270
8/4/77

1278

MLM-2428

MLM-2428

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It has been reproduced from the best available copy to permit the broadest possible availability.

Safety Analysis Report
for Packaging (SARP): ATMX-500
Railcar Nuclear Packaging

James F. Griffin, James B. Peterson,
Don A. Edling and Richard K. Blauvelt

July 8, 1977

MASTER

Monsanto

MOUND LABORATORY

Miamisburg, Ohio
operated by

MONSANTO RESEARCH CORPORATION

a subsidiary of Monsanto Company

for the

**UNITED STATES ENERGY RESEARCH
AND DEVELOPMENT ADMINISTRATION**

U. S. Government Contract No. EY-76-C-04-0053

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Safety Analysis Report for Packaging (SARP): Railcar Nuclear Packaging

**James F. Griffin, James B. Peterson,
Don A. Edling and Richard K. Blauvelt**

Issued: July 8, 1977

PRINTED IN THE UNITED STATES OF AMERICA

Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy \$4.00; Microfiche \$3.00

MONSANTO RESEARCH CORPORATION

A Subsidiary of Monsanto Company

MOUND LABORATORY

Miamisburg, Ohio 45342

operated for

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

U. S. Government Contract No. EY-76-C-04-0053

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Table of Contents

	<u>Page</u>
LIST OF ILLUSTRATIONS	3
SUMMARY	4
INTRODUCTION.	5
DEVELOPMENT OF THE CONTAINER CONCEPT.	5
DESCRIPTION OF THE ATMX-500 MODIFICATION	6
Prior to Modification.	6
Structural Modification Sequence	6
Underframe and Floor	8
Sides.	8
Top Cover Frames and Insulation.	8
Ends	12
The Lock and Slide Mechanism	12
Partitions	12
AUTHORIZED PACKAGES	
Packages	12
Contents of Packaging	12
Maximum Heat from Contents	14
NORMAL CONDITIONS OF TRANSPORT EVALUATION	15
HYPOTHETICAL ACCIDENT INVESTIGATION	
General.	15
Free Drop.	16
Puncture	16
Thermal.	16
Water Immersion.	17
Other Credible Accident Conditions	17
RADIATION SHIELDING AND RADIOLOGICAL SAFETY	
Radiation Shielding.	17
Radiological Safety.	17
NUCLEAR CRITICALITY SAFETY.	18
QUALITY CONTROL	18
EXPERIENCE AND LOADING OPERATIONS	19
REFERENCES.	22
APPENDIX I: The Story of the Special Railcars.	23
APPENDIX II: Union Carbide ATMX-500 Free Drop and Thermal Evaluations.	26
APPENDIX III: ATMX-600 Series Railcar Engineering Evaluation	32
APPENDIX IV: ATMX Railcar Inspections.	34
GLOSSARY.	43

List of Illustrations

<u>Figure</u>	<u>Illustration</u>	<u>Page</u>
1	External view of ATMX-500 series railcar prior to modification by Mound Laboratory.	5
2	ATMX-500 top covers before modification.	7
3	Internal view of ATMX-500 prior to modification.	7
4	View of ATMX-500 floor looking toward one end of the railcar prior to modification.	8
5	View of the ATMX-500 floor after voids are filled with welded 3/16-in. (0.48-cm) steel plates.	8
6	ATMX-500 sidewall cross section showing overall design and dimensions.	9
7	Internal view of the modified ATMX-500 showing three bays are separated by two partitions made of 3/4-in. (1.91-cm) plywood.	9
8	Top cover frame design and dimensions.	10
9	ATMX-500 top cover insulated with polyurethane foam.	10
10	Top cover cross section design and specifications.	11
11	External view of the ATMX-500 end structure.	11
12	Internal view of the end superstructure.	12
13	Basic design and dimensions of the ATMX-500 end superstructure with relocated access door.	13
14	The lock and slide mechanism on the modified ATMX-500 which replaced the bolt-down method.	13
15	Design specifications for the lock and slide mechanism.	13
16	Partition design and dimensions of a bay partition.	14
17	General design of the ATMX-500 after modification by Mound Laboratory.	19
18	Four drums on steel pallet ready for loading into railcar.	21
19	Palletized drums loaded into railcar. Inflatable dunnage is in void at left of photograph.	21
20	In this photograph, the palletized drums are separated by inflatable dunnage, and plywood sheets have been placed on top of the drums in preparation for loading a second layer of drums.	21
21	Second layer of drums in railcar. The drums are close enough to the top that there is no need for banding.	21

Summary

This Safety Analysis Report for Packaging (SARP) makes available to all potential users the technical specifications and limits pertinent to the modification and use of the ATMX Railcars for which the Department of Transportation has issued Special Permit No. 5948. This SARP includes discussions of structural integrity, thermal resistance, radiation shielding and radiological safety, nuclear criticality safety, and quality control. Much of the information was previously published in a similar report. A complete physical and technical description of the package is presented. The packaging consists of a specially modified ATMX Series 500 Railcar loaded with DOT Specification steel drums or fiberglass coated plywood boxes. The results of the nuclear criticality safety analysis provide the maximum quantities of each fissile isotope which may be shipped as Fissile Class I in 30- and 55-gal drums. A limit of 5 g/ft³ was established for wooden boxes. Design and development considerations regarding the packaging concept and modification of the ATMX-500 Railcar are presented. Tables, dimensional sketches, sequential photographs of the structural modifications, technical references, loading and shipping guidelines, and results of Mound Laboratory's experience in using this container are included. An internal review of this SARP was performed in compliance with the requirements of ERDA Manual Chapter 5201-Part V.

Introduction

The ATMX-600 railroad cars, as modified under the provisions of DOT Special Permit No. 5948, have proven to be effective and efficient means of shipping large volumes of radioactive waste materials [1]. However, the potential value of this shipping mode is reduced somewhat because of the limited number of cars that are available for this purpose and the conditional aspects of their use. Because of these limitations, a search of suitable alternative methods of shipment was undertaken.

The basic objective was to develop a shipping system for radioactive wastes that would provide

compliance with existing regulations as well as economic and efficient handling at each point along the packaging, shipping, and receiving chain. Since Mound Laboratory was already using two ATMX-600 railroad cars for waste shipments, the shipping system for the ATMX-500 railroad cars would have to blend with existing operations. Additionally, the ATMX-500 had to be adaptable to a conceptual plan being studied for minimizing transportation hazards within the laboratory. The alternative of modifying an ATMX-500 (Figure 1) was then evaluated and accepted. A design of an overpack container for truck use was considered, but this proved too costly and was abandoned [2].

FIGURE 1 - External view of the ATMX-500 series railcar prior to modification by Mound Laboratory.

Development of the Container Concept

The ATMX-500 railroad car is the first generation ATMX car and embodies the same principles of protection as the ATMX-600, i.e., a massive double-walled, all-steel, protective envelope. The modifications developed by Adcock for the ATMX-600 waste container were, for the most part, directly transferable to the ATMX-500 railroad car [1]. However, it was found that additional modifications were necessary to upgrade the ATMX-500 to the level of handling ease provided by the ATMX-600 railroad cars. Packing requirements and the basic theory of use were essentially the same as the ATMX-600 and were presented in the original petition for the DOT Special Permit.

As a result of the ATMX-500 petition, one major change incorporated in DOT Special Permit No. 5948, was an increase in the thermal wattage limitation. A nuclear criticality study conducted at Mound Laboratory with respect to shipment of large quantities of fissile waste material was also in support of this change [3]. The special permit content specifications now state that a 10-W limitation is to be placed on each drum as opposed to the 5-W limitation in the original permit. Another study [4] conducted at Mound Laboratory showed that the temperature on the external surface of a single 55-gal drum containing 10-W(th), as discussed in this

report, will be only approximately 1°F above the ambient temperature within the railcars.

Since the ATMX-500 railcars were available for

continued use and could be modified to handle radioactive waste material, modification and use of these cars were far more economical than the purchase of new 600 Series railcars.

Description of the ATMX-500 Modification

PRIOR TO MODIFICATION

The ATMX-500 Series railroad cars were originally constructed for shipment of special weapon materials. In addition, the cars were designed to provide the maximum practical structure and fire resistant qualities to prevent or minimize damage to the contents in the event of a train wreck. They were constructed to batter their way through all obstructions, yet remain intact. General dimensional specifications are presented in Table 1.

Table 1

GENERAL DESIGN SPECIFICATIONS OF THE ATMX-500 SERIES RAILCARS

Overall Dimensions:

Length over end sills	60 ft
Width over frame	10 ft 1/4 in.
Height over sills	6 ft 6 in.

Usable Inside Bay Dimensions (Three permanent bays):

Length	16 ft 9-5/8 in.
Width	9 ft 3 1/2 in.
Height	6 ft 3 in.

Weights (nominal):

Allowable weight at rail	210,000 lb
Light weight	117,000 lb
Capacity	90,000 lb

The ATMX-500, unlike the ATMX-600, was not built for handling ease and was not adaptable to varying loads. The ATMX-500 is separated into three permanent bays, with securing devices welded to the deck plates. Additionally, the top covers on the ATMX-500 are secured by a series of bolts. Figure 2 shows that many bolts are necessary to secure the three top covers. Figure 3 shows the detail of the securing devices on the floor inside the car.

As stated previously, modifications were necessary both to achieve additional structural strength for containment of the radioactive material and to facilitate the handling operations

associated with the car. The ATMX-500 railcars are designed to meet all American Association of Railroads (AAR) and Interstate Commerce Commission (ICC) standards. The all-steel, fully enclosed railcar design incorporates every practical protective device.

STRUCTURAL MODIFICATION SEQUENCE

In summary, structural modifications in the ATMX-500 construction design follow the sequence outlined below:

- (1) Remove all mounting fixtures from the railcar bed and super-structure. Since most of these are welded in place, burning operations are required.
- (2) Close the voids in the floor casting and super-structure by welding 3/16-in. steel plate over them.
- (3) Cover the side walls with 3/16 in. steel plate to a height of 4 ft.
- (4) Fill the voids in the top covers with insulating material and close the envelope by welding with 14 gage sheet steel.

Additionally, to bring the handling ease of the ATMX-500 up to ATMX-600 standards, the following modifications are necessary:

- (5) Move the access door from the center of the railroad car super-structure to one end of the railroad car.
- (6) Fabricate and install a locking slide mechanism, similar to that used on the ATMX-600 railroad car, to replace hold-down closure requirements.
- (7) Sheath floors and bay partitions with 3/4 in. plywood.

The following sections present more detailed descriptions of these modifications. However, these descriptions cannot cover all the facets of the modifications. More complete specifications are given on Mound Laboratory Drawings 5-1819, 4-8695, 4-8696, and 4-8697. Duplicate copies of

FIGURE 2 - ATMX-500 top covers before modification.

FIGURE 3 - Internal view of the ATMX-500 prior to modification.

these drawings may be obtained by writing Drawing Control, Facilities Engineering, Mound Laboratory, Miamisburg, Ohio 45342.

UNDERFRAME AND FLOOR

The underframe is a one piece steel casting similar in design to a pulp wood railcar frame. Removal of the weapons mounting fixtures created voids in the floor casing and superstructure. These voids must be closed. The irregular rectangular openings in the casting were filled by welding in 3/16 in. steel plates, supported by 2 x 2 x 1/4 in. angle iron, to produce a continuous railcar floor. (Compare Figures 4 and 5). This underframe is the structural backbone of the ATMX 500 (see Appendix I).

The floors and bay partitions are sheathed with plywood to provide an even surface for loading, blocking, and shoring and to provide an easily replaceable surface in the event of contamination. The floor is covered with two layers of fire-proofed 3/4 in. plywood that is bolted to the floor casting. All seams are caulked with water-repelling sealant.

FIGURE 4 - View of ATMX-500 floor looking toward one end of the railcar prior to modification.

SIDES

The side walls are covered with 3/16 in. thick steel plate to a height of 4 ft. The purpose of this is threefold:

- (1) To strengthen side wall construction, particularly against puncture type penetrations.
- (2) To provide a 4 in. void which could be filled with shielding material as

required to meet DOT external radiation dose level requirements.

- (3) To provide an even loading surface inside the car for ease of positioning, bracing, and shoring the load.

The 3/16 in plate is plug-welded to the 4 x 4 x 1/2 in. steel structural tees on approximately 2 1/4 ft centers. The crack at the bottom of the side wall plates where they meet the floor surface is caulked full length with a weather sealant caulking compound. Figures 6 and 7 show this modification.

FIGURE 5 - View of the ATMX-500 floor after voids are filled with welded 3/16 in. steel plates. The floor will also be sheathed with two layers of 3/4 in. plywood.

TOP COVER FRAMES AND INSULATION

The three top covers are framed with 5 x 5 x 3/8 in angles with cross bracing sections as shown in Figure 8. Each of the three covers is modified

FIGURE 6 - ATMX-500 sidewall cross section showing overall design and dimensions.

to allow installation of insulating material (Figure 9). Mound has used fire resistant polyurethane foam of 2 lb/ft³ density, but any equivalent insulating material is satisfactory. The

14 gauge steel sheets are plug-welded to the underbracing of the covers to contain the foam. In addition to enhancing the insulating qualities, this modification provides additional puncture protection for the covers.

Another modification was made to provide for an opening sequence starting with the center cover. The 4 x 4 x 1/4 in. angles are welded to the center cover edges and overlap the adjacent covers so the center cover would have to be removed first. A 3/8 in. Neoprene* gasket provides a weather seal for covers in the closed position (see Figure 10). The other covers also have this angle welded to the edges to protect the locking slide arrangement.

*Chloroprene rubber: resistant to oils, heat and insulation.

FIGURE 7 - Internal view of ATMX-500. This view shows the three bays which have (currently being installed) 1/4 in. steel plate (all the way to top) welded on each surface. Steel plates are plug welded to form internal sidewalls 4 ft. high and with a 4 in. void for additional shielding material.

- (1) 4 x 4 x 1/4 in. Steel angles welded to center cover only.
- (2) 3 x 5 x 3/8 in. Steel angles.
- (3) 5 x 5 x 3/8 in. Steel angles.
- (4) 2 x 2 in. @ 4.3 lb/ft Steel T's.

FIGURE 8 - Top cover frame design and dimensions.

FIGURE 9 - ATMX-500 top cover insulated with polyurethane foam.

FIGURE 10 - Top cover cross section design and specifications.

FIGURE 11 - External view of the ATMX-500 end structure.

ENDS

The major structural members on each end of the car are shown in Figures 11 and 12. The external superstructure will, in an accident, allow an object such as another railcar to be deflected up and over the heavily reinforced sloping end. As a part of the overall modification, the access door is moved from its center hull position to one end (see Figure 13). The door and frame may be removed in one piece to facilitate modification.

The door opening is framed with 3 1/4 x 3 1/2 x 1/4 in. angle, with the door itself fabricated from 3/10 in. steel plate on a 2 x 3 x 1/4 in. angle frame. The door has security pinned hinges on one side and a sealable door latch on the other. Thus, a properly closed door provides

FIGURE 12 - Internal view of the end superstructure.

both containment and security. This change allows more convenient entry into the railcar for inspection when it is loaded.

THE LOCK AND SLIDE MECHANISM

Fabrication and installation of a locking slide mechanism (Figure 14) similar to the cover closing mechanism on the ATMX-600 were necessary. A series of 33 bayonet-type lugs along each side of the top cover engages a corresponding series of notches in the railcar frame. A sliding bar mechanism with similar notches runs down each side of the railcar (Figure 15). Movement is effected by a screw and lock nut mechanism located on either end of the bars. Security is provided by a dead bolt to prevent slide movement from the closed position. This bolt can be removed only by combined effort of two people, one inside and one outside the railcar. This modification eliminates the cumbersome bolt-down method of closure and provides more ease in mounting or removing the top covers.

PARTITIONS

As shown in Figures 7 and 17, the car is permanently divided into three 16-ft 10-in. x 10-ft 1/4-in. Figures 5 and 16 show the structural components. These partitions act as roll bars to prevent buckling in the event of a roll-over. Modifications include sheathing both sides of these partitions with 1/4 in. steel plate (see Figure 16 and Figure 7).

Authorized Packages

PACKAGES

Steel drums must conform to DOT Specification 7A or equivalent. Each drum is lined with a polyethylene, polyvinyl chloride, or equivalent sheet having a minimum thickness of 5 mil.

Boxes must meet DOT Specification 7A, or equivalent. Each crate is lined with a polyethylene, polyvinyl chloride, or equivalent sheet having a minimum thickness of 8 mil.

CONTENTS OF PACKAGING

The authorized contents of each package consist of radioactive and/or fissile radioactive waste

materials up to and including large quantities. Contents, which must be in a form that is not readily dispersible (not bulk powder or liquid), are further described as follows:

Drums - Not more than 100 g (for drums of not less than 30-gal capacity) or 200 g (for drums of 55-gal capacity or greater) of fissile material per drum, with a maximum thermal decay energy of 10-W per drum, in the form of process wastes (greases or sludges hardened to a solid or semi-solid state with 'oil dry' cement, or equal) or line-generated waste (graphite, molds, filter-sludge, insulation, miscellaneous

FIGURE 13 - Basic design and dimensions of the ATMX-500 end superstructure with relocated access door.

FIGURE 14 - The lock and slide mechanism on the modified ATMX-500 which replaced the bolt-down method.

FIGURE 15 - Design specifications for the lock and slide mechanism.

FIGURE 16 - Partition design and dimensions of a bay partition.

residues, etc.). Each drum shall be limited to a maximum of 200 lb of graphite.

Boxes - Contents are similar to the line-generated wastes, except that the size or bulk of the items precludes use of drums (pipe, lumber, equipment, machinery, etc.). The fissile material content of each crate shall not exceed 5 g/ft³,

MAXIMUM HEAT FROM CONTENTS

An experiment was performed at Mound Laboratory [4] to determine the temperature profile within a 55-gal insulated metal drum at steady state resulting from containment of materials producing 10-W of heat from radioactive decay. An electrical heater was placed inside an inner container centered within the insulated drum to simulate the radioactive materials. The heat input was set at 10-W and the temperatures were permitted to stabilize for 96 hr.

The resulting temperatures within the drum using this test configuration are considerably higher than would be encountered in a typical package of waste since the waste packages are not insulated, as such, and the decay heat is not concentrated near the center of the package. The external surface temperature of a 55-gal waste drum containing 10-W of decay heat was accurately determined by this test method. The resulting temperature increases above ambient were determined to be as follows:

Horizontal Distance from Drum Centerline	Temperature Increase Above Ambient With 10-W of Decay Heat	
	°F	°C
5 in.	59	33
7 in.	11	6
11-1/4 in. (outside surface)	<1	<1

The temperature increases at 5 in. and 7 in. from the drum center cannot easily be used for evaluation of waste packages, except to establish upper limits because they are much higher than any temperature increase that would be expected within a waste package. It can be concluded that the

surface temperature of the drums or boxes will increase above ambient temperature on the order of 1°F when they contain the maximum anticipated thermal load of 10 W. Thus, no damage to the drums, boxes or the ATMX car will result even after an extended period of time.

Normal Conditions of Transport Evaluation

ERDA Manual Chapter 0529 requires nuclear packaging to be capable of satisfactory containment when subjected to the following nine tests simulating normal transportation environmental and handling conditions:

1. Heat
2. Cold
3. Pressure
4. Vibration
5. Water Spray
6. Free Drop
7. Corner Drop
8. Penetration
9. Compression

It was not necessary to actually perform any of the nine tests listed above on the ATMX-500 railcar because of sufficient existing test data and experience.

All the drums and boxes used as inner containers are Department of Transportation Specification 7A containers [5] that are capable of providing the necessary containment when subjected to the normal transportation conditions. The drums and boxes are secured in place within the railcar to ensure their integrity within the railcar environment. In addition, shipments made from Mound Laboratory have traveled approximately 36,600 (loaded) miles without encountering any containment problems. In fact, the palletizing technique described later provides such strong securing of the drums that not even minor scratches or dents are incurred during routine (many times rough) handling of the railcars enroute. This securing of the load, so obviously beneficial for normal handling, would be a major contributor to packaging performance under possible accident conditions.

Hypothetical Accident Evaluation

GENERAL

ERDA Manual Chapter 0529 requires satisfactory performance of packaging when subjected to a series of four tests simulating accident conditions. Escape of radioactive materials must be below defined limits and the package must remain subcritical. The free drop, puncture, thermal, and water immersion tests must be considered in the listed sequence.

It was not necessary to actually perform any of the four tests. This evaluation is based on information regarding the railcar design criteria (Appendix I), calculations performed by Union Carbide (ORNL) for the ATMX-500 railcar (Appendix II), and an evaluation by Dow Chemical Company (Rocky Flats) for the ATMX-600 railcar [1] (Appendix III). The Union Carbide evaluation was concerned specifically with the Free Drop and

Thermal tests as defined in ERDAM 0529. A different approach was taken by Dow Chemical in that this evaluation was based on definition of an accident environment which is considered more realistic for a railcar. Even though the approaches were quite different and each discussed a different type of railcar, the results of both evaluations support the conclusion that a hypothetical accident may cause a few of the steel drums within the railcar to be breached, but that contamination would be localized due to the form of the materials being shipped. It is assumed that the railcar could be punctured if subjected to the puncture test and could leak water if subjected to the water immersion test since these results are of little consequence.

FREE DROP

This test requires a free drop through a distance of 30 ft onto a flat, essentially unyielding, horizontal surface. The package must be positioned to strike the surface in a position for which maximum damage is expected.

The calculations performed by Union Carbide (Appendix II) indicate that the ATMX-500 railcar will withstand the free drop. Flat drops on the top of the car, the side of the car, and the end of the car were considered. The top drop was found to be the worst case. It was determined that, in this case, a very dramatic permanent distortion would result, but that the railcar would not come apart or rupture.

PUNCTURE

This test requires a free drop through a distance of 40 in. striking, in a position maximum damage is expected, the top end of a vertical, cylindrical, mild-steel bar mounted on an essentially unyielding horizontal surface. The bar will have a 6 in. diameter, with the top horizontal and its edge rounded to a radius of not more than 1/4 in., and of such a length as to cause maximum damage to the package, but not less than 8 in. long. The long axis of the bar shall be perpendicular to the unyielding horizontal surface.

It is assumed that the steel bar could puncture the side of the railcar and a limited number of

boxes and/or drums. However, it is inconceivable that any additional damage would be caused.

THERMAL

This test requires exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 1475°F for 30 min with an emissivity coefficient of 0.9, assuming the surfaces of the package have an absorption coefficient of 0.8. The package is not to be cooled artificially until 3 hr after the test period, unless it can be shown that the temperature on the inside of the package has begun to fall in less than 3 hr.

The Dow Chemical engineering evaluation [1] indicated that the statistical probability of an ATMX car being involved in a fire is negligible. Nonetheless, the consequences of such a fire must be considered.

Calculations performed by Union Carbide (Appendix II) determined the temperatures expected for the ATMX-500 railcar if subjected to the thermal test specified above. Dow Chemical evaluated the ATMX-600 railcar when subjected to the "maximum conceivable fire" [1]. Selected temperatures resulting from the two studies are presented in Table 2.

Table 2
RESULTS OF THERMAL EVALUATIONS

Location	Temperature (°F)	
	ERDAM 0529 Test Union Carbide Study for ATMX-500	Maximum Conceivable Fire - Dow Chemical Study for ATMX-600
1 Bulk air in the railcar.	100	-
2 Average temperature of railcar contents.	-	<200
3 Inside drum mounted in center of railcar.	<175	-
4 Outside surface of drum mounted in center of railcar.	200	-
5 Plywood floor at outside edge of railcar after 25 min.	400	-
6 Surface of crate or drum located near the railcar skin.	-	625
7 Mean temperature of the railcar.	-	875
8 Maximum temperature of hot spots at sides and ends of railcar.	950	-

Both studies [1] (Appendix II) support the conclusion that the drums and boxes located away from the exterior walls of the railcar will not exceed 200°F and the contents of these containers will be at lower temperatures. Also, drums located at the exterior edge of the railcar can be expected to desorb and vent any water vapor that may have been absorbed. Adcock and Cash [6] subjected fiberglass coated plywood boxes to the thermal test. At a constant surface temperature of 1290°F, which is 340°F in excess of the maximum predicted hot spot on the sides and ends of the railcar, the fiberglass box was breached only after 2 1/2 hr. It is concluded from these data and the fact that in the Union Carbide study of the ATMX-500 railcar a significantly lower temperature occurred at the surface of the fiberglass box under the thermal test conditions, that the fiberglass-coated plywood box would not be breached under expected thermal accident conditions.

WATER IMMERSION

This test is necessary for fissile material packages only. The test requires immersion in water to the extent that all portions of the package to be tested are under at least 3 ft of water for a period of not less than 8 hr.

It is assumed that the railcar would leak if previously subjected to the Free Drop, Puncture, and Thermal tests. Also, a few of the drums and boxes would undoubtedly leak, especially any boxes located near the side wall of the railcar which were charred during the thermal test. For the purpose of the criticality evaluation, it is assumed that water will leak into all the inner

containers, and this assumption is accounted for in the criticality evaluation.

However, circulation of water through the railcar and inner containers would be modest and it is expected that contamination spread would be limited.

OTHER CREDIBLE ACCIDENT CONDITIONS

In this section, the expected effects of rolling the railcar downhill, a head-on crash, and penetration by a strong, sharp object are discussed. These conditions are credible and are more severe than the Free Drop or Puncture tests discussed above. This evaluation summarizes the design intent of the ATMX-500 railcars (Appendix I), and the Dow Chemical engineering evaluation for the ATMX-600 railcars [1].

The superstructure of the cars is sufficiently strong to protect and firmly contain the cargo if the railcar should be rolled over in an accident. Head-on impact on the cast frame would transmit a shock to the load but is expected to leave the car intact. Head-on impact above the cast frame would cause the impacting object to be deflected up over the sloping ends of the railcar and the car would remain intact. Conservatively, it is assumed that a strong pointed object, such as a corner of a cast steel car frame, could penetrate both the side of the ATMX car and one or more of the boxes or drums.

Thus, under the worst possible circumstances, it is conceivable that a few of the inner containers would be breached and localized contamination would result.

Radiation Shielding and Radiological Safety

RADIATION SHIELDING

Calculations and shipping experience have shown that, for the shipments made and anticipated by Mound Laboratory (tritium and plutonium-238 in oxide form), no additional shielding or special administrative controls will be required to comply with the requirements of "200 mrem/hr at any point on the external surface of the car", and "10 mrem/hr at 6 ft from the external surface of

the car". Should other radioisotopes be transported an analysis would be required for each.

RADIOLOGICAL SAFETY

The inner containers offer a high degree of containment integrity since Type "A" (paragraph 173.389(j) of Tariff No. 30) packages are required as part of this permit. All contamination levels (removable and fixed) will be met on both packages and transport vehicle/car.

Nuclear Criticality Safety

A nuclear criticality safety analysis of package arrays [3], which was initially conducted for DOT-SP-6000 containers, is applicable to packaging and shipment of fissile waste material in the ATMX railcars. It was previously reported [7] that the results of the analysis indicate that when the quantities of any fissile isotope in the 55- and 30-gal drums are restricted to a maximum of 138 and 90 g, respectively, then the containers can be shipped as Fissile Class I. However, since these limits are unnecessarily restrictive for certain fissile isotopes, separate limits have been established for each fissile isotope. These limits are discussed in this section.

The limits for the uranium isotopes are based on the DOT-SP-6000 analysis, which used the density analog method for the calculations. These calculations indicate that 100 g of uranium-235 or of uranium-233 may be shipped in a 30-gal drum, and 180 g of uranium-235 or 150 g of uranium-233 may be shipped in a 55-gal drum as Fissile Class I.

However, the results obtained by the density analog method in the DOT-SP-6000 analysis seem unnecessarily restrictive for the shipment of plutonium-239 wastes. More detailed calculations [1] indicate that 200 g of plutonium-239 in 55-gal containers and 100 g of plutonium-239 in 30-gal containers satisfy Fissile Class I shipment criteria. These calculations were made using the DTF discrete ordinates computer code, assuming a maximum of 200 lb of graphite per container. Since the conservatism in the density analog method is recognized, these values are taken to be upper limits for Fissile Class I shipments of plutonium-239, these same values are conservatively taken to be the upper limits for Fissile Class I shipments of plutonium-238. For the purpose of establishing an actual upper limit

for shipments of plutonium-238 in the ATMX-500, the limiting factor is the maximum thermal decay energy of 10-W per drum, which is only 17.6 g of plutonium-238 and does not constitute a criticality risk.

The resulting criticality limits for Fissile Class I are summarized below.

FISSILE CLASS I LIMITS

Fissile Isotope	Maximum for 30-gal Drum (g)	Maximum for 55-gal Drum (g)	Basis
²³⁵ U	100	180	Density Analog
²³³ U	100	150	Density Analog
²³⁹ Pu	100	200	DTF Computer Code
²³⁸ Pu	100 ^a	200 ^a	Use ²³⁹ Pu Values

^aFor the ATMX-500, the actual shipping maximum is 17.6 g per drum based on the limitation of a maximum thermal decay energy of 10-W.

Since no restrictions will be required to segregate the containers at the burial site, it is desirable to ship all fissile waste material for burial as Fissile Class I.

In relation to the shipment of boxes contaminated with fissile material, Mound Laboratory will adopt for the ATMX-500 railcar the same restrictions established in the DOT Special Permit No. 5948 for ATMX-600 railcar which states, "The fissile material content of each crate shall not exceed 5 g/ft³."

Quality Control

The ATMX-500 railcars are inspected, and the inspections are documented in compliance with ERDAM 0529. The particulars of the inspections are provided in Mound Laboratory drawing SPA740374, which is contained in Appendix IV of this report. Visual and functional inspections are performed by both Mound Laboratory personnel and by railway inspectors. Three types of in-

spections are performed. First, Mound Laboratory personnel thoroughly inspect each railcar on return after each shipment. Second, each railcar is checked just prior to shipment after being loaded. Third, periodically, each car is dispatched to a railway shop where it is thoroughly inspected, reconditioned, and repaired as specified by the AAR interchange rules.

Experience and Loading Operations

Mound Laboratory has modified two ATMX-500 railroad cars for use in waste shipment. To date, 28 shipments have been made in these cars. The average load consisted of 98 drums and 5 boxes, or 1,378 ft³ averaging 48,200 lb (21,800 kg) and 1,221 Ci of plutonium-238. These shipments represent approximately 36,600 rail miles and no problems have been experienced with these cars. The overall design of the modified ATMX-500 is shown in Figure 17.

Because of space limitations and the unavailability of standardized transport containers, Mound Laboratory has loaded the drums and boxes directly into the railroad car.

The size of the bays and their permanent type construction do not permit efficient packaging of the cargo. Pallet loading may be used for ease of handling but the handling methods used do not exempt the load from meeting the securing conditions listed below. The securing conditions are divided into conditions for (1) boxed materials and (2) drums. Instructions are as follows:

(1) Box Loading Instructions

- a. Boxes shall be loaded and blocked into position using wood blocking or inflatable dunnage. Blocking should be such that boxes will not shift in transit.
- b. Overall crate height shall be less than the inside height of the car (73.5 in) and shall not interfere with the top closure.
- c. Heavy items or unusually shaped crates may be secured by employing appropriate fittings welded to the car frame, coupled with chains and/or cables.

(2) Drum Loading Instructions (when drums are loaded individually).

- a. Load the bottom layer of drums and block the drums in place using timbers and plywood sheets or using inflatable type dunnage. The height of all drums on the bottom layer should be the same if a two-layer load arrangement is to be used.

FIGURE 17 - General design of the ATMX-500 after modification by Mound Laboratory.

- b. Place 3/4 in sheets of plywood over the bottom layer to form a level loading platform. Fill the top layer with drums and block in the same manner as the bottom layer. The height of the top layer of drums must not interfere in any manner with the top closure. Note that fireproof sheets of plywood are used to separate drum layers, and the load is secured by banding, blocking, and/or inflatable dunnage. The optimum capacities for various size drums, as well as other pertinent data, are given in Table 3.

- c. Each layer of drums should be banded together with steel banding to form a single floating load.

(3) Drum Loading Instructions (when drums are palletized)

- a. Palletized drums are loaded four 55-gal drums to a steel pallet. These drums are banded together with two 1 1/4 x 0.035 in. steel bands around the sides and across the tops to form a single unit (Figure 18). These pallets are then loaded into a bay of the railcar and inflatable dunnage inserted in void (Figure 19).

When weight allows two layers of drums per bay, the first layer is placed in the bay and 3/4 in. plywood placed on top of drums and inflatable dunnage inserted in void (Figure 20). The second layer is then loaded and inflatable dunnage is inserted in void. The second layer of drums will be within 1 to 1 1/2 in. of the lid not allowing any movement during transport (Figure 21); hence, no banding is required across the tops of pallets.

When loading, the weight should be distributed evenly across all three bays. If only one bay is double stacked, it should be the center. If two bays are double stacked, they should be the end bays.

Table 3
Loading Data - ATMX-500

<u>Loading Pattern and Drum Type</u>	<u>Height (in.)</u>	<u>Clearance (in.)</u>	<u>Optimum Load (drums)</u>
Inside clear height	73.5	-	No load
Single layer of 83-gal drums	38.5	35.0	90
2 layers of 30-gal drums	57.75	15.75	350
2 layers of 55-gal drums	70.75	2.75	200
2 layers of 30- and 55-gal drums	63.5	10.0	275
2 layers of 30- and 83-gal drums	67.0	6.5	265
2 layers of 55-gal drums on pallet	72.75	0.75	192

FIGURE 18 - Four drums on steel pallet ready for loading into railcar.

FIGURE 19 - Palletized drums loaded into railcar. Inflatable dunnage is in void at left of photograph.

FIGURE 20 - In this photograph, the palletized drums are separated by inflatable dunnage, and plywood sheets have been placed on top of the drums in preparation for loading a second layer of drums.

FIGURE 21 - Second layer of drums in railcar. The drums are close enough to the top that there is no need for banding.

References

1. F. E. Adcock, ATMX-600 Railcars for Radioactive Waste Shipments, RFP-2244 Rev. 1 (February 21, 1977).
2. E. P. McDonald, An Analysis of Transportation Method - The Shipment of Radioactive Material, MLM-1814(LD) (April 15, 1970).
3. R. A. Wolfe, Nuclear Criticality Safety of DOT Special Permit No. 6000 Package for Large Quantities of Fissile Waste Material, MLM-1714 (February 20, 1970) 13 pp.
4. Unpublished Mound data.
5. "Hazardous Materials Regulations of the Department of Transportation," R. M. Graziano's Tariff No. 30, January 14, 1976.
6. F. E. Adcock and D. L. Cash, Safety Analysis Report for Packaging - DOT-7A Fiberglass-Coated Plywood Box For Transuranium Solid Waste, RFP-2460 (July 23, 1976).
7. E. P. McDonald and J. F. Griffin, Documentation of DOT-SP-5948 for ATMX-500 and ATMX-600 Railcar Packaging, MLM-1912 (April 28, 1972).

Appendix I

The Story of the Special Railcars

by

F. A. Kunz

Sandia Corporation, Albuquerque, N. M.

August 30, 1963

The story of the evolution of the criteria that was used in designing and building the 500 Series A.T.M.X. railcars is long and involved. Nearly two years of investigation, testing, and consultation developed an entirely unforeseen conclusion.

Initially, efforts to provide protection for the surrounding environment from the effects of an incident were considered. Blast tests, mock ups, and calculations proved this to be an impractical approach. Generally speaking any barricades or other shielding that could be provided, and that would be in any degree effective, was of such bulk and general configuration that it left too little room on the car for a reasonable pay load.

Abandoning this concept, attention was directed to the philosophy of protecting the contents of the railcar from the adverse effects of its surrounding environment. This philosophy, coupled with the efforts to provide the safest possible outer environment, eventually became the basis criteria for the design of this transportation media.

In designing the railcars it was decided to employ every practical protective device possible that was compatible with the desired usefulness of the equipment. Design decisions started with the car frame. For this first series, designated the 500 Series, it was decided that the car frame should constitute the main area of car strength. Investigation of the various types of standard car frames available discovered that cast steel car frames were being used in the most severe and demanding of railcar services. An experienced and able manufacture of cast steel car frames was consulted. A pulp wood car frame without end bulkheads, and with various easily made alterations to adapt it dimensionally was suggested. Special details were worked out and this type frame adopted for use as the backbone of the 500 Series A.T.M.X. railcar.

Car trucks were the next consideration. Requirements here were for easy riding qualities, freedom from bearing troubles, high speed capability, and braking reliability. To satisfy such requirements a truck designed for commodity cars in high speed service was chosen. This truck embodies the basic principles of passenger car truck design with wheel base and applications condition comparable to those of freight car side frame trucks. The truck designation is BX type having the following features included in the construction:

1. A one piece cast steel frame machined to insure true alignment of wheels and axles. Double drop equalizer bars are forgings. Houdaille vertical friction snubbers to control spring action. Axles are A.A.R.-E type with 6" x 11" journals fitted with Timken roller bearings. Wheels are 33"

diameter cast steel with triple thick treads. The frame has hardened steel wear plates and equalizer spring seats. Truck bolsters have integral center plates. There are hardened steel pedestal liners. Springs are double coil type with 140,000 lbs. total capacity. The trucks are attached to the frame with locking type center pins so that trucks will not come loose under any circumstance.

2. The brake system for these cars consisted of a double set of AB brakes with two 10" x 12" air cylinders controlled by a single valve system. Braking action is applied through suitable rigging to hanger type brake beams pressing shoes against the inner peripheral surfaces of the car wheels. The brake rigging includes Westinghouse automatic slack adjusters to compensate for brake shoe wear. In addition to the air brake system a mechanical hand brake is provided as required by A.A.R. regulation.
3. A very important feature built into these cars for the protection of the lading is the shock absorbing draft gear. This consists of a cartridge containing multiple layers of rubber and metal that is fitted into the draft gear pockets of the frame. Connection is made to the car frame and the coupler in such a manner that shocks imposed upon the couplers are absorbed by the compression of the rubber layers. The shock absorbing capacity of this draft gear is 53,800 ft. lbs. at rated travel, and 61,700 ft. lbs. at maximum travel. Such shock mitigating capacity greatly reduces the effects of coupling bumps upon the cargo shipped in the cars.
4. Couplers, those fist like mechanism that fasten railcars together into trains, used on the A.T.M.X. railcars are of a type known as Type F locking couplers. This type coupler has extra protruding lugs cast into its construction that prevent them from uncoupling from another coupler of the same type due to vertical movement. Vertical movement of the couplers can be introduced by inadvertent derailment of a single car; on which case these couplers prevent the uncoupling of a train of cars and the consequent loss of braking control on the entire train of cars. Such couplers greatly increase the probability of a train remaining together and under control at all times.

One of the requirements placed upon the car designers was that the superstructure of the cars made strong enough to protect and firmly contain the cargo in the event the railcar should be rolled over in an accident. This has been accomplished by the use of massive structural steel braced bulkheads at either end of the car and at two locations along the car length. There are strong top rails along the sides and the cover frames make up the remainder of a very rigid rectangular box structure. Since the cover frames are a part of this structure the necessity for the large number of bolts used in the cover is established.

Another protective feature built into the superstructure of the car is the sloping ends. Each end of the car is heavily braced and covered with thicker steel plates. The slope of the ends

directs colliding cars or other material up and over the top of the Special Railcar in the event of an accident. This feature has been proved to be effective in an actual incident.

Compliant to the philosophy of providing the greatest amount of mechanical protection possible to the cargo shipped; these cars were built to embody every practical safety feature available within the technology of the time when they were constructed.

The 600 Series railcars are a taller version of railcar built to provide more cargo volume. All of the features built into the car trucks are repeated on this series car. A cast steel frame is used but a majority of the car strength is not concentrated in this frame as in the 500 Series car. Since the car superstructure of the 600 Series is higher it is possible to build more beam strength into the deeper section of the car body. Hence the 600 car has the strength of its construction more evenly divided between the frame and the superstructure.

These 600 Series cars have several unique features of construction as well as all the original safety features built into the 500 Series car. The center bulkheads of the 600 Series car are adjustable for and aft to allow a larger loading area if desired. The covers of the 600 Series car are fastened in place by means of a mechanical locking device operated at the end of the car. This device eliminates the numerous cover bolts used in the 500 Series and facilitates the removal of the car covers. It was possible to provide such a device in the 600 Series car due to greater strength built into the car superstructure.

Both the 500 and 600 Series railcars have satisfactorily fulfilled the function for which they were designed.

Appendix II

Union Carbide ATMX-500 Free Drop and Thermal Evaluations

INTERNAL CORRESPONDENCE

NUCLEAR DIVISION

POST OFFICE BOX Y, OAK RIDGE, TENNESSEE 37830

To (Name) W. T. Mee
Division Criticality Safety
Location 9711-1

Date May 16, 1973

Originating Dept. Civil and Architectural
Engineering

Answering letter date

Copy to J. A. Parsons
File

Subject Special Rail Car

As per your request an analysis was performed to determine the effects of dropping a special rail car a distance of thirty feet. The ability of the car to withstand such a drop test is a measure or index of its suitability for transporting certain hazardous materials. Drawings and other information were furnished by you to indicate the weight, dimensions, and construction details of the car. The calculations made indicate that the car will withstand the prescribed drop tests without rupturing.

The car was constructed in 1957 from a design by Sandia Corporation. The superstructure is of structural steel shapes and plate (assumed to be A7). The underframe is a single steel casting for a 70 ton flat car. The empty weight of the complete car is 116,000 pounds and the maximum weight of the cargo was given as 40,000 pounds.

The criteria of suitability is based upon the car being dropped a distance of thirty feet in three different positions: (1) on its top, (2) on its side and (3) on its end. In each case the car is assumed to land with the face in question parallel to a reasonably unyielding surface. It is assumed that all of the energy of the collision will be consumed in strain energy in deforming the car.

The car does have the capacity to absorb in strain energy all of the energy of collision without coming apart or rupturing. This is true in all three cases of dropping (top, side, and end). The greatest deformation will occur from falling on its top; in this case the strain is approximately 10% of the strain that accompanies rupture of the material. Permanent deformation of the steel occurs at below 1/2% of the ultimate strain so it is easily seen that very dramatic, permanent distortion of the car will result from the envisioned drop tests. The analysis performed was cursory and disregarded secondary stresses, stress concentrations, etc. While these effects would be considered in a more detail analysis it is felt that their inclusion will not significantly change the results.

Approved:

W. J. Carter

J. T. Offaker

INTERNAL CORRESPONDENCE

NUCLEAR DIVISION

POST OFFICE BOX Y, OAK RIDGE, TENNESSEE 37830

To (Name) W. T. Mee
Division
Location Building 9711-1

Date June 4, 1973
Originating Dept. Process Analysis

Answering letter date

Copy to D. M. Lang
R. D. Smith
W. J. Wilcox, Jr.
File

Subject High Temperature Incident
Analysis

Attached is an analysis of the situation in which an ATMX special transport rail car is exposed to a 1475° F radiating environment for 30 minutes. This analysis pertains to the thermal properties only of the car and assumes maintenance to the car that will properly seal it from the outside environment and provide it with a plywood floor. Under these conditions, it is concluded that the ATMX rail car will meet the thermal containment requirements of the AEC shipping standards for nuclear materials.

J. M. Younkin
J. M. Younkin

JMY:mdh

Attachment

HIGH TEMPERATURE INCIDENT ANALYSIS

Introduction

In the near future, obsolete weapons manufactured prior to the current AEC shipping standards for nuclear materials will be returned to Y-12 for disassembly. The containers for these weapons may not meet these shipping standards. An ATMX special transport rail car made for Sandia Corporation in 1957 has been resurrected for shipping these weapons. It is hoped that this car will meet the thermal containment requirements of the shipping standards. The purpose of this analysis is to evaluate the hypothetical situation in which the rail car is exposed to a 1475° F radiating environment for 30 minutes. These conditions could occur in an accidental fire.

The ATMX rail car has a massive cast steel frame that is 10 feet wide and 60 feet long. Portions of the frame are as much as 20 inches thick. Several large openings in the frame are covered with 3/16-inch steel plates. The sides of the car are 6-1/2 feet high and made of 3/16-inch steel sheet. The top of the car is covered with six removable 3/8-inch steel sheets. The ends of the car are sloped and made of 5/16-inch steel sheets. Steel mounting rails that are 6 inches high run the length of the floor of the rail car. A one-inch thick plywood floor is to be attached to these mounting rails by the Y-12 Plant. The weapons being shipped are to be mounted on this plywood floor.*

Assumptions

1. The ATMX rail car is perfectly sealed from outside surroundings.
2. The car is at a uniform temperature of 75° F before being heated.
3. The sources of heat are: (a) radiation from the surroundings at 1475° F and (b) natural convection-conduction from the surrounding air at 1475° F.
4. The emissivity of the surface materials is 0.9 since these surfaces would probably pick up a carbon deposit from the fire.

Conclusions

1. The massive steel frame of the rail car will heat to a maximum temperature of only 335° F. However, the steel plates covering the openings in the frame allow internal surface hot spots of 950° F.
2. The inside surface temperature of the sides of the car will reach 950° F.
3. The inside surface temperature of the top of the car will reach only 500° F.

* Drawing Set 2552, Rail Car, Special Transport, Sandia Corporation, 1957.

4. The plywood floor, mounted six inches above the frame, will reach a temperature of only 180° F directly over the hot spots. However, where the plywood contacts the mounting rails and the sides of the car, it will reach a temperature of 400° F after about 25 minutes and will start to char and burn.
5. The outside surface of weapons or containers mounted on the plywood floor and not in contact with the inside surface of the rail car will reach a maximum temperature of 200° F.
6. Since previous analyses have shown that weapons can withstand surface temperatures much greater than 200° F without suffering any hazardous effects,* the ATMX rail car provides these nuclear materials with ample containment in an accidental fire as required by the AEC shipping standards.

Discussion

The ATMX rail car is made up of many sheets of steel welded together and to a massive cast steel frame. For this analysis, it was assumed that all joints were welded. However, examination of the rail car revealed many open gaps, especially along the steel plates covering the large openings in the frame. In an accidental fire, it is most important that the car be sealed from the outside hostile environment. This will also limit possible burning inside the car by allowing only a limited oxygen supply within the car.

The rail car is essentially a 6-1/2 x 10 x 60 feet rectangular steel container. An analysis was made on a cross section of this "infinitely long box." An initial heat input of 23,500 Btu/hr/ft² was used. This corresponds to radiation, natural convection, and conduction from a fire instantaneously at 1475° F. Figure 1 shows the temperature profile of the cross section of the rail car after 30 minutes. Although the maximum inside surface temperature will reach 950° F, the air away from the walls will still be essentially at room temperature. These temperatures are accurate over the length of the car except near its ends.

A separate analysis of the rail car end was made to determine the end effects. The ends of the car slope outward from top to bottom, a design that would create higher temperatures than that of a rectangle. Because of the thicker walls, however, the maximum temperature on the inside surface will still reach only 950° F. The air in the end compartments will become a warm 100° F. These temperatures are similar to those of the rest of the car.

The plywood floor will be heated by radiation and natural convection from the inside surfaces of the car and by conduction where it contacts the mounting rails and the

* Y-EK-85, March 17, 1971, and Y-DS-15, February 11, 1972.

sides of the car. After about 25 minutes in the fire, the plywood will begin to char and burn at these contact points. Non-contact areas of the plywood will reach a temperature of 180° F on the bottom side above the maximum inside surface temperature of 950° F. The plywood plays a very important function in holding the weapons away from the intense heat of the steel floor.

The weapons are mounted within the rail car so as not to come in contact with any inside surfaces of the car. These weapons will be heated by radiation and natural convection from the inside surfaces of the car. As an example of the effects on a weapon or weapon container, an analysis was made of a steel drum mounted on the plywood floor. A time dependent heat input based on the internal surface temperatures of the rail car was applied to the steel drum. Figure 2 shows the temperature profile of the cross section of the steel drum and the plywood floor after 30 minutes. The outside surface will reach a maximum temperature of 200° F, while temperatures inside the drum will not exceed 175° F. Thermal effects on weapons under these conditions will not be nearly sufficient to cause contaminant releases during or after the incident.

This study made extensive use of a heat transfer program, HEATING3, by W. D. Turner and M. Siman-Tov of ORNL.*

* "HEATING3 - An IBM 360 Heat Conduction Program," ORNL-TM-3203.

FIGURE II-1 - Temperature distribution of railcar after 30 min.

FIGURE II-2 - Temperature distribution of steel drum after 30 min.

Appendix III

ATMX-600 Series Railcar Engineering Evaluation

Excerpt from: F. A. Adcock, ATMX-600 Railcars for Radioactive Waste Shipments, RFP-1411, January 7, 1970.

Method:

The ATMX-600 Series car with drums or crates for inner containers is a safe, reliable transportation system for shipping radioactive waste materials. The adequacy of the system was demonstrated by relating it to the three principal factors upon which all regulations for transporting hazardous materials are based: (1) Transportation environment, (2) Relative hazard potential, and (3) Package performance. This is the only suitable type of evaluation since a package of this size cannot be subjected to the hypothetical accident conditions (30-foot drop, half-hour fire, etc.) nor can strength, resistance to impact loads, or other calculations be related directly to package performance during these tests.

Transportation Environment:

The chance of a serious accident¹ per 1000 miles of travel is approximately one in 82,000 for standard freight cars. This is based on data collected during a study of 3122 freight train accidents involving derailments for the period 1952 through 1954.² The report mentions that specially designed cars, such as the ATMX will "substantially" reduce the chance of a serious accident. Of the accidents reported in the study, fire or explosion followed a collision and or derailment incident in only 1% of the cases.

By observing the precautions required for the rail transportation of hazardous materials, as required by the DOT, the chance of a serious accident would be reduced still further. In summary, the environment that the ATMX car will see is favorable. With no special precautions one could expect a freight car to experience a serious accident once in 82 million miles of travel. With a high strength car such as the ATMX-600 and using special precautions, the chance of a serious accident is very remote.

Relative Hazard Potential:

CONTAMINATION - Contents of plywood crates (machinery, etc.) have been cleaned to eliminate removable surface contamination. Residual contamination slightly exceeds the level allowed for "low specific activity;" however, it is fixed well enough that it would not be readily dispersible in the event the package were breached.

Drummed waste is processed in a treatment plant where it is dried and then fixed with Portland cement or other suitable hardener. Should the drum be ruptured in an accident, the contamination would remain well fixed to the inert medium.

In each case, contamination is in the less hazardous insoluble form. In the event of a fire, because of its density and non-volatility, the radioactive material would tend to remain at the burning site and therefore would constitute a hazard only in the immediate vicinity of the accident.

PENETRATING RADIATION - The radioactive material considered here emits alpha particles along with very low energy beta particles and as such is primarily an internal hazard. Although some x- and gamma-rays are associated with the radioactive decay of the material, radiation fields are not of a magnitude which constitutes a hazard either when the material is contained or if it should be lost from its container.

Package Performance:

IMPACT AND PENETRATION - In any type of railroad accident or derailment, there is the possibility that the cars involved could roll down an embankment. The ATMX car was especially designed and reinforced to withstand this situation. The heavy top longitudinal members are supported at each end and by the two center braces to prevent the sides or top from collapsing.

A direct head-on crash is relatively unlikely. However, the ATMX car could survive this type of crash with little damage. Impact on the end of the cast frame would transmit a shock to the load but would leave the car intact. Impact higher up on the car would cause the impacting object to be deflected over the sloping end. Shock load transmitted to the contents would be less than in the first case and the car again would be left intact.

A more likely type of impact would be a glancing blow on the side of the car caused either from the car itself skidding into a solid structure or from another car skidding into the ATMX-600. In this case, impact speed would be somewhat less than the original car (or missile) speed. Some bending and crushing of the car and a change in car (or missile) velocity would

tend to dissipate much of the available energy. To be conservative, it must be assumed that a strong, pointed object such as a corner of a cast steel car frame, could penetrate both the inner and outer skin of the ATMX car's side or roof. The penetrating object in this case could also penetrate one or more inner containers.

In any collision or impact the shock transmitted to the inner containers is greatly attenuated by the car itself. This shock is further reduced by the packaging or blocking material. One could expect the inner containers whether crates or drums, to remain reasonably intact, except for those few that may be punctured or crushed by an object penetrating the car.

In conclusion, the forces required to damage the ATMX-600 car are of a considerably greater magnitude than those generated in the drop, impact, and penetration tests of an ordinary radioactive material container. While the car can, with the worst combination of conditions, be penetrated, overall damage to the car and contents will be minor.

FIRE - Even though the statistical probability of the ATMX car being involved in a fire is negligible, the possibility must still be considered.

The thermal test conditions specified in the regulations can hardly apply to a container as large as the ATMX car. Sandia Corporation tests show that even for a medium-size container, the following conditions are necessary to assure proper test conditions: A fire pit between 400 and 2000 square feet containing approximately 5000 gallons of fuel, wind under 5 mph, test item positioned a certain optimum distance above the surface of the fuel, and at least 3-feet of flame surrounding the container. It is hard to conceive of these conditions existing, either by design or accident when the package is $10 \times 13 \times 60$ feet.

With the maximum conceivable fire, it can be assumed that only 50-percent of the car's outside surface will be enveloped in flame. This is based on the car being (1) partly submerged in a pool of fuel where the submerged portions are inaccessible to the flame, or (2) suspended above the flame by virtue of stacking on a pile of derailed cars in which case the supported areas and the upper surface would likely be inaccessible to the flame.

The car, even without contents, constitutes a massive heat sink (119,000 pounds of steel). Assuming a net heat input of 17,000 BTU/ft²/hour, mean temperature

of the car would not exceed 875°F.⁴ Contents would be at a significantly lower temperature. The surface of crates or drums nearest to the car skin would reach approximately 625°F.⁵

Average temperature of the contents cannot be accurately predicted; however, it should not exceed 200°F. Since plywood will start to char and burn around 400°F, some burning can be expected on those portions of the crates nearest the surface of the car. In the limited oxygen atmosphere within the car, the burning crates should be self-extinguishing once the external heat-source has been removed.

Work done at Rocky Flats by D. L. Ziegler⁶ shows that hardened process waste in steel drums will survive long exposure to 212°F without damage. Drums in the hotter portions of the car would be expected to vent due to steam pressure. In both this case and in case of partially consumed crates, contamination would be slight because of the types of material involved.

WATER IMMERSION - Crated waste, when flooded, would not constitute a criticality hazard, since fissile material is limited to only 5-grams per cubic foot. The criticality evaluation for drums has considered flooding of one container, and of all the containers in the array since there is a possibility of some leakage after a severe impact or fire. The criticality evaluation shows that the flooded array is over moderated and therefore less reactive than the case considered.

Water circulation through the car should be slight. Circulation through the inner containers would be nil. Therefore, contamination loss from the car during a 24-hour immersion would be negligible.

CONCLUSIONS

The engineering evaluation has shown that the transportation environment of the ATMX-600 Series railcar is excellent and that the chance of a serious accident is very remote. Hazard potential of the contaminated waste is relatively low since the radioactive materials are well fixed.

In summary, the ATMX-600 Series car and its steel drum or plywood crate inner containers represents an ideal solution to the problem of safely transporting radioactive waste materials at a reasonable cost.

REFERENCES

1. Defined as an accident that damages the car beyond economical repair.
2. Harold A. Knapp, Cost and Safety Considerations in the Transportation of Radioactive Materials as published in the "Proceedings of the 1958 AEC and Contractor Safety and Fire Protection Conference," YD-7569, May 15, 1959.
3. Alan Fairbairn, I K A E A, Sandia Corporation Report SC-RR-65-98, p. 618-619. During discussion period Mr. Fairbairn gives 1.3 calories per second per square centimeter (17,000 Btu/hr ft²) as a possible figure for net heat flux into a large cask. In this

same report, p. 111, Mr. Apetit gives 3.15 w/cm^2 (10,000 Btu/hr ft²) as the net heat flux during an IAEA standard fire test.

4. Average car temperature based on the above assumptions and using infinite conductivity. Hot spots on the inside surface might reach this temperature, but the average would be lower.
5. Previous thermal tests have shown a 250°F temperature differential across small air gaps under similar conditions.
6. F. F. Adcock, RFD Container - Model 5530, 2012-68RPF, Rocky Flats Division, The Dow Chemical Company, September 1968

Appendix IV

ATMX Railcar Inspections

SHEET													
ISSUE													
SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13
ISSUE	B	A	A	A	A	A	B	B	B	B	B	B	B

<div style="border: 1px solid black; height: 150px; margin-bottom: 5px;"></div> <div> DWG CLASSIFICATION LEVEL & CAT UNCL BY _____ TITLE _____ DATE 5-4-77 </div>	<div> MONSANTO RESEARCH CORPORATION <small>MOUHO LABORATORY MIAMI, FLORIDA</small> </div> <div> NUCLEAR SHIPPING CONTAINER ATMX RAIL CAR ACCEPTANCE AND REUSE INSPECTION PROCEDURE </div> <div> DRAWN: SHARIZ DATE: 5-13-77 APPROVALS: _____ CHECKED: _____ DATE: _____ 1 SPONSOR: _____ DATE: 5-17-77 2 APPROVED: _____ DATE: 5-22-77 3 JOB NO: 740374 4 DWG NO: SPA740374 SHT 1 OF 13 </div>
--	--

SP	CODE IDENT NO	
DWG TYPE	14065	

THIS PRINT IS THE PROPERTY OF MONSANTO RESEARCH CORPORATION AND MUST BE RETURNED TO DRAWING CONTROL MOUND LABORATORY. REPRODUCTION IS PROHIBITED WITHOUT PERMISSION OF MOUND LABORATORY.

TABLE OF CONTENTS

1.	GENERAL	
1.1	Scope	
1.2	Introduction	
2.	APPLICABLE DOCUMENTS	
2.1	Monsanto Research Corporation Drawings	
2.2	Other Documents	
3.	GENERAL PROVISIONS	
3.1	Responsibilities	
3.2	Inspection and Acceptance	
3.2.1	Definition of Defects	
3.2.2	Inspection of Major Assemblies	
3.2.3	Inspection of Final Assembly	
3.2.4	Sampling Plan	
3.3	Inspection Record	
	Sub-Appendix I:	INSPECTION DATA SHEET FOR ATMX 500 AND 600 SERIES RAIL CARS
	Sub-Appendix II:	REQUEST FOR RAIL CAR USE AND INSPECTION CERTIFICATE

1. GENERAL.

- 1.1 Scope. This inspection requirement document is applicable to the ATMX Rail Car, Series 500 and 600, when the rail car is used as a radioactive waste materials shipping container.

It defines the complete inspection prior to use, as required by ERDA Manual, chapter 0529. This includes responsibilities, inspection criteria, and documentation records. The purpose of this documentation is to establish an effective system for assuring compliance with the drawings, specifications and design intent.

- 1.2 Introduction. The ATMX rail car, as modified under the provisions of DOT Special Permit number 5948, provides an effective and efficient means of shipping large volumes of radioactive waste materials when packaged in DOT Specification 7A boxes.

The ATMX-500 series rail car will be loaded directly whereas the ATMX-600 series rail car will accept (2 each) standardized cargo containers or may be loaded directly.

2. APPLICABLE DOCUMENTS

- 2.1 Monsanto Research Corporation Drawings:

4-8695 - Locking Slide
4-8696 - Locking Slide Mechanism
4-8697 - Cover
5-1819 - Body structural modifications

- 2.2 Other Documents.

ERDA Manual, Chapter 0529

J. F. Griffin, J. B. Peterson, D. A. Edling, and L. F. Rodriguez
Safety Analysis Report for Packaging (SARP): ATMX-500 Rail Car Nuclear Packaging, MLM-2145 (May 1974).

Field Manual of the American Association of Railroads
Interchange Rules

American Association of Railroads Wheel and Axle Manual

3. GENERAL PROVISIONS.

- 3.1 Responsibilities. The manufacturer is responsible for assuring that all specification requirements are met and shall utilize accepted quality control measures during manufacture. Monsanto Research Corporation (MRC) reserves the right to audit the manufacturer's facilities and procedures as required. MRC Engineering is responsible for establishing inspection criteria for receiving acceptance, for reinspection prior to reuse, and for providing this document. MRC Nuclear Operations Quality Control is responsible for auditing the Quality Control Program and review of applicable drawings and specifications to assure that the Quality Control Program is carried out as defined. MRC Special Materials Handling Group is responsible for assuring the rail car closures are secure and the proper labels affixed prior to shipment. MRC Administration Waste Management Group is responsible for coordinating related functions, such as, providing the necessary information pertinent to the materials being shipped, appropriate packaging and loading procedures for these materials, and the initiation of procurement and inspection activities in cooperation with the MRC Engineering Inspection Group. MRC Engineering Inspection Group is responsible for the physical inspections of the rail cars as a vehicle and a shipping container in conjunction with the carrier as stated in the A.A.R. Interchange Rules. MRC Traffic is responsible for retaining the appropriate files to document these inspections. MRC Purchasing is responsible for coordinating maintenance, repair, and reconditioning activities with the railway company.
- 3.2 Inspection and Acceptance. Each rail car shall be inspected and tested for defects in accordance with Appendix I. Major and Critical defects which are found during the examination and/or testing must be corrected prior to acceptance or reuse of the rail car.
- 3.2.1 Definition of Defects. Defects are classified as critical, major or minor. A critical defect is a defect that judgement and experience indicate is likely to result in hazardous or unsafe conditions for the individuals using or depending on the rail car for its intended purpose. A major defect is a defect other than critical, that is likely to result in failure or to reduce materially the usability of the rail car for its intended purpose. A minor defect is a defect that is not likely to reduce materially the usability of the rail car for its intended purpose, or is a departure from established standards having little bearing on the effective use of the rail car.

- 3.2.2 Inspection of Major Assemblies. This inspection shall consist of visual, dimensional and functional examination and tests of major assemblies which make up the complete ATMX rail car shipping container.

The major assemblies to be inspected are listed below:

2. Underframe
3. Truck Assembly
4. Brake Assembly
5. Coupler Assembly
6. Safety Appliances and Adjuncts
7. Superstructure and Fittings

- 3.2.3 Inspection of Final Assembly. The final assembly shall be examined visually and functionally with regard to meeting the requirements specified in this document.

- 3.2.4 Sampling Plan. Each rail car is to be inspected for all attributes listed.

- 3.3 Inspection Record. A detailed data list and inspection certification is completed and retained in MRC Traffic, documenting the receiving acceptance and reinspection prior to reuse as shown in Appendices IV-I and IV-II.

Appendix IV-I

ACCEPTANCE INSPECTION DATA SHEET FOR ATMX 500 and 600 SERIES RAIL CARS

ACCEPTANCE INSPECTION DATA SHEET FOR ATMX 500 AND 600 SERIES RAIL CARS

1. IDENTIFICATION

1.1 Rail Car Serial Number _____

1.2 Manufactured by _____

2. UNDERFRAME VISUAL INSPECTION

Signature

Date

2.1 One piece cast underframe is free
of cracks. (Major)

2.2 Underframe center sill is not
bowed. (Major)

3. TRUCK ASSEMBLY VISUAL INSPECTION.

3.1 Truck Bolster bowl rim has no
missing sections. (Major)

3.2 Side Bearings are not frozen
or missing. (Major)

3.3 Side frames have no cracks.
(Major).

3.4 Column guide wear plates are not
worn out or missing. (Major)

3.5 Coil springs are not broken, weak
or missing. (Major)

3.6 Roller Bearings have no missing or
loose bolts (3 each), or leaking
lubricant. (Critical)

3.7 All keepers are securely in
place. (Minor)

	<u>Signature</u>	<u>Date</u>
3.8 Axle has no deep cuts (0.5 inch max.) or signs of recent wear from brake rigging contact. (Major)	_____	_____
3.9 Wheels are Class B, one wear or multi-wear design. (Major)	_____	_____
3.10 Wheels have no grooves, cracks or chips on tread or flange. (Major)	_____	_____
3.11 Wheels have no uneven wear or flat spots on the tread. (Minor)	_____	_____
4. <u>BRAKE ASSEMBLY VISUAL INSPECTION.</u>		
4.1 No indication that brake rigging (actuating rods) is contacting the axles. (Critical)	_____	_____
4.2 Brake shoe and retaining key is not missing. (Critical)	_____	_____
4.3 Metal brake shoes are not worn to a minimum of 1/2 inch, including the backing plate. (Major)	_____	_____
4.4 Air hose and pipe have no loose, broken or missing sections. (Major)	_____	_____
4.5 Air cylinders have no loose or missing nuts or bolts. (Major)	_____	_____
4.6 Hand brake wheel is not loose, bent or missing. (Critical)	_____	_____
4.7 Hand brake chain is not worn out or broken. (Critical)	_____	_____

	<u>Signature</u>	<u>Date</u>
5. <u>COUPLER ASSEMBLY VISUAL INSPECTION.</u> (Figure 5)		
5.1 Coupler shank is free of cracks. (Major)	_____	_____
5.2 Striker plate is not bent, cracked or broken. (Major)	_____	_____
5.3 Wear plate is not cracked, worn or missing. (Major)	_____	_____
5.4 Draft gear yoke, slot and key wear does not exceed 1/2 inch at the bottom of the slot and key. (Major)	_____	_____
5.5 Draft gear carrier bolts are not loose or missing. (Minor)	_____	_____
5.6 Coupler and shank pin cotter keys are in place. (Minor)	_____	_____
6. <u>SAFETY APPLIANCES AND ADJUNCTS</u> <u>VISUAL INSPECTION.</u>		
6.1 Superstructure platforms and walkways are not loose or broken creating a tripping hazard. (Major)	_____	_____
6.2 Hand rails (grab irons) are not loose or missing. (Major)	_____	_____
6.3 Placard holders are not missing, bent or loose. (Major)	_____	_____
6.4 Defect card holders on side of the car are not missing. (Minor)	_____	_____
6.5 Paint and markings are in good condition and legible. (Major)	_____	_____

Signature

Date

7. SUPERSTRUCTURE AND FITTINGS VISUAL INSPECTION.

- 7.1 Superstructure has no puncture holes, gouges or other damage to the top covers, sides, ends or car lining. (Major)
- 7.2 Interior of superstructure is clean and in good condition. (Major)
- 7.3 Top cover closure lugs (bayonet type) are not missing or broken. (Major)
- 7.4 Top cover lock and slide mechanism is not bent or broken. (Major)

_____	_____
_____	_____
_____	_____
_____	_____

8. ATMX RAIL CAR FUNCTIONAL INSPECTION

- 8.1 With the rail car wheels blocked the hand brake may be released and applied. The hand brake functions properly. (Critical)
- 8.2 Coupler works freely with the draft gear yoke when released. (Major)
- 8.3 Access doors and locking mechanism are in good working order. (Major)
- 8.4 Top cover locking and slide mechanism functions properly. (Major)

_____	_____
_____	_____
_____	_____
_____	_____

9. ATMX RAIL CAR DIMENSIONAL INSPECTION

- 9.1 If the MRC engineering inspector determines from the visual inspection a particular area may need a dimensional check, a railroad company inspector shall be notified according to the A.A.R. Interchange rules; otherwise, dimensions will not be a part of this inspection document.

Appendix IV-II

REQUEST FOR RAIL CAR USE AND INSPECTION CERTIFICATE

REQUEST FOR RAILCAR USE INSPECTION CERTIFICATE

	Requested Ship Date
I	<div>Ship To:</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div>Description of Material to be Shipped:</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Originator</div> <div>Date</div> </div>
II	<div>Assigned Car #</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div>Date Car is Available</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Traffic</div> <div>Date</div> </div>
III	<div>We certify that we have this day examined Car No. _____ and that, as applicable to the type of car, there are no holes or other openings in the roof, sides, ends or car lining; that the floor is cleaned and in good condition and it and the car lining are free of projecting uncovered pieces of metal or nails; and therefore suitable for loading.</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Special Mat'ls Handling Group</div> <div>Date</div> </div>
IV	<div>We have this day examined the above car and hereby certify that the materials in or on this car; or in or on vehicles or in containers; have been loaded (or unloaded) and braced, and that placards have been applied, according to the regulations prescribed by the Department of Transportation.</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Supervisor, Loading Group</div> <div>Date</div> </div>
V	<div>We certify that we have this date examined Car No. _____ and that the seals, placards, labels are properly affixed. The doors, roof and closures are secure and sealed, and the overall appearance of the car is satisfactory.</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Special Mat'ls Handling Group</div> <div>Date</div> </div>
VI	<div>Shipment Data</div> <div>Shipping Date</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div>Shipper #</div> <div style="border: 1px solid black; height: 20px; margin-bottom: 5px;"></div> <div style="display: flex; justify-content: space-between;"> <div>Traffic</div> <div>Date</div> </div>

Distribution (by Traffic):

1. Traffic
2. Originator
3. Special Materials Handling Group
4. Loading Group
5. Nuclear Program Planning
6. _____

Form MRC-ML-176 (10/70)

Glossary

DEFINITIONS FROM AEC APPENDIX 0529

"SAFETY STANDARDS FOR THE PACKAGING OF RADIOACTIVE AND FISSILE MATERIALS"

1. Containment Vessel means the receptacle on which principal reliance is placed to retain the radioactive materials during transport.
2. Package means packaging and its radioactive contents.
3. Packaging means one or more receptacles and wrappers and their contents, excluding fissile material and other radioactive material, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for cooling and for absorbing mechanical shock, external fittings, neutron moderators, nonfissile neutron absorbers, and other supplementary equipment.

RADIOACTIVE MATERIALS DEFINITIONS

The following definitions are derived from the Code of Federal Regulations Title 49 - Transportation, Part 173.389.

FISSILE CLASSES - The groupings into which radioactive material packages are classified according to the controls needed to provide nuclear criticality safety during transportation. (173.389(a)(1)-(3))

FISSILE MATERIAL - Plutonium-238, plutonium-239, plutonium-241, uranium-233, uranium-235, or any material containing any of the foregoing. (173.389(a) and 173.396(a))

LARGE QUANTITY RADIOACTIVE MATERIALS - A quantity the aggregate radioactivity of which exceeds that specified in Part 173.389(b). (Large quantities are quantities exceeding a Type B quantity, and also are sometimes referred to as "large sources.")

SMALL QUANTITY RADIOACTIVE MATERIALS - A quantity of radioactivity which does not exceed the limits specified in Part 173.391(a). Small quantities and certain radioactive devices 173.391(b), are exempt from specification packaging, marking and labeling requirements, but still are subject to certain requirements, such as shipping paper requirements.

LOW SPECIFIC ACTIVITY MATERIAL - Material in which the activity is essentially uniformly distributed and in which the estimated average concentration per gram of contents does not exceed the specifications of Part 173.389 (c).

SPECIAL FORM RADIOACTIVE MATERIALS - Those materials which, if released from package, might present some direct radiation hazard but would present little hazard due to radiotoxicity and little possibility of contamination. (173.389(g))

NORMAL FORM RADIOACTIVE MATERIALS - Those materials which do not meet the requirements of Special Form Radioactive Materials. Normal form radioactive materials are grouped into "transport groups." (173.389(d))

TRANSPORT GROUP - Any one of seven groups into which normal form radionuclides are classified according to their radiotoxicity and their relative potential hazard in transportation. (173.389(h))

TRANSPORT INDEX - A number placed on a package of "Yellow Label" radioactive materials by the shipper to denote the degree of control to be exercised by the carrier, i.e., the number of yellow labeled packages which may be placed in a single vehicle or storage location. The transport index is actually the measured dose rate of radiation at three feet from the surface of the package. (173.389(i))

TYPE "A" PACKAGING - Packaging which is designed in accordance with the general packaging requirements of Parts 173.24 and 173.393 and which is adequate to prevent the loss or dispersal of the radioactive contents and to retain the efficiency of its radiation shielding properties if the package is subjected to the test prescribed in Part 173.398(b) (Normal conditions of transport). (173.389(j))

TYPE "A" QUANTITY RADIOACTIVE MATERIAL - That material which may be transported in Type "A" Packaging. (173.389(l))

TYPE "B" PACKAGING - Packaging which meets the standards for Type "A" Packaging, and in addition, meets the standards for the hypothetical accident conditions of transport as prescribed in Part 173.398(c). (173.389(k))

TYPE "B" QUANTITY RADIOACTIVE MATERIAL - That material which may be transported in Type "B" Packaging. (173.398(l))

The following definitions, though not derived from the Code of Federal Regulations, Title 49, are held as generally accepted meanings of the terms listed.

ALPHA PARTICLES - One of the three primary forms of radioactive emissions from radioactive atoms. Alpha Particles are positively charged particles emitted from the nucleus of atoms having a mass and charge equal to the nucleus of a helium atom (2 protons + 2

neutrons). Alpha Particles have very little penetrating ability and therefore are chiefly internal radiation hazards. They travel very short distances in air and are shielded very easily.

BETA PARTICLES - One of three primary forms of radioactive emissions from radioactive atoms. Beta Particles are negatively charged particles emitted from the nucleus of an atom and have a mass and charge equal to that of an electron. They travel greater distances in air than alpha particles, have an intermediate penetrating ability, but still are relatively easily shielded.

GAMMA RAYS - One of the three primary forms of radioactive emissions from radioactive atoms. Gamma Rays are not particulate (as opposed to alpha and beta particles) but are short wave length electromagnetic radiations from the nucleus of radioactive atoms. Except for their origin (the nucleus of the atom rather than the outer shell) they are identical in characteristics to X-rays. Gamma Rays are the most penetrating form of radiation and travel great distances in air. They require heavy shielding materials such as lead to attenuate the radiation.

CURIE - An expression of the quantity of radiation in terms of the number of atoms which disintegrate (decay) per second. A curie (Ci) is that quantity of radioactive material which decays such that 37 billion atoms disintegrate per second. One thousandth of a curie is a millicurie (mCi).

RADIATION LEVEL - A term sometimes used instead of radiation "dose rate." It generally refers to the effect of radiation on matter, that is, the energy imparted to and absorbed by matter due to radioactive emissions per unit of time.

MILLIREM - One-one thousandth of a Rem. The rem is a unit sometimes used to express radiation level or dose rate (millirem per hour). Technically speaking, the rem is an expression of radiation level or dose rate which considers the effect of the radiation on persons. Do not confuse millirem with curie.

ENCAPSULATION - A term used to denote an additional fabrication technique often used in preparation of radiation sources, wherein the basic material is physically placed within sealed, high physical integrity capsules or envelopes to provide further assurance that in the event, a package breaks and the capsule escapes, there would be little possibility of a spread of particulate contamination.

NUCLEAR CRITICALITY - This term denotes the occurrence of an accidental chain reaction with fissile radioactive materials. The purpose of the Fissile Classes is to prevent the occurrence of a nuclear criticality during the transport of Fissile Materials. (Controlled nuclear criticality is the objective within a nuclear power reactor)

RADIOISOTOPE AND RADIONUCLIDE - For the purpose of transportation, these terms are synonymous with "Radioactive Materials."

RADIOTOXICITY - A term used to denote the relative hazards of the various radionuclides, that is, their internal radioactive effect within the body.

SWIPE SAMPLE - A test for loose or removable radioactive contamination on surfaces (also sometimes referred to as a "smear" test).

This material may be reproduced without special permission from this Office.

DEPARTMENT OF TRANSPORTATION
Office of Hazardous Materials
Operations Division, TSA-24
400 Sixth Street, S. W.
Washington, D. C. 20590

16772

Revised July 1972

Distribution

EXTERNAL

TID-4500, UC-41 (266)

J. R. Roeder, ALO (15)

J. A. Chacon, DAO (3)

R. K. Flitcraft, MRC

INTERNAL

A. G. Barnett

R. K. Blauvelt

J. D. Braun

W. T. Cave

D. A. Edling (5)

J. F. Griffin

A. F. Heitkamp

D. R. Hopkins

C. W. Huntington

L. V. Jones

B. R. Kokenge

M. L. Mullins

J. B. Peterson

A. F. Schmidt

A. R. Stambaugh

H. L. Williams

Library (15)

Publications (11)