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COMMENTS ON M16 RELIABILITY TEST DATA

by

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ABSTRACT

This report presents the results of an analysis of malfunction data which was obtained during acceptance testing of M16 rifle lots. The prime objective of the effort was to obtain insight into the nature of the distribution of malfunction-occurrences. These data were also examined to test for changes in malfunction occurrences between early and recently produced weapons. The analysis is then related to current and proposed acceptance testing procedures.

COMMENTS ON M16 RELIABILITY-ACCEPTANCE TEST DATA

SUMMARY:

The surprising result of this exercise is the difference in the estimated mean-time-to-malfunction for Category II[1] malfunctions between the first occurrence and the second malfunction, given the first has occurred (second/first). The first malfunction signals a change in the weapon-system operation and the second malfunction is expected to occur in fewer rounds than the first. The cause of this change, whether mechanical wear, a defective magazine, introduction of debris, or carbon accumulation is not known at this time. Also of note are the decreasing failure rates for certain distributions and the resemblance between the second/first and third/second malfunction distributions in the one case examined. A significant difference in malfunction occurrences was found for the malfunction bolt-fail-to-hold; this was attributed to redesign. Significant differences were also found for the number of extractor springs and ejector springs replaced when measured with respect to the change in buffer design. Fewer replacements are required; here again, a change in spring production procedures was noted. The other categories did not test significant. This test is sensitive only to the total effect on the weapon and not to the occurrence of a new malfunction-type which may be a sub-category of one of the malfunction-types considered, or the disappearance of an infrequently occurring malfunction sub-category.

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[1] Malfunctions which are not clearable by cycling the weapon but can be corrected without weapon disassembly.

A mission performance test was described which would test rifles to first-malfunction or until a mission of n-rounds have been fired ($n < 1000$). This test could be the basis for lot acceptance while the current "reliability test" would be modified to monitor gross defects in production processes.

CONTENTS

INTRODUCTION:

This study is part of a U. S. Army Weapons Command investigation into current acceptance testing of the M16 rifle. The prime objective of this portion of the effort was to obtain insight into the nature of the distributions of malfunction occurrences as a function of the number of rounds fired. These distributions were to be obtained for each malfunction-type considered when sufficient data existed. They would then be used as a basis for developing a test for rifle malfunction performance. Knowledge of these distribution functions would yield a greater confidence in assessing weapon performance, for a given sample size, than a test based on a "percent-defective-in-lot" basis. A portion of this study consisted of testing the frequency of occurrences of the malfunction-types for early and recently produced weapons. Acceptance of the null hypothesis, "the frequency is the same", would allow the combining of the data gathered for both classes of weapons, otherwise, the more recent data would be used.

At this point, a summary of the current "reliability test" contained in the Springfield Armory Purchase Description, appears to be in order (Reference 1). Only the points pertinent to this exercise will be discussed. One rifle is randomly selected from a lot of 10,000 and fired 6000 rounds, or until it fails. The rifle can fail the test by: 1) the occurrence of more than a specified number of malfunctions either within a particular malfunction type or total number of malfunctions or, 2) the occurrence of more than a specified number of unservicable parts either within a category or for all parts combined (Table 1). The lot is accepted if the rifle passes the test; further testing occurs if the rifle does not pass. This additional testing consists of randomly selecting two additional weapons from the lot and subjecting them to the 6000 round test.[1] Each of the weapons must pass the test or the lot is rejected. The status of the rejected lot is not clear, but one case of a rejected lot was observed. In this case, the rejected lot was accepted by selecting two additional weapons which ultimately passed the test. The "reliability" test was apparently designed to assess gross defects in the production process rather than evaluate the reliability of the rifles in terms of "probability of completing a specified mission under specified conditions".

The following analysis is based on data generated from these reliability tests. This analysis does not purport to stringent scientific technique; but to examine the data in a manner to gain insight into the character of the malfunction distributions. This approach is thought to be in keeping with the quality of the data base.

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[1] The 6000 rounds are fired in 100 round sets in the sequence-60 semi-automatic and 40 automatic. See Reference 1 for additional details of the test procedure.

Table I. Malfunctions and unserviceable parts

Malfunctions[1]	Number permitted in the 6,000-round reliability test
Failure of forward assist assembly to assist bolt closure (XM16E1 only)	0 (See note 2)
Failure of bolt to lock	3
Failure of bolt stop to hold bolt open (last round of each magazine)	3
Failure to eject cartridge case	4
Failure to feed (cartridge visible)	4
Failure to feed (cartridge not visible)	3
Failure to fire semiautomatic (single rounds)	3
Light blow	3
Other malfunctions	1
Total malfunctions - above malfunctions combined	11

Unserviceable parts[1]	Number permitted in the 6,000-round reliability test	
	First 3,000 rounds	Second 3,000 rounds
Magazine assembly	0	1
Ejector spring	0	1
Extractor	0	1
Extractor spring	0	2
Other parts[3]	0	1
Total unserviceable parts - above unserviceable parts combined	0	3

[1] When malfunctions are traceable to particular parts, it is permissible to replace such parts and record them as unserviceable, subject to limitations of table I. When it is definitely established by the Government representative that previously recorded malfunctions are attributable to an unserviceable part, such malfunctions shall not be counted against the rifle being tested, provided that they occurred not more than 200 rounds prior to replacement of the unserviceable part. These 200 rounds shall have been fired with the unserviceable part. However, such malfunctions shall remain recorded and properly identified. An unserviceable part is one that causes malfunctions or impairs the safety of the weapon. Malfunctions attributable to ammunition shall not be counted against the rifle however, such malfunctions shall be recorded.

[2] In the event of any failure of bolt to lock, the forward assist assembly shall be operated. Failure of the forward assist assembly to remain engaged with the bolt carrier assembly during manual attempt to lock the bolt shall be counted as a failure of forward assist assembly to assist bolt closure malfunction.. All failures of bolt to lock shall be counted as malfunctions.

[3] One unserviceable part other than those specified shall be allowed if in the judgment of the Government representative the failure does not represent an unsafe or defective condition which is prevalent throughout the lot of items involved.

DATA:

The data considered for this investigation are the result of 131 reliability tests (as described in the introduction). These data, list for each weapon the round at which the malfunction and/or part failure occurred and the malfunction-type (as categorized in Table I). If the contractor can convince the government inspector that a malfunction was caused by an unserviceable part, the part would be replaced and cited against the contractor. The benefit to the contractor would be discounting of malfunctions which could be attributed to the part and which occurred within 200 rounds prior to the part replacement. These rules could generate a strategy which the contractor may use to increase his chances of passing the reliability test. No claim is being made that this strategy was employed, but some suspicion was attached to the observed higher order malfunctions data, i.e., occurrence of the third, fourth or fifth malfunction.

Another area of concern was the treatment of the rejected weapons. Was the rejected weapon a defective weapon from the viewpoint of undesirable manufacture, (i.e., tolerance, finish, material quality, etc.) or was the weapon an observation from the population of weapons manufactured in accordance with specifications (Type I error) ? As only the first and second order failures were considered for the graphical analysis, it was decided the penalties would be greater (for this initial analysis) if the rejected weapons were included. The inclusion of the rejected rifles would show decreasing failure rates for the population as the rejects were removed from the test (if they were in fact defective, i.e., high failure rate items). However, the predictions made by the estimated malfunction distributions were compared with the observed number of malfunctions including, as well as excluding, the rejected rifles.

The data was examined to check the malfunctions not cited against the weapon against the inspectors comment. These malfunctions, not specifically discounted according to the provisions of Reference 1, were cited against the weapon.

CHANGE IN FREQUENCY OF MALFUNCTION TESTS:

Tests were made of the hypothesis: Rifles of early manufacture malfunction at the same rate as the recently produced rifles. The alternative hypothesis is, of course, that they do not. The division between early and recent rifles was made at the introduction of rifles with the new buffer design.[2] This appeared to be the first significant engineering change. The most recent change "chrome chamber" was represented by only 13 rifles and was not considered as a separate category.

The statistic used for these tests is the χ^2- statistic (reference 2):

$$\chi^2 = n \cdot \sum_{i=1}^{2} \sum_{j=1}^{k} \frac{f^2_{ij}}{n_i c_j} - 1$$

Where n = total sample (131) weapons
k = highest order of malfunctions
i = 1, weapons before buffer change
2, weapons after buffer change
f_{ij} = no. malfunctions of order "j" observed for weapons in set "i"
n_i = no. weapons in set "i"
c_j = no. malfunctions of order "j" occurring in total sample

The higher order malfunctions were combined into a single category "j" in an attempt to maintain min $n_i c_j / n \geq 5$ (Reference 2).

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[2] A more detailed analysis of differences in rate of malfunction occurrences is in progress at the Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland.

This goal was not always attained, and therefore, the distribution of some of the statistics is in question. However, the reason for these small values is the small number of malfunctions which occurred during the test for these malfunction-types. Detecting small changes for these malfunction types was not considered important, especially in view of the computed x^2-statistic (Table II) and so an exact test was not performed.

Table II presents the computed x^2-statistics for each malfunction type considered and the two unserviceable parts which tested significant. The malfunction type which tested significant was bolt-fail-to-hold. It is believed that this malfunction has been eliminated through redesign. The other malfunction-types did not test significant, and so the data was combined for the graphical analysis.

The above test is sensitive only to changes in occurrence by malfunction-types. Many of the malfunction-types are symptoms of one of several possible causes. The elimination or introduction of a new cause will be detected only insofar as it affects a malfunction-type.

TABLE II

COMPARISON OF MALFUNCTION OCCURRENCES

								UNSERVICEABLE PARTS	
Malfunction	bolt-fail-to-lock	bolt-fail-to-hold	fail-to-eject	fail-to-feed-CV	fail-to-feed-CNV	fail-to-fire-semi	light blow	extractor springs	ejector springs
Malfunction order:	0 [4]	0 [4]	0 1 [5]	0 1 [5]	0 [4]	0 [4]	0 [4]	0 [4]	0 [4]
Number of Malfunctions before new buffer (90 weapons)	85 5	73 17	63 16 11	54 15 21	75 15	84 6	83 7	59 31	72 18
Number of Malfunctions after new buffer (41 weapons)	38 3	41 0	24 8 9	24 6 11	35 6	40 1	39 2	36 5	39 2
Computed Statistic	[1]	[2]				[1]	[1]	[2]	[3]
x^2(df)	$x^2(1)= .2$	$x^2(1)=8.9$	$x^2(2)=2.4$	$x^2(2)=.1$	$x^2(1)=0.1$	$x^2(1)=1.0$	$x^2(1)=.4$	$x^2(1)=7.0$	$x^2(1)=5.0$

[1] minimum $n_i c_i/n<5$

[2] significant at $\alpha=0.1$

[3] Significant at $\alpha=0.5$

[4] at least one failure

[5] at least two failures

GRAPHICAL ANALYSIS:

The data were divided into three categories by personnel in the USAWECOM R & D Directorate for the purpose of analysis. These categories are differentiated by the corrective action required to return the weapon to an operable state. Category I malfunctions are those which can be cleared by recharging (cycling) the weapon. Failure-of-bolt-to-hold and light-blow (insufficient force delivered to primer) are malfunctions of this type. The second category, Category II, are those which are not immediately clearable (Category I) but do not require "teardown" of the weapon. This category contains the malfunction types: Failure-to-eject, failure-to-feed-CV (cartridge visible) and failure-to-feed-CNV (cartridge not visible). Category III malfunctions require weapon teardown as part of the corrective action; failure-to-fire-semi-automatic and failure-to-extract are in the category.

The most frequently occurring malfunctions are the three which comprise Category II. These were examined separately. The malfunction types in Category I were combined, as were those in Category III, due to the paucity of data in these categories.

Part failures were not examined as a function of time. This decision was based on: (1) parts were declared unserviceable only when they caused malfunctions, or found while cleaning the weapon, so the time of failure was not well established, (2) the part may have been declared unserviceable due to the occurrence of one or more malfunctions(possible strategy of contractor),(3) the most frequently replaced parts throughout the tests appear to have fewer replacements in the more recent tests (see Table III).

The data was initially examined with the assumption that malfunctions, which were not attributed to unserviceable parts, would occur at a constant rate and could be described by an exponential distribution. Plots of the number-of-rounds-to-failure for the categories, suggested that this was not appropriate and that other distributions should be considered.

The next approach was to describe the distribution of <u>first-failure</u> for Category I, Category III and each malfunction-type in Category II. The plots of the ordered first failures[3] of category I, Category III and fail-to-eject on semi-log paper suggest that these could be described by exponential distributions. These plots are found in Figure 1, 2 and 8, together with the distribution (straight line) obtained by using the maximum likelihood estimate of the parameter, η[4] estimated for each case. However, the plots of the malfunctions fail-to-feed-CNV and fail-to-feed-CV on semi-log paper suggested a decreasing failure rate. The plots of each of these malfunctions on Weibull paper (Figures 3 and 4) indicated a linear trend, and therefore, that these data could be described by a

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[3] The malfunctions were ordered according to increasing numbers of rounds to malfunctions. These ordered observations were plotted against the corresponding median ranks.

[4] The Exponential distribution is:

$P(r) = 1-\exp[-(r/\eta)]$

$P(r)$ = probability of a malfunction occurring within r rounds

The maximum likelihood estimate of η is based on the 6000 round terminated test.

$\hat{\eta} = 6000 / [\ln (n) - \ln(n-f)]$

n = sample size (the 119 acceptable weapons were used for these estimates)

f = no. weapons which malfunctioned

Weibull distribution.[5] The parameters β and η were obtained graphically.

No further attempt was made to describe the distribution of higher order failures for Category I and Category III malfunctions because of insufficient data. Estimates were made of the distribution of second failures given that the first failure has occurred for each Category II malfunction type. Each of the plots on semi-log paper indicated decreasing failure rates, so Weibull plots were obtained, Figures 4, 9, and 15. Again, the parameters were estimated graphically. (The non-linear scale distorts the magnitude of the deviation at the lower end of the graph.) The estimated parameters and mean-round-to-malfunction (MRTM) for these distributions are presented in Table II. The MRTM appears substantially smaller for the second malfunction (given the first occurrence) than for the first malfunction for each Category II malfunction. The implication is that the weapon is not restored to its former state after the malfunction is cleared and the weapon is placed back into service.

The ordered data of the occurrences of third malfunctions, given the second malfunctions have occurred, is plotted in Figure 16. The graphically estimated distribution of the second malfunctions given the first occurred, is presented as a straight line. The resemblance between the data plotted in Figure 15 and 16 suggest the same underlying distribution.

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[5] The form of the Weibull distribution used is:

$$P(r) = 1 - \exp -(r/n)^{\beta}$$

TABLE II

ESTIMATED DISTRIBUTION PARAMETERS

Malfunction-Type	β^1	η	Mean-Round-to Malfunction (MRTM)
Category I	1.0	53000	53000
Category II			
Fail-to-feed-CNV			
1st Malf.	.69	60500	131,200
2nd/1st Malf.	.47	2700	16,800
Fail-to-Eject			
1st Malf.	1.0	15100	15100
2nd/1st Malf.	.76	4500	9300
Fail-to-feed-CV			
1st Malf.	.72	15600	33100
2nd/1st Malf.	.73	3000	6300
Category III	1.0	58300	58300

(1) $\beta = 1.0$ indicates exponential distribution i.e., constant failure rate.

CATEGORY II

Estimates of the probability distributions of second, third, fourth and fifth order failures were obtained by numerically convoluting the estimates of first-malfunction distributions with the distributions of second malfunction given first malfunction (second/first) representing all succeeding distributions i.e., second/first, third/second, fourth/third and fifth/fourth. Admittedly, the extrapolations are "way out". These distributions are plotted for fail-to-feed-CNV in Figures 5 - 7 for fail-to-eject in Figures 10 - 13 and for fail-to-feed-CV in Figures 17-20.

The ordered observations of the occurrence of second failures for the 119 accepted rifles are plotted together with the estimated distributions. The other source of comparison is found in Table III. The predictions are compared with the observations for the 119 accepted weapons (2nd and 3rd order failures) and the total 131 tested weapons (including rejects).

These estimated distributions are not claimed to describe the malfunction distributions adequately, but to indicate that the malfunction can be described by these techniques. Acceptance testing can then be based on testing against the distribution rather than on a "percent-defective-per-lot" basis.

The data presented here represents the combination of automatic fired and semi-automatic fired rounds. This approach was judged to be adequate for the current test in which rounds are fired in the sequence- 60 semi-automatic, 40 automatic - throughout the test. A change in sequence (e.g.-30 semi. - 20 automatic) or change in the ratio (e.g. - 40 semi. - 60 automatic) is expected to change the frequency of malfunction. The test data indicates that Category I and fail-to-eject malfunctions occur more frequently in automatic fire while the opposite is true for fail-to-feed-CV and Category III (since fail-to-fire-semi, is the major contribution in Category III). Fail-to-feed-CNV appears to occur independently of the mode of fire.

TABLE III

Comparison of Predicted and Observed Malfunctions

No. of Malfunctions	2	3[1]	4	2	3	4	5	2	3	4	5
119 accepted rifles											
predicted no. occurrences	13.8	9		18.8	7.6			30.5	17.9		
observed no. occurrences	11	4		14	3			27	10		
131 tested rifles											
predicted no. occurrences	14.1	9.4	4.1	19.4	7.8	3.5	1.3	31.7	18.5	6.8	4.1
observed no. occurrences	13	5	0	20	9	5	3	32	13	9	4

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(1) maximum allowable number of this malfunction-type

CONCLUSIONS:

Endurance Testing

The difficulty in constructing a performance test based on a "maximum-allowable number-of-malfunctions" for each malfunction type is apparent. The problem is the estimation of the distributions of higher order malfunctions based on the available test data. In order to develop a test with a producer's (Type I) error of, say, ten percent, would require that the Type I error associated with each malfunction-type of about one-two percent (depending on the number of categories considered and assuming independence). Thus, our estimates of these distributions are required to be precise in the upper tail of the distribution. This implies a requirement for many observations of higher-order malfunctions.

The basis for constructing the existing allowable limits for each malfunction type in the "Reliability Test" (Reference 1) was the assumption that this malfunction had an equally likely chance of occurring for each round fired. This binomial distribution was then approximated by a Poisson-Distribution and the upper bound was taken to be the "expected value" plus a 3.σ (std. dev.) interval. Test data were generated and used as described to compute the values in Table I. This procedure may be adequate when second malfunctions are rarely observed (Categories I and III), but definitely not adequate when applied to Category II malfunction types and the combined malfunctions. This latter assertion is based on the graphical analysis which shows that these malfunctions do not occur with equally likely probability throughout the test and is further illustrated in Figure 22 for the combined malfunction data. The Poisson Distribution is observed to inadequately fit the data as compared to a "discrete-exponential" (which appears to be appropriate under conditions of decreasing reliability for each renewal) (see Reference 3 for additional information on this topic).

The inability to adequately describe the higher-order malfunction distribution for each malfunction-type leads to a consideration of a non-parametric (distribution free) approach. We are stymied in this instance by not having the sample sizes and complete data necessary for a thorough treatment of all malfunction-types. These techniques can be used together with judgement in considering selected malfunction types.

The following recommendations were made with the objective of constraining the producer to produce at current performance levels with respect to this endurance test:

(1) Reduce the allowable number of malfunctions for those cases in which the maximum was never observed. For these cases we are 95% confident that this maximum will not occur more than 97.5% of the trials (reference 5).

(2) Eliminate the categories "other-malfunction" and create a category "failure-to-eject". All malfunctions in the category "other-malfunctions" have been attributed to unserviceable parts with the exception of "failure-to-extract". The occurrence of a new malfunction-type should be cause for concern.

(3) Eliminate the malfunction-type "bolt-fail-to-hold" as this problem was solved by redesign.

(4) Use the Poisson Distribution to approximate the malfunction types in which second order failures are infrequent occurrences. Category I malfunction-types, failure-to-extract and parts failures are considered in this class. Compute new allowable limits on this basis.

(5) Maintain the maximum values of Table I for the remaining malfunction-types.

Based on these considerations, the AWC-Quality Assurance Directorate is developing a table of allowable malfunctions and parts replacement to replace Table I.

Apparently, the "reliability test" of Reference 1 is an inadequate basis for testing rifle reliability for acceptance purposes. However, it may have contributed a great deal to product improvement (as indicated in Table II). On this basis, it is suggested that this type of test of individual malfunction-types be retained, but not as a basis for lot acceptance. Failure of the test would require, from the contractor, an explanation of cause for failure. The nature of the cause would lead either to production improvement or immediate change in production processes (given that required or attainable production quality is not being obtained).

Mission Performance Test

An acceptance test which would avoid these difficulties could be based on the occurrences of first-malfunctions. Estimations of the distributions of first-malfunctions can be obtained from existing data. In addition, Table II illustrates that this is a significant event which signals a change in the mean-round-to-malfunction (MRTM).

Another factor which can be considered to simplify testing would be testing to the first-malfunction, regardless of type. The distributions of number-of-rounds to first malfunction appears exponential with the exception of the two failure-to-feed malfunction types. However, those can be approximated by an exponential distribution during some "short" interval of number-of-rounds-fired. With this consideration the distribution of rounds-to-malfunction was assumed to be exponential over the interval 0-1000 rounds. Figure 21 presents a lot of the ordered observations of first-failures, without regard to type, as a function of number-of-rounds fired in the interval 0-1000 rounds. Also displayed is the distribution (straight line) obtained using the maximum liklihood estimate of the parameter "η" of the exponential distribution. The χ^2 goodness-of-fit statistic was computed to be 6.1 for the comparison of the data and estimated distribution. If this statistic exceeded 16.9 ($\chi^2_{.95}$(9df)), the hypothesis that "the observations were generated by this distribution" would have been rejected.

These considerations would generate an acceptance test as follows: each of a sample of n-weapons would be fired a mission of r-rounds ($r<1000$) or until a malfunction occurred. The lot from which the n-weapons were sampled would be accepted if no more than m-malfunctions occurred. The parameters "n" and "m" would be selected according to the provisions of Reference 4. The parameter "r" would be selected for some specified mission criteria.

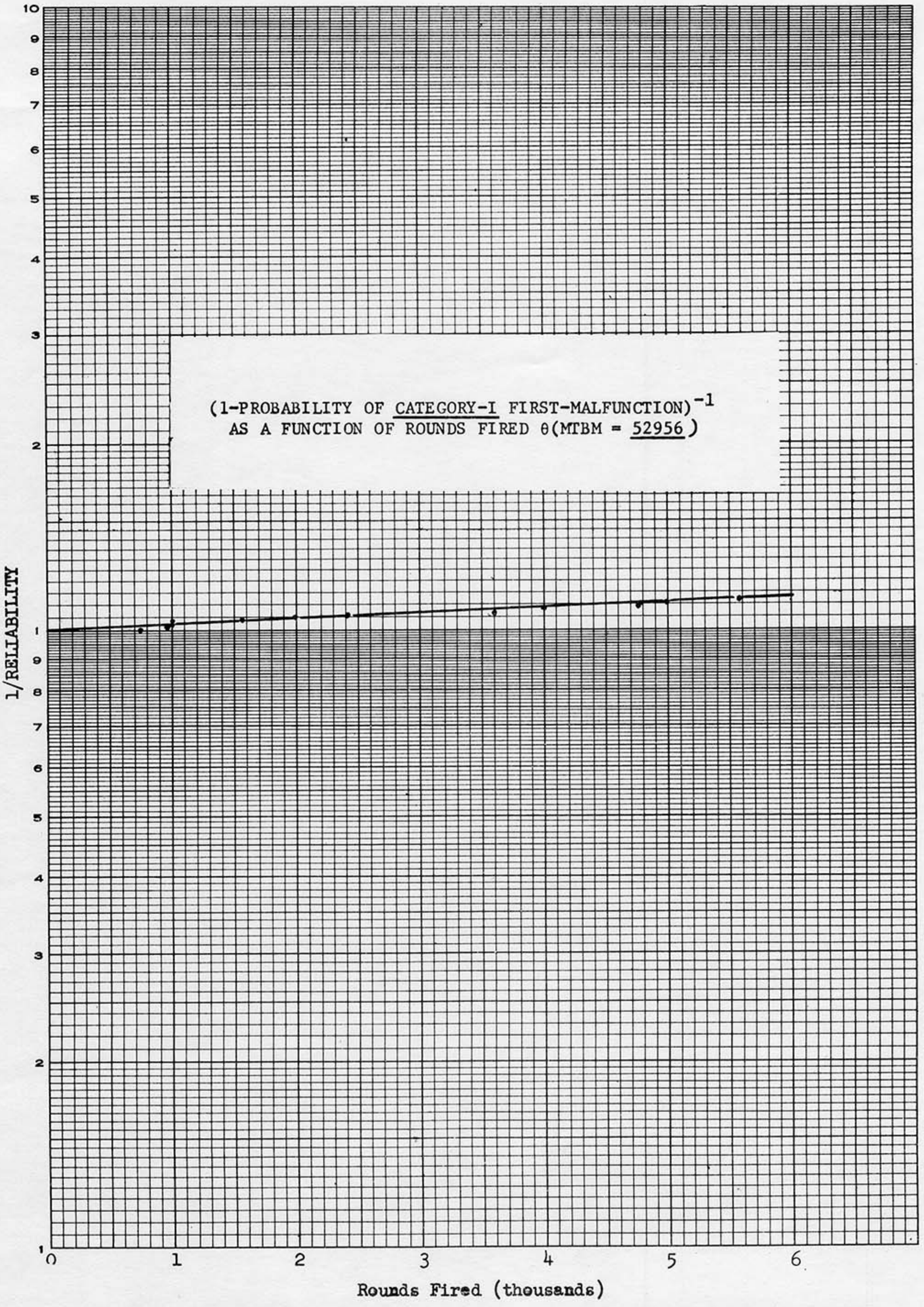
REFERENCES

1. Springfield Armory Purchase Description, Acceptance Testing Specification for Rifles, 5.56 MM M16 and XM16E1, SAPD 253A, August, 1964.

2. Natrella, M. G., Experimental Statistics, National Bureau of Standards Handbook 91, issued August, 1963.

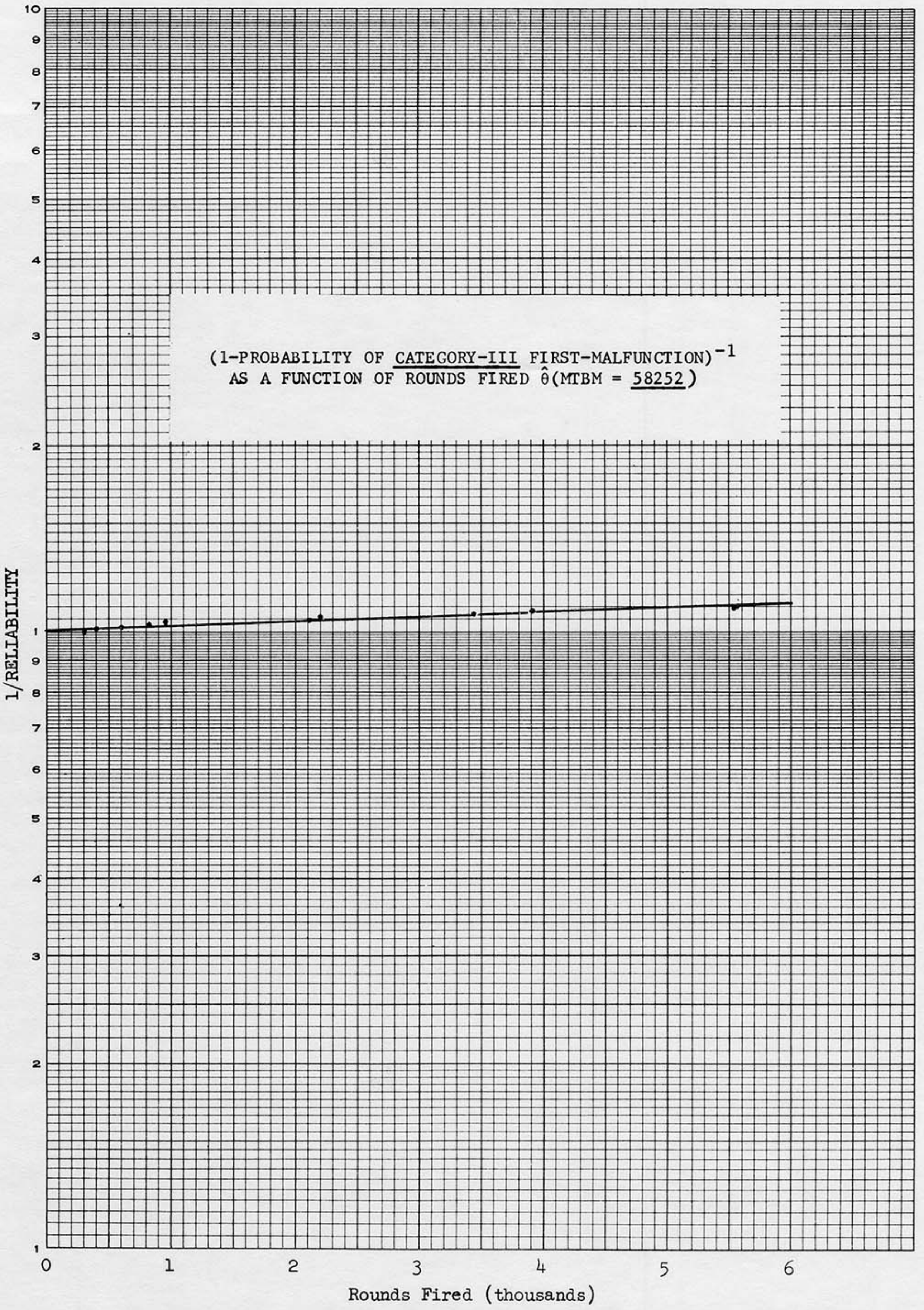
3. Schlenker, G., Numerical Methods in Renewal Theory. OR 68-2 Weapons Operations Research Office, U.S. Army Weapons Command, Rock Island, Illinois, February, 1968.

4. DOD Quality Control and Reliability Handbook (Interim) H-108, Sampling Procedures and Tables for Life and Reliability Testing (Based on Exponential Distribution) 29 April, 1960.



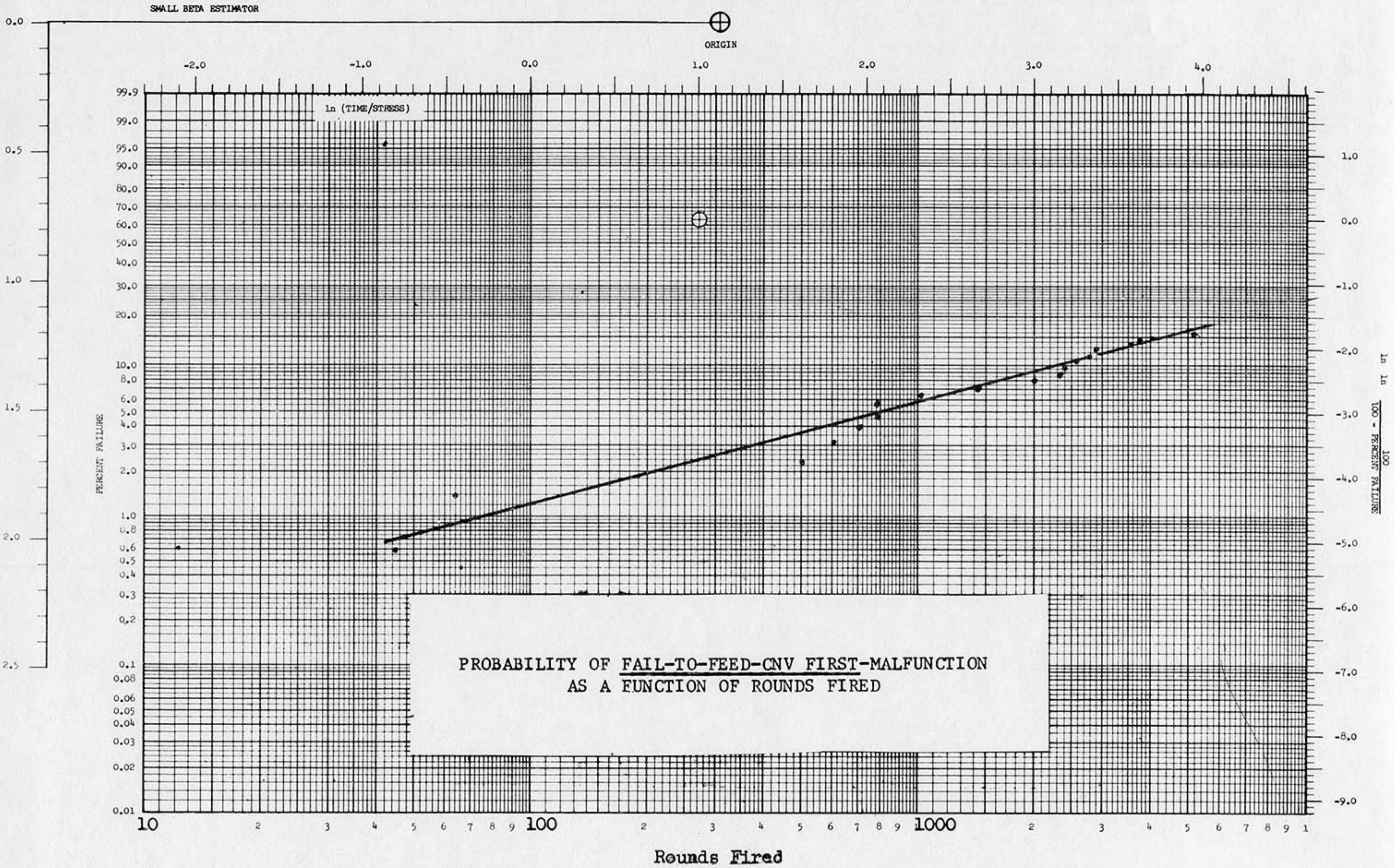
(1-PROBABILITY OF CATEGORY-I FIRST-MALFUNCTION)$^{-1}$
AS A FUNCTION OF ROUNDS FIRED θ(MTBM = 52956)

Figure 1



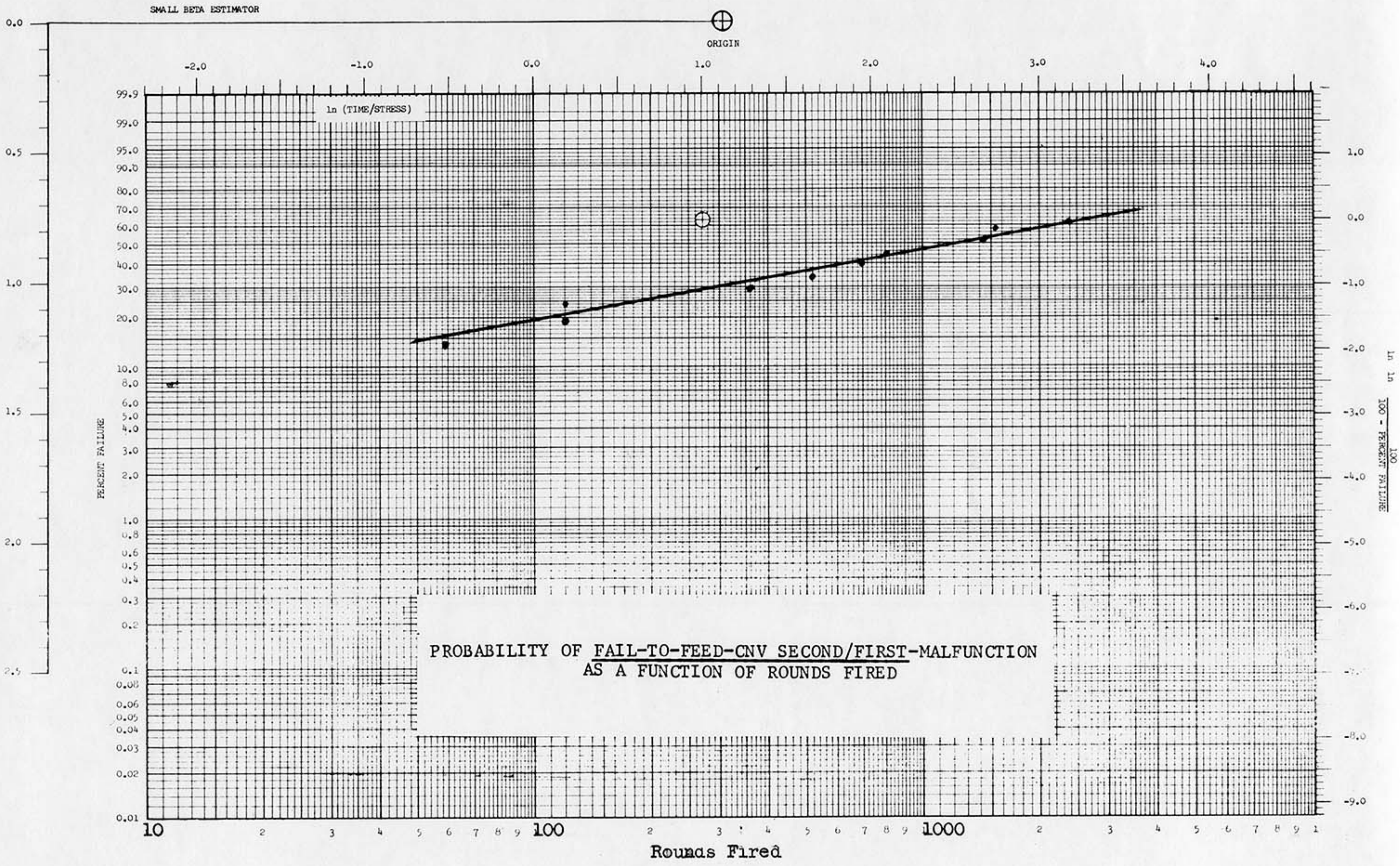
(1-PROBABILITY OF CATEGORY-III FIRST-MALFUNCTION)$^{-1}$
AS A FUNCTION OF ROUNDS FIRED $\hat{\theta}$(MTBM = 58252)

Figure 2



PROBABILITY OF FAIL-TO-FEED-CNV FIRST-MALFUNCTION AS A FUNCTION OF ROUNDS FIRED

Figure 3



PROBABILITY OF FAIL-TO-FEED-CNV SECOND/FIRST-MALFUNCTION AS A FUNCTION OF ROUNDS FIRED

Figure 4

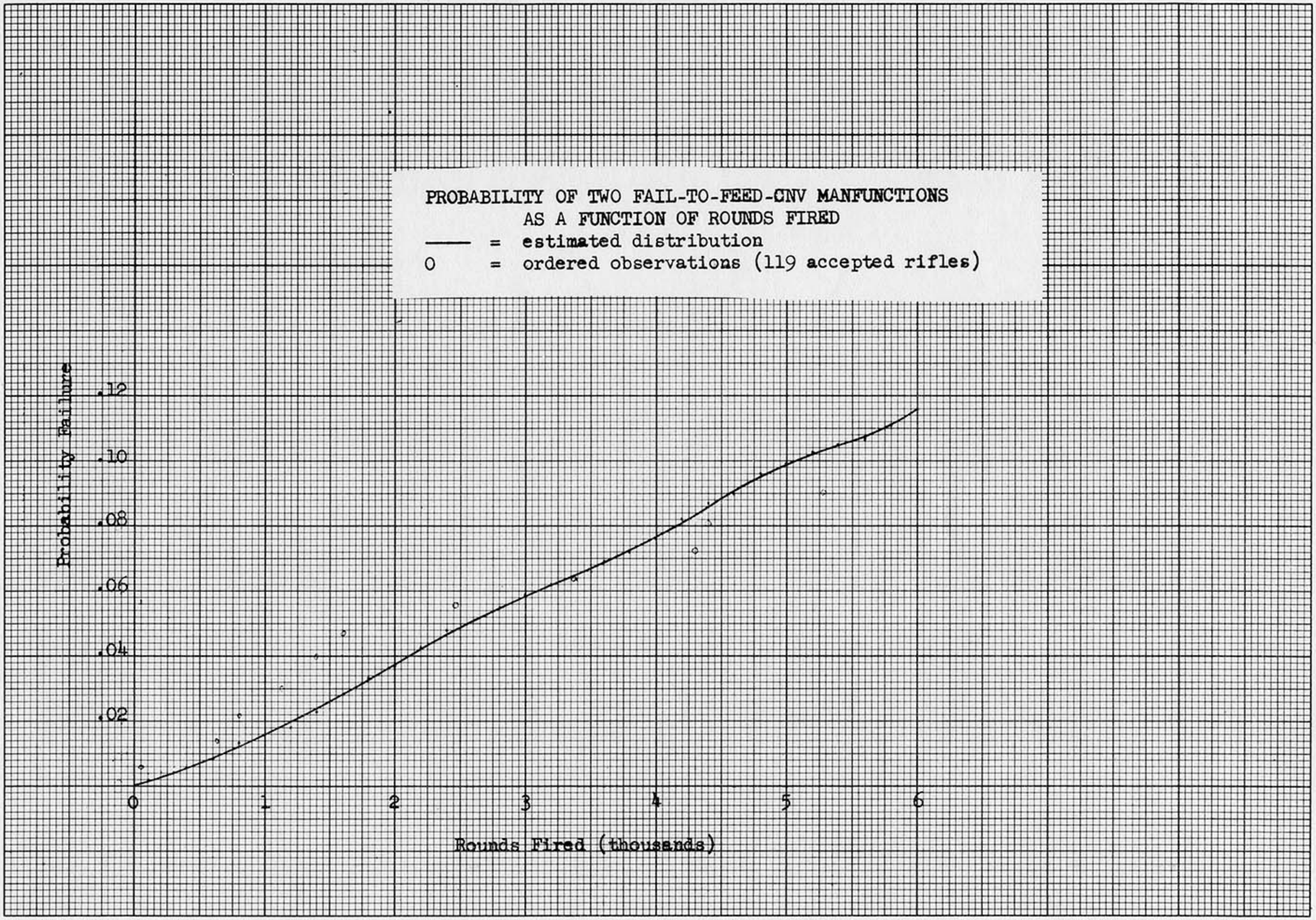
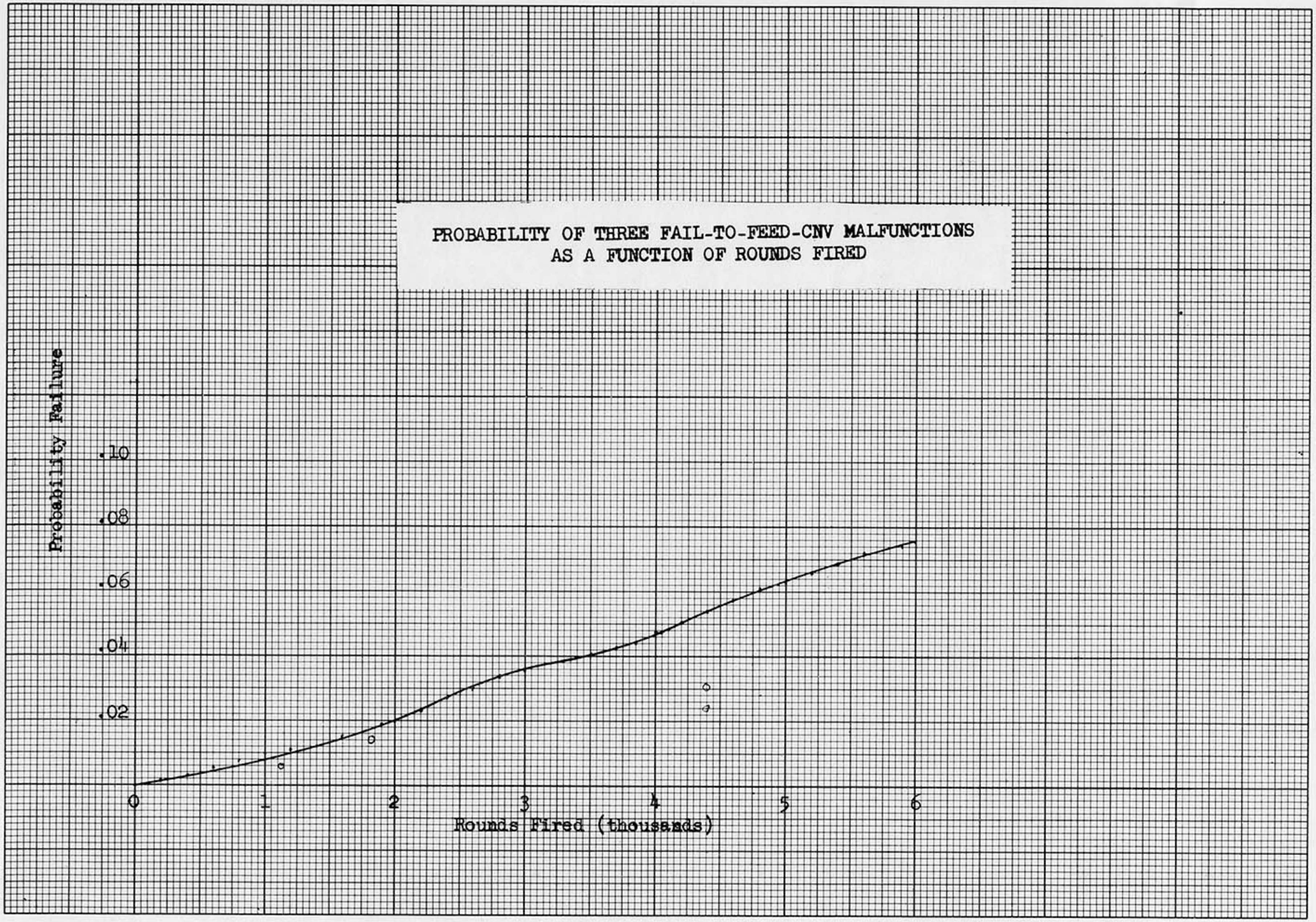
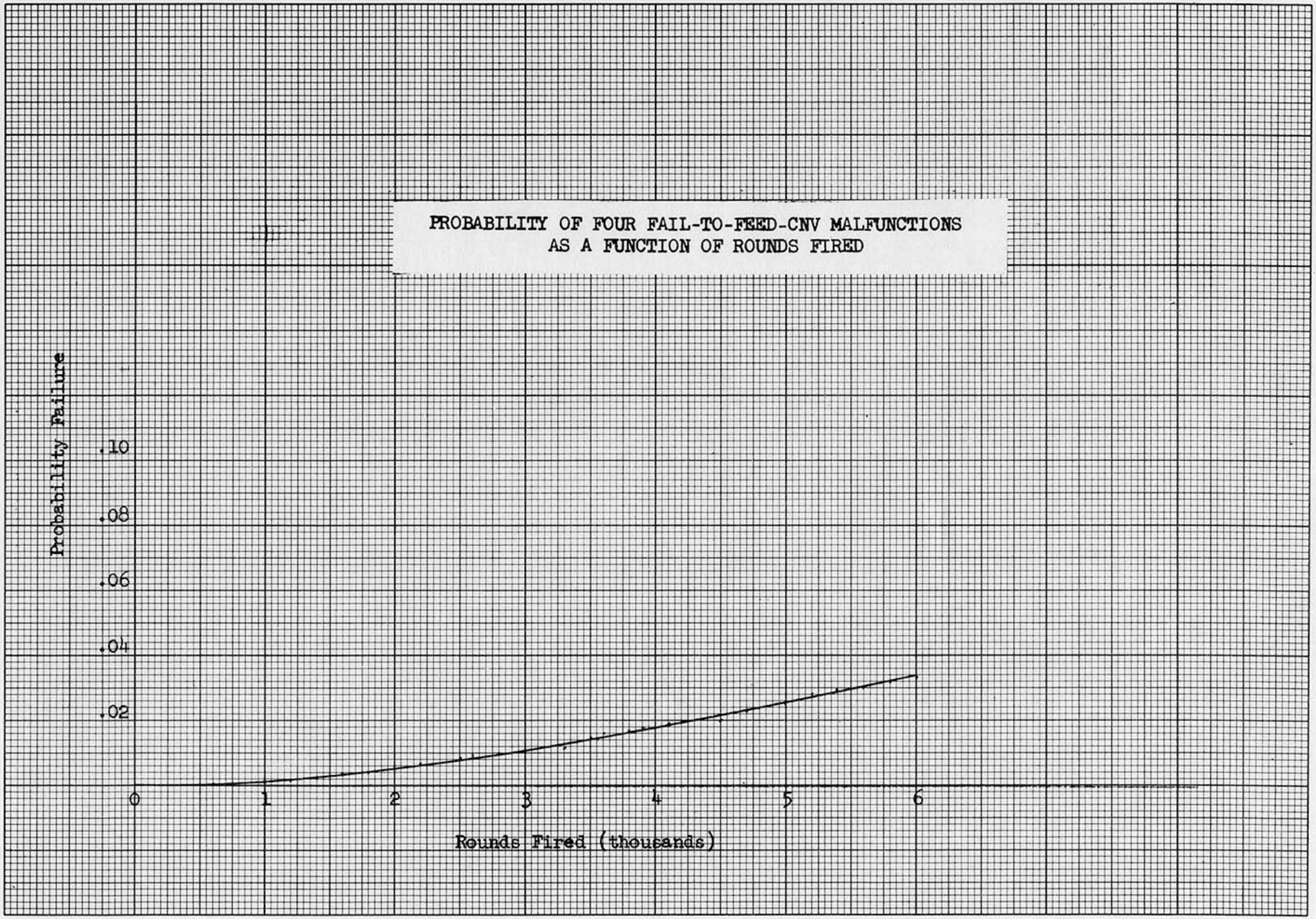

PROBABILITY OF TWO FAIL-TO-FEED-CNV MANFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED
—— = estimated distribution
0 = ordered observations (119 accepted rifles)
Probability Failure
.12
.10
.08
.06
.04
.02
0
1
2
3
4
5
6
Rounds Fired (thousands)

Figure 5



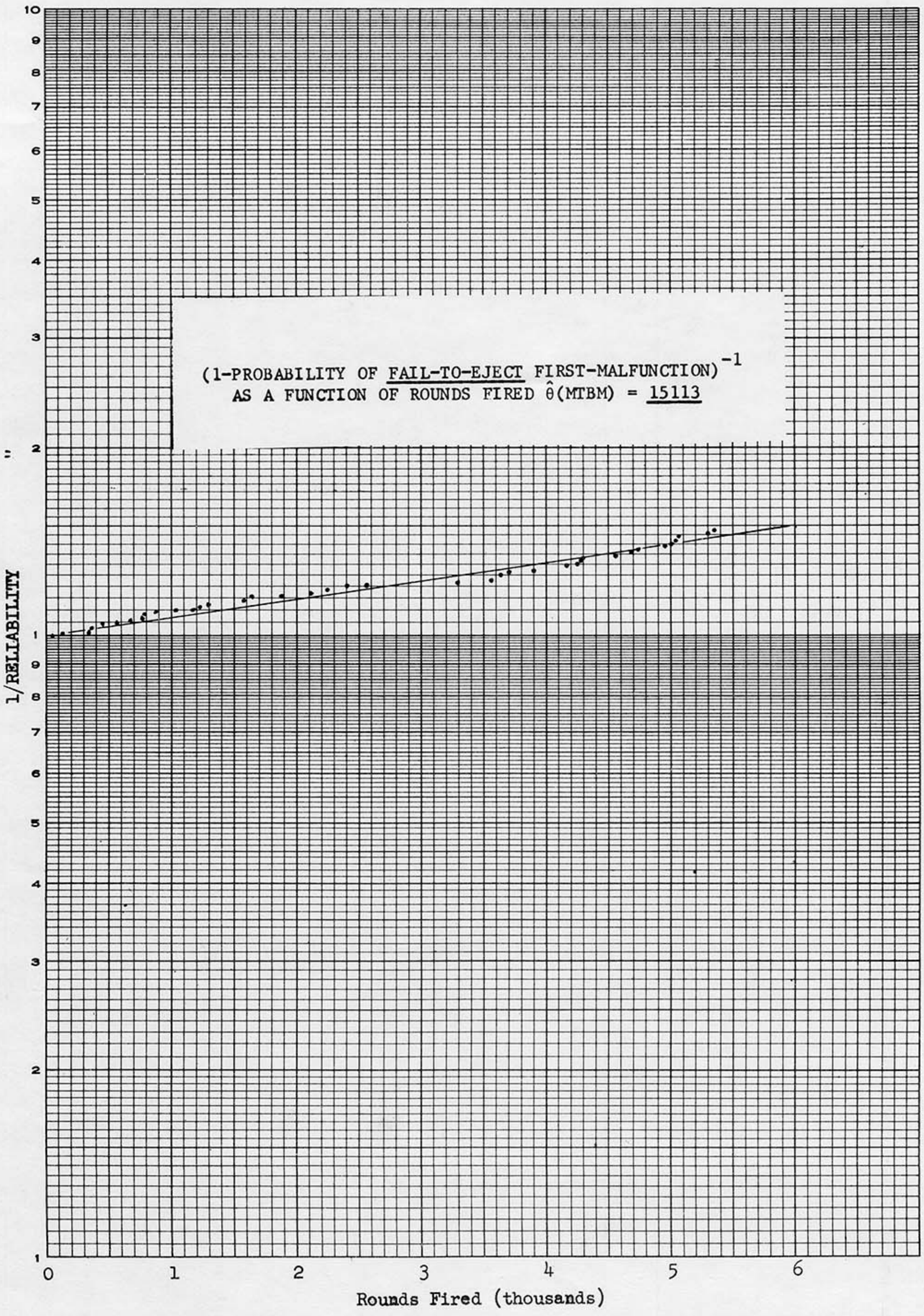
PROBABILITY OF THREE FAIL-TO-FEED-CNV MALFUNCTIONS AS A FUNCTION OF ROUNDS FIRED

Figure 6



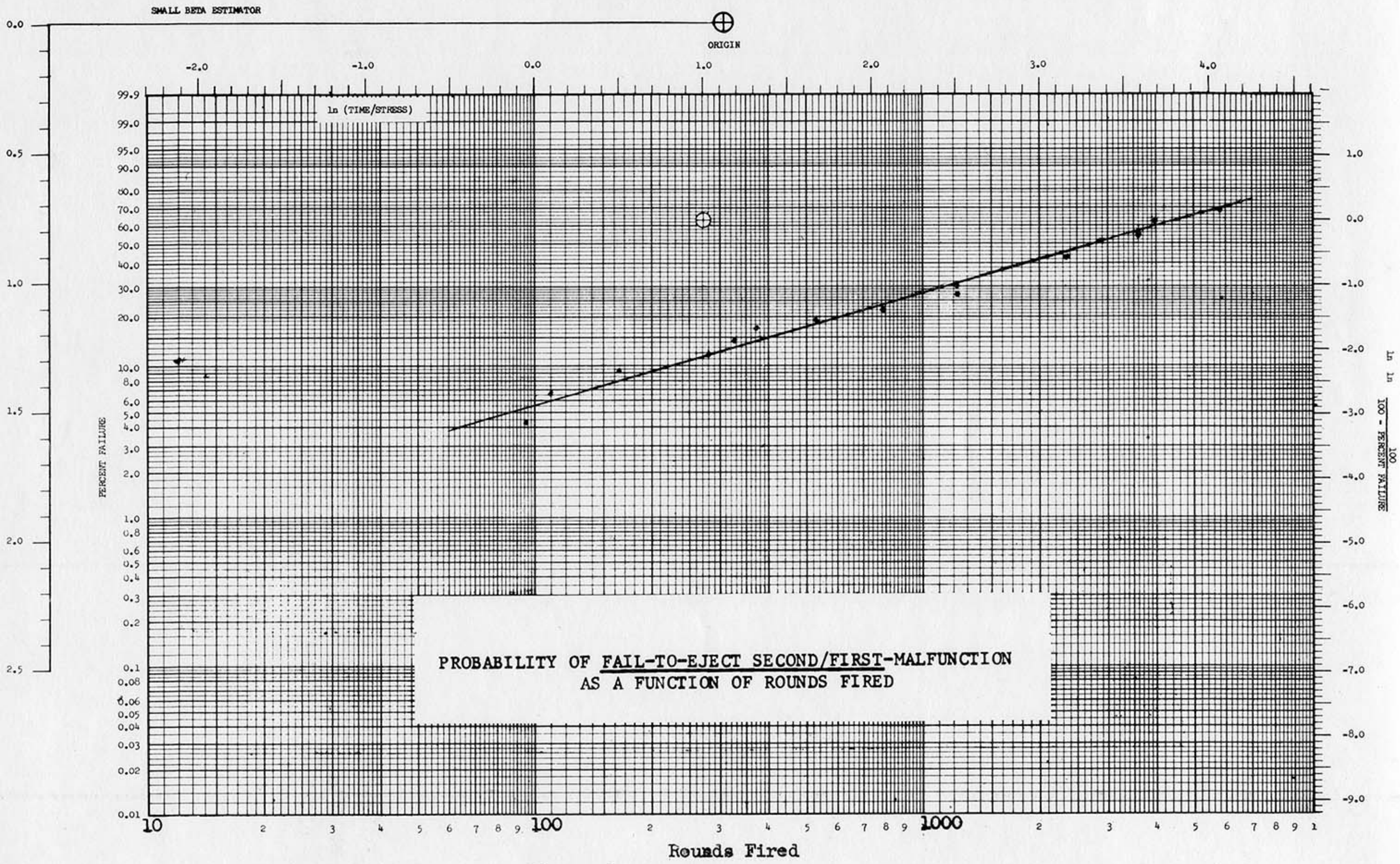
PROBABILITY OF FOUR FAIL-TO-FEED-CNV MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED

Figure 7



(1-PROBABILITY OF __FAIL-TO-EJECT__ FIRST-MALFUNCTION)$^{-1}$
AS A FUNCTION OF ROUNDS FIRED $\hat{\theta}$(MTBM) = __15113__

Figure 8



PROBABILITY OF FAIL-TO-EJECT SECOND/FIRST-MALFUNCTION AS A FUNCTION OF ROUNDS FIRED

Figure 9

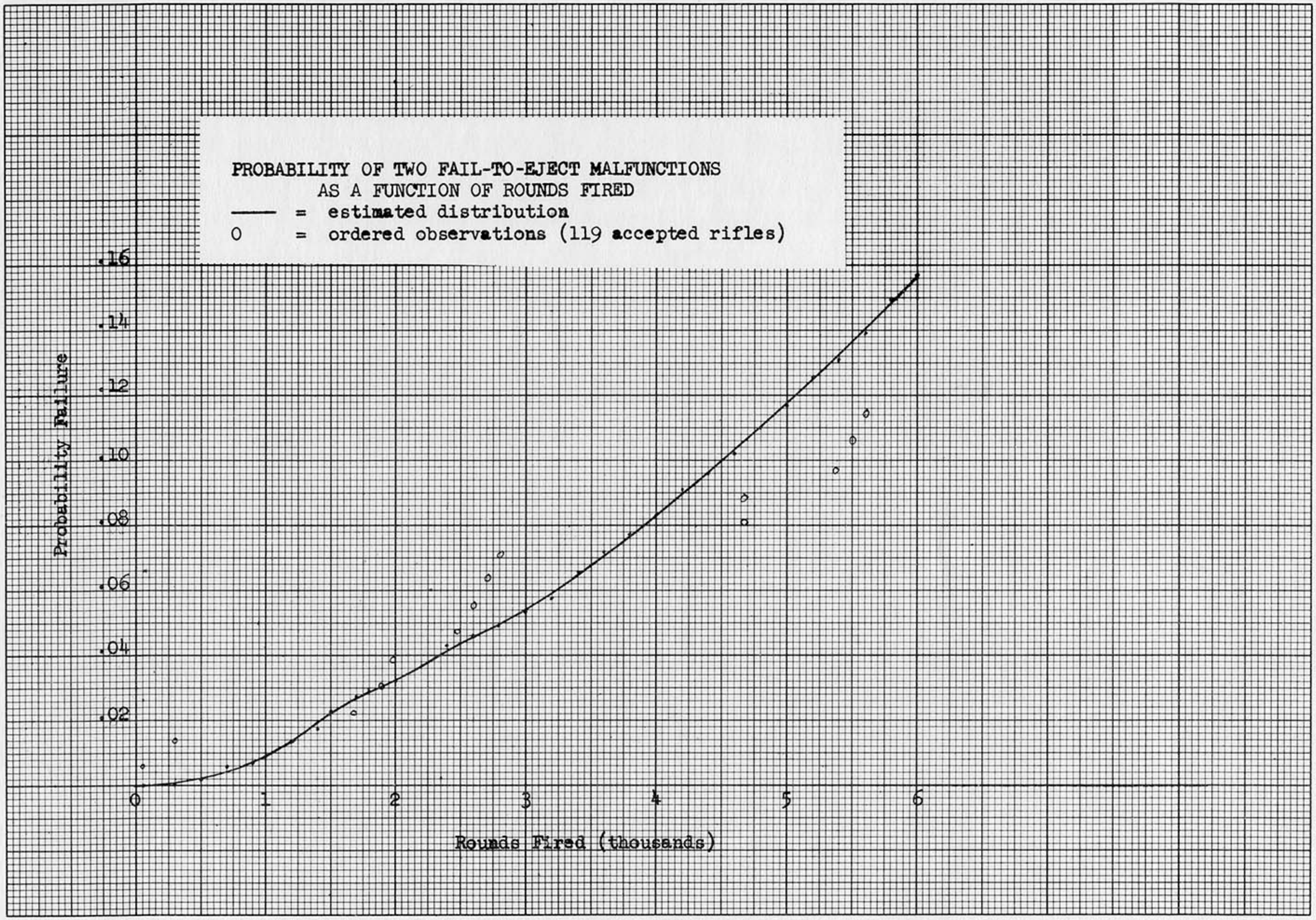
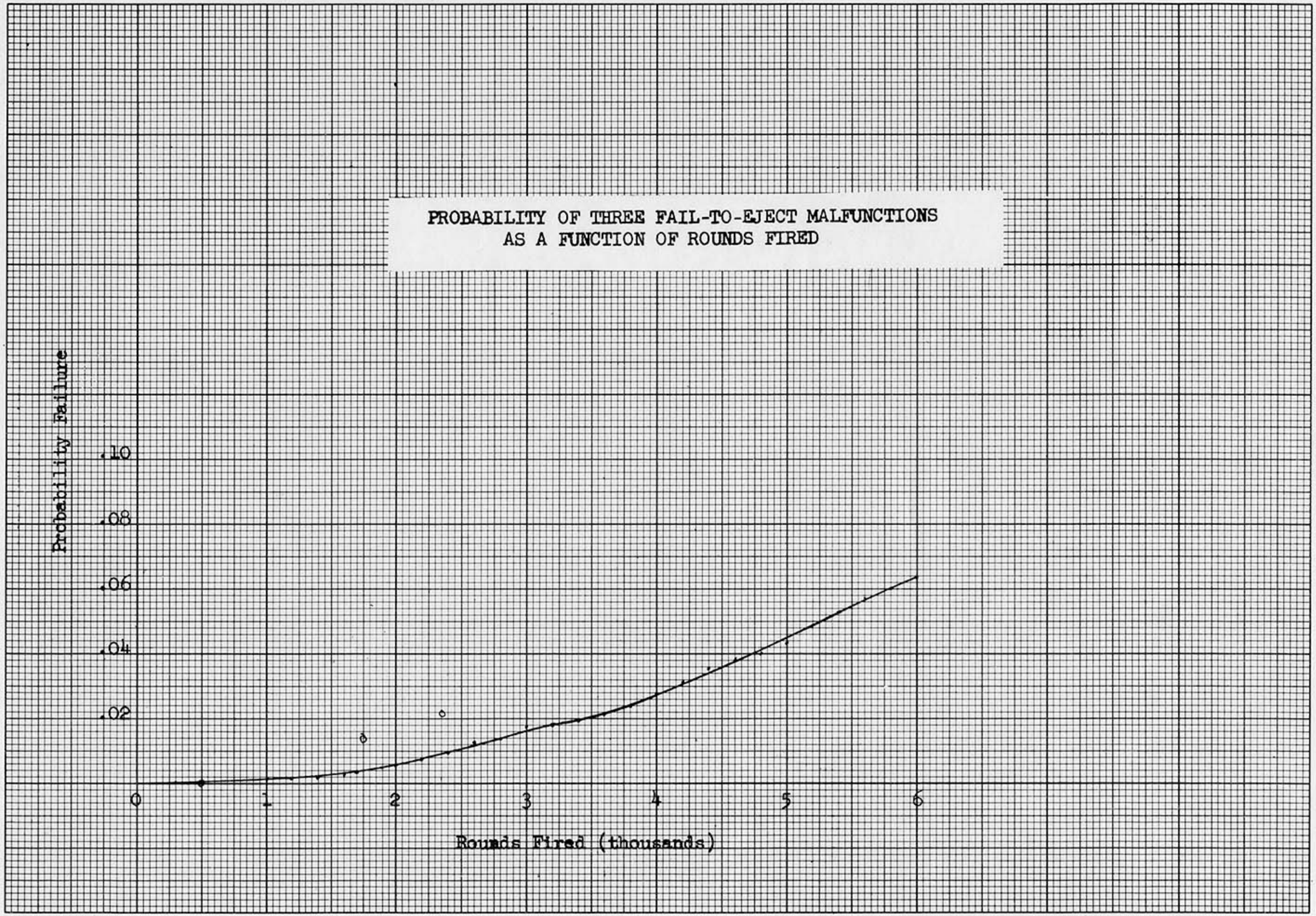
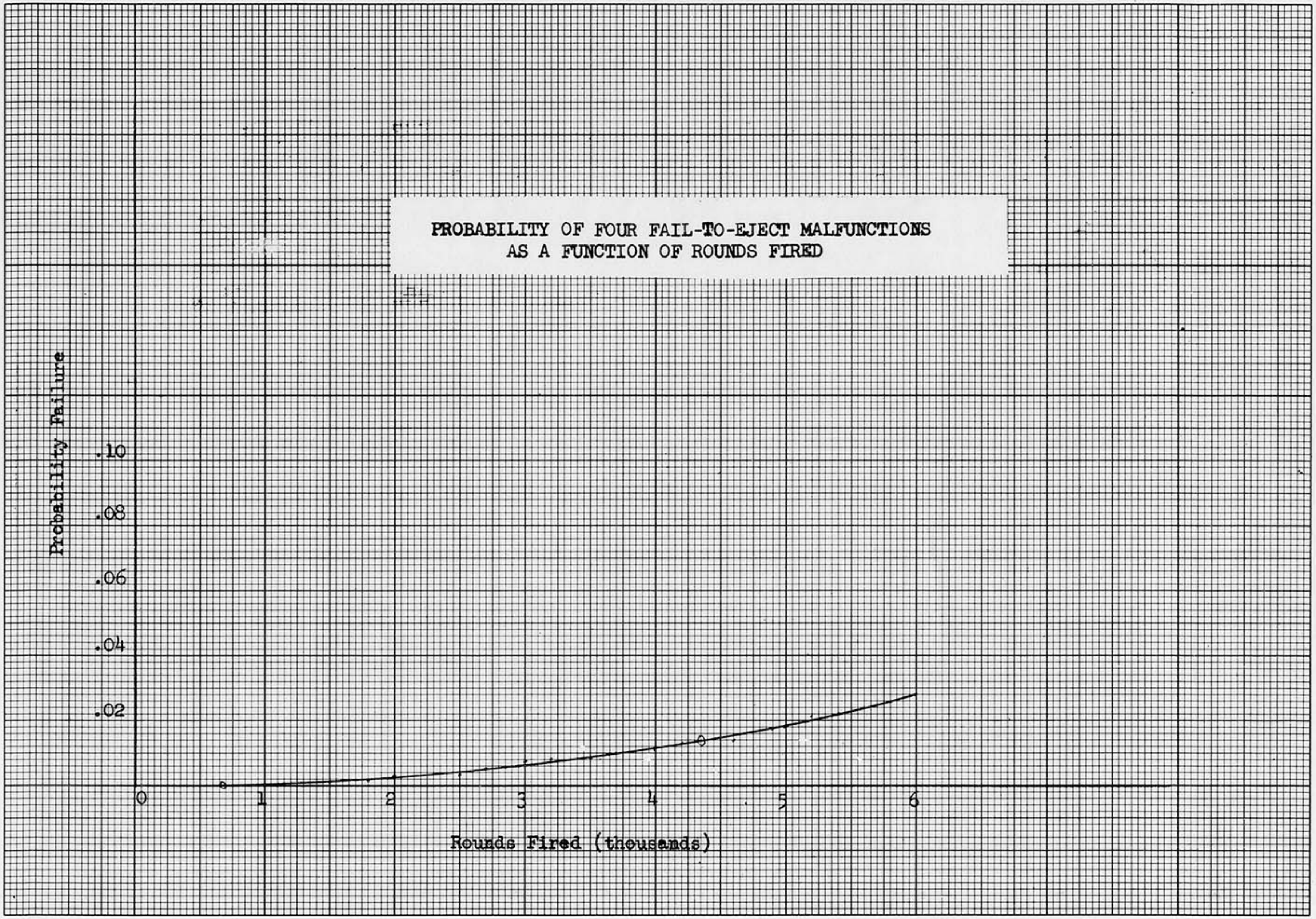
PROBABILITY OF TWO FAIL-TO-EJECT MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED
—— = estimated distribution
0 = ordered observations (119 accepted rifles)
Probability Failure
.16
.14
.12
.10
.08
.06
.04
.02
0
1
2
3
4
5
6
Rounds Fired (thousands)

Figure 10



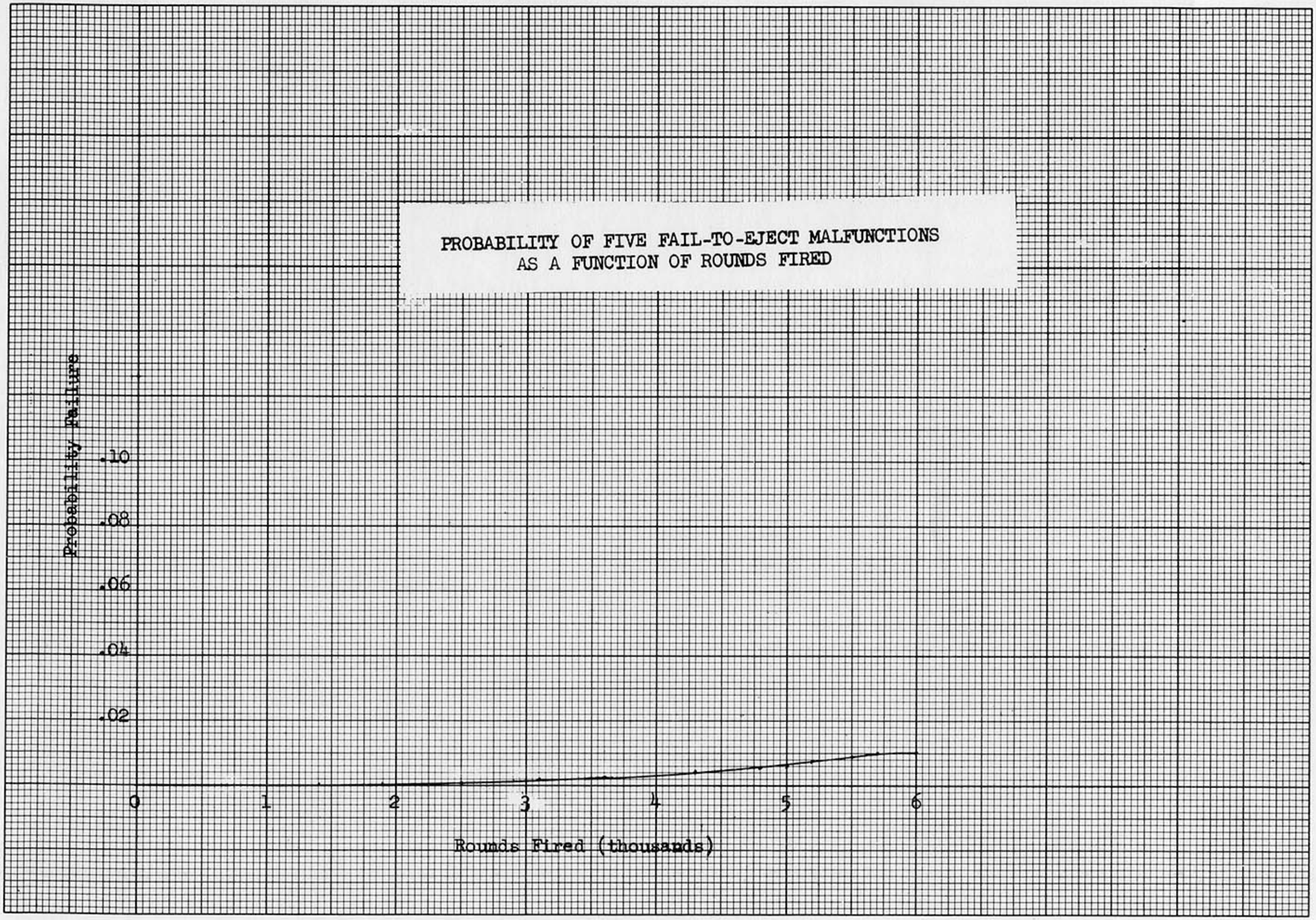
PROBABILITY OF THREE FAIL-TO-EJECT MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED

Figure 11



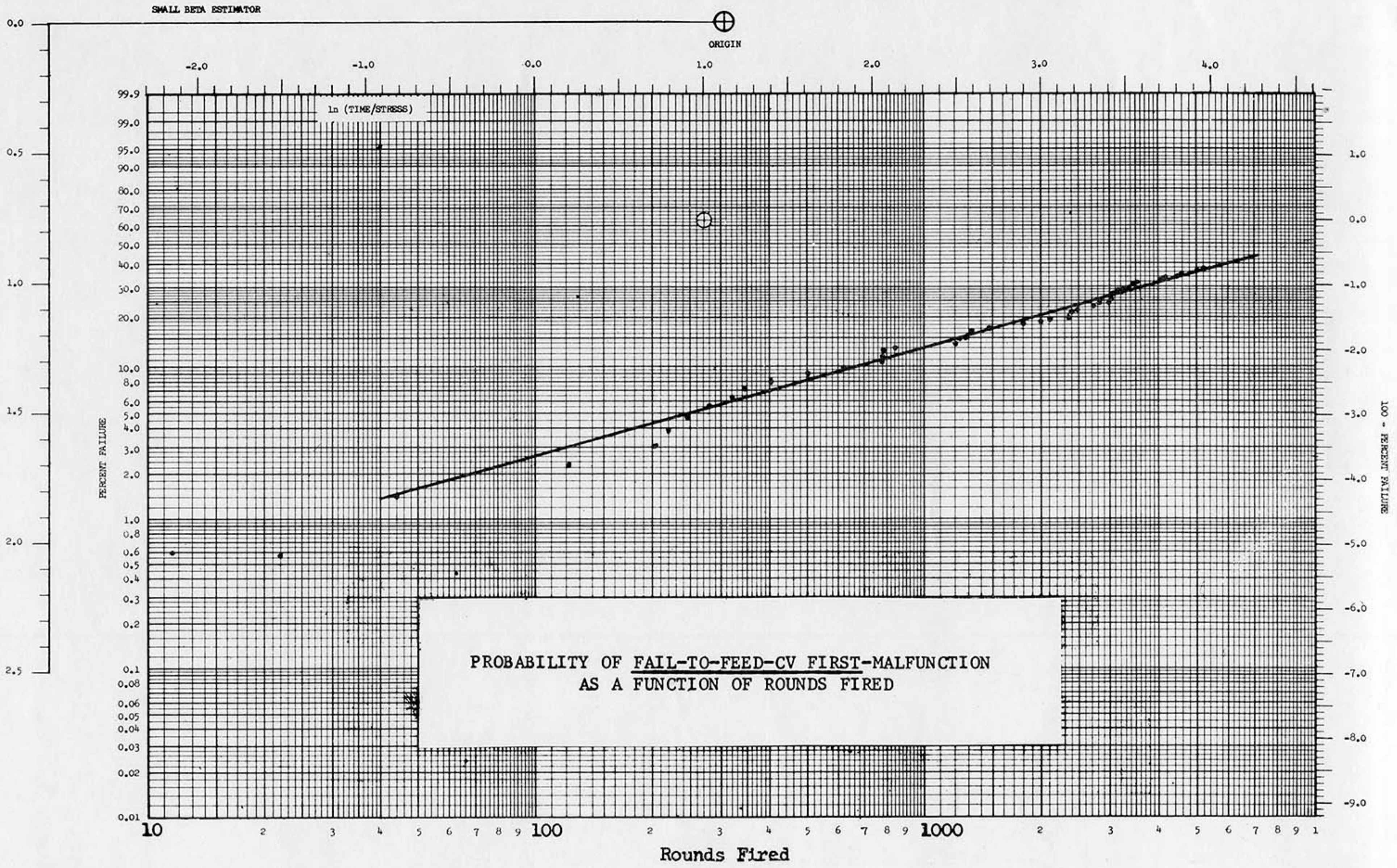
PROBABILITY OF FOUR FAIL-TO-EJECT MALFUNCTIONS AS A FUNCTION OF ROUNDS FIRED

Figure 12



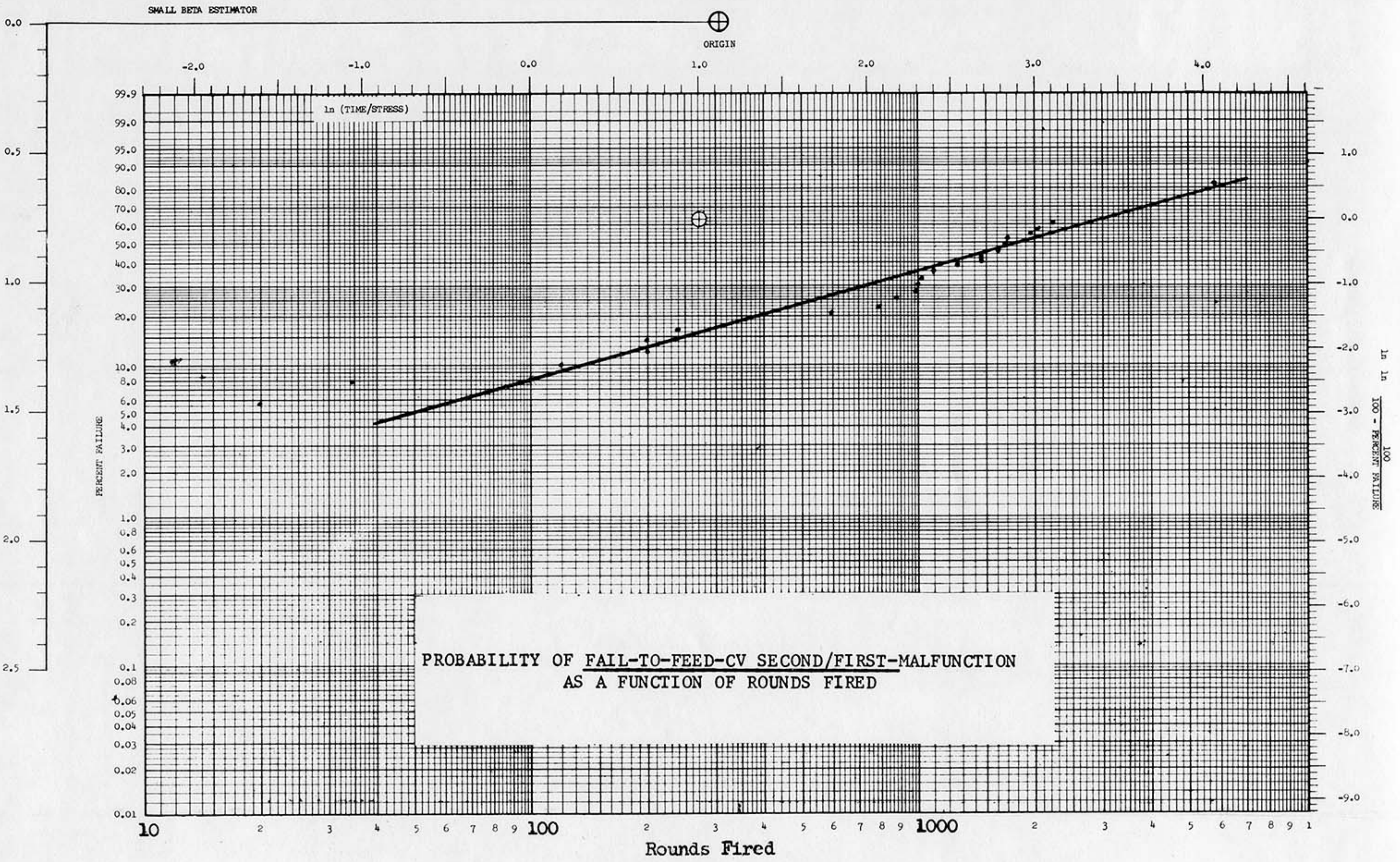
PROBABILITY OF FIVE FAIL-TO-EJECT MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED

Figure 13



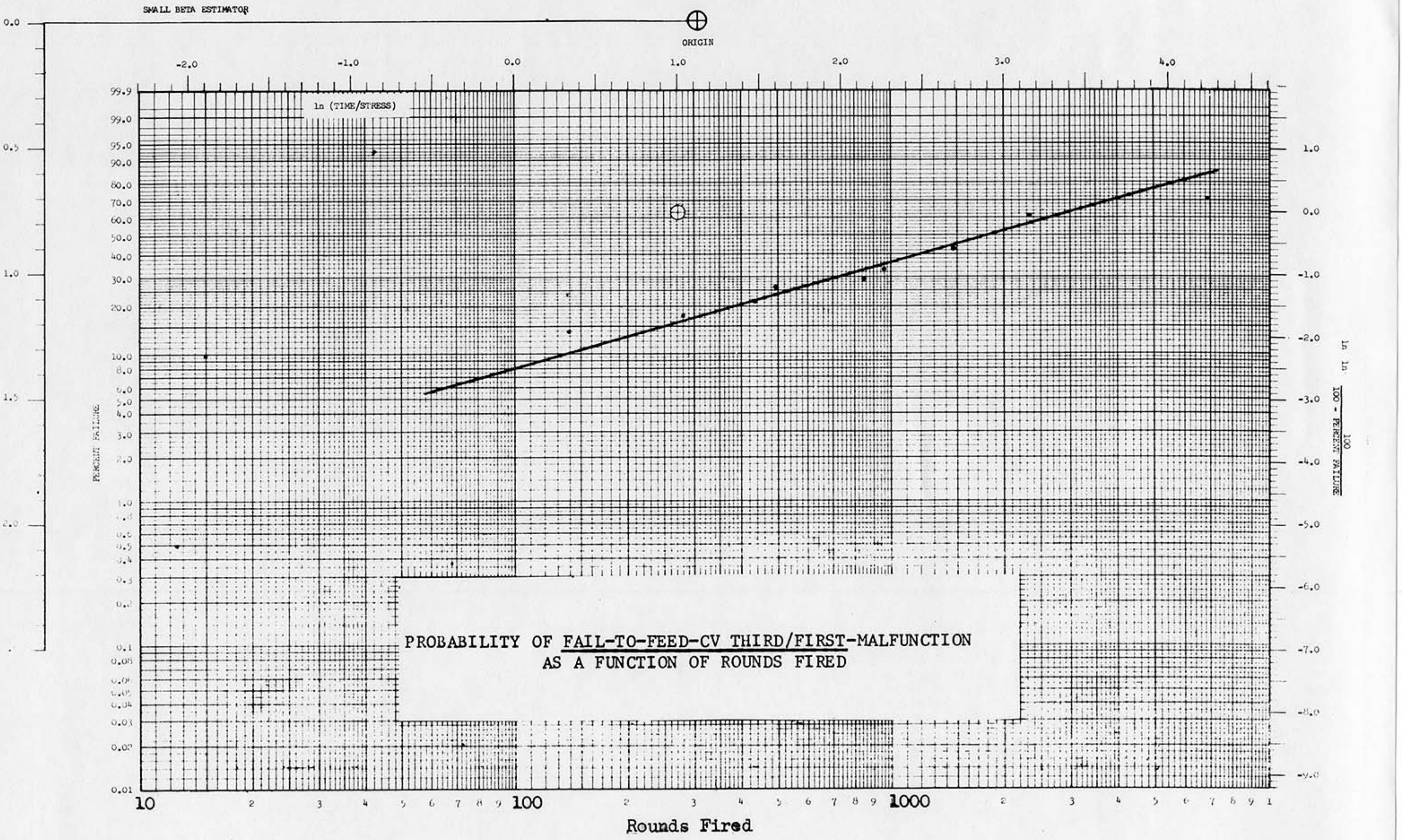
PROBABILITY OF FAIL-TO-FEED-CV FIRST-MALFUNCTION
AS A FUNCTION OF ROUNDS FIRED

Figure 14



PROBABILITY OF FAIL-TO-FEED-CV SECOND/FIRST-MALFUNCTION
AS A FUNCTION OF ROUNDS FIRED

Figure 15



PROBABILITY OF FAIL-TO-FEED-CV THIRD/FIRST-MALFUNCTION
AS A FUNCTION OF ROUNDS FIRED

Figure 16

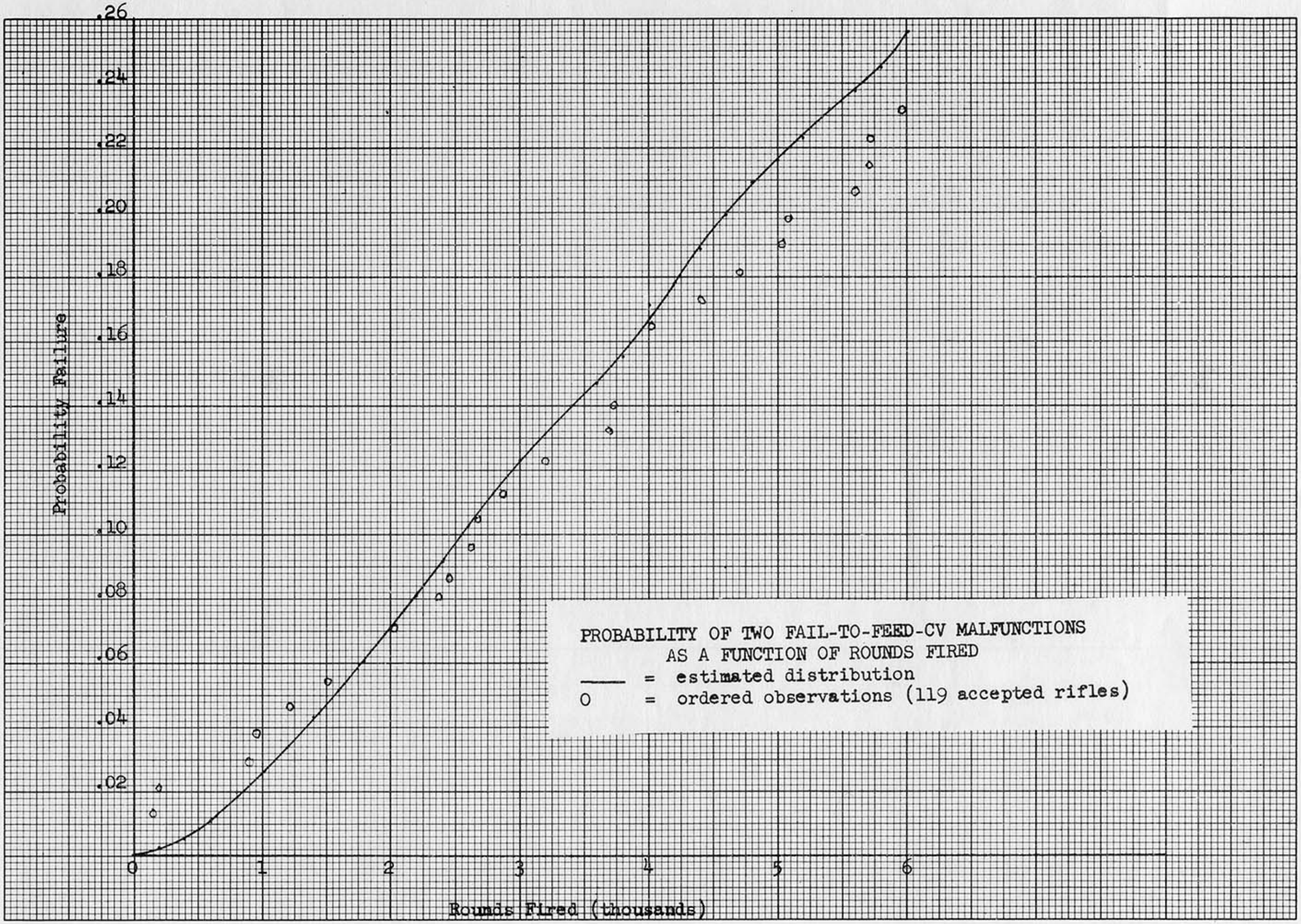
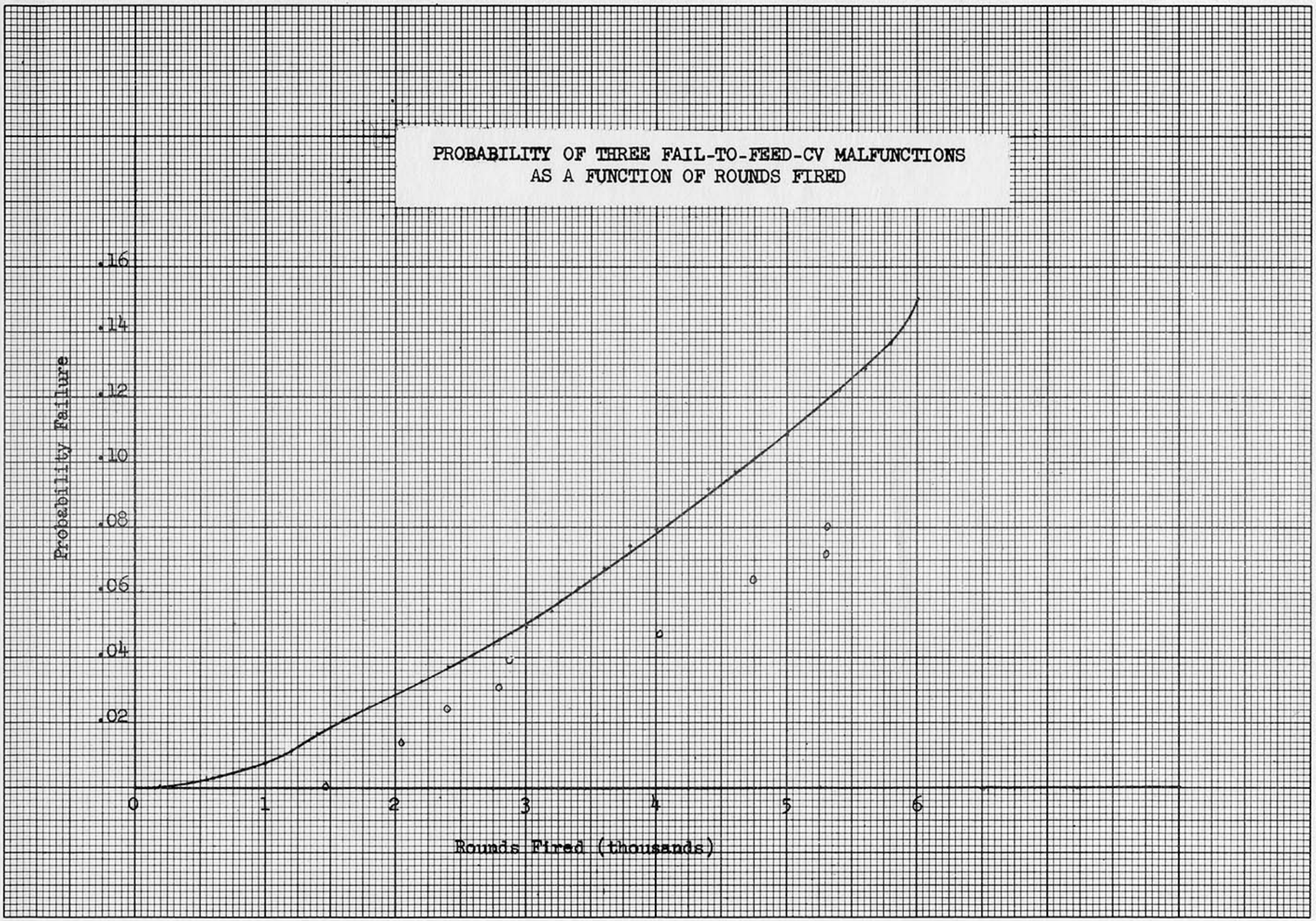
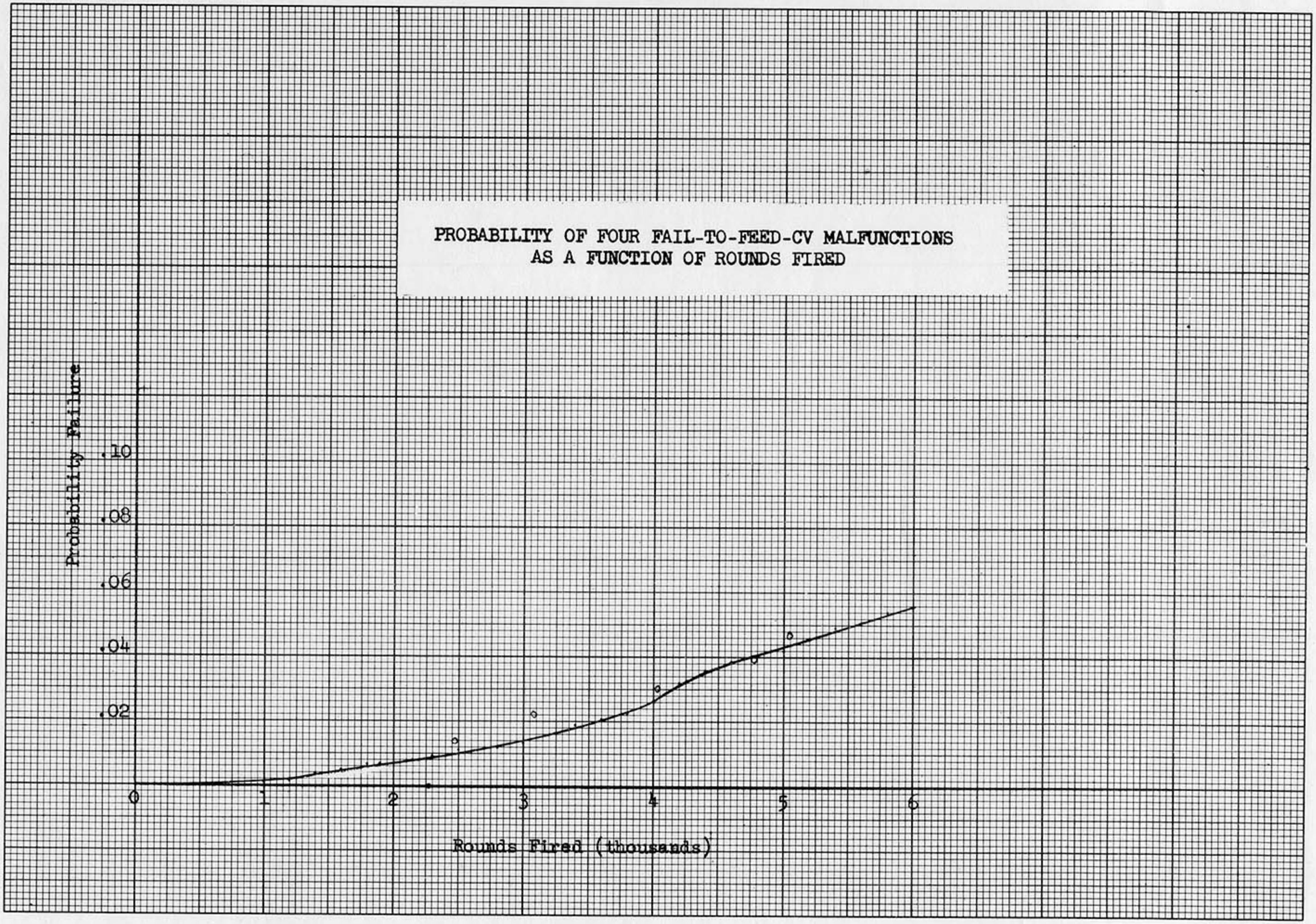

PROBABILITY OF TWO FAIL-TO-FEED-CV MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED
—— = estimated distribution
O = ordered observations (119 accepted rifles)
Probability Failure
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
1
2
3
4
5
6
Rounds Fired (thousands)

Figure 17



PROBABILITY OF THREE FAIL-TO-FEED-CV MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED

Figure 18



PROBABILITY OF FOUR FAIL-TO-FEED-CV MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED

Figure 19

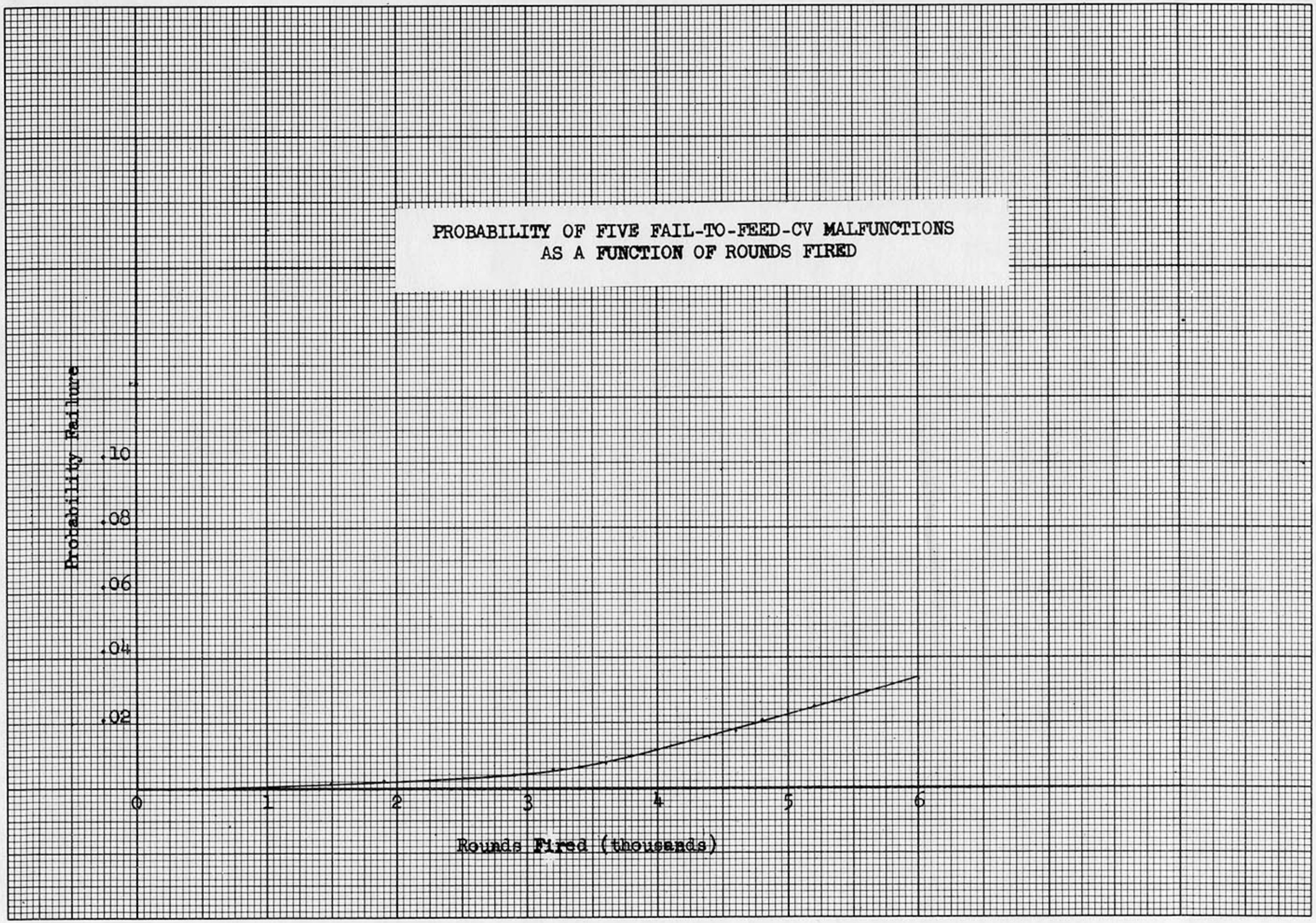
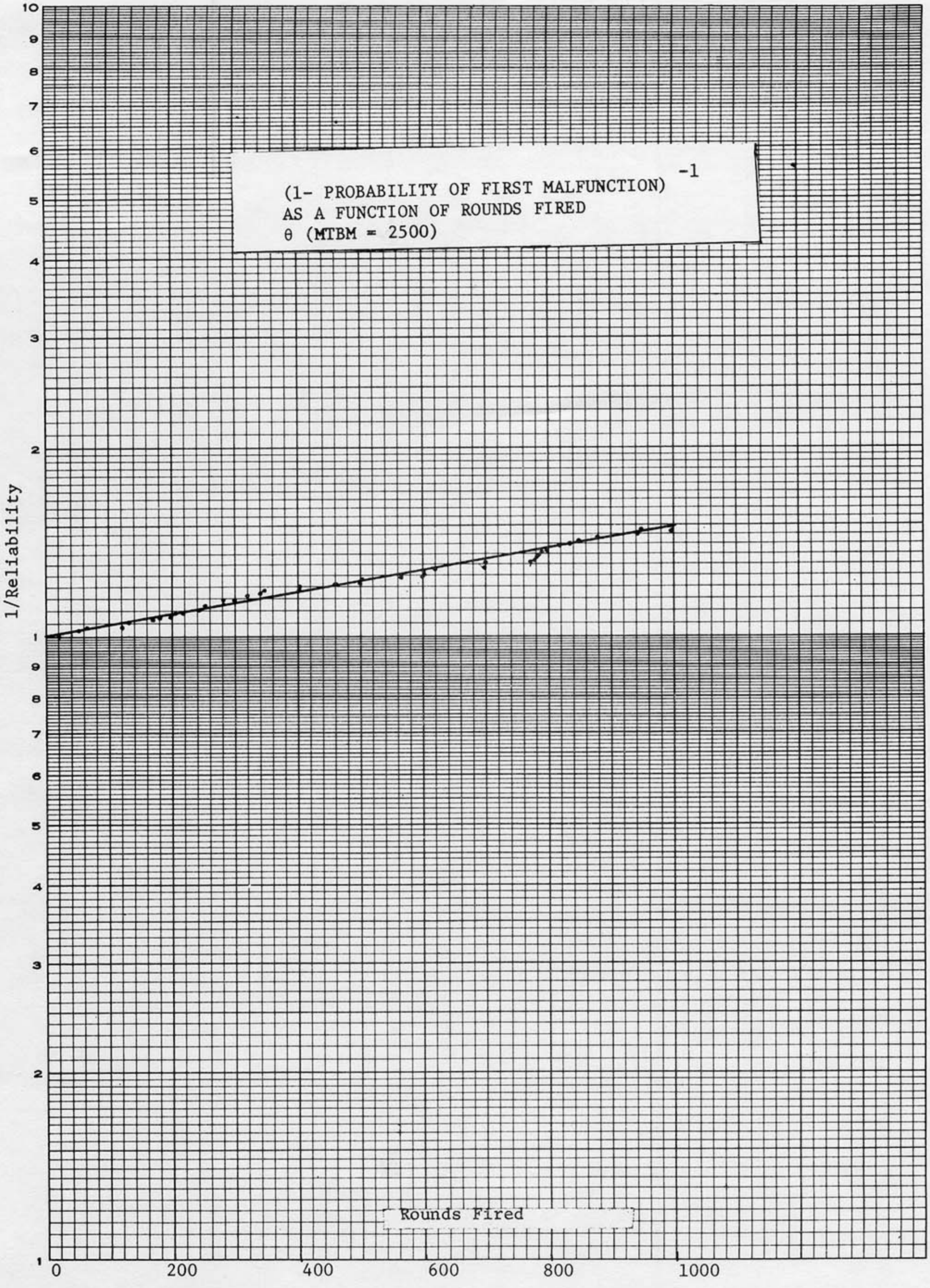

PROBABILITY OF FIVE FAIL-TO-FEED-CV MALFUNCTIONS
AS A FUNCTION OF ROUNDS FIRED
Probability Failure
.10
.08
.06
.04
.02
0
1
2
3
4
5
6
Rounds Fired (thousands)

Figure 20



$(1-\text{ PROBABILITY OF FIRST MALFUNCTION})^{-1}$
AS A FUNCTION OF ROUNDS FIRED
θ (MTBM = 2500)

Figure 21

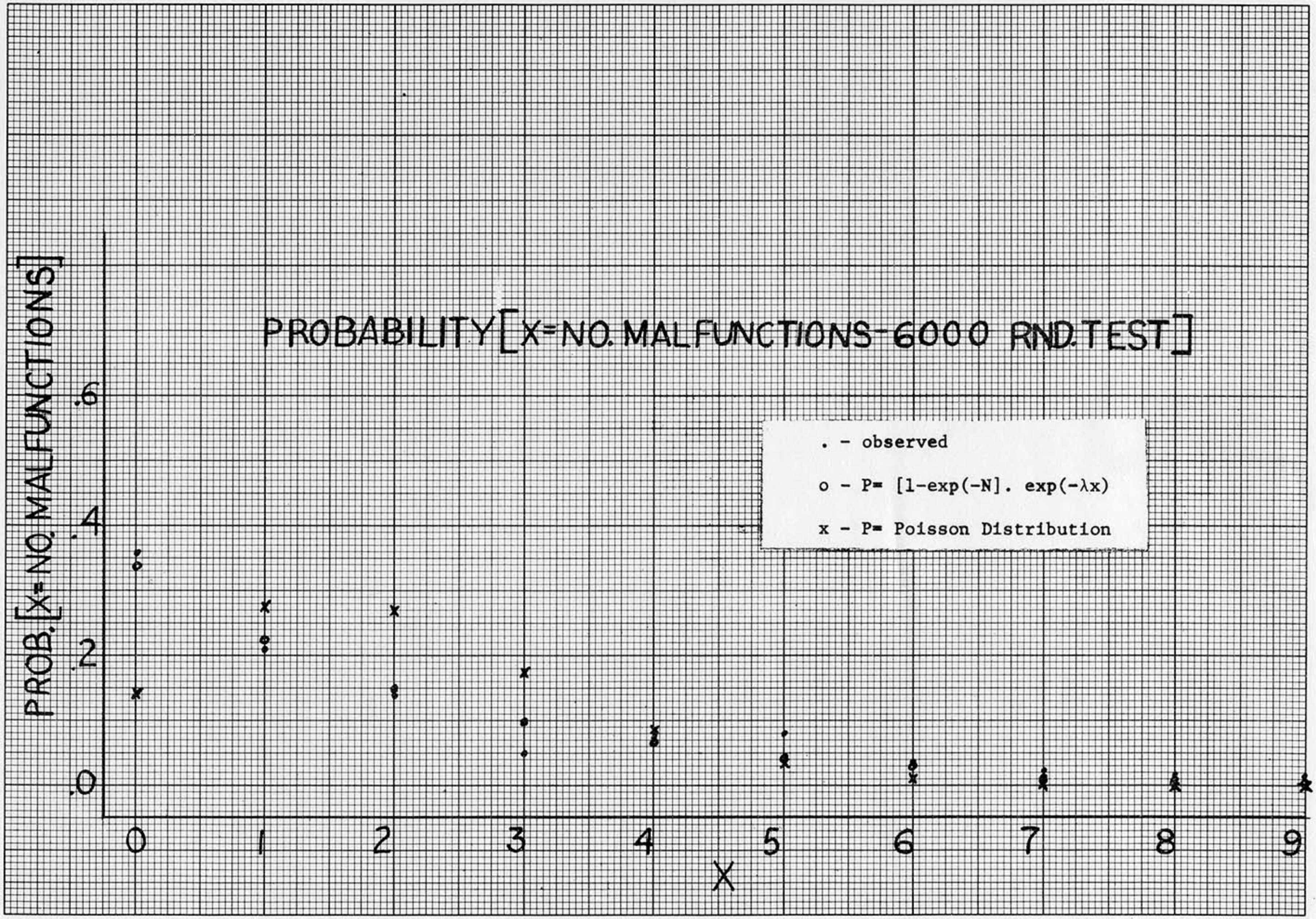

PROBABILITY[X=NO. MALFUNCTIONS-6000 RND. TEST]
PROB.[X=NO. MALFUNCTIONS]
.6
.4
.2
.0
0
1
2
3
4
5
6
7
8
9
X
. - observed
o - P= [1-exp(-N]. exp(-λx)
x - P= Poisson Distribution

Figure 22