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NSWC/DL TR-3478

UNDERLYING CONCEPTS AND ASSUMPTIONS FOR FAULTY HARDWARE SAFETY TESTING

by
J. S. NERRIE
Technical Evaluation Department

AUGUST 1976

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nswc

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Ground rules, techniques, and examples are presented for a testing technique which deliberately uses faulty hardware to determine the consequences of manufacturing errors or out-of-tolerance conditions. The concept additionally offers a means of estimating some tolerance limits for the design and a means of obtaining useful data from tests usually considered to be worthless because of errors in configuration or test conditions.

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FOREWORD

The Naval Surface Weapons Center/Dahlgren Laboratory (NSWC/DL) has been involved for a number of years in attempts to reduce the incidence of in-bore premature explosion of gun-launched, high-explosive projectiles. In the process, a number of innovative and advanced techniques have been developed for accident investigation and development program safety testing. This report discusses the basic approach used in one of those techniques called Faulty Unit Testing.

This report has been reviewed and approved by S. H. McElroy, Head, Weapons Safety Division.

Released by:

W. L. Anderson

W. L. ANDERSON, Head
Technical Evaluation Department

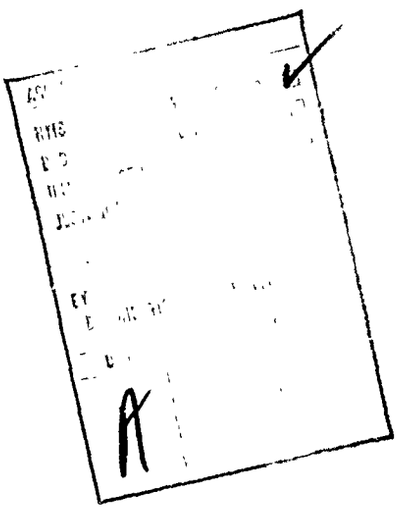


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

BACKGROUND

Weapon developers are charged with the responsibility for assuring that new systems will be relatively free of hazardous events during testing and Fleet use. Normal design and test practices provide a reasonable means for eliminating hazardous events that would otherwise occur frequently (more frequently than one occurrence per 100 opportunities). The developer is also charged with the anticipation and resolution of hazards that are, at best, rare occurrences (less frequently than one occurrence per 100 opportunities). Inasmuch as the systems considered here are new, there exists no historical data to provide guidance about what can go wrong, although experience with similar systems can frequently point out likely areas. Formalized safety analysis techniques, such as Failure Modes and Effects and Fault Tree and Preliminary Hazard Analyses have been developed in recent years to provide valuable assistance in identifying hazard-producing conditions in systems where the results of faults and failures can be predicted from common technical experience (e.g., mechanical, electrical, and pneumatic systems). In the area of explosive material response, however, the formalized techniques have not yet identified all known causes of explosive hazards. The prediction of explosive response to various energy inputs has not reached the level of predictability of mechanical and electrical systems. The most productive techniques available are those used in "after-the-fact" explosive accident investigation where various postulated causes are introduced in an attempt to recreate the accident. The "Faulty Unit Testing Concept" uses this technique to identify potential accident causes for new systems before the fact.

The concept of fault testing arises from the need to find a rational means for incorporating past experience into new systems without burdening the new system with "fears and superstitions." The Faulty Unit Testing Concept is able to provide assistance in orienting the priorities for safety requirements in such a manner that the "most likely" hazards can be addressed first. Unless an organized approach is followed for separating the highly likely hazard causes from those not so likely, accident statistics will not improve. Except by testing, one cannot decide, for example, which defect in a gun-fired projectile (explosive in base plug threads, missing base plug gas check, or gaps and low-density explosive) is the most important one to attack with limited resources.

Faulty Unit Testing is not expected to be of practical value in all system development programs. In general, the greatest reward will be in programs where there is a potential hazard induced by a repetitious, extreme environment (e.g., in-bore prematures for a gun-launched projectile) and where units that can be tested are relatively inexpensive.

A guided missile, for example, would gain very little from Faulty Unit Testing since there is no repetitious explosive hazard which confines itself to a specific logistic event, and the test unit would be too expensive to conduct a meaningful test series. Therefore, this method is not proposed as a solution for all safety problems.

OBJECTIVE

The objective of this report is to present the basic philosophy of Faulty Unit Safety Testing and to illustrate its practical applications.

HISTORICAL SAFETY TESTING TECHNIQUES

Frequently, weapon developers will decide that normal functioning tests of their system will suffice for safety purposes, with no attempts to overtest or look for possible weaknesses. This is a shortsighted view, proving only that well-made units function properly under ideal conditions. Safety investigators must always prepare for the worst case. A development test program consisting of testing only "good units" would not really establish the "acceptable unit" criteria that is required in the production phase. The production phase controls are established (using MIL-STD-105) to maximize the amount of hardware accepted for use. The delivered quality level is then a function of the Navy-imposed tolerances, combined with the quality of the production process. If the tolerances are too stringent the hardware will be more expensive than necessary because of the large number of rejects which will, in turn, cause more careful (expensive) production processes. If the tolerances are too loose, safety, among other things, will suffer. It is therefore necessary to devise a test program which will provide adequate performance data and which will define the lower quality limits that will meet performance and safety requirements. The Faulty Unit Test Concept is that type of test program. A case in point is the recent rash of 5-in. in-bore explosions where firing of 1.8 million 5"/38 and 0.72 million 5"/54 supposedly acceptable units did nothing to prevent the accidents or to aid in identifying causes and corrective action. The solutions arose from Faulty Unit type of testing during the post-accident investigation.

WR-50 (Warhead Safety Tests Minimum for Air, Surface, and Underwater Launched Weapons) is the safety testing document for explosive units and has been relied upon for many years. Using test units representative of production hardware, WR-50 requires sequential environmental overtesting (vibration and temperature-humidity) and a destructive test (40-ft drop), requiring that the unit be safe for disposal. Further destructive testing simulating a fire environment (fast and slow cook-off) is conducted to ensure that initiation of the explosive does not occur at too low a temperature. WR-50 and the many other similar test specifications have done well in screening out initial design defects, but they do not address the errors, omissions, and out-of-tolerance problems which are passed on by the production and inspection processes.

Proof testing is the practice of subjecting a unit to an overtest of its normal functioning environment. In gun-fired ammunition, it consists of preparing a special propelling charge to produce a firing chamber pressure which is 115 percent of maximum allowable service pressure. This test provides useful design assurance but, again, does not attempt to deal with defective hardware used by the "customer" under normal service conditions.

Environmental testing (followed by functional tests) is usually conducted in development programs to assure that the unit will function as advertised. Frequently, effects are uncovered which will adversely affect safety. These safety effects lead to design corrections which are important to the user, but again the matter of defective hardware is usually avoided.

THE FAULTY UNIT TESTING CONCEPT

The Faulty Unit Testing Concept is not:

1. A means of predicting the service use accident rate nor of proving that the accident rate will be less than some specified number.

2. A means of proving that a given flaw will never cause a safety problem.

3. A practical method where the results of a flaw or failure can be precalculated with precision. (Mechanical devices and electrical circuits, for example, are usually predictable and therefore would not ordinarily require testing to show failure consequences.)

4. A substitute for normal environmental qualification or for a thorough safety engineering analysis.

5. A means of uncovering the effects of anomalies introduced by factors outside the "faulty" test unit; that is, the input environments must be known and controlled.

In contrast to the previously listed items of what the concept does not provide, the following is a list of items which describe what the concept is and what it will provide. The concept:

1. Is a rational method for systematic identification of potential accident cause , making use of specific design data pertinent to the hardware to be t ted.

2. Is open-ended in that useful data can be obtained from a limited number of tests, and the test series can be added to subsequently for additional information. The extent of testing is limited only by time, budget, and hardware.

3. Allows one to recognize the value in "wasted" tests, wherein unintended faults or errors are discovered after the testing of supposedly perfect hardware.

4. Works well in evaluating synergistic fects of several flaws, especially when used in "factorial" type st series. The "factorial" technique has the advantage of allowing the testing of several variables for a minimal cost.

5. Can provide a rational basis for establishing allowable tolerances for safety-critical parts of the hardware design.

6. Can reduce the likelihood of future accidents, and provide a good data base for planning any accident investigations which might be required. By having data available on the consequences of various faults, the accident investigation can be oriented quickly into profitable areas and, if the cause is external to the item, this fact is likely to be more apparent than if no fault consequence data were available.

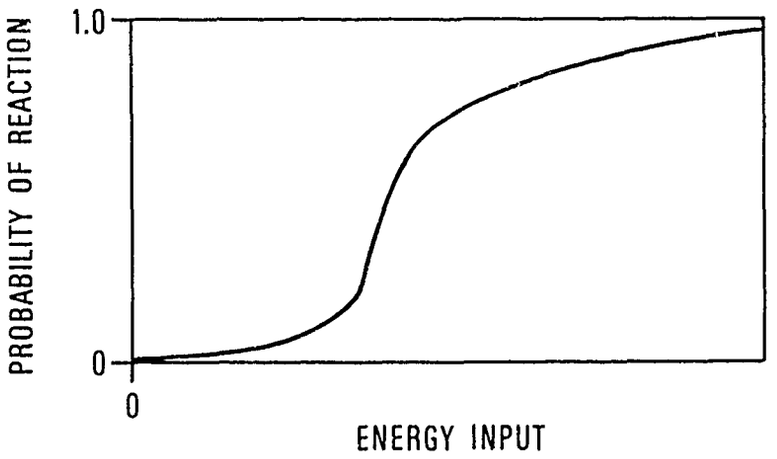
7. Provides a means to counteract the "negativistic label" frequently applied to safety efforts. Having done the detailed engineering work with the drawings to select and size the faults, and later having demonstrated the reality of the hazard, communication and cooperation between safety engineers and designers is much improved. In some cases at NSWC/DL, the designers thus "educated" have surpassed the safety engineer in their zeal to eliminate hazards.

ASSUMPTIONS AND GROUND RULES

Prior to detailed planning of fault testing, thorough safety analysis should be accomplished ' clearly identify both hazards and potential causes for those hazards.

As previously mentioned, faulty unit testing is usually impractical where the results can be precalculated with certainty. Most mechanical devices and electrical circuits, for example, are usually predictable and therefore seldom require verification testing of this sort. Explosives, on the other hand, are not sufficiently understood to allow precalculation of the effects of various flaws when subjected to severe environmental stress.

In the case of explosives, an energy input is assumed to be the cause of any reaction, and the relationship between probability of reaction and energy input per unit volume is assumed to be of the form:



Specific manufacturing flaws which have the potential for causing an energy input must be identified. Examples include cracks, gaps, voids, low-density areas within explosives, and dimensional, assembly, and materials variations in formed parts.

Flaws and faults fall into two general categories: component omission and variable magnitude. In the case of component omission, there is no meaningful intermediate state between flaw and no flaw. In the variable magnitude case, it generally becomes clear that there is a (dimensional) condition where no hazard is expected and where departure from that state in one direction moves toward increased probability of hazard. Testing of the missing component type is relatively simple, but testing of the variable magnitude type may

involve testing at several levels. Hopefully, one will be able to select an extreme value of a variable magnitude flaw which produces no hazard.

Careful consideration must be given to the stress levels at which the testing is to be performed. If overtesting (above the normal service level) is to be done, one should be sure that the overtest actually increases the probability of getting results. In some cases in gun ammnuition testing, the standard methods for overtesting will actually reduce the particular condition contributing to the explosive initiation. A good rule of thumb is to avoid departing from service conditions unless you have positive knowledge that you are gaining more useful information by so doing.

OBTAINING AND USING THE RESULTS

Figure 1 is a flow diagram which illustrates the actions and decision points inherent in a sample fault testing program.

Selection of the number of units to be tested is usually driven very strongly by economics. The safety investigator requires some rather detailed arguments in order to obtain a reasonable quantity of hardware and money for safety test purposes.

Anticipating the arguments in favor of dealing with safety problems after they are discovered during service use, Figure 2 illustrates the effectiveness with which inspections can be conducted to find a small number of defectives in a large group of units. It is apparent that nearly 100-percent inspection is required to find all the defectives. This has great economic impact, after many units are out in the Fleet, when a small number of safety defects are thought to be present, and it is desired to screen these defects out before the first, or another, accident is caused. Even simple inspections of a large number of units are very costly; thus one advantage of an early fault testing program is to provide some data to aid in the decision about whether the cost of screening is justified.

Table 1, a standard table which is available in most reliability references, provides some indication of how much engineering confidence can be gained from testing. For example, the table indicates that if a 95-percent confidence level is desired and 29 units are tested experiencing no failure (reaction in the explosive fault test case), no more than 10 percent failures would be expected in a test of a large random sample, configured identically. The reliability of .9 in this case is the reliability of the (no failure) result at the

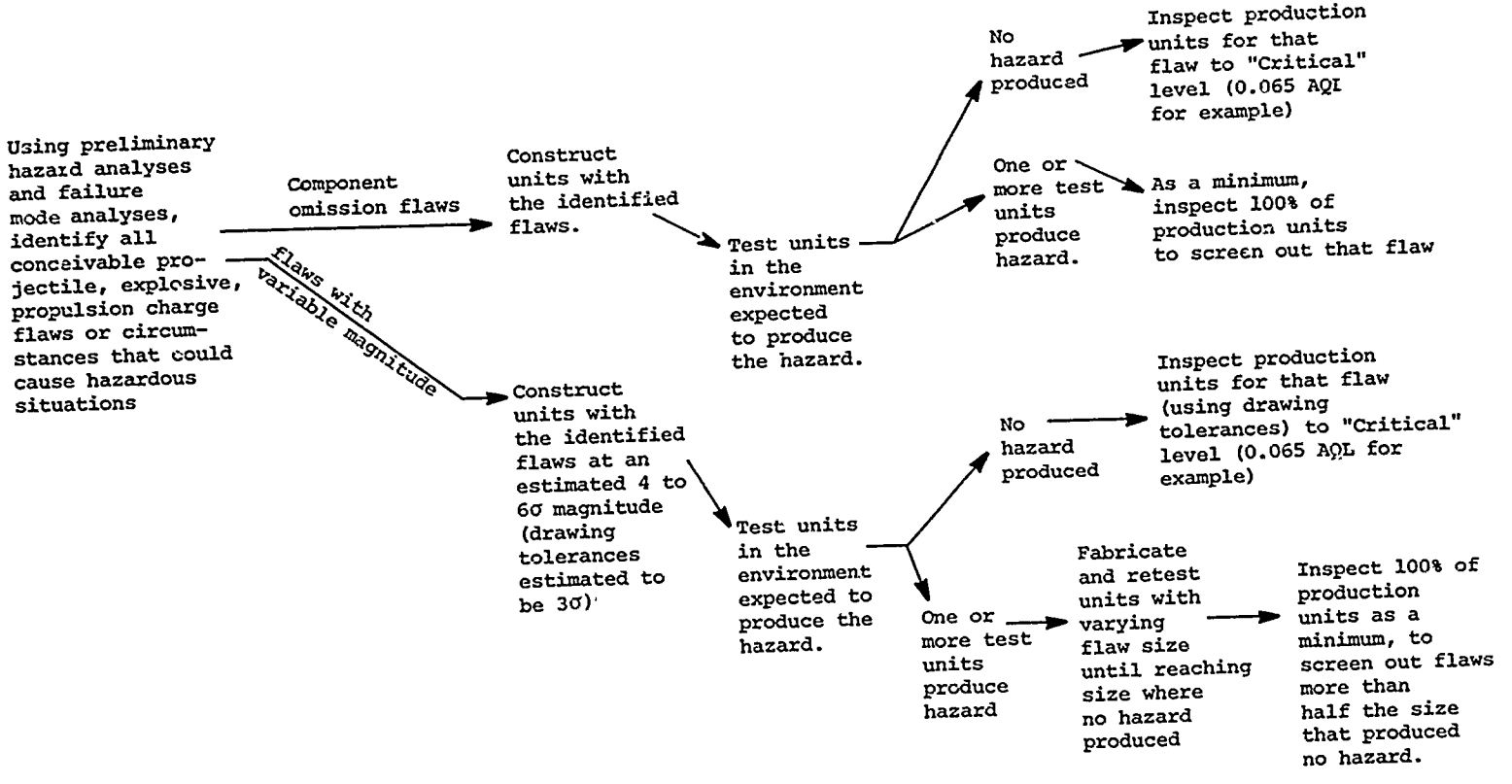


Figure 1. Sample Faulty Unit Program Flow Diagram

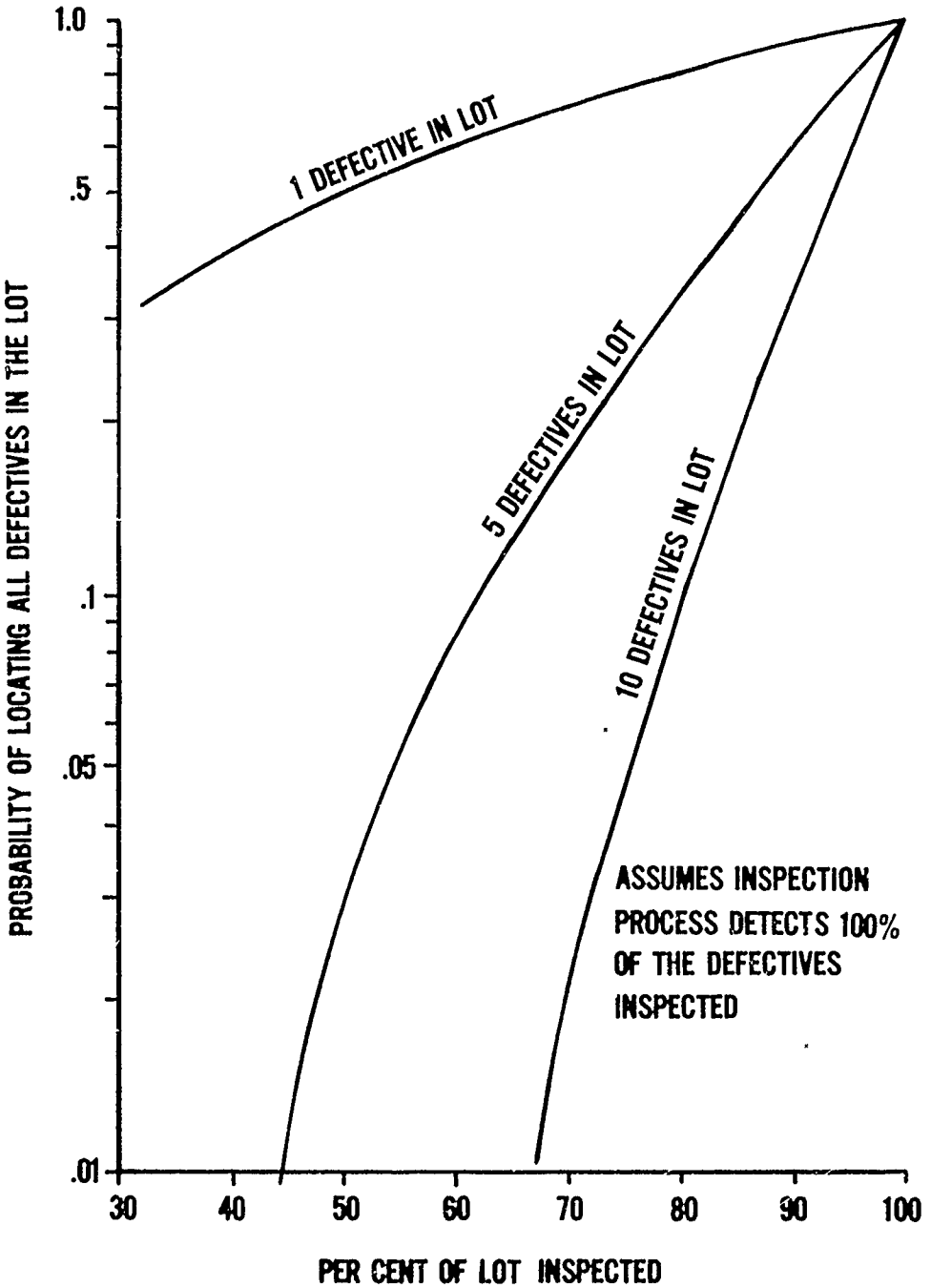


Figure 2. Inspection Effectiveness for Lots of Any Size

Table 1. Number of Tests Without Failure Versus Reliability and Confidence (Binomial Distribution)

Reliability	Confidence Level (%)							
	50	60	70	80	90	95	99	99.9
.9999	6,932	9,163	12,040	16,094	23,026	29,957	46,052	69,078
.999	693	916	1,204	1,609	2,303	2,996	4,605	6,908
.998	347	458	602	805	1,152	1,498	2,303	3,454
.997	231	305	401	537	768	999	1,535	2,303
.996	173	229	301	401	575	747	1,149	1,723
.995	138	183	241	321	460	598	920	1,379
.994	115	152	201	267	383	498	765	1,148
.993	99	130	174	229	328	427	657	985
.992	86	114	150	200	287	373	574	860
.991	77	101	134	178	255	332	510	764
.99	69	92	120	160	229	298	459	688
.98	34	45	60	80	114	149	228	342
.97	23	30	40	53	76	99	151	227
.96	17	23	30	39	57	74	113	170
.95	14	18	24	31	45	58	90	135
.94	11	15	20	26	37	49	75	112
.93	10	13	17	22	32	42	64	96
.92	9	11	15	19	28	36	55	83
.91	8	10	13	17	25	32	49	74
.90	7	9	12	15	22	29	44	66
.89	6	8	11	14	20	26	40	60
.88	6	8	10	13	18	24	36	54
.87	5	7	9	12	17	22	33	50
.86	5	7	8	11	16	20	31	46
.85	5	6	8	10	15	19	29	43
.80	3	4	6	7	11	14	21	31
.75	3	4	5	6	8	11	16	24
.70	2	3	4	5	7	9	13	20
.65	2	2	3	4	6	7	11	16
.60	2	2	3	4	5	6	9	14
.50	1	2	2	3	4	5	7	10

95-percent confidence level. By using this sort of information in the context of the program's economic limitations, more rational tradeoffs can be made to obtain reasonably sized test programs.

Figure 3 presents information of both an encouraging and discouraging nature. On the discouraging side, it illustrates that if the reaction being investigated does not always occur when the fault is present (a low true probability of failure) it may take a very large number of tests to uncover it. On the encouraging side, if a fault test of a few units does produce a reaction, it confirms that there is a significant real probability of a reaction occurring if this fault shows up in service use. The major value of this sort of information is to make the safety engineer more aware of the economic tradeoffs and the overall significance of the test results.

The action to be taken on the basis of Faulty Unit Test results is clearly one of the most troublesome aspects of the whole endeavor. At this writing, it is believed that mere suspicion that a fault is a potential hazard calls for inspection of the production units (for that fault) to at least a "critical" level (0.065 AQL). This inspection should occur whether or not any hazardous events are produced in the test program. On the other hand, reactions produced in the test programs call for the creation of a "super critical" category entailing 100-percent inspection of production units to screen out the prescribed flaws. In the case of variable magnitude flaws, it is intended to first test exaggerated (4- to 6-Sigma size) flaws to determine whether an event can be produced. If a reaction occurs, reduced severity flaws will be tested until no event is produced (in a 30-unit test). The 100-percent production inspection requirement will then be established to screen out flaws greater than half the size or severity of the one that finally produced no hazardous event. Figure 2 offers a convenient graph for assessing the effectiveness of inspection in weeding out faulty units if they are randomly dispersed in the production run. The graph makes no allowance for inspection error (human inspectors are not perfect, and, despite the scarcity of data, it has been assumed that an "average" inspector would detect only 80 percent of the faulty units that pass through his inspection).

In the case of "variable size" faults, the process for selecting the size of the flaw is an exercise in engineering judgment. Because a test must be conducted before adequate part manufacturing history has been generated, the best information available must be used with caution.

The magnitude of expected manufacturing flaws can be crudely estimated from manufacturing drawings during development, more accurately from subsequent production experience, or from the history

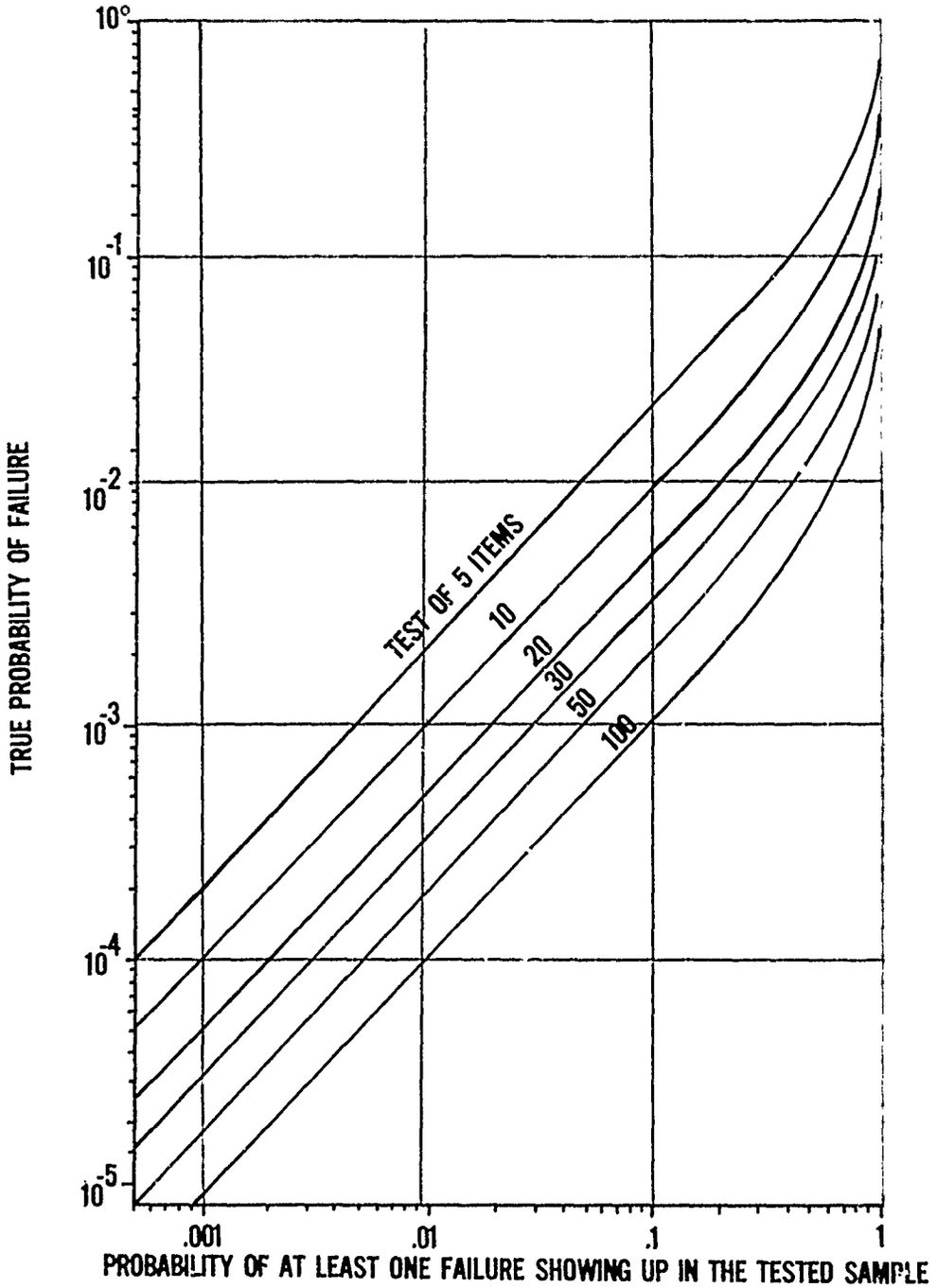


Figure 3. Relationship Between the Real Probability of Failure and the Likelihood of Experiencing Failure in Testing Various Numbers of Items

of similar manufacturing techniques. In the absence of better information about the magnitude and frequency of dimensional flaws, the manufacturing drawing tolerances may be assumed to represent 3-Sigma values in a normal distribution. Some assumption of this sort is required in order for testing to provide timely feedback to a development program. Assuming that the drawing tolerances are 3 Sigma, in a normal distribution, the value of 1 Sigma can be obtained by dividing by 3. Since the range from -1 Sigma to +1 Sigma is a dimensional value that includes 68.26 percent of the observed cases, -2 Sigma to +2 Sigma includes 95.46 percent etc., it follows that by deciding what probability level (of experiencing the flaw in service use) one wants to consider, Figure 4 can be used to determine the number of Sigmas, and thus the dimensions necessary for creation of the test flaws. Because selecting the flaw size to be tested necessitates assumptions about the quality of future production, careful thought should be devoted to the matter since a small error in the value of Sigma is multiplied when the flaw size is chosen. Appendix A contains samples and illustrative examples of the selection of flaw sizes and the use of results.

One area of free safety information frequently arises where, after a nonsafety test is finished, it is discovered that a disqualifying defect was present. The normal program reaction is to consider it a "no test" and never mention it again. The "fault test engineer" should be alert for these unintended fault tests since they may be a significant addition to the faulty unit data base. In the program which inspired this report there were 390 intended fault tests and 280 unintended "free" tests!

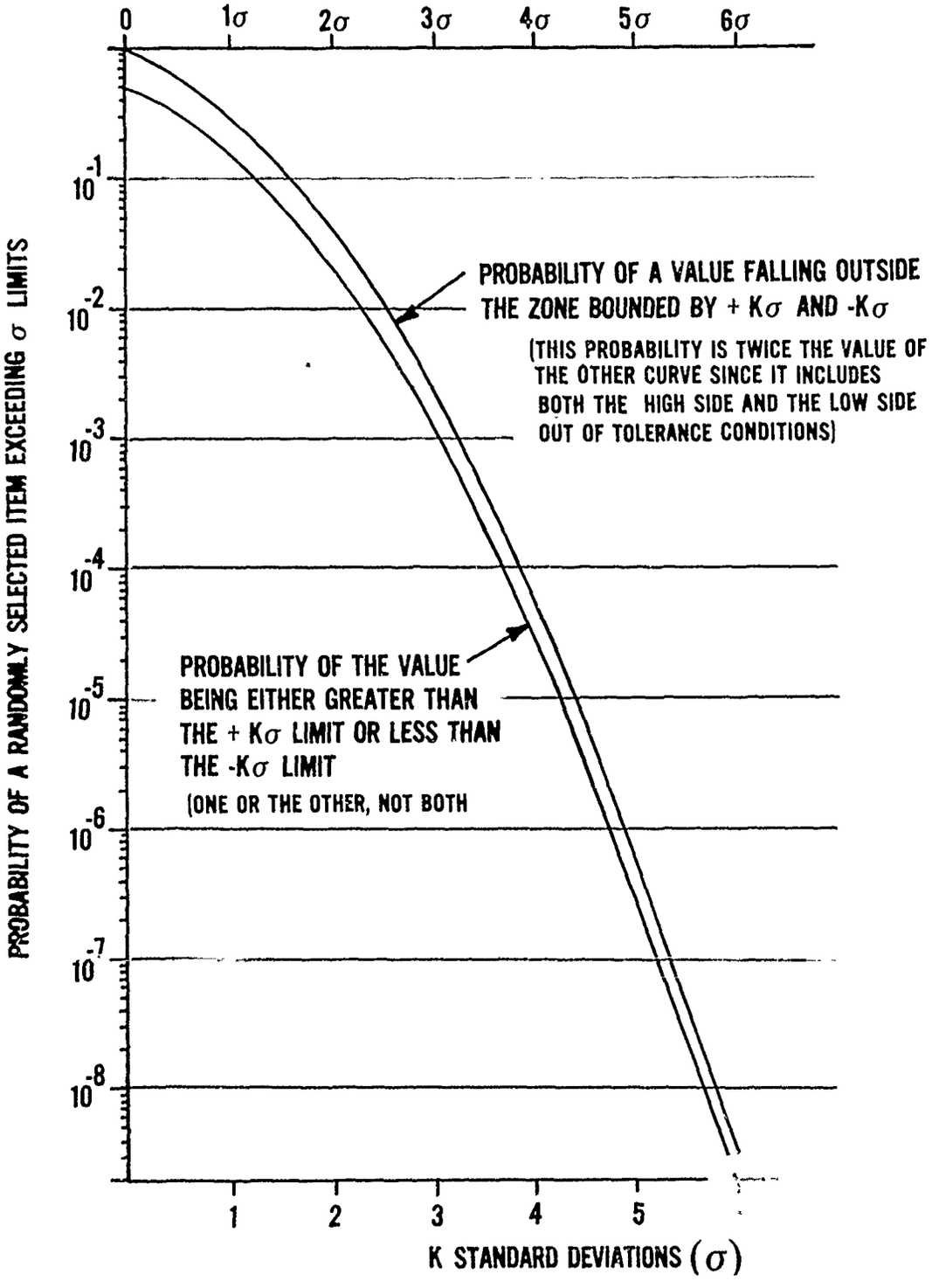


Figure 4. The Relationship Between Standard Deviations and Their Numerical Probability Values

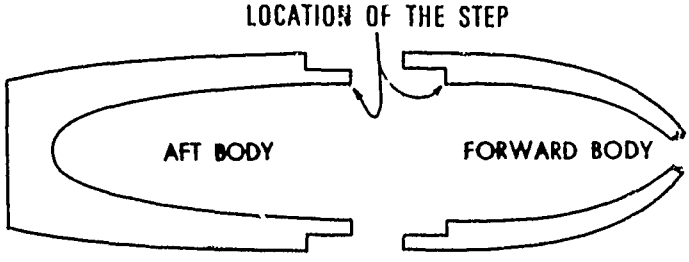
APPENDIX A

APPLICATION EXAMPLES

SIZING OF FAULTS

As discussed in the text covering flaws with various possible sizes, a means of deciding the flaw size for the test must be developed. One means of doing this is as follows:

1. To determine a test configuration for evaluating the gun-fire consequences, to the contained explosive, of a step existing where the forward and aft projectile body sections join (Reference NSWC/DL EPT Dwg 1842).



SOURCES OF THE STEP

1. CENTERLINE MISALIGNMENT BETWEEN FORWARD AND AFT SECTIONS (DRAWING ALLOWS .020")
2. INTERIOR CAVITY DIAMETER DIFFERENCES BETWEEN FORWARD AND AFT SECTIONS (DRAWING ALLOWS .007" DIFFERENCE)

3 SIGMA STEP SIZE

.020
+.007
.027 in.

Assume:

a. Normal distribution of dimensions about the mean,

b. Random assembly of parts, and

c. Drawing tolerances represent 3-Sigma values.

Using Figure 4:

	3-Sigma Case	4-Sigma Case
Probability of fwd section being large	$1.4 \cdot 10^{-3}$	$3 \cdot 10^{-5}$
Probability of fwd section having centerline misaligned	$1.4 \cdot 10^{-3}$	$3 \cdot 10^{-5}$
Probability of aft section being small	$1.4 \cdot 10^{-3}$	$3 \cdot 10^{-5}$
Probability of aft section having centerline misaligned	$1.4 \cdot 10^{-3}$	$3 \cdot 10^{-5}$

Probability of combining large forward section and small aft section (maximum radial difference)

P_r (3-Sigma case fwd & aft) = $1.4 \cdot 10^{-3} \times 1.4 \cdot 10^{-3} = 1.96 \cdot 10^{-6}$

P_r (4-Sigma case fwd & aft) = $3 \cdot 10^{-5} \times 3 \cdot 10^{-5} = 9 \cdot 10^{-10}$

Probability of having both forward and aft section centerlines misaligned (maximum misalignment)

P_m (3-Sigma case misalign) = $1.4 \cdot 10^{-3} \times 1.4 \cdot 10^{-3} = 1.96 \cdot 10^{-6}$

P_m (4-Sigma case misalign) = $3 \cdot 10^{-5} \times 3 \cdot 10^{-5} = 9 \cdot 10^{-10}$

Probability of having both maximum radial difference and maximum misalignment coexisting

P_t (for 3-Sigma case) = $1.96 \cdot 10^{-6} \times 1.96 \cdot 10^{-6} = 3.84 \cdot 10^{-12}$

P_t (for 4-Sigma case) = $9 \cdot 10^{-10} \times 9 \cdot 10^{-10} = 81 \cdot 10^{-20}$

Note: The additional factor of the likelihood of having the centerline misalignments exactly opposite instead of on the same side is being ignored for simplicity.

Conclusion: Compared to the often quoted safety number of $1 \cdot 10^{-6}$, selection of the 4-Sigma dimension appears to be an extreme enough choice for testing.

Calculate the 4-Sigma dimensions:

Total of 3-Sigma dimensions = 0.027 in.

Total of 4-Sigma dimensions = $0.027 \cdot \frac{4}{3} = 0.036$ in.

2. To provide a single test to evaluate both a forward facing lip and a rear facing lip, machine .036 in. from one side of the forward and one side of the aft section and assemble so that the machined areas are on opposite sides of the projectile. Machine in accordance with NSWC/DL Dwgs 40314C and 40315C.

OVERALL FAULT TESTING RESULTS

In an explosive-loaded gun ammunition development program extending over several years and several types and calibers of projectiles, a total of over 2000 rounds were gunfired with the same explosive. Of this number, 390 contained various deliberately induced faults which were fired for safety investigations. Fifty-two premature (unsafe) reactions occurred and their causes identified. Additionally, another 280 faulty rounds were fired wherein the faults were unexpected, having been accidentally introduced during manufacture or environmental testing. Upon gunfire, 10 of these gave premature reactions for which examination of the fault condition provided reasonable correlation with the premature causes in the deliberate cases.

Appendix B contains a copy of a memorandum citing the conclusions drawn near the end of the above program. In this case the fault testing was found to be very helpful in the decision making process.

APPENDIX B

FAULT TEST RESULTS

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17 October 1974

[redacted]

MEMORANDUM

From: ES
To: GW (Klaus)

Subj: Safety Summary of two piece projectiles with [redacted] Explosive (U)

Encl: (1) Safety Non-Problems
(2) Possible Premature Reaction Causes
(3) Identified Premature Reaction Causes
(4) Gunfire Experience with [redacted] Loaded Projectiles
(5) [redacted] Faulty Ammunition Firings - Projectile Flaws, Explosive Flaws, Single Assembly Flaws, Multiple Assembly Flaws

1. (U) It is the purpose of this memo to collect and discuss the safety lessons we have learned through the extensive testing of the subject explosive in various projectile configurations. In order to simplify a very complicated set of data, the test results will be broken down into three categories; those clearly demonstrating no safety problems, those demonstrating possible problems and those demonstrating definite problems. Accordingly, enclosures (1) - (3) will discuss the test results in that order. Enclosures (4) and (5) are complete listings of the total gunfire and faulty round firings, respectively.

2. (U) Some of the following terms have, over the years been synonymous with destructive projectile accidents. As used herein, this is not the case, therefore, the definitions are as follows:

Premature Reaction - Initiation of a burning reaction in the projectile explosive prior to the expected fuze function. The results of this burning are non-destructive and non-violent, except where noted. In both two piece and conventional projectiles, unless detonation is achieved, the firing s? ? will often be unaware of its occurrence.

Detonation - An explosion characterized by propagation of the reaction front at supersonic velocity (within the reacting medium) and motion of the reaction products in the same direction as the reaction front. Detonation results in projectile break up into small fragments traveling at 2000 to 3500 fps. If it occurs inside a gun barrel, barrel fracture occurs (in greater than 3 inch gun sizes) and the subsequent large fragments, hot gas and shock waves cause further destruction and crew injury.

Transition from Burning to Detonation - The condition where burning can give rise to a shock wave. This only occurs when pressure rises exponentially in a few microseconds to several thousand atmospheres and coalescence of pressure waves gives rise to a shock wave.

3. (U) In prior experience with [redacted], all premature reactions were classified as "in-bore". The photographic indications of this type are visible and distinct separation of projectile pieces as soon as they emerge from the smoke at the muzzle. In the 128 round factorial test of the [redacted] round, unusual out-of-bore prematures were experienced. Upon emergence from the muzzle smoke, at about 25 feet out, the projectile parts were still attached together. In subsequent photos, the projectile could be seen to separate, achieving complete separation by about 75 feet. These reactions were characterized by much less vigorous burning of the explosive, than the inbore reactions, once the projectile opened. As with the in-bore reactions, the out-of-bore prematures were non-destructive.

4. (U) The purpose of the safety investigation was to categorize the safety consequences of projectile flaws. Table 1 indicates the categories of the flaws, which are discussed in detail in enclosures (1)-(3). Collectively, the safety results may be summarized as follows:

a. [redacted] seems less likely to have a burning reaction transition to detonation than Comp A-3 explosive. In 62 premature reactions, only one round experienced any detectable detonation, in this case only a small portion of the burning explosive charge achieved detonation during an overpressure rupture of the gun barrel (the detonation is not thought to have caused the rupture). Another round (with the same flaw responsible for the above incident) resulted in a relatively non-violent split in the gun barrel due to overpressurization. The remaining 60 premature reactions were limited to burning with consequent non-violent opening of the projectile and resulting in no gun damage. Comp A-3 on the other hand has experienced 79 premature reactions (exclusive of fuze caused prematures) from 1950 to 1974 in 5"/38 and 5"/54 guns, 37 of which were low order (non-violent) reactions and 42 of which were high order, destructive reactions. Most of these events occurred in the 5"/38 guns while three occurred in 5"/54 guns, two high order and one low order.

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Table 1

SAFETY CATEGORY OF PROJECTILE FLAWS

Safety Non-Problems (See Enclosure (1))

Enlarged Cavity Base Diameter (Forging Flaw)
Misaligned Cavity
Hot Gas Leakage (Through Projectile Mid-Body Joint)
Water In Explosive Cavity

Possible Premature Reaction Causes (See Enclosure (2))

Cracked Encapsulant
Excessive Explosive Radial Clearance
Uncured Explosive

Identified Premature Reaction Causes (See Enclosure (3))

Holes In Projectile Base

Joint Rotation

Large Bubbles

Base Gaps or Base Cracks

Small Bubbles and Base Gaps

HTPB Encapsulant

Sawed Explosive Nose Surface

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b. Experience to date indicates that Comp A-3 is subject to premature initiation only when the explosive load is insufficiently pressed, giving a low density. In this condition a circumstance of a base gap or an excessive gunfire shock input can result in a premature reaction, which can remain low order or proceed to a detonation, as previously discussed.

c. [redacted] can be prematurely initiated, in the [redacted] configuration, by hot gas leakage through holes in the projectile base, relative rotation of the forward and aft projectile body sections (knurling being the major control feature), large (> 1/4 inch) bubbles or voids in the explosive and base area anomalies (gaps, failed adhesive or missing adhesive). Admittedly, this is a longer list of potential causes than for Comp A-3 and quality assurance will need to be rigorous to eliminate them. The safety trade-off question is whether the lower proability of transition to detonation of [redacted] out weighs its greater number of initiation sources.

d. The major unknown areas at this time are the changes in base anomaly effects due to the [redacted] hemispherical cavity base (the [redacted] base was relatively flat) and the use of cross-linked polyethylene encapsulant (vice ethyl cellulose) and the frequency of the premature causing flaws in ammunition delivered to the fleet. The changes in the hardware design will be evaluated in a factorial test during TECHEVAL and estimates of flaw frequency will be developed using TECHEVAL hardware production for a data base.

5. (U) The findings of the safety investigations thus far indicate that continuation into TECHEVAL is justified. The safety investigations during TECHEVAL should be especially directed toward the understanding and resolution of the base anomaly problems.

S. H. McELROY, Head
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IN REPLY REFER TO:
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25 January 1977

From: Commander, Naval Surface Weapons Center, Dahlgren Laboratory (Code DX-40), Dahlgren, Virginia 22448
To: Distribution

Subj: Pen and Ink Corrections to Unclassified NSWC/DL Technical Report TR-3478, Underlying Concepts and Assumptions for Faulty Hardware Safety Testing, dated August 1976

1. The following pen and ink changes should be made to the subject technical report:

a. Front cover--Change TR number from "TR-3478" to "TR-3602"
b. DD Form 1473--Change TR number from "TR-3478" to "TR-3602"

2. This correction notice should be attached to the inside front cover of the subject technical report.

K. G. McCOLLUM
By direction