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A STUDY OF THE FACTORS AFFECTING THE SIGHTING OF SURFACE VESSELS FROM AIRCRAFT

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PREFACE

This study was done at the Visibility Laboratory, Scripps Institution of Oceanography, University of California, San Diego, by Mr. Richardson outside of working hours as his thesis for the degree of Master of Science in Engineering from the University of California, Los Angeles. Although the study was done at no cost to the Laboratory contracts, it is pertinent and of interest to the program of the Laboratory and, as such, is presented as a Laboratory report.

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ABSTRACT OF THE THESIS

A Study of the Factors Affecting the Sighting of Surface Vessels from Aircraft

by

William Hadley Richardson

A collection of 3,465 detailed reports of sightings of surface vessels from aircraft of the U. S. Coast Guard are analyzed by probit analysis to determine visual thresholds and measures of variance of the thresholds. Each of seventeen conditions affecting the sighting range is studied separately to determine its effect. Empirical functions are developed to describe the threshold effects of each of the eleven following conditions in decreasing order of importance: (1) meteorological visibility, (2) altitude of aircraft, (3) ship size, (4) height of major swells, (5) cloud cover, (6) wind velocity, (7) relative bearing of target, (8) sun altitude, (9) relative bearing of sun, (10) wake size, and (11) wind azimuth. Thresholds are developed for the six following discrete conditions in decreasing order of importance: (12) visual aid, (13) range determination method, (14) type of observing unit, (15) time of day, (16) observer, (17) station. In each case, tables of probit results and graphs are included. Only wind azimuth is found to have an insignificant effect. Classification of data is made by mechanical card sorter, probit analysis by electronic computer and the remainder of the calculations by desk calculator. Measures of precision are listed and X^2, F and t tests are used at the 0.05 level. A table of factors for each condition is included to allow forecasting of sighting thresholds and explanation of use for any probability level. A random selection of sightings is made in order to supply conditions for use of these factor tables as a demonstration of forecasting and as a test of the reliability of the data and of the forecasting method. Suggestions for further study are made.

1.0 Purpose

The purpose of this study is to determine, from given data, the factors affecting the sighting of surface vessels from aircraft and to evaluate the factors and to develop a method of forecasting the sighting of surface vessels under particular circumstances.

2.0 Discussion of the Problem

2.1 Origin

The initial impetus toward the final results in this project came from the work of the Visibility Laboratory, Scripps Institution of Oceanography, University of California, and from the idea that an empirical study and analysis of actual sightings of targets would be of assistance in the Laboratory's research into vision, visibility, perception and recognition theory. The first opportunity to develop this idea came with the discovery (1956) of a series of reports of the sighting of submarines by aircraft, made under the supervision of Captain Dayton Brown, U.S.N.R., Retired, U. S. Navy Electronics Laboratory. A preliminary study of this data indicated the feasibility of statistical analysis, although there were some disadvantages inherent in the data. For example an insufficient number of conditions were reported and, most important, the data were classified under national security acts. The classification could not be removed. Since precisely this type of study had been chosen as a thesis project, the security difficulty was frustrating. However, enough work was done in the study cited to demonstrate the possibilities of extending such an investigation. It should be noted here that the implications of this initial work were borne out by the eventual conclusions presented in this paper.

At about the time that the security aspect of the first material was becoming rather discouraging, there was a fortunate development

(1958) in that a similar project was reported to have been completed recently by the U. S. Coast Guard (Appendix U and V). Investigation showed that it was a very thorough reporting of practically all of the factors affecting visibility of surface craft, that could be readily determined by a trained observer. The reports covered almost 10,000 sightings of surface craft from both surface and air craft.

The results of this project had been given to the Operations Evaluation Group, U. S. Navy, for analysis. A visit to the Group (1958) elicited the assistance of Dr. J. H. Engel, Deputy Director. He explained the scope of the Group's work and was kind enough to turn over an abstract of the data on IBM cards. From his description of their work, it appeared that more could be done than they had planned. Thus emerged the possibility of developing the Coast Guard data into this thesis.

The Operations Evaluation Group has made an internal report of their study of the data, but this material has not been released. It is sufficient to say that the approach was different from that of the study presented herein, and there is a marked difference between results, in general, and between interpretations in several cases.

2.2 Approach to the Study

The original goal of the study was a statistical analysis of the various factors affecting sighting of ships from aircraft and determination of the effect of these factors on the sighting range, thus the sighting range became the dependent variable in the relationships and the factors affecting it became the independent variables. After consideration of time and facilities available, and the appropriate scope of the study, it was decided to analyze first the sighting range in terms of each variable in turn, and then to determine which variables had significant effects. The data would not be analyzed further unless required for a satisfactory completion of the study within the stated limits. Furthermore it was decided that detailed consideration of the interaction of subclassifications of the variables would be beyond the scope of such a study. Finally, there did not seem to be a place for consideration of visibility theory at this stage of development.

The statistical concepts to be used were originally planned to be central tendency, and variance. The variation of these measures with changes in each variable were to be determined. The work was to be done on an automatic desk calculator, leaving a more thorough computer investigation for a later study based on the results of this one. Such a preliminary development had been made for the abandoned Brown data (Section 2.1) and had indicated the probable value of this approach.

2.3 Development of the Approach

While preliminary processing of the data was proceeding (1960), there was a requirement in the psychophysics research of the Vision Branch, Visibility Laboratory, for a computer treatment by probit analysis of perceptual threshold experiments. In this application a visual threshold is that point at which there is an arbitrary probability of seeing a given target. A probit analysis program (Section 2.4) was made for the Burroughs 220 computer based on a previously developed automatic calculator method of the author. A consideration of this program indicated that it would be suitable for a study of the Coast Guard data, and it was immediately evident that a threshold study of the data would be superior to, and more useful than, a straight mean and standard deviation study. It would have been intellectually uneconomical not to use the fine tool (probit analysis) that was at hand. So the standard statistical approach and the desk calculator were relinquished in favor of probit analysis on the high speed computer.

2.4 Probit Analysis

The probit analysis method comes from several diverse sources. Essentially it is a method of fitting distribution functions to weighted data obtained from experiments. Early phases of its development were motivated by the requirement for the determination of kill dosages of insecticides. The probit method is based mathematically on the maximum likelihood method for estimation of parameters. The analysis was developed principally by Fisher (8)*, Garwood (10), and Finney (7), among others to be mentioned later. The transformation from experimental frequencies to normal deviates was introduced by Hazen (11), and Whipple (24) by graphical means and later developed analytically, as now used in probit analysis, by Wright (25) and Gaddum (9), apparently independently. The weighting method involved in the transformation of experimental frequencies is due to Muller (17) and was rigorously developed by Urban (21). Bliss (1 and 2) was responsible for the name "probit" and for a general description of the process.

In the development of the probit analysis method, equations of estimation were derived by the use of the maximum likelihood method. A likelihood function was set up which was proportional to the product of the probabilities of empirical ratios of number of responses to number of presentations of stimuli. Taking the

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* Parenthesized numbers following authors' names refer to the corresponding numbers in the bibliography.

logarithm of this function simplified development and did not change the character of the process. The logarithm of the likelihood function was then maximized with respect to the two unknown parameters, threshold and standard deviation, by equating the partial derivatives to zero. The result was a system of two simultaneous equations which could lead to determining the unknown parameters mentioned above. The simultaneous system generally could not be solved by direct methods but could be solved approximately by iteration after expanding in Taylor's series and using trial values of the parameters. The solution of the equations was further simplified by substituting for the threshold and standard deviation their equivalents in terms of the slope and intercept of the linear transformation from the stimulus domain to the normal domain, since the new trial parameters could be found readily, either graphically, or analytically by the method of least squares, or other fitting method. The solution of the transformed system of simultaneous equations was then formulized after introduction of a device called the working probit, which further simplified the formulation.

The probit analysis method is adaptable to many experimental problems involving cumulative quantal data. The method is in use in psychophysical research at the University of Michigan and the University of California. It has been adapted for desk calculator use by Kincaid and Blackwell (13), and by the author (18); to digital computers by Moldauer and Kincaid (16) for MIDAC, by Lamphiear and Wendel (14) for IBM 650, and by the author for

Burroughs 220 (future publication) and CDC 1604 and IBM 7090 (future publication).

The adaptation used in this project is that of the author for the Burroughs 220 (future publication) which in turn is based on his adaptation for desk calculators (18). Given cumulative positive responses to stimuli over the range of the stimuli, ratios or empirical probabilities are calculated and transformed to abscissas of the normal distribution function, normal (0,1), that is with mean of zero and standard deviation of one. Finney (7) uses a 5-biased normal distribution, normal (5,1), to avoid negative abscissas. The resulting abscissa is called the probit, hence the name of the method. In the digital computer treatment negative abscissas are no disadvantage so the 5-bias is not used, though the liberty is taken of calling this abscissa a probit also, since the use is the same. The probit which has been determined is termed the empirical probit. A trial linear transformation function of the form $y = a + bx$ to transform from the experimental domain to the normal domain is determined, in this method, by the method of least squares. The resulting probits, y, corresponding to the experimental stimulus points, x, are termed trial probits. Having determined the trial probits for the range of stimuli, the weighting factor is applied to account for the instability of the empirical probabilities toward the tails of the distribution function. All of the requirements are now available for the solution of the maximum likelihood system. The solution is facilitated by the introduction of the working probit, sometimes and incorrectly called the corrected probit, which allows a simply calculated, next approximation to the parameters of the transformation function. Approximate values of the threshold and standard deviation are determined directly from the parameters and are used to make a χ^2 test of the relation between the empirical frequency ratio and the ratio calculated from the threshold and standard deviation. If the test shows a significant difference, the transformation parameters are used as corrected trial parameters to reenter the process in order to improve the results by iteration. The computer application used in this project continues iteration until an acceptable χ^2 value results or until the process begins to diverge. If an acceptable χ^2 value results, the final approximation of the threshold and standard deviation are recorded.

The flow of the computation is shown in Appendix W.

It may be of interest that the computer process requires a computation time of 2 to 3 seconds, since card input of data is folded into the computation. Print-out time is about 30 seconds since a Soroban teletype printer is used. Use of an IBM 407 printer would cut overall problem time to about 5 seconds.

3.0 Discussion of the Analysis Process

3.1 Sorting

The initial step in processing the mass of data was to separate the air sightings from the 10,000 cards that included both air and surface sightings. This was done on an IBM mechanical card sorter and the cards were sorted both by type of observing vehicle and by observer to assure that no surface sightings were included in the 3,465 cards, each of which documented an air sighting. This sorting was done before the decision was made to use probit analysis. The data were next sorted to classify them for a standard statistical analysis. This sort was with respect to the dependent variable, sighting range. The range of the variable was checked and it appeared that the last class should include 22 miles and more, since any further classes would contain too few sightings for reliable analysis. This procedure was very convenient: the optimum number of classes from the standpoint of both reliability and practicality is usually taken as from ten to fifteen; thus, using an increment of two miles from zero to twenty-two miles, there were twelve classes.

3.2 Counting and Tabulating

The card sorter was equipped with a counter and the next procedure was to sort each class of the dependent variable into classes of an independent variable and then rerun each class of the independent variable to determine the count. Here the number of classes does not depend on statistical theory but on a logical division of the ranges of the independent variable so as to give useful results in the case of a continuous type variable. Some of the independent variables were inherently broken down into discrete classes as in the case of the visual aids used. The result of this sort and count on the seventeen independent variables was tabulated and produced seventeen frequency matrices.

3.3 Arranging for Probit Analysis

One more processing step remained before the data could be presented to the computer. Probit analysis treats cumulative distribution functions and not Gaussian frequency functions. A distribution matrix was compiled with each class of the independent variable becoming a distribution function vector with respect to the sighting range. In other words, the sighting range then became the independent variable for probit purposes, and the frequency within the class of the independent variable became the dependent variable, or distribution function of the sighting range. This resulted in 147 probit problems.

In sorting and counting on the independent variables, cards coded for no-report-entry or anomalous entry were tabulated and given a balancing check against the over-all count. They were also included in the probit analysis of the variable as an extra class, but no significance was noted other than that, as sighting conditions become more difficult, observers tend to be more meticulous (which was inferred from the lower proportion of faulty cards).

The data were ready for computer manipulation at this point.

3.4 Computer Processing and Problems in the Probit Analysis

The data were now punched into cards for entry to the computer. The original classification was followed, each sighting range increment of two miles becoming a point determining the distribution. In general this gave twelve points on the abscissa for even numbered miles. The distribution functions were found to be of the log-normal type, considered to be a result of the exponential attenuation of radiance and contrast. The computer program provided for both normal and log-normal distributions. The input data called for a selection of log-normal analysis and the computation was started on this basis. Apparently a major task in the processing had been completed and the results of the computation were ready for analysis of effects and trends. Unfortunately this proved not to be the case.

The computer output consists of the parameters of the probit transfer function, the threshold, the fiducial limits, the standard deviations of the data, threshold, standard deviation and parameters, and last, but far from least, the χ^2 measure of goodness of fit.

An examination of the χ^2 measure showed that only a little over half of the functions were fitted at the 0.05 level, which had been selected as the acceptable criterion. The unacceptable functions were checked and end points in the tails of the distributions, that showed very small numbers in the frequency table, were stripped out. This is usual procedure in probit analysis, since it does not affect the results, and the instability in the tails may affect the

χ^2 measure, not the essential character of the distribution. Reruns were made of the unacceptable data sets and, while there was a marked gain in production, there was still about a quarter of the sets that were not acceptable.

It was at this point that what had been noticed as an interesting sidelight in the data counting became a matter of crucial importance: it had been evident in the sorting and counting that observers tend to estimate, or round off, to multiples of five, and the stacks in these bins were disproportionately high. It was now evident that, with the relatively fine definition of a two mile increment in sighting range, this tendency was introducing an extraneous scallop in the distribution functions.

An obvious method of removing this scallop was to increase the increment in the sighting range so that the data divisions were located at points where the data character was consistent, such as on multiples of five miles. Here the sorting on even miles might have been a possible handicap, for the only alternative to resorting and recounting the basic card deck was to choose the divisions of the existing sort that included the multiples of five miles. This course was decided for trial, and all of the data sets were set up again with abscissa points at zero, four, ten, fourteen and twenty miles, since these included the five mile divisions. The results of this run were gratifying, for only about a tenth of the problems were not acceptable at the 0.05 level and most of these were acceptable at the 0.01 level. This last level was not considered acceptable and the tail points with very few numbers were stripped out. Most of these were equivalent to probabilities of less than 0.01 and in no case as much as 0.03. It is of interest to note here that many of the acceptable problems included probabilities of less than 0.01, which is not usually expected. A rerun was made of the stripped problems and, out of those that might be expected to give good results, only three remained unacceptable at the 0.05 level. That is, the few others remaining had less than six sightings to a problem.

While one can solve for any probability threshold in probit analysis, depending on the needs of the analysis, in this study the 0.5 threshold is found. This is also known as the "50% threshold," or the "mean threshold." It is the point at which the probability of sighting is 0.5, or that point at which an observer is as likely to see as not to see an object. The conversion of the 0.5 threshold to a threshold of any other probability is given later.

3.5 Development of the Produced Data

3.5.1 Tables

The computer-processed results are tabulated (Appendices A through P) to show the initial data and the probit analysis parameters: threshold (T), standard deviation of the distribution (s), standard deviation of the threshold (s_T) and the chi-square measure of goodness of fit (χ^2). Where a small probability tail value is dropped, it is shown in parenthesis.

The mean standard deviation ($\bar{s}$), the standard deviation of the standard deviations (s_s), the standard deviation of the mean standard deviation ($s_{\bar{s}}$) were also added to the tables.

3.5.2 Graphical Display

The thresholds are plotted on graph paper, in a linear plot or in a logarithmic plot if this appears appropriate. (Appendices B through P). This procedure aids in determining the type of empirical function to be fitted to the data. Where a sine or cosine type curve appears suitable, double plotting is used to facilitate visual interpretation. In this case the original plot is made and the supplement or complement of the angle is used to plot the corresponding thresholds on the same abscissa axis.

3.5.3 Fitting Empirical Functions

After a survey of the data graphs, empirical functions are fitted to the threshold data using standard least square methods of fit. In the case of parabolic functions, Cholesky's method (19) of reduction of matrices is used in the solution of the normal least square equations. This method greatly facilitates the solution of simultaneous linear systems. It is described by Salvadori and Baron (19). The simplest function is chosen which gives a high correlation coefficient and preserves the character of the data. These functions are added to the tables along with a factor function (f) which is the empirical function normalized to the normal range which will be described in the section on the general distribution of sightings (Section 4.1). Functional threshold values are then calculated and added to the graphs for comparison purposes.

3.5.4 Testing for Significance

Maximum and minimum functional threshold values are tested to determine whether or not the effect of the variable is significant. The t test for difference of two means is used, based on Student's t distribution. The only case of insignificant effect is that of wind azimuth which is to be discussed in detail in that section.

3.5.5 Notes on Results

It is very important to keep in mind that, while the threshold T is in the linear domain and dimensioned in nautical miles, s, s_T, $\bar{s}$, $s_{\bar{s}}$ are in the logarithmic domain and are dimensionless constants in this application. χ^2, t and F also apply to the logarithmic domain.

To use the standard deviation as a probability tool in determining a threshold of other than 0.5, the following relationship holds:

$$T(p) = T\,e^{-D(p)s}$$

where $T(p)$ is the threshold for the desired cumulative probability p.

T is the threshold which is always for a $p = 0.5$ in this study.

$D(p)$ is the normal deviate for the probability p.

s is the standard deviation.

The reason for the negative exponent in the above relationship is that these are reverse distribution functions; the distribution function is monotonically decreasing in the positive abscissa direction.

The above formula is specialized and, if the user is working in other units than nautical miles, T must be converted to the new units in order to compute $T(p)$. The s is not converted in any way.

It is interesting to note the extreme sensitivity of the probit analysis technique in conjunction with the χ^2 test. Twenty of the problems, not acceptable on the first run, are made acceptable by removing the very small numbers in the extreme tails of the distributions. In nineteen of the problems, this change results in an average reduction of χ^2 from 10.253 to 1.894 while there is an average absolute change of only 0.00965 of the value of the threshold. This result definitely indicates the inherent stability and excellence of the method. In the one remaining problem, removing the small tail number proportionally changes the threshold 0.186 while reducing χ^2 from 72.157 to the magnitude of 10^{-11}. It is surely a coincidence with the criterion of acceptance that this one reading is 0.05 of the twenty readings in this category.

4.0 The Analysis: Discussion of Graphs and Tables

In this section a detailed discussion is made, where appropriate, of the input data to, and results of, the probit analysis. In particular, comments are made on the graphical evidence and empirical function determination. The empirical threshold function, T(.); the normalized threshold or factor function, f(.); and the correlation coefficient, r are stated in this section. Any other significant observations are included with each variable treated.

The mean of the computed standard deviations is entered in the appendix tables for information and possible use, since the standard deviations of the thresholds appear generally level enough so that the mean standard deviation might well be used through the range of most of the variables.

4.1 General Distribution (See Appendix A)

In this case all records that have sighting ranges are lumped together and a distribution set up. The data shows a typically log-normal character. The probit calculation gives a threshold of 6.599 nautical miles with a χ^2 of 4.308, which is acceptable at the 0.05 level.

This threshold for all sightings is based on 3,465 sightings taken on the Atlantic and Pacific coasts from Puerto Rico to Alaska and should be a representative measure of central tendency of the class of all sightings of surface vessels from aircraft. This conclusion is borne out by the estimate of the coefficient of variation of the threshold, 0.0015. Hence this threshold range, 6.599 miles, is taken as the standard reference range in this study and is used as the normalizing range where normalization is carried out, as in the development of the threshold factors. This range is called the "normal range," T_N, and is so marked on the graphs.

4.2 Meteorological Visibility (Appendix B)

Meteorological visibility is defined as follows by the U. S. Weather Bureau (23): "... the greatest distance toward the horizon that prominent objects such as mountains, buildings, towers, etc., can be seen and identified by the normal eye, unaided by special optical devices, such as binoculars, telescopes, glare eliminators, goggles, etc., and which distance must prevail over the range of more than half the horizon." Granting that this procedure does not present a rigorous measure of atmospheric turbidity, it is still the best one now in general use and is the one in which all observers are trained, have used, and that most will use for some time to come. However it should be noted that precise definitions of visibility have been formulated in terms of "meteorological range," a quantity that can be defined analytically, measured instrumentally and used in the solution of visibility problems.

The 0 - 1 mile visibility classification has only three sightings, one at six miles sighting range and two at zero miles. While the cumulative data are routinely introduced in the probit analysis, this classification, as might be expected, gives a T of the order of 10^{-11}, s of 10^{-38}, s_T of 10^{-42}. Any further consideration of this classification is ruled out. There is an apparent anomaly in the data for the classification of 10 - 19 miles visibility between the sighting ranges of ten and twenty miles. Numerous efforts with various combinations of input result in no convergence at the 0.05

level. The count has been rechecked and the only possible conclusion is that this is one of the things that sometimes happens. This is the only case in this study where the 0.05 acceptance criterion is relaxed. The data included for this classification in the appendix are acceptable at the 0.01 level with a χ^2 of 10.094 and are the best fit obtained. The next best fit is at a χ^2 of 15.837 which has a proportional difference of 0.00239 from the accepted threshold. Since the stability of the mean is established thus, and because of the fact that all other results group very closely about the accepted threshold, the number that appears in the table is accepted. This procedure is admittedly subjective reasoning to a certain extent but it is a considered judgment.

A plot on semi-logarithmic paper shows a distinct linearity of the type $T(V) = a + b \ln V$. A least square fit gives this equation:

$$T(V) = 3.476 \ln V - 2.064, \quad V = \text{Visibility}$$

$$f(V) = 0.527 \ln V - 0.313$$

$$r = 0.969 \text{, in the logarithmic domain.}$$

The sighting range may well approach an asymptote as visibility increases, but there is insufficient evidence to determine this effect at this time.

A point of interest in the threshold table is the sharp and (at first thought) surprising drop in sighting range with unlimited visibility. It would appear that when an observer has no definite landmarks but good, clear air, he terms this condition "unlimited."

However, if he states visibility is 70 miles, he doubtless identifies an object at that known range. May we assume that the classification "unlimited" really means, "I think I can see a long way"? Meteorologists agree with this assumption and consider that a report of unlimited visibility should be taken to mean "more than fifteen miles."

4.3 Altitude (See Appendix C)

The data on this variable require discussion only in the 9,000 foot classification. No difficulty is involved in the solution of any of the other classes. The usual run at 9,000 feet including the multiples of five miles sighting range gives anomalous results. Previously, when run at increments of two miles, acceptable results had appeared, and even better results with respect to χ^2 had occurred on increments of four miles. This last interval is the number used. The irregularity results no doubt from only seven sightings at this altitude. The data shows a linear trend in a semi-logarithmic domain with a functional form of $T(A) = ae^{bA}$. The best fit function is:

$$T(A) = 5.385\, e^{0.116A}, \quad A = \text{altitude in 1000's of feet.}$$

$$f(A) = 0.816\, e^{0.116A}$$

$$r = 0.963, \text{ in the fitting domain.}$$

There is no apparent reason for the reverse trend from 2,000 to 4,000 feet, such as a general hemispheric tendency to a 3,000 foot haze layer. The linear plot shows close grouping about the fitted line. Hence no attempt is made to fit a cubic equation. This might be a matter for further investigation.

4.4 Ship Size (See Appendix D)

The data here appear unremarkable, and the probit analysis presents no difficulty, requiring reruns only where there are four and five tail sightings in the classes: less than 30 feet bright-colored; 30 to 60 feet bright colored.

It is in this variable that the only major criticism of the report form (Appendix V) arises. The dimension of the variable changes at 100 feet from length to tonnage. This discontinuity requires a transformation from tonnage to length. With the help of Fahey's catalog of U. S. Navy auxiliaries (6), a function is developed to effect this transformation. It appears that the list of auxiliaries is a representative cross-section of ships that a Coast Guard patrol would sight. The function adopted is:

$$L = 21.4 \; T_W^{1/3} - 16$$

where T_W is full load tonnage and L is length in feet. This function has a correlation coefficient of 0.985. (See Appendix D-3 and 4)

After transforming the data tonnages to length, the threshold data show a very decided linearity in the semi-logarithmic domain of the type $T(L) = a + b \ln L$. The best fit function is:

$$T(L) = 1.844 \ln L - 1.100, \quad L = \text{Length in feet}$$

$$f(L) = 0.280 \ln L - 0.167$$

$$r = 0.982$$

The effect of shading of target might be handled in a number of ways, but various trials show that a simple and satisfactory correction is to add 0.279 miles to the threshold for bright vessels and subtract 0.279 miles for dark vessels, both types under 100 feet. There is insufficient basis to apply this correction to larger targets. The correction is based on a fit made to the separate bright and dark classes.

4.5 Height of Major Swells (See Appendix E)

There is no need to comment on the data here other than to mention that mean swell height for the ten-feet-and-more classification is 15.381 feet and is so used in the fitting process. The probit analysis turns out well.

The data show a sufficient linear trend to adopt an empirical function of the $T(S) = a + bS$ type. The fit produced is:

$$T(S) = 6.170 + 0.239\ S\ , \quad S = \text{Swell height in feet}$$

$$f(S) = 0.935 + 0.0362\ S$$

$$r = 0.707$$

The correlation coefficient is not as large as would be desired, due mainly to the two highest values. Including these values might be questioned, in view of the few sightings in these classifications. However they show no anomalies, have $p(\chi^2)$ values of greater than 0.9 and 0.4 respectively, and they straddle the fitted line. It is considered better to retain them, lacking further evidence.

It may seem surprising that one sees objects better in higher swells, but there may be three causes for this. One is the relative motion of the object with respect to the water masses, which attracts attention. Another is that the higher swells break up the grazing reflection of the brighter horizon sky. A third perhaps is that the object is seen against a surface sloped toward the observer which may have some effect by giving a generally darker background rather than the horizon sky reflection. This same trend has been noticed by

Coast Guard observers.

4.6 Cloud Cover (See Appendix F)

No difficulty is encountered with this data or with the probit analysis. An inspection of the linear plot clearly indicates a parabolic fit of the form $T(C) = a + bC + cC^2$. The least square method gives:

$T(C) = 7.069 + 2.871C - 4.717C^2$, C = Cloud cover in decimal fraction

$f(C) = 1.071 + 0.435C - 0.715C^2$

$r = 0.903$, in the linear domain

The maximum value of this function, $T(0.304) = 7.506$ miles threshold, bears out informal Coast Guard impressions that an observer sees best with about one-third cloud cover. This may be a result of diminution of surface glare and glitter with enough direct lighting remaining to give good contrasts.

4.7 Wind Velocity (See Appendix G)

The one sighting of 45 - 49 knots is disregarded. At 50 knots and greater there are only four sightings. The probit analysis is good until the 50 knot results are inspected carefully. Here the parameters of the probit transfer equation are of an entirely different magnitude and character from the rest of the family. Since there are so few sightings (and this is an extremely erratic threshold of low dependability: $S_T = 0.43$ in the log domain) it is rejected. The other two erratic points are accepted. There is no clear reason for their rejection.

The accepted thresholds, when plotted, indicate a parabolic trend of the type $T(WV) = a + bWV + c(WV)^2$. The best fit is:

$$T(WV) = 5.488 - 0.142\ WV - 0.002673(WV)^2$$

WV = Wind velocity in knots

$$f(WV) = 0.832 + 0.0214\ WV - 0.000405(WV)^2$$

$$r = 0.531$$

Here the correlation coefficient is lower than desirable, due to the two erratic points included. However, the empirical function is the only simple function typical of the trend of the data. The maximum value of the function, $T(26.6) = 7.378$ miles indicates the best seeing is where the meteorologists say a breeze becomes a gale between 27 and 28 knots, or between force six and force seven winds on the Beaufort scale. This conclusion is reasonable since in this velocity range the surface becomes very disturbed and spray and foam appear. This condition explains the different character of the variable, WV , from that of swell height.

4.8 Relative Bearing of the Target (See Appendix H)

This variable is also termed "clock code" in the report form (See Appendix V). The data show very few sightings in the rear field of view. This sighting lack raises the question of the practicality of designing patrol planes with tail observations a major factor.

The probit analysis gives good results although the character of the few sightings at seven o'clock defeats efforts to determine an acceptable threshold. The low number of sightings to the rear and their somewhat erratic behavior make it tempting to discard them. However, double plotting shows the data are consistent in character and follow a cyclic pattern of the type $T(B) = a + b \cos B$. The best fit function is:

$$T(B) = 6.046 + 0.808 \cos B$$

B = Relative bearing or $30 \cdot$(clock code) degrees

$$f(B) = 0.916 + 0.122 \cos B$$

$$r = 0.697$$

Again, the relatively low r is the result of the erratic rear sightings. However, a polar plot of this function shows an apparently less erratic trend to the rear.

4.9 Sun Altitude (See Appendix I)

Here the only case demanding comment is that at 90 degrees where there are only six sightings. The probit analysis does not give an acceptable fit and this classification is disregarded. Otherwise the probit analysis is normal.

A survey of the plotted thresholds indicates an empirical function of the type $T(SA) = a + b \sin (SA)$, and the least square method produces:

$$T(SA) = 7.795 - 1.564 \sin (SA), \quad SA = \text{Sun altitude:} \quad 0^\circ \angle SA \angle 90^\circ$$

$$f(SA) = 1.208 - 0.238 \sin (SA)$$

$$r = 0.915 \text{ in the fitting domain}$$

Thus, it appears that seeing deteriorates with increasing sun altitude. This conclusion seems reasonable since a low sun results in stronger internal contrasts in the target while a high sun gives a flatter lighting.

4.10 Relative Bearing of Sun (See Appendix J)

This bearing is with respect to the target. The data here is worthy of comment in that the total number of sightings in each classification of bearing alternate in magnitude with the high number applying to the classifications containing the four major divisions of the circle, multiples of 90 degrees. There is no probit trouble and every problem develops acceptably the first time.

Double plotting of the data (as in Section 3.5.2) clearly indicates an empirical cyclic function of the type $T(SB) = a + + \cos(\pi - SB)$. The character of the data necessitates the phase shift. The fitting process gives:

$T(SB) = 7.043 + 0.342 \cos(\pi - SB)$, SB = Sunbearing in degrees

$f(SB) = 1.067 + 0.0518(\pi - SB)$

$r = 0.987$ in the fitting domain

This conclusion shows, as might be expected, that an observer sees better with the sun behind him as he looks at the target. However, the change from minimum to maximum of 6.701 miles to 7.385 is not as great as one might expect.

The question may be raised why the minimum threshold is greater than the normal range. Does one expect, on the basis of this behavior, always to see better than the normal range? Examination of the data leads to the explanation that in total overcast, cloud cover of 1.0, relative bearing of sun with respect to target is frequently not reported and under these overcast conditions the threshold is much less than the normal range.

A further point of interest is that the alternate classifications with low numbers of sightings, mentioned above in the first paragraph, are also the classifications having the larger thresholds. Perhaps this distribution means that those who are meticulous in noting exact bearing, rather than the nearest 90 degree direction, are also more meticulous and alert in their search operation.

4.11 Proportional Wake Size (See Appendix K)

This is the last of the conditions that lead to a continuous type threshold function and, in effect, the least important. The choice of proportional instead of actual wake size was due, doubtless, to plan rather than fortune. This proportional measure automatically rules out such aberrations as might result from large slow ships with little wake in comparison with small fast vessels leaving large wakes. The effect here is small though significant statistically.

The data appears good as is proven by no failures on the first probit runs. A survey of the plotted thresholds indicates an exponential curve approaching a non-zero asymptote. The type curve is $T(WS) = a + be^{c(WS)}$. Taking the asymptote, $T(WS) = a$, to be the threshold of the classification defined as greater than twice the length of the vessel, the following function develops:

$$T(WS) = 7.295 - 1.066e^{-1.284(WS)}, \quad WS = \text{Wake size, as a multiple of ship length}$$

$$f(WS) = 1.105 - 0.162e^{-1.284(WS)}$$

$$r = 0.920 \text{ in the fitting domain}$$

The correlation is even better in the linear domain so no attempt is made to determine the asymptote analytically, a doubtful procedure at best with as few data points as are available here.

4.12 Wind Azimuth (See Appendix L)

It is unfortunate that the definition of wind direction as an azimuth was prescribed in the report form (see Appendix V). It seems very unlikely that wind azimuth would show a significant effect on thresholds of sightings, whose azimuths must be assumed to be more or less random. A much better and more valuable definition would be wind bearing with respect to target, in the same manner as sun direction is defined.

The data show no anomalies, and the first probit run gives a total success with excellent χ^2 values.

The plotted thresholds exhibit an undistinguished scatter about the normal range. A fit of $y = a$ type produces $a = 6.556$. A t test shows that this distribution is not significantly different from the normal range and a χ^2 test shows the points normally distributed about the normal range with $0.95 \angle p(\chi^2) \angle 0.98$. It is necessary to disregard any effect of this condition.

4.13 Visual Aid (See Appendix M)

This is the first of the conditions that must be treated discretely, and it has the greatest effect, considering the spread between the high and low thresholds. Binoculars show a great advantage from a threshold standpoint, but this must be a questionable advantage when only 0.01 of the sightings are made with them. The interpretation might well be that, <u>if</u> an observer sees a target with binoculars, he sees it farther away. Probably a more factual interpretation is that observers do not consider binoculars valuable as a search aid.

The difference between no visual aid and the use of sunglasses is very important however. Many people feel that, since sunglasses protect the eyes from glare and strong light and are more restful, they are an aid to vision. The advantage of eye relief is evidently outweighed by the attenuation of contrast in the colored lens and the consequent threshold reduction. A t test shows a strong significance here and it is necessary to accept the definite difference between using and not using sunglasses. The results are tabulated:

	T	f
Binoculars	8.908	1.350
No aid	6.637	1.002
Sunglasses	6.265	0.949

4.14 Range Determination Method (See Appendix N)

The results of this probit analysis are somewhat surprising. It had not been considered that the means by which sighting range was determined after the sighting would have any effect on the threshold. However, the following explanations may be worth considering. If an observer estimates the sighting range with radar, the inference is that he has his radar activated prior to sighting and picks up the target on it, thereby having a strong clue as to where to look. His advantage over the uninformed observer is obvious. The other explanation, possibly valid, is that while time-distance checks (calculating distance by speed, and time to reach target) are quite accurate, and this is borne out by the threshold developed, the unaided observer tends to underestimate distances. A tabulation of results follows:

	T	f
Radar	8.611	1.298
Time-distance	6.629	1.001
Estimate	6.147	0.923

4.15 Type of Observing Aircraft (See Appendix P)

The results here are interesting and may well measure the effectiveness of the types of sighting craft. However missions and method of operation should be considered. Considering operating altitude, the measure of effectiveness becomes weaker. The operating altitudes are not normally distributed but are more nearly log-normal. The log normal means are computed and the following table shows probit results with a consideration of altitude added:

Type	T	f	Mean Altitude	T(Altitude) (Expected)	T/T(Alt.)
Patrol	6.694	1.014	1278	6.247	1.072
Utility	5.836	0.884	1083	6.107	0.956
Helicopter	4.836	0.733	606	5.778	0.836

While this analysis is not too precise, the T/T(Alt.) measure is slightly more generous to the utility plane and the helicopter than is the f measure. Again, a consideration of missions might alter these indications.

4.16 Time of Day (See Appendix P)

This condition is defined for day, twilight, and night, since sun altitude takes care of lighting variation during the day. The usefulness of the thresholds of this condition are open to question since the t test at the 0.05 level shows a significant difference between day and twilight but not between day and night. The thresholds for twilight and night may be taken as the same. However the populations sampled may be different. At night it is probable that many of the sightings are of lights, not ships as in daytime. In view of the day-twilight significance, the factors are tentatively accepted. This subject merits further study.

The computed values are tabulated as follows:

	T	f
Day	6.614	1.002
Night	5.583	0.846
Twilight	5.496	0.833

4.17 Observer (See Appendix Q)

Here the pilot and copilot appear to observe equally well, and this is confirmed by the t test with a $p(t)$ of 0.920. There is a significant difference between pilot-copilot and bow lookout. This might seem unusual unless one considers the situation of the bow-lookout and his excellent view almost straight down. It is a great temptation to concentrate on the area directly under him when he realizes he sees better there. As far as the waist lookout is concerned, he would be expected to see less well than the pilot-copilot since he is looking to the side. The data from the section on relative bearing of the target shows that at 90 degrees he would expect to have a threshold at about 6.2 miles. He is still seeing less than this, though perhaps not significantly so.

A table of thresholds and factors follows:

	T	f
Pilot	6.603	1.0006
Copilot	6.616	1.002
Waistlookout	5.853	0.887
Bowlookout	5.553	0.841

The low number of three sightings by the tail lookout reinforces the previously inferred suggestion that this search position might well be abandoned. Tail observations were not considered here.

4.18 Station (See Appendix R)

The data are presented herein but no analysis was attempted. There are too many extraneous influences, such as local weather and local operating procedures and policies, to permit analysis of the effects within the restricted scope of this study.

There is certainly a fertile field here for cultivation by a full scale operations research study.

One small scale operations study was carried out after a number of very odd quantities showed up in the card sorting. These were such reports as a bearing of 540 degrees, a sighting range of 85 miles, cloud cover of 1.40 and so on. Curiosity suggested pulling out these cards to see what they might have in common. It was first found that they all come from the same station. A further investigation showed that they were all made on the same day, 1 January 1956. The reader is left to his own inference.

4.19 Tabular Extract of Threshold Factors (See Appendix S)

The factors (thresholds normalized to normal range) are included in Appendix S and need no comment.

5.0 The Test (See Appendix T)

The original plan was to present the preceding analysis of the sighting data as the complete study. It became a matter of curiosity to see if the normalized thresholds could be used to forecast sighting thresholds. The results of this curiosity are so gratifying that they are included as a test of the process and as a demonstration of the possibilities that further and more detailed work may develop.

5.1 Description

The entire deck of cards recording air sightings were disarranged by sorting on the second digit of the wind azimuth number, a classification that should result in no pattern. Then 20 cards were drawn at approximately equal increments of distance through the length of the deck. This procedure should give a random assortment of sightings and a survey of the reconstituted records shows this to be apparently true. (See Appendix T - 3 ff.)

The factors corresponding to the conditions of a particular sighting are taken from the factor tables in Appendix S and the product of all of these and the normal range give the calculated threshold for that sighting. This technique is followed without consideration, at this stage, of the reported range. If a condition is not reported, it is omitted, which is essentially judging that the expected value of this condition pertained at the time of the sighting.

5.2 The Results (See Appendix T)

The results of the twenty computations are plotted on the graph against the reported value. A mean line is included, as is the ideal line. If the forecast were perfect, the computed points would be expected to be normally distributed about the ideal line. As it results, a χ^2 test shows the points are normally distributed about the mean line with a $p(\chi^2)$ between 0.90 and 0.95.

The correlation coefficient, 0.695, shows the strength of the trend. The coefficient is not expected to be high for the computed points are forecasted thresholds, and sightings based on the conditions determining the forecast should vary normally with resepct to the threshold.

These results suggest strongly that thresholds can be effectively forecasted by proper consideration of the conditions affecting sighting at the time.

6.0 Conclusions

6.1 General Observations

The limited scope of this study precludes detailed study of all the inter-relations suggested by the work on the data. Some of the deficiencies are that dependence of variables is treated only superficially; trends of sub-classes of the conditions are not determined; complete study of the few anomalies occurring in the computations are not possible at this time. However it appears that the study indicates a positive method of forecasting sightings and sighting probabilities. Further, it would seem that, until more conclusive information is available, the factor table as it stands might well be a valuable tool in forecasting.

It is not possible to estimate the total number of possible sightings in any particular case, since sightings not made generally cannot be reported. In a standard analysis of variance procedure the missed sightings would lead to an obviously erroneous result. However one must assume that these missing possibilities are accounted for, to a certain extent, in probit analysis which considers, in fitting a curve to the data, the character of the distribution function as well as the numerical values of the frequencies. This assumption is further reinforced when the characteristics of the log-normal distribution are reviewed. In a normal distribution the missed sightings would result in a cumulative probability of less than one at zero range which infers that it would be possible, technically, to compute some sightings at negative range. This situation is not true in the log-normal case for the cumulative probability at zero range must be one.

It is possible that further development of the probit analysis method will allow accounting for these missed sightings.

6.2 Value of the Study

This study is expected to be of value in vision and visibility research as a factual basis for checking theoretical studies.

The matter herein should be of use to the Coast Guard and Navy in refining search procedures and methods as defined in the "National Search and Rescue Manual" (22).

The study should also be of use in any operational research involving searching and visibility at sea.

6.3 Further Studies Suggested

The most apparent future project is a similar analysis of the sightings from surface craft and a comparison with these results.

There is a fertile field for anyone interested in the psychological study of the choice of values when estimating quantities and related fields. In some processes observers tend to prefer the number seven to eight, while in others, the reverse is true. It is understood that much research has been done on this subject, and this basic data should yield a mass of supportive evidence.

Further analysis of perturbations in the distributions other than those caused by choice of numbers would be desirable. The fact that, in distributions involving large numbers of sightings, high χ^2 values generally occur would indicate that in the limit these populations might wander from the log-normal.

Additional investigation would probably determine asymptotes at extremes of some of the variables, such as altitude and meteorological visibility.

Further investigation should be made of twilight and night sightings with perhaps a data collection program incorporated.

The odd curvature indicated by the altitude data is intriguing and suggests an attempt at determination of whether these two points of inflection are real or only coincidental vagaries. It might be that there is a haze layer or other condition generally existent which causes such an effect.

Further study should be made of the few erratic thresholds noted in the discussion to determine whether or not they are simple manifestations of probability theory.

Finally, one definite recommendation: the Coast Guard and other search agencies should give serious thought toward eliminating tail lookouts, since, as was noted above in Sections 4.8 and 4.17, the probability of stern sightings is close to zero.

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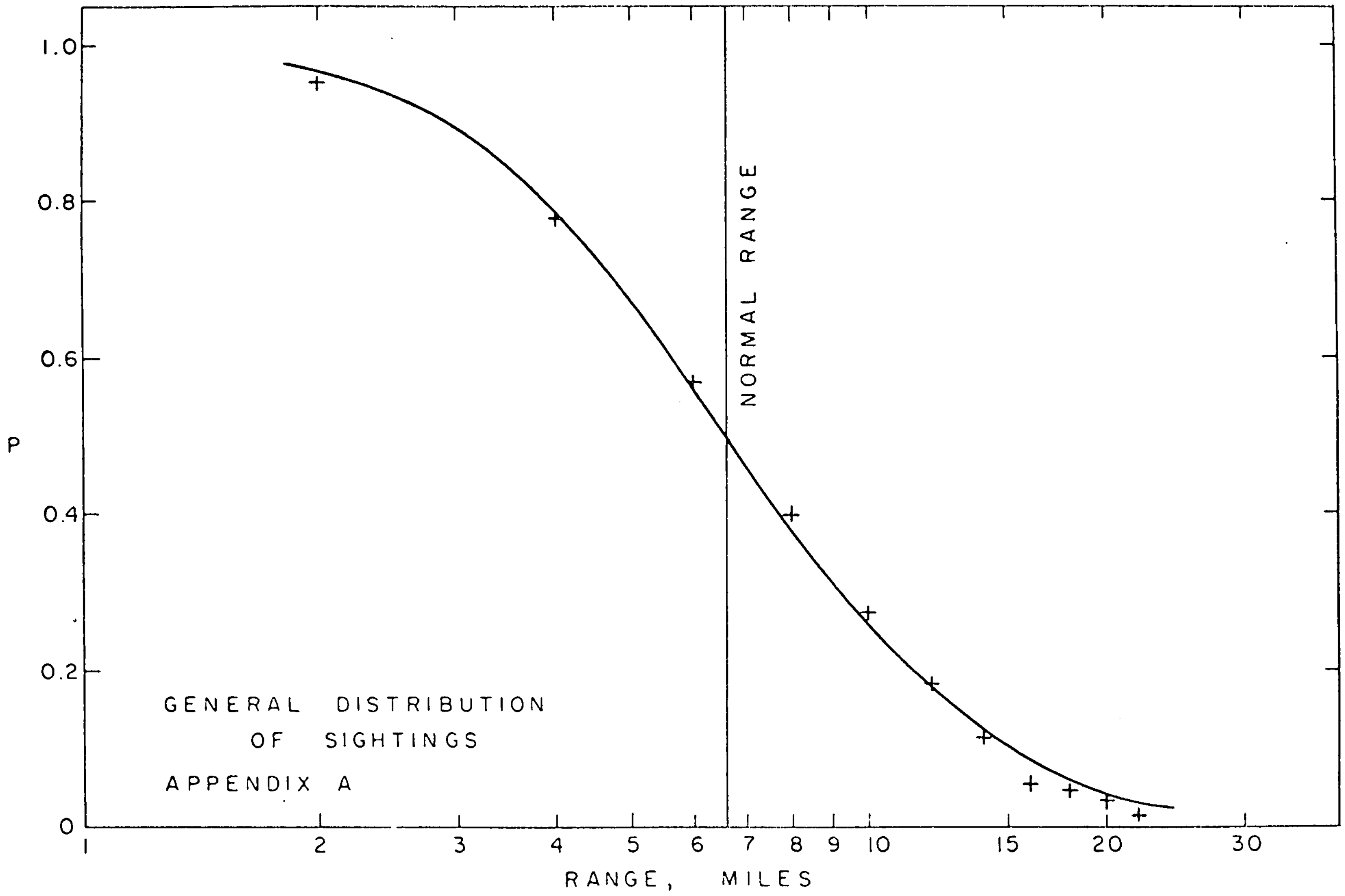
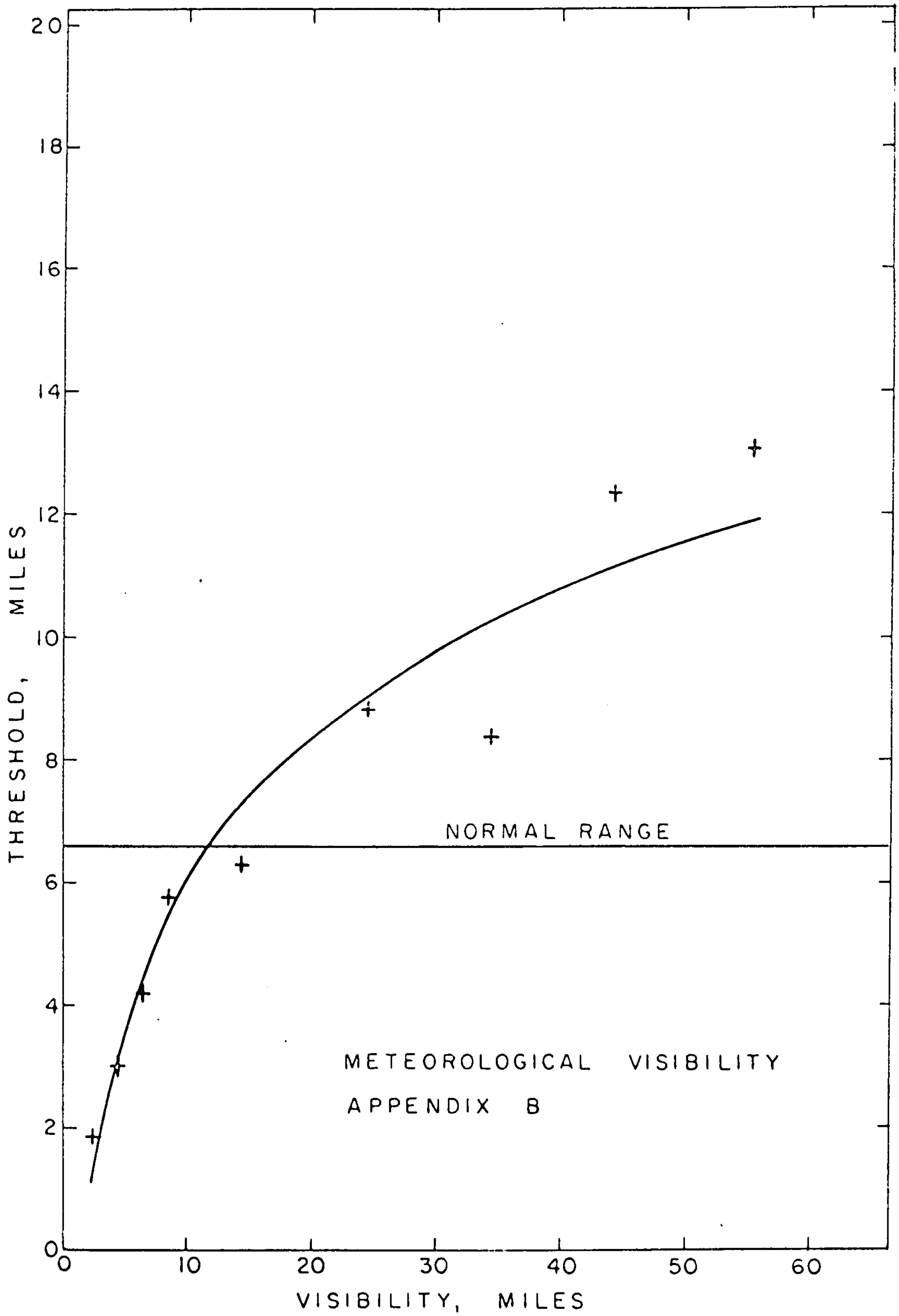

GENERAL DISTRIBUTION
OF SIGHTINGS
APPENDIX A
NORMAL RANGE
P
1.0
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
15
20
30
RANGE, MILES

ALL SIGHTINGS

Range	Frequency
0	3465
4	2691
10	948
14	397
20	109

T	6.599
S	0.65
S_T	0.0096
χ^2	4.308

APPENDIX A-2


THRESHOLD, MILES
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
VISIBILITY, MILES
NORMAL RANGE
METEOROLOGICAL VISIBILITY
APPENDIX B

METEOROLOGICAL VISIBILITY (Miles)

Range (Miles)	0-1	2-3	4-5	6-7	8-9	10-19	20-29	30-39	40-49	50^+	Unlimited
0	3	63	148	144	163	1701	840	185	79	47	22
4	1	3	51	77	122	1344	751	147	71	43	20
10	0	0	5	1	3	373	376	85	49	30	12
14	0	0	3	0	0	96	173	53	38	23	8
20	0	0	1	0	0	15	39	18	19	13	2
T	(No	1.885	2.999	4.189	5.719	6.281	8.812	8.345	12.364	13.026	9.790
S	Fit)	0.33	0.70	0.61	0.53	0.54	0.61	0.81	0.83	0.83	0.71
S_T	-	0.064	0.099	0.070	0.095	0.012	0.017	0.044	0.064	0.084	0.11
X^2	-	1.341	0.679	0.208	10^{-11}	10.094	3.233	4.869	0.884	0.181	1.457

$\bar{S}$ 0.650

S_s 0.15

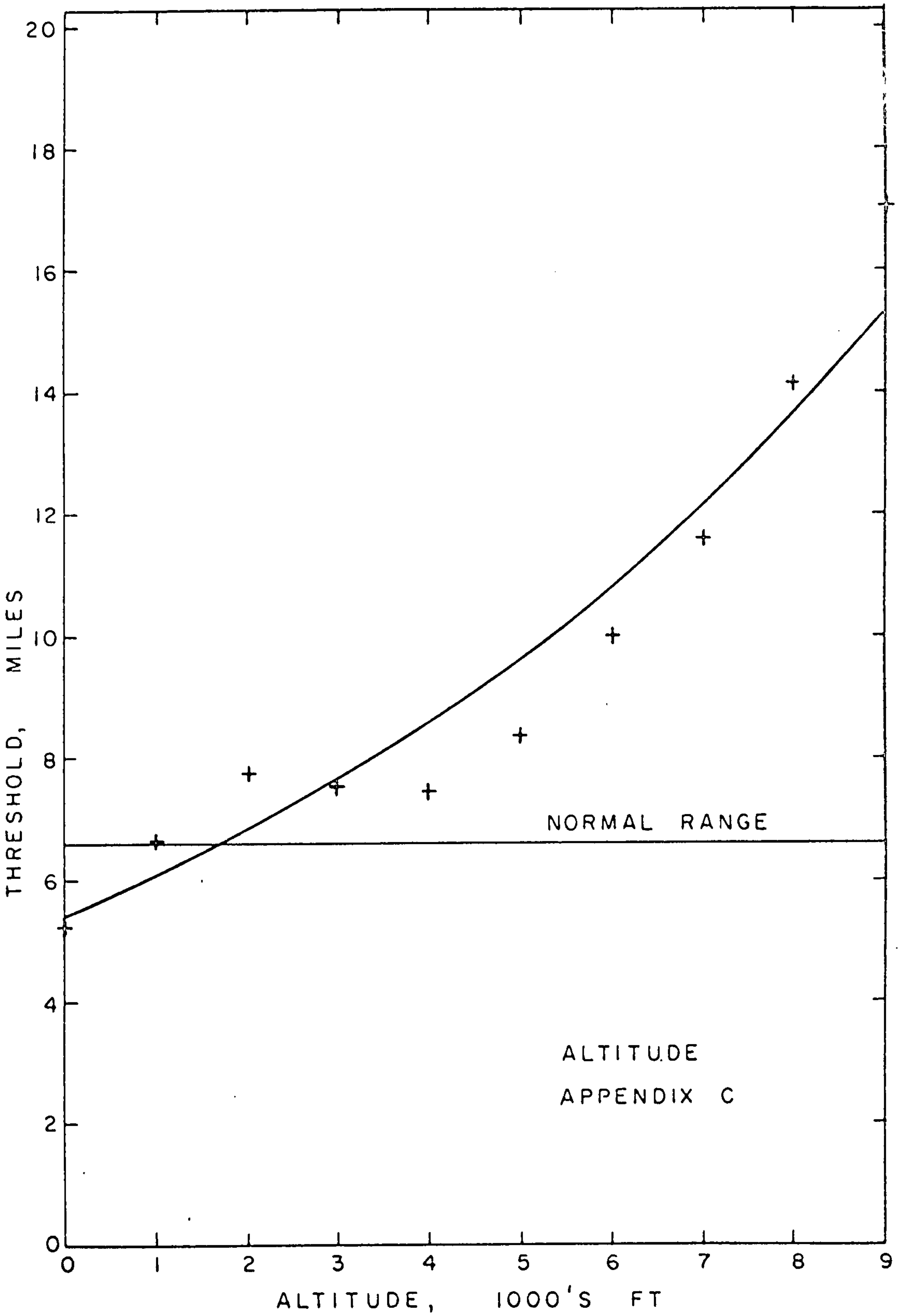
$S_{\bar{s}}$ 0.048

$T(V) = 3.476 \ln V - 2.064$, V = Visibility (Miles)

$\text{Factor} = 0.627 \ln V - 0.313$

$r = 0.969$

APPENDIX B-2


THRESHOLD, MILES
0
2
4
6
8
10
12
14
16
18
20
NORMAL RANGE
ALTITUDE
APPENDIX C
0
1
2
3
4
5
6
7
8
9
ALTITUDE, 1000'S FT

ALTITUDE (Feet)

Range (Miles)	0	1000	2000	3000	4000	5000	6000	7000	8000	9000
0	981	1453	492	135	97	65	48	8	26	7
4	639	1169	425	118	82	59	46	8	26	7
10	169	400	177	41	37	26	23	5	21	6
14	69	160	74	19	10	11	13	4	14	4
20	20	39	24	5	2	2	6	1	6	2
T	5.219	6.674	7.783	7.562	7.487	8.371	10.043	11.64	14.14	17.02
S	0.67	0.60	0.59	0.56	0.55	0.53	0.56	0.79	0.88	1.2
S_T	0.021	0.014	0.022	0.041	0.050	0.055	0.063	0.18	0.12	0.38
χ^2	0.465	5.070	1.398	0.0847	3.861	0.865	0.158	1.160	2.492	1.182

$\bar{S} = 0.698$

$S_s = 0.20$

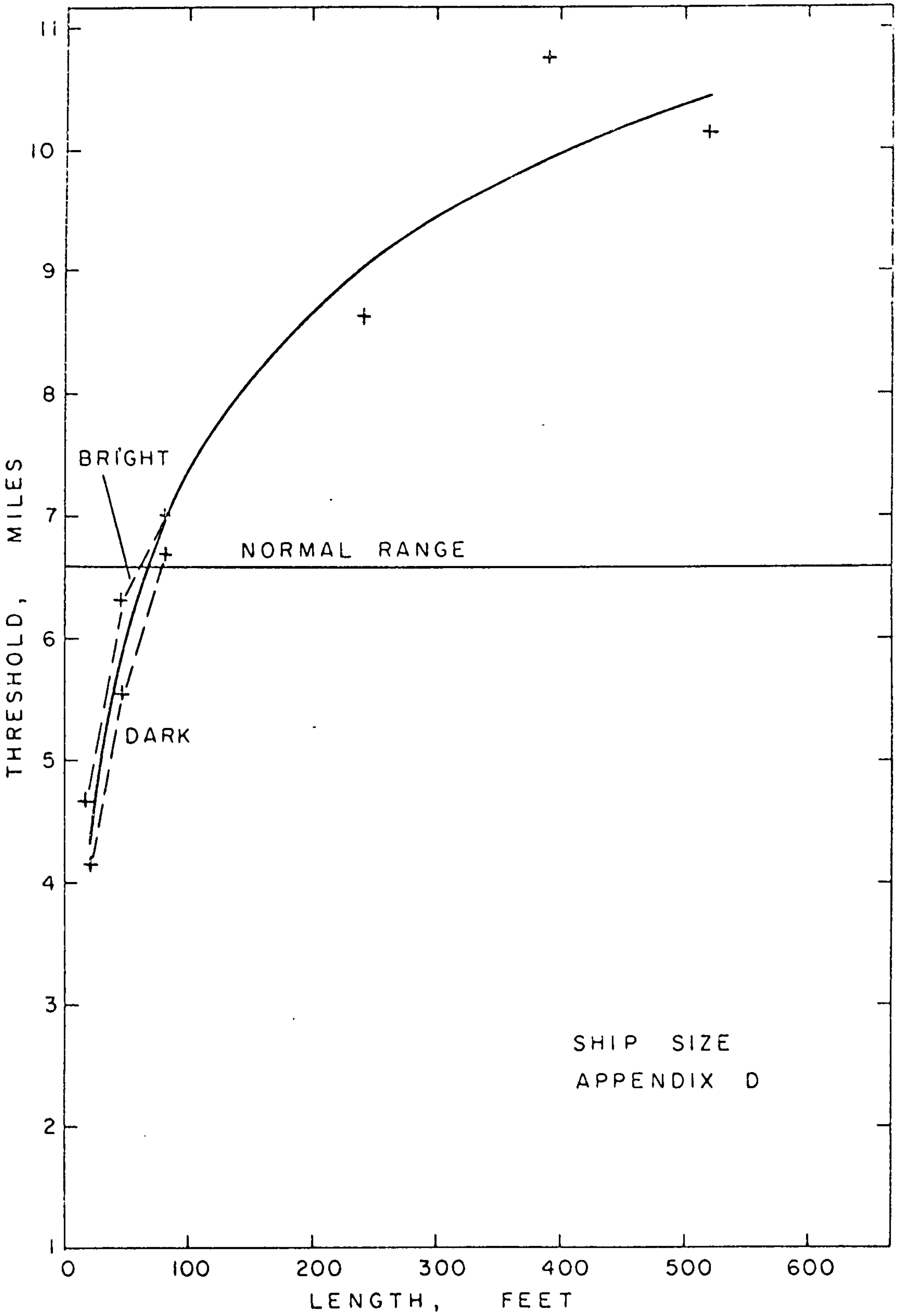
$S_{\bar{s}} = 0.064$

$T(A) = 5.385\, e^{0.116A}$, A: Altitude (1000's of feet)

$f(A) = 0.816\, e^{0.116A}$

$r = 0.963$

APPENDIX C-2


THRESHOLD, MILES
LENGTH, FEET
1
2
3
4
5
6
7
8
9
10
11
0
100
200
300
400
500
600
BRIGHT
DARK
NORMAL RANGE
SHIP SIZE
APPENDIX D

SHIP SIZE

Range (Miles)	Less than 30'		30' - 60'		60' - 100'		500-5000T	5000-10000T	Over 10000T
	Bright	Dark	Bright	Dark	Bright	Dark			
0	475	269	753	297	172	127	356	414	310
4	295	141	603	227	152	103	320	389	288
10	42	18	154	30	41	33	157	251	167
14	4	3	49	5	10	11	65	132	94
20	0	0	5	0	0	2	21	48	31
T	4.658	4.154	6.305	5.548	7.018	6.669	8.619	10.743	10.104
S	0.61	0.56	0.52	0.45	0.46	0.56	0.57	0.58	0.59
S_T	0.028	0.041	0.018	0.028	0.034	0.045	0.024	0.021	0.025
X^2	1.911	0.700	6.524	0.266	0.476	0.960	2.668	4.583	2.580

$\bar{S}$ = 0.544 ± 0.053(S)

S_s = 0.053

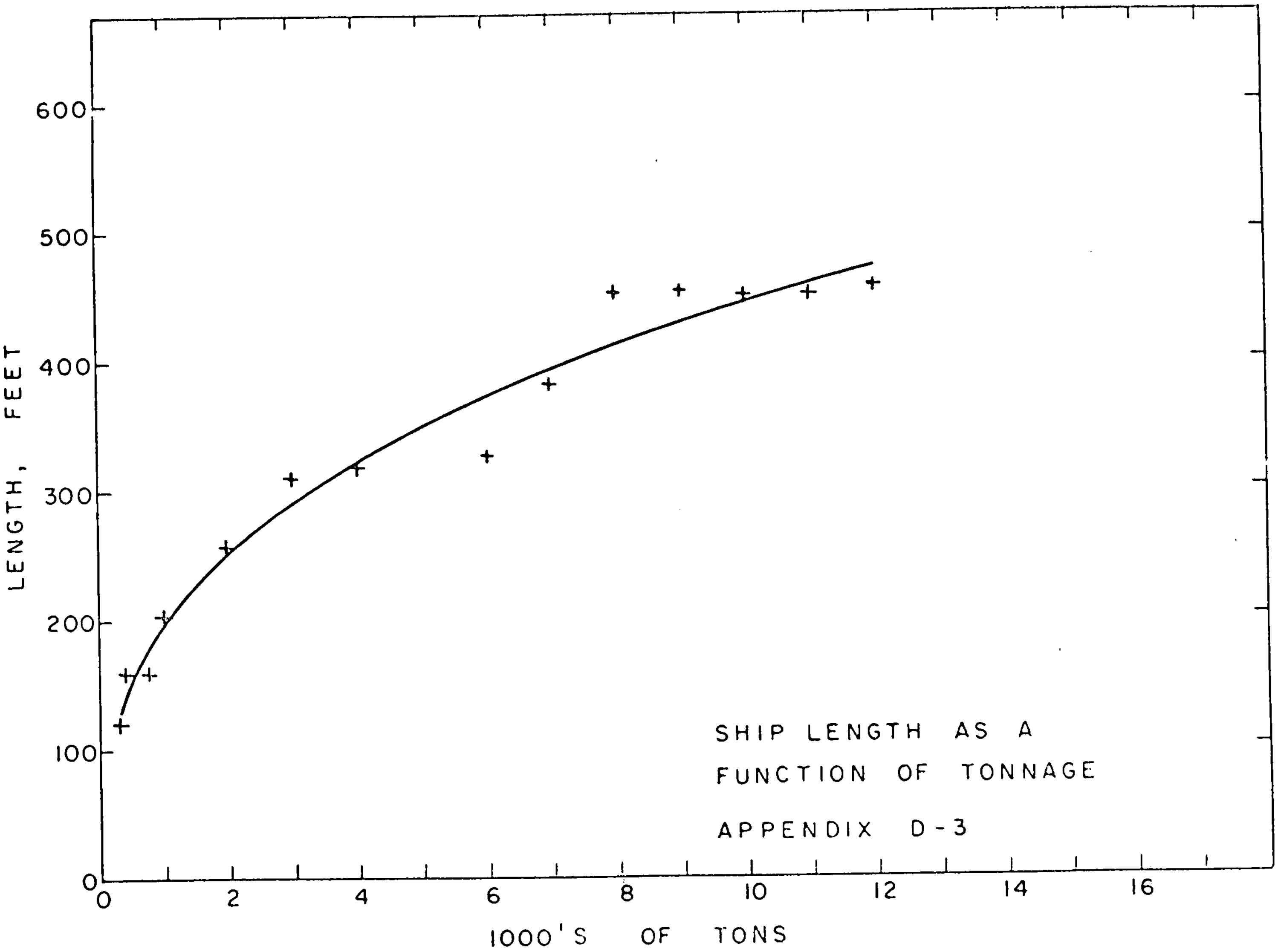
$S_{\bar{s}}$ = 0.017

T(L) = 1.844 lnL- 1.100, L: Ship size(feet)

f(L) = 0.280 lnL- 0.167

r = 0.982

APPENDIX D-2



SHIP LENGTH AS A FUNCTION OF TONNAGE

APPENDIX D-3

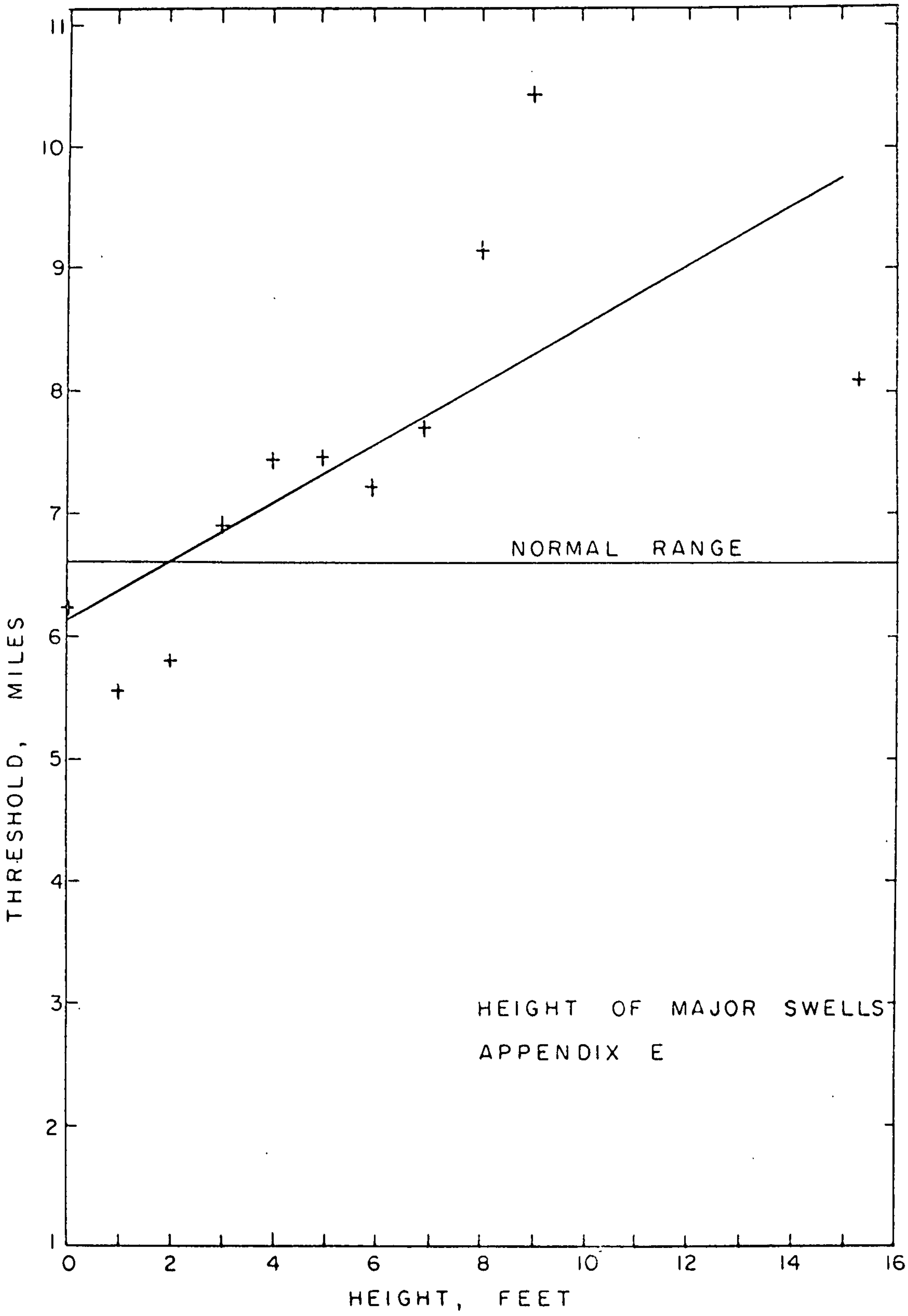
LENGTH AS A FUNCTION OF TONNAGE

Gross Tonnage	Mean Length (Feet)
300	120
750	158
1000	203
2000	257
3000	310
4000	319
6000	326
7000	382
8000	451
9000	464
10000	450
11000	450
12000	456

$$\text{Length} = 21.4\,(\text{Tonnage})^{1/3} - 16.0$$

$$r = 0.985$$

APPENDIX D-4


NORMAL RANGE
HEIGHT OF MAJOR SWELLS
APPENDIX E
THRESHOLD, MILES
HEIGHT, FEET
1
2
3
4
5
6
7
8
9
10
11
0
2
4
6
8
10
12
14
16

HEIGHT OF MAJOR SWELLS

Range (Miles)	0	1	2	3	4	5	6	7	8	9	10+
0	531	482	625	612	451	270	188	26	50	5	24
4	399	342	429	507	381	222	157	21	43	4	20
10	129	81	154	173	141	99	55	8	26	2	11
14	52	26	72	66	69	42	26	6	15	2	3
20	9	3	17	20	17	13	11	5	3	2	3
T	6.215	5.559	5.801	6.989	7.403	7.485	7.239	7.724	9.168	10.341	8.097
S	0.62	0.57	0.72	0.58	0.60	0.64	0.62	0.88	0.67	1.4	0.70
S_T	0.025	0.026	0.026	0.021	0.024	0.032	0.038	0.13	0.071	0.41	0.11
χ^2	5.989	4.153	6.549	0.827	1.549	2.491	0.289	0.951	3.888	0.250	2.072

$\bar{S} = 0.727$

$S_s = 0.23$

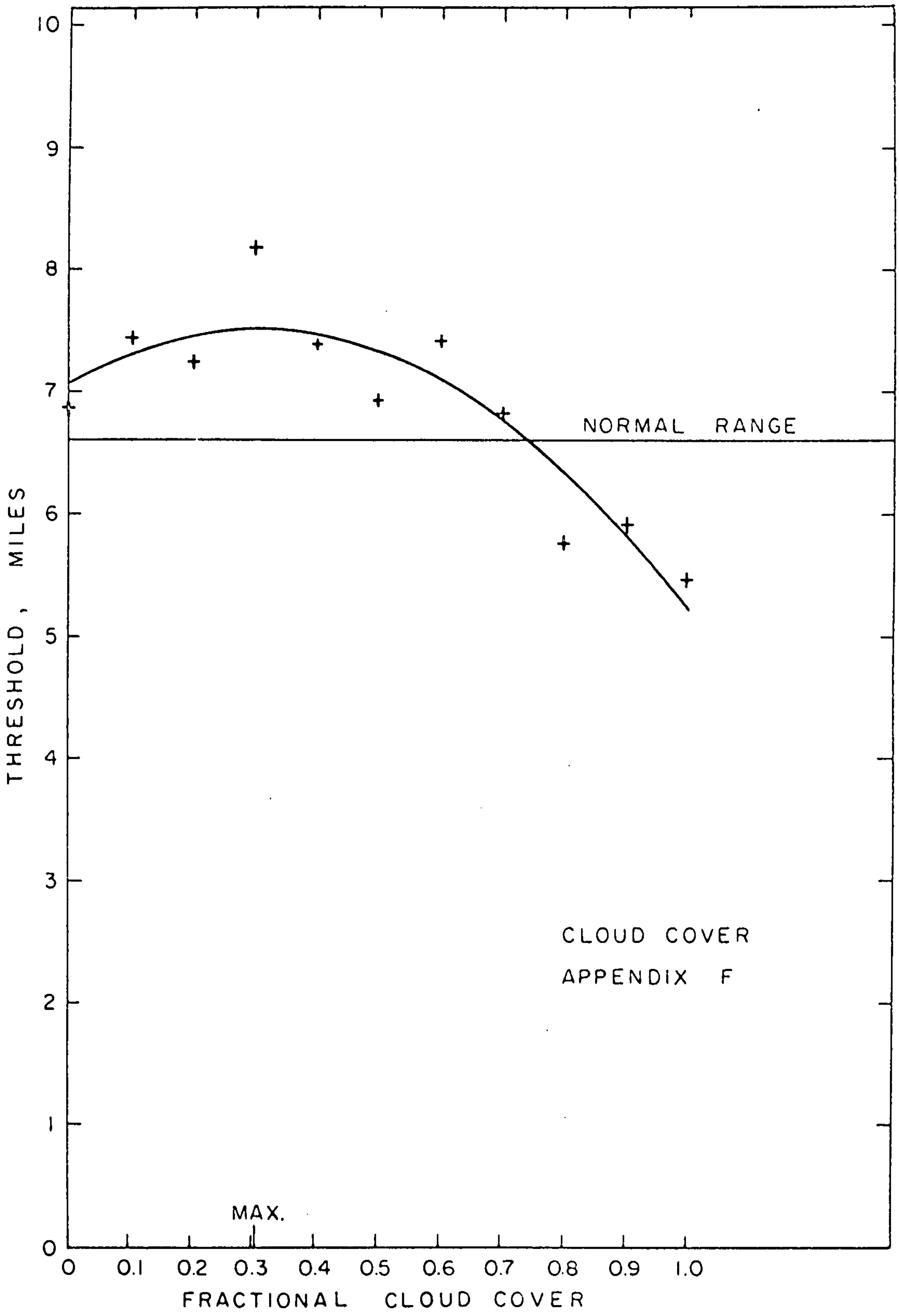
$S_{\bar{s}} = 0.068$

$T(S) = 6.170 + 0.239\,S$, S: Swell height (Feet)

$f(S) = 0.935 + 0.0362\,S$

$r = 0.707$

APPENDIX E-2


10
9
8
7
6
5
4
3
2
1
0
THRESHOLD, MILES
NORMAL RANGE
CLOUD COVER
APPENDIX F
MAX.
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
FRACTIONAL CLOUD COVER

FRACTIONAL CLOUD COVER

Range (Miles)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0	1041	345	182	156	139	197	110	124	182	244	690
4	822	293	148	136	115	153	95	98	128	181	475
10	320	112	62	58	45	62	32	33	40	50	122
14	131	46	25	35	23	29	15	20	15	14	43
20	31	16	8	8	8	15	4	5	5	3	5
T	6.884	7.444	7.229	8.191	7.398	6.920	7.405	6.809	5.761	5.904	5.471
S	0.66	0.59	0.63	0.61	0.65	0.72	0.56	0.66	0.66	0.57	0.63
S_T	0.018	0.027	0.040	0.040	0.045	0.043	0.047	0.051	0.046	0.035	0.023
X^2	3.456	0.501	1.283	2.209	0.0604	0.523	0.0752	0.887	0.426	1.565	0.562

$\bar{S} = 0.631$

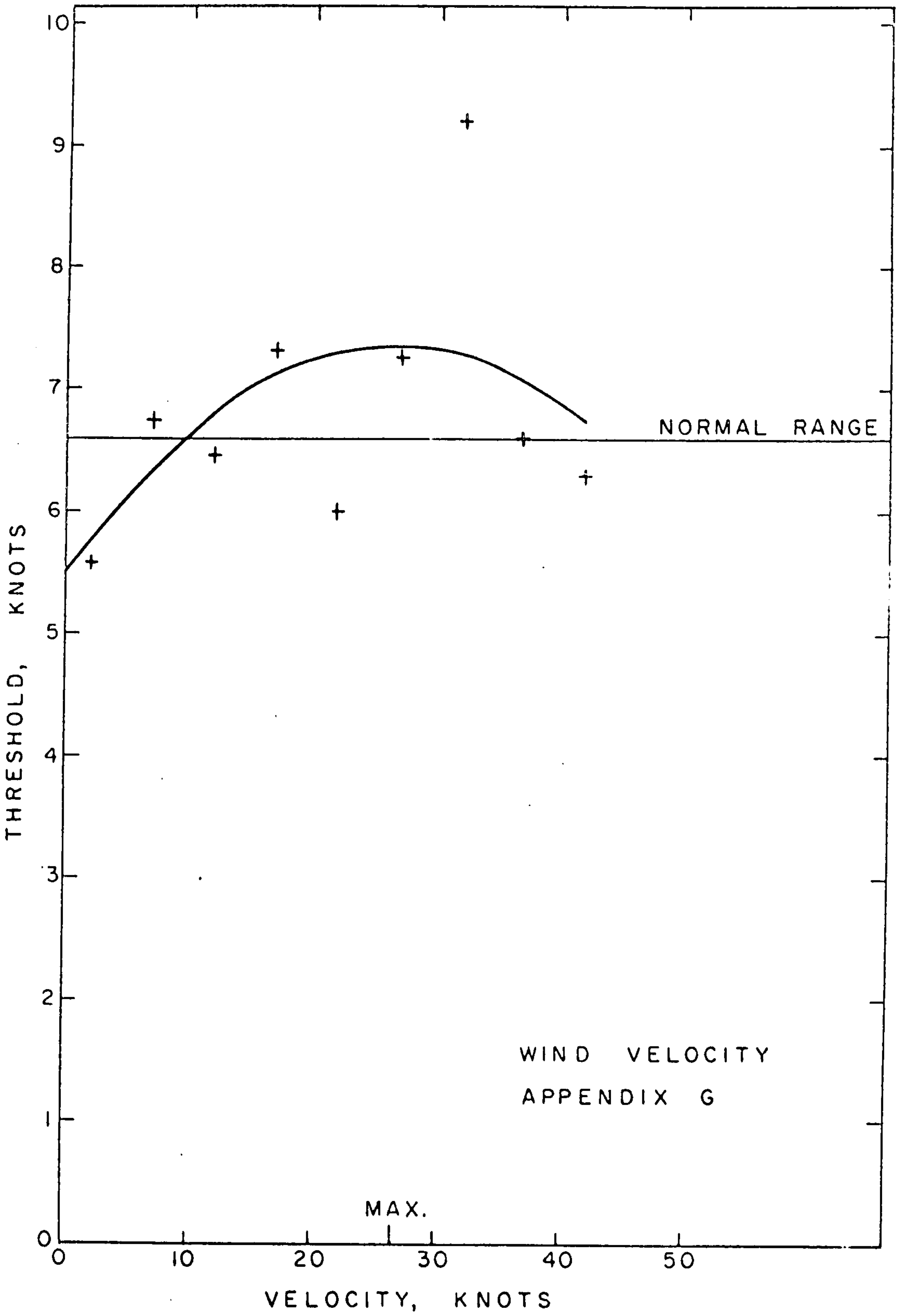
$S_s = 0.044$

$S_{\bar{s}} = 0.013$

$T(C) = 7.069 + 2.871C - 4.717C^2$, C: Cloud cover (Decimal fraction)

$f(C) = 1.07 + 0.435\,C - 0.715C^2$

$r = 0.903$


THRESHOLD, KNOTS
0
1
2
3
4
5
6
7
8
9
10
NORMAL RANGE
WIND VELOCITY
APPENDIX G
MAX.
0
10
20
30
40
50
VELOCITY, KNOTS

WIND VELOCITY (KNOTS)

Range	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50+
0	396	1094	832	487	311	117	46	15	12	1	4
4	278	863	639	411	220	96	41	14	11	1	3
10	88	310	216	161	83	38	21	2	1	0	2
14	40	130	95	56	32	18	13	0	0	0	2
20	6	40	28	15	8	6	5	0	0	0	1
T	5.806	6.732	6.464	7.325	6.003	7.292	9.236	6.604	6.308	(No)	(No)
S	0.70	0.63	0.64	0.60	0.69	0.64	0.66	0.49	0.45	(Data)	(Fit)
S_T	0.033	0.017	0.020	0.022	0.036	0.050	0.073	0.11	0.12	–	*
χ^2	0.0603	2.383	1.161	3.945	4.233	0.160	0.130	0.593	0.802	–	*

$\bar{S} = 0.611$

$S_s = 0.081$

$S_{\bar{s}} = 0.027$

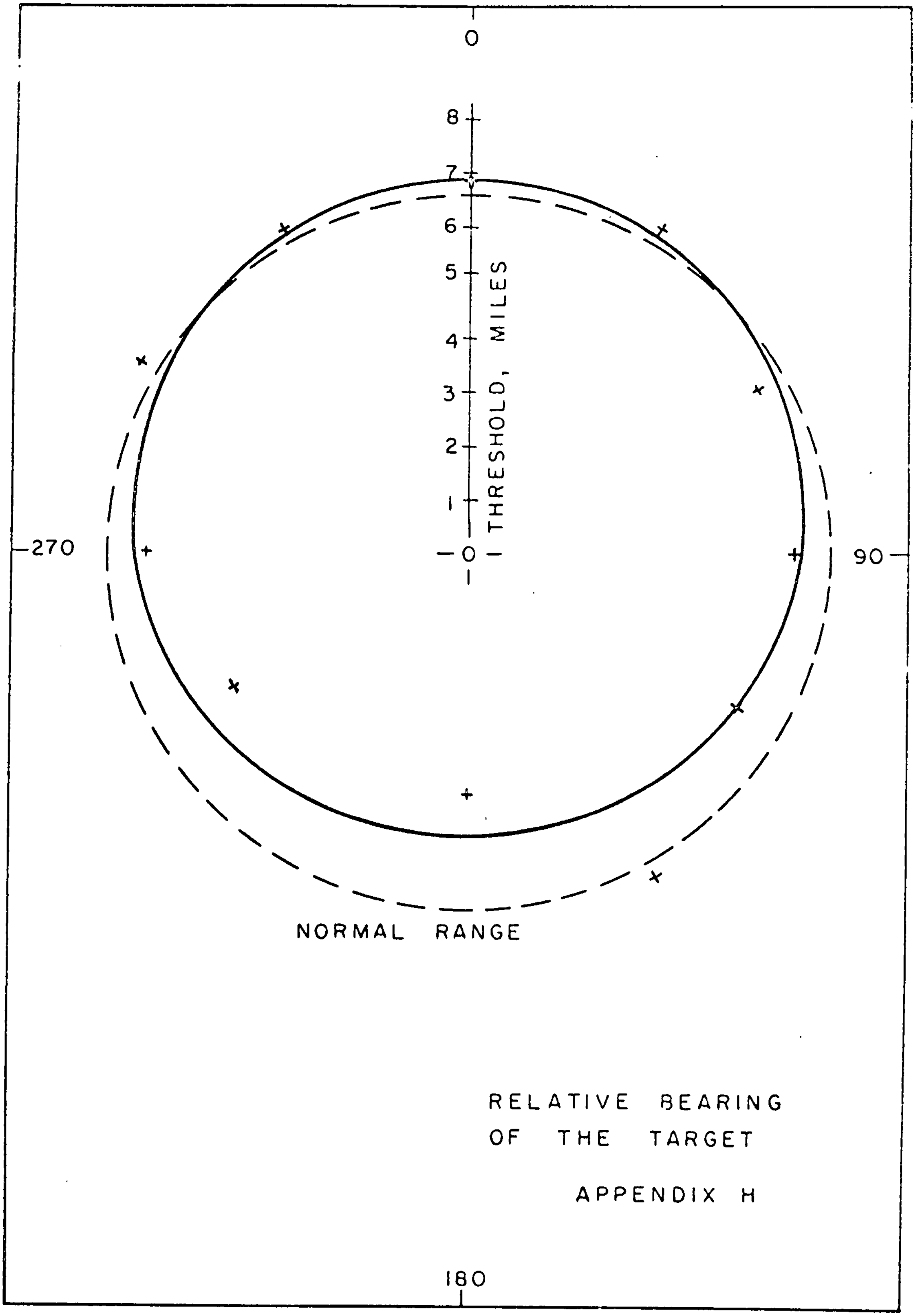
$T(WV) = 5.488 - 0.142WV - 0.002673(WV)^2$

WV: Wind velocity

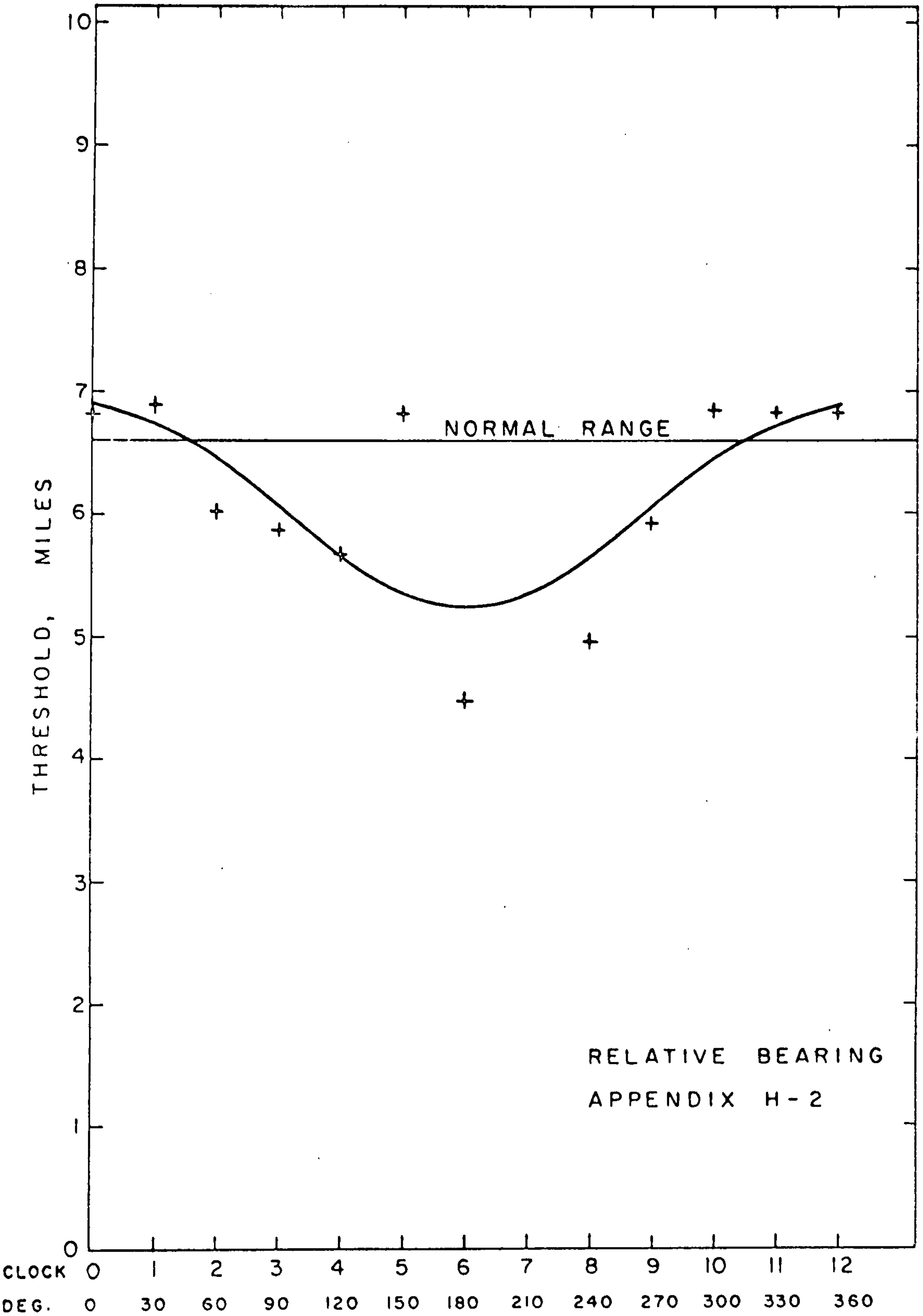
$f(WV) = 0.832 + 0.0214WV - 0.000405(WV)^2$

$r = 0.531$

*Rejected on basis of entirely different type of curve from rest of family


0
8
7
6
5
4
3
2
1
0
THRESHOLD, MILES
270
90
180
NORMAL RANGE
RELATIVE BEARING
OF THE TARGET

APPENDIX H


THRESHOLD, MILES
0
1
2
3
4
5
6
7
8
9
10
NORMAL RANGE
RELATIVE BEARING
APPENDIX H-2
CLOCK 0 1 2 3 4 5 6 7 8 9 10 11 12
DEG. 0 30 60 90 120 150 180 210 240 270 300 330 360

SIGHTING BEARING (CLOCK CODE)

Range (Miles)	1	2	3	4	5	6	7	8	9	10	11	12
0	530	450	271	31	6	5	6	15	192	365	529	764
4	427	327	198	22	5	3	4	10	138	299	419	580
10	154	109	57	6	2	1	3	0	44	101	153	255
14	65	46	20	2	2	0	0	0	17	37	67	105
20	17	13	7	0	1	0	0	0	1	15	23	25
T	6.892	6.056	5.899	5.674	6.804	4.466	(No)	4.972	5.922	6.982	6.816	6.814
S	0.61	0.66	0.62	0.62	0.50	2.425	(Fit)	0.70	0.66	0.59	0.64	0.73
S_T	0.023	0.029	0.035	0.10	0.17	0.86	-	0.12	0.044	0.027	0.024	0.022
χ^2	1.899	1.355	0.481	0.060	0.071	0.096	-	0.346	0.347	1.169	0.586	5.944

$\bar{S} = 0.80$

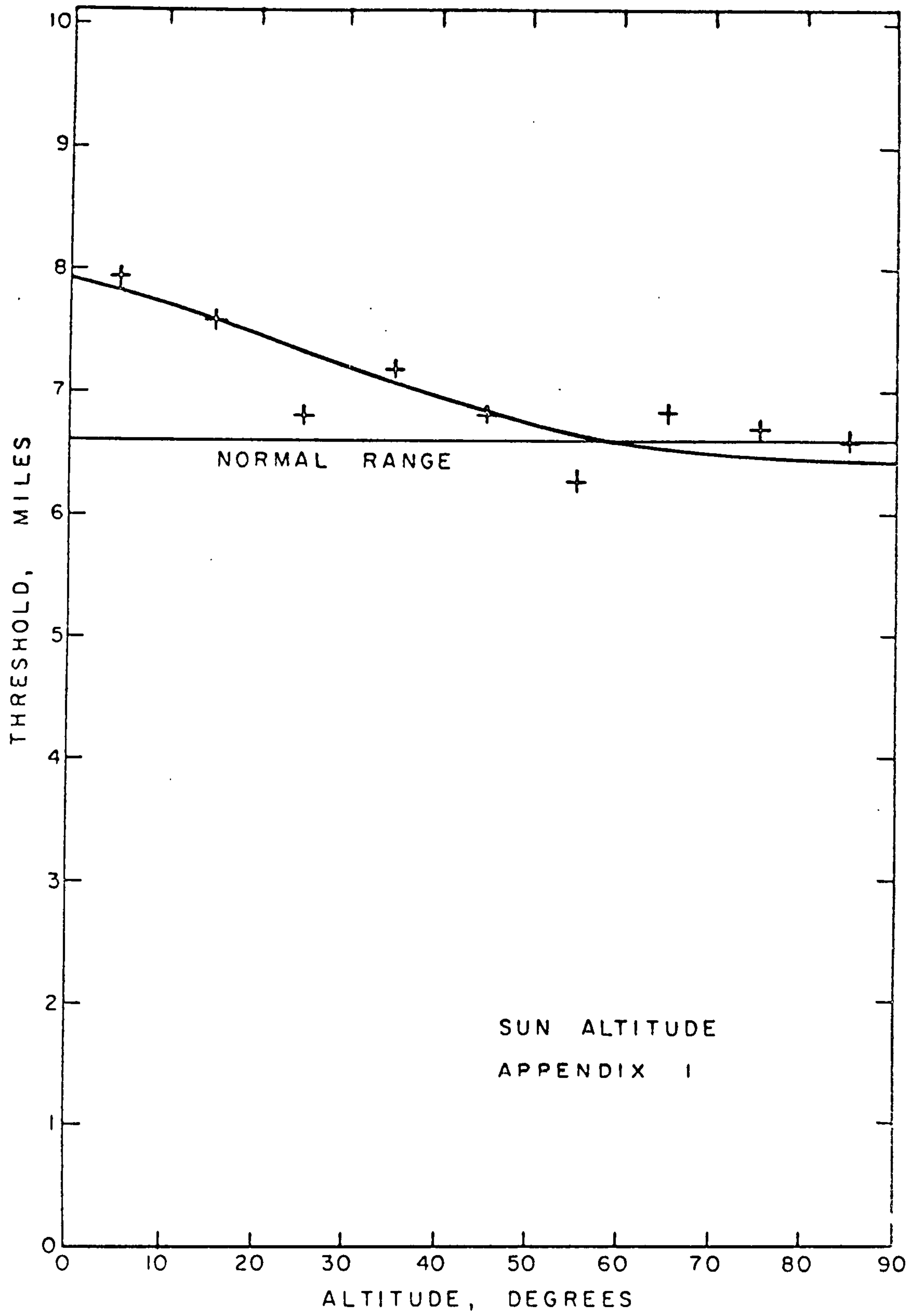
$S_s = 0.51$

$S_{\bar{s}} = 0.16$

$T(B) = 6.046 + 0.808 \cos B$, B: Relative bearing on 30X (Clock Code)

$f(B) = 0.916 + 0.122 \cos B$

$r = 0.697$


10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
THRESHOLD, MILES
ALTITUDE, DEGREES
NORMAL RANGE
SUN ALTITUDE
APPENDIX I

SUN ALTITUDE (Degrees)

Range (Miles)	0	10	20	30	40	50	60	70	80	90
0	35	159	334	572	757	306	296	230	130	6
4	29	132	268	467	591	231	241	190	106	5
10	14	52	94	197	221	75	84	55	33	4
14	6	28	38	90	109	33	28	17	6	0
20	4	16	11	24	23	8	8	6	0	0
T	7.926	7.569	6.805	7.333	6.816	6.285	6.832	6.679	6.555	(No)
S	0.72	0.70	0.61	0.64	0.68	0.64	0.58	0.54	0.52	(Fit)
S_T	0.094	0.044	0.029	0.022	0.021	0.033	0.030	0.033	0.044	-
χ^2	0.506	0.884	0.723	5.083	0.0817	1.039	1.594	0.773	3.161	-

$\bar{S}$ = 0.626

S_s = 0.066

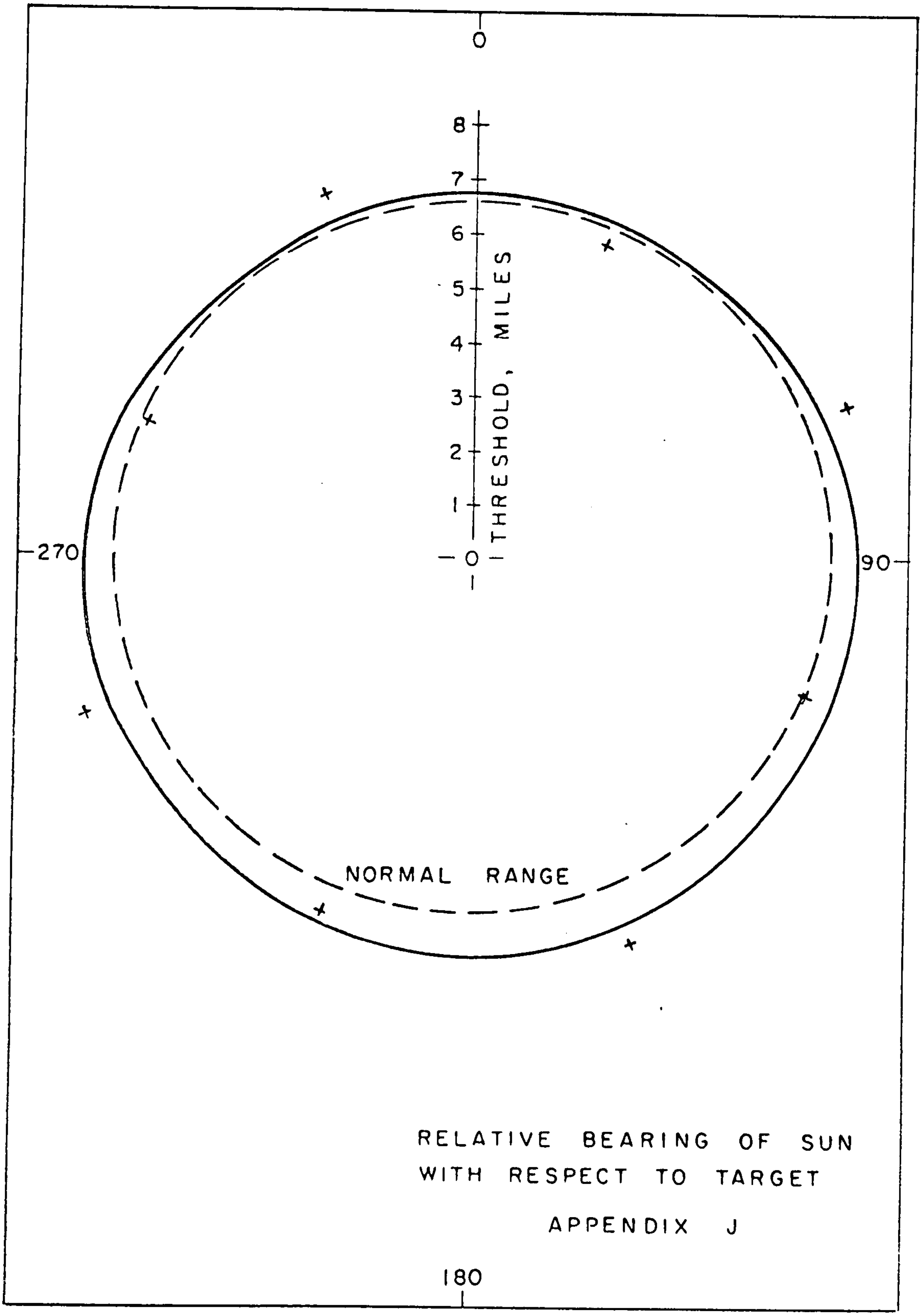
$S_{\bar{s}}$ = 0.021

T (SA) = 7.975 - 1.564 sin SA, SA: Sun altitude degrees

f (SA) = 1.208 - 0.238 sin SA

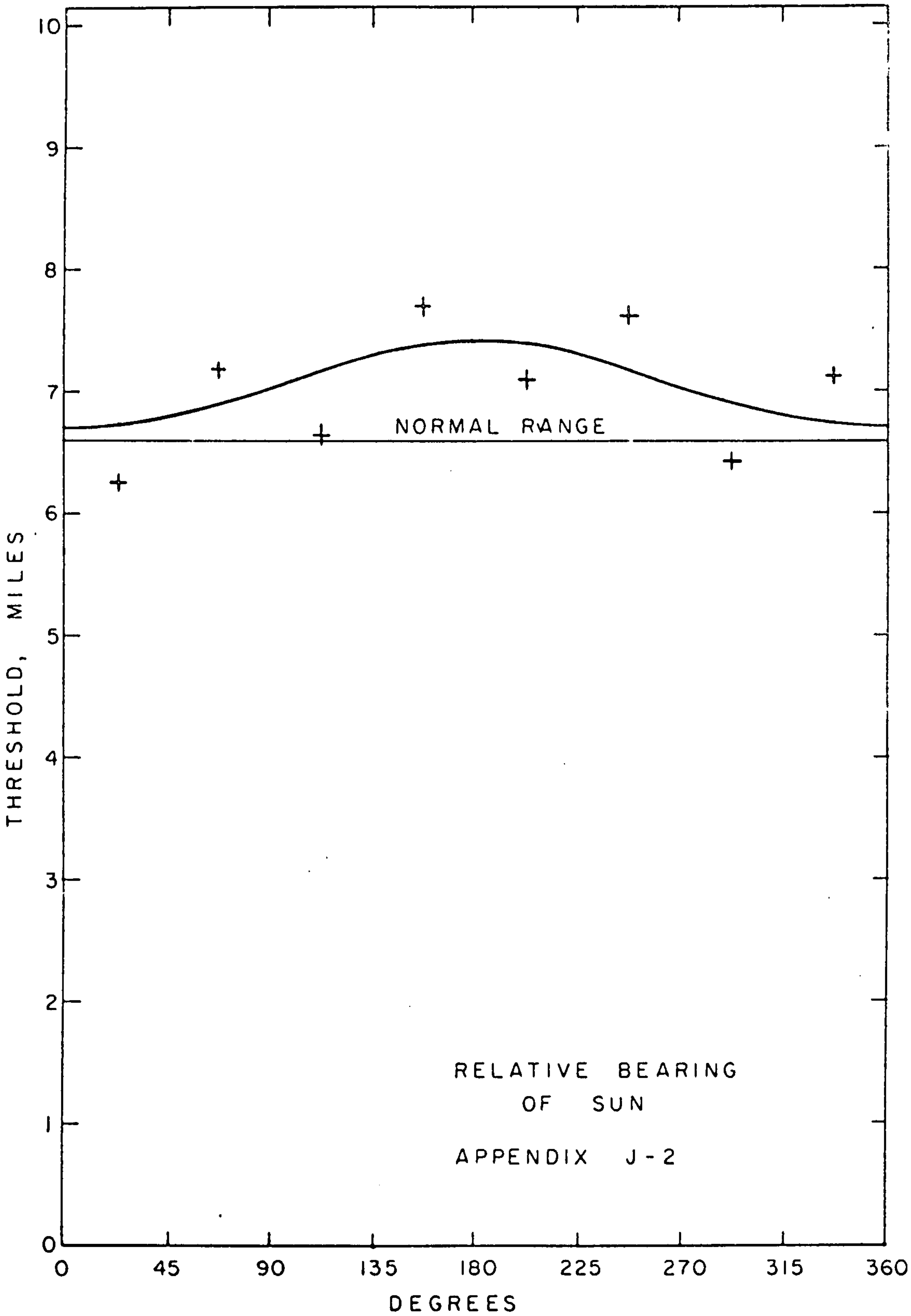
r = 0.915

APPENDIX I-2



RELATIVE BEARING OF SUN WITH RESPECT TO TARGET

APPENDIX J



RELATIVE BEARING OF SUN

APPENDIX J-2

RELATIVE BEARING OF SUN (Degrees)

Range (Miles)	0-45	45-89	90-134	135-174	180-224	225-269	270-314	315-359
0	572	208	398	209	593	194	422	286
4	428	180	307	168	487	155	325	242
10	149	66	112	81	178	67	108	85
14	56	28	52	45	79	25	43	36
20	12	13	14	15	20	11	13	6
T	6.253	7.397	6.624	7.700	7.089	7.600	6.427	7.220
S	0.64	0.67	0.66	0.72	0.60	0.62	0.63	0.56
S_T	0.023	0.034	0.028	0.040	0.021	0.038	0.027	0.029
χ^2	6.503	2.885	1.917	1.958	2.053	1.541	0.745	2.773

$\bar{S} = 0.64$

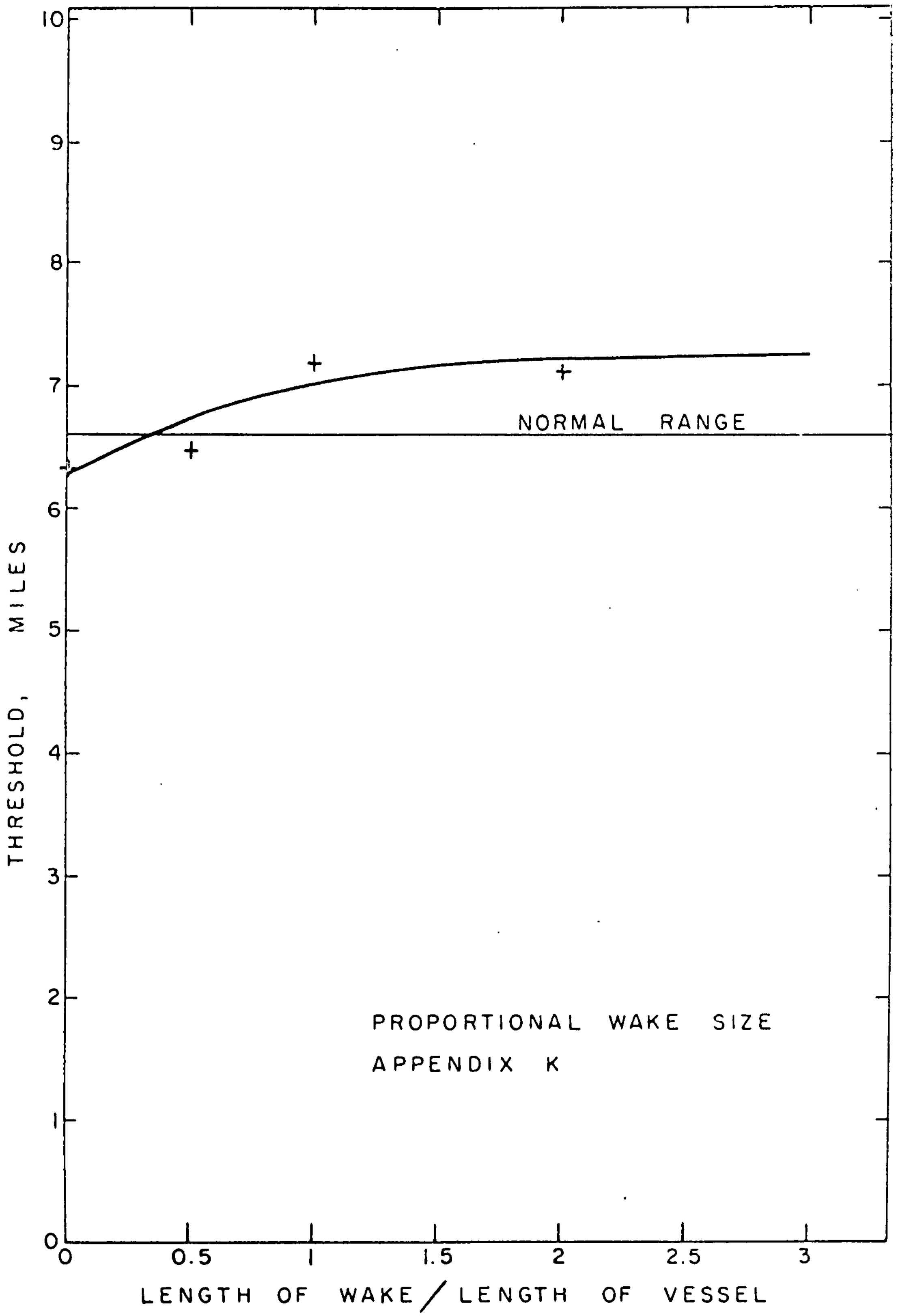
$S_s = 0.045$

$S_{\bar{s}} = 0.016$

$T\,(SB) = 7.043 + 0.342 \cos(\pi - SB)$, SB: Bearing of sun (Degrees)

$f\,(SB) = 1.067 + 0.0518 \cos(\pi - SB)$

$r = 0.987$


10
9
8
7
6
5
4
3
2
1
0
THRESHOLD, MILES
0
0.5
1
1.5
2
2.5
3
LENGTH OF WAKE / LENGTH OF VESSEL
NORMAL RANGE
PROPORTIONAL WAKE SIZE
APPENDIX K

PROPORTIONAL WAKE SIZE

Range (Miles)	0	0.5X	1.0X	2.0X	More than 2.0X
0	1769	410	385	353	370
4	1328	327	313	292	323
10	452	103	123	115	105
14	197	39	57	41	39
20	55	9	15	15	6
T	6.308	6.575	7.163	7.203	7.295
S	0.65	0.58	0.63	0.60	0.51
S_T	0.014	0.026	0.027	0.027	0.024
χ^2	4.826	1.073	2.189	2.284	1.943

$\bar{S} = 0.594 \pm 0.048\ (S_s)$

$S_s = 0.048$

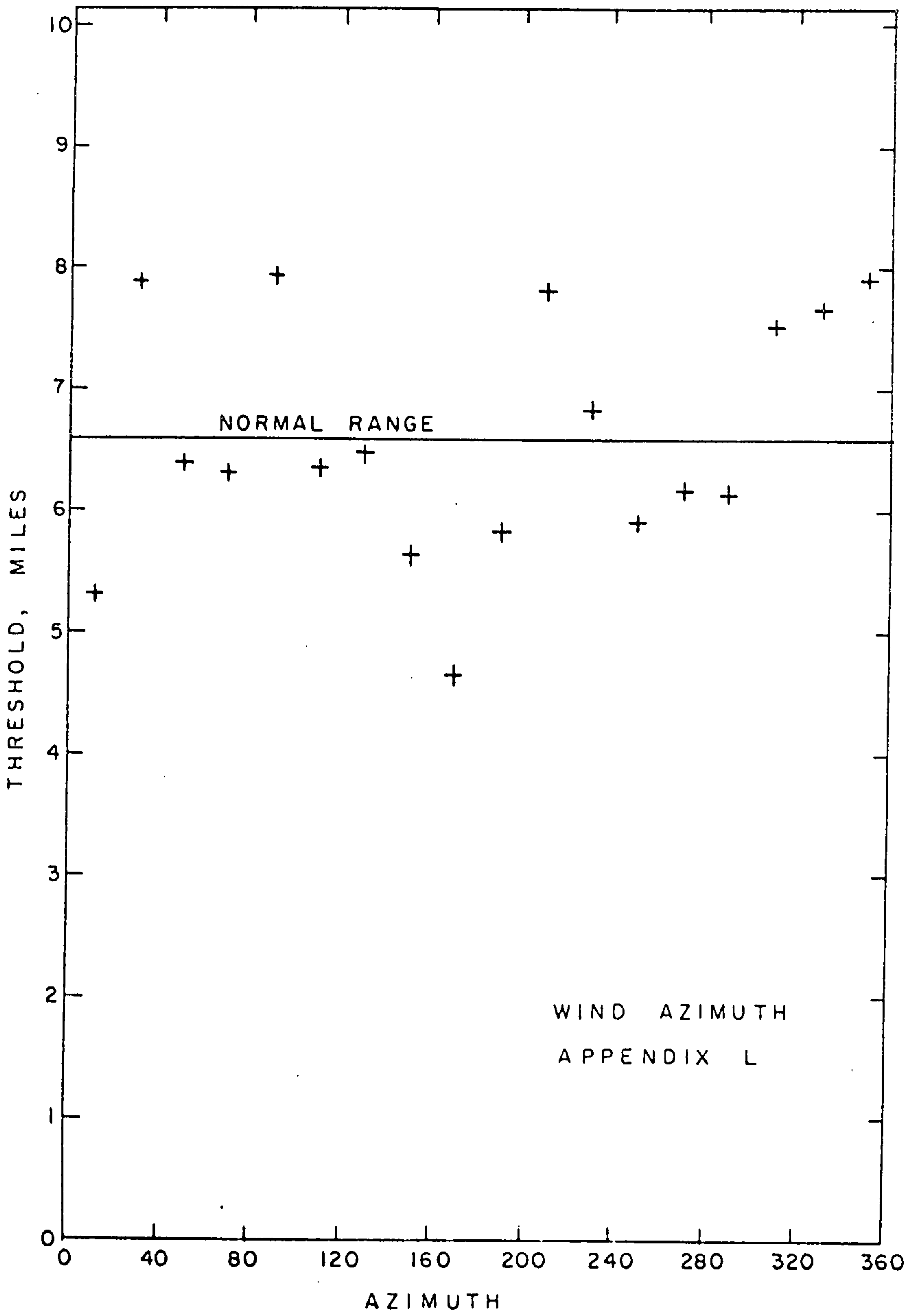
$S_{\bar{s}} = 0.017$

$T(W) = 7.295 - 1.066\, e^{-1.284W}$, W: Wake size (Multiple of vessel length)

$f(W) = 1.105 - 0.162\, e^{-1.284W}$

$r = 0.920$

APPENDIX K-2


NORMAL RANGE
WIND AZIMUTH
APPENDIX L
THRESHOLD, MILES
AZIMUTH
0
1
2
3
4
5
6
7
8
9
10
0
40
80
120
160
200
240
280
320
360

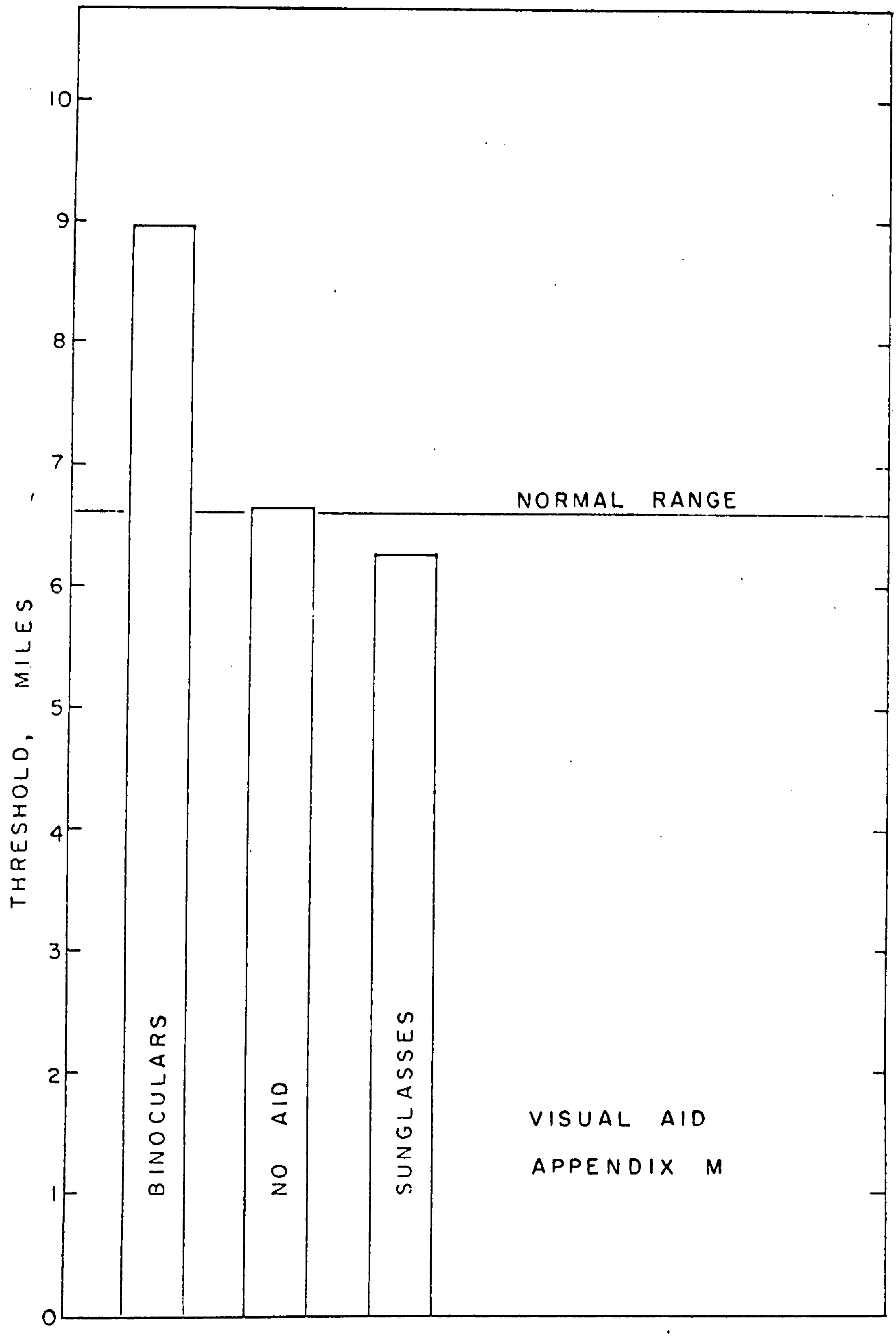
WIND AZIMUTH (Degrees)

Range	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179
0	199	84	140	170	352	95	180	114	83
4	129	73	118	137	301	72	145	79	51
10	41	33	33	50	137	24	39	24	6
14	15	12	15	19	61	10	15	9	1
20	4	2	3	6	19	5	4	1	0
T	5.311	7.881	6.886	6.880	7.939	6.362	6.467	5.646	4.652
S	0.69	0.55	0.54	0.61	0.62	0.67	0.56	0.64	0.51
S_T	0.048	0.052	0.042	0.041	0.027	0.061	0.038	0.058	0.062
χ^2	1.372	2.569	0.309	0.600	2.278	0.337	0.00344	3.183	0.113

No functions accepted

APPENDIX L-2

	WIND AZIMUTH (Degrees)								
Range (Miles)	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
0	189	88	97	126	444	291	371	150	105
4	135	78	79	93	334	219	311	125	90
10	40	28	24	25	105	63	136	53	40
14	17	13	13	10	41	35	51	28	18
20	3	5	4	2	12	6	16	10	6
T	5,821	7.807	6.840	5.914	6.194	6.189	7.540	7.676	7.921
S	0.64	0.67	0.61	0.60	0.63	0.63	0.60	0.66	0.62
S_T	0.044	0.051	0.054	0.051	0.027	0.034	0.026	0.044	0.049
χ^2	1.543	0.163	0.283	0.293	0.689	3.027	3.800	0.171	0.402
$\bar{S}$	0.614								
S_s	0.047								
$S_{\bar{s}}$	0.011								


THRESHOLD, MILES
0
1
2
3
4
5
6
7
8
9
10
NORMAL RANGE
BINOCULARS
NO AID
SUNGLASSES
VISUAL AID
APPENDIX M

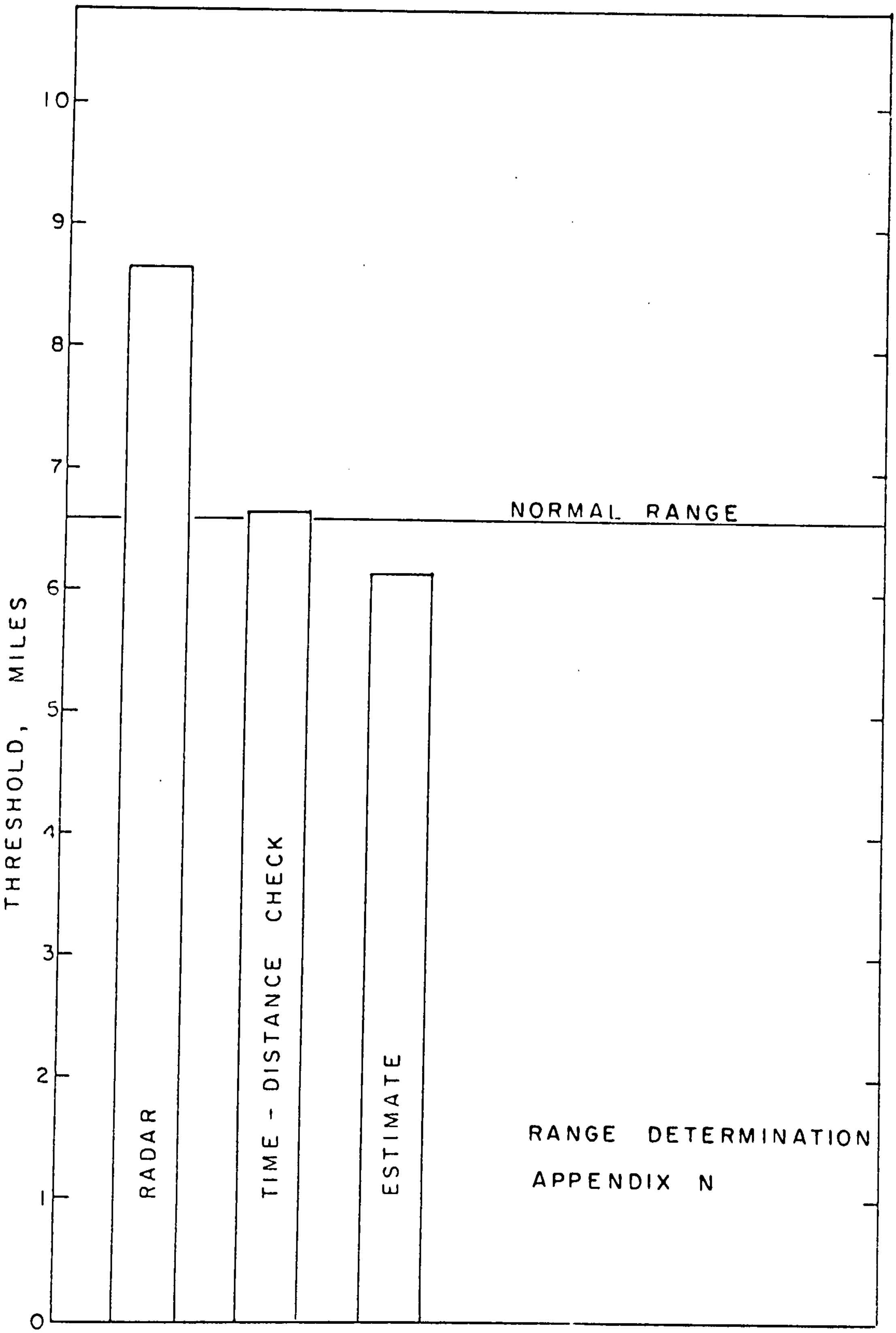
VISUAL AID

Range (Miles)	None	Binocular	Sun Glass
0	2812	36	561
4	2179	32	438
10	784	16	126
14	345	9	38
20	93	3	8
T	6.637	8.908	6.205
S	0.66	0.63	0.56
S_T	0.011	0.081	0.022
χ^2	2.391	0.173	2.708
Factor	1.002	1.350	0.949

$\bar{S} = 0.617$

$S_s = 0.042$

$S_{\bar{s}} = 0.024$



RANGE DETERMINATION

APPENDIX N

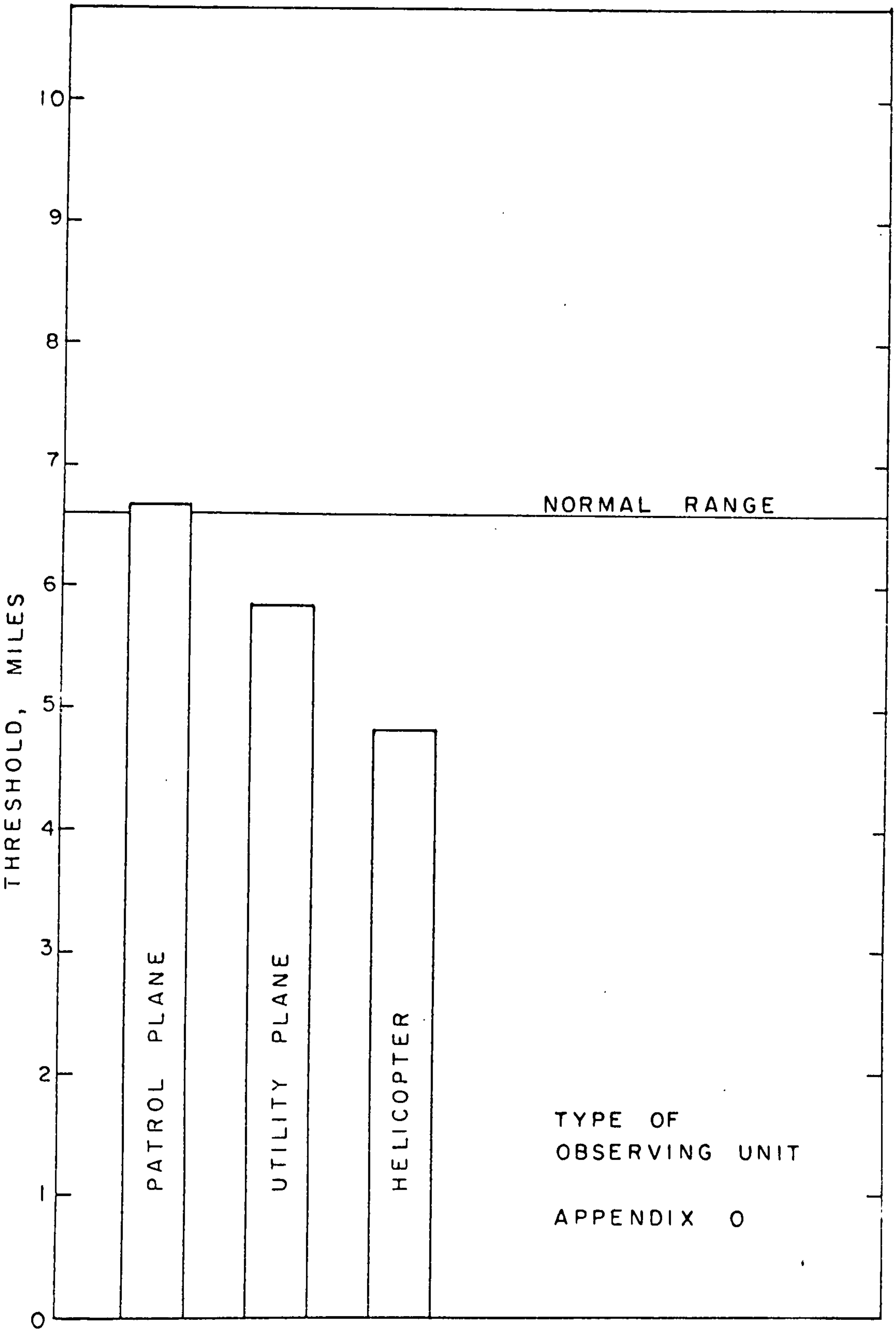
RANGE DETERMINATION METHOD

Range (Miles)	Radar	Time-Distance	Estimate
0	453	1336	1604
4	400	1053	1182
10	184	354	392
14	103	146	140
20	37	33	36
T	8.611	6.629	6.147
S	0.65	0.63	0.66
S_T	0.025	0.015	0.015
χ^2	0.0106	0.988	4.470
Factor	1.298	1.001	0.923

$\bar{S} = 0.647$

$S_s = 0.012$

$S_{\bar{s}} = 0.0072$


THRESHOLD, MILES
0
1
2
3
4
5
6
7
8
9
10
NORMAL RANGE
PATROL PLANE
UTILITY PLANE
HELICOPTER
TYPE OF OBSERVING UNIT

APPENDIX O

TYPE OF OBSERVING AIRCRAFT

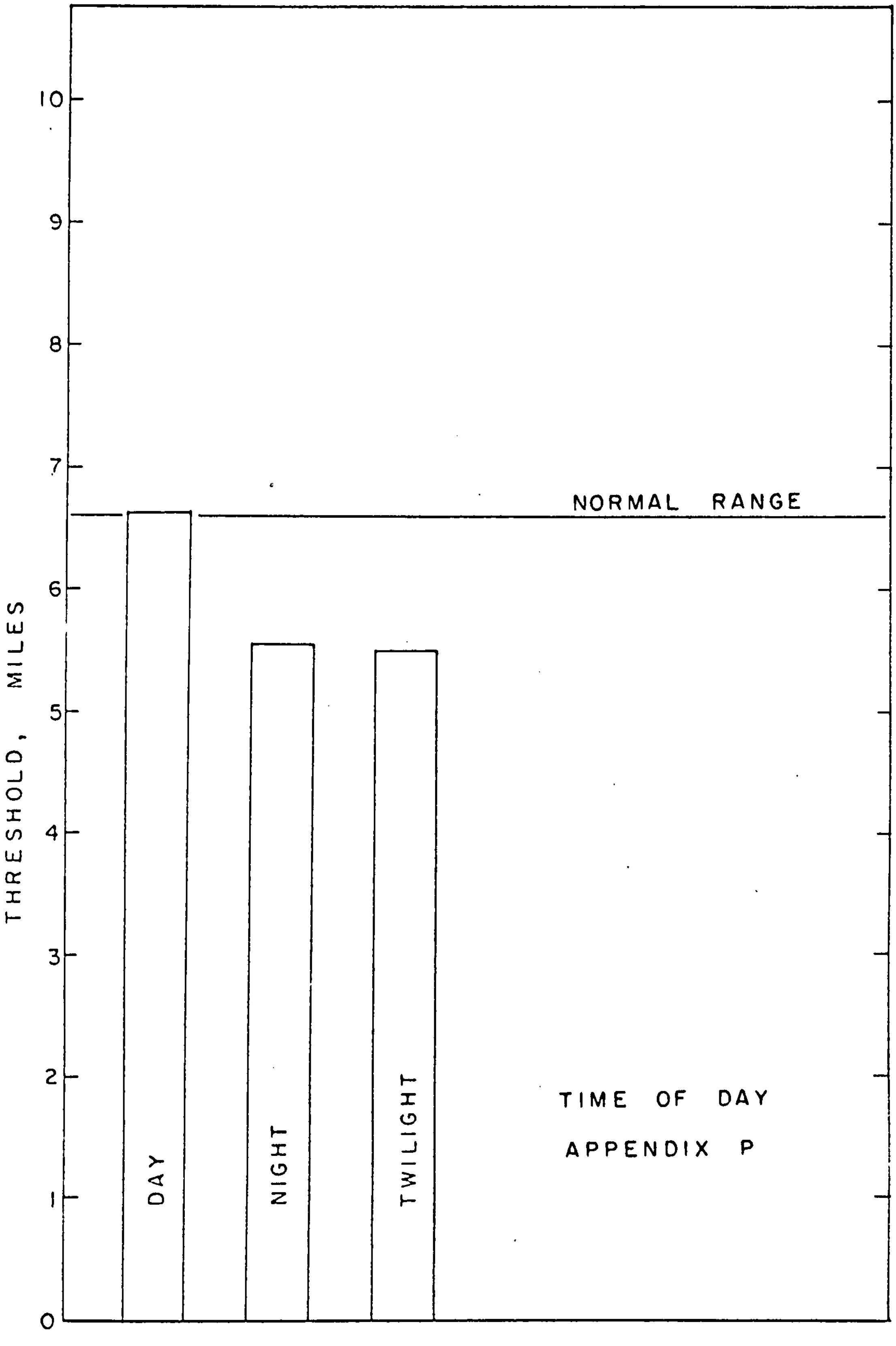
Range (Miles)	Patrol	Utility	Helicopter
0	3138	165	113
4	2403	119	67
10	872	37	22
14	373	9	4
20	99	4	1
T	6.694	5.836	4.836
S	0.64	0.62	0.73
S_T	0.010	0.045	0.071
χ^2	2.843	2.480	4.933
Factor	1.014	0.884	0.733

$\bar{S} = 0.663$

$S_s = 0.048$

$S_{\bar{s}} = 0.028$

APPENDIX O-2


10
9
8
7
6
5
4
3
2
1
0
THRESHOLD, MILES
NORMAL RANGE
DAY
NIGHT
TWILIGHT
TIME OF DAY
APPENDIX P

TIME OF DAY

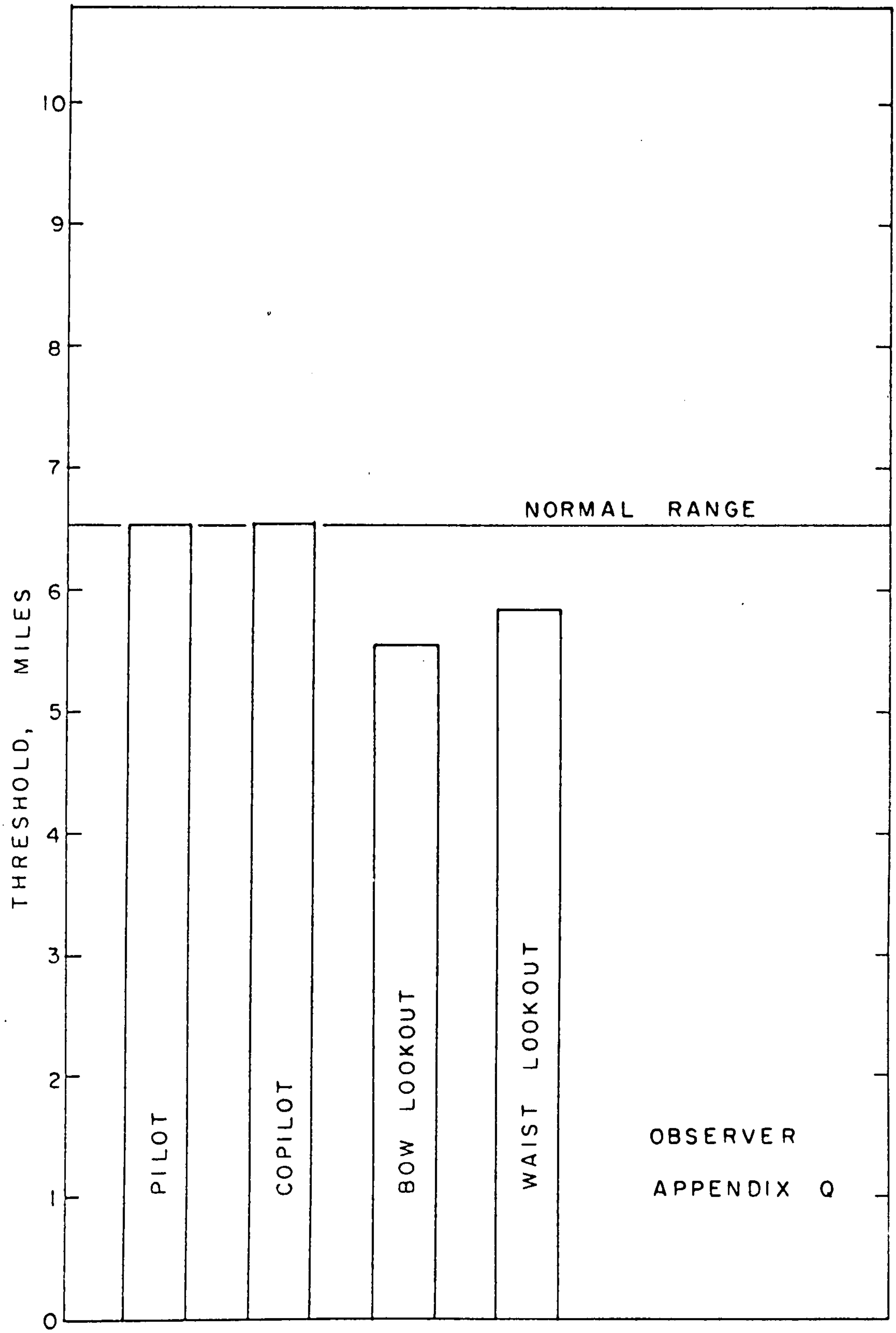
Range (Miles)	Day	Night	Twilight
0	3309	47	62
4	2579	32	45
10	917	10	9
14	388	4	1
20	105	2	0
T	6.614	5.583	5.496
S	0.67	0.71	0.51
S_T	0.0096	0.098	0.007
χ^2	5.770	0.145	1.381
Factor	1.002	0.846	0.833

$\bar{S} = 0.630$

$S_s = 0.086$

$S_{\bar{s}} = 0.050$

APPENDIX P-2


THRESHOLD, MILES
0
1
2
3
4
5
6
7
8
9
10
NORMAL RANGE
PILOT
COPILOT
BOW LOOKOUT
WAIST LOOKOUT
OBSERVER
APPENDIX Q

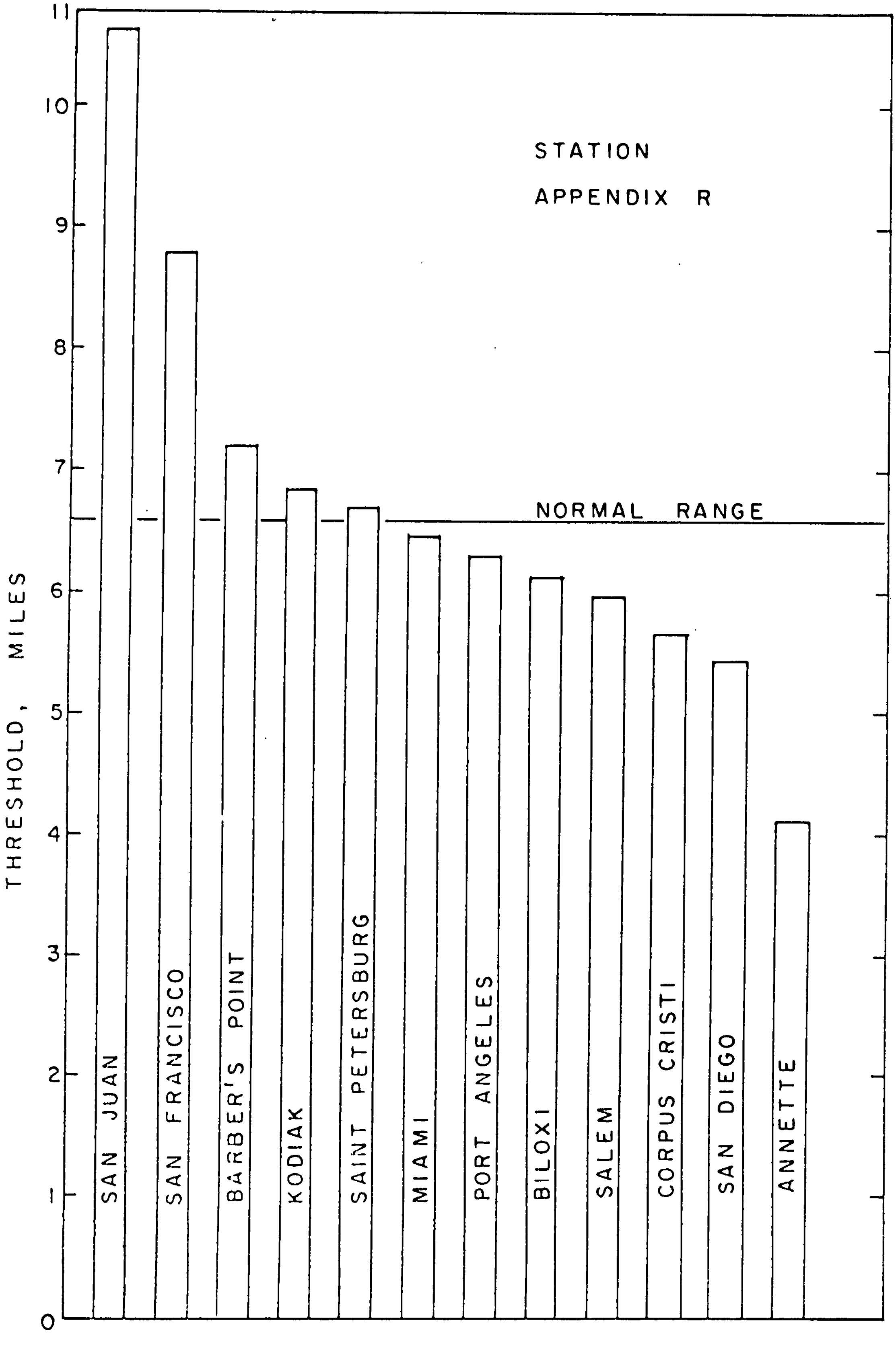
	OBSERVER				
Range (Miles)	Pilot	Copilot	Bow Lookout	Waist Lookout	Tail Lookout
0	1772	1452	59	122	3
4	1377	1140	40	82	2
10	494	382	13	34	1
14	192	170	4	15	0
20	42	51	0	7	0
T	6.603	6.616	5.553	5.853	(No)
S	0.64	0.63	0.68	0.80	(Fit)
S_T	0.013	0.015	0.085	0.079	-
X^2	5.184	0.997	0.501	0.588	-
Factors	1.0006	1.0026	0.841	0.887	-

$\bar{S} = 0.688$

$S_s = 0.068$

$S_{\bar{s}} = 0.034$

APPENDIX Q-2


STATION
APPENDIX R
NORMAL RANGE
THRESHOLD, MILES
0
1
2
3
4
5
6
7
8
9
10
11
SAN JUAN
SAN FRANCISCO
BARBER'S POINT
KODIAK
SAINT PETERSBURG
MIAMI
PORT ANGELES
BILOXI
SALEM
CORPUS CRISTI
SAN DIEGO
ANNETTE

STATION

Range (Miles)	San Juan	San Francisco	Barber's Point	Kodiak	Saint Petersburg	Miami	Port Angeles	Biloxi	Salem
0	179	315	102	13	97	181	1533	276	112
4	167	292	84	10	77	140	1171	210	78
10	106	141	35	4	23	46	360	66	32
14	58	51	10	2	14	20	153	17	10
20	20	13	3	0	5	4	38	3	3
T	10.601	8.782	7.158	6.836	6.689	6.456	6.288	6.163	5.959
S	0.59	0.51	0.58	0.72	0.65	0.62	0.62	0.57	0.69
S_T	0.033	0.024	0.050	0.17	0.058	0.041	0.014	0.033	0.060
X^2	2.317	3.098	2.122	0.00651	0.623	1.242	2.551	4.788	2.617
Factor	1.606	1.331	1.085	1.036	1.014	0.978	0.953	0.934	0.903

$\bar{S} = 0.613$

$S_s = 0.087$

$S_{\bar{s}} = 0.025$

APPENDIX R-2

Range (Miles)	STATION		
	Corpus Cristi	San Diego	Annette
0	80	218	62
4	63	141	32
10	8	46	5
14	1	27	1
20	0	7	1
T	5.654	5.393	4.119
S	0.43	0.77	0.61
S_T	0.052	0.050	0.093
X^2	0.81	1.449	0.186
Factor	0.857	0.817	0.454

APPENDIX R-3

TABLE OF FACTORS

	Ship Size		Range Method					
Tonnage (C)	Length	Factor		Factor	Clock Code	Factor	Length Wake / Length Ship	Factor
0.1	8	0.415	Estimate	0.923	0-12	1.039	0	0.954
0.5	16	0.609	Time-Distance	1.001	1-11	1.022	0.5	1.020
3	30	0.785	Radar	1.298	2-10	0.977	1.0	1.061
25	60	0.979			3-9	0.916	2.0	1.093
100	100	1.122			4-8	0.855		
1000	200	1.316			5-7	0.810		
3000	300	1.430			6	0.794		
7500	400	1.510						
15000	500	1.573						
25000	600	1.624						

APPENDIX S

TABLE OF FACTORS

Visual Aid	Factor	Time of Day	Factor	Altitude	Factor	Wind Velocity	Factor
Sunglasses	0.949	Twilight	0.833	0	0.816	0	0.832
None	1.002	Night	0.846	1K	0.916	5	0.929
Binocular	1.350	Day	1.002	2	1.029	10	1.006
				3	1.155	15	1.062
				4	1.297	20	1.098
				5	1.457	30	1.110
				6	1.637	40	1.040
				7	1.838	50	0.890
				8	2.064		
				9	2.318		
				10	2.608		

APPENDIX S-2

TABLE OF FACTORS

Major Swell Height	Factor	Fractional Cloud Cover	Factor	Meteorological Visibility	Factor	Relative Sun Bearing	Factor
0	0.935	0	1.071	2	0.052	0-360	1.015
1	0.971	0.1	1.100	5	0.535	30-330	1.021
2	1.007	0.2	1.130	10	0.901	60-300	1.041
3	1.044	0.3	1.137	15	1.114	90-270	1.067
4	1.080	0.4	1.131	20	1.266	120-240	1.093
5	1.116	0.5	1.110	30	1.479	150-210	1.112
6	1.152	0.6	1.075	40	1.631	180	1.119
7	1.189	0.7	1.025	50	1.749		
8	1.225	0.8	0.962				
9	1.261	0.9	0.884	Unlimited	1.484		
10	1.297	1.0	0.791				
15	1.478						

APPENDIX S-3

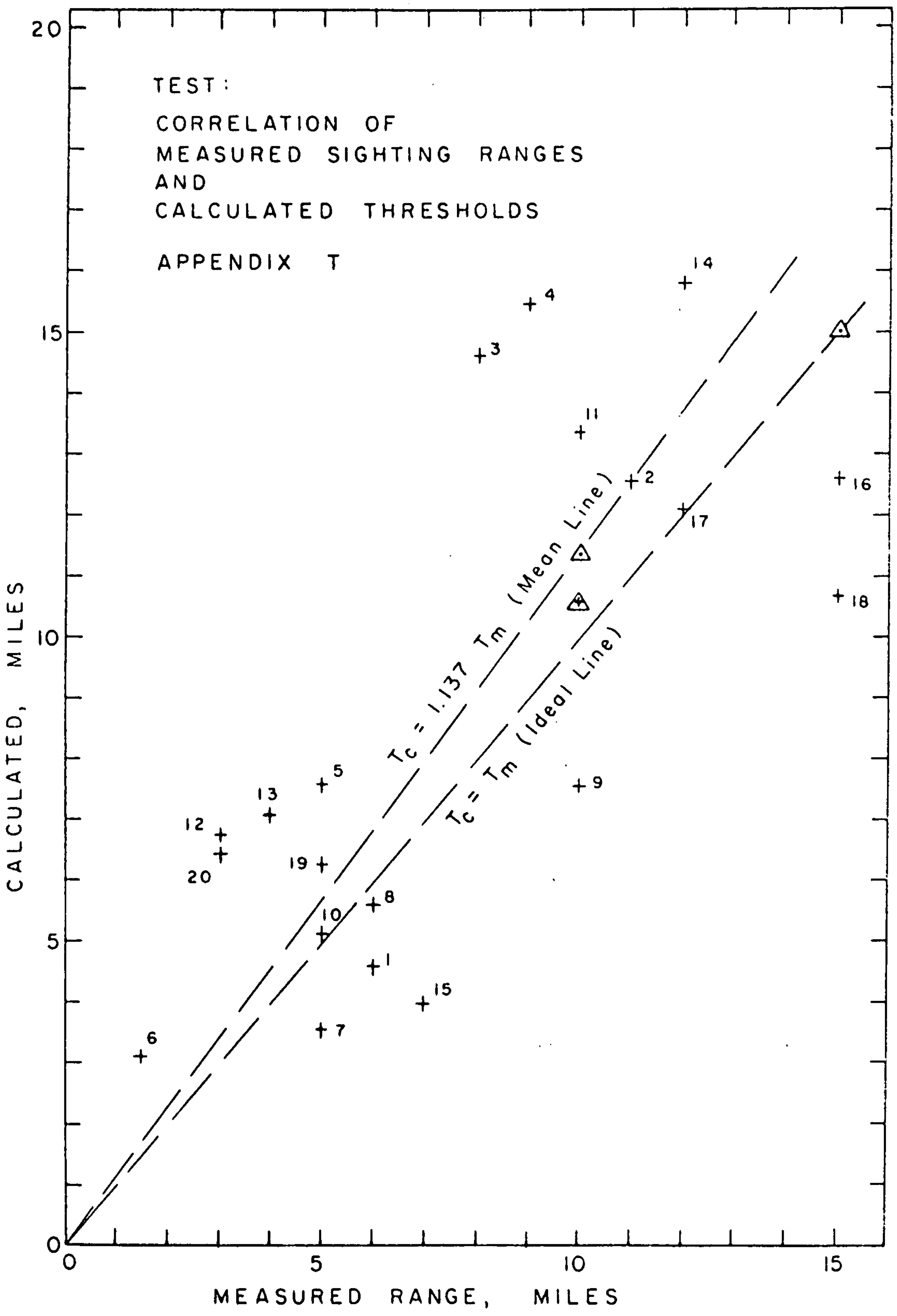
TABLE OF FACTORS

Sun Altitude	Factor
0	1.208
10	1.167
20	1.126
30	1.089
40	1.055
50	1.025
60	1.001
70	0.984
80	0.974
90	0.970

Observer	Factor
Pilot	1.001
Copilot	1.000
Bow L'kout	0.841
Waist L'kout	0.887
Tail L'kout	(0.032)

Observing Unit	Factor
Patrol	1.014
Utility	0.884
Helicopter	0.733

APPENDIX S-4


TEST:
CORRELATION OF
MEASURED SIGHTING RANGES
AND
CALCULATED THRESHOLDS
APPENDIX T
Tc = 1.137 Tm (Mean Line)
Tc = Tm (Ideal Line)
CALCULATED, MILES
MEASURED RANGE, MILES
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

TEST

T_D Data	T_C Calculated	Error $T_C - T_D$	T_D Data	T_C Calculated	Error $T_C - T_D$
6.0	4.561	- 1.439	10.0	13.351	+ 3.351
11.0	12.548	+ 1.548	3.0	6.725	+ 4.725
8.0	14.610	+ 6.611	4.0	7.075	+ 3.075
9.0	15.456	+ 6.456	12.0	15.787	+ 3.787
5.0	7.563	+ 2.563	7.2	3.979	- 3.221
1.5	3.102	+ 1.602	15.0	12.606	- 2.394
5.0	3.538	- 1.462	12.0	12.078	+ 0.078
6.0	5.497	- 0.503	15.0	9.649	- 5.351
10.0	7.517	- 2.483	5.0	6.250	+ 1.250
5.0	5.115	+ 0.115	3.0	6.430	+ 3.430

$r = 0.695$

APPENDIX T-2

TESTS

	1	Factor	2	Factor	3	Factor	4	Factor
Date	10 Jul 56	-	5 Dec 56	-	1 Sep 56	-	1 Jan 56	-
Source	Biloxi	-	San Juan	-	-	-	Miami	-
Type	30-60'	0.882	30-60'	0.882	30-60'	0.882	30-60'	0.882
	Bright	1.060	Bright	1.060	Bright	1.060	Bright	1.060
Range	6.0	-	11	-	8	-	9	-
Method	Est	0.923	Radar	1.298	Radar	1.298	Radar	1.298
Clock Code	9	0.916	10	0.977	0	1.039	11	1.022
Wake	2X	1.093	0	0.954	2X	1.093	0	0.954
Vis. Aid	Sun Gl.	0.949	None	1.002	Sun Gl.	0.949	None	0.949
Time Day	Day	1.002	Day	1.002	Day	1.002	Day	1.002
Altitude	2500	1.092	1200	0.939	1500	0.973	5300	1.511
Wind Vel.	10	1.006	12	1.028	10	1.006	25	1.104
Wind Az.	180	-	80	-	290	-	90	-
Swells	0	0.935	4	1.080	5	1.116	1	0.971
% Cloud	70	1.025	0	1.071	40	1.131	0	1.071
Visibility	10	0.901	25	1.373	20	1.266	20	1.266
Sun Brng.	270	1.067	100	1.075	035	1.024	015	1.031
Sun Alt.	80	0.974	60	1.001	45	1.040	45	1.040
Observer	Waist	0.887	Pilot	1.001	Pilot	1.001	Copilot	1.000
Obs. Unit	Patrol	1.014	Patrol	1.014	Patrol	1.014	Util.	0.884
Computed Threshold	4.561		12.548		14.610		15.456	

APPENDIX T-3

TEST

	5	Factor	6	Factor	7	Factor	8	Factor
Date	3 Apr 57	-	1 Aug 56	-	3 Oct 57	-	18 Mar 57	-
Source	-	-	Annette	-	Pt. Ang.	-	Pt. Ang.	-
Type	30-	0.609	30-60'	0.882	30-	0.609	10 KT+	1.624
	Bright	1.060	Dark	0.943	Bright	1.060	-	-
Range	5	-	1.5	-	5	-	6	-
Method	Est	0.923	Est	0.923	Est	0.923	Radar	1.296
Clock Code	1	1.022	2	0.977	3	0.916	12	1.039
Wake	2 X+	1.093	3X	1.093	0	0.954	0	0.954
Vis. Aid	None	1.002	None	1.002	Sun Gl.	0.949	Sun Gl.	0.949
Time Day	Day	1.002	Twi	0.833	Day	1.002	Day	1.002
Altitude	1500	0.973	800	0.896	700	0.886	400	0.856
Wind Vel.	8	0.975	5	0.929	3	0.890	3	0.890
Wind Az.	200	-	0	-	0	-	315	-
Swells	3	1.044	0	0.935	3	1.044	0	0.935
% Cloud	0	1.071	100	0.791	0	1.071	100	0.791
Visibility	30	1.479	15	1.114	15	1.114	8	0.755
Sun Brng.	185	1.118	-	-	170	1.116	-	-
Sun Alt.	50	1.025	-	-	80	0.974	-	0.974
Observer	Copilot	1.000	-	-	Copilot	1.000	Copilot	1.000
Obs. Unit	Patrol	1.014	-	-	Patrol	1.014	Patrol	1.014
Computed Threshold	7.563		3.102		3.538		5.497	

TEST

	9	Factor	10	Factor	11	Factor	12	Factor
Date	22 Mar 56	-	19 Sep 57	-	14 Oct 56	-	3 Apr 57	-
Source	Salem	-	Pt. Ang.	-	St. Pet.	-	-	-
Type	5 Oct-5KT	1.430	30-60'	0.882	5K-10K	1.510	30-60'	0.882
	-	-	Dark	0.943	-	-	Dark	0.943
Range	10	-	5	-	10	-	3	-
Method	Est	0.923	Est	0.923	Est	0.923	Radar	1.298
Clock Code	10	0.977	3	0.916	3	0.916	11	1.072
Wake	0	0.954	0.5X	1.020	1X	1.061	0.5X	1.020
Vis. Aid	None	1.002	Sun El.	0.949	-	-	None	1.002
Time Day	Day	1.002	Day	1.002	-	-	Day	1.002
Alt.	1000	0.916	100	0.826	-	-	1500	0.973
Wind Vel.	5	0.929	8	0.975	25	1.104	6	0.944
Wind Az.	110	-	220	-	20	-	135	-
Swells	2	1.007	3	1.044	11	1.333	3	1.044
% Cloud	0	1.071	0	1.071	-	-	1	1.074
Visibility	15	1.114	15	1.114	-	-	8	0.755
Sun Brng.	20	1.019	280	1.058	-	-	10	1.017
Sun Alt.	60	1.001	40	1.055	-	-	35	1.072
Observer	Pilot	1.001	Copilot	1.000	Pilot	1.001	Pilot	1.001
Obs. Unit	Utility	0.884	Patrol	1.014	Patrol	1.014	Patrol	1.014
Computed Threshold	7.517		5.115		13.351		6.725	

	TEST							
	13	Factor	14	Factor	15	Factor	16	Factor
Date	18 Sep 57	-	16 May 56	-	23 Feb 56	-	21 Dec 55	-
Source	Pt. Ang.	-	San Juan	-	Biloxi	-	Biloxi	-
Type	30-60'	0.882	500T-5KT	1.430	30-	0.609	5-10KT	1.510
	Dark	0.943	-	-	Dark	0.943	-	-
Range	4	-	12	-	7.2	-	15	-
Method	T-D	1.001	T-D	1.001	T-D	1.001	Est	0.923
Clock	2	0.977	11	1.022	11	1.022	12	1.039
Wake	0	0.954	0	0.954	0	0.954	2X	1.093
Vis.Aid	None	1.002	None	1.002	None	1.002	None	1.002
Time Day	Day	1.002	Day	1.002	Day	1.002	Day	1.002
Altitude	1500	0.973	2000	1.029	300	0.846	1500	0.973
Wind Vel.	14	1.051	6	0.944	14	1.051	15	1.062
Wind Az.	340	-	140	-	350	-	50	-
Swells	1	0.971	3	1.044	2	1.007	4	1.080
% Cloud	0	1.071	50	1.110	0	1.071	40	1.131
Visibility	15	1.114	20	1.266	15	1.114	10	0.901
Sun Brng.	210	1.112	180	1.119	20	1.019	350	1.017
Sun Alt.	50	1.025	40	1.055	70	0.984	50	1.025
Observer	Pilot	1.001	Pilot	1.001	Pilot	1.001	Copilot	1.000
Obs. Unit	Patrol	1.014	Patrol	1.014	Heli.	0.733	Patrol	1.014
Computed Threshold	7.075		15.787		3.979		12.606	

TEST

	17	Factor	18	Factor	19	Factor	20	Factor
Date	3 Jun 56	-	26 Mar 57	-	10 June	-	30 Aug 56	-
Source	San Juan	-	Pt. Ang.	-	Pt. Ang.	-	San Diego	-
Type	10KT+	1.573	10KT+	1.573	-	-	30-60'	0.882
	-	-	-	-	-	-	Dark	0.943
Range	12	-	15	-	5	-	3	-
Method	T-D	1.001	Est	0.923	Radar	1.298	T-D	1.001
Clock	12	1.039	12	1.039	12	1.039	11	1.022
Wake	2X	1.093	0	0.954	0	0.954	2X	1.093
Vis. Aid	None	1.002	None	1.002	None	1.002	None	1.002
Time Day	Day	1.002	Day	1.002	Day	1.002	Twi	0.833
Altitude	1000	0.916	1200	0.939	2000	1.029	500	0.866
Wind Vel.	20	1.098	5	0.929	5	0.929	11	1.017
Wind Az.	60	-	270	-	270	-	270	-
Swells	8	1.225	4	1.080	1	0.971	4	1.080
% Cloud	100	0.791	90	0.884	80	0.962	5	1.110
Visibility	12	0.986	15	1.114	8	0.755	12	1.029
Sun Brng.	270	1.067	15	1.018	0	1.015	90	1.067
Sun Alt.	60	1.001	40	1.055	40	1.055	30	1.089
Observer	Pilot	1.001	Pilot	1.001	Pilot	1.001	Pilot	1.001
Obs. Unit	Patrol	1.014	Patrol	1.014	Patrol	1.014	Patrol	1.014
Computed Threshold	12.078		9.649		6.258		6.430	

SIO Ref: 62-13

C O P Y

UNITED STATES COAST GUARD

ADDRESS REPLY TO:
COMMANDANT
U.S. COAST GUARD
HEADQUARTERS
WASHINGTON 25, D.C.

0
8 September 1955

OPERATIONS INSTRUCTION NO. 58-55

Subj: Sighting Data Report (Form CG-3627); instructions for

1. Purpose. To prescribe procedures which are required of aircraft and certain floating units relative to the preparation and submission of data collected in connection with the program for the collection of sighting data.

2. Objective. This program is designed to collect reports of 8-10,000 sightings of life rafts, emergency visual signals, small boats and vessels under many visibility and air and sea conditions.

3. Information. Presently available "Effective Visibility" tables do not include small boats and vessels with which the Coast Guard is commonly concerned, nor is the condition of air and sea taken into consideration. Therefore, in order to obtain more realistic tables on this important subject, the U. S. Navy, at the request of the Coast Guard, has agreed to evaluate (by use of Univac machines) sighting data collected by the Coast Guard and to derive empirical formulae from which curves for search, sweep width, and sighting effectiveness may be drawn. These results will ultimately be incorporated in a Coast Guard Search and Rescue Manual.

4. Action.

a. Floating units 83' in length and over and aircraft shall fill in subject form, which is self explanatory, on each sighting deemed to be advantageous to the program. Data must be complete for each sighting reported. Forms should be carried on all flights over water and on bridges of floating units ready for use as may be practicable.

b. Units shall submit forms to Commandant (O) in lots of 100 sighting reports.

5. Availability of Forms. An initial distribution of Form CG-3627 will be made in the near future to all aviation units and floating units 83' in length and over. The form will be included in the Catalog of Forms (CG 218) with source of supply "SC".

APPENDIX U

COPY

OPERATIONS INSTRUCTION NO. 58-55

6. Effective date. This instruction is effective upon receipt and will be canceled by separate instruction upon completion of the project.

H. C. PERKINS
By direction

Encl: (1) Sighting Data Report,
Form CG-3627

Dist. (SDL No. 61)
A: a,aabcd(5); efi(3); g.1.2.3. hjklmn(1)
B: C(15); eghi(5); jl(3); d(2); b(1)
C: A(5); bd(3)
D: NONE

SIO Ref: 62-13

TREASURY DEPARTMENT
U. S. COAST GUARD
CG-3627 (8-55)

SIGHTING DATA REPORT

1. DATE SIGHTED *(Day, month, year)*

TO:

Commandant (O)

FROM *(Forwarding letter not necessary)*:

2. TARGET TYPE *(Check and complete)*

	01	ONE MAN LIFE RAFT		06	MK-13 NIGHT SIGNAL		11	TYPE III SMALL BOAT 1/		16	MEDIUM VESSEL *(5000 to 10000 tons)*
	02	SEVEN MAN LIFE RAFT		07	VERY'S PISTOL SIGNAL		12	TYPE IV SMALL BOAT 1/		17	LARGE VESSEL *(Over 10000 tons)*
	03	TWENTY MAN LIFE RAFT		08	SIGNALLING MIRROR		13	TYPE V SMALL BOAT 1/	18 OTHER *(Describe)*		
	04	ORANGE SMOKE SIGNAL		09	TYPE I SMALL BOAT 1/		14	TYPE VI SMALL BOAT 1/			
	05	SEA DYE-MARKER		10	TYPE II SMALL BOAT 1/		15	SMALL VESSEL *(500 to 5000 tons)*			

3. SIGHTING RANGE *(Naut. miles & tenths)*

METHOD *(Check)*		RANGE
	ESTIMATED	
	RADAR	
	TIME-DISTANCE CHECK	

4. CLOCK CODE *(Relative bearing, 0-12 hours)*

5. WAKE SIZE *(Check)*

	0	NEGLIGIBLE
	1	ONE-HALF LENGTH OF OBJECT
	2	ONE LENGTH OF OBJECT
	3	TWICE LENGTH OF OBJECT
	4	OVER TWICE THE LENGTH

6. VISUAL AID *(Check and complete)*

	1	NONE
	2	BINOCULARS
	3	SUN GLASSES

4 OTHER *(Describe)*

7. TIME OF DAY *(Check)*

	N	NIGHT
	D	DAY
	T	TWILIGHT *(Morning or evening)*

8. ALTITUDE *(100's of ft.)* FOR SIGHTING FROM AIRCRAFT

8a. HEIGHT OF EYE IN FEET *(For sighting from vessel)*

9. SURFACE WIND

KNOTS	FROM *(Degrees true)*

10. HEIGHT OF MAJOR SWELLS *(Feet)*

11. CLOUD COVER (%)

12. METEOROLOGICAL VISIBILITY *(Miles)* 2/

13. POSITION OF SUN

RELATIVE BEARING FROM LINE OF SIGHT *(Degrees)*.	ALTITUDE *(Degrees)*

14. OBSERVER *(Check and complete)*

a. AIRCRAFT			b. VESSEL		
	1	PILOT		11	CO
	2	CO-PILOT		12	OOD
	3	BOW LOOKOUT		13	OW
	4	WAIST LOOKOUT		14	BRIDGE LOOKOUT
	5	TAIL LOOKOUT		15	DECK LOOKOUT
6 OTHER *(Specify)*			16 OTHER *(Specify)*		

15. TYPE OF OBSERVING UNIT *(Check and complete)*

	1	PATROL PLANE *(Including UF's)*		4	VESSEL OVER 200 FEET
	2	UTILITY PLANE		5	VESSEL 150-200 FEET
	3	HELICOPTER		6	VESSEL UNDER 150 FEET

7 OTHER *(Describe)*

1/ Types of boats are as follows:

TYPE	LENGTH	DESCRIPTION
I	Less than 30 Feet	Bright colors such as white, orange, yellow, red. Little or no superstructure.
II	Less than 30 Feet	Dark colors such as black, blue, green, grey, offering little or no contrast with water.
III	30 to 60 Feet	Bright colors such as white, orange, yellow, red.
IV	30 to 60 Feet	Dark colors such as black, blue, green, grey.
V	60 to 100 Feet	Bright colors such as white, orange, yellow, red.
VI	60 to 100 Feet	Dark colors such as black, blue, green, grey.

2/ Meteorological visibility should be estimated by determining range at which land masses, ships, or other targets can be seen.

NOTE: This form should be filled out using heavy, dark-colored pencil or pen and ink. Prepare original only. USE REVERSE FOR REMARKS.

SIGNATURE OR INITIALS OF CO, OIC OR PLANE COMMANDER

GPO 897739

APPENDIX V

FLOW OF PROBIT CALCULATION

The notation herein is defined for this appendix only.

1. Given (x_i, n_i, r_i) , stimulus levels, number of presentations and number of responses at each level, determine frequency, $p = \frac{r}{n}$. Note: Hereafter the subscripts, i , are to be inferred.

2. Determine experimental probits, EP, such that:

$$p = \int_{-\infty}^{EP} \frac{1}{2\pi} e^{-1/2\,U^2} du$$

3. Determine best fit trial line and trial probits Y by least square method giving approximate regression of EP on x by:

$$Y = a + bx$$

4. Determine weights $w = \frac{Z^2}{PQ}$

$$Z = \frac{1}{2\pi} e^{-1/2\,Y^2}$$

$$P = \int_{-\infty}^{Y} 1/2\pi \; e^{-1/2\,U^2} du; \quad Q = 1 - P$$

5. Determine working probits $y = \frac{p - P}{Z} + Y$

6. Determine Σnw, Σnwx, Σnwy, Σnwx^2, Σnwy^2, $\Sigma nwxy$

7. Determine $\bar{x} = \frac{\Sigma nwx}{\Sigma nw}$ $\bar{y} = \frac{\Sigma nwy}{\Sigma nw}$

8. Now: $S_{xx} = \Sigma nwx^2 - \frac{\Sigma^2 nwx}{\Sigma nw}$

$$S_{xy} = \Sigma nwxy - \frac{\Sigma nwx \, \Sigma nwy}{\Sigma nw}$$

$$S_{yy} = \Sigma nwy^2 - \frac{\Sigma^2 nwy}{\Sigma nw}$$

9. Then: $b_1 = \frac{S_{xy}}{S_{xx}}$ and $a_1 = \bar{y} - b\bar{x}$

10. $Y_1 = a_1 + b_1 x$. The subscripts here and in 9. above indicate a next approximation.

11. The χ^2 test is applied and, if not satisfactory, recycling begins at 3. above using a_1 and b_1 in place of a and b .

12. When iteration proves satisfactory the following are determined.

Threshold, $T = \frac{-a}{b}$

Variance, $S^2 = \frac{1}{b^2}$

Variance of threshold, $S_T^2 = \frac{1}{b^2}\left[\frac{1}{\Sigma nw} + \frac{(m - \bar{x}^2)}{S_{xx}}\right]$

Variance of a, $S_a^2 = \frac{\Sigma nwx^2}{S_{xx}}$

Variance of b, $S_b^2 = \frac{1}{S_{xx}}$

Variance of standard deviation, $S_s^2 = \frac{S^4}{S_{xx}}$

NOTATION

A	Altitude, 1000's feet
B	Target bearing, degrees
C	Cloud cover, decimal fraction
$D(p)$	Normal deviate for probability p
f	Factor
$F(.)$	Factor function of . , any variable
L	Length of vessel, feet
OB	Observer
OU	Observing unit
p	Cumulative probability of sighting
$p(.)$	Probability of . , any function
r	Correlation coefficient
RD	Range determination method
S	Height of major swells, feet
s	Standard deviation
$\bar{s}$	Mean standard deviation
s_s	Standard deviation of s
$s_{\bar{s}}$	Standard deviation of $\bar{S}$
s_t	Standard deviation of T
SA	Sun altitude, degrees
SB	Sun bearing, relative to observer-target line, degrees
ST	Air station
T	Threshold, miles
T_N	Normal range, miles

T(.)	Threshold function of . , any variable, miles
TD	Time of day, general
t	Student's t function
V	Visibility, miles
VA	Visual aid
WA	Wind azimuth, degrees
WS	Wake size, proportional to length of vessel
WV	Wind velocity, knots
X^2	The accumulated value of the measure of goodness of fit and other statistical tests.