barrier followed by a fire, the probability calculations for total shipment distance of 11.3 million km indicate that, for a velocity of 115 km/h, the probability of occurrence for impact is expected to be approximately once every 5900 years, and for a velocity of 130 km/h, no more than once every 18 000 years. These values do not include the combined impact and fire environment, which are at least 1000 times less likely to happen.

In the three full-scale impact tests conducted to date, the accidents of the severities described have not breached the container; therefore, had these casks been involved in such severe accidents during the transport of spent fuel, the public would not have been exposed to irradiated fuel elements.

CONCLUSION

The program objectives have been met successfully thus far. It has been shown that current analytical and scale-modeling techniques can predict vehicular and cask damage in extremely severe accident environments. In addition, much data have been collected on the response of transport systems in accident environments. These tests have shown that the spent-fuel casks tested are extremely rugged containers capable of surviving very severe accidents. The strong implication is that modern casks, designed and constructed to more rigid requirements, will survive equally well. Moreover, the capability to predict their survivability without full-scale testing has been shown to be feasible through mathematical analysis and scale-model testing.

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Safe Transport of Munitions

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The U.S. Department of Defense is conducting a study to determine procedures and methods that are technically and operationally feasible and economically acceptable to prevent, or limit, the effects of explosives incidents in rail cars and mass detonation of containerized munitions in port areas and aboard ships. Selected U.S. Department of Defense components, whose inherent mission, expertise, and physical assets are appropriate to developing solutions, will conduct technical and operational feasibility studies. Each performing agency will coordinate its areas of study with other governmental and industrial organizations. The 13 tasks have been categorized into six major areas of consideration. These include background information, traffic patterns, equipment, fire protection, buffering, and sea containers. The study, including a final report, is programmed to be completed within 33 months, ending in September 1980. The total cost is estimated to be approximately $3 million, which will be funded by both the Army and the Navy.

The importance of the safe transport of munitions (STROM) has been magnified tremendously in the past few years. There are countless technical and legal aspects of this subject, but we will be mainly concerned with four areas:

1. The magnitude of the problems involved,
2. What the U.S. Department of Defense (DOD) is doing,
3. Its basic considerations and involvements, and
4. What it hopes to achieve.

History books document reports of accidental explosions from the time that gunpowder was first developed. But now, due to the introduction of more sophisticated weapons along with more powerful explosives, as well as population increases near shipping routes, the problems have magnified. The days of relatively confined incidents and limited personal injury have been replaced by horrendous explosions and, in some instances, considerable loss of life.

A review of incidents that occurred in Roseville, California (Figure 1), and Benson, Arizona (Figure 2), will help to understand the magnitude of the problems.

A Southern Pacific train arrived in the Roseville, California, rail yard at approximately 6:00 a.m., on April 28, 1973. Included in the train were rail cars loaded with high-explosive bombs destined for Vietnam. At approximately 8:00 a.m., an explosion occurred in one of the bomb-laden cars. By propagation, 18 of the cars were destroyed by explosions over a period of 2.5 h. Bombs strewn throughout the remaining burning debris continued to explode until 4:00 p.m. the following day.

One hypothesis as to the cause of the incident was that heavy braking on mountain grades caused heat buildup in the car wheels. Oil and grease on the car underside subsequently ignited and created a floor char, which smouldered for hours and eventually broke into flames that caused the explosions. This is only one hypothesis. A complete report of the incident is not yet available due to ongoing litigation involving both the Southern Pacific Railroad and the United States government..

A little less than a month later, on May 24 at approximately 7:00 p.m., another Southern Pacific train, this one with 12 cars, loaded again with high-explosive bombs destined for Vietnam, was near Benson, Arizona, when it was racked by a series of explosions, which continued for 6.5 h, destroying all 12 bomb-laden cars. Fortunately, the train was 8 km (5 miles) from the nearest home.

The National Transportation Safety Board hypothesized, in its report of the Benson incident, that the initial explosions were caused by a fire, which most likely originated when sparks were thrown from the car brake shoes and ignited the floor boards, which were impregnated with sodium nitrate from a previous lading. Again, this is only a hypothesis.

Although property damage was quite extensive, totaling well over $3 million, the Roseville and Benson incidents caused only few personal injuries and no fatalities.

However, a recent explosives incident occurred in Iri, South Korea (Figure 3), where nearly 60 people were killed and hundreds injured by the explosion of one carload of dynamite. We can imagine what would have happened had the Roseville and Benson incidents occurred as the trains were passing through heavily populated urban areas. This potential for disaster has long been recognized and a special note of it was made by the National Transportation Safety Board in its Benson report. One point must be stressed—this potential for disaster is of the greatest concern to all involved in the STROM program.

The Benson incident, occurring so soon after Roseville, brought an old problem to the surface: How to prevent or limit the effects of explosives incidents in rail cars and mass detonation of containerized munitions in port areas and aboard ships. Our task is to learn everything we can about the problem and determine what corrective actions can be taken.

DOD started to attack the problem soon after the Benson incident and developed the STROM study plan. The plan stemmed from recommendations made by their Explosives Safety Board in the fall of 1974. The safety board recommended that technical and operational feasibility studies be conducted in six areas:

1. Limited use of spacer cars,
2. Heat sensors with alarm systems,
3. Use of fire experience and test data previously acquired,
4. Use of installed fire protection systems,
5. Use of buffer systems other than spacer cars, and
6. The use of all-steel cars.

The safety board also recommended that a project manager be named by the Military Traffic Management

Figure 1. Roseville, California.

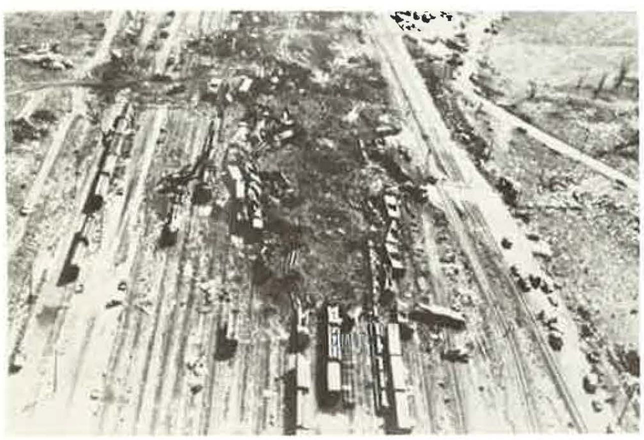

Figure 2. Benson, Arizona.

Figure 3. Iri, South Korea.

A woman cries and a man buries his head in sorrow over the damage. (AP) A man stands near the crater made by the bomb. (AP)

Command (MTMC), with the safety board and other DOD components to be on call as required. MTMC prepared the study plan, which outlined the various actions that comprise the STROM program and served as program coordinator.

The study plan is flexible so that other areas can be considered as the program progresses. Two additional areas of study have already been incorporated into the plan. The first encompasses rail car stability, as well as shock and vibration control. The second is concerned with containerized munitions.

The study does have one specific constraint. There are several classes of explosives, but in order to confine the scope of the study to an acceptable limit, only Class A, or detonating explosives, are under consideration.

Our study objective is to determine procedures and methods that are technically and operationally feasible and economically acceptable to prevent or limit the effects of explosives incidents in rail cars and mass detonation of containerized munitions in port areas and aboard ships.

In order to meet this objective, certain tasks were assigned to study participants according to the availability of special expertise and physical assets. The four primary DOD participants are the Army Ballistic Research Laboratory, the Army Ammunition Center, the Navy Weapons Center, and MTMC. Other organizations, both within and outside the government, will be approached for information and consultation as required.

There are 13 tasks to be completed by the participants. So as to logically develop all aspects of our objective, the tasks have been categorized as follows.

Background

1. Identify the regulations that govern the shipment of munitions by rail and estimate carrier compliance.
2. Identify the hazard characteristics of DOD munitions during transportation.
3. Determine, on a statistical basis, accident cause and scope of damage to personnel and property, in reference to munitions transported by rail.

Traffic Pattern

4. Analyze the distribution of munitions and determine whether cargo flow patterns minimize in-transit exposure, in regard to population density.

Equipment Considerations

5. Study the consequences of restricting future munition shipments to rail cars of all steel, or otherwise noncombustible construction.
6. Determine if rail car stability, as well as shock and vibration control, can aid in the prevention of explosives incidents in the rail movement of munitions.

Fire Protection Systems

7. Determine if sensors in a car carrying munitions, coupled to an appropriate alarm system, will provide adequate detection of dangerous heat buildup in the car.
8. Study the use of fire protection systems, within or on rail cars transporting munitions, with the objective of preventing or controlling fires.
9. Examine the application of test data and fire experience acquired by the Naval Weapons Center to the reduction of the risk of fire in railroad rolling stock.

Buffer Systems

10. Investigate the use of buffer systems, other than spacer cars, to reduce the risk of explosives propagation from car to car.
11. Study the use of spacer cars to prevent the propagation of an explosion between rail cars.
12. Study the use of containers on flat cars and trailers on flat cars for transporting munitions, as a means to prevent or minimize explosives incidents.

Port Areas and Ships

13. Analyze methods for preventing, or limiting the effects of, mass detonation of containerized munitions in port areas and aboard ships.

Each of the tasks, as well as subtasks, has a time schedule and all are projected to be completed within a 27-month time frame. The plan calls for a report, with recommendations, to be submitted for each task. These reports are to be analyzed by MTMC, which will then develop and publish a final report.

The total cost of the program is almost $3 million. Both the Army and the Navy have allocated funds in support of the STROM effort.

The first coordination meeting for the program was held in Washington, D.C., on November 16, 1977, and the first working meeting was on March 29, 1978, in Newport News, Virginia. Program plans have been finalized and a number of tasks begun in January 1978. The remainder of the tasks are scheduled to start sometime prior to October 1978. Quarterly progress reports are being submitted, and general review meetings are held semiannually. The final report is scheduled to be published in September 1980, 6 months after all tasks are completed.

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