government messages in which Z was used as a word-separator and X was used for both X_p and Z_p.

2d Ltr

1st Ltr	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	28	154	142	137	17	90	99	13	118	16	43	220	157	427	18	112	2	625	526	347	56	52	20	3	66	546
B	63	14	7	1	193	1		1	43	33		148	6	18	61	2		59	17	8	15	1	1	3	60	19
C	123	1	19	8	260	22	28	183	115		48	95	390	5	414	3	1	63	66	161	47	1	5	3	27	122
D	360	12	33	30	270	4	16		141	2	1	7	4	6	102	11	11	33	32	34	38	38	17	1	11	1026
E	180	34	226	383	620	131	35	13	275	3	6	185	144	758	75	118	91	857	329	187	40	210	28	76	29	1715
F	44	16	10	3	100	122	4	1	365	2		28	23	4	536	68		114	8	32	34	1	1	2	3	343
G	78	29	7	18	258	5	31	260	25		1	11	5	31	20	18		73	29	17	25	2			1	275
H	194	1	6	12	193	14	1	24	213	3	9	7	2	24	93	3	24	229	26	257	17	2	6	1	3	428
I	85	10	209	30	152	53	330	5	5	1	46	181	40	704	200	92	1	128	303	217	2	272	2	193	1	56
J	26		3	2	31	3		1	18	20		3	1	4	35	1		5	2	18	7	2	1		2	19
K	28		2	6	108	2			54	3	20	11	3	10	9		1	1	9	2	1	1	2	1	10	59
L	159	6	6	48	328	14		4	194	2	1	237	20	65	120	5		5	41	25	41	5		1	71	296
M	581	68	36	12	198	1	58	1	92	4	1	2	62	4	43	101		10	53	20	17	1	3	6	86	231
N	112	13	157	286	733	77	244	4	234		14	15	9	76	169	16	16	13	135	267	64	10	7	7	14	910
O	25	67	46	100	56	317	66	26	23	6	23	161	230	873	59	57	2	418	129	143	413	49	59	92	13	916
P	304	5	8	363	169		2	37	27	3		75	46	9	145	104	3	153	26	351	44	2	2	1	4	122
Q	2	1	1		7			4	1			1	5	11	1	1	9	5	7		117		1			46
R	261	5	44	86	967	26	59	5	191	5	30	61	122	45	570	310	4	72	208	174	60	19	14	13	74	733
S	143	14	66	6	389	85	52	426	334	1	16	16	34	6	99	47	13	5	143	305	138	13	12	1	43	788
T	171	1	67	22	357	32	6	572	275	2	10	27	18	49	372	9	2	119	99	156	37	1	313	10	48	1106
U	45	48	26	60	87	4	61	2	35	1	3	56	61	96	32	38		453	140	48	5	5	5	1	1	44
V	39		10	2	496	1	1		91		1	3	1	8	19	4	1	3	4	7	1	9	1	1	7	34
W	111	1	3	7	34	1	11	33	107	2	1	10		12	367	7	2	3	11	5			13	13	2	30
X	9	1	8	7	350	9		2	10	1	2		2	2	10	20	3	12	9	32	1	1		32	3	203
Y	8	3	6	3	14	6	3	2	5			4	9	10	49	27		3	18	8	4	1	1		8	432
Z	902	264	1058	613	364	844	120	171	328	98	69	135	294	349	750	823	36	700	768	1046	130	46	278	271	42	
	4081	768	2206	2245	6751	1864	1227	1790	3319	208	345	1699	1628	3606	4568	1997	222	4161	3198	3872	1354	744	792	732	629	10499

In the text which gave rise to this and the following two tables, the frequently-used punctuation signs "comma" and "period" were abbreviated as CMA and PD, respectively, and the procedure term "repeat" was abbreviated as RPT; thus, the digraphs CM, PD, PT, and RP, which usually do not occur frequently (see Table 6-A), are of relatively high frequency here.

Table 16-B.--Frequency distribution of digraphs, based on the text used for Table 16-A, from which the Z word-separator has been omitted (total· 53,866 letters).

2d Ltr

1st Ltr	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	78	175	190	164	40	136	111	26	139	19	52	227	166	439	58	147	3	657	619	395	65	58	40	23	67	
B	63	14	9	2	193	5		1	43	32		149	6	18	62	2		62	17	13	15	2	3	3	60	
C	133	1	31	20	263	32	29	184	119		48	98	393	11	416	8	2	78	79	180	47	1	6	4	27	
D	443	66	102	74	307	86	26	13	183	7	5	23	32	22	151	97	16	142	118	153	59	40	55	2	18	
E	299	70	384	481	690	283	48	37	326	21	12	201	190	855	181	278	93	931	476	367	53	215	87	134	34	
F	60	19	42	25	109	137	7	2	380	3	1	39	25	10	582	80	1	148	56	67	49	3	9	3	7	
G	102	39	20	59	266	19	32	262	37	5	2	12	10	41	45	38	4	91	53	38	31	2	3	7	1	
H	270	8	34	28	215	54	13	31	220	14	11	8	13	34	139	14	23	239	64	315	18	3	16	5	3	
I	86	10	213	41	156	55	330	8	5	1	46	182	40	705	202	96	1	148	303	218	2	270	3	196	1	
J	28		7	2	31	7		1	21	20		3	1	5	36	2		6	2	19	7	2	2		2	
K	35	4	7	10	108	10	2		56	3	20	11	4	13	12	7	1	6	11	5	2	1	4	1	10	
L	197	21	38	61	338	47	2	13	207	7	4	243	26	68	134	19		21	59	50	44	8	14	1	72	
M	595	72	66	18	206	22	64	4	96	6	1	6	67	17	63	123	3	26	61	40	22	2	10	15	86	
N	213	27	280	336	748	139	254	12	263	6	19	31	47	86	234	92	24	66	202	352	75	23	28	28	17	
O	63	82	191	155	93	426	72	47	37	13	27	172	252	910	99	112	2	473	204	214	417	51	68	170	17	
P	311	7	16	388	170	5	3	40	29	4		76	46	11	150	111	3	179	37	365	44	2	2	1	5	
Q	14	4	3		7	2		4	5		1	2	5	11	8	2	9	10	10	2	117		3	1		
R	298	12	131	146	1011	84	66	14	207	17	40	69	142	59	639	369	8	103	266	263	67	19	29	30	74	
S	237	37	143	31	396	149	55	453	369	5	19	25	60	36	173	129	16	62	178	385	144	14	34	2	43	
T	277	30	167	70	400	97	21	592	308	14	16	43	67	100	463	95	5	195	150	282	52	12	338	30	57	
U	48	48	33	61	88	7	61	2	36	4	4	56	61	97	35	40		454	148	50	6	5	6	6	1	
V	41		13	5	499	7	1		92		2	4	3	8	21	6	2	4	9	8	1	9	1	1	7	
W	113	6	6	9	37	2	12	35	107	3	1	10	1	14	367	10	2	3	11	6	1		13	13	4	
X	18	2	23	22	361	20		4	12	3	10	2	9	11	24	41	3	26	29	47	4	1		54	3	
Y	59	14	57	37	19	33	18	5	22	1	4	7	22	25	74	77	1	31	36	38	10	1	18		13	
Z																										
	4081	768	2206	2245	6751	1864	1227	1790	3319	208	345	1699	1688	3606	4368	1997	222	4161	3198	3372	1354	744	792	732	629	

Table 16-C.--The 53 digraphs from Table 6-A which comprise 50% of the total, arranged according to frequencies reduced to a base of 5,000 digraphs, shown with the corresponding frequencies of the same digraphs from Table 16-B (also reduced to a base of 5,000).[1]

Dig.	6-A	16-B	Dig.	6-A	16-B
EN	111	79	FO	40	54
RE	98	94	FI	39	35
ER	87	86	RA	39	28
NT	82	33	ET	37	34
TH	78	55	LE	37	31
ON	77	84	OU	37	39
IN	75	65	MA	36	55
TE	71	36	TW	36	31
AN	64	41	EA	35	28
OR	64	44	IS	35	28
ST	63	36	SI	34	34
ED	60	45	DE	33	29
NE	57	69	HI	33	20[1]
VE	57	46	AL	32	21[1]
ES	54	44	CE	32	24
ND	52	31	DA	32	41
TO	50	43	EC	32	36
SE	49	37	RS	31	25
AT	47	37	UR	31	42
TI	45	29	NI	30	24
AR	44	61	RI	30	19[1]
EE	42	64	EL	29	19[1]
RT	42	24	HT	28	29
AS	41	57	LA	28	18[1]
CO	41	39	RO	28	59
IO	41	19[1]	TA	28	26
TY	41	5[1]			

[1] With the exception of AL, EL, HI, IO, LA, RI, TY, the digraphs of this table are all from among the 65 digraphs from Table 16-B which comprise 50% of the total.

APPENDIX 3

WORD AND PATTERN LISTS - ENGLISH

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A. LIST OF WORDS USED IN MILITARY TEXT ARRANGED ALPHABETICALLY ACCORDING TO WORD LENGTH

TWO LETTER WORDS

AM
AN
AS
AT
BE
BN
BY
CO
CP
CQ
DO
EM
GO
HE
HQ
IF
IN
IS
IT
MC
ME
MM
MP
MY
NO
OF
OK
ON
OR
QM
SO
TO
US
WD
WE
WO

THREE LETTER WORDS

ACT
ADD
ADJ
AGE
AGO
AID
AIM
AIR
ALL
AND
ANY
APT
ARC
ARE
ARM
ASK
BAD
BAG
BAR
BID
BIG
BOX
BUT
BUY
CAM
CAN
CAR
CAV
COL
CPL
CUT
CWT
DAY
DID
DIE
DOG
DRY
DUE
DUN
EAT
END
EYE
FAR
FEW
FIT
FIX
FOR
FOX
GAL
GAS
GEN
GET
GHQ
GOT
GUN
HAD
HAM
HAS
HER
HIM
HIS
HOW
ILL
ITS
JIG
JOB
KEG
LAW
LAY
LET
LOT
LOW
MAJ
MAN
MAT
MEN
MIX
NAN
NET
NEW
NOT
NOW
OFF
OLD
ONE
OUR
OUT
OWE
OWN
PAR
PAY
PEN
PER
PIN
PUT
PVT
QMC
RED
RID
ROB
RUN
SAW
SAY
SEA
SEE
SET
SGT
SHE
SIX
SPY
SUM
SUN
TAN
TAX
TEN
THE
TIN
TON
TOO
TOP
TRY
TUB
TWO
USE
VAT
WAR
WAS
WAY
WET
WGT
WON
YET
YOU

FOUR LETTER WORDS

ABLE
AIDE
ALLY
ALSO
AREA
ARMY
ASIA
AWAY
AXIS
BACK
BASE
BEEN
BLUE
BODY
BOMB
BOOK
BOTH
BULB
BULK
CALL
CELL
CITY
CODE
COOK
DARK
DASH
DATE
DAYS
DIRT
DOWN
DRAW
DUMP
EACH
EAST
EASY
EDGE
EYES
FALL
FARM
FAST
FEEL
FEET
FELL
FILE
FIRE
FIRM
FIVE
FLAG
FLEE
FORM
FOUR
FROM
FULL
FUSE
FUZE
GUNS
HALF
HALT
HAND
HARD
HAVE
HEAD
HERD
HERE
HIGH
HILL
HITS
HOLD
HOOK
INTO
ITEM
JOIN
JULY
JUNE
JUST
KEEP
KIND
KING
LAND
LAST
LATE
LEAD
LEAK
LEFT
LESS
LIEU
LINE
LIST
LOAD
LONG
LOOK
LOSS
LOST
LOVE
MADE
MAIM
MAIN
MANY
MASK
MASS
MEAT
MEET
MESS
MIKE
MILE
MINE
MORE
MOVE
MTCL
MULE
NAVY
NEAR

~~RESTRICTED~~

~~RESTRICTED~~

FOUR LETTER WORDS—Continued

NEXT
NINE
NOON
NOTE
OBOE
OMIT
ONCE
ONLY
OPEN
ORAL
OVER

PARK
PASS
PIPE
PLAN
POST
PUMP
PUSH
RAID
RAIL
RAIN
RANK

REAR
RIOT
ROAD
ROUT
RULE
RUSH
SAID
SAME
SANK
SEEN
SHIP

SHOT
SIDE
SOME
SOON
STOP
SUNK
TAKE
TALK
TANK
TARE
TASK

TEAM
TENT
TEXT
THAN
THAT
THEM
THEN
THEY
THIS
TIME
TONS

TOOK
TOOL
TOWN
TYPE
UNIT
VARY
VERY
WEAK
WEEK
WELL
WERE

WEST
WHAT
WHEN
WILL
WIRE
WITH
XRAY
YOKE
ZERO
ZONE

FIVE LETTER WORDS

ABOUT
AFTER
AGAIN
AGENT
ALARM
ALERT
ALIGN
ALINE
ALLOW
ALONG
AMONG
ANNEX
APPLY
APRIL
AREAS
ARMOR
ASSET
AWAIT
AWARD
BAKER
BANKS
BARGE
BEACH
BEGIN
BEING
BLACK
BLIND

BOATS
BOMBS
BOOTH
BREAK
BRIBE
BROKE
BURST
CANAL
CASES
CAUSE
CEASE
CHECK
CHIEF
CLEAR
CLERK
CLOSE
COAST
COLON
COMMA
CORPS
COUNT
COVER
CREEK
CREST
CROSS
CURVE
DAILY

DECKS
DEFER
DELAY
DEPOT
DEPTH
DOCKS
DRAWN
DRESS
DRILL
DRIVE
EAGER
EARLY
EIGHT
ENEMY
ENTER
EQUAL
EQUIP
ERASE
ERROR
ETHER
EVERY
FATAL
FEARS
FERRY
FIELD
FIFTH
FIFTY

FIGHT
FIRES
FIRST
FLANK
FLARE
FLATS
FLEET
FOGGY
FORCE
FORTY
FRESH
FRONT
GATES
GAUGE
GIVEN
GOING
GROUP
GUARD
GUEST
HEAVY
HONOR
HORSE
HOURS
HOUSE
ISSUE
JAPAN
LARGE

LATER
LEAST
LEAVE
LEVEL
LIGHT
LIMIT
LOCAL
MAJOR
MARCH
METER
MILES
MOTOR
NAVAL
NIGHT
NINTH
NORTH
ORDER
OTHER
PACKS
PAIRS
PARTY
PETER
PLACE
PLAIN
PLANS
POINT
PRESS

PRIOR
PROOF
PROVE
QUEEN
QUICK
QUIET
RADIO
RAFTS
RAIDS
RALLY
RANGE
RAPID
REACH
READY
REFER
REPEL
RIDGE
RIGHT
RIGID
RIVER
ROGER
ROUTE
SCALE
SEIZE
SEVEN
SHELL
SHIFT

SHIPS
SHORE
SIEGE
SIGHT
SIXTH
SIXTY
SLOPE
SMALL
SMOKE
SOUTH
SPEED
SPELL
SPLIT
SQUAD
STAFF
STAKE
START
STEEL
SUGAR
TAKEN
TANKS
TENTH
THEIR
THERE
THESE
THIRD
THREE

TITLE
TODAY
TOTAL
TRACT
TRAIN
TROOP
TRUCE
TRUCK
UNDER
UNION
UNITS
USUAL
VALOR
VISIT
VITAL
VOCAL
VOICE
WAGON
WEIGH
WHEEL
WHERE
WHICH
WIDTH
WIPED
WOODS
YARDS
ZEBRA

~~RESTRICTED~~

SIX LETTER WORDS

ACCEPT
ACCESS
ACROSS
ACTION
ACTIVE
ADJUST
ADVICE
ADVISE
AFFAIR
ALASKA
ALLEGE
ALLIED
ALLIES
ALWAYS
ANIMAL
ANNUAL
ANYWAY
APPEAR
ARABIA
ARMIES
ARMORY
ARREST
ARRIVE
ASSETS
ASSIST
ASSURE
ATTACH
ATTACK
ATTAIN
AUGUST
BANNER
BARBED
BARGES
BATTEN
BATTLE
BEETLE
BEFORE
BETTER
BEYOND
BILLET
BITTER
BODIES

BOMBED
BOMBER
BOTTOM
BRANCH
BREACH
BREEZE
BRIDGE
BROKEN
BUREAU
CANADA
CANCEL
CANNOT
CANVAS
CASUAL
CAUSED
CENTER
CHANGE
CHARGE
CHEESE
CHURCH
CIPHER
CIRCLE
COFFEE
COLORS
COLUMN
COMBAT
COMMIT
COMMON
CONVEY
CONVOY
COURSE
CREDIT
CRISIS
CRITIC
DAMAGE
DEBARK
DECIDE
DECODE
DECREE
DEFEAT
DEFECT
DEFEND

DEGREE
DEPART
DEPEND
DEPLOY
DESERT
DETACH
DETAIL
DEVICE
DEVISE
DIRECT
DIVERT
DIVIDE
DOCTOR
DOLLAR
DOWNED
DRYRUN
DUGOUT
DURING
EFFECT
EFFORT
EIGHTH
EIGHTY
EITHER
ELEVEN
EMBARK
EMPLOY
ENCODE
ENGAGE
ENGINE
ENROLL
ENTIRE
ERASER
ESCORT
EUROPE
EXCEPT
EXCESS
EXCITE
EXPECT
EXPELS
EXPEND
EXTEND
EXTENT

FIERCE
FILING
FINISH
FIRING
FLIGHT
FLYING
FOLLOW
FORCES
FORMAL
FORMED
FOUGHT
FOURTH
FRIDAY
FUTURE
GARAGE
GEORGE
GREASE
GROUND
GUNNER
HALTED
HAMMER
HAPPEN
HARBOR
HELPER
HIGHER
HOURLY
INDEED
INFORM
INLAND
INTEND
INTENT
INVENT
ISLAND
ISSUES
KEEPER
KILLED
LADDER
LANDED
LAUNCH
LEADER
LEAGUE

LESSON
LETTER
LINING
LIQUID
LITTER
LITTLE
LOCATE
LOSSES
MANAGE
MANNER
MANUAL
MEAGER
MEDIUM
MEMBER
METHOD
METRIC
MINING
MINUTE
MIRROR
MOBILE
MONDAY
MORALE
MORTAR
MOVING
MURDER
MUZZLE
NAUGHT
NEARER
NINETY
NORMAL
NOTING
NOUGHT
NOVICE
NOZZLE
NUMBER
OCCUPY
OFFEND
OFFICE
OPPOSE
ORDERS
ORIENT

OTHERS
OUTPUT
PANAMA
PARADE
PARLEY
PASSED
PASSES
PATROL
PERIOD
PICKET
PINCER
PISTOL
PLACES
PLANES
POINTS
POISON
POLICE
PONTON
POSTAL
PREFER
PROMPT
PPOPER
PURSUE
RADIAL
RAIDED
RATION
RAVINE
RECORD
REDUCE
REFILL
REFUGE
REFUSE
REJECT
RELIEF
REMAIN
REMEDY
REPAIR
REPORT
RESCUE
RESIST
RESULT

RESUME
RETIRE
RETURN
REVIEW
RIDING
ROCKET
ROUTED
ROUTES
RUBBER
RUNNER
SALARY
SCHEME
SCHOOL
SCORED
SCREEN
SEAMAN
SEAMEN
SEARCH
SECOND
SECTOR
SECURE
SELECT
SERIAL
SETTLE
SEVERE
SHELLS
SIGCOM
SIGNAL
SINGLE
SLIGHT
SPHERE
SPOOLS
SPOONS
STATES
STATUS
STRAFE
STREET
STRESS
STRIPS
SUBMIT
SUDDEN

SUFFER
SUMMER
SUMMIT
SUMMON
SUNDAY
SUNKEN
SUNSET
SUPPLY
SURVEY
SWITCH
SYSTEM
TABLES
TANKER
TARGET
TATTOO
TERROR
THIRTY
THOUGH
THREAT
TRAINS
TRENCH
TROOPS
TURRET
TWELVE
TWENTY
UNABLE
UNITED
UNLESS
VALLEY
VERBAL
VERIFY
VESSEL
VICTIM
VICTOR
VISITS
VISUAL
WEIGHT
WIRING
WITHIN
WOODED
ZIGZAG

SFVEN LETTER WORDS

ABANDON
ABSENCE
ADDRESS
ADVANCE
AGAINST

ALMANAC
AMMETER
ANALYZE
ANOTHER
ANTENNA

APPOINT
APPROVE
ARMORED
ARRANGE
ARRIVAL

ASIATIC
ASSAULT
ATTACKS
ATTEMPT
AVERAGE

AVIATOR
AWKWARD
BAGGAGE
BALLOON
BARRAGE

BATTERY
BATTLES
BEARING
BECAUSE
BEDDING

BETWEEN
BICYCLE
BINDING
BIVOUAC
BOMBARD

SEVEN LETTER WORDS—Continued

BOMBERS
BOMBING
BOYCOTT
BRIBERY
BRIGADE
CALIBER
CALIBRE
CAPTAIN
CAPTIVE
CARRIER
CAVALRY
CENTRAL
CHANGES
CHANNEL
CHARLIE
CHASSIS
CIRCUIT
CLIPPER
COASTAL
COLLECT
COLLEGE
COLONEL
COMMAND
COMMEND
COMMENT
COMMUTE
COMPANY
COMPASS
CONCEAL
CONDEMN
CONDUCT
CONFINE
CONTACT
CONTAIN
CONTROL
CORRECT
COUNCIL
COURIER
COVERED
CROSSED
CRUISER
CURRENT
CYCLONE
DAMAGED

DEBOUCH
DECIDED
DECLARE
DECODED
DEFENSE
DELAYED
DELIVER
DERRICK
DESTROY
DETRAIN
DETRUCK
DEVELOP
DIAGRAM
DISCUSS
DISEASE
DISMISS
DISTILL
DROPPED
EASTERN
ECHELON
ELEMENT
ELEVATE
EMBASSY
ENCODED
ENEMIES
ENFORCE
ENGAGED
ENTENTE
ENTRAIN
ENTRUCK
ENVELOP
EXCLUDE
EXPLAIN
EXPRESS
EXTRACT
EXTREME
FALLING
FARTHER
FEDERAL
FIFTEEN
FIGHTER
FILLING
FINDING
FISHING

FITTING
FOGHORN
FORCING
FORGING
FORWARD
FOXHOLE
FUELOIL
FURNISH
FURTHER
GASSING
GENERAL
GETTING
GLASSES
GRADUAL
GRENADE
GUARDED
HALTING
HASBEEN
HEADING
HEAVIER
HIGHEST
HOLDING
HORIZON
HOSTILE
HUNDRED
ICEBERG
ILLEGAL
ILLNESS
INCLUDE
INFLICT
INITIAL
INQUIRE
INQUIRY
INSPIRE
INSTALL
INSTANT
INVADED
ISLANDS
ISSUING
JANUARY
JUMPOFF
KITCHEN
KILLING

LANDING
LEADING
LECTURE
LIAISON
LIBRARY
LICENSE
LIFTING
LOADING
LOGICAL
LOOKOUT
MACHINE
MANDATE
MANNING
MAPPING
MARCHED
MARSHAL
MARTIAL
MAXIMUM
MEDICAL
MESSAGE
MESSING
MILITIA
MINIMUM
MISFIRE
MISSING
MISSION
MORNING
NATURAL
NEAREST
NIGHTLY
NOTHING
NUMBERS
OBSERVE
OCTOBER
OFFENSE
OFFICER
OMITTED
OPERATE
OPINION
ORDERED
OUTPOST
OUTSIDE
PACIFIC

PACKAGE
PASSAGE
PASSIVE
PATROLS
PAYROLL
PLACING
PLATOON
POUNDER
PRAIRIE
PRECEDE
PREPARE
PRESENT
PRESSED
PRIMARY
PROCEED
PROGRAM
PROMOTE
PROPOSE
PROTECT
PROTEST
PROVOST
PURPOSE
PURSUIT
PUSHING
QUARTER
QUICKLY
RADIATE
RAIDING
RAILWAY
RAINING
RAPIDLY
REACHED
RECEIPT
RECEIVE
RECOVER
RECRUIT
REDUCED
REFUGEE
REGULAR
RELEASE
RELIEVE
REPAIRS
REPLACE

REQUEST
REQUIRE
RESERVE
RESPECT
RESPOND
RETIRED
RETREAT
REVENUE
REVERSE
REVOLVE
ROUTINE
RUNNING
SAILORS
SATISFY
SECRECY
SECTION
SECTORS
SERVICE
SESSION
SETBACK
SEVENTH
SEVENTY
SEVERAL
SHELLED
SHORTLY
SIGNIFY
SIMILAR
SIMPLEX
SINKING
SIXTEEN
SLOPING
SMOKING
SOLDIER
STARTER
STATION
STEAMER
STOPPED
STORAGE
SUCCESS
SUGGEST
SUMMARY
SUNRISE
SUPPORT

SUPPOSE
SURPLUS
SUSPEND
TACTICS
TALKING
TARGETS
TERRAIN
THATTHE
THROUGH
TOBACCO
TONIGHT
TONNAGE
TORPEDO
TRACTOR
TRAFFIC
TRAWLER
TRIGGER
TUESDAY
TWELFTH
UNKNOWN
UNUSUAL
USELESS
UTILITY
VACANCY
VARYING
VESSELS
VICTORY
VILLAGE
VISIBLE
VISITOR
WARFARE
WARSHIP
WEATHER
WESTERN
WHETHER
WILLIAM
WINDAGE
WITHOUT
WITHTHE
WITNESS
WOUNDED
WRECKED
WRITTEN

EIGHT LETTER WORDS

ACTIVITY
ACTUALLY
ADJACENT
ADJUTANT

ADVANCED
ADVANCES
ADVISING
ADVISORY

AIRBORNE
AIRCRAFT
AIRDROME
AIRFIELD

AIRPLANE
ALTITUDE
AMERICAN
ANALYSIS

ANNOUNCE
ANTITANK
APPARENT
APPEARED

APPROACH
APPROVAL
ARMAMENT
ARRESTED

ASSEMBLE
ASSEMBLY
ASSIGNED
ASSOONAS

EIGHT LETTER WORDS—Continued

ATLANTIC
ATTACKED
ATTEMPTS
AVIATION
BARRACKS
BARRAGES
BATTERED
BATTLING
BESEIGED
BILLETED
BOUNDARY
BREAKING
BUILDING
BULLETIN
BUSINESS
CALAMITY
CAMPAIGN
CANISTER
CAPACITY
CAPTURED
CARELESS
CARRIAGE
CARRIERS
CARRYING
CASUALTY
CAUSEWAY
CEMETERY
CENTERED
CHAPLAIN
CHEMICAL
CIRCULAR
CITATION
CIVILIAN
CLERICAL
CODEBOOK
COMMANDS
COMMENCE
COMMERCE
COMPLETE
COMPOSED
CONCLUDE
CONCRETE
CONFLICT
CONGRESS
CONTINUE
CONTRACT
CORPORAL
CORRIDOR
COVERING
CRITICAL

CRITIQUE
CROSSING
CRUISERS
DAMAGING
DARKNESS
DAYLIGHT
DECEMBER
DECIPHER
DECISION
DECISIVE
DECLARED
DECREASE
DEDICATE
DEFEATED
DEFENDED
DEFENDER
DEFENSES
DEFERRED
DEFINITE
DELAYING
DEMANDED
DEPARTED
DEPLOYED
DEPORTED
DESCRIBE
DESERTED
DESERTER
DESPATCH
DETACHED
DETECTOR
DETONATE
DEVELOPE
DICTATED
DICTATOR
DIMINISH
DIRECTOR
DISARMED
DISASTER
DISLODGE
DISPATCH
DISPERSE
DISTANCE
DISTRESS
DISTRICT
DIVIDING
DIVISION
DOCTRINE
DOMINANT
DRESSING

DRIFTING
EASTERLY
EASTWARD
ECONOMIC
EFFECTED
EFFICACY
EIGHTEEN
ELEMENTS
ELEVENTH
ELIGIBLE
EMPLOYEE
EMPLOYER
ENCIPHER
ENCIRCLE
ENFILADE
ENGAGING
ENGINEER
ENLISTED
ENORMOUS
ENROLLED
ENTERING
ENTRENCH
ENVELOPE
EQUALIZE
EQUIPAGE
ESCORTED
ESTIMATE
EUROPEAN
EVACUATE
EXCAVATE
EXCHANGE
EXERCISE
EXPANDED
EXPEDITE
EXPELLED
EXPENDED
EXPENSES
EXTENDED
EXTERIOR
FACTIONS
FATALITY
FEBRUARY
FERRYING
FIGHTERS
FIGHTING
FINISHED
FLANKING
FLEXIBLE
FOOTHOLD

FORENOON
FORTRESS
FOURTEEN
FRONTAGE
FUSELAGE
GARRISON
GROUNDED
GROUPING
GUARDING
HAVEBEEN
HINDERED
HOSPITAL
HOWITZER
IDENTIFY
IGNITION
IMPROPER
IMPROVED
INCIDENT
INDICATE
INDIRECT
INFANTRY
INFECTED
INITIATE
INSECURE
INSIGNIA
INSTRUCT
INTEREST
INTERIOR
INTERNAL
INTRENCH
INVADING
INVASION
INVENTED
JETPLANE
JUNCTION
LANGUAGE
LATITUDE
LETTERED
LIMITING
LOCATION
LUMINOUS
MAINTAIN
MANDATED
MANEUVER
MARCHING
MARITIME
MATERIAL
MATERIEL
MECHANIC

MEDICINE
MEMORIAL
MERCIFUL
MESSAGES
MIDNIGHT
MILITARY
MISFIRES
MISSIONS
MOBILIZE
MONOPOLY
MOUNTAIN
MOVEMENT
NATIONAL
NAUTICAL
NINETEEN
NORTHERN
NOVEMBER
OBSERVED
OBSERVER
OBSOLETE
OBSTACLE
OCCUPIED
OFFENDED
OFFICERS
OFFICIAL
OPERATOR
OPPOSING
OPPOSITE
ORDINATE
ORDNANCE
OUTBOARD
OUTGUARD
OUTPOSTS
PAINTING
PARALLAX
PARALLEL
PASSPORT
PLANNING
POLITICS
PONTOONS
POSITION
POSITIVE
POSSIBLE
POSTPONE
PREPARED
PRESERVE
PRESSING
PRESSURE
PRINTING

PRIORITY
PRISONER
PROBABLE
PROBABLY
PROGRESS
PROHIBIT
PROTESTS
PROTOCOL
PURPOSES
QUARTERS
RAILHEAD
RAILROAD
RALLYING
RECEIVER
RECORDER
REDCROSS
REENLIST
REGIMENT
REGISTER
REJECTED
REJECTOR
REMEDIES
REMEMBER
REPAIRED
REPEATER
REPELLED
REPLACED
REPORTED
REPULSED
REQUIRED
RESEARCH
RESERVES
RESPECTS
RESTORED
RETIRING
RETURNED
REVIEWED
REVOLVER
RIGOROUS
SABOTAGE
SANITARY
SATURDAY
SCHEDULE
SEABORNE
SEALEVEL
SELECTED
SENTENCE
SENTINEL
SEPARATE

SERGEANT
SHELLING
SHIPPING
SIGHTING
SKIRMISH
SOLDIERS
SOUTHERN
SPECIFIC
SPOTTING
SQUADRON
STANDARD
STATIONS
STRATEGY
SUFFERED
SUITABLE
SUPERIOR
SUPPLIES
SURPRISE
SURROUND
SURVIVED
SUSPENSE
SWEEPING
SWIMMING
TACTICAL
TAXATION
TELEGRAM
TERRIBLE
TERRIFIC
THATHAVE
THIRTEEN
THOUSAND
THURSDAY
TOMORROW
TOTALING
TRAILERS
TRAINING
TRANSFER
TRAVERSE
TRAWLERS
VEHICLES
VICINITY
VIGOROUS
WARSHIPS
WESTERLY
WESTWARD
WINDWARD
WIRELESS
WITHDRAW
WITHDREW

~~RESTRICTED~~

NINE LETTER WORDS

ACCESSORY
ACCOMPANY
ACCORDING
ADDRESSED
ADDRESSES
ADMISSION
ADVANCING
ADVANTAGE
AERODROME
AEROPLANE
AFTERNOON
AGREEMENT
AIRDROMES
AIRPLANES
ALLOTMENT
ALLOWANCE
ALTERNATE
AMBULANCE
AMUSEMENT
ANNOUNCED
ANONYMOUS
APPARATUS
APPOINTED
ARBITRARY
ARTILLERY
ASCENSION
ASSAULTED
ASSISTANT
ASSOCIATE
ASSURANCE
ATTACKING
ATTEMPTED
ATTENTION
AUTOMATIC
AVAILABLE
BALLISTIC
BAROMETER
BATTALION
BATTERIES
BEACHHEAD
BEGINNING
BLOCKADED
BOMBARDED
BRIGADIER
BUILDINGS
CABLEGRAM
CAMPAIGNS
CANCELLED
CARTRIDGE

CENTERING
CHALLENGE
CHARACTER
CHAUFFEUR
CHRONICAL
CIGARETTE
CIRCULATE
CIVILIANS
CLEARANCE
COALITION
COLLAPSED
COLLISION
COMBATANT
COMMANDED
COMMANDER
COMMITTEE
COMPANIES
COMPELLED
COMPLETED
CONDEMNED
CONDENSED
CONDITION
CONFERRED
CONFIDENT
CONFLICTS
CONQUERED
CONTINUAL
CONTINUED
CONTINUES
COOPERATE
CORRECTED
CRITICISE
CRITICISM
DEBARKING
DECREASED
DEFECTIVE
DEFENSIVE
DEFICIENT
DEPARTURE
DEPENDENT
DESCRIBED
DESIGNATE
DESTITUTE
DESTROYED
DESTROYER
DETENTION
DETERMINE
DETONATED
DETRAINED

DEVELOPED
DIETITIAN
DIFFERENT
DIFFICULT
DIMENSION
DIRECTION
DIRIGIBLE
DISAPPEAR
DISCUSSED
DISINFECT
DISMISSAL
DISPERSED
DISTRICTS
DIVISIONS
DOMINANCE
DOMINATED
ECHELONED
EFFECTIVE
EFFICIENT
ELABORATE
ELEVATION
ELSEWHERE
EMBASSIES
EMERGENCY
EMPLOYING
ENDURANCE
ENGINEERS
ENLISTING
ENTRAINED
EQUIPMENT
ESTABLISH
ESTIMATED
ESTIMATES
EXCESSIVE
EXCLUSION
EXCLUSIVE
EXECUTIVE
EXERCISES
EXHIBITED
EXPANSION
EXPANSIVE
EXPENSIVE
EXPLOSION
EXPLOSIVE
EXTENDING
EXTENSION
EXTENSIVE
FIFTEENTH
FIREALARM

FORMATION
FORTIFIED
FRONTLINE
GROUPMENT
GYROMETER
HOSTILITY
HURRICANE
IDENTICAL
IMMEDIATE
IMPORTANT
IMPRESSED
INCENTIVE
INCIDENCE
INCIDENTS
INCLINING
INCLUDING
INCLUSIVE
INCREASED
INDEMNITY
INDICATED
INFLATION
INFLICTED
INFLUENCE
INHABITED
INSTANTLY
INTEGRITY
INTENSIVE
INTENTION
INTERCEPT
INTERDICT
INTERFERE
INTERMENT
INTERPOSE
INTERRUPT
INTERVENE
INTERVIEW
INVENTION
IRREGULAR
KILOMETER
LAUNCHING
LIABILITY
LOGISTICS
LONGITUDE
MAINTAINS
MANGANESE
MECHANISM
MEMORANDA
MESSENGER
MOTORIZED

MOVEMENTS
MUNITIONS
NAVALBASE
NECESSARY
NECESSITY
NEGLIGENT
NEWSPAPER
NORTHEAST
NORTHERLY
NORTHWARD
NORTHWEST
NUMBERING
OBJECTION
OBJECTIVE
OBTAINING
OCCUPYING
OFFENSIVE
OFFICIALS
OPERATING
OPERATION
OSCILLATE
OUTSKIRTS
PARACHUTE
PARAGRAPH
PARTITION
PASSENGER
PATRIOTIC
PENETRATE
PERMANENT
PERSONNEL
PLACEMENT
POLITICAL
POPULATED
POSITIONS
PRACTICAL
PRECEDING
PREFERRED
PREMATURE
PREPARING
PRESIDENT
PRINCIPAL
PRINCIPLE
PRISONERS
PROCEDURE
PROCEEDED
PROJECTOR
PROMOTION
PROPOSALS
PROTECTED

PROTECTOR
PROTESTED
PROVISION
PROXIMITY
RADIATION
RADIOGRAM
READINESS
REARGUARD
REBELLION
RECEIVING
RECOGNIZE
RECOMMEND
REENFORCE
REFERENCE
REFILLING
REGARDING
REINFORCE
REINSTATE
REMAINDER
REMAINING
REPRESENT
REPRISALS
REQUESTED
REQUIRING
RESOURCES
RESTRAINT
RETENTION
RETURNING
REVIEWING
SCREENING
SEAPLANES
SECRETARY
SEMICOLON
SEMIRIGID
SEPTEMBER
SERIOUSLY
SERVICING
SEVENTEEN
SHELLFIRE
SITUATION
SIXTEENTH
SOUTHEAST
SOUTHWARD
SOUTHWEST
SPEARHEAD
STANDARDS
STATEMENT
STRAGGLER
STRATEGIC

~~RESTRICTED~~

NINE LETTER WORDS—Continued

SUBMITTED
SUCCEEDED
SURRENDER
SUSPECTED
SUSPENDED
SUSPICION
TECHNICAL
TECHNIQUE
TELEPHONE
TENTATIVE
TERRITORY
THEREFORE
TRANSPORT
TWENTIETH
UNTENABLE
VARIATION
WATERTANK
WEDNESDAY
WITNESSES
YESTERDAY

TEN LETTER WORDS

ACCEPTABLE
ACCEPTANCE
ACCIDENTAL
ACCORDANCE
ACTIVITIES
ADDITIONAL
AIRCONTROL
AIRSUPPORT
ALLEGIANCE
ALLOCATION
AMBASSADOR
AMMUNITION
ANTEDATING
ANTICIPATE
APPARENTLY
APPEARANCE
APPROACHED
ARMOREDCAR
ARTIFICIAL
ASPOSSIBLE
ASSEMBLIES
ASSESSMENT
ASSIGNMENT
ASSISTANCE
ATOMICBOMB
ATTACHMENT
ATTAINMENT
ATTEMPTING
AUDIBILITY
AUTOMOBILE
BALLISTICS
BATTLESHIP
BEENNEEDED
BRIDGEHEAD
CAMOUFLAGE
CAPABILITY
CASUALTIES
CENSORSHIP
CENTRALIZE
CIRCUITOUS
COASTGUARD
COLLECTING
COLLECTION
COLLISIONS
COMMANDANT
COMMANDEER
COMMANDING
COMMISSARY
COMMISSION
COMMITMENT
COMMUNIQUE
COMPENSATE
COMPLETELY
COMPRESSED
CONCERNING
CONCESSION
CONCLUSION
CONDITIONS
CONFERENCE
CONFESSION
CONFIDENCE
CONNECTING
CONNECTION
CONSPIRACY
CONSTITUTE
CONTINGENT
CONTINUOUS
CONTRABAND
CONVENIENT
COORDINATE
CORRECTION
CREDENTIAL
CROSSROADS
DEBOUCHING
DECIPHERED
DECORATION
DEDICATION
DEFICIENCY
DEFINITION
DEMOBILIZE
DEPARTMENT
DEPENDABLE
DEPLOYMENT
DEPRESSION
DESIGNATED
DESPATCHED
DESPATCHES
DESTROYERS
DETACHMENT
DETERMINED
DETONATION
DETRAINING
DETRUCKING
DIFFERENCE
DIPLOMATIC
DIRECTIONS
DISCIPLINE
DISCUSSION
DISPATCHED
DISPATCHER
DISPATCHES
DISPERSION
DISTRESSED
DISTRIBUTE
DIVEBOMBER
DOMINATION
EFFICIENCY
EIGHTEENTH
ELEMENTARY
EMPLOYMENT
ENCIPHERED
ENCIRCLING
ENEMYTANKS
ENGAGEMENT
ENLISTMENT
ENROLLMENT
ENTERPRISE
ENTRENCHED
ENTRUCKING
EQUIVALENT
ESTIMATION
EVACUATING
EVACUATION
EVALUATION
EXCAVATION
EXCITEMENT
EXHIBITION
EXPEDITING
EXPEDITION
EXPENDABLE
EXPERIENCE
EXPERIMENT
EXPLOSIONS
EXTINGUISH
FACILITIES
FLASHLIGHT
FORMATIONS
FOUNDATION
FOURTEENTH
FRONTLINES
GEOGRAPHIC
GONIOMETER
GOVERNMENT
GYROSCOPIC
HYDROMETER
HYGROMETER
ILLITERATE
ILLUMINATE
ILLUSTRATE
IMPASSIBLE
IMPOSSIBLE
IMPRESSION
IMPRESSIVE
INCENDIARY
INDICATING
INDICATION
INDIVIDUAL
INFLICTING
INSECURITY
INSPECTION
INSTRUCTED
INSTRUCTOR
INSTRUMENT
INTERNMENT
INVITATION
IRRIGATION
KILOMETERS
LABORATORY
LIEUTENANT
LIMITATION
LOCOMOTIVE
MACHINEGUN
MAINTAINED
MANAGEMENT
MECHANIZED
MEMORANDUM
MILLIMETER
MOTORCYCLE
NATURALIZE
NAVIGATION
NEGLIGENCE
NEWSPAPERS
NINETEENTH
OBJECTIVES
OCCUPATION
ONEHUNDRED
OPERATIONS
OPPOSITION
OVERCOMING
PATROLLING
PERMISSION
PERSISTENT
PHOSPHORUS
POPULATION
POSSESSION
POSTOFFICE
PRECEDENCE
PREFERENCE
PRESCRIBED
PROHIBITED
PROPORTION
PROTECTION
PROVISIONS
QUARANTINE
RECEPTACLE
RECREATION
RECRUITING
REENFORCED
REENLISTED
REGIMENTAL
REGULATION
REINFORCED
RESISTANCE
RESPECTFUL
RESTRICTED

TEN LETTER WORDS—Continued

REVOLUTION
SANITATION
SEPARATION
SIGNALLING
SIMILARITY
STATISTICS
SUBMARINES
SUBMISSION
SUBSTITUTE
SUCCESSFUL
SUCCESSIVE
SUFFICIENT
SUPPORTING
SUSPENSION
SUSPICIONS
SUSPICIOUS
THIRTEENTH
THREATENED
TRAJECTORY
TRANSPORTS
TRANSVERSE
TROOPSHIPS
TWENTYFIVE
UNDERSTAND
UNDERSTOOD
UNEXPENDED
UNSUITABLE
VICTORIOUS
VISIBILITY
WILLATTACK
WITHDRAWAL

ELEVEN LETTER WORDS

ACCESSORIES
AERONAUTICS
ALTERNATING
APPLICATION
APPOINTMENT
APPROACHING
APPROPRIATE
APPROXIMATE
ARBITRATION
ARMOREDCARS
ARRANGEMENT
ASSESSMENTS
ASSIGNMENTS
ASSOCIATION
BATTLEFIELD
BATTLESHIPS
BELLIGERENT
BLOCKBUSTER
BOMBARDMENT
CATASTROPHE
CERTIFICATE
CIRCULATION
COEFFICIENT
COINCIDENCE
COMMUNICATE
COMMUNIQUES
COMPARTMENT
COMPETITION
COMPOSITION
COMPUTATION
CONCEALMENT
CONCENTRATE
CONFINEMENT
CONSTITUTED
CONSUMPTION
CONTINENTAL
CONTROVERSY
COOPERATION
CORPORATION
CORRECTNESS
CREDENTIALS
CUSTOMHOUSE
DEBARKATION
DEMONSTRATE
DESCRIPTION
DESCRIPTIVE
DESIGNATION
DESTRUCTION
DETERIORATE
DEVELOPMENT
DISAPPEARED
DISCONTINUE
DISCREPANCY
DISINFECTED
DISPOSITION
DISTINCTION
DISTINGUISH
DYNAMOMETER
ECHELONMENT
EFFECTIVELY
ELECTRICITY
EMBARKATION
EMPLACEMENT
ENCOUNTERED
ENEMYPLANES
ENFORCEMENT
ENGAGEMENTS
ENGINEERING
ESTABLISHED
ESTIMATEDAT
EXAMINATION
EXPLANATION
EXTENSIVELY
EXTERMINATE
FINGERPRINT
FIRECONTROL
HEAVYBOMBER
HEAVYLOSSES
HOSTILITIES
IMMEDIATELY
IMMIGRATION
IMPEDIMENTA
IMPROVEMENT
INCOMPETENT
INDEPENDENT
INFLAMMABLE
INFORMATION
INSPIRATION
INSTITUTION
INSTRUCTION
INSTRUMENTS
INTELLIGENT
INTERCEPTED
INTERCERPTS
INTERESTING
INTERFERING
INTERPRETER
INTERRUPTED
INTERVENING
INVESTIGATE
LEGISLATION
LIGHTBOMBER
MAINTENANCE
MANUFACTURE
MEASUREMENT
NATIONALISM
NATIONALITY
NAVALATTACK
NAVALBATTLE
NAVALFORCES
NECESSITATE
OBSERVATION
OVERWHELMED
PARENTHESIS
PARENTHESES
PENETRATION
PERFORMANCE
PHILIPPINES
PHOTOGRAPHY
PREARRANGED
PREPARATION
PRELIMINARY
PROGRESSIVE
RANGEFINDER
REAPPOINTED
RECOGNITION
RECOMMENDED
RECONNOITER
REPLACEMENT
REQUIREMENT
REQUISITION
RESERVATION
RESIGNATION
RESPONSIBLE
RESTRICTION
RETALIATION
RETROACTIVE
SCHOOLHOUSE
SEVENTEENTH
SEVENTYFIVE
SIGNIFICANT
SMOKESCREEN
STRATEGICAL
SUBSISTENCE
SUITABILITY
SUPERIORITY
SURRENDERED
SYNCHRONIZE
TEMPERATURE
THERMOMETER
TOPOGRAPHIC
TRADITIONAL
TRANSFERRED
WITHDRAWING

TWELVE LETTER WORDS

ADVANTAGEOUS
AGRICULTURAL
ANNOUNCEMENT
ANTIAIRCRAFT
ANTICIPATION
BREAKTHROUGH
CANCELLATION
CARELESSNESS
COMMENCEMENT
COMMENDATION
COMMISSIONED
COMMISSIONER
COMPENSATION
COMPLETENESS
CONCENTRATED
CONCILIATION
CONFIDENTIAL
CONFIRMATION
CONFISCATION
CONFORMATION
CONSCRIPTION
CONSIDERABLE
CONSTITUTING
CONSTITUTION
CONSTRUCTION
CONTINUATION
CONVALESCENT
CONVERSATION
COORDINATION
DECENTRALIZE
DECIPHERMENT
DEMONSTRATED
DEPARTMENTAL
DIFFICULTIES
DISORGANIZED

TWELVE LETTER WORDS—Continued

DISPLACEMENT
DISSEMINATED
DISTRIBUTING
DISTRIBUTION
EMPLACEMENTS
ENCIPHERMENT
ENTANGLEMENT
ENTERPRISING
FIGHTERPLANE
GENERALALARM
GENERALSTAFF
GEOGRAPHICAL
HEADQUARTERS
HEAVYBOMBERS
HYDROGRAPHIC
ILLUMINATING
ILLUMINATION
ILLUSTRATION
INAUGURATION
INCOMPETENCE
INEFFICIENCY
INSTRUCTIONS
INTELLIGENCE
INTERDICTION
INTERFERENCE
INTERMEDIATE
INTERRUPTION
INTERVENTION
INTRODUCTION
INTRODUCTORY
IRREGULARITY
LIGHTBOMBERS
MARKSMANSHIP
MEASUREMENTS
MEDIUMBOMBER
MOBILIZATION
NONCOMBATANT
NORTHWESTERN
OBSTRUCTIONS
ORGANIZATION
PREPARATIONS
PREPAREDNESS
PRESERVATION
PRESIDENTIAL
PROCLAMATION
PSYCHROMETER
RADIOSTATION
RECREATIONAL
REENLISTMENT
REGISTRATION
REPLACEMENTS
RESPECTFULLY
ROADJUNCTION
SATISFACTORY
SEARCHLIGHTS
SHARPSHOOTER
SIGNIFICANCE
SIMULTANEOUS
SOUTHWESTERN
SUBSTITUTION
SUCCESSFULLY
TRANSFERRING
TRANSMISSION
TRANSPACIFIC
UNIDENTIFIED
UNITEDSTATES
UNSUCCESSFUL
VERIFICATION
VETERINARIAN

THIRTEEN LETTER WORDS

ACCOMMODATION
APPROXIMATELY
CHRONOLOGICAL
CIRCUMSTANCES
COMMUNICATION
CONCENTRATING
CONCENTRATION
CONGRESSIONAL
CONSIDERATION
CORRESPONDING
COUNTERATTACK
DECENTRALIZED
DEMONSTRATION
DEPENDABILITY
DETERMINATION
DISAPPEARANCE
DISCREPANCIES
DISSEMINATION
DISTINGUISHED
ENTERTAINMENT
ESTABLISHMENT
EXTERMINATION
EXTRAORDINARY
FIGHTERPLANES
IMPRACTICABLE
INDETERMINATE
INSTALLATIONS
INSTANTANEOUS
INTERNATIONAL
INVESTIGATION
MEDIUMBOMBERS
MISCELLANEOUS
PRELIMINARIES
QUALIFICATION
QUARTERMASTER
REAPPOINTMENT
REENFORCEMENT
REIMBURSEMENT
REINFORCEMENT
REINSTATEMENT
REVOLUTIONARY
SPECIFICATION
TRANSATLANTIC
WARDEPARTMENT

FOURTEEN LETTER WORDS

ADMINISTRATION
ADMINISTRATIVE
CENTRALIZATION
CHARACTERISTIC
CIRCUMSTANTIAL
CLASSIFICATION
CORRESPONDENCE
DEMOBILIZATION
DISCONTINUANCE
DISTINGUISHING
IDENTIFICATION
INTERPRETATION
INVESTIGATIONS
IRREGULARITIES
METEOROLOGICAL
NATURALIZATION
RECOMMENDATION
RECONNAISSANCE
RECONNOITERING
RECONSTRUCTION
REORGANIZATION
REPRESENTATIVE
RESPONSIBILITY
SATISFACTORILY
TRANSPORTATION

8. LIST OF WORDS USED IN MILITARY TEXT ARRANGED IN RHYMING ORDER ACCORDING TO WORD LENGTH

THREE LETTER WORDS

SEA
JOB
ROB
TUB
QMC
ARC
BAD
HAD
ADD
RED
AID
BID
DID
RID
OLD
AND
END

SEE
AGE
SHE
THE
DIE
ONE
ARE
USE
DUE
OWE
EYE
OFF
BAG
KEG
BIG
JIG
DOG

MAJ
ADJ
ASK
GAL
ALL
ILL
COL
CPL
CAM
HAM
AIM
HIM
ARM
SUM
CAN
MAN
NAN

TAN
GEN
MEN
PEN
TEN
PIN
TIN
TON
WON
DUN
GUN
RUN
SUN
OWN
AGO
TOO
TWO

TOP
GHQ
BAR
CAR
FAR
PAR
WAR
HER
PER
AIR
FOR
OUR
GAS
HAS
WAS
HIS
ITS

EAT
MAT
VAT
ACT
GET
LET
NET
SET
WET
YET
SGT
WGT
FIT
GOT
LOT
NOT

APT
BUT
CUT
OUT
PUT
PVT
CWT
YOU
CAV
LAW
SAW
FEW
NEW
HOW
LOW
NOW

TAX
FIX
MIX
SIX
BOX
FOX
DAY
LAY
PAY
SAY
WAY
ANY
SPY
DRY
TRY
BUY

FOUR LETTER WORDS

AREA
ASIA
BULB
BOMB
HEAD
LEAD
LOAD
ROAD
RAID
SAID
HOLD
HAND
LAND
KIND
HARD
HERD
ONCE
MADE
AIDE
SIDE
CODE
FLEE
EDGE
TAKE

MIKE
YOKE
ABLE
FILE
MILE
MULE
RULE
SAME
TIME
SOME
LINE
MINE
NINE
ZONE
JUNE
OBOE
PIPE
TYPE
TARE
HERE
WERE
FIRE
WIRE
MORE

BASE
FUSE
DATE
LATE
NOTE
BLUE
HAVE
FIVE
LOVE
MOVE
FUZE
HALF
FLAG
KING
LONG
EACH
HIGH
DASH
PUSH
RUSH
WITH
BOTH
LEAK
BACK

WEEK
TALK
BULK
RANK
SANK
TANK
SUNK
BOOK
COOK
HOOK
LOOK
TOOK
DARK
PARK
MASK
TASK
ORAL
MTCL
FEEL
RAIL
CALL
FALL
CELL

FELL
WELL
HILL
WILL
FULL
TOOL
TEAM
THEM
ITEM
MAIM
FROM
FARM
FIRM
FORM
THAN
PLAN
BEEN
SEEN
THEN
WHEN
OPEN
MAIN
RAIN

JOIN
NOON
SOON
DOWN
TOWN
ZERO
ALSO
INTO
KEEP
SHIP
DUMP
PUMP
STOP
NEAR
REAR
OVER
FOUR
EYES
THIS
AXIS
TONS
GUNS
MASS

PASS
LESS
MESS
LOSS
HITS
DAYS
MEAT
THAT
WHAT
FEET
MEET
LEFT
OMIT
UNIT
HALT
TENT
SHOT
RIOT
DIRT
EAST
FAST
LAST
WEST

LIST
LOST
POST
JUST
ROUT
NEXT
TEXT
LIEU
DRAW
XRAY
AWAY
BODY
THEY
ALLY
ONLY
JULY
ARMY
MANY
VARY
VERY
EASY
CITY
NAVY

FIVE LETTER WORDS

COMMA
ZEBRA
SQUAD
SPEED
WIPED
RIGID
RAPID
FIELD
BLIND
GUARD
AWARD
THIRD
BRIBE
PLACE
VOICE
FORCE
TRUCE
THREE
RIDGE
SIEGE
RANGE
BARGE
LARGE
GAUGE
STAKE
SMOKE
BROKE

SCALE
TITLE
ALINE
SLOPE
FLARE
THERE
WHERE
SHORE
CEASE
ERASE
THESE
CLOSE
HORSE
CAUSE
HOUSE
ROUTE
ISSUE
LEAVE
DRIVE
PROVE
CURVE
SEIZE
CHIEF
STAFF
PROOF
BEING
GOING

ALONG
AMONG
BEACH
REACH
WHICH
MARCH
WEIGH
FRESH
WIDTH
FIFTH
TENTH
NINTH
BOOTH
DEPTH
NORTH
SOUTH
SIXTH
BREAK
BLACK
CHECK
QUICK
TRUCK
CREEK
FLANK
CLERK
LOCAL
VOCAL

CANAL
FATAL
VITAL
TOTAL
EQUAL
USUAL
NAVAL
WHEEL
STEEL
REPEL
LEVEL
APRIL
SMALL
SHELL
SPELL
DRILL
ALARM
JAPAN
QUEEN
TAKEN
SEVEN
GIVEN
ALIGN
AGAIN
PLAIN
TRAIN
BEGIN

WAGON
UNION
COLON
DRAWN
RADIO
EQUIP
TROOP
GROUP
CLEAR
SUGAR
UNDER
ORDER
DEFER
REFER
EAGER
ROGER
ETHER
OTHER
BAKER
LATER
METER
PETER
AFTER
ENTER
RIVER
COVER
THEIR

PRIOR
MAJOR
VALOR
ARMOR
HONOR
ERROR
MOTOR
AREAS
BOMBS
RAIDS
WOODS
YARDS
MILES
FIRES
CASES
GATES
PACKS
DECKS
DOCKS
BANKS
TANKS
PLANS
SHIPS
CORPS
FEARS
PAIRS
HOURS

DRESS
PRESS
CROSS
FLATS
BOATS
RAFTS
UNITS
TRACT
FLEET
QUIET
ASSET
SHIFT
EIGHT
FIGHT
LIGHT
NIGHT
RIGHT
SIGHT
AWAIT
SPLIT
LIMIT
VISIT
AGENT
POINT
FRONT
COUNT
DEPOT

START
ALERT
LEAST
COAST
CREST
GUEST
FIRST
BURST
ABOUT
ALLOW
ANNEX
TODAY
DELAY
READY
FOGGY
DAILY
RALLY
APPLY
EARLY
ENEMY
EVERY
FERRY
FIFTY
PARTY
FORTY
SIXTY
HEAVY

SIX LETTER WORDS

CANADA
ARABIA
ALASKA
PANAMA
METRIC
CRITIC
BOMBED
BARBED
RAIDED
LANDED
WOODED
INDEED
ALLIED
KILLED
FORMED
DOWNED
SCORED
PASSED
CAUSED
UNITED

HALTED
ROUTED
LIQUID
INLAND
ISLAND
DEFEND
OFFEND
DEPEND
EXPEND
INTEND
EXTEND
SECOND
BEYOND
GROUND
METHOD
PERIOD
RECORD
OFFICE
POLICE
ADVICE

DEVICE
NOVICE
FIERCE
REDUCE
PARADE
DECIDE
DIVIDE
DECODE
ENCODE
COFFEE
DECREE
DEGREE
STRAFE
ENGAGE
DAMAGE
MANAGE
GARAGE
BRIDGE
ALLEGE
CHANGE

CHARGE
GEORGE
REFUGE
MORALE
UNABLE
CIRCLE
SINGLE
MOBILE
BEETLE
BATTLE
SETTLE
LITTLE
NOZZLE
MUZZLE
SCHEME
RESUME
ENGINE
RAVINE
EUROPE
SPHERE

SEVERE
RETIRE
ENTIRE
BEFORE
SECURE
ASSURE
FUTURE
GREASE
CHEESE
ADVISE
DEVISE
OPPOSE
COURSE
REFUSE
LOCATE
EXCITE
MINUTE
RESCUE
LEAGUE
PURSUE

ARRIVE
ACTIVE
TWELVE
BREEZE
RELIEF
ZIGZAG
RIDING
FILING
LINING
MINING
FIRING
WIRING
DURING
NOTING
MOVING
FLYING
BREACH
DETACH
ATTACH
BRANCH

TRENCH
LAUNCH
SEARCH
CHURCH
SWITCH
THOUGH
FINISH
EIGHTH
FOURTH
ATTACK
DEBARK
EMBARK
VERBAL
RADIAL
SERIAL
ANIMAL
FORMAL
NORMAL
SIGNAL
POSTAL

MANUAL
ANNUAL
CASUAL
VISUAL
CANCEL
VESSEL
DETAIL
REFILL
ENROLL
SCHOOL
PATROL
PISTOL
SYSTEM
VICTIM
SIGCOM
BOTTOM
INFORM
MEDIUM
SUDDEN
SCREEN

SIX LETTER WORDS—Continued

SUNKEN
BROKEN
SEAMEN
HAPPEN
BATTEN
ELEVEN
REMAIN
ATTAIN
WITHIN
COLUMN
RATION
ACTION
COMMON
SUMMON
POISON
LESSON
PONTON
RETURN
DRYRUN
TATTOO
APPEAR
DOLLAR

MORTAR
RUBBER
MEMBER
BOMBER
NUMBER
PINCER
LEADER
LADDER
MURDER
PREFER
SUFFER
MEAGER
HIGHER
CIPHER
EITHER
TANKER
HAMMER
SUMMER
BANNER
MANNER
GUNNER

RUNNER
KEEPER
HELPER
PROPER
NEARER
ERASER
CENTER
BETTER
LETTER
BITTER
LITTER
AFFAIR
REPAIR
HARBOR
TERROR
MIRROR
SECTOR
VICTOR
DOCTOR
CANVAS
PLACES

FORCES
BARGES
BODIES
ALLIES
ARMIES
TABLES
PLANES
PASSES
LOSSES
STATES
ROUTES
ISSUES
CRISIS
SHELLS
SPOOLS
TRAINS
SPOONS
STRIPS
TROOPS
ORDERS
OTHERS

COLORS
ACCESS
EXCESS
UNLESS
STRESS
ACROSS
ASSETS
VISITS
POINTS
STATUS
ALWAYS
COMBAT
DEFEAT
THREAT
DEFECT
EFFECT
REJECT
SELECT
EXPECT
DIRECT
STREET

TARGET
PICKET
ROCKET
BILLET
TURRET
SUNSET
WEIGHT
FLIGHT
SLIGHT
NAUGHT
FOUGHT
NOUGHT
CREDIT
SUBMIT
COMMIT
SUMMIT
RESULT
ORIENT
INTENT
EXTENT
INVENT

CANNOT
ACCEPT
EXCEPT
PROMPT
DEPART
DESERT
DIVERT
ESCORT
EFFORT
REPORT
ARREST
RESIST
ASSIST
AUGUST
ADJUST
DUGOUT
OUTPUT
BUREAU
REVIEW
FOLLOW
FRIDAY

MONDAY
SUNDAY
ANYWAY
REMEDY
VALLEY
PARLEY
CONVEY
SURVEY
VERIFY
SUPPLY
HOURLY
DEPLOY
EMPLOY
CONVOY
OCCUPY
SALARY
ARMORY
NINETY
EIGHTY
TWENTY
THIRTY

SEVEN LETTER WORDS

MILITIA
ANTENNA
ALMANAC
BIVOUAC
TRAFFIC
PACIFIC
ASIATIC
REDUCED
INVADED
DECIDED
DECODED
ENCODED
WOUNDED
GUARDED
PROCEED
ENGAGED
DAMAGED
REACHED
MARCHED
WRECKED
SHELLED
DROPPED
STOPPED
HUNDRED
ORDERED

COVERED
RETIRED
ARMORED
PRESSED
CROSSED
OMITTED
DELAYED
COMMAND
COMMEND
SUSPEND
RESPOND
BOMBARD
AWKWARD
FORWARD
REPLACE
SERVICE
ADVANCE
ABSENCE
ENFORCE
BRIGADE
GRENADE
PRECEDE
OUTSIDE
INCLUDE
EXCLUDE

REFUGEE
WINDAGE
BAGGAGE
PACKAGE
VILLAGE
TONNAGE
AVERAGE
STORAGE
BARRAGE
PASSAGE
MESSAGE
COLLEGE
ARRANGE
WITHTHE
THATTHE
CHARLIE
PRAIRIE
VISIBLE
BICYCLE
HOSTILE
EXTREME
CONFINE
MACHINE
ROUTINE
CYCLONE

WARFARE
DECLARE
PREPARE
CALIBRE
MISFIRE
INSPIRE
REQUIRE
INQUIRE
LECTURE
RELEASE
DISEASE
SUNRISE
LICENSE
DEFENSE
OFFENSE
PROPOSE
SUPPOSE
PURPOSE
REVERSE
BECAUSE
MANDATE
RADIATE
OPERATE
ELEVATE
ENTENTE

PROMOTE
COMMUTE
REVENUE
RELIEVE
RECEIVE
PASSIVE
CAPTIVE
REVOLVE
APPROVE
OBSERVE
RESERVE
ANALYZE
JUMPOFF
BOMBING
PLACING
FORCING
HEADING
LEADING
LOADING
BEDDING
RAIDING
HOLDING
LANDING
BINDING
FINDING

FORGING
FISHING
PUSHING
NOTHING
TALKING
SINKING
SMOKING
FALLING
FILLING
KILLING
RAINING
MANNING
RUNNING
MORNING
SLOPING
MAPPING
BEARING
GASSING
MESSING
MISSING
LIFTING
HALTING
GETTING
FITTING
ISSUING

VARYING
ICEBERG
DEBOUCH
THROUGH
FURNISH
TWELFTH
SEVENTH
SETBACK
DERRICK
DETRUCK
ENTRUCK
MEDICAL
LOGICAL
CONCEAL
ILLEGAL
MARSHAL
INITIAL
MARTIAL
FEDERAL
GENERAL
SEVERAL
CENTRAL
NATURAL
COASTAL
GRADUAL

SEVEN LETTER WORDS—Continued

UNUSUAL
ARRIVAL
CHANNEL
COLONEL
COUNCIL
FUELOIL
INSTALL
DISTILL
PAYROLL
CONTROL
WILLIAM
DIAGRAM
PROGRAM
MINIMUM
MAXIMUM
HASBEEN
FIFTEEN
SIXTEEN
BETWEEN
KITCHEN
WRITTEN
EXPLAIN
TERRAIN
DETRAIN

ENTRAIN
CONTAIN
CAPTAIN
CONDEMN
ABANDON
OPINION
SESSION
MISSION
STATION
SECTION
ECHELON
BALLOON
PLATOON
LIAISON
HORIZON
EASTERN
WESTERN
FOGHORN
UNKNOWN
TOBACCO
TORPEDO
WARSHIP
DEVELOP

ENVELOP
SIMILAR
REGULAR
CALIBER
OCTOBER
OFFICER
POUNDER
TRIGGER
WEATHER
WHETHER
ANOTHER
FARTHER
FURTHER
SOLDIER
CARRIER
COURIER
HEAVIER
TRAWLER
STEAMER
CLIPPER
CRUISER
AMMETER
FIGHTER

STARTER
QUARTER
DELIVER
RECOVER
AVIATOR
TRACTOR
VISITOR
TACTICS
ISLANDS
CHANGES
ENEMIES
BATTLES
GLASSES
CHASSIS
ATTACKS
VESSELS
PATROLS
BOMBERS
NUMBERS
REPAIRS
SAILORS
SECTORS
COMPASS

SUCCESS
USELESS
ILLNESS
WITNESS
ADDRESS
EXPRESS
DISMISS
DISCUSS
TARGETS
SURPLUS
RETREAT
EXTRACT
CONTACT
COLLECT
RESPECT
CORRECT
PROTECT
INFLICT
CONDUCT
TONIGHT
CIRCUIT
RECRUIT
PURSUIT

ASSAULT
INSTANT
ELEMENT
COMMENT
CURRENT
PRESENT
APPOINT
RECEIPT
ATTEMPT
SUPPORT
SUGGEST
HIGHEST
NEAREST
PROTEST
REQUEST
AGAINST
OUTPOST
PROVOST
BOYCOTT
WITHOUT
LOOKOUT
SIMPLEX
TUESDAY

RAILWAY
SECRECY
VACANCY
SIGNIFY
SATISFY
RAPIDLY
QUICKLY
NIGHTLY
SHORTLY
COMPANY
DESTROY
PRIMARY
SUMMARY
LIBRARY
JANUARY
BRIBERY
BATTERY
INQUIRY
CAVALRY
VICTORY
EMBASSY
UTILITY
SEVENTY

EIGHT LETTER WORDS

INSIGNIA
SPECIFIC
TERRIFIC
ECONOMIC
MECHANIC
ATLANTIC
RAILHEAD
RAILROAD
REPLACED
ADVANCED
DEMANDED
EXPANDED
DEFENDED
OFFENDED
EXPENDED
EXTENDED
GROUNDED
BESIEGED
DETACHED
FINISHED
OCCUPIED
ATTACKED
REPELLED

EXPELLED
ENROLLED
DISARMED
ASSIGNED
RETURNED
APPEARED
DECLARED
PREPARED
HINDERED
SUFFERED
CENTERED
BATTERED
LETTERED
REPAIRED
REQUIRED
RESTORED
DEFERRED
CAPTURED
REPULSED
COMPOSED
MANDATED
DEFEATED
REPEATED

DICTATED
EFFECTED
INFECTED
REJECTED
SELECTED
BILLETED
INVENTED
DEPARTED
DESERTED
ESCORTED
DEPORTED
REPORTED
ARRESTED
ENLISTED
SURVIVED
IMPROVED
OBSERVED
REVIEWED
DEPLOYED
AIRFIELD
FOOTHOLD
THOUSAND
SURROUND

STANDARD
OUTBOARD
OUTGUARD
WINDWARD
EASTWARD
WESTWARD
DESCRIBE
ORDNANCE
DISTANCE
COMMENCE
SENTENCE
ANNOUNCE
COMMERCE
ENFILADE
CONCLUDE
LATITUDE
ALTITUDE
EMPLOYEE
CARRIAGE
FUSELAGE
EQUIPAGE
FRONTAGE
SABOTAGE

LANGUAGE
DISLODGE
EXCHANGE
PROBABLE
SUITABLE
ELIGIBLE
TERRIBLE
POSSIBLE
FLEXIBLE
ASSEMBLE
OBSTACLE
ENCIRCLE
SCHEDULE
MARITIME
AIRDROME
AIRPLANE
JETPLANE
MEDICINE
DOCTRINE
POSTPONE
SEABORNE
AIRBORNE
DEVELOPE

ENVELOPE
INSECURE
PRESSURE
DECREASE
EXERCISE
SURPRISE
SUSPENSE
DISPERSE
TRAVERSE
DEDICATE
INDICATE
INITIATE
ESTIMATE
ORDINATE
DETONATE
SEPARATE
EVACUATE
EXCAVATE
OBSOLETE
COMPLETE
CONCRETE
EXPEDITE
DEFINITE

OPPOSITE
CONTINUE
CRITIQUE
THATHAVE
DECISIVE
POSITIVE
PRESERVE
EQUALIZE
MOBILIZE
INVADING
DIVIDING
BUILDING
GUARDING
ENGAGING
DAMAGING
MARCHING
BREAKING
FLANKING
TOTALING
SHELLING
BATTLING
SWIMMING
TRAINING

EIGHT LETTER WORDS—Continued

PLANNING
SWEEPING
SHIPPING
GROUPING
ENTERING
COVERING
RETIRING
ADVISING
OPPOSING
DRESSING
PRESSING
CROSSING
DRIFTING
FIGHTING
SIGHTING
LIMITING
PAINTING
PRINTING
SPOTTING
DELAYING
RALLYING
CARRYING
FERRYING
APPROACH
ENTRENCH
INTRENCH
RESEARCH
DESPATCH
DISPATCH
SKIRMISH
DIMINISH

ELEVENTH
ANTITANK
CODEBOOK
CHEMICAL
CLERICAL
TACTICAL
CRITICAL
NAUTICAL
OFFICIAL
MATERIAL
MEMORIAL
NATIONAL
INTERNAL
CORPORAL
HOSPITAL
APPROVAL
MATERIEL
PARALLEL
SENTINEL
SEALEVEL
PROTOCOL
MERCIFUL
TELEGRAM
AMERICAN
EUROPEAN
CIVILIAN
HAVEBEEN
NINETEEN
EIGHTEEN
THIRTEEN
FOURTEEN

CAMPAIGN
CHAPLAIN
MAINTAIN
MOUNTAIN
BULLETIN
INVASION
DECISION
DIVISION
LOCATION
AVIATION
CITATION
TAXATION
JUNCTION
IGNITION
POSITION
FORENOON
SQUADRON
GARRISON
NORTHERN
SOUTHERN
CIRCULAR
DECEMBER
REMEMBER
NOVEMBER
DEFENDER
RECORDER
ENGINEER
TRANSFER
DECIPHER
ENCIPHER

PRISONER
IMPROPER
REPEATER
DESERTER
DISASTER
REGISTER
CANISTER
RECEIVER
REVOLVER
OBSERVER
MANEUVER
EMPLOYER
HOWITZER
CORRIDOR
SUPERIOR
INTERIOR
EXTERIOR
OPERATOR
DICTATOR
REJECTOR
DIRECTOR
DETECTOR
ASSOONAS
POLITICS
COMMANDS
ADVANCES
BARRAGES
MESSAGES
REMEDIES
SUPPLIES

VEHICLES
MISFIRES
DEFENSES
EXPENSES
PURPOSES
RESERVES
ANALYSIS
BARRACKS
MISSIONS
STATIONS
FACTIONS
PONTOONS
WARSHIPS
OFFICERS
SOLDIERS
CARRIERS
TRAILERS
TRAWLERS
CRUISERS
FIGHTERS
QUARTERS
CARELESS
WIRELESS
BUSINESS
DARKNESS
CONGRESS
PROGRESS
FORTRESS
DISTRESS
REDCROSS

RESPECTS
ELEMENTS
ATTEMPTS
PROTESTS
OUTPOSTS
ENORMOUS
LUMINOUS
RIGOROUS
VIGOROUS
CONTRACT
INDIRECT
CONFLICT
DISTRICT
INSTRUCT
AIRCRAFT
DAYLIGHT
MIDNIGHT
PROHIBIT
SERGEANT
DOMINANT
ADJUTANT
ADJACENT
INCIDENT
ARMAMENT
MOVEMENT
REGIMENT
APPARENT
PASSPORT
INTEREST
REENLIST

WITHDRAW
WITHDREW
TOMORROW
PARALLAX
SATURDAY
THURSDAY
CAUSEWAY
EFFICACY
IDENTIFY
STRATEGY
PROBABLY
ASSEMBLY
ACTUALLY
MONOPOLY
EASTERLY
WESTERLY
BOUNDARY
MILITARY
SANITARY
FEBRUARY
CEMETERY
ADVISORY
INFANTRY
CAPACITY
FATALITY
CALAMITY
VICINITY
PRIORITY
ACTIVITY
CASUALTY

NINE LETTER WORDS

MEMORANDA
STRATEGIC
AUTOMATIC
PATRIOTIC
BALLISTIC
BEACHHEAD
SPEARHEAD
DESCRIBED
ANNOUNCED
BLOCKADED
SUCCEEDED
PROCEEDED
COMMANDED
SUSPENDED
BOMBARDED
FORTIFIED

CANCELLED
COMPELLED
DETRAINED
ENTRAINED
CONDEMNED
ECHELONED
DEVELOPED
CONQUERED
PREFERRED
CONFERRED
DECREASED
INCREASED
CONDENSED
COLLAPSED
DISPERSED
ADDRESSED

IMPRESSED
DISCUSSED
INDICATED
POPULATED
ESTIMATED
DOMINATED
DETONATED
SUSPECTED
CORRECTED
PROTECTED
INFLICTED
COMPLETED
INHABITED
EXHIBITED
ASSAULTED
APPOINTED

ATTEMPTED
PROTESTED
REQUESTED
SUBMITTED
CONTINUED
DESTROYED
MOTORIZED
SEMIRIGID
RECOMMEND
REARGUARD
NORTHWARD
SOUTHWARD
AMBULANCE
DOMINANCE
CLEARANCE
ENDURANCE

ASSURANCE
ALLOWANCE
INCIDENCE
REFERENCE
INFLUENCE
REENFORCE
REINFORCE
LONGITUDE
COMMITTEE
ADVANTAGE
CARTRIDGE
CHALLENGE
AVAILABLE
UNTENABLE
DIRIGIBLE
PRINCIPLE

AERODROME
HURRICANE
AEROPLANE
INTERVENE
FRONTLINE
DETERMINE
TELEPHONE
INTERFERE
ELSEWHERE
SHELLFIRE
THEREFORE
PROCEDURE
PREMATURE
DEPARTURE
NAVALBASE
MANGANESE

NINE LETTER WORDS—Continued

CRITICISE
INTERPOSE
ASSOCIATE
IMMEDIATE
OSCILLATE
CIRCULATE
DESIGNATE
ALTERNATE
COOPERATE
ELABORATE
PENETRATE
REINSTATE
CIGARETTE
PARACHUTE
DESTITUTE
TECHNIQUE
EXPANSIVE
DEFENSIVE
OFFENSIVE
EXPENSIVE
INTENSIVE
EXTENSIVE
EXPLOSIVE
EXCESSIVE
INCLUSIVE
EXCLUSIVE
TENTATIVE
DEFECTIVE
EFFECTIVE
OBJECTIVE
INCENTIVE
EXECUTIVE
RECOGNIZE
SERVICING
ADVANCING
PRECEDING
EXTENDING

REGARDING
ACCORDING
INCLUDING
LAUNCHING
ATTACKING
DEBARKING
REFILLING
SCREENING
REMAINING
OBTAINING
INCLINING
BEGINNING
RETURNING
PREPARING
NUMBERING
CENTERING
REQUIRING
OPERATING
ENLISTING
RECEIVING
REVIEWING
EMPLOYING
OCCUPYING
PARAGRAPH
ESTABLISH
TWENTIETH
FIFTEENTH
SIXTEENTH
WATERTANK
TECHNICAL
CHRONICAL
PRACTICAL
POLITICAL
IDENTICAL
PRINCIPAL
DISMISSAL
CONTINUAL

PERSONNEL
CABLEGRAM
RADIOGRAM
FIREALARM
CRITICISM
MECHANISM
DIETITIAN
SEVENTEEN
SUSPICION
BATTALION
REBELLION
COLLISION
PROVISION
EXPANSION
ASCENSION
DIMENSION
EXTENSION
EXPLOSION
ADMISSION
EXCLUSION
RADIATION
VARIATION
INFLATION
FORMATION
OPERATION
SITUATION
ELEVATION
OBJECTION
DIRECTION
CONDITION
COALITION
PARTITION
DETENTION
RETENTION
INTENTION
ATTENTION

INVENTION
PROMOTION
SEMICOLON
AFTERNOON
DISAPPEAR
IRREGULAR
SEPTEMBER
COMMANDER
SURRENDER
REMAINDER
PASSENGER
MESSENGER
BRIGADIER
STRAGGLER
NEWSPAPER
CHARACTER
KILOMETER
BAROMETER
GYROMETER
DESTROYER
PROJECTOR
PROTECTOR
CHAUFFEUR
LOGISTICS
STANDARDS
RESOURCES
COMPANIES
BATTERIES
EMBASSIES
AIRDROMES
SEAPLANES
AIRPLANES
EXERCISES
WITNESSES
ADDRESSES
ESTIMATES

CONTINUES
BUILDINGS
OFFICIALS
REPRISALS
PROPOSALS
CIVILIANS
CAMPAIGNS
MAINTAINS
DIVISIONS
MUNITIONS
POSITIONS
ENGINEERS
PRISONERS
READINESS
CONFLICTS
DISTRICTS
INCIDENTS
MOVEMENTS
OUTSKIRTS
ANONYMOUS
APPARATUS
DISINFECT
INTERDICT
DIFFICULT
COMBATANT
IMPORTANT
ASSISTANT
CONFIDENT
PRESIDENT
DEPENDENT
NEGLIGENT
DEFICIENT
EFFICIENT
PLACEMENT
AGREEMENT
AMUSEMENT

STATEMENT
EQUIPMENT
GROUPMENT
INTERMENT
ALLOTMENT
PERMANENT
DIFFERENT
REPRESENT
RESTRAINT
INTERCEPT
INTERRUPT
TRANSPORT
NORTHEAST
SOUTHEAST
NORTHWEST
SOUTHWEST
INTERVIEW
YESTERDAY
WEDNESDAY
EMERGENCY
NORTHERLY
SERIOUSLY
INSTANTLY
ACCOMPANY
ARBITRARY
NECESSARY
SECRETARY
ARTILLERY
ACCESSORY
TERRITORY
LIABILITY
HOSTILITY
PROXIMITY
INDEMNITY
INTEGRITY
NECESSITY

TEN LETTER WORDS

ATOMICBOMB
GEOGRAPHIC
GYROSCOPIC
DIPLOMATIC
BRIDGEHEAD
PRESCRIBED
REENFORCED
REINFORCED
BEENNEEDED
UNEXPENDED

APPROACHED
ENTRENCHED
DESPATCHED
DISPATCHED
THREATENED
MAINTAINED
DETERMINED
ONEHUNDRED
DECIPHERED,
ENCIPHERED

COMPRESSED
DISTRESSED
DESIGNATED
RESTRICTED
INSTRUCTED
PROHIBITED
REENLISTED
MECHANIZED
CONTRABAND
UNDERSTAND

UNDERSTOOD
COASTGUARD
POSTOFFICE
ACCORDANCE
ALLEGIANCE
APPEARANCE
ACCEPTANCE
RESISTANCE
ASSISTANCE
PRECEDENCE

CONFIDENCE
NEGLIGENCE
EXPERIENCE
PREFERENCE
DIFFERENCE
CONFERENCE
CAMOUFLAGE
DEPENDABLE
EXPENDABLE
UNSUITABLE

TEN LETTER WORDS—Continued

ACCEPTABLE
IMPASSIBLE
IMPOSSIBLE
ASPOSSIBLE
RECEPTACLE
MOTORCYCLE
AUTOMOBILE
DISCIPLINE
QUARANTINE
ENTERPRISE
TRANSVERSE
COORDINATE
ILLUMINATE
ANTICIPATE
ILLITERATE
ILLUSTRATE
COMPENSATE
DISTRIBUTE
SUBSTITUTE
CONSTITUTE
COMMUNIQUE
TWENTYFIVE
SUCCESSIVE
IMPRESSIVE
LOCOMOTIVE
CENTRALIZE
NATURALIZE
DEMOBILIZE
COMMANDING
DEBOUCHING
DETRUCKING
ENTRUCKING
ENCIRCLING
SIGNALLING
PATROLLING
OVERCOMING
DETRAINING
CONCERNING
INDICATING
ANTEDATING

EVACUATING
COLLECTING
CONNECTING
INFLICTING
EXPEDITING
RECRUITING
ATTEMPTING
SUPPORTING
EXTINGUISH
NINETEENTH
EIGHTEENTH
THIRTEENTH
FOURTEENTH
WILLATTACK
ARTIFICIAL
CREDENTIAL
ADDITIONAL
ACCIDENTAL
REGIMENTAL
INDIVIDUAL
WITHDRAWAL
AIRCONTROL
SUCCESSFUL
RESPECTFUL
MEMORANDUM
SUSPENSION
DISPERSION
CONCESSION
CONFESSION
DEPRESSION
IMPRESSION
POSSESSION
SUBMISSION
COMMISSION
PERMISSION
DISCUSSION
CONCLUSION
DEDICATION
INDICATION

ALLOCATION
FOUNDATION
RECREATION
IRRIGATION
NAVIGATION
REGULATION
POPULATION
ESTIMATION
DOMINATION
DETONATION
OCCUPATION
SEPARATION
DECORATION
LIMITATION
SANITATION
INVITATION
EVACUATION
EVALUATION
EXCAVATION
COLLECTION
CONNECTION
INSPECTION
CORRECTION
PROTECTION
EXHIBITION
EXPEDITION
DEFINITION
AMMUNITION
OPPOSITION
PROPORTION
REVOLUTION
MACHINEGUN
BATTLESHIP
CENSORSHIP
ARMOREDCAR
DIVEBOMBER
COMMANDEER
DISPATCHER
MILLIMETER

GONIOMETER
HYDROMETER
HYGROMETER
AMBASSADOR
INSTRUCTOR
BALLISTICS
STATISTICS
CROSSROADS
DESPATCHES
DISPATCHES
ASSEMBLIES
FACILITIES
ACTIVITIES
CASUALTIES
FRONTLINES
SUBMARINES
OBJECTIVES
ENEMYTANKS
SUSPICIONS
COLLISIONS
PROVISIONS
EXPLOSIONS
FORMATIONS
OPERATIONS
DIRECTIONS
CONDITIONS
TROOPSHIPS
NEWSPAPERS
KILOMETERS
DESTROYERS
TRANSPORTS
SUSPICIOUS
VICTORIOUS
CIRCUITOUS
CONTINUOUS
PHOSPHORUS
FLASHLIGHT
COMMANDANT
LIEUTENANT

CONTINGENT
SUFFICIENT
CONVENIENT
EQUIVALENT
ENGAGEMENT
MANAGEMENT
EXCITEMENT
DETACHMENT
ATTACHMENT
EXPERIMENT
ENROLLMENT
ASSIGNMENT
ATTAINMENT
INTERNMENT
GOVERNMENT
ASSESSMENT
COMMITMENT
DEPARTMENT
ENLISTMENT
INSTRUMENT
DEPLOYMENT
EMPLOYMENT
PERSISTENT
AIRSUPPORT
CONSPIRACY
DEFICIENCY
EFFICIENCY
COMPLETELY
APPARENTLY
INCENDIARY
COMMISSARY
ELEMENTARY
LABORATORY
TRAJECTORY
CAPABILITY
AUDIBILITY
VISIBILITY
SIMILARITY
INSECURITY

ELEVEN LETTER WORDS

IMPEDIMENTA
TOPOGRAPHIC
RECOMMENDED
PREARRANGED
ESTABLISHED
OVERWHELMED
DISAPPEARED

SURRENDERED
ENCOUNTERED
TRANSFERRED
DISINFECTED
REAPPOINTED
INTERCEPTED
INTERRUPTED

CONSTITUTED
BATTLEFIELD
PERFORMANCE
MAINTENANCE
COINCIDENCE
SUBSISTENCE
CATASTROPHE

INFLAMMABLE
RESPONSIBLE
NAVALBATTLE
TEMPERATURE
MANUFACTURE
SCHOOLHOUSE
CUSTOMHOUSE

CERTIFICATE
COMMUNICATE
INVESTIGATE
APPROPRIATE
APPROXIMATE
EXTERMINATE
DETERIORATE

ELEVEN LETTER WORDS—*Continued*

CONCENTRATE
DEMONSTRATE
NECESSITATE
DISCONTINUE
SEVENTYFIVE
PROGRESSIVE
RETROACTIVE
DESCRIPTIVE
SYNCHRONIZE
APPROACHING
INTERVENING
ENGINEERING
INTERFERING
ALTERNATING
INTERESTING
WITHDRAWING
DISTINGUISH
SEVENTEENTH
NAVALATTACK
STRATEGICAL
TRADITIONAL
CONTINENTAL
FIRECONTROL
NATIONALISM

SMOKESCREEN
APPLICATION
ASSOCIATION
RETALIATION
DEBARKATION
EMBARKATION
LEGISLATION
CIRCULATION
INFORMATION
EXPLANATION
DESIGNATION
RESIGNATION
EXAMINATION
PREPARATION
COOPERATION
IMMIGRATION
INSPIRATION
CORPORATION
PENETRATION
ARBITRATION
COMPUTATION
OBSERVATION
RESERVATION
RESTRICTION

DISTINCTION
DESTRUCTION
INSTRUCTION
RECOGNITION
REQUISITION
COMPOSITION
DISPOSITION
COMPETITION
DESCRIPTION
CONSUMPTION
INSTITUTION
LIGHTBOMBER
HEAVYBOMBER
RANGEFINDER
DYNAMOMETER
THERMOMETER
INTERPRETER
RECONNOITER
BLOCKBUSTER
AERONAUTICS
NAVALFORCES
ACCESSORIES
HOSTILITIES
ENEMYPLANES

PHILIPPINES
PARENTHESES
HEAVYLOSSES
COMMUNIQUES
PARENTHESIS
CREDENTIALS
BATTLESHIPS
ARMOREDCARS
CORRECTNESS
ENGAGEMENTS
ASSIGNMENTS
ASSESSMENTS
INSTRUMENTS
INTERCERPTS
ESTIMATEDAT
SIGNIFICANT
INDEPENDENT
INTELLIGENT
COEFFICIENT
BOMBARDMENT
REPLACEMENT
EMPLACEMENT
ENFORCEMENT
ARRANGEMENT

CONFINEMENT
REQUIREMENT
MEASUREMENT
IMPROVEMENT
CONCEALMENT
ECHELONMENT
DEVELOPMENT
APPOINTMENT
COMPARTMENT
BELLIGERENT
INCOMPETENT
FINGERPRINT
DISCREPANCY
PHOTOGRAPHY
IMMEDIATELY
EXTENSIVELY
EFFECTIVELY
PRELIMINARY
CONTROVERSY
ELECTRICITY
NATIONALITY
SUITABILITY
SUPERIORITY

TWELVE LETTER WORDS

TRANSPACIFIC
HYDROGRAPHIC
UNIDENTIFIED
COMMISSIONED
DISSEMINATED
CONCENTRATED
DEMONSTRATED
DISORGANIZED
SIGNIFICANCE
INTELLIGENCE
INTERFERENCE
INCOMPETENCE
CONSIDERABLE
FIGHTERPLANE
INTERMEDIATE
DECENTRALIZE
GENERALSTAFF
TRANSFERRING
ENTERPRISING
ILLUMINATING
DISTRIBUTING

CONSTITUTING
BREAKTHROUGH
GEOGRAPHICAL
CONFIDENTIAL
PRESIDENTIAL
RECREATIONAL
AGRICULTURAL
DEPARTMENTAL
UNSUCCESSFUL
GENERALALARM
VETERINARIAN
TRANSMISSION
VERIFICATION
CONFISCATION
COMMENDATION
CONCILIATION
CANCELLATION
PROCLAMATION
CONFIRMATION
CONFORMATION
COORDINATION

ILLUMINATION
ANTICIPATION
REGISTRATION
ILLUSTRATION
INAUGURATION
COMPENSATION
CONVERSATION
RADIOSTATION
CONTINUATION
PRESERVATION
MOBILIZATION
ORGANIZATION
INTERDICTION
ROADJUNCTION
INTRODUCTION
CONSTRUCTION
INTERVENTION
CONSCRIPTION
INTERRUPTION
DISTRIBUTION
SUBSTITUTION

CONSTITUTION
NORTHWESTERN
SOUTHWESTERN
MARKSMANSHIP
MEDIUMBOMBER
COMMISSIONER
PSYCHROMETER
SHARPSHOOTER
DIFFICULTIES
UNITEDSTATES
PREPARATIONS
OBSTRUCTIONS
INSTRUCTIONS
LIGHTBOMBERS
HEAVYBOMBERS
HEADQUARTERS
PREPAREDNESS
COMPLETENESS
CARELESSNESS
SEARCHLIGHTS
REPLACEMENTS

EMPLACEMENTS
MEASUREMENTS
ADVANTAGEOUS
SIMULTANEOUS
ANTIAIRCRAFT
NONCOMBATANT
CONVALESCENT
DISPLACEMENT
COMMENCEMENT
ANNOUNCEMENT
ENTANGLEMENT
DECIPHERMENT
ENCIPHERMENT
REENLISTMENT
INEFFICIENCY
SUCCESSFULLY
RESPECTFULLY
SATISFACTORY
INTRODUCTORY
IRREGULARITY

THIRTEEN LETTER WORDS

TRANSATLANTIC
DISTINGUISHED
DECENTRALIZED
DISAPPEARANCE
IMPRACTICABLE
INDETERMINATE
CORRESPONDING
CONCENTRATING
COUNTERATTACK
CHRONOLOGICAL
CONGRESSIONAL
INTERNATIONAL
SPECIFICATION
QUALIFICATION
COMMUNICATION
ACCOMMODATION
INVESTIGATION
DISSEMINATION
DETERMINATION
EXTERMINATION
CONSIDERATION
CONCENTRATION
DEMONSTRATION
QUARTERMASTER
CIRCUMSTANCES
DISCREPANCIES
PRELIMINARIES
FIGHTERPLANES
INSTALLATIONS
MEDIUMBOMBERS
MISCELLANEOUS
INSTANTANEOUS
REENFORCEMENT
REINFORCEMENT
REIMBURSEMENT
REINSTATEMENT
ESTABLISHMENT
ENTERTAINMENT
REAPPOINTMENT
WARDEPARTMENT
APPROXIMATELY
EXTRAORDINARY
REVOLUTIONARY
DEPENDABILITY

FOURTEEN LETTER WORDS

CHARACTERISTIC
RECONNAISSANCE
DISCONTINUANCE
CORRESPONDENCE
ADMINISTRATIVE
REPRESENTATIVE
DISTINGUISHING
RECONNOITERING
METEOROLOGICAL
CIRCUMSTANTIAL
CLASSIFICATION
IDENTIFICATION
RECOMMENDATION
ADMINISTRATION
INTERPRETATION
TRANSPORTATION
CENTRALIZATION
NATURALIZATION
DEMOBILIZATION
REORGANIZATION
RECONSTRUCTION
IRREGULARITIES
INVESTIGATIONS
SATISFACTORILY
RESPONSIBILITY

C. LIST OF WORDS USED IN MILITARY TEXT ARRANGED ALPHABETICALLY ACCORDING TO WORD PATTERN

PATTERN AA

A CC EPT
A CC ORDING
O CC UPY
A DD
SU DD EN
LA DD ER
BE DD ING
FL EE
S EE
THR EE
PROC EE D
SP EE D
CR EE K
W EE K
F EE L
ST EE L
WH EE L
B EE N
FOURT EE N
HASB EE N
QU EE N
SCR EE N
S EE N
SIXT EE N
R EE NLIST
K EE P
SW EE PING
F EE T
FL EE T
M EE T
JUMPO FF
O FF
STA FF
O FF END
SU FF ER
TRA FF IC
O FF ICE
O FF ICER
E FF ORT
FO GG Y
A LL
CA LL
CE LL
DRI LL
ENRO LL

FA LL
FE LL
FU LL
HI LL
I LL
INSTA LL
PAYRO LL
REFI LL
SHE LL
SMA LL
SPE LL
WE LL
WI LL
VI LL AGE
CO LL APSED
DO LL AR
OSCI LL ATE
KI LL ED
BI LL ET
BU LL ETIN
VA LL EY
A LL IED
A LL IES
FA LL ING
PATRO LL ING
SHE LL ING
A LL OW
A LL Y
RA LL Y
CO MM A
CO MM AND
CO MM ANDER
SU MM ARY
CO MM END
CO MM ENTY
HA MM ER
SU MM ER
CO MM IT
SU MM IT
SU MM ON
CO MM UTE
TO NN AGE
CHA NN EL
BA NN ER
GU NN ER

MA NN ER
A NN EX
CA NN OT
T OO
W OO DS
PR OO F
B OO K
C OO K
H OO K
L OO K
T OO K
SCH OO L
T OO L
PLAT OO N
S OO N
TR OO PS
C OO RDINATE
B OO TH
STO PP ED
HA PP EN
CLI PP ER
MA PP ING
A PP LY
SU PP LY
A PP OINT
A PP OINTED
SU PP ORT
SU PP ORTING
A PP ROVE
TE RR AIN
CU RR ENT
A RR EST
HU RR ICANE
DE RR ICK
GA RR ISON
A RR IVE
CA RR Y
FE RR Y
ACRO SS
COMPA SS
CONGRE SS
CRO SS
DARKNE SS
DRE SS
LE SS

PATTERN AA—Continued

LO SS
MA SS
ME SS
PA SS
PRE SS
UNLE SS
WITNE SS
PA SS ED
A SS EMBLY
A SS ET
PO SS IBLE

A SS IGNED
CRO SS ING
DRE SS ING
ME SS ING
PA SS IVE
LE SS ON
I SS UE
A SS URE
EMBA SS Y
OMI TT ED
SUBMI TT ED

BA TT EN
WRI TT EN
BI TT ER
LI TT ER
BA TT ERY
SPO TT ING
BA TT LE
BA TT LESHIP
MU ZZ LE
NO ZZ LE

MISCELLANEOUS PATTERNS

AABA	AGR EEME NT	AABCB	SU FFICI ENT
AABA	K EEPE R	AABCB	A LLEGE
AABA	CH EESE	AABCB	CO LLEGE
AABA	BR EEZE	AABCB	BI LLETE D
AABA	MA NNIN G	AABCB	A MMETE R
AABA	PLA NNIN G	AABCB	W OODED
AABA	RU NNIN G	AABCB	TE RRIFI C
AABA	L OOKO UT	AABCB	BA TTERE D
AABA	E RROR	AABCBDEB	DI FFERENCE
AABA	MI RROR	AABCC	A CCESS
AABA	TE RROR	AABCC	A CCESS ORY
AABA	GLA SSES	AABCC	CO MMISS ARY
AABA	LO SSES	AABCCB	WI LLATTA CK
AABA	PA SSES	AABCCDD	CO MMITTEE
AABA	CHA SSIS	AABCCDEFBC	A CCESSORIES
AABA	A SSIS T	AABCDA	I LLEGAL
AABAACB	A SSESSME NT	AABCDA	A TTEMPT
AABAACBDEA	A SSFSSMENTS	AABCDAB	A TTEMPTE D
AABAB	PROC EEDED	AABCDB	O FFENSE
AABB	CO FFEE	AABCDB	CHA LLENGE
AABB	BA LLOO N	AABCDB	BA LLISTI C
AABBAACAC	B EENNEEDED	AABCDB	A RRESTE D
AABBCBC	SU CCEEDED	AABCDB	PA SSENGE R
AABCA	B EETLE	AABCDB	BA TTERIE S
AABCA	A NNOUN CE	AABCDBA	SU RRENDER
AABCA	F OOTHO LD	AABCDBABD	SU RRENDERED
AABCA	CA RRIER	AABCDBC	CO MMANDAN T
AABCA	A SSETS	AABCDBD	O FFENDED
AABCA	I SSUES	AABCDBEC	BA LLISTICS
AABCADEC	CO MMITMENT	AABCDC	E FFICAC Y
AABCADEC	A TTENTION	AABCDD	A DDRESS
AABCADEFEA	A NNOUNCEMEN T	AABCDD	I LLNESS
AABCB	SCR EENIN G	AABCDDCA	A DDRESSED
AABCB	SU FFERE D	AABCDDCD	A DDRESSES
AABCB	DI FFERE NT	AABCDEB	CO MMUNIQU E
AABCB	O FFICI AL	AABCDEB	TR OOPSHIP

MISCELLANEOUS PATTERNS—Continued

AABCDEB	A SSEMBLE	ABA	INVA DED
AABCDEBC	TR OOPSHIPS	ABA	LAN DED
AABCDEC	CO MMANDIN G	ABA	RAI DED
AABCDECB	BA TTLEFIEL D	ABA	WOUN DED
AABCDED	CO MMANDED	ABA	DID
AABCDEDFC	A MMUNITION	ABA	IC EBE RG
AABCDEE	CO MMANDEE R	ABA	PR ECE DING
AABCDEFA	R EENLISTE D	ABA	R ECE IPT
AABCDEFA	I RREGULAR	ABA	CR EDE NTIAL
AABCDEFB	O FFENSIVE	ABA	F EDE RAL
AABCDEFBA	A SSEMBLIES	ABA	D EFE AT
AABCDEFC	A LLOTMENT	ABA	D EFE CT
AABCDEFC	C OOPERATE	ABA	D EFE R
AABCDEFD	I LLUSTRAT E	ABA	SI EGE
AABCDEFD	A SSIGNMEN T	ABA	R EJE CT
AABCDEFDGA	A SSIGNMENTS	ABA	S ELE CT
AABCDEFGA	C OOPERATIO N	ABA	T ELE GRAM
AABCDEFGABF	R EENLISTMENT	ABA	ELE VATION
AABCDEFGD	BA TTLESHIPS	ABA	SCH EME
AABCDEFGDAE	C OORDINATION	ABA	R EME DY
AABCDEFGDE	A PPOINTMENT	ABA	DISPLAC EME NT
ABA	AGA IN	ABA	PLAC EME NT
ABA	AGA INST	ABA	ENE MY
ABA	C ALA MITY	ABA	G ENE RAL
ABA	ALA RM	ABA	R EPE L
ABA	S ALA RY	ABA	H ERE
ABA	D AMA GE	ABA	SPH ERE
ABA	M ANA GE	ABA	TH ERE
ABA	C ANA L	ABA	W ERE
ABA	ANA LYZE	ABA	WH ERE
ABA	J APA N	ABA	CONQU ERE D
ABA	P ARA CHUTE	ABA	COV ERE D
ABA	P ARA DE	ABA	TH ESE
ABA	SEP ARA TION	ABA	PR ESE NT
ABA	F ATA L	ABA	D ESE RT
ABA	N AVA L	ABA	COMPL ETE
ABA	N AVA LFORCES	ABA	KILOM ETE R
ABA	C AVA LRY	ABA	M ETE R
ABA	EXC AVA TION	ABA	P ETE R
ABA	AWA IT	ABA	D EVE LOP
ABA	AWA RD	ABA	S EVE N
ABA	AWA Y	ABA	S EVE NTH
ABA	PRO BAB LE	ABA	S EVE NTY
ABA	PRO BAB LY	ABA	S EVE RAL
ABA	BI CYC LE	ABA	EVE RY
ABA	CYC LONE	ABA	EYE
ABA	BLOCKA DED	ABA	FIF TH
ABA	GROUN DED	ABA	FIF TY
ABA	GUAR DED	ABA	EIG HTH

PATTERN AA—Continued

LO SS
MA SS
ME SS
PA SS
PRE SS
UNLE SS
WITNE SS
PA SS ED
A SS EMBLY
A SS ET
PO SS IBLE

A SS IGNED
CRO SS ING
DRE SS ING
ME SS ING
PA SS IVE
LE SS ON
I SS UE
A SS URE
EMBA SS Y
OMI TT ED
SUBMI TT ED

BA TT EN
WRI TT EN
BI TT ER
LI TT ER
BA TT ERY
SPO TT ING
BA TT LE
BA TT LESHIP
MU ZZ LE
NO ZZ LE

MISCELLANEOUS PATTERNS

AABA	AGR EEME NT	AABCB	SU FFICI ENT
AABA	K EEPE R	AABCB	A LLEGE
AABA	CH EESE	AABCB	CO LLEGE
AABA	BR EEZE	AABCB	BI LLETE D
AABA	MA NNIN G	AABCB	A MMETE R
AABA	PLA NNIN G	AABCB	W OODED
AABA	RU NNIN G	AABCB	TE RRIFI C
AABA	L OOKO UT	AABCB	BA TTERE D
AABA	E RROR	AABCBDEB	DI FFERENCE
AABA	MI RROR	AABCC	A CCESS
AABA	TE RROR	AABCC	A CCESS ORY
AABA	GLA SSES	AABCC	CO MMISS ARY
AABA	LO SSES	AABCCB	WI LLATTA CK
AABA	PA SSES	AABCCDD	CO MMITTEE
AABA	CHA SSIS	AABCCDEFBC	A CCESSORIES
AABA	A SSIS T	AABCDA	I LLEGAL
AABAACB	A SSESSME NT	AABCDA	A TTEMPT
AABAACBDEA	A SSESSMENTS	AABCDAB	A TTEMPTE D
AABAB	PROC EEDED	AABCDB	O FFENSE
AABB	CO FFEE	AABCDB	CHA LLENGE
AABB	BA LLOO N	AABCDB	BA LLISTI C
AABBAACAC	B EENNEEDED	AABCDB	A RRESTE D
AABBCBC	SU CCEEDED	AABCDB	PA SSENGE R
AABCA	B EETLE	AABCDB	BA TTERIE S
AABCA	A NNOUN CE	AABCDBA	SU RRENDER
AABCA	F OOTHO LD	AABCDBABD	SU RRENDERED
AABCA	CA RRIER	AABCDBC	CO MMANDAN T
AABCA	A SSETS	AABCDBD	O FFENDED
AABCA	I SSUES	AABCDBEC	BA LLISTICS
AABCADEC	CO MMITMENT	AABCDC	E FFICAC Y
AABCADEC	A TTENTION	AABCDD	A DDRESS
AABCADEFEA	A NNOUNCEMEN T	AABCDD	I LLNESS
AABCB	SCR EENIN G	AABCDDCA	A DDRESSED
AABCB	SU FFERE D	AABCDDCD	A DDRESSES
AABCB	DI FFERE NT	AABCDEB	CO MMUNIQU E
AABCB	O FFICI AL	AABCDEB	TR OOPSHIP

MISCELLANEOUS PATTERNS—Continued

AABCDEB	A SSEMBLE	ABA	INVA DED
AABCDEBC	TR OOPSHIPS	ABA	LAN DED
AABCDEC	CO MMANDIN G	ABA	RAI DED
AABCDECB	BA TTLEFIEL D	ABA	WOUN DED
AABCDED	CO MMANDED	ABA	DID
AABCDEDFG	A MMUNITION	ABA	IC EBE RG
AABCDEE	CO MMANDEE R	ABA	PR ECE DING
AABCDEFA	R EENLISTE D	ABA	R ECE IPT
AABCDEFA	I RREGULAR	ABA	CR EDE NTIAL
AABCDEFB	O FFENSIVE	ABA	F EDE RAL
AABCDEFBA	A SSEMBLIES	ABA	D EFE AT
AABCDEFC	A LLOTMENT	ABA	D EFE CT
AABCDEFC	C OOPERATE	ABA	D EFE R
AABCDEFD	I LLUSTRAT E	ABA	SI EGE
AABCDEFD	A SSIGNMEN T	ABA	R EJE CT
AABCDEFDGA	A SSIGNMENTS	ABA	S ELE CT
AABCDEFGA	C OOPERATIO N	ABA	T ELE GRAM
AABCDEFGABF	R EENLISTMENT	ABA	ELE VATION
AABCDEFGD	BA TTLESHIPS	ABA	SCH EME
AABCDEFGDAE	C OORDINATION	ABA	R EME DY
AABCDEFGDE	A PPOINTMENT	ABA	DISPLAC EME NT
ABA	AGA IN	ABA	PLAC EME NT
ABA	AGA INST	ABA	ENE MY
ABA	C ALA MITY	ABA	G ENE RAL
ABA	ALA RM	ABA	R EPE L
ABA	S ALA RY	ABA	H ERE
ABA	D AMA GE	ABA	SPH ERE
ABA	M ANA GE	ABA	TH ERE
ABA	C ANA L	ABA	W ERE
ABA	ANA LYZE	ABA	WH ERE
ABA	J APA N	ABA	CONQU ERE D
ABA	P ARA CHUTE	ABA	COV ERE D
ABA	P ARA DE	ABA	TH ESE
ABA	SEP ARA TION	ABA	PR ESE NT
ABA	F ATA L	ABA	D ESE RT
ABA	N AVA L	ABA	COMPL ETE
ABA	N AVA LFORCES	ABA	KILOM ETE R
ABA	C AVA LRY	ABA	M ETE R
ABA	EXC AVA TION	ABA	P ETE R
ABA	AWA IT	ABA	D EVE LOP
ABA	AWA RD	ABA	S EVE N
ABA	AWA Y	ABA	S EVE NTH
ABA	PRO BAB LE	ABA	S EVE NTY
ABA	PRO BAB LY	ABA	S EVE RAL
ABA	BI CYC LE	ABA	EVE RY
ABA	CYC LONE	ABA	EYE
ABA	BLOCKA DED	ABA	FIF TH
ABA	GROUN DED	ABA	FIF TY
ABA	GUAR DED	ABA	EIG HTH

MISCELLANEOUS PATTERNS—Continued

ABA	L	IAI	SON
ABA	PROH	IBI	T
ABA	SERV	ICI	NG
ABA	RA	IDI	NG
ABA	R	IDI	NG
ABA	R	IGI	D
ABA	F	ILI	NG
ABA	M	ILI	TARY
ABA	MOB	ILI	ZE
ABA	S	IMI	LAR
ABA	L	IMI	T
ABA	PROX	IMI	TY
ABA	F	INI	SH
ABA	F	IRI	NG
ABA	RET	IRI	NG
ABA	W	IRI	NG
ABA	V	ISI	BLE
ABA	D	ISI	NFECT
ABA	ADV	ISI	NG
ABA	DEC	ISI	ON
ABA	V	ISI	T
ABA	V	ISI	TOR
ABA	POL	ITI	CS
ABA	CR	ITI	QUE
ABA	POS	ITI	VE
ABA		MEM	ORIAL
ABA		NAN	
ABA	DOMI	NAN	CE
ABA	ORD	NAN	CE
ABA	DOMI	NAN	T
ABA		NIN	E
ABA		NIN	ETY
ABA	MOR	NIN	G
ABA		NIN	TH
ABA		OBO	E
ABA	C	OLO	N
ABA	SEMIC	OLO	N
ABA	C	OLO	RS
ABA	AUT	OMO	BILE
ABA	PR	OMO	TE
ABA	H	ONO	R
ABA	VIG	ORO	US
ABA	M	OTO	R
ABA	M	OTO	RIZED
ABA	PR	OVO	ST
ABA		PIP	E
ABA		POP	ULATED
ABA	LIB	RAR	Y
ABA	AI	RDR	OME
ABA	CA	RTR	IDGE
ABA	D	RYR	UN
ABA	DI	SAS	TER
ABA	CA	SES	
ABA	RE	SIS	T
ABA		SUS	PEND
ABA		SYS	TEM
ABA	S	TAT	ION
ABA	DIC	TAT	OR
ABA		TIT	LE
ABA	AL	TIT	UDE
ABA	LA	TIT	UDE
ABA		TOT	AL
ABA		TOT	ALING
ABA	A	UGU	ST
ABA		USU	AL
ABA	F	UTU	RE
ABA	SUR	VIV	ED
ABAA	HAV	EBEE	N
ABAA		SESS	ION
ABAACC		TATTOO	
ABAB	DETRA	ININ	G
ABAB	L	ININ	G
ABAB	M	ININ	G
ABAB	OBTA	ININ	G
ABAB	RA	ININ	G
ABAB	REMA	ININ	G
ABAB	TRA	ININ	G
ABAB	CR	ISIS	
ABAB	WI	THTH	E
ABAB	PAR	TITI	ON
ABACA	C	ANADA	
ABACA	P	ANAMA	
ABACA	PR	ECEDE	
ABACA		ELEME	NT
ABACA		ELEME	NTARY
ABACA		ELEVE	N
ABACA	C	EMETE	RY
ABACA	S	EVERE	
ABACA	AUD	IBILI	TY
ABACA	EXH	IBITI	ON
ABACA	V	ICINI	TY
ABACA	M	ILITI	A
ABACA	FAC	ILITI	ES
ABACA	D	IMINI	SH
ABACA	L	IMITI	NG
ABACA		INITI	AL
ABACA	DEF	INITI	ON
ABACA	D	IRIGI	BLE

MISCELLANEOUS PATTERNS—Continued

ABACA	SEM	IRIGI D
ABACA	REQU	ISITI ON
ABACA	C	IVILI AN
ABACA	D	IVISI ON
ABACA	L	OCOMO TIVE
ABACA	M	ONOPO LY
ABACA	PR	OTOCO L
ABACA	CONS	TITUT E
ABACA		UNUSU AL
ABACADA	V	ISIBILI TY
ABACADB	DEF	INITION
ABACADBA	PR	ECEDENCE
ABACADC		INITIAT E
ABACADD	COMPL	ETENESS
ABACADDA	N	AVALATTA CK
ABACADEC	D	IVISIONS
ABACB	V	ACANC Y
ABACB	COMB	ATANT
ABACB	C	ATAST ROPHE
ABACB	D	ETECT OR
ABACB	V	ISITS
ABACB		MEMBE R
ABACBDEC	D	ETENTION
ABACBDEC	R	ETENTION
ABACBDEFGFAG		NONCOMBATANT
ABACC	R	EBELL ION
ABACC	N	ECESS ARY
ABACC	N	ECESS ITY
ABACC	CAR	ELESS
ABACC	WIR	ELESS
ABACCA	P	ARALLA X
ABACCA	R	EPELLE D
ABACCA	T	OMORRO W
ABACCDACC	CAR	ELESSNESS
ABACCDC	P	ARALLEL
ABACCDEFEA	N	ECESSITATE
ABACDA		ALASKA
ABACDA		ARABIA
ABACDA	N	AVALBA SE
ABACDA	R	ECEIVE
ABACDA	D	ECEMBE R
ABACDA	D	EFENSE
ABACDA	R	EJECTE D
ABACDA	R	ELEASE
ABACDA	S	ELECTE D
ABACDA	R	EMEDIE S
ABACDA		EMERGE NCY
ABACDA		ENEMIE S
ABACDA	R	EPEATE D
ABACDA	R	EVENUE
ABACDA	U	NKNOWN
ABACDA	PR	OMOTIO N
ABACDAAC	S	EVENTEEN
ABACDAACD	S	EVENTEENT H
ABACDAC	D	ESERTER
ABACDAD	D	EFENSES
ABACDAED		AVAILABL E
ABACDAEEC	N	AVALBATTL E
ABACDB	F	ATALIT Y
ABACDB	A	NONYMO US
ABACDB	C	OLONEL
ABACDBA	TH	EREFORE
ABACDC	R	ECEIVI NG
ABACDC	DYNA	MOMETE R
ABACDCA	L	IMITATI ON
ABACDCCA		NINETEEN
ABACDCCAD		NINETEENT H
ABACDCEA	S	TATEMENT
ABACDCECFGHIE	M	ETEOROLOGICAL
ABACDD		FIFTEE N
ABACDD	FO	RTRESS
ABACDDEC		FIFTEENT H
ABACDEA		ELEVATE
ABACDEA	D	EVELOPE
ABACDEA	VER	IFICATI ON
ABACDEA	S	IMILARI TY
ABACDEAD		SUSPENSE
ABACDEAFGE		SUSPENSION
ABACDEB	EXPL	ANATION
ABACDEB	T	OPOGRAP HIC
ABACDEBFA	R	ECEPTACLE
ABACDEC		ABANDON
ABACDEC	D	AMAGING
ABACDEC	QU	ARANTIN E
ABACDECA	P	ENETRATE
ABACDECFBA	D	ETERIORATE
ABACDECFGB	P	ENETRATION
ABACDED	C	APABILI TY
ABACDED	M	OTORCYC LE
ABACDED		SUSPICI ON
ABACDEDEDC	G	ENERALALAR M
ABACDEDFBA		SUSPICICUS
ABACDEDFGA		SUSPICIONS
ABACDEFA	D	EFECTIVE
ABACDEFA	D	EFENSIVE
ABACDEFA	T	ELEPHONE
ABACDEFA	D	ETERMINE
ABACDEFA	D	EVELOPME NT

MISCELLANEOUS PATTERNS—Continued

ABACDEFA	EXERCISE	ABBA	SH IPPI NG
ABACDEFAF	EXERCISES	ABBA	M ISSI NG
ABACDEFB	DEDICATE	ABBA	ADM ISSI ON
ABACDEFB	ENEMYTAN KS	ABBA	M ISSI ON
ABACDEFC	DEDICATI ON	ABBA	PERM ISSI ON
ABACDEFCDFE	V ETERINARIAN	ABBA	F ITTI NG
ABACDEFCFD	ELECTRICIT Y	ABBA	AFTER NOON
ABACDEFD	SUSPECTE D	ABBA	NOON
ABACDEFDF	SUSPENDED	ABBA	F OLLO W
ABACDEFE	ANALYSIS	ABBA	C OMMO N
ABACDEFGA	EXECUTIVE	ABBA	OPPO SE
ABACDEFGB	POPULATIO N	ABBA	OPPO SITE
ABACDEFGBA	ENEMYPLANE S	ABBA	B OTTO M
ABACDEFGBA	S EVENTYFIVE	ABBAB	B AGGAG E
ABACDEFGBEHF	D ETERMINATION	ABBAB	WITN ESSES
ABACDEFGDHH	G ENERALSTAFF	ABBACA	APPARA TUS
ABACDEFGE	MEMORANDA	ABBACA	L ETTERE D
ABACDEFGHA	MEMORANDUM	ABBACB	V ESSELS
ABACDEFGHIA	D ECENTRALIZE	ABBACDA	M ESSENGE R
ABBA	AFFA IR	ABBACDA	EFFECTE D
ABBA	APPA RENT	ABBACDB	M ISSIONS
ABBA	APPA RENTLY	ABBACDEA	IRRIGATI ON
ABBA	B ARRA CKS	ABBACDEDA	OPPOSITIO N
ABBA	B ARRA GE	ABBACDEFA	EFFECTIVE
ABBA	ARRA NGE	ABBACDEFA	D IFFICULTI ES
ABBA	P ASSA GE	ABBACDEFA	IMMIGRATI ON
ABBA	ASSA ULT	ABBACDEFCD	ILLITERATE
ABBA	ATTA CH	ABBACDEFDB	ATTAINMENT
ABBA	ATTA CK	ABBACDEFEC	ARRANGEMEN T
ABBA	ATTA IN	ABBACDEFGB	ATTACHMENT
ABBA	B ATTA LION	ABBCA	ANNUA L
ABBA	IN DEED	ABBCA	APPEA R
ABBA	EFFE CT	ABBCA	DIS APPEA R
ABBA	COMP ELLE D	ABBCA	C ARRIA GE
ABBA	SH ELLE D	ABBCA	S ETTLE
ABBA	CONF ERRE D	ABBCA	ISSUI NG
ABBA	COMPR ESSE D	ABBCA	FOUR TEENT H
ABBA	IMPR ESSE D	ABBCA	SIX TEENT H
ABBA	PR ESSE D	ABBCA	CHA UFFEU R
ABBA	V ESSE L	ABBCA	S URROU ND
ABBA	CIGAR ETTE	ABBCADAEFC	APPEARANCE
ABBA	B ETTE R	ABBCADAEFC	DIS' APPEARANCE
ABBA	L ETTE R	ABBCADC	APPEARE D
ABBA	D IFFI CULT	ABBCBBDA	P OSSESSIO N
ABBA	W ILLI AM	ABBCBDA	ASSISTA NCE
ABBA	F ILLI NG	ABBCBDAED	ASSISTANT
ABBA	K ILLI NG	ABBCCDAB	ASSOONAS
ABBA	REF ILLI NG	ABBCDA	ALLOWA NCE
ABBA	SW IMMI NG	ABBCDA	APPROA CH

MISCELLANEOUS PATTERNS—Continued

ABBCDA	ARRIVA L	ABCA	ADVA NCE
ABBCDA	ASSURA NCE	ABCA	DI AGRA M
ABBCDA	M ESSAGE	ABCA	EV ALUA TION
ABBCDA	ILLUMI NATE	ABCA	ALWA YS
ABBCDAB	M ESSAGES	ABCA	C AMPA IGN
ABBCDAB	C ORRIDOR	ABCA	M ANDA TE
ABBCDAEA	B ELLIGERE NT	ABCA	M ANUA L
ABBCDAEFC	ALLOCATIO N	ABCA	J ANUA RY
ABBCDAEFC	IMMEDIATE	ABCA	C ANVA S
ABBCDAEFGAE	ILLUMINATIN G	ABCA	CH APLA IN
ABBCDAEFGAHE	ILLUMINATION	ABCA	C APTA IN
ABBCDAEFGAHE	D ISSEMINATION	ABCA	AREA
ABBCDBCEA	APPROPRIA TE	ABCA	DEB ARKA TION
ABBCDCA	EFFICIE NT	ABCA	EMB ARKA TION
ABBCDCA	C OLLISIO N	ABCA	ASIA
ABBCDCAED	EFFICIENC Y	ABCA	CO ASTA L
ABBCDCAED	C OLLISIONS	ABCA	C ASUA L
ABBCDCEFA	ADDITIONA L	ABCA	C ASUA LTY
ABBCDDCA	C OMMISSIO N	ABCA	AVIA TOR
ABBCDDCA	C OMMISSIO NER	ABCA	BARB ED
ABBCDDCEAFGC	ACCOMMODATIO N	ABCA	BOMB
ABBCDEA	ACCOMPA NY	ABCA	BOMB ARD
ABBCDEA	APPROVA L	ABCA	BOMB ER
ABBCDEA	ASSOCIA TE	ABCA	LIGHT BOMB ER
ABBCDEA	SH ELLFIRE	ABCA	BRIB E
ABBCDEA	T ERRIBLE	ABCA	BULB
ABBCDEAFB	ACCORDANC E	ABCA	CANC EL
ABBCDEAFB	REENFORCE	ABCA	CHEC K
ABBCDEAFBC	ACCEPTANCE	ABCA	CIRC LE
ABBCDEAFBGBC	REENFORCEMEN T	ABCA	CIRC ULATE
ABBCDEAFD	APPLICATI ON	ABCA	CONC EAL
ABBCDEAFEC	ASSOCIATIO N	ABCA	CONC LUDE
ABBCDEAFGC	ACCEPTABLE	ABCA	HUN DRED
ABBCDEAFGC	ALLEGIANCE	ABCA	L EADE R
ABBCDEAFGHF	C ORRESPONDIN G	ABCA	EAGE R
ABBCDEFGA	ACCIDENTA L	ABCA	M EAGE R
ABBCDEFGA	APPROXIMA TE	ABCA	S EAME N
ABBCDEFGA	OCCUPATIO N	ABCA	ST EAME R
ABBCDEFGBAHAC	IRREGULARITIE S	ABCA	N EARE ST
ABBCDEFGBA	IRREGULARI TY	ABCA	C EASE
ABBCDEFGEA	ILLUSTRATI ON	ABCA	GR EASE
ABBCDEFGHAD	C OMMENDATION	ABCA	INCR EASE D
ABCA	P ACKA GE	ABCA	L EAVE
ABCA	EV ACUA TING	ABCA	ECHE LON
ABCA	EV ACUA TION	ABCA	WR ECKE D
ABCA	R ADIA L	ABCA	INF ECTE D
ABCA	R ADIA TE	ABCA	EDGE
ABCA	ADJA CENT	ABCA	S EIZE
ABCA	GR ADUA L	ABCA	R ELIE F

MISCELLANEOUS PATTERNS—Continued

ABCA	H	ELPE	R	ABCA	I	NFAN	TRY
ABCA	TW	ELVE		ABCA	CO	NFIN	E
ABCA	NOV	EMBE	R	ABCA	U	NION	
ABCA	ABS	ENCE		ABCA	SU	NKEN	
ABCA	LIC	ENSE		ABCA	FLA	NKIN	G
ABCA	C	ENTE	R	ABCA	I	NLAN	D
ABCA		ENTE	R	ABCA	I	NTEN	D
ABCA		ENVE	LOP	ABCA	CO	NTIN	UAL
ABCA	R	EQUE	ST	ABCA	CO	NTIN	UE
ABCA	FI	ERCE		ABCA	I	NVEN	T
ABCA	S	ERGE	ANT	ABCA		OCTO	BER
ABCA	MAT	ERIE	L	ABCA	D	OCTO	R
ABCA	REV	ERSE		ABCA	F	OGHO	RN
ABCA	OBS	ERVE		ABCA	P	OISO	N
ABCA	R	ESPE	CT	ABCA	C	OMPO	SED
ABCA	W	ESTE	RLY	ABCA	C	ONVO	Y
ABCA	W	ESTE	RN	ABCA	EN	ORMO	US
ABCA		ETHE	R	ABCA	EXPL	OSIO	N
ABCA	MAN	EUVE	R	ABCA		PUMP	
ABCA	R	EVIE	W	ABCA		PURP	OSE
ABCA		EXCE	PT	ABCA	HA	RBOR	
ABCA		EXPE	CT	ABCA	AI	RBOR	NE
ABCA		EXPE	ND	ABCA	MU	RDER	
ABCA		EXTE	ND	ABCA	O	RDER	
ABCA		GAUG	E	ABCA	O	RDER	S
ABCA		GEOG	RAPHIC	ABCA		REAR	
ABCA	FOR	GING		ABCA		RECR	UIT
ABCA	W	HICH		ABCA	COU	RIER	
ABCA		HIGH		ABCA	P	RIOR	
ABCA		HIGH	ER	ABCA	SUPE	RIOR	
ABCA		HIGH	EST	ABCA	A	RMOR	
ABCA	V	ICTI	M	ABCA	A	RMOR	Y
ABCA	M	IDNI	GHT	ABCA	P	ROGR	AM
ABCA	DR	IFTI	NG	ABCA	MO	RTAR	
ABCA	L	IFTI	NG	ABCA	QUA	RTER	
ABCA	S	IGNI	FY	ABCA	QUA	RTER	S
ABCA	BU	ILDI	NG	ABCA	FEB	RUAR	Y
ABCA		INDI	CATE	ABCA	FO	RWAR	D
ABCA		INDI	RECT	ABCA	CEN	SORS	HIP
ABCA	DESCR	IPTI	ON	ABCA		SUNS	ET
ABCA	L	IQUI	D	ABCA	IMPOR	TANT	
ABCA	A	IRFI	ELD	ABCA	S	TART	
ABCA		REPR	ISAL	ABCA	PRO	TECT	
ABCA	M	ISFI	RE	ABCA		TENT	
ABCA	F	ISHI	NG	ABCA		TENT	H
ABCA	W	ITHI	N	ABCA	PRO	TEST	
ABCA	FUE	LOIL		ABCA		TEXT	
ABCA		MAIM		ABCA		THAT	
ABCA	LA	NDIN	G	ABCA	S	TRAT	EGIC

MISCELLANEOUS PATTERNS—Continued

ABCA	S	TRAT EGY
ABCA	D	UGOU T
ABCA		UNSU ITABLE
ABCA	P	URSU E
ABCA	P	URSU IT
ABCA	O	UTGU ARD
ABCAA	D	ECREE
ABCAA	D	EGREE
ABCAA	B	ETWEE N
ABCAA	DI	SCUSS
ABCAA	A	SPOSS IBLE
ABCAAB	P	ONTOON
ABCAAB		THATTH E
ABCAACDEB	P	REARRANGE D
ABCAB	W	ARFAR E
ABCAB	S	ECREC Y
ABCAB	OBS	ERVER
ABCAB	W	HETHE R
ABCAB	B	INDIN G
ABCAB	F	INDIN G
ABCAB	S	INKIN G
ABCAB	PA	INTIN G
ABCAB	PR	INTIN G
ABCAB	I	NTENT
ABCAB	P	ONTON
ABCAB	C	ORPOR AL
ABCAB		RECRE ATION
ABCAB	P	RIORI TY
ABCAB	SUPE	RIORI TY
ABCAB	DI	SEASE
ABCAB	PRO	TECTE D
ABCAB	PRO	TESTE D
ABCAB	O	UTPUT
ABCABA	INT	ERFERE
ABCABB	D	ISMISS
ABCABB	D	ISMISS AL
ABCABC		THATHA VE
ABCABCA		ENTENTE
ABCABDA	S	ENTENCE
ABCABDB		REPRESE NT
ABCABDBEFGFHIB		REPRESENTATIVE
ABCABDBEFGFHIED		REPRESENTATIONS
ABCABDC		RETREAT
ABCABDED	M	ANGANESE
ABCABDEFA	C	ORPORATIO N
ABCABDEFGHD		RECREATIONA L
ABCAC		ARMAM ENT
ABCAC	N	EARER
ABCAC		PROPO SE
ABCAC	P	RAIRI E
ABCAC	PRO	TESTS
ABCACA	D	IETITI AN
ABCACB	O	RDERED
ABCACBDEC		PROPORTIO N
ABCACDEFD		PROPOSALS
ABCADA		ALMANA C
ABCADA	R	ELIEVE
ABCADA	C	ENTERE D
ABCADA	B	ESIEGE D
ABCADA	R	EVIEWE D
ABCADAB	CO	NTINENT AL
ABCADAC	S	EALEVEL
ABCADAC		INDIVID UAL
ABCADAEC		IGNITION
ABCADAEFB		TENTATIVE
ABCADAEFC	S	IGNIFICAN T
ABCADAEFCE	S	IGNIFICANC E
ABCADAEFGHF		SUBSISTENCE
ABCADB		ATLANT IC
ABCADB		BRIBER Y
ABCADB		CIRCUI T
ABCADB	W	EDNESD AY
ABCADB	LOG	ISTICS
ABCADB	EXPL	OSIONS
ABCADB		PREPAR ING
ABCADB	IM	PROPER
ABCADB		PROPER
ABCADBA		INSIGNI A
ABCADBC		PREPARE
ABCADBCEFCGG		PREPAREDNESS
ABCADBD		PREPARA TION
ABCADBEFD		CIRCUITOU S
ABCADC	R	ADIATI ON
ABCADC	ST	ANDARD
ABCADC	V	ARIATI ON
ABCADC		ASIATI C
ABCADC		AVIATI ON
ABCADC	R	EVIEWI NG
ABCADC		EXTENT
ABCADC	I	NVENTE D
ABCADC		TACTIC S
ABCADC	S	TARTER
ABCADC		ZIGZAG
ABCADCA	CO	NVENIEN T
ABCADCB	CO	NDENSED
ABCADCB		TACTICA L
ABCADCEFBGABC		ENTERTAINMENT
ABCADCEFGED		CONCENTRATE

MISCELLANEOUS PATTERNS—Continued

ABCADCEFGEHC	CONCENTRATIN G
ABCADCEFGEHBC	CONCENTRATION
ABCADD	D EPRESS ION
ABCADD	EXCESS
ABCADD	D ISTILL
ABCADD	P OSTOFF ICE
ABCADD	B OYCOTT
ABCADDA	AMBASSA DOR
ABCADDA	EXPELLE D
ABCADDECCFA	UNSUCCESSFU L
ABCADDEFA	EXCESSIVE
ABCADEA	ADVANTA GE
ABCADEA	ADVANTA GEOUS
ABCADEA	D ECREASE
ABCADEA	S EPTEMBE R
ABCADEA	R EQUESTE D
ABCADEA	D ISCIPLI NE
ABCADEAB	CO NTINGENT
ABCADEAE	EXPENDED
ABCADEAE	EXPENSES
ABCADEAE	EXTENDED
ABCADEAFA	ELSEWHERE
ABCADEAFGA	EXPERIENCE
ABCADEB	C ENTERIN G
ABCADEB	ENTERIN G
ABCADEB	R ESPECTS
ABCADEB	INCIDEN T
ABCADEB	M ISFIRES
ABCADEBCE	INCIDENCE
ABCADEC	M ANDATED
ABCADEC	S ECRETAR Y
ABCADEC	GYR OSCOPIC
ABCADECA	REARGUAR D
ABCADECAFD	D ISTINCTION
ABCADECFC	CONCERNIN G
ABCADEDA	CO NFINEMEN T
ABCADEDAFB	INVITATION
ABCADEDBD	SUBSTITUT E
ABCADEDBDE	SUBSTITUTI ON
ABCADEDC	LI EUTENANT
ABCADEDFGA	ENTERPRISE
ABCADEDFGDBC	CONCILIATION
ABCADEDFGFB	ENTERPRISIN G
ABCADEE	P ROGRESS
ABCADEEBFGHC	CANCELLATION
ABCADEED	CANCELLE D
ABCADEEFBC	CONCESSION
ABCADEEFGD	P ROGRESSIVE
ABCADEFA	ECHELONE D
ABCADEFA	ENVELOPE
ABCADEFA	EXPEDITE
ABCADEFA	EXPERIME NT
ABCADEFAB	INDICATIN G
ABCADEFAB	D ISTINGUIS H
ABCADEFABGADE	D ISTINGUISHING
ABCADEFAGB	INDICATION
ABCADEFB	ADVANCED
ABCADEFBA	EXT RAORDINAR Y
ABCADEFC	BOMBARDM ENT
ABCADEFC	CIRCULAR
ABCADEFC	U NTENABLE
ABCADEFCGHB	RETROACTIVE
ABCADEFD	ADVANCIN G
ABCADEFD	EXTENDIN G
ABCADEFD	EXTERIOR
ABCADEFE	CONCRETE
ABCADEFE	EXPEDITI NG
ABCADEFE	EXPEDITI ON
ABCADEFE	OBSOLETE
ABCADEFE	G ONIOMETE R
ABCADEFE	PURPOSES
ABCADEFE	RECRUITI NG
ABCADEFEA	C OMPOSITIO N
ABCADEFGA	EXPENSIVE
ABCADEFGA	EXTENSIVE
ABCADEFGAF	ECHELONMEN T
ABCADEFGB	C ASUALTIES
ABCADEFGB	CIRCULATI ON
ABCADEFGBC	CONCLUSION
ABCADEFGC	INDICATED
ABCADEFGC	S TRATEGICA L
ABCADEFGD	EXTENSION
ABCADEFGDC	CONCEALMEN T
ABCADEFGE	REPRISALS
ABCADEFGF	BOMBARDED
ABCADEFGHAB	C ONFORMATION
ABCADEFGHCA	EXTERMINATE
ABCADEFGHCFIG	EXTERMINATION
ABCADEFGHEIGCF	REORGANIZATION
ABCADEFGHH	R ESPECTFULL Y
ABCADEFGHIAJF	CIRCUMSTANCES
ABCADEFGHIB	RETROACTIVE
ABCADEFGHIE	GEOGRAPHICA L
ABCADEFGHIGBH	CIRCUMSTANTIA L
ABCBA	COMP LETEL Y
ABCBA	AWKWA RD
ABCBA	CAPAC ITY
ABCBA	PA CIFIC

MISCELLANEOUS PATTERNS—Continued

ABCBA	SPE CIFIC
ABCBA	HIN DERED
ABCBA	DIVID E
ABCBA	GARAG E
ABCBA	C ITATI ON
ABCBA	LEVEL
ABCBA	P REFER
ABCBA	REFER
ABCBA	P RESER VATION
ABCBA	RESER VATION
ABCBA	TAXAT ION
ABCBA	HOS TILIT Y
ABCBA	U TILIT Y
ABCBA	AC TIVIT Y
ABCBAA	U SELESS
ABCBAAB	P REFERRE D
ABCBAB	DIVIDI NG
ABCBAB	AC TIVITI ES
ABCBABDEB	P REFERENCE
ABCBABDEB	REFERENCE
ABCBADA	MINIMUM
ABCBADB	P RESERVE
ABCBADB	RESERVE
ABCBADB	REVERSE
ABCBADBC	RESERVES
ABCBADEB	SPE CIFICATI ON
ABCBCDBA	REMEMBER
ABCBDA	DEFEND
ABCBDA	DEPEND
ABCBDA	MU NITION S
ABCBDA	RESEAR CH
ABCBDA	STATES
ABCBDA	STATUS
ABCBDA	IN TEREST
ABCBDAB	DEFENDE R
ABCBDAB	E NGAGING
ABCBDABA	DEFENDED
ABCBDABD	DEPENDEN T
ABCBDABDEA	STATISTICS
ABCBDAEFGB	DEPENDABLE
ABCBDAEFGHG	DEPENDABILI TY
ABCBDCBA	PARAGRAP H
ABCBDDBA	DEFERRED
ABCBDEA	E CONOMIC
ABCBDEA	DAMAGED
ABCBDEA	PO LITICAL
ABCBDEAEC	MANAGEMEN T
ABCBDEBA	DEFEATED
ABCBDEBA	DESERTED
ABCBDEBA	RECEIVER
ABCBDEBA	REPEATER
ABCBDEFA	REJECTOR
ABCBDEFA	STATIONS
ABCBDEFBA	DEVELOPED
ABCBDEFGA	R ESISTANCE
ABCBDEFGBA	DETERMINED
ABCBDEFGHFA	DISINFECTED
ABCBDEFGHIJBA	DECENTRALIZED
ABCCA	LITTL E
ABCCA	PASSP ORT
ABCCA	S TREET
ABCCABDEC	C ROSSROADS
ABCCBADED	MILLIMETE R
ABCCBCA	BE GINNING
ABCCBDA	INF LAMMABL E
ABCCDA	COLLEC T
ABCCDA	CORREC T
ABCCDA	T RIGGER
ABCCDA	RUBBER
ABCCDA	RUNNER
ABCCDA	SPOOLS
ABCCDA	SPOONS
ABCCDA	SUGGES T
ABCCDA	SUPPOS E
ABCCDA	TURRET
ABCCDAA	SUCCESS
ABCCDAAEB	SUCCESSFU L
ABCCDAAEBFF	SUCCESSFULL Y
ABCCDAAEFD	SUCCESSIVE
ABCCDAB	P RESSURE
ABCCDAEC	TERRITOR Y
ABCCDAED	CORRECTE D
ABCCDAEFB	COLLECTIO N
ABCCDAEFB	CORRECTIO N
ABCCDAEFBC	CONNECTION
ABCCDAEFC	CONNECTIN G
ABCCDAEFDGG	CORRECTNESS
ABCCDEA	GASSING
ABCCDEA	GETTING
ABCCDEA	ST RAGGLER
ABCCDEA	IN TERRUPT
ABCCDEAB	IN TERRUPTE D
ABCCDEAD	COMMENCE
ABCCDEAD	COMMERCE
ABCCDEADCDE	COMMENCEMEN T
ABCCDEBFGHDA	DISSEMINATED
ABCCDEFA	COMMUNIC ATE
ABCCDEFA	SUPPLIES

MISCELLANEOUS PATTERNS—Continued

ABCCDEFAGHFBE		COMMUNICATION		ABCDA		INSPI	RE
ABCCDEFBGHDGAD		CORRESPONDENCE		ABCDA		LOCAL	
ABCCDEFGA	R	EAPPOINTE	D	ABCDA	LAU	NCHIN	G
ABCCDEFGHAFG	R	EAPPOINTMENT		ABCDA	CO	NDEMN	
ABCDA	S	ABOTA	GE	ABCDA	MACHI	NEGUN	
ABCDA	R	AILWA	Y	ABCDA		NOTIN	G
ABCDA		ANIMA	L	ABCDA	EXPA	NSION	
ABCDA	S	ANITA	RY	ABCDA	CO	NTAIN	
ABCDA	M	ARSHA	L	ABCDA	MOU	NTAIN	
ABCDA	M	ARTIA	L	ABCDA	I	NTERN	AL
ABCDA	E	ASTWA	RD	ABCDA	FRO	NTLIN	E
ABCDA	N	ATURA	L	ABCDA	I	NTREN	CH
ABCDA	N	ATURA	LIZE	ABCDA	C	ONTRO	L
ABCDA	TE	CHNIC	AL	ABCDA	H	ORIZO	N
ABCDA		COUNC	IL	ABCDA		OUTBO	ARD
ABCDA	R	EACHE	D	ABCDA		PROMP	T
ABCDA	L	EAGUE		ABCDA		RECOR	D
ABCDA		EASTE	RLY	ABCDA		REPOR	T
ABCDA		EASTE	RN	ABCDA		RETUR	N
ABCDA	W	EATHE	R	ABCDA	P	RIMAR	Y
ABCDA	H	EAVIE	R	ABCDA		RIVER	
ABCDA	INS	ECURE		ABCDA		ROGER	
ABCDA	S	ECURE		ABCDA	FA	RTHER	
ABCDA	R	EDUCE		ABCDA	FU	RTHER	
ABCDA	SCH	EDULE		ABCDA	NO	RTHER	LY
ABCDA	B	EFORE		ABCDA		SATIS	FY
ABCDA	R	EFUGE		ABCDA		SHIPS	
ABCDA	R	EFUSE		ABCDA	WAR	SHIPS	
ABCDA	R	EGIME	NT	ABCDA		THIRT	Y
ABCDA	R	EGIME	NTAL	ABCDA	WI	THOUT	
ABCDA		EITHE	R	ABCDA	EX	TRACT	
ABCDA	FUS	ELAGE		ABCDA		TRACT	
ABCDA	D	ELIVE	R	ABCDA	INS	TRUCT	
ABCDA	GR	ENADE		ABCDA	DES	TRUCT	ION
ABCDA		ERASE		ABCDA		TWENT	Y
ABCDA	OP	ERATE		ABCDA	B	UREAU	
ABCDA	R	ESCUE		ABCDA		WESTW	ARD
ABCDA	PR	ESIDE	NT	ABCDAA	R	EFUGEE	
ABCDA	R	ESUME		ABCDAA	C	ODEBOO	K
ABCDA	D	EVICE		ABCDAA	BU	SINESS	
ABCDA	D	EVISE		ABCDAA	DI	STRESS	
ABCDA		GOING		ABCDAA		STRESS	
ABCDA	T	HOUGH		ABCDAAD	F	ORENOON	
ABCDA	C	HURCH		ABCDAB		DECIDE	
ABCDA	F	IGHTI	NG	ABCDAB		DECODE	
ABCDA		INFLI	CT	ABCDAB	SP	EARHEA	D
ABCDA	EXT	INGUI	SH	ABCDAB	R	EDUCED	
ABCDA		INQUI	RE	ABCDAB		ENTREN	CH
ABCDA		INQUI	RY	ABCDAB		ERASER	

MISCELLANEOUS PATTERNS—Continued

ABCDAB		GEORGE	ABCDAECD	L	ABORATOR Y
ABCDAB		POSTPO NE	ABCDAECE		OUTPOSTS
ABCDAB		RETIRE	ABCDAECFD	EX	AMINATION
ABCDAB	ES	TIMATI ON	ABCDAED	T	RAVERSE
ABCDABA		DECIDED	ABCDAEE		ACTUALL Y
ABCDABAB		INCLININ G	ABCDAEE		EXPRESS
ABCDABC	M	AINTAIN	ABCDAEE		THIRTEE N
ABCDABC	M	AINTAIN ED	ABCDAEEFAB		THIRTEENTH
ABCDABCEFD		PHOSPHORUS	ABCDAEFA	OV	ERWHELME D
ABCDABEFA		ENTRENCHE D	ABCDAEFAB		INFLICTIN G
ABCDAC	L	ANGUAG E	ABCDAEFB	P	RESCRIBE D
ABCDAC		ANYWAY	ABCDAEFBE	O	NEHUNDRED
ABCDAC	GOV	ERNMEN T	ABCDAEFC	M	ANUFACTU RE
ABCDAC	I	NSTANT	ABCDAEFC	PR	ESIDENTI AL
ABCDAC	I	NSTANT LY	ABCDAEFC	D	ISTRIBUT E
ABCDAC	DI	SPERSE	ABCDAEFCA	D	ISTRIBUTI NG
ABCDAC	RES	TRICTI ON	ABCDAEFCA	D	ISTRIBUTI ON
ABCDAC	PA	TRIOTI C	ABCDAEFD	F	LASHLIGH T
ABCDACB	CO	NDEMNED	ABCDAEFD	C	ONTROVER SY
ABCDACDAEFGB	I	NSTANTANEOUS	ABCDAEFD	A	SCENSION
ABCDACEFDAF		COINCIDENCE	ABCDAEFD		WINDWARD
ABCDAD		MOVEME NT	ABCDAEFDB		RESTRICTE D
ABCDAD	A	MUSEME NT	ABCDAEFDE		RESTRICTI ON
ABCDAD		RIGORO US	ABCDAEFE	PAR	ENTHESIS
ABCDADC	S	ANITATI ON	ABCDAEFE		RETURNIN G
ABCDADEDAFB		INSTITUTION	ABCDAEFEGE	RE	SPONSIBILI TY
ABCDADEFEAGC		ANTIAIRCRAFT	ABCDAEFF		REDCROSS
ABCDAEA		EXTREME	ABCDAEFGAHB		INSPIRATION
ABCDAEA		MAXIMUM	ABCDAEFGC		REGARDING
ABCDAEAB	SU	ITABILIT Y	ABCDAEFGD		RESTRAINT
ABCDAEABD	UNI	TEDSTATES	ABCDAEFGFE	TR	ANSPACIFIC
ABCDAEAE	PAR	ENTHESES	ABCDAEFGHC		TWENTYFIVE
ABCDAEB	F	IGHTING	ABCDAEFGHFBC		CONSCRIPTION
ABCDAEB	S	IGHTING	ABCDBA	PR	ACTICA L
ABCDAEB		RAILROA D	ABCDBA	W	ATERTA NK
ABCDAEB		REPORTE D	ABCDBA	DIV	EBOMBE R
ABCDAEB		RETURNE D	ABCDBA		ENGINE
ABCDAEB		TRACTOR	ABCDBA	S	ENTINE L
ABCDAEB	INS	TRUCTOR	ABCDBA	R	EVOLVE
ABCDAEBA		RECORDER	ABCDBA	S	ITUATI ON
ABCDAEBC	DE	TONATION	ABCDBAA		ENGINEE R
ABCDAEBFBDC	U	NIDENTIFIED	ABCDBAAEDBC		ENGINEERING
ABCDAEBFC		SATISFACT ORY	ABCDBAB		LIABILI TY
ABCDAEC		AVERAGE	ABCDBAD	RE	TALIATI ON
ABCDAEC	D	ISTRICT	ABCDBAEAD	D	ISPOSITIO N
ABCDAEC		OUTPOST	ABCDBAEBE	U	NEXPENDED
ABCDAECA		TWENTIET H	ABCDBBA		ANTENNA
ABCDAECAB	I	NTERNMENT	ABCDBBA	D	ISCUSSI ON
ABCDAECB	D	ISTRICTS	ABCDBBDEA	TRA	NSMISSION

MISCELLANEOUS PATTERNS—Continued

ABCDBCAEB		INTENTION	ABCDCEBA		ELIGIBLE
ABCDBCEA	A	ERODROME	ABCDCECA	D	ESTITUTE
ABCDBEA		INCENDI ARY	ABCDCECDA	CO	NSTITUTIN G
ABCDBEA	PR	OTECTIO N	ABCDCEFGAB		PHOTOGRAPH Y
ABCDBEA	IN	TERCEPT	ABCDCEFGCA	DEM	OBILIZATIO N
ABCDBEAB	IN	TERCEPTE D	ABCDCEFGCA	M	OBILIZATIO N
ABCDBEAE	C	ONTINUOU S	ABCDDA	R	ECOMME ND
ABCDBEAFB		INVENTION	ABCDDA	T	OBACCO
ABCDBEAFCDB	QU	ARTERMASTER	ABCDDA		SHELLS
ABCDBEAFD		INCENTIVE	ABCDDAB	B	EACHHEA D
ABCDBEAFD		INTENSIVE	ABCDDAEACBE		INEFFICIENC Y
ABCDBECA	E	NCIRCLIN G	ABCDDAEFAF	R	ECOMMENDED
ABCDBEFAGABC		ENTANGLEMENT	ABCDDAEFGHICE	R	ECOMMENDATION
ABCDBEFAGEB		TEMPERATURE	ABCDDEA		DROPPED
ABCDBEFBA		DECREASED	ABCDDEA	AI	RSUPPOR T
ABCDBEFCDAB	C	ONTINUATION	ABCDDEA	A	RTILLER Y
ABCDBEFGA		YESTERDAY	ABCDDEAEC		COEFFICIE NT
ABCDBEFGAB		ARMOREDCAR	ABCDDECDFA		SCHOOLHOUS E
ABCDBEFGBCHIA		DISTINGUISHED	ABCDDEFCGHA	MI	SCELLANEOUS
ABCDBEFGHA	P	ERFORMANCE	ABCDDEFEACGE		CLASSIFICATI ON
ABCDCA		AIRCRA FT	ABCDDEFGGEDBA	R	ECONNAISSANCE
ABCDCA		CRITIC	ABCDEA		AERONA UTICS
ABCDCA		CRITIC AL	ABCDEA	R	AILHEA D
ABCDCA	D	EFICIE NT	ABCDEA		AIRPLA NE
ABCDCA		ENGAGE	ABCDEA		AMBULA NCE
ABCDCA	P	OSITIO N	ABCDEA	CO	ASTGUA RD
ABCDCA	PR	OVISIO N	ABCDEA	M	ATERIA L
ABCDCA	FI	REALAR M	ABCDEA	S	ATURDA Y
ABCDCAAC		PHILIPPI NES	ABCDEA	C	AUSEWA Y
ABCDCAB		ANTITAN K	ABCDEA	N	AUTICA L
ABCDCABCA	I	NDEPENDEN T	ABCDEA		BLOCKB USTER
ABCDCAC		CRITICI SE	ABCDEA	ME	CHANIC
ABCDCAC		CRITICI SM	ABCDEA		CHEMIC AL
ABCDCAD		OPINION	ABCDEA		CONDUC T
ABCDCAEAB		ENGAGEMEN T	ABCDEA		DISLOD GE
ABCDCAEB	P	OSITIONS	ABCDEA		DOWNED
ABCDCAED	D	EFICIENC Y	ABCDEA	B	ECAUSE
ABCDCAED	PR	OVISIONS	ABCDEA	D	ECIPHE R
ABCDCAEFD		CHARACTER	ABCDEA	D	ECLARE
ABCDCAEFDGHEGA		CHARACTERISTIC	ABCDEA	OBJ	ECTIVE
ABCDCBABC	IN	TERPRETER	ABCDEA	L	ECTURE
ABCDCBCEA	HO	STILITIES	ABCDEA	V	EHICLE S
ABCDCEA	BRI	DGEHEAD	ABCDEA		ENCODE
ABCDCEA	M	EDICINE	ABCDEA	COMP	ENSATE
ABCDCEA	D	EFINITE	ABCDEA		ENTIRE
ABCDCEA	S	EPARATE	ABCDEA	R	EPLACE
ABCDCEA		SURPRIS E	ABCDEA	R	EPULSE D
ABCDCEAFC	QU	ALIFICATI ON	ABCDEA	CONSID	ERABLE
ABCDCEAFE	P	ERSISTENT	ABCDEA	INT	ERPOSE

MISCELLANEOUS PATTERNS—Continued

ABCDEA	S	ERVICE	ABCDEABFD		NATIONALI SM
ABCDEA		EUROPE	ABCDEABFDC		NATIONALIT Y
ABCDEA		EUROPE AN	ABCDEABFE		MARKSMANS HIP
ABCDEA		EXCITE	ABCDEABFFGHD		SHARPSHOOTER
ABCDEA	T	HROUGH	ABCDEABFGDHF	W	ARDEPARTMENT
ABCDEA		IDENTI CAL	ABCDEAC		AUTOMAT IC
ABCDEA		IDENTI FY	ABCDEAC	AI	RCONTRO L
ABCDEA		INHABI TED	ABCDEACFB		ANTEDATIN G
ABCDEA	D	IRECTI ON	ABCDEAD		CONTACT
ABCDEA		MEDIUM	ABCDEAD	V	ICTORIO US
ABCDEA	SY	NCHRON IZE	ABCDEAD	C	RUISERS
ABCDEA	JU	NCTION	ABCDEADFD		THREATENE D
ABCDEA	CO	NFIDEN T	ABCDEAE		ENCODED
ABCDEA		NOTHIN G	ABCDEAE	P	ERMANEN T
ABCDEA	E	NTRAIN	ABCDEAE		FORTIFI ED
ABCDEA	L	OCATIO N	ABCDEAE		REQUIRI NG
ABCDEA	REV	OLUTIO N	ABCDEAEFGC		TRADITIONA L
ABCDEA	DEC	ORATIO N	ABCDEAFA	R	EPLACEME NT
ABCDEA	T	ORPEDO	ABCDEAFAGE		EXCITEMENT
ABCDEA		OVERCO MING	ABCDEAFAGHEAID		IDENTIFICATION
ABCDEA	T	RAILER S	ABCDEAFB		CLERICAL
ABCDEA	T	RAWLER	ABCDEAFB		INVASION
ABCDEA	DI	RECTOR	ABCDEAFBC		RESOURCES
ABCDEA		REPAIR	ABCDEAFC	DES	IGNATION
ABCDEA	NO	RTHWAR D	ABCDEAFC	RES	IGNATION
ABCDEA	C	RUISER	ABCDEAFC	CO	NFIDENTI AL
ABCDEA	I	SLANDS	ABCDEAFD	D	IMENSION
ABCDEA		STRIPS	ABCDEAFE		ADJUTANT
ABCDEA		SUNRIS E	ABCDEAFE		INTERIOR
ABCDEA		TARGET	ABCDEAFE	I	NFLUENCE
ABCDEA	NOR	THEAST	ABCDEAFF	R	EADINESS
ABCDEA		THREAT	ABCDEAFGA	D	ECIPHERME NT
ABCDEA	NOR	THWEST	ABCDEAFGAFB		MEDIUMBOMBE R
ABCDEA		TWELFT H	ABCDEAFGD		LEGISLATI ON
ABCDEA	L	UMINOU S	ABCDEAFGE	CO	MPARTMENT
ABCDEAA		EIGHTEE N	ABCDEAFGEE		SMOKESCREE N
ABCDEAAE		SUBMISSI ON	ABCDEBA		DELAYED
ABCDEAAFED		EIGHTEENTH	ABCDEBA	D	ETONATE
ABCDEAB		INVADIN G	ABCDEBA		INDEMNI TY
ABCDEAB	F	LEXIBLE	ABCDEBA	D	ISPERSI ON
ABCDEAB		NATIONA L	ABCDEBA		RECOVER
ABCDEAB		REQUIRE	ABCDEBA		SURPLUS
ABCDEAB		RESTORE D	ABCDEBAB		ARBITRAR Y
ABCDEAB	OU	TSKIRTS	ABCDEBAED		ARBITRATI ON
ABCDEABA		DEMANDED	ABCDEBFA	B	RIGADIER
ABCDEABD		IMPEDIME NTA	ABCDEBFAGA		ENCOUNTERE D
ABCDEABE	AT	OMICBOMB	ABCDEBFCAGBF		INTERNATIONA L
ABCDEABF		REPAIRED	ABCDEBFDGA		NAVIGATION
ABCDEABFB		REQUIREME NT	ABCDEBFGAF	H	EADQUARTER S

MISCELLANEOUS PATTERNS—Continued

ABCDEBFGHA	R	ESPONSIBLE	ABCDEEA		ENROLLE D
ABCDEBFGHBCGIA		NATURALIZATION	ABCDEEA	P	ERSONNE L
ABCDECA	E	NLISTIN G	ABCDEEA		IMPASSI BLE
ABCDECA		PRINCIP AL	ABCDEEA		IMPOSSI BLE
ABCDECA		PRINCIP LE	ABCDEEACB	S	IGNALLING
ABCDECA		SKIRMIS H	ABCDEEAFDBC		INTELLIGENT
ABCDECAB	I	NTERMENT	ABCDEEAFDBGD		INTELLIGENCE
ABCDECAC	I	NTERVENE	ABCDEEDFGBA		RECONNOITER
ABCDECACFE	M	AINTENANCE	ABCDEEDFGBAFE		RECONNOITERIN G
ABCDECAFCDA		TRANSATLANT IC	ABCDEEFAB		ENROLLMEN T
ABCDECBA		NEGLIGEN T	ABCDEEFAB	C	ONFESSION
ABCDECBA		REVOLVER	ABCDEEFAE		EMBASSIES
ABCDECBA	P	ROTECTOR	ABCDEEFDGFA		DISAPPEARED
ABCDECBAFB		NEGLIGENCE	ABCDEEFGCAHB		INTERRUPTION
ABCDECCFA		DISCUSSED	ABCDEFA	C	ABLEGRA M
ABCDECDCAFC	I	NTERFERENCE	ABCDEFA		AMERICA N
ABCDECFA		ENCIRCLE	ABCDEFA	C	AMOUFLA GE
ABCDECFA		EVACUATE	ABCDEFA		CHRONIC AL
ABCDECFBA		SEAPLANES	ABCDEFA		CONFLIC T
ABCDECFEA		STANDARDS	ABCDEFA	DIS	CREPANC Y
ABCDEDA	N	EWSPAPE R	ABCDEFA	S	EABORNE
ABCDEDA		MARITIM E	ABCDEFA		EMPLOYE R
ABCDEDA	CO	NTRABAN D	ABCDEFA		ENCIPHE R
ABCDEDA	C	OALITIO N	ABCDEFA		ENFORCE
ABCDEDA	BA	ROMETER	ABCDEFA		ENLISTE D
ABCDEDA	GY	ROMETER	ABCDEFA	D	EPLOYME NT
ABCDEDA	HYD	ROMETER	ABCDEFA		EQUIPME NT
ABCDEDA	HYG	ROMETER	ABCDEFA	FIGHT	ERPLANE
ABCDEDA	PSYCH	ROMETER	ABCDEFA		ESCORTE D
ABCDEDAB	C	ONDITION	ABCDEFA	D	ESCRIBE
ABCDEDAC	REC	OGNITION	ABCDEFA	J	ETPLANE
ABCDEDAFC	N	EWSPAPERS	ABCDEFA		EXCLUDE
ABCDEDFA		DICTATED	ABCDEFA		INCLUSI VE
ABCDEDFA		EXCAVATE	ABCDEFA		LOGICAL
ABCDEDFA		EXHIBITE D	ABCDEFA	F	ORMATIO N
ABCDEDFAC		ANTICIPAT E	ABCDEFA	T	RANSFER
ABCDEDFAC		CLEARANCE	ABCDEFA		REGULAR
ABCDEDFACDGB		ANTICIPATION	ABCDEFA	P	RISONER
ABCDEDFCAB		INTERESTIN G	ABCDEFA		SAILORS
ABCDEDFCGAHB		INAUGURATION	ABCDEFA		SECTORS
ABCDEDFDA		ARTIFICIA L	ABCDEFA		SERIOUS LY
ABCDEDFDEAB	C	ONSTITUTION	ABCDEFA	E	STABLIS H
ABCDEDFDGHAIF		CHRONOLOGICAL	ABCDEFA		TONIGHT
ABCDEDFGA	PR	OCLAMATIO N	ABCDEFAA		EMPLOYEE
ABCDEDFGA	P	RELIMINAR Y	ABCDEFAAF	T	RANSFERRE D
ABCDEDFGABHED		INDETERMINATE	ABCDEFAAGC	T	RANSFERRIN G
ABCDEDFGADB	P	RELIMINARIE S	ABCDEFAB		INCLUDIN G
ABCDEDFGHAGD		ADMINISTRATI VE	ABCDEFAB		RADIOGRA M
ABCDEDFGHAGDIE		ADMINISTRATION	ABCDEFAB	P	REMATURE

MISCELLANEOUS PATTERNS—Continued

ABCDEFABA		EMPLACEME NT	ABCDEFBABGHD		MEASUREMENTS
ABCDEFAC		INTEGRIT Y	ABCDEFBGA		ENDURANCE
ABCDEFAC	P	RISONERS	ABCDEFBGBA		DECIPHERED
ABCDEFACB	IN	TRODUCTOR Y	ABCDEFCA		ESTIMATE
ABCDEFACD		ALTERNATE	ABCDEFCA		NORTHERN
ABCDEFACGF		ALTERNATIN G	ABCDEFCAB		ESTIMATES
ABCDEFAD		CONTRACT	ABCDEFCAD	D	OMINATION
ABCDEFAD	D	ESTROYER	ABCDEFCAGFC		ESTIMATEDAT
ABCDEFAD		INTERVIE W	ABCDEFCBA		DETONATED
ABCDEFAD		OPERATOR	ABCDEFCCFA		DISTRESSED
ABCDEFAD	FI	RECONTRO L	ABCDEFCEA		DISPERSED
ABCDEFAD	P	ROCEDURE	ABCDEFCGA		ELABORATE
ABCDEFADB	D	ESTROYERS	ABCDEFDA	D	EPARTURE
ABCDEFADF	T	RANSVERSE	ABCDEFDAB	C	USTOMHOUS E
ABCDEFAE	D	ISCONTIN UE	ABCDEFDBAB		INTERVENIN G
ABCDEFAEGHEC	D	ISCONTINUANC E	ABCDEFDBCAGB		INTERVENTION
ABCDEFAF		EXPANDED	ABCDEFDEAB		INTERFERIN G
ABCDEFAF	I	MPROVEME NT	ABCDEFDGAB	DEM	ONSTRATION
ABCDEFAFCD	R	ADIOSTATIO N	ABCDEFDGAHCD		INTERMEDIATE
ABCDEFAGA		ENCIPHERE D	ABCDEFDGHA		HYDROGRAPH IC
ABCDEFAGAB		ENFORCEMEN T	ABCDEFEA	R	EINSTATE
ABCDEFAGB		AEROPLANE	ABCDEFEAB	F	INGERPRIN T
ABCDEFAGB	D	ETACHMENT	ABCDEFEAGACE	R	EINSTATEMENT
ABCDEFAGB		INFLATION	ABCDEFEAGDB		CERTIFICATE
ABCDEFAGB		REINFORCE	ABCDEFECACD		THERMOMETER
ABCDEFAGB		TRAJECTOR Y	ABCDEFECAE		CONFERENCE
ABCDEFAGBDB		REIMBURSEME NT	ABCDEFEDCGCAHB		INTERPRETATION
ABCDEFAGBHBD		REINFORCEMEN T	ABCDEFEFA	C	OMPETITIO N
ABCDEFAGC		INTERDICT	ABCDEFEGA	D	EMOBILIZE
ABCDEFAGCAHB		INTERDICTION	ABCDEFEGA	C	OMPUTATIO N
ABCDEFAGE	D	EPARTMENT	ABCDEFFA	UN	DERSTOOD
ABCDEFAGEC	D	EPARTMENTA L	ABCDEFFA		IMPRESSI ON
ABCDEFAGFD		REGISTRATI ON	ABCDEFFAGE		IMPRESSIVE
ABCDEFAGHAB		ENCIPHERMEN T	ABCDEFFEDAGBC		INSTALLATIONS
ABCDEFAGHEBC		CONFISCATION	ABCDEFFGAB	C	ONGRESSION AL
ABCDEFAGHFD		INVESTIGATE	ABCDEFGA		DISARMED
ABCDEFAGHFAIB		INVESTIGATION	ABCDEFGA	M	ECHANIZE D
ABCDEFAGHFAIBE		INVESTIGATIONS	ABCDEFGA	T	ECHNIQUE
ABCDEFAGHIF	B	REAKTHROUGH	ABCDEFGA	R	ECOGNIZE
ABCDEFBA		DECLARED	ABCDEFGA		ENFILADE
ABCDEFBA		DEPARTED	ABCDEFGA		EQUALIZE
ABCDEFBA		DEPLOYED	ABCDEFGA		EQUIPAGE
ABCDEFBA		DEPORTED	ABCDEFGA		EQUIVALE NT
ABCDEFBA		DETACHED	ABCDEFGA	D	ESIGNATE
ABCDEFBA		EMPLOYME NT	ABCDEFGA		EXCHANGE
ABCDEFBA		ENTRAINE D	ABCDEFGA		GROUPING
ABCDEFBA		REGISTER	ABCDEFGA		GUARDING
ABCDEFBA	P	ROJECTOR	ABCDEFGA		INSECURI TY
ABCDEFBAB		MEASUREME NT	ABCDEFGA	D	IPLOMATI C

MISCELLANEOUS PATTERNS—Continued

ABCDEFGA	E NTRUCKIN G
ABCDEFGA	NUMBERIN G
ABCDEFGA	OBJECTIO N
ABCDEFGA	OPERATIO N
ABCDEFGA	SOLDIERS
ABCDEFGA	DI SPATCHES
ABCDEFGA	WITHDRAW
ABCDEFGA	WITHDREW
ABCDEFGAB	D ESPATCHES
ABCDEFGAB	U NDERSTAND
ABCDEFGAB	WITHDRAWI NG
ABCDEFGABF	ENLISTMENT
ABCDEFGAC	I NSTRUMENT
ABCDEFGAC	F OUNDATION
ABCDEFGACB	I NSTRUMENTS
ABCDEFGAD	SOUTHEAST
ABCDEFGAD	SOUTHWEST
ABCDEFGADG	SOUTHWESTE RN
ABCDEFGAEHBC	CONSTRUCTION
ABCDEFGAFE	IMPRACTICA BLE
ABCDEFGAG	WITHDRAWA L
ABCDEFGAHB	INSPECTION
ABCDEFGAHCGIDE	RECONSTRUCTION
ABCDEFGBA	DESCRIBED
ABCDEFGBA	DESTROYED
ABCDEFGBA	DETRAINED
ABCDEFGBA	REMAINDER
ABCDEFGBA	TRANSPORT
ABCDEFGBACAHGD	TRANSPORTATION
ABCDEFGBAE	TRANSPORTS
ABCDEFGBHA	ESTABLISHE D
ABCDEFGBHIAKC	ESTABLISHMENT
ABCDEFGCAG	CONFIDENCE
ABCDEFGCHEA	RANGEFINDER
ABCDEFGDAHB	INSTRUCTION
ABCDEFGDAHBC	INSTRUCTIONS
ABCDEFGDBFHA	CE NTRALIZATION
ABCDEFGDHAIC	OBSTRUCTIONS

ABCDEFGDHFAE	ORGANIZATION
ABCDEFGEA	H EAVYBOMBE R
ABCDEFGEHA	D ESCRIPTIVE
ABCDEFGFABF	I NCOMPETENCE
ABCDEFGFAG	I NCOMPETENT
ABCDEFGGAG	H EAVYLOSSES
ABCDEFGHA	CONSPIRAC Y
ABCDEFGHA	DOMINATED
ABCDEFGHA	C ENTRALIZE
ABCDEFGHA	EXCLUSIVE
ABCDEFGHA	EXPANSIVE
ABCDEFGHA	EXPLOSIVE
ABCDEFGHA	MECHANISM
ABCDEFGHAB	C ONSUMPTION
ABCDEFGHADB	INFORMATION
ABCDEFGHAGC	CONVALESCEN T
ABCDEFGHBA	DESIGNATED
ABCDEFGHBA	DESPATCHED
ABCDEFGHBIKA	DISORGANIZED
ABCDEFGHCAEB	INTRODUCTION
ABCDEFGHCAEB	D ISCREPANCIES
ABCDEFGHDAB	C ONFIRMATION
ABCDEFGHDGCA	NORTHWESTERN
ABCDEFGHDIKA	REVOLUTIONAR Y
ABCDEFGHEEHA	COUNTERATTAC K
ABCDEFGHFA	D EMONSTRATE
ABCDEFGHFCAG	AGRICULTURAL
ABCDEFGHIA	DISPATCHED
ABCDEFGHIA	OBSERVATIO N
ABCDEFGHIA	SUBMARINES
ABCDEFGHIAB	C ONVERSATION
ABCDEFGHIAE	C OMPENSATION
ABCDEFGHIAF	R OADJUNCTION
ABCDEFGHIDAB	C ONSIDERATION
ABCDEFGHIFKA	SEARCHLIGHTS
ABCDEFGHIGBA	DEMONSTRATED
ABCDEFGHIJDA	SIMULTANEOUS

D DIGRAPHIC IDIOMORPHS GENERAL

			AB	AB				
–G	EN	ER	AL	AL	AR	M–		
		NE	ED	ED				
–P	RO	CE	ED	ED				
–S	UC	CE	ED	ED				
–D	ET	RA	IN	IN	G–			
		–L	IN	IN	G–			
		–M	IN	IN	G–			
	OB	TA	IN	IN	G–			
		QU	IN	IN	E–			
		RA	IN	IN	G–			
	RE	MA	IN	IN	G–			
		SH	IN	IN	G–			
	–T	RA	IN	IN	G–			
		CR	IS	IS				
PO	SI	TI	ON	ON				
		–A	RE	RE	EN	FO	RC	ED
		–A	SU	SU	AL			
		BO	TH	TH	E–			
		WI	TH	TH	E–			
	–P	AR	TI	TI	ON			
	RE	PE	TI	TI	ON			
			VI	VI	D–			

		AB	—	AB		
	–M	AI	NT	AI	N–	
	RE	AR	GU	AR	D–	
		CH	UR	CH		
		DE	CI	DE		
		DE	CO	DE		
		DI	VI	DI	NG	
	SP	EA	RH	EA	D–	
	–R	ED	UC	ED		
–S	CH	ED	UL	ED		
	–B	EE	NN	EE	DE	D–
		EM	BL	EM		
	AM	EN	DM	EN	T–	
CO	NT	EN	TM	EN	T–	
–S	EV	EN	TE	EN		
–S	EV	EN	TE	EN	TH	
		EN	TR	EN	CH	
		ER	AS	ER		

			AB	—	AB		
		TH	ER	EF	ER	EN	CE
		TH	ER	ES	ER	VE	
		WH	ER	EV	ER		
–C	AR	EL	ES	SN	ES	S–	
			GE	OR	GE		
		SC	hO	OL	HO	US	E–
–I	LL	UM	IN	AT	IN	G–	
			IN	CL	IN	E–	
	–F	IR	IN	GL	IN	E–	
		MA	IN	TA	IN		
–I	NF	AL	LI	BI	LI	TY	
		–A	ME	ND	ME	NT	
		SO	ME	TI	ME		
		–O	NE	NI	NE		
			NO	TK	NO	WN	
			NO	WK	NO	WN	
–A	PP	OI	NT	ME	NT		
–C	ON	TE	NT	ME	NT		
		–C	OM	PR	OM	IS	E–
		–P	ON	TO	ON		
	–T	HR	OU	GH	OU	T–	
		–N	OW	KN	OW	N–	
			PH	OS	PH	OR	US
			PO	ST	PO	NE	
	TR	OO	PS	HI	PS		
		PA	RA	PH	RA	SE	
		–P	RE	FE	RE	NC	E–
			RE	FE	RF	NC	E–
	–T	HE	RE	FO	RE		
		–P	RE	PA	RE		
			RE	TI	RE		
			RE	VE	RE	NT	
		–C	RO	SS	RO	AD	S–
CA	RE	LE	SS	NE	SS		
		AT	TE	MP	TE	D–	
			TH	AT	TH	E–	
	–F	OR	TH	WI	TH		
–I	NV	ES	TI	GA	TI	ON	
		ES	TI	MA	TI	ON	
	–D	ES	TI	NA	TI	ON	
		AC	TI	VI	TI	ES	
		–H	UM	DR	UM		

```
          AB — — AB

       -P|AN AM AC AN|AL
         |AR BI TR AR|Y-
         |AS SO ON AS|
       AC|CE PT AN CE|
         |EM PL AC EM|EN T-
 -Q UA RT|ER MA ST ER|
    -I NT|ER PR ET ER|
    -A CC|ES SO RI ES|
         |IN CL UD IN|G-
       -D|IR EC TF IR|E-
       TO|MO RR OW MO|RN IN G-
       PA|NA MA CA NA|L-
       -I|NT ER ME NT|
       -I|NT ER VE NT|IO N-
       CO|NT IN GE NT|
       -C|ON DI TI ON|
    -T OM|OR RO WM OR|NI NG
         |RA DI OG RA|M-
         |RE AS SU RE|
       -P|RE MA TU RE|
 -D EF EN|SI VE PO SI|TI ON
       IN|TE RD IC TE|D-
    QU AR|TE RM AS TE|R-
       IN|TE RP RE TE|R-
       IN|TE RR UP TE|D-
    -F OR|TI FI CA TI|ON
```

```
          AB — — — AB

         |AR MO RE DC AR|
         |EN FO RC EM EN|T-
       RE|EN FO RC EM EN|TS
         |IN DE TE RM IN|AT E-
         |IN TE RE ST IN|G-
         |IN TE RF ER IN|G-
         |IN TE RV EN IN|G-
       -I|NC OM PE TE NC|E-
       -C|ON GR ES SI ON|AL
    -D EM|ON ST RA TI ON|
       -C|ON SU MP TI ON|
         |PH OT OG RA PH|
         |TH IR TE EN TH|
```

```
     AB — — — — AB

  -I|NS TA LL AT IO NS|
  -C|ON CE NT RA TI ON|
  -C|ON FL AG RA TI ON|
  -C|ON SI DE RA TI ON|
```

```
      AB — AB AB

    |IN CL IN IN|G-
  MA|IN TA IN IN|G-
```

E DIGRAPHIC IDIOMORPHS PLAYFAIR

	AB BA	
SC	AB BA	RD
	AF FA	BL E–
	AF FA	IR
–B	AG GA	GE
–H AW	AI IA	N–
	AL LA	RE AS
–B	AL LA	ST
–F	AL LA	CY
IN ST	AL LA	TI ON S–
–P AR	AL LA	X–
	AP PA	RA TU S–
	AP PA	RE L–
	AP PA	RE NT
	AP PA	RE NT LY
	AR RA	NG E–
	AR RA	Y–
–B	AR RA	CK S–
–B	AR RA	GE
–E MB	AR RA	SX SE D–
–N	AR RA	TI ON
	AS SA	IL AN T–
	AS SA	UL T–
–A MB	AS SA	DO R–
–I MP	AS SA	BL E–
–M	AS SA	CR E–
–P	AS SA	GE
	AT TA	CH
	AT TA	CK
	AT TA	IN
–B	AT TA	LI ON
–R	AT TA	N–
	BO OB	YT RA P–
IN	DE ED	
–W	EB BE	D–
	EF FE	CT
	EF FE	CT IV E–
CO MP	EL LE	D–
–E XC	EL LE	NC E–
–E XC	EL LE	NT
–E XP	EL LE	D–
–I MP	EL LE	D–
–P	EL LE	T–
PR OP	EL LE	D–
–R EP	EL LE	D–

SH	EL LE	D–
–H	EM ME	DI N–
ST	EM ME	D–
ST	EP PE	D–
AV	ER RE	D–
CO NF	ER RE	D–
–I NT	ER RE	D–
–R EF	ER RE	D–
	ES SE	NC E–
	ES SE	NT IA L–
AD DR	ES SE	S–
–C OM PR	ES SE	D–
CO NF	ES SE	D–
IM PR	ES SE	D–
–L	ES SE	N–
–M	ES SE	NG ER
PR	ES SE	D–
PR OF	ES SE	D–
–P RO GR	ES SE	D–
–S TR	ES SE	D–
–S TR	ES SE	S–
–V	ES SE	L–
WI TN	ES SE	S–
AB	ET TE	D–
–C IG AR	ET TE	S–
–B	ET TE	R–
–L	ET TE	R–
–E IG	HT TH	RE E–
–R	IB BI	NG
FO RB	ID DI	NG
–D	IF FI	CU LT
–B	IL LI	ON
–F	IL LI	NG
–K	IL LI	NG
–M	IL LI	ME TE R–
–M	IL LI	NG
–M	IL LI	ON
SH	IL LI	NG
SP	IL LI	NG
–T	IL LI	NG
–W	IL LI	AM
–W	IL LI	NG
	IM MI	GR AN T–
	IM MI	GR AT IO N–

~~RESTRICTED~~

	AB BA	
	IM MI	NE NT
SW	IM MI	NG
-B EG	IN NI	NG
SP	IN NI	NG
-W	IN NI	NG
CL	IP PI	NG
SH	IP PI	NG
-S TR	IP PI	NG
	IR RI	GA TI ON
-M	IS SI	NG
-M	IS SI	ON
-A DM	IS SI	ON
EM	IS SI	ON
-H	IS SI	NG
PE RM	IS SI	ON
TR AN SM	IS SI	ON
EM	IT TI	NG
-F	IT TI	NG
-S PL	IT TI	NG
PE RM	IT TI	NG
-A FT ER	NO ON	
FO RE	NO ON	
	NO ON	TI ME
-F	OL LO	W-
-H	OL LO	W-
-C	OM MO	N-
-C	OM MO	TI ON
PO SI TI	ON NO	RT HO F-
-R EC	ON NO	IT ER
	OP PO	RT UN E-
	OP PO	RT UN IT Y-
	OP PO	SE
	OP PO	SI TE
	OP PO	SI TI ON
-C	OR RO	BO RA TE
-C	OR RO	DE
-T OM	OR RO	W-
-B	OT TO	M-
-C	OT TO	N-
CA	RE ER	
-S	UC CU	MB ED

	AB — BA	
PR	AC TI CA	BL E-
PR	AC TI CA	L-
-T	AC TI CA	L-
-D IV	EB OM BE	R-
	EN GI NE	ER
-G	EN UI NE	
-I NT	ER FE RE	
-I NT	ER FE RE	NC E-
-P EN	ET RA TE	
-R	EV OL VE	R-
	IN FI NI	TE
-D	IS PO SI	TI ON
-S	IT UA TI	ON
CA	NA DI AN	
VE TE RI	NA RI AN	
NI	NE TE EN	
NI	NE TE EN	TH
	PE RC EP	TI ON
-P	RE MI ER	
-S UR	RE ND ER	
-O UR	SE LV ES	
TH EM	SE LV ES	
DE	SE RV ES	
RE	SE RV ES	
	SE RV ES	

	AB	—	—	BA		
	DE	BA	RK	ED		
	DE	CL	AR	ED		
	DE	FE	ND	ED		
	DE	MA	ND	ED		
	DE	PA	RT	ED		
	DE	PL	OY	ED		
	DE	PO	RT	ED		
	DE	SE	RT	ED		
	DE	TA	CH	ED		
PR	EC	ED	EN	CE		
	EM	PL	OY	ME	NT	
	EN	TR	AI	NE	D–	
	ME	AS	UR	EM	EN	T–
	NE	GL	IG	EN	CE	
	NO	TA	TI	ON		
	PA	RA	GR	AP	H–	
	RE	CE	IV	ER		
	RE	CO	RD	ER		
	RE	GI	ST	ER		
	RE	PE	AT	ER		
	RE	PO	RT	ER		
	RE	VO	LV	ER		
–P	RO	JE	CT	OR		
AS	SE	MB	LI	ES		

	AB	—	—	—	BA	
	DE	SE	CR	AT	ED	
	DE	SI	GN	AT	ED	
	DE	SP	AT	CH	ED	
	EN	EM	YP	LA	NE	S–
–D	ET	ER	IO	RA	TE	
–S	EV	EN	TY	FI	VE	
	IR	RE	GU	LA	RI	TY
	NO	MI	NA	TI	ON	
	SU	SP	IC	IO	US	

AB	—	—	—	—	BA
DE	MO	NS	TR	AT	ED
NO	TI	FI	CA	TI	ON

F. DIGRAPHIC IDIOMORPHS: FOUR-SQUARE[1]

(Grouped by number of significant letters in the idiomorphic pattern)

Two letters

```
            A- A-
   B LO CK AD ED
      I NV AD ED
         D AM AG E
      CO MM AN DS
      I SL AN DS
   A IR PL AN ES
E NE MY PL AN ES
   DE SI GN AT ED
   E ST IM AT ED
   I ND IC AT ED
         C AV AL RY
         N AV AL
      P RO CE DU RE
         ME CH AN IZ ED
      IM ME DI AT EL Y
      WI TH DR AW
      WI TH DR EW
            EM ER GE NC Y
   L IE UT EN AN T
            FI FT EE N
            FI FT H
            FI FT Y
      BR ID GE HE AD
         V IC IN IT Y
         W IT HD RA W
      A DD IT IO NA L
   A MM UN IT IO N
      CO ND IT IO N
   RE CO GN IT IO N
         E LE ME NT
            MI LI TA RY
            MI NI MU M
            NI NT H
         P OI NT
         T OM OR RO W
            PO NT ON
            RE QU ES T
            RE QU IR E
         P RI SO NE R
         RE SI ST AN CE
   D IS PO SI TI ON
         PO SI TI ON
            SO UT H
```

```
         A- A-
         SQ UA DR ON
   FI GH TE RP LA NE
      MO TO RI ZE D
D EP AR TU RE
         UN US UA L

      A- -- A-
   S AB OT AG E
D ET AC HM EN T
   H AS BE EN
      BA TT AL IO N
      BO MB ED
      CA SU AL TI ES
      CA SU AL TY
      CO MB AT
      CO OR DI NA TE S
      DI RE CT IO N
      DI SP AT CH
   ME DI UM BO MB ER
      DI VE BO MB ER
R OA DJ UN CT IO N
   R EP LA CE ME NT
   R ET RE AT
   S EV ER AL
   JU NC TI ON
   CO NF IR MA TI ON
   I NF OR MA TI ON
   I NT EL LI GE NC E
      PA TR OL
      SA BO TA GE
      SE VE RE
   AC TI VI TY
   A TT EN TI ON
   S UC CE SS FU LL Y

      A- -- -- A-
      AR TI LL ER Y
      AT TA CK ED
   R EE NF OR CE
   R EE NF OR CE ME NT
      ID EN TI FY
      IM PA SS IB LE
      IM PO SS IB LE
```

```
      A- -- -- A-
      MO VE ME NT
   E MP LA CE ME NT
      PE RS ON NE L
   A RT IL LE RY

      A- -- -- -- A-
      CO MM UN IC AT IO NS
      CO NC EN TR AT E
   R EO PG AN IZ AT IO N
      LI EU TE NA NT
   CO NS TR UC TI ON

      A- -- -- -- -- A-
      CO MM IS SI ON ED

            -B -B
         UN AB LE
      OB ST AC LE
            AD VA NC E
            AG AI NS T
         R AI LH EA D
      PR EP AR AT IO N
      A SS AU LT
      B OM BA RD
      A IR BO RN E
      S EA BO RN E
   A DV AN CI NG
         VI CI NI TY
            DE TA CH
            DE TA CH ME NT
      H AV EB EE N
      M OV EM EN T
            EN EM Y
         R ES ER VE
         R ET UR N
            FL AN K
            FO LL OW
      B AG GA GE
            HA SB EE N
A PP RO AC HI NG
   DE BO UC HI NG
   L AU NC HI NG
   I MM ED IA TE LY
```

[1] See subpar. ___, Section IX.

Two letters (cont.)

```
         -B -B
   IN IT IA TE
       F IF TH
   TE RR IT OR Y
       S IX TY
 M IS CE LL AN EO US
       E LE VA TI ON
       E LE VE N
         LI AI SO N
      DA MA GE
         MO RN IN G
       U NU SU AL
         OB JE CT IV E
       C OL ON
       C OL ON EL
SU PE RI OR IT Y
       M OT OR IZ ED
         OU TS KI RT S
   EQ UI PM EN T
    A VE RA GE
    B AR RA GE
      AI RC RA FT
AN TI AI RC RA FT
         RE MA IN
 R EQ UI RE ME NT
    M IS SI NG
```

```
         -B -B
    P ER SO NN EL
ES TI MA TE DA T
    P LA TO ON
       S UP PL Y
       S UP PO RT
      NA VA LB AS E
    F OR WA RD
   WI ND WA RD

         -B -- -B
       C AS UA LT Y
       P AT RO LS
 B AT TL ES HI PS
         GE NE RA L
    W IL LA TT AC K
    T RA NS MI SS IO N
    R EC OG NI TI ON
    T RO OP SH IP
         RE GI ME NT
      CA RR IE RS
      MI SS IO NS
         TW EN TY
    R EQ UE ST ED
```

```
   -B -- -- -B
 I DE NT IF IC AT IO N
 M EC HA NI ZE D
 D EP LO YM EN T
 M ES SE NG ER
 D ES TR OY ER
 A IR SU PP OR T
 V IS IB IL IT Y
   ME SS EN GE R
 I MP AS SI BL E
 I MP OS SI BL E
 A NT IA IR CR AF T
 C OM MA ND IN G
   OP ER AT IO N
   PR IS ON ER
   PR OC ED UR E
   RE EN FO RC E
   TR AN SP OR TA TI ON
   YE ST ER DA Y

       -B -- -- -- -B
     R EC OM ME ND ED
       HE AV YL OS SE S
 R EC OM ME ND AT IO N
     C OM MU NI CA TI ON
 R EC ON NO IT ER IN G
```

Three letters

```
         A- A- A-
       N AV AL BA SE
    R EQ UI SI TI ON
```

```
A- A- -- A-
RE QU ES TE D
```

```
       -B -B -B
  B OM BA RD ME NT
       EL EM EN TS
    EN GA GE ME NT
```

Four letters

```
   AB A- -B
 H EA DQ UA RT ER S
   EL EV EN

   AB -B A-
   CA NC EL
RE CO NN AI SS AN CE

   AB -B -- A-
   AD VA NC ED
   EN EM YT AN KS

   AB -- A- -B
   SI GH TI NG
```

```
   A- AB -B
   AD DI TI ON AL

   A- AB -- -B
   SO UT HW ES T

   A- A- -B -B
 W IT HD RA WA L

   A- A- -- A- A-
   CO MM AN DI NG

   A- A- -- -B -B
   RE QU IR EM EN T
```

```
     A- -B AB
   M OR NI NG
   P OS TP ON E

     A- -B -B -- A-
     RE CO NN OI TE R

     A- -B -- AB
     IN TE RD IC T

     A- -B -- A- -B
   S AT IS FA CT OR Y

     A- -- A- C- C-
     DI SP AT CH ES
```

Four letters (cont.)

```
A- -- -- C- A- C-
RO AD JU NC TI ON
```

```
      -B AB A-
DI SP OS IT IO N
    P OS IT IO N
      PR ES EN T
   RE PR ES EN T
```

```
   -B A- AB
RE PE AT ED
```

```
   -B A- A- -B
   DE ST RO YE R
```

```
   -B A- -B -- A-
   UN ID EN TI FI ED
```

```
  -B A- -- AB
U NS UC CE SS FU L
```

```
-B A- -- A- -B
ME DI UM BO MB ER
```

```
-B A- -- -B A-
VI SI BI LI TY
```

```
-B A- -- -- AB
IN FO RM AT IO N
```

```
-B A- -- -- A- -B
IN ST AL LA TI ON
```

```
-B -D -B -- -D
CR OS SR OA DS
```

```
   -B -D -D -B
AI RS UP PO RT
```

```
   -B -D -- -D -B
   IN ST RU CT IO N
 C ON ST RU CT IO N
```

```
            -B -- A- AB
 F IG HT ER PL AN ES
```

```
   -B -- A- -- -- AB
 E ST AB LI SH ME NT
```

```
   -B -- -B A- A-
   EN CO UN TE RE D
```

```
   -B -- -- -B -D -D
   RE IN FO RC EM EN T
```

Five letters

```
     A- -B AB -- -B
     NA VA LA TT AC K

     A- -B -- -B AB
R EC ON NA IS SA NC E
```

```
   -B A- A- -- AB
   DI ST RI BU TI ON

   -B A- -B AB
RE PL AC EM EN T
```

```
-B -D -- -D -B -D
IN ST RU CT IO NS
```

Six letters

```
  AB CB C- A-
P OS IT IO NS

  AB -D -D AB
C ON DI TI ON
  RA DI OG RA M
```

```
     A- A- -B AB A-
     RE QU IS IT IO N

     A- CB -- A- CB
Q UA RT ER MA ST ER

     A- CB -- CB A-
     SC HO OL HO US E
```

```
  A- -- CB A- -- CB
  ID EN TI FI CA TI ON

  -B AE AD -D
A DM IN IS TR AT IV E
```

Seven letters

```
-B AD -- -B -D AD
RE EN FO RC EM EN T
```

Eight letters

```
AB -B AD -- -B AD
QU AR TE RM AS TE R
```

```
AB -B C- AB CB
EM PL AC EM EN T
```

```
AB -D C- AD C- -B
IN TE RD IC TI ON
```

(BLANK)

APPENDIX 4

SERVICE TERMINOLOGY & STEREOTYPES

Familiarity with the style and peculiar phraseology which exist in military messages greatly facilitates the cryptanalytic recovery of the plain text of any such messages which have been encrypted. Thus, this appendix has been compiled to comprise notes on those idiosyncrasies present in military messages which are of particular interest and aid to the cryptanalyst. The notes which are applicable to the messages of all Services are grouped together in Section A, those which are applicable to messages of ground, naval, and air origin, respectively, constitute Sections B, C, and D; those which apply to special types of messages, such as weather messages, are contained in Section E; and remarks on stereotypic beginnings and endings of messages comprise Section F.

Although the notes contained herein derive primarily from U. S. military communications, many apply as well to the military communications of other countries. At the very least, this appendix indicates the types of information on message style and phraseology which, when known concerning the messages of any source, can be quite helpful in the cryptanalysis of such messages.

A. REMARKS APPLICABLE TO MESSAGES OF ALL SERVICES

1. When mention is made of time in military messages, it is conventionally specified in terms of the 24-hour clock system (ending at midnight), in which time is expressed as a group of four numerals. The first two numerals of the group denote the hour and the last two numerals, the minute after the hour; for example, 6:00 AM appears as 0600 and 6:00 PM appears as 1800. For any current month, the day may be indicated by prefixing the four-digit time group with a two-digit date group, indicating the day of the month; for example, 080600 denotes 6:00 AM on the 8th day of the month. In some instances, a four-digit time group or six-digit date-time group occurring in a message may be found with a literal suffix, giving rise to such groups as 1800Z, 080600Q, etc; this suffix may be any one of the letters A to I or K to Z and is a type of designator used in communications practices to refer to a particular one of the 24 time zones of the earth.

2. Administrative messages in general often contain many sequences of numbers, brought about by numerous references to previous messages and to various Service regulations (among other items), reference generally being made on the basis of identifying serial numbers and dates which such items usually bear; specific illustrations of this fact appear in several of the succeeding paragraphs in this appendix. Furthermore, administrative messages contain references to items having literal designations; to minimize errors in this connection such designations are often spelled out phonetically, by means of a phonetic alphabet, such as one of the following:

ABLE
BAKER
CHARLIE
DOG
EASY
FOX
GEORGE
HOW
ITEM
JIG
KING
LOVE
MIKE
NAN
OBOE
PETER
QUEEN
ROGER
SUGAR
TARE
UNCLE
VICTOR
WILLIAM
XRAY
YOKE
ZEBRA

ALFA
BRAVO
COCA
DELTA
ECHO
FOXTROT
GOLF
HOTEL
INDIA
JULIETT
KILO
LIMA
METRO
NECTAR
OSCAR
PAPA
QUEBEC
ROMEO
SIERRA
TANGO
UNION
VICTOR
WHISKEY
EXTRA
YANKEE
ZULU

3. The messages of all Services exhibit a high content of abbreviations; for this reason, the following list of frequently-encountered abbreviations is included:

NAVY OFFICER RANKS

FADM....fleet admiral
ADM.....admiral
VADM....vice admiral
RADM....rear admiral
COMO....commodore
CAPT....captain
CDR.....commander
LCDR....lt. commander
LT......lieutenant
LTJG....lieut. jr. grade
ENS.....ensign

ARMY, AIR OFFICER RANKS

GEN......general
LTGEN....lt. general
MAJGEN...major general
BRIGGEN..brigadier general
COL......colonel
LTCOL....lt. colonel
MAJ......major
CAPT.....captain
1ST LT...first lieutenant
2ND LT...second lieutenant

PUNCTUATION	MISCELLANEOUS	
CLN...colon	CG....commanding general	HQ...headquarters
CMA...comma	CO....commanding officer	LAT..latitude
PARA..paragraph	COM...commander	LONG.longitude
PAREN.parenthesis	COMDT.commandant	LTR..letter
PD....period	DET...detachment	MSG..message
RPT...repeat	ETA...estimated time of arrival	NR...number
	ETD...estimated time of departure	RE...reference
	GMT...Greenwich mean time	UR...your

4. The identity of the person originating a military message may appear as a signature at the end of a message and the addressee's identity may appear at the beginning; or either, or both, of these may be "buried" in the middle of the message, set off by parentheses. If the signature is at the end of the message, it may be preceded by STOP (or PERIOD or SIGNED, or both. The identification of the originator or addressee may consist merely of his command designation (e.g., COMMANDING GENERAL, FIRST ARMY) or it may consist of his name and rank, followed by COMMANDING or some other appropriate amplifying data (e.g., in the Army, his branch of service).

Examples:

JONES, COLONEL, ARTILLERY

COMMANDING OFFICER, THIRD REGIMENT

COMMANDER, DESTROYER SQUADRON SIX

SMITH, FLIGHT LEADER, SECOND SQUADRON

5. In military communications, long messages are often broken into parts, each part subsequently being treated as a separate message. Thus, messages arise which begin "PART (number) OF (number) PARTS", or "(number) PART MESSAGE PART (number)", often separated from the following message text by STOP or simply by an "X".

B. REMARKS ON ITEMS APPEARING IN GROUND (ARMY) MESSAGES

1. When mention of an army unit appears in a military message, its size (echelon) is indicated, generally preceded by a numerical or literal designation and, as further information concerning the unit, its branch of service may be included. The several echelons of the U. S. Army, listed in descending order of size, are: army, corps, division (DIV), brigade, regiment (REGT), battalion (BN), company[1] (CO), platoon. Some of the branches of service which may appear, as mentioned above, are: Infantry (INF), Artillery (ARTY), Signal Corps (SIG C), Armor, Ordnance (ORD), Engineers (ENG), Quartermaster (QM).

Examples of unit designations:

(a) "A" Company, 39th Infantry Regiment, 9th Infantry Division

[1] An artillery unit at this echelon is termed a battery.

(b) 1st Armored Division

(c) 57th Signal Battalion

2. In connection with 1, above, an army is the normal command of a general (four stars); a corps being the command of a lieutenant general, a division, the command of a major general; and a brigade, the command of a brigadier general. A regiment is normally commanded by a colonel, a battalion may be commanded by a lieutenant colonel or a major; a company, by a captain, and a platoon, by a lieutenant.

3. For reference purposes, when giving locations of units, readily-recognizable landmarks such as hills, crossroads and road junctions may be referred to in terms of their altitude above sea level (in number of feet), if such landmarks do not bear proper names which are suitable for the purpose. Thus, a reference, in a military message, to CROSSROADS SIX FIVE ZERO would apply to that particular crossroads within a preselected area which is located at an altitude of 650 feet. If, within any preselected area of reference, there are two or more landmarks of any given type which are both at the same altitude, it is necessary to affix a distinctive letter or number to the altitude designation of each, in order to clearly identify a particular one, thus, such a reference as CROSSROADS SIX FIVE ZERO DASH /hyphen/ B may be encountered. In this connection, CROSSROADS may be found abbreviated as "CR", and ROADJUNCTION as "RJ".

4. The location of any particular unit may be specified in terms of its location with respect to a particular place or locality, or to a particular landmark. However, its location may also be specified by stating how it is located on a specific map or portion of a map. This gives rise in military messages to phrases such as COORDINATES ONE FIVE POINT TWO FOUR DASH ONE NINE FOUR POINT SEVEN, wherein the numbers before the "dash" indicate the unit's location with respect to the horizontal grid lines of a preselected map and the numbers after the "dash" indicate its location with respect to the vertical grid lines.

5. Specific highways, turnpikes, and other roadways are often identified in military messages by stating the place names of their terminal points; thus the highway running between Grizurbeto and Bolzano could be called the GRIZURBETO DASH /hyphen/ BOLZANO HIGHWAY. Similarly, when reference is made to an imaginary straight line across the terrain in a particular area, such a line may be identified by specifying any recognizable landmarks between which the line runs, for example, LINE CROSSROADS THREE ONE FIVE DASH ROADJUNCTION TWO NINE EIGHT.

6. Included below is a brief list of frequent words appearing in low-echelon ground traffic, the abbreviation for certain ones are appended in parentheses after them. In addition to the words listed below, numbers and ranks/titles will be found to have a high frequency of occurrence.

ACROSS
ACTIVITY
ADDITIONAL
ADVANCE
ADVISE
AFTERNOON
AIRPLANE
AMMUNITION (AMMO)
AREA

ARMORED
ARMY
ARRIVE
ARTILLERY (ARTY)
ATTACK
BARRAGE
BATTALION (BN)
BRIDGE
CAPTURE
CASUALTIES
COMMA
COMMAND POST (CP)
COMMUNICATION (COMM)
COMPANY (CO)
CONCENTRATION
COUNTERATTACK
CROSSROADS (CR)
DAILY
DASH
DEFEND
DEFENSIVE
DISPOSITION
DIVISION (DIV)
EAST
EMPLACEMENTS
ENEMY
ENLISTED PERSONNEL
FIRE
FLANK
FORCE
FROM (FM)
HEADQUARTERS (HQ)
HEAVY
HILL
HOSTILE
IDENTIFICATION (IDENT)
IMMEDIATELY
INFANTRY (INF)
INFORMATION (INFO)
LARGE
LEFT
LIGHT
LINE
LOCATION
MACHINEGUN (MG)
MESSAGE (MSG)
MORNING
MORTAR
MOUNTAIN
MOVE
MOVEMENT
NEAR
NEUTRALIZE
NIGHT
NORTH
NOTHING
OBJECTIVE
OFFENSIVE
OFFICER
ORDER
PATROL
PLANE
POSITION
PREPARE
PRISONER
PROCEED
RADIO
RAILROAD
READY
RECEIVE
RECONNAISSANCE (RCN)
REFERENCE (RE) (REF)
REGIMENT (REGT)
REINFORCEMENTS
REPORTS
REQUEST
REQUIRE
REQUISITION
RESERVES
RIGHT
RIVER
ROAD
ROADJUNCTION (RJ)
ROCKET
SEND
SMALL
SOUTH
STOP
SUPPLY
SUPPORT
TANKS
TODAY
TOMORROW
TONIGHT
TROOPS
VICINITY
WEST
WOODS
YESTERDAY

C. REMARKS ON ITEMS APPEARING IN NAVAL MESSAGES

1. Mention of various sized groupings of vessels are found in messages of naval origin, among which those mentioned below are quite frequently encountered. A major naval force is called a fleet, and the levels of echelonment (or subdivision) within a fleet are the task force, task group, and task unit (in descending order of size). The basic unit of all fleet vessels is termed a division, and is comprised of two or more vessels of the same type; in this connection, when mention is made of a division in a naval message, the particular type of vessel of which the division is made up is often specified; for example, CRUISER DIVISION. A squadron is made up of two or more divisions of submarines, destroyers, landing ships or other light vessels, and a flotilla comprises two or more such squadrons.

2. In connection with 1, above, a fleet is normally commanded by an admiral (four stars), a task force being the command of a vice admiral; and a task group, the command of a rear admiral. Furthermore, in time of war the officer in command of a convoy or flotilla often holds the rank of commodore; the officer commanding an individual ship may range in rank from captain on down, depending on the type of ship.

3. A list of the main combat vessels is included below, the approximate maximum speed of each, which is expressed in KNOTS, is shown in parentheses.

BATTLESHIP	(35)
CARRIER	(35)
CARRIER ESCORT	(15)
CRUISER	(30)
DESTROYER	(35)
DESTROYER ESCORT	(25)
SUBMARINE	(20, on surface; 10, submerged)

When a particular vessel is mentioned in a naval message, it may be identified by a numerical designation, by a group of letters, or by some proper name.

4. In naval messages, the direction of an object from a ship, or the course of a particular naval vessel or unit at sea is given as a compass bearing expressed in degrees (from 0 to 359), for example, BEARING ZERO EIGHT FIVE. In some instances the statement of a bearing will be followed by the word TRUE or MAGNETIC, indicating that the bearing is measured from the geographical pole (true north) or the magnetic pole (not corrected for variation), respectively.

5. The position of a particular naval vessel or unit at sea may be specified in a naval message by stating its latitude and longitude in degrees and minutes. The latitude may be from 0 to 90 degrees and the longitude from 0 to 180 degrees, a specified latitude is generally followed by NORTH or SOUTH (as appropriate) and, similarly, longitude is followed by EAST or WEST. For example, LATITUDE THREE ZERO DEGREES TWO ONE MINUTES NORTH LONGITUDE ONE FOUR TWO DEGREES ONE SIX MINUTES WEST, or more briefly LATITUDE THREE ZERO DASH TWO ONE NORTH LONGITUDE ONE FOUR TWO DASH ONE SIX WEST. If position is stated in conjunction with a bearing, it is not necessary to state both latitude and longitude, and the location, NORTH or SOUTH, with respect to the equator or EAST or WEST with respect to Greenwich Meridian may be found omitted where no ambiguity arises. Positions are also sometimes given as a bearing and distance in miles from a specific point.

6. The following words may be expected to appear frequently in a selection of naval messages of various types:

AIRCRAFT
ALTITUDE
BEACH
BLOCKADE
BOMBED
CARGO
CHANNEL
COASTAL
COMMAND
CONTACT
CONVOY
CORRECTED
COURSE
CRAFT
DEPART
DEPLOY
EMBARK
ESCORT
EXECUTE
FLEET
FLIGHT
FORMATION
FUEL
GUARDING
HARBOR
KNOTS
LATITUDE
LONGITUDE
MILES
MINE (FIELD)
MISSION
NAVAL
NAVY
OPERATIONS
PILOT
PORT
RADAR
REJOIN
RENDEZVOUS
SAIL
SEA
SHIFT
SHIP
SORTY
SQUADRON
STARBOARD
STRAFED
STRAIT
TARGET
VESSELS
VIA
VOYAGE
WEATHER

D. REMARKS ON ITEMS APPEARING IN AIR MESSAGES

1. The various elements of which an air force is composed and which may be mentioned in air messages are given below. The smallest grouping of aircraft, composed of one or more aircraft of a particular type, is called a flight. A squadron is two or more flights of the same type; a group is made up of two or more squadrons, a wing comprises two or more groups, an air division is composed of two or more wings, and two or more divisions constitute an air force.

2. In connection with 1, above, a flight is usually commanded by a major, a squadron being the command of a lieut. colonel, a group being the command of a colonel, a wing, the command of a brigadier general; and an air force, the command of a major general.

3. Some of the types of aircraft which may be mentioned frequently in air messages are listed below, an indication of the range of speed of each type, expressed in KNOTS, is shown in parentheses.

BOMBER	(250-400)
CARGO PLANE	(150-350)
FIGHTER	(250-500)
JET BOMBER	(350-600)
JET FIGHTER	(250-500)
LIAISON PLANE	(65-150)

4. The position of a particular aircraft may be specified in an air message by stating its latitude and longitude in degrees and minutes, sometimes in conjunction with its altitude in feet. (Latitude may be from 0 to 90 degrees and longitude from 0 to 180 degrees.)

E. REMARKS ON SPECIAL TYPES OF MESSAGES

1. Weather messages. Any generalization on the specific elements which a weather message will contain would perforce be rather tenuous, the contents of a particular weather message generally being dependent on its source and purpose. However, there are certain elements which may be expected to appear in most weather messages, these are listed below with an indication of the terms in which each is generally expressed:

a. Identification of the originating station (by code number, or location).

b. Wind speed (knots) and direction (tens of degrees, from 00-36).

c. Amount of low clouds (tenths of sky covered) and their height (hundreds of feet).

d. Types of low, medium, and high clouds (e.g., cumulus, stratus, cirrus, etc.).

e. Temperature of the air and temperature of the dew point (both in degrees Fahrenheit).

f. Present and past weather (e.g., clear, partly cloudy, cloudy or overcast, fog, drizzle, rain, snow, showers, thunderstorm, etc.).

g. Horizontal visibility (miles).

h. Atmospheric pressure (tens, units, and tenths digits in millibars) and barometric tendency (e.g., falling, steady, rising, etc.)

2. Air-to-ground position reports. Position reports made by aircraft in flight may be expected to contain the majority of the following elements of information:

a. Position of the aircraft (in latitude and longitude or with respect to some locality on the ground).

b. Time.

c. Speed.

d. Altitude.

e. Weather conditions.

f. Estimated time of arrival at next reporting point or at destination.

F. STEREOTYPIC BEGINNINGS AND ENDINGS

Within the confines of the comparatively limited scope of military messages, stereotypy of phraseology is inevitable. Particularly in the beginnings of messages is this limitation apparent; thus these positions lend themselves most readily to attack by the cryptanalyst. The following list of stereotypes have a high frequency of positional occurrence, and therefore may provide a fruitful source for cribs. It is to be noted that a stereotypic initial word often may suggest a whole opening phrase. For example, if a message of low-echelon ground origin begins with the word HEAVY, then it is not too unlikely that the opening phrase is "HEAVY ARTILLERY (FIRE, BARRAGE) (FALLING, INTERDICTING)....," which might be expanded into "HEAVY ARTILLERY FIRE FALLING ON OUR POSITIONS (NORTH, EAST, SOUTH, WEST) OF...."

BEGINNINGS

ACKNOWLEDGE
ADVANCE
ADVISE (THIS COMMAND)
(THIS HEADQUARTERS)
ARRIVE
ATTACK
ATTENTION
CANCEL
CITE
COMMANDING (GENERAL)
COMMUNICATION (OFFICER)
CONCENTRATE (-ION OF)
CONFIRM
CONTINUE
DEPART (-URE)
DISCONTINUE
EFFECTIVE
ENEMY
EQUIPMENT
EXPEDITE (SHIPMENT)
FOLLOWING (ARE) (IS)
FOR
FROM
HEAVY
HOSTILE
INFORM (-ATION)
IN REPLY (TO YOUR) (MESSAGE)
LOCATION (OF)

NUMBERS (1, 1st, 2, 2d, etc.)
ORDERS
OUR
PARAPHRASE
PLEASE
POSITION
PREPARE (TO) (-ATIONS FOR)
PROCEED
RECEIPT
RECEIVE
RECOMMEND (-ATION) (-ED)
REFER (-RING) (TO) (YOUR)
REFERENCE (YOUR, MY) (MESSAGE, RADIOGRAM, TELEGRAM) (NUMBER) (DATED, OF)
REPEAT
REPORT
REQUEST
REQUIRE
RERAD
REURAD
SEND
SITUATION REPORT
STATUS REPORT
SUPPLY
VERIFY
YOUR (COMMAND) (ORGANIZATION)

ENDINGS

ACKNOWLEDGE
ADVISE (IMMEDIATELY)
CONFIRM
END
END OF MESSAGE
IMMEDIATELY
NUMBERS (1, 1st, 2, 2d, etc.)

PERIOD
REPLY
REFERENCE
REQUESTED
SIGNED (NAME)
STOP
TITLES (MAJ, COL, etc.)

(BLANK)

APPENDIX 5

LETTER FREQUENCY DATA - FOREIGN LANGUAGES

The letter frequency data contained herein has been compiled from selected newspaper and magazine articles comprising war communiqués and other military-type text. In the material which was processed there were place names and words foreign to each particular language, these words account for the presence of certain non-characteristic letters in the data given herein for those languages which make use of the Roman alphabet.

A. GERMAN LETTER FREQUENCY DATA

1-a. Absolute frequencies of single letters of German plain text, arranged alphabetically, based on 60,046 letters of text. (The letters X and Y are derived from foreign words contained in German plain text).

A	3,601	G	1,921	L	1,988	Q	6	V	523
B	1,023	H	2,477	M	1,360	R	4,339	W	899
C	1,620	I	4,879	N	6,336	S	4,127	X	12
D	3,248	J	192	O	1,635	T	3,447	Y	24
E	10,778	K	747	P	499	U	2,753	Z	654
F	958								
									60,046

1-b. Monographic kappa plain, German language = .0787

1-c. Frequency distribution of single letters based on 60,046 letters of German plain text, reduced to 1,000 letters, arranged according to their relative frequencies.

E	180	T	57	G	32	F	16	P	8
N	106	D	54	O	27	W	15	J	3
I	81	U	46	C	27	K	13	Y	-
R	72	H	41	M	23	Z	11	X	-
S	69	L	33	B	17	V	9	Q	-
A	60								
									1,000

1-d. Percentage of vowels, high-frequency consonants, medium frequency consonants, and low-frequency consonants in 60,046 letters of German plain text. Percentage of 8 most frequent letters in German plain text.

Vowels A,E,I,O,U, and Y = 39.4%
High-Frequency Consonants D,N,R,S, and T = 35.8%
Medium-Frequency Consonants B,C,F,G,H,L,M, and W = 20.4%
Low-Frequency Consonants J,K,P,Q,V,X, and Z = 4.4%

(In descending order of frequency)

8 most frequent letters E,N,I,R,S,A,T, and D = 67.9%

1-e. Absolute frequencies of single letters as initial letters of 9,568 words in German plain text, arranged according to their frequencies.

D	1,716	U	550	Z	343	K	263	O	135
A	762	N	544	M	339	P	181	T	106
S	698	G	461	N	306	R	167	E	22
E	686	B	460	F	280	L	158	Q	2
I	581	V	408	H	265	J	135		
									9,568

2-a. Frequency distribution of digraphs based on 60,046 letters of German plain text, reduced to 5,000 digraphs.

1st Letter	2d Letter																									
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	4	14	10	4	33	7	9	7	1	1	2	33	13	48		2		22	27	23	36	1	1			1
B	6				48		1	1	5			3			3			11	2	1	3		1			1
C								130			5															
D	29	2		8	127	1	2	2	60		1	3	2	2	4	1		5	6	2	9	2	2			2
E	13	22	10	31	13	12	32	24	90	2	6	28	25	235	3	6		195	68	28	24	9	15			7
F	7	1		3	15	7	2		2			2	1	1	3			10	2	10	12					
G	10	1		8	78	1	2	2	8		2	7	1	3	1			11	8	5	8	2	1			1
H	29	1		8	64	1	2	1	14		2	8	3	6	6	1		20	4	23	7	2	3			1
I	3	1	39	7	91	2	18	7	2		7	12	11	84	13	1		7	53	44	1	2	1			1
J	4				8																3					
K	12	1		1	11		1	1	1			5			9			10	1	5	4					
L	26	3	1	6	27	1	2		37		3	20	1	2	4				10	12	6	1				1
M	16	3		4	26	2	2	1	14	1	2	1	11	1	8	5		1	3	3	9	1	1			1
N	39	12	1	118	58	9	57	8	35	4	10	6	10	18	8	5		4	36	27	20	10	17			14
O	1	3	5	5	11	3	3	3			1	18	6	33	1	5		18	12	4	1	1	5			1
P	10				5	4		1	2			1			7	2		7		1	1					
Q																					1					
R	34	11	5	35	60	9	12	9	37	2	11	6	8	12	19	3		6	22	18	26	6	8			5
S	14	6	55	13	46	3	7	3	30	1	5	4	7	3	16	6		2	40	57	9	5	5		1	5
T	25	3		17	88	2	4	6	40	1	3	7	3	4	4			14	20	7	16	2	10			13
U	1	2	8	2	37	15	5	1			2	2	11	76		2		18	28	14	1	1	2			1
V	1				19				3						21											
W	16				24				20	3					6						6					
X																										
Y																										
Z	1			1	8				5			1			2					4	27		4			

2-b. Digraphic kappa plain, German language = .0111

2-c. The 95 digraphs comprising 75% of German plain text, based on the table of 5,000 digraphs (Item 2-a), arranged according to their relative frequencies.

EN	235	RE	60	NA	39	ED	31	TA	25	HR	20	TU	16
ER	195	DI	60	LI	37	SI	30	EM	25	LL	20	WA	16
CH	130	NE	58	UE	37	HA	29	EH	24	VE	19	UF	15
DE	127	NG	57	RI	37	DA	29	EU	24	RO	19	FE	15
ND	118	ST	57	AU	36	EL	28	WE	24	OR	18	EW	15
IE	91	SC	55	NS	36	US	28	HT	23	UR	18	AB	14
EI	90	IS	53	NI	35	ET	28	AT	23	NN	18	HI	14
TE	88	BE	48	RD	35	AS	27	AR	22	RT	18	TR	14
IN	84	AN	48	RA	34	LE	27	RS	22	OL	18	SA	14
GE	78[1]	SE	46	AE	33	NT	27	EB	22	IG	18	MI	14
	1236	IT	44		2508[2]	ZU	27	VO	21	NW	17	NZ	14
UN	76	SS	40	ON	33	LA	26	NU	20	TD	17	UT	14
ES	68	TI	40	AL	33	ME	26	WI	20	MA	16	SD	13
HE	64	IC	39	EG	32	RU	26	TS	20	SO	16		3750

2-d. Frequent digraphs in German plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

EN	235	NE	58	IE	91	EI	90	ES	68	SE	46	AN	48	NA	39
ER	195	RE	60	IN	84	NI	35	IS	53	SI	30	IT	44	TI	40
DE	127	ED	31	GE	78	EG	32								

2-e. Frequent digraphs in German plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

CH	130	HC	0	ND	113	DN	2	NG	57	GN	3	SC	55	CS	0

2-f. Doublets occurring in German plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

SS	40	EE	13	FF	7	RR	6	GG	2	PP	2	OO	1
LL	20	MM	11	TT	7	AA	4	II	2	HH	1	UU	1
NN	18	DD	8										

2-g. The 22 digraphs appearing 100 or more times as beginnings of words in 9,568 words in German plain text, arranged according to their absolute frequencies.

DE	805	EI	300	DA	244	WE	192	ER	153	ZU	124	ST	112
DI	567	GE	299	VO	214	VE	172	HA	140	MI	117	IN	111
UN	428	BE	252	SI	197	WI	155	AL	134	SN	112	SE	111
AU	318												

[1] The 10 digraphs above this line compose 25% of German plain text.

[2] The 37 digraphs above this line compose 50% of German plain text.

3-a. The 102 trigraphs appearing 100 or more times in 60,046 letters of German plain text, arranged according to their absolute frequencies.

SCH	666	ERE	313	NEN	198	AUS	162	IST	142	HRE	124	FAU	108
DER	602	ENS	270	SSE	191	TIS	159	STA	141	HER	122	TSC	107
CHE	599	CHT	264	KEI	190	BER	157	DES	140	ACH	119	ENN	106
DIE	564	NGE	263	TER	188	ENI	157	FUE	139	GES	118	ERG	106
NDE	541	NDI	259	REN	185	ENG	155	NTE	139	ABE	117	RIT	106
EIN	519	IND	254	EIT	184	TON	154	UER	138	ERA	117	EHR	105
END	481	ERD	248	EBE	178	SEN	152	ERU	137	BEN	116	CHA	104
DEN	457	INE	247	ENE	175	ITI	151	TUN	136	MEN	115	VON	104
ICH	453	AND	246	LIC	175	AUF	149	SEI	133	RIE	112	SIC	103
TEN	425	RDE	239	EGE	173	IES	149	ESE	132	VER	110	ICE	102
UNG	377	ENA	214	DAS	172	ASS	148	ERT	128	LAN	109	ITE	101
HEN	332	ERS	212	ENU	171	EIW	148	NDA	127	ENB	108	ENZ	100
UND	331	EDE	209	NUN	169	ENT	146	IED	126	ESS	108	ERB	100
GEN	321	STE	205	NER	166	ERI	143	ERN	125	LLE	108	EUT	100
ISC	317	VER	204	RUN	163	EST	142						

3-b. The 25 trigraphs appearing 50 or more times as beginnings of words in 9,568 words in German plain text, arranged according to their absolute frequencies.

EIN	242	DAS	79	SCH	73	AUF	64	DEU	61	UNT	57	UEB	53
VER	170	BRI	79	AUS	69	NER	63	GES	60	GRO	56	POL	52
FUE	89	DIE	76	SEI	68	IND	62	GEG	59	AUC	55	WIR	51
SIC	86	NIC	73	STA	65	ALL	61						

4. The 121 tetragraphs appearing 50 or more times in 60,046 letters of German plain text, arranged according to their absolute frequencies.

SCHE	398	TSCH	107	ENIN	80	RITI	66	WERD	61	DIEB	54
ISCH	317	NUND	106	NICH	80	ATIO	65	RSCH	60	ENZU	54
CHEN	296	ITIS	104	UNGD	80	GEND	65	EDEN	59	ITEN	54
NDER	243	SICH	103	EITE	79	TEND	65	ERGE	59	KRIE	54
EINE	218	RUNG	101	DEUT	78	EBER	64	ESSE	59	RIEG	54
ENDE	216	ANDE	100	FUER	78	GEGE	64	UNTE	59	SDIE	54
NDIE	176	UNGE	100	CHTE	77	POLI	64	EICH	58	URCH	53
LICH	168	EREI	94	EGEN	76	SIND	64	TLIC	58	ALLE	52
ICHT	151	TION	93	NEIN	76	TUNG	64	INER	57	DERS	52
TISC	146	SEIN	92	IESE	75	ENSI	62	EBEN	56	ENWE	52
ERDE	144	IEDE	91	ERST	74	EUTS	62	ENDA	56	HABE	52
ENDI	141	LAND	91	RDIE	74	LITI	62	ENST	56	OHEN	52
NDEN	136	SSEN	90	ERDI	72	UEBE	62	IGEN	56	SCHI	52
RDEN	133	BRIT	89	STEN	72	UTSC	62	ONDE	56	DEND	51
ENUN	120	DASS	86	CHER	71	AUCH	61	TENS	56	DISC	51
ICHE	120	NTER	86	INDI	71	DENS	61	EDIE	55	ENEN	51
INDE	111	EDER	83	REIH	71	EIND	61	ERTE	55	NACH	51
NGEN	110	EREN	83	DERE	70	OLIT	61	HREN	55	NDAS	51
ERUN	109	ENGE	81	NGDE	70	SCHA	61	TDIE	55	UNGS	51
DIES	108	ENAU	80	ENBE	68	SCHL	61	ATEN	54	AVEN	50
										NBER	50

5. Average length of words in German plain text = 6.3

B. FRENCH LETTER FREQUENCY DATA

1-a. Absolute frequencies of single letters of French plain text, arranged alphabetically, based on 55,758 letters of text.

A	4,480	G	624	L	2,737	Q	616	V	801
B	406	H	276	M	1,617	R	4,117	W	6
C	1,944	I	4,230	N	4,406	S	4,564	X	317
D	2,198	J	184	O	3,255	T	4,057	Y	100
E	9,334	K	25	P	1,689	U	3,045	Z	84
F	646								

1-b. Monographic kappa plain, French language = .0777

1-c. Frequency distribution of single letters based on 55,758 letters in French plain text reduced to 1,000 letters, and arranged according to their frequencies.

E	167	T	73	C	35	G	11	J	3
S	82	O	58	P	30	Q	11	Y	2
A	80	U	55	M	29	B	7	Z	2
N	79	L	49	V	14	X	6	K	1
I	76	D	39	F	12	H	5	W	-
R	74								1,000

1-d. Percentage of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants in 55,758 letters of French plain text. Percentage of 8 most frequent letters in French plain text.

Vowels A,E,I,O,U, and Y = 43.8%
High-Frequency Consonants N,R,S, and T = 30.7%
Medium-Frequency Consonants C,D,L,M, and P = 18.3%
Low-Frequency Consonants B,F,G,H,J,K,Q,V,W,X, and Z = 7.2

(In descending order of frequency)

8 most frequent letters E,S,A,N,I,R,T, and O = 68.9%

1-e. Absolute frequencies of single letters as initial letters of 10,748 words in French plain text, arranged according to their frequencies. (One-letter words have been omitted).

D	1445	L	784	I	315	U	240	H	67
P	929	S	664	F	313	O	177	Z	7
E	894	Q	394	T	305	G	146	K	5
A	866	R	389	N	278	B	115	W	3
C	816	M	337	V	263	J	98	Y	3
									9,853

2-a. Frequency distribution of digraphs based on 55,758 letters of French plain text, reduced to 5,000 digraphs.

1st Letter											2d Letter															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	2	6	20	12	4	6	11		50	1		36	12	68	1	21	3	41	17	46	29	13			2	1
B	4				4				4			12			4			5	2	1	2					
C	15		6		47			11	20			5			48			4	1	8	8					
D	18			1	109			1	20	1			1		10	1		6	2		26					
E	30	4	49	48	30	15	14	3	13	5		56	58	105	4	38	12	89	154	58	27	17		8		3
F	10		2	1	9	6			8			1			8	1		10	1		1					
G	6				16		1		2			3	1	7	6			8		4	2					
H	6				6				4						3			1			4					
I	9	3	12	10	41	4	4			1		27	8	49	51	5	12	27	57	47		9		7		1
J	4				6										5						2					
K															1											
L	57		1	5	95	1		1	23			26		3	10	1			5	4	12				1	
M	22	9	1	1	52				23				13		8	9			1		4					
N	19	1	29	40	54	9	11	1	20	1		3	2	10	19	6	4	3	53	99	4	7				1
O		5	7	3	1	1	2	1	21	1		10	21	109		7		27	13	8	52	2			2	
P	30		1	1	13			2	3			11			35	9		34	1	6	4	-				
Q			1																		54					
R	62	2	10	13	127	2	6		24	1		16	11	8	27	5	3	7	14	19	6	7				1
S	42	2	16	32	75	5	2	1	36	2		15	8	6	22	24	11	8	41	33	24	4			1	
T	40	1	7	22	78	4	1	2	67	1		12	4	4	14	11	7	44	23	10	11	2				
U	12	3	10	5	39	4	3	1	24	3		13	6	26	1	8	1	48	26	19	1	8		13	1	
V	9				24				16						16			5			2					
W																										
X	4		3	3	3			1	1				1	1		4	1	1	2	3		1				
Y	2				2										1				2							
Z					3				1						1											

2-b. Digraphic kappa plain, French language = .0093

2-c. The 87 digraphs comprising 75% of French plain text, based on the table of 5,000 digraphs (Item 2-a), arranged according to their relative frequencies.

ES	154		1,237[1]	EC	49	ND	40	EE	30	SP	24	NI	20
RE	127	ET	58	LU	49		2,515[2]	NC	29	SU	24	DT	20
ON	109	EM	58	ED	48	TA	40	AU	29	RI	24	CI	20
DE	109	LA	57	CO	48	UE	39	IR	27	VE	24	AC	20
EN	105	EL	56	UR	48	EP	38	EU	27	TS	23	UT	19
NT	99	QU	54	CE	47	AL	36	IL	27	MI	23	NO	19
LE	95	NE	54	IT	47	SI	36	RO	27	LI	23	RT	19
ER	89	NS	53	AT	46	PO	35	OR	27	SO	22	NA	19
TE	78	ME	52	TR	44	PR	34	DU	26	MA	22	DA	18
SE	75	IS	52	SA	42	ST	33	LL	26	TD	22	AS	17
AN	68	OU	52	IE	41	SD	32	US	26	AP	21	EV	17
TI	67	IO	51	AR	41	PA	30	UN	26	OI	21		
RA	62	AI	50	SS	41	EA	30	UI	24	OM	21		3,751

2-d. Frequent digraphs in French plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

ES	154	SE	75	LE	95	EL	56	RA	62	AR	41	IS	52	SI	36
RE	127	ER	89	TE	78	ET	58	EM	58	ME	52	EC	49	CE	47
DE	109	ED	48	TI	67	IT	47	LA	57	AL	36	AT	46	TA	40
EN	105	NE	54												

2-e. Frequent digraphs in French plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

NT	99	TN	4	QU	54	UQ	1	NS	53	SN	6	OU	52	UO	1

2-f. Doublets occurring in French plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

SS	41	LL	26	NN	10	PP	9	CC	6	AA	2	GG	1
EE	30	MM	13	TT	10	RR	7	FF	6	DD	1	UU	1

2-g. The 22 digraphs appearing 100 or more times as beginnings of words in 10,748 words in French plain text, arranged according to their absolute frequencies.

DE	501	RE	283	PO	222	SU	168	AU	150	DI	124	SO	117
CO	394	PA	268	IN	178	CE	163	NO	133	AL	122	VO	112
QU	347	LE	240	SE	178	ET	153	TR	127	UN	122	FR	101
PR	291												

[1] The 13 digraphs above this line compose 25% of French plain text.

[2] The 39 digraphs above this line compose 50% of French plain text.

3-a. The 97 trigraphs appearing 100 or more times in 55,758 letters of French plain text, arranged according to their absolute frequencies.

ENT	588	CON	271	EST	188	ESS	151	NSE	130	EUR	115	TRA	105
ION	555	ERE	267	ERA	185	AIT	147	REN	127	NTA	115	ISS	104
TIO	433	ANT	238	ECO	184	POU	146	SQU	124	SER	115	INT	103
ONS	373	ESE	230	ESD	179	TER	146	AIR	123	ESO	112	TEN	103
RES	367	ELA	227	OND	175	COM	143	EPA	120	DEC	110	UEL	102
QUE	338	LLE	216	LEM	173	ESP	139	QUI	120	EPR	110	ANS	101
DES	313	PAR	213	NCE	173	OUS	139	SET	120	ALL	109	BLE	101
EDE	305	NDE	211	ELE	172	AIS	137	REC	119	ECE	109	QUA	101
EME	288	SDE	210	ESA	163	EMA	137	AND	118	UNE	108	CES	100
ATI	287	DEL	209	TDE	163	IER	136	ETA	118	RAI	106	ETE	100
LES	284	PRE	206	ITE	162	NTS	135	SEN	118	RLE	106	ETR	100
NTE	281	OUR	205	SSE	160	TES	135	PRO	117	SSI	106	OMM	100
TRE	280	RAN	196	ONT	157	EQU	133	ISE	116	ENE	105	TAT	100
MEN	272	IRE	191	ANC	153	IQU	131	REP	116	SUR	105		

3-b. The 20 trigraphs appearing 50 or more times as beginnings of words in 10,748 words in French plain text, arranged according to their absolute frequencies.

CON	213	COM	129	FRA	93	INT	75	ETA	69	SER	61	VOU	56
POU	144	PRO	105	PAR	87	CEN	72	DAN	68	TRA	57	FAI	50
PRE	135	ALL	104	QUA	80	NOU	69	RED	65	RES	56		

4. The 82 tetragraphs appearing 50 or more times in 55,758 letters of French plain text, arranged according to their absolute frequencies.

TION	431	CONS	98	LEME	83	ERAL	71	EREN	58	RESS	55
MENT	251	EPAR	98	QUEL	83	ERES	70	ESSE	58	IERE	53
ATIO	220	RESE	96	LEMA	80	DANS	67	NOUS	58	IRES	53
IONS	208	ENTE	95	PORT	80	OUVE	67	TRES	58	TEDE	53
EMEN	200	LLEM	93	ENTS	78	EMAN	66	ENER	57	EQUE	52
POUR	136	FRAN	91	EPRE	77	SENT	66	NDES	57	NDEL	52
IQUE	128	PRES	91	EDES	76	ANDE	63	NSEI	57	ECOM	51
IOND	124	ENTA	90	ESET	76	PART	62	NTDE	57	GENE	51
DELA	120	RANC	90	INTE	76	SDES	62	CAIS	56	SEIL	51
AIRE	117	ANCE	89	ALLE	75	ESEN	61	ESTI	56	ELES	50
ONDE	107	SION	89	ANTE	75	RAIT	61	ITIO	55	ETAT	50
ECON	102	COMM	88	MAND	75	ENTD	60	NEME	55	ILLE	50
ESDE	102	ELLE	84	CENT	74	SSIO	60	NERA	55	SQUE	50
ONSE	101	NTER	84	QUES	72	ENCE	59				

5. Average length of words in French plain text = 5.2 letters.

C. ITALIAN LETTER FREQUENCY DATA

In all calculations, accented letters have been combined with the corresponding unaccented letter.

1-a. Absolute frequencies of single letters of Italian plain text, arranged alphabetically, based on 57,906 letters of text.

A	6,771	G	1,168	L	3,592	Q	227	V	1,024
B	527	H	493	M	1,441	R	4,037	W	13
C	2,367	I	6,568	N	4,094	S	2,967	X	9
D	2,258	J	18	O	5,022	T	4,139	Y	14
E	6,784	K	28	P	1,616	U	1,547	Z	527
F	655								
									57,906

1-b. Monographic kappa plain, Italian language = .0745

1-c. Frequency distribution of single letters based on 57,906 letters in Italian plain text, reduced to 1,000 letters and arranged according to their frequencies.

E	117	R	70	P	28	F	11	K	-
A	117	L	62	U	27	B	9	J	-
I	113	S	51	M	25	Z	9	Y	-
O	87	C	41	G	20	H	9	W	-
T	72	D	39	V	18	Q	4	X	-
N	71								
									1,000

1-d. Percentage of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants in 57,906 letters of Italian plain text. Percentage of 8 most frequent letters in Italian plain text.

Vowels A,E,I,O,U, and Y = 46.1%
High-Frequency Consonants L,N,R, and T = 27.4%
Medium-Frequency Consonants C,D,G,M,P,S, and V = 22.2%
Low-Frequency Consonants B,F,H,J,K,Q,W,X, and Z = 4.3%

(Listed in descending order of frequency)

8 most frequent letters E,A,I,O,T,N,R,L - 70.8%

1-e. Absolute frequencies of single letters as initial letters of 10,481 words in Italian plain text, arranged according to their frequencies. (One letter words have been omitted.)

D	1,381	L	500	T	337	U	217	J	13
C	1,041	R	403	G	333	Q	172	W	9
S	885	N	396	F	298	B	153	K	6
P	830	E	374	V	263	H	69	Y	3
A	822	M	371	O	235	Z	29	X	2
I	685								
									10,481

2-a. Frequency distribution of digraphs based on 57,847 letters of Italian plain text, reduced to 5,000 digraphs.

2d Letter

1st Letter	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	18	9	39	41	14	12	22	1	19			76	24	78	5	24	4	57	36	63	6	24				12
B	10	7			7				10			1			4			4			2					
C	32		10		20			33	33			2			64		1	5			6					
D	31			1	65				64						23			2			9					
E	23	7	31	53	15	8	22	2	25			66	18	73	6	22	4	96	62	27	6	17				4
F	9				11	7			11			1			10			6			3					
G	9				11		8	2	20			17		8	9			11			6					
H	6				27				9																	
I	66	8	52	30	31	11	11	2	11			35	31	62	44	20	3	20	48	45	15	16				7
J																					1					
K																										
L	62	3	8	6	49	2	7		56			52	4	2	21	5	1	3	6	15	7	3				
M	31	5			35				17				4		18	13					2					
N	32	1	15	26	51	6	11	1	37			3	1	10	50	4	5	2	11	66	8	4				11
O	17	4	22	27	10	5	10	1	20			45	24	86	4	25	2	55	40	14	3	18				2
P	23				30				14			2			28	11		23			7					
Q																					20					
R	64	1	8	8	71	1	7		63			4	13	9	45	2		12	9	16	10	3				3
S	20		15	1	32	2			45			2	3		25	9			31	58	12	1				
T	83		1		65	1			59			1		1	56			43	1	37	10					
U	12	2	4	3	15	1	3		10			6	3	24	8	6		9	11	15						1
V	26				23				23						10			2			2	2				
W																										
X																										
Y																										
Z	13				4				20						3											5

2-b. Digraphic kappa plain, Italian language = .0081

2-c. The 89 digraphs comprising 75% of Italian plain text, based on the table of 5,000 digraphs, (Item 2-a), arranged according to their relative frequencies.

ER	96	RI	63	LL	52	AC	38	MA	31	HE	25	VE	23
ON	86	IA	63	IC	51	TT	37	SS	31	OP	25	OC	22
TA	78	LA	62	NE	50		2,495[2]	DA	31	AM	24	AG	22
AN	78	IN	62	NO	50	NI	37	EC	30	UN	24	EG	22
AL	76		1,260[1]	LE	49	ME	35	PE	30	EI	24	EP	22
EN	73	RA	62	IS	48	AS	35	ID	30	AV	24	LO	21
RE	71	ES	61	IT	45	IL	35	IE	30	OM	24	IP	20
NT	66	TI	59	OL	45	CH	33	PO	28	PA	23	ZI	20
DE	65	ST	58	RO	45	CJ	33	OD	27	DQ	23	SA	20
TE	65	AR	57	SI	44	NA	32	ET	27	VI	23	CE	20
EL	65	TO	56	IO	43	SE	32	VA	26	AP	23	QU	20
DI	64	LI	56	TR	43	CA	32	ND	26	PR	23	GI	20
CO	64	OR	55	OS	40	IM	31	SO	25	EA	23		3,762
AT	63	ED	52	AD	39								

2-d. Frequent digraphs in Italian plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

ER	96	RE	71	EL	66	LE	49	LI	56	IL	35
ON	86	NO	50	DE	65	ED	53	OR	55	RO	45
TA	83	AT	63	RA	64	AR	57	IC	52	CI	33
AN	78	NA	32	IN	62	NI	37	IS	48	SI	45
AL	76	LA	62	ES	62	SE	32	AD	41	DA	31
EN	73	NE	51	TI	59	IT	45	AC	39	CA	32

2-e. Frequent digraphs in Italian plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

NT	66	TN	1	ST	58	TS	1	CH	33	HC	0

2-f. Doublets occurring in Italian plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

LL	52	AA	18	II	11	NN	10	FF	7	MM	4	VV	2
TT	37	EE	15	PP	11	GG	8	ZZ	5	OO	4	DD	1
SS	31	RR	12	CC	10	BB	7						

2-g. The 26 digraphs appearing 100 or more times as beginnings of words in 10,481 words in Italian plain text, arranged according to their absolute frequencies.

CO	543	PE	210	PR	184	NO	154	SE	121	MA	112	RE	108
DE	505	CH	197	QU	172	PA	153	SO	121	UN	111	ES	107
ST	222	AL	186	NE	169	PO	141	TR	121	SU	109	TE	103
DI	215	IN	185	RI	162	CA	132	DA	120				

[1] The 18 digraphs above this line comprise 25% of Italian plain text.

[2] The 43 digraphs above this line comprise 50% of Italian plain text.

3-a. The 90 trigraphs appearing 100 or more times in 57,906 letters of Italian plain text, arranged according to their absolute frequencies.

DEL	348	STA	215	ERE	169	ICA	145	SSI	130	ODI	114	ESI	107
ENT	348	ALT	213	ZIO	166	RAN	145	NEL	127	ORI	114	COR	106
ELL	314	EDI	212	ATO	165	STR	145	ACO	125	RMA	114	IAN	106
CON	306	ALL	201	NTI	165	ALE	144	ATI	125	AME	113	TAN	105
CHE	276	ITA	198	ANT	163	IDI	143	IDE	123	ETT	113	ATE	104
LLA	274	ANO	197	ERA	163	COM	139	ADI	121	ODE	113	NON	103
ION	265	OST	196	TRA	160	ECO	137	AND	121	PRE	112	VER	103
ONE	247	ERI	187	ESS	158	LLE	137	TEN	120	NDO	110	ICA	101
PER	238	ARE	186	ATT	157	ONT	136	ONO	119	ONI	110	OLA	101
EDE	228	TAL	184	NTO	156	TER	136	ARI	117	AZI	109	STI	101
NTE	227	LIA	180	ADE	155	TAT	134	NTR	117	ENE	109	OCO	100
ICO	216	IST	174	EST	151	TTA	132	PAR	116	ELA	107	RIA	100
MEN	216	GLI	171	RES	146	ATA	130	TRO	116	ERO	107		

3-b. The 19 trigraphs appearing 50 or more times as beginnings of words in 10,481 words in Italian plain text, arranged according to their absolute frequencies.

DEL	217	STA	106	QUA	81	PRE	62	DAL	57	PER	55	GRA	53
CON	195	ALL	100	PRO	75	NEL	57	ANC	56	RUS	55	STO	51
COM	137	ITA	94	QUE	74								

4. The 57 tetragraphs appearing 50 or more times in 57,906 letters of Italian plain text, arranged according to their absolute frequencies.

DELL	209	ALIA	99	ICON	74	AGLI	66	LIAN	59	OPER	56
MENT	188	CONT	93	VANO	74	ICHE	66	TORI	59	RUSS	56
IONE	160	ADEL	92	ECON	73	IDEL	64	ALLE	58	TATO	55
ELLA	150	OSTR	88	IONI	71	ELLE	63	ANDO	58	TEDE	55
ZION	147	ENTO	87	STAT	70	NELL	63	DALL	58	OCON	54
TALI	125	AMEN	83	STRA	70	IMEN	61	NTRO	58	SION	53
AZIO	106	ALLA	81	GLIA	69	ANTI	60	OCHE	58	TANT	53
EDEL	106	ENZA	75	ISTA	68	ATTA	60	ANTE	57	STOP	52
ITAL	106	ONTR	75	ODEL	68	PART	60	EPER	57	NOST	51
ENTE	105	ENTI	74	ACON	66						

5. Average length of words in Italian plain text = 5.5 letters.

D. SPANISH LETTER FREQUENCY DATA

1-a. Absolute frequencies of single letters of Spanish plain text, arranged alphabetically, based on 60,115 letters of text.

A	6,681	G	823	L	2,174	Q	346	V	602
B	799	H	367	M[1]	1,740	R	4,628	W[2]	36
C	3,137	I	4,920	N	4,823	S	4,140	X	127
D	2,687	J	190	O	5,859	T	3,180	Y	413
E	7,801	K	22	P	1,785	U	2,172	Z	182
F	481								
									60,115

1-b. Monographic kappa plain, Spanish language = .0747

1-c. Frequency distribution of single letters based on 60,115 letters in Spanish plain text, reduced to 1,000 letters, and arranged according to their frequencies.

E	130	S	69	U	36	V	10	J	3
A	111	T	53	P	30	F	8	Z	3
O	97	C	52	M	29	Y	7	X	2
I	82	D	45	G	14	H	6	W	1
N	80	L	36	B	13	Q	6	K	-
R	77								
									1,000

1-d. Percentage of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants in 60,115 letters of Spanish plain text. Percentage of 8 most frequent letters in Spanish plain text.

Vowels A,E,I,O,U, and Y = 46.3%
High-Frequency Consonants N,R, and S = 22.6%
Medium-Frequency Consonants C,D,L,M,P, and T = 24.5%
Low-Frequency Consonants B,F,G,H,J,K,Q,V,W,X, and Z = 6.6%

(In descending order of frequency)

8 most frequent letters, E,A,O,I,N,R,S, and T = 69.9%

1-e. Absolute frequencies of single letters as initial letters of 10,129 words in Spanish plain text, arranged according to their frequencies. (One-letter words have been omitted).

P	1,128	L	435	Q	286	V	183	Y	27
C	1,081	R	425	I	281	F	177	W	19
D	1,012	M	403	H	230	O	169	Z	2
E	989	N	346	U	219	B	124	K	1
S	789	T	298	G	206	J	47	X	-
A	761								
									10,129

[1] Includes Ñ throughout all tables.

[2] From foreign words appearing in Spanish plain text.

2-a. Frequency distribution of digraphs based on 60,115 letters of Spanish plain text, reduced to 5,000 digraphs.

2d Letter

1st Letter	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	12	14	54	64	15	5	8	4	10	8		41	30	64	4	24	5	81	62	18	9	9			11	4
B	11				5				14	1		12			5			12	2	1	3					
C	39		5		17			8	80			3			69			6		13	18					
D	32		1	2	84			1	30					1	59	2	1	3	1		6				1	
E	20	5	47	26	17	8	21	6	9	3		44	26	126	5	23	4	94	119	17	5	10	1	8	2	3
F	2				9				12			1			7			4			5					
G	12				12				5			1		2	15			11		1	11					
H	15				3				5						6						1					
I	43	8	42	29	40	5	8			1		14	16	50	67	4	1	16	27	24	1	8				5
J	4				5										3						3					
K					1																					
L	44		5	5	35	1	3		28			9	5	1	17	5	1	2	4	5	5	3			1	
M	32	10			42				30						15	10					6					
N	41	2	33	37	41	10	6	2	28	1		5	4	3	43	10	2	4	21	91	12	6			1	1
O	19	17	28	26	16	6	5	5	4	1		22	33	104	4	29	7	58	73	12	3	5		2	9	1
P	30		1		16				5			8			31			34	1	3	19					
Q																					29					
R	74	1	12	10	94	1	12		45	1	1	6	15	11	43	7	3	10	10	15	9	6			1	1
S	32	2	18	15	57	3	2	4	41	1		5	7	5	22	26	4	6	10	57	23	2			4	
T	60		1		67				,35						56			34			11					
U	13	6	11	5	52	1	3		9			9	6	34	1	3		9	10	4		1			2	
V	12			1	15				15						7											
W	1				1																				1	
X			1						4							3				2						
Y	5	1	3	2	5	1	1					1	1	1	5	2	1	1	3	1	1					
Z	6		1	1											3						2					

2-b. Digraphic kappa plain, Spanish language = .0091

2-c. The 87 digraphs comprising 75% of Spanish plain text, based on the table of 5,000 digraphs, (Item 2-a), arranged according to their relative frequencies.

EN	126	TE	67	IN	50	NA	41	MA	32	IS	27	EA	20
ES	119	AN	64	EC	47	IE	40	SA	32	EM	26	OA	19
ON	104		1,287[1]	PI	45		2,513[2]	PO	31	SP	26	PU	19
ER	94	AD	64	EL	44	CA	39	MI	30	ED	26	SC	18
RE	94	AS	62	LA	44	ND	37	PA	30	OD	26	AT	18
NT	91	TA	60	RO	43	TI	35	AD	30	AP	24	CU	18
DE	84	DO	59	NO	43	LE	35	DI	30	IT	24	EE	17
AR	81	OR	58	IA	43	TR	34	ID	29	EP	23	OB	17
CI	80	SE	57	IC	42	UN	34	CU	29	SU	23	CE	17
RA	74	CT	57	ME	42	PR	34	OP	29	SO	22	ET	17
OS	73	TO	56	AL	41	OM	33	LI	28	OL	22	LO	17
CO	69	AC	54	SI	41	NC	33	NI	28	MS	21		
IO	67	UE	52	NE	41	DA	32	OC	28	EG	21		3,753

2-d. Frequent digraphs in Spanish plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a)

EN	126	NE	41	AR	81	RA	74	AS	62	SA	32	LA	44	AL	41
ES	119	SE	57	CI	80	IC	42	OR	58	RO	43	EL	44	LE	35
ON	104	NO	43	AN	64	NA	41	AC	54	CA	39	MA	32	AM	30
ER	94	RE	94	AD	64	DA	32								

2-e. Frequent digraphs in Spanish plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

NT	91	TN	0	ST	57	TS	0	ND	37	DN	1	NC	33	CN	0
IO	67	OI	4												

2-f. Doublets occurring in Spanish plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

EE	17	AA	12	RR	10	SS	10	LL	9	CC	5	OO	4	NN	3	DD	2

2-g. The 21 digraphs appearing 100 or more times as beginnings of words in 10,129 words in Spanish plain text, arranged according to their absolute frequencies

CO	684	PR	307	PA	263	SE	189	CA	151	PE	111	MA	101
RE	335	ES	286	PO	247	DI	175	SI	137	UN	109	CU	100
DE	323	QU	286	IN	235	PU	157	MI	117	HA	108	SO	100

[1] The 15 digraphs above this line comprise 25% of Spanish plain text.

[2] The 40 digraphs above this line comprise 50% of Spanish plain text.

3-a. The 105 trigraphs appearing 100 or more times in 60,115 letters of Spanish plain text, arranged according to their absolute frequencies.

ENT	596	ARA	229	POR	176	OSE	147	ERO	131	NDE	121	PER	111
ION	564	ONE	227	TER	174	ONS	144	ONT	131	RAN	121	ASE	109
CIO	502	ESE	217	ODE	168	REC	144	ANA	130	STE	119	CAN	109
NTE	429	ADE	202	ERE	166	ORE	143	ARE	130	REN	118	UNI	108
CON	415	PAR	193	ERA	165	OCO	142	UNT	129	ARI	117	OSI	107
EST	355	CIA	190	TRA	165	EDE	141	ANO	127	TEN	116	GEN	105
RES	335	ENC	190	AME	163	ICI	140	TAR	127	OND	115	NCO	105
ADO	307	NCI	188	ERI	162	END	139	ANT	126	RIA	115	RIO	105
QUE	294	PRE	184	MER	159	SEN	139	ESA	126	ECI	114	ERN	104
ACI	277	DEL	183	ELA	158	TAD	138	IER	126	IST	113	OMI	104
NTO	270	NDO	183	PRO	155	ECO	135	ADA	125	ONA	113	SCO	104
IEN	267	NES	183	ACO	153	STR	134	DEN	124	DAD	112	TES	103
COM	246	DOS	182	ENE	151	TOS	133	AND	123	INT	112	BIE	101
ICA	242	MEN	181	UES	150	IDA	132	DES	121	NTR	112	NTI	100
STA	240	NTA	176	ESP	149	SDE	132	IDO	121	ESI	111	TOR	100

3-b. The 19 trigraphs appearing 50 or more times as beginnings of words in 10,129 words in Spanish plain text, arranged according to their absolute frequencies.

CON	298	PAR	154	PUN	93	INT	72	UNI	55	CUA	52	REP	51
COM	218	PRO	139	PER	80	RES	72	DES	53	TRA	52	ARG	50
EST	194	PRE	114	GOB	77	NUE	66	INF	53				

4. The 86 tetragraphs appearing 50 or more times in 60,115 letters of Spanish plain text, arranged according to their absolute frequencies.

CION	444	CONS	104	ERNO	79	AMER	72	FORM	62	EEST	55
ACIO	252	CONT	99	IERN	78	IEND	72	SENT	62	SCON	55
ENTE	233	PUNT	95	OQUE	78	IDAD	71	ICIO	61	SIDE	55
ESTA	174	ANDO	91	IONA	77	ENDO	70	ONTR	60	CIEN	54
IONE	159	TADO	91	UEST	77	ERIC	70	SION	60	NFOR	54
MENT	150	ACON	90	BIER	76	NTOS	70	CCIO	59	OPOR	54
ONES	146	ANTE	89	ICAN	76	MIEN	69	GENT	58	RESP	54
IENT	141	NTER	85	RESE	76	IOND	67	COMA	57	ARIO	53
ENTO	137	INTE	84	GOBI	75	MERI	67	ESDE	57	ESTR	53
ENCI	128	NTES	82	OBIE	75	NTRA	67	ORES	57	ARGE	51
PARA	117	ADOS	81	ECON	74	DELA	65	RECI	57	ECTO	51
ENTA	115	AMEN	81	RGEN	73	ENTI	64	AQUE	56	PART	51
NCIA	115	OCON	81	RICA	73	NTIN	64	IONP	56	POSI	51
PRES	111	ESEN	80	STAD	73	COMI	63	QUES	56	EPRE	50
UNTO	111	ONDE	80								

5. Average length of words in Spanish plain text = 5.9 letters

E. PORTUGUESE LETTER FREQUENCY DATA

1-a. Absolute frequencies of single letters of Portuguese plain text, arranged alphabetically, based on 45,106 letters of text.

A	5,362	G	724	L	1,245	Q	348	V	737
B	470	H	304	M	1,699	R	3,292	W	24
C	2,285	I	3,314	N	2,912	S	3,409	X	166
D	1,900	J	160	O	5,001	T	2,679	Y	22
E	5,441	K	17	P	1,377	U	1,491	Z	207
F	520								
									45,106

1-b. Monographic kappa plain, Portuguese language = .0746

1-c. Frequency distribution of single letters based on 45,106 letters of Portuguese plain text, reduced to 1,000 letters.

E	121	N	65	U	33	F	11	X	4
A	119	T	59	P	30	B	10	J	3
O	111	C	51	L	28	Q	8	W	1
S	76	D	42	V	16	H	7	Y	-
I	73	M	38	G	16	Z	5	K	-
R	73								
									1,000

1-d. Percentage of vowels, high-frequency consonants, medium-frequency consonants, and low frequency consonants in 45,106 letters of Portuguese plain text. Percentage of 8 most frequent letters in Portuguese plain text.

Vowels A,E,I,O,U, and Y = 45.8%
High-Frequency Consonants N,R, and S = 21.3%
Medium-Frequency Consonants C,D,L,M,P, and T = 24.8%
Low-Frequency Consonants B,F,G,H,J,K,Q,V,W,X,Y, and Z = 8.1%

(In descending order of frequency)

8 most frequent letters E,A,O,S,I,R,N, and T = 69.7%

1-e. Absolute frequencies of single letters as initial letters of 7,058 words in Portuguese plain text, arranged according to their frequencies.

P	847	M	405	I	264	B	113	Z	14
C	731	T	348	F	222	G	111	W	11
E	608	R	316	Q	222	J	92	K	7
S	601	N	299	O	187	U	77	Y	4
A	597	V	271	L	143	H	60	X	2
D	506								
									7,058

2-a. Frequency distribution of digraphs based on 44,921 letters of Portuguese plain text, reduced to 5,000 digraphs.

2d Letter

1st Letter	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	11	11	52	60	15	9	14	2	18	2		38	36	56	49	23	8	68	72	22	8	16	1			5
B	11			1	10				5			2	1		9			9	2	1	2					
C	60		2		30			4	39			5		1	85			7		8	12					
D	45				61				33				1		61			2	1	1	5					
E	15	5	48	22	11	11	23	1	27	6	1	31	44	97	6	18	6	76	95	20	7	12	1	15		5
F	9				14				13			1			15			2			3					
G	15				14				4			1		1	14			14			15					
H	10				8				3						11						1					
I	42	3	34	31	6	7	9		1			16	22	53	26	5	2	25	39	27	2	10		2		7
J	7				2										2						7					
K																										
L	24	1	4	4	24	1	5	9	21			2	4	2	14	4	2	1	4	7	6	2				
M	41	10	3	4	51	1			26	1		1	2	1	16	15	1	3	5	2	6	2				
N	31		29	35	14	7	8	12	18						25	1			19	114	4	4				1
O	21	9	32	25	27	10	7	3	20	4		20	36	79	5	35	8	71	85	18	12	22	1	1	1	1
P	26		2		25				2			4		1	60	1	1	28	1	1	3					
Q					1																37					
R	75	2	14	9	86	3	7	1	46	1		2	18	8	34	7	3	11	8	18	4	6				1
S	41	6	22	10	62	6	3	2	23	2		3	12	5	23	35	7	4	40	47	18	5				
T	65		1	1	69	1			26					1	88			33		1	13					
U	22	5	5	7	26	1	4		18	1		14	11	17	2	4		9	6	11		1				2
V	11				37				23						9			1								
W	1																									
X	10		3		1				2							3				1						
Y																										
Z	7		1		9				2				1		1		1	1								

2-b. Digraphic kappa plain, Portuguese language = .0084

2-c. The 91 digraphs comprising 75% of Portuguese plain text, based on the table of 5,000 digraphs (Item 2-a), arranged according to their relative frequencies.

NT	114	TA	65	ST	47	AM	36	CE	30	OD	25	AT	22
EN	97		1,224[1]	RI	46		2,505[2]	NC	29	NO	25	UA	22
ES	95	SE	62	DA	45	ND	35	PR	28	LA	24	OA	21
TO	88	DO	61	EM	44	OP	35	IT	27	LE	24	LI	21
RE	86	DE	61	IA	42	SP	35	OE	27	AP	23	OL	20
CO	85	AD	60	MA	41	RO	34	EI	27	EG	23	ET	20
OS	85	PO	60	SA	41	IC	34	UE	26	VI	23	OI	20
ON	79	CA	60	SS	40	TR	33	MI	26	SO	23	NS	19
ER	76	AN	56	CI	39	DI	33	IO	26	SI	23	SU	18
RA	75	IN	53	IS	39	OC	32	PA	26	OV	22	RT	18
AS	72	AC	52	AL	38	EL	31	TI	26	SC	22	EP	18
OR	71	ME	51	VE	37	ID	31	PE	25	IM	22	UI	18
TE	69	AO	49	QU	37	NA	31	IR	25	ED	22		3,755
AR	68	EC	48	OM	36								

2-d. Frequent digraphs in Portuguese plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

ES	95	SE	62	OR	71	RO	34	ME	51	EM	44
RE	86	ER	76	CA	60	AC	52	EC	48	CE	30
CO	85	OC	32	AD	60	DA	45	MA	41	AM	36
RA	75	AR	68	PO	60	OP	35	CI	39	IC	34
AS	72	SA	41	AN	56	NA	31	DI	33	ID	31

2-e. Frequent digraphs in Portuguese plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

NT	114	TN	1	ST	47	TS	0	ND	35	DN	0

2-f. Doublets occurring in Portuguese plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

SS	40	EE	11	OO	5	LL	2	II	1	PP	1	TT	1
AA	11	RR	11	CC	2	MM	2						

2-g. The 20 digraphs appearing 100 or more times as beginnings of words in 6,803 words in Portuguese plain text, arranged according to their absolute frequencies.

CO	464	RE	276	IN	188	PA	143	MA	130	ME	111	TR	103
PO	386	DE	259	ES	173	NA	133	PE	122	MI	105	DI	102
SE	333	QU	220	PR	169	TE	132	VE	115	NO	104		

[1] The 15 digraphs above this line compose 25% of Portuguese plain text.

[2] The 42 digraphs above this line compose 50% of Portuguese plain text.

3-a. The 59 trigraphs appearing 100 or more times in 45,106 letters of Portuguese plain text, arranged according to their absolute frequencies.

ENT	474	TOS	191	ERE	150	IDA	133	OSE	126	ECE	115	ASE	105
NTO	457	EST	186	CIA	145	TER	132	ARE	125	NCI	114	ITO	104
ONT	303	ACA	182	ADE	143	OPO	130	ESE	124	REC	113	ELE	103
NTE	284	RES	181	STA	143	SPO	130	OVE	124	PAR	112	ERI	103
CON	255	QUE	172	ICA	142	ADA	129	SSA	124	ESS	110	PRO	102
PON	236	NTA	167	OCO	140	TRA	129	DES	123	DAD	109	AME	101
CAO	227	POR	159	ARA	136	NDO	127	ECO	121	ORE	108	OSS	101
ADO	211	ACO	158	DOS	134	ENC	126	ODE	118	EDI	107	IME	100
MEN	205	COM	154	OES	134								

3-b. The 19 trigraphs appearing 50 or more times as beginnings of words in 6,497 words in Portuguese plain text, arranged according to their absolute frequencies.

CON	224	QUE	109	PRO	93	QUA	83	TRA	66	VEX	53	RES	52
PON	213	EST	105	POR	88	DES	71	MIL	61	IND	52	REC	51
COM	136	PAR	93	NAO	86	SER	70	REF	56				

4. The 38 tetragraphs appearing 50 or more times in 45,106 letters of Portuguese plain text, arranged according to their absolute frequencies.

ONTO	233	ENTA	97	AMEN	81	CONT	68	CONS	58	RENT	52
PONT	221	NCIA	95	PARA	81	FORM	67	NTES	58	TELE	52
MENT	183	PORT	87	COES	73	OCON	66	ANDO	57	EGRA	51
ENTO	173	DADE	86	IDAD	71	ELEG	61	ANTE	57	NFOR	51
ENTE	147	ESTA	85	CENT	70	ADOS	60	ORMA	54	OPON	51
ACAO	142	ENCI	83	INTE	70	IMEN	60	VEXA	54	LEGR	50
NTOS	141	SPON	83								

5. Average length of words in Portuguese plain text = 6.48

F. RUSSIAN LETTER FREQUENCY DATA

1-a. Absolute frequencies of single letters of Russian plain text, arranged alphabetically, based on 67,850 letters of text.

А	5,122	З	1,280	Н	4,463	У	1,578	Щ	257
Б	1,095	И	4,923	О	8,078	Ф	127	Ы	1,421
В	3,543	Й	961	П	1,815	Х	941	Ь	960
Г	1,141	К	2,324	Р	3,427	Ц	369	Э	173
Д	2,076	Л	2,747	С	3,917	Ч	902	Ю	455
Е	5,537	М	1,936	Т	4,041	Ш	554	Я	1,185
Ж	502								
									67,850

1-b. Monographic kappa plain, Russian language = .0568

1-c. Frequency distribution of single letters based on 67,850 letters of Russian plain text, reduced to 1,000 letters, arranged according to their relative frequencies.

О	119	В	52	П	27	Б	16	Ж	7
Е	82	Р	50	У	23	Й	14	Ю	7
А	75	Л	40	Ы	21	Ь	14	Ц	5
И	73	К	34	З	19	Х	14	Щ	4
Н	66	Д	31	Я	17	Ч	13	Э	3
Т	60	М	29	Г	17	Ш	8	Ф	2
С	58								
									1,000

1-d. Percentage of vowels, high-frequency consonants, medium-frequency consonants, and low-frequency consonants in 67,850 letters of Russian plain text. Percentage of 10 most frequent letters in Russian plain text.

Vowels А, Е, И, Й, О, У, Ы, Э, Ю, and Я = 43.4%
High-Frequency Consonants В, Н, Р, С, and Т = 28.6%
Medium-Frequency Consonants Б, Г, Д, З, К, Л, М, П, Х, Ч, and Ь = 25.4%
Low-Frequency Consonants Ж, Ф, Ц, Ш, and Щ = 2.6%

10 most frequent letters (in descending order of frequency) О, Е, А, И, Н, Т, С, В, Р, and Л = 67.5%

1-e. Absolute frequencies of single letters as initial letters of 10,601 words in Russian plain text, arranged according to their frequencies. (One-letter words have been omitted.)

П	1,210	Д	496	И	321	Х	120	Ф	58
С	983	М	446	Г	292	А	116	Ц	47
Н	800	Р	429	У	229	Е	92	Я	41
В	731	Т	418	Ч	182	Ж	72	Ю	34
О	650	З	404	Э	147	Ш	63	Щ	2
К	555	Б	344	Л	146				
									10,601

2-a. Frequency distribution of digraphs based on 67,850 letters of Russian plain text, reduced to 5.000 digraphs.

2d Letter

1st Letter	А	Б	В	Г	Д	Е	Ж	З	И	Й	К	Л	М	Н	О	П	Р	С	Т	У	Ф	Х	Ц	Ч	Ш	Щ	Ы	Ь	Э	Ю	Я
А	2	12	35	8	11	7	6	15	7	7	19	27	19	15	5	11	26	31	27	3	1	10	6	7	10	1			2	6	9
Б	5					9	1		6			6		2	21		8	1		6						1	11				2
В	35	1	5	3	3	32		2	17		7	10	3	9	58	6	6	19	6	7		1	1	2	4	1	18	1	2		3
Г	7				3	3			5		1	5		1	50		7			2											
Д	25		3	1	1	29	1	1	13		1	5	1	13	22	3	6	8	1	10			1	1	1		5	1			1
Е	2	9	18	11	27	7	5	10	6	15	13	35	24	63	7	16	39	37	33	3	1	8	3	7	3	3			1	1	2
Ж	5	1			6	12			5					6				1													
З	35	1	7	1	5	3			4		2	1	2	9	9	1	3	1		2							4				4
И	1	6	22	5	10	21	2	23	19	11	19	21	20	32	8	13	11	29	29	3	1	17	3	11	1	1			1	3	17
Й	1	1	4	1	3		1	2	4		5	1	2	7	9	7	3	10	2				1	3	2						
К	24	1	4	1		4	1	1	26		1	4	1	2	66	2	10	3	7	10			1								
Л	25	1	1	1	1	33	2	1	36		1	2	1	8	30	2		3	1	6		4		1			2	30		4	9
М	18	2	4	1	1	21	1	2	23		3	1	3	7	19	5	2	5	3	9	1			2			5	1	1		3
Н	54	1	2	3	3	34			58		3		1	24	67	2	1	9	9	7	1		5	2			36	3			5
О	1	28	84	32	47	15	7	18	12	29	19	41	38	30	9	18	13	50	39	3	2	5	2	12	4	3			2	3	2
П	7					15			4			9		1	46		41	1		6							2				2
Р	55	1	4	4	3	37	3	1	24		3	1	3	7	56	2	1	5	9	16		1	1	1	2		8	3			5
С	8	1	7	1	2	25			6		40	13	3	9	27	11	4	11	82	6		1	1	2	2		1	8			17
Т	35	1	27	1	3	31		1	28		5	1	1	11	56	4	26	18	2	10				1			11	21			4
У	1	4	4	4	11	2	6	3	2		8	5	5	5	1	5	7	14	7			1		8	3	2				9	1
Ф	2					2			2						1		1	1													
Х	4	1	4	1	3	1		2	3		4	3	3	4	18	5	3	4	2	2	1			1							
Ц	3					7			10		2				1					1							1				
Ч	12					23			13		2			6					7	1					1			1			
Ш	5					11			14		1	2		2	2					1								1			
Щ	3					8			6					1						1											
Ы		1	9	1	3	12		2	4	7	3	6	6	3	2	10	3	9	4	1		16		1	2						
Ь		2	4	1	1	2		2	2		6		3	13	2	4	1	11	3					1	4				1	3	1
Э											1			1				1	9												
Ю		2	1	2	1			3	1		1		1	1	1	3	1	1	7				1	1		4					
Я	1	3	9	1	3	3	1	5	3	2	3	3	4	6	3	6	3	6	10			2	1	4	1	1			1	1	1

2-b. Digraphic kappa plain, Russian language = .0052

2-c. The 159 digraphs comprising 75% of Russian plain text, based on the table of 5,000 digraphs (Item 2-a), arranged according to their relative frequencies.

ОВ	84	ЕР	39	ЛО	30	ЕМ	24	АМ	19	АД	14	ИР	11	ВП	10
СТ	82	ОМ	38	ЛЬ	30	РИ	24	ОК	19	ШИ	14	СС	11	АШ	10
НО	67	ГЕ	37	ДЕ	29	НП	24	ТС	18	УС	14	ШЕ	11	ЛЯ	9
КО	66		1258[1]	ИТ	29	ИЗ	23	ВЫ	18	ЬН	13	АП	11	РТ	9
ЕН	63	ЕС	37	ОЙ	29	ЧЕ	23	ОЗ	18	СЛ	13	ИЧ	11	ЯВ	9
НИ	58	ЛИ	36	ИС	29		2492[2]	МА	18	ДН	13	ТН	11	ВН	9
ВО	58	НЫ	36	ТИ	28	МИ	23	ХО	18	ДИ	13	ИЙ	11	НС	9
РО	56	ВА	35	ОБ	28	ДО	22	ОП	18	ЕК	13	УД	11	БЕ	9
ТО	56	ЗА	35	АТ	27	ИВ	22	ЕВ	18	ИП	13	ЕГ	11	ЗН	9
РА	55	ЕЛ	35	ТВ	27	ИЛ	21	СЯ	17	ЧИ	13	ИД	10	ЕБ	9
НА	54	АВ	35	ЕД	27	ТЬ	21	ИХ	17	ОИ	12	ЕЗ	10	МУ	9
ГО	50	ТА	35	АЛ	27	МЕ	21	ИЯ	17	ЖЕ	12	ЙС	10	ЫВ	9
ОС	50	НЕ	34	СО	27	ИЕ	21	ВИ	17	АБ	12	ЫП	10	НТ	9
АН	48	ЕТ	33	КИ	26	БО	21	РУ	16	ЧА	12	АХ	10	ЭТ	9
ОД	47	ЛЕ	33	АР	26	ИМ	20	ЕП	16	ЫЕ	12	ЦИ	10	АЯ	9
ПО	46	ОГ	32	ТР	26	ВС	19	ЫХ	16	ОЧ	12	ЯТ	10	СН	9
ОР	43	ВЕ	32	ДА	25	ИИ	19	ПЕ	15	ТЫ	11	КУ	10	УЮ	9
ПР	41	ИН	32	СЕ	25	МО	19	АЗ	15	СП	11	ДУ	10	ЗО	9
ОЛ	41	ТЕ	31	ЛА	25	АК	19	ЕЙ	15	ЬС	11	КР	10	ОО	9
СК	40	АС	31	КА	24	ИК	19	ОЕ	15	БЫ	11	ТУ	10		3750
ОТ	39	ОН	30												

2-d. Frequent digraphs in Russian plain text whose reversals are also frequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

ОВ	84	ВО	58	РО	56	ОР	43	ГО	50	ОГ	32	ВА	35	АВ	35
НО	67	ОН	30	ТО	56	ОТ	39	ОЛ	41	ЛО	30	ЕЛ	35	ЛЕ	33
ЕН	63	НЕ	34	НА	54	АН	45	ЕР	39	РЕ	37	ЕТ	33	ТЕ	31
НИ	58	ИН	32												

2-e. Frequent digraphs in Russian plain text whose reversals are rare or infrequent, accompanied by their frequencies from the table of 5,000 digraphs (Item 2-a).

ПР	41	РП	2	СК	40	КС	3

2-f. Doublets occurring in Russian plain text, arranged according to their frequencies from the table of 5,000 digraphs (Item 2-a).

НН	24	СС	11	ЕЕ	7	ММ	3	ЛЛ	2	ДД	1	РР	1	ЯЯ	1
ИИ	19	ОО	9	ВВ	5	АА	2	ТТ	2	КК	1				

[1] The 24 digraphs above this line compose 25% of Russian plain text.

[2] The 66 digraphs above this line compose 50% of Russian plain text.

2-g. The 24 digraphs appearing 100 or more times as beginnings of words in 10,601 words in Russian plain text, arranged according to their absolute frequencies.

ПР	470	РА	250	ГО	169	ОБ	146	ДО	120	КА	110	ЧЕ	107
ПО	405	НА	246	СЕ	167	ДЕ	137	ОТ	115	ПЕ	110	ВС	101
ЗА	292	СО	220	СТ	161	НЕ	122	ЭТ	111	ТО	108	МА	101
КО	287	ВО	179	ВЫ	159								

3-a. The 69 trigraphs appearing 100 or more tires in 67,850 letters of Russian plain text, arranged according to their absolute fiequencies

ОГО	318	ТЕЛ	188	ТОР	152	ПРИ	137	РОД	128	РОВ	116	ЧЕБ	104
ЕНИ	295	НОВ	181	ЛЬН	151	РЕД	137	КОГ	123	СТИ	115	ИНА	103
СКО	270	ЕЛЬ	176	ПОЛ	149	ЕТС	135	АВО	119	ИЛИ	113	ТВО	103
СТВ	267	ОВА	169	ЛЕН	146	ННЫ	135	ПЕР	119	АСТ	112	АБО	101
ОСТ	260	ОРО	167	НЫХ	145	ОВЕ	134	ТВЕ	119	АНА	111	ИСТ	101
ПРО	233	СТР	165	НИЕ	143	КОВ	130	ЗАВ	118	НЫЕ	110	ТРА	101
СТА	217	ЕСТ	159	НИЯ	143	ННО	130	ВАН	117	ОЛЬ	110	ВЕТ	100
ОВО	204	АНИ	158	КОМ	139	СОВ	130	КОД	117	ПОС	110	ОВС	100
ВОД	203	СКИ	158	ИТЕ	138	ПРЕ	129	НОЙ	117	СТО	110	РАЗ	100
ЕНН	198	ТОВ	158	НОС	138	НОГ	128	ЕРЕ	116	ЕГО	104		

3-b. The 20 trigraphs appearing 50 or more tires as beginnings of words in 10,601 words in Russian plain text, arranged according to their absolute frequencies

ПРО	205	ПРИ	95	ПОС	81	ВЫП	73	ПОД	61	СТА	59	ГОД	51
ПРЕ	116	СОВ	87	ПЕР	78	РАБ	72	БОЛ	60	РАЗ	53	ГОР	50
ЗАВ	108	КОЛ	84	ПОЛ	74	НАР	71	РАЙ	60	КОН	52		

4. The 58 tetragraphs appearing 50 or more times in 67,850 letters of Russian plain text, arranged according to their absolute frequencies

НОГО	114	СОВЕ	87	ЕЛЬН	78	ВЛЕН	68	ПРОИ	60	ОИЗВ	54
ТЕЛЬ	111	АВОД	86	СТВО	78	СКОЙ	66	РОИЗ	60	КОТО	53
ИТЕЛ	107	ЗАВО	85	ИЧЕС	76	СТАВ	66	ОТОВ	59	ННЫХ	53
КОГО	99	СТВЕ	84	ОВЕТ	74	АРОД	65	ВЕТС	56	БОДС	52
НОСТ	98	ЛЬНО	83	ЧЕСК	74	ЕЛЬС	65	ТОРО	56	ЕТСК	52
ЕНИЯ	97	ПОЛН	82	АНОВ	72	ЕСТВ	64	АТЕЛ	55	ОТОР	51
ЕННО	95	СКОГ	82	ОСТА	70	СТАН	64	ГОТО	55	ВСКО	50
ЕНИЕ	88	ЕННЫ	81	СТРО	70	НАРО	63	ЕТСЯ	55	ОЛХО	50
ПРЕД	87	АБОТ	80	ВЕНН	69	ОВАН	62	СТВА	55	СКИЙ	50
РАБО	87	ЛЕНИ	80	ТВЕН	69	СТРА	61				

5. Average length of words in Russian plain text = 6.4

The following are in preparation:

APPENDIX 6

LIST OF FREQUENT WORDS - ENGLISH AND FOREIGN LANGUAGES

APPENDIX 7

CRYPTOGRAPHIC SUPPLEMENT

APPENDIX 8

LESTER S. HILL ALGEBRAIC ENCIPHERMENT

APPENDIX 9

CONCEALMENT SYSTEMS

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PRINCIPLES OF CRYPTOSECURITY

APPENDIX 12

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APPENDIX 13

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FOREIGN LANGUAGE PROBLEMS

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