# AERODYNAMIC AND GEOMETRIC PARAMETERS AFFECTING AIRCRAFT WEIGHT

Thesis by

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## SUMMARY

A number of single engine conventional aircraft are studied to investigate the possibility of applying statistical methods to the problem of aircraft weight estimation. It is shown that the statistical treatment is definitely useful. It is also shown that, without proper care and judgment, such a statistical treatment leads to somewhat misleading results. The need for structural and aerodynamic training and experience together with essential weight estimating experience is evident. Such experience is requisite to arriving at proper weight estimates when basing these estimates upon the weights of aircraft which have previously been designed and built.

It was hoped that the effects of all of the important aerodynamic and geometric parameters upon aircraft weight would be found from this study of successful single engine aircraft. It was further hoped that the results of this study would be applicable to the difficult problem of estimating the weight of new aircraft. The number of aircraft in the sample for which pertinent information was available was not large enough to permit the evaluation of the effects of all of the parameters although most of the important parameters and their essential effects have been indicated. Lack of complete information due to the restricted or confidential nature of the data was one of the most troublesome handicaps. The latter problem of obtaining weight estimating procedures has, however, been solved since satisfactory weight

SUMMARY (Continued)

estimating formulas have been developed for use in basic design weight estimates.

It is this latter result for which the entire study was made. That is, the study was initiated to offer assistance to practicing preliminary design engineers by providing usable information concerning the effects of such factors as gross weight, load factor, and wing span upon aircraft weight. Such information should be invaluable to assist in arriving at the optimum aircraft design with respect to performance, maneuverability, and utility.

All the useful estimating formulas are summarized on page 43. Also included are the calculated probable errors of estimate.

## INTRODUCTION

The idea of having available accurate information concerning the relative effects of the various aerodynamic and geometric parameters upon aircraft weight has probably occurred to many engineers who have been assigned the task of the basic design of aircraft to do a specific job, to have certain performance, and to meet specified maneuverability requirements. The need for such information first became apparent to the writer several years ago. At that time the effects of airfoil shape were being considered with respect to the performance of a proposed aircraft. The far-reaching effects of changing airfoil shape were intriguing. For more camber the return was better stalling characteristics, lower drag for cruising, and lower landing speed. This was clear to the aerodynamicist. The structures engineer saw an increase in the design wing torque, the design balancing tail load, and the increased possibilities of torsional divergence. The price of these increases would be paid in structural weight. Exactly how much weight such a change would cost was not accurately known. Perhaps the increase in structural weight might over-shadow the beneficial effects of the lower drag by reducing the allowed fuel for a given gross weight. The lack of accurate knowledge of the interactions of these parameters led to the further realization that, as a result of this lack of knowledge, most of the compromises in aircraft basic design are made only after many

INTRODUCTION (Continued)

cuts and tries. Such a lack of knowledge was the impetus which lead to the initiation of this study.

The first study was made upon sixteen aircraft of successful production types. All of the aircraft were single engine land type, land or carrier based. In this original study there is no breakdown of weight into separate parts of the various components, only the total weights of the several components are given. The components considered are:

1. Wing (without flaps or ailerons)
2. Useful load
3. Fixed equipment
4. Combined fixed equipment and useful load
5. Main and auxiliary landing gear
6. Engine and nacelle groups
7. Fuselage
8. Horizontal tail surface
9. Vertical tail surface
10. Landing flaps
11. Ailerons

Since this part of the study is primarily for finding the relative effects of gross weight upon component weight, it was felt that the component weight information was sufficient to arrive at the desired results. Here again it should be emphasized that this first part of the study is useful to the preliminary design engineer and in many cases its results will serve as an excellent starting point for original weight estimates. The results in some instances are much better than had been anticipated at the start of the study.

It should be realized that the best and most useful weight estimating curves for use at the start of a design are those which are based upon parameters that are tentatively

INTRODUCTION (Continued)

with probable errors of less than 10% can be made of all component weights with the use of very simple parameters. It is suggested that further work be done by considering the breakdown of the weight of the components into bending, shear, and torque material. Then a detailed study of the effects of many more important parameters can be made to yield an excellent set of procedures for estimating aircraft component weight.

# PART I

# GENERAL DISCUSSION

## OUTLINE OF THE PROBLEM

Since weight is one of the most important factors affecting aircraft utility and success, design for minimum weight is essential to the aircraft engineer. While the detailed design can successfully be controlled with trained engineers under proper supervision, very often uneconomic compromises must be made in the basic design while it is in its early stages. Many such uneconomic compromises could be eliminated if sufficient knowledge were available to the preliminary design engineer. In other words, if the engineer knew beforehand what the cost of adding some certain feature meant in actual final weight he might be able to suggest less costly alternatives, or if he could properly show that such cost was excessive, he might prove that this particular feature should be eliminated entirely.

The problem then, is to determine what parameters affect aircraft weight and in what manner they affect it. This complex problem cannot be set into a system of exact relations. At best, any relations derived would be approximate. It is clear that judgment must play an important part in the solution of the problem. Judgment alone is not enough, however, and it is the purpose of this paper to supply a portion of the solution in the form of weight estimating formulas for single engine aircraft, as well as calculated probable errors which might be made in applying such formulas. These formulas may be considered to be

OUTLINE OF THE PROBLEM (Continued)

correct within approximately 10% for the particular types of aircraft studied. Thus, judgment is eliminated from 90% of the problem and need only be applied to the remaining 10% of the estimate.

It should be emphasized that while an estimate can be made in seconds and may be considered correct, the exercise of proper discretion based upon experience may indicate whether the estimate is slightly lower or higher than it should be. Thus it is important that the procedures be applied intelligently.

To illustrate the necessity for developing better estimating procedures, several estimates have been made based upon some existing formulas. Actual data are plotted on cartesian and logarithmic coordinates and the currently suggested estimating lines are included in pages 45 to 53. It is seen from the plots that the obvious deviations from the estimating curves indicate that present procedures are not applicable to modern single engine aircraft. It should be remembered that these existing procedures were probably very good with respect to the aircraft which were included in the study at the time it was made, however, changes in design practices, specifications, and materials have made such curves obsolete. Another reason for such large deviations is that the procedures probably were not developed for single engine aircraft in particular, but rather for aircraft of other types.

OUTLINE OF THE PROBLEM (Continued)

This suggests that for arriving at valid estimating procedures the aircraft should first be classified with respect to type, then weight estimates for a new craft can be matched against the corresponding weights of other craft of its type. This is an obvious although often overlooked procedure. Its importance is even more evident when reference is made to the useful load versus actual gross weight study of all the aircraft in the sample, compared with the estimate for fighter aircraft taken separately. The probable error of estimate is reduced from 10.3% to 7.9% even though the number of aircraft in the sample is reduced from sixteen to eleven. The probable error apparently is a gage against which all the estimating formulas should be checked. In this entire study all the formulas developed from the data are checked with respect to probable error by the same general procedure.

## GENERAL PROCEDURE FOR ANALYZING THE DATA

Weight information for sixteen different single engine land type aircraft was obtained in the form of group weight statements from several aircraft manufacturers. The arrangements under which the data were made available prohibit reference to particular models, thus limiting the ability freely to discuss some of the interesting tendencies which were exhibited. Only general statements are made and even those are without reference, so that some of the value of the work done is lost to the reader since the judiciousness of the detailed steps cannot be explained, supported, or discussed in full measure.

The general treatment of the data consists of fitting the data with two well known systems; first, the data are treated as if plotted in a cartesian coordinate system and a best straight line is passed through the data points. This yields an equation $y = a + bx$; second, the data are treated as if plotted on logarithmic coordinates, and again a best straight line is passed through the points. This yields an equation $y = a(x)^b$. These two systems are used for all the primary study. Some of the more detailed work, which is done to obtain effects of particular parameters, is treated only logarithmically. Such treatment of the data is relatively simple and has been used effectively in the past.

GENERAL PROCEDURE FOR ANALYZING THE DATA (Cont.)

An innovation which is not new to statisticians and mathematicians familiar with probability theory is introduced. That is, probability theory is used to indicate the probable error of estimate which can be expected based upon the study of existing data. This probable error, it is believed, will serve to assist engineers who may use the suggested estimating procedures by pointing out the relative accuracy of any estimate attempted. To make an estimate is simple. To know where this estimate places one with respect to other existing aircraft is indispensable to the proper exercise of judgment in evaluating the validity of the estimate. Thus, it is felt that one of the most valuable contributions made here is the introduction of the use of probable error information with each estimating formula.

## DISCUSSION OF SIMPLE PROBABILITY THEORY

The entire study of the probable errors of estimate from the available data is conducted using the existing theory of probability and the Gaussian error function or law of error. Here it is advisable to review the theory of probability and the ideas upon which Gauss' error function is based.

If a number of measurements of a certain physical quantity are taken and the mean value is computed it is possible to determine the difference between each measured value and the mean. These differences are referred to as the deviations from the mean, or the errors in the individual measurements. It is apparent that errors of one magnitude have a certain probability of occurrence, while those of another have a distinctly difference probability of occurrence. It is clear that in measuring the weights of ball bearings of a certain size weighing one pound the probability of finding errors of plus or minus one ounce is much greater than the probability of finding errors of plus or minus one pound. A rough idea of the shape of the probability versus error curve is given under just such simple observations and it is apparent that it will look something like the curve in Figure A.

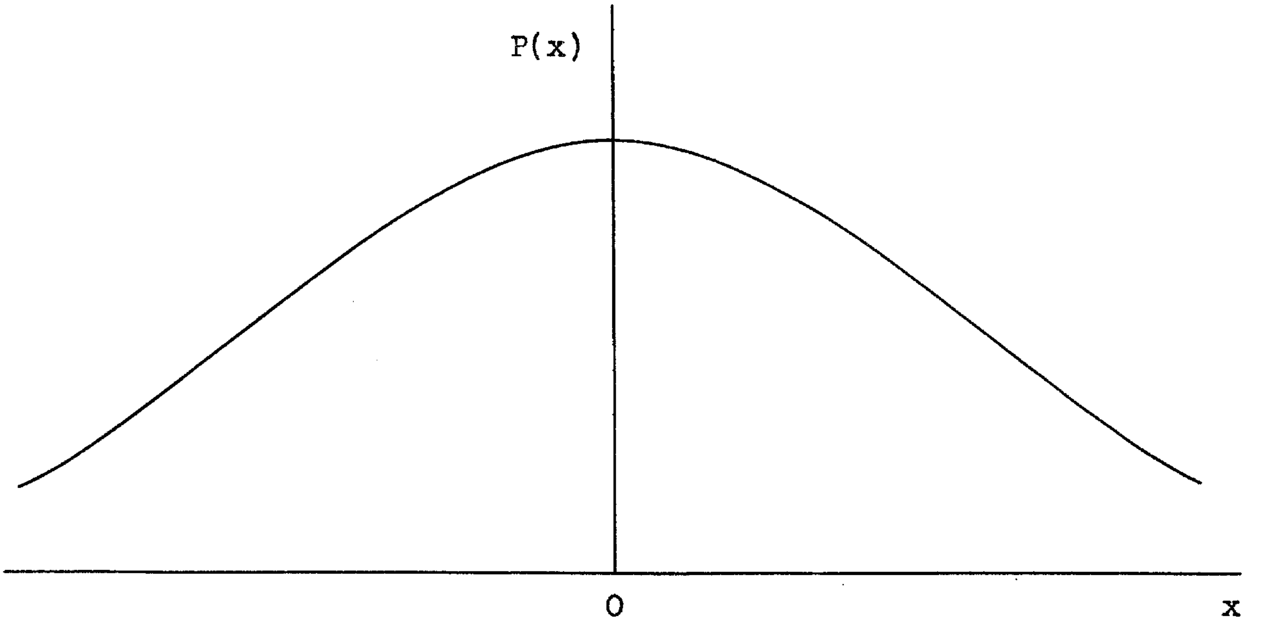



Figure A

Consider n measurements of some physical property. Designate the measurements by $m_1$, $m_2$, $m_3$. . . . .$m_n$. The mean of these measurements is

$$m = \frac{\sum m_i}{n}$$

The errors, or deviations from the mean are

$$E_1 = m_1 - m, \; E_2 = m_2 - m, \; . \; . \; . \; . \; E_n = m_n - m$$

If the probability of occurrence of the error of a certain magnitude is some function of the error as previous discussion has indicated, it should be possible to express this function mathematically.

Consider F(E) to be such a function. It is apparent that if E is calculated with respect to the mean there is just as much chance of obtaining a positive error as a negative one. Thus, one property of the function is that it is even or

$$F(E) = F(-E)$$

It is evident that as E becomes large the chance of obtaining errors decreases so that

$$F(\infty) \longrightarrow 0$$

All the errors which it is possible to find are included as E passes from $-\infty$ to $+\infty$. The probability of obtaining all the errors is unity. Hence, another condition is imposed upon the function, namely

$$\int_{-\infty}^{+\infty} F(E)dE = \underline{1}$$

It may be implied that the probability of occurrence of errors of a definite range may be obtained by integrating between the specified limits, thus the probability of occurrence of +10% to +20% is expressed as

$$P_{10-20} = \int_{+.10m}^{+.20m} F(E)dE$$

If the n measurements have been made completely independently each error has the probability of occurrence P where

$$P = P_1 P_2 P_3 P_4 P_5 . \; . \; . \; . \; . \; . \; P_n$$

and $P_i$ is the probability of occurrence of the individual errors $E_i$. But $P_i$ is defined to be $F(E_i)$, thus

$$P = F(E_1)F(E_2). \; . \; . \; . \; . \; F(E_n)$$

Remembering that $E_i = m_i - m$

$$P = F(m_1 - m)\ F(m_2 - m) \ldots F(m_n - m)$$

It is obvious that P is some function of m. Gauss introduced a procedure for determining F under the assumption that the mean value is the most probable value. If m is such a value then P will be a maximum and $\log_e P$ will be a maximum. But

$$\log_e P = \log_e F(m_1 - m) + \log_e F(m_2 - m) + \ldots \log_e F(m_n - m)$$

Differentiating with respect to m gives

$$\frac{P'}{P} = \frac{F'(m_1 - m)}{F(m_1 - m)} + \frac{F'(m_2 - m)}{F(m_2 - m)} + \ldots \frac{F'(m_n - m)}{F(m_n - m)} = 0$$

or

$$\frac{F'(E_1)}{F(E_1)} + \frac{F'(E_2)}{F(E_2)} + \ldots \frac{F'(E_n)}{F(E_n)} = 0$$

Remembering that m is the mean value it is evident that the summation of positive errors is exactly equal to the summation of negative errors so that

$$\sum^{n} E_i = 0$$

This equation and the preceding one must hold simultaneously. Consider n = 2: then from these equations

$$\frac{F'(E_1)}{F(E_1)} = \frac{F'(E_2)}{F(E_2)} \quad ; \qquad E_1 = E_2$$

it is evident that

$$\frac{F'(E_1)}{F(E_1)} = \frac{F'(-E_1)}{F(-E_1)}$$

Consider n = 3, now

$$\frac{F'(E_1)}{F(E_1)} + \frac{F'(E_2)}{F(E_2)} + \frac{F'(E_3)}{F(E_3)} = 0 \quad ; \qquad E_1 + E_2 + E_3 = 0$$

But F is such that

$$\frac{F'(E_n)}{F(E_n)} = \frac{F'(-E_n)}{F(-E_n)}$$

so it is possible to write

$$\frac{F'(E_1)}{F(E_1)} + \frac{F'(E_2)}{F(E_2)} = \frac{F'(E_1 + E_2)}{F(E_1 + E_2)}$$

Let

$$Q_1 = \frac{F'(E_1)}{F(E_1)}, \quad Q_2 = \frac{F'(E_2)}{F(E_2)}, \quad Q_3 = \frac{F'(E_3)}{F(E_3)} = \frac{F'(E_1 + E_2)}{F(E_1 + E_2)}$$

then

$$Q_1 + Q_2 = Q_3$$

Now differentiate this equation partially by $E_1$ and then by $E_2$ to obtain

$$\frac{\partial Q_1}{\partial E_1} = \frac{\partial Q_3}{\partial E_1} \; ; \qquad \frac{\partial Q_2}{\partial E_2} = \frac{\partial Q_3}{\partial E_2}$$

But since $Q_3 = Q(E_1 + E_2)$ ,

$$\frac{\partial Q_3}{\partial E_1} = \frac{\partial Q_3}{\partial E_2}$$

$$\frac{\partial Q_1}{\partial E_1} = \frac{\partial Q_2}{\partial E_2}$$

Such a partial differential equation is satisfied only if each side of the equation is equal to the same constant, thus

$$\frac{\partial Q_1}{\partial E_1} = k \qquad \frac{\partial Q_2}{\partial E_2} = k$$

the solutions are

$$Q_1 = kE_1 \qquad Q_2 = kE_2$$

But

$$Q_1 = \frac{F'(E_1)}{F(E_1)} \quad \text{and} \quad Q_2 = \frac{F'(E_2)}{F(E_2)}$$

So

$$\frac{F'(E_1)}{F(E_1)} = kE_1 \qquad \frac{F'(E_2)}{F(E_2)} = kE_2$$

Or simply

$$\frac{F'(E)}{F(E)} = kE$$

The solution of this equation is

$$F(E) = C_1\, e^{\frac{k}{2} E^2}$$

One of the original conditions on F was

$$\int_{-\infty}^{+\infty} F(E)dE = 1$$

Now it may be used to find $C_1$ since

$$C_1 \int_{-\infty}^{+\infty} e^{\frac{k}{2} E^2} dE = 1$$

If k is replaced by $-2\ a^2$

$$2\ C_1 \int_0^{\infty} e^{-a^2E^2} dE = 1$$

$$C_1 = \frac{a}{\sqrt{\pi}} \qquad \text{since} \qquad \int_0^{\infty} e^{-a^2E^2}\ dE = \frac{\sqrt{\pi}}{2a}$$

Thus, $F(E) = (a/\sqrt{\pi})e^{-a^2E^2}$ is the Gaussian Law of Error. The constant a is still to be determined. It is usually termed the precision constant and is a function of the quality of observation. The expressions derived for a are

$$a = 1/(\bar{E}\sqrt{\pi}) \qquad \text{or,}\ a = 1/\sqrt{\Sigma E^2}\ \sqrt{2}$$

where

$$\bar{E} = \frac{\sum E_i}{n} \qquad \bar{E}^2 = \frac{\sum E_i}{n}$$

Where there is an equal chance that a certain circumstance may occur or not, the probability of occurrence is one-half. Thus, in a similar manner the probable error is the error which is just as likely to be exceeded as not. The error $E_p$, positive or negative, which is just as likely to be exceeded or not is such that

$$\int_{-E_p}^{E_p} F(E)dE = \tfrac{1}{2}$$

The probable error is

$$\frac{2}{\sqrt{\pi}}\int_0^{E_p} e^{-E^2}\ dE = \tfrac{1}{2}$$

If this integral is expanded by Maclaurin's Theorem and integrated term by term

$$E_p = \frac{0.4769}{a} = .6745\sqrt{\frac{\sum(E)^2}{n}}$$

It should be remembered that each of the errors, $E_i$, has been obtained using the mean value of the measurements m. Since the study is restricted to n measurements the true mean value may not be equal to the mean value calculated by

$$m = \frac{\sum m_i}{n}$$

Consider the true mean value to be $\bar{m}$. Then if $D_i$ is considered to be the deviation of $m_i$ from the true mean

$$D_i = m_i - \bar{m}$$

If we add n deviations

$$\sum D_i = \sum(m_i - \bar{m}) = \sum m_i - n\bar{m}$$

or

$$\sum m_i = n\bar{m} + \sum D_i$$

from the definition of the mean above

$$m = \bar{m} + (1/n)\sum D_i$$

Thus it is seen that as the number of measurements increases the mean value of the measurements approaches the true mean value; this should, of course, be obvious. In order to account for the fact that only a finite number of measurements is taken the precision constant a is modified to

$$A = a\sqrt{n / (n-1)}$$

And the probable error becomes

$$E_p = .6745 \sqrt{\sum (E_i)^2/(n-1)}$$

In this study there are no measurements of a particular physical quantity as such. Actually, the weights given are measured but they are for similar components of different aircraft. Obviously, the mean value of a certain component will not be the most probable. The mean value of a corrected weight will be the most probable if these corrected weights are established by the proper choice of parameters which affect weight. Thus, if a reasonable set of parameters which affect a certain component weight is taken as the independent variable, and the component weights are plotted as dependent variable, a mean line through the plotted points will represent the most probable value of the component weight for any given value of the set of parameters. Thus, the mean line can be associated with the mean value, and deviations from the mean line can be associated with errors or deviations from the mean value.

To find the probable error, which here will be the probable error of estimate, it is necessary to choose a set of pertinent parameters for any particular component, determine the mean line through the plotted points of the component weight versus parameter data, calculate for each of the values of the independent variable a corresponding value of the dependent variable by means of the mean line or estimating formula, find the deviations or differences between actual and estimated weights, square these deviations, sum the squares, and multiply by

$$\frac{.6745}{\sqrt{n - 1}}$$

to obtain the probable error of estimate. This is done in tables especially arranged to facilitate the entire computation. The results of such calculations are: first, an estimating formula which is the mean line, and second, the probable error of an estimate based on the derived formula.

It is a necessary condition that the probable error be small if the choice of parameters is to be considered reasonable. It is not a sufficient condition, however, since it can be shown that parameters can be chosen such that the probable error is zero yet the practical validity of the choice of such parameters can immediately be questioned.

There are several factors which affect the probable error. One is the number of observations taken for any given study. This is apparent from the equation for probable error,

$$E_p = \frac{.6745}{\sqrt{n - 1}} \sqrt{\sum (E_i)^2}$$

Obviously, as n increases the factor $1/\sqrt{(n-1)}$ decreases.

The rate of decrease is largest for small values of n, and for large values of n, increasing n is less effective. The curve of $1/\sqrt{n-1}$ as a function of n is sketched in figure B to indicate its general appearance. It is thus seen that it

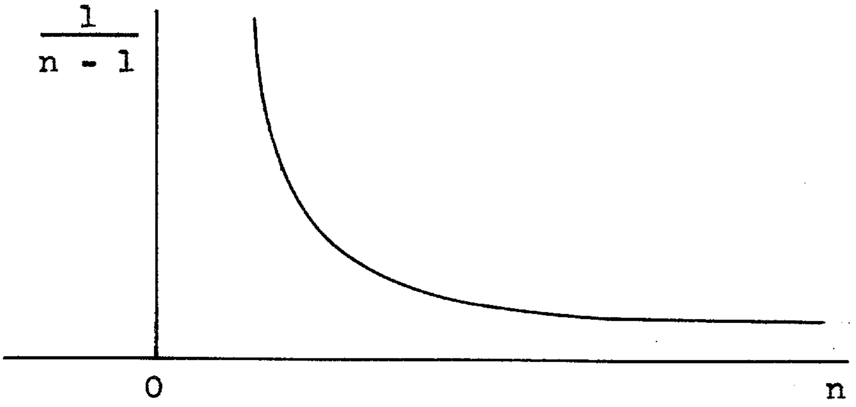



Figure B

is important to obtain as much information as possible for a study such as this.

Another factor which is important to the probable error is, of course, the choice of parameters. It is obvious that a proper choice of parameters will tend to lower the probable error, however, it is not necessary to reduce the error to zero by the choice of parameters. It will be shown that such a choice leaves no flexibility in the formula to account for design deviations. Such flexibility is necessary since it is apparent that no two wings will be built for the same weight by two different manufacturers, even if the wings are geometrically similar and are for similar aircraft. A certain amount of scatter is inherent in such designing and manufacturing processes, and such scatter is best accepted as design deviations.

It is evident that there are poor designs and good designs. Wherever poor designs are indicated, such information should be eliminated from the mean line and probable error calculations. One reason for this study is to assist in a fundamental manner the constant striving for better design. It is best, therefore, to know what weight a component should cost for good design, and then to insure that no more weight is built into that component by close control of the design from a weight standpoint. Thus, if certain components of a particular aircraft are known to be overweight or overstrength, such component weights should be eliminated from the trends. The estimating curves then will represent estimates of the weights to be expected for well designed components. It is evident that with the development of new high strength alloys lighter structures should result, so that the estimates should favor the negative probable error whenever 75ST or any other high strength duralumin alloys are used in the structure.

# PART II

## PRIMARY WEIGHT VARIATION

## PRIMARY WEIGHT VARIATION

This portion of the study is conducted to investigate the behavior of component or group weights with varying basic design gross weight. For some components the dependence upon gross weight alone is remarkably strong. For others there is a noticeable but insignificant relation between component weight and gross weight. A best straight line is passed through the data points in both cartesian and logarithmic coordinate plots, as discussed in Section I, and equations of these lines are derived. Deviations from these mean lines are calculated in each instance and the probable errors of estimate, based on the integral of Gauss' distribution curve, are computed for both the cartesian and logarithmic variations. The logarithmic plots are presented in pages 54 to 65. The probable errors of estimates based upon this primary study are listed below.

| | PROBABLE ERRORS % (Cart.) | (Log.) |
|---|---|---|
| 1. Wing | 9.0 | 8.4 |
| 2. Useful load | 12.9 | 10.3 |
| 3. Fixed equipment | 11.0 | 9.9 |
| 4. Combined fixed equipment and useful load | 10.6 | 8.8 |
| 5. Landing gear | 9.0 | 11.2 |
| 6. Engine and nacelle groups | 11.6 | 12.4 |
| 7. Fuselage | 16.2 | 15.5 |
| 8. Horizontal tail | 17.8 | 20.2 |
| 9. Vertical tail | 26.8 | 22.0 |
| 10. Flaps | 27.3 | 29.4 |
| 11. Ailerons | 28.24 | 28.0 |

Obviously, the flaps, ailerons, vertical and horizontal tail surfaces are not accurately estimated by the lone parameter gross weight. Such considerations as size, load to be carried, and arrangement are important factors for these as well as the other component weights. Wing, landing gear, fixed equipment, useful load, and combined useful load and fixed equipment evidently depend to a large measure upon gross weight. It is interesting to note that for the larger, heavier aircraft such as torpedo bombers, the increase in span necessitated by the high load carrying requirement is compensated for, to a certain extent, by a reduced maximum design load factor. This peculiarity helps to make the various aircraft line up much better with respect to wing weight than might be expected.

An interesting condition is found in considering total wing weight as a function of gross weight. Better results are obtained if the entire wing including landing flaps and ailerons is considered as a function of gross weight rather than considering each of these components separately. This is evident from the values in the table at the beginning of this section. For an original estimate then, it is better to consider the entire wing weight as a function of design gross weight.

It is important to explain why useful load, fixed equipment, and the combination of these items, are considered as functions of actual gross weight while all other components except landing gear weight, are considered with respect to design gross weight. Actual gross weight is, of course, the gross weight of the aircraft fully loaded ready for take off.

Design gross weight is usually somewhat less than actual since some fuel or portions of the pay load are considered expended for purposes of obtaining the value of design gross weight. Obviously, the relative reduction in pay load is considerably greater than that in gross weight, thus any aircraft having a lighter design gross weight than actual would appear to be inefficient from a pay load to gross weight ratio consideration. For reasonable comparison then it is best to use actual gross weight as an independent variable for these items.

One of the most valuable results of this basic study is the derivation of the equations for the mean lines for useful load, fixed equipment, and combined useful load and fixed equipment. If the inverse functions are determined, there will result six equations which may be used to estimate the gross weight of an aircraft proposed to carry a certain fixed equipment and useful load, Thus, if a proposed aircraft falls within the classification of this study, i.e., if it is a single engine trainer, fighter, attack, or dive, or torpedo bomber, and if the fixed equipment and useful load are known or estimated, the gross weight of the aircraft can be estimated once with each of the six formulas and the results may be averaged to yield the probable gross weight of the completed aircraft. This should prove to be of considerable value in aircraft weight estimating.

Another use is that increases in gross weight due to adding items of fixed equipment and useful load may be estimated in the early design stages. This is important when guaranteed weights are a part of the sale contract. It is apparent that, if the fixed equipment is increased 100 pounds, the increase in gross weight will be greater than 100 pounds. Exactly what difference exists between fixed equipment and gross weight increments has not previously been determined. These formulas presented here are an attempt to evaluate the difference in increments or the ratio of increments.

The curves and formulas for the mean lines will serve as an indication of what the relative magnitudes of the weight of each of the various components should be for any given gross weight. The use of such curves or formulas for weight estimating is not recommended in all instances, but their general use as a check upon original component weight estimates is suggested.

If performance data as well as dimensional and weight data are available, it should be possible to determine the effects of maximum range, and speed for maximum range, upon the ratios of the pay load items to gross weight. Again the complexity of the problem becomes evident. In this field of combined study the interactions of aircraft performance, weight and strength are so complex that a large amount of work is yet to be done before the surface of the problem is penetrated. The serious handicap is lack of sufficient performance, dimensional, and weight data. If the existing information of the various aircraft companies could be made available for study by experienced, competent men thoroughly trained in the principles of aerodynamics and structures and having associated experience in weight estimation, or being assisted by experienced weight estimators, it is believed that the problem could be solved to the extent that the various interdependencies of performance, weights, and structural integrity could be derived so that consistently accurate weight estimates could be made for any given performance and structural loading as dictated by the design specification.

# PART III

## *DEVELOPMENT OF*

## SATISFACTORY ESTIMATING FORMULAS

## DEVELOPMENT OF SATISFACTORY ESTIMATING FORMULAS

Each particular component is taken separately and the geometric and aerodynamic parameters which are considered to have some bearing upon its weight are studied in various possible combinations to observe the effects of these parameters upon aircraft weight. It is evident that if a component weight is plotted against some set of parameters, and a definite trend is indicated, the approximate effects of each of the members of the set can be deduced from observation. Subsequent treatment of the combination of parameters can yield reasonable estimating formulas. This procedure yields valuable positive as well as negative information with which reasonable estimating formulas can be developed. Here the study of the important heavy components is rather extensive and yields excellent results - - - probable errors of 6% to 10% - - - while that of the lighter and less important components is limited to a few attempts having reasonably good results - - - probable errors of 10% to 20%. The justification for this is clear. Ten per cent of wing weight may mean 200 pounds while twenty per cent of vertical tail weight may mean 30 pounds.

WING

Wing weight/area and weight/span are plotted versus span, area, gross weight, gross weight times load factor, gross weight times load factor and span, and gross weight times load factor and span divided by thickness as independent variables. The first two plots are done for information, the succeeding ones are actually useful enough so that straight line trends and probable errors of estimate are calculated. The results are:

| FORMULA | PROBABLE ERROR |
|---|---|
| $W_W/b = 5.60\ (Wn \times 10^{-4})^{.720} \times b$ | 11.1% |
| $W_W/b = 12.82\ (Wnb \times 10^{-6})^{.589} \times b$ | 9.4% |
| $W_W/b = 3.44\ (W \times \frac{b}{t} \times 10^{-3})^{.693} \times b$ | 14.06% |
| $W_W/b = 2.235\ (Wnb/t \times 10^{-4})^{.811} \times b$ (One overweight wing eliminated from trend.) | 11.05% (7.1%) |

The last equation can be considered to be very good since it is known that the single aircraft which must be eliminated to bring the probable error to 7.1% is inefficient in its wing design. It is seen that if two wings are being considered and they are to have similar external geometry but one has fifty feet span and the other fifty-five feet span, the ratio of the wing weights should be $(55/50)^{1.81}$ if the useful load is reduced enough to maintain a constant gross weight. If the useful load is to remain constant, the gross weight will increase by an increment

$$W = \frac{55}{50}^{1.811} \quad \frac{W + (55/50)^{1.811}\ W_W}{W}^{.811}$$

if all other components are kept the same size. Actually, the other components would tend to increase in some manner with $W_{new}/W_{old}$, and if the design is not fixed this should be taken into account. If the design has progressed to an appreciable extent, however, changes in loads of about 2% to 4% will not usually be reflected in increased structural weight. The important fact to be kept in mind is that the increase of the weight of one component which increases the gross weight of the aircraft has a tendency to cause slight increases in the weight of all other components. Obviously, a change in wing weight of 100 pounds in a 15,000 pound airplane will have a negligible effect upon the weight of the other components, since 100 pounds is only 0.67% of the gross weight.

## MAIN AND AUXILIARY LANDING GEAR

Since the main gear weight is estimated within nine or ten per cent by the single parameter landing gross weight, and since not enough landing gear structural and dimensional data are available, the two formulas for estimating main gear weight and the formulas for tail wheel and nose gear weight which were all based on landing gross weight are presented here for actual use:

Main Gear Weight $= .068\ W_L^{.994}$ PE = 11.2%

Main Gear Weight $= 58.3 + .059\ W_L$ PE = 9.03%

Nose Gear Weight $= .00234\ W^{1.208}$

Tail Wheel Weight $= .00091\ W^{1.208}$

ENGINE SECTION AND POWER PLANT

The engine section and power plant weight is not broken down into smaller components. It is found that, if engine weight, as installed, is taken as independent variable, the total engine section and power plant weight can be estimated by:

$$W_{E.P.} = 1.69\ (W_E)^{1.010} \qquad PE = 7.89\%$$

The data and the mean line are plotted in page . The low probable error is sufficiently close for all practical purposes.

It is not advisable to use engine horsepower as a parameter since various ways of rating the power plants introduce considerable inconsistencies. The "as installed" weight is a parameter which varies imperceptibly with changing rpm, manifold pressure, or compression ratio while each of these has considerable effect upon the rated horsepower.

FUSELAGE

Fuselage weight is extremely difficult to estimate since there are no clear-cut parameters which affect the weight directly. One of the most obvious parameters is gross weight since this implies not only fuselage weight but fuselage size. Obviously, fuselage structures having large cut-outs and definite discontinuities in structural members will have higher weight than those of smooth, continuous construction. In general, flat-sided or at least straight line element fuselages are lighter than those having curved structural members or doubly curved surfaces. It is apparent that length is important to weight since the bending moments become larger, the loads have to be taken over longer distances, and the covering material increases if geometric similarity is maintained. Width and depth are not obvious in their relation to weight since increasing the surface area and thereby the covering skin, may add weight without contributing substantially to strength; on the other hand the concentrated structural members become lighter as the width and depth are increased.

Fuselage weight/length and fuselage weight/(length/depth) are plotted versus gross weight in pages 74 and 75.

The results of fitting straight lines through the data are:

$$W_F = .127\ b\ (W)^{.55948} \qquad PE = 14.0\%\ (11.1\%)$$

$$W_F = 11.86 + 9.896\ \frac{W}{10000} \qquad PE = 15.56\%\ (12.68\%)$$

The lower percentages are obtained by eliminating one and two inefficient aircraft from the trends in computations for the first and second probable errors, respectively. It is evident that the probable error is slightly less than the figures in the parentheses since a new mean line would fit the data slightly better than the one calculated using the bad point.

HORIZONTAL AND VERTICAL TAIL SURFACE

The horizontal tail surface has a number of design conditions which make the estimate of its weight almost impossible if the estimates are to be based upon such variables as elevator setting, elevator load, and other factors. The complexity of the structure tends to increase the difficulties. Any estimates of tail surface weight which can be made a priori to within 15% must be considered good, anything in the neighborhood of 10% excellent. Here, as with the wing, the tail surface weight/span and weight/area are plotted versus span, area, tail load. The resulting formulas are considered sufficiently accurate for basic weight estimates.

The vertical tail surfaces are handled in much the same manner as the horizontal tail surfaces, since the problem of developing estimating formulas is of almost exactly the same nature.

Certain aircraft are excluded for obvious inefficiencies and the results of the study are:

| HORIZONTAL TAIL | PROBABLE ERROR |
|---|---|
| $W_h/b_h = .1466\ (b_h)^{1.506}$ | 17.0% (8.5%) |
| $W_h/b_h = .702\ (S_h)^{.654}$ | 25.2% (14.3%) |
| $W_h/b_h = .0455\ (TL_h)^{.591}$ | 15.8% (10.4%) |
| $W_h/S_h = .0768\ (TL_h)^{.385}$ | 14.3% (7.8%) |

| VERTICAL TAIL | |
|---|---|
| $W_v/S_v = .384\ (b_v)^{1.064}$ | 20.7% |
| $W_v/S_v = .1737\ (TL_v)^{.339}$ | 22.3% |
| $W_v/b_v = .403\ (S_v)^{1.021}$ | 19.8% |
| $W_v/b_v = .0635\ (TL_v)^{.664}$ | 19.9% |

The values in the parentheses indicate the errors when certain off-trend points are eliminated. The mean lines and the data are plotted in pages 76 to 83.

LANDING FLAPS AND AILERONS

The development of satisfactory estimating curves for the landing flaps and ailerons is hampered by a lack of detailed information. It is seen from pages and that by plotting aileron and flap weight/span and weight/area versus span and area no clear-cut trend is exhibited with respect to size and geometry parameters. The procedure of including ailerons and flaps with wing weight in making original estimates appears to be advisable. Thus, if gross weight is known the wing weight with and without flaps and ailerons can be estimated and the difference in weight can be considered to be the weight of flaps and ailerons combined.

More detailed data are required than were available for this study. A more detailed treatment of flaps and ailerons should yield satisfactory estimating formulas; for this study the actual weights involved are so small that they are obscured when attempting to handle the problem from a general macroscopic stand point. Since the purpose of this paper is to establish estimating formulas for use in basic design it was not worthwhile at this time to enter into the detailed study that would be required to develope estimating formulas for flaps and ailerons.

# PART IV

# PURELY STATISTICAL TREATMENT

## PURELY STATISTICAL TREATMENT

A purely statistical analysis of the available data could yield results such that the estimating curve would pass through each of the data points. This treatment, in effect, would supply an estimating curve which would pass directly through each point of available data. Thus, the deviations from the statistical mean line would each be zero; the summation of the deviations would be zero; and the probable error of estimate indicated by applying the integral of Gauss' distribution curve would obviously be zero. The parameters would be exact.

It is interesting here to point out that the scatter of the data is completely eliminated. This at first appears to be a most desirable consequence, however, the result is that the true and accurate effects of the chosen parameters are probably obscured by the scatter of the data; thus, the possibility of accurately determining the effects of the separate parameters in such a general study is rather remote. When the scatter is eliminated the effects of the parameters that are found are distorted by the analytical conditions which enforce the requirement that there be no scatter.

Such a peculiarity of the purely statistical treatment is easily demonstrated by considering a simple example. Let the original data be composed entirely of information from only six aircraft. The six chosen are D E G L M O from the complete data of the first part of the report. The most important parameters relative to wing weight are considered to be

| | | | |
|---|---|---|---|
| 1. | Design gross weight | W | W |
| 2. | Maximum normal load factor | n | |
| 3. | Wing span | b | feet |
| 4. | Wing area | S | $feet^2$ |
| 5. | Wing root thickness | $t_r$ | inches |
| 6. | Wing aspect ratio | AR | |
| 7. | Wing root chord | $C_r$ | inches |

The first five of these parameters are listed for the five aircraft to be considered

| | W (#) | n | b'(ft) | $S(ft^2)$ | t(in) |
|---|---|---|---|---|---|
| D | 3,400 | 12.00 | 27.50 | 100 | 10.725 |
| G | 5,280 | 8.50 | 42.00 | 254 | 13.500 |
| M | 7,372 | 13.50 | 41.50 | 325 | 18.600 |
| E | 12,700 | 12.00 | 40.78 | 300 | 17.900 |
| O | 24,000 | 6.38 | 70.33 | 609 | 21.400 |
| L | 14,798 | 6.10 | 54.17 | 490 | 22.000 |

It is possible to pass a power curve through the points or it is possible to pass a straight line through the points on log paper if the parameters are properly combined. Here it is considered that the logarithmic procedure is more advisable since there is no breakdown into component parts, and products of parameters indicating relative effects will be more useful than sums of separate elements.

The procedure consists of setting up a sufficient number of simultaneous equations to account for the number of data points. The number of parameters considered must be equal to the number of data points. These simultaneous equations are in terms of the logarithms of the parameters. The total set is

$$A \log W_i + B \log b_i + C \log S_i + D \log n_i + E \log T_i + F_i = \log W_{W_i}$$

where

$i = 1, 2, 3, \ldots . M$

A, B, C, D, E, F are constants to be determined

$W_W$ = wing weight in pounds

The six equations are solved by the use of matrix methods in Appendix I. The solution of the equations for A B C D E F gives

$A = 1.039015$

$B = -.257488$

$C = .043659$

$D = -.168050$

$E = .152192$

$F = -.72748 = \log k$

Thus, the expression for wing weight is

$$W_W = K\, W^A\, b^B\, S^C\, n^D\, t^E$$

$$= .1873 \frac{W^{1.039}\, S^{.044}\, t^{.152}}{b^{.257}\, n^{.168}}$$

Such an estimating formula will fit the data exactly. In fact, the remaining aircraft wing weights are estimated by the formula and the probable error of estimate is only 8.6%. This appears to be quite good, yet if such an equation were submitted to a practicing design engineer to be used as an estimating curve, he would be alarmed by the fact that as the span of a wing increases while the area, gross weight, load factor, and thickness are held constant the wing weight decreases. Obviously this is not true even though it is indicated by the estimating formula. Apparently, the formula holds only for aspect ratios in the neighborhood of 6. This conclusion suggests that another aircraft be added to the study, that the parameter aspect ratio be substituted for span, and that root chord in inches be included with the other parameters. This is done in the appendix and the solution of the new set of seven equation gives

$$A = .97846$$

$$B = -.23480$$

$$C = -.02596$$

$$D = -.20395$$

$$E = .42753$$

$$F = -.33928$$

$$G = -.16364$$

The resulting estimating formula is

$$Ww = .686 \frac{W^{.978}\ t_r^{.428}}{AR^{.235}\ S^{.026}\ n^{.204}\ C_r^{.339}}$$

The calculated probable error to be expected when using this formula for estimating wing weight is PE = 8.7%.

Again, finding thickness in the numerator and aspect ratio, load factor and area in the denominator throws suspicion upon the validity of this formula. The same argument can be stated for this equation as that stated for the previously derived formula for five parameters.

While these formulas might, at first, appear to be useless, such a conclusion is not completely justified. Each of the separate parameters implies some quantity other than its own particular value. Consider, for example, gross weight in its effects upon wing weight: gross weight implies a certain value of the span in order to meet certain range requirements, it also implies a certain value of the wing area since the landing speed requirement must be satisfied. While span and area do not, in general, imply thickness, present aircraft having 15% to 18% thickness ratio wing airfoils fairly well establish a range of possible thickness associated with span and area and, in turn, gross weight. It is seen then that there is some validity to the two above estimating formulas. The only stipulation is that the proposed wing to be estimated be similar to the others in the study; that is, there should be average taper ratio, thickness ratio, aspect ratio rather than extreme values of these dimensionless geometric parameters.

# PART V

# CONCLUSION AND RECOMMENDATIONS

## CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that useful aircraft weight estimating formulas can be developed using probability theory and careful analyses of the component weights of existing aircraft. In general, the probable errors of the estimating formulas proposed here are appreciably better than any currently in general use for aircraft of the classes treated herein. It is felt that the primary goal established at the start of the study - - - the development of estimating formulas for use in preliminary design - - - has been attained. The secondary goal - - - the development of accurate detailed weight estimating formulas - - - has been attained only in part. There is still much work to be done in this field.

Since lack of information is a limiting factor on the breadth of these studies it is suggested that further work be done with more information which can only come from the aircraft manufacturers or the military and naval air forces. Only with the fullest cooperation can accurate solutions to the problem be derived.

It is not necessary to exaggerate the value of such solutions of the problem to practicing design engineers as well as the organizations they serve. If the solutions were put in such a form that they were readily usable, many "design compromises" could be made in a matter of minutes with consistent accuracy, rather than in days with doubtful validity.

## SUMMARY OF ESTIMATING FORMULAS AND PROBABLE ERRORS

| COMPONENT | | |
|---|---|---|
| Wing (without flaps or ailerons) | $W_W = .1472\ W - 65.4$ | 9.03 |
| | $W_W = 0.062\ W^{1.052}$ | 8.40 |
| | $W_W = 5.60\ b(Wn x 10^{-4})^{.720}$ | 11.1 |
| | $W_W = 12.82\ b(Wnb x 10^{-6})^{.589}$ | 9.4 |
| | $W_W = 2.235\ b(\frac{Wnb}{t} x 10^{-4})^{.811}$ | 11.05 |
| Wing (including flaps and ailerons) | $W_W = 0.0899\ W^{1.058}$ | 8.57 |
| Useful Load | $U.L. = -278 + 0.287\ W$ | 12.9 |
| | $U.L. = .0723\ W^{1.136}$ | 10.3 |
| Useful Load (Fighters only) | $U.L._{F.} = 9.45 + 0.231\ W$ | 7.02 |
| | $U.L._{F.} = .036\ W^{1.206}$ | 7.92 |
| Fixed Equipment | $F.E. = 57.5 + 0.100\ W$ | 11.03 |
| | $F.E. = 0.455\ W^{.842}$ | 9.96 |
| Fixed Equipment plus Useful Load | $F.E. + U.L. = -194 + 0.385\ W$ | 10.6 |
| | $F.E. + U.L. = 0.233\ W^{1.047}$ | 8.75 |
| Fixed Equipment plus Useful Load (Efficient aircraft only) | $F.E. + U.L. = 0.210\ W^{1.065}$ | 6.33 |
| Main Landing Gear | $W_{MG} = 58.3 + .059\ W$ | 9.03 |
| | $W_{MG} = .068\ W^{.994}$ | 11.2 |
| Nose Gear | $W_{NG} = 2.35 \times 10^{-3}\ W^{1.208}$ | -- |
| Tail Wheel | $W_{TW} = 9.15 \times 10^{-4}\ W^{1.208}$ | -- |

## SUMMARY OF ESTIMATING FORMULAS AND PROBABLE ERRORS (Cont.)

| COMPONENT | | |
|---|---|---|
| Engine and Nacelle | $W_{E\&N} = 587 + 0.268\ W$ | 11.58 |
| | $W_{E\&N} = 0.747\ W^{.910}$ | 12.4 |
| | $W_{E\&N} = 1.69\ W_E^{1.01}$ | 7.89 |
| Fuselage | $W_f = 186 + .057\ W$ | 16.2 |
| | $W_f = 0.241\ W^{.874}$ | 15.5 |
| | $W_f = (12 + 9.90\ W \times 10^{-4})\ L_f$ | 15.6 |
| Horizontal Tail | $W_h = -69 + .0249\ W$ | 17.8 |
| | $W_h = .00323\ W^{1.179}$ | 20.2 |
| | $W_h = 0.147\ b_h^{2.51}$ | 17.1 |
| | $W_h = 0.702\ S_h^{.654}\ b_h$ | 25.2 |
| | $W_h = .0455\ TL^{.591}\ b_h$ | 15.8 |
| | $W_h = 2.69(TL_h\ b_h \times 10^{-4})^{.487}\ b_h$ | 13.1 |
| Vertical Tail | $W_v = 0.871\ b_v^{2.47}$ | 29.3 |
| | $W_v = 0.403\ S_v^{1.02}\ b_v$ | 19.9 |
| | $W_v = .0635\ TL_v^{.664}\ b_v$ | 19.9 |
| | $W_v = 2.38\ (TL_v\ b_v \times 10^{-3})^{.586}$ | 16.5 |

NOTE: Weights and tail loads are in pounds; spans, lengths, and areas are in feet; thicknesses are in inches.

Figures 1 to 9

CURRENT ESTIMATING CURVES

COMPARED WITH

ACTUAL COMPONENT WEIGHTS

HORIZONTAL STABILIZER WEIGHT/AREA

vs.

HORIZONTAL STABILIZER AREA

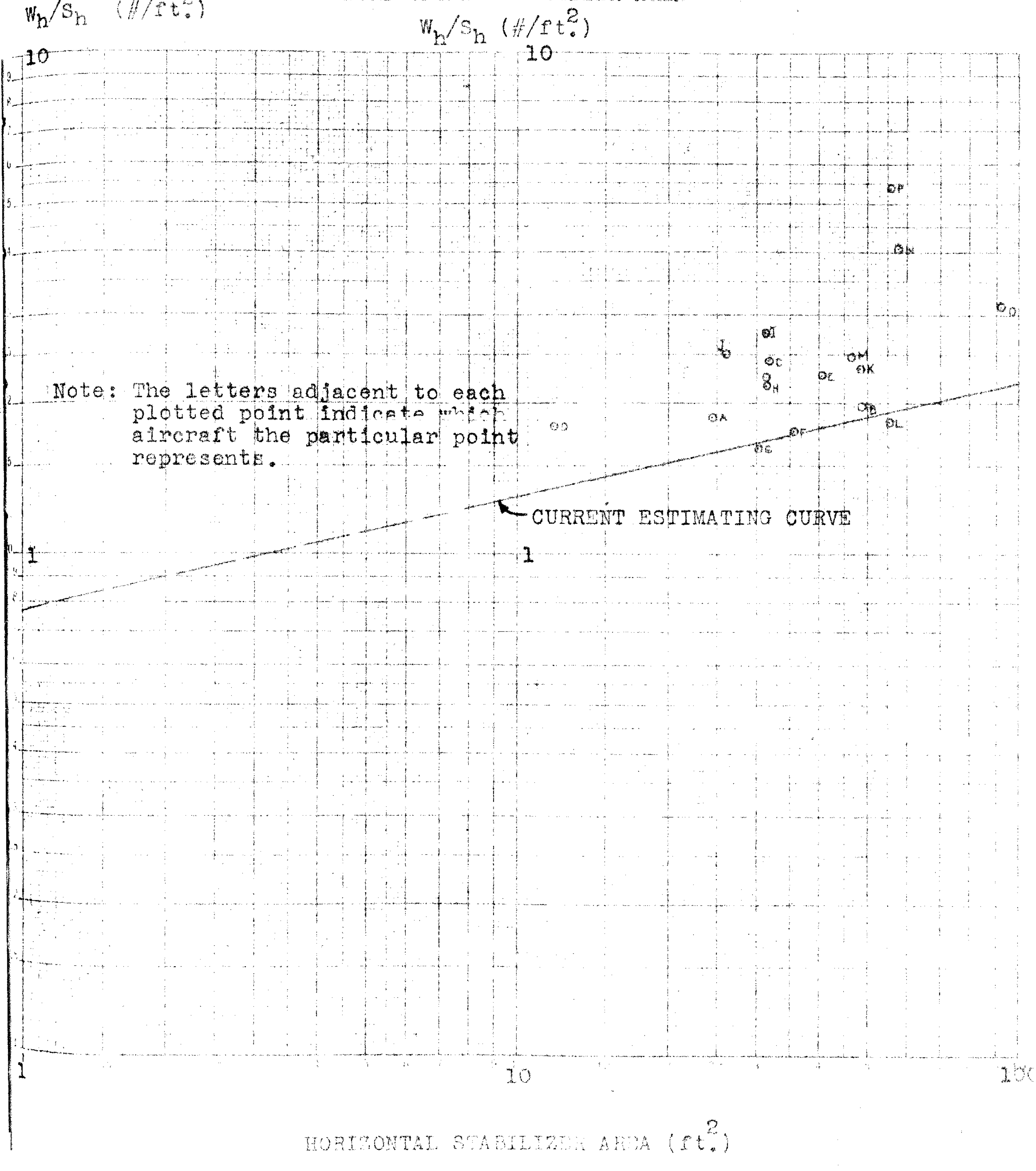



Figure 1

HORIZONTAL STABILIZER WT./AREA

vs.

HORIZONTAL STABILIZER AREA

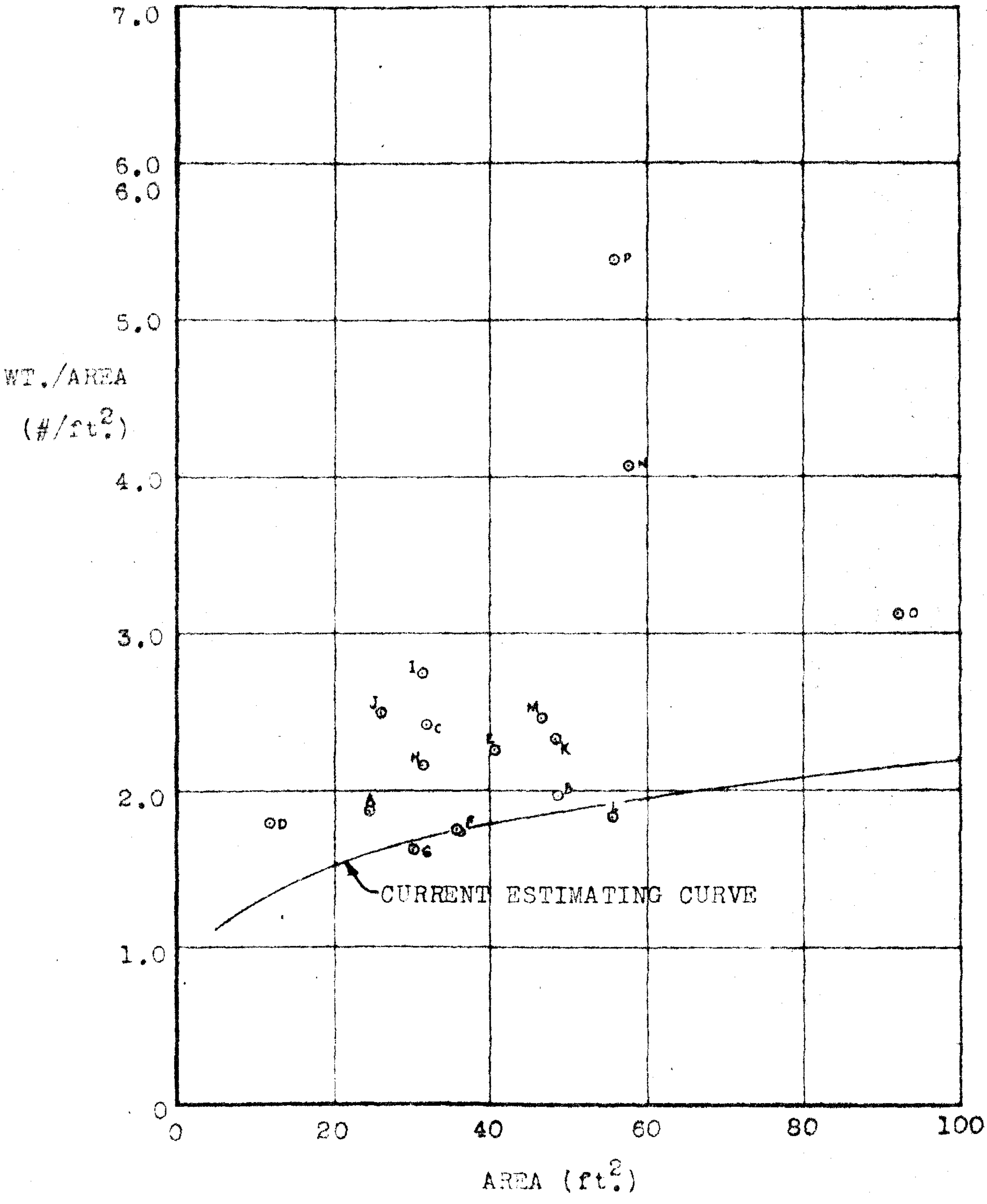



Figure 2

ELEVATOR WEIGHT/AREA

vs.

ELEVATOR AREA

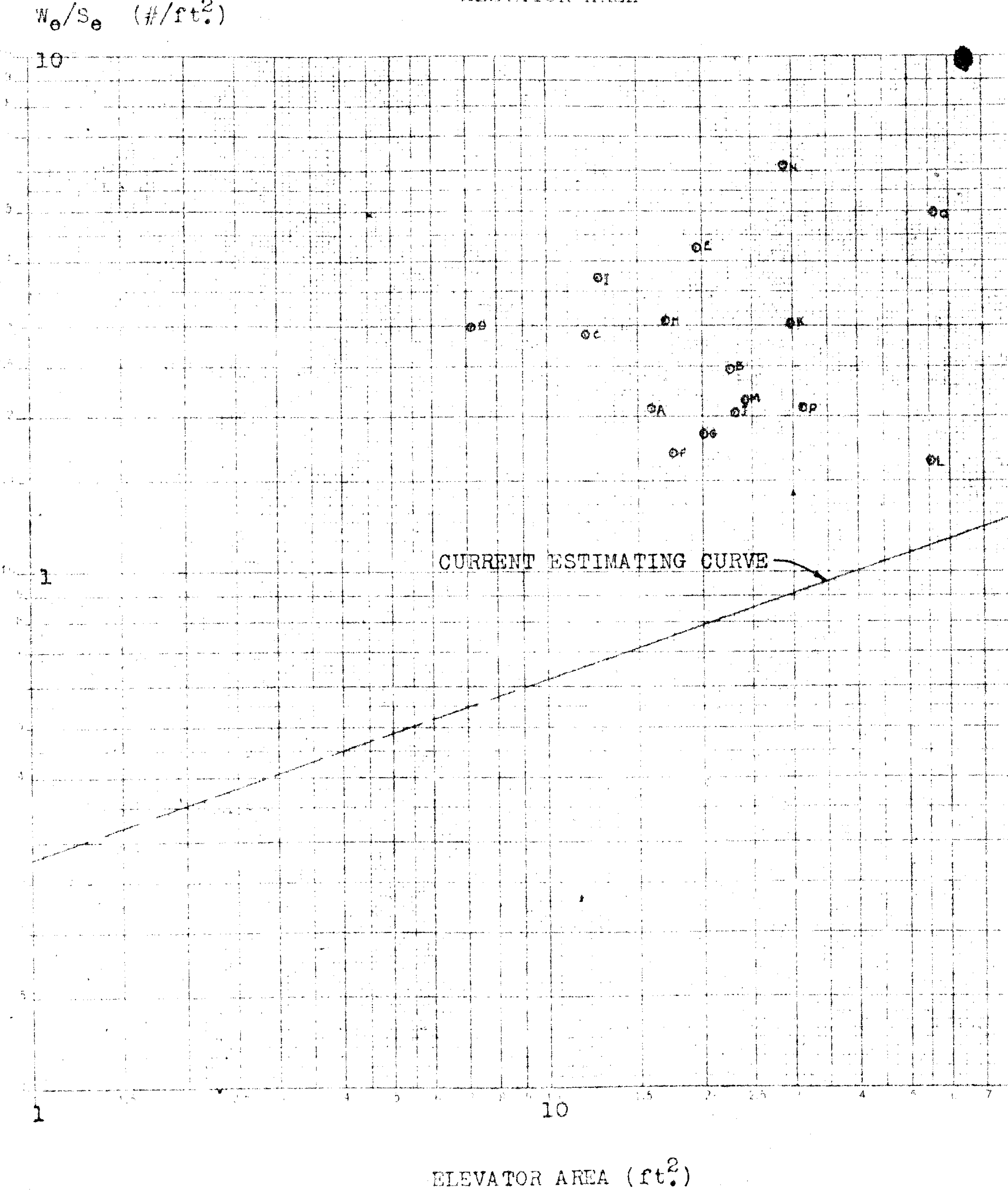



Figure 3

ELEVATOR WT./AREA

vs

ELEVATOR AREA

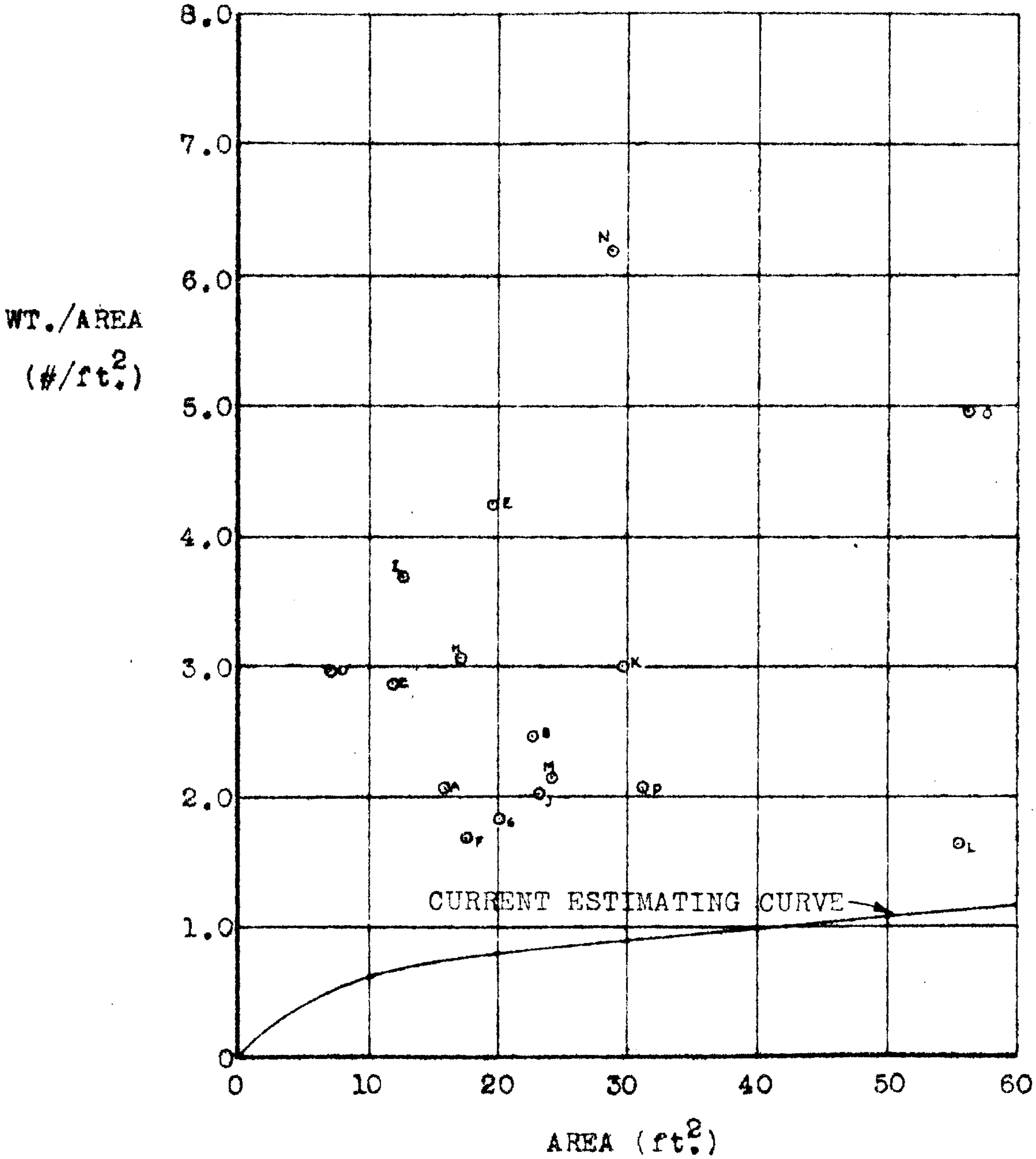



Figure 4

VERTICAL FIN WEIGHT/AREA

vs.

VERTICAL FIN AREA

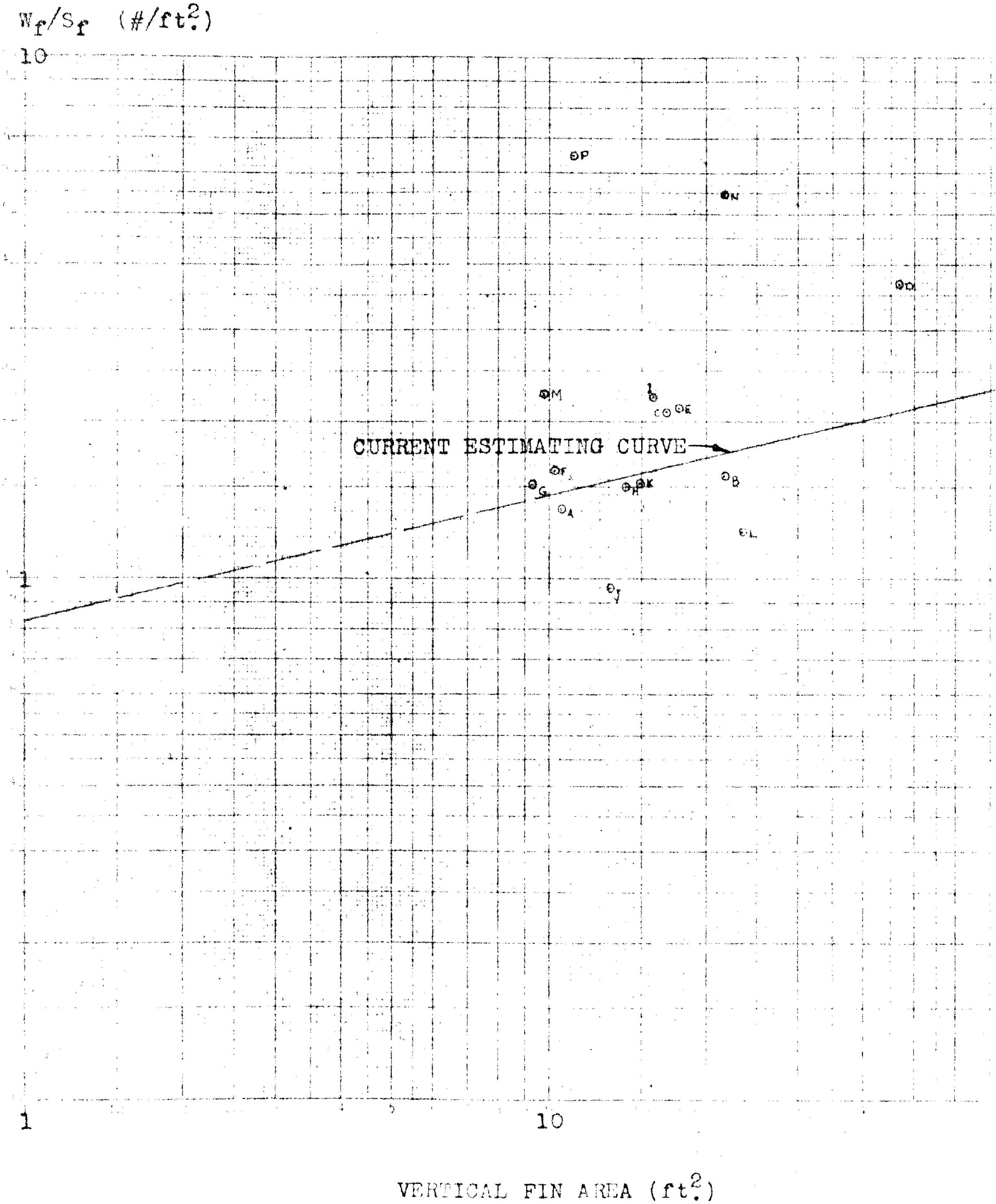



Figure 5

VERTICAL FIN WT./AREA

vs.

VERTICAL FIN AREA

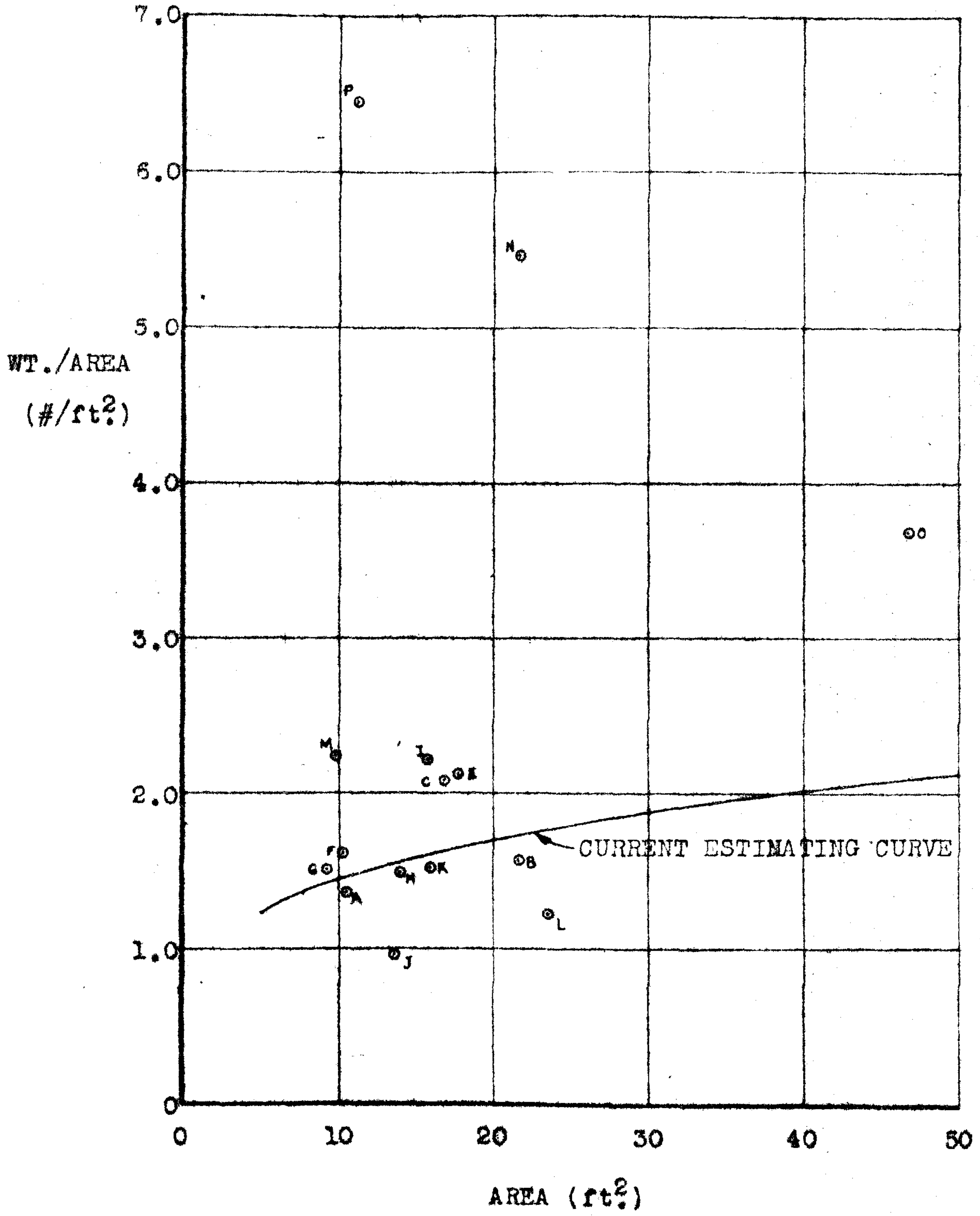



Figure 6

RUDDER WEIGHT/AREA

VS.

RUDDER AREA

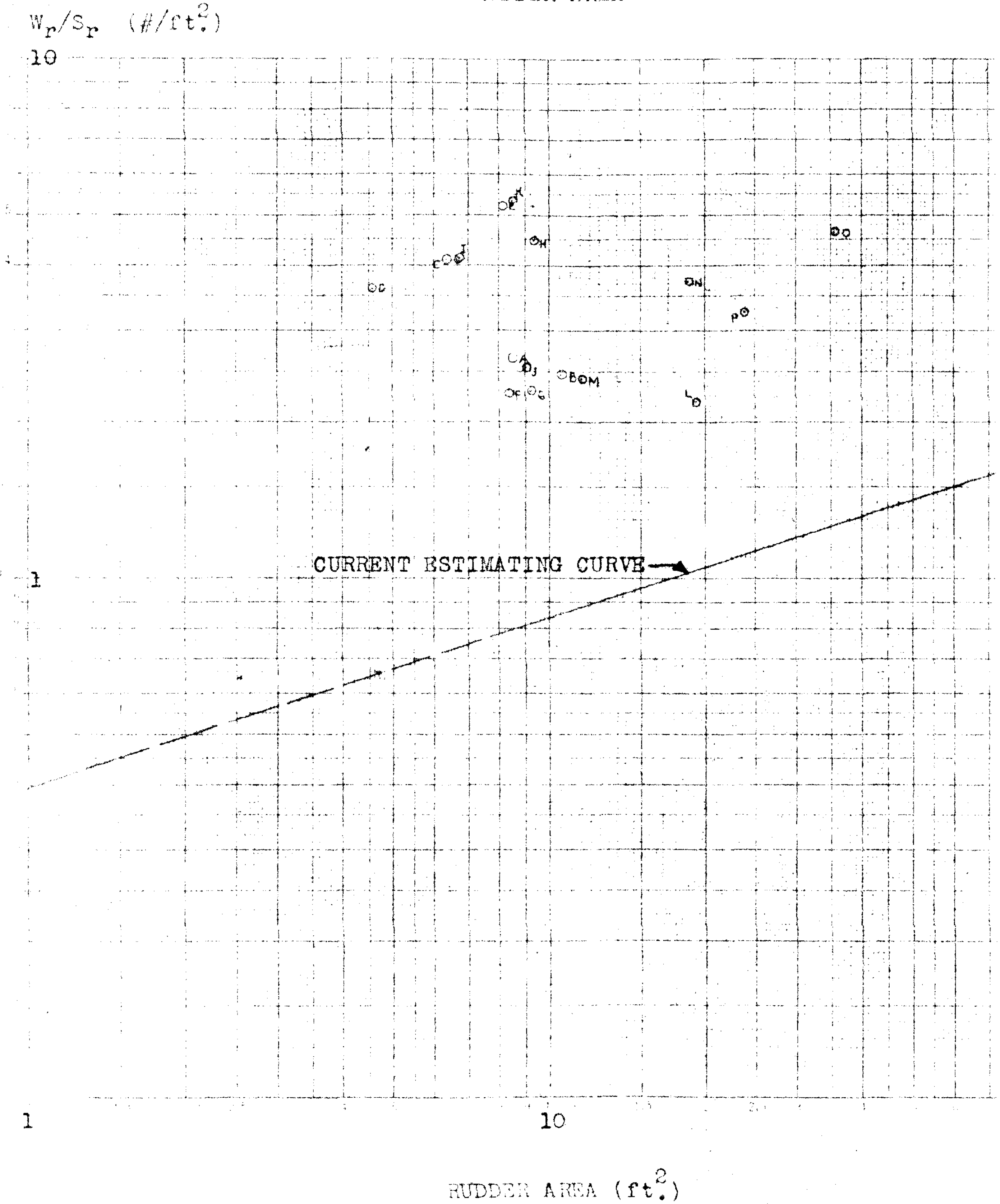



Figure 7

RUDDER WT./AREA

vs.

RUDDER AREA

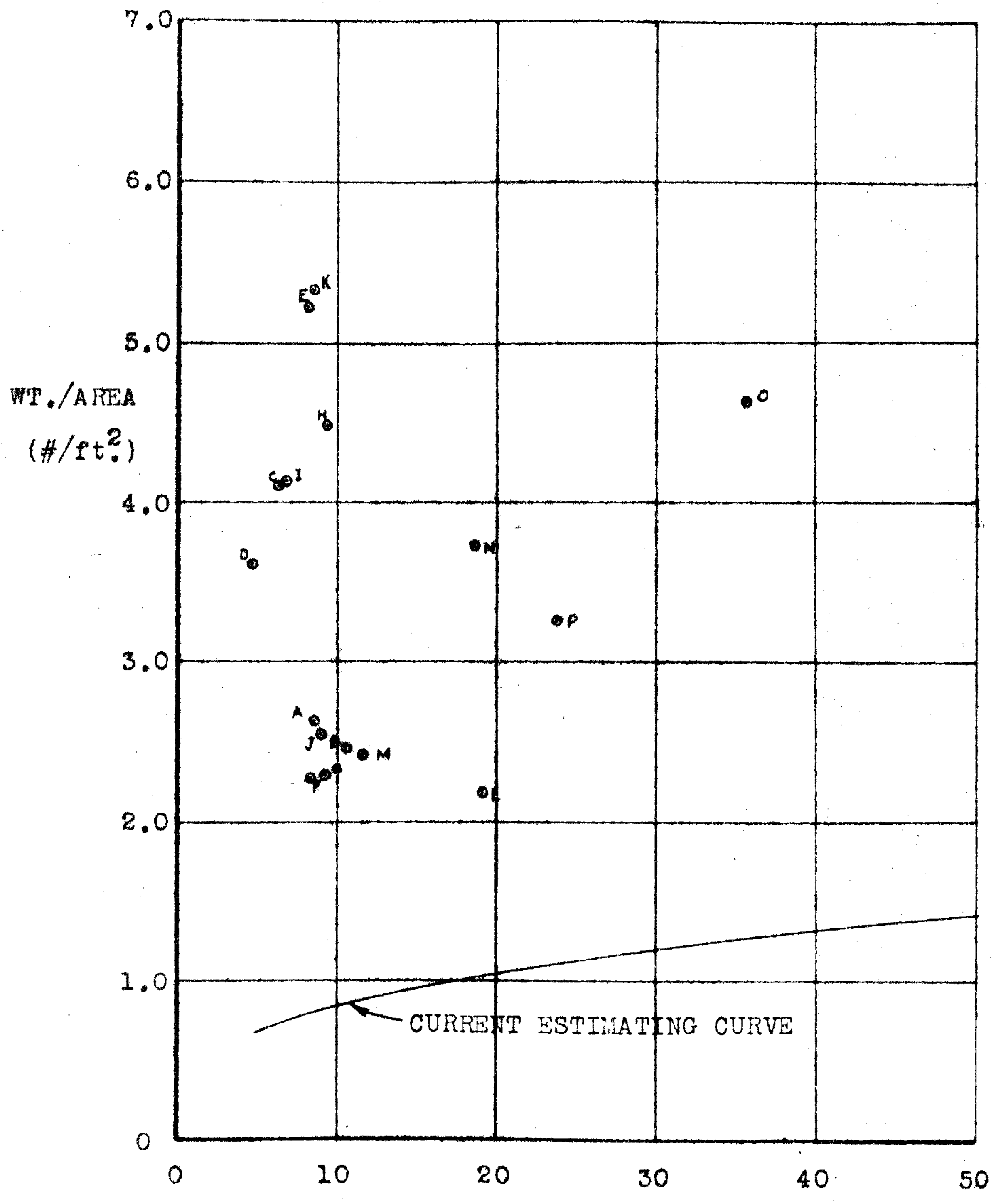



Figure 8

WING WEIGHT/(LOAD FACTOR x GROSS WEIGHT)

vs.

WING SPAN

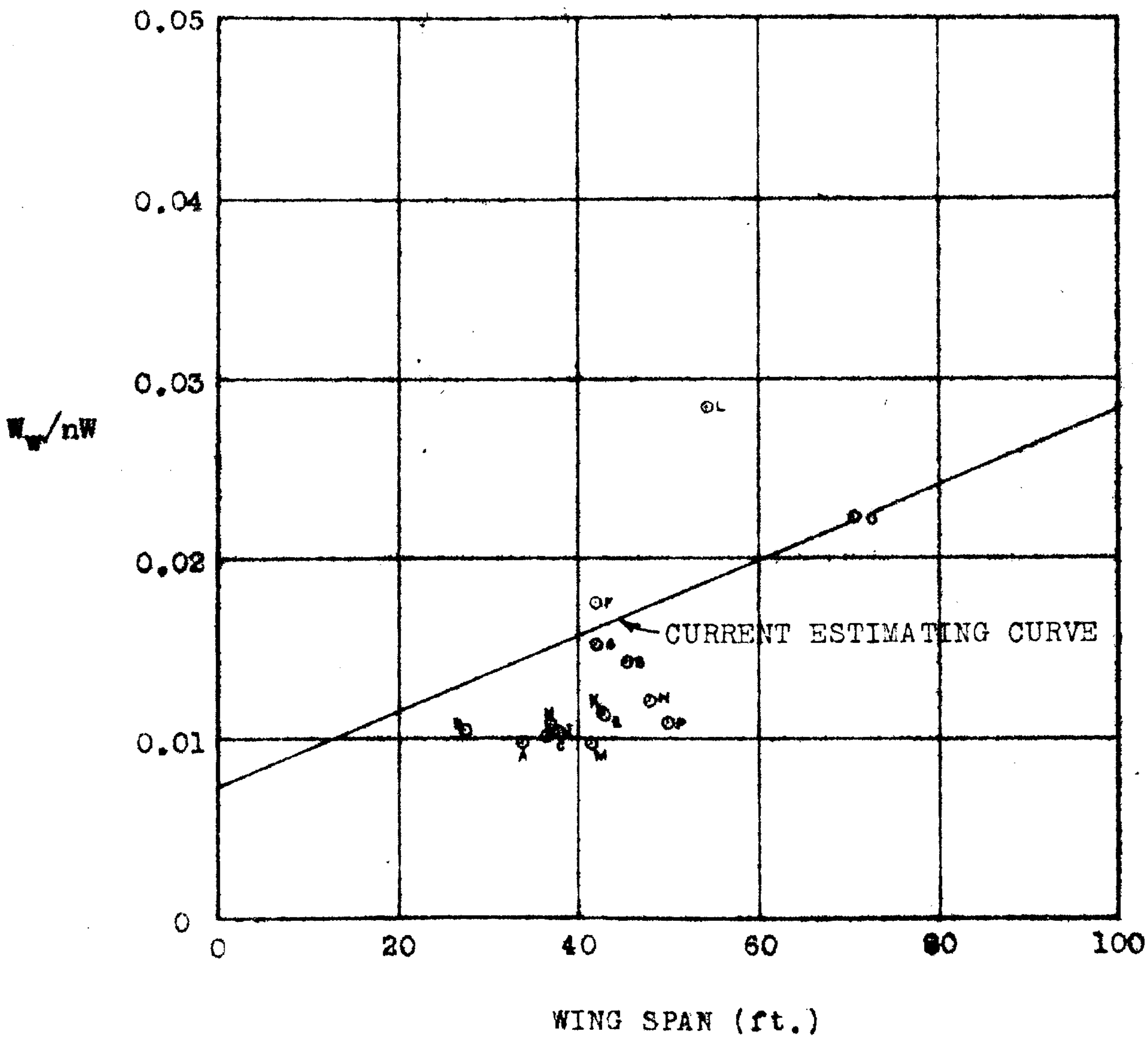



Figure 9

**Figures 10 to 21**

PRIMARY WEIGHT VARIATION

WING WEIGHT

vs.

DESIGN GROSS WEIGHT

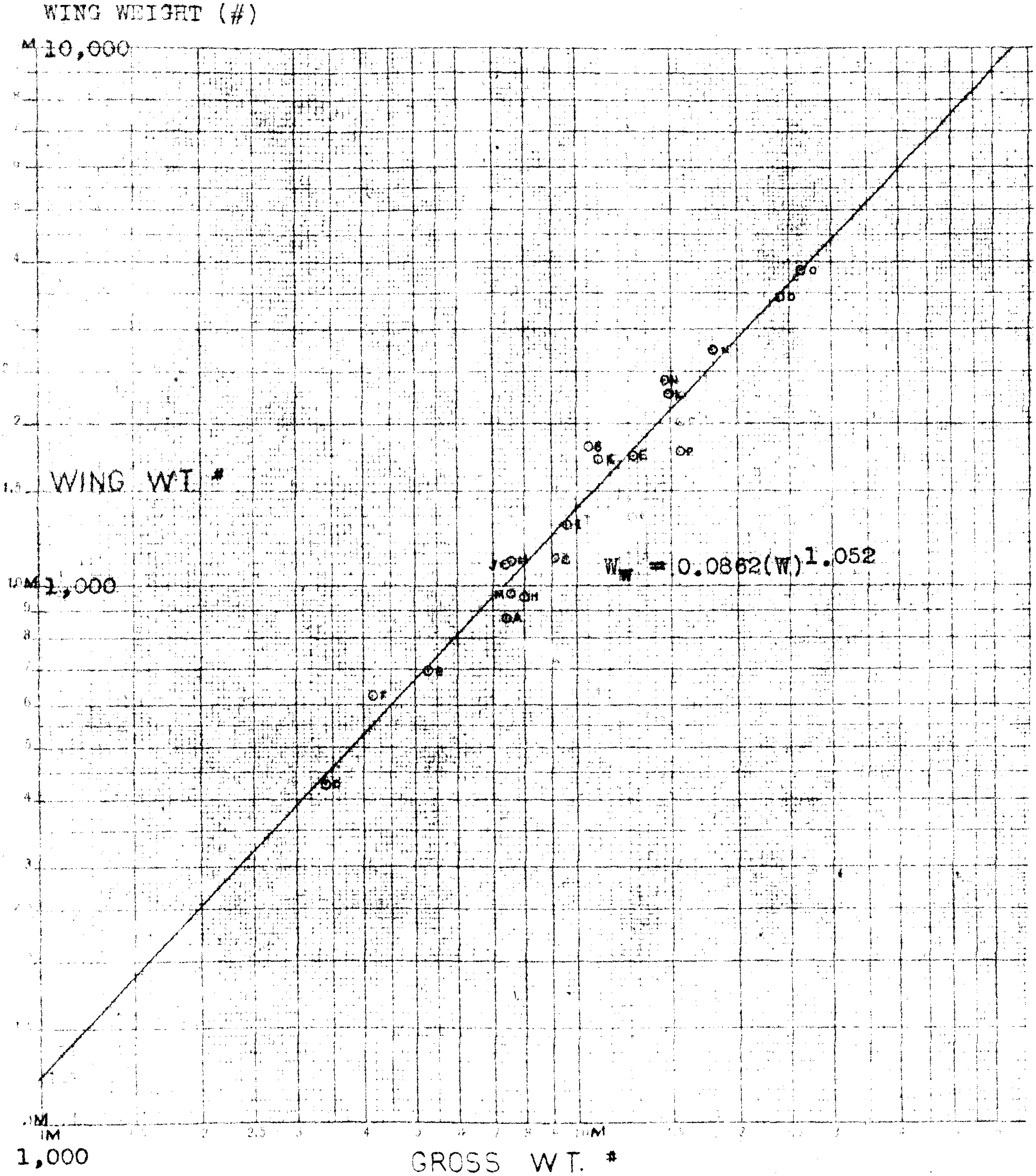
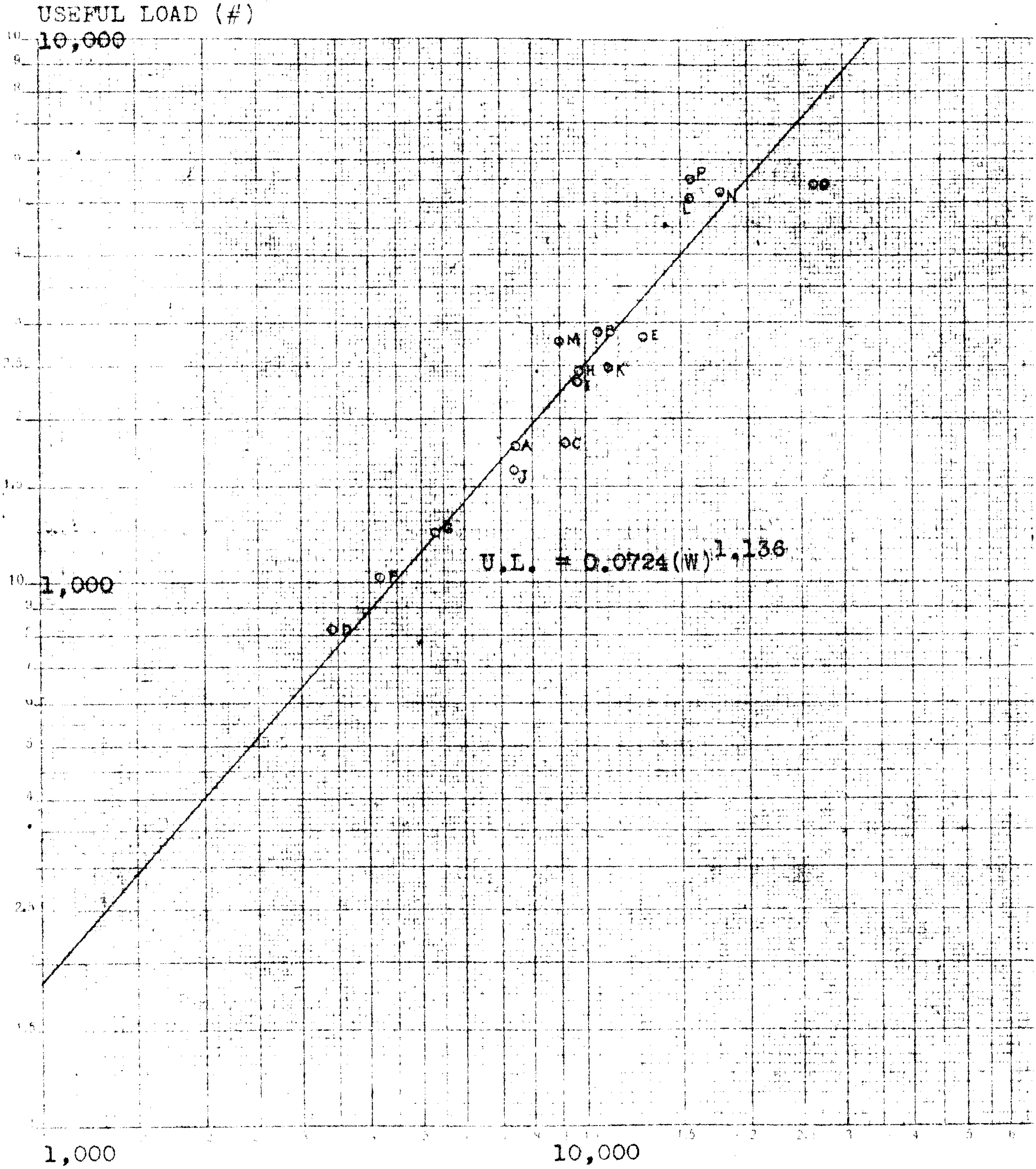



Figure 10

USEFUL LOAD

vs.

ACTUAL GROSS WEIGHT




Note: Fighters Only-- U.L. = $0.0364(W)^{1.207}$

Figure 11

FIXED EQUIPMENT

vs.

ACTUAL GROSS WEIGHT

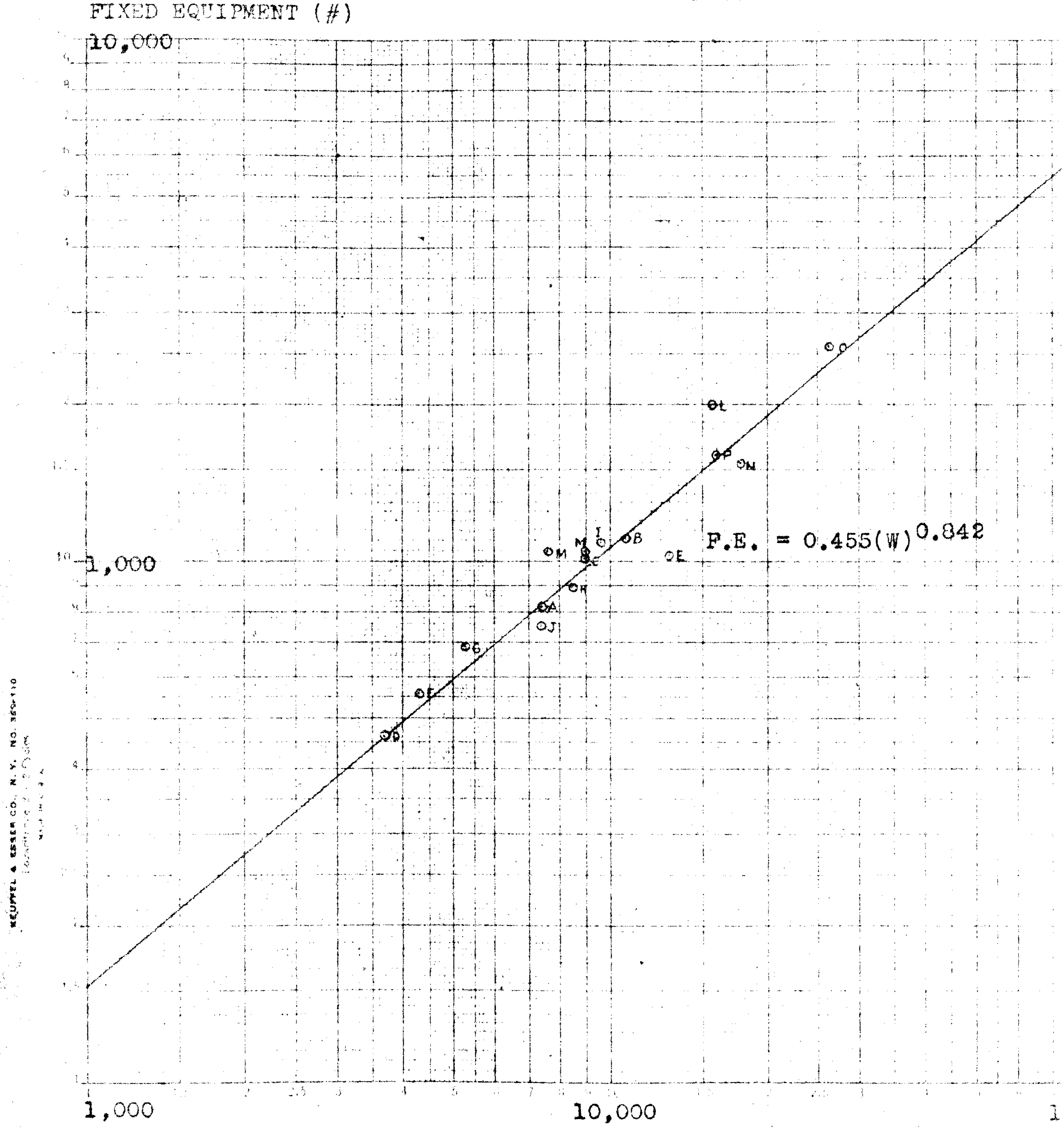
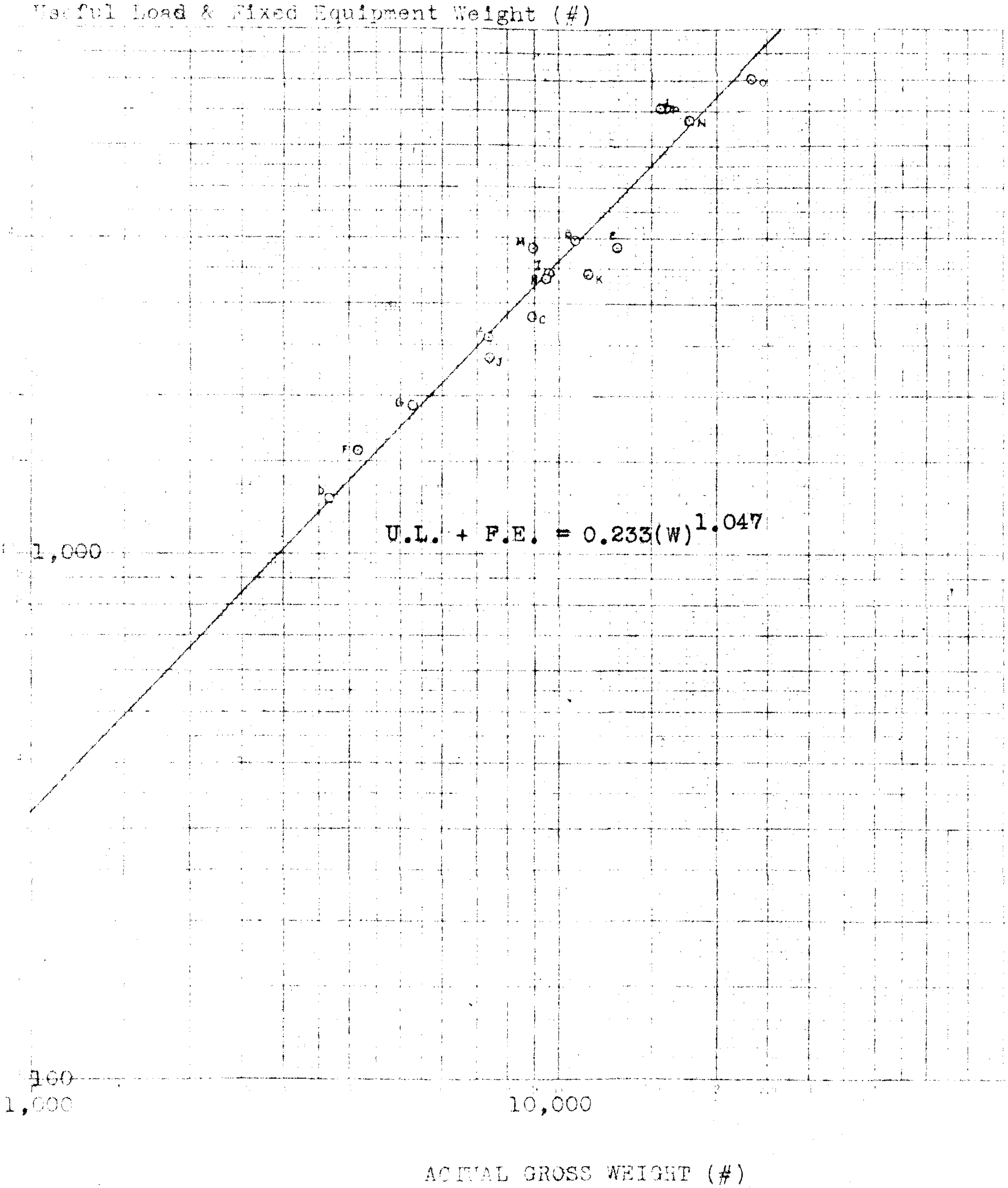



Figure 12

USEFUL LOAD AND FIXED EQUIPMENT WEIGHT
vs.
ACTUAL GROSS WEIGHT




Note: Efficient Aircraft Only---U.L.+F.E. = $0.210(W)^{1.065}$

Figure 13

LANDING GEAR WEIGHT vs. LANDING GROSS WEIGHT

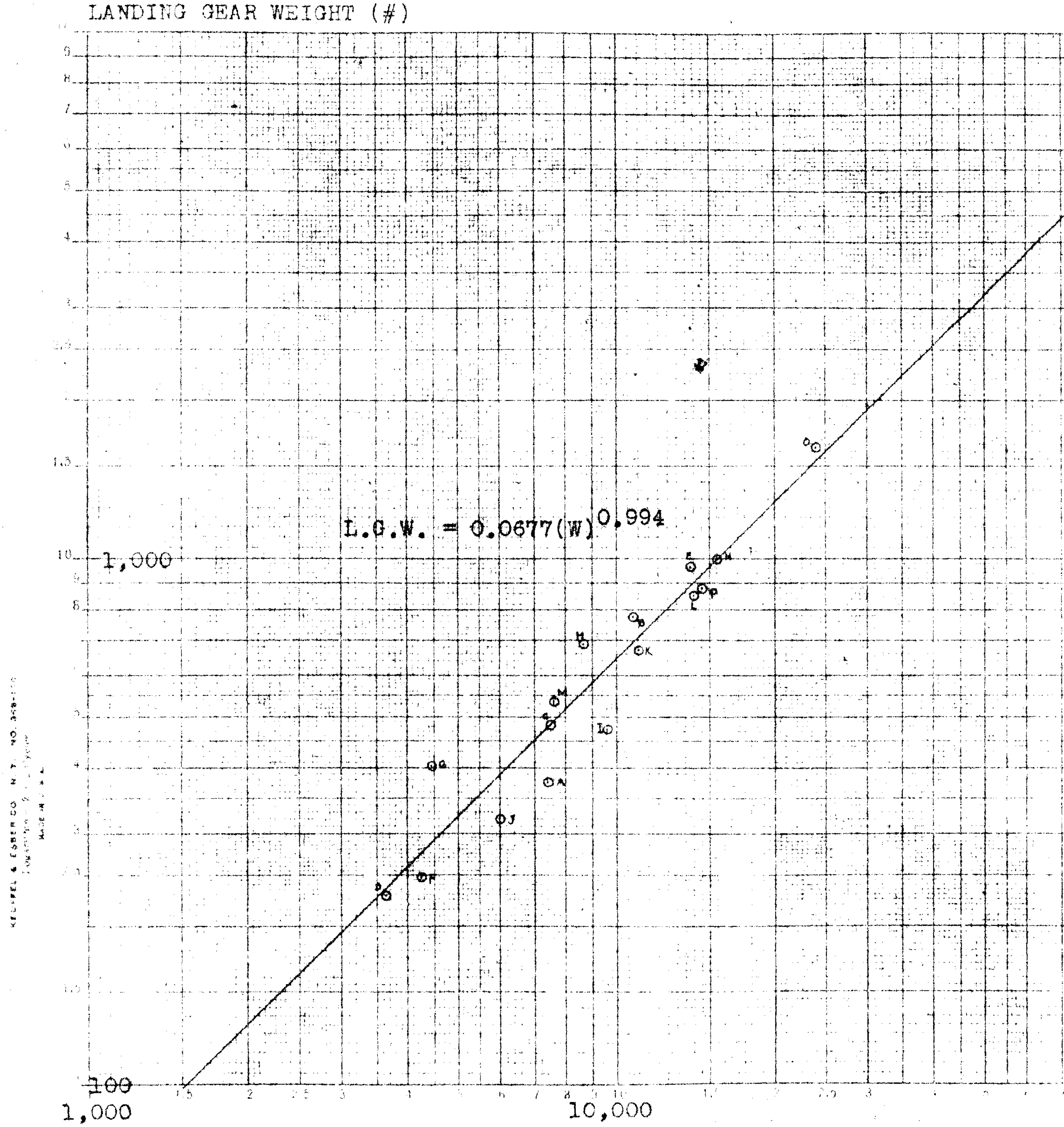



**Figure 14**

NOSE LANDING GEAR OR TAIL WHEEL WEIGHT

vs.

LANDING GROSS WEIGHT

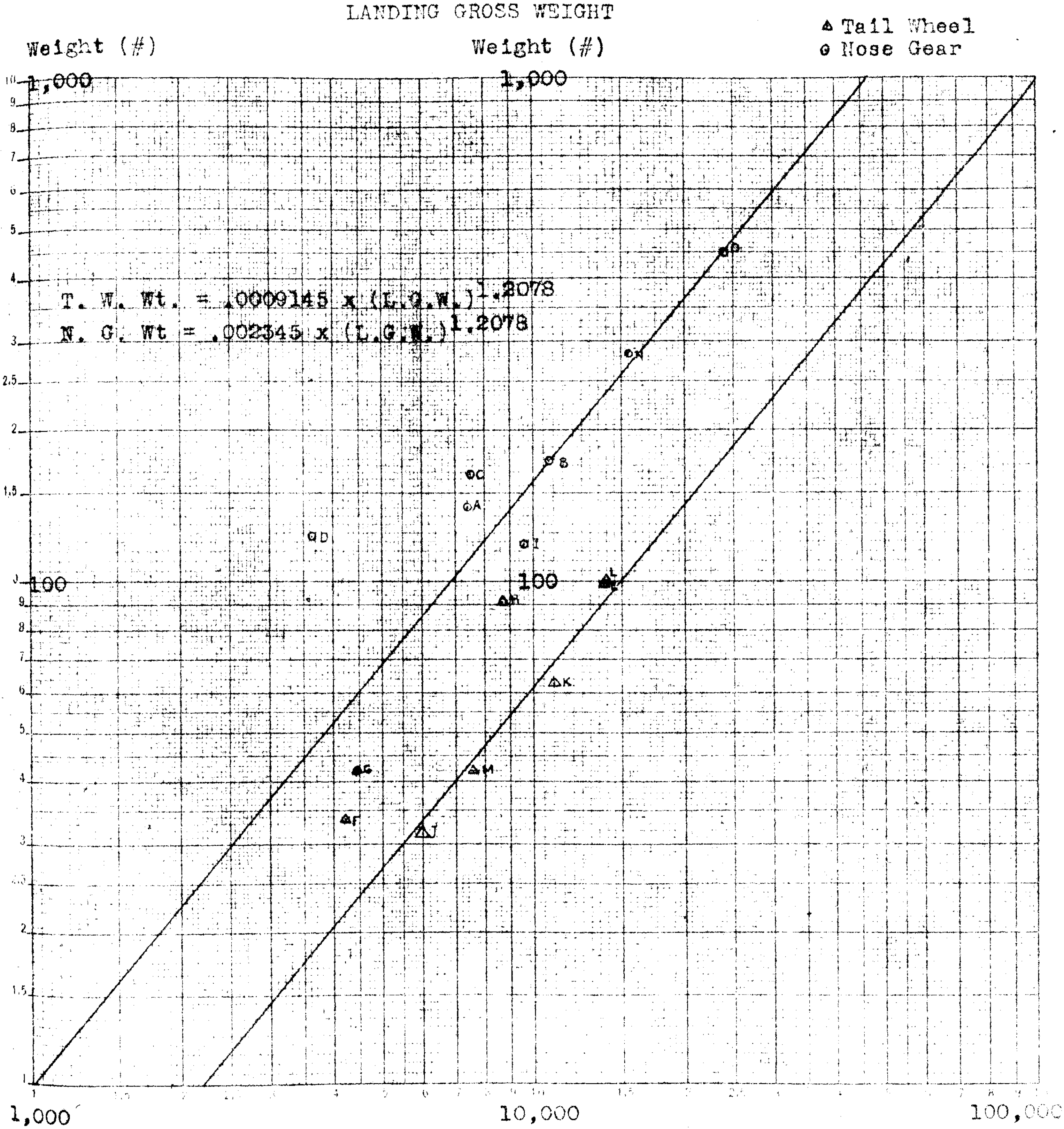



Figure 15

TOTAL ENGINE AND NACELLE GROUP WEIGHT

vs.

DESIGN GROSS WEIGHT

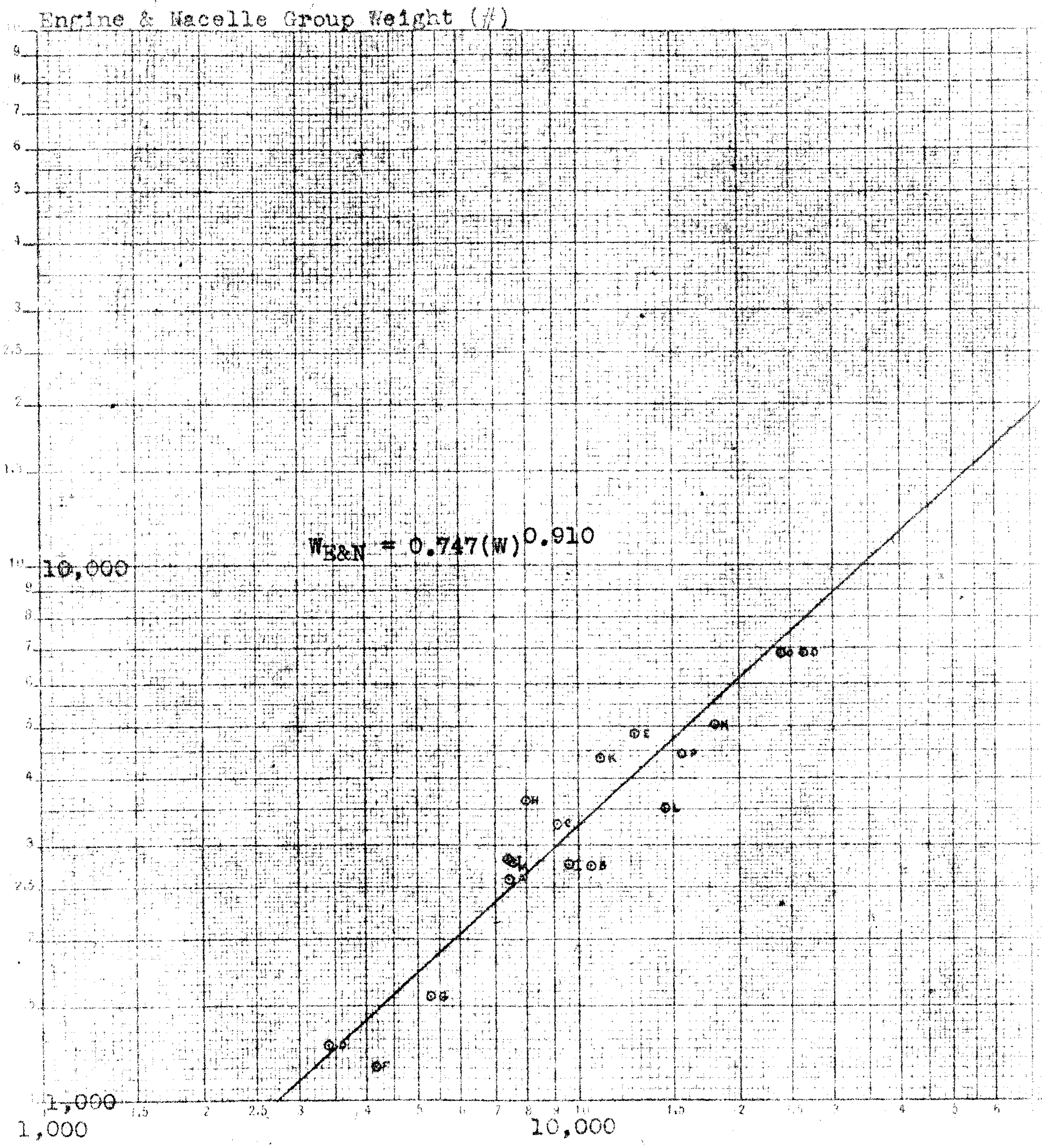



Figure 16

FUSELAGE WEIGHT

vs.

DESIGN GROSS WEIGHT

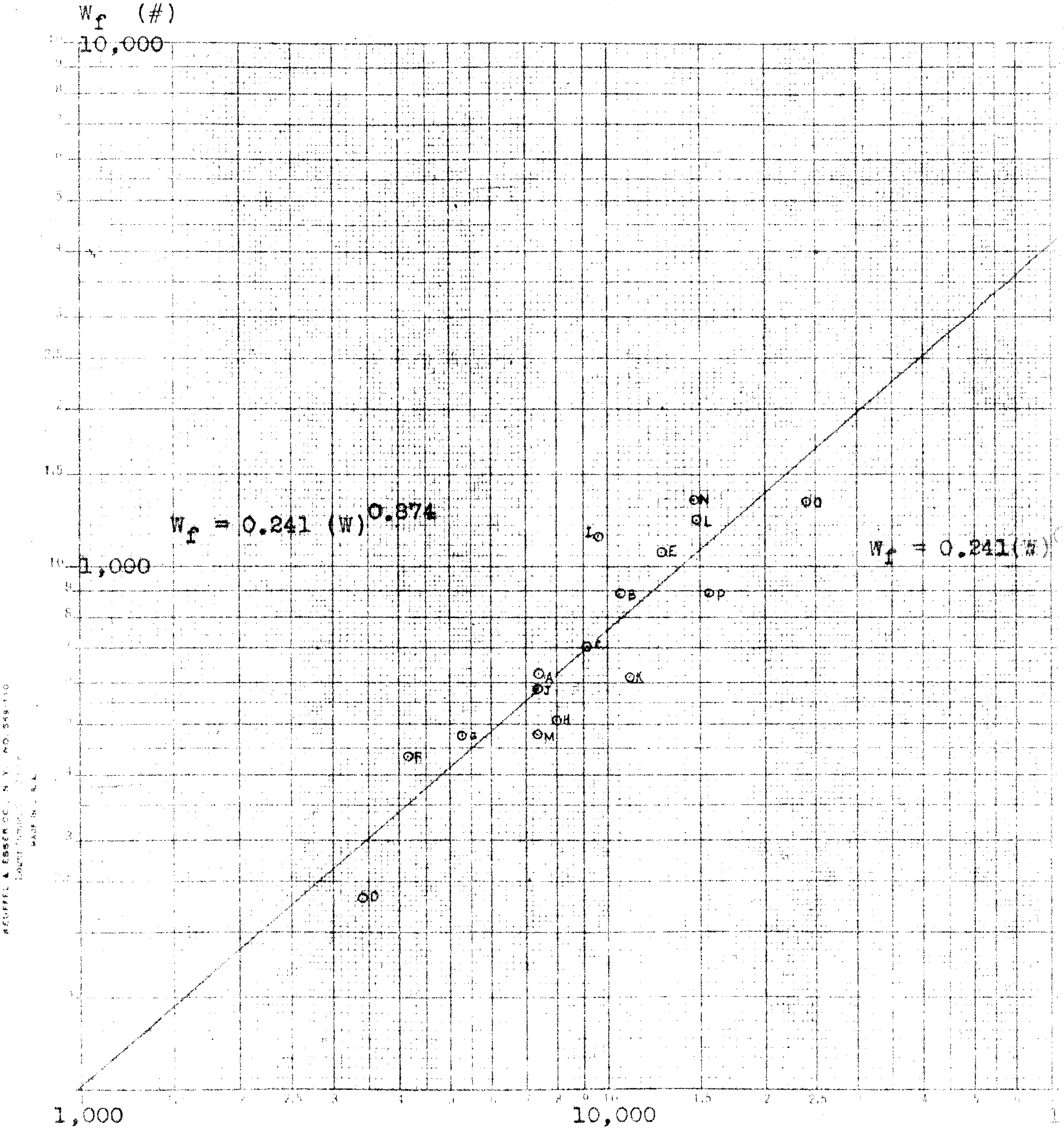



**Figure 17**

HORIZONTAL STABILIZER AND ELEVATOR WEIGHT

vs.

DESIGN GROSS WEIGHT

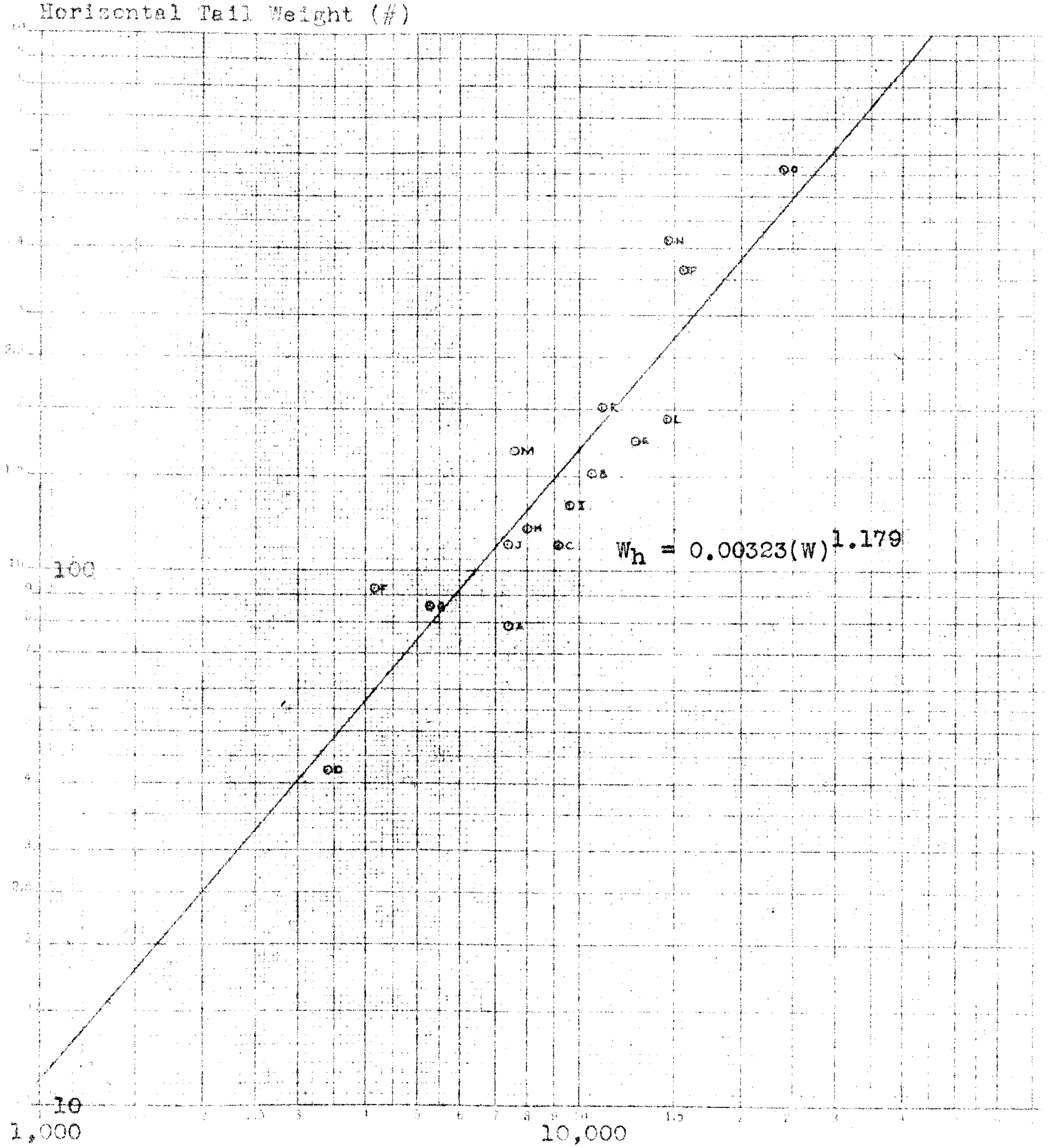



**Figure 18**

FIN AND RUDDER WEIGHT vs. DESIGN GROSS WEIGHT

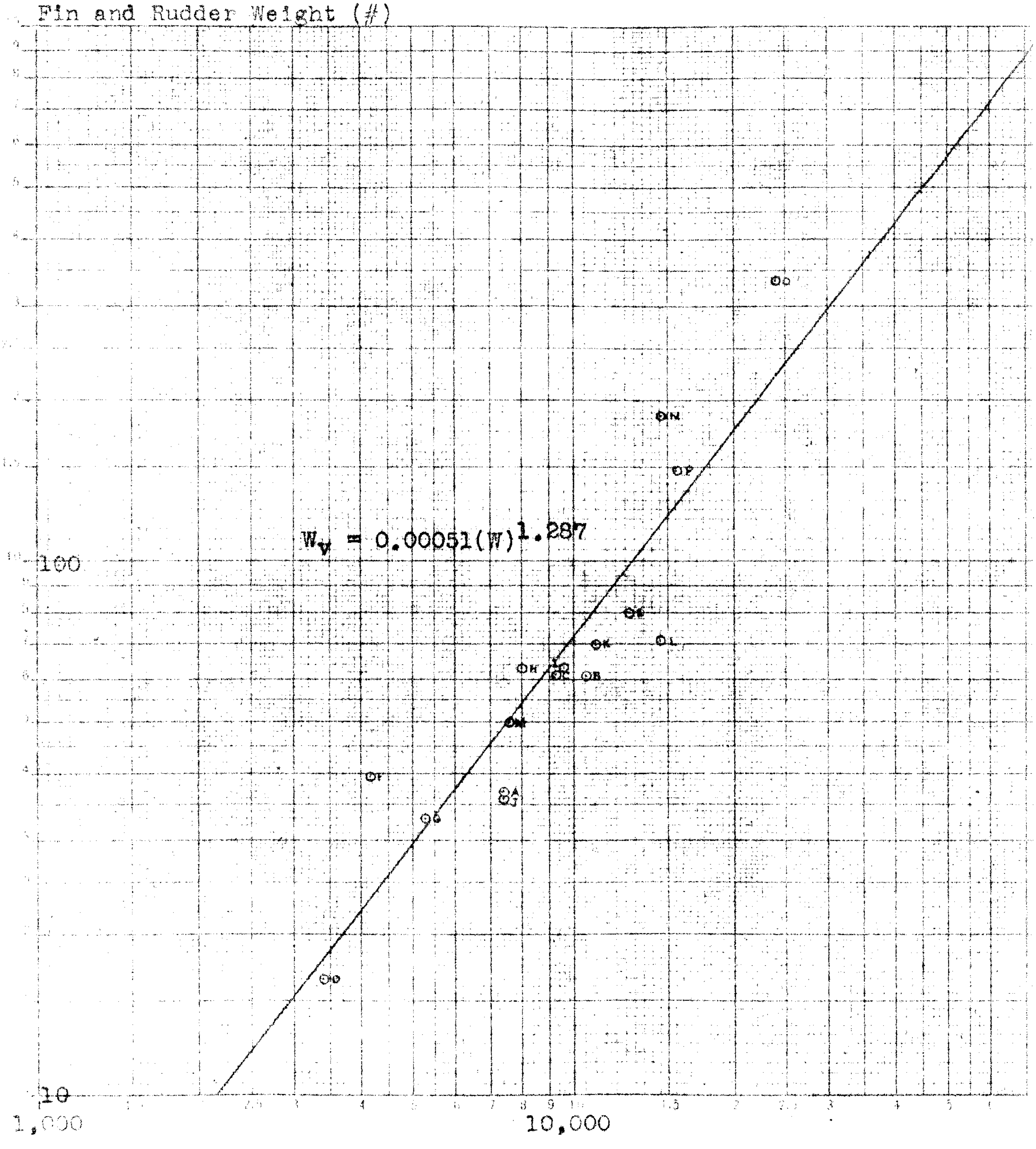



**Figure 19**

LANDING FLAPS WEIGHT

vs.

DESIGN GROSS WEIGHT

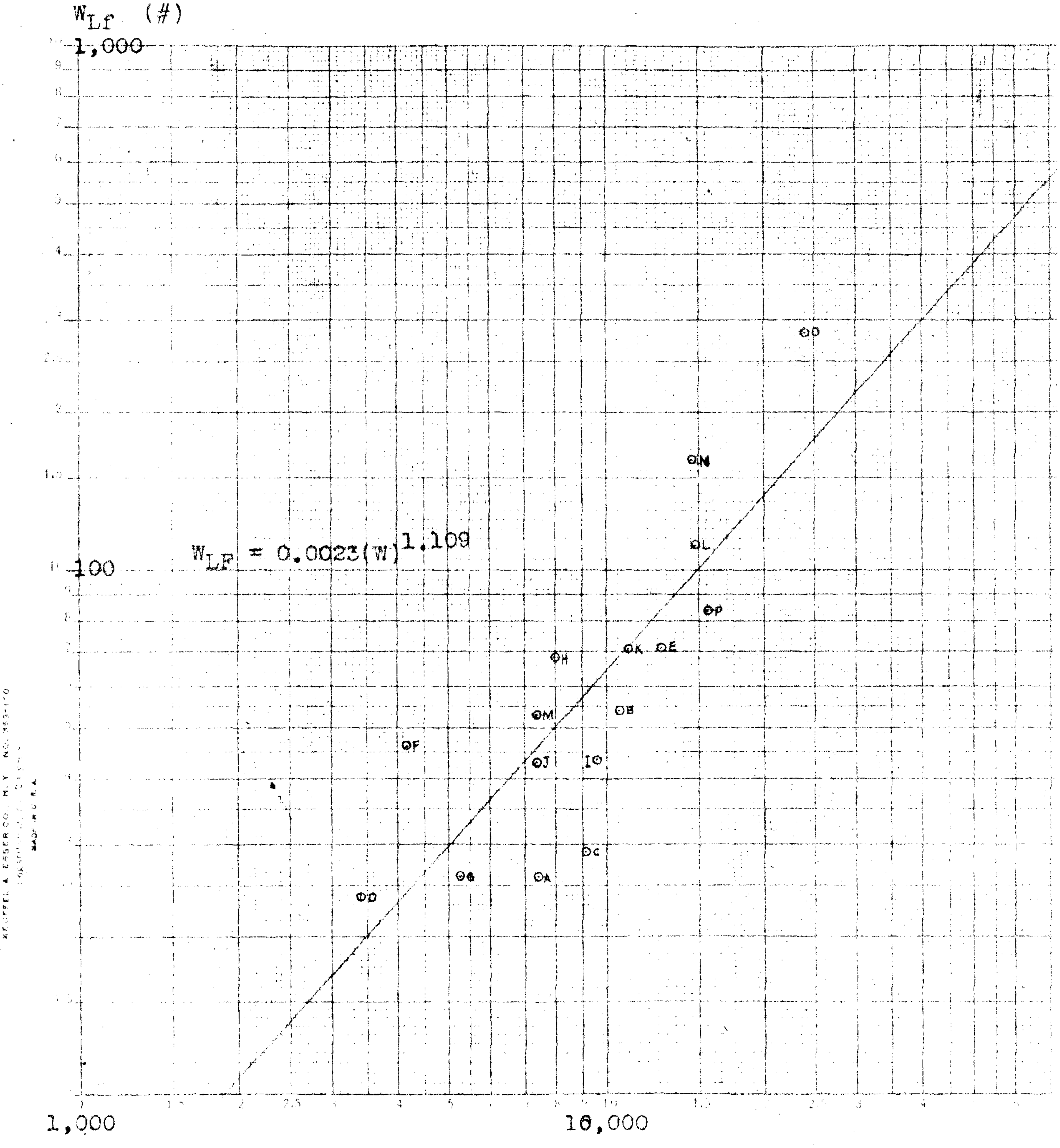



Figure 20

Figures 22 to 41

DEVELOPMENT OF SATISFACTORY ESTIMATING FORMULAS

TOTAL WEIGHT OF WING

vs.

DESIGN GROSS WEIGHT

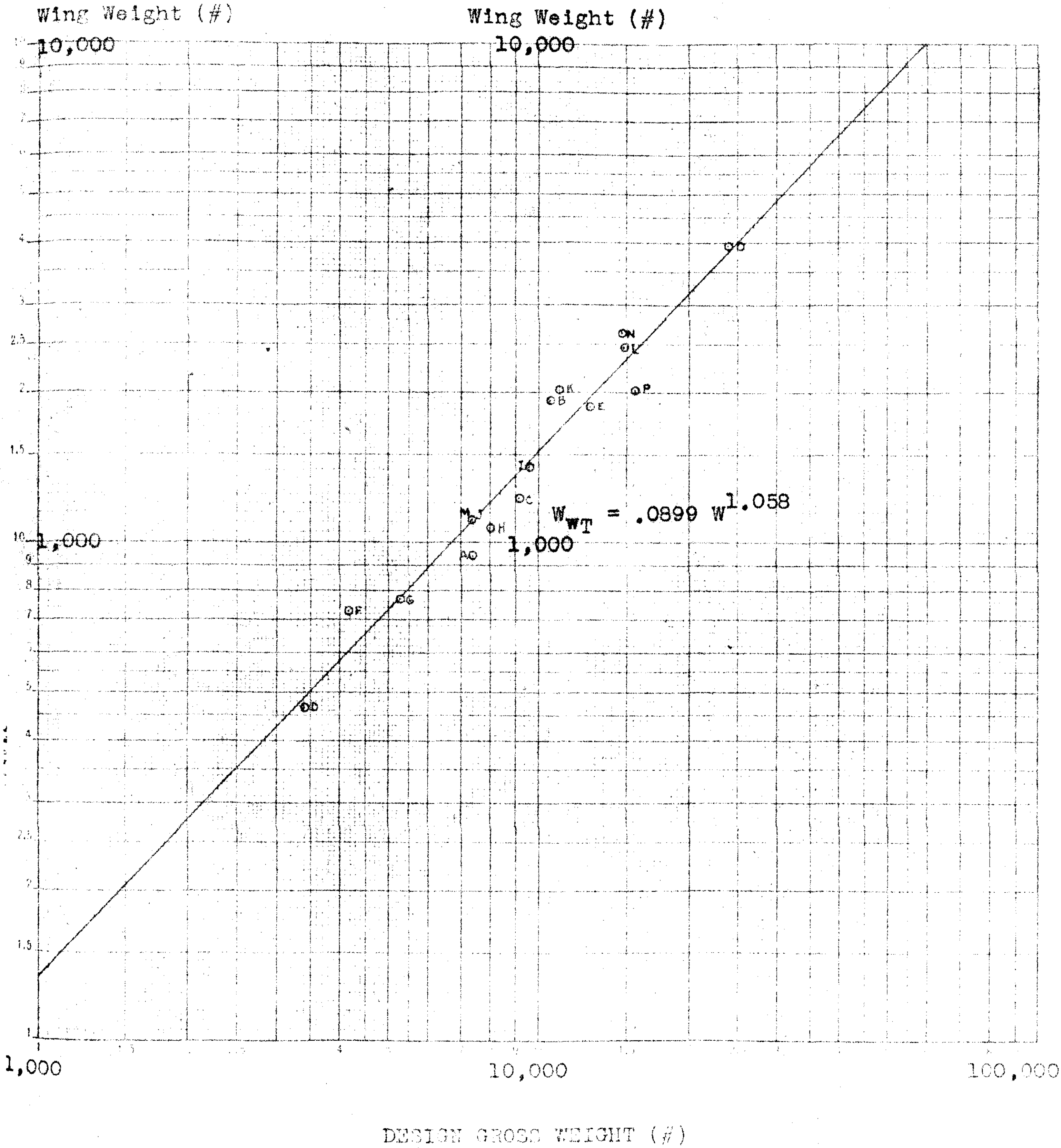



Figure 22

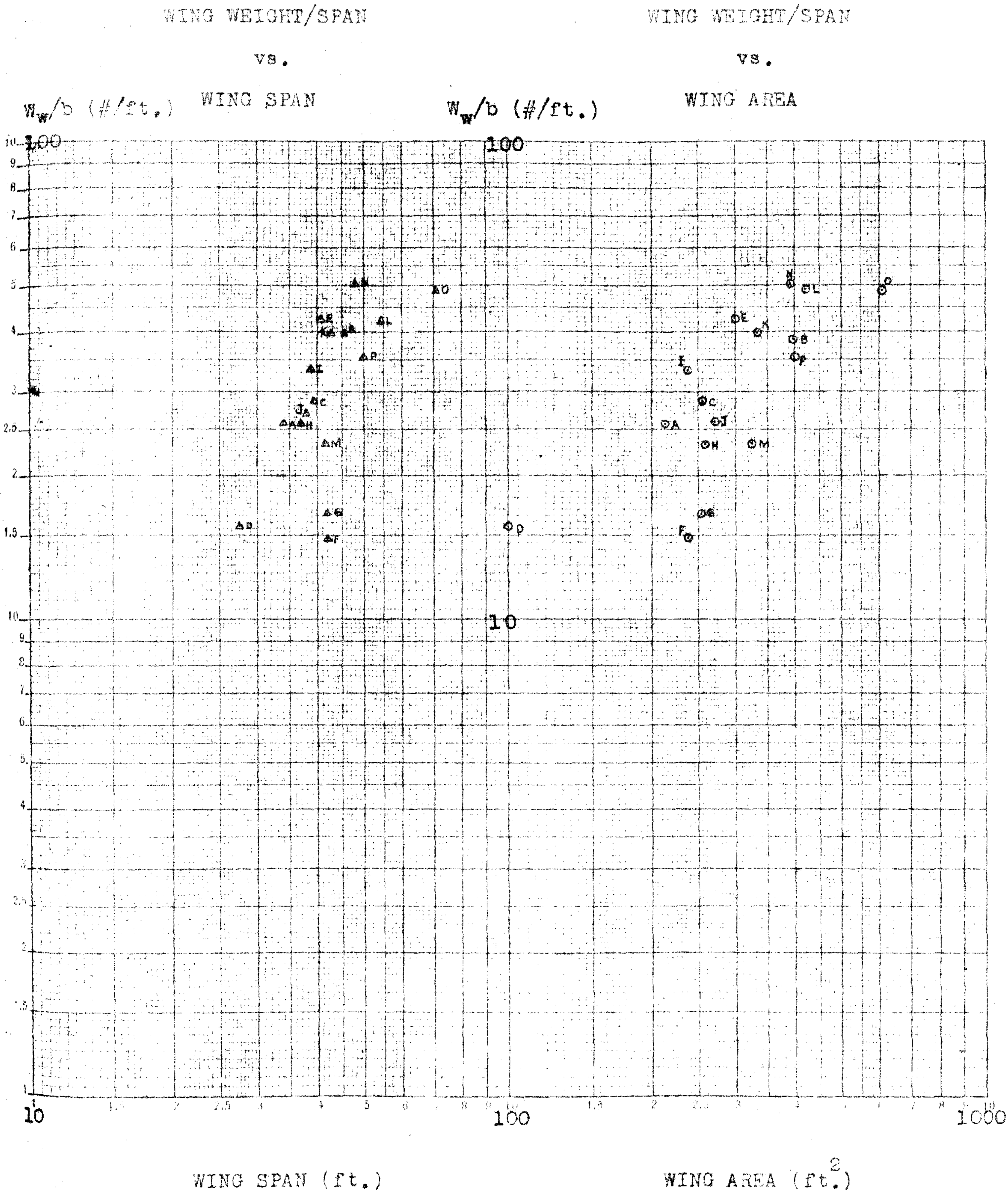

WING WEIGHT/SPAN
vs.
WING SPAN
WING WEIGHT/SPAN
vs.
WING AREA
$W_w/b$ (#/ft.)
$W_w/b$ (#/ft.)
100
10
1000
WING SPAN (ft.)
WING AREA ($ft.^2$)

Figure 23

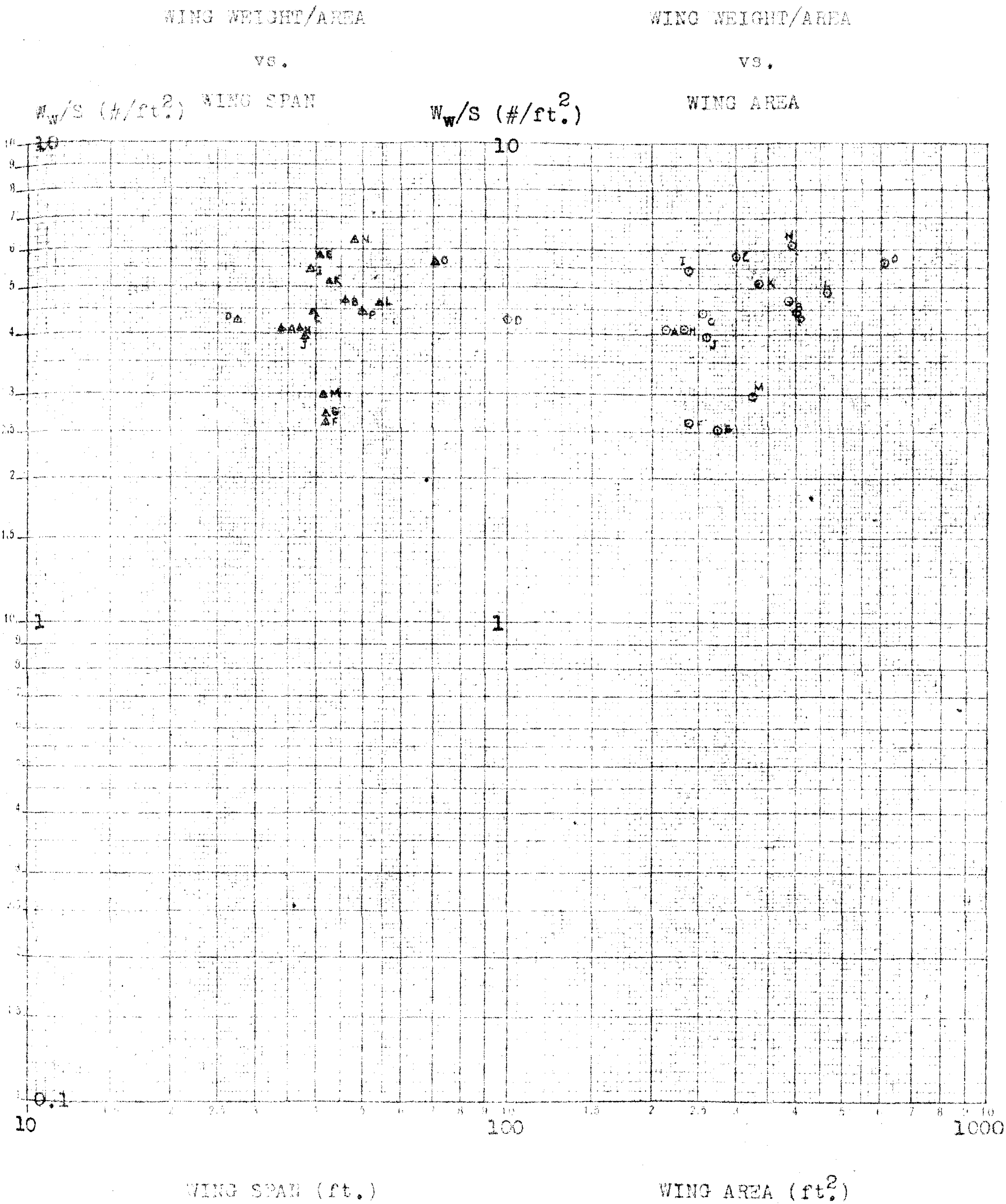

WING WEIGHT/AREA
vs.
WING SPAN
WING WEIGHT/AREA
vs.
WING AREA
$W_w/S$ (#/ft.$^2$)
$W_w/S$ (#/ft.$^2$)
10
1
0.1
10
100
1000
WING SPAN (ft.)
WING AREA (ft.$^2$)

Figure 24

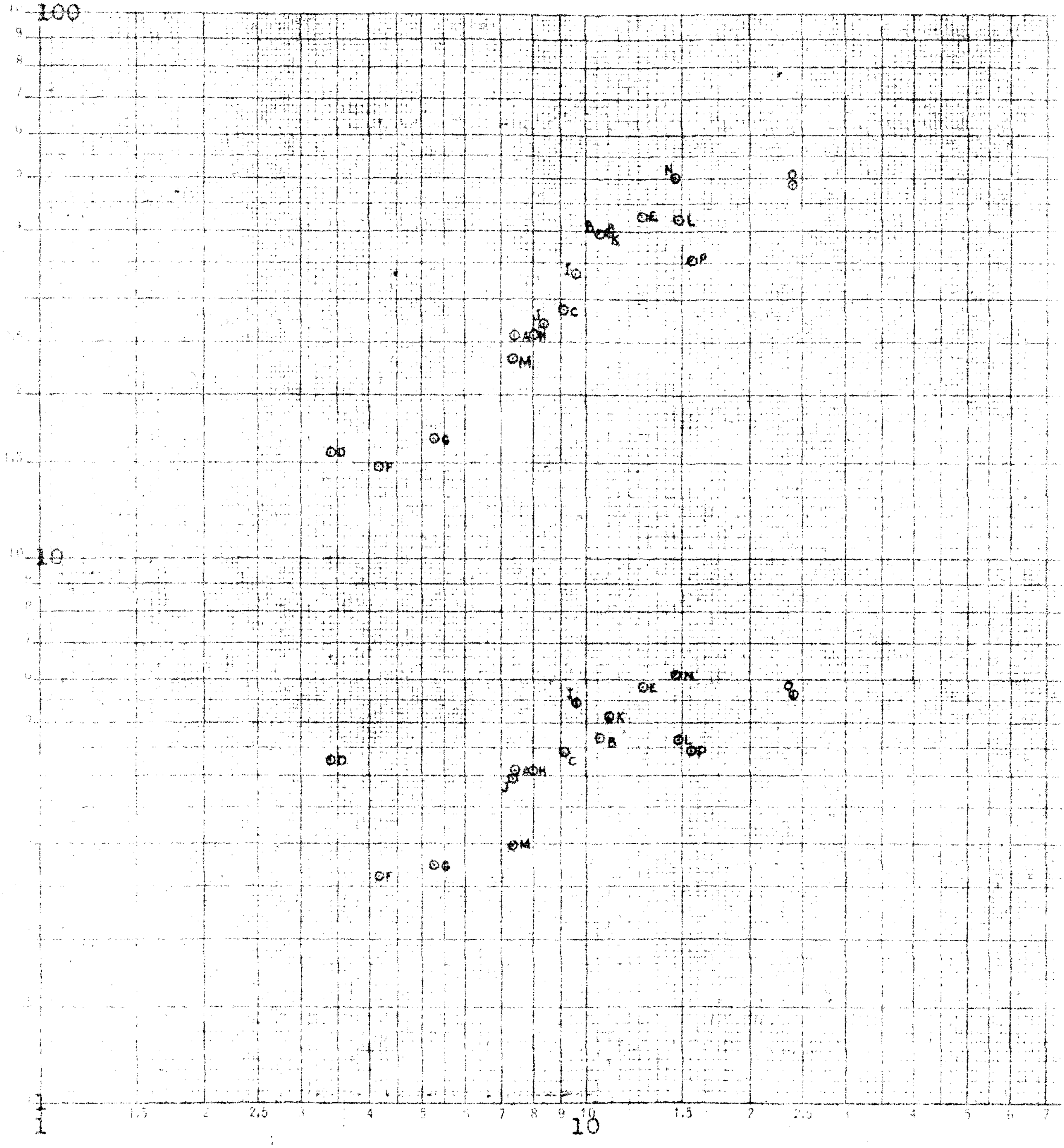
WING WEIGHT/SPAN AND WING WEIGHT/AREA

vs.

GROSS WEIGHT

$W_w/b$ (#/ft.)

$W_w/S$ (#/ft$^2$.)




W x $10^{-3}$ (#)

Figure 25

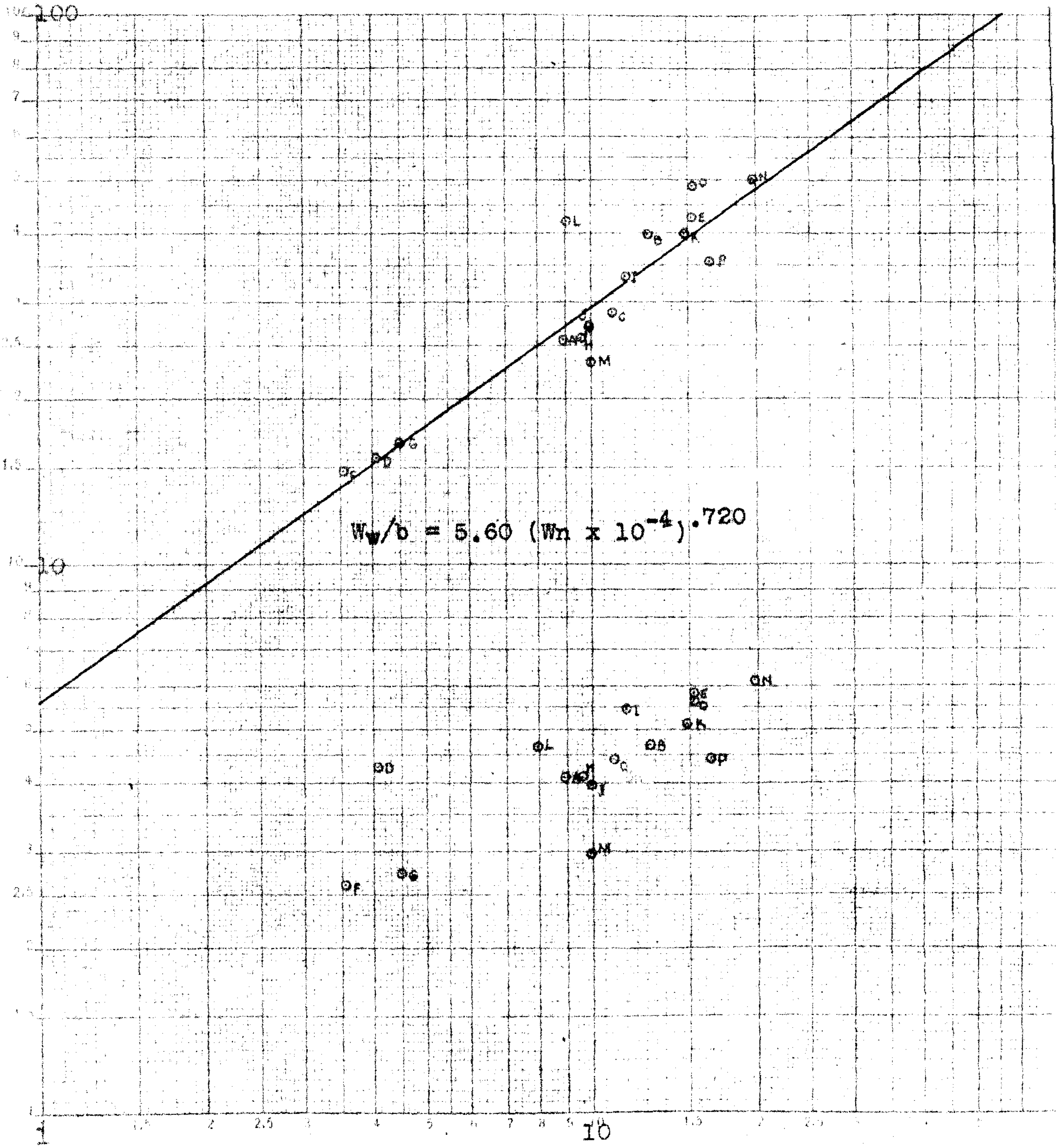
WING WEIGHT/SPAN AND WING WEIGHT/AREA

vs.

(GROSS WEIGHT) x (LOAD FACTOR) x $10^{-4}$

$W_w/b$ (#/ft.)

$W_w/S$ (#/ft.$^2$)



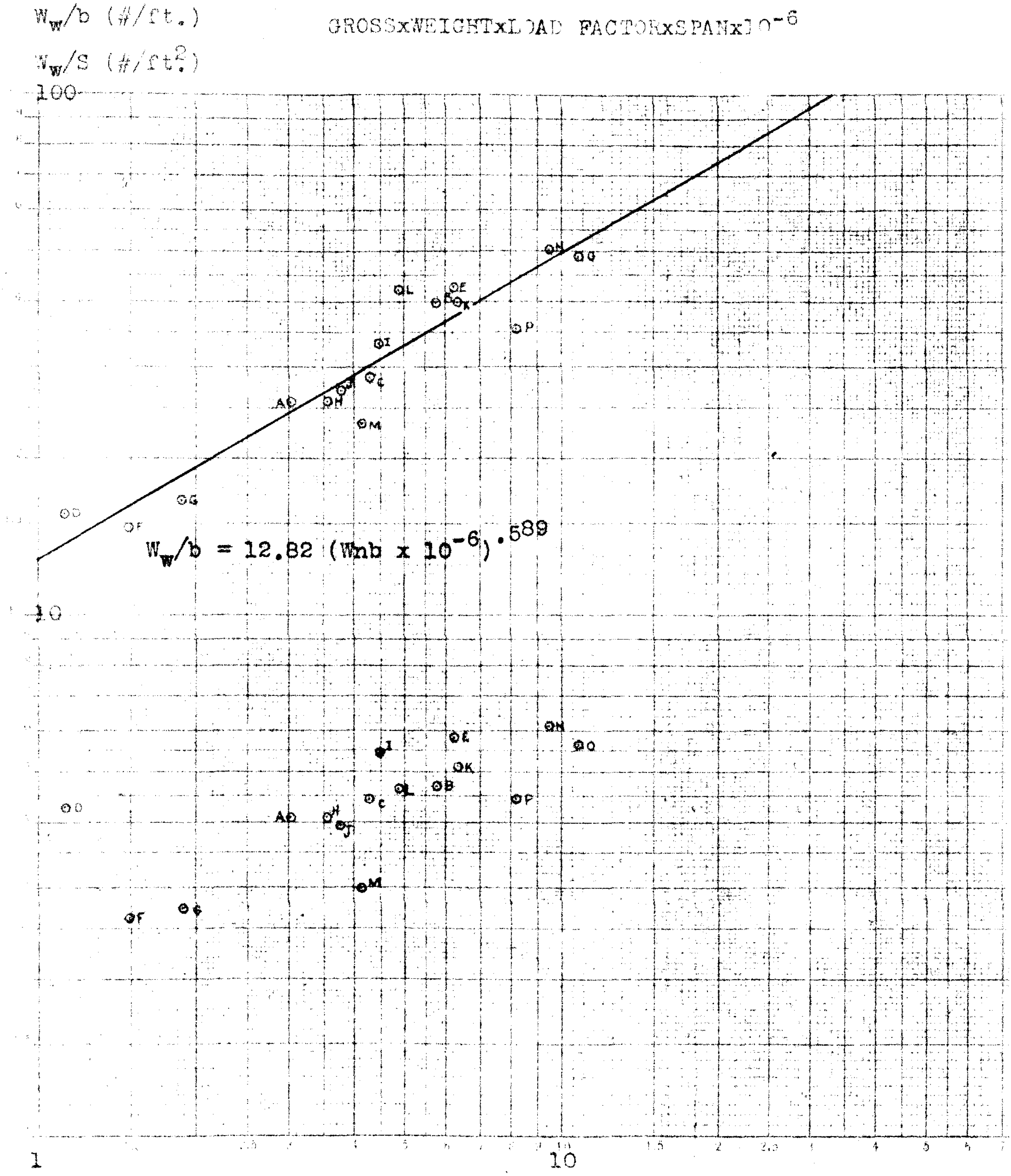

$Wn \times 10^{-4}$ (#)

Figure 26

WING WEIGHT /SPAN AND WING WEIGHT/AREA

vs.

GROSSxWEIGHTxLOAD FACTORxSPANx$10^{-6}$




$Wnb \times 10^{-6}$ (#-ft.)

Figure 27

WING WEIGHT/SPAN

vs.

$$\frac{\text{(GROSS WEIGHT)x(LOAD FACTOR)x(SPAN)}}{\text{WING ROOT THICKNESS}} \times 10^{-4}$$

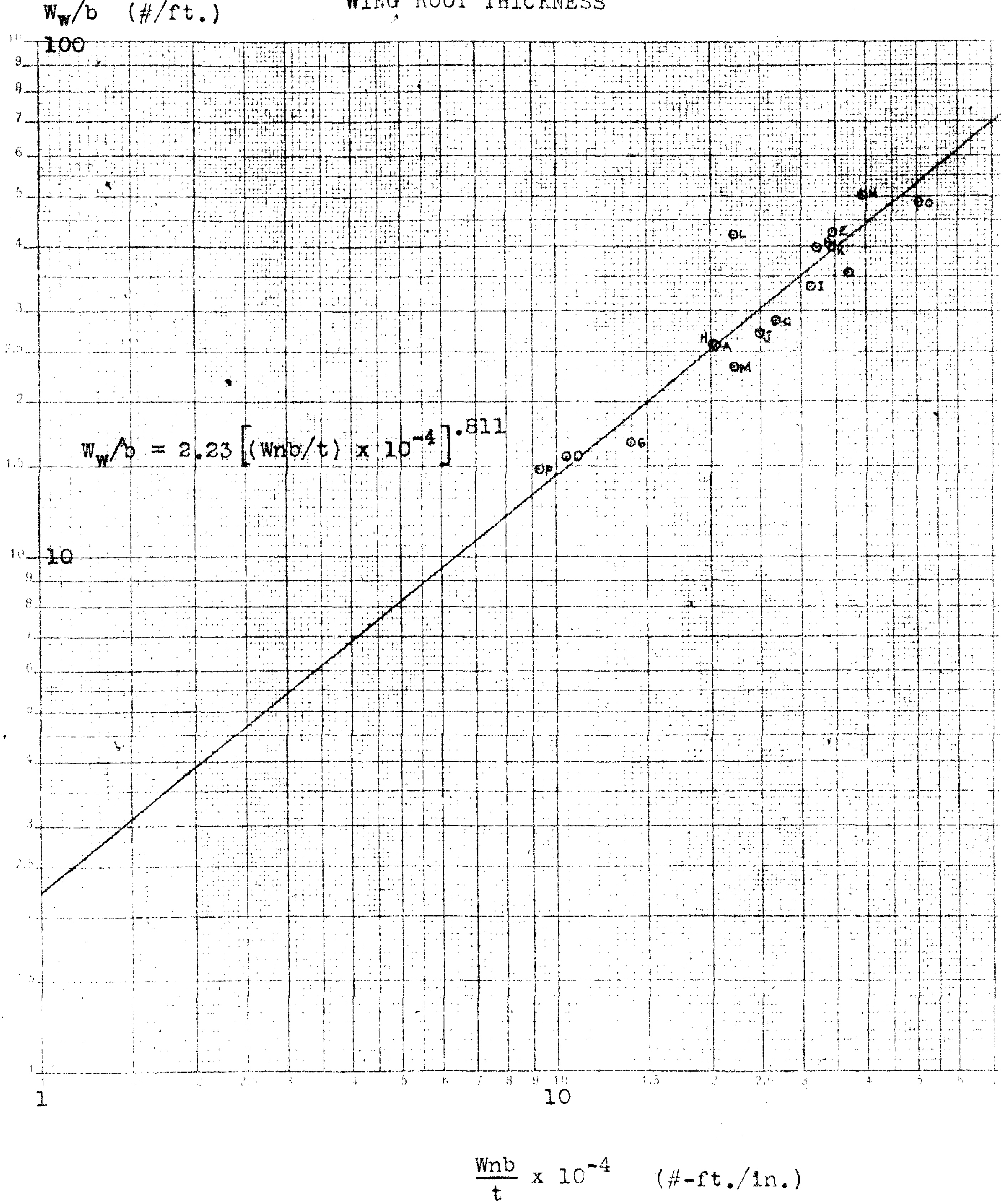



Figure 28

ENGINE AND NACELLE GROUP WEIGHTS

vs.

AS INSTALLED ENGINE WEIGHT

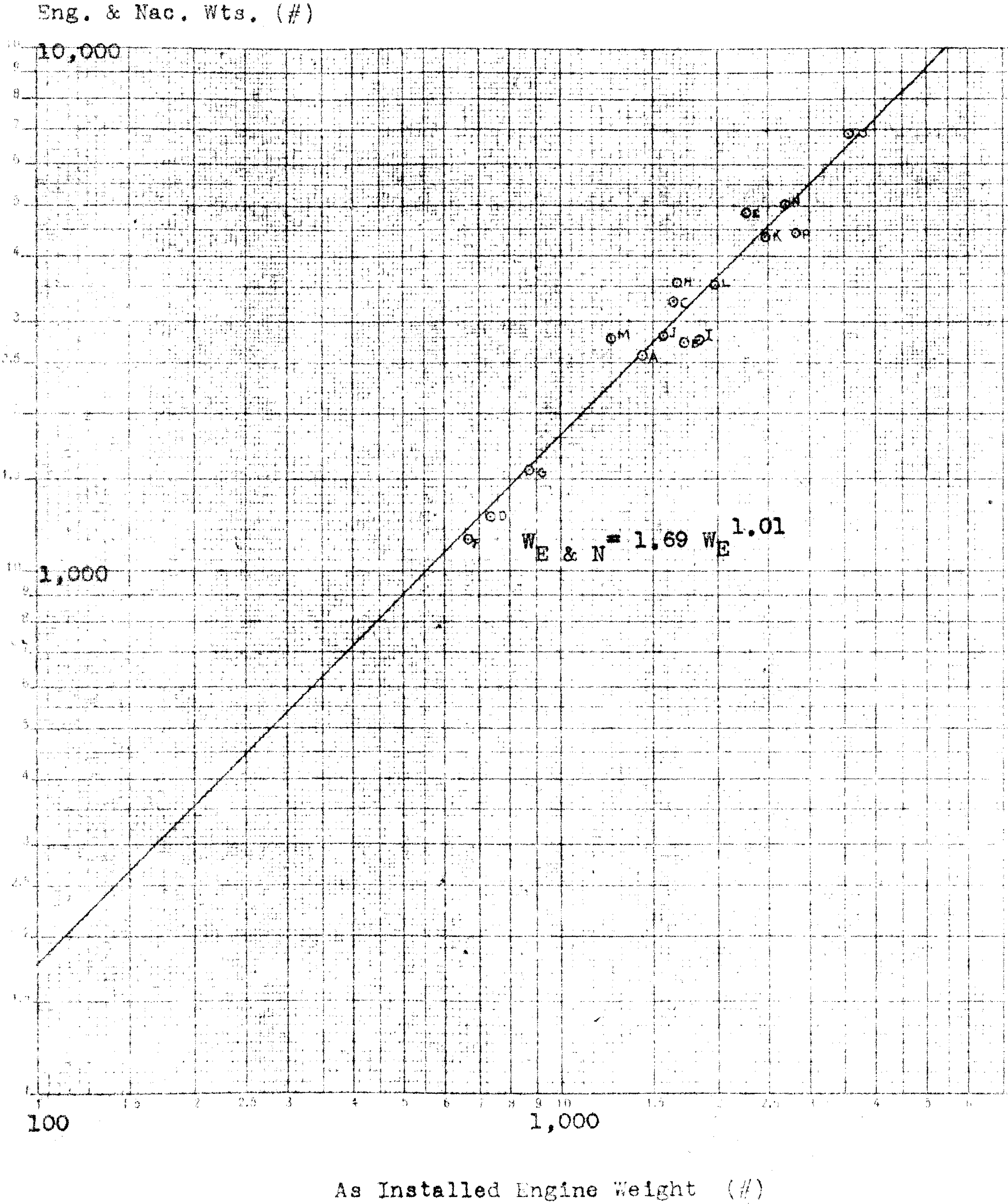



Figure 29

FUSELAGE WEIGHT/LENGTH

vs.

DESIGN GROSS WEIGHT

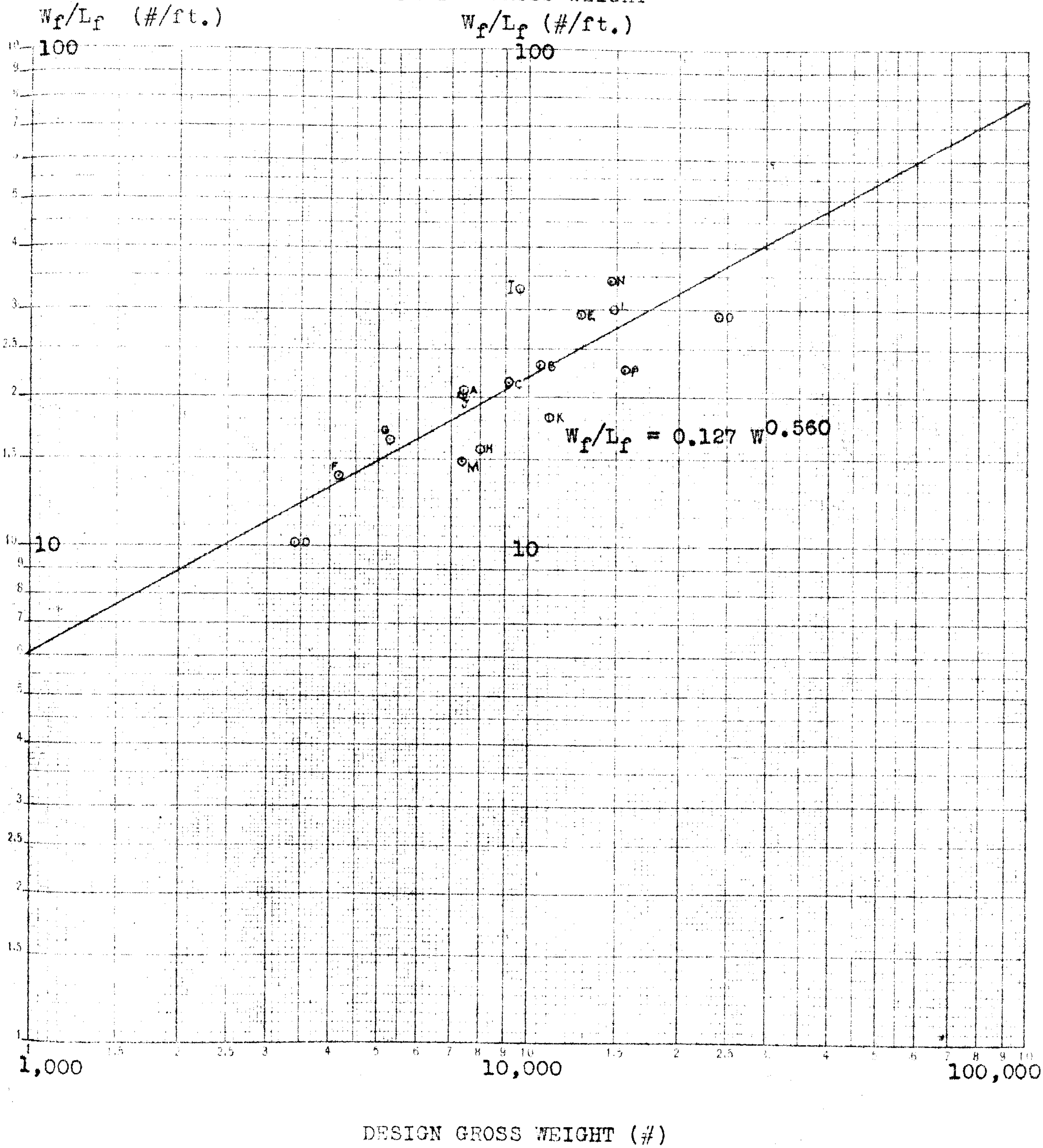


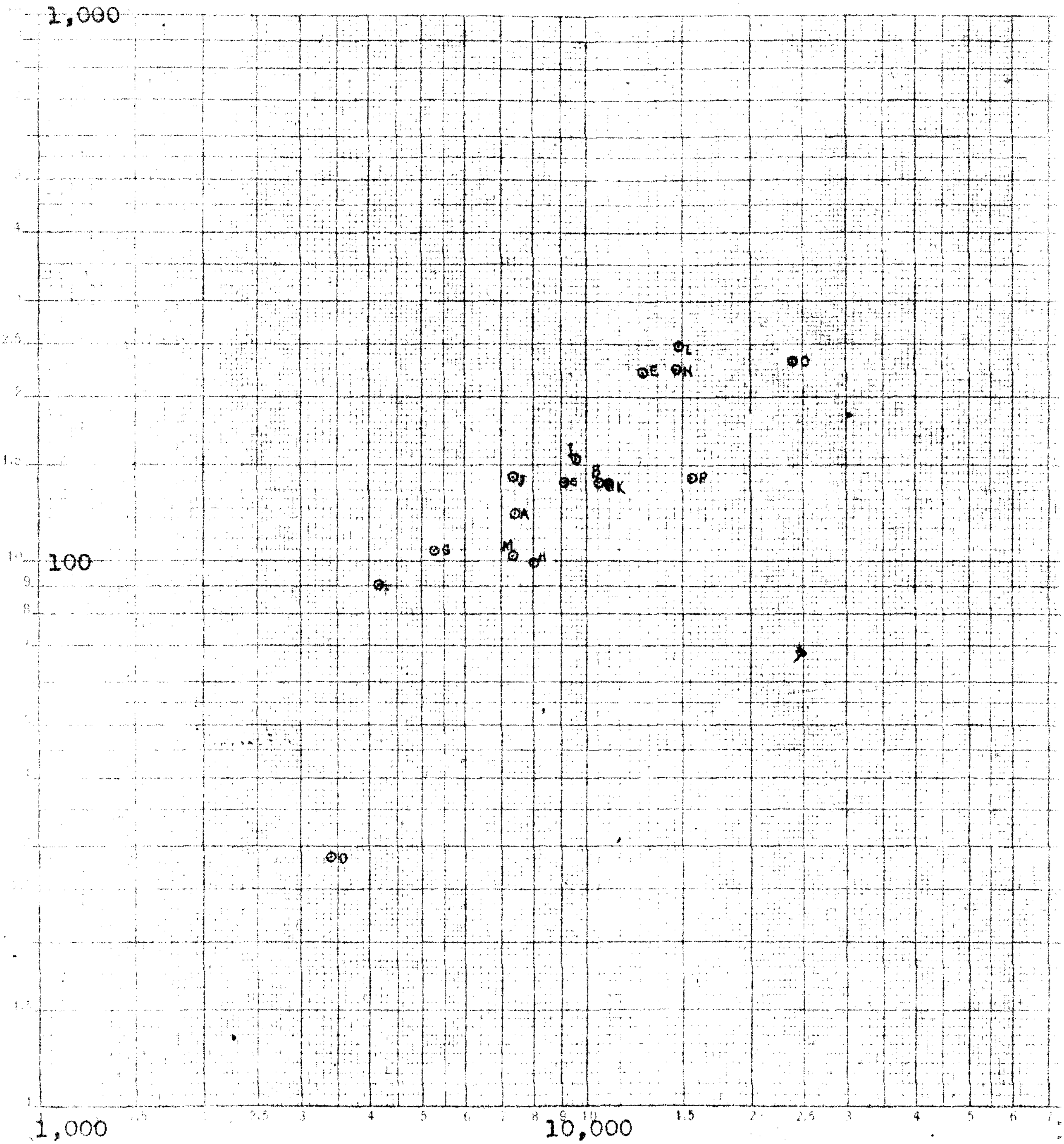

Figure 30

FUSELAGE WEIGHT x (MAXIMUM DEPTH/MAXIMUM LENGTH)

vs.

DESIGN GROSS WEIGHT

$W_f \times \frac{D_{max}}{L_{max}}$ $(\frac{\#\text{-in}}{\text{in}})$

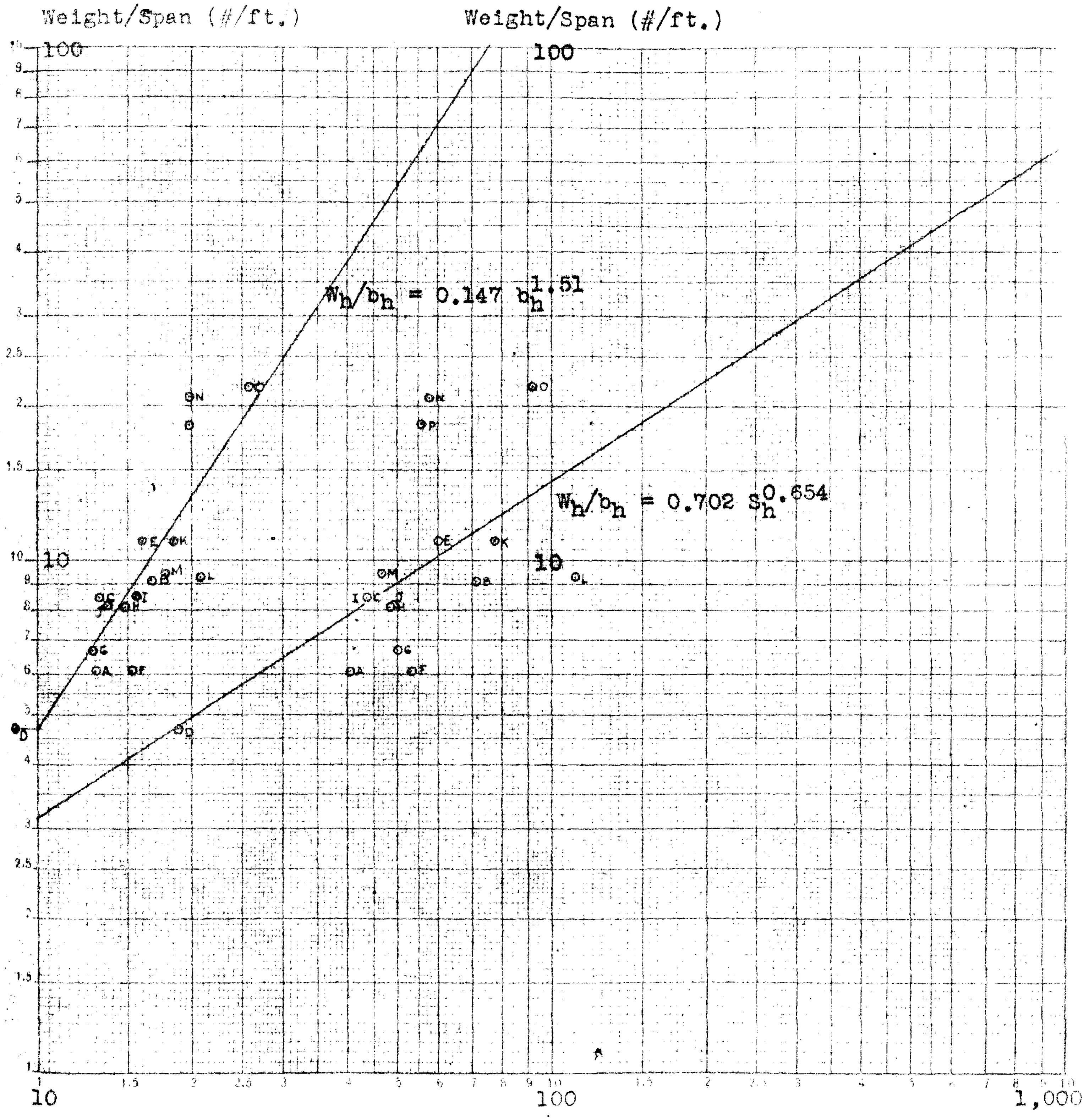



DESIGN GROSS WEIGHT (#)

Figure 31

HORIZONTAL TAIL WEIGHT/SPAN vs. HORIZONTAL TAIL SPAN

HORIZONTAL TAIL WEIGHT/SPAN vs. HORIZONTAL TAIL AREA



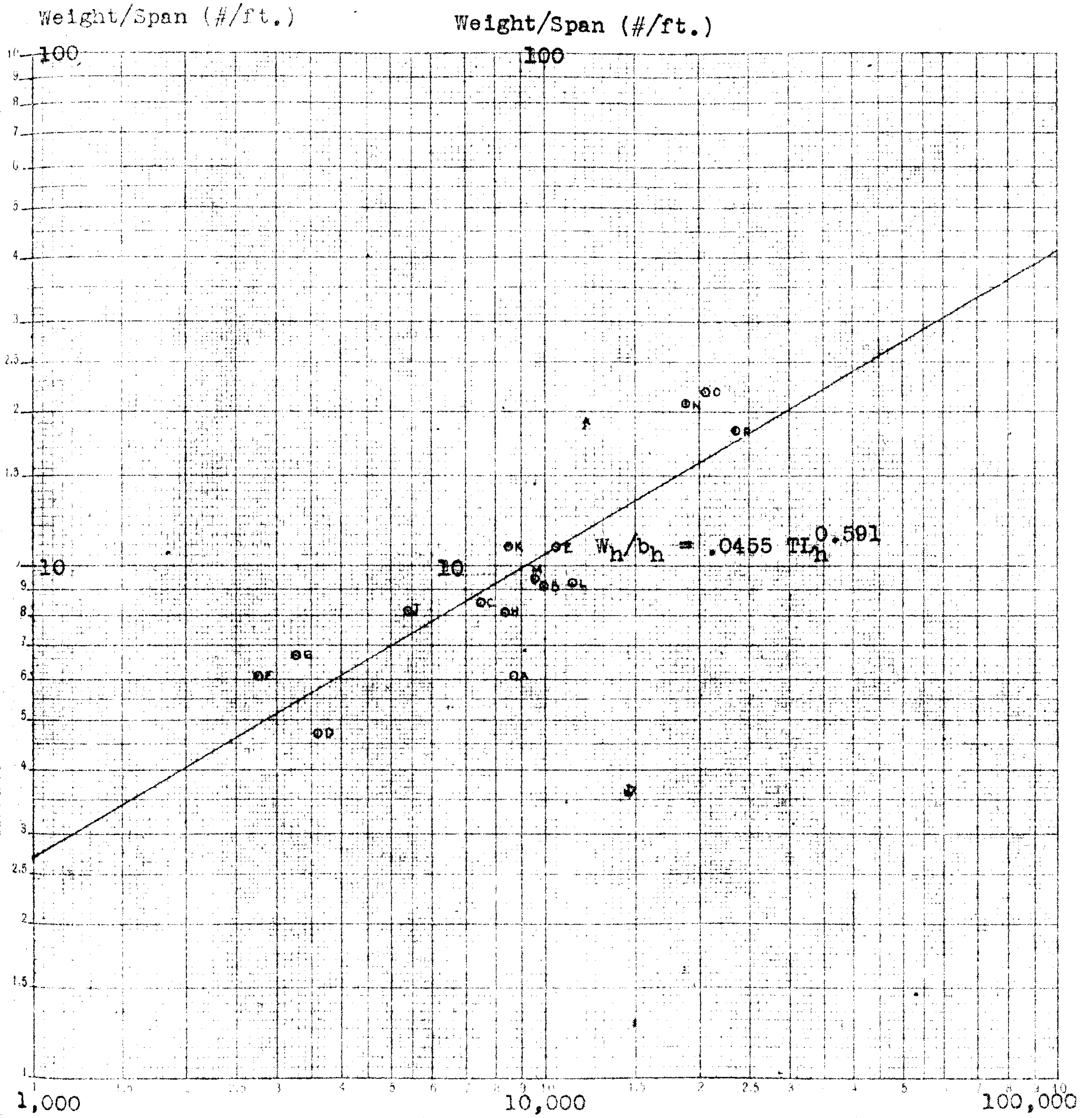

HORIZONTAL TAIL SPAN OR AREA (ft. or ft$^2$.)

Figure 32

HORIZONTAL TAIL WEIGHT/SPAN

vs.

HORIZONTAL TAIL LOAD



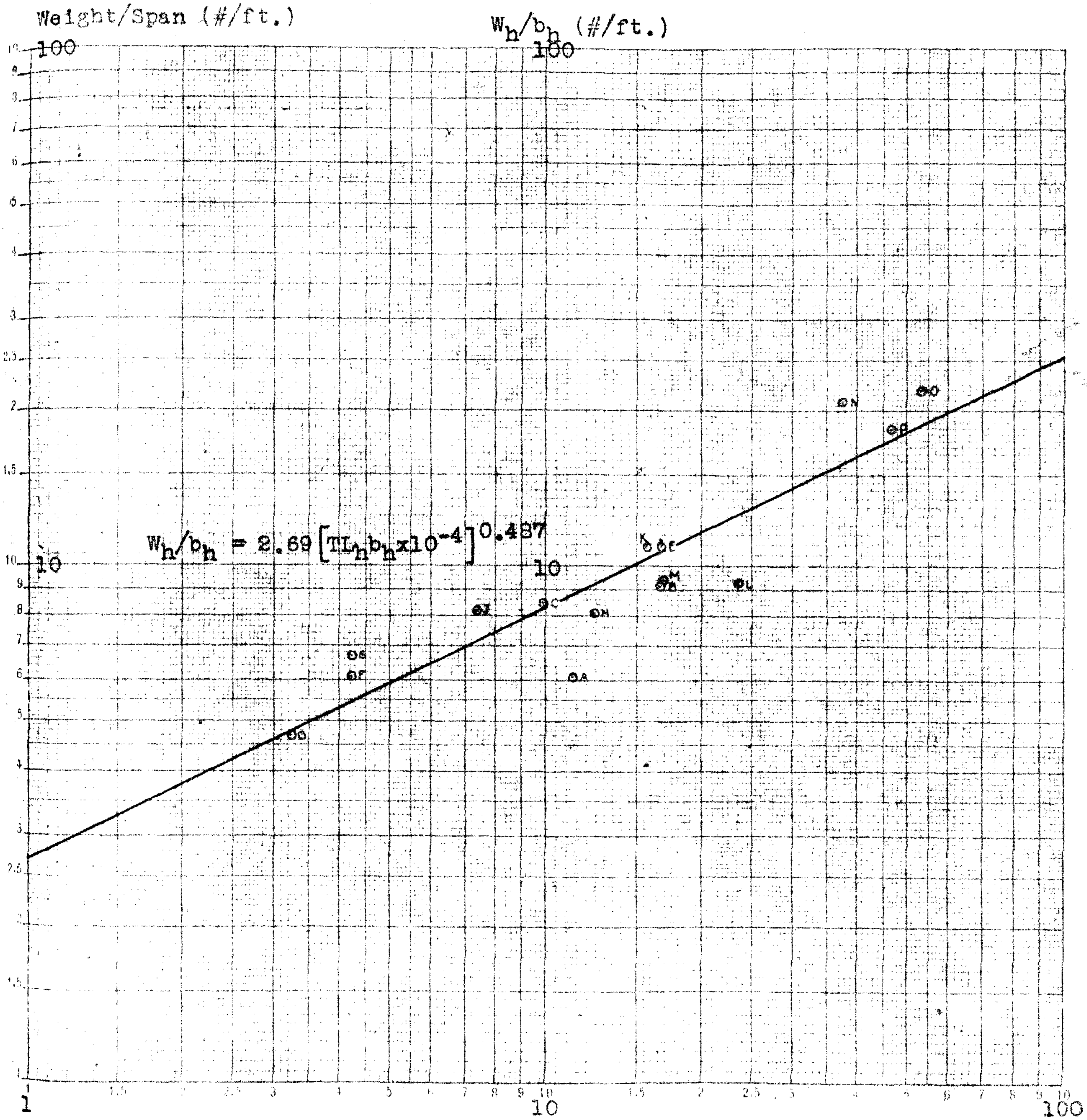

HORIZONTAL TAIL LOAD (#)

Figure 33

HORIZONTAL TAIL WEIGHT/SPAN

vs.

(TAIL LOAD) x (SPAN) x $10^{-4}$



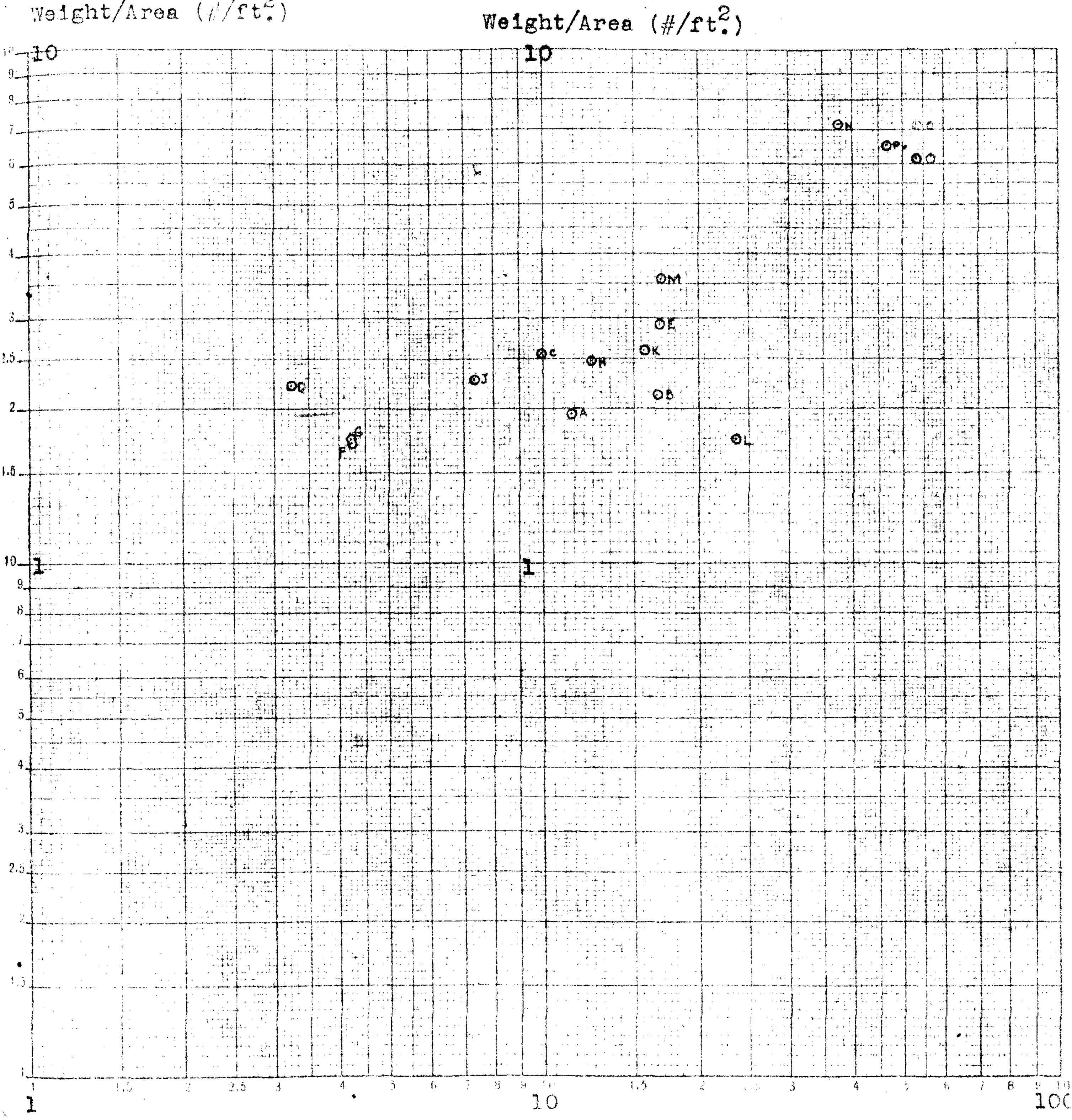

(TAIL LOAD) x (SPAN) x $10^{-4}$ (#-ft.)

Figure 34

HORIZONTAL TAIL WEIGHT/AREA

vs.

(TAIL LOAD) x (SPAN) x $10^{-4}$




(TAIL LOAD) x (SPAN) x $10^{-4}$ (#-ft.)

Figure 35

VERTICAL TAIL SURFACES

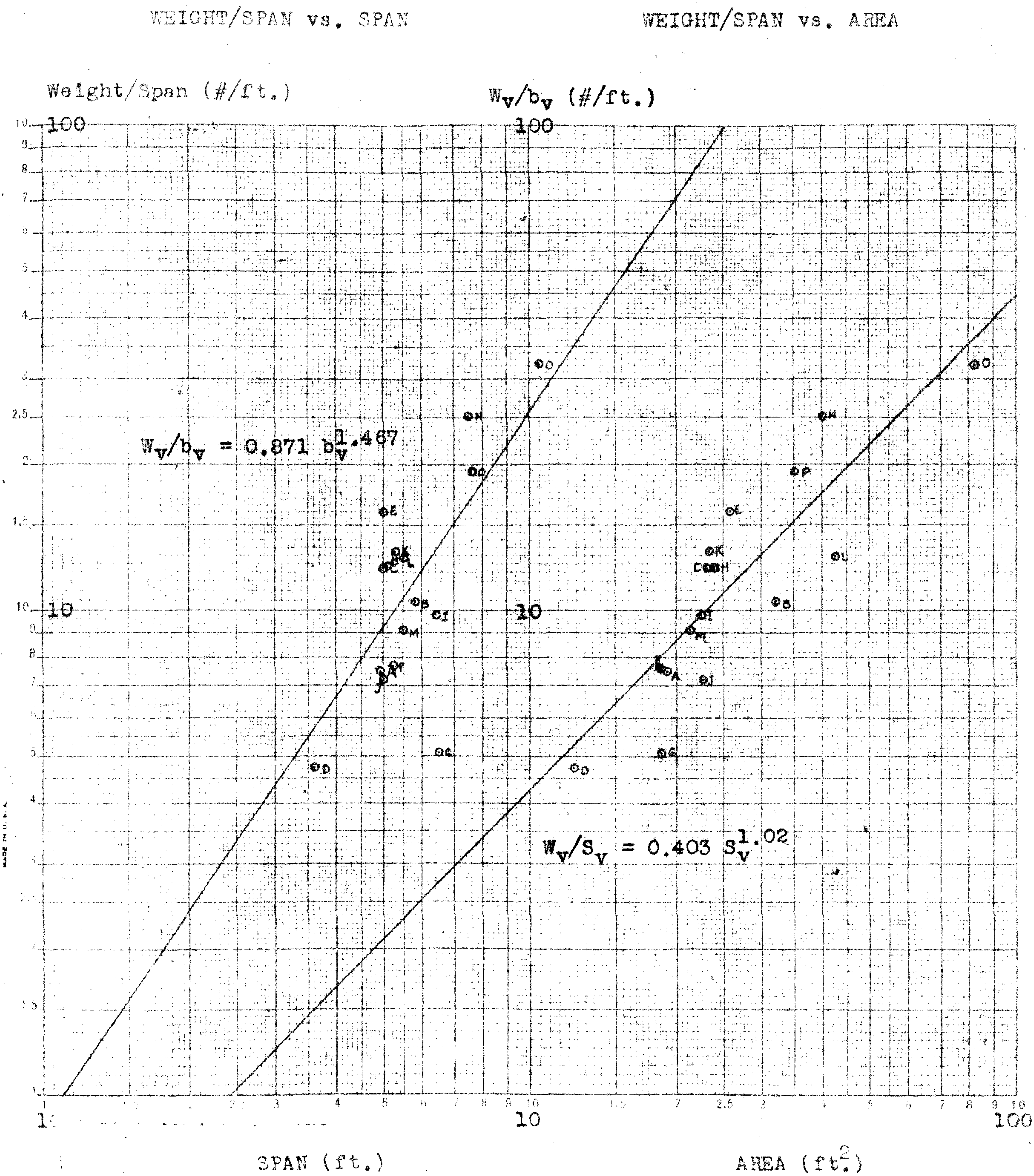
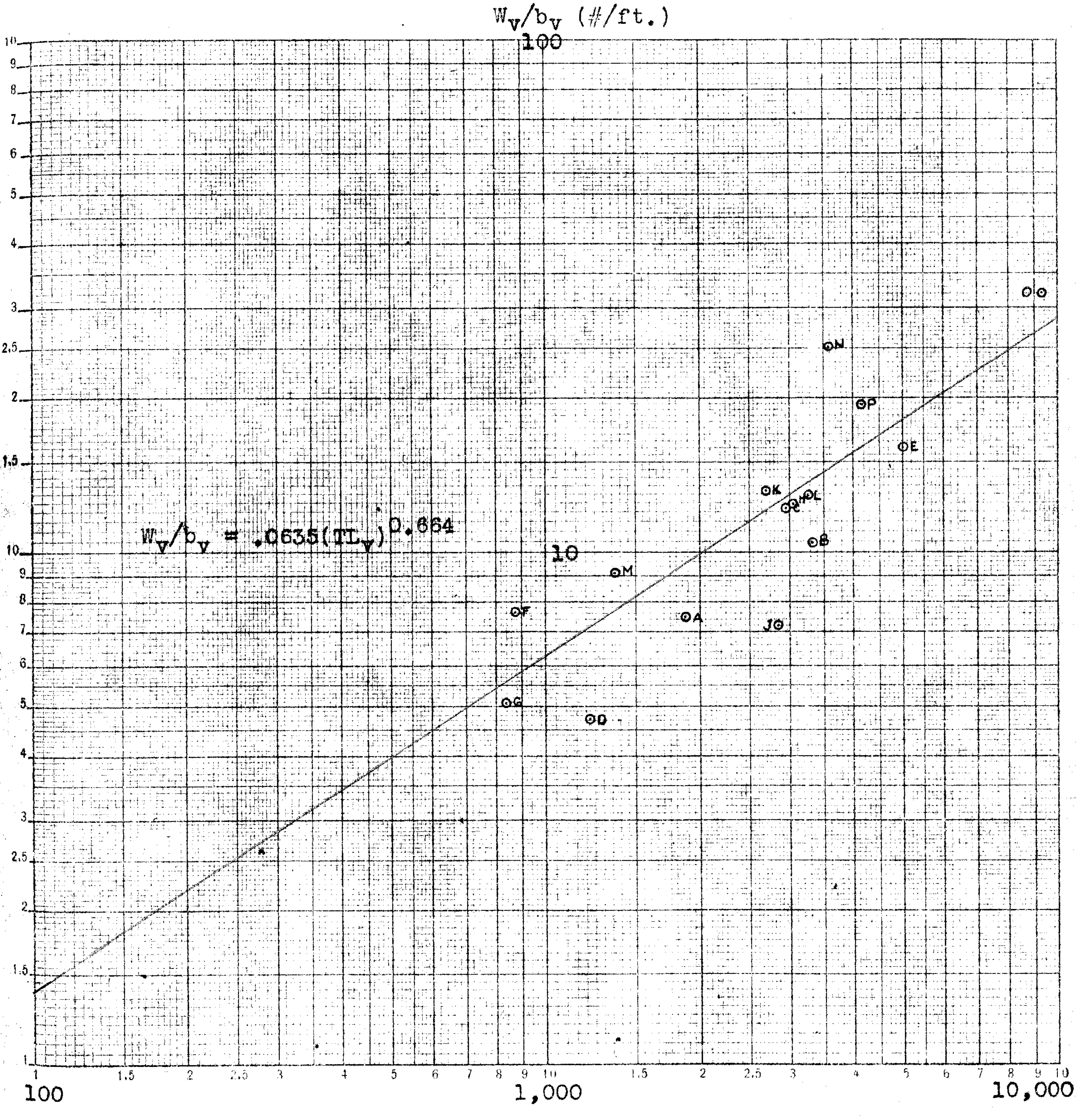



Figure 36

VERTICAL TAIL WEIGHT/SPAN

vs.

VERTICAL TAIL LOAD




VERTICAL TAIL LOAD (#)

VERTICAL TAIL SURFACES WEIGHT/SPAN

vs.

(TAIL LOAD) x (SPAN) x $10^{-3}$

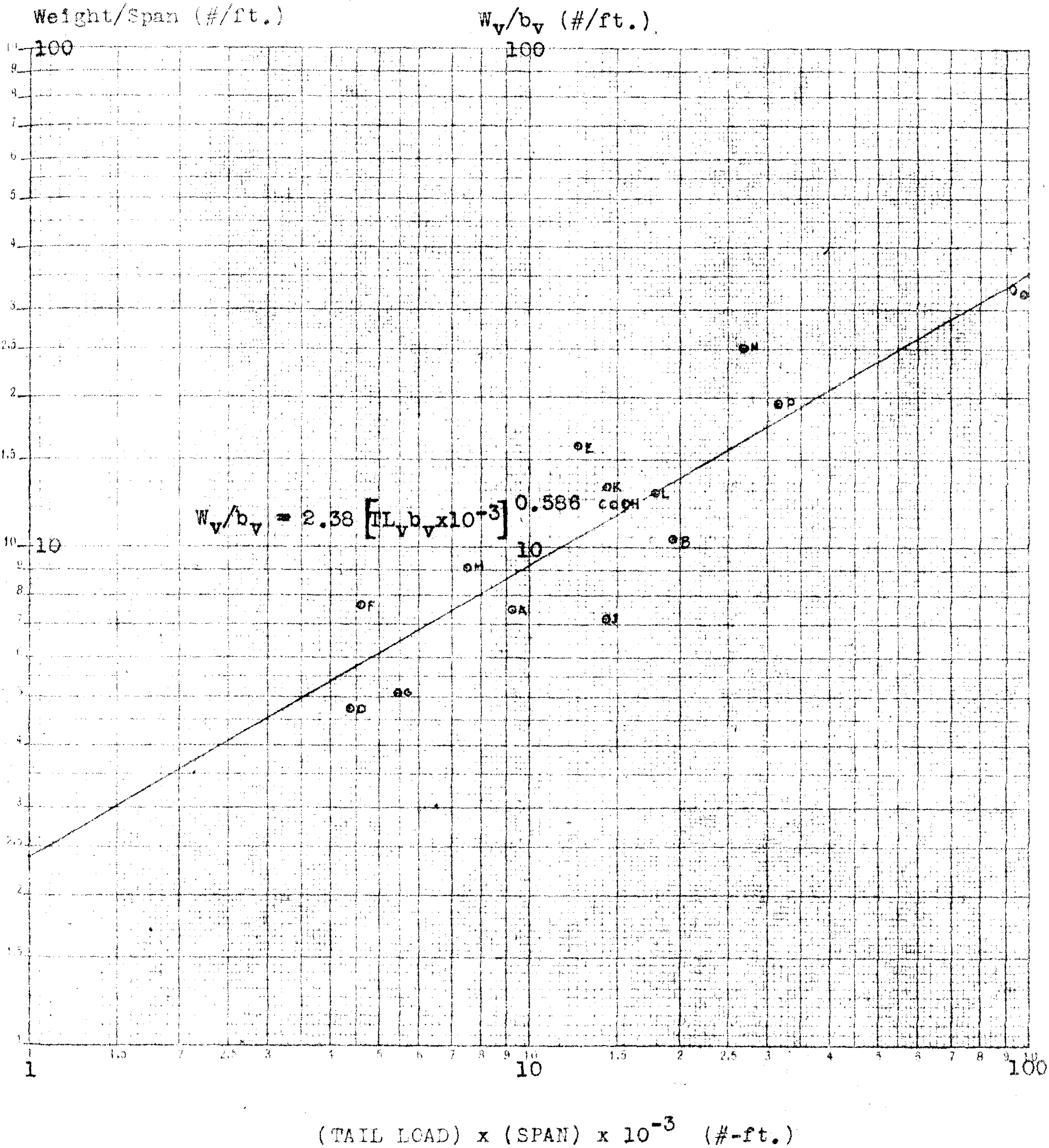
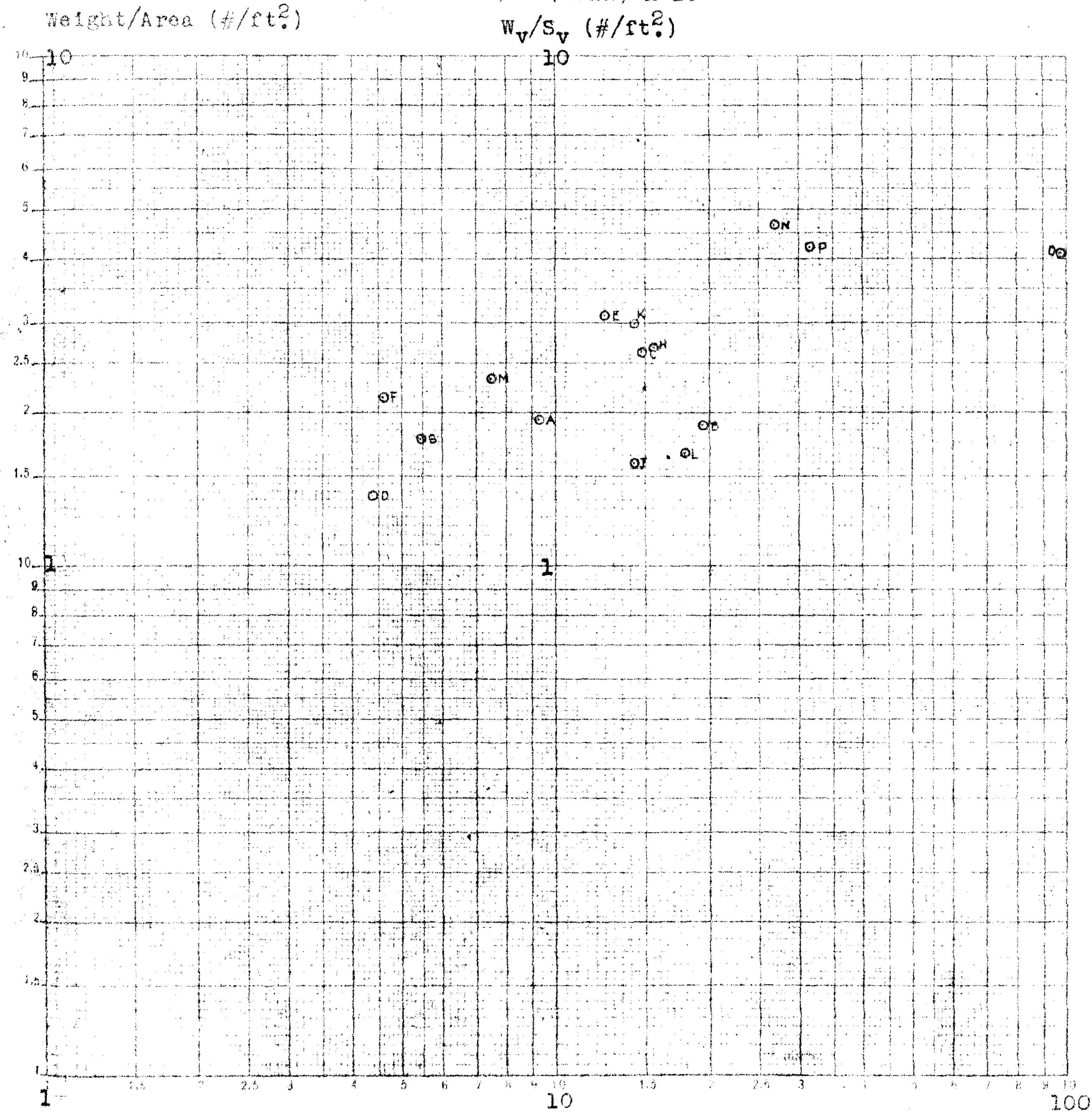



Figure 38

VERTICAL TAIL SURFACES WEIGHT/AREA

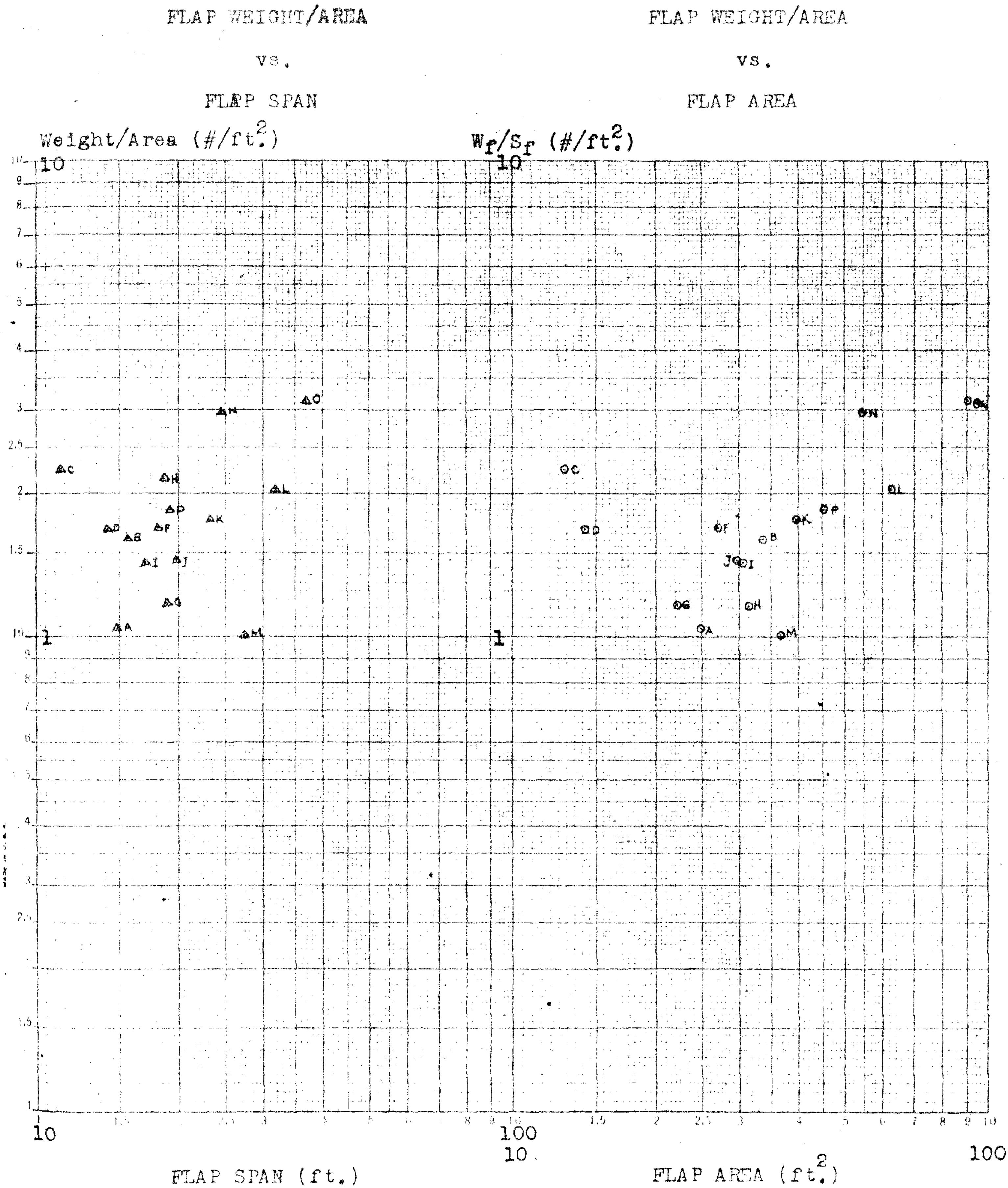
vs.

(TAIL LOAD) x (SPAN) x $10^{-3}$




(TAIL LOAD) x (SPAN) x $10^{-3}$ (#-ft.)

Figure 39



FLAP WEIGHT/AREA
vs.
FLAP SPAN
FLAP WEIGHT/AREA
vs.
FLAP AREA
Weight/Area (#/ft.²)
Wf/Sf (#/ft.²)
FLAP SPAN (ft.)
FLAP AREA (ft.²)


Figure 40

AILERON WEIGHT/AREA vs. AILERON SPAN

AILERON WEIGHT/AREA vs. AILERON AREA

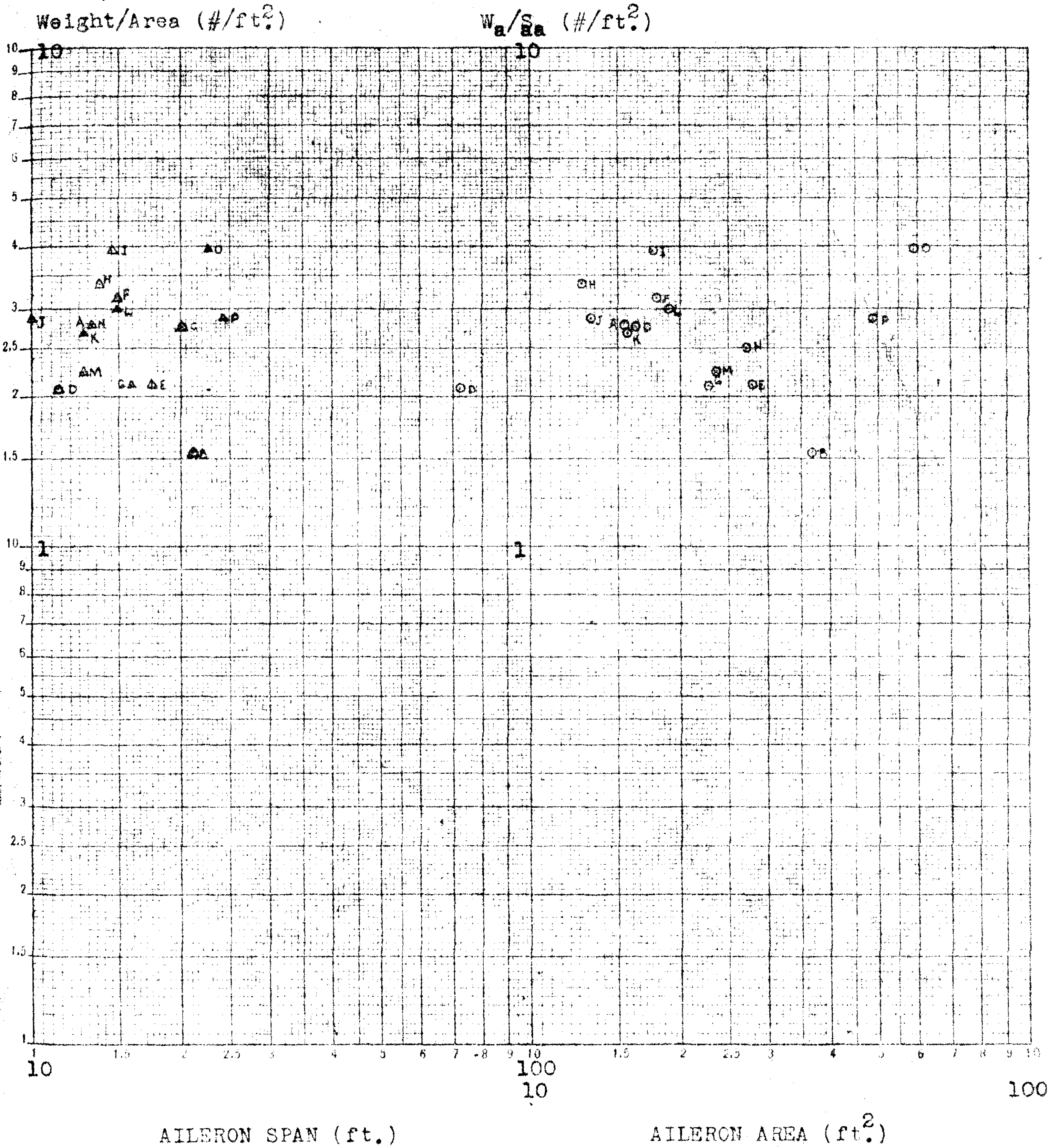



Figure 41

# APPENDIX I

## CALCULATIONS ASSOCIATED WITH FIGURES 1 TO 10

CALCULATIONS FOR HORIZONTAL STABILIZER AND ELEVATOR

WT./AREA vs. SURFACE AREA

| Model | $W_{HS}$ | $S_{HS}$ | $W_{HS}/S_{HS}$ | $W_E$ | $S_E$ | $W_E/S_E$ |
|---|---|---|---|---|---|---|
| A | 46.0 | 24.50 | 1.878 | 33.0 | 15.94 | 2.070 |
| B | 96.0 | 48.60 | 1.973 | 56.0 | 22.62 | 2.470 |
| C | 77.2 | 31.80 | 2.428 | 34.4 | 11.95 | 2.878 |
| D | 21.3 | 11.81 | 1.803 | 21.0 | 7.09 | 2.968 |
| E | 92.0 | 40.50 | 2.270 | 83.0 | 19.50 | 4.255 |
| F | 62.9 | 35.70 | 1.761 | 29.7 | 17.52 | 1.695 |
| G | 49.0 | 30.10 | 1.628 | 37.0 | 20.01 | 1.848 |
| H | 68.0 | 31.40 | 2.165 | 52.0 | 16.95 | 3.068 |
| I | 86.0 | 31.20 | 2.755 | 46.8 | 12.60 | 3.712 |
| J | 65.0 | 26.00 | 2.500 | 47.0 | 23.10 | 2.032 |
| K | 112.8 | 48.20 | 2.340 | 89.0 | 29.60 | 3.007 |
| L | 102.0 | 55.40 | 1.842 | 91.0 | 55.40 | 1.641 |
| M | 115.0 | 46.64 | 2.465 | 52.0 | 24.14 | 2.152 |
| N | 235.0 | 57.66 | 4.080 | 178.6 | 28.87 | 6.190 |
| O | 287.0 | 92.00 | 3.120 | 278.9 | 56.15 | 4.960 |
| P | 300.6 | 55.83 | 5.390 | 64.9 | 31.20 | 2.078 |

CALCULATION FOR VERTICAL FIN AND RUDDER WT./AREA vs. SURFACE AREA

| Model | $W_F$ | $S_F$ | $W_F/S_F$ | $W_R$ | $S_R$ | $W_R/S_R$ |
|---|---|---|---|---|---|---|
| A | 14.3 | 10.53 | 1.356 | 22.7 | 8.53 | 2.663 |
| B | 34.0 | 21.60 | 1.573 | 26.0 | 10.54 | 2.465 |
| C | 35.1 | 16.77 | 2.092 | 26.1 | 6.35 | 4.110 |
| D | - | - | - | 16.5 | 4.57 | 3.610 |
| E | 37.5 | 17.66 | 2.125 | 42.5 | 8.14 | 5.220 |
| F | 16.5 | 10.24 | 1.611 | 19.1 | 8.38 | 2.280 |
| G | 14.0 | 9.3 | 1.508 | 19.0 | 9.26 | 2.300 |
| H | 21.0 | 14.04 | 1.496 | 42.0 | 9.36 | 4.490 |
| I | 35.2 | 15.75 | 2.832 | 27.9 | 6.75 | 4.135 |
| J | 13.0 | 13.56 | .960 | 23.0 | 9.02 | 2.550 |
| K | 24.2 | 15.90 | 1.522 | 45.4 | 8.50 | 5.340 |
| L | 29.0 | 23.50 | 1.234 | 42.0 | 19.17 | 2.190 |
| M | 22.0 | 9.78 | 2.250 | 28.0 | 11.60 | 2.415 |
| N | 118.8 | 21.59 | 5.470 | 69.4 | 18.55 | 3.740 |
| O | 172.1 | 46.62 | 3.690 | 164.5 | 35.55 | 4.640 |
| P | 71.7 | 11.11 | 6.460 | 77.9 | 23.90 | 3.260 |

CALCULATIONS FOR WING WEIGHT/LOAD FACTOR x GROSS WEIGHT vs. WING SPAN

| Model | $W_w$ | W | f | Wf | b | $W_w/Wf$ |
|---|---|---|---|---|---|---|
| A | 873 | 7406 | 12.00 | 88,872 | 34.00 | .00982 |
| B | 1815 | 10,550 | 12.00 | 126,600 | 45.50 | .01434 |
| C | 1123 | 9,193 | 12.00 | 109,668 | 33.30 | .01024 |
| D | 429 | 3,400 | 12.00 | 40,800 | 27.50 | .01051 |
| E | 1745 | 12,700 | 12.00 | 152,400 | 42.80 | .011450 |
| F | 623 | 4,167 | 8.50 | 35,420 | 42.00 | .01759 |
| G | 697 | 5,280 | 8.50 | 44,880 | 42.00 | .01553 |
| H | 955 | 8,000 | 11.00 | 88,000 | 37.00 | .01085 |
| I | 1300 | 9,600 | 12.00 | 115,200 | 38.95 | .01127 |
| J | 1030 | 7,380 | 13.50 | 99,630 | 38.00 | .01034 |
| K | 1712 | 11,000 | 13.50 | 148,500 | 42.83 | .01153 |
| L | 2279 | 14,798 | 5.40 | 79,909 | 54.16 | .02852 |
| M | 971 | 7,372 | 13.50 | 99,522 | 41.50 | .00976 |
| N | 2408 | 14,600 | 13.50 | 197,100 | 48.00 | .012217 |
| O | 3442 | 24,000 | 6.38 | 153,120 | 70.33 | .02248 |
| P | 1776 | 15,600 | 10.50 | 163,800 | 50.00 | .01084 |

ESTIMATE OF LANDING GEAR WEIGHT BY EXISTING FORMULAS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Model | LDG.G.W. | .035W | LDG.LD.FAC. | STRUT LENG, $\ell$ | $.0003\frac{\ell nW}{12}$ | $W_{L.G.}(3+6)$ |
| A | 7,406 | 259.2 | 7 | 31.00 | 40.2 | 299.4 |
| B | 10,739 | 375.9 | 7 | 33.75 | 63.4 | 439.3 |
| C | 7,500 | 262.5 | 7 | 31.00 | 40.7 | 303.2 |
| D | 3,632 | 127.1 | 7 | 28.80 | 18.3 | 145.4 |
| E | 13,823 | 483.8 | 6 | 55.00 | 114.0 | 595.8 |
| F | 4,227 | 147.9 | 6 | 36.00 | 22.8 | 170.7 |
| G | 4,440 | 155.4 | 6 | 49.00 | 32.6 | 188.0 |
| H | 8,000 | 280.0 | 6 | 55.70 | 66.8 | 346.8 |
| I | 9,600 | 336.0 | - | - | - | - |
| J | 6,000 | 210.0 | 5 | 66.00 | 49.5 | 259.5 |
| K | 11,000 | 385.0 | 7 | 57.00 | 109.7 | 494.7 |
| L | 14,000 | 490.0 | 4.9 | 65.50 | 112.3 | 602.3 |
| M | 7,590 | 265.7 | 5.4 | 37.50 | 38.4 | 304.1 |
| N | 15,500 | 542.5 | 5.4 | 37.50 | 78.5 | 621.0 |
| O | 24,000 | 840.0 | 3.75 | 58.60 | 131.9 | 971.9 |
| P | 14,545 | 509.1 | 5.4 | 43.90 | 86.20 | 595.3 |

ERROR IN EXISTING FORMULA FOR ESTIMATING LANDING GEAR WEIGHT

| Model | ACT.WT. | ESTIMATED | $\Delta W$ | $\Delta W^2$ |
|---|---|---|---|---|
| A | 377 | 299.4 | 77.6 | 6,021 |
| B | 775 | 439.3 | 335.7 | 112,694 |
| C | 484 | 303.2 | 180.8 | 32,689 |
| D | 229 | 145.4 | 83.6 | 6,989 |
| E | 965 | 595.8 | 369.2 | 136,309 |
| F | 248 | 170.7 | 77.3 | 5,975 |
| G | 403 | 188.0 | 215.0 | 46,225 |
| H | 690 | 346.8 | 343.2 | 117,786 |
| J | 320 | 259.5 | 60.5 | 3,660 |
| K | 671 | 494.7 | 176.3 | 31,082 |
| L | 854 | 602.3 | 251.7 | 63,353 |
| M | 536 | 304.1 | 231.9 | 53,778 |
| N | 1001 | 621.0 | 380.0 | 144,400 |
| O | 1633 | 971.9 | 661.1 | 437,053 |
| P | 883 | 595.3 | 287.7 | 82,771 |
| | 10069 | | | 1,280,785 |

PROBABLE ERROR OF ESTIMATE:

$$PE = \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma\Delta} \; \frac{15}{\Sigma I}$$

$$= .1803 \times 1131.7 \times (15/10,069) = 30.4\%$$

# APPENDIX II

## CALCULATIONS FOR PRIMARY WEIGHT VARIATION

# STRAIGHT LINE TREND

WING WEIGHT
vs. DESIGN GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y′ | $\Delta y$ | $\Delta y^2$ |
| A | 7,406 | 873 | 6,465,438 | 54,848,836 | 1090 | 1025 | 152 | 23,104 |
| B | 10,550 | 1815 | 19,148,250 | 111,302,500 | 1553 | 1488 | 327 | 106,929 |
| C | 9,139 | 1123 | 10,263,097 | 83,521,321 | 1345 | 1280 | 157 | 24,649 |
| D | 3,400 | 429 | 1,458,600 | 11,560,000 | 501 | 436 | 7 | 49 |
| E | 12,700 | 1745 | 22,161,500 | 161,290,000 | 1870 | 1805 | 60 | 3,600 |
| F | 4,167 | 623 | 2,596,041 | 17,363,889 | 614 | 549 | 74 | 5,476 |
| G | 5,280 | 697 | 3,680,160 | 27,878,400 | 777 | 712 | 15 | 225 |
| H | 8,000 | 955 | 7,640,000 | 64,000,000 | 1178 | 1113 | 158 | 24,964 |
| I | 9,600 | 1300 | 12,480,000 | 92,160,000 | 1414 | 1349 | 49 | 2,401 |
| J | 7,380 | 1100 | 8,118,000 | 54,464,400 | 1087 | 1022 | 78 | 6,084 |
| K | 11,000 | 1712 | 18,832,000 | 121,000,000 | 1620 | 1555 | 157 | 24,649 |
| L | 14,798 | 2279 | 33,724,642 | 218,980,804 | 2179 | 2114 | 165 | 27,225 |
| M | 7,372 | 971 | 7,158,212 | 54,346,384 | 1085 | 1020 | 49 | 2,401 |
| N | 14,600 | 2408 | 35,156,800 | 213,160,000 | 2150 | 2085 | 323 | 104,329 |
| O | 24,000 | 3442 | 82,608,000 | 576,000,000 | 3534 | 3469 | 27 | 729 |
| P | 15,600 | 1776 | 27,705,600 | 243,360,000 | 2297 | 2232 | 456 | 207,936 |
| | 164,992 | 23248 | 299,196,340 | 2,105,236,534 | | | | 564,750 |

CALCULATION OF STRAIGHT LINE a and b:

$$23{,}248 = 16a + 164{,}992b \quad (k = 10{,}312)$$
$$299{,}196{,}340 = 164{,}992a + 2{,}105{,}236{,}534b$$

$$b = \frac{-23{,}248(10{,}312) + 299{,}196{,}340}{403{,}839{,}030} = .147244222$$

$$a = \frac{23{,}248 - .147244225(164{,}992)}{16}$$

$$a = -65.4$$

$$y = a + bx = -65.4 + .147244222x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\;\frac{n}{\Sigma 3}$$

$$= .1742 \times 751.6\;\frac{16}{23{,}248}$$

$$PE = 9.03\%$$

WING WEIGHT
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 2.94101 | 11.380473 | 14.973649 | 4.069711 | 3.005086 | .064076 | .004106 |
| B | 4.02325 | 3.25888 | 13.111289 | 16.186541 | 4.231328 | 3.166703 | .092177 | .008497 |
| C | 3.96090 | 3.05038 | 12.082250 | 15.688729 | 4.165754 | 3.101129 | .050749 | .002575 |
| D | 3.53148 | 2.63246 | 9.296470 | 12.471351 | 3.714125 | 2.649500 | .017040 | .000290 |
| E | 4.10380 | 3.24180 | 13.303699 | 16.841174 | 4.316044 | 3.251419 | .009619 | .000093 |
| F | 3.61982 | 2.79449 | 10.115551 | 13.103097 | 3.807033 | 2.742408 | .052080 | .002713 |
| G | 3.72263 | 2.84323 | 10.584293 | 13.857974 | 3.915161 | 2.850536 | .007306 | .000053 |
| H | 3.90309 | 2.98000 | 11.633622 | 15.240435 | 4.104954 | 3.040329 | .060329 | .003640 |
| I | 3.98227 | 3.11394 | 12.400550 | 15.858474 | 4.188229 | 3.123604 | .009664 | .000093 |
| J | 3.86806 | 3.04139 | 11.764279 | 14.961888 | 4.068112 | 3.003487 | .037903 | .001437 |
| K | 4.04139 | 3.23350 | 13.067835 | 16.332833 | 4.250407 | 3.185782 | .047718 | .002277 |
| L | 4.17026 | 3.35774 | 14.002649 | 17.391068 | 4.385942 | 3.321317 | .036423 | .001327 |
| M | 3.86759 | 2.98722 | 11.553342 | 14.958252 | 4.067618 | 3.002993 | .015773 | .000249 |
| N | 4.16435 | 3.38166 | 14.082416 | 17.341811 | 4.379726 | 3.315101 | .066559 | .004430 |
| O | 4.38021 | 3.53681 | 15.491971 | 19.186240 | 4.606750 | 3.542125 | .005315 | .000028 |
| P | 4.19033 | 3.24944 | 13.616266 | 17.558866 | 4.407049 | 3.342424 | .092984 | .008646 |
| | 63.39901 | 49.64395 | 197.485865 | 251.952382 | | | | .040436 |

CALCULATION OF STRAIGHT LINE a and b:

$$49.643950 = 16a + 63.39901b \quad (k = 3.962348)$$
$$197.486965 = 63.39901a + 251.952382b$$

$$.775891 = 0.737736b$$

$$b = 1.051719$$

$$\log a = \frac{49.643950 - 66.841196}{16}$$

$$\log a = -1.0646246$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\sum 9} - 1$$

$$= \log^{-1} .1742 \times .20108 - 1$$

$$= \log^{-1} .03503 - 1$$

$$PE = 8.40\%$$

$$y = a\,(W)^b = .08617383W^{1.051719}$$

STRAIGHT LINE TREND

USEFUL LOAD
vs. ACTUAL GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | ACT.GW | USE.LD | 2 x 3 | $2^2$ | 2b | y' | Δy | $\Delta y^2$ |
| A | 7,380 | 1771 | 13,069,980 | 54,464,400 | 2119.5 | 1,841.8 | 70.8 | 5,012.6 |
| B | 10,734 | 2879 | 30,903,186 | 115,218,756 | 3082.8 | 3,805.1 | 73.9 | 5,461.2 |
| C | 8,890 | 1800 | 16,002,000 | 79,032,100 | 2553.2 | 2,275.5 | 475.5 | 226,100.3 |
| D | 3,671 | 816 | 2,995,536 | 13,476,241 | 1054.3 | 776.6 | 39.4 | 1,552.4 |
| E | 12,947 | 2820 | 36,510,540 | 167,624,809 | 3718.4 | 3,440.8 | 620.8 | 385,392.6 |
| F | 4,302 | 1015 | 4,366,530 | 18,507,204 | 1235.5 | 957.8 | 57.2 | 3,271.8 |
| G | 5,280 | 1233 | 6,510,240 | 27,878,400 | 1516.4 | 1,238.7 | 5.7 | 32.5 |
| H | 9,650 | 2447 | 23,613,550 | 93,122,500 | 2771.5 | 2,493.8 | 46.8 | 2,190.2 |
| I | 9,600 | 2327 | 22,339,200 | 92,160,000 | 2757.1 | 2,479.4 | 152.4 | 23,225.8 |
| J | 7,380 | 1604 | 11,837,520 | 54,464,400 | 2119.6 | 1,841.9 | 237.9 | 56,596.4 |
| K | 11,423 | 2472 | 28,237,656 | 130,484,929 | 3280.7 | 3,003.0 | 531.0 | 28,196.1 |
| L | 15,530 | 5092 | 79,078,760 | 241,180,900 | 4460.3 | 4,182.6 | 909.4 | 827,008.4 |
| M | 8,995 | 2751 | 24,745,245 | 80,910,025 | 2583.4 | 2,305.7 | 445.3 | 198,292.1 |
| N | 17,707 | 5216 | 92,359,712 | 313,537,849 | 5085.5 | 4,807.8 | 408.2 | 166,627.2 |
| O | 23,281 | 5415 | 126,066,615 | 542,004,961 | 6686.4 | 6,408.7 | 993.7 | 987,439.7 |
| P | 15,936 | 5501 | 87,663,936 | 253,956,096 | 4576.9 | 4,299.2 | 1,201.8 | 1,444,323.2 |
| | 172,706 | 45159 | 606,300,206 | 2,278,023,570 | | | | 4,360,722.5 |

CALCULATION OF STRAIGHT LINE **a** and b:

45,159 = 16a + 172,706b (k = 10,794.125)
606,300,206 = 172,706a + 2,278,023,570b
118,848,315 = 413,813,418b

b = .28720266

$$a = \frac{45,159 - 49,601.6}{16}$$

a = -277.66

U.L. = a + bW = -278 + 0.2872W

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\ \frac{16}{\Sigma 3}$$

$$= .1742 \times 2088.24\ \frac{16}{45159}$$

PE = 12.88%

USEFUL LOAD
vs. ACTUAL GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86806 | 3.24822 | 12.564310 | 14.961888 | 4.392221 | 3.251707 | .003487 | .000012 |
| B | 4.02976 | 3.45924 | 13.939910 | 16.238986 | 4.575833 | 3.435319 | .023921 | .000572 |
| C | 3.94890 | 3.25527 | 12.854736 | 15.593811 | 4.484015 | 3.343501 | .088231 | .007785 |
| D | 3.56478 | 2.91169 | 10.379534 | 12.707656 | 4.047843 | 2.907329 | .004361 | .000019 |
| E | 4.11217 | 3.45025 | 14.188015 | 16.909942 | 4.669410 | 3.528896 | .078646 | .006185 |
| F | 3.63367 | 3.00647 | 10.924520 | 13.203558 | 4.126069 | 2.985555 | .020915 | .000437 |
| G | 3.72263 | 3.09096 | 11.506500 | 13.857974 | 4.227084 | 3.086570 | .004390 | .000019 |
| H | 3.97543 | 3.38863 | 13.471261 | 15.804044 | 4.514141 | 3.373627 | .015003 | .000225 |
| I | 3.98227 | 3.36680 | 13.407507 | 15.858474 | 4.521907 | 3.381393 | .014593 | .000213 |
| J | 3.86806 | 3.20520 | 12.397906 | 14.961888 | 4.392221 | 3.251707 | .046507 | .002163 |
| K | 4.05778 | 3.39305 | 13.768250 | 16.465579 | 4.60750 | 3.467136 | .074085 | .005489 |
| L | 4.1917 | 3.70689 | 15.536206 | 17.565906 | 4.759115 | 3.618601 | .088289 | .007795 |
| M | 3.95400 | 3.43949 | 13.599743 | 15.634116 | 4.489807 | 3.349293 | .090197 | .008135 |
| N | 4.24815 | 3.71734 | 15.791818 | 18.046778 | 4.823817 | 3.683303 | .034037 | .001159 |
| O | 4.36702 | 3.73360 | 16.304706 | 19.070864 | 4.958795 | 3.818281 | .084681 | .007171 |
| P | 4.20238 | 3.74044 | 15.718750 | 17.659998 | 4.771845 | 3.631331 | .109109 | .011905 |
| | 63.72623 | 54.11354 | 216.353672 | 254.541442 | | | | .059284 |

CALCULATION OF STRAIGHT LINE a and b:

54.11354 = 16a + 63.72623b  (1 = 3.982889)
216.353672 = 63.72623a + 254.541442b

.825449 = .726941b

b = 1.135510

$\log a = \frac{-18.248231}{16}$

log a = -1.140514

a = 0.072358    $y = .072358W^{1.135510}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$

$= \log^{-1} .1742 \times .2435 - 1$

$= \log^{-1} .04242 - 1$

PE = 10.26%

STRAIGHT LINE TREND

USEFUL LOAD
vs. GROSS WEIGHT (FIGHTER ONLY)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Fighters | $x$ | $y$ | $xy$ | $x^2$ | $bx$ | $y'$ | $\Delta y$ | $\Delta y^2$ |
| A | 7,380 | 1,771 | 13,069,980 | 54,646,400 | 1705 | 1714 | 57 | 3,249 |
| B | 10,734 | 2,879 | 30,903,186 | 115,218,756 | 2480 | 2489 | 447 | 199,809 |
| C | 8,890 | 1,800 | 16,002,000 | 79,032,100 | 2054 | 2063 | 263 | 69,169 |
| D | 3,671 | 816 | 2,995,536 | 13,476,241 | 848 | 857 | 41 | 1,681 |
| E | 12,947 | 2,820 | 36,510,540 | 167,624,809 | 2991 | 3000 | 180 | 32,400 |
| F | 4,302 | 1,015 | 4,366,530 | 18,507,204 | 994 | 1003 | 12 | 144 |
| G | 5,280 | 1,233 | 6,510,240 | 27,878,400 | 1220 | 1229 | 4 | 16 |
| H | 9,650 | 2,447 | 23,613,550 | 93,122,500 | 2229 | 2238 | 209 | 43,681 |
| I | 9,600 | 2,327 | 22,339,200 | 92,160,000 | 2218 | 2227 | 100 | 10,000 |
| J | 7,380 | 1,604 | 11,837,520 | 54,464,400 | 1705 | 1714 | 110 | 12,100 |
| K | 11,423 | 2,472 | 28,237,656 | 130,484,929 | 2639 | 2648 | 176 | 30,976 |
| | 91,257 | 21,184 | 196,365,938 | 846,433,739 | | | | 403,225 |

CALCULATION OF STRAIGHT LINE a and b:

$$21,184 = 11a + 91,257b \quad (k = 8,296.091)$$
$$196,385,938 = 91,257a + 846,433,739b$$
$$20,641,548 = 0 + 34,892,971b$$

$$b = .230999947$$

$$a = \frac{21,184 - 21,080}{11}$$

$$a = 9.454545$$

$$y = a + bx = 9.4545 + .2309999x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} \; \frac{11}{\Sigma 3}$$

$$= .2133 \times 634.23 \times \frac{11}{21,184}$$

$$= 7.02\%$$

## STRAIGHT LINE TREND

USEFUL LOAD
vs. ACTUAL GROSS WEIGHT (FIGHTERS ONLY)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86806 | 3.24822 | 9.969354 | 14.973649 | 4.666927 | 3.227681 | .020539 | .000422 |
| B | 4.02976 | 3.45924 | 11.646653 | 16.248639 | 4.862022 | 3.422777 | .036463 | .001330 |
| C | 3.94890 | 3.25527 | 10.403955 | 15.016090 | 4.764462 | 3.325217 | .069947 | .004893 |
| D | 3.56478 | 2.91169 | 8.401384 | 12.674668 | 4.301010 | 2.861765 | .049925 | .002493 |
| E | 4.11217 | 3.45025 | 12.357745 | 17.144568 | 4.961452 | 3.522207 | .071957 | .005178 |
| F | 3.63367 | 3.00647 | 8.682348 | 13.148094 | 4.384128 | 2.944883 | .061587 | .003793 |
| G | 3.72263 | 3.09096 | 9.502556 | 13.303381 | 4.491461 | 3.052216 | .038744 | .001501 |
| H | 3.97534 | 3.38863 | 11.181577 | 15.513909 | 4.796363 | 3.357118 | .009682 | .000094 |
| I | 3.98227 | 3.36680 | 10.659302 | 15.858474 | 4.804724 | 3.365479 | .001321 | .000002 |
| J | 3.86806 | 3.20520 | 9.464832 | 14.274417 | 4.666927 | 3.227681 | .022481 | .000505 |
| K | 4.05778 | 3.39305 | 11.423878 | 16.332833 | 4.894829 | 3.455584 | .062534 | .003911 |
| | 42.77351 | 35.77578 | 139.402449 | 166.563780 | | | | .024122 |

### CALCULATION OF STRAIGHT LINE a and b:

35.77578 = 11a + 42.77351b (k = 3.888501)
139.402449 = 42.77351a + 166.563780

.288893 = .238944b

b = 1.206529

$\log a = \frac{-15.831700}{11}$

log a = -1.439245

a = 0.03637

$U.L. = a(W)^b = 0.03637(W)^{1.20653}$

### CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$

= .2133 x .1553 - 1

= .033125 - 1

PE = 7.92%

FIXED EQUIPMENT
vs. ACTUAL GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | ACT.GW | FIXED EQ. | 2 x 3 | $2^2$ | 2b | y' | $\Delta y$ | $\Delta y^2$ |
| A | 7,380 | 821 | 6,058,980 | 54,464,400 | 737.0 | 794.5 | 26.5 | 702 |
| B | 10,734 | 1115 | 11,946,942 | 115,218,756 | 1071.9 | 1129.4 | 16.4 | 269 |
| C | 8,890 | 1015 | 9,023,350 | 79,032,100 | 887.7 | 945.2 | 69.8 | 4,872 |
| D | 3,671 | 463 | 1,699.673 | 13,476,241 | 366.6 | 424.1 | 38.9 | 1,513 |
| E | 12,947 | 1030 | 13,335,410 | 167,624,809 | 1292.9 | 1350.4 | 320.4 | 102,656 |
| F | 4,302 | 559 | 2,404,818 | 18,507,204 | 429.6 | 487.1 | 71.9 | 5,170 |
| G | 5,280 | 688 | 3,632,640 | 27,878,400 | 527.2 | 584.7 | 102.3 | 10,465 |
| H | 9,650 | 898 | 8,665,700 | 93,122,500 | 963.6 | 1021.1 | 123.1 | 15,154 |
| I | 9,600 | 1093 | 10,492,800 | 92,160,000 | 958.6 | 1016.1 | 76.9 | 5,914 |
| J | 7,380 | 756 | 5,579,280 | 54,464,400 | 737.0 | 794.5 | 38.5 | 1,482 |
| K | 11,423 | 929 | 10,611,967 | 130,484,929 | 1140.7 | 1198.2 | 259.2 | 72,469 |
| L | 15,530 | 2008 | 31,184,240 | 241,180,900 | 1550.8 | 1608.3 | 399.7 | 159,760 |
| M | 8,995 | 1050 | 9,444,750 | 80,910,025 | 898.2 | 955.7 | 94.3 | 8,892 |
| N | 17,707 | 1543 | 27,321,901 | 313,537,849 | 1768.2 | 1825.7 | 282.7 | 79,919 |
| O | 23,281 | 2597 | 60,460,757 | 542,004,961 | 2324.8 | 2382.3 | 213.8 | 45,710 |
| P | 15,936 | 1603 | 25,545,408 | 253,956,096 | 1591.3 | 1648.8 | 45.8 | 2,098 |
| | 172,706 | 18166 | 237,408,616 | 2,278,023,570 | | | | 517,045 |

CALCULATION OF STRAIGHT LINE a and b:

$$18,166 = 16a + 172,706b \quad (k = 10,794,125)$$
$$237,408,616 = 172,706a + 2,278,023,570b$$
$$41,322,541 = 413,813,418b$$
$$b = .0998579$$
$$a = \frac{18,166 - 17,246.06}{16}$$
$$a = 57.50$$

F.E. = 57.5 + 0.099858W

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\ \frac{16}{\Sigma 3}$$
$$= .1742 \times 719.06 \times \frac{16}{18,166}$$
$$= 11.03\%$$

FIXED EQUIPMENT
vs. ACTUAL GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86806 | 2.91434 | 11.272842 | 14.961888 | 3.257843 | 2.915842 | .001502 | .000002 |
| B | 4.02976 | 3.04650 | 12.276664 | 16.238966 | 3.394033 | 3.052032 | .005532 | .000031 |
| C | 3.94890 | 3.00647 | 11.872249 | 15.593811 | 3.325929 | 2.983928 | .022542 | .000508 |
| D | 3.56478 | 2.66558 | 9.502206 | 12.707656 | 3.002407 | 2.660406 | .005174 | .000027 |
| E | 4.11217 | 3.01284 | 12.389310 | 16.909942 | 3.463442 | 3.121441 | .108601 | .011794 |
| F | 3.63367 | 2.74741 | 9.983181 | 13.203558 | 3.060429 | 2.718428 | .028982 | .000840 |
| G | 3.72265 | 2.83759 | 10.563300 | 13.857974 | 3.135355 | 2.793354 | .044236 | .001957 |
| H | 3.97543 | 2.95328 | 11.740558 | 15.804044 | 3.348274 | 3.006273 | .052993 | .002808 |
| I | 3.98227 | 3.03862 | 12.100605 | 15.858474 | 3.354025 | 3.012024 | .026596 | .000707 |
| J | 3.86806 | 2.87362 | 11.134288 | 14.961888 | 3.257843 | 2.915842 | .037322 | .001393 |
| K | 4.05778 | 2.96802 | 12.043572 | 16.465579 | 3.417643 | 3.075642 | .107622 | .011582 |
| L | 4.19117 | 3.30276 | 13.842429 | 17.565906 | 3.529979 | 3.187978 | .114782 | .013175 |
| M | 3.95400 | 3.02119 | 11.945785 | 15.634116 | 3.330225 | 2.988224 | .032966 | .001087 |
| N | 4.24815 | 3.18837 | 13.544674 | 18.046778 | 3.57790 | 3.235969 | .047599 | .002266 |
| O | 4.36702 | 3.41447 | 14.911059 | 19.070864 | 3.678088 | 3.336087 | .088383 | .007812 |
| P | 4.20238 | 3.20493 | 13.468334 | 17.659998 | 3.539421 | 3.197420 | .007510 | .000056 |
| | 63.72623 | 48.20089 | 192.591056 | 254.541442 | | | | .056045 |

CALCULATION OF STRAIGHT LINE a and b:

48.20089 = 16a + 63.72623b (k = 3.982889)
192.591056 = 63.72623a + 254.541442b

.612261 = .72694ab

b = .842242

$\log a = \frac{-5.472017}{16}$

log a = -.342001

$a = 0.454969\ y = .454969W^{.842242}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{[illegible]} - 1$

$= \log^{-1} .1742 \times .2367 - 1$

= .04123 - 1

PE = 9.96%

## STRAIGHT LINE TREND

FIXED EQUIPMENT + USEFUL LOAD
vs. ACTUAL GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | ACT.GW | F.E.+U.L. | 2 x 3 | $2^2$ | 2b | y' | Δy | $\Delta y^2$ |
| A | 7,380 | 2592 | 19,128,960 | 54,464,400 | 2838.7 | 2644.7 | 52.7 | 2,777 |
| B | 10,734 | 3992 | 42,850,128 | 115,218,756 | 4128.8 | 3934.8 | 57.2 | 3,272 |
| C | 8,890 | 2815 | 25,025,350 | 79,032,100 | 3419.5 | 3225.5 | 410.5 | 168,510 |
| D | 3,671 | 1280 | 4,698,880 | 13,476,241 | 1412.0 | 1218.0 | 62.0 | 3,844 |
| E | 12,947 | 3850 | 49,845,950 | 167,624,809 | 4980.0 | 4786.0 | 936.0 | 876,096 |
| F | 4,302 | 1574 | 6,771,348 | 18,507,204 | 1654.7 | 1460.7 | 113.3 | 12,837 |
| G | 5,280 | 1921 | 10,142,880 | 27,878,400 | 2030.9 | 1836.9 | 84.1 | 7,073 |
| H | 9,650 | 3345 | 32,279,250 | 93,122,500 | 3711.8 | 3517.8 | 172.8 | 29,860 |
| I | 9,600 | 3420 | 32,832,000 | 92,160,000 | 3692.6 | 3498.6 | 78.6 | 6,178 |
| J | 7,380 | 2360 | 17,416,800 | 54,464,400 | 2838.7 | 2644.7 | 284.7 | 81,054 |
| K | 11,423 | 3401 | 38,849,623 | 130,484,929 | 4393.8 | 4199.8 | 798.8 | 638,081 |
| L | 15,530 | 7100 | 110,263,000 | 241,180,900 | 5973.6 | 5779.6 | 1320.4 | 1,743,456 |
| M | 8,995 | 3801 | 34,189,995 | 80,910,025 | 3459.9 | 3265.9 | 535.1 | 286,332 |
| N | 17,707 | 6759 | 119,681,613 | 313,537,849 | 6810.9 | 6616.9 | 142.1 | 20,192 |
| O | 23,231 | 8012 | 186,535,384 | 542,004,961 | 8954.9 | 8760.9 | 748.9 | 560,851 |
| P | 15,936 | 7104 | 113,209,344 | 253,956,096 | 6129.7 | 5935.7 | 1169.0 | 1,366,561 |
| | 172,706 | 63326 | 842,702,505 | 2,278,023,570 | | | | 5,806,974 |

CALCULATION OF STRAIGHT LINE a and b:

63,326 = 16a + 172,706b    (k = 10,794,125)
842,720,505 = 172,706a + 2,278,023,570b

159,171,745 = 415,813,418b

b = .38464 62

$$a = \frac{63,326 - 66,430.7}{16}$$

a = -194.04

F. E. + U. L. = -194 + 0.38464W

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} \quad \frac{16}{\Sigma 3}$$

$$= .1742 \times 2409.76 \times \frac{16}{63,326}$$

PE = 10.60%

FIXED EQUIPMENT + USEFUL LOAD
vs. ACTUAL GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86806 | 3.41363 | 13.204126 | 14.961888 | 4.050253 | 3.418308 | .004678 | .000022 |
| B | 4.02976 | 3.60119 | 14.511931 | 16.238996 | 4.219570 | 3.587625 | .013565 | .000184 |
| C | 3.94890 | 3.44948 | 13.621652 | 15.593811 | 4.134901 | 3.502956 | .053476 | .002860 |
| D | 3.56478 | 3.10721 | 11.076520 | 12.707656 | 3.732688 | 3.100743 | .006467 | .000042 |
| E | 4.11217 | 3.58546 | 14.744021 | 16.909942 | 4.305861 | 3.673916 | .088456 | .007824 |
| F | 3.63367 | 3.19700 | 11.616843 | 13.203558 | 3.804823 | 3.172878 | .024122 | .000582 |
| G | 3.72263 | 3.28353 | 12.223367 | 13.857974 | 3.897973 | 3.266028 | .017502 | .000306 |
| H | 3.97543 | 3.52440 | 14.011005 | 15.804044 | 4.162681 | 3.530736 | .006336 | .000040 |
| I | 3.98227 | 3.53403 | 14.073462 | 15.858474 | 4.169843 | 3.537898 | .003868 | .000015 |
| J | 3.86806 | 3.37291 | 13.046618 | 14.961888 | 4.050253 | 3.418308 | .045398 | .002061 |
| K | 4.05778 | 3.53161 | 14.330496 | 16.465579 | 4.248910 | 3.616965 | .085355 | .007285 |
| L | 4.19117 | 3.85126 | 16.141285 | 17.565906 | 4.388582 | 3.756637 | .094623 | .008954 |
| M | 3.95400 | 3.57990 | 15.154925 | 15.634116 | 4.140241 | 3.508296 | .071504 | .005127 |
| N | 4.24815 | 3.82988 | 16.269905 | 18.046778 | 4.448246 | 3.816301 | .013579 | .000184 |
| O | 4.36702 | 3.90374 | 17.047711 | 19.070864 | 4.572715 | 3.940770 | .037030 | .001371 |
| P | 4.20238 | 3.85150 | 16.185467 | 17.659998 | 4.400321 | 3.768376 | .083124 | .006910 |
| | 63.72623 | 56.61673 | 226.259334 | 254.541442 | | | | .045767 |

CALCULATION OF STRAIGHT LINE a and b:

56.61673 = 16a + 63.72623b (k = 3.982889)
226.259334 = 63.72623a + 254.541442b

.761183 = .726942b

b = 1.047102

$\log a = \frac{-10.111133}{16}$

log a = -.631945

a = 0.233372    $y = .233372x^{1.047102}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$

$= \log^{-1} .1742 \times .2092 - 1$

$PE = \log^{-1} .03644 - 1$

PE = 8.75%

STRAIGHT LINE TREND

FIXED EQUIPMENT AND USEFUL LOAD
vs. ACTUAL GROSS WEIGHT (EFFICIENT AIRCRAFT ONLY)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2 x 3 | $2^2$ | (2)b | log y' | Δlog y | (Δlog y)$^2$ |
| A | 3.86806 | 3.41363 | 13.204126 | 14.961888 | 4.117828 | 3.439106 | .025476 | 649 |
| B | 4.02976 | 3.60119 | 14.511931 | 16.238996 | 4.289970 | 3.611248 | .010058 | 101 |
| D | 3.56478 | 3.10721 | 11.076520 | 12.707656 | 3.794965 | 3.116243 | .009033 | 82 |
| F | 3.63367 | 3.19700 | 11.616843 | 13.203558 | 3.868303 | 3.189581 | .007419 | 55 |
| G | 3.72263 | 3.28353 | 12.223367 | 13.857974 | 3.963008 | 3.284286 | .000756 | 1 |
| H | 3.86543 | 3.52440 | 14.011005 | 15.804044 | 4.232131 | 3.553409 | .029009 | 842 |
| I | 3.98227 | 3.53403 | 14.073462 | 15.858474 | 4.239413 | 3.560691 | .026661 | 711 |
| L | 4.19117 | 3.85126 | 16.141285 | 17.565906 | 4.461802 | 3.783080 | .068180 | 4649 |
| M | 3.95400 | 3.57990 | 14.154925 | 15.634116 | 4.209318 | 3.530596 | .049304 | 2431 |
| N | 4.24815 | 3.82988 | 16.269905 | 18.046778 | 4.522462 | 3.843740 | .013860 | 192 |
| O | 4.36702 | 3.90374 | 17.047711 | 19.070864 | 4.649007 | 3.970285 | .066545 | 4428 |
| P | 4.20238 | 3.85150 | 16.185467 | 17.659998 | 4.473736 | 3.795014 | .056486 | 3191 |
| | 47.739320 | 42.677270 | 170.516547 | 190.610222 | | | | .017332 |

CALCULATION OF STRAIGHT LINE a and b:

$$42.677270 = 12a + 47.739320b \quad (k = 3.978276)$$
$$170.516547 = 47.739320a + 190.610222b$$

$$.734588 = .690031b$$

$$b = 1.064572$$

$$\log a = \frac{-8.144673}{12}$$

$$\log a = -.678722$$

$$a = .20955$$

$$y = a(W)^b = .20955W^{1.064572}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\sum 9} - 1$$

$$= \log^{-1} .2034 \times .1317 - 1$$

$$= .02678 - 1$$

$$PE = 6.33\%$$

MAIN LANDING GEAR
vs. LANDING GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | Δy | $Δy^2$ |
| A | 7,406 | 377 | 2,792,062 | 54,848,836 | 438 | 496 | 119 | 14,161 |
| B | 10,739 | 775 | 8,322,725 | 115,326,121 | 634 | 692 | 83 | 6,889 |
| C | 7,500 | 484 | 3,630,000 | 56,250,000 | 443 | 501 | 17 | 289 |
| D | 3,632 | 229 | 831,728 | 13,191,424 | 215 | 273 | 44 | 1,936 |
| E | 13,823 | 965 | 16,791,000 | 302,760,000 | 817 | 875 | 90 | 8,100 |
| F | 4,227 | 248 | 1,048,296 | 17,867,529 | 250 | 308 | 60 | 3,600 |
| G | 4,440 | 403 | 1,789,320 | 19,713,600 | 262 | 320 | 83 | 6,889 |
| H | 8,685 | 690 | 5,992,650 | 75,429,225 | 513 | 571 | 119 | 14,161 |
| I | 9,600 | 475 | 4,560,000 | 92,160,000 | 567 | 625 | 150 | 22,500 |
| J | 6,000 | 320 | 1,920,000 | 36,000,000 | 354 | 412 | 92 | 8,464 |
| K | 11,000 | 671 | 7,391,000 | 121,000,000 | 650 | 708 | 37 | 1,369 |
| L | 14,000 | 854 | 11,956,000 | 196,000,000 | 827 | 885 | 31 | 961 |
| M | 7,590 | 536 | 4,068,240 | 57,608,100 | 448 | 506 | 30 | 900 |
| N | 15,500 | 1,001 | 15,515,500 | 240,250,000 | 916 | 974 | 27 | 729 |
| O | 24,000 | 1,633 | 31,192,000 | 576,000,000 | 1,418 | 1,476 | 157 | 24,649 |
| P | 15,545 | 883 | 12,843,235 | 211,557,025 | 859 | 917 | 34 | 1,156 |
| | 162,687 | 10,544 | 138,633,756 | 2,185,961,860 | | | | 116,753 |

CALCULATION OF STRAIGHT LINE a and b:

$$10,544 = 16a + 162,687b$$
$$138,633,756 = 162,687a + 2,185,860b \quad (k = .00009834836)$$
$$13,634 = 214,986b$$

$$3,090 = 52,299b$$

$$b = 0.059083$$

$$a = \frac{10,544 - 9,612}{16} = \frac{932}{16}$$

$$= 58.250$$

$$y = 58.250 + .059083x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\ \frac{n}{\Sigma 3}$$

$$= .1742 \times 341.7 \times \frac{16}{10,544}$$

$$= 9.03\%$$

MAIN LANDING GEAR
vs. LANDING GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 2.57634 | 9.969354 | 14.973649 | 3.846630 | 2.677081 | .100741 | .060186 |
| B | 4.03096 | 2.88930 | 11.646653 | 16.248639 | 4.007052 | 2.837503 | .051797 | .002683 |
| C | 3.87506 | 2.68485 | 10.403955 | 15.016090 | 3.852077 | 2.682528 | .002322 | .000005 |
| D | 3.56015 | 2.35984 | 8.401384 | 12.674668 | 3.539035 | 2.369486 | .009646 | .000093 |
| E | 4.14060 | 2.98453 | 12.357745 | 17.144568 | 4.116042 | 2.946493 | .038037 | .001447 |
| F | 3.62603 | 2.39445 | 8.682348 | 13.148094 | 3.604524 | 2.434975 | .040525 | .001642 |
| G | 3.64738 | 2.60531 | 9.502556 | 13.303381 | 3.625747 | 2.456198 | .149112 | .022234 |
| H | 3.93877 | 2.83885 | 11.181577 | 15.513909 | 3.915409 | 2.745860 | .092990 | .008647 |
| I | 3.98227 | 2.67669 | 10.659302 | 15.858474 | 3.958651 | 2.789122 | .112432 | .012641 |
| J | 3.77815 | 2.50515 | 9.464832 | 14.274417 | 3.755742 | 2.586193 | .081043 | .006568 |
| K | 4.04139 | 2.82672 | 11.423878 | 16.332833 | 4.017421 | 2.847872 | .021152 | .000447 |
| L | 4.14613 | 2.93146 | 12.154214 | 17.190394 | 4.121539 | 2.951990 | .020530 | .000421 |
| M | 3.88024 | 2.72916 | 10.589796 | 15.056262 | 3.857226 | 2.687677 | .041483 | .001721 |
| N | 4.19033 | 3.00043 | 12.572792 | 17.558866 | 4.165477 | 2.995928 | .004502 | .000020 |
| O | 4.38021 | 3.21299 | 14.073571 | 19.186240 | 4.354251 | 3.184682 | .028308 | .000801 |
| P | 4.16271 | 2.94596 | 12.263177 | 17.328155 | 4.138021 | 2.968472 | .022512 | .000507 |
| | 63.24996 | 44.16203 | 175.347134 | 250.808639 | | | | .070026 |

CALCULATION OF STRAIGHT LINE a and b:

44.16203 = 16a + 63.24996b (k = 3.953122)
175.347134 = 63.249962 + 250.8086396

.769242 = .773831b

b = .994069

$\log a = \frac{-18.712794}{16}$

log a = -1.169549

a = 0.067677  $y = .067677x^{.994069}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$

$= \log^{-1} .1742 \times .2646 - 1$

$= \log^{-1} .04609 - 1$

PE = 11.20%

ENGINE AND NACELLE GROUP
vs. DESIGN GROSS WEIGHT

## STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | $\Delta y$ | $\Delta y^2$ |
| A | 7,406 | 2589 | 19,174,134 | 54,848,836 | 1984 | 2571 | 18 | 324 |
| B | 10,550 | 2743 | 28,938,650 | 111,302,500 | 2826 | 3413 | 670 | 448,900 |
| C | 9,139 | 3282 | 29,994,198 | 83,521,321 | 2448 | 3035 | 247 | 61,009 |
| D | 3,400 | 1267 | 4,307,800 | 11,560,000 | 911 | 1498 | 231 | 53,361 |
| E | 12,700 | 4845 | 61,531,500 | 161,290,000 | 3402 | 3989 | 856 | 732,736 |
| F | 4,167 | 1161 | 4,796,217 | 17,363,889 | 1116 | 1703 | 552 | 304,704 |
| G | 5,280 | 1560 | 8,236,800 | 27,878,400 | 1414 | 2001 | 441 | 194,481 |
| H | 8,000 | 3366 | 28,528,000 | 64,000,000 | 2143 | 2730 | 836 | 698,896 |
| I | 9,600 | 2753 | 26,429,800 | 92,160,000 | 2571 | 3158 | 405 | 123,525 |
| J | 7,380 | 2825 | 20,848,500 | 54,464,400 | 1977 | 2564 | 261 | 68,121 |
| K | 11,000 | 4376 | 48,136,000 | 121,000,000 | 2946 | 3533 | 843 | 710,649 |
| L | 14,798 | 3507 | 51,896,586 | 218,980,804 | 3963 | 4550 | 1043 | 1,087,849 |
| M | 7,372 | 2790 | 20,567,880 | 54,346,384 | 1975 | 2562 | 228 | 51,984 |
| N | 14,600 | 5025 | 73,365,000 | 213,160,000 | 3910 | 4497 | 528 | 278,784 |
| O | 24,000 | 6862 | 164,688,000 | 576,000,000 | 6428 | 7015 | 153 | 23,409 |
| P | 15,600 | 4438 | 69,232,800 | 243,360,000 | 4175 | 4765 | 327 | 106,929 |
| | 164,992 | 53579 | 660,670,865 | 2,105,236,534 | | | | 4,945,661 |

CALCULATION OF STRAIGHT LINE a and b:

$$53,579 = 16a + 164,992b \quad (k = 10,312)$$
$$660,670,865 = 164,992a + 2,105,236,534b$$

$$b = \frac{-53,579(10312) + 660,670,865}{403,839,030} = .267840$$

$$a = \frac{53,579 - .267840(164,992)}{16}$$

$$a = 586.7$$

$$y = a + bx = 586.7 + .26784x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma_9}\ \frac{n}{\Sigma_3}$$

$$= .1742 \times 2223 \quad \frac{16}{53,579}$$

$$PE = 11.58\%$$

ENGINE AND NACELLE GROUP WEIGHT vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2xz | $z^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 3.41313 | 13.207380 | 14.973649 | 3.521318 | 3.394824 | .018306 | .000335 |
| B | 4.02325 | 3.43823 | 13.832859 | 16.186541 | 3.661158 | 3.534664 | .096434 | .009300 |
| C | 3.96090 | 3.51614 | 13.927079 | 15.688729 | 3.604419 | 3.477926 | .038215 | .001460 |
| D | 3.53148 | 3.10278 | 10.957406 | 12.471351 | 3.213847 | 3.087153 | .015627 | .000244 |
| E | 4.10380 | 3.68529 | 15.123693 | 16.841174 | 3.734458 | 3.607964 | .077326 | .005979 |
| F | 3.61982 | 3.06108 | 11.080559 | 13.103097 | 3.294036 | 3.167542 | .106462 | .011334 |
| G | 3.72263 | 3.19312 | 11.886304 | 13.857974 | 3.387593 | 3.261099 | .067979 | .004621 |
| H | 3.90309 | 3.55213 | 13.864478 | 15.240435 | 3.551812 | 3.425318 | .126862 | .016094 |
| I | 3.96227 | 3.43981 | 13.698252 | 15.858474 | 3.623866 | 3.497372 | .057562 | .003313 |
| J | 3.86806 | 3.45102 | 13.348752 | 14.961888 | 3.519935 | 3.393441 | .057579 | .003315 |
| K | 4.04139 | 3.64108 | 14.715024 | 16.332833 | 3.677665 | 3.551171 | .089909 | .008084 |
| L | 4.17026 | 3.54494 | 14.783321 | 17.391068 | 3.794937 | 3.668443 | .123503 | .015253 |
| M | 3.86759 | 3.44560 | 13.326168 | 14.958252 | 3.519507 | 3.393013 | .052587 | .002765 |
| N | 4.16435 | 3.70114 | 15.412842 | 17.341811 | 3.789559 | 3.663065 | .038075 | .001450 |
| O | 4.38021 | 3.83645 | 16.804457 | 19.186240 | 3.985991 | 3.859497 | .023047 | .000531 |
| P | 4.19033 | 3.64719 | 15.282930 | 17.558868 | 3.813200 | 3.686706 | .039516 | .001562 |
| | 63.39901 | 55.66918 | 221.252004 | 251.952382 | | | | .085640 |

CALCULATION OF STRAIGHT LINE a and b:

$$55.669180 = 16a + 63.39901b \quad (k = 3.962348)$$
$$221.252004 = 63.39901a + 251.952382b$$

$$.671340 = 0.737736b$$

$$b = \frac{.671340}{0.737736} = .910000$$

$$\log a = \frac{-2.023919}{16}$$

$$\log a = -.126494$$

$$a = 0.74733 \qquad y = a\,(W)^b = .74733\,W^{.910000}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .05098 - 1$$

$$PE = 12.4\%$$

FUSELAGE GROUP WEIGHT
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | $\Delta y$ | $\Delta y^2$ |
| A | 7,406 | 622 | 4,606,532 | 54,848,836 | 499 | 583 | 39 | 1521 |
| B | 10,550 | 886 | 9,347,300 | 111,302,500 | 711 | 795 | 91 | 8281 |
| C | 9,139 | 701 | 6,406,439 | 83,521,321 | 616 | 700 | 1 | 1 |
| D | 3,400 | 231 | 785,400 | 11,560,000 | 229 | 313 | 82 | 6724 |
| E | 12,700 | 1058 | 13,436,600 | 161,290,000 | 856 | 940 | 118 | 13924 |
| F | 4,167 | 433 | 1,804,311 | 17,363,889 | 231 | 365 | 68 | 4624 |
| G | 5,280 | 476 | 2,513,280 | 27,878,400 | 356 | 440 | 36 | 1296 |
| H | 8,000 | 509 | 4,072,000 | 64,000,000 | 539 | 623 | 114 | 12996 |
| I | 9,600 | 1140 | 10,944,000 | 92,160,000 | 647 | 731 | 409 | 167281 |
| J | 7,380 | 515 | 3,800,700 | 54,464,400 | 438 | 582 | 67 | 4489 |
| K | 11,000 | 616 | 6,776,000 | 121,000,000 | 742 | 826 | 210 | 44100 |
| L | 14,798 | 1229 | 18,186,742 | 218,980,804 | 998 | 1082 | 147 | 21609 |
| M | 7,372 | 479 | 3,531,188 | 54,346,384 | 497 | 581 | 102 | 10404 |
| N | 14,600 | 1342 | 19,593,200 | 213,160,000 | 984 | 1068 | 274 | 75076 |
| O | 24,000 | 1334 | 32,016,000 | 576,000,000 | 1618 | 1702 | 368 | 135424 |
| P | 15,600 | 894 | 13,946,400 | 243,360,000 | 1052 | 1136 | 242 | 58564 |
| | 164,992 | 12465 | 151,766,092 | 2,105,236,534 | | | | 566314 |

CALCULATION OF STRAIGHT LINE **a** and **b**:

$$12,465 = 16a + 164,992b \quad (k = 10,312)$$
$$151,766,092 = 164,992a + 2,105,236,534b$$

$$27,227,012 = 403,839,030b$$

$$b = .057516$$

$$a = \frac{12,465 - .057516(164,992)}{16}$$

$$a = 185.962$$

$$y = a + bx = 185.962 + .057516x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} \; \frac{n}{\Sigma 3}$$

$$= .1742 \times 725.2 \; \frac{16}{12,465}$$

$$PE = 16.21\%$$

STRAIGHT LINE TREND

FUSELAGE WEIGHT
vs. DESIGN GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 2.79379 | 10.810794 | 14.973649 | 3.382690 | 2.764344 | .030446 | .000927 |
| B | 4.02325 | 2.94743 | 11.858248 | 16.186541 | 3.517025 | 2.898679 | .048751 | .002377 |
| C | 3.96090 | 2.84572 | 11.271612 | 15.688729 | 3.462520 | 2.844174 | .001546 | .000002 |
| D | 3.53148 | 2.36361 | 8.347041 | 12.471351 | 3.087132 | 2.468786 | .105176 | .011062 |
| E | 4.10380 | 3.02449 | 12.411902 | 16.841174 | 3.587439 | 2.969093 | .055397 | .003069 |
| F | 3.61982 | 2.63649 | 9.543619 | 13.103097 | 3.164356 | 2.546010 | .090480 | .008187 |
| G | 3.72263 | 2.67761 | 9.967751 | 13.857974 | 3.254230 | 2.635884 | .041726 | .001741 |
| H | 3.90309 | 2.70672 | 10.564572 | 15.240435 | 3.411984 | 2.793638 | .086918 | .007555 |
| I | 3.98227 | 3.05690 | 12.173401 | 15.858474 | 3.481201 | 2.862855 | .194045 | .037653 |
| J | 3.86806 | 2.71181 | 10.489444 | 14.961888 | 3.381361 | 2.763015 | .051205 | .002622 |
| K | 4.04139 | 2.78958 | 11.273781 | 16.332833 | 3.532882 | 2.914536 | .124956 | .015614 |
| L | 4.17026 | 3.08955 | 12.884227 | 17.391068 | 3.645537 | 3.027191 | .062359 | .003889 |
| M | 3.86759 | 2.68034 | 10.366456 | 14.958252 | 3.380950 | 2.752604 | .082264 | .006767 |
| N | 4.16435 | 3.12775 | 13.025046 | 17.341811 | 3.640371 | 3.022025 | .105725 | .011178 |
| O | 4.38021 | 3.12516 | 13.688857 | 19.186240 | 3.829070 | 3.210724 | .085564 | .007321 |
| P | 4.19033 | 2.95134 | 12.367088 | 17.558866 | 3.663082 | 3.044736 | .093396 | .008723 |
| | 63.39901 | 45.52829 | 181.043839 | 251.952382 | | | | .128637 |

CALCULATION OF STRAIGHT LINE a and b:

45.52829 = 16a + 63.39901b (k = 3.962348)
181.043839 = 63.39901a + 251.952382b

$.644910 = 0.737736b$

$b = \frac{.644910}{0.737736} = .8741745$

$\log a = \frac{-9.393539}{16}$

$\log a = -.518346$

$a = 0.240783$

$y = a\,(W)^b = .240783\ W^{.874175}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$

$= \log^{-1} .1742 \times .35873 - 1$

$= \log^{-1} .06249 - 1$

PE = 15.48%

HORIZONTAL TAIL
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | $\Delta y$ | $\Delta y^2$ |
| A | 7,406 | 79 | 585,074 | 54,848,836 | 185 | 116 | 37 | 1369 |
| B | 10,550 | 152 | 1,603,600 | 111,302,500 | 263 | 194 | 42 | 1764 |
| C | 9,139 | 112 | 1,023,568 | 83,521,321 | 228 | 159 | 47 | 2209 |
| D | 3,400 | 42 | 142,800 | 11,560,000 | 85 | 16 | 26 | 676 |
| E | 12,700 | 175 | 2,222,500 | 161,290,000 | 317 | 248 | 73 | 5329 |
| F | 4,167 | 93 | 387,531 | 17,363,889 | 104 | 25 | 58 | 3364 |
| G | 5,280 | 86 | 454,080 | 27,878,400 | 132 | 63 | 23 | 529 |
| H | 8,000 | 120 | 960,000 | 64,000,000 | 199 | 130 | 10 | 100 |
| I | 9,600 | 133 | 1,276,800 | 92,160,000 | 239 | 170 | 37 | 1369 |
| J | 7,380 | 112 | 826,560 | 54,464,400 | 184 | 115 | 3 | 9 |
| K | 11,000 | 202 | 2,222,000 | 121,000,000 | 274 | 205 | 3 | 9 |
| L | 14,798 | 193 | 2,856,014 | 218,980,804 | 369 | 300 | 7 | 49 |
| M | 7,372 | 167 | 1,231,124 | 54,346,384 | 184 | 115 | 52 | 2704 |
| N | 14,600 | 414 | 6,044,400 | 213,160,000 | 364 | 295 | 119 | 14191 |
| O | 24,000 | 566 | 13,584,000 | 576,000,000 | 598 | 529 | 37 | 1369 |
| P | 15,600 | 366 | 5,709,600 | 243,360,000 | 389 | 320 | 46 | 2116 |
| | 164,992 | 3012 | 41,129,651 | 2,105,236,534 | | | | 37156 |

CALCULATION OF STRAIGHT LINE a and b:

$$3,012 = 16a + 164,992b \quad (k = 10,312)$$
$$41,129,651 = 164,992a + 2,105,236,534b$$

$$b = \frac{-3012(10312) + 41,129,651}{403,839,030} = .0249354476$$

$$a = \frac{3012 - .0249354476(164,992)}{16}$$

$$a = -68.88$$

$$y = a + bx = -68.88 + .024935x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\ \frac{n}{\Sigma 3}$$

$$= .1742 \times 1928 \quad \frac{16}{3012}$$

$$PE = 17.84\%$$

HORIZONTAL TAIL WEIGHT
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2xy | $2^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 1.89763 | 7.343031 | 14.973649 | 4.562281 | 2.071591 | .173961 | .030262 |
| B | 4.02325 | 2.18184 | 8.778088 | 16.186541 | 4.743460 | 2.252770 | .040930 | .001675 |
| C | 3.96090 | 2.04922 | 8.116755 | 15.688729 | 4.669949 | 2.179259 | .130039 | .016910 |
| D | 3.53148 | 1.62325 | 5.7342475 | 12.471351 | 4.163657 | 1.672967 | .049717 | .002472 |
| E | 4.10380 | 2.24304 | 9.204988 | 16.841174 | 4.838429 | 2.347739 | .104699 | .010962 |
| F | 3.61982 | 1.96848 | 7.125543 | 13.103097 | 4.267811 | 1.777121 | .191359 | .036618 |
| G | 3.72263 | 1.93450 | 7.201428 | 13.857974 | 4.389025 | 1.898335 | .036165 | .001308 |
| H | 3.90309 | 2.07918 | 8.115227 | 15.240435 | 4.601790 | 2.111100 | .031920 | .001019 |
| I | 3.98227 | 2.12385 | 8.457744 | 15.858474 | 4.695144 | 2.204454 | .080604 | .006497 |
| J | 3.86806 | 2.04922 | 7.926506 | 14.961888 | 4.560489 | 2.069799 | .020579 | .000423 |
| K | 4.04139 | 2.30535 | 9.316818 | 16.332833 | 4.764847 | 2.274157 | .031193 | .000973 |
| L | 4.17026 | 2.28556 | 9.531379 | 17.391068 | 4.916787 | 2.426097 | .140537 | .019751 |
| M | 3.86759 | 2.22272 | 8.596570 | 14.958252 | 4.559935 | 2.069245 | .153475 | .023555 |
| N | 4.16435 | 2.61700 | 10.898104 | 17.341811 | 4.909819 | 2.419129 | .197871 | .039153 |
| O | 4.38021 | 2.75282 | 12.057930 | 19.186240 | 5.164320 | 2.673630 | .079190 | .006271 |
| P | 4.19033 | 2.56348 | 10.741827 | 17.558866 | 4.940449 | 2.449759 | .113721 | .012932 |
| | 63.39901 | 34.89714 | 139.144413 | 251.952382 | | | | .210781 |

CALCULATION OF STRAIGHT LINE a and b:

34.897140 = 16a + 63.39901b (k = 3.962348)
139.144413 = 63.39901a + 251.952382b

.869800 = 0.737736b

$$b = \frac{.869800}{0.737736} = 1.179012$$

$$\log a = \frac{-39.851054}{16}$$

log a = -2.490690

$$y = a\,(W)^b = .003231W^{1.179012}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\sum 9} - 1$$

$$= \log^{-1} .1742 \times .4591 - 1$$

$$= \log^{-1} .07998 - 1$$

PE = 20.2%

VERTICAL SURFACES
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | Δy | $\Delta y^2$ |
| A | 7,406 | 37 | 274,022 | 54,848,836 | 103 | 44 | 7 | 49 |
| B | 10,550 | 61 | 643,550 | 111,302,500 | 147 | 88 | 27 | 729 |
| C | 9,139 | 61 | 557,479 | 83,521,321 | 127 | 68 | 7 | 49 |
| D | 3,400 | 17 | 57,800 | 11,560,000 | 47 | -12 | 29 | 841 |
| E | 12,700 | 80 | 1,016,000 | 161,290,000 | 177 | 118 | 38 | 1444 |
| F | 4,167 | 40 | 166,680 | 17,363,889 | 58 | -1 | 41 | 1681 |
| G | 5,280 | 33 | 174,240 | 27,878,400 | 74 | 15 | 18 | 324 |
| H | 8,000 | 63 | 504,000 | 64,000,000 | 111 | 52 | 11 | 121 |
| I | 9,600 | 63 | 604,800 | 92,160,000 | 134 | 75 | 12 | 144 |
| J | 7,380 | 36 | 265,680 | 54,464,400 | 103 | 44 | 8 | 64 |
| K | 11,000 | 70 | 770,000 | 121,000,000 | 153 | 94 | 16 | 256 |
| L | 14,798 | 71 | 1,050,658 | 218,980,804 | 206 | 147 | 73 | 5329 |
| M | 7,372 | 50 | 368,600 | 54,346,384 | 103 | 44 | 6 | 36 |
| N | 14,600 | 188 | 2,744,800 | 213,160,000 | 203 | 144 | 44 | 1936 |
| O | 24,000 | 337 | 8,088,000 | 576,000,000 | 334 | 275 | 62 | 3844 |
| P | 15,600 | 148 | 2,308,800 | 243,360,000 | 217 | 158 | 10 | 100 |
| | 164,992 | 1355 | 19,595,109 | 2,105,236,534 | | | | 16947 |

**CALCULATION OF STRAIGHT LINE a and b:**

$$1355 = 16a + 164{,}992b \quad (k = 10{,}312)$$
$$19595109 = 164{,}992a + 2{,}105{,}236{,}534b$$

$$5{,}622{,}349 = 403{,}839{,}030b$$

$$b = .01392225263$$

$$a = \frac{1355 - 2297}{16}$$

$$a = -58.875$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n - 1}} \sqrt{\Sigma 9} \; \frac{n}{\Sigma 3}$$

$$= .1742 \times 1302 \; \frac{16}{1355}$$

$$PE = 26.78\%$$

$$y = a + bx = -58.875 + .0139222x$$

VERTICAL TAIL SURFACES
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 1.56820 | 6.068275 | 14.973649 | 4.980498 | 1.687692 | .119492 | .014278 |
| B | 4.02325 | 1.78533 | 7.182829 | 16.186541 | 5.178285 | 1.885479 | .100149 | .010030 |
| C | 3.96090 | 1.78533 | 7.071514 | 15.688729 | 5.098035 | 1.805229 | .019899 | .000396 |
| D | 3.53148 | 1.23045 | 4.345310 | 12.471351 | 4.545333 | 1.252527 | .022077 | .000487 |
| E | 4.10380 | 1.90309 | 7.809901 | 16.841174 | 5.281960 | 1.989154 | .086064 | .007407 |
| F | 3.61982 | 1.60206 | 5.799169 | 13.103097 | 4.659034 | 1.366228 | .235932 | .055617 |
| G | 3.72263 | 1.51851 | 5.652851 | 13.857974 | 4.791360 | 1.498554 | .019956 | .000398 |
| H | 3.90309 | 1.79934 | 7.022986 | 15.240435 | 5.023628 | 1.730822 | .068518 | .004695 |
| I | 3.98227 | 1.79934 | 7.165458 | 15.858474 | 5.125540 | 1.832734 | .033394 | .001115 |
| J | 3.86806 | 1.55630 | 6.019862 | 14.961888 | 4.978541 | 1.685735 | .129435 | .016753 |
| K | 4.04139 | 1.84510 | 7.456769 | 16.332833 | 5.201633 | 1.908827 | .063727 | .004061 |
| L | 4.17026 | 1.85126 | 7.720236 | 17.391068 | 5.367500 | 2.074694 | .223434 | .049923 |
| M | 3.86759 | 1.69897 | 6.570919 | 14.958252 | 4.977936 | 1.685130 | .013840 | .000192 |
| N | 4.16435 | 2.27416 | 9.470398 | 17.341811 | 5.359893 | 2.067087 | .207073 | .042879 |
| O | 4.38021 | 2.52763 | 11.071550 | 19.186240 | 5.637724 | 2.344918 | .182712 | .033384 |
| P | 4.19033 | 2.17026 | 9.094106 | 17.558866 | 5.393332 | 2.100526 | .069734 | .004863 |
| | 63.39901 | 28.91533 | 115.522133 | 251.952382 | | | | .246478 |

CALCULATION OF STRAIGHT LINE a and b:

28.91533 = 16a + 63.39901b (k = 3.962348)
115.522133 = 63.39901a + 251.952382b

.949533 = 0.737736b

$$b = \frac{.949533}{0.737736} = 1.287090$$

$$\log a = \frac{-52.684902}{16}$$

log a = -3.292808

a = 0.0005095

$$y = a\,(W)^b = .00050955W^{1.287090}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .49646 - 1$$

$$= \log^{-1} .08648 - 1$$

PE = 22.03%

FLAPS
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | Δy | $\Delta y^2$ |
| A | 7,406 | 26 | 192,556 | 54,848,836 | 84.0 | 41.7 | 15.7 | 246.49 |
| B | 10,550 | 54 | 569,700 | 111,302,500 | 119.6 | 77.3 | 23.3 | 542.89 |
| C | 9,139 | 29 | 265,031 | 83,521,321 | 103.6 | 61.3 | 32.3 | 1043.29 |
| D | 3,400 | 24 | 81,600 | 11,560,000 | 38.5 | -3.8 | 27.8 | 772.84 |
| E | 12,700 | 71 | 901,700 | 161,290,000 | 144.0 | 101.7 | 30.7 | 942.49 |
| F | 4,167 | 46 | 191,682 | 17,363,889 | 47.2 | 4.9 | 41.1 | 1689.21 |
| G | 5,280 | 26 | 137,280 | 27,878,400 | 59.9 | 17.6 | 8.4 | 70.56 |
| H | 8,000 | 68 | 544,000 | 64,000,000 | 90.7 | 48.4 | 20.4 | 416.16 |
| I | 9,600 | 44 | 422,400 | 92,160,000 | 108.8 | 66.5 | 22.5 | 506.25 |
| J | 7,380 | 43 | 317,340 | 54,464,400 | 83.7 | 41.4 | 1.6 | 2.56 |
| K | 11,000 | 70 | 770,000 | 121,000,000 | 124.7 | 82.4 | 12.4 | 153.76 |
| L | 14,798 | 111 | 1,642,579 | 218,980,804 | 167.8 | 125.5 | 14.5 | 210.25 |
| M | 7,372 | 53 | 390,716 | 54,346,384 | 83.6 | 41.3 | 11.7 | 136.89 |
| N | 14,600 | 163 | 2,379,800 | 213,160,000 | 165.5 | 123.2 | 39.8 | 1584.04 |
| O | 24,000 | 283 | 6,792,000 | 576,000,000 | 272.1 | 229.8 | 53.2 | 2830.24 |
| P | 15,600 | 84 | 1,310,400 | 243,360,000 | 176.9 | 134.6 | 50.6 | 2560.36 |
| | 164,992 | 1,195 | 16,907,783 | 2,105,236,534 | | | | 13708.28 |

CALCULATION OF STRAIGHT LINE a and b:

$$1{,}195 = 16a + 164{,}992b \quad (k = 96.974\times10^{-6})$$
$$16{,}907{,}783 = 164{,}992a + 2{,}105{,}236{,}534b$$

$$444 = 39{,}162b$$

$$b = .011338$$

$$a = 1195 - \frac{1871}{16}$$

$$a = -42.25$$

$$y = a + bx = -42.25 + .011338x$$

CALCULATION OF PROBABLE ERROR:

$$PE = \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9}\ \frac{n}{\Sigma 3}$$

$$= .1742 \times 117.08\ \frac{16}{1195}$$

$$PE = 27.30\%$$

FLAP WEIGHT vs.
DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 Model | 2 log x | 3 log y | 4 2x3 | 5 2² | 6 2xb | 7 log y' | 8 Δlog y | 9 (Δlog y)² |
|---|---|---|---|---|---|---|---|---|
| A | 3.86958 | 1.41497 | 5.47534 | 14.973649 | 4.29310 | 1.66144 | .24647 | .06075 |
| B | 4.02325 | 1.73239 | 6.96984 | 16.186541 | 4.46359 | 1.83193 | .09954 | .00991 |
| C | 3.96090 | 1.46240 | 5.79242 | 15.688729 | 4.39441 | 1.76275 | .30035 | .09021 |
| D | 3.53148 | 1.38021 | 4.87418 | 12.471351 | 3.91799 | 1.28633 | .09388 | .00881 |
| E | 4.10380 | 1.85126 | 7.59720 | 16.841174 | 4.55295 | 1.92129 | .07003 | .00490 |
| F | 3.61982 | 1.66276 | 6.01889 | 13.103097 | 4.01600 | 1.38434 | .27842 | .07752 |
| G | 3.72263 | 1.41497 | 5.26741 | 13.857974 | 4.13006 | 1.49840 | .08343 | .00696 |
| H | 3.90309 | 1.83251 | 7.15245 | 15.240435 | 4.33028 | 1.69862 | .13389 | .01793 |
| I | 3.98227 | 1.64345 | 6.54466 | 15.858474 | 4.41812 | 1.78646 | .14301 | .02045 |
| J | 3.86806 | 1.63347 | 6.31836 | 14.961888 | 4.29141 | 1.65975 | .02628 | .00069 |
| K | 4.04139 | 1.84510 | 7.45677 | 16.332833 | 4.48371 | 1.85205 | .00695 | .00005 |
| L | 4.17026 | 2.04532 | 8.52952 | 17.391068 | 4.62669 | 1.99503 | .05029 | .00253 |
| M | 3.86759 | 1.72428 | 6.66881 | 14.958252 | 4.49089 | 1.65923 | .06505 | .00423 |
| N | 4.16435 | 2.21219 | 9.21233 | 17.341811 | 4.62013 | 1.98847 | .22372 | .05005 |
| O | 4.38021 | 2.45179 | 10.73936 | 19.186240 | 4.85962 | 2.22796 | .22383 | .05010 |
| P | 4.19033 | 1.92428 | 8.06337 | 17.558866 | 4.64895 | 2.01729 | .09301 | .00865 |
| | 63.39901 | 28.23135 | 112.68091 | 251.952382 | | | | .41374 |

CALCULATION OF STRAIGHT LINE a and b:

28.23135 = 16a + 63.39901b (k = 3.962348)
112.68091 = 63.39901a + 251.952382b

111.86243 = 0.737736b

b = 1.109448

$$\log a = \frac{28.23135 - 70.33790}{16}$$

log a = -2.63166

a = 0.002335

$$y = a\,(W)^b = .0023353W^{1.109448}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .64323 - 1$$

$$= \log^{-1} .11205 - 1$$

PE = 29.44%

AILERON WEIGHT
vs. DESIGN GROSS WEIGHT

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | Δy | $\Delta y^2$ |
| A | 7,406 | 42.6 | 315,496 | 54,848,836 | 62.7 | 41.1 | 1.5 | 2.25 |
| B | 10,550 | 57.0 | 601,350 | 111,302,500 | 89.3 | 67.7 | 10.7 | 114.49 |
| C | 9,139 | 45.2 | 413,083 | 83,521,321 | 77.3 | 55.7 | 10.5 | 110.25 |
| D | 3,400 | 14.8 | 50,320 | 11,560,000 | 28.8 | 7.2 | 7.6 | 57.76 |
| E | 12,700 | 59.0 | 749,300 | 161,290,000 | 107.5 | 85.9 | 26.9 | 723.61 |
| F | 4,167 | 57.1 | 237,936 | 17,363,889 | 35.3 | 13.7 | 43.4 | 1883.56 |
| G | 5,280 | 48.0 | 253,440 | 27,878,400 | 44.7 | 23.1 | 24.9 | 620.01 |
| H | 8,000 | 43.0 | 344,000 | 64,000,000 | 67.7 | 46.1 | 3.1 | 9.61 |
| I | 9,600 | 68.5 | 657,600 | 92,160,000 | 81.2 | 59.6 | 8.9 | 79.21 |
| J | 7,380 | 38.0 | 280,440 | 54,464,400 | 62.4 | 40.8 | 2.8 | 7.84 |
| K | 11,000 | 41.9 | 460,900 | 121,000,000 | 93.1 | 71.5 | 29.6 | 876.16 |
| L | 14,798 | 57.0 | 843,486 | 218,990,304 | 125.2 | 103.6 | 46.6 | 2171.56 |
| M | 7,372 | 37.0 | 272,764 | 54,346,384 | 62.4 | 40.8 | 3.8 | 14.44 |
| N | 14,600 | 68.2 | 995,720 | 213,160,000 | 123.5 | 101.9 | 33.7 | 1135.69 |
| O | 24,000 | 232.6 | 5,532,400 | 576,000,000 | 203.1 | 181.5 | 51.1 | 2611.21 |
| P | 15,600 | 140.3 | 2,188,680 | 243,360,000 | 132.0 | 110.4 | 29.9 | 894.01 |
| | 164,992 | 1050.2 | 14,246,915 | 2,105,236,534 | | | | 11311.66 |

CALCULATION OF STRAIGHT LINE a and b:

$1,050.2 = 16a + 164,992b \quad (x = 10,312)$
$14,246,915 = 164,992a + 2,105,236,534b$

$3,417,253 = 403,839,030b$

$b = .00846192$

$a = \frac{1050.2 - 1396.1}{16}$

$a = -21.619$

CALCULATION OF PROBABLE ERROR:

$PE = \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} \; \frac{n}{\Sigma 3}$

$= .1742 \times 106.4 \; \frac{16}{1050.2}$

$PE = 28.24\%$

$y = a + bx = -21.62 + 8.462W \times 10^{-3}$

## STRAIGHT LINE TREND

AILERON WEIGHT
vs. DESIGN GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2 x 3 | $2^2$ | 2 x b | log y' | Δ log y | $(\Delta \log y)^2$ |
| A | 3.86958 | 1.62941 | 6.30518 | 14.973649 | 3.56296 | 1.64962 | .02021 | .00041 |
| B | 4.02325 | 1.75587 | 7.06430 | 16.186541 | 3.70446 | 1.79112 | .03525 | .00124 |
| C | 3.96090 | 1.65514 | 6.55584 | 15.688729 | 3.64705 | 1.73371 | .07857 | .00617 |
| D | 3.53148 | 1.17026 | 4.13275 | 12.471351 | 3.25166 | 1.33832 | .16806 | .02824 |
| E | 4.10380 | 1.77085 | 7.26721 | 16.841174 | 3.77863 | 1.86529 | .09444 | .00892 |
| F | 3.61982 | 1.75664 | 6.35872 | 13.103097 | 3.33300 | 1.41966 | .33698 | .11356 |
| G | 3.72263 | 1.68124 | 6.25863 | 13.857974 | 3.42766 | 1.51432 | .16692 | .02786 |
| H | 3.90309 | 1.63347 | 6.37558 | 15.240435 | 3.59382 | 1.68048 | .04701 | .00221 |
| I | 3.98227 | 1.83569 | 7.31021 | 15.858474 | 3.66673 | 1.75339 | .08230 | .00677 |
| J | 3.86806 | 1.57978 | 6.11068 | 14.961868 | 3.56157 | 1.64823 | .06845 | .00469 |
| K | 4.04139 | 1.62221 | 6.55598 | 16.332833 | 3.72116 | 1.80782 | .18561 | .03445 |
| L | 4.17026 | 1.75587 | 7.32243 | 17.391068 | 3.83982 | 1.92648 | .17061 | .02911 |
| M | 3.86759 | 1.56820 | 6.06515 | 14.958252 | 3.56113 | 1.64779 | .07959 | .00633 |
| N | 4.16435 | 1.83378 | 7.63650 | 17.341811 | 3.83438 | 1.92104 | .08726 | .00761 |
| O | 4.38021 | 2.36661 | 10.36625 | 19.186240 | 4.03314 | 2.11980 | .24681 | .06092 |
| P | 4.19033 | 2.14706 | 8.99689 | 17.558866 | 3.85830 | 1.94496 | .20210 | .04084 |
| | 63.39901 | 27.76208 | 110.68230 | 251.952382 | | | | .37933 |

CALCULATION OF STRAIGHT LINE a and b:

27.76208 = 16a + 63.39901b  (k = 3.962348)
110.68230 = 63.39901a + 251.952382b

.67928 = 0.737736b

b = .920763

$$\log a = \frac{27.76208 - 58.37546}{16}$$

log a = -1.91334

a = .012208

$$y = a\,(W)^b = .0122\,(W)^{.921}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .61590 - 1$$

$$= \log^{-1} .10729 - 1$$

PE = 28%

# APPENDIX III

## CALCULATIONS FOR

## DEVELOPMENT OF SATISFACTORY ESTIMATING FORMULAS

STRAIGHT LINE TREND

TOTAL WING WEIGHT
vs. GROSS WEIGHT

| 1- | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2 x 3 | $2^2$ | 2 x b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 2.97377 | 11.50724 | 14.973649 | 4.09342 | 3.04719 | .07342 | .00539 |
| B | 4.02325 | 3.28466 | 13.21501 | 16.186541 | 4.25597 | 3.20974 | .07492 | .00561 |
| C | 3.96090 | 3.08800 | 12.23126 | 15.688729 | 4.19002 | 3.04379 | .04421 | .00195 |
| D | 3.53148 | 2.66978 | 9.42827 | 12.471351 | 3.73576 | 2.68953 | .01975 | .00039 |
| E | 4.10380 | 3.27295 | 13.43153 | 16.841174 | 4.34118 | 3.29495 | .02200 | .00048 |
| F | 3.61982 | 2.86356 | 10.36557 | 13.103097 | 3.82921 | 2.78298 | .08058 | .00649 |
| G | 3.72263 | 2.88705 | 10.74742 | 13.857974 | 3.93797 | 2.89174 | .00469 | .00002 |
| H | 3.90309 | 3.02776 | 11.81762 | 15.240435 | 4.12886 | 3.08263 | .05487 | .00301 |
| I | 3.98227 | 3.14983 | 12.54347 | 15.858474 | 4.21262 | 3.16639 | .01656 | .00027 |
| J | 3.86806 | 3.04571 | 11.78099 | 14.961838 | 4.09121 | 3.04558 | .00013 | .00000 |
| K | 4.04139 | 3.30632 | 13.36213 | 16.332833 | 4.27516 | 3.22893 | .07739 | .00599 |
| L | 4.17026 | 3.39164 | 14.14402 | 17.391068 | 4.41149 | 3.36526 | .02638 | .00070 |
| M | 3.86759 | 3.04571 | 11.77956 | 14.958252 | 4.09131 | 3.04508 | .00063 | .00000 |
| N | 4.16435 | 3.42137 | 14.24778 | 17.341811 | 4.40524 | 3.35901 | .06236 | .00389 |
| O | 4.38021 | 3.59744 | 15.75754 | 19.186240 | 4.63358 | 3.58735 | .01009 | .00010 |
| P | 4.19033 | 3.30112 | 13.83278 | 17.558866 | 4.43272 | 3.38649 | .08537 | .00729 |
| | 63.39901 | 50.32667 | 200.19219 | 251.952382 | | | | .04158 |

CALCULATION OF STRAIGHT LINE a and b:

$$50.32667 = 16a + 63.39901b \quad (k = 3.962348)$$
$$200.19219 = 63.39901a + 251.952382b$$

$$.78041 = 0.737736b$$

$$b = 1.057845$$

$$\log a = \frac{50.32667 - 67.066326}{16}$$

$$\log a = -1.046228$$

$$a = .0899078$$

$$y = a\,(W)^b = .0899078W^{1.057845}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .20391 - 1$$

$$= \log^{-1} .03552$$

$$PE = 8.57\%$$

STRAIGHT LINE TREND

WING WT/b
vs. GROSS WT. x LOAD FACTOR x $10^{-4}$

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log GWxnx$10^{-4}$ | log $W_w$/b | 2 x 3 | $2^2$ | 2 x b | log y' | Δlogy | $(\Delta \log y)^2$ |
| A | .94876 | 1.40943 | 1.33721 | .90015 | .68331 | 1.43184 | .02241 | .00050 |
| B | 1.10243 | 1.60087 | 1.76485 | 1.21535 | .79398 | 1.54251 | .05836 | .00340 |
| C | 1.04008 | 1.45743 | 1.51584 | 1.08177 | .74908 | 1.49761 | .04018 | .00161 |
| D | .61066 | 1.19313 | .72860 | .37291 | .43980 | 1.18833 | .00480 | .00002 |
| E | 1.18298 | 1.64135 | 1.94168 | 1.39944 | .85199 | 1.60052 | .04083 | .00167 |
| F | .54924 | 1.17124 | .64329 | .30166 | .39557 | 1.14410 | .02714 | .00034 |
| G | .65205 | 1.21998 | .79549 | .42517 | .46961 | 1.21814 | .00184 | .00000 |
| H | .98227 | 1.41156 | 1.38653 | .96485 | .70744 | 1.45597 | .04441 | .00197 |
| I | 1.06145 | 1.52433 | 1.61800 | 1.12668 | .76447 | 1.51300 | .01133 | .00013 |
| J | .99839 | 1.43306 | 1.43075 | .99678 | .71905 | 1.46758 | .03452 | .00125 |
| K | 1.17172 | 1.60175 | 1.87680 | 1.37293 | .84388 | 1.59241 | .00934 | .00009 |
| L | .95559 | 1.62368 | 1.55157 | .91315 | .68823 | 1.43676 | .18692 | .03494 |
| M | .99792 | 1.36886 | 1.36601 | .99584 | .71871 | 1.46724 | .09838 | .00968 |
| N | 1.29468 | 1.70042 | 2.20150 | 1.67620 | .93244 | 1.68097 | .01945 | .00038 |
| O | 1.18503 | 1.68967 | 2.00231 | 1.40430 | .85347 | 1.60200 | .08767 | .00769 |
| P | 1.21431 | 1.55047 | 1.88275 | 1.47455 | .87456 | 1.62309 | .07262 | .00527 |
| | 15.94756 | 23.59723 | 24.04318 | 16.62173 | | | | .06934 |

CALCULATION OF STRAIGHT LINE a and b:

$$23.59723 = 16a + 15.94756b \qquad (k = 1.00328)$$
$$24.04318 = 15.94756a + 16.62173b$$

$$-.52431 = -.72869b$$

$$b = .72021$$

$$\log a = \frac{23.59723 - 11.62083}{16}$$

$$\log a = .74853$$

$$a = 5.6044$$

$$y = a\,(Wn \times 10^{-4})^{b} = 5.6044\,(Wn \times 10^{-4})^{.72021}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .26333 - 1$$

$$= \log^{-1} .04587 - 1$$

$$PE = 11.1$$

# STRAIGHT LINE TREND

WING WT/SPAN
vs. GROSS WT x b x n x $10^{-6}$

| 1<br>Model | 2<br>log Wbnx$10^{-6}$ | 3<br>log Ww/b | 4<br>2 x 3 | 5<br>$2^2$ | 6<br>2 x 6 | 7<br>log y' | 8<br>Δlog y | 9<br>$(\Delta \log y)^2$ |
|---|---|---|---|---|---|---|---|---|
| A | .48024 | 1.40943 | .67686 | .23063 | .28294 | 1.39031 | .01862 | .00035 |
| B | .76044 | 1.60087 | 1.21736 | .57827 | .44303 | 1.55590 | .04497 | .00202 |
| C | .63303 | 1.45743 | .92260 | .40073 | .37296 | 1.43033 | .02340 | .00055 |
| D | .04999 | 1.19313 | .05964 | .00250 | .02945 | 1.13732 | .05581 | .00311 |
| E | .78343 | 1.64135 | 1.28588 | .61376 | .46157 | 1.56944 | .07191 | .00517 |
| F | .17249 | 1.17124 | .20203 | .02975 | .10163 | 1.20950 | .03826 | .00146 |
| G | .27530 | 1.21998 | .33586 | .07579 | .16220 | 1.27007 | .05079 | .00258 |
| H | .55071 | 1.41136 | .77736 | .30328 | .32446 | 1.43233 | .02077 | .00043 |
| I | .65106 | 1.52433 | .99243 | .42388 | .38358 | 1.49145 | .03288 | .00108 |
| J | .57817 | 1.43306 | .82855 | .33428 | .34064 | 1.44851 | .01545 | .00024 |
| K | .80347 | 1.60175 | 1.28696 | .64556 | .47338 | 1.58125 | .02050 | .00042 |
| L | .68935 | 1.62368 | 1.11928 | .47520 | .40614 | 1.51401 | .10967 | .01203 |
| M | .61628 | 1.36886 | .84360 | .37980 | .36309 | 1.47096 | .10210 | .01042 |
| N | .97592 | 1.70042 | 1.65947 | .95242 | .57498 | 1.68285 | .01757 | .00031 |
| O | 1.03217 | 1.68867 | 1.74303 | 1.06537 | .60812 | 1.71539 | .02632 | .00069 |
| P | .91328 | 1.55047 | 1.41601 | .83408 | .53808 | 1.64595 | .09548 | .00912 |
| | 9.96533 | 23.59723 | 15.36792 | 7.34530 | | | | .04998 |

CALCULATION OF STRAIGHT LINE a and b:

$$23.59723 = 16a + 9.96533b$$
$$15.36792 = 9.96533a + 7.34530b \quad (k = 1.60557)$$

$$-1.07704 = -1.82806b$$

$$b = .58917$$

$$\log a = \frac{23.59723 - 5.87127}{16}$$

$$\log a = 1.10787$$

$$a = 12.8193$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .22357$$

$$= \log^{-1} .038946$$

$$PE = 9.43$$

$$y = a\,(Wbn \times 10^{-6})^{b} = 12.8193(Wbn \times 10^{-6})^{.58917}$$

STRAIGHT LINE TREND

WING WEIGHT/SPAN
vs. (GW x SPAN x LOAD FACTOR/THICKNESS) x $10^{-4}$

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log Wbn/t x$10^{-4}$ | log $W_x/b$ | 2 x 3 | $2^2$ | 2 x b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 1.31145 | 1.40943 | 1.84840 | 1.71990 | 1.06343 | 1.41261 | .00318 | .00001 |
| B | 1.50759 | 1.60087 | 2.41346 | 2.27283 | 1.22247 | 1.57165 | .02922 | .00085 |
| C | 1.42891 | 1.45743 | 2.08254 | 2.04178 | 1.15867 | 1.50785 | .05042 | .00254 |
| D | 1.02939 | 1.19313 | 1.22820 | 1.05964 | .83471 | 1.18389 | .00924 | .00009 |
| E | 1.53058 | 1.64135 | 2.51222 | 2.34268 | 1.24111 | 1.59029 | .05106 | .00261 |
| F | .97027 | 1.17124 | 1.13642 | .94142 | .78677 | 1.13595 | .03529 | .00125 |
| G | 1.14497 | 1.21998 | 1.39684 | 1.31096 | .92843 | 1.27761 | .05763 | .00332 |
| H | 1.30274 | 1.41156 | 1.83890 | 1.69713 | 1.05636 | 1.40554 | .00602 | .00004 |
| I | 1.49572 | 1.52433 | 2.28271 | 2.23937 | 1.21285 | 1.56203 | .03770 | .00142 |
| J | 1.39776 | 1.43306 | 2.00307 | 1.95373 | 1.13341 | 1.48259 | .04953 | .00245 |
| K | 1.53326 | 1.60175 | 2.45590 | 2.35089 | 1.24329 | 1.59247 | .00928 | .00009 |
| L | 1.34693 | 1.62368 | 2.18698 | 1.81422 | 1.09220 | 1.44138 | .18230 | .03323 |
| M | 1.34677 | 1.36386 | 1.84354 | 1.81379 | 1.09207 | 1.44125 | .07239 | .00524 |
| N | 1.59390 | 1.70042 | 2.71030 | 2.54052 | 1.29246 | 1.64164 | .05878 | .00346 |
| O | 1.70176 | 1.69897 | 2.89124 | 2.89599 | 1.37992 | 1.72910 | .03013 | .00091 |
| P | 1.56839 | 1.55047 | 2.43252 | 2.46142 | 1.27218 | 1.62136 | .07089 | .00503 |
| | 22.21089 | 23.59723 | 33.26324 | 31.45677 | | | | .06254 |

CALCULATION OF STRAIGHT LINE a and b:

$23.59723 = 16a + 22.21089b$

$33.26324 = 22.21089a + 31.45677b$   (k = 1.3881806)

$.50602 = .62404b$

$b = .8108775$

$\log a = \dfrac{23.59723 - 18.01031}{16}$

$\log a = .34918$

$a = 2.2345$

$$y = a\left(\frac{Wbn}{t} \times 10^{-4}\right)^b = 2.2345\left[\frac{Wbn}{t} \times 10^{-4}\right]^{.8108775}$$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \dfrac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$

$= \log^{-1} .1742 \times .25008 - 1$

$= \log^{-1} .04356 - 1$

$PE = 11.05\%$

ENGINE AND NACELLE GROUPS
vs. ENGINE WT (as installed)

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log $W_E$ | log PP | 2 x 3 | $2^2$ | 2b | log y' | log y | $(\log y)^2$ |
| A | 3.15537 | 3.41313 | 10.76969 | 9.95636 | 3.18754 | 3.41533 | .00220 | .00000 |
| B | 3.23447 | 3.43823 | 11.12085 | 10.46180 | 3.26746 | 3.49524 | .05701 | .00325 |
| C | 3.21722 | 3.51614 | 11.31220 | 10.35050 | 3.255002 | 3.47781 | .03833 | .00147 |
| D | 2.86806 | 3.10278 | 8.89896 | 8.22577 | 2.89730 | 3.12509 | .02231 | .00050 |
| E | 3.35468 | 3.68529 | 12.36297 | 11.25388 | 3.38888 | 3.61667 | .06852 | .00471 |
| F | 2.82419 | 3.06108 | 8.64507 | 7.97605 | 2.85298 | 3.08077 | .01969 | .00039 |
| G | 2.94052 | 3.19312 | 9.38943 | 8.64666 | 2.97050 | 3.19829 | .00517 | .00003 |
| H | 3.22272 | 3.55218 | 11.44768 | 10.38592 | 3.25558 | 3.48337 | .06881 | .00473 |
| I | 3.26600 | 3.43981 | 11.23480 | 10.66712 | 3.29930 | 3.52709 | .08728 | .00762 |
| J | 3.19521 | 3.45102 | 11.02673 | 10.20937 | 3.22779 | 3.45559 | .00456 | .00002 |
| K | 3.39252 | 3.64108 | 12.35244 | 11.50919 | 3.42711 | 3.65490 | .01382 | .00019 |
| L | 3.29623 | 3.54494 | 11.68494 | 10.86513 | 3.32984 | 3.55763 | .01269 | .00016 |
| M | 3.09691 | 3.44560 | 10.67071 | 9.59085 | 3.12848 | 3.35627 | .08933 | .00798 |
| N | 3.43136 | 3.70114 | 12.69994 | 11.77423 | 3.46634 | 3.69413 | .00701 | .00005 |
| O | 3.55374 | 3.83645 | 13.63375 | 12.62907 | 3.58997 | 3.81776 | .01869 | .00035 |
| P | 3.45025 | 3.64719 | 12.58372 | 11.90423 | 3.48543 | 3.71322 | .06603 | .00436 |
| | 51.49945 | 55.66918 | 179.83388 | 166.40613 | | | | .03581 |

CALCULATION OF STRAIGHT LINE a and b:

$55.66918 = 16a + 51.49945b$

$179.83388 = 51.49945a + 166.40613b \quad (k = .3106829)$

$.20213 = .200009b$

$b = 1.010195$

$\log a = \dfrac{55.66918 - 52.02449}{16}$

$\log a = .22779$

$a = 1.6896$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \dfrac{.6745}{\sqrt{n-1}} \sqrt{\sum 9} - 1$

$= \log^{-1} .1742 \times .18923 - 1$

$= \log^{-1} .03296 - 1$

$PE = 7.885\%$

$y = a \times (W_E)^b = 1.6896\ (W_E)^{1.0102}$

STRAIGHT LINE TREND

FUSELAGE WT/LENGTH
vs. DESIGN GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | x | y | xy | $x^2$ | xb | y' | Δy | $\Delta y^2$ |
| A | 7,406 | 20.65 | 152,934 | 54,848,836 | 7.33 | 19.19 | 1.46 | 2.13 |
| B | 10,550 | 23.25 | 245,288 | 111,302,500 | 10.44 | 22.30 | 0.95 | .90 |
| C | 9,139 | 21.45 | 196,032 | 83,521,321 | 9.04 | 20.90 | 0.55 | .30 |
| D | 3,400 | 10.10 | 34,340 | 11,560,000 | 3.36 | 15.22 | 5.12 | 26.12 |
| E | 12,700 | 29.30 | 372,110 | 161,290,000 | 12.57 | 24.43 | 4.87 | 23.72 |
| F | 4,167 | 13.88 | 57,838 | 17,363,889 | 4.12 | 15.98 | 2.10 | 4.41 |
| G | 5,280 | 16.42 | 86,670 | 27,878,400 | 5.22 | 17.08 | 0.66 | .44 |
| H | 8,000 | 15.76 | 126,080 | 64,000,000 | 7.92 | 19.78 | 4.02 | 16.16 |
| I | 9,600 | 33.00 | 316,800 | 92,160,000 | 9.50 | 21.36 | 11.64 | 135.49 |
| J | 7,380 | 20.33 | 150,035 | 54,464,400 | 7.30 | 19.16 | 1.17 | 1.37 |
| K | 11,000 | 18.20 | 200,200 | 121,000,000 | 10.89 | 22.75 | 4.55 | 20.70 |
| L | 14,798 | 30.00 | 443,940 | 218,980,804 | 14.64 | 26.50 | 3.50 | 12.25 |
| M | 7,372 | 14.91 | 109,917 | 54,346,384 | 7.29 | 19.15 | 4.24 | 17.98 |
| N | 14,600 | 34.15 | 498,590 | 213,160,000 | 14.45 | 26.31 | 7.84 | 61.47 |
| O | 24,000 | 29.00 | 696,000 | 576,000,000 | 23.75 | 35.61 | 6.61 | 43.69 |
| P | 15,600 | 22.68 | 353,808 | 243,360,000 | 15.44 | 27.30 | 4.62 | 21.34 |
| | 164,992 | 353.08 | 4,040,582 | 2,105,236,534 | | | | 388.56 |

**CALCULATION OF STRAIGHT LINE a and b:**

$$353.08 = 16a + 164{,}992b \quad (k = 10{,}312)$$
$$4{,}040{,}582 = 164{,}992a + 2{,}105{,}236{,}534b$$

$$399{,}621 = 403{,}839{,}030b$$

$$b = .000989555$$

$$a = \frac{353.08 - 163.27}{16}$$

$$a = 11.863$$

**CALCULATION OF PROBABLE ERROR:**

$$PE = \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} \; \frac{n}{\Sigma 3}$$

$$= .1742 \times 19.712 \; \frac{16}{353.08}$$

$$PE = 15.56\%$$

$$y = a + bx = 11.863 + 9.896W \times 10^{-4}$$

STRAIGHT LINE TREND

FUSELAGE WT./LENGTH
vs. DESIGN GROSS WEIGHT

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log x | log y | 2x3 | $2^2$ | 2xb | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.86958 | 1.31492 | 5.08818 | 14.973649 | 2.16495 | 1.26835 | .04637 | .00215 |
| B | 4.02325 | 1.36642 | 5.49734 | 16.186541 | 2.25093 | 1.35453 | .01189 | .00014 |
| C | 3.96090 | 1.33143 | 5.27366 | 15.688729 | 2.21604 | 1.31964 | .01179 | .00014 |
| D | 3.53148 | 1.00432 | 3.54674 | 12.471351 | 1.97579 | 1.07939 | .07507 | .00564 |
| E | 4.10380 | 1.46687 | 6.01974 | 16.841174 | 2.29590 | 1.39959 | .06728 | .00453 |
| F | 3.61982 | 1.14239 | 4.13525 | 13.103097 | 2.02522 | 1.12882 | .01357 | .00018 |
| G | 3.72263 | 1.21537 | 4.52437 | 13.857974 | 2.08274 | 1.18634 | .02903 | .00084 |
| H | 3.90309 | 1.19756 | 4.67418 | 15.240435 | 2.18370 | 1.28730 | .08974 | .00805 |
| I | 3.98227 | 1.51851 | 6.04712 | 15.858474 | 2.22800 | 1.33160 | .18691 | .03494 |
| J | 3.86806 | 1.30814 | 5.05996 | 14.961888 | 2.16410 | 1.25770 | .04044 | .00164 |
| K | 4.04139 | 1.26007 | 5.09243 | 16.332833 | 2.26108 | 1.36468 | .10461 | .01094 |
| L | 4.17026 | 1.47712 | 6.15997 | 17.391068 | 2.33318 | 1.43678 | .04034 | .00163 |
| M | 3.86759 | 1.17348 | 4.53854 | 14.958252 | 2.16384 | 1.26744 | .09396 | .00883 |
| N | 4.16435 | 1.53339 | 6.38557 | 17.341811 | 2.32987 | 1.43347 | .09992 | .00998 |
| O | 4.38021 | 1.46240 | 6.40562 | 19.186240 | 2.45064 | 1.55424 | .09184 | .00843 |
| P | 4.19033 | 1.35564 | 5.68058 | 17.558866 | 2.34441 | 1.44801 | .09237 | .00853 |
| | 63.39901 | 21.12803 | 84.12936 | 251.952382 | | | | .10659 |

CALCULATION OF STRAIGHT LINE a and b:

$$21.12803 = 16a + 63.39901b \quad (k = 3.962348)$$
$$84.12936 = 63.39901a + 251.952382b$$

$$.41275 = 0.737736b$$

$$b = .55948$$

$$\log a = \frac{21.12803 - 35.47048}{16}$$

$$\log a = -.89641$$

$$a = .12694$$

$$y = a\,(W)^b = .127W^{.5595}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .32650 - 1$$

$$= .05688 - 1$$

$$PE = 14.0\%$$

HORIZONTAL TAIL SURFACE WT/SPAN vs. SPAN

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | $\log b_h$ | $\log W_h/b_h$ | 2 x 3 | $2^2$ | b x 2 | log y' | $\Delta \log y$ | $(\Delta \log y)^2$ |
| A | 1.11394 | .78390 | .87322 | 1.24086 | 1.67748 | .84377 | .05987 | .00358 |
| B | 1.21880 | .96047 | 1.17063 | 1.48547 | 1.83538 | 1.00167 | .04120 | .00170 |
| C | 1.12222 | .92686 | 1.04014 | 1.25938 | 1.68994 | .85623 | .07063 | .00499 |
| D | .95424 | .67210 | .64134 | .91057 | 1.43698 | .60327 | .06883 | .00474 |
| E | 1.20412 | 1.03902 | 1.25110 | 1.44990 | 1.81328 | .97957 | .05945 | .00353 |
| F | 1.18554 | .78319 | .92850 | 1.40551 | 1.78530 | .95159 | .16840 | .02836 |
| G | 1.10890 | .82543 | .91532 | 1.22966 | 1.66989 | .83618 | .01075 | .00012 |
| H | 1.17173 | .90741 | 1.06324 | 1.37295 | 1.76450 | .93079 | .02338 | .00055 |
| I | 1.19257 | .93146 | 1.11083 | 1.42222 | 1.79588 | .96217 | .03071 | .00094 |
| J | 1.13577 | .91328 | 1.03728 | 1.28997 | 1.71035 | .87664 | .03664 | .00134 |
| K | 1.26717 | 1.03822 | 1.31560 | 1.60572 | 1.90822 | 1.07451 | .03629 | .00132 |
| L | 1.31869 | .96708 | 1.27528 | 1.73894 | 1.98581 | 1.15210 | .18502 | .03423 |
| M | 1.24920 | .97359 | 1.21621 | 1.56050 | 1.88116 | 1.04745 | .07386 | .00546 |
| N | 1.29732 | 1.31973 | 1.71211 | 1.68304 | 1.95363 | 1.11992 | .19981 | .03992 |
| O | 1.41212 | 1.34064 | 1.89314 | 1.99408 | 2.12650 | 1.29279 | .04785 | .00229 |
| P | 1.29732 | 1.26623 | 1.64271 | 1.68304 | 1.95363 | 1.11992 | .14631 | .02141 |
| | 19.24965 | 15.64861 | 19.08664 | 23.33181 | | | | .15448 |

CALCULATION OF STRIGHT LINE a and b:

15.64861 = 16a + 19.24965b
19.08664 = 19.24965a + 23.33181b (k = .8311839)

.21590 = .14337b

b = 1.505894

$$\log a = \frac{15.64861 - 28.98793}{16}$$

log a = -.83371

a = .146651

$$y = a(b_h)^b = .146651(b_h)^{1.505894}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1742 \times .39305 - 1$$

$$= \log^{-1} .06847 - 1$$

PE = 17.08%

HORIZONTAL TAIL SURFACE WT/SPAN
vs. AREA

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log $S_h$ | log $W_h/b_h$ | 2 x 3 | $2^2$ | b x 2 | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 1.60681 | .78390 | 1.25958 | 2.58184 | 1.05131 | .89770 | .11380 | .01295 |
| B | 1.85260 | .96047 | 1.77937 | 3.43213 | 1.21212 | 1.05851 | .09804 | .00961 |
| C | 1.64098 | .92686 | 1.52096 | 2.69282 | 1.07366 | .92005 | .00681 | .00005 |
| D | 1.27646 | .67210 | .85791 | 1.62935 | .83516 | .68155 | .00945 | .00009 |
| E | 1.77815 | 1.03902 | 1.84753 | 3.16182 | 1.16341 | 1.00980 | .02922 | .00085 |
| F | 1.72607 | .78319 | 1.35184 | 2.97932 | 1.12933 | .97572 | .19253 | .03707 |
| G | 1.69992 | .82543 | 1.40316 | 2.88973 | 1.11223 | .95862 | .13319 | .01774 |
| H | 1.68440 | .90741 | 1.52844 | 2.83720 | 1.10207 | .94846 | .04105 | .00169 |
| I | 1.64147 | .93146 | 1.52896 | 2.69442 | 1.07398 | .92037 | .01109 | .00012 |
| J | 1.69064 | .91328 | 1.54403 | 2.85826 | 1.10615 | 1.02254 | .10926 | .01194 |
| K | 1.89120 | 1.03822 | 1.96348 | 3.57664 | 1.23738 | 1.08377 | .04555 | .00207 |
| L | 2.04470 | .96708 | 1.97739 | 4.18080 | 1.33781 | 1.18420 | .21712 | .04714 |
| M | 1.66876 | .97359 | 1.62469 | 2.78476 | 1.09184 | .93723 | .03536 | .00125 |
| N | 1.76087 | 1.31973 | 2.32387 | 3.10066 | 1.15210 | .99849 | .32124 | .10320 |
| O | 1.96379 | 1.34064 | 2.63274 | 3.85647 | 1.28487 | 1.13126 | .20938 | .04384 |
| P | 1.74687 | 1.26623 | 2.21194 | 3.05155 | 1.14294 | 1.11262 | .15361 | .02360 |
| | 27.67369 | 15.64861 | 27.35589 | 48.30777 | | | | .31321 |

CALCULATION OF STRAIGHT LINE $\underline{a}$ and $\underline{b}$:

$15.64861 = 16a + 27.673696$

$27.35589 = 27.67369a + 48.30777b$ (k = 0.578166)

$.16764 = .25622b$

$b = .654281$

$\log a = \frac{15.64861 - 18.10637}{16}$

$\log a = -.15361$

$a = .702084$

$y = a(S_h)^b = .702084(S_h)^{.654281}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma\, 9} - 1$

$= \log^{-1} .1742 \times .55965 - 1$

$= \log^{-1} .09749 - 1$

$PE = 25.24\%$

HORIZONTAL TAIL SURFACE WT/SPAN vs. TAIL LOAD

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log T.L. | log $W_h/b_h$ | 2 x 3 | $2^2$ | b x 2 | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.93952 | .78390 | 3.08819 | 15.51982 | 2.32966 | .98788 | .20398 | .04161 |
| B | 3.99826 | .96047 | 3.84021 | 15.98608 | 2.36440 | 1.02262 | .06215 | .00386 |
| C | 3.87447 | .92686 | 3.59109 | 15.01152 | 2.29119 | .94941 | .02255 | .00051 |
| D | 3.55630 | .67210 | 2.39019 | 12.64727 | 2.10304 | .76126 | .08916 | .00795 |
| E | 4.02119 | 1.03902 | 4.14553 | 16.16997 | 2.37795 | 1.03617 | .00285 | .00001 |
| F | 3.43981 | .78319 | 2.69402 | 11.83229 | 2.03415 | .69237 | .09082 | .00825 |
| G | 3.51601 | .82543 | 2.90222 | 12.36233 | 2.07921 | .73743 | .08800 | .00774 |
| H | 3.92169 | .90741 | 3.55858 | 15.37965 | 2.31911 | .97733 | .06992 | .00489 |
| J | 3.73199 | .91328 | 3.40835 | 13.92775 | 2.20693 | .86515 | .04813 | .00232 |
| K | 3.92840 | 1.03822 | 4.07854 | 15.43233 | 2.32308 | .98130 | .05692 | .00324 |
| L | 4.05308 | .96708 | 3.91965 | 16.42746 | 2.39681 | 1.05503 | .08795 | .00774 |
| M | 3.98019 | .97359 | 3.87507 | 15.84191 | 2.35371 | 1.01193 | .03834 | .00147 |
| N | 4.27669 | 1.31973 | 5.64408 | 18.29908 | 2.52905 | 1.18727 | .13246 | .01755 |
| O | 4.31408 | 1.34064 | 5.78363 | 18.61129 | 2.55116 | 1.20938 | .13126 | .01723 |
| P | 4.37014 | 1.26623 | 5.53360 | 19.09812 | 2.58431 | 1.24253 | .02370 | .00056 |
| | 58.92183 | 14.71715 | 58.45295 | 232.53787 | | | | .12493 |

CALCULATION OF STRAIGHT LINE a and b:

$$14.71715 = 15a + 58.92183b$$
$$58.45295 = 58.92183a + 232.53787b \quad (k = .254575)$$

$$.16351 = .27650b$$

$$b = .591356$$

$$\log a = \frac{14.71715 - 34.84378}{15}$$

$$\log a = -1.34178$$

$$a = .045521$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 9} - 1$$

$$= \log^{-1} .1803 \times .35346 - 1$$

$$= .06373$$

$$PE = 15.81\%$$

$$y = a(TL)^b = .045521(TL)^{.591356}$$

## STRAIGHT LINE TREND

HORIZONTAL TAIL SURFACE WT/SPAN
vs. TAIL LOAD x SPAN x $10^{-4}$

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | $\log TL_h x b_h x 10^{-4}$ | $\log W_h/b_h$ | 2 x 3 | $2^2$ | b x 2 | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 1.05346 | .78390 | .82581 | 1.10978 | .51302 | .94294 | .15904 | .02529 |
| B | 1.21706 | .96047 | 1.16895 | 1.48124 | .59269 | 1.02261 | .06214 | .00386 |
| C | .99669 | .92686 | .92379 | .92379 | .48537 | .91529 | .01157 | .00013 |
| D | .51054 | .67210 | .34313 | .26065 | .24862 | .67854 | .00644 | .00004 |
| E | 1.22531 | 1.03902 | 1.27312 | 1.50138 | .59670 | 1.02662 | .01240 | .00015 |
| F | .62535 | .78319 | .48977 | .39106 | .30453 | .73445 | .04874 | .00238 |
| G | .62491 | .82543 | .51582 | .39051 | .30432 | .73424 | .09119 | .00832 |
| H | 1.09342 | .90741 | .99218 | 1.19557 | .53247 | .96239 | .05498 | .00302 |
| J | .86776 | .91328 | .79251 | .75301 | .42258 | .85250 | .06078 | .00369 |
| K | 1.19557 | 1.03822 | 1.24126 | 1.42939 | .58222 | 1.01214 | .02608 | .00068 |
| L | 1.37177 | .96708 | 1.32661 | 1.88175 | .66803 | 1.09795 | .13087 | .01713 |
| M | 1.22939 | .97359 | 1.19692 | 1.51140 | .59869 | 1.02861 | .05502 | .00303 |
| N | 1.57401 | 1.31973 | 2.07727 | 2.47751 | .76651 | 1.19643 | .12330 | .01520 |
| O | 1.72620 | 1.34064 | 2.31421 | 2.97977 | .84063 | 1.27055 | .07009 | .00491 |
| P | 1.66746 | 1.26623 | 2.11139 | 2.78042 | .81202 | 1.24194 | .02429 | .00059 |
| | 16.97891 | 14.71715 | 17.59274 | 21.13683 | | | | .08842 |

CALCULATION OF STRAIGHT LINE a and b:

$14.71715 = 15a + 16.97891b$
$17.59274 = 16.97891a + 21.13683b$ (k = .8334489)

$.82514 = 1.69440b$

$b = .486981$

$\log a = .429916$

$a = 2.6910$

$W_h/b_h = 2.69\,(TL_h \times b_h \times 10^{-4})^{.487}$

CALCULATION OF PROBABLE ERROR:

$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\sum 9} - 1$

$= \log^{-1} .1803 \times .29736 - 1$

$= \log^{-1} .05361 - 1$

$PE = 13.1\%$

VERTICAL TAIL SURFACE WT/SPAN
vs. SPAN

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log $b_V$ | log $W_V/b_V$ | 2 x 3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | .69373 | .87448 | .60665 | .48126 | 1.01751 | .95768 | .08320 | .00692 |
| B | .76641 | 1.01912 | .78106 | .58738 | 1.12412 | 1.06429 | .04517 | .00204 |
| C | .69897 | 1.08636 | .75933 | .48856 | 1.02520 | .96537 | .12099 | .01464 |
| E | .69897 | 1.20412 | .84164 | .48856 | 1.02520 | .96537 | .23975 | .05700 |
| F | .72016 | .88195 | .63515 | .51863 | 1.05628 | .99645 | .11450 | .01311 |
| G | .81291 | .70586 | .57380 | .66082 | 1.19232 | 1.13249 | .42663 | .18201 |
| H | .70757 | 1.09167 | .77243 | .50066 | 1.03781 | .97798 | .11369 | .01293 |
| I | .80754 | .99167 | .80081 | .65212 | 1.18444 | 1.12461 | .13294 | .01767 |
| J | .69897 | .85733 | .59925 | .48856 | 1.02520 | .96537 | .10804 | .01167 |
| K | .72427 | 1.12090 | .81183 | .52457 | 1.06231 | 1.00248 | .11842 | .01402 |
| L | .74036 | 1.11093 | .82249 | .54813 | 1.08591 | 1.02608 | .08485 | .00720 |
| M | .74036 | .95856 | .70968 | .54813 | 1.08591 | 1.02608 | .06752 | .00456 |
| N | .87506 | 1.39915 | 1.22434 | .76573 | 1.28348 | 1.22365 | .17550 | .03080 |
| O | 1.02119 | 1.50651 | 1.53843 | 1.04283 | 1.49781 | 1.43798 | .06853 | .00470 |
| P | .88081 | 1.28937 | 1.13569 | .77583 | 1.29191 | 1.23208 | .05729 | .00328 |
| | 11.58729 | 16.09798 | 12.61258 | 9.07177 | | | | .38255 |

CALCULATION OF STRAIGHT LINE a and b:

16.09798 = 15a + 11.58729b
12.61258 = 11.58729a + 9.07177b (k = 1.294522)

16.32726 = 11.74361

.22928 = .156326

b = 1.46673

$$\log a = \frac{16.09798 - 16.99543}{15}$$

log a = -.05983
a = .87131

$$y = a\,(b_V)^b = .87131 b_V^{1.46673}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\Sigma\, 9} - 1$$

$$= \log^{-1} .1803 \times .61851 - 1$$

$$= \log^{-1} .11152 - 1$$

PE = 29.28%

STRAIGHT LINE TREND

VERTICAL TAIL SURFACE WT/SPAN
vs. VERTICAL TAIL SURFACE AREA

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log Sv | log Wv/bv | 2 x 3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 1.28012 | .87448 | 1.11944 | 1.63871 | 1.30703 | .91212 | .03764 | .00142 |
| B | 1.50705 | 1.01912 | 1.53586 | 2.27120 | 1.53873 | 1.14382 | .12470 | .01555 |
| C | 1.36399 | 1.08636 | 1.48178 | 1.86047 | 1.39266 | .99775 | .08861 | .00785 |
| E | 1.41162 | 1.20412 | 1.69976 | 1.99267 | 1.44129 | 1.04638 | .15774 | .02488 |
| F | 1.26998 | .88195 | 1.12006 | 1.61285 | 1.29667 | .90176 | .01981 | .00039 |
| G | 1.26858 | .70566 | .89544 | 1.60930 | 1.29525 | .90034 | .19448 | .03782 |
| H | 1.36922 | 1.09167 | 1.49474 | 1.87476 | 1.39800 | 1.00309 | .08858 | .00785 |
| I | 1.35218 | .99167 | 1.34092 | 1.82839 | 1.38060 | .98569 | .00598 | .00004 |
| J | 1.35372 | .85733 | 1.16059 | 1.83257 | 1.38218 | .98727 | .12994 | .01688 |
| K | 1.36922 | 1.12090 | 1.54376 | 1.87476 | 1.39800 | 1.00309 | .11781 | .01388 |
| L | 1.63012 | 1.11093 | 1.81095 | 2.65729 | 1.66439 | 1.26948 | .15855 | .02514 |
| M | 1.33001 | .95856 | 1.27489 | 1.76893 | 1.35797 | .96306 | .00450 | .00002 |
| N | 1.60358 | 1.39915 | 2.24365 | 2.57147 | 1.63729 | 1.24238 | .15677 | .02458 |
| O | 1.91471 | 1.50651 | 2.88453 | 3.66611 | 1.95496 | 1.56005 | .05354 | .00287 |
| P | 1.54419 | 1.28937 | 1.99103 | 2.38452 | 1.57665 | 1.18174 | .10763 | .01158 |
| | 21.56829 | 16.09798 | 23.58840 | 31.44500 | | | | .19075 |

CALCULATION OF STRAIGHT LINE a and b:

$$16.09798 = 15a + 21.56829b$$
$$23.58840 = 21.56829a + 31.44500b \quad (k = .695465)$$

$$16.40491 = 21.86890b$$

$$b = 1.02102$$

$$\log a = \frac{16.09798 - 22.02166}{15}$$

$$\log a = -.39491$$

$$a = .402803$$

$$y = a\,(S_V)^b = .40280S_v^{1.02102}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}}\sqrt{\sum 9} - 1$$

$$= \log^{-1} .1803 \times .43675 - 1$$

$$= \log^{-1} .07875 - 1$$

$$PE = 19.85\%$$

VERTICAL TAIL SURFACE WT/SPAN
vs. TAIL LOAD

STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log $TL_V$ | log $W_V/b_V$ | 2 x 3 | $2^2$ | (2)b | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | 3.27300 | .87448 | 2.86217 | 10.71253 | 2.17326 | .97608 | .10160 | .01032 |
| B | 3.52244 | 1.01912 | 3.58979 | 12.40758 | 2.33889 | 1.14171 | .12259 | .01503 |
| C | 3.46982 | 1.08636 | 3.76947 | 12.03965 | 2.30395 | 1.10677 | .02041 | .00042 |
| E | 3.69897 | 1.20412 | 4.45400 | 13.68238 | 2.45610 | 1.26892 | .05480 | .00300 |
| F | 2.94300 | .88195 | 2.59558 | 8.66125 | 1.95414 | .75696 | .12499 | .01562 |
| G | 2.92376 | .70586 | 2.06377 | 8.54837 | 1.94137 | .74419 | .03833 | .00147 |
| H | 3.48458 | 1.09167 | 3.80401 | 12.14230 | 2.31375 | 1.11657 | .02490 | .00062 |
| J | 3.45423 | .85733 | 2.96142 | 11.93170 | 2.29360 | 1.09642 | .23909 | .05716 |
| K | 3.43136 | 1.12090 | 3.84621 | 11.77423 | 2.27841 | 1.08123 | .03967 | .00157 |
| L | 3.51455 | 1.11093 | 3.90331 | 12.34855 | 2.33365 | 1.13647 | .02554 | .00065 |
| M | 3.13513 | .95856 | 3.00521 | 9.82904 | 2.08172 | .88454 | .07402 | .00548 |
| N | 3.55509 | 1.39915 | 4.97410 | 12.63866 | 2.36057 | 1.16339 | .23576 | .05558 |
| O | 3.96848 | 1.50651 | 5.97855 | 15.74883 | 2.63506 | 1.43788 | .06863 | .00471 |
| P | 3.61805 | 1.28937 | 4.66501 | 13.09029 | 2.40237 | 1.20519 | .08418 | .00709 |
| | 47.99246 | 15.10631 | 52.47260 | 165.55536 | | | | .17872 |

CALCULATION OF STRAIGHT LINE a and b:

$$15.10631 = 14a + 47.99246b$$
$$52.47260 = 47.99246a + 165.55536 \quad (k = .2917125)$$

$$.20060 = .30211b$$

$$b = .663997$$

$$\log a = \frac{15.10631 - 31.86685}{14}$$

$$\log a = -1.19718$$

$$a = .063508$$

$$y = a(TL_V)^b = .06351 TL_V^{.663997}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n - 1}} \sqrt{\sum 9} - 1$$

$$= \log^{-1} .1871 \times .42280 - 1$$

$$= \log^{-1} .07911 - 1$$

$$PE = 19.9\%$$

VERTICAL TAIL SURFACE WT/SPAN
vs. TAIL LOAD x SPAN x $10^{-3}$

## STRAIGHT LINE TREND

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Model | log TLxbvx$10^{-3}$ | log Wv/bv | 2 x 3 | $2^2$ | b x 2 | log y' | Δlog y | $(\Delta \log y)^2$ |
| A | .96673 | .87448 | .84539 | .93457 | .56622 | .94356 | .06908 | .00477 |
| B | 1.28885 | 1.01912 | 1.31349 | 1.66113 | .75489 | 1.13223 | .11311 | .01279 |
| C | 1.16879 | 1.08636 | 1.26973 | 1.36607 | .68457 | 1.06191 | .02445 | .00060 |
| E | 1.39794 | 1.20412 | 1.68329 | 1.95424 | .81878 | 1.19612 | .00800 | .00006 |
| F | .66316 | .88195 | .58487 | .43978 | .38842 | .86576 | .11619 | .01350 |
| G | .73667 | .70586 | .51999 | .54268 | .43147 | .80881 | .10295 | .01060 |
| H | 1.19215 | 1.09167 | 1.30143 | 1.42122 | .69825 | 1.07559 | .01608 | .00026 |
| J | 1.15320 | .85733 | .98867 | 1.32987 | .67544 | 1.05278 | .19545 | .03820 |
| K | 1.15563 | 1.12090 | 1.29535 | 1.33548 | .67686 | 1.05420 | .06670 | .00445 |
| L | 1.25491 | 1.11093 | 1.39412 | 1.57480 | .73501 | 1.11235 | .00142 | .00000 |
| M | .87549 | .95856 | .83921 | .76648 | .51278 | .89012 | .06844 | .00468 |
| N | 1.43015 | 1.39915 | 2.00099 | 2.04533 | .83765 | 1.21499 | .18416 | .03391 |
| O | 1.98967 | 1.50651 | 2.99746 | 3.95879 | 1.16537 | 1.54271 | .03620 | .00131 |
| P | 1.49886 | 1.28937 | 1.93259 | 2.24658 | .87789 | 1.25523 | .03414 | .00117 |
| | 16.77220 | 15.10631 | 18.96658 | 21.57702 | | | | .12630 |

CALCULATION OF STRAIGHT LINE a and b:

15.10631 = 14a + 16.77220b
18.96658 = 16.77220a + 21.57702b    (k = .8347145)

.72537 = 1.23845b

b = .585708

log a = .37734

a = 2.3842

$$W_v/b_v = 2.38\,(TL_v \times b_v \times 10^{-3})^{.586}$$

CALCULATION OF PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\sum 9} - 1$$

$$= \log^{-1} .1871 \times .35539 - 1$$

$$= \log^{-1} .06649 - 1$$

PE = 16.5%

# APPENDIX IV

## CALCULATIONS FOR PURELY STATISTICAL TREATMENT

WING LOG DATA FOR DERIVATION OF AND ESTIMATE BY "EXACT FORMULAS"

| Model | log W | log b | log S | log n | log $t_r$ | log $W_w$ | log $C_r$ | log AR |
|---|---|---|---|---|---|---|---|---|
| A | 3.86958 | 1.53148 | 2.32879 | 1.07918 | 1.16879 | 2.94091 | 1.99388 | .75417 |
| B | 4.02325 | 1.65801 | 2.58625 | 1.07918 | 1.25285 | 3.25888 | 2.10721 | .72977 |
| C | 3.96090 | 1.59295 | 2.40654 | 1.07918 | 1.20412 | 3.05038 | 2.00000 | .77936 |
| D | 3.53148 | 1.43933 | 2.00000 | 1.07918 | 1.02060 | 2.63246 | 1.81954 | .87866 |
| E | 4.10380 | 1.60045 | 2.47712 | 1.07918 | 1.25285 | 3.24180 | 2.03743 | .72378 |
| F | 3.61982 | 1.62325 | 2.37840 | .92942 | 1.20222 | 2.79449 | 1.96848 | .86810 |
| G | 3.72263 | 1.62325 | 2.40432 | .92942 | 1.13033 | 2.84323 | 1.95424 | .86810 |
| H | 3.90309 | 1.56844 | 2.36736 | 1.07918 | 1.24797 | 2.98000 | 2.01703 | .76952 |
| I | 3.98227 | 1.58961 | 2.37585 | 1.07918 | 1.15534 | 3.11394 | 2.04139 | .80337 |
| J | 3.86806 | 1.57978 | 2.41497 | 1.13033 | 1.18041 | 3.01284 | 2.02078 | .74459 |
| K | 4.04139 | 1.63175 | 2.52375 | 1.13033 | 1.27021 | 3.23350 | 2.07700 | .73975 |
| L | 4.17026 | 1.73376 | 2.69020 | .78533 | 1.34242 | 3.35774 | 2.15534 | .77732 |
| M | 3.86759 | 1.61836 | 2.51188 | 1.13033 | 1.26951 | 2.98722 | 2.09342 | .72484 |
| N | 4.16435 | 1.68124 | 2.59273 | 1.13033 | 1.38202 | 3.38166 | 2.17210 | .76975 |
| O | 4.38021 | 1.84714 | 2.78462 | .80482 | 1.33041 | 3.53681 | 2.07555 | .90966 |
| * | 4.19312 | 1.69897 | 2.60206 | 1.02119 | 1.34439 | 3.24944 | 2.10823 | .79588 |

MATRIX FOR SOLVING FOR FIVE "EXACT" EXPONENTS

| Model | A | B | C | D | E | F | | G |
|---|---|---|---|---|---|---|---|---|
| | A log W + | B log b + | C log S + | D log n + | E log t + | log K | | log Ww |
| D | 3.53148 | 1.43933 | 2.00000 | 1.07918 | 1.02060 | 1.00000 | = | 2.6324600 |
| G | 3.72263 | 1.62325 | 2.40432 | .92942 | 1.13033 | 1.00000 | = | 2.8432300 |
| M | 3.86759 | 1.61836 | 2.51188 | 1.13033 | 1.26951 | 1.00000 | = | 2.9872200 |
| E | 4.10380 | 1.60045 | 2.47712 | 1.07918 | 1.25285 | 1.00000 | = | 3.2418000 |
| O | 4.38021 | 1.84714 | 2.78462 | .80482 | 1.33041 | 1.00000 | = | 3.5368100 |
| L | 4.17026 | 1.73376 | 2.6902 | .73239 | 1.34242 | 1.00000 | = | 3.3577400 |
| | 3.53148 | .4705713 | .5663348 | .3055886 | .2890006 | .2831674 | | .7454268 |
| | 3.72263 | .1060128 | 2.7927283 | -1.9636609 | .5139725 | -.5105745 | | .6440901 |
| | 3.86759 | .0420413 | .2041192 | .1518399 | .6376963 | -.3611133 | | .3778986 |
| | 4.1038 | -.0721411 | .3544657 | -.3703771 | .3297006 | .1914089 | | -.2571184 |
| | 4.38021 | .0618321 | .1311068 | -.4320944 | .0915713 | -.8592323 | | .7772685 |
| | 4.17026 | .0340817 | .2332557 | -.5104865 | .1392567 | .1381168 | | -.7274825 |

$$W_W = .187291 \frac{W^{1.039015} S^{.043659} t^{.152192}}{b^{.257488} n^{.168050}}$$

A = 1.0390153
B = -.2574877
C = .0436594
D = -.1680496
E = .1521920
log k = -.7274825
k = .1872920

MATRIX FOR SOLVING FOR SIX "EXACT" EXPONENTS

| | A | B | C | D | E | F | G | | |
|---|---|---|---|---|---|---|---|---|---|
| | DES.G.WT. LOG | ASPECT RATIO LOG | AREA LOG | LD.FAC. LOG | THICK LOG | ROOT CHD. LOG | CONST. LOG | | WING WT. LOG |
| D | 3.53148 | .87866 | 2.00000 | 1.07918 | 1.02060 | 1.81954 | 1.00000 | = | 2.63246 |
| G | 3.72263 | .86810 | 2.40432 | .92942 | 1.13033 | 1.95424 | 1.00000 | = | 2.84323 |
| M | 3.86759 | .72484 | 2.51188 | 1.13033 | 1.26951 | 2.09342 | 1.00000 | = | 2.98722 |
| E | 4.10380 | .72378 | 2.47712 | 1.07918 | 1.25285 | 2.03743 | 1.00000 | = | 3.24180 |
| O | 4.38021 | .90966 | 2.78462 | .80482 | 1.33041 | 2.07555 | 1.00000 | = | 3.53681 |
| L | 4.17026 | .77732 | 2.69020 | .73239 | 1.34242 | 2.15534 | 1.00000 | = | 3.35774 |
| I | 3.98227 | .58973 | 2.37658 | 1.07918 | 1.15534 | 2.04139 | 1.00000 | = | 3.11394 |
| | 3.53148 | .2488079 | .5663348 | .3055886 | .289006 | .5152344 | .2831674 | | .7454268 |
| | 3.72263 | -.0581197 | -5.0940529 | 3.5817995 | -.9375074 | -.6230750 | .9313092 | | -1.1748473 |
| | 3.86759 | -.2374469 | -.8880378 | -.8996528 | .0797647 | .0531989 | -.1418420 | | .1967811 |
| | 4.10380 | -.2972779 | -1.3613541 | -.3348506 | .3083849 | .5667983 | .2338413 | | -.3026725 |
| | 4.38021 | -.1801709 | -.6138454 | -.4406339 | +.0804631 | -.1384287 | -.7030361 | | .5395392 |
| | 4.17026 | -.2602736 | -.9974108 | -.5070695 | .1291347 | .2028518 | .6378986 | | -.4436679 |
| | 3.98227 | -.4010902 | -1.9218928 | -.4301679 | -.0856070 | .0738888 | -.0334425 | | -.1636370 |

$$W = .686063 \frac{W^{.97846}\, t^{.427530}}{AR^{.23480}\, S^{.025962}\, n^{.203946}\, C_r^{.163637}}$$

A = .9784639
B = -.2347972
C = -.0259619
D = -.2039455
E = .4275298
F = -.3392841
log k = G = -.1636370
k = .686063

PROBABLE ERROR OF ESTIMATE BY "EXACT" FORMULA #1

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| Model | A log W | B log b | C log S | D log n | E log $t_r$ | log $W_w'$ | log $W_w$ | $\Delta$log $W_w$ | $(\Delta \log W_w)^2$ |
| A | 4.02055 | -.39434 | .101681 | -.18736 | .17788 | 2.99693 | 2.94091 | .05602 | .00341 |
| B | 4.18022 | -.42692 | .11291 | -.18136 | .19067 | 3.14804 | 3.25888 | .11084 | .01229 |
| C | 4.11544 | -.41017 | .10507 | -.18136 | .18326 | 3.08476 | 3.05038 | .03438 | .00118 |
| F | 3.76105 | -.41797 | .10384 | -.15619 | .18297 | 2.74622 | 2.79449 | .04827 | .00233 |
| H | 4.05537 | -.40385 | .10336 | -.18136 | .18993 | 3.03597 | 2.98000 | .05597 | .00313 |
| I | 4.13764 | -.40931 | .10373 | -.18136 | .17583 | 3.09905 | 3.11394 | .01489 | .00022 |
| J | 4.01897 | -.40677 | .10544 | -.18995 | .17965 | 2.97986 | 3.01284 | .03298 | .00109 |
| K | 4.19907 | -.42016 | .11019 | -.18995 | .19332 | 3.16499 | 3.23350 | .06851 | .00469 |
| N | 4.32682 | -.43290 | .11320 | -.18995 | .21033 | 3.30002 | 3.38166 | .08164 | .00667 |
| P | 4.35672 | -.43746 | .11360 | -.17161 | .20461 | 3.33838 | 3.24944 | .08894 | .00791 |
| | | | | | | | | | .04265 |

PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\sum 10} - 1$$

$$= \log^{-1} .1742 \times .20652 - 1$$

$$= \log^{-1} .03598 - 1$$

$$PE = 8.6\%$$

PROBABLE ERROR OF ESTIMATE BY "EXACT" FORMULA #2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| Model | A log W | B log AR | C log S | D log n | E log $t_r$ | F log $C_r$ | log $W_w'$ | log $W_w$ | $\Delta$log $W_w$ | $(\Delta \log W_w)^2$ |
| A | 3.78624 | -.17708 | -.06046 | -.22009 | .49969 | -.67649 | 2.98817 | 2.94091 | .04726 | .00223 |
| B | 3.93660 | -.17135 | -.06714 | -.22009 | .53563 | -.71494 | 3.13507 | 3.25838 | .12381 | .01533 |
| C | 3.87560 | -.18299 | -.06248 | -.22009 | .51480 | -.67857 | 3.08263 | 3.05038 | .03225 | .00104 |
| F | 3.54186 | -.20383 | -.06175 | -.18955 | .51398 | -.66787 | 2.76920 | 2.79449 | .02529 | .00064 |
| H | 3.81903 | -.18068 | -.06146 | -.22009 | .53354 | -.68435 | 3.04235 | 2.98000 | .06235 | .00389 |
| J | 3.78476 | -.17483 | -.06270 | -.22009 | .50466 | -.68562 | 2.98254 | 3.01284 | .03030 | .00092 |
| K | 3.95435 | -.17369 | -.06552 | -.23053 | .54305 | -.70469 | 3.15933 | 3.23350 | .07417 | .00550 |
| N | 4.07467 | -.18074 | -.06731 | -.23053 | .59085 | -.72169 | 3.30161 | 3.38166 | .08005 | .00641 |
| P | 4.10282 | -.18687 | -.06755 | -.20827 | .57477 | -.71529 | 3.33597 | 3.24944 | .08653 | .00749 |
| | | | | | | | | | | .04345 |

PROBABLE ERROR:

$$PE = \log^{-1} \frac{.6745}{\sqrt{n-1}} \sqrt{\Sigma 11} - 1$$

$$= \log^{-1} .1742 \times .20845 - 1$$

$$= \log^{-1} .03631 - 1$$

$$PE = 8.7\%$$

# APPENDIX V

## COMPONENT WEIGHT AND DIMENSIONAL INFORMATION

## WING INFORMATION

| Model | $W_w$ | S | Ww/S | b | $t_r$ | Ww/b | GWxn | GWxnxbx10-6 | $\frac{GWxnb}{t}$ $10^{-4}$ |
|---|---|---|---|---|---|---|---|---|---|
| A | 873 | 213 | 4.10 | 34.00 | 14.75 | 25.68 | 88,372 | 3.022 | 20.488 |
| B | 1815 | 386 | 4.70 | 45.50 | 17.00 | 39.89 | 126,600 | 5.760 | 32.179 |
| C | 1123 | 255 | 4.41 | 39.17 | 16.00 | 28.67 | 109,668 | 4.296 | 26.850 |
| D | 429 | 100 | 4.29 | 27.50 | 10.725 | 15.60 | 40,800 | 1.122 | 10.462 |
| E | 1745 | 300 | 5.81 | 40.78 | 17.90 | 42.79 | 152,400 | 6.215 | 34.721 |
| F | 623 | 239 | 2.61 | 42.00 | 15.93 | 14.83 | 35,420 | 1.488 | 9.341 |
| G | 697 | 254 | 2.74 | 42.00 | 13.50 | 16.60 | 44,880 | 1.885 | 13.963 |
| H | 955 | 233 | 4.10 | 37.00 | 17.70 | 25.81 | 96,000 | 3.552 | 20.068 |
| I | 1300 | 238 | 5.46 | 38.88 | 14.30 | 33.44 | 115,200 | 4.479 | 31.322 |
| J | 1030 | 280 | 3.96 | 38.00 | 15.15 | 27.11 | 99,630 | 3.786 | 24.990 |
| K | 1712 | 334 | 5.13 | 42.83 | 18.63 | 39.97 | 148,500 | 6.360 | 34.138 |
| L | 2279 | 490 | 4.65 | 54.17 | 22.00 | 42.07 | 90,268 | 4.890 | 22.227 |
| M | 971 | 325 | 2.99 | 41.50 | 18.60 | 23.40 | 99,522 | 4.130 | 22.204 |
| N | 2408 | 392 | 6.15 | 48.00 | 24.10 | 50.17 | 197,100 | 9.461 | 39.257 |
| O | 3442 | 609 | 5.65 | 70.33 | 21.40 | 48.94 | 153,120 | 10.769 | 50.322 |
| P | 1776 | 400 | 4.44 | 50.00 | 22.10 | 35.52 | 163,800 | 8.190 | 37.059 |

LANDING GEAR DATA

| Model | MAIN GEAR WEIGHT | NOSE GEAR WEIGHT | TAIL WHEEL WEIGHT |
|---|---|---|---|
| A | 376.9 | 142.0 | - |
| B | 775.0 | 174.0 | - |
| C | 484.2 | 164.4 | - |
| D | 228.8 | 123.4 | - |
| E | 965.0 | - | 99.0 |
| F | 248.1 | - | 33.6 |
| G | 403.0 | - | 42.0 |
| H | 690.0 | - | 91.0 |
| I | 474.6 | 118.4 | - |
| J | 286.0 | - | 31.5 |
| K | 671.1 | - | 62.7 |
| L | 854.0 | - | 100.0 |
| M | 536.0 | - | 42.0 |
| N | 1001.0 | 284.2 | - |
| O | 1633.1 | 449.9 | - |
| P | 883.0 | - | 93.8 |

FUSELAGE INFORMATION

| Model | FUS.WT. | L(') | d(") | W(") | WT/L' | $\frac{WT}{L'}$xd" | $\frac{W}{L'}$xd' |
|---|---|---|---|---|---|---|---|
| A | 622 | 30.17 | 70.66 | 34.75 | 20.65 | 1460 | 121.7 |
| B | 886 | 38.10 | 72.00 | 36.00 | 23.25 | 1673 | 139.4 |
| C | 701 | 32.70 | 78.29 | 34.75 | 21.45 | 1680 | 140.0 |
| D | 231 | 22.88 | 58.75 | 34.00 | 10.10 | 343.5 | 28.6 |
| E | 1058 | 36.15 | 91.00 | 54.00 | 29.30 | 2665 | 222.1 |
| F | 433 | 31.20 | 78.00 | 54.00 | 13.88 | 1083 | 90.3 |
| G | 476 | 29.00 | 76.50 | 46.81 | 16.42 | 1258 | 104.8 |
| H | 509 | 32.28 | 75.75 | 35.00 | 15.76 | 1193 | 99.4 |
| I | 1140 | 34.50 | 56.00 | 56.00 | 33.00 | 1848 | 154.0 |
| J | 585 | 28.78 | 84.00 | | 20.33 | 1709 | 142.4 |
| K | 616 | 33.83 | 92.00 | 60.25 | 18.20 | 1674 | 139.5 |
| L | 1229 | 40.96 | 99.50 | 60.00 | 30.00 | 2990 | 249.2 |
| M | 479 | 32.10 | 82.00 | 50.50 | 14.91 | 1223 | 101.9 |
| N | 1342 | 39.27 | 79.00 | 62.50 | 34.15 | 2696 | 224.7 |
| O | 1334 | 46.00 | 96.00 | 62.00 | 29.00 | 2783 | 231.9 |
| P | 894 | 39.41 | 75.00 | 60.00 | 22.68 | 1700 | 141.7 |

## HORIZONTAL TAIL SURFACES DATA

| Model | $W_H$ | $b_H$ | $S_H$ | $(TL)_H$ | $W_H/b_H$ | $W_H/S_H$ | $TL_H x b_H x 10^{-4}$ |
|---|---|---|---|---|---|---|---|
| A | 79 | 13.00 | 40.44 | 8,700 | 6.08 | 1.953 | 11.31 |
| B | 152 | 16.65 | 71.22 | 9,960 | 9.13 | 2.134 | 16.58 |
| C | 112 | 13.25 | 43.75 | 7,490 | 8.45 | 2.560 | 9.92 |
| D | 42 | 9.00 | 18.90 | 3,600 | 4.70 | 2.222 | 3.24 |
| E | 175 | 16.00 | 60.00 | 10,500 | 10.94 | 2.916 | 16.80 |
| F | 93 | 15.33 | 53.22 | 2,753 | 6.07 | 1.747 | 4.22 |
| G | 86 | 12.85 | 50.11 | 3,281 | 6.69 | 1.716 | 4.22 |
| H | 120 | 14.85 | 48.35 | 8,350 | 8.08 | 2.481 | 12.40 |
| I | 133 | 15.58 | 43.80 | - | 8.54 | 3.036 | - |
| J | 112 | 13.67 | 49.05 | 5,395 | 8.19 | 2.283 | 7.37 |
| K | 202 | 18.50 | 77.84 | 8,480 | 10.92 | 2.595 | 15.69 |
| L | 193 | 20.83 | 110.84 | 11,300 | 9.27 | 1.741 | 23.54 |
| M | 167 | 17.75 | 46.64 | 9,554 | 9.41 | 3.580 | 16.96 |
| N | 414 | 19.83 | 57.66 | 18,906 | 20.88 | 7.180 | 37.49 |
| O | 566 | 25.83 | 92.00 | 20,610 | 21.91 | 6.152 | 53.24 |
| P | 366 | 19.83 | 55.83 | 23,530 | 18.46 | 6.555 | 46.66 |

## VERTICAL TAIL SURFACE DATA

| Model | $W_v$ | $b_v$ | $S_v$ | $(TL)_v$ | $W_v/b_v$ | $W_v/S_v$ | $TL_v x b_v x 10^{-3}$ |
|---|---|---|---|---|---|---|---|
| A | 37 | 4.94 | 19.06 | 1,875 | 7.49 | 1.941 | 9.26 |
| B | 61 | 5.84 | 32.14 | 3,330 | 10.45 | 1.897 | 19.45 |
| C | 61 | 5.00 | 23.12 | 2,950 | 12.20 | 2.638 | 14.75 |
| D | 17 | 3.60 | 12.37 | 1,220 | 4.72 | 1.374 | 4.39 |
| E | 80 | 5.00 | 25.80 | 5,000 | 16.00 | 3.100 | 12.50 |
| F | 40 | 5.25 | 18.62 | 877 | 7.62 | 2.148 | 4.60 |
| G | 33 | 6.50 | 18.56 | 839 | 5.08 | 1.778 | 5.45 |
| H | 63 | 5.10 | 23.40 | 3,052 | 12.35 | 2.692 | 15.57 |
| I | 63 | 6.42 | 22.50 | - | 9.81 | 2.800 | |
| J | 36 | 5.00 | 22.58 | 2,846 | 7.20 | 1.594 | 14.23 |
| K | 70 | 5.30 | 23.40 | 2,700 | 13.21 | 2.991 | 14.31 |
| L | 71 | 5.50 | 42.67 | 3,270 | 12.91 | 1.663 | 17.99 |
| M | 50 | 5.50 | 21.38 | 1,365 | 9.09 | 2.338 | 7.51 |
| N | 188 | 7.50 | 40.14 | 3,590 | 25.07 | 4.683 | 26.92 |
| O | 337 | 10.50 | 82.17 | 9,300 | 32.10 | 4.101 | 97.65 |
| P | 148 | 7.60 | 35.01 | 4,150 | 19.47 | 4.227 | 31.54 |

# LANDING FLAP DATA

| Model | $W_F$ | $b_F$ | $S_F$ | $\delta_{F_{max}}$ | $W_F/S_F$ | $W_F/b_F$ |
|---|---|---|---|---|---|---|
| A | 26 | 14.92 | 24.94 | 43° | 1.042 | 1.743 |
| B | 54 | 15.65 | 33.70 | 45° | 1.602 | 3.450 |
| C | 29 | 11.34 | 12.90 | 45° | 2.250 | 2.560 |
| D | 25 | 14.24 | 14.24 | 60° | 1.686 | 1.686 |
| E | 71 | 20.30 | | 40° | | 3.500 |
| F | 46 | 18.17 | 27.10 | 60° | 1.698 | 2.530 |
| G | 26 | 18.95 | 22.20 | 45° | 1.171 | 1.371 |
| H | 68 | 18.73 | 31.50 | 50° | 2.160 | 3.630 |
| I | 44 | 17.00 | 30.70 | 45° | 1.433 | 2.590 |
| J | 43 | 19.92 | 29.70 | 43° | 1.450 | 2.160 |
| K | 70 | 23.32 | 39.80 | 50° | 1.760 | 3.000 |
| L | 128 | 31.90 | 62.50 | 45° | 2.047 | 4.010 |
| M | 37 | 27.44 | 36.80 | 43° | 1.004 | 1.350 |
| N | 163 | 24.50 | 54.80 | 35° | 2.973 | 6.653 |
| O | 283 | 36.98 | 90.40 | 55° | 3.130 | 7.652 |
| P | 84 | 19.26 | 45.40 | 40° | 1.850 | 4.361 |

# AILERON SURFACE DATA

| Model | $W_A$ | $b_A$(total) | $S_A$(both) | $A_{max}$ | $W_A/S_A$ | $W_A/b_A$ |
|---|---|---|---|---|---|---|
| A | 43 | 13.26 | 15.46 | $10^o$ | 2.780 | 3.24 |
| B | 57 | 21.10 | 36.90 | $13.5^o$ | 1.546 | 2.70 |
| C | 45 | 20.10 | 16.30 | $15^o$ | 2.760 | 2.24 |
| D | 15 | 11.36 | 7.22 | $20^o$ | 2.080 | 1.32 |
| E | 59 | 17.50 | 27.97 | $13^o$ | 2.110 | 3.37 |
| F | 57 | 14.92 | 17.94 | $11.5^o$ | 3.180 | 3.82 |
| G | 48 | 15.90 | 22.80 | $15^o$ | 2.105 | 3.02 |
| H | 43 | 13.71 | 12.70 | $12^o$ | 3.385 | 3.58 |
| I | 69 | 14.50 | 17.60 | $20^o$ | 3.920 | 4.76 |
| J | 38 | 10.00 | 13.30 | $15^o$ | 2.860 | 3.80 |
| K | 42 | 12.75 | 15.70 | $17^o$ | 2.677 | 3.30 |
| L | 57 | 14.96 | 19.00 | $20^o$ | 3.000 | 3.82 |
| M | 53 | 12.70 | 23.60 | $10^o$ | 2.245 | 4.17 |
| N | 68 | 13.16 | 27.20 | $15^o$ | 2.500 | 5.17 |
| O | 233 | 22.68 | 59.00 | $15^o$ | 3.950 | 10.27 |
| P | 140 | 24.28 | 49.00 | $12^o$ | 2.855 | 5.77 |
| | | | | | 43.953 | |