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TECHNICAL REPORT ARRAD-TR-85002

SIMULATION OF AREA WEAPONS EFFECTS (SAWE) SAFETY CRITERIA

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This report provides quantified safety criteria for the Simulation of Area Weapons Effects (SAWE) Program. It discusses four specific areas: blast overpressure, blunt trauma, burn, and eye flash hazards. Each hazard is defined as to potential severity and classified according to Army regulation hazard severity levels. Acceptable risk criteria are developed based on severity and probability.

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INTRODUCTION

The Simulation of Area Weapons Effects (SAWE) Program objective is to develop an improved and effective training device to integrate indirect fire support into Multiple Integrated Laser Engagement System (MILES) exercises. This must be done to provide realistic training to Fire Support Team (FIST) personnel and to realistically simulate the incoming sound, flash, bang, and smoke of impacting artillery/mortar projectiles. The basic SAWE indirect fire concept is shown in figure 1. Realistic simulation of the incoming projectiles will cause the maneuver personnel to react and impart a sense of being under fire. The system developed through the SAWE Program must be capable of providing the surprise of an actual artillery or mortar attack and be accurate enough to provide realistic training for the FIST personnel who must be able to adjust the impact onto the target by communicating necessary corrections through normal fire direction channels (ref 1).

The Jet Propulsion Laboratory (JPL) has been tasked to define the technical feasibility of developing an indirect fire system (IFS) that will meet all of the SAWE Program criteria. As part of that effort, JPL has defined eight specific safety hazards that must be fully addressed during the program: blast overpressure, blunt trauma, burn, chemical simulants, eye flash, eye shrapnel, sharp trauma, and smoke inhalation. JPL has indicated that quantifiable safety standards are not available from the Army in these areas. Additionally, there is no official Army position on acceptable risk criteria for application in developing training devices.

This report provides quantified safety criteria for the SAWE Program in four of the eight areas of concern. Criteria are provided for blast overpressure, blunt trauma, burn, and eye flash hazards. Each hazard is defined as to potential severity and classified according to the MIL-STD-882A (ref 2) classification as Category I, II, III, or IV hazards, as follows:

Category I - Catastrophic. May cause death or system loss.

Category II - Critical. May cause severe injury, severe occupational illness, or major system damage.

Category III - Marginal. May cause minor injury, minor occupational illness, or minor system damage.

Category IV - Negligible. Will not result in injury, occupational illness, or system damage.

A separate section is provided to address the concept of acceptable risk criteria. This concept, although not new, has historically been difficult to define. It is necessary that risk be defined not only with respect to the equipment developed through the SAWE Program, but also with respect to the scenario in which that equipment will be used and the ultimate benefit to the Army that the equipment will produce. To meet these three requirements, the risk criteria must be developed jointly by the developer and the user. The acceptable risk criteria presented in this report stem solely from the development community. As such, they are proposals rather than established criteria, pending user review and acceptance.

TECHNICAL SAFETY CRITERIA

Blast Overpressure

The IFS must be capable of simulating the audio signal of an incoming artillery or mortar projectile. This requires the generation of a "bang" cue to alert maneuver personnel to the presence of incoming rounds (ref 1). Realism of this cue cannot approach that of real artillery weapons; however, the cue level will directly influence the effectiveness of the simulator. To meet the training requirements of the simulator, the overpresssure must be designed to reach the maximum level consistent with safe operation.

Specific safety criteria for the type of exposure expected from the indirect fire effects simulator are given in table 1 and figure 2 (ref 3). Safety limits for impulse noise either without hearing protection or with single or double hearing protection are provided in figure 2. Noise levels greater than curve Z are not permitted due to the possibility of non-auditory physiological injury.

Table 1. Impulse noise limit selection criteria

Maximum expected number of exposures in a single day	Impulse noise limit		
	No protection	Either plugs or muffs	Both plugs and muffs
1000	W	X	Y
100	W	Y	Z
5	W	Z	Z

The criteria defined in figure 2 consider normal operating conditions of the IFS which cannot be exceeded. When the noise is generated by an abnormal condition, such as an accident or malfunction, the safety criteria in figure 2 cannot be realistically applied because of the inability to control the circumstances. Although an attempt can be made to make the system "fail-safe," this may be too costly, or it may significantly reduce operational effectiveness. Therefore, a certain risk will have to be assumed which will depend on the severity and probability of the hazard.

In the case of impulse noise, severity is easily correlated to figure 2. This correlation is discussed below and presented in tables 2 and 3. Peak pressure levels exceeding the Z curve are considered Category I, catastrophic. This is because of the possibility of non-auditory physiological injury at levels greater than the Z curve. Peak pressure levels at or below 140 db (curve W)

Table 2. Blast overpressure hazard severity (without hearing protection)

CATEGORY I (CATASTROPHIC)	NOISE LEVELS GREATER THAN CURVE Z
CATEGORY II (CRITICAL)	NOISE LEVELS BETWEEN CURVE W AND Z
CATEGORY III (MARGINAL)	N/A
CATEGORY IV (NEGLIGIBLE)	NOISE LEVELS BELOW CURVE W

Table 3. Blast overpressure hazard severity (single hearing protection)

CATEGORY I - CATASTROPHIC	
• NOISE LEVELS GREATER THAN CURVE Z	
CATEGORY II - CRITICAL	MAXIMUM EXPECTED NUMBER OF EXPOSURE PER SINGLE DAY
• NOISE LEVELS BETWEEN CURVE W AND Z	>1000
• NOISE LEVELS BETWEEN CURVE X AND Z	1000
• NOISE LEVELS BETWEEN CURVE Y AND Z	100
• NOT APPLICABLE	5
CATEGORY III - MARGINAL	N/A
CATEGORY IV - NEGLIGIBLE	
• NOISE LEVEL BELOW CURVE X	1000
• NOISE LEVEL BELOW CURVE Y	100
• NOISE LEVEL BELOW CURVE Z	5

require no hearing protection and are considered Category IV, negligible. If single hearing protection is used, peak pressure levels at or below curve X are considered Category IV, negligible. Considering no hearing protection, peak pressure levels greater than curve W, but less than Z are assumed to be capable of inducing permanent hearing damage. Therefore, this falls into the hazard severity of Category II, critical. In the case of single hearing protection, the area between curve X and Z is considered to have a hazard severity of Category II. This also depends on the number of exposures per day.

This is considered a conservative approach, but without a clear definition of injury expectation as noise levels exceed curve W, it is impossible to justify a more liberal approach. A probability distribution curve that depicts the probability of severe injury with respect to noise level and frequency would identify areas within the graph where the hazard severity level could be Category III, marginal.

Eye Flash

The IFS must be designed to simulate both a bang and a flash signature at the point of impact for artillery and mortar projectiles with point detonating and/or air burst fuzes (ref 1). As with the audio signal, the flash signal design will reflect trade-offs between maximum levels of safety and maximum levels of training effectiveness (realism). This type of simulation has the potential of damaging the eyes of troops involved in the training exercise.

The eye hazard from the IFS depends on the optical spectrum, intensity, duration, and distance of the source from the viewer. Depending on the status of these variables, the viewer may experience no impairment, (flash) blindness, or permanent eye damage. To provide a visual cue that simulates bursting artillery/mortar projectiles, the IFS flash must fall within the optical spectrum ranging from 400 to 1400 nm and be of a momentary (<10 seconds) nature. The primary concern is retinal thermal injury which causes permanent eye damage.

The permissible retinal irradiance for momentary viewing of extended sources as a function of retinal image size is shown in figure 3. Curve B is a maximum permissible exposure (MPE) level developed by the U.S. Army Environmental Hygiene Agency (AEHA) (ref 4) while curve A is an MPE level developed by Ham, et al. (ref 5). Personnel exposed to a retinal irradiance in the region between these two curves have a low probability of injury and if retinal injury occurs, it would be minor.[1]

Based on the data presented in figure 3, eye flash hazards are categorized as follows:

Category I - Catastrophic. There are no catastrophic hazards associated with eye flash.

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[1] Meeting, 17 November 1981, between S. Hoxha of ARRADCOM and J. Franks, AEHA.

Category II - Critical. Includes personnel exposure to retinal irradiance exceeding curve B.

Category III - Marginal. Includes personnel exposure to retinal irradiance falling between curve A and curve B.

Category IV - Neglibible. Will include personnel exposure to retinal irradiance on or below curve A. This is an acceptable exposure level.

The criteria established by the AEHA considers normal operating conditions of the IFS; therefore, personnel exposure to retinal irradiance greater than curve A is not permitted under normal conditions. The hazard categories defined above for eye flash have been developed to address abnormal situations, such as an accident or malfunction, that may be encountered in training with IFS.

An additional safety concern with high intensity light is that of flash blindness. Although flash blindness does not cause eye damage, it is capable of temporarily blinding an individual. This temporary blindness may produce catastrophic results if an individual is performing a function that will not tolerate even a temporary loss of sight (i.e., driving a vehicle or piloting an airplane). In evaluating the hazard due to flash blindness, it is important to know the function that may be carried out at that time and the detrimental effect flash blindness would have. Flash blindness can be considered an acceptable hazard if it does not significantly affect operation of critical functions. Therefore, the hazard severity depends on the operations affected during the exercise and the hazards that may result.

Due to the nature of flash blindness, it is nearly impossible to quantify a threshold value. The degree of hazard depends on the extent of blindness (partial or total) and the duration of blindness (less than one second to several minutes). As such, flash blindness criteria have not been developed. This is, however, an area that needs to be quantitatively evaluated during testing of the IFS.

Burn Hazard

One method of providing both the audio and visual cues that the IFS must produce in a single package is through the use of an explosive or pyrotechnic composition. If this method is used, the potential exists to expose individuals to burn hazard. Burns are classified as first, second, or third degree based on the skin damage. Burn levels are defined as follows:

First degree. This will result in no more than a severe reddening of the exposed skin. It is equivalent to a sunburn.

Second Degree. Produces blistering, but normally there is no immediate breakage of the skin.

Third Degree. Results in charring or blackening of the skin, damage to the flesh underneath, and normally produces open wounds.

The degree of burn injury depends on the total dose of radiant energy received by the skin and the rate at which the energy is received. In attempting to establish safety criteria for burn hazard, the most difficult problem is defining the values of heat flux required to generate first-, second-, and third-degree burns. A variety of studies on thermal effects have been performed and thermal thresholds identified for each degree of burn; however, there is little consistency in the results.

During the 1950's, Alice M. Stoll and associates at the Aerospace Medical Research Department of the Naval Air Development Center in Johnsville, Pennsylvania, studied skin reaction to radiant heat. They measured the time taken at different heat flux levels for pain to be felt and for blisters to appear. Results are presented in figure 4. They found that for a heat flux of 0.25 $cal/cm^2/sec$, pain would be felt in 4 seconds; blisters would start to appear in about 10 seconds; and full blisters would have formed after 10 seconds (ref 6).

In 1952, J. B. Perkins, H. E. Pearse, and H. D. Kingsley, of the University of Rochester, investigated the relation of intensity of applied thermal energy to the severity of burns for flash burns. Results of this study are presented in figure 5. Comparing results of this study with those of Alice M. Stoll shows that a larger amount of energy is required to induce a first-degree burn. For example, a 5-second duration of radiant energy of 0.8 $cal/cm^2/sec$ produces a first-degree burn in most cases; however, there were a small number of cases that developed a mild second-degree burn (ref 7).

In 1970, Arthur N. Takata, of IIT Research Institute, performed a study for the Armed Services Explosive Safety Board (now called Department of Defense Explosive Safety Board) investigating fire hazard distances, specifically addressing irradiance in the vicinity of fires involving solid fuels and personnel exposure to thermal energy. Results are presented in figure 6, which depicts the relationship between incident radiant intensity and exposure time for various burn severities. Comparison of these data with the previous data shows that these curves lie between those proposed by Alice M. Stoll and those proposed by the University of Rochester study (ref 8).

After reviewing the three studies, it was concluded that the curves presented by Mr. Takata are most applicable to evaluating the type of burn hazard expected with the IFS. The thermal radiation expected from the IFS is a visible flash of flame produced by the detonation of an explosive, which ge[illegible]ates a high degree of thermal energy over a very short period of time. The [illegible] performed by Alice M. Stoll and her associates is not applicable to this case [illegible]ice it does not address explosive-type fires. The University of Rochester study was disqualified because of the number of observed cases in which the thermal flux identified with a specific degree of burn produced burns of a higher degree. Mr. Takata's study is a good choice for a number of reasons: (1) it has been accepted by the Department of Defense Explosive Safety Board; (2), it specifically considers explosive-type fires; (3) it is more conservative than the University of Rochester study and, therefore, minimizes cases where the burn severity for a specific thermal flux exceeds the associated degree of burn; and (4) the study findings fall in the middle ground between the other two studies available and is less open to criticism.

Using the curves presented in figure 6, the following burn hazard categories are provided:

Category I - Catastrophic. Any combination of incident radiant intensity and exposure time on or exceeding the third-degree burn curve.

Category II - Critical. Any combination of incident radiant intensity and exposure time between the second and third-degree burn curves.

Category III - Marginal. Any combination of incident radiant intensity and exposure time between the first and second-degree burn curves.

Category IV - Negligible. Any combination of incident radiant intensity and exposure time below the first-degree burn curve.

Blunt Trauma

The IFS is a training device specifically designed for firing into areas of friendly troops. If it operates properly, it is expected to burst a certain distance overhead, presenting a negligible hazard; however, should it fail to airburst, there is a possibility that the round may hit a soldier during its downrange flight. Such a hit may cause death or injury due to blunt trauma. The term "blunt trauma" is used to describe impacts whose predominant mechanism of wounding is a blunt crushing or contusing of tissues, as opposed to cutting or penetrating injuries.

The best source of information regarding probability of injury or lethality due to blunt trauma is presented in the draft report by L. Sturdivan of the Biophysics Division of the U.S. Army Chemical Research and Development Command, entitled, "Modeling of Blunt Trauma Research" (ref 9). In this report, Mr. Sturdivan defines a predictive model of human lethality and produces a probability distribution function for death from blunt trauma.

The predictive model proposed by Mr. Sturdivan is in the form of an inequality discriminant model:

$$\frac{MV^2}{W^{2/3}TD} < k\mu_o/\rho^{1/3}$$

where

M = Mass of the impacting projectile (g)

V = Velocity of the impacting projectile (m/s)

D = Diameter of projectile (cm)

W = Body mass (kg)

T = Thickness of body wall over vulnerable organ (cm)

μ_o = Lowest lethal shear stress (dynes/cm^2)

ρ = Average density of body mass (kg/cm^3)

k = Constant determined from data

The model implies that a body mass receiving a blunt impact which satisfies the inequality model would be expected to survive; if not, the injury would be expected to be lethal. The probability for lethality to occur is:

$$p = \frac{1}{1 + \exp\{\alpha + \beta \ln (MV^2/W^{1/3} TD)\}}$$

Where α and β are the curve fitting parameters determined by the principle of least squares. A curve of probability of death versus level of blunt impact over lung and liver is presented in figure 7 (ref 9) (the two organs most vulnerable to fatal injury from projectile-induced blunt trauma).

The coefficients α and β are:

	α	β
Lung (thorax)	34.13	-3.597
Liver (abdomen)	65.23	-6.847

The values chosen for T which is the thickness of body wall over the vulnerable organ are 2 cm for a small man, 3 cm for an average man, and 4 cm for a large man (ref 10).[2]

Hazard severity levels for blunt trauma can be derived from figure 7, which gives the probability of lethality versus level of blunt impacts to lung and liver. Therefore, a Category I, catastrophic hazard can be defined as the level of blunt impacts that produce lethality. Categories II and III, critical hazard and marginal hazard, respectively, can also be defined since they are related to the probability curve in figure 7. The relationship which exists is that a blunt impact level capable of a probability of lethality greater than 50% will result

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[2] These models are designed to define male susceptibility to blunt trauma; female susceptibility has not been considered. It is not known at this time if these models can be used to address susceptibility of women to blunt trauma.

in a Category II, severe injury if it does not kill the victim. Also blunt impact to the eye will produce a severe injury. A blunt impact level capable of producing a lethality less than 50% will result in a Category III, minor injury if it does not kill the victim or impact the eye. Category IV is a negligible hazard, that is, a blunt impact of zero probability of kill and incapable of producing injury.[3]

Hazard severity for blunt trauma is categorized as follows:

Category I - Catastrophic. Blunt impact levels capable of producing lethality.

Category II - Critical. Blunt impact levels capable of producing a probability of lethality greater than 50% will produce a severe injury if it does not produce a lethality. Also, blunt impacts to the eye.

Category III - Marginal. Blunt impact doses capable of producing a probability of lethality of less than 50% will produce a minor injury if it does not produce a lethality or impact to the eye.

Category IV - Negligible. Blunt impact levels not capable of producing lethality or injury.

The probability formula and curves are derived for perpendicular impact into the body. Impact angles other than 90 degrees may affect the probability curves significantly and should be taken into consideration when evaluating the blunt trauma hazard risk.

ACCEPTABLE RISK CRITERIA

Safety, as defined in the dictionary, is "freedom from injury or risk." This implies that safety is an "absolute" measurable condition. However, absolute safety, as the definition implies, cannot be realistically achieved because every human endeavor incurs a degree of risk. Based on these fundamental principles, it must be concluded that safety is a relative condition, which depends on the acceptability of risk, and that determining the degree of safety involves both measuring the risk and determining its acceptability. Measuring risk is a scientific process that determines the probability and severity of a hazard; determining its acceptability is a subjective process that depends on social and political implications, operational constraints, cost, time, technology, and the availability of alternatives.

At this time, there is no formal Army definition of acceptable risk criteria. Informally, however, the 1×10^{-6} probability of a catastrophic event is

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3 Meeting, 17 November 1981, between S. Hoxha of the ARRADCOM Safety Office and Mr. Sturdivan of the Chemical Research and Development Command.

considered acceptable and is alluded to in various government and industrial documents.

DARCOM Pamphlet 385-23, System Safety, discusses the concept of acceptable risk and provides specific risk levels for the various hazard severity levels (figure 8) (ref 10). However, the pamphlet states that these values should be used as a guide. Also, the values are applicable to the hazard severity categories defined in MIL-STD-882, not 882A. The hazard severity definitions in 882A are different and the risk levels suggested in the DARCOM pamphlet would have to be modified accordingly. The risk level as defined by the DARCOM pamphlet is the "largest acceptable probability of an undesired event taking place." One drawback with this definition is that it is an absolute probability value, as opposed to a probability rate. As such, it does not depend on time, events, population, items, or activity. To define a realistic acceptable risk criterion, it is imperative that an acceptable probability rate be assigned for each hazard category.

The Air Force System Safety Design Handbook, AFSC DH1-6 (ref 11) also recommends an acceptable risk level of a 1×10^{-6} fatality probability. This is based on the fatality probability associated with normal hazards experienced in day-to-day living. The handbook also provides a hazard spectrum with classifications based on risk probabilities (fig. 9). Comparing these hazard classifications with those of MIL-STD-882A reveals that the former depend on the probability of fatality, while the latter are based on hazard severity.

In contrast to the documents which recommend only an acceptable risk criteria, MIL-STD-1316C (ref 12) specifically defines a minimum acceptable failure rate for fuze design. It requires that as a minimum, the fuze safety system failure rate not exceed one failure in one million before intentioanl initiation of the arming sequence.

The concept of acceptable risk has been the subject of various studies within the nuclear community. In his book, Product Safety Management and Engineering, Willie Hammer summarizes some of these studies. Mr. Hammer indicates that when the probability of death from an accident is 1×10^{-3} or greater per person, per year, the risk is considered unacceptable and immediate action is required. On the other hand, when the probability of death from an accident is 1×10^{-5} or less per person, per year, the average person is not unduly concerned and the risk is considered acceptable (ref 13).

It is obvious from the consistency of these documents that a minimum acceptable risk level of one in a million for a catastrophic hazard can be applied. As the hazard severity drops, the acceptable risk level drops accordingly. For example, a critical hazard correlates to an acceptable risk level of 10^{-5}, a marginal hazard corresponds to an acceptable risk level of 10^{-3}, and a negligible, to risk level of one. However, these are absolute probability values and without defined units are considered to have no significant meaning. Risk presented in proper units is as important as the magnitude and can bring about positive changes. However, if units are improperly used, they can understate the importance of a hazard and can actually portray a safe condition. How these units are selected depends on the effects to be generated, comparisons to be made, decisions to be made, and the risk to be evaluated.

With respect to the IFS, the specific risk to be evaluated is associated with the training exercise. And the decision that needs to be made is whether the training exercise can be safely conducted using the IFS. Therefore, for the specific purpose of measuring the risk associated with the IFS, it is proposed that the acceptable probability rate be defined as the largest acceptable probability of an undesired event taking place during a single given training exercise.

For the specific purpose of evaluating the IFS, it is proposed that the acceptable probability rate be defined as the largest acceptable probability of an undesired event taking place during a given single training exercise. The exact scenario of the training exercise and its duration must be defined by the Combined Arms Center, U.S. Army Training and Doctrine Command. The proposed acceptable risk criteria for the SAWE Program for the various hazard severity classifications are presented in figure 10.

The acceptable risk criteria provided in figure 10 express the probability of a mishap resulting in a specific hazard severity during the length of the exercise. To determine whether or not the SAWE Program meets the acceptable risk criteria, it will be necessary to use the concept of fault tree analysis, as follows:

1. Place the undesired event at the top and assign a probability rate that would be acceptable for that event to occur.

2. Working down the fault tree, identify all independent hazardous conditions that are contributory events. These must be connected to the undesired event through an "OR" gate.

Fault tree diagrams for the three undesired events for the SAWE Program are represented in figures 11, 12, and 13. Also shown are the hazard severity and the acceptable probability rate. The acceptable risk level of the individual hazards considered in this report is dependent on the number of other hazards of a specific severity and their probability of occurrence.

CONCLUSIONS

1. Safety design criteria have been developed for the Simulation Area Weapons Effects (SAWE) Program in the areas of blast overpressure, blunt trauma, burn, and eye flash hazards.

2. Each potential hazard has been defined as to severity and classified according to the MIL-STD-882A hazard severity levels.

3. Acceptable risk criteria have been proposed. These criteria stem solely from the developer's viewpoint and must be considered proposals. Full coordination with the user is required.

RECOMMENDATIONS

1. The findings in this report should be fully coordinated with the user to insure that the proposed risk criteria are acceptable.

2. For blast overpressure, the Surgeon General should be requested to develop threshold curves for Category III hazards.

3. Flash-blindness should be qualitatively evaluated during testing to determine its impact on the safety of the training exercise.

4. For blunt trauma, the Biophysics Division of the Chemical Research and Development Center should be requested to develop lethality curves for blunt impacts at angles other than at 90 degrees.

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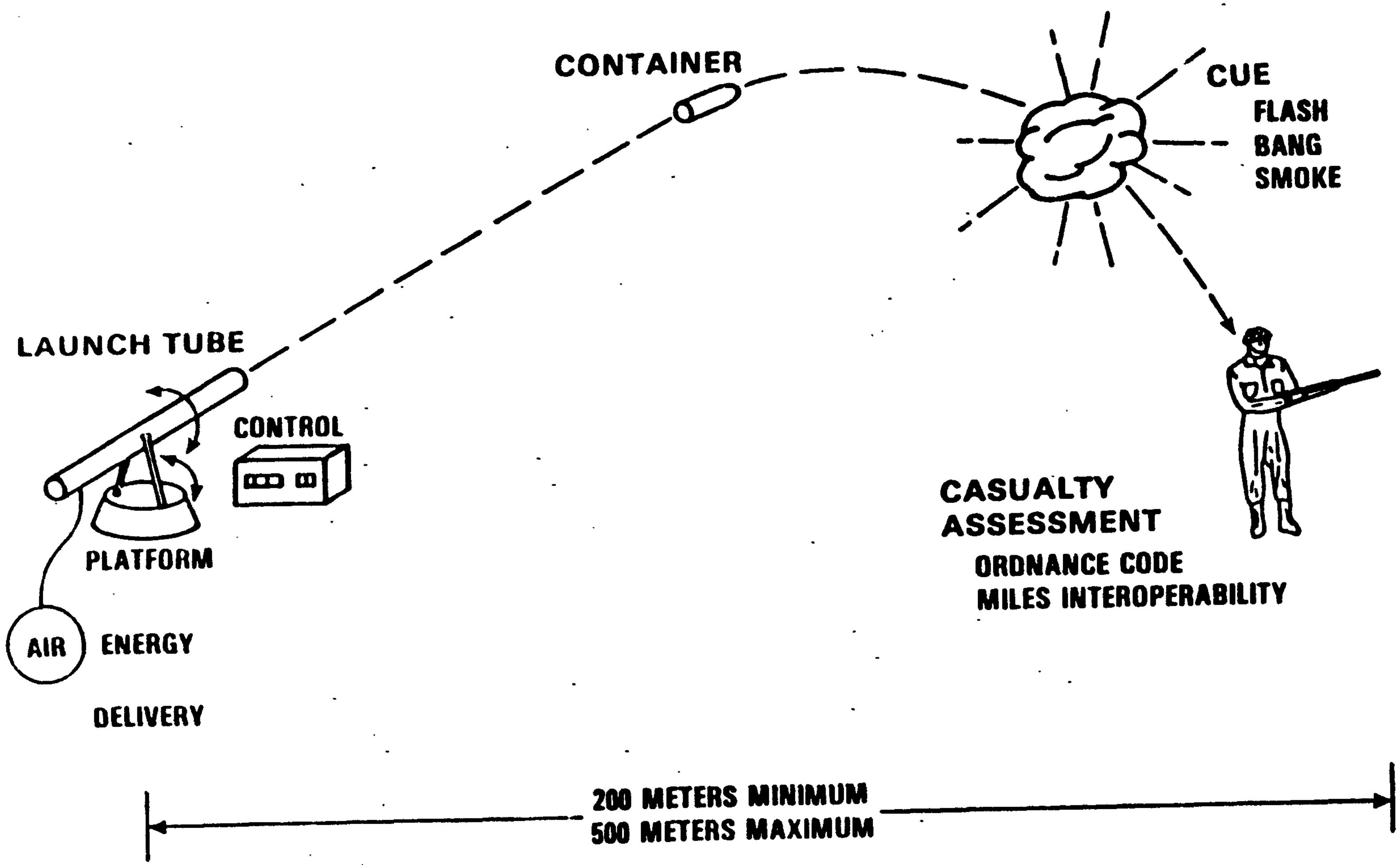


Figure '. Basic SAWE indirect fire concept

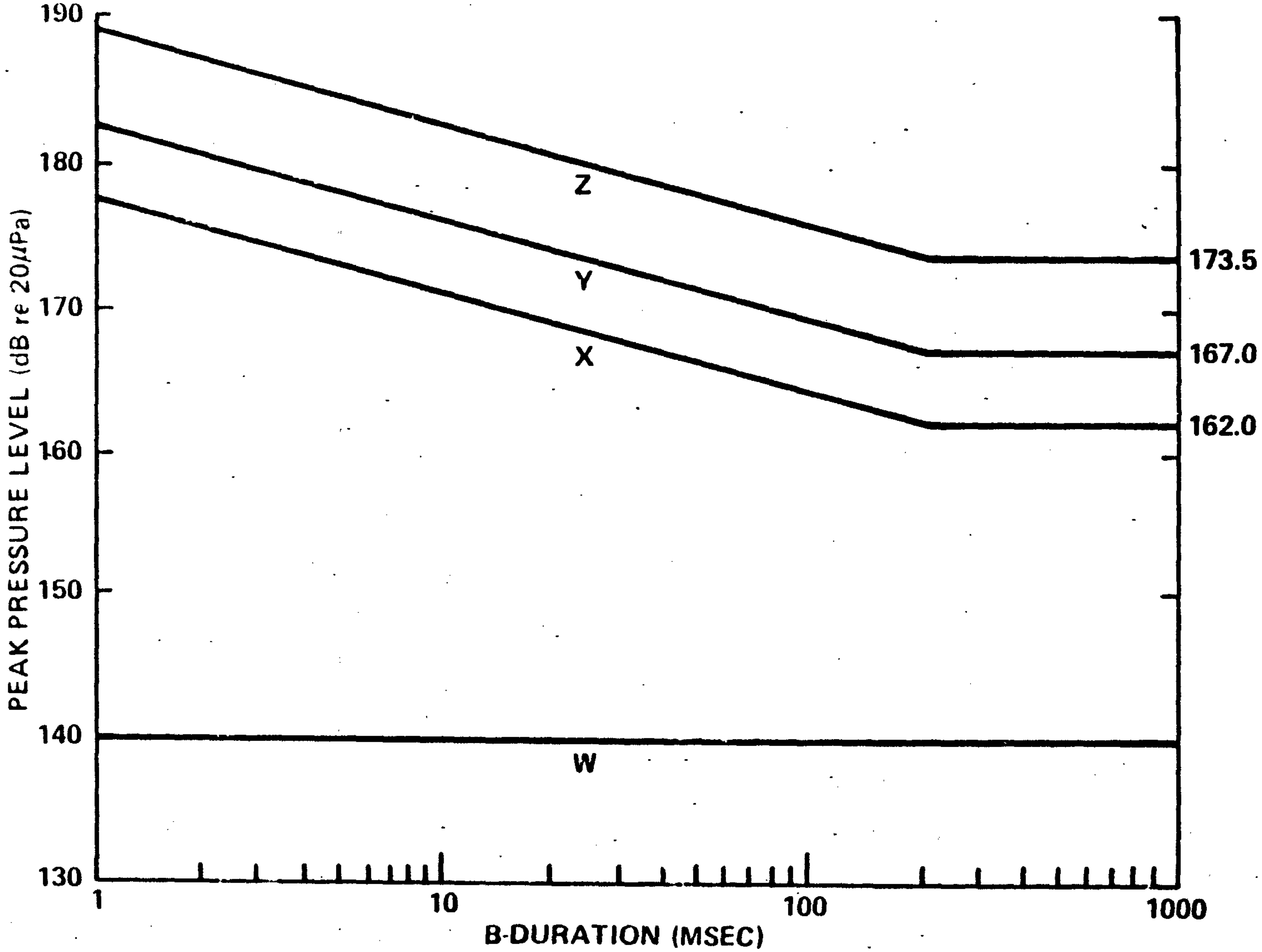


Figure 2. Peak pressure level and B-duration limits for impulse noise

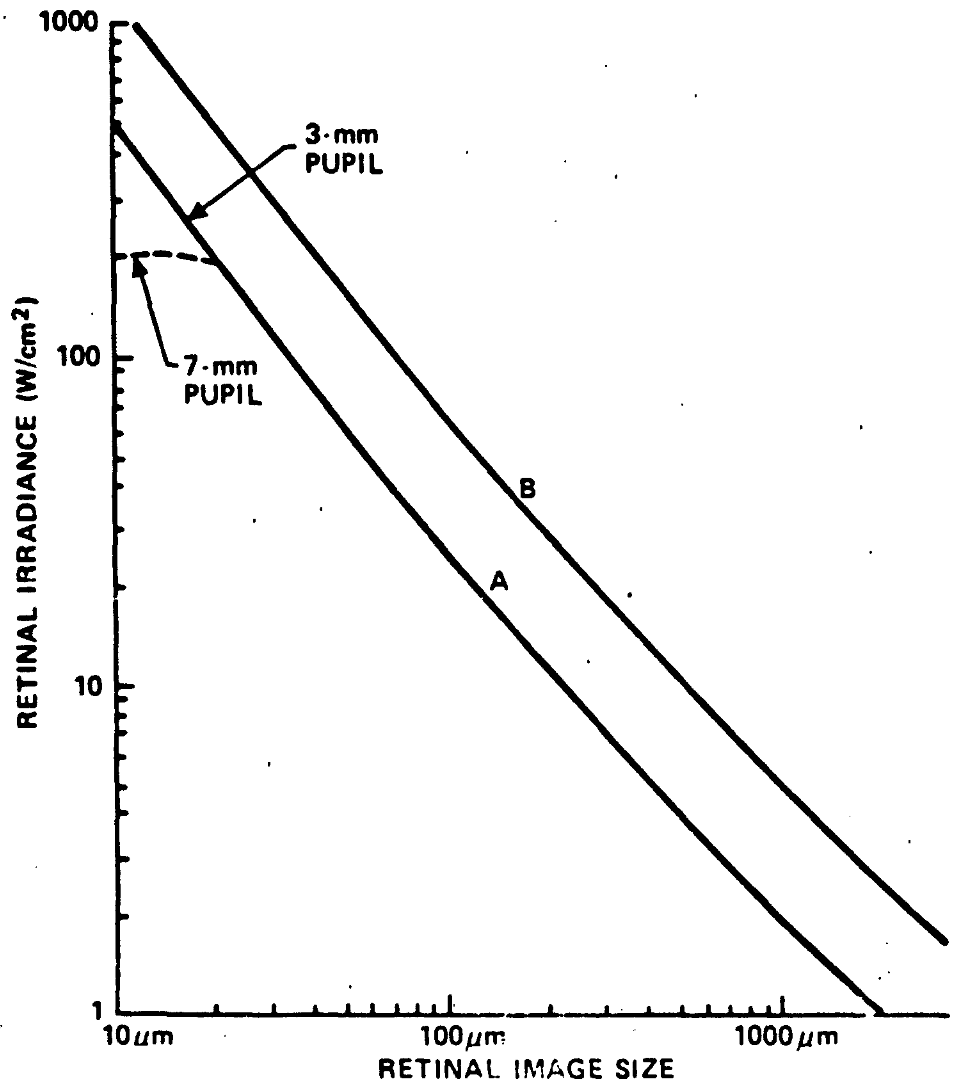


Figure 3. Permissible retinal irradiance for momentary viewing of extended sources as a function of retinal image size

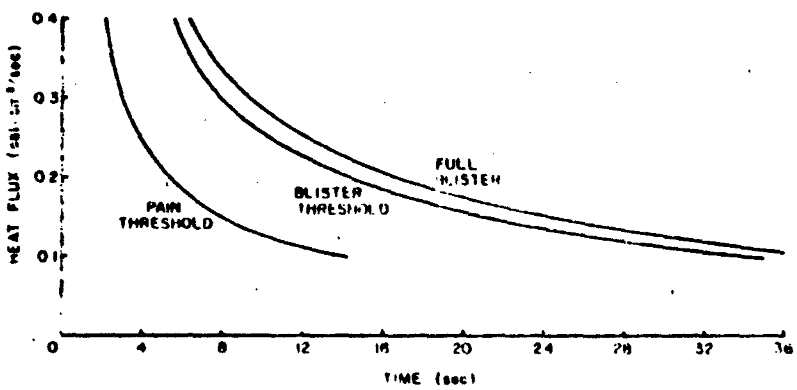


Figure 4. Physiological skin reaction to radiant heat exposure

NOTE: Figure 4 excerpted by special permission from the <u>Journal of Applied Physiology</u>, vol 14, 1959, copyright © 1959, by the American Physiological Society, Bethesda, MD 20814.

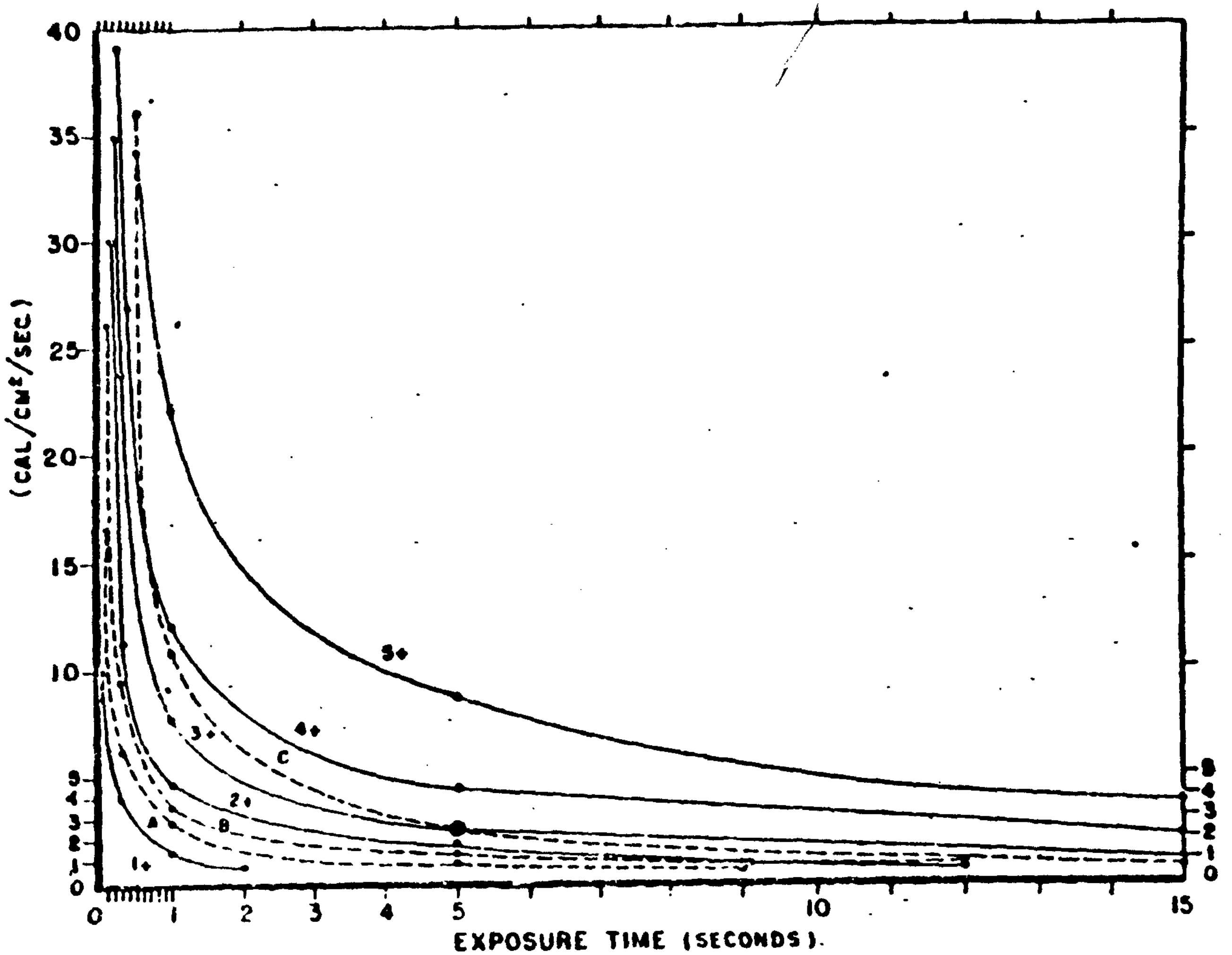


Figure 5. Flux density causing 50% probability thresholds versus exposure time (linear scale)

NOTE: The flux density required to cause the thresholds of five grades of surface change and three levels of penetration in depth is plotted on a linear scale against exposure time. The macroscopic thresholds of 1+ through 5+ are shown in solid lines and the microscopic changes of (A) epidermal, (B) transepidermal, and (C) deep dermal penetration are shown in dotted lines.

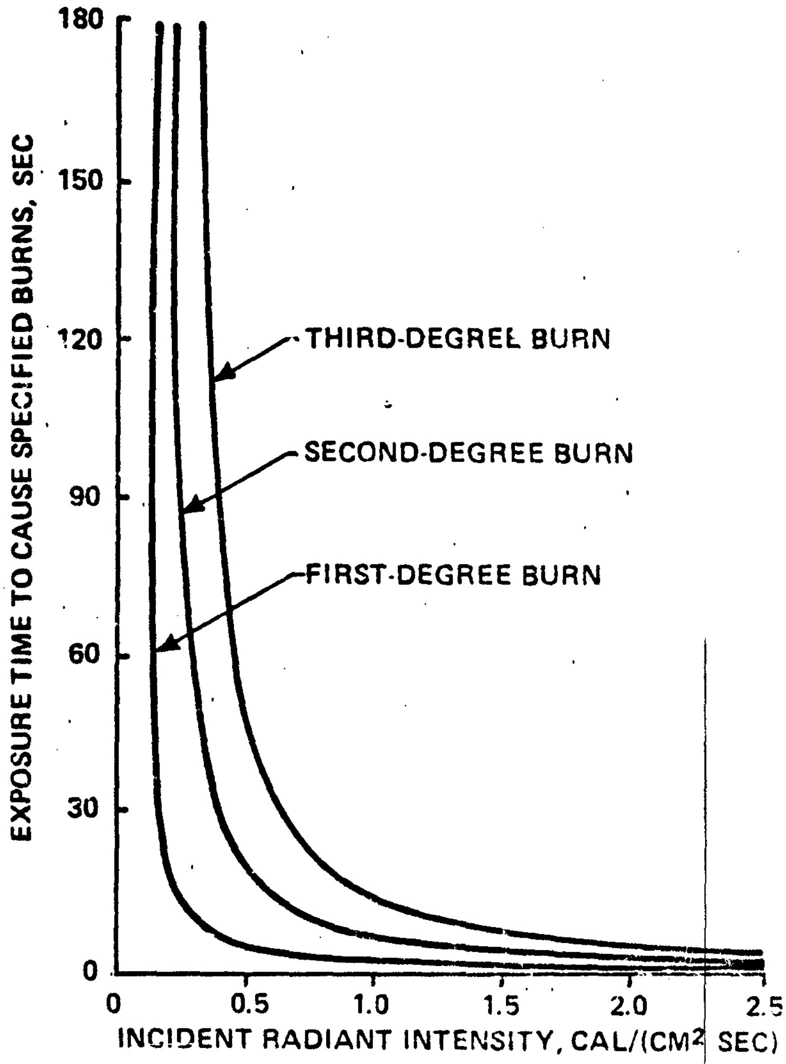


Figure 6. Radiant exposures to cause various flesh burns

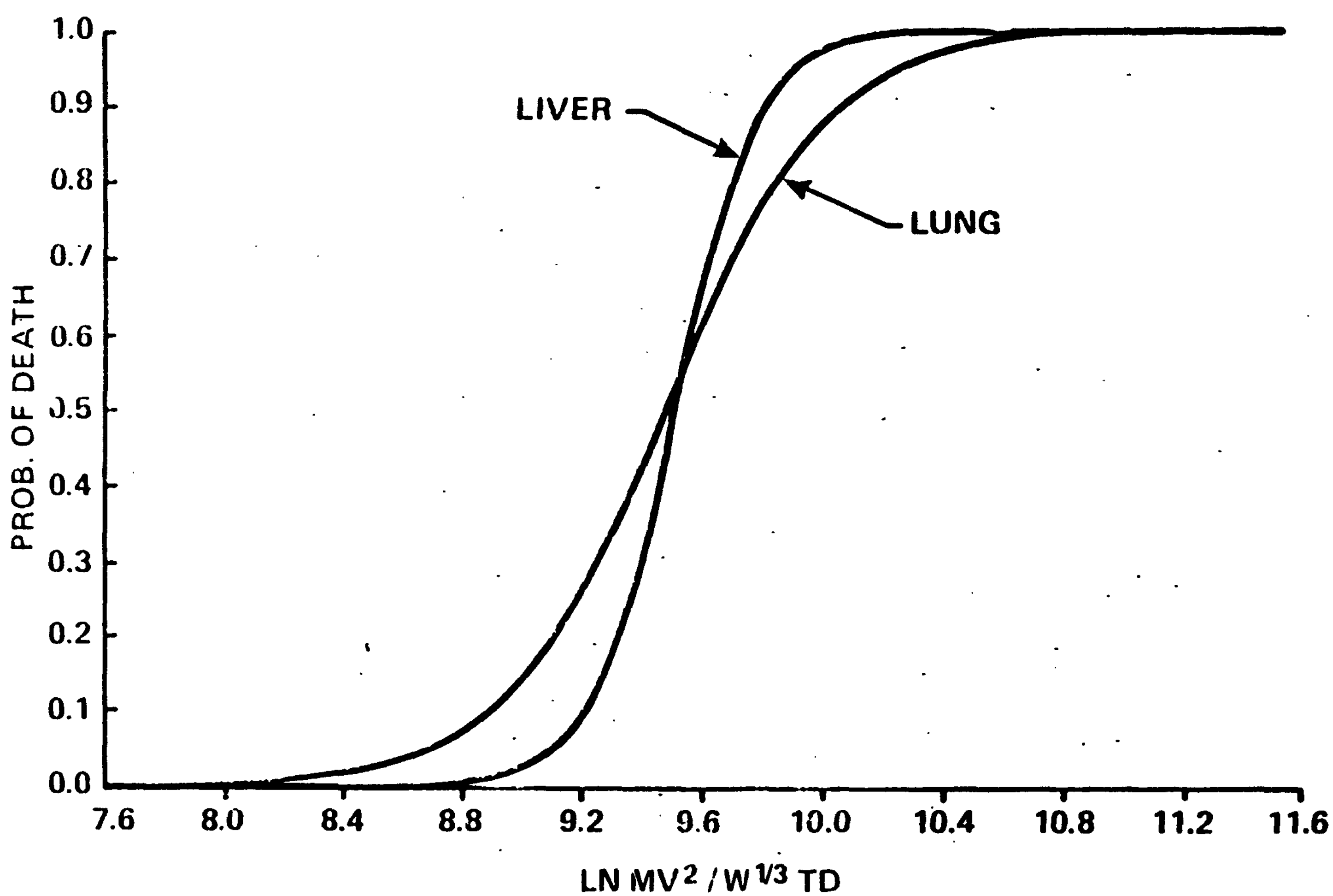


Figure 7. Lethality versus level of blunt impacts over lung and liver

HAZARD CATEGORY	RISK LEVEL* (LARGEST ACCEPTABLE PROBABILITY OF UNDESIRED EVENT TAKING PLACE)
CATEGORY I (NEGLIGIBLE)	1
CATEGORY II (MARGINAL)	10^{-2}
CATEGORY III (CRITICAL)	10^{-5}
CATEGORY IV (CATASTROPHIC)	10^{-6}

* See DARCOM Pamphlet 385-23.

Figure 8. Risk levels

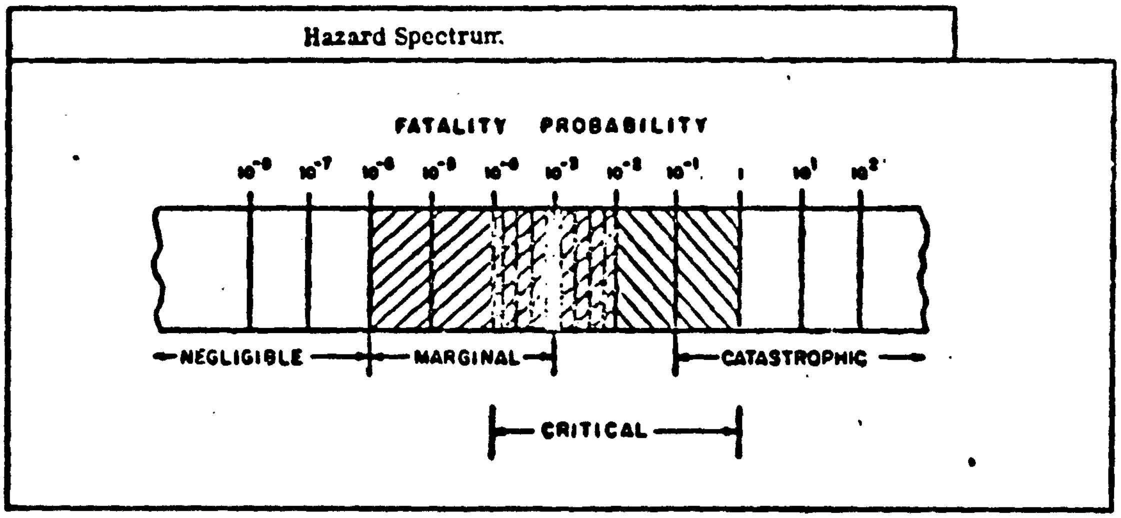
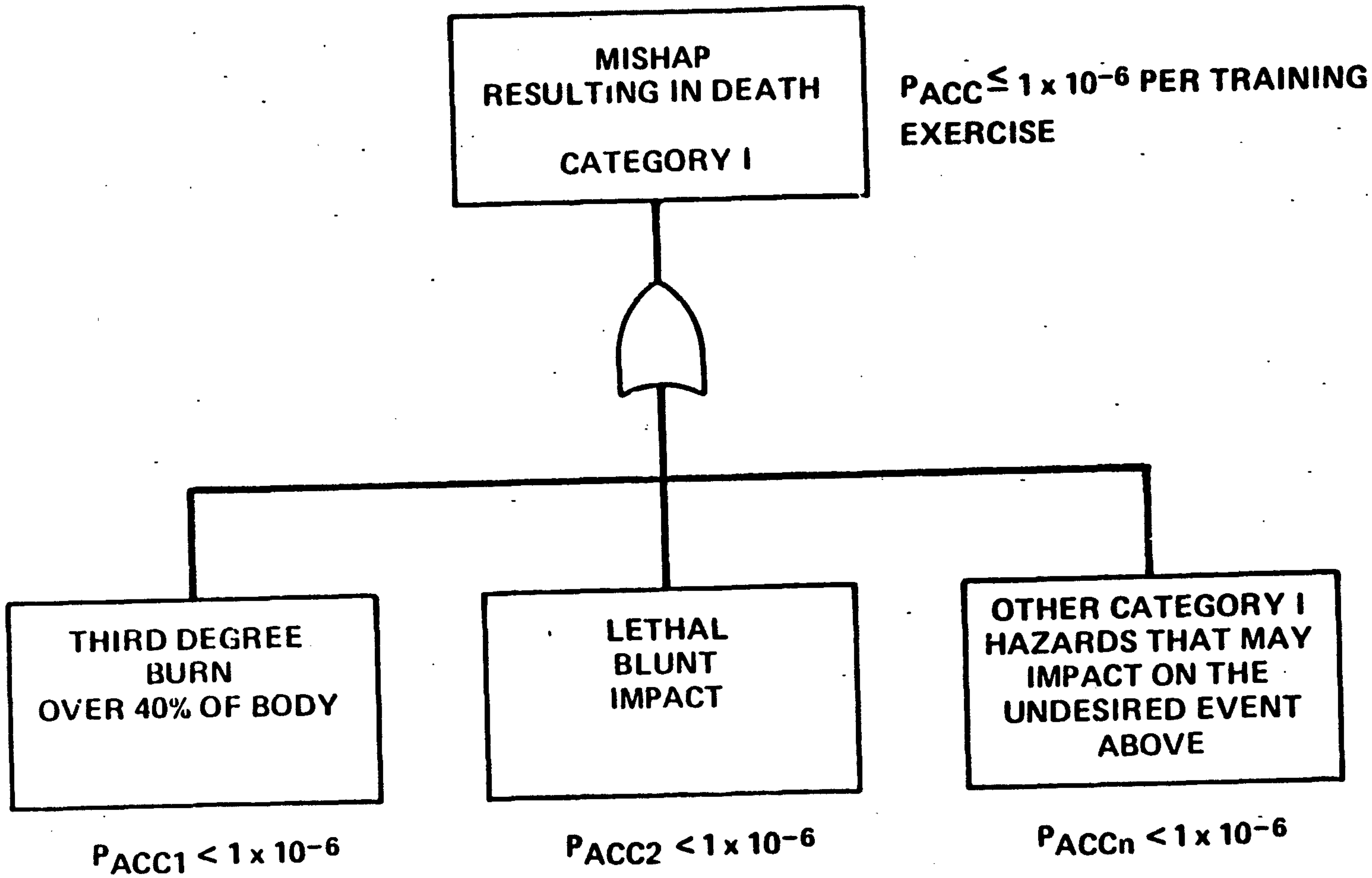


Figure 9. Air Force risk levels

HAZARD CATEGORY	ACCEPTABLE RISK LEVEL PER TRAINING EXERCISE
CATEGORY I (CATASTROPHIC)	10^{-6}
CATEGORY II (CRITICAL)	10^{-5}
CATEGORY III (MARGINAL)	10^{-3}
CATEGORY IV (NEGLIGIBLE)	1

Figure 10. Proposed acceptable risk levels for the SAWE Program



$P_{ACC} = P_{ACC1} + P_{ACC2} + \ldots\ldots + P_{ACCn} \leq 1 \times 10^{-6}$ PER TRAINING EXERCISE

Figure 11. Fault tree for a Category I mishap

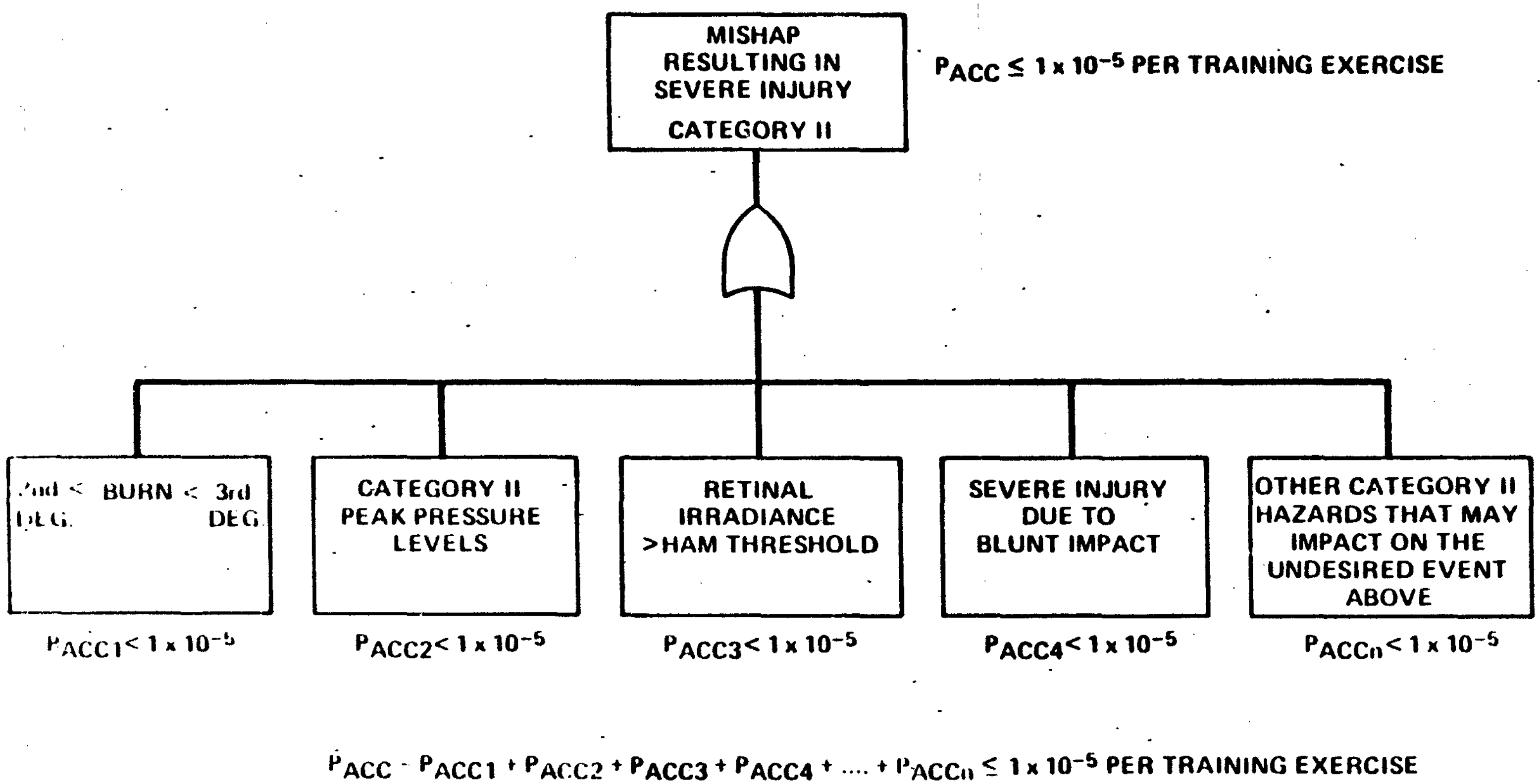
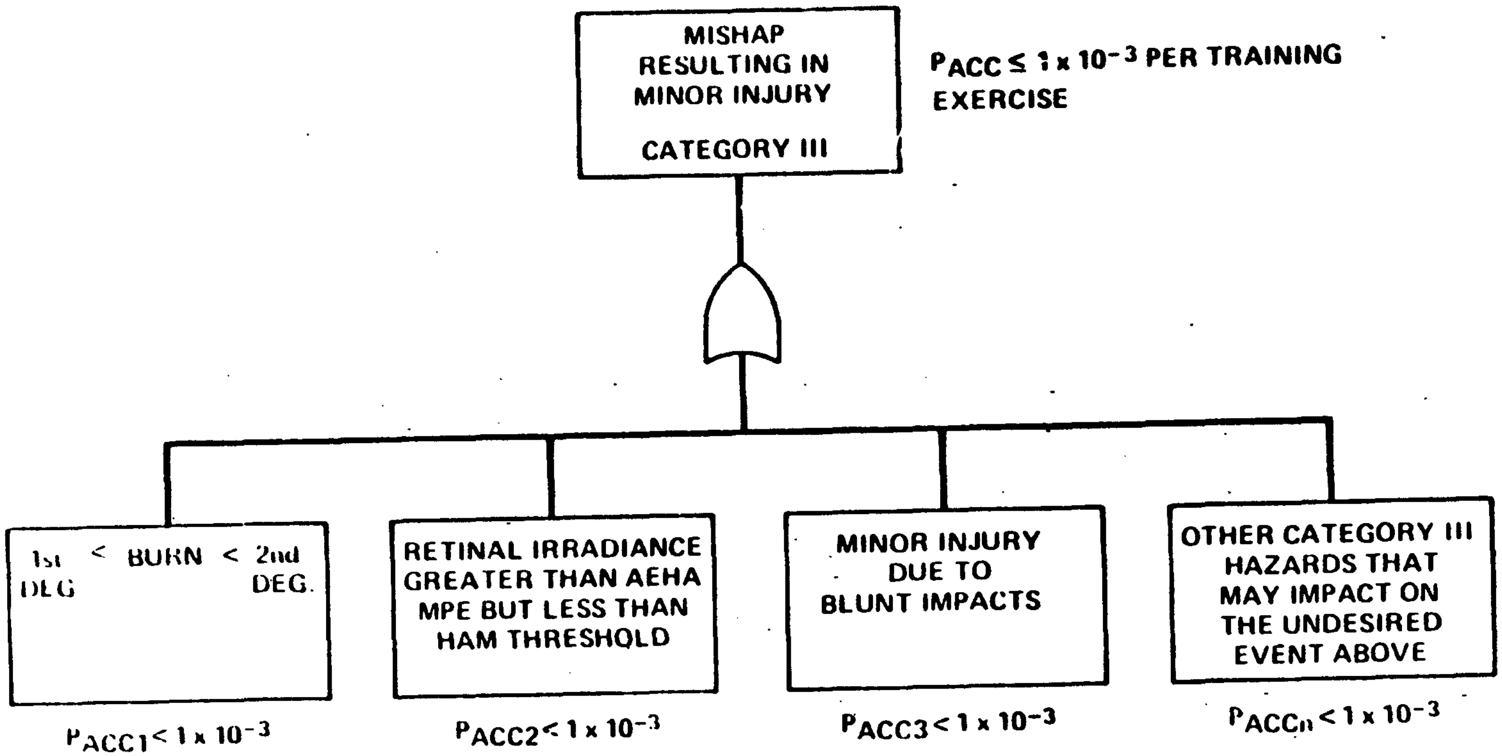


Figure 12. Fault tree for a Category II mishap



$P_{ACC} = P_{ACC1} + P_{ACC2} + P_{ACC3} + \ldots + P_{ACCn} \leq 1 \times 10^{-3}$ PER TRAINING EXERCISE

Figure 13. Fault tree for a Category III mishap

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