SY-R7-70

ANALYSIS OF M16 RIFLE DISPERSION AND DIMENSIONAL DATA

By
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December 1970

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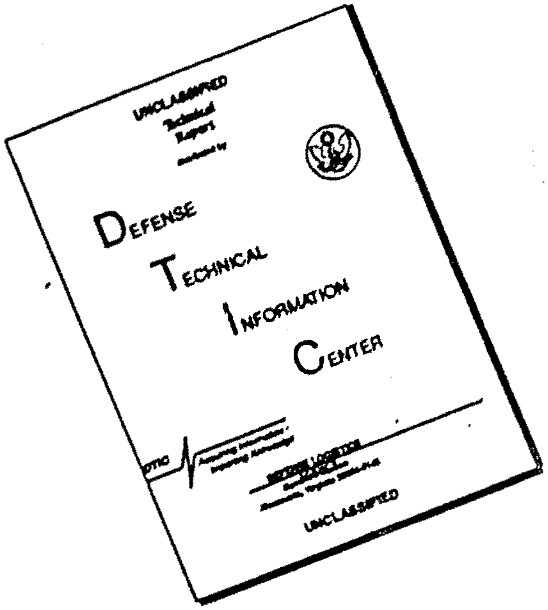

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ABSTRACT

An analysis of the M-16 rifle barrel dimensions and dispersion was conducted. Dispersion prediction equations were obtained using several categories of dimensional data. A discriminating procedure was developed suitable for use by field troops to separate barrels with "acceptable" dispersion from those "not acceptable". Depth-of-muzzle-penetration by the erosion gage was selected as the discriminating variable. A brief discussion contrasts the widely used Extreme-Spread dispersion statistic with the more efficient, and slightly more troublesome, Figure-of-Merit statistic.

I. Introduction

This study was initiated as part of an effort to investigate reports of inadequate accuracy of certain M16 rifles in Viet Nam. The barrels on suspect weapons passed the existing depth-of-breech-penetration-by-erosion-gage criterion but were noted to have enlarged muzzles. These facts prompted a "sample-measure-fire" program of M16 rifle barrels at the U. S. Army Weapons Command. This report presents an analysis of dispersion and dimensional data obtained under this program.

This study purports to treat only the dispersion (round-to-round variation) aspects of accuracy. Characteristics which contribute to aiming (bias) errors (e.g., bent barrel, loose sight, etc.) were not addressed in this phase of the effort. In addition, the environment and local maintenance procedures will be considered peculiar to Viet Nam. Conclusions should not be extended to the total population of M16 rifles. With these caveats, the study objectives were:

1. identify barrel physical characteristics highly correlated with dispersion,
2. develop an equation to predict dispersion as a function of barrel physical characteristics,
3. develop a discriminating procedure, suitable for use by field troops, to separate barrels with "acceptable" dispersion characteristics from those "not acceptable".

The first and second objectives were to provide the engineers with an empirical basis for the formulation of theories on factors contributing to dispersion and the initiation of possible corrective action. Objective 3 was to provide an easy-to-apply criterion for immediate field use.

Details considering sample selection, dimensional data, and firing procedures will be published in a separate Technical Note by the USAWECOM Research & Engineering Directorate. This information will, however, be summarized in this report.

II. Sample

Data Sources

A sample of 125 barrels was obtained during the course of the study according to dispersion or dimensional characteristics of interest or to furnish a basis for comparison with other weapons in the sample. They do not constitute a random sample from a population of interest. The following is a list of the barrel sources in order of entry into this study:

1. Initial Sample - Nineteen barrels were selected from a combat infantry division. The characteristic of interest in this selection was erosion gage penetration of the muzzle.

2. Twenty-Nine US Marine Corps Weapons - The chambers of these barrels were re-chromed at Rock Island Arsenal due to wear from use in Viet Nam. They were selected as weapons which have been used in the field but were thought to have acceptable dispersion characteristics and, thus, serve as a basis for comparison with the previous rifles.

3. Ten Endurance Weapons - These weapons fired 6000 rounds during the endurance test of new production rifles. Firing was done under favorable environmental conditions and maintenance procedures. Poor dispersion characteristics produced by environment and/or maintenance was expected to appear in comparison with these weapons.

4. Six new barrels.

5. Sixty-One barrels were requested of the field with the characteristic that muzzle penetration of the erosion gage was at least 1/8". These barrels originated from three US Army Divisions which will be designated A, B and C.

<u>Measurement Data</u>

The barrel dimensions measured in this study were selected by small arms experts of the US Army Weapons Command Research & Engineering Directorate as critical factors which may be related to dispersion. Table 1 presents a description of the measurements and the precision of the readings. The pitting factor entered the study at the suggestion of Laurence Moore (AMSWE-REE) who estimated the pitting factor for each barrel. The pitting factor is a numerical expedient which categorizes no, light, moderate, and heavy pitting as 0, 1, 2, 3 or 4 respectively. Mr. Moore wrote the pitting criteria contained in Appendix A. These criteria are not to be considered complete, but rather to illustrate the category characteristics and serve as a guide for further definition.

TABLE 1

	Measurement	Tolerance
a.	erosion gage penetration into muzzle	nearest 1/16 inch
b.	erosion gage penetration into breech, including barrel extension	nearest 1/16 inch
c.	diameter 1/16" into muzzle	nearest .0001 inch
d.	diameter 1/2" into muzzle	nearest .0001 inch
e.	pitting factor* = 0 no pitting 1 light pitting 2 moderate pitting 3 heavy pitting	
f.	diameter bore**	nearest .0001 inch
g.	diameter groove**	nearest .0001 inch

*These estimates were made by Mr. Laurence Moore of AMSWE-REE.

**These measurements were taken at 0.2" intervals from muzzle for the first inch, 1.0" increments in the interval (1", 17").

Measurements a through e (Table 1) entered the study directly. Those measurements of bore and groove diameters which were taken in the region penetrated by the erosion gage were excluded. This involved only a few measurements near the muzzle, a region described by measurements a, c, and d. The measurements are graphically displayed in Fig. 1.

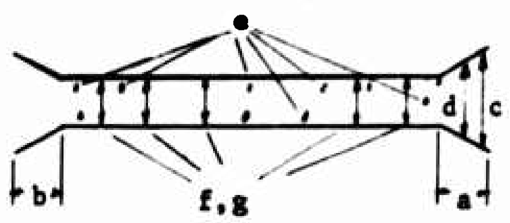


Figure 1. Schematic of Barrel Measurements
(See Table 1)

Measurements f and g were summarized by a smaller number of statistics. Maximum and minimum values and maximum variability in these measurements were assumed to be the significant statistics from previous experience with these types of data, Ref. 1. The bore and groove statistics which entered the analysis were:

a. maximum bore diameter

b. minimum bore diameter

c. maximum bore-sample-standard-deviation$\cdot 10^3$, σ_{bore}

d. maximum groove diameter

e. minimum groove diameter

f. maximum groove-sample-standard-deviation$\cdot 10^3$, σ_{groove}

(Note the maximum sample standard deviation was used, when more than one bore/groove was measured.)

Measurements f and g were taken only on the initial sample which consisted of the first four enumerated sources. They were not taken on barrels in the last source. This was due to the difficulty of obtaining these measurements and because of conclusions derived from the initial sample.

Dispersion Data

Dispersion data were obtained by firing each sample barrel at the Rock Island Arsenal 100 meter indoor firing range. Five ten-shot targets were fired from each barrel. Ball ammunition, from the same lot, was used throughout firing.

Each barrel was defouled prior to obtaining the data set used in this study. An analysis of barrels before and after defouling was made for the Initial Sample. A slight reduction in average dispersion was observed, but the effect appeared of secondary importance. Further consideration of fouling (gilding metal and tracer deposits) should include some measure of "degree-of-fouling" as an interaction between fouling-pitting and dispersion has been hypothesized.[1]

---

[1] Consider the following conjectures by Laurence Moore, AMSWE-REE:

1. An unfouled, heavily pitted barrel may cause changes in bullet configuration which would tend to increase dispersion.
2. Initial stages of fouling may fill or coat the pits. This would act to decrease roughing and therefore tend to decrease dispersion.
3. Continued fouling may cause formations of "hills" on pit edges. These obstacles could cause deformation of the bullet with resulting dispersion increases.

The above is conjecture and testing of the effects of fouling is planned by the US Army Weapons Command Research and Engineering Directorate.

Five fouling shots were fired prior to commencement of dispersion firing. The same armorer, receiver, and firing stand were used throughout the study. These variables were not addressed, but assumed of secondary importance to variables considered.

The measurement and dispersion statistics obtained for each barrel are presented in Appendix B according to barrel source. A plot of the observed dispersion is presented in Figure 2 according to source. The intent of the field sources in obtaining their sample is not clear. Division C may have sought the worst barrels with the specified 1/8" penetration, but Division A could have made a random sample with the specified constraint, etc. Although the dispersion data from these sources overlap, the mean values and variability appear different.

Dispersion Statistics

Let the horizontal and vertical coordinates of the center of the ith bullet-hole be x_i, y_i, respectively. Then, the two statistics used in this study are defined as:

1. Extreme Spread (ES) = $\max_{i,j}[(x_i - x_j)^2 + (y_i - y_j)^2]^{1/2}$

   (i.e., maximum distance between holes)

2. Figure-of-Merit (FOM) = $[\max_{i,j}|x_i - x_j| + \max_{h,k}|y_h - y_k|]/2$

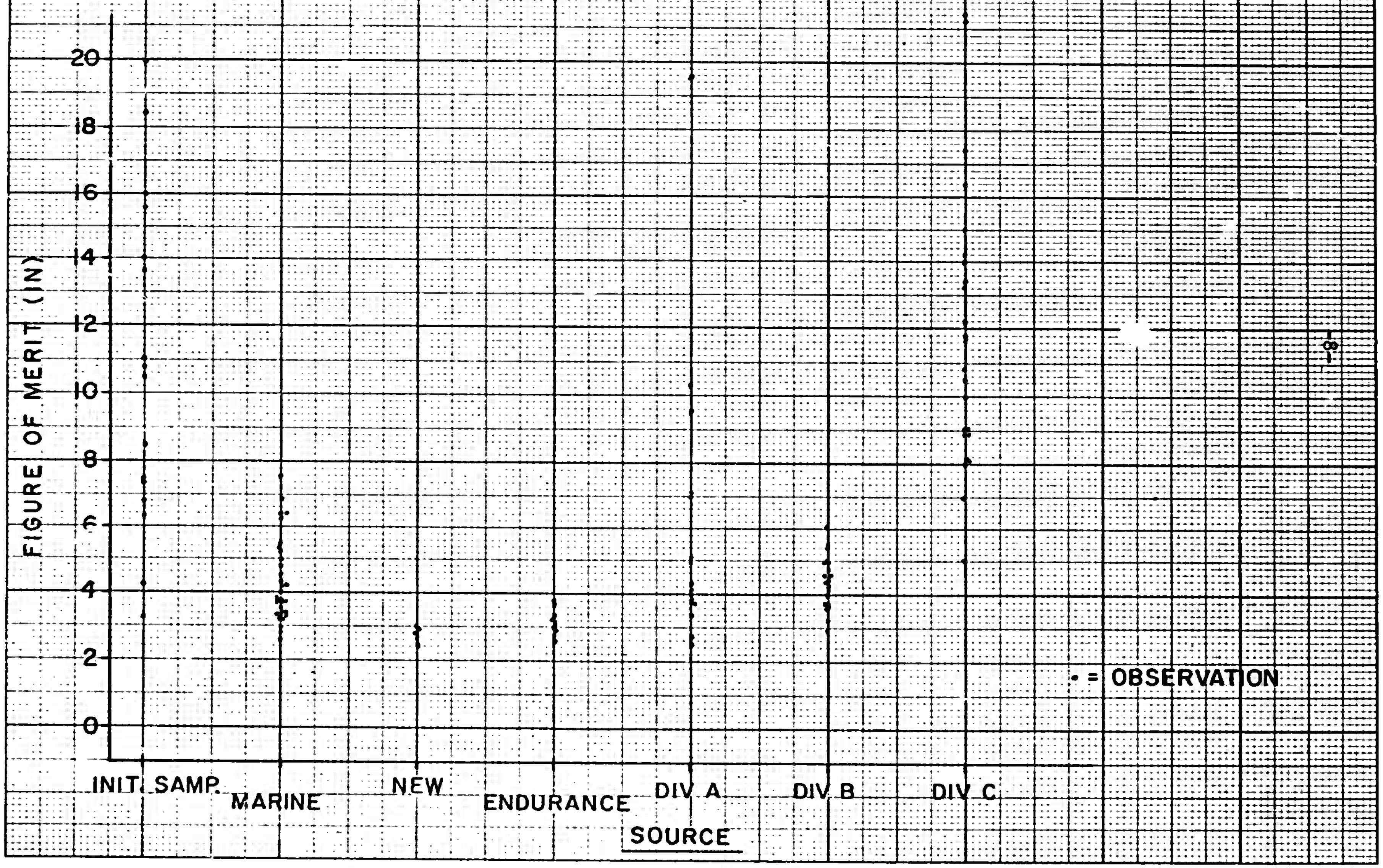
   $i,j,h,k = 1,10$

   (i.e., arithmetic average of extreme horizontal and extreme vertical spreads)

The FOM statistic is slightly more troublesome to obtain but is a more efficient statistic.

PLOT OF OBSERVED DISPERSION BY SOURCE

FIGURE 2



Assume, for a moment, that the shot pattern is circular normal with $\sigma_x = \sigma_y = \sigma$. Then, for ten shot targets,

$$E[\hat{ES}] = 3.77\sigma \qquad \text{(Ref 2)}$$
("average ES")

$$Var[\hat{ES}] = .555\sigma^2$$
(These values were based on 200 Monte-Carlo trials.)

$$\begin{aligned} E[FOM] &= E[(ES_x + ES_y)/2] \\ &= E[ES_x] \\ &= 3.077\sigma \qquad \text{(Ref 3)} \end{aligned}$$

$$\begin{aligned} Var[FOM] &= V[ES_x]/2 \\ &= .318\sigma^2 \end{aligned}$$

Defining relative efficiency of unbiased statistics as the ratio of their variances (Ref 4) we find that the estimated efficiency of the FOM statistic is 1.75 times that of the ES statistic. Consider next that a sample of five targets is measured for FOM and another sample of size N_2 is measured for the ES statistic. Setting the variances of the averaged statistics equal we have

$$\begin{aligned} Var\ FOM &= Var\ ES \\ .318\sigma^2/5 &= .555\sigma^2/N_2 \\ N_2 &= 8.75 \end{aligned}$$

Therefore, nine targets fired and measured for ES would yield slightly more information than five targets measured for FOM while eight targets would yield less.

The above permits an estimate of the relationship between expected values of the statistics ES and FOM:

$$E[FOM] = 3.077\sigma$$
$$= 3.077\ E[ES]/3.77$$
$$= .816\ E[ES]$$

This relationship was also empirically estimated from the firing data. Computing for the "ith" barrel, the statistic for the 5-target sample,

$$x_i = \overline{fom}_i \ / \ \overline{es}_i \qquad \text{(ratio of observed averages)}$$

and for the 125 barrel sample the statistic

$$x = \Sigma x_i/125$$
$$= .787.$$

We have

$$E[FOM] = .787\ E[ES].$$

This analysis points up the distribution difficulties which will be encountered in the regression. The dependent variable, FOM, is non-normal (from Ref. 5, a gamma distribution would be a good approximation), and the variance is proportional to the square of the mean. The usual test procedures and Gauss-Markov Theorem are not applicable. Reference 6 suggests the use of the logarithm of the observations in this situation to obtain a more constant variance. The least square computations will be performed for both FOM and LnFOM.

The current field-dispersion-criterion status that an acceptable weapon shall fire ten-shot groups with an extreme-spread not greater than 7" at a range of 100 yards. This scales (linearly) to a 7.7" criterion at 100 meters. This requirement will be reinterpreted as: the weapon shall fire an extreme-spread not greater than 7.7" at 100 meters with probability at least 0.90. This change in interpretation stemmed from the assumption of an underlying bivariate-normal distribution. This assumption implies that a positive probability exists for exceeding any specified extreme-spread. The reinterpreted criterion states this probability shall be less than 0.10. Estimates for ten-shot groups are:

$$P[\frac{ES}{\sigma} < 4.7] = .90, \qquad \text{(Ref 2)}$$

setting $4.7\sigma = 7.7$ we obtain

$$\sigma = 1.63.$$

Using $\hat{E}[ES] = 3.77\sigma$ we obtain

$$E[ES] \approx 6.1.$$

Thus, barrel dispersion will be judged acceptable if the average ES, $\overline{ES}$ is less than 6.1". Using the estimated E[FOM] = .816 E[ES], this is equivalent to an E[FOM] of 5.0".

III. Analysis

The technique used to develop the dispersion prediction equations is called stepwise regression, see Ref. 7. This technique selects variables one at a time from the proposed set of independent variables for inclusion into the prediction equation. The first variable selected is the one most highly correlated with dispersion (the dependent variable). The second variable selected is the one most highly correlated with dispersion, after allowing for the effect of the first, etc. A variable may be deleted if its contribution to prediction is made superfluous by more recently entered variables. Addition and deletion continues until a specified level of signal/noise, F, is encountered.

Several regressions were executed to illuminate different aspects of the data.

Regression Number 1

The purpose of the regressions performed under this section was the simultaneous analysis of all the measurement statistics. Therefore, the sample used was that subset of all observations (63 obs.) with bore and groove measurements. These data were obtained from the first four enumerated sources.

Table 2 presents the list of variables entered into the analysis and the variable regression-identification-number. Since the total number of interaction terms was considered unwieldy, only those involving σ_{bore} and σ_{groove} were considered in this regression. These variables appear to tie the bore and groove measurements most strongly to dispersion. Additional interaction terms will be subsequently considered. The estimated means, variances and correlations of the variables, are presented in Appendix C.

Table 3 presents a list of variables whose sample correlations, with dispersion, are greater than 0.5. Pitting, muzzle enlargement and factors involving bore or groove variability show high correlations with dispersion. Pitting appears to be strongly correlated with muzzle diameter (Var. 3), and maximum standard deviation of bore measurements (see Appendix C). The former correlation is not as strong when the total sample is considered.

TABLE 2

No.	Variable
	Independent Variables
1	erosion gage penetration of muzzle
2	erosion gage penetration of breech
3	diameter bore, 1/16" into muzzle
4	diameter bore, 1/2" into muzzle
5	maximum groove diameter
6	(")^2
7	minimum groove diameter
8	(")^2
9	maximum sample standard-deviation of groove measurements
10	(")^2
11	maximum bore diameter
12	(")^2
13	minimum bore diameter
14	(")^2
15	maximum sample standard-deviation of bore measurements
16	(")^2
17	pitting factor
18	(")^2
19	maximum groove-minimum groove, No. 5 - No. 7
20	maximum bore-minimum bore, No. 12 - No. 13
21	standard deviation groove (No. 9), x No. 1
22	("), x No. 2
23	("), x No. 3
24	("), x No. 17
25	standard deviation bore (No. 15), x No. 1
26	("), x No. 2
27	("), x No. 3
28	("), x No. 17
	Dependent Variables
29	Figure-of-Merit, (FOM)
30	Natural Log FOM, (LnFOM)

TABLE 3 Regression No. 1

Strong Variable-Dispersion (Ln FOM) Sample Correlations

Var. No.	Sample Correlations With Dispersion Greater Than 0.5	
1	.53	- muzzle penetration
3	.84	- muzzle enlargement
4	.59	
11	.69	- maximum bore diameter
12	.69	
17	.87	- pitting
18	.90	
9	.65	- factors involving bore/groove variability
15	.79	
16	.79	
20	.55	
21	.68	
22	.62	
23	.65	
24	.85	
25	.68	
26	.78	
27	.80	
28	.89	

The first set of regression equations was synthesized using a low signal/noise ratio (F = 1.0) for selection and rejection of variables. Prediction equations were obtained for Ln FOM and FOM and are presented in Table 4. Only the Ln FOM prediction equation will be examined for reasons discussed under Dispersion Statistics; Ln FOM will be treated as a normal variable.

The first examination of the equation concerned "lack-of-fit"; does the residual (differences between predicted and observed values) mean-square provide an unbiased estimate of the variance of Ln FOM (assumed constant). True repeat observations were not available but the new-barrels exhibited small perturbations about their mean measurement values and were used as repeats. The residual-mean-square of the Ln FOM prediction equation was decomposed into that portion due to the new-barrels (pure error) and the remainder (lack-of-fit). Table 5 presents the ANOVA table and the sample F statistic. No lack-of-fit is indicated and the residual-mean-square will be used to estimate Var(Ln FOM),σ^2.

The Ln FOM equation is now examined for significance of the variables with respect to predicting power. Table 6 presents each variable ordered as to entry into the equation. The F value represents the additional predicting power due to the variable inclusion. These values are compared to $4xF_{.95}(1.54) = 11.15$. (The multiplier, 4, was tentatively proposed in Ref. 7.) Only the first two entries tested significant.

The equation utilizing these two variables is presented in Table 7 together with a corresponding FOM prediction equation. The residuals are graphically presented in Appendix C. Note the apparent increase in residual dispersion with predicted FOM.

TABLE 4

Regression 1 Prediction Equations (F = 1.0)

$$D = B_0 + B_1X_1 + B_2X_2 + \cdots + B_hX_h$$

D = Ln FOM

$h = 8$

i (entry order)	X_i	B_i
1	18	.2077
2	25	.5341
3	27	183.0
4	7	171.9
5	12	-1531.
6	28	- 1.496
7	15	- 35.02
8	13	511.5

Residual Root-Mean-Square = .200

D = FOM

$h = 5$

i (entry order)	X_i	B_i
1	24 entered	---
2	25	37.52
3	18	.7648
4	1	- 6.9[illegible]0
5	24 rejected	---
6	4	-1153.
7	7	1134.

Residual Root-Mean-Square = 1.68

TABLE 5

ANOVA

Lack-of-fit of Ln FOM Prediction Equation (F = 1.0)

Source	df	SS	MS	F
Total (corrected)	62	22.570	0.364	
Regression	3	19.665		
Residual	59	2.905	.0492	
Lack-of-fit	54	2.782	.0515	2.1
"Pure Error"	5	.122	.0245	

$F_{.90}(54,5) > 2.1$

TABLE 6

ANOVA

Additional Regression Sums-of-Squares Ln FOM Prediction

Order of Entry	Variable	Additional Regression Sum-of-Squares	F ($\sigma^2 = .04$)
1	18	18.229	455.72*
2	25	1.387	34.68*
3	27	.255	6.38
4	7	.094	2.35
5	12	.104	2.60
6	28	.126	3.15
7	15	.086	2.15
8	13	.132	3.30

$4 \times F_{.95}(1,54) = 11.15$

*Significant

TABLE 7

Regression 1 Prediction Equations

$$\ln FOM = 1.153 + .1309 \times Pitting^2 + 1.034 \cdot \sigma_{bore} \cdot \text{Muzzle Penetration}$$

$\hat{\sigma}_{residual} = .22$

Multiple Correlation Coefficient = .93

$$FOM = 2.777 + 7.027 \cdot \sigma_{groove} \cdot \text{Pitting} + 9.508 \cdot \sigma_{bore} \cdot \text{Muzzle Penetration}$$

Residual Root-Mean-Square = 2.18

Multiple Correlation Coefficient = .90

An additional run was made to evaluate the effects of the sample origin (e.g., climate, maintenance, etc.). Dummy variables were introduced which took numerical values to indicate the observation source. No increase in predicting power was obtained.

The significant variables in our prediction equations are pitting, maximum bore, and maximum groove variation. Unfortunately, these measurements are not easily obtained.

Regression Number 2

Bore and groove measurements were not considered in this phase of the analysis: all 125 observations were used. The remaining measurements comprise an easier to obtain set than that in Regression 1. The variable list is presented in Table 8 and is seen to include all second order terms.

Sample means, standard deviations and correlations are presented in Appendix D.

A list of the variables in Regression No. 2 which show strong correlations with dispersion (Ln FOM) are presented in Table 9. The predominance of pitting and enlarged bore is clear. These variables appear strongly correlated ($\rho = .70$, Appendix C). Equations were synthesized from the total list of variables for a $F = 1.0$ criterion; these equations are presented in Table 10. The contribution to Ln FOM prediction of each additional term in the equation was computed using the estimate of σ^2 obtained in Regression No. 1. Again only the first two entries tested significant, see Table 11.

The equation using these variables is presented in Table 12 together with a corresponding FOM equation. The large residual-mean-square of this equation is significantly larger than the estimate of σ^2 obtained in Regression No. 1 indicating bias in the equation

$(F_{.95}(122,54) > (\text{residual M.S. Reg. No. } 2)/\sigma^2 = 2.62)$.

Plots of residuals versus predicted dispersion statistics are presented in Appendix D.

The significant variables are pitting and the bore diameters taken 1/16" and 1/2" into the muzzle.

TABLE 8

Regression No. 2 Variable List

No.	Independent Variable
1	erosion gage penetration of muzzle
2	(" $)^2$
3	erosion gage penetration of breech
4	(" $)^2$
5	diameter bore, 1/16" into muzzle
6	(" $)^2$
7	diameter bore, 1/2" into muzzle
8	(" $)^2$
9	pitting factor
10	(" $)^2$
11	No. 1 x No. 3
12	No. 1 x No. 5
13	No. 1 x No. 7
14	No. 1 x No. 9
15	No. 3 x No. 5
16	No. 3 x No. 7
17	No. 3 x No. 9
18	No. 5 x No. 7
19	No. 5 x No. 9
20	No. 7 x No. 9
	Dependent Variable
21	Figure-of-Merit (FOM)
22	Natural Log FOM (Ln FOM)

TABLE 9

Regression No. 2 (n = 125)

Strong Variable-Dispersion Sample Correlations

Variable No.	Sample Correlation Greater Than 0.5	
1	.53	- penetration muzzle
5,6	.81	- muzzle diameter 1/16"
7,8	.65	- muzzle diameter 1/2"
9,10	.73	- pitting
11,12,13	.53	- interactions involving muzzle penetrations
14	.56	
17	.74	- pitting interactions
18	.81	
19,20	.73	

TABLE 10

Regression No. 2 Prediction Equations (F = 1.0)

$$D = B_0 + B_1X_1 + B_2X_2 + \quad + B_kX_k$$

$D = \ln FOM$

$k = 7$

i	X_i	B_i
0		-22.37
1	18	496.2
2	10	.1235
3	2	- .1443
4	11	.2292
5	20	- 2.488
6	4	- .05511
7	17	.1233

Residual Root-Mean-Square = .2853

$D = FOM$

$k = 7$

0		33.87
	6(entered)	---
1	10	1.116
2	19	-10.85
3	18	3142.
	6(deleted)	---
4	2	-2.005
5	12	27.21
6	14	1.758
7	8	-3775.

Residual Root-Mean-Square = 2.80

TABLE 11

ANOVA

Additional Regression Sums-of-Squares

Order of Entry	Variable	Additional Regression Sums-of-Squares	F (σ^2 from Regression 1)
1	18	31.926	798.15*
2	10	3.559	88.98*
3	2	.3152	7.88
4	11	2.355	58.89[1]
5	20	.0229	.57
6	4	.1514	3.79
7	17	.1393	3.48

$4 \cdot F_{.95}(1,54) = 11.15$

*Significant

[1]High F value due to numerical procedures caused by high sample correlation of variables 2 and 11.

TABLE 12

Regression 2 Prediction Equations

$$\text{Ln FOM} = -29.71 + 639.1\ (\text{dia. @ } 1/2")(\text{dia. @ } 1/16") + .06693\ \text{pitting}^2$$

Residual Root-Mean-Square = .3237

Multiple Correlation Coefficient = .86

$$\text{FOM} = -128.6 + 2709.\ (\text{dia. @ } 1/2")^2 + .6843\ \text{pitting}^2$$

Residual Root-Mean-Square = 3.25

Multiple Correlation Coefficient = .81

Regression Number 3

The dispersion statistics were regressed on powers of depth-of-erosion-gage-penetration of the muzzle. The purpose of this run was to illustrate the rather poor predicting power obtained using only this variable and introduce its use as a discriminator. The variable list is presented in Table 13, the means, variances and correlation matrix in Appendix D. The high correlations between successive powers of muzzle penetration generated numerical problems which lead to poor estimates of the coefficients. These numerical problems could be resolved, and together with the elimination of certain outlying observations, a much better predicting equation could be obtained. However, the resultant equation would still be poor by comparison with those obtained in the previous regressions so the effort was not made. Therefore, only the equation using the linear term is presented. Figure 3 is a plot of the regression equation, predicting Ln FOM, and a plot of the observations. Heavily pitted observations are distinquished by an "X" character. The plot illustrates that all heavily pitted weapons had muzzle penetration measurements at least 1/4". Although muzzle penetration is not a good dispersion predictor, it may be a satisfactory discriminator.

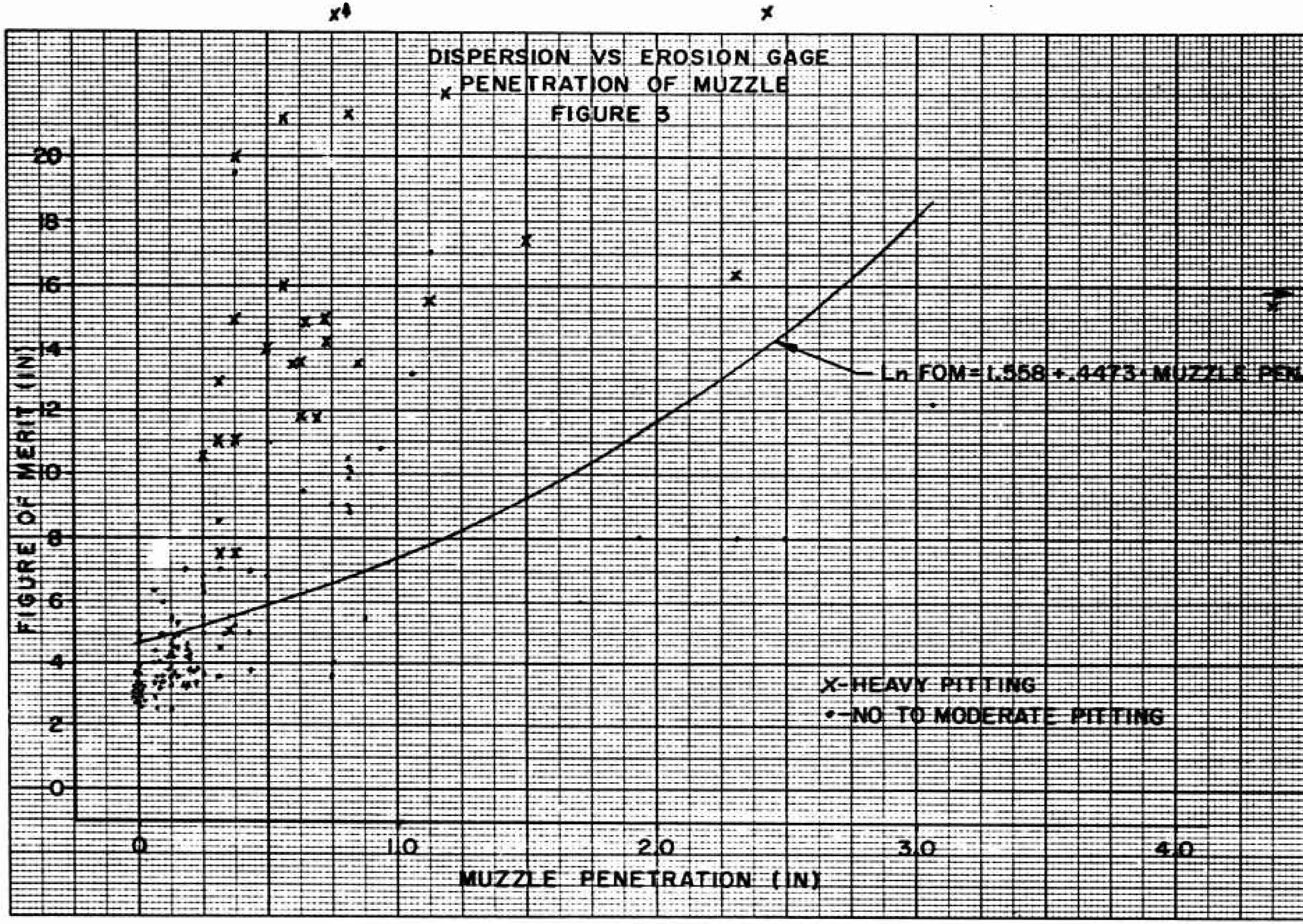

DISPERSION VS EROSION GAGE
PENETRATION OF MUZZLE
FIGURE 3
Ln FOM=1.558+.4473·MUZZLE PEN.
X-HEAVY PITTING
•-NO TO MODERATE PITTING
FIGURE OF MERIT (IN)
MUZZLE PENETRATION (IN)
0
2
4
6
8
10
12
14
16
18
20
0
1.0
2.0
3.0
4.0

TABLE 13

Regression No. 3 Variable List

No.	Independent Variable
1	erosion gage penetration of muzzle
2	(")^2
3	(")^3
4	(")^4
5	(")^5
	Dependent Variable
6	Figure-of-Merit (FOM)
7	Natural Log FOM (Ln FOM)

Discriminant Analysis

A prime objective of this study was to provide a measurement criterion for discriminating between barrels with acceptable dispersion and those not acceptable. Field implementation constrain the type of equipment and therefore the number and precision of the measurements. The only measurements in the feasible category are the depths of penetration of the erosion gage. Pitting is not currently feasible due to lack of adequate bore viewing devices (i.e., inexpensive and rugged), universal pitting criteria and trained cadre. Pitting alone would be a good filter for eliminating the extremely poor dispersion barrels. Almost all (there was one exception) barrels judged to have heavy pitting generated large FOM.

(A test is in progress at USAWECOM in which heavy to moderate pitting is being chemically induced in new barrels. Preliminary results indicate significant increases in dispersion.)

Criteria currently exists for rejecting barrels based on depth of erosion gage penetration into the breech. The field criterion is:

reject if penetration $\geq$ 3.625

accept if penetration $<$ 3.625

Therefore, our field sample was censored by this criterion; only twelve field weapons had penetration greater than three inches. The low sample correlation between FOM and breech penetration (ρ = .33) indicates that in this censored population breech penetration would be a poor choice for a discriminant function. Since breech penetration is said to be highly correlated with the number of rounds fired through the barrel, (Ref. 9 contains data and conclusions but lacks analysis), we note that many poor dispersion barrels do not appear to have been fired extensively (e.g., 9540, 9608, Appendix E). Compared with the endurance barrels, a guess at the total maximum number of rounds fired by a sample barrel would be in the neighborhood of 7000. The remaining candidate is erosion gage penetration of the muzzle.

Most current techniques for developing discriminant functions depend on random samples from the categories to be discriminated. This sample is not random and these techniques are inappropriate. The following techniques are proposed; only those barrels with a history of Viet Nam service were considered. The $\overline{ES}$ statistic was used in the following analysis with a discriminating value of 6.14".

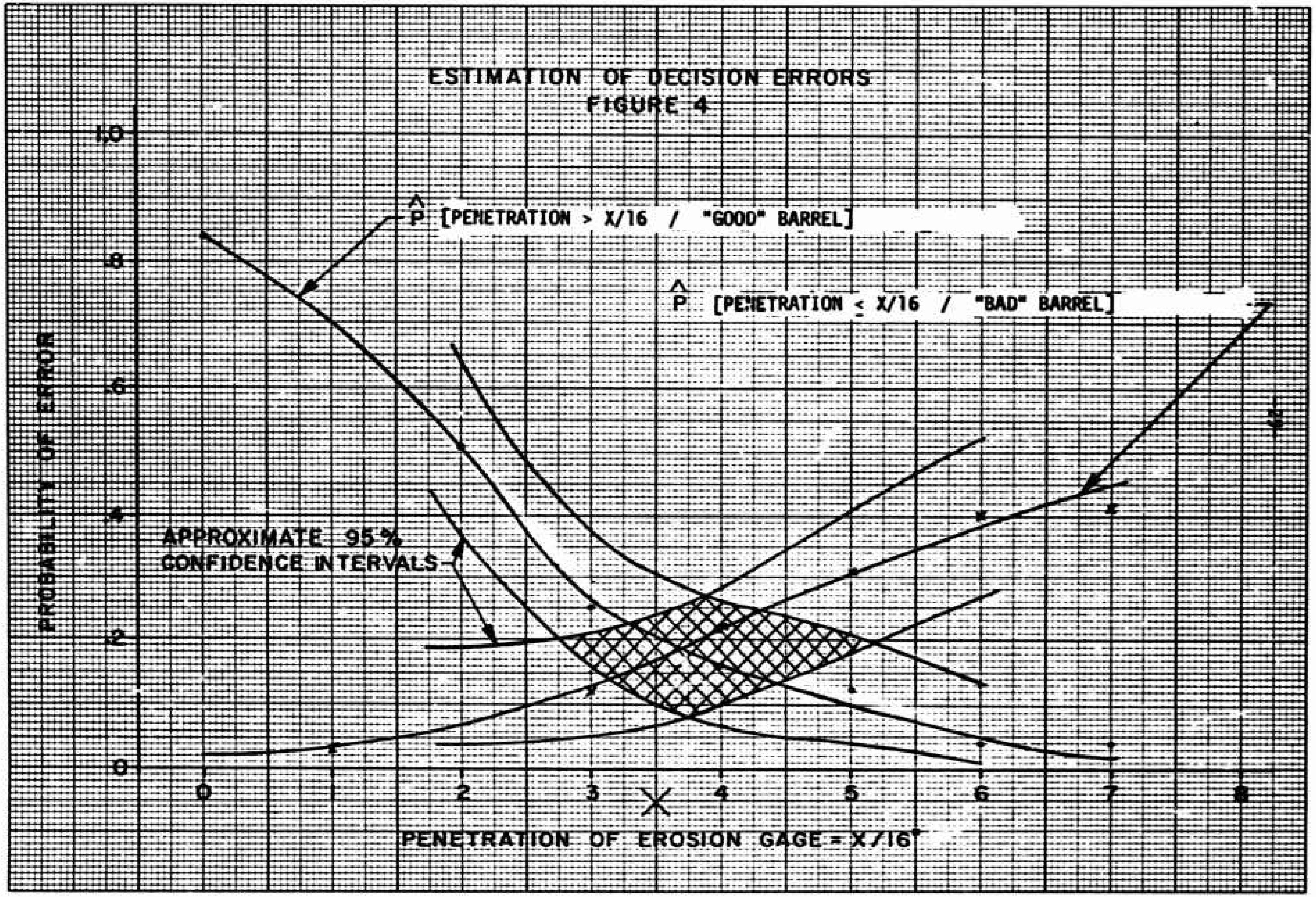
A simple approach to the problem was to consider the possible errors at each judgment:

1. reject a good barrel, or
2. accept a bad barrel.

The distribution of "good" and "bad" barrels is unknown, so the probability of a Type 1 (Type 2) error conditioned on the "goodness" ("badness") of the barrel will be considered. A reasonable assumption is that these conditional probabilities are monotonic functions of the depth of muzzle penetration; one decreasing the other increasing. The penetration at which the curves intersect represents a decision point expressing equal concern for each error. The sample data was used to estimate:

1. P[penetration $>$ d/"good" barrel]
2. P[penetration $\leq$ d/"bad" barrel]

for penetration depths, d = x/16", x = 1,2,...,8, (measurements precision was $\pm$ 1/32"). These values are plotted in Fig. 4 together with 95 percent confidence intervals about each estimate, in the range of interest. "Eyeball" curves are sketched through the estimated probabilities; intersection appears to take place at about 1/4". However, the intersection of the confidence intervals indicates values 3/16" and 5/16" should also be considered. An unpublished analysis performed by the Project Manager M16 Rifle Office indicated a 5/16" penetration criterion was satisfactory. The hypothesis of "no-difference-in-error-probabilities" tests significant around the α = .04 level for the 5/16" criterion. The following approach is a technique for deciding between a 1/4" and a 5/16" criterion.



ESTIMATION OF DECISION ERRORS
FIGURE 4
P̂ [PENETRATION > X/16 / "GOOD" BARREL]
P̂ [PENETRATION ≤ X/16 / "BAD" BARREL]
APPROXIMATE 95%
CONFIDENCE INTERVALS
PROBABILITY OF ERROR
1.0
.8
.6
.4
.2
0
0
1
2
3
4
5
6
7
8
X
PENETRATION OF EROSION GAGE = X/16"

Define the random variables:

$$Y = \begin{cases} 0 & \text{muzzle penetration} < 1/4'' \\ 1 & \text{muzzle penetration} \geq 1/4'' \end{cases}$$

$$Z = \begin{cases} 0 & \text{muzzle penetration} < 5/16'' \\ 1 & \text{muzzle penetration} \geq 5/16'' \end{cases}$$

$$\theta = \begin{cases} 0 & \text{acceptable dispersion} \\ 1 & \text{not acceptable dispersion} \end{cases}$$

decision function:

$$D(S) = \begin{cases} 0 & \text{accept barrel if } S = 0 \\ 1 & \text{reject barrel if } S = 1 \end{cases}$$

loss function:

$$L(D,\theta) = \begin{cases} \ell_1: D = 1, \ \theta = 0 \\ \ell_2; D = 0, \ \theta = 1 \\ 0 \quad \text{otherwise} \end{cases}$$

So ℓ_1 is a measure of loss incurred in rejecting a "good" barrel and ℓ_2 is the loss in accepting a "bad" barrel. Let D = depth of erosion gage penetration.

$$E[L(D(Y),\theta)] = \ell_1 P[Y = 1, \theta = 0] + \ell_2 P[Y = 0, \theta = 1]$$

$$\begin{aligned} E[L(D(Y),\theta) - L(D(Z),\theta)] &= \ell_1\{P[Y = 1, \theta = 0] - P[Z = 1, \theta = 0]\} \\ &+ \ell_2\{P[Y = 0, \theta = 1] - P[Z = 0, \theta = 1]\} \\ &= \ell_1 \; P[1/4 < D \leq 5/16, \theta = 0] \\ &- \ell_2 \; P[1/4 < D \leq 5/16, \theta = 1] \\ &= \ell_1 \; P[1/4 < D \leq 5/16, \theta = 0] \\ &- \ell_2\{P[1/4 < D \leq 5/16] - P[1/4 < D \leq 5/16, \theta = 0]\} \\ &= (\ell_1+\ell_2)P[1/4 < D \leq 5/16, \theta = 0] - \ell_2 P[1/4 < D \leq 5/16] \\ &= (\ell_1+\ell_2)P[\theta = 0|1/4 < D \leq 5/16] \cdot P[1/4 < D \leq 5/16] \\ &- \ell_2 \; P[1/4 < D \leq 5/16] \\ &= P[1/4 < D \leq 5/16]\{(\ell_1+\ell_2)P[\theta = 0|1/4 < D \leq 5/16] - \ell_2\}. \end{aligned}$$

Thus, the decision function D(Y) is preferred if

$$P[\theta = 0|1/4 < D \leq 5/16] \leq \ell_2/(\ell_1+\ell_2),$$

otherwise choose D(Z). Putting $\ell_1 = \ell_2$, $\ell_2/(\ell_1+\ell_2) = 0.5$. The available data yields

$$\hat{P}[\theta = 0|1/4 < D \leq 5/16] = .28$$

$$P[.04 < P[\theta = 0|1/4 < D \leq 5/16] < .58] = .95.$$

The "best" estimate of the probability is less than 0.5, indicating D(Y) is preferred; however, the need for additional data is indicated as the confidence interval includes 0.5.

IV. Conclusions

Dispersion prediction equations have been synthesized from a set of barrel measurements. The best equation obtained predicts log FOM with a multiple correlation coefficient of .93 (i.e., 87% of the variability is contained in the prediction equation). Caution in the use of the equation is urged due to sample sources used in obtaining data. (These sources were: new, endurance fired, US Marine Corps, and one US Army Division.) Although explicit designation of sample source did not increase the predicting power of the equation, source was somewhat implicit in the ranges of dispersion values observed.

The additional sample data overlapped the previous in dispersion ranges. A prediction equation utilizing the total sample, but without bore and groove measurements, was obtained. This equation does not "appear" to have the predicting power of the first, but the sample was taken over more varied sources and the measurements are easier to obtain.

The variables highly correlated with dispersion and significant predictors in the regression equations were bore and groove variation, pitting and muzzle enlargement. Arguments can be developed assigning barrel diameter variation, pitting and uneven muzzle wear as factors which contribute to dispersion.

The barrels obtained from Viet Nam were censored by an erosion-gage-penetration-of-breech criterion. Breech penetration is correlated with rounds fired, so the criterion is based on use. As use does not appear strongly in the sample (due to censoring) maintenance and/or climate factors are hypothesized as leading to short barrel life.

Only erosion-gage-penetration-of-muzzle is a currently feasible field discriminating variable. The criterion discriminating acceptable and unacceptable barrels was shown to be contained in the set (3/16", 1/4", 5/16") with high probability. Two techniques were utilized to estimate the point when rejecting good barrels was of the same concern as accepting bad barrels. The two techniques chose 1/4" as the most likely candidate. Additional data is required for more precision. Both analyses dealt with conditional probabilities, e.g., $P[\text{penetration} < X \mid \text{barrel is good}]$. An estimate of expected number of errors when applying a penetration criterion cannot be made until an estimate of penetration distribution is obtained.

V. References

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APPENDIX A

Notes on Visual Inspection of Rifle Barrels

27 October 1970

NOTES ON VISUAL INSPECTION OF RIFLE BARRELS

1. The Office of the Product Manager, Rifles requested that Mr. Moore visually inspect M16A1 rifle barrels at Rock Island Arsenal and in Viet Nam during August and September 1970. Visual inspection is an effective means for observing bore deficiencies and especially those caused by rusting. However, observations made on visual inspections depend on the inspecting conditions (light intensity, magnification, etc.) and the experience of the inspector, and therefore visual standards are relatively imprecise.

2. The procedure used in these inspections was to first assure that the bore surface was free of loose dirt and fouling. A cotton patch was passed through the bore and, if the bore surface was not free of dirt and fouling, a brass brush was passed through the bore several times and another patch was used. The bore was inspected first without magnification and then with a 3X magnifier.

3. Badly bent, bulged and pitted bores can be observed without magnification. Magnification is helpful for inspecting imperfections in the bore surface and especially for determining the degree of pitting. Most M16A1 barrels inspected were pitted most severly in the first few inches from the muzzle and therefore the most severely pitted area could be inspected readily with a magnifier.

4. Pitting is difficult to categorize because of the manner in which it develops. Should rusting occur uniformly over the entire bore surface as would be expected if a rifle were fired and left uncleaned and protected, the entire surface will become pitted with time. The depth of pit will determine the severity. However, should the bore be protected somewhat by a preservative or metal fouling, the rusting will not occur uniformly over the surface and greater judgment is required to determine the category of pitting. It is unlikely that two barrels would be pitted in exactly the same manner under field conditions and therefore an infinite number of bore conditions is possible. In this exercise three categories were used to describe the pitted bores but a considerable variation in pitting characteristics is possible within a category.

5. In this exercise the category of pitting was based on the most heavily pitted area. The depth and extent of the pits were considered. A description of the categories of pitting follows:

a. Light pitting was observed without magnification as a dull surface. When observed with a magnification of 3X it was seen as a roughness of the surface or a number of depressions which did not cover more than 25 per cent of the bore surface in the most heavily pitted area.

b. Medium pitting was observed without magnification as a dull to dark surface. When observed with magnification the surface was seen as a number of depressions having significant depth which, in the most heavily pitted area, covered over 25 per cent of the bore surface but which did not form an area greater than 1/4 inch in length which was pitted completely.

c. Heavy pitting was observed without magnification as a dark surface. When observed with magnification, the most heavily pitted area was seen as a large number of depressions having significant depth and which covered an area greater than 1/4 inch in length in which none of the original bore surface remained.

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Systems-Ammunition Coordinator
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APPENDIX B

Sample Measurement and Dispersion Statistics

Comments on Data

a. Barrel No. 1 from category I was sectioned for analysis before bore and groove measurements were obtained.

b. Barrels 2 thru 19 were measured along two grooves (g) and one bore (f).

c. Barrels with ID number 5XXX were measured along two bores and two grooves.

d. Bore and groove measurements were not obtained on the remaining barrels.

e. A value .2258 was the largest groove diameter recorded by the air gage and so was used as a reading when the gage capability was exceeded. A value of .2210 was the theoretical and observed maximum bore diameter recorded.

f. All measurements in inches except pitting, sigma bore and sigma groove. These last two are statistics, have been measured in inches, then scaled by 10^3.

INITIAL SAMPLE FROM VA 19 ORS

ID	FOM	DEN MOZ	DEN BRCH	DIA 1/2	DIA 1/16	MAX GROV	MIN GROV	SIGMA GROV	MAX BORE	MIN BORE	SIGMA BORE	PIT
8	6.32	0.250	2.750	0.2240	0.2200	0.2248	0.2244	0.1309	0.2203	0.2196	0.1933	2.
9	8.54	0.312	2.625	0.2250	0.2200	0.2247	0.2236	0.2770	0.0	0.2193	0.4499	2.
14	6.78	0.250	2.687	0.2240	0.2195	0.2248	0.2241	0.2062	0.2209	0.2195	0.3784	2.
1	15.50	5.250	2.875	0.2300	0.2225	0.0	0.0	0.0	0.2208	0.2203	0.1676	3.
2	13.71	0.625	2.875	0.2250	0.2195	0.2249	0.2239	0.3250	0.2206	0.2194	0.3252	3.
4	21.99	1.187	2.875	0.2250	0.2205	0.0	0.2241	0.7320	0.0	0.2197	0.4718	3.
5	19.90	0.375	3.000	0.2250	0.2200	0.0	0.2239	0.4537	0.2206	0.2195	0.4005	3.
6	14.09	0.375	2.625	0.2240	0.2205	0.2252	0.2241	0.2964	0.2210	0.2196	0.5146	3.
7	12.79	0.312	2.500	0.2250	0.2205	0.2240	0.2235	0.1725	0.2205	0.2192	0.3611	3.
10	16.04	0.562	2.625	0.2260	0.2205	0.2247	0.2239	0.2216	0.2207	0.2194	0.3578	3.
11	10.53	0.250	2.937	0.2230	0.2205	0.2254	0.2244	0.2565	0.2210	0.2198	0.3548	3.
12	25.33	2.437	2.312	0.2290	0.2225	0.0	0.2244	0.5009	0.0	0.2200	0.3815	3.
13	7.54	0.375	2.562	0.2240	0.2205	0.2250	0.2236	0.4363	0.0	0.2197	0.4390	3.
15	11.08	0.312	3.000	0.2200	0.2195	0.0	0.2240	0.4435	0.2206	0.2197	0.2940	3.
16	7.39	0.312	3.250	0.2250	0.2205	0.2254	0.2240	0.3401	0.0	0.2196	0.4196	3.
17	10.76	0.375	2.875	0.2260	0.2205	0.2251	0.2238	0.3796	0.0	0.2193	0.4030	3.
19	15.61	1.125	3.000	0.2240	0.2205	0.0	0.2246	0.4254	0.2210	0.2201	0.3416	3.
18	3.29	0.187	3.000	0.2235	0.2195	0.0	0.2235	0.8034	0.0	0.2192	0.3750	1.
3	4.19	0.187	2.812	0.2260	0.2200	0.2241	0.2235	0.1905	0.2199	0.2190	0.2305	2.

MARINE BARRELS 29 OBS

ID	EDM	PEN MUZ	PEN BRCH	DIA 1/2	DIA 7/16	MAX GROV	MIN GROV	SIGMA GROV	MAX BORE	MIN BORE	SIGMA BORE	PIT
5001	5.50	0.875	2.750	0.2220	0.2208	0.2246	0.2242	0.1131	0.2204	0.2195	0.2808	1.
5007	5.30	0.375	2.625	0.2230	0.2204	0.2249	0.2241	0.2183	0.2207	0.2194	0.2974	1.
5013	6.41	3.500	2.937	0.2240	0.2215	0.2250	0.2246	0.1141	0.2207	0.2199	0.2148	1.
5016	6.15	0.062	2.625	0.2210	0.2204	0.2248	0.2241	0.1715	0.2204	0.2194	0.2467	1.
5028	6.88	0.500	2.625	0.2230	0.2202	0.2245	0.2238	0.1698	0.2203	0.2192	0.2724	1.
5046	6.36	0.250	2.750	0.2220	0.2205	0.2250	0.2240	0.2064	0.2205	0.2198	0.1803	2.
5049	5.59	0.250	2.750	0.2220	0.2205	0.2247	0.2240	0.1881	0.2206	0.2192	0.3170	2.
5061	3.86	0.0	2.375	0.2200	0.2199	0.2247	0.2242	0.1787	0.2199	0.2192	0.1812	0.
5091	3.33	0.062	2.625	0.2200	0.2199	0.2245	0.2241	0.1177	0.2199	0.2192	0.1706	0.
5004	3.73	0.218	2.625	0.2220	0.2200	0.2247	0.2241	0.1576	0.2204	0.2192	0.3052	1.
5019	3.61	0.312	2.625	0.2220	0.2200	0.2247	0.2241	0.1670	0.2202	0.2194	0.1986	1.
5040	3.24	0.125	2.625	0.2210	0.2200	0.2242	0.2239	0.1121	0.2200	0.2196	0.1155	1.
5043	3.48	0.125	2.625	0.2210	0.2202	0.2245	0.2239	0.1861	0.2203	0.2193	0.2613	1.
5052	3.87	0.125	2.625	0.2210	0.2202	0.2250	0.2242	0.2354	0.2205	0.2196	0.2365	1.
5055	4.29	0.125	2.375	0.2210	0.2198	0.2245	0.2239	0.1709	0.2199	0.2191	0.2085	1.
5058	4.17	0.187	2.625	0.2210	0.2200	0.2249	0.2239	0.2262	0.2205	0.2194	0.2439	1.
5064	4.17	0.125	2.375	0.2210	0.2198	0.2147	0.2242	0.1333	0.2202	0.2193	0.2152	1.
5067	4.77	0.187	2.750	0.2210	0.2201	0.2251	0.2243	0.2462	0.2204	0.2195	0.2304	1.
5070	4.50	0.187	2.375	0.2200	0.2199	0.2250	0.2240	0.2805	0.2201	0.2193	0.2278	1.
5073	3.34	0.187	2.375	0.2210	0.2198	0.2250	0.2239	0.2562	0.2202	0.2193	0.2202	1.
5076	2.94	0.0	2.375	0.2200	0.2202	0.2247	0.2241	0.1882	0.2201	0.2194	0.1939	1.
5079	3.31	0.062	2.375	0.2200	0.2196	0.2242	0.2236	0.1424	0.2201	0.2189	0.2906	1.
5082	3.07	0.0	2.375	0.2192	0.2192	0.2241	0.2237	0.0868	0.2193	0.2189	0.1041	1.
5085	2.62	0.062	2.375	0.2200	0.2197	0.2241	0.2239	0.0750	0.2198	0.2194	0.0958	1.
5088	3.32	0.062	2.625	0.2200	0.2198	0.2247	0.2241	0.1472	0.2200	0.2192	0.2160	1.
5094	3.80	0.437	2.875	0.2210	0.2204	0.2250	0.2244	0.1585	0.2205	0.2195	0.2330	1.
5301	2.91	0.0	2.375	0.2200	0.2198	0.2243	0.2238	0.1326	0.2198	0.2193	0.1217	1.
5097	5.01	0.0	2.375	0.2200	0.2197	0.2241	0.2239	0.0658	0.2196	0.2191	0.1390	0.
5025	4.01	0.750	2.625	0.2220	0.2207	0.2246	0.2242	0.1098	0.2206	0.2195	0.2647	2.

NEW BARRELS 6 OBS

ID	FOM	REM MOT	REM ARCH	DIA 1/2	DIA 1/16	MAX GROV	MIN GROV	SIGMA GROV	MAX BORE	MIN BORE	SIGMA BORE	PIT
5101	2.81	0.0	2.375	0.2195	0.2193	0.2236	0.2234	0.0456	0.2193	0.2192	0.0510	0.
5104	3.03	0.0	2.375	0.2200	0.2195	0.2242	0.2238	0.1162	0.2196	0.2192	0.0899	0.
5107	2.80	0.0	2.375	0.2200	0.2197	0.2243	0.2240	0.0744	0.2196	0.2191	0.1323	0.
5110	2.88	0.0	2.375	0.2200	0.2197	0.2245	0.2241	0.1090	0.2197	0.2195	0.0796	0.
5113	2.72	0.0	2.375	0.2198	0.2195	0.2237	0.2234	0.0785	0.2194	0.2191	0.0740	0.
5116	2.49	0.0	2.375	0.2199	0.2194	0.2241	0.2238	0.0935	0.2193	0.2189	0.0972	0.

ENDURANCE BARRELS 10 OBS

ID	FOM	REM MOT	REM ARCH	DIA 1/2	DIA 1/16	MAX GROV	MIN GROV	SIGMA GROV	MAX BORE	MIN BORE	SIGMA BORE	PIT
5150	3.71	0.0	2.625	0.2200	0.2196	0.2248	0.2243	0.0908	0.2205	0.2193	0.2671	0.
5151	2.97	0.0	3.000	0.2200	0.2197	0.2246	0.2242	0.0827	0.2201	0.2195	0.1322	0.
5152	2.60	0.0	3.375	0.2200	0.2198	0.2241	0.2237	0.0898	0.2205	0.2196	0.1707	0.
5153	3.39	0.0	3.000	0.2200	0.2200	0.2244	0.2240	0.1054	0.2202	0.2196	0.1434	0.
5154	3.19	0.0	2.750	0.2200	0.2196	0.2246	0.2243	0.0796	0.2198	0.2193	0.1117	0.
5155	3.00	0.0	3.125	0.2200	0.2196	0.2246	0.2243	0.0912	0.2201	0.2193	0.1590	0.
5156	2.87	0.0	2.875	0.2197	0.2194	0.2258	0.2235	0.0946	0.2199	0.2190	0.1632	0.
5157	3.22	0.0	3.250	0.2200	0.2198	0.2244	0.2240	0.0780	0.2205	0.2196	0.1798	0.
5158	2.72	0.0	3.250	0.2200	0.2198	0.2242	0.2238	0.1098	0.2205	0.2197	0.1678	0.
5159	3.88	0.0	3.000	0.2197	0.2194	0.2244	0.2239	0.1066	0.2202	0.2191	0.1936	0.

DIVISION A 16 OBS

ID	FOM	REM MOT	REM ARCH	DIA 1/2	DIA 1/16	PIT
4531	6.98	0.312	2.375	0.2230	0.2204	1.
4546	7.04	0.187	2.750	0.2210	0.2204	1.
4510	4.94	0.093	2.500	0.2240	0.2195	2.
4528	10.28	0.812	3.000	0.2250	0.2210	2.
4540	19.61	0.375	2.625	0.2230	0.2204	2.
4543	9.56	0.656	2.875	0.2240	0.2210	2.
4534	5.12	0.344	2.875	0.2230	0.2205	3.
4525	4.35	0.156	2.500	0.2220	0.2203	1.
4513	3.41	0.218	2.625	0.2230	0.2199	1.
4522	3.96	0.218	2.875	0.2240	0.2200	1.
4544	4.15	0.219	2.625	0.2220	0.2202	1.
4555	2.72	0.125	2.375	0.2210	0.2199	1.
4501	3.92	0.125	2.625	0.2210	0.2190	2.
4516	2.68	0.125	2.500	0.2210	0.2197	2.
4519	3.76	0.156	2.625	0.2220	0.2201	2.
4537	3.77	0.750	2.500	0.2210	0.2215	2.

DIVISION 8 20 [illegible]

ID	FLOW	REM MID	REM ARCH	DIA 1/2	DIA 1/16	PIT
9716	5.38	0.156	2.500	0.2210	0.2198	1.
9719	5.45	0.125	2.500	0.2210	0.2196	1.
9737	5.01	0.250	2.625	0.2230	0.2204	1.
9740	4.97	0.156	2.625	0.2210	0.2201	2.
9701	2.27	0.0	2.625	0.2200	0.2196	0.
9710	3.70	0.0	2.500	0.2200	0.2195	0.
9713	3.63	0.062	2.562	0.2206	0.2195	1.
9728	3.96	0.062	2.500	0.2206	0.2201	1.
9749	4.43	0.062	2.625	0.2206	0.2196	1.
9722	4.75	0.125	2.500	0.2210	0.2196	1.
9734	3.73	0.218	2.625	0.2220	0.2201	1.
9743	4.49	0.156	2.500	0.2210	0.2199	1.
9746	3.26	0.0	2.500	0.2206	0.2199	1.
9752	3.64	0.093	2.500	0.2206	0.2193	1.
9755	4.52	0.312	2.500	0.2220	0.2206	1.
9758	4.06	0.187	2.875	0.2220	0.2203	1.
9704	4.41	0.156	2.437	0.2210	0.2200	2.
9707	4.17	0.125	2.625	0.2210	0.2203	2.
9725	6.08	0.093	2.500	0.2206	0.2198	0.
9731	4.99	0.0	2.375	0.2195	0.2193	1.

DIVISION C 25 OBS

ID	FOM	PEN MHZ	PEN BRCH	DIA 1/2	DIA 1/16	PTI
9603	9.03	0.750	2.625	0.2240	0.2212	1.
9604	13.32	1.062	2.562	0.2240	0.2207	1.
9605	8.89	0.812	2.625	0.2240	0.2207	1.
9606	7.01	0.437	2.500	0.2230	0.2205	1.
9608	12.19	3.000	2.625	0.2240	0.2212	1.
9801	11.80	0.625	2.688	0.2240	0.2207	3.
9802	13.42	0.594	2.812	0.2220	0.2207	3.
9803	13.98	0.500	2.938	0.2270	0.2205	3.
9804	31.66	0.750	3.000	0.2250	0.2206	3.
9806	11.70	0.688	3.000	0.2240	0.2208	3.
9900	14.98	0.656	2.750	0.2240	0.2207	3.
9901	14.16	0.719	3.000	0.2250	0.2208	3.
9903	21.24	0.562	3.188	0.2250	0.2206	3.
9904	17.40	1.500	3.188	0.2250	0.2212	3.
9906	21.43	0.812	3.125	0.2250	0.2208	3.
9601	16.38	1.125	2.625	0.2240	0.2207	1.
9602	8.07	2.312	2.562	0.2240	0.2213	1.
9607	7.98	2.500	2.687	0.2240	0.2210	1.
9609	4.97	0.343	2.562	0.2230	0.2204	1.
9610	10.54	0.812	2.687	0.2240	0.2210	1.
9611	8.12	1.937	2.500	0.2240	0.2208	1.
9612	9.04	0.812	2.625	0.2240	0.2207	1.
9613	10.79	0.937	2.562	0.2240	0.2208	1.
9614	9.89	0.812	2.625	0.2240	0.2208	1.
9615	8.92	0.812	2.625	0.2250	0.2208	1.

APPENDIX C

Regression No. 1 Statistics

STEPWISE REGRESSION ANALYSIS

VARIABLE	MEAN	STD. DEV.
1	0.300920635	0.5[illegible]
2	2.686460317	0.27[illegible]
3	0.221746667	0.0021[illegible]
4	0.22002[illegible]	[illegible]
5	0.224571426	0.001[illegible]
6	0.050434174	0.00[illegible]
7	0.225964127	0.000277[illegible]
8	0.050165965	0.0001244[illegible]
9	0.204050794	0.14[illegible]
10	0.063100399	0.11164[illegible]
11	0.220304757	0.00047[illegible]
12	0.048534411	0.00021[illegible]
13	0.219390476	0.00026[illegible]
14	0.048132248	0.00011[illegible]
15	0.241069841	0.10[illegible]
16	0.069973715	0.059977[illegible]
17	1.222222222	1.099038445
18	2.682539683	3.44460[illegible]
19	0.000587299	0.0013[illegible]
20	0.000914281	0.00036[illegible]
21	0.087901537	0.19756[illegible]
22	0.553204627	0.43660[illegible]
23	0.045230555	0.03358[illegible]
24	0.353346032	0.47485[illegible]
25	0.093942676	0.1644[illegible]
26	0.653604770	0.3145[illegible]
27	0.053647[illegible]	0.0246[illegible]
28	0.349904762	0.4473[illegible]
29	6.154126984	4.9958111[illegible]
30	1.601203196	0.60[illegible]

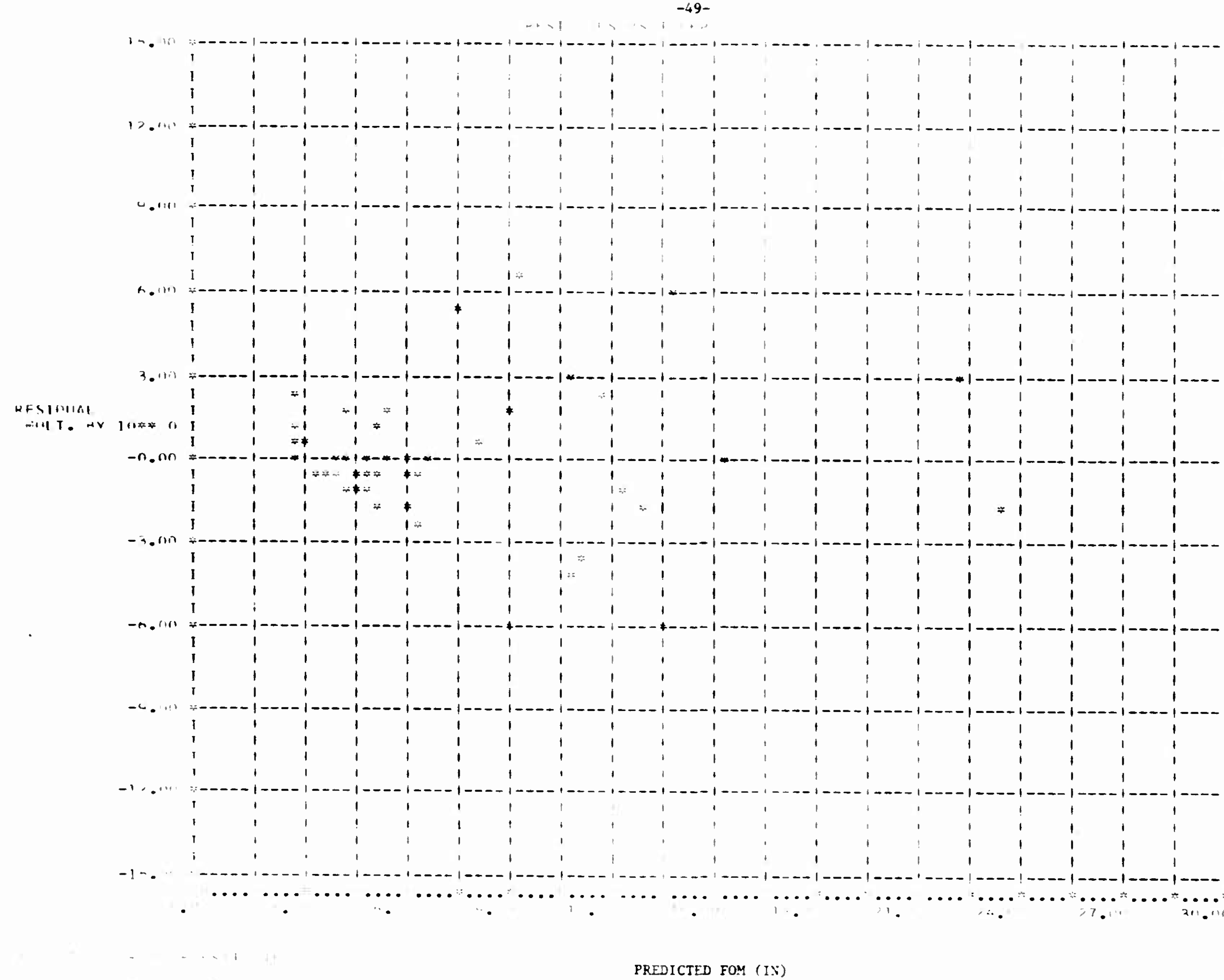
SIMPLE CORRELATION COEFFICIENTS. (ROW BY COL.)

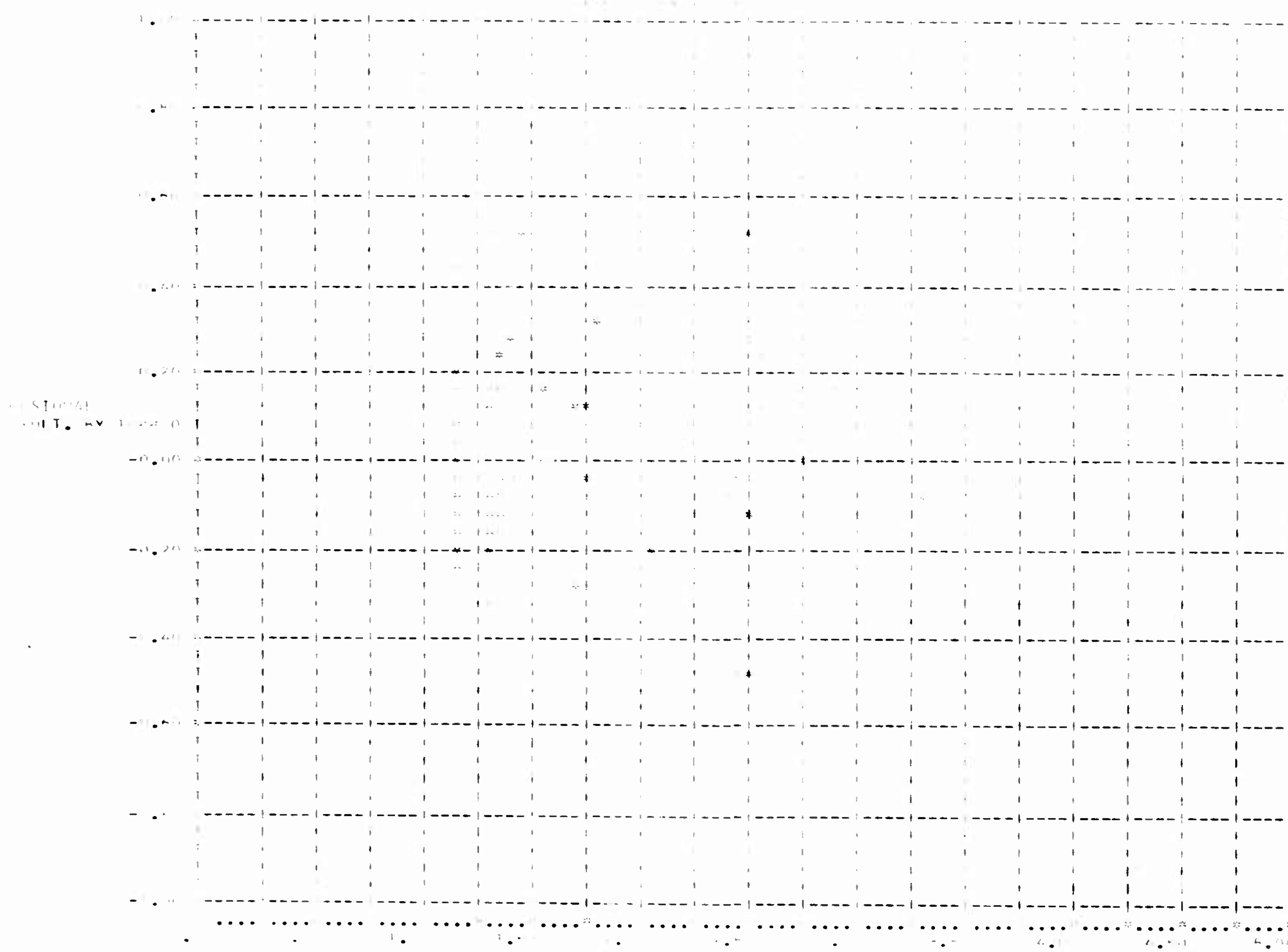
1.0000	R(1, 1)	0.0924	R(1, 2)	0.5493	R(1, 3)	0.7664	R(1, 4)	0.1432	R(1, 5)
0.1962	R(1, 6)	0.4238	R(1, 7)	0.4241	R(1, 8)	0.4258	R(1, 9)	0.2804	R(1,10)
0.4465	R(1,11)	0.4466	R(1,12)	0.5391	R(1,13)	0.5394	R(1,14)	0.3541	R(1,15)
0.3253	R(1,16)	0.3983	R(1,17)	0.3655	R(1,18)	0.1065	R(1,19)	0.1997	R(1,20)
0.7624	R(1,21)	0.2991	R(1,22)	0.3322	R(1,23)	0.4186	R(1,24)	0.4445	R(1,25)
0.3410	R(1,26)	0.3606	R(1,27)	0.3776	R(1,28)	0.5447	R(1,29)	0.5325	R(1,30)
1.0000	R(2, 2)	0.1490	R(2, 3)	0.0474	R(2, 4)	0.2662	R(2, 5)	0.2663	R(2, 6)
0.1578	R(2, 7)	0.1578	R(2, 8)	0.2032	R(2, 9)	0.2119	R(2,10)	0.5020	R(2,11)
0.5018	R(2,12)	0.4303	R(2,13)	0.4302	R(2,14)	0.2405	R(2,15)	0.1959	R(2,16)
0.1292	R(2,17)	0.2047	R(2,18)	0.2325	R(2,19)	0.3499	R(2,20)	0.0453	R(2,21)
0.3047	R(2,22)	0.2027	R(2,23)	0.2182	R(2,24)	0.0743	R(2,25)	0.4110	R(2,26)
0.2383	R(2,27)	0.1744	R(2,28)	0.1198	R(2,29)	0.1585	R(2,30)		
1.0000	R(3, 3)	0.6509	R(3, 4)	0.2311	R(3, 5)	0.2347	R(3, 6)	0.0793	R(3, 7)
0.0794	R(3, 8)	0.6273	R(3, 9)	0.4904	R(3,10)	0.7116	R(3,11)	0.7119	R(3,12)
0.3976	R(3,13)	0.3977	R(3,14)	0.7900	R(3,15)	0.7813	R(3,16)	0.8257	R(3,17)
0.8035	R(3,18)	0.2134	R(3,19)	0.6446	R(3,20)	0.6457	R(3,21)	0.6017	R(3,22)
0.6365	R(3,23)	0.7475	R(3,24)	0.6787	R(3,25)	0.7708	R(3,26)	0.8000	R(3,27)
0.8381	R(3,28)	0.7978	R(3,29)	0.8365	R(3,30)				
1.0000	R(4, 4)	0.2070	R(4, 5)	0.2098	R(4, 6)	0.4455	R(4, 7)	0.4456	R(4, 8)
0.3248	R(4, 9)	0.2038	R(4,10)	0.5933	R(4,11)	0.5933	R(4,12)	0.6155	R(4,13)
0.6156	R(4,14)	0.4990	R(4,15)	0.4538	R(4,16)	0.5292	R(4,17)	0.4786	R(4,18)
0.1158	R(4,19)	0.3367	R(4,20)	0.6840	R(4,21)	0.2761	R(4,22)	0.3323	R(4,23)
0.4470	R(4,24)	0.8000	R(4,25)	0.4570	R(4,26)	0.5050	R(4,27)	0.5102	R(4,28)
0.5761	R(4,29)	0.5893	R(4,30)						
1.0000	R(5, 5)	1.0000	R(5, 6)	0.0640	R(5, 7)	0.0641	R(5, 8)	0.3496	R(5, 9)
0.3013	R(5,10)	0.2922	R(5,11)	0.2924	R(5,12)	0.2434	R(5,13)	0.2405	R(5,14)
0.2749	R(5,15)	0.2745	R(5,16)	0.2409	R(5,17)	0.2717	R(5,18)	0.4796	R(5,19)
0.2103	R(5,20)	0.2576	R(5,21)	0.3591	R(5,22)	0.3495	R(5,23)	0.3293	R(5,24)
0.2401	R(5,25)	0.3129	R(5,26)	0.2756	R(5,27)	0.2705	R(5,28)	0.2764	R(5,29)
0.2701	R(5,30)								
1.0000	R(6, 6)	0.0671	R(6, 7)	0.0672	R(6, 8)	0.3553	R(6, 9)	0.3063	R(6,10)
0.2973	R(6,11)	0.2974	R(6,12)	0.2441	R(6,13)	0.2442	R(6,14)	0.2796	R(6,15)
0.2788	R(6,16)	0.2451	R(6,17)	0.2758	R(6,18)	0.4791	R(6,19)	0.2142	R(6,20)
0.2619	R(6,21)	0.3649	R(6,22)	0.3552	R(6,23)	0.3547	R(6,24)	0.2434	R(6,25)
0.3178	R(6,26)	0.2803	R(6,27)	0.2748	R(6,28)	0.2609	R(6,29)	0.2747	R(6,30)
1.0000	R(7, 7)	1.0000	R(7, 8)	-0.0004	R(7, 9)	-0.0644	R(7,10)	0.2940	R(7,11)
0.2987	R(7,12)	0.5738	R(7,13)	0.5738	R(7,14)	0.0442	R(7,15)	0.0114	R(7,16)
0.0910	R(7,17)	0.0671	R(7,18)	-0.1376	R(7,19)	-0.0167	R(7,20)	0.2990	R(7,21)
-0.0025	R(7,22)	0.0004	R(7,23)	0.0888	R(7,24)	0.3751	R(7,25)	0.0433	R(7,26)
0.0823	R(7,27)	0.0455	R(7,28)	0.1905	R(7,29)	0.2155	R(7,30)		

1.0000	R(8, 8)	-0.0003	R(8, 9)	[illegible]	R(8,10)	[illegible]	R(8,11)	0.2647	R(8,12)
0.5740	R(8,13)	0.5739	R(8,14)	[illegible]	R(8,15)	[illegible]	R(8,16)	[illegible]	R(8,17)
0.0672	R(8,18)	-0.1376	R(8,19)	-[illegible]167	R(8,20)	0.2442	R(8,21)	-0.0024	R(8,22)
0.0005	R(8,23)	0.0689	R(8,24)	[illegible]	R(8,25)	0.0433	R(8,26)	[illegible]	R(8,27)
0.0456	R(8,28)	0.1904	R(8,29)	[illegible]	R(8,30)				
1.0000	R(9, 9)	0.9491	R(9,10)	[illegible]	R(9,11)	0.6555	R(9,12)	0.3626	R(9,13)
0.3621	R(9,14)	0.7256	R(9,15)	[illegible]	R(9,16)	0.6523	R(9,17)	0.6425	R(9,18)
0.3470	R(9,19)	0.5964	R(9,20)	[illegible]	R(9,21)	0.9904	R(9,22)	0.9999	R(9,23)
0.8771	R(9,24)	0.4966	R(9,25)	0.7617	R(9,26)	0.7275	R(9,27)	0.7003	R(9,28)
0.6625	R(9,29)	0.6450	R(9,30)						
1.0000	R(10,10)	0.5189	R(10,11)	0.5193	R(10,12)	0.2652	R(10,13)	0.2652	R(10,14)
0.5737	R(10,15)	0.5966	R(10,16)	0.6615	R(10,17)	0.4690	R(10,18)	0.3120	R(10,19)
0.4876	R(10,20)	0.6027	R(10,21)	0.9530	R(10,22)	0.9483	R(10,23)	0.7633	R(10,24)
0.4418	R(10,25)	0.6033	R(10,26)	0.5760	R(10,27)	0.5244	R(10,28)	0.5398	R(10,29)
0.4823	R(10,30)								
1.0000	R(11,11)	1.0000	R(11,12)	0.6481	R(11,13)	0.6480	R(11,14)	0.8717	R(11,15)
0.8106	R(11,16)	0.7030	R(11,17)	0.6700	R(11,18)	0.2299	R(11,19)	0.8428	R(11,20)
0.4814	R(11,21)	0.6622	R(11,22)	0.6577	R(11,23)	0.6777	R(11,24)	0.5322	R(11,25)
0.8956	R(11,26)	0.8710	R(11,27)	0.7430	R(11,28)	0.5986	R(11,29)	0.6947	R(11,30)
1.0000	R(12,12)	0.6481	R(12,13)	0.6490	R(12,14)	0.8719	R(12,15)	0.8110	R(12,16)
0.7033	R(12,17)	0.6704	R(12,18)	0.2301	R(12,19)	0.8428	R(12,20)	0.4818	R(12,21)
0.6625	R(12,22)	0.6581	R(12,23)	0.6782	R(12,24)	0.5325	R(12,25)	0.8959	R(12,26)
0.8712	R(12,27)	0.7435	R(12,28)	0.5989	R(12,29)	0.6949	R(12,30)		
1.0000	R(13,13)	1.0000	R(13,14)	0.3397	R(13,15)	0.3282	R(13,16)	0.4476	R(13,17)
0.4646	R(13,18)	0.1231	R(13,19)	0.1362	R(13,20)	0.5300	R(13,21)	0.3683	R(13,22)
0.3644	R(13,23)	0.4860	R(13,24)	0.5670	R(13,25)	0.3903	R(13,26)	0.3426	R(13,27)
0.4290	R(13,28)	0.4879	R(13,29)	0.4979	R(13,30)				
1.0000	R(14,14)	0.3396	R(14,15)	0.3282	R(14,16)	0.4477	R(14,17)	0.4647	R(14,18)
0.1232	R(14,19)	0.1361	R(14,20)	0.5303	R(14,21)	0.3655	R(14,22)	0.3644	R(14,23)
0.4861	R(14,24)	0.5673	R(14,25)	0.3902	R(14,26)	0.3425	R(14,27)	0.4290	R(14,28)
0.4880	R(14,29)	0.4990	R(14,30)						
1.0000	R(15,15)	0.9744	R(15,16)	0.8108	R(15,17)	0.7606	R(15,18)	0.2559	R(15,19)
0.9938	R(15,20)	0.4796	R(15,21)	0.7118	R(15,22)	0.7263	R(15,23)	0.7828	R(15,24)
0.6007	R(15,25)	0.9790	R(15,26)	0.9998	R(15,27)	0.8915	R(15,28)	0.7055	R(15,29)
0.7939	R(15,30)								
1.0000	R(16,16)	0.7995	R(16,17)	0.7971	R(16,18)	0.2701	R(16,19)	0.8225	R(16,20)
0.4917	R(16,21)	0.7133	R(16,22)	0.7418	R(16,23)	0.8084	R(16,24)	0.4962	R(16,25)
0.9564	R(16,26)	0.9799	R(16,27)	0.9180	R(16,28)	0.7245	R(16,29)	0.7892	R(16,30)

STEPWISE REGRESSION ANALYSIS

1.0000	R(17,17)	[illegible]	R(17,18)	[illegible]	R(17,19)	[illegible]	R(17,20)	[illegible]	R(17,21)
[illegible]	R(17,22)	[illegible]	R(17,23)	[illegible]	R(17,24)	[illegible]	R(17,25)	[illegible]	R(17,26)
[illegible]	R(17,27)	[illegible]	R(17,28)	[illegible]	R(17,29)	[illegible]	R(17,30)		
1.0000	R(18,18)	[illegible]	R(18,19)	[illegible]	R(18,20)	[illegible]	R(18,21)	[illegible]	R(18,22)
0.6477	R(18,23)	[illegible]	R(18,24)	[illegible]	R(18,25)	[illegible]	R(18,26)	[illegible]	R(18,27)
[illegible]	R(18,28)	[illegible]	R(18,29)	[illegible]	R(18,30)				
1.0000	R(19,19)	0.2120	R(19,20)	[illegible]	R(19,21)	[illegible]	R(19,22)	[illegible]	R(19,23)
0.3130	R(19,24)	0.1626	R(19,25)	[illegible]	R(19,26)	[illegible]	R(19,27)	[illegible]	R(19,28)
0.2360	R(19,29)	0.2247	R(19,30)						
1.0000	R(20,20)	0.2516	R(20,21)	0.6011	R(20,22)	[illegible]	R(20,23)	[illegible]	R(20,24)
0.2916	R(20,25)	[illegible]	R(20,26)	[illegible]	R(20,27)	[illegible]	R(20,28)	[illegible]	R(20,29)
0.5517	R(20,30)								
1.0000	R(21,21)	[illegible]	R(21,22)	0.6431	R(21,23)	[illegible]	R(21,24)	[illegible]	R(21,25)
0.4543	R(21,26)	0.4885	R(21,27)	0.5467	R(21,28)	[illegible]	R(21,29)	[illegible]	R(21,30)
1.0000	R(22,22)	[illegible]	R(22,23)	0.8660	R(22,24)	[illegible]	R(22,25)	[illegible]	R(22,26)
0.7136	R(22,27)	[illegible]	R(22,28)	[illegible]	R(22,29)	[illegible]	R(22,30)		
1.0000	R(23,23)	[illegible]	R(23,24)	0.5047	R(23,25)	[illegible]	R(23,26)	[illegible]	R(23,27)
0.7052	R(23,28)	[illegible]	R(23,29)	[illegible]	R(23,30)				
1.0000	R(24,24)	[illegible]	R(24,25)	[illegible]	R(24,26)	[illegible]	R(24,27)	[illegible]	R(24,28)
0.8663	R(24,29)	[illegible]	R(24,30)						
1.0000	R(25,25)	0.4759	R(25,26)	[illegible]	R(25,27)	[illegible]	R(25,28)	[illegible]	R(25,29)
0.6801	R(25,30)								
1.0000	R(26,26)	[illegible]	R(26,27)	[illegible]	R(26,28)	[illegible]	R(26,29)	0.7787	R(26,30)
1.0000	R(27,27)	[illegible]	R(27,28)	[illegible]	R(27,29)	[illegible]	R(27,30)		
1.0000	R(28,28)	0.8367	R(28,29)	0.6940	R(28,30)				
1.0000	R(29,29)	0.9550	R(29,30)						
1.0000	R(30,30)								


RESIDUAL
MULT. BY 10** 0
3.00
-0.00
-3.00
-6.00
27.00
30.00
PREDICTED FOM (IN)


PREDICTED Ln FOM (IN)

APPENDIX D

Regression No. 2 Statistics

STEPWISE REGRESSION ANALYSIS   REGRESSION NO.2.   F=19.0   PROBLEM NO. 1

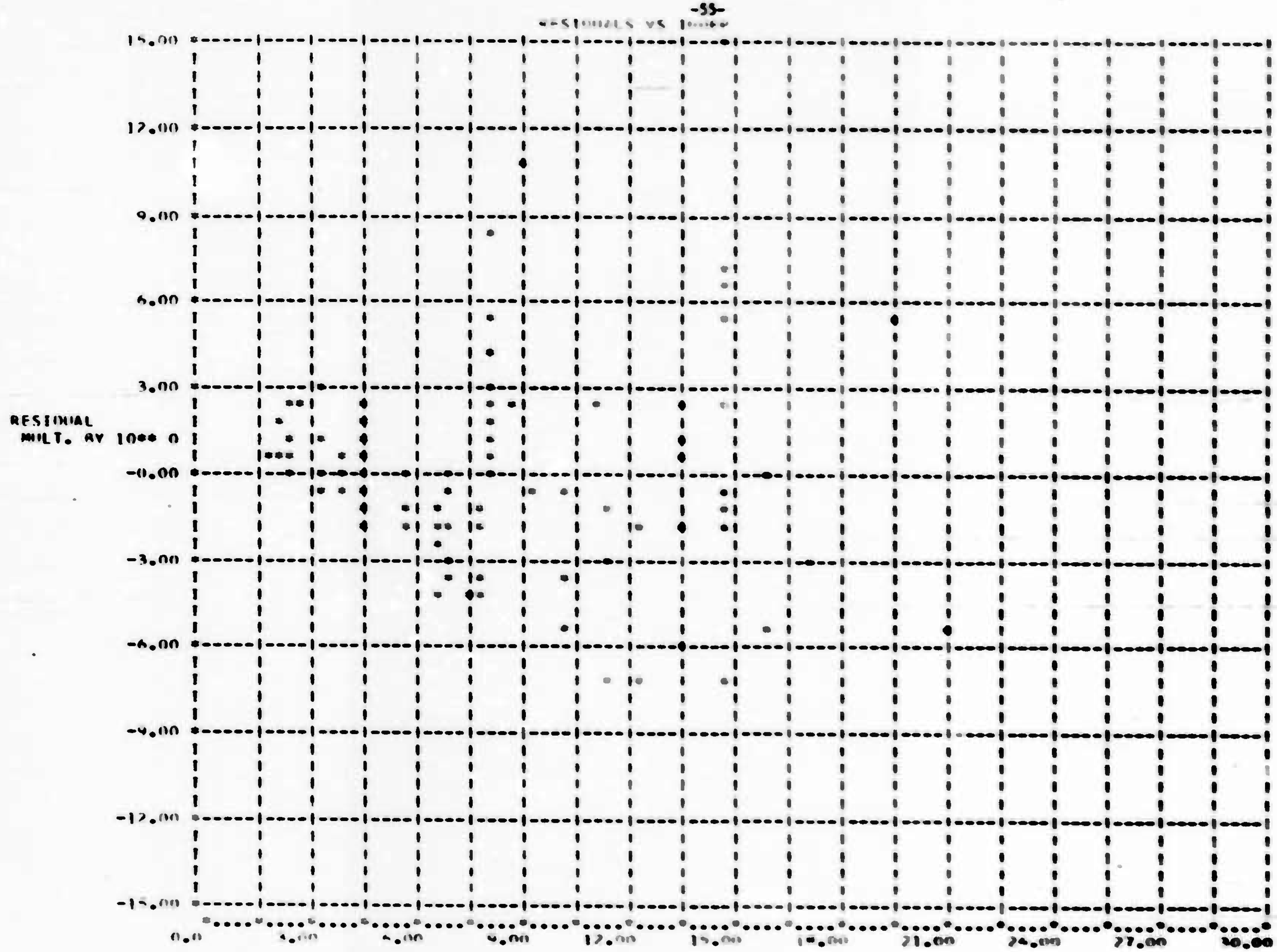
NO. OF OBSERVATIONS 125

VARIABLE	MEAN	STD. DEV.
1	0.458288000	0.736160260
2	0.747624624	2.919637741
3	2.672456000	0.236461665
4	7.187447288	1.314861297
5	0.222275200	0.002115063
6	0.049410702	0.000943692
7	0.220208800	0.000601883
8	0.048492275	0.000265425
9	1.368000000	0.996250796
10	2.956000000	3.303721440
11	1.250875640	2.046139327
12	0.102847598	0.166799593
13	0.101260237	0.163275145
14	0.849224000	1.715321617
15	0.593728586	0.054855364
16	0.588087042	0.052731508
17	3.729944000	2.901449409
18	0.048947876	0.000571573
19	0.305545600	0.224099483
20	0.301531200	0.219837690
21	7.229360000	5.454436608
22	1.763265335	0.623898873

SIMPLE CORRELATION COEFFICIENTS, [illegible]

1.0000	R(1, 1)	[illegible]	R(1, 2)	[illegible]	R(1, 3)	[illegible]	R(1, 4)	[illegible]	R(1, 5)
0.6371	R(1, 6)	0.7762	R(1, 7)	0.7771	R(1, 8)	[illegible]	R(1, 9)	[illegible]	R(1,10)
0.9964	R(1,11)	[illegible]	R(1,12)	[illegible]	R(1,13)	[illegible]	R(1,14)	[illegible]	R(1,15)
0.1755	R(1,16)	[illegible]	R(1,17)	[illegible]	R(1,18)	[illegible]	R(1,19)	[illegible]	R(1,20)
0.4774	R(1,21)	0.5276	R(1,22)						
1.0000	R(2, 2)	0.0946	R(2, 3)	0.0904	R(2, 4)	[illegible]	R(2, 5)	[illegible]	R(2, 6)
0.5778	R(2, 7)	0.5740	R(2, 8)	0.1572	R(2, 9)	[illegible]	R(2,10)	[illegible]	R(2,11)
0.9089	R(2,12)	0.9055	R(2,13)	0.8770	R(2,14)	[illegible]	R(2,15)	[illegible]	R(2,16)
0.1581	R(2,17)	0.5036	R(2,18)	0.1644	R(2,19)	[illegible]	R(2,20)	[illegible]	R(2,21)
0.2831	R(2,22)								
1.0000	R(3, 3)	0.9948	R(3, 4)	0.2981	R(3, 5)	[illegible]	R(3, 6)	[illegible]	R(3, 7)
0.1973	R(3, 8)	0.3167	R(3, 9)	0.4056	R(3,10)	[illegible]	R(3,11)	0.1507	R(3,12)
0.1507	R(3,13)	0.2206	R(3,14)	0.9900	R(3,15)	[illegible]	R(3,16)	[illegible]	R(3,17)
0.2891	R(3,18)	0.3196	R(3,19)	[illegible]	R(3,20)	[illegible]	R(3,21)	0.3223	R(3,22)
1.0000	R(4, 4)	0.2907	R(4, 5)	[illegible]	R(4, 6)	0.1929	R(4, 7)	0.1925	R(4, 8)
0.3138	R(4, 9)	0.4055	R(4,10)	0.1855	R(4,11)	0.1460	R(4,12)	0.1460	R(4,13)
0.2192	R(4,14)	0.9922	R(4,15)	0.9979	R(4,16)	0.3965	R(4,17)	0.2819	R(4,18)
0.3167	R(4,19)	0.5142	R(4,20)	0.3313	R(4,21)	0.3134	R(4,22)		
1.0000	R(5, 5)	1.0000	R(5, 6)	0.7295	R(5, 7)	0.7295	R(5, 8)	0.7048	R(5, 9)
0.6659	R(5,10)	0.6319	R(5,11)	0.6371	R(5,12)	0.6550	R(5,13)	0.6751	R(5,14)
0.3987	R(5,15)	0.3255	R(5,16)	0.7035	R(5,17)	[illegible]	R(5,18)	0.7132	R(5,19)
0.7065	R(5,20)	0.7446	R(5,21)	0.8110	R(5,22)				
1.0000	R(6, 6)	0.7296	R(6, 7)	0.7297	R(6, 8)	0.7041	R(6, 9)	0.6661	R(6,10)
0.6336	R(6,11)	0.6388	R(6,12)	0.6366	R(6,13)	0.6785	R(6,14)	0.3983	R(6,15)
0.3251	R(6,16)	0.7025	R(6,17)	[illegible]	R(6,18)	0.712[illegible]	R(6,19)	0.7059	R(6,20)
0.7448	R(6,21)	0.8104	R(6,22)						
1.0000	R(7, 7)	1.0000	R(7, 8)	[illegible]	R(7, 9)	0.4245	R(7,10)	0.7641	R(7,11)
0.7753	R(7,12)	0.7760	R(7,13)	0.7061	R(7,14)	0.2725	R(7,15)	0.2340	R(7,16)
0.4705	R(7,17)	[illegible]	R(7,18)	0.4855	R(7,19)	[illegible]	R(7,20)	0.5754	R(7,21)
[illegible]	R(7,22)								
1.0000	R(8, 8)	[illegible]	R(8, 9)	0.4244	R(8,10)	[illegible]	R(8,11)	0.7762	R(8,12)
0.7766	R(8,13)	[illegible]	R(8,14)	0.2721	R(8,15)	[illegible]	R(8,16)	[illegible]	R(8,17)
[illegible]	R(8,18)	[illegible]	R(8,19)	[illegible]	R(8,20)	[illegible]	R(8,21)	[illegible]	R(8,22)
1.0000	R(9, 9)	[illegible]	R(9,10)	[illegible]	R(9,11)	[illegible]	R(9,12)	[illegible]	R(9,13)
[illegible]	R(9,14)	[illegible]	R(9,15)	[illegible]	R(9,16)	[illegible]	R(9,17)	[illegible]	R(9,18)
[illegible]	R(9,19)	[illegible]	R(9,20)	[illegible]	R(9,21)	[illegible]	R(9,22)		
1.0000	R(10,10)	[illegible]	R(10,11)	[illegible]	R(10,12)	[illegible]	R(10,13)	[illegible]	R(10,14)
[illegible]	R(10,15)	[illegible]	R(10,16)	[illegible]	R(10,17)	[illegible]	R(10,18)	[illegible]	R(10,19)
[illegible]	R(10,20)	[illegible]	R(10,21)	[illegible]	R(10,22)				

1.0000	R(11.11)	[illegible]	R(11.12)	[illegible]	R(11.13)	[illegible]	R(11.14)	0.2562	R(11.15)
0.2174	R(11.16)	0.3274	R(11.17)	[illegible]	R(11.18)	[illegible]	R(11.19)	[illegible]	R(11.20)
0.4796	R(11.21)	0.5289	R(11.22)						
1.0000	R(12.12)	[illegible]	R(12.13)	[illegible]	R(12.14)	0.2197	R(12.15)	0.1770	R(12.16)
0.3068	R(12.17)	0.7020	R(12.18)	[illegible]	R(12.19)	[illegible]	R(12.20)	[illegible]	R(12.21)
0.5269	R(12.22)								
1.0000	R(13.13)	[illegible]	R(13.14)	[illegible]	R(13.15)	[illegible]	R(13.16)	[illegible]	R(13.17)
0.7013	R(13.18)	0.3121	R(13.19)	[illegible]	R(13.20)	[illegible]	R(13.21)	[illegible]	R(13.22)
1.0000	R(14.14)	0.2566	R(14.15)	[illegible]	R(14.16)	[illegible]	R(14.17)	[illegible]	R(14.18)
0.4911	R(14.19)	0.4557	R(14.20)	[illegible]	R(14.21)	[illegible]	R(14.22)		
1.0000	R(15.15)	[illegible]	R(15.16)	[illegible]	R(15.17)	[illegible]	R(15.18)	[illegible]	R(15.19)
[illegible]	R(15.20)	[illegible]	R(15.21)	[illegible]	R(15.22)				
1.0000	R(16.16)	0.4204	R(16.17)	[illegible]	R(16.18)	[illegible]	R(16.19)	[illegible]	R(16.20)
0.3527	R(16.21)	0.3441	R(16.22)						
1.0000	R(17.17)	[illegible]	R(17.18)	[illegible]	R(17.19)	[illegible]	R(17.20)	[illegible]	R(17.21)
0.7407	R(17.22)								
1.0000	R(18.18)	[illegible]	R(18.19)	[illegible]	R(18.20)	[illegible]	R(18.21)	[illegible]	R(18.22)
1.0000	R(19.19)	[illegible]	R(19.20)	[illegible]	R(19.21)	[illegible]	R(19.22)		
1.0000	R(20.20)	[illegible]	R(20.21)	[illegible]	R(20.22)				
1.0000	R(21.21)	[illegible]	R(21.22)						
1.0000	R(22.22)								



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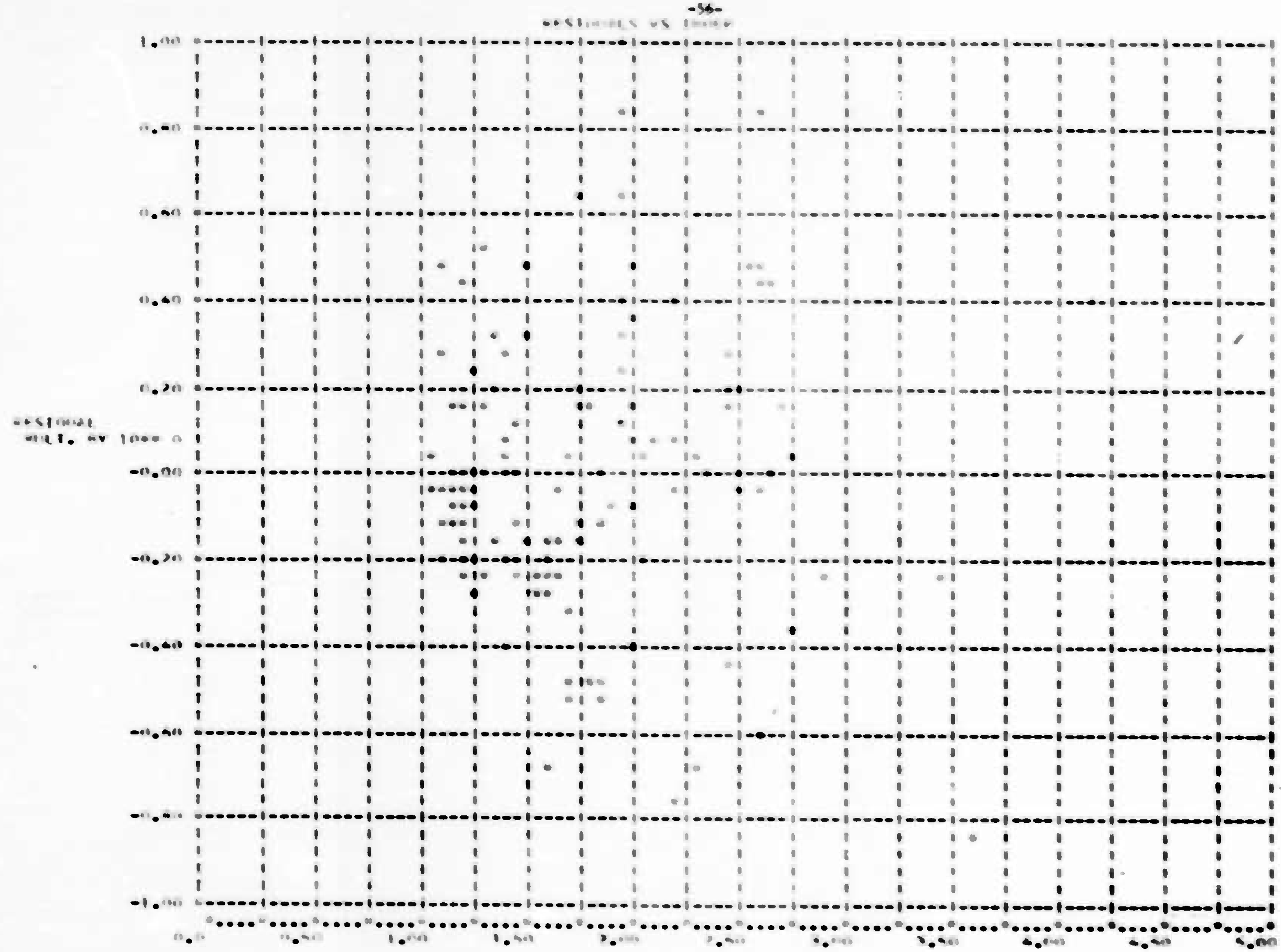
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PREDICTED LS

APPENDIX E

Regression No. 3 Statistics

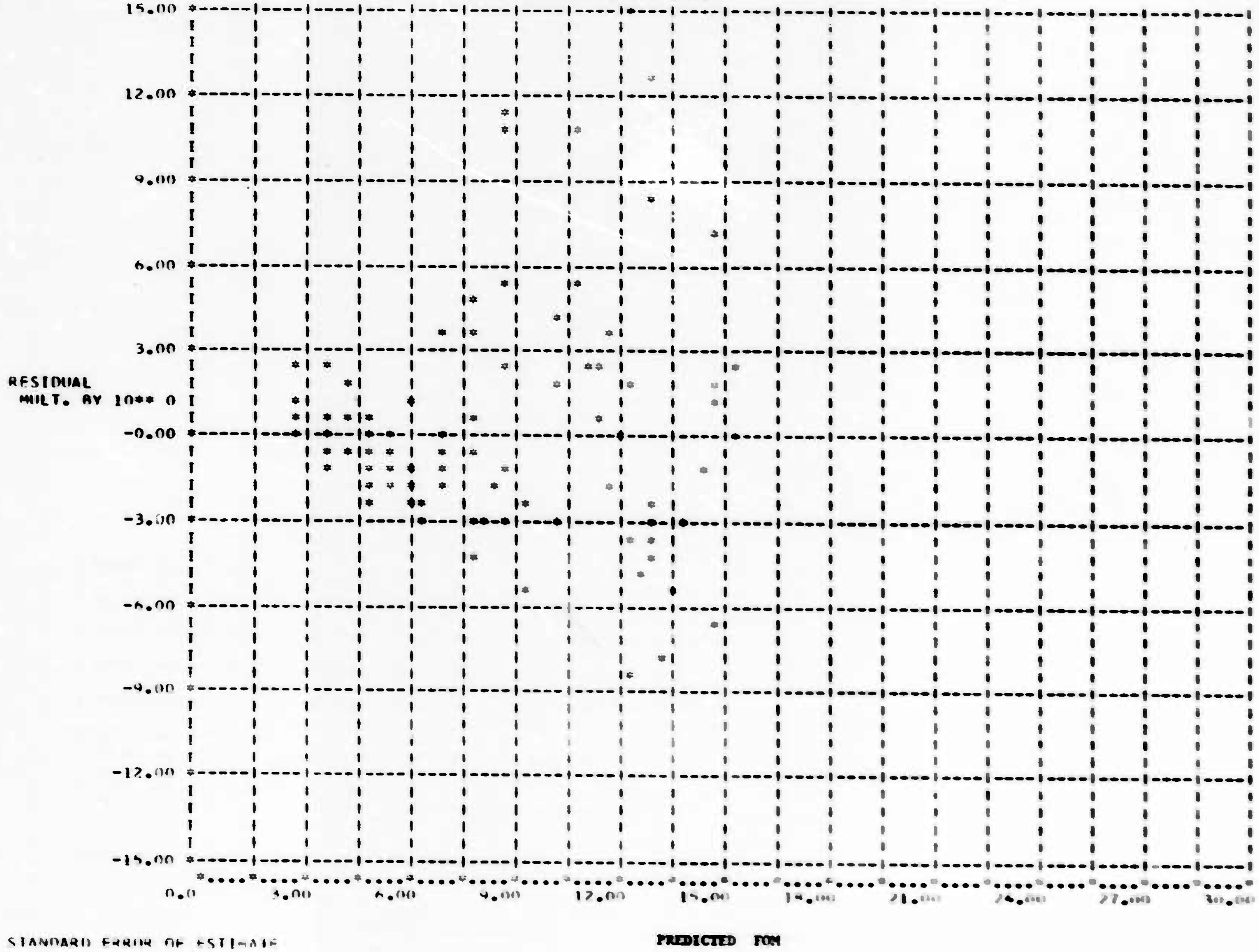
NO. OF OBSERVATIONS 125

VARIABLE	MEAN	STD DEV.
1	0.458288000	0.736160260
2	0.747624624	2.919637741
3	2.271291598	13.779599262
4	9.015036939	69.553612264
5	40.433966285	359.881399194
6	7.229360000	5.454436608
7	1.763265335	0.623898873

SIMPLE CORRELATION COEFFICIENTS. (ROW BY COL.)

1.0000 R(1, 1)	0.9046 R(1, 2)	0.7924 R(1, 3)	0.7147 R(1, 4)	0.[illegible] R(1, 5)
0.4774 R(1, 6)	0.5278 R(1, 7)			
1.0000 R(2, 2)	0.9706 R(2, 3)	0.9272 R(2, 4)	0.8932 R(2, 5)	0.2[illegible] R(2, 6)
0.2831 R(2, 7)				
1.0000 R(3, 3)	0.9895 R(3, 4)	0.9734 R(3, 5)	0.1845 R(3, 6)	0.2001 R(3, 7)
1.0000 R(4, 4)	0.9962 R(4, 5)	0.1576 R(4, 6)	0.1643 R(4, 7)	
1.0000 R(5, 5)	0.1464 R(5, 6)	0.1557 R(5, 7)		
1.0000 R(6, 6)	0.9500 R(6, 7)			
1.0000 R(7, 7)				

RESIDUALS VS



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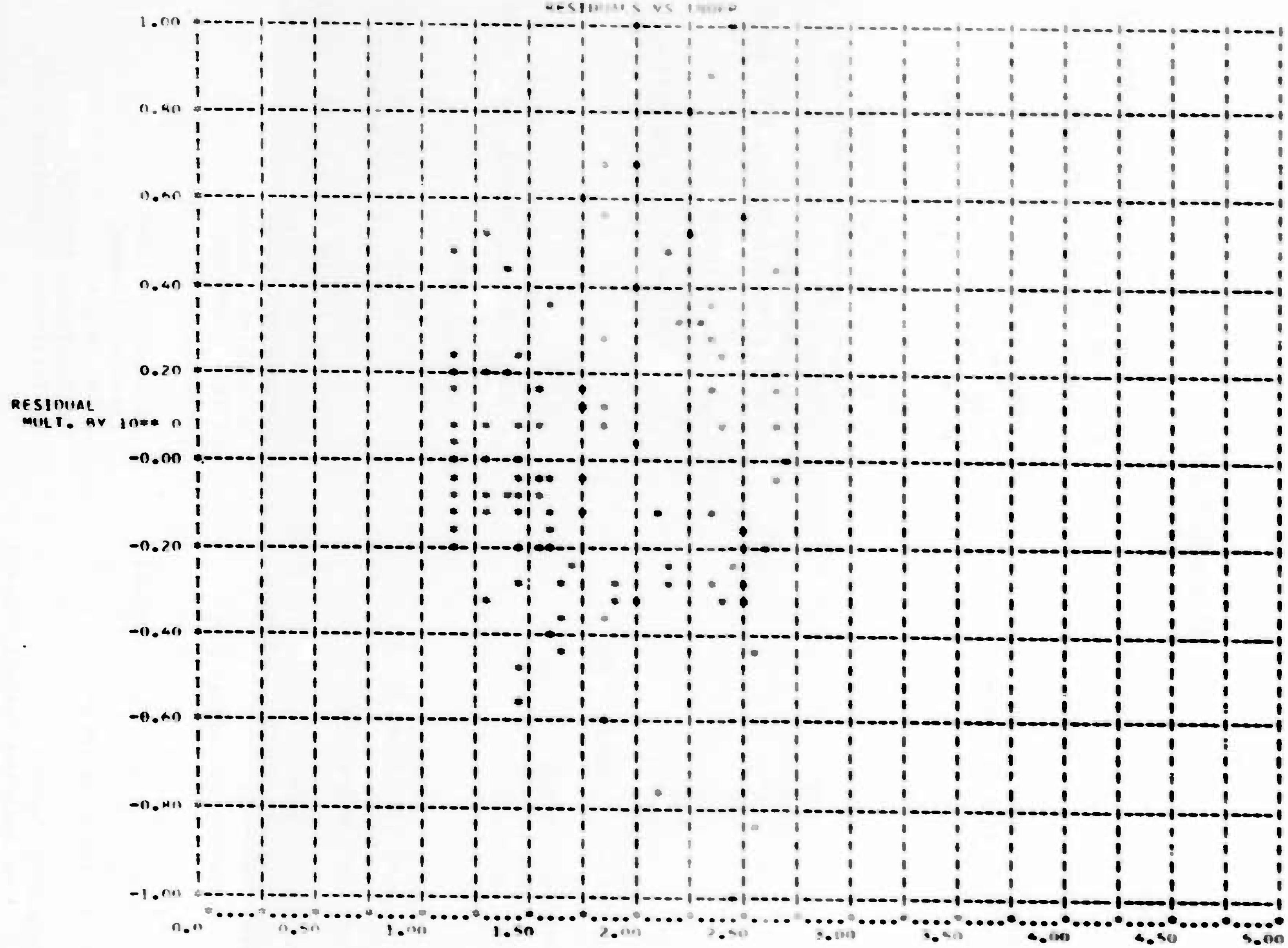

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PREDICTED LOG FUM

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13. ABSTRACT

An analysis of the M-16 rifle barrel dimensions and dispersion was conducted. Dispersion prediction equations were obtained using several categories of dimensional data. A discriminating procedure was developed suitable for use by field troops to separate barrels with "acceptable" dispersion from those "not acceptable". Depth-of-muzzle-penetration by the erosion gage was selected as the discriminating variable. A brief discussion contrasts the widely used Extreme-Spread dispersion statistic with the more efficient, and slightly more troublesome, Figure-of-Merit statistic.

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