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Accident-Resistant Container: Safety for Warhead Transport Executive Summary

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ACCIDENT-RESISTANT CONTAINER: SAFETY FOR WARHEAD TRANSPORT

EXECUTIVE SUMMARY

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ABSTRACT

Development testing of model and full-scale hardware to the abnormal environments created during a cargo aircraft crash has demonstrated that the accident-resistant container (ARC) can protect an enclosed warhead from these abnormal environments. This protection reduces the probability of initiation of the warhead HE.

Transfer of the plutonium limit to the ARC may permit transporting increased numbers of warheads on a single transport vehicle.

Testing of one warhead configuration has been completed. Production can be initiated for transporting that system in the ARC. Other systems need test evaluation and certification before being transported in the ARC.

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Introduction

The accident-resistant container (ARC) has an inner container size and shape which will dimensionally accommodate about two-thirds of those weapons currently in stockpile. The ARC will not accommodate the bombs without disassembly. Weapons with a diameter greater than 0.520 m or a length greater than 1.54 m cannot be placed in the ARC.

The ARC design (Figure 1) incorporates a bolster attached to the cylindrical body by shear pads. The bolster has handling and tiedown provisions, whereas the shear pads provide for mitigation of the normal environments.

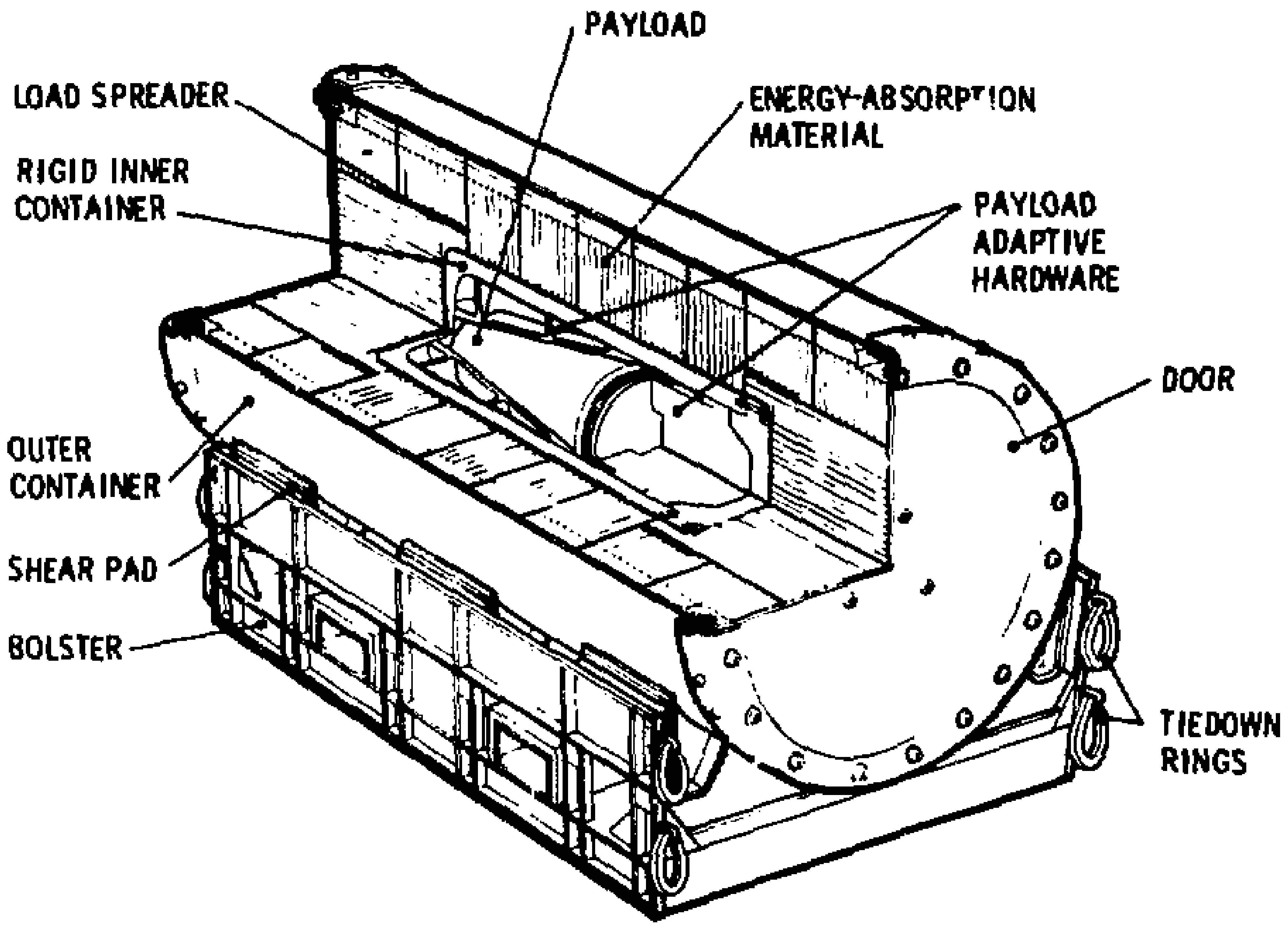

Figure 1. Accident-Resistant Container With Typical Payload

The ARC differs from the standard H-container currently used for weapon shipments in that it provides protection to the weapon from both the normal environments of shipping and handling and the abnormal environments which might occur in a cargo vehicle accident. In severe accidents involving an H-container with a weapon, there is a high probability that the weapon's high explosive would be initiated. The ARC provides resistance to abnormal environments and would reduce the probability of HE initiation and the subsequent dispersal of fissile material. Analysis of available data indicates that the cargo aircraft accident creates the most severe environments.[5,6]

The ARC has also been designed to mitigate transportation loads to acceptable weapon levels during normal shipping and handling of weapons. These criteria were compiled from the Sandia Environmental Data Bank and represent collection of data over an extended period of time on all modes of transportation.

The normal and abnormal environments used for the test evaluation of the ARC are listed in Table I.

TABLE I

ARC Design Criteria

A. Normal	
Temperature	230 to 325 K
Humidity	5% to 100% RH
Pressure/Altitude	-120 m to +9145 m
Unidirectional Shock	43 g's, 20 ms, 1/2 sine (boxcars)[1]
	17 g's, 52ms, 1/2 sine (ATMX)
Recurrent Shock	3-g peaks, 2-5 Hz
	1.5-g peaks, 5-20 Hz
Vibration	2-2000 Hz, random, shaped for each carrier
Radiation	1130 W/m^2, 14 hr, 1/2 sine
B. Abnormal	
Impact - Any Angle	84 m/s
Sympathetic Detonation	81.6-kg HE donor (in ARC)
Fire	1285 K blackbody for 1 hour
Puncture	9 g at 810 m/s
Crush	30,000-kg line load
Immersion	460 m of water, salt or fresh

The normal environments are not expected to present any problems in certifying the weapon for shipment. Calculations for the shear pad design indicate proper mitigation of the normal input environments to levels acceptable for weapon shipment. Testing has not been completed to verify compliance with the normal environments.

Test evaluations of the ARC to abnormal environments of impact, sympathetic detonation, fire, and puncture have been completed. Crush and immersion have not been tested.

Test data are available to demonstrate resistance to the abnormal environments as follows:

Impact: Models and full-scale hardware have been impacted into a hard, flat steel target and have survived at the 84-m/s impact velocity.[11-20,22,23]

Sympathetic Detonation: Models and full-scale hardware have been subjected to explosive disassembly and fragment impact. An evaluation of the acceptor units demonstrated their successful survival of the explosive environment.[11,13,20]

Fire: Models and full-scale test panels have been subjected to 1285 K blackbody radiation. An evaluation showed that the hardware survived the environment.[10,11]

The ARC was also tested for its ability to dissipate the internal heat generated by the weapon.[21]

Puncture: Full-scale panels representative of the ARC construction were tested with both 7.62-mm and 12.7-mm armor-piercing projectiles fired at maximum velocity for resistance to penetration. No penetrations were observed.[25]

Crush: Loading the ARC to 30,000 kg is not considered a threat to the integrity of the ARC because of its ability to withstand high-velocity impact.

Immersion: Calculations indicate that the ARC has positive buoyancy.

The features designed into the ARC to provide a system which will survive the abnormal environments and thereby provide safety for the weapon during transportation also provide a limited resistance to weapon diversion. The size of the ARC makes it difficult to move without the proper equipment. With the proper equipment, the removal of a weapon from the ARC takes about 1 to 1.5 hours.

The accident-resistant container has a demonstrated capability to reduce the probability of HE initiation when the weapon is subjected to abnormal (accident) environments. Based upon the test evaluation completed on the ARC, production would be possible in 12 to 18 months after authorization for the weapon evaluated by full-scale testing.

Background

The consensus of the AEC-DOD study[1] and the Sandia Laboratories study[2-4] is that recent dissident group activities within the U. S. emphasize the need for greater security and safety in shipment of nuclear weapons. Reference 4 calls attention to the need for greater security and safety in all modes of transportation (truck, rail, and air).

Sandia is currently procuring armored tractors and safe-secure trailers and is designing a safe-secure railcar. The ARC was developed to provide the desired safety for air transport of weapons. Air transport provides security after the aircraft is airborne, but the ARC is required to provide safety — or at least a reduced probability of scattering fissile material — when an accident occurs. The safe-secure trailer can be used for transporting the weapons to and from the air terminal, thereby enhancing the security of the ground movement required in air transport.

Using ARC in conjunction with either rail or truck shipments enhances the safety of the weapon, as the ARC resistance to accident environments provides additional protection. Figures 2 and 3 are plots of the impact and fire environments to be expected from an accident involving aircraft, train, or truck. The ARC capability to withstand these environments is shown as a vertical dotted line. For example, in Figure 2 the ARC capability is 84 m/s and, by following this line vertically, one observes that the ARC provides protection for approximately 83 percent of fixed-wing aircraft impact and nearly all the rotary-wing aircraft, train, and truck impacts.

Figure 3 shows the ARC capability to be 3 hours exposure to 1285 K blackbody radiation and, by following this line vertically, one observes that the ARC provides protection for approximately 80 percent of train fires, approximately 95 percent of truck fires, and nearly all rotary-wing and fixed-wing aircraft fires.

The need for the ARC was established in Reference 4, and the feasibility was reported in References 5 and 6. From the design shown in the feasibility study, a limited number of one-eighth- and one-fourth-scale models were procured and tested.[7] These tests served to demonstrate not only that scaling laws are valid but that several of the concepts in the feasibility study needed to be reviewed.

The program plan[8] was submitted for approval in April 1971, and formal approval was obtained[9] in November 1971.

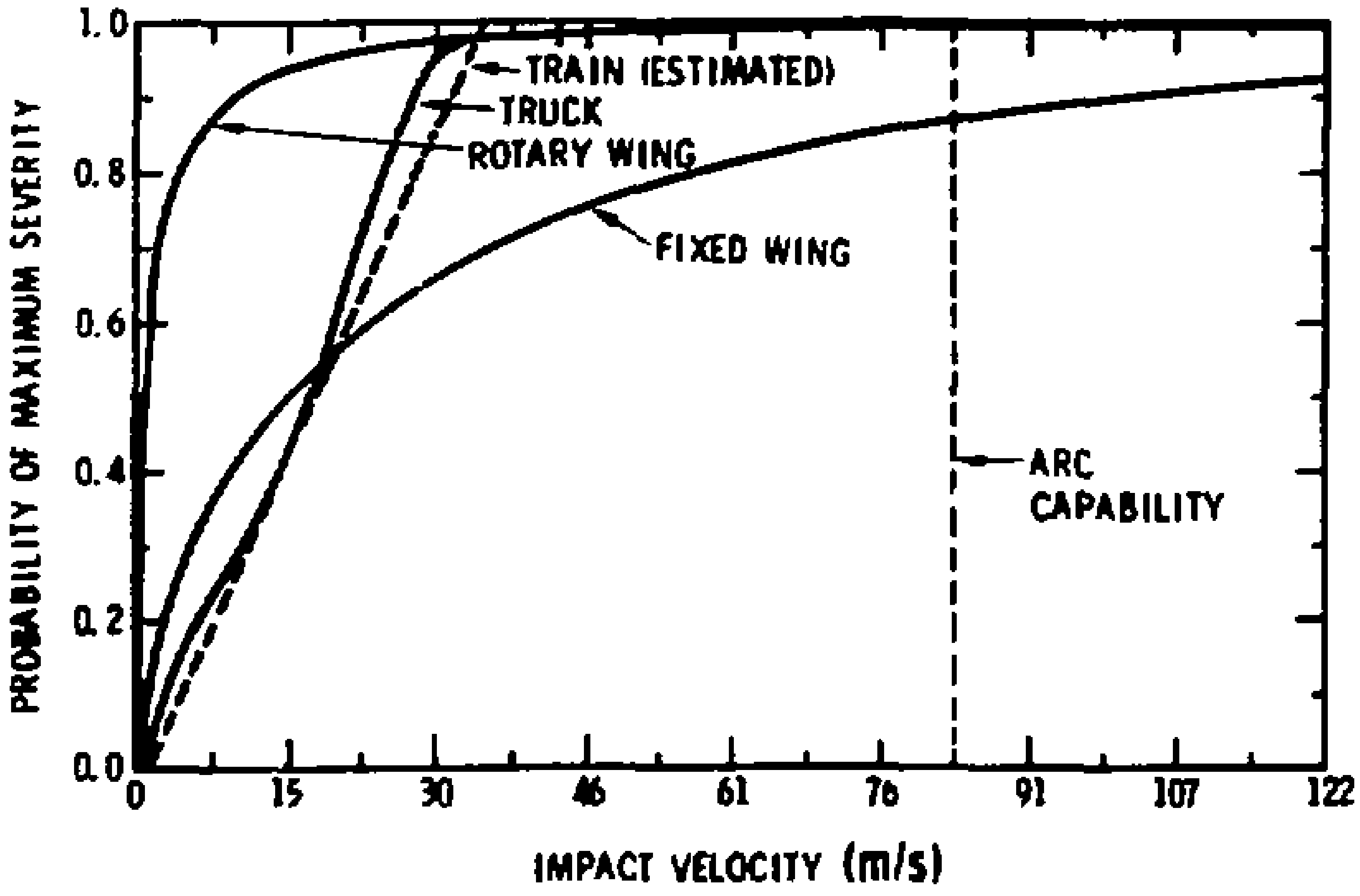

Figure 2. ARC Cumulative Distrubtion Function in Accidents Involving Impact

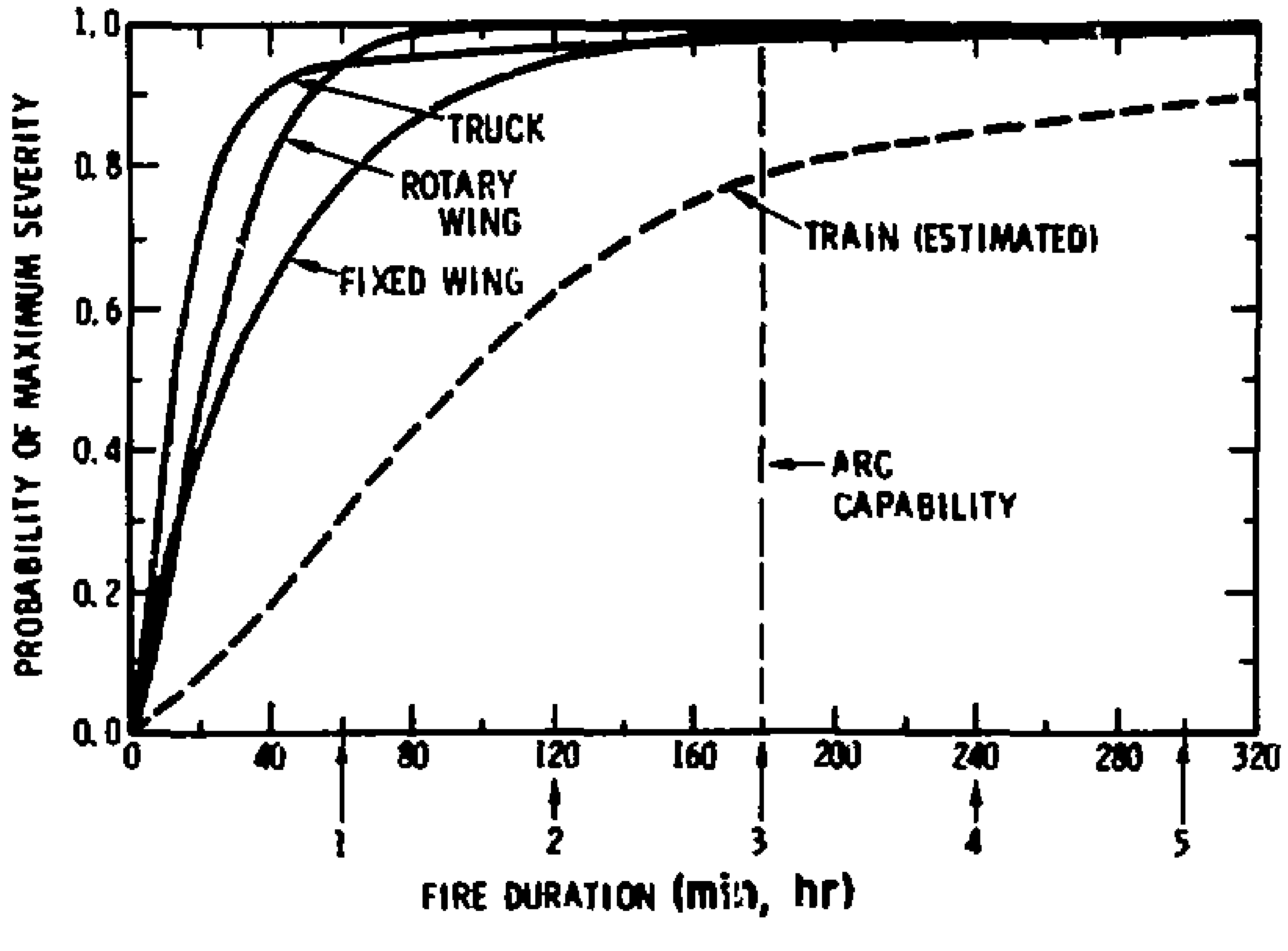

Figure 3. ARC Cumulative Distribution Function in Accidents Involving Fire

Basic Problems

Problems related to the dynamic crush stress of materials, the fire resistance of materials, and the ability of materials to deform dynamically without significant rupture have been solved. The materials of construction and the configurations for the ARC have been selected and tested for their demonstrated performance capability.

Impact performance has been demonstrated both on scale models and on full-scale ARC's. Fragment impacts from explosively destroyed models, as well as 7.62-mm (.30 cal) and 12.7-mm (.50 cal) armor-piercing projectiles impacting a full-scale panel, have not penetrated the ARC structure. Demonstration tests on models have indicated that load spreaders will prevent the inner container from chiseling through the fire-barrier redwood and approaching the outer container during oblique impact. Compressed wood or virgin wood will provide the fire-resistance capability.

Most modern weapons produce heat from radioactive material decay; this heat must be dissipated to the outside air by conduction through the ARC materials. With single-weapon transport in the ARC, the combination of heat storage in the adaptive hardware aluminum casting and aluminum inner container and the subsequent conduction to the outer container appear to give adequate heat dispersal to keep weapon temperatures within limits. When a multiple quantity of high-heat-producing weapons is transported, however, it may be necessary to install heat pipes for the conduction of heat to the outer container. The heat pipes, which provide more efficient heat-conduction paths, will remove greater quantities of heat and thereby keep the weapon temperature within acceptable limits.

A full-scale demonstration of the ability of the ARC/warhead to resist sympathetic propagation of detonation has been completed successfully. Also, scale-model sympathetic detonation tests have been performed with excellent results. The explosion tests have demonstrated that the ARC can be expected to prevent sympathetic detonation. The models and full-scale ARC's showed no penetration of fragments beyond the outer skin, even with a 1.3-kg (full-scale, 81.6 kg) explosive donor.

Construction

The ARC is constructed of concentric shells of aluminum, redwood, and steel. A three-quarter section (Figure 1) illustrates the construction of the unit.

The inner container is made from a 77.5-mm closed-end forged 7075-T73 aluminum alloy. The cylinder is closed with a contour-machined aluminum disc forging and is held in place by 12 high-strength steel bolts 3/4 inch in diameter. This aluminum inner cylinder is surrounded by redwood with the grain oriented to provide maximum compressive stress. The redwood compressed parallel to the grain exhibits a strength of about 37 MPa; when compressed perpendicular to the grain, it exhibits a strength of only 7 MPa. The redwood exhibits a 70-percent compression at nearly constant load when loaded in either direction. For maximum load-carrying or energy-absorbing capability, therefore, the redwood must be compressed parallel to the grain. This configuration requires that the wood across the ends of the inner cylinder have the grain oriented parallel to the longitudinal axis and that the wood along the sides of the cylinder have the grain oriented along radial lines (perpendicular to the longitudinal axis of the inner cylinder).

A ring of redwood with the grain oriented parallel to the inner cylinder longitudinal axis was placed around both the end-grain redwood across the ends of the inner container and the radial-grain redwood covering the cylindrical portions of the inner cylinder. This longitudinal-grain redwood was placed at the outer diameter to provide additional energy-absorption capability for longitudinal impact. Lumber of 50- by 50-mm dimensions was used to fabricate this ring.

The redwood is surrounded by a 6.4-mm HY-80 alloy steel shell. This material is tough and, although it has 550-MPa yield strength, it also exhibits 22-percent elongation. The HY-80 steel shell is closed with stainless steel (304 alloy) doors with a yield strength of 240 MPa and 60-percent elongation. Both doors are held in place with 36 high-strength steel bolts 1.0 inch in diameter. The construction of the door provides a spun angle over the outside of the steel cylinder and a spun flanged head inside to captivate the cylinder between two rings. The flanged head also provides the structure for mounting nutplates.

The ARC is mounted on a bolster which provides the means for handling, transport, and tiedown (Figure 1). The bolster, although not intended to help in the energy absorption of high-velocity impact, is designed to be as light in weight as possible and to provide additional positive buoyancy for the ARC.

The ARC is 2.85 m long and has an OD of 1.31 m; the payload cavity is 1.69 m long at the centerline and has an ID of 520 mm. The ARC weighs approximately 3630 kg, including a payload of 340 kg.

Bonding of the entire assembly forces each component to act in shear on the adjacent members during high-velocity impact.

Compatibility

The ARC has a warhead cavity, 520 mm in diameter by 1.54 m long (cylindrical) and 1.69 m long (centerline), that can accommodate a variety of warheads. Special adaptive hardware fitted to the warhead is designed for maximum protection of the warhead high explosive during accident environments. It may be stored separately from the ARC. Movement of warheads without the ARC would require a dolly designed to mitigate handling loads to acceptable levels for the specific warhead. Also, for storage and local transportation, present weapon H-containers are available.

ARC Applications

The ARC is dimensionally compatible with approximately two-thirds of the stockpile weapons, as well as with both air and ground transportation. The utility of ARC is further enhanced by the transportation of one, two, or three warheads in a single ARC. This multiple-warhead capability for some weapons, coupled with the transfer of the plutonium limit from the vehicle to the ARC, results in a greater weapon load capacity and fewer trips for the transport vehicle. Reference 24 provides data on the quantity of plutonium contained in all stockpiled warheads, some of which may be transported by the ARC in multiple quantities.

ARC/Air Transport

The ARC's demonstrated capability to withstand cargo aircraft accident environments and thereby reduce the probability of initiation of the weapon HE permits assigning the plutonium limit to the ARC.

Using the plutonium limit transfer and the 29,930-kg payload capability of the C-141A, as published by Lockheed in the Standard Aircraft Characteristics C-141A, eight ARC units could be transported. This number of ARC units per trip would result in an approximate 30-percent reduction in the number of trips required. A recent informal conversation with a representative of the Air Force indicates that the aircraft is loaded only to 18,140 kg, and this reduces the number of ARC units to five.

ARC/Truck Transport

Using the ARC with the safe-secure trailer provides redundant protection for impact, fire, and projectile impact, and may, for a few weapons, increase the number which may be transported. Transfer of the plutonium limit to the ARC would permit carrying the greater quantity.

ARC/Railcar Transport

The ATMX railcar used for nuclear weapon transport was designed for impact resistance. Resistance to fire and penetration was not included in the original design. Again, the transfer of the plutonium limit to the ARC may permit an increased number of weapons to be transported. Further, close packaging of the ARC units in the ATMX railcar would provide delay in the removal of the ARC and also in the removal of a weapon; security would therefore be increased.

Use of the ARC in the ATMX railcar (Figure 4) would enhance the protection of the weapon by providing increased impact protection (Figure 2), increased fire protection (Figure 3), increased projectile penetration protection (no penetration from 12.7 mm-AP), and limited increase in the time required to remove a weapon from the railcar.

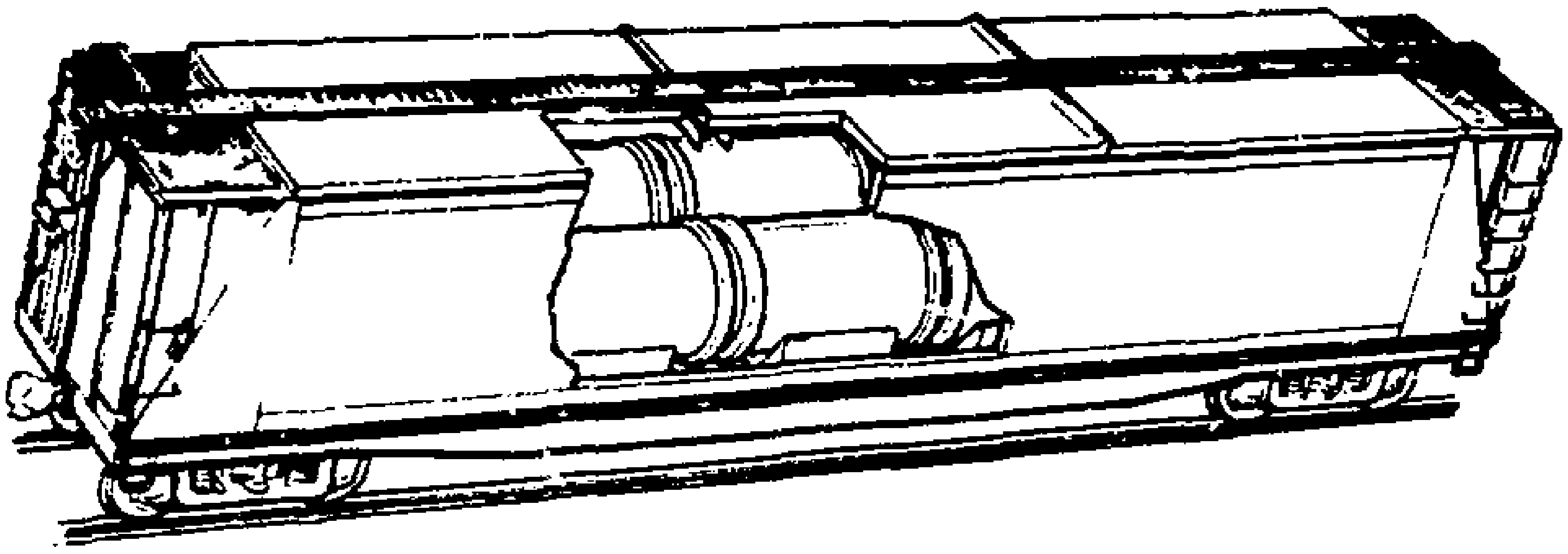

Figure 4. ATMX Railcar With ARC

Even though the railcar may be breached easily, the ARC must be removed before the initiation of disassembly procedures. The closely packed ARC units would hamper disassembly operations within the railcar. Cutting the railcar, cutting tiedown hardware, removing an ARC, and disassembly of the ARC would provide a delay which would give a response force additional time to arrive and prevent the diversion of a weapon.

If circumstances required the transport of weapons in a standard freight railcar, the ARC would provide increased protection over that provided by the H-container.

Environmental Effects Assessment

The ARC, through its designed accident resistance, provides a benefit to the environment by offering increased resistance to all modes of attack that have the potential for scattering fissile material. The ARC is designed to resist aircraft crash environments and, therefore, would resist the crash environment created during truck or rail transport, as these environments are reduced in their magnitude and intensity. As a result of the design for impact resistance, the ARC has a fire resistance equivalent to a 3-hour exposure to a 1285 K blackbody radiation. Further, the ARC has a demonstrated resistance to penetration of 12.7-mm armor-piercing projectiles at maximum muzzle velocity. Full-scale testing to demonstrate resistance to sympathetic detonation has been completed.

Conclusions and Recommendations

The ARC design goals given in Table II have been fulfilled by the present ARC design.

TABLE II

ARC Design Goals

1. To reduce probability of HE detonation from
    - High-velocity container impact
    - Long-term fuel fire
    - High-velocity fragment/projectile impact
    - Sympathetic initiation
2. To render the container
    - Compatible with as many stockpile weapons as possible
    - Compatible with current transportation carriers (air - truck - rail)
    - Capable of meeting STS requirement for each weapon
3. To achieve the following passive system attributes
    - No special handling required
    - Long-term usage
    - Minimum maintenance
    - Minimum cost

Development testing of scale models and full-scale ARC's has successfully demonstrated that the ARC Design Criteria (Table I) and the ARC Design Goals (Table II) have been fulfilled. Evaluation of the design and calculations performed have permitted a judgment that the STS or normal environments can be met, even though actual testing has not been completed.

The safety of weapon transport is enhanced by the ARC in all modes of transportation, and the delay time of removal and disassembly provides security by giving increased time for the arrival of a response force.

The uniform appearance of the weapons in a shipment precludes selection of a specific type for diversion or initiation attempts.

Demonstrated resistance to accident environments will reduce the probability of HE initiation and the subsequent spread of fissile material.

Assignment of the plutonium limited to the ARC, permitted by a demonstrated resistance to sympathetic initiation of the weapon's HE, can increase the number of weapons transported by a vehicle.

ARC capabilities may be summarized as follows:

- Resistance to a fuel fire for 3 hours at 1285 K
- Resistance to impact up to 84 m/s
- Resistance to penetration of high-velocity armor-piercing projectiles up to 12.7 mm
- Potential for permitting an increased number of weapons to be transported on a single vehicle by transferring the plutonium limit to the ARC
- Dimensional compatibility with transporting about two-thirds of the currently stockpiled weapons
- Compatibility with all modes of transportation.

The ARC described in this report has been designed and tested to a specific set of design criteria, but the basic technology assembled during this program can be used to design an ARC to meet any desired criteria. Short development times are possible for new designs with this currently available technology.

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