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ARMED FORCES SPECIAL WEAPONS PROJECT

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~~DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW~~
~~1ST REVIEW-DATE: [illegible]~~
~~AUTHORITY: ☐ DC ☒ DD~~
~~NAME: [illegible]~~
~~2ND REVIEW-DATE: 4/8/09~~
~~AUTHORITY: DD~~
~~NAME: [illegible]~~
~~DETERMINATION (CIRCLE NUMBER(S))~~
~~1. CLASSIFICATION RETAINED~~
~~2. CLASSIFICATION CHANGED TO: FRD~~
~~3. CONTAINS NO DOE CLASSIFIED INFO~~
~~4. COORDINATE WITH: [illegible]~~
~~5. CLASSIFICATION CANCELLED~~
~~6. CLASSIFIED INFO BRACKETED~~
~~7. OTHER (SPECIFY): [illegible]~~

940.012 (Unclassified Title)

ACCEPTABLE PREMATURE PROBABILITIES FOR NUCLEAR WEAPONS

By (b)(6) DTRA

1 Oct 1957

Short Title: FC/10570136

This document consists of 30 Page(s)

No. 2 of 5 copies, Series A

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HEADQUARTERS FIELD COMMAND
ARMED FORCES SPECIAL WEAPONS PROJECT
Office of the Deputy Chief of Staff, Research and Development
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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940.012 (Unclassified Title)

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Reviewed By:

DTRA (b)(6)

Lt Col USAF
Chief, Systems Analysis Branch

Approved By:

(b) (6) DTRA

Lt Col CS
Director Research Division

ABSTRACT (U)

This report establishes acceptable premature probabilities for nuclear weapons exposed to the conditions experienced in stockpile-to-target sequences. Utilizing data from a study by United States Continental Army Command, Office of Special Weapons Developments, wherein major U. S. catastrophes of the past 50 years were analyzed and assigned equivalent nuclear yields, the author assumes a stockpile configuration and composition, and by straightforward mathematical methods reaches conclusions and makes recommendations on numbers to be used for future weapon systems designs. Accidents due to random component failure are assumed to be one-tenth of those attributable to human error. Values given in recent military characteristics are tabulated for comparison.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Commander, Field Command, AFSWP, of the conclusions or the recommendations herein. It is published only for the exchange and stimulation of ideas.

FOR THE COMMANDER:

(b) (6)

Colonel, USAF
Deputy Chief of Staff
Research and Development

DTRA

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A STUDY ON PREMATURE PROBABILITIES FOR NUCLEAR WEAPONS

1. Problem:

To establish acceptable premature probabilities for nuclear weapons exposed to the conditions experienced in stockpile-to-target sequences.

2. Facts Bearing on the Problem:

a. A survey of military characteristics for nuclear weapons, proposed or approved during the period January 1956 to March 1957, showed variations and inconsistencies in requirements for premature probabilities. (Appendix A quotes the military characteristics surveyed). These include:

(1) Variations in specific premature probabilities for a particular weapon condition with no immediate explanation for these variations.

(2) Inconsistency in definitions of the different environments or conditions experienced by the weapons in their stockpile-to-target sequences.

(3) Premature probabilities which are expressed as random component failures, exclusive of human error. These numbers lead to unrealistic conclusions of the safety of the weapon as random component failures are small compared to other factors such as human error.

b. Probability figures clearly state that they apply to bombs and warheads only except where a missile system is completely defined. These numbers, therefore, do not describe the overall safety of the weapon.

c. A survey of available literature uncovered only one study that might furnish a logical basis for determining premature probability requirements (Reference 1). This study, by United States Continental Army Command, Office of Special Weapons Development (OSWD), attempted to relate accidental nuclear explosions to the disasters (rate and magnitude) which the nation has experienced in the past half century.

3. Discussion:

a. The consequences of an accidental nuclear detonation could be catastrophic. These consequences might be one or all of the following:

(1) A significant portion of our atomic weapons and carriers might be destroyed, thereby reducing our military capability.

(2) Large numbers of our military and civilian population might be killed or injured.

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(3) Vast areas might be rendered uninhabitable.

(4) The psychological impact of a nuclear detonation might well be disastrous. Whether or not the accident would be considered in the same light as a naturally occurring catastrophe (earthquake, flood, tornado, etc) is problematical. In acts of nature, the tendency seems to be to treat these as tragic but unavoidable. In a nuclear disaster, there will likely be a tendency to blame the "irresponsible" military and scientists. As a result, public reaction could cause political pressures to be placed upon the military, thereby hampering or curtailing weapon programs.

(5) A potential enemy might possibly be triggered into starting an aggressive war under the assumption that the resultant confusion and/or the loss of part of our stockpile might give him sufficient military advantage.

(6) Under certain conditions, it might be difficult to distinguish between a nuclear accident and an enemy attack. It is conceivable that this could result in premature retaliatory actions on our part, resulting in an international crisis.

b. In the aforementioned OSWD study, major U. S. catastrophes of the past 50 years were analyzed and an equivalent yield associated with each, based upon the people killed and/or property damage resulting from them. From this data, a frequency versus yield curve was drawn and the inference reached that since the nation has survived these, it could survive a similar rate in the future. Different acceptable rates were proposed for peacetime and wartime. TABLE I shows the proposed rates. Values are the acceptable number of weapon accidents per year within each yield range shown.

TABLE I

Yield Range	NUMBER OF WEAPON ACCIDENTS PER YEAR Peacetime	Wartime
> 10 MT	$1x10^{-5}$	$2x10^{-4}$
1-10 MT	$5x10^{-5}$	$8x10^{-4}$
100-1000 KT	$3x10^{-4}$	$4x10^{-3}$
10-100 KT	$2x10^{-3}$	$2x10^{-2}$
1-10 KT	$8x10^{-3}$	$8x10^{-2}$
0.1-1 KT	$5x10^{-2}$	$5x10^{-1}$

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(1) In general, the wartime rates correspond to the "normal" accident rate with the peacetime rate approximately one-tenth of this.

(2) The figures presented are debatable.

(a) During a full scale war, the number of accidental detonations will be overshadowed by disasters resulting from enemy action. Therefore, it is doubtful whether there should be a prescribed rate based on peacetime safety considerations. The acceptable wartime rate should be that which would not significantly hamper our operational capability.

(b) The conversion from "normal" peacetime disasters to equivalent kiloton nuclear accidents neglects public reaction.

(3). These figures appear to be the most comprehensive published to date.

(4) A conclusion of this study was that safety criteria should habitually be stringent and only relaxed when advantages are demonstrated.

c. Full scale nuclear accidents could be caused by the following general means:

(1) Random failure of components -- this mode of premature detonation is the easiest to estimate. Sandia Corporation makes a priori estimates of the probability of prematures from random failures based on statistical evidence on random component failure, specific weapon circuitry and intuitive estimates. To date no other agency prepares comparable estimates for atomic weapons. Consequently, Sandia Corporation figures are generally quoted as the premature probability for that particular weapon.

(2). Storage and handling accidents -- these accidents include transportation accidents, fires in stockpile and during transportation, etc. A priori estimates for this type of accident are more difficult to make. The rate of such events could be correlated to previous experience but it is extremely difficult to state just what orientation, sequence of events, etc., would cause a nuclear explosion rather than one-point detonations, HE burning or no detonation at all. Fortunately, this type of accident is easiest to design against. For example, insofar as fire is concerned thermal fuzes which melt at lower temperatures than that necessary to activate thermal batteries are essentially positive safing against simultaneous detonator detonation and thus against full scale nuclear explosions.

(3) Human error -- these accidents are even more difficult to predict and almost impossible to prevent. Steps in design can reduce the likelihood of errors resulting in detonations by limiting the number of chances for error such as testing requirements, assembly and disassembly, etc. Other steps can be taken to reduce human errors by rigorous training, careful inspection and rigid procedures. Whether or not the number of accidents can be predicted in the form of a precise probability is questionable. The Air Force and Sandia Corporation agree in their estimates that 1 bomb in 10 dropped will dud because of human error. A priori estimates on duds due to random component failure are as low as 1 in 100. From these figures it can be seen that duds due to human error are as high as 10 times that due to random component failure. It appears, therefore, that the accident rate due to human error might be as high as 10 times the probability of premature detonations attributed to random component failure.

(4) Sabotage -- detonations attributable to sabotage are impossible to predict or to prevent completely. However, it appears that sabotage can be reduced by careful screening of personnel, security surveillance, and design efforts.

d. The unpredictable behavior of human beings is a grave problem when dealing with nuclear weapons. It was mentioned in paragraph 3.b.(3) above that the assignment of a precise probability to human error is questionable, and any attempt to determine this probability is beyond the scope of this study. However, the selection of any acceptable premature probability must be made with the understanding that it is inclusive of human error. #5

(1) Since it is conceded that random component failure is very small when compared to human error, any requirement for an (a more or less) exact limit on premature probability caused by random component failure is somewhat meaningless and is useful only as a comparative standard for weapon design. In addition, such a comparison is valid only when a common method of estimating such probabilities is specified.

(2) Representatives of Sandia Corporation have stated that many of their a priori premature probabilities are not meaningful, especially when the numbers become smaller than 10^{-6}. This is not so much the question of the reliability of input data but that the basic assumption of the independence of events is questionable.

(3) It should be pointed out that the validity of a premature probability calculated by a priori estimates cannot be demonstrated by experiment.

e. The data in TABLE I indicate a yield dependence for the acceptable number of accidental nuclear detonations. It is also assumed that an accident would result in a full scale nuclear yield of one weapon only. If these data are valid, the acceptable premature probabilities for our weapons can be calculated.

(1) An event will be defined as the stockpile life of one weapon.

(2) For the purpose of this study, an assumption will be made as to the number of weapons in the national stockpile. If one wishes to compare the probabilities presented with actual stockpile figures, the following formula can be used:

$$P_a = \frac{N_a \times t}{n}$$

where P_a = premature probability per weapon during the stockpile life of the weapon

N_a = the acceptable number of accidents per year for weapons of various yields found in TABLE I

n = number of weapons of that yield in stockpile

t = life in years of the weapon in stockpile

(3) By assuming numbers of weapons in several yield ranges for the 1960-65 period and that the average life of a weapon in stockpile is ten years, an acceptable probability for a nuclear accident can be calculated, working from the peacetime data in TABLE I.

TABLE II

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(a) During peacetime it is desired that there be no nuclear accidents. If the premature probabilities of TABLE II are accepted, what assurance is given that there will be no nuclear accidents? TABLE III, using the number of weapons and premature probabilities of TABLE II, shows the assurance of no prematures.

TABLE III

YIELD RANGE	ASSURANCE OF NO PREMATURES *
> 10 MT	.99
1-10 MT	.99
100-1000 KT	.99
10-100 KT	.98
1-10 KT	.92
0.1-1 KT	.60

* Based on the Poisson distribution

(b) Inspection of TABLE III indicates satisfactory assurance values for yields greater than one kiloton. However, for the subkiloton yields the assurance level is too low. By assigning a premature probability of $1x10^{-5}$, the assurance level is increased to 0.95; it appears that a probability of $1x10^{-5}$ would be acceptable.

(c) If the estimated number of weapons in the stockpile is reasonable, then a probability of $1x10^{-7}$ or smaller is acceptable for all weapons except the subkiloton range for which a probability of $1x10^{-5}$ appears acceptable. Assurance of no prematures for these probabilities are shown in TABLE IV.

TABLE IV

YIELD RANGE	ASSURANCE OF NO PREMATURES
> 10 MT	.99
1-10 MT	.99
100-1000 KT	.99
10-100 KT	.99
1-10 KT	.99
0.1-1 KT	.95

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(4) Military characteristics for various weapons and weapon systems contain a section on premature probabilities. A weapon condition is defined and a premature probability is assigned to this condition. These desired premature probabilities are very low for stockpile storage, as defined in Reference 2, and increase as conditions change in the stockpile-to-target sequence. However, paragraph 3.e.(3) implied a definite probability according to yield.

(5) A priori estimates by Sandia Corporation for premature probabilities on sealed pit weapons in stockpile storage range from less than "1 in 10^6" to "1 in 1015". For other than stockpile storage, premature probabilities are much larger and in most cases are larger than the probabilities shown in TABLE II. The question then arises as to whether or not these larger probabilities are acceptable or should be revised downward to fall in line with TABLE II. In answering this question, several approaches may be taken:

(a) Weapon design could be made to conform with the acceptable probabilities shown in TABLE II. This approach appears mandatory if safety is to be the primary criterion in the design of weapons. Weapon reliability, on the other hand, will undoubtedly be degraded if safety designs are carried to the extreme and a militarily unusable weapon might result. [redacted] It is doubtful if the Services will accept any further degradation of reliability.

DOE b(3)

(b) TABLE I also indicates maximum acceptable wartime nuclear accident rates which are approximately ten times larger than peacetime rates. These wartime rates actually correspond to past, primarily peacetime, experience. If this nation is to maintain a retaliatory capability, it must accept some degree of risk. It is, therefore, suggested that these "wartime rates" (actual natural disaster rate) be accepted for operational storage, as defined in Reference 2.

(c) The number of weapons in operational storage will be much smaller than the number in stockpile storage. If the number of weapons in operational storage is assumed to be 10 percent of the estimated number of weapons shown in TABLE II, new probabilities based on wartime rates in TABLE I may be calculated and are shown in TABLE V.

(d) New operational concepts could change and invalidate TABLE V by increasing significantly the number of weapons in operational storage.

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TABLE V

[redacted]

DOE b(3)

1. Using the number of weapons and probabilities found in TABLE V, assurance values for no prematures can be determined as was done in TABLE III.

TABLE VI

YIELD RANGE	ASSURANCE OF NO PREMATURES
> 10 MT	.99
1-10 MT	.99
100-1000 KT	.96
10-100 KT	.82
1-10 KT	.47
0.1-1 KT	.004

2. Inspection of TABLE VI indicates that the assurance values for yields less than 10 KT are too low. By decreasing the premature probabilities for these yields to $1x10^{-4}$, assurance values of 0.78 and 0.95 are obtained for the 1-10 KT and 0.1-1 KT ranges respectively.

3. It, therefore, appears that for yields greater than 10 KT, a premature probability of $2x10^{-5}$ will be acceptable and for yields less than 10 KT, $1x10^{-4}$. Assurance of no prematures for these probabilities are shown in TABLE VII.

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TABLE VII

YIELD RANGE	ASSURANCE OF NO PREMATURES
> 10 MT	.99
1-10 MT	.99
100-1000 KT	.99
10-100 KT	.95
1-10 KT	.78
0.1-1 KT	.95

f. The premature probabilities for operational storage are defined to include any condition of the weapon prior to the generation of any intentional arming signal. This would include weapons loaded aboard aircraft awaiting strike, missiles on a launcher, and during weapon flight over friendly territory. After the initiation of the drop sequence * in the case of bombs or the first arming signal in the case of missiles is given, the premature probability is increased. Just what an acceptable premature probability would be in these cases appears to depend on the reliability required of the weapon, the danger to aircraft and launch personnel, and the danger to friendly forces.

(1) For bombs, the using Service is in a better position to establish acceptable premature probabilities after initiation of the drop sequence. A review of approved military characteristics indicates that for bombs, a premature probability of 1 in 1000 after the initiation of the drop sequence has been acceptable.

(2) For missiles, the using Service will have to determine acceptable premature probabilities after launch, considering each missile system separately and based on the following factors:

(a) Weapon Yield
(b) Location of launch site
(c) Value of launch site
(d) Missile trajectory
(e) Reliability required

(3) It appears that for missiles launched or employed in the United States or friendly held areas and where trajectories are such that

* Initiation of the drop sequence (for bombs) is defined for the purpose of this study as the switching of the T-249, or equivalent, control box from the safe to the arm position. This is to be considered the first arming signal.

a premature would endanger friendly troops and/or populations, little if any degradation below operational storage figures can be tolerated. After the danger zone for friendly troops and/or populations is passed, then the accepted premature probability need not be greater than 1 in 1000 per weapon or the acceptable dud probability, whichever is larger.

g. Present military characteristics express premature probabilities as random component failure exclusive of human error in order to provide weapon designers with a design goal. The premature probabilities derived in paragraph 3.e. are considered to be the maximum permissible under any circumstances. Therefore, the probability of a nuclear detonation due to random component failure must necessarily be smaller than the total premature probability. Based on current limited knowledge of human error and educated guesses, it appears that a premature due to random component failure will be approximately one-tenth of that due to human error. It is hoped that the application of human engineering concepts in future weapon development and strict compliance with prescribed assembly, test, and handling procedures will decrease the occurrences of human error. This could, in time, relax the requirement on random component failure.

4. Conclusions:

Based on the assumptions made and discussed earlier: (1) that the conclusions of Reference 1 are valid, (2) that the numbers used are for a hypothetical stockpile configuration for the 1960-65 period, (3) that the average life of a weapon in stockpile is ten years, and (4) that ten percent of the hypothetical stockpile are in operational storage, it is concluded that:

a. An accidental detonation of a nuclear weapon might be catastrophic; therefore, the possibility of an accidental nuclear detonation is not acceptable unless necessary to provide for an adequate national defense.

b. In order to survive or to maintain a retaliatory capability as a restraint, a certain degree of risk in living with nuclear weapons must be accepted. The accepted risk must depend on the number of weapons and their yields and whether the weapons are in operational or stockpile storage. The premature probabilities discussed herein are based on a natural disaster rate and are the highest this nation can accept for peacetime operation. Therefore, all causes of premature nuclear detonation must be considered in the overall calculation of an a priori estimate of premature probability. However, in order to provide for design goals which are based on random component failure, it can be assumed at the present time that the acceptable premature probability from this source is one-tenth of the total acceptable premature probability.

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5. Recommendations:

a. Since it appears that the contribution from human error to the total probability of a premature nuclear detonation will be large, intensive effort should be devoted to reducing this cause. This includes analysis of the complete system to discover the possibilities of the occurrence of human error, the application of human engineering principals to minimize these possibilities, the elimination of unnecessary test and handling operations, and strict compliance with prescribed procedures during necessary operations.

b. It is recommended that in the determination of premature probabilities in military characteristics for all new weapons consideration be given to the following criteria: (Appendix B illustrates the application of these criteria).

It shall be a design goal that the probability of a premature nuclear detonation from all causes (including random component failure, human error, transportation and handling accidents, sabotage, etc.) for all weapon systems in the stockpile-to-target sequence be less than 1 in 10,000,000 per weapon per stockpile life.

If the criterion for meeting the design goal recommended above leads to a militarily unusable weapon system, the following premature probabilities from (1) all causes and (2) from random component failure alone for the environments indicated should be the maximum permissible:

(1) During stockpile storage including transportation, handling, and maintenance:

(a) For yields greater than 1 KT

1. From all causes...1 in 10,000,000 per weapon per stockpile life.

2. Random component failure alone...1 in 100,000,000 per weapon per stockpile life.

(b) For yields less than 1 KT

1. From all causes...1 in 100,000 per weapon per stockpile life.

2. Random component failure alone...1 in 1,000,000 per weapon per stockpile life.

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(2) During operational storage, including transportation of the ready weapon, handling, maintenance, assembly and test operations, and loaded aboard the aircraft prior to initiation of the drop sequence, and on a missile launcher prior to firing:

(a) For yields greater than 10 KT

1. From all causes...1 in 50,000 per weapon per stockpile life.

2. Random component failure alone...1 in 500,000 per weapon per stockpile life.

(b) For yields less than 10 KT

1. From all causes...1 in 10,000 per weapon per stockpile life.

2. Random component failure alone...1 in 100,000 per weapon per stockpile life.

(3) During a missile trajectory over areas where friendly troops and/or populations might be endangered by a nuclear detonation:

(a) For yields greater than 10 KT

1. From all causes...1 in 50,000 per weapon per stockpile life.

2. Random component failure alone...1 in 500,000 per weapon per stockpile life.

(b) For yields less than 10 KT

1. From all causes...1 in 10,000 per weapon per stockpile life.

2. Random component failure alone...1 in 100,000 per weapon per stockpile life.

(4) During a missile trajectory over areas where friendly troops and/or populations will not be endangered by a nuclear detonation -- 1 in 1000 per weapon or the maximum dud probability, whichever is larger.

(5) After initiation of the drop sequence and during the period wherein a nuclear detonation might endanger the launching aircraft or crew assuming standard release techniques are employed -- 1 in 1000 per weapon.

REFERENCES

1. Secret RD report, OSWDD 55-20-W/A7, Continental Army Command, Office of Special Weapons Development, Fort Bliss, Texas, dated 1 June 1955, subject: "Acceptable Military Risks from Accidental Detonation of Atomic Weapons".

2. Secret RD report, AFSWP 4-1, Departments of the Army, Navy and Air Force, Washington 25, D. C., dated 1 March 1956, subject: "Glossary of Military Field of Atomic Energy".

APPENDIX A

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PROPOSED
MILITARY CHARACTERISTICS FOR A
HIGH YIELD WEAPON IN THE
25,000 pound WEIGHT CLASS

* * * * *

RELIABILITY AND SAFETY

15. The probability of premature detonation of the weapon, so as to endanger the launching aircraft and crew, shall be no greater than 1 in 1000, assuming that standard delivery tactics are employed. The design features adopted to achieve this premature probability should not restrict the operational flexibility of the delivery vehicle.

16. With the introduction to the weapon of the proper arming and fuzing signals, the probability of securing the design yield ± 10% shall be no less than .999.

17. The probability of a premature detonation of the weapon without proper arming and fuzing signals shall be no greater than one in fifty-thousand.

18. The weapon shall be so designed to preclude any nuclear yield resulting from detonation by means other than the intended fuzing system.

19. The probability of a dud weapon due to malfunction of the arming and fuzing system shall be no greater than one in two hundred (200) whether the airburst or contact has been selected.

20. Manual safing, remote arming and safing, and positive indication of the armed or safe condition of the weapon shall be provided during ground handling. During flight only remote control and indication are required.

21. It is desired that the reliability of the arming, fuzing, and firing system shall be such that no preflight preparation or checks will be required. If this reliability cannot be provided, then the system shall be designed so that the preflight check can be accomplished without disassembly of the weapon when the weapon is either on the ground at the A/C or loaded aboard the A/C.

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PROPOSED
MILITARY CHARACTERISTICS FOR
CLASS B WEAPON

SECTION I PART I

* * * * *

DESIGN FEATURES

11. With power supplied, and assuming no arming or firing signal supplied, the probability of an explosion before the intended time of operation shall not be greater than 1 in 50,000 (.002%). In addition, the warhead shall be so designed to preclude any nuclear yield resulting from detonation by means other than the intended fuzing system.

* * * * *

SECTION I PART II

BOMB APPLICATION

* * * * *

OPERATIONAL DESIGN FEATURES

11. The probability of premature detonation of the weapon, so as to endanger the launching aircraft and crew, shall be no greater than 1 in 10,000, assuming that standard delivery tactics are employed. The design features adopted to achieve this premature probability should not restrict the operational flexibility of the delivery vehicle.

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HEADQUARTERS FIELD COMMAND
ARMED FORCES SPECIAL WEAPONS PROJECT
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

SUBJECT: PROPOSED MILITARY CHARACTERISTICS FOR A NEW CLASS C WEAPON

* * * * *

E. Reliability

27. Premature Probabilities -- Exclusive of human error and fire, the probability of a premature nuclear detonation of the warhead shall not exceed the probabilities listed below for the various environments. The design features adopted to achieve these requirements shall not restrict the operational flexibility of the weapons in which the warhead shall be employed.

a. During storage, transportation, handling, maintenance, assembly and test operations - 1 in 200,000.

b. Installed in weapon in strike configuration and prior to receipt of any arming signals - 1 in 100,000.

c. After receipt of all arming signals and prior to receipt of any firing signals - 1 in 20,000.

28. Other Accident Probabilities -- The warhead shall be designed to minimize possibility of human error. Exclusive of human error, the probability of occurrence of the type of accidents listed below shall not exceed the values shown.

a. High explosive detonation of warhead during weapon assembly and disassembly test of major components - 1 in 10,000.

b. Accidental exposure of handling personnel to nuclear radiation or contaminated material - 1 in 10,000.

c. Nuclear detonation in event of fire - 1 in 1,000,000.

* * * * *

Subject: Proposed Military Characteristics for a New Class C Weapon (Cont'd)

* * * * * *

15. Premature Probabilities -- Exclusive of human error, the probability of a premature nuclear detonation of the weapon shall not exceed the probabilities listed below for the various environments. The design features adopted to achieve these requirements shall not restrict the operational flexibility of the weapon or delivery vehicle.

a. During storage, transportation, handling, maintenance, assembly and test operations - 1 in 100,000.

b. When loaded aboard aircraft in strike configuration and prior to initiation of the drop sequence - 1 in 50,000.

c. After initiation of the drop sequence and during the period wherein a nuclear detonation might endanger the launching aircraft or crew, assuming standard release techniques are employed -- 1 in 1,000.

* * * * * *

MILITARY CHARACTERISTICS FOR A THERMONUCLEAR
WEAPON IN THE 3000 POUND WEIGHT CLASS

SECTION I

* * * * *

SAFETY

11. b. With power supplied and assuming no arming or firing signals applied, the probability of an explosion before the intended time of operation shall not be greater than 1 in 50,000 (0.002%). In addition, the warhead shall be so designed to preclude, with a probability of at lease 99%, any nuclear contribution resulting from detonation by means other than the intended fuzing system.

SECTION I - PART II - BOMB APPLICATION

FUZING AND FIRING

12. ....A device or devices having a functional reliability of 0.999 is required in order to provide safe separation between the bomb and the bombing aircraft at the time of burst.

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MILITARY CHARACTERISTICS FOR AN
11 3/4 INCH DIAMETER, 150 POUND, ATOMIC WARHEAD (C)

Approved by the MLC 4 December 1956

* * * * *

V. RELIABILITY

24. FUNCTIONAL RELIABILITY

b. The probability of premature destruction due to a malfunction of the one point safe destruct device shall be 1/10,000 and the probability of functional reliability of the one point safe destruct device shall be 9999/10,000.

25. PREMATURE PROBABILITIES - Exclusive of human error or events listed in paragraph 15, as a design goal the probability of a premature nuclear detonation of the warhead shall not exceed the following:

a. In storage and prior to assembly in weapon - 1/1,000,000

b. During installation, assembly, disassembly and test - 1/1,000,000

c. Installed in weapon and prior to FINAL ARM signal:

(1) Prior to ARM signal, or upon receipt of SAFE signal - 1/200,000

(2) Upon receipt of ARM signal - 1/100,000

d. After receipt of FINAL ARM signal - 1/10,000

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PROPOSED MILITARY CHARACTERISTICS FOR A TACTICAL/LAYDOWN FAMILY OF ATOMIC WEAPONS (U)

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II. E. Reliability

28. Premature Probabilities -- Exclusive of human error, the probability of a premature nuclear detonation of the warhead shall not exceed the following:

a. Prior to marriage with weapon and under conditions other than b. through e., below -- 1/100,000

b. During installation in the weapon -- 1/20,000

c. Installed in the weapon prior to receipt of any arming signal -- 1/20,000

d. After receipt of all arming signals -- 1/10,000

e. During warhead assembly, disassembly, and major component test -- 1/20,000

* * * * * *

III. E. Reliability

51. Premature Probabilities -- The probability of premature detonation of the weapon, so as to endanger the launching aircraft and crew, shall be no greater than 1/10,000 assuming that proper delivery tactics are employed. The design features adopted to achieve this premature probability should not restrict the operational flexibility of the delivery vehicle.

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Summary of Military Characteristics

Condition	New Class A	New Class B	New Class C	TX-27/28	11 3/4" W/H	Laydown
Prior to warhead marriage with weapon (storage, transportation handling, etc)	1/1,000,000	--	1/200,000	----	1/1,000,000	1/100,000
Bomb during storage transportation and handling, etc.			1/100,000			
During installation in weapon						1/20,000
With power supplied and assuming no arm or fire signal				1/50,000		
Installed in weapon prior to receipt of any arming signal	1/50,000	1/50,000	1/100,000(whd) 1/50,000(bomb)		1/200,000	1/20,000
Upon receipt of all arming signals			1/20,000		1/10,000	
During warhead assembly disassembly and major component test						1/20,000
Nuclear detonation case of fire			1/1,000,000			1/1,000,000
Premature so as to endanger launch aircraft assuming proper delivery techniques	1/1,000	1/10,000	1/1,000	1/1,000		1/10,000

APPENDIX B

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1. The probabilities derived in paragraph 3e of the basic study are for the complete weapon system and apply to prematures arising "from all causes". They are not directly applicable for inclusion in Military Characteristics for AEC guidance because the weapon designers cannot be required to minimize causes of prematures of which they have incomplete knowledge and over which they have only limited or no control.

2. One such cause of possible prematures is human error. As noted in the study, human error would seem to be a major contributor to the probability of a nuclear accident. However, only meager information concerning human error is available. The possibilities of human error, its frequency of occurrence, and the possible repercussions therefrom are under study, but knowledge is still limited. At present it would be impossible to state probabilities in any quantitative or even semi-quantitative way. Military Characteristics as now written include the phrase "exclusive of human error". The numbers stated in the premature probability requirements are for random component failure alone.

3. Some other causes of possible warhead prematures are those associated with other components in the complete weapon system. The connection between various such causes might be indicated by the following equation:

$$P_a \approx P_{wh} + P_{ak} + P_c$$

where P_a is the acceptable premature probability from all causes per weapon per stockpile life, P_{wh} is the probability arising in or associated with the warhead alone, P_{ak} is the same probability for the adaption kit alone, and P_c is the same for the carrier alone. The approximate equality sign is used because there are undoubtedly cross products of the terms on the right entering into the sum. These are probably second or third-order terms, however, and are neglected. Each of the terms in the equation above is itself, of course, a sum including contributions from human error and random component failure. Using small letters to indicate only random component failure contributions, and following the arguments developed in the basic study concerning their probable relative magnitude with respect to human error contributions, we can write

$$p_a \approx p_{wh} + p_{ak} + p_c \approx 1/10\ P_a$$

It is this number, p_a, which is included in the recommendations of paragraph 5b of the basic study for "random component failure alone".

4. The problem that now arises is how to apportion the total acceptable premature probability from random component failure alone, p_a, among p_{wh}, p_{ak} and p_c. Since (1) nothing is known or can reasonably be guessed

concerning the probable relative magnitudes of these three terms, (2) p_a has already been assigned a value one order of magnitude less than P_a, and (3) it does not appear reasonable to attempt too great refinement in an order of magnitude argument of the present sort, it is recommended that the acceptable value of p_{wh} be taken as approximately 1/10 P_a. This means, of course, that if p_{ak} and p_c are also of this approximate magnitude, then

$$p_{wh} + p_{ak} + p_c \approx 3/10 \ P_a \quad ,$$

but this does not appear of major significance, especially when the extremely small magnitude of all the numbers under discussion and the large relative uncertainties in them are considered. This recommendation is equivalent to that contained in paragraph 5b of the basic study for "random component failure alone". Its adoption leads to the following proposals for the premature probabilities section of Military Characteristics:

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PROPOSED MILITARY CHARACTERISTICS FOR A 10 KT OR LARGER WARHEAD

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Premature Probabilities: It shall be a design goal that the probability of a premature nuclear detonation of the warhead from random component failure alone in the entire stockpile to target sequence be less than 1 in 10^8 per weapon per stockpile life. In event the criteria for meeting this design goal lead to a militarily unusable weapon, the following premature probabilities from random component failure alone for the environments indicated are the maximum permissible.

a. During stockpile storage (weapon in an unready condition) including transportation, handling, and maintenance: 1 in 10^8. 1 – 100,000,000

b. During operational storage (weapon in a ready condition) including transportation, handling, maintenance, assembly and test operations, and loaded aboard the aircraft prior to the initiation of the drop sequence, and on a missile launcher prior to firing: 1 in 5×10^5. 1 – 500,000

c. During a missile trajectory over areas where friendly forces and/or populations might be endangered by a nuclear detonation: 1 in 5×10^4. 1 - 50,000

d. During that portion of the flight where friendly forces and/or populations will not be endangered by a nuclear detonation -- prematures occurring during this period will be considered operational duds and included as part of the functional reliability.

e. After initiation of the drop sequence and during the period wherein a nuclear detonation might endanger the launching aircraft or crew, assuming standard release techniques are employed -- 1 in 10^3. 1 – 1,000

PROPOSED MILITARY CHARACTERISTICS FOR A 1 TO 10 KT WARHEAD

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Premature Probabilities: It shall be a design goal that the probability of a premature nuclear detonation of the warhead from random component failure alone in the entire stockpile to target sequence be less than 1 in 10^6 per weapon per stockpile life. In event the criteria for meeting this design goal lead to a militarily unusable weapon, the following premature probabilities from random component failure alone for the environments indicated are the maximum permissible.

a. During stockpile storage (weapon in an unready condition) including transportation, handling, and maintenance: 1 in 10^8.

b. During operational storage (weapon in ready condition) including transportation, handling, maintenance, assembly and test operations, and loaded aboard the aircraft prior to the initiation of the drop sequence, and on a missile launcher prior to firing: 1 in 10^5.

c. During a missile trajectory over areas where friendly forces and/or populations might be endangered by a nuclear detonation: 1 in 10^4.

d. During that portion of the flight where friendly forces and/or populations will not be endangered by a nuclear detonation - - prematures occurring during this period will be considered operational duds and included as part of the functional reliability.

e. After initiation of the drop sequence and during the period wherein a nuclear detonation might endanger the launching aircraft or crew, assuming standard release techniques are employed - - 1 in 10^3.

PROPOSED MILITARY CHARACTERISTICS FOR A LESS THAN 1 KT WARHEAD

<u>Premature Probabilities</u>: It shall be a design goal that the probability of a premature nuclear detonation of the warhead from random component failure alone in the entire stockpile to target sequence be less than 1 in 10^8 per weapon per stockpile life. In the event the criteria for meeting this design goal lead to a militarily unusable weapon, the following premature probabilities from random component failure alone for the environments indicated are the maximum permissible.

a. During stockpile storage (weapon in an unready condition) including transportation, handling, and maintenance: 1 in 10^6.

b. During operational storage (weapon in ready condition) including transportation, handling, maintenance, assembly and test operations, and loaded aboard the aircraft prior to the initiation of the drop sequence, and on a missile launcher prior to firing: 1 in 10^5.

c. During a missile trajectory over areas where friendly forces and/or populations might be endangered by a nuclear detonation: 1 in 10^4.

d. During that portion of the flight where friendly forces and/or populations will not be endangered by a nuclear detonation -- prematures occurring during this period will be considered operational duds and included as part of the functional reliability.

e. After initiation of the drop sequence and during the period wherein a nuclear detonation might endanger the launching aircraft or crew, assuming standard release techniques are employed -- 1 in 10^3.

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