UNDERSTANDING THE RISK OF AMMUNITION KICKOUT

FROM EXPLOSION-SUPPRESSIVE STRUCTURES

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ABSTRACT

UNDERSTANDING THE RISK OF AMMUNITION KICKOUT FROM EXPLOSION SUPPRESSIVE STRUCTURES

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This paper presents a system safety model that justifies relaxing operating restrictions at weapons and ammunition test facilities.

The mission of the U.S. Army Combat Systems Test Activity (USACSTA or CSTA), Aberdeen Proving Ground (APG), MD, includes the evaluation of large caliber weapons. As these weapons increase in size, so does the danger associated with testing them. The availability of land for large caliber firing ranges is decreasing. Because of that unavailability, incompatible operations are often conducted contiguously. In such cases, personnel and facilities are exposed to the dangers associated with weapons testing.

There is no guarantee an explosive accident will never happen in a test structure, but it is a very unlikely occurrence. For an accident to occur, a complex sequence of events must happen. If that sequence is explicitly identified, then it can be controlled. By controlling selected hazards, the risk (risk is the expected value of an event or accident) can be reduced. If it has been reduced to an acceptable degree, the requirements applied to the design and subsequent operation of any facility can be relaxed.

Because of the high cost of constructing weapons test facilities, alternatives must be designed in the context of the risks associated with such testing. Using System Safety techniques, those risks can be identified and modeled. This paper suggests a model from which can be derived safe and cost-effective construction, design and operating alternatives for weapons testing facilities.

DIGEST

TITLE Understanding the Risk of Ammunition Kickout from Explosion Suppressive Structures

PURPOSE To inform a reader of the risk of ammunition being thrown from a containment structure (e.g. a magazine or explosive operating building), and whether that risk varies with the design style of the structure.

CENTRAL IDEA Understanding the circumstances that could lead to an unsuppressed detonation of a munition in an industrial, depot, or testing environment will make such an event more predictable, hence more preventable. An explicit model defining those circumstances demonstrates the low risk associated with a kickout, and it allows the risk to be compared between construction styles.

CONCLUSION Whatever the risk of ammunition kickout, it is not markedly different for any suppressive structure, regardless of construction style, if that structure has a frangible wall that will be lost in a detonation or an entrance way that allows direct access from the outside. This is explicitly defined by the fault tree contained herein.

ACKNOWLEDGMENT

This paper synopsizes a study conducted at the U.S. Army Combat Systems Test Activity (USACSTA or CSTA) by Mr. Thomas A. Lucas and I from January 1986 through October 1988. That study was recently published by the AMC Action Committee for System Safety as Technical Report 90-4. The quality and thoroughness of that original study are creditable to Mr. Lucas.

I also acknowledge Mr. William Watson who generated the cut sets in this paper using the software: Fault Tree Analysis using Personal Computers version 6, August 1987, developed by Mr. Jack Copeland. A special appreciation is extended to Misters Martin Mossa and Rodolfo Gil, from the USACSTA Safety Office, whose insights and criticisms helped focus and guide the technical considerations of this paper.

Historical Background

The mission of the U.S. Army Combat Systems Test Activity (USACSTA or CSTA), Aberdeen Proving Ground, MD, includes the evaluation of ammunition and weapons. As these systems increase in effectiveness, so does the risk associated with storing, handling, and testing them. That increase in risk is a result of encroachment, since the availability of land area for storing and testing those high-risk systems is decreasing. Because of that decrease, incompatible operations are often conducted contiguously. In such cases, personnel are subject to high risk exposure. The danger inherent in weapon testing, then, is an unexpected, unconfined detonation - an ammunition explosion. This is so because high-value facilities and equipment are necessarily exposed to the effects of such an event, and more important, people are exposed as well.

Weapons testing is not confined to weapon firing. It is a range of tests that demonstrate the reliability of a weapon and its ammunition. In addition to weapon firing, the testing includes regimes to demonstrate the hardiness of ammunition. Rough handling and environmental tests are conducted to prove that hardiness. The tests are conducted in sophisticated facilities which must meet the operational requirements of the testing and still embody explosion-suppressive qualities. That those operational and protective requirements are contradictory has resulted in facilities being designed and built that are adequately suppressive, but operationally restrictive.

To mitigate the real and political costs that would result from an explosive accident has necessitated expensive and conservative construction. This has been true at USACSTA, especially where test areas abut densely populated, public areas. At Aberdeen Proving Ground, there are two recent examples: a 14M $ welded steel containment facility and a 10M $ MCA project for laced, reinforced concrete firing barricades, both at USACSTA. Facilities so designed and constructed meet the dogmatic requirements of design codes, but may exaggerate or understate real dangers and may,then, be more costly than necessary. Because of the high cost of constructing test facilities, alternatives designed in the context of a risk profile (risk is the expected value of an accident) are desirable. Using analytic techniques, like the fault tree analysis described in this paper, such a profile can be developed. This report suggests a profile from which can be derived safe and cost-effective construction, design and operating alternatives. This paper defines the risk of an unconfined explosion.

Defining Kickout

The purpose of an explosion-suppressive structure is to mitigate the effects of a detonation; an explosion occurring outside the confinement provided by such a structure defeats its purpose. An unconfined detonation creates concern only in the case where personnel, facilities, or assets are exposed and incur some chance of injury or damage. Kickout is one such exposure. It is the escape from a containment structure (such as a storage, operating, or test facility) of an unexploded round of ammunition following an explosion in the structure. Although there is no guarantee an explosion will never happen in a suppressive structure, nor is there a guarantee a round of ammunition will never be ejected, a kickout is a very unlikely occurrence. For a kickout to occur, a complex sequence of events must happen. If that sequence is explicitly identified, then it can be controlled. If negligible, then it can be accepted.

This paper models the problem of kickout, which affects the design of magazines, barricades, and other suppressive structures. The model defines the mechanisms which cause an unconfined, unsuppressed explosion, and logically describe the order of their occurrence. The solution provided in this report is an identification of the events and hazards associated with the kickout phenomenon so its risk can be understood.

Describing the Fault Tree

The problem, then, is to create a model from which can be deduced the causes of an unsuppressed, unconfined explosion at an operating, test or storage facility. From that generic model, the case of kickout can be deduced as well. The logical choice for a model is a fault tree.

The tree defining the conditions necessary for an uncontained, unsuppressed detonation is a logic diagram consisting of three branches, each representing one variable of a mathematical statement. Logically, the top event can occur only if the underlying conditions in each branch have been satisfied. Each of the three branches defines one of the general conditions leading to the undesired outcome. That outcome is defined as "injury to personnel or facility damage caused by an unconfined detonation". The tree flows downward from the top event to the specific root causes. General outcomes at the head of the tree are connected to intermediate and root causes by logic gates. The gates depict the logical conditions of union and intersection that are analogous to addition and multiplication. Where describing a fault tree gate in the text, an additive or union condition is represented by an underlined, italic *or*, a multiplicative or intersection condition by an underlined, italic *and*.

The Head Event

Although kickout and a detonation that might result from a kickout are the principal interests of the fault tree, the tree is more general. In it are addressed many cases other than kickout. The conditions necessary for the top event are these: a round of ammunition is unconfined (it is outside the suppressive structure), *and* a person or facility is exposed, *and* the unconfined round of ammunition transmits energy. Further, it is probable that in a densely populated area, *given* an unconfined detonation, some damage or injury will occur.

There are three ways a munition might cause damage. If it is intact, the round can impart energy only if it is thrown or propelled *and* directly strikes a receiver. Alternatively, it can detonate. *Given* a detonation, energy might be transmitted via propelled fragments, *or* heat flux, *or* blast overpressure. Where the detonation occurs is significant. An exploding bomb can cause damage within some limited radius. If no exposed asset is within that radius, no damage or injury can be imparted. At military installations, undesirable exposures often exist; people and facilities are usually within the radius at which a munition, detonating unsuppressed, can cause damage or injury. Explosives are stored in a way that limits this exposure. They are isolated from populated areas and stored in bunkers designed to contain or direct missiles and the shock wave that result from an explosion.

Exposure of Assets

Exposure of personnel and facilities to the hazards of kickout is briefly detailed in the central branch of the tree. The branch is separated into two sections. One is the blast hazard - overpressure and heat flux - and the other a missile or fragment hazard. Neither of these conditions have been developed because of their complexity, although both normally exist.

Energy Released by Munition

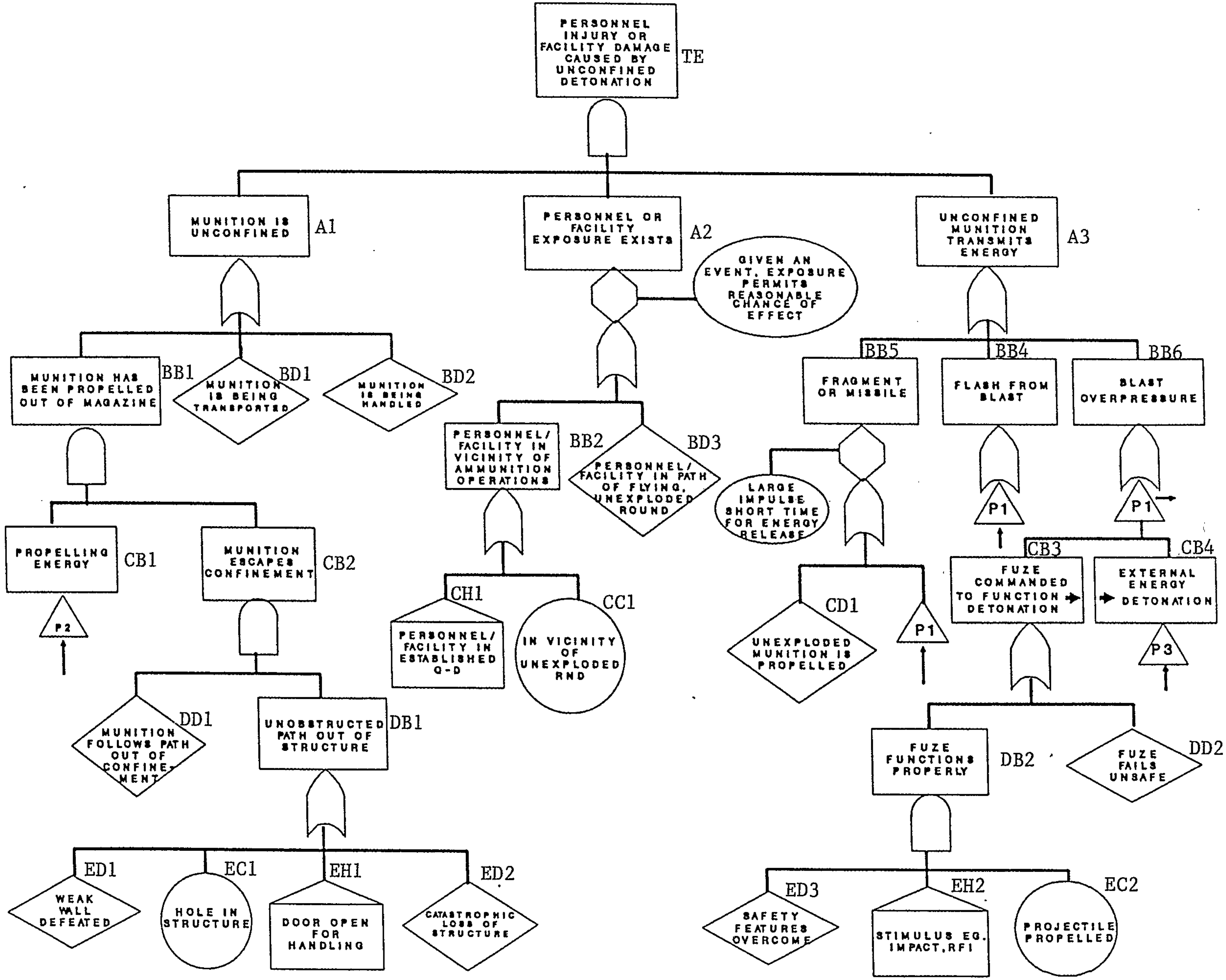
The third condition that must be met for the top event to occur is defined in the right branch of the tree. For exposed assets to incur damage, the unconfined munition must transfer energy. The transfer might result from the blast shock of the detonation, *or* from missiles and fragments, *or* the heat flux of the fireball. A fragment can only cause damage if it directly strikes a receiving asset *and* transfers sufficient energy (the accepted lower limit for that energy transfer is 79 Joules). Another way for a munition to cause injury or damage is by its detonation. This could be caused by the proper functioning of internal mechanical *or* electrical mechanisms, *or* by the application of heat from an external energy source.

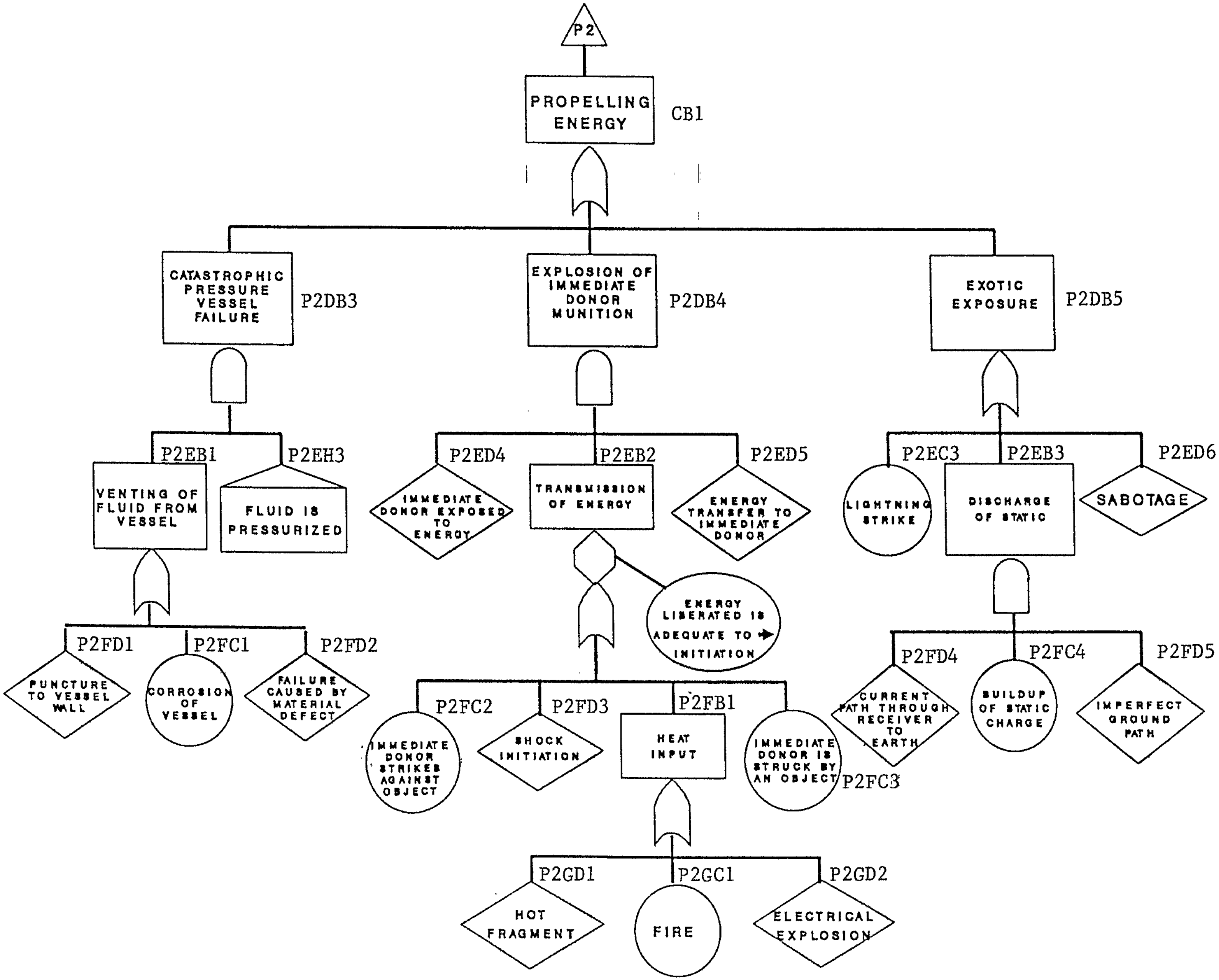
Munition is Unconfined

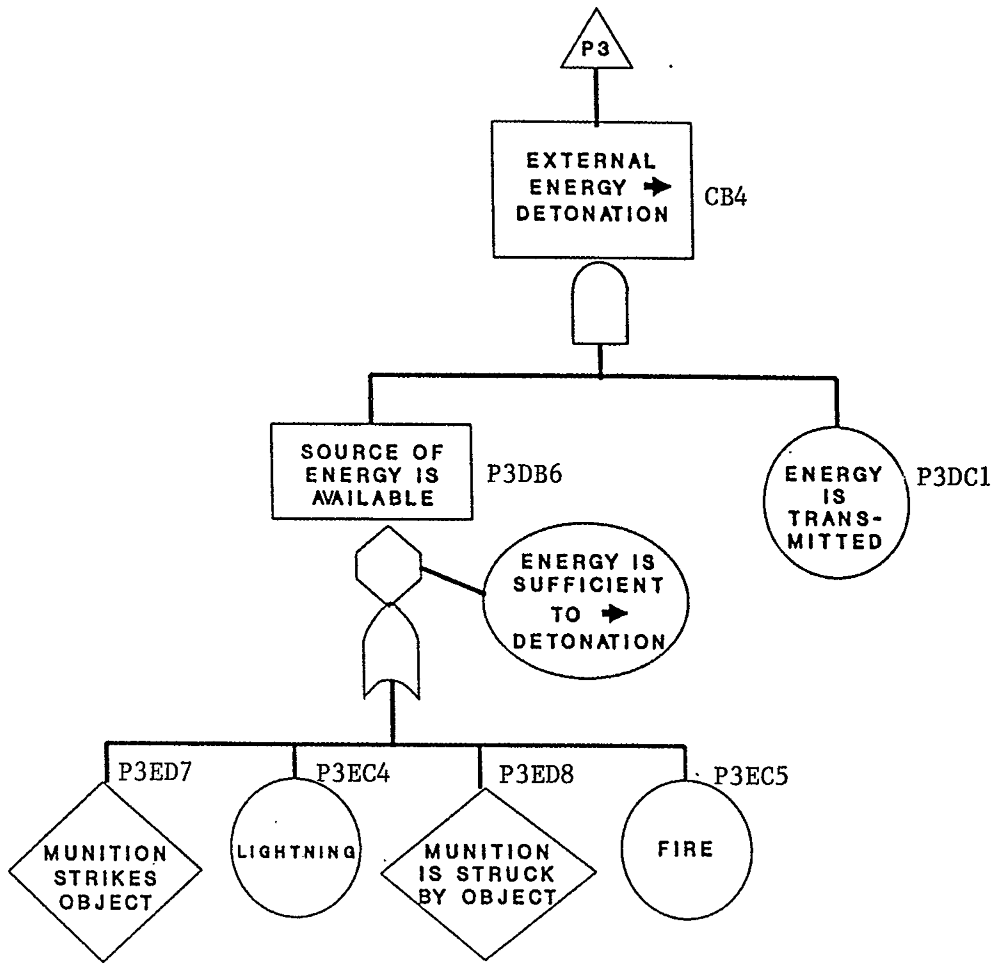
The left branch of the tree details the way blast and fragmentation mitigation features of a protective structure can be defeated. This branch defines the circumstances that must exist for a receiver to be directly exposed to an unexpected energy transfer.

Most often, direct exposure occurs when ammunition is being packed or unpacked, transported, _or_ handled during testing. While exposure clearly exists in these cases, the risk of an accident is controlled through the use of training and special procedures which minimize the likelihood of an event.

For a kickout to occur, a relatively intact round of ammunition must be thrown outside a suppressive structure. An impulsive energy source _and_ a path out of the structure must be present, _and_ the round, when thrown, must travel along that path. An impulsive release of energy is necessary for a kickout to occur. That release might result from a detonation, _or_ a pressure vessel failure, _or_ an electrical explosion. A path out of the containment structure might exist because of a structural failure, _or_ an inherent weakness, _or_ because a natural opening exists (e.g. doors, windows, or frangible surfaces). It is important to recognize that all suppressive structures with frangible walls or surfaces _or_ with access doors can permit a kickout. This weakness is an inherent characteristic of the suppressive qualities of those structures, and is irrespective of the construction medium, whether concrete, steel, earth, or sheet metal and sand.


PERSONNEL INJURY OR FACILITY DAMAGE CAUSED BY UNCONFINED DETONATION
TE
MUNITION IS UNCONFINED
A1
PERSONNEL OR FACILITY EXPOSURE EXISTS
A2
GIVEN AN EVENT, EXPOSURE PERMITS REASONABLE CHANCE OF EFFECT
UNCONFINED MUNITION TRANSMITS ENERGY
A3
MUNITION HAS BEEN PROPELLED OUT OF MAGAZINE
BB1
MUNITION IS BEING TRANSPORTED
BD1
MUNITION IS BEING HANDLED
BD2
PERSONNEL/ FACILITY IN VICINITY OF AMMUNITION OPERATIONS
BB2
PERSONNEL/ FACILITY IN PATH OF FLYING, UNEXPLODED ROUND
BD3
BB5
FRAGMENT OR MISSILE
BB4
FLASH FROM BLAST
BB6
BLAST OVERPRESSURE
LARGE IMPULSE SHORT TIME FOR ENERGY RELEASE
PROPELLING ENERGY
CB1
P2
MUNITION ESCAPES CONFINEMENT
CB2
CH1
PERSONNEL/ FACILITY IN ESTABLISHED Q-D
IN VICINITY OF UNEXPLODED RND
CC1
UNEXPLODED MUNITION IS PROPELLED
CD1
P1
P1
P1
CB3
FUZE COMMANDED TO FUNCTION DETONATION
CB4
EXTERNAL ENERGY DETONATION
P3
MUNITION FOLLOWS PATH OUT OF CONFINE-MENT
DD1
UNOBSTRUCTED PATH OUT OF STRUCTURE
DB1
FUZE FUNCTIONS PROPERLY
DB2
FUZE FAILS UNSAFE
DD2
ED1
WEAK WALL DEFEATED
EC1
HOLE IN STRUCTURE
EH1
DOOR OPEN FOR HANDLING
ED2
CATASTROPHIC LOSS OF STRUCTURE
ED3
SAFETY FEATURES OVERCOME
EH2
STIMULUS EG. IMPACT, RFI
EC2
PROJECTILE PROPELLED


P2
PROPELLING ENERGY
CB1
CATASTROPHIC PRESSURE VESSEL FAILURE
P2DB3
EXPLOSION OF IMMEDIATE DONOR MUNITION
P2DB4
EXOTIC EXPOSURE
P2DB5
P2EB1
VENTING OF FLUID FROM VESSEL
P2EH3
FLUID IS PRESSURIZED
P2ED4
IMMEDIATE DONOR EXPOSED TO ENERGY
P2EB2
TRANSMISSION OF ENERGY
P2ED5
ENERGY TRANSFER TO IMMEDIATE DONOR
P2EC3
LIGHTNING STRIKE
P2EB3
DISCHARGE OF STATIC
P2ED6
SABOTAGE
ENERGY LIBERATED IS ADEQUATE TO INITIATION
P2FD1
PUNCTURE TO VESSEL WALL
P2FC1
CORROSION OF VESSEL
P2FD2
FAILURE CAUSED BY MATERIAL DEFECT
P2FC2
IMMEDIATE DONOR STRIKES AGAINST OBJECT
P2FD3
SHOCK INITIATION
P2FB1
HEAT INPUT
IMMEDIATE DONOR IS STRUCK BY AN OBJECT
P2FC3
P2FD4
CURRENT PATH THROUGH RECEIVER TO EARTH
P2FC4
BUILDUP OF STATIC CHARGE
P2FD5
IMPERFECT GROUND PATH
P2GD1
HOT FRAGMENT
P2GC1
FIRE
P2GD2
ELECTRICAL EXPLOSION


P3
EXTERNAL ENERGY → DETONATION
CB4
SOURCE OF ENERGY IS AVAILABLE
P3DB6
ENERGY IS TRANSMITTED
P3DC1
ENERGY IS SUFFICIENT TO → DETONATION
P3ED7
P3EC4
P3ED8
P3EC5
MUNITION STRIKES OBJECT
LIGHTNING
MUNITION IS STRUCK BY OBJECT
FIRE

FAULT TREE DATA

INPUT DATA LIST

TOP EVENT: PERSONNEL INJURY/FACILITY DAMAGE

GATE DATA

1	TE A 3 0 A1 A2 A3
2	A1 O 1 2 BB1 BD1 BD2
3	A2 O 1 1 BB2 BD3
4	A3 O 3 0 BB3 BB4 BB5
5	BB1 A 2 0 CB1 CB2
6	BB2 O 0 2 CH1 CC1
7	BB3 O 2 1 CB3 CB4 CD1
8	BB4 O 2 0 CB3 CB4
9	BB5 O 2 0 CB3 CB4
10	CB1 O 3 0 P2DB3 P2DB4 P2DB5
11	CB2 A 1 1 DB1 DD1
12	CB3 O 1 1 DB2 DD2
13	CB4 A 1 1 P3DB6 P3DC1
14	DB1 O 0 4 ED1 EC1 EH1 ED2
15	DB2 A 0 3 ED3 EH2 EC2
16	P2DB3 A 1 1 P2EB1 P2EH3
17	P2DB4 A 1 2 P2EB2 P2ED4 P2ED5
18	P2DB5 O 1 2 P2EB3 P2EC3 P2ED6
19	P2EB1 O 0 3 P2FD1 P2FC1 P2FD2
20	P2EB2 O 1 3 P2FB1 P2FC2 P2FD3 P2FC3
21	P2EB3 A 0 3 P2FD4 P2FC4 P2FD5
22	P2FB1 O 0 3 P2GD1 P2GC1 P2GD2
23	P3DB6 O 0 4 P3ED7 P3EC4 P3ED8 P3EC5

FAULT TREE DATA

FAULT EVENT DATA

1	BD1	D	MUNITION IS BEING TRANSPORTED
2	BD2	D	MUNITION IS BEING HANDLED
3	BD3	D	PERSONNEL/FACILITY IN PATH
4	CH1	H	PERSONNEL/FACILITY IN QD
5	CC1	F	IN VICINITY OF UNEXPLODED RND
6	CD1	D	UNEXPLODED IS MUNITION IS PROPELLED
7	DD1	D	MUNITION FOLLOWS PATH OUT
8	DD2	D	FUZE FAILS UNSAFE
9	ED1	D	WEAK WALL DEFEATED
10	EC1	F	HOLE IN STRUCTURE
11	EH1	H	DOOR OPERD FOR HANDLING
12	ED2	D	CATASTROPHIC LOSS OF STRUCTURE
13	ED3	D	SAFETY FEATURES OVERCOME
14	EH2	H	STIMULUS e.g. IMPACT
15	EC2	F	PROJECTILE PROPELLED
16	P2EH3	H	FLUID IS PRESSURIZED
17	P2ED4	D	IMMEDIATE DONOR EXPOSED TO ENERGY
18	P2ED5	D	ENERGY TRANSFER TO IMMEDIATE DONOR
19	P2EC3	F	LIGHTNING STRIKE
20	P2ED6	D	SABOTAGE
21	P2FD1	D	PUNCTURE TO VESSEL WALL
22	P2FC1	F	CORROSION OF VESSEL
23	P2FD2	D	FAILURE CAUSED BY MATERIAL DEFECT
24	P2FC2	F	IMMEDIATE DONOR STRIKES AGAINST OBJECT
25	P2FD3	F	SHOCK INITIATION
26	P2FC3	F	IMMEDIATE DONOR IS STRUCK BY AN OBJECT
27	P2FD4	D	CURRENT PATH THROUGH RECEIVER TO EARTH
28	P2FC4	F	BUILDUP OF STATIC CHARGE
29	P2FD5	D	IMPERFECT GROUND PATH
30	P2GD1	D	HOT FRAGMENT
31	P2GC1	F	FIRE
32	P2GD2	D	ELECTRICAL EXPLOSIVE
33	P3DC1	F	ENERGY IS TRANSMITTED
34	P3ED7	D	MUNITION STRIKES OBJECT
35	P3EC4	F	LIGHTNING
36	P3ED8	D	MUNITION IS STRUCK BY OBJECT
37	P3EC5	F	FIRE

FAULT TREE DATA

GATE TE WAS NOT USED

(GATE MAY BE 'TOP EVENT' GATE)

****

FAULT TREE ANALYSIS PROGRAM

****

EXAMPLE CUT SETS FOR PERSONNEL INJURY/FACILITY DAMAGE

CUT SET # 37

BD1	MUNITION IS BEING TRANSPORTED
CH1	PERSONNEL/FACILITY IN QD
ED3	SAFETY FEATURES OVERCOME
EH2	STIMULUS e.g. IMPACT
EC2	PROJECTILE PROPELLED

CUT SET # 42

CH1	PERSONNEL/FACILITY IN QD
CD1	UNEXPLODED IS MUNITION IS PROPELLED
DD1	MUNITION FOLLOWS PATH OUT
ED1	WEAK WALL DEFEATED
P2ED6	SABOTAGE

CUT SET # 51

CC1	IN VICINITY OF UNEXPLODED RND
CD1	UNEXPLODED IS MUNITION IS PROPELLED
DD1	MUNITION FOLLOWS PATH OUT
ED1	WEAK WALL DEFEATED
P2EC3	LIGHTNING STRIKE

CUT SET # 93

CH1	PERSONNEL/FACILITY IN QD
DD1	MUNITION FOLLOWS PATH OUT
DD2	FUZE FAILS UNSAFE
ED1	WEAK WALL DEFEATED
P2FD4	CURRENT PATH THROUGH RECEIVER TO EARTH
P2FC4	BUILDUP OF STATIC CHARGE
P2FD5	IMPERFECT GROUND PATH

CUT SET # 101	
BD3	PERSONNEL/FACILITY IN PATH
CD1	UNEXPLODED IS MUNITION IS PROPELLED
DD1	MUNITION FOLLOWS PATH OUT
EH1	DOOR OPENED FOR HANDLING
P2FD4	CURRENT PATH THROUGH RECEIVER TO EARTH
P2FC4	BUILDUP OF STATIC CHARGE
P2FD5	IMPERFECT GROUND PATH

CUT SET # 102	
BD3	PERSONNEL/FACILITY IN PATH
CD1	UNEXPLODED IS MUNITION IS PROPELLED
DD1	MUNITION FOLLOWS PATH OUT
ED2	CATASTROPHIC LOSS OF STRUCTURE
P2FD4	CURRENT PATH THROUGH RECEIVER TO EARTH
P2FC4	BUILDUP OF STATIC CHARGE
P2FD5	IMPERFECT GROUND PATH

CUT SET # 107	
BD3	PERSONNEL/FACILITY IN PATH
DD1	MUNITION FOLLOWS PATH OUT
DD2	FUZE FAILS UNSAFE
EH1	DOOR OPERD FOR HANDLING
P2FD4	CURRENT PATH THROUGH RECEIVER TO EARTH
P2FC4	BUILDUP OF STATIC CHARGE
P2FD5	IMPERFECT GROUND PATH

Logic Model of the Top Event

The figure is a depiction of the fault tree described in the text. It has 59 basic events connected through 33 gates to intermediate events leading to the head or top event. At least some of the fault events at the bottom of the tree must exist before the top event can occur. This can be shown using the Laws of Boolean Algebra. The following symbols are directly taken from the figure:

$$P_{Top\ Event} = P_{A1} \times P_{A2} \times P_{A3}$$

where: $P_{Top\ Event}$ = the probability of occurrence of the Top Event.

P_{A1} = the probability a round of ammunition is outside the structure, left branch of the tree.

P_{A2} = the probability a person or facility is exposed, center branch of the tree.

P_{A3} = the probability a round of ammunition transmits energy, right branch of the tree.

If the probability of occurrence of the undesired event, $P_{Top\ Event}$, were to be calculated, it would be the product of probabilities of the three directly contributing branches.

The tree depicted in this paper has been condensed from one contained in AMC Action Committee for System Safety Technical Report 90-4. It has roughly an eighth the resolution of that tree.

Logic Model of the Kickout Branch

Kickout is the only event in the third rank of the left-hand branch that is a rare event. Both BD1 and BD2 are regularly occurring events. Discount the cases where a munition is outside a containment structure while being manipulated - as in BD1 and BD2, and consider the case of the undesired outcome occurring as a result of a kickout. What contribution does a kickout play in the probability of occurrence of the Top Event?

Kickout is very unlikely. This is obvious because of the circumstances necessary to cause it. For a kickout to occur, there must be an impulsive event. That event must create an opening in the structure or magazine containing the munitions, *and* given an event has occurred, there must be munitions remaining that are then propelled through the opening in the structure.

BB1 = CB1*CB2

CB1 = DB3+DB4+DB5

CB2 = DD1*(ED1+EC1+EH1+ED2)

DB3 = EH3*(FD1+FC1+FD2)

DB4 = ED4*EB2*ED5

= ED4*ED5*(FC2+FD3+FC3+GD1+GC1+GD2)

DB5 = EC3+ED6+FD4*FC4*FD5

So That: CB1 = EH3*(FD1+FC1+FD2)+EC3+ED6+FD4*FC4*FD5 +ED4*ED5*(FC2+FD3+FC3+GD1+GC1+GD2)

And: CB2 = DD1*ED1+DD1*EC1+DD1*EH1+DD1*ED2

Therefore: BB1 = {EH3*(FD1+FC1+FD2)+EC3+ED6+FD4*FC4*FD5+ED4*ED5*(FC2+FD3+FC3+GD1+GC1+GD2)}*{ DD1*ED1+DD1*EC1+DD1*EH1+DD1*ED2}

By examining the Boolean statement for kickout (Event BB1), 48 cut sets can be identified. The cut sets are three, four, or five point failures. This implies that the Top Event occurring as a result of a kickout requires the contribution of at least five basic events. For this case, TE seems to have a remote probability of occurrence - at least qualitatively - since it depends on the sum of five, six, and seven point failures. The probability of the top event's occurring is the sum of the products of the probabilities of the minimal cut sets.

Conclusion

Because the developed Fault Tree model was more extensive than was anticipated, it was impractical, given the scope of this study, to quantify. Even so, it is clear the possibility of the Top Event occurring does exist, but only if the complex set of conditions defined by the tree have been satisfied. The fault tree confirms a number of scenaria whereby an injury or damage resulting from a kickout could occur. There are many event combinations that could cause this. Equally obvious is that there is no way to reduce $P_{(TOP\ EVENT)}$ to zero. This implies there will always be a risk of kickout.

Elimination of the possibility of the head Event is impossible. However, a long string of events, which is diagramed in each branch of the tree, is required to satisfy that condition. What makes the chance of a kickout that causes injury or damage seem so remote is each of the events that can cause that outcome is an accident. Further, these accidental events must occur in combinations of five, six, or seven; since they must occur serially, the combination of events is very unlikely.

Whatever the risk of ammunition kickout, it is not markedly different for any suppressive structure, regardless of construction style, if that structure has a frangible wall that will be lost in a detonation or an entrance way that allows direct access from the outside. This is explicitly defined by the fault tree contained herein.

GLOSSARY

Cut Set - a combination of fault events whose occurrence as a set will cause the top event.

Donor - a round of ammunition which functions in the vicinity of other rounds of ammunition thus imparting energy to them.

Event

a. When regarding ammunition, a detonation or explosion.

b. An occurrence in the tree.

Head or Top Event - the main event of the fault tree, the undesired outcome.

Immediate Donor - The donor munition that initiates an unconfined munition.

Kickout - when a round of ammunition which does not detonate from an initial event in a structure is thrown from the structure.

Receiver - a round of ammunition which receives energy when another round of ammunition in the vicinity functions.

Risk - the expected value associated with a given hazard; it is the product of the severity of a hazard and the likelihood of its occurrence. Probabilities have not been calculated or assigned to individual events because it is beyond the scope of this report to do so. In this report, risk has several contexts: when pertaining to kickout, it is the consequence caused by a round detonating or escaping a containment structure after an event has occurred; when pertaining to a fault tree, it is the head event.

Unrelated - People or facilities which are not directly involved in a testing scenario but could be injured or damaged because of their proximity to a test when a kickout occurs.

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