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USATEA REPORT 71-36 RESEARCH MEMORANDUM

MONITORING OF

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A SHIPMENT OF RADIOACTIVE CONTROL RODS

FROM GATUN, CANAL ZONE, TO WEST JEFFERSON, OHIO

DECEMBER 1971

Prepared by

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ABSTRACT

This research memorandum describes the monitoring of a shipment of spent reactor control rods from the floating nuclear power plant, MH-1A <u>Sturgis</u>, located in Gatun Lake, Panama Canal Zone, to West Jefferson Ohio. The movement was made by ocean and highway modes. The ride was relatively smooth and no damage to the cargo occurred. The memorandum describes loading and unloading methods used, transportation environments encountered, and suggests new criteria for design of cargo securement systems for the ocean mode.

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INTRODUCTION

General

This memorandum covers the monitoring of a shipment of spent reactor control rods from Gatun Lake, Panama Canal Zone, to West Jefferson, Ohio. The control rods were removed from a floating nuclear power plant, Seagoing Barge MH-1A <u>Sturgis</u> (ex <u>Charles H. Cogle</u>), located in Gatun Lake near Gatun Locks. To provide extra protection in addition to that afforded by the storage cask, the cargo was shipped in a special shipping cradle, Figure 1. Movement was via landing craft, commercial ship, and tractor-trailer to Battelle Memorial Institute in West Jefferson, Ohio. The movement began on 17 December 1970 and was completed on 24 December 1970. No severe or extraordinary shock and vibration environments were encountered. The ocean segment movement was characterized by caim-to-moderate seas with occasional rain. Most of the highway segment movement occurred during a snowstorm, but the ride was comparatively smooth.



Figure 1. Shipping Cradle for MH-1A Sturgis Control Rod Cask.

Background

U.S. Army Transportation Engineering Agency (USATEA) was requested by letter from Headquarters, U.S. Army Engineer Reactor Group, Fort Belvoir, Virginia, dated 28 May 1970, to monitor the shipment. At the time, contracts were being negotiated for work to be performed on the control rods in a CONUS laboratory, and application for certification of the shipping cask was pending. To facilitate delivery of the control rods to the laboratory, a special permit was issued by Department of Transportation on 10 November 1970. The permit (Special Permit No. 6358) authorized a limited series of shipments using the cask via cargo vessel and motor vehicle providing that each shipment was escorted by a person designated by the Department of Defense.

Itinerary

<u>17 December 1970</u> - The cargo was transferred from the MH-1A <u>Sturgis</u> to the LCM 8028 and moved from Gatun Locks, Panama Canal Zone, to Pier 20, Balboa, Panama Canal Zone.

18 December 1970 - The cargo moved on LCM 8028 from Pier 20, Balboa, Panama Canal Zone, to port side of the SS <u>Santa Mariana</u>, Pier 18, Balboa, Panama Canal Zone. The SS <u>Santa Mariana</u> began transit of the canal at approximately 1430 hours and exited the canal at Cristobal at approximately 1900 hours.

23 December 1970 - The cargo arrived aboard the SS <u>Santa Mariana</u> at Shed 140, Port Newark, New Jersey, at approximately 0600 hours. At approximately 1400 hours, the cargo was off-loaded from the ship to a tractor-semitrailer. At approximately 1730 hours, the cargo moved from Shed 140 to the tractor-semitrailer en route to West Jefferson, Ohio.

24 December 1970 - At approximately 0930 hours, the cargo arrived at Battelle Memorial Institute, West Jefferson, Ohio, via tractor-semitrailer. At approximately 1300 hours, off-loading was completed.

II. OBJECTIVES

1. To obtain shock and vibration, temperature, and humidity data during ocean and highway transit.

2. To obtain shock and vibration data during terminal handling operations.

3. To observe and report on transportability of cargo throughout movement.

III. CONCLUSIONS

1. Shock and vibration, temperature, and humidity data were obtained during ocean transit. Due to malfunction of the TEMARS system, shock and vibration data only were obtained during the highway transit.

2. Shock and vibration data were obtained during terminal handling operations.

3. Transportability of the cradle would be improved by rounding the ends of the cradle base to facilitate skidding.

4. Environmental conditions encountered were moderate, and no damage to cargo or the cargo securement system occurred during transit.

5. The tiedowns used to secure the cargo during the ocean mode, the greatest risk to cargo security, were capable of preventing dislocation of the cargo during a roll of at least 65 degrees at a rate equivalent to 10 cycles per minute.

IV. RECOMMENDATIONS

1. Modify the cradle base to facilitate skidding.

2. Monitor additional nuclear material movements as a means of developing criteria for future design of casks and tiedowns for all modes of transport.

V. DISCUSSION

Description of Cargo

The cargo consisted of a number of spent reactor control rods contained in a storage cask, which was assembled inside a special shipping cask (see Figure 1). Shipping weight and overall dimensions of the complete cargo assembly are as follows:

| Weight | - | 36,450 pounds |
|--------|---|-------------------|
| Length | - | ll feet l inch |
| Width | - | 5 feet 10 inches |
| Height | - | 5 feet 6.5 inches |
| Cube | - | 402 cubic feet |

Loading and Off-loading Procedures

1. MH-1A Sturgis to LCM 8028

Since the storage cask and the shipping cask had not previously been assembled together, a trial assembly was made aboard the Sturgis. This is recounted here because of interest in the procedure from a materials handling viewpoint.

The storage cask is cylindrical and is normally handled in the upright position. The shipping cask accommodates the storage cask in a horizontal position. To facilitate reorientation of the storage cask, it was equipped with trunnions at the base, and stanchions to accept the cask trunnions were installed on the deck of the ship. The storage cask was then lowered into the stanchions and tilted so that it could be further lowered to the deck of the ship (Figure 2). Slings were then secured at both ends of the storage cask, and it was placed in the shipping cask in a horizontal attitude as shown in Figure 3.

The crane on the <u>Sturgis</u> did not have sufficient capacity to handle the full weight of the cargo assembly. Consequently, after the trial assembly was made and necessary minor cask modifications completed, the casks were transferred separately and reassembled aboard the LCM 8028. Figure 4 shows the storage cask being lowered with the <u>Sturgis</u> crane into the shipping cradle which had previously been placed aboard the LCM. Because the cradle base was not designed for skidding, it was necessary to use the crane for each movement of the base. Although this presented no serious obstacle, minor relocations would have been made easier in some cases if the base had been designed for skidding.



Figure 2. Reorienting Storage Cask From Upright to Horizontal Attitude.



Figure 3. Storage Cask Being Placed in Shipping Cask for Trial Assembly.



Figure 4. Transferring Storage Cask from MH-1A <u>Sturgis</u> to LCM 8028 for Reassembly with Shipping Cask.

2. LCM 8028 to SS Santa Mariana

The SS <u>Santa Mariana</u> is equipped for handling containers. In this case, a flatbed container was set in place on the deck of the ship. At Balboa, Canal Zone, the control rods were transferred from the LCM using the ocean vessel's container handling gear with slings, as shown in Figure 5. Figure 6 shows the cargo on the flatbed container. The polyethelene sheeting shown at the end of the cask in Figure 6 protects instrumentation used for monitoring the shipment.







Figure 6. Control Rods on SS Santa Mariana.

3. SS Santa Mariana to Highway Vehicle

At Port Newark, New Jersey, the control rods were transferred from the ship to a flatbed trailer alongside using the ship's container gear with slings.

6

Highway Vehicle to Laboratory Building 4.

The building at Battelle Memorial Institute was equipped with a traveling overhead crane. However, the crane did not have the dimension and weight capacity required for this lift. To accomplish the lift, the semitrailer was spotted adjacent to the loading dock under the crane tracks. Slings were attached to the inboard side of the shipping cask. A forklift truck was then driven to the outboard side of the trailer and positioned for lifting the outboard side of the cask. With both the crane and forklift lifting, the cask was raised clear of the semitrailer platform. The semitrailer was then pulled from beneath the cask and the cask lowered.

Instrumentation

For ocean environment: 1.

One RM-3-W Accelerometer:

| Manufacturer: | Inpact Register Co. |
|---------------|--|
| Calibrations: | ± 10 g's vertical, ± 5 g's lateral, ± 15 g's longitudinal |
| Location: | On base of shipping cask. |

Six Strain Gage Accelerometers; Statham Type A-3-350, 0-3g's range:

Three perpendicularly oriented on deck of flatbed container; three perpendicularly oriented on exterior of shipping cask. System installed complete with strip chart recorder (Visicorder) and bridge balance unit.

One Brown 7-day Temperature and Humidity Recorder:

Manufacturer: Honeywell, 0-100 percent relative humidity, 0-100 degrees Fahrenheit.

On exterior of shipping cask. Location:

NOTE: RM-3-W Accelerometer and Brown Temperature and Humidity Recorder remained active during all modal transfers.

2. For highway environment:

One RM-3-W Accelerometer:

Calibrations: Same as for ocean environment.

One Transportation Environment Measurement and Recording System (TEMARS).

VI. ANALYSIS

Cargo Restraining System

The combination of high density, low center of gravity, and effective friction surfaces enhanced the stability of this cargo during shipment. No dislocation of cargo occurred in transit. The relatively low lateral and longitudinal accelerating forces measured (0.1 to 0.125g range in both ocean and highway modes) were not large enough to overcome normal static friction. Under such conditions the cask would not be expected to move relative to the supporting surface even if no tiedowns were used. For the ocean move, a 3/4-inch-diameter wire rope was looped over each end of the cask through the tiedown eyes. Both ends of each cable were clamped into a 1-1/4-inch-diameter turnbuckle, which, in turn, was secured to a deck cleat with a loop of 5/8-inch steel chain. The tiedowns are shown diagrammatically in Figures 7 and 8. Estimated safe working load for the cable is at least 14,100 pounds. Estimated safe working load for the chain loop is 13,200 pounds. Estimated safe working load for the turnbuckle is 10,700 pounds (using a safety factor of 5). Therefore, the weakest element of this tiedown configuration is the turnbuckle.

For the highway move, the cask was secured to the trailer by 5/8-inchdiameter chain looped at each of the four tiedown eyes.

In the ocean/highway movements, the greatest risk to security of the cargo is associated with the ocean mode. Damaging stresses may occur if the vessel rolls and pitches severely, and since such conditions result from weather, they are considered normal and not accidental. It would be extremely difficult if not impossible to recover cargo lost overboard. Therefore, the cargo securement system should be designed for the worst condition expected. Although not required by this study, it is of interest to know in the case of nuclear deck cargo, whether the cargo will remain in position if the ship rolls to the point of capsizing. Precise information on the roll angle required to capsize this vessel under the existing condition of loading is not available. Consequently, for purposes of this study, a condition of roll of 65 degrees at a rate of 10 cycles per minute was



Figure 7. Cask Tiedown Arrangement Used on SS Santa Mariana (Front Quarter View).



Figure 8. Cask Tiedown Arrangement Used on SS <u>Santa Mariana</u> (Rear Quarter View).

assumed. This assumption is based on roll-frequency experience and on criteria that the righting moment should be positive from 0 to 65 degrees for seagoing vessels. (See <u>Mark's Standard Handbook for Mechanical</u> <u>Engineers</u>, 7th ed. pp 11-47.) The calculations show that this cargo would probably have remained in place under the assumed roll conditions. The safe working load of the turnbuckle would be exceeded by about 100 percent, but this is still less than one-half the breaking strength.

Environmental Data, Ocean

Inasmuch as relatively calm weather prevailed through the ocean voyage, accelerations were of relatively low magnitude. Figure 9 is a cumulative distribution of acceleration amplitudes measured by the Statham accelerometers and recorded on the strip chart recorder. Maximum values and associated frequencies ranged as follows:

| <u>Orientation</u> | Maximum (g) | Frequency (c.p.m.) |
|--------------------|----------------|-----------------------|
| Vertical | 0.5 | 9-10 |
| Longitudinal | 0.1 | 9-10 |
| Lateral | 0.11 | 9-10 |

Maximum accelerations recorded during loading operations associated with ocean transport were as follows:

| <u>Sturgis</u> to LCM 8028 (Empty Shipping Cask Cradle) | LCM 8028 to SS Santa Mariana | SS <u>Santa Mariana</u> to Semitrailer |
|---|---------------------------------|---|
| 0.5g vertical | 0.25g vertical | 0.lg vertical |
| 0.75g lateral | 0.5g lateral | 0.3g lateral |
| 1.5g's longitudinal | 0.5g longitudinal | 0.lg(-) longitudinal |



CUMULATIVE DISTRIBUTION (%)

Figure 9. Cumulative Distribution of Peak Accelerations, Ocean Mode, MH-1A Spent Control Rod Shipment.

During the first 4 days of the voyage, temperature ranged from a high of 78 degrees Fahrenheit to a low of 65 degrees Fahrenheit. At about noon on 22 December 1970, the temperature began dropping steadily and by noon on 23 December had reached a low of 28 degrees Fahrenheit. When the temperature started the rapid drop, the ship was 300 miles from Ambrose Light at latitude 35° -27' north and longitude 74° -59' west.

Relative humidity varied from a low of 50 percent to a high of 99 percent. During the period of dropping temperature described above, relative humidity was maintained at 80 to 86 percent.

Environmental Data, Highway

The RM-3-W recorder chart revealed that accelerations during highway movement were unusually low. Perhaps the prevailing snow condition was a contributing factor. The snowstorm tended to reduce the amount of traffic on the road, induced the drivers to be extremely cautious and careful, and tended to "smooth over" road defects. The maximum acceleration recorded was 0.125g in the lateral direction. Longitudinal and vertical accelerations were of such low magnitude (below 0.1g) that they were not readable from the RM-3-W chart.

The same RM-3-W recorder used to record highway data was active during the off-loading procedure at Battelle Memorial Institute. During offloading, the following maximum accelerations were recorded: 2g's vertical, 0.5g lateral, and 1.0g longitudinal.