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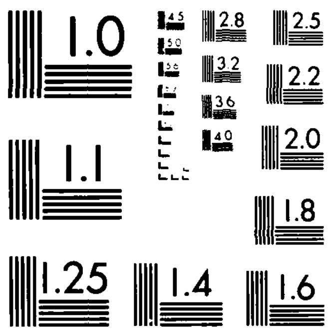

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MEMORANDUM REPORT BRL-MR-3420

APPLICATION OF SUPPRESSIVE SHIELDING AND ANTIFRATRICIDE TECHNOLOGIES TO THE TRANSPORTATION OF M55 ROCKETS

Ona R. Lyman

December 1984

US ARMY BALLISTIC RESEARCH LABORATORY
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1. REPORT NUMBER: MEMORANDUM REPORT BRL-MR-3420	2. GOVT ACCESSION NO.: AD-A149 422	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): APPLICATION OF SUPPRESSIVE SHIELDING AND ANTIFRATRICIDE TECHNOLOGIES TO THE TRANSPORTATION OF M55 ROCKETS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): ONA R. LYMAN		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Ballistic Research Laboratory, ATTN: AMXBR-TBD, Aberdeen Proving Ground, MD 21005-5066		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 72801221100
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Ballistic Research Laboratory, ATTN: AMXBR-OD-ST, Aberdeen Proving Ground, MD 21005-5066		12. REPORT DATE: December 1984
		13. NUMBER OF PAGES: 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M55 Rocket
ammunition storage
containment vessel
antifratricide
suppressive shielding

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Methods for reducing the maximum credible event (MCE) while moving pallets of M55 rockets are discussed. The use of containment vessels to prevent the dispersion of chemical agent should an explosion of a warhead occur is suggested and a program to investigate both phases of the problem is recommended.

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I. INTRODUCTION

The Army Materiel Systems Analysis Activity (AMSAA) is making an independent study of the transport hazard of certain chemical munitions. As a part of this overall study AMSAA tasked the Ballistic Research Laboratories (BRL) to consider the specific problem of safely transporting pallets of rockets from their igloo storage area to the demilitarization facility. The initial BRL response to this request was based on experience derived from antifratricide work on stowed munitions and work performed for the suppressive structures program. On this basis, it was recommended that a cylindrical container with hemispherical end caps be designed strong enough to totally contain the detonation effects of one rocket warhead. Furthermore, it was suggested that the technology existed to guarantee that one and only one rocket would participate in an explosive event. As a result of this exchange AMSAA then forwarded funds to make a very quick study to answer five specific questions:

1. Estimate the probability of round to round communication of reaction in a fifteen round pallet of M55 rockets

2. Provide a conceptual design to prevent communication of reaction and estimate hazard reduction

3. Calculate wall thickness and weight of cylindrical container with hemispherical end caps. Fifty inches in diameter for axial charge weights of 3.2 lbs. (one munition) and 6.4 lbs. (two munitions)

4. Provide an estimate of the cost of such a containment vessel

5. Provide follow-on plans to accurately define, design, and test a total containment vessel.

II. RESPONSE TO REQUEST

The following is a response to the AMSAA requests in the order listed in the Introduction.

A. Communication of Reaction

A cross section of the M55 rocket warhead is shown in Figure 1. In their palletized configuration they are in a rectangular array with 2.1 cm separation horizontally and 3.5 cm separation vertically. The diagonal separation is 9.1 cm. For those conditions, it was the opinion of the author that it was unlikely that detonation of one warhead would cause detonation of its neighbor. This is verified by tests described in reference 1. These warheads, because of

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[1] Smith and Kennet, "Propagation Between Munition for Palletized M61 Rockets," AEO Report #24-77 T-410, Ammunition Equipment Office, Tooele Army Depot, 3 Oct 77.

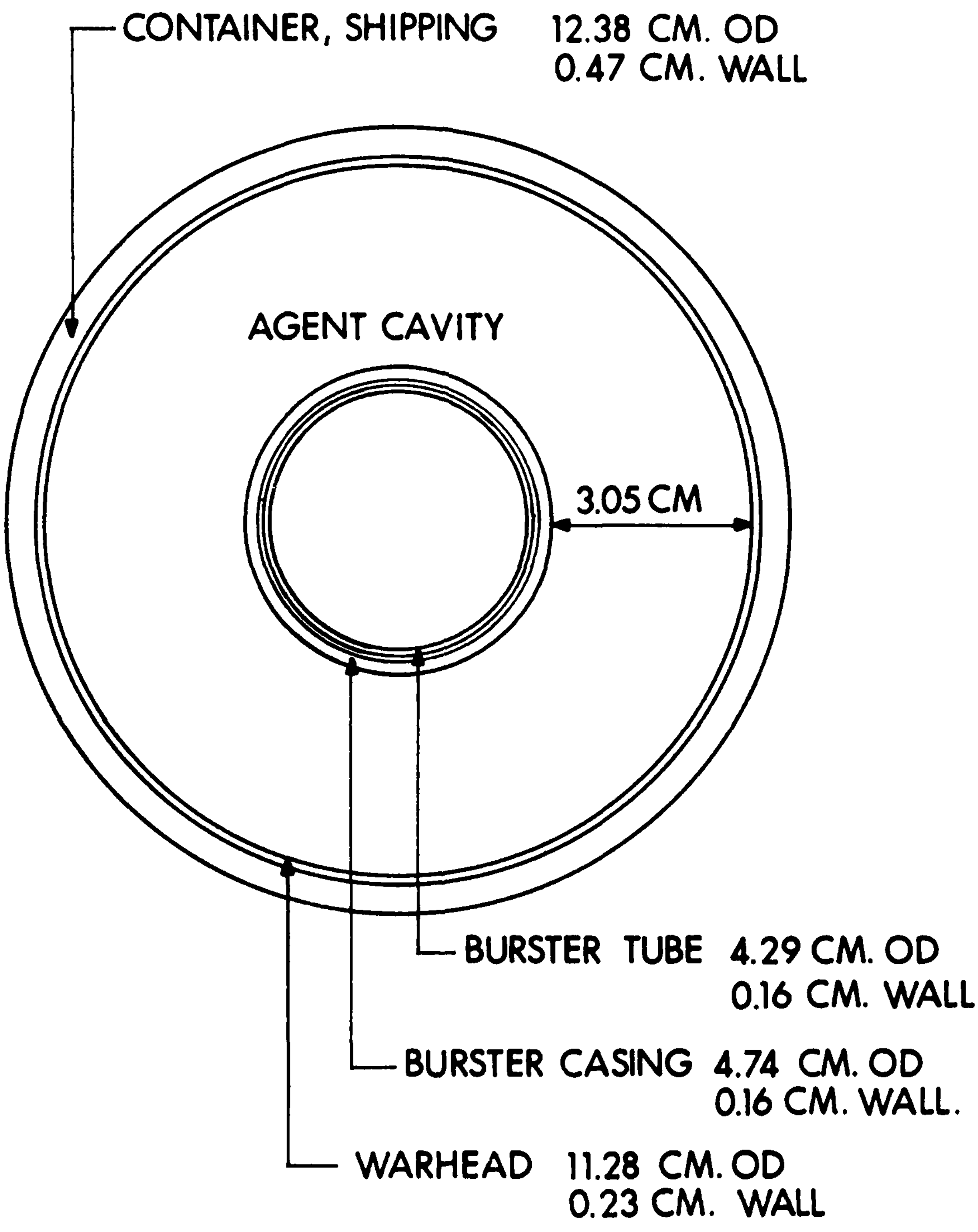

Figure 1. Cross Section of M55 Rocket Warhead

their light construction, pose little fragment threat to adjacent warheads. Because of their light construction, they also provide little protection to the explosive charge when an adjacent round is detonated. Previous antifratricide work at BRL provided no insight as to the effect of the liquid surrounding the explosive.

Reference 1 says nothing about recovering explosive from burster tubes of warheads adjacent to the detonated warhead. Most burster tubes were recovered, however, even though they had received considerable damage. This confirms our judgement that without some protection, rounds adjacent to a detonated warhead will receive substantial crushing and quite possibly the explosive will react although the reaction will be milder than a detonation.

Due to the short time available, it was decided to test a mock-up of the warhead to obtain first hand information. Because the M61 rocket warheads could not be obtained quickly, a mock-up of the warhead was made from material on hand. It was further decided that where appropriate material in the proper dimensions could not be found, to err on the side of making the mock-up more susceptible to communication of reaction. Two mock-up warheads were made, one as a donor, the other as an acceptor. The principal difference between the mock-up and the warhead were:

1. The outside diameter of the mock-up was 9 mm smaller and the wall thickness 3 mm thinner.

2. The burster tube in the mock-up was 8 mm larger in diameter giving nearly forty percent increase in the charge weight per unit length.

3. The space between the burster tube and the outer wall was 8.0 mm less than for the warhead.

These differences combine to make a very severe test of probability of communication of reaction, but was the closest we could achieve on a short notice. Considering the possible results we concluded that: (a) if the acceptor round detonated we would have learned nothing, (b) if the acceptor round burster was recovered with some explosive intact the problem was very mild, and (c) if the acceptor burster was not recovered and no explosive was recovered, but also, if there was no evidence of detonation we would face a solvable, but possibly difficult problem.

The test was fired with a separation distance of 2 cm between donor and acceptor. Both rounds were placed on end on a 2.5 cm thick rolled homogeneous armor plate used as a witness plate. A mild steel witness plate 1.3 cm thick was placed 10 cm away from the side wall of each round, and backed by sand bags. The donor round was initiated at its top end by a detonator and tetryl booster charge. The witness plate beneath the charges showed the typical detonation signature under the donor round, i.e.: indentation and disk of steel spalled from the back surface. No such signature was found under the acceptor round. The side witness plates were deformed with the plate nearer the donor showing more deformation. No explosive from the acceptor was recovered, but a few fragments of the acceptor burster tube were recovered. The explosive reaction in the acceptor was less than a detonation, but still a rather violent reaction.

The conclusion is that nearest neighbors to a M55 palletized round that detonates will not detonate sympathetically, but the explosive charge in the neighboring burster tube may react quite violently. In order to prevent any reaction some antifratricide protection must be provided between adjacent rounds. The nature of this protection will be discussed in the following section.

B. Antifratricide Protection

The apparent mechanism for communication of reaction is a crushing of the adjacent round and ignition of the explosive. This is in contrast to shock initiation or initiation by fragment impact. The goal of the protection in this application is the prevention of rupture of the burster tube. A less desirable, but still acceptable goal, would allow rupture but preclude ignition of the explosive. The current level of knowledge as to the details of interaction when one warhead detonates is limited, but none-the-less indicates the above goals are reasonable and attainable.

The exact design of the protective device used will depend on the final design of the containment vessel. Constraints which must be accommodated are:

(1) Devices must be easily installed by two men maximum.

(2) Devices must be reusable.

(3) Protection should not require depalletization of the munition.

(4) Protection should not preclude the use of the SPORT (Single Pallet Only Rocket Transporter).

Discussion in a following section shows alternative solutions, but for this section the constraints above will apply. The concepts described below are only concepts and the detailed design must await the testing and experiments with actual M61 rockets.

Figures 2 and 3 show the palletized rocket configurations, an end view and a side view. The end view indicates that there is a space available extending through the pallet saddles for insertion of material to provide round to round protection in the horizontal rows of munitions. Between rounds in a vertical column, material inserted from the front can only extend as far as the first pallet saddle, approximately midway along the warhead. Likewise, should protection be required between second nearest neighbors (along a diagonal) from front insertion these can only extend to the first pallet saddle. Protection aft of the first pallet saddle between rounds in a vertical column can be provided by insertion of plates between the center row and the top and bottom rows. Protection between second nearest neighbors aft of the first pallet saddle is possible by insertion of vertical plates.

Designation of the most efficient material for antifratricide protection cannot be determined at this point because of the lack of test data. Because protection from crushing is the expected requirement, metallic cylinders may be the best approach, but one must be cautious as the potential exists to create a fragment threat where none exists at the moment. An example of how protection might be achieved is to design a plate to replace the panel currently on the

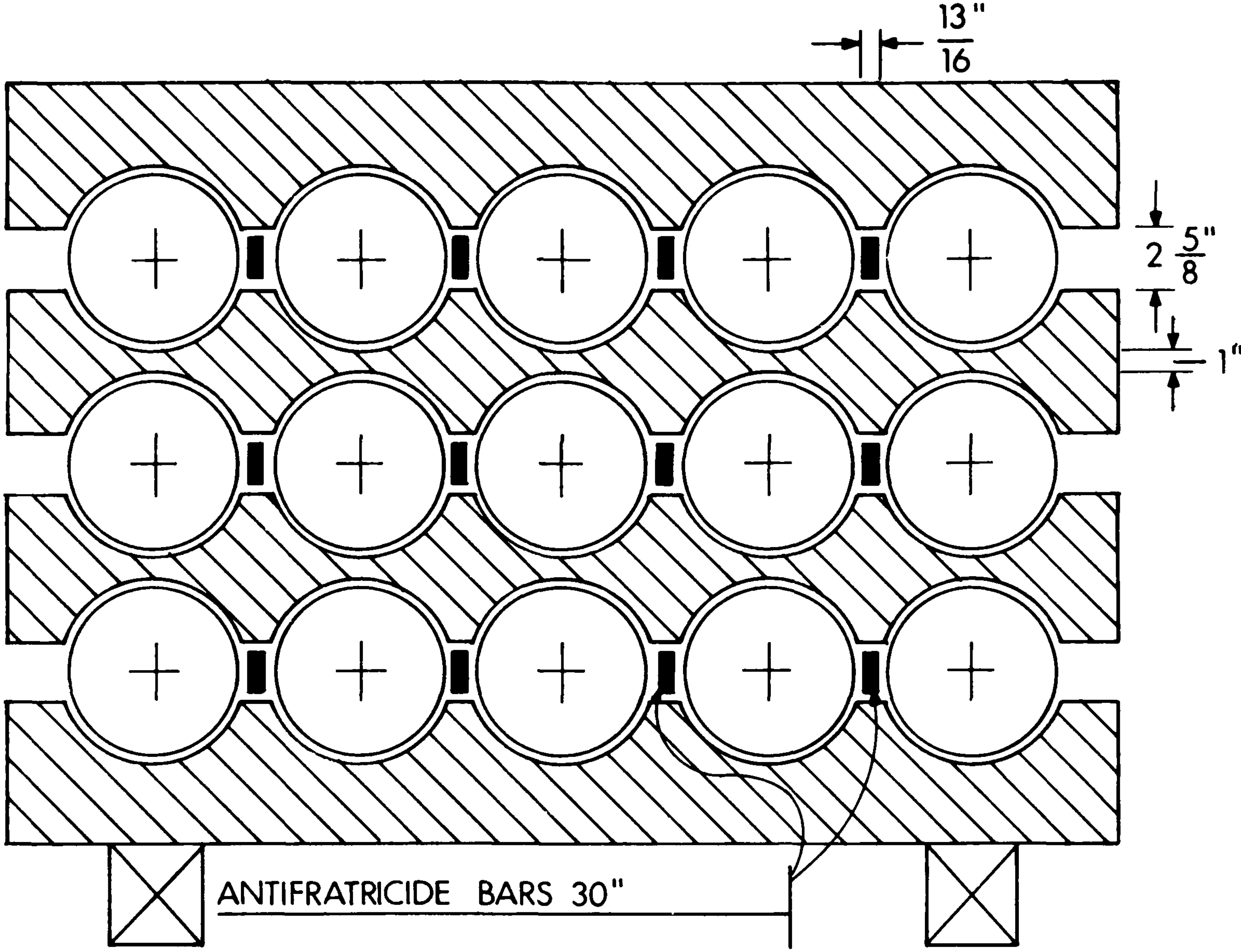

Figure 2. End View of Palletized M55 Rockets Showing Available Space for Antifratricide Bars

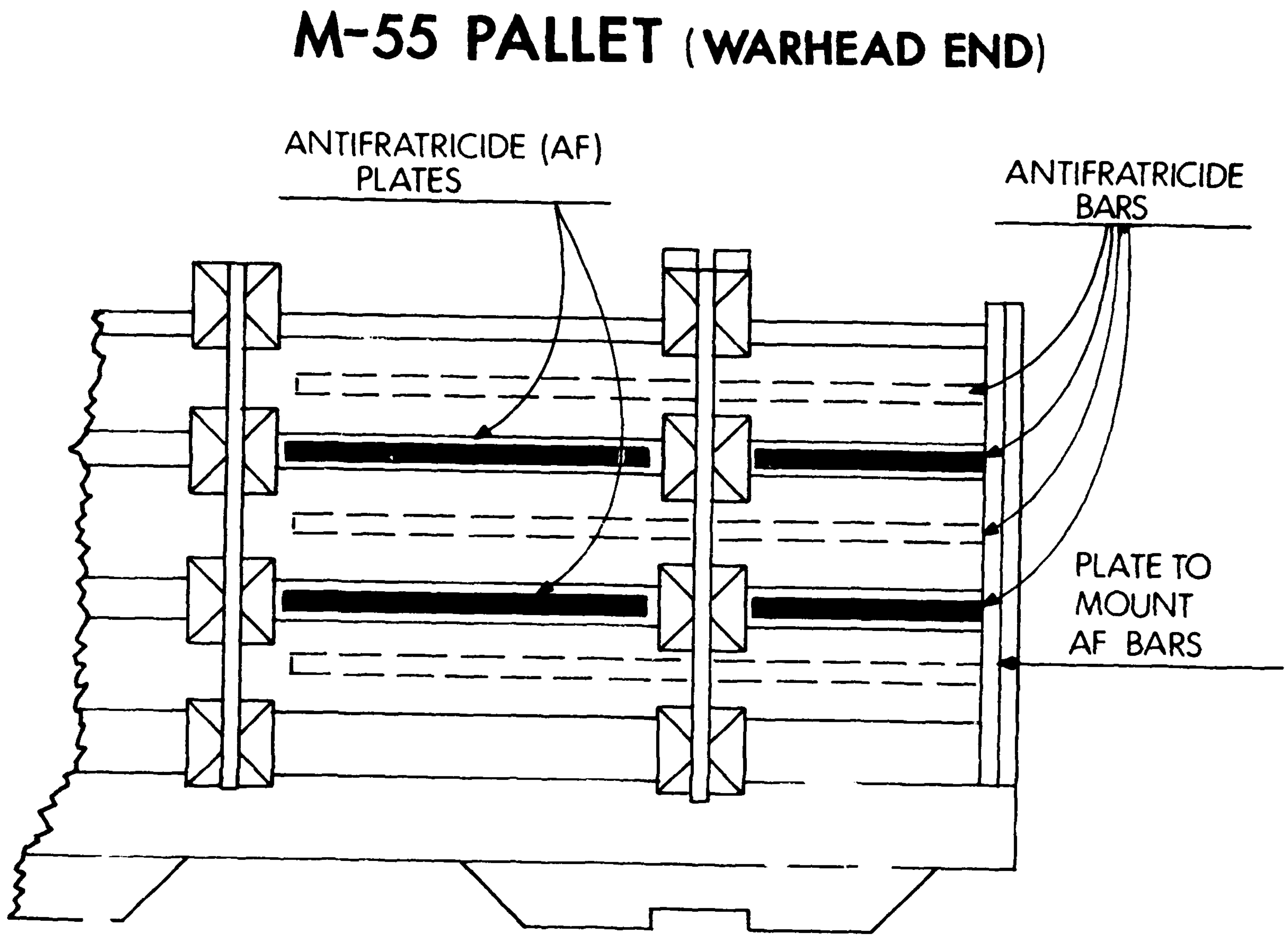

Figure 3. Side View of Palletized M55 Rockets Showing Placement of Antifratricide Plates AFT of Front Saddle

front of the pallet which could support protective devices for the section of the warhead forward of the first pallet saddle, and between rounds in horizontal rows aft of the saddle. Such a plate would be easily handled by two men and provide the bulk of the required pallet protection in one operation. In spite of the lack of test data, the uncertainties of the best antifratricide materials to use, and the lack of a firm design concept for the containment structure; it can be stated with a high level of confidence that an antifratricide design can be fabricated which will limit the maximum credible event to the detonation of one and only one munition. An extensive test series would be required to optimize the design.

C. Container Wall Thickness Calculations

To perform calculations on the thickness of steel required in a cylindrical containment vessel it is necessary to specify the blast loads and load duration. There was insufficient time to exercise available computer codes to establish these loads and their time history. Analytical techniques were used to calculate the maximum loads and load durations. For the dynamic load calculation the cylinder was assumed to be infinitely long with an inside diameter of 1.278 meters. For the static loads the cylinder was assumed to be 2.54 meters long. Charge weights were selected to be 1.45 kilograms and 2.90 kilograms. Charges were assumed to be spherical and located on the cylinder axis.

The steel chosen for these calculations was 1020 which is a common mild steel, and the yield stress value used was 240 megapascals. Typical one dimensional tensile tests show an ultimate stress limit of 475 megapascals for 1020 steel. Thus a safety factor of nearly two is built into the calculations. The results obtained gave wall thickness of 27 mm and 39 mm to contain the dynamic loads from the two charge weights used. Similarly static loads were contained by wall thickness of 15 mm and 30 mm respectively.

In these calculations no account was taken of potential fragment damage, off center charge location, finite cylinder length for dynamic loads, charge shapes other than spherical, and other practical but complicating considerations. Modeling of these aspects can be done with existing computer programs and is a part of the proposed follow-on program.

D. Containment Vessel Conceptual Designs and Cost Estimates:

The concepts considered in this study are all based on the assumption that the maximum credible event is the detonation of one and only one rocket warhead. The designs are such that the explosion fragments and agent are totally contained within the vessel. The most efficient design for containing pressure is a cylindrical container with hemispherical end caps. All containment vessel designs are the same with only size variation to accommodate various operational approaches, and each have their own set of advantages and disadvantages. The designs sketched in Figures 4, 5, and 6 have only approximate dimensions assigned to obtain weights and costs. No consideration was given to the details of closure or internal hardware.

Concept No. 1 is large enough to contain a full pallet of M55 rockets in a SPORT. This design is too large to fit through the igloo door and consequently

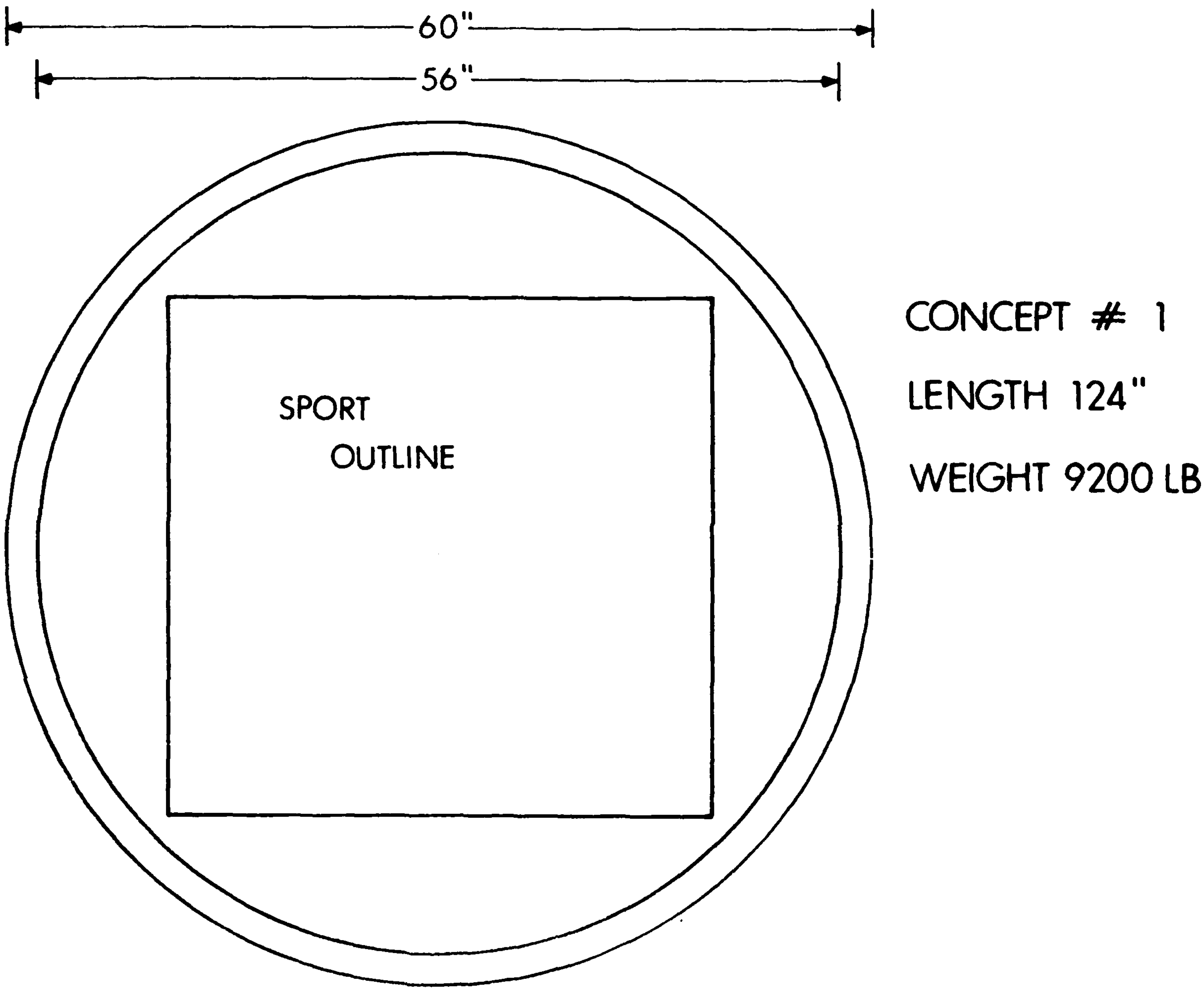

Figure 4. Cross Section of Concept One

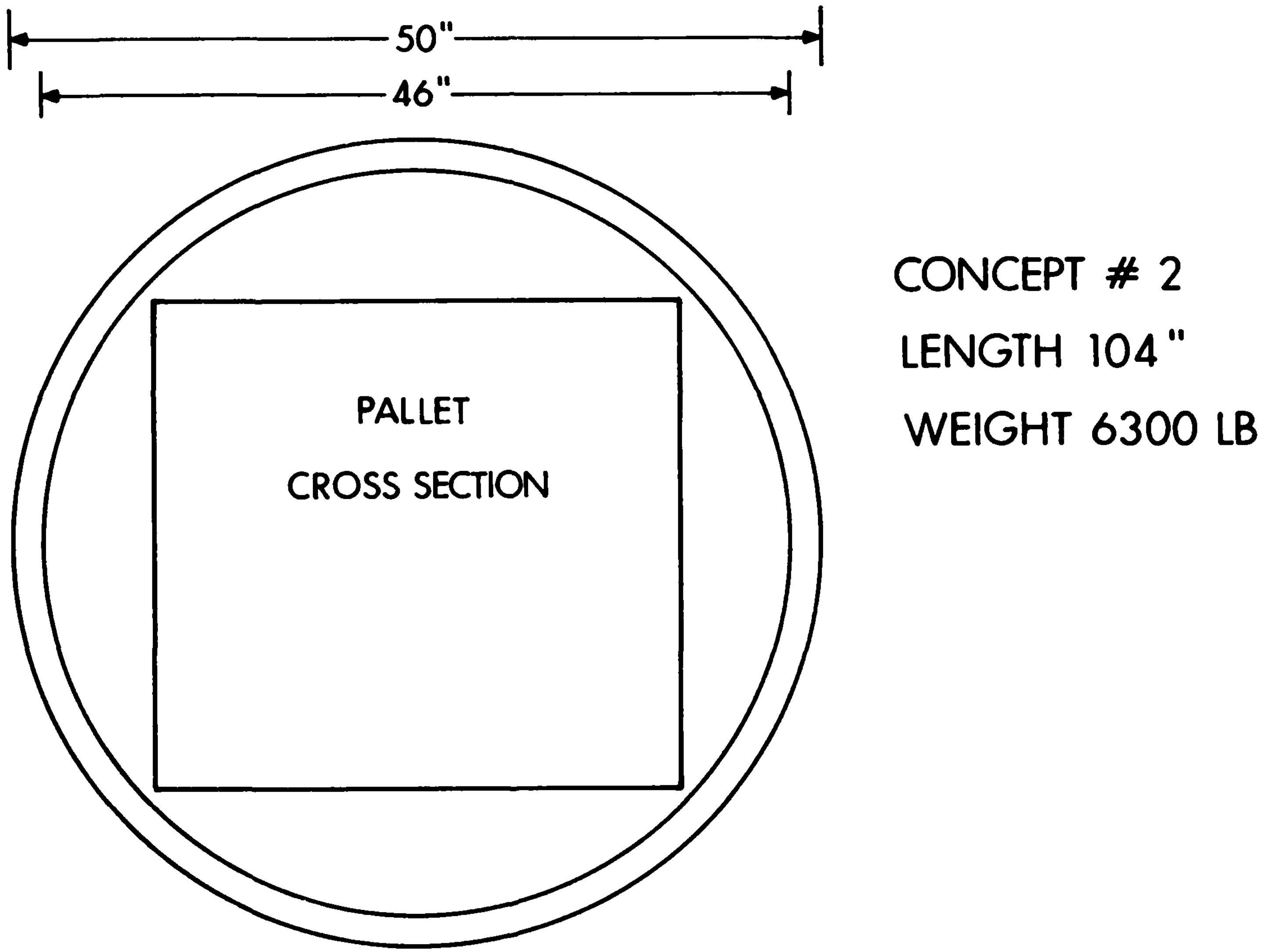

Figure 5. Cross Section of Concept Two

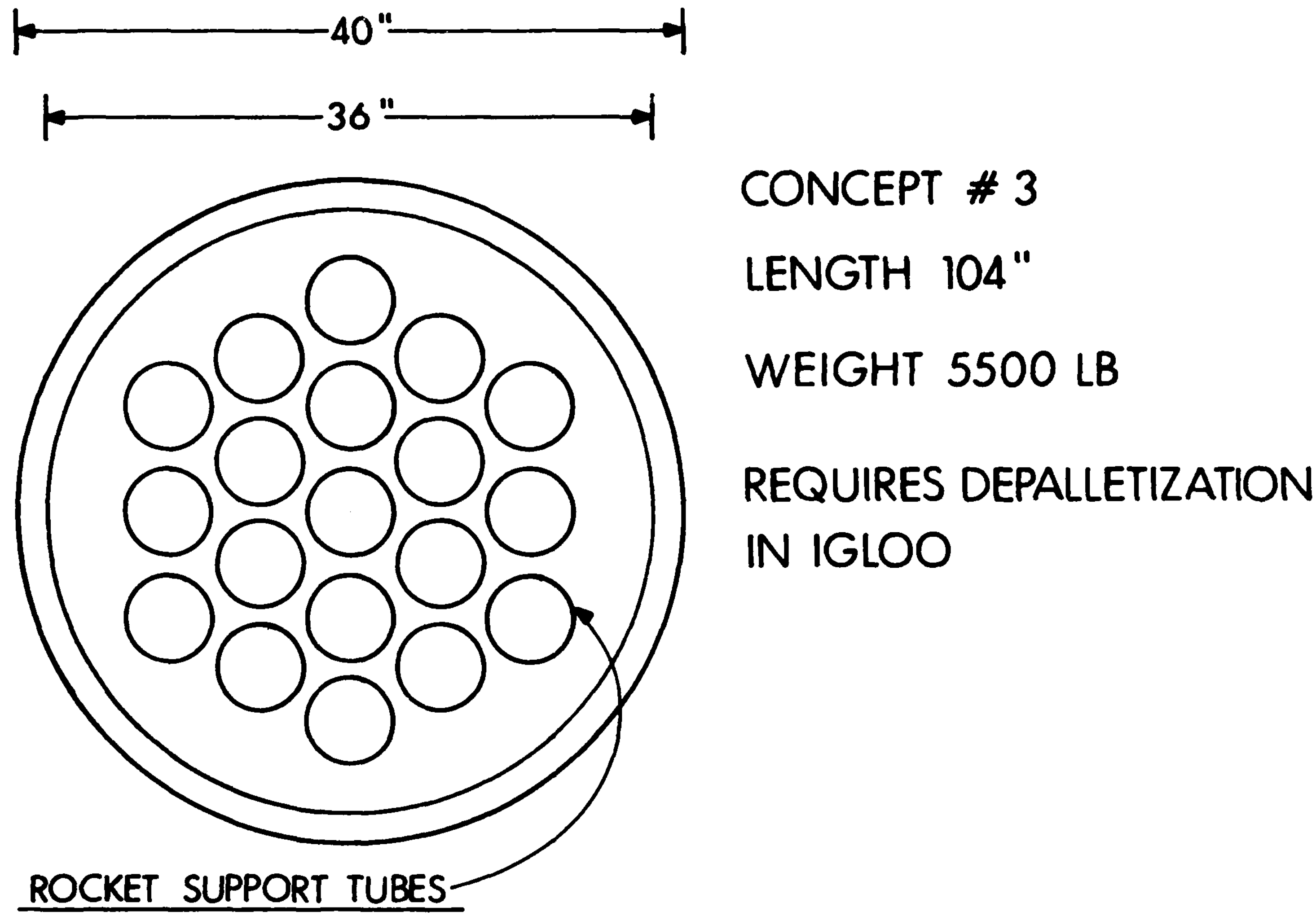

Figure 6. Cross Section of Concept Three

provisions must be made for insertion of the SPORT outside the igloo. This is not a major problem as transport can be done with a conveyor track .

Concept No. 2 is smaller than the previous design, but is still too large to fit through the igloo door. It will contain a fully loaded pallet without the SPORT. It's weight is substantially less, but still pallet loading must be outside the igloo.

Concept No. 3 is small enough to fit through the igloo door. It can accept slightly more than one full pallet of M55 rockets, but the rockets must be depalletized inside the igloo which means the dunnage must be transported separately for disposal.

Each of these containment vessel designs can be readily mounted on a trailer for hauling to the demil facility. The two larger designs would be mounted crosswise on a trailer while the latter would be better mounted lengthwise. Each design can also be fitted with various monitoring ports, drains, etc. as required giving consideration to the structural integrity of the container. Concept No. 3 has many advantages, but requires handling individual rockets, and this handling may possibly produce leaks in the warhead. This possibility is under investigation now by other agencies. This design allows for larger round to round spacing than does the pallet, and antifratricide can be built in, as an integral part of the vessel. Furthermore, these containers would serve as ready storage at the demil site while awaiting processing with only security to prevent tampering required. Decontamination could be easily accomplished. The ease with which they could be loaded would lead to rapid turn around times. The major advantage seems to be that less material handling equipment is required.

Table No. 1 compares the dimensions, weights, and rough cost estimates for these three designs. Here again, the smaller design has advantages in both weight and cost. For example, if one planned to process 10 containers a day, 15 containers of the smallest size could be obtained for the cost of 10 of the next larger size. This allows some to be used as ready storage at the demil site.

Table 1. CONTAINMENT CONCEPTS

CONCEPT	DIAMETER IN METERS (INCH)	LENGTH IN METERS (INCH)	WEIGHT IN KILOGRAMS (POUNDS)	COST IN K DOLLARS
ENCLOSE SPORT	1.50	3.12	4182	30
	(59)	(123)	(9200)	
ENCLOSE PALLET	1.24	2.62	2864	22
	(49)	(103)	(6300)	
DEPALLETIZE	0.99	2.62	2500	15
	(39)	(103)	(5500)	

E. Follow-on Study

The implementation of a container for safely transporting M55 rockets to a demil facility would require a more detailed study in order to specify more accurately the container wall thickness and the necessary antifratricide protection. A brief narrative description follows which is keyed to an outline with cost estimates (Table 2).

1. Computational Effort. This part of the program would be devoted first to establishing blast loads that a container would experience given the detonation of one warhead. This must be done for an axially located warhead and also for one at the corner of the pallet and must include to the extent possible the effect of the surrounding rockets. Additionally, this task differs from previous work with bare or cased explosive charges in that the effects of the liquid surrounding the explosive and, if necessary, the effect of the SPORT surrounding the pallet will be included. When completed the time space history of the loads on the structure will be predicted in detail including the long term quasi-static loads.

Having predicted the load history it is now possible to examine the structural response of the container. The program will predict both elastic and plastic response, although with safety factors required, it is probable that plastic response will not be allowed.

The results will be examined and the advantage/disadvantge of high strength steel vs mild steel will be examined, including cost trade-offs. Furthermore, the location of utilities, such as sampling ports and drains, will be considered, to be sure the structure is not weakened by inappropriate utility location.

2. FRATRICIDE TESTS. Previous work (see reference 1), plus our own study, indicates that some protection is required between warheads to prevent communications of reaction, even though acceptor reaction may not be very violent. It will be the goals of these tests to determine the protection sufficient to keep the burster tubes of nearest neighbors to a detonated warhead from rupturing. This is a much more difficult task than allowing rupture but not ignition. The specific materials and configurations to accomplish this goal will be determined as a results of these tests.

3. DESIGN AND FABRICATION. Once computations are completed or at least far enough along to allow specification, this final design, including access door and utility penetrations will commence. It is recommended that this be a contractual effort with a commercial steel fabricator. This allows the experience and expertise, not readily available at BRL, to be applied to this task. It is the intent of this program to have quarter scale containers made first for test purposes. This is a more cost efffective approach and will reveal any design deficiencies which may exist. When quarter scale designs have passed their tests, a full scale structure can be fabricated and tested as final proof.

4. QUARTER SCALE TESTS. This test series represents the most economical approach to test designs and concept that will be applied to a full scale vessel. It validates design calculations prior to the expense of full scale fabrication. It cannot replace the need to perform full scale tests, but will

reveal any weaknesses in design of the structure and accessories and allow corrective actions to be taken. Successful completion of these tests allows the full scale structure to be fabricated with high confidence in its successful performance. Instrumentation for these tests will include strain gauges to measure deformation of the structure, blast and pressure gauges to measure internal forces, and thermocouples to monitor interior temperatures as well as high speed photographic coverage.

5. FULL SCALE TESTS. These tests will provide the final proof of the safety of this structure and will include documentary film coverage which may be useful in demonstrating that M55 rockets can be safely transported or stored in this container. The remaining instrumentation will be similiar in nature to that used in the quarter scale tests.

Preparation of cost and time estimates for a follow-on program as described above are difficult because the task is not suitably defined. The estimates for the antifratricide work and the computational efforts are reasonably straight forward. Estimates of contract costs are very nebulous, partly because no decision has been made as to the size and other requirements of the containment vessel, and additionally, because until computations are completed, the required wall thickness cannot be specified. Test of the quarter scale and full scale vessels also have some hidden costs primarily in material handling which have a less firm basis for making estimates. Nevertheless, what follows is the best estimate of time and costs required for each segment of the program.

Table 2. *FOLLOW-ON STUDY COST BREAKDOWN*

SEGMENT	COST	
Antifratricide Study	100 K	6 months
Computation Work	100 K	6 months
Contractual Work (Includes fabrication costs)	200 K	18 months
Quarter Scale Tests	50 K	3 months
Full Scale Tests	30 K	2 months
Report Preparation	10 K	2 months
TOTAL COST	490 K	24 months

The total time required is not cumulative because some efforts proceed concurrently.

III. SUMMARY

It is the author's opinion based on limited hard data (at this time), but considerable experience, that the goal of limiting the maximum credible event can be accomplished and that a containment vessel can be built to contain the maximum credible event. To prove this opinion is not easy, nor is it cheap, as evidenced by the previous cost estimates. Estimates of the time required to produce hard facts, supportable by good test data, will not warm the heart of any project manager, but in the author's opinion are reasonable and necessary.

Whether or not these proposed efforts are attractive to those individuals responsible for the overall pergram requires that these efforts be evaluated in the context of the total program goals and constraints.

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