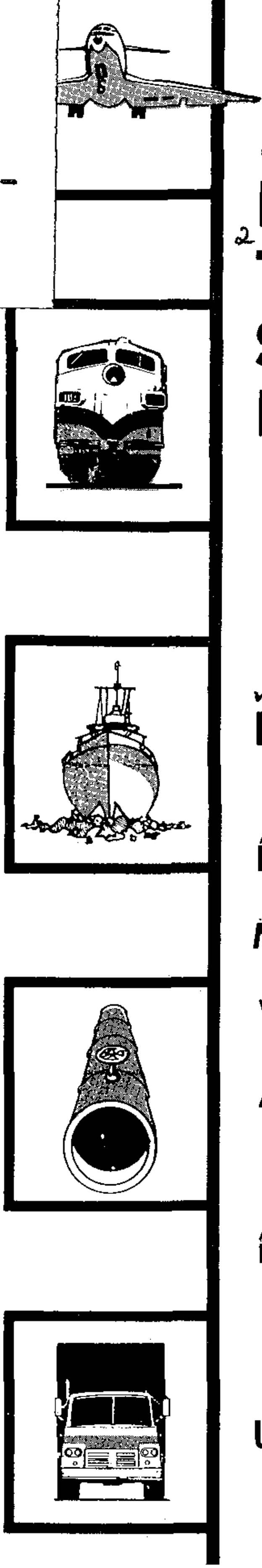

NATIONAL TRANSPORTATION SAFETY BOARD

RAILROAD ACCIDENT REPORT

BURLINGTON NORTHERN INC.
MONOMETHYLAMINE NITRATE EXPLOSION
WENATCHEE, WASHINGTON
AUGUST 6, 1974

REPORT NUMBER: NTSB-RAR-76-1

UNITED STATES GOVERNMENT

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16. Abstract

At 12:32 p.m. on August 6, 1974, a shipment of monomethylamine nitrate solution (PRM) detonated during routine switching operations in the Burlington Northern Inc. Apple Yard in Wenatchee, Washington. The explosion killed 2 persons, injured 113, and destroyed equipment and buildings. Estimated losses exceeded $7,500,000.

The National Transportation Safety Board was unable to determine the probable cause of the accident. A partial list of the possibilities that could not be ruled out completely includes a reaction of dried crystals, a reaction of spilled or leaking crystals in the insulation space, a reaction in one of the tank components, cavitation and recompression of the solution, compression of an air bubble entrained in the solution, a reaction of solution or crystals sensitized by contamination, or the ignition of escaped product by friction. The Safety Board concludes that the classification of monomethylamine nitrate as a "flammable solid" permitted shipment of the chemical without proper safeguards against predictable hazardous conditions.

The National Transportation Safety Board made five recommendations to the Department of Transportation.

17. Key Words
Railroad accident; tank car explosion; monomethylamine solution; PRM; hazardous material classification system; special permit.

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FOREWORD

The accident described in this report has been designated a major accident by the National Transportation Safety Board under the criteria established in the Safety Board's regulations.

This report is based on facts obtained from a public hearing and an investigation conducted by the Safety Board. The Board was assisted in developing the facts by:

The State of Washington
Chelan County, Washington
City of Wenatchee, Washington
Brotherhood of Locomotive Engineers
Congress of Railway Unions
Federal Railroad Administration
General American Transportation Corporation
E.I. DuPont de Nemours Company
Association of American Railroads
Department of Defense
Treasury Department
U.S. Bureau of Mines
Department of Energy Mines and Resources (Canada)
Burlington Northern Inc.

The conclusions and the determination of probable cause are those of the Safety Board.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: February 2, 1976

BURLINGTON NORTHERN INC.
MONOMETHYLAMINE NITRATE EXPLOSION
WENATCHEE, WASHINGTON
AUGUST 6, 1974

SYNOPSIS

At 12:32 p.m. on August 6, 1974, a shipment of monomethylamine nitrate solution (PRM) detonated during routine switching operations in the Burlington Northern Inc. Apple Yard in Wenatchee, Washington. The explosion killed 2 persons, injured 113, and destroyed equipment and buildings. Estimated losses exceeded $7,500,000.

The National Transportation Safety Board was unable to determine the probable cause of the accident. A partial list of the possibilities that could not be ruled out completely includes a reaction of dried crystals, a reaction of spilled or leaking crystals in the insulation space, a reaction in one of the tank components, cavitation and recompression of the solution, compression of an air bubble entrained in the solution, a reaction of solution or crystals sensitized by contamination, or the ignition of escaped product by friction. The Safety Board concludes that the classification of monomethylamine nitrate as a "flammable solid" permitted shipment of the chemical without proper safeguards against predictable hazardous conditions.

FACTS

The Accident

On July 29, 1974, about 10,000 gallons of monomethylamine nitrate (PRM) water solution was shipped by E.I. DuPont de Nemours from Biwabik, Minnesota, to DuPont, Washington, in tank car DUPX 16009. The car moved from Duluth to Superior, Wisconsin, via the Duluth, Missabe, and Iron Range Railroad, and was accepted in interchange by Burlington Northern Inc. The tank car arrived in Wenatchee, Washington, at 6:55 a.m. on August 6, 1974. Tank car DUPX 16009 was switched routinely several times and at 11:30 a.m., it was moved in a 13-car cut to track 12 in Apple Yard. Two more cars were switched onto track 12, which made DUPX 16009 the fifth car from the east end of the cars on track 12.

During routine switching of a train on the main track (train 97), 14 cars and a caboose were removed from the train. Five of the 14 cars were cut off and allowed to roll toward track 12 and the remaining 9 cars were moved back with the locomotive to couple again with train 97.

Shortly after the five cars should have coupled to the cars on track 12, the shipment in DUPX 16009 began to spew smoke and fire and then detonated. (Figure 1 depicts the cone-shaped crater that was created by the explosion.) Two persons were killed in Apple Yard and many persons in the yard and vicinity were injured. The blast demolished many railcars, damaged many others, and damaged many structures near the yard.

Postaccident Activities

The Chelan County Fire Department responded immediately to the emergency and called for assistance from surrounding communities. Police secured the area and helped firefighters transport the injured to the hospitals. Firefighters fought numerous grass fires which were ignited by hot fragments from the tank car.

Pumps used to bring water from the Columbia River were inoperative because the accident interrupted electrical power to Apple Yard. Burlington Northern brought in tank cars of water to the yard and aircraft dropped a fire suppressant on the yard.

Emergency personnel conducted a life search in the yard and the adjacent area. The evacuation of emergency personnel was ordered after it was learned that there were other hazardous materials cars in the yard. After it was determined that the yard was safe, the fire department resumed its attempt to put out the fire.

Accident Site

Apple Yard of the Burlington Northern lies on the west bank of the Columbia River, south of Wenatchee in Chelan County, Washington. The Burlington Northern main track runs along the west boundary of the yard. There are 13 primary yard tracks. (See Figure 2.) At the time of the explosion, the temperature was 82°F.

At the time of the detonation, the east end of the cut of cars on track 12 was about 1,440 feet west of the switch leading from the main track into the yard. The grade of the tracks from the switch in the main track onto track 12 is -0.317 percent for 800 feet, +0.19 percent for 400 feet, 0 percent for 55 feet, and +0.212 percent for 95 feet up to the point of coupling. The track layout requires a car to pass over four switches and curved track; this decelerates free-rolling cars.

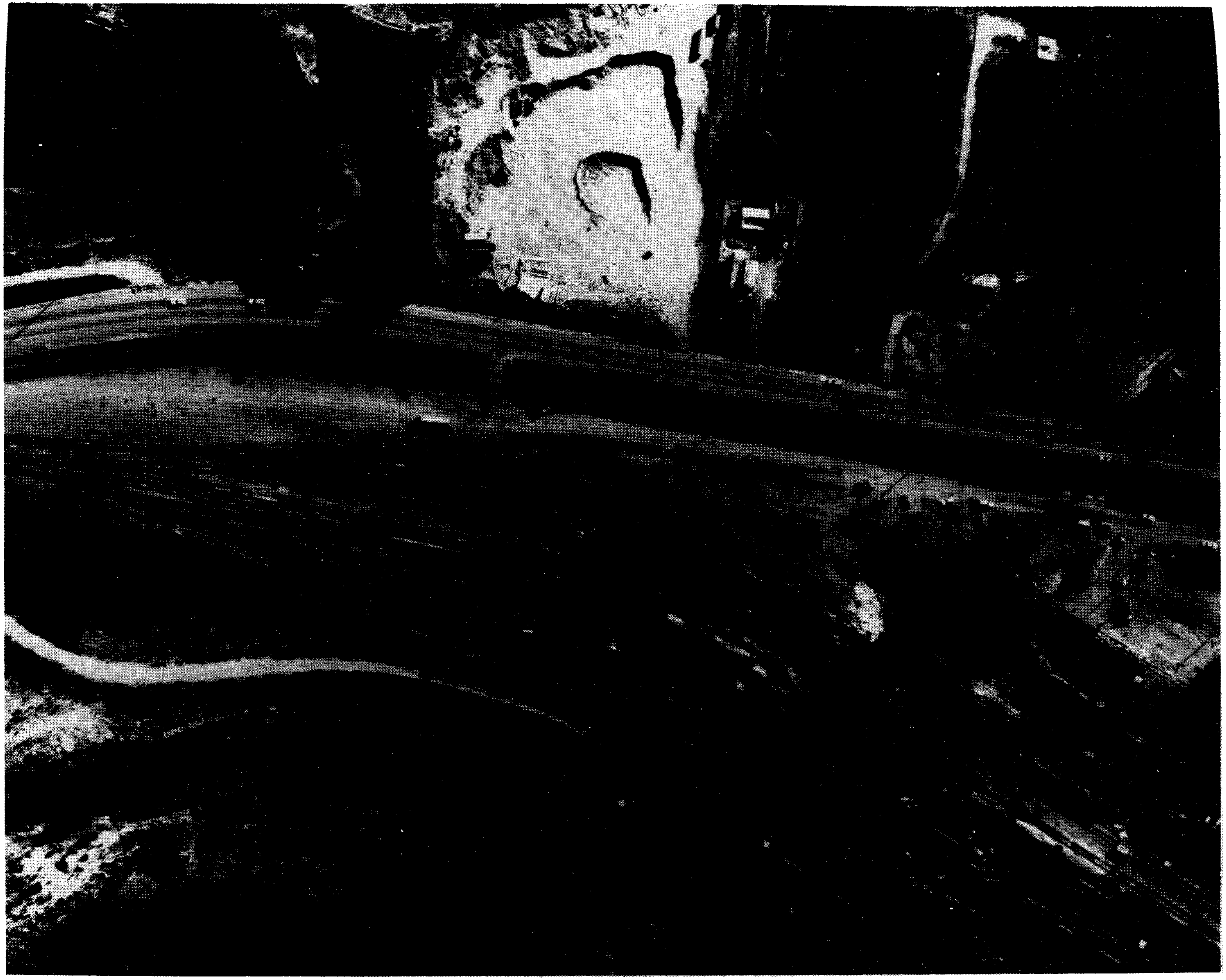


Figure 1. Burlington Northern Inc.'s Apple Yard after the explosion.

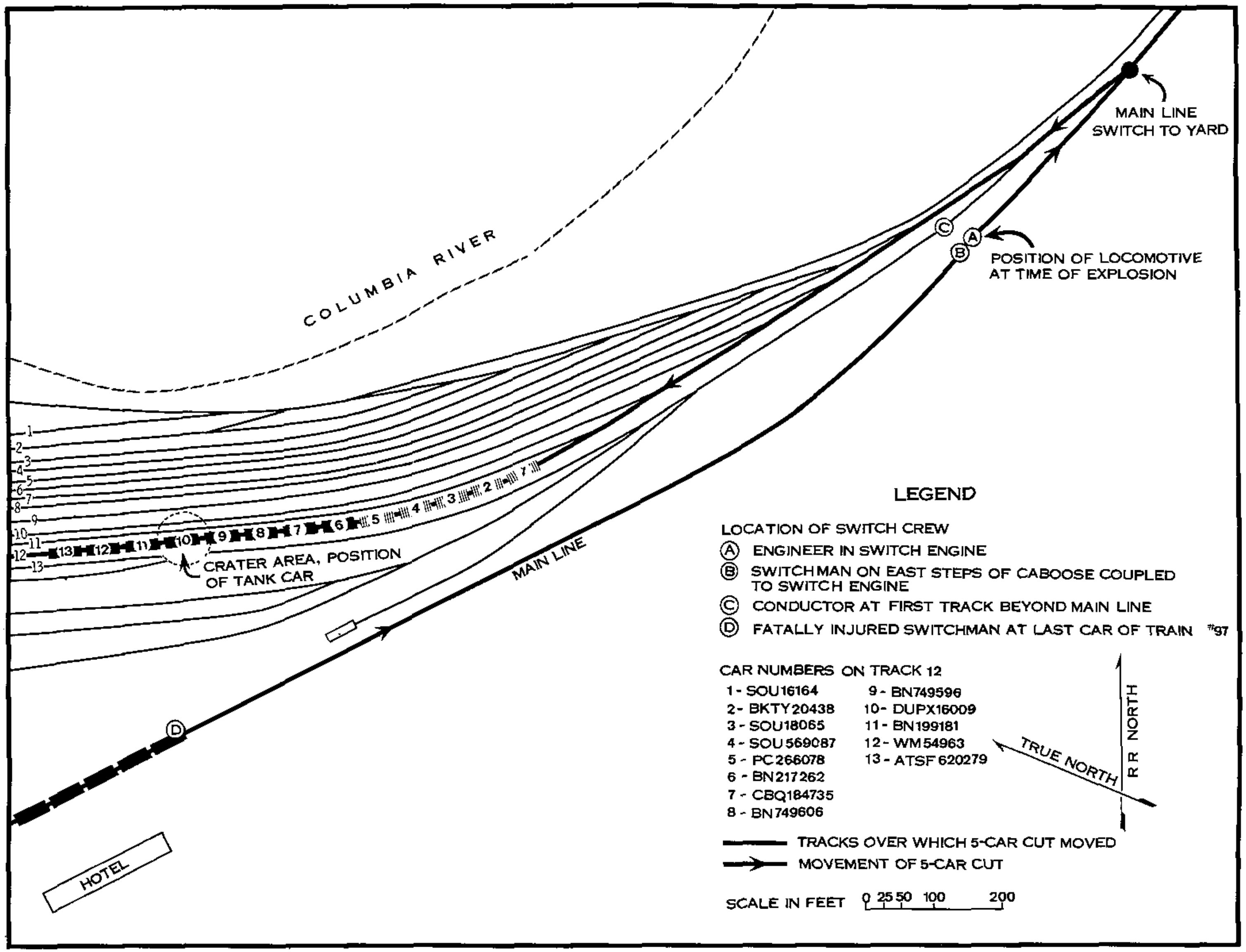


Figure 2. Accident area, Wenatchee, Washington, August 6, 1974.

At the time of the explosion, there were nine cars standing on track 13 adjacent to DUPX 16009; there were no cars on tracks 10 and 11, but there were cars standing on all other tracks.

The area surrounding the yard was residential, with small farms and orchards. There were some commercial and light industrial properties.

Detonation

Before the detonation, the yard crew had cut off five cars and accelerated them westward toward track 12 from a position on the switching lead near the road crossing. The conductor was near the road crossing and the locomotive; the remaining cars had returned to the main track and were moving westward toward train 97 when the detonation occurred. One switchman was near the rear of train 97 and the other was near the main track by the yard locomotive.

It could not be determined whether the five-car cut of cars had coupled to the cars standing in track 12 before the explosion. A postaccident examination of the remaining cars on the east end of track 12 showed no evidence of overspeed impact between the fifth and sixth cars, which were coupled. 1/ However, marks on the sill of the eighth car indicated a recent, longer-than-normal travel.

The Bureau of Alcohol, Tobacco, and Firearms, U.S. Treasury Department, found no evidence that the explosion was initiated intentionally.

Witnesses saw a straight, gray-white column of smoke and orange fire before the explosion. They described the explosion as loud and severe, and said that it was followed by a mushroom-shaped cloud of gray or black smoke. The switch foreman said that he saw a flash of fire beneath the cars on track 11 immediately before he heard and felt the effects of the explosion.

Damage

Concussion and fire caused most of the damage. (See Figure 3.) Parts of the tank car were found up to 1 mile from the site. Many cars in Apple Yard were ignited, and hundreds of acres of grassland in Chelan and Douglas Counties burned. Most of the structural damage was within a radius of about 1 mile, but broken glass was reported 3.5 miles east and 2.5 miles north.

Seventy-one cars and 4 containers were demolished; 101 freight cars and 29 trailers were damaged. Total estimated damage is shown below:

1/ Cars on the east end of track 12 will be identified in sequential numerical order from east to west.

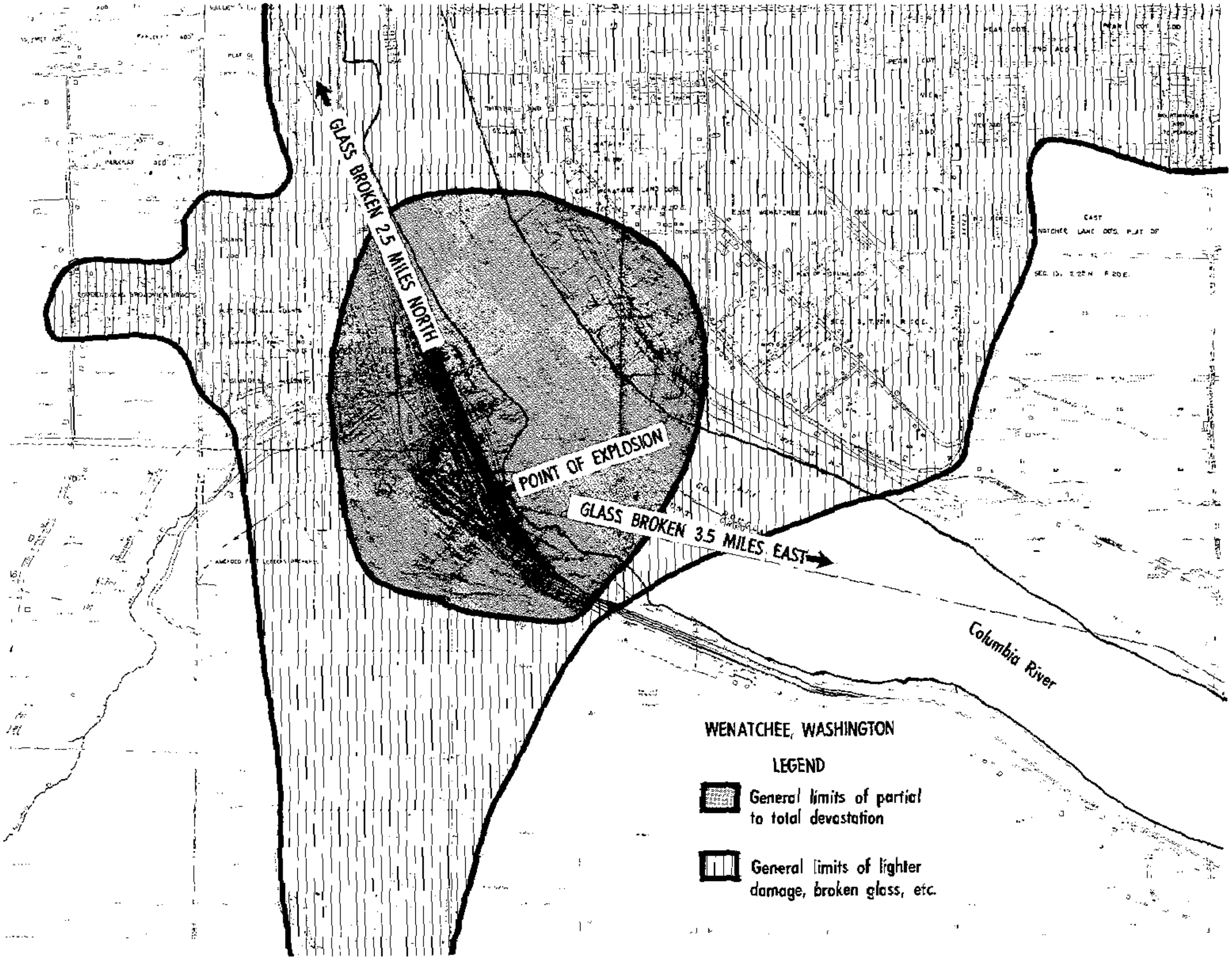


Figure 3. Explosion damage patterns, Wenatchee, Washington, August 6, 1974.

Railroad		
Freight Cars	$	1,444,000
Other	$	1,152,000
Casualty and Third		
Party Property		5,100,000
Total	$	7,696,000

Method of Operation at Apple Yard

Flat switching and yard service is performed at Apple Yard by Burlington Northern yard crews who are supervised by a yardmaster at Wenatchee. Operating employees are instructed directly by the yardmaster. They operate under requirements of the Burlington Northern's Consolidated Code of Operating Rules, general rules, and bulletins.

Instructions regarding the proper handling of cars containing hazardous materials are posted routinely on bulletin boards and in yard offices. No special handling of DUPX 16009 was required or performed.

The Tank Car

DUPX 16009 was one of 12 DuPont tank cars constructed to transport caprolactam. The tank car was built in April 1961 in compliance with Interstate Commerce Commission (now Department of Transportation) specification 111A-100W-6. The inner tank was made of type 304-L, 1/2-inch stainless steel, insulated with 10-inch glass wool with binder, in an outer jacket of 3/16-inch-thick carbon steel.

On June 11, 1964, the heating coils were modified at the top and bottom because of unloading difficulties. In September 1969, the car was cleaned and assigned to transport sodium hydrosulphide. In September 1970, it was cleaned and assigned to transport dimethyl hydroxylamine. In May 1971, the car was inspected because of a reported leak inside the heating coil; the coil was tested but no leak was found. The car was cleaned again and assigned to Biwabik, Minnesota, to transport PRM. During the car's PRM service, the lower outlet leg and heater coil were not used. From September 1972 until July 1974, DUPX 16009 completed 11 round trips from Biwabik to DuPont, Washington.

On October 12, 1973, DUPX 16009 was in a Duluth, Missabe, and Iron Range freight train which was struck from the rear by another train at 28 mph. No visible damage to the tank car was observed. The owner was not notified of the incident and DUPX 16009 subsequently made five trips from Biwabik to DuPont.

Before loading DUPX 16009 for this trip, the plant operator saw residue on the bottom of the tank. The residue was the result of the unloading practice, in which iron impurities were separated from the shipment before the top unloading of the car. This left iron-enriched residue at the bottom of the car. The residue was not removed after every trip. DUPX 16009 was not washed out before the July 29 trip.

The Cargo

The cargo was PRM crystals in a water solution. The bill of lading described the shipment as "86 percent monomethylamine nitrate solution, Flammable Solid N.O.S.," and referred to Department of Transportation (DOT) Special Permit No. 5737. The material was being transported to DuPont, Washington, for use in formulation of an explosive product line called TOVEX.

Both PRM crystals and PRM solutions can detonate. Dry crystals detonate more readily than PRM in solution. There is always some possibility of detonation whenever a detonable material is burned, and the probability is greater in a large quantity of confined detonable material. However, there were no incidents before the Wenatchee accident in which PRM solutions or crystals did detonate accidentally.

The shipment was loaded into DUPX 16009, directly from the manufacturing process, to a liquid level about 8 inches from the top of the car. During the 3 days the car was being loaded, the plant operator, who was responsible for the loading of the car, noted nothing unusual about the car or the loading; he prepared the car for shipment in the usual manner. The operator did not operate the bottom outlet valve or remove the cap from the bottom outlet leg assembly during loading. It is unclear from his testimony whether the coil caps were in place during that time. The manway cover was not closed during loading, because the PRM was introduced into the car through a fitting clamped to the manway.

Plant records indicate that the PRM in DUPX 16009 was about 87 to 88 percent PRM, with a pH ranging from 7.1 to 7.8; pH of 4.5 is called for in the plant operating instructions. The freezing point for 85-percent PRM solutions is 99°F, and for 88-percent solutions it is 120°F.

The PRM produced at the Biwabik plant is not analyzed chemically. To control the PRM's quality, the raw material quality, the reaction temperature, the product pH, and the density are monitored; and the finished products in which the PRM is used are tested for performance.

DOT Special Permit 5737

The packaging and transporting of the PRM in tank cars were authorized under the provisions of DOT Special Permit 5737. (See Appendix A.)

A special permit is an authorization by which the regulatory agency allows shipments to be transported in a manner not otherwise provided for under regulations issued by the Federal Railroad Administration, DOT. The original permit authorized transportation of the PRM in DOT-specification 103AL and 103W tank cars. Upon petition of DuPont, the permit was amended to authorize DOT 111A-100W-6 tank cars; DUPX 16009 was this type of tank car.

The special permit was necessitated by the classification of the PRM solution as a flammable solid and because the shipper wanted to transport it in tank cars. PRM was first tested for classification by the Bureau of Explosives of the Association of American Railroads (AAR) in January 1968; when the tests showed that dry crystals could detonate, the Bureau of Explosives recommended classifying them as DOT "Explosives Class A, type 3."

At DuPont's request, the Bureau of Explosives observed DuPont conduct further testing on PRM in a water solution. Based on those tests, the Bureau recommended classification of PRM in solution as a "flammable solid." The recommended classification conformed with the regulatory requirements then in effect.

The material used for the classification tests was produced in small quantities and was tested in laboratory quantities. The purity and composition of the material tested were not measured. However, these tests were reportedly conducted with an 85- to 86-percent solution of PRM.

Under DOT regulations, hazardous materials must be placed into a "hazard" class before they can be transported. These regulations also define the "hazard" classes. During the hearing, witnesses stated various reasons that classification is necessary; there was no agreement among them as to the reasons for classification.

DuPont's application for the special permit was reviewed by the Office of Hazardous Materials, the Federal Highway Administration, and the Federal Railroad Administration. Technical criteria for their approval of the special permit application were not recorded. Approval by the Federal Railroad Administration was based on the judgment of the authorizing official. The original permit was recommended by the Bureau of Explosives, although the Bureau was not involved in the authorization of the type 111A-100W-6 car. Technical criteria and the method of safety analysis upon which the Bureau recommendation was based were not documented.

Since there were no leaks or accidents reported to DOT involving shipments under the permit, it was renewed each time DuPont made application. This shipment was the 45th in a 5-year period. Although the PRM solution was known to be detonable, neither DuPont nor the approving authorities believed that it would detonate under the conditions which could occur under the special permit.

In addition to the classification testing of the PRM required under the regulation, DuPont conducted performance tests on PRM to determine its safety in transportation before DuPont applied for the special permit. The full range of safety concerns addressed by these tests was not documented.

DuPont conducted extensive safety analyses on PRM and prepared plant safety rules to assure safe manufacturing and handling in its facility. However, no similar analyses for transportation safety were made. Neither DuPont, the carriers, the Bureau of Explosives, nor DOT documented the safety analysis methods used to govern the test decisions, the issuance of the special permit, or the risk-taking decisions.

Following the explosion, Special Permit 5737 was suspended.

Tests and Research

Examination of the Crater and Track 12--After the accident, debris from DUPX 16009 and adjacent cars and soil samples were taken from the crater and examined by the Bureau of Alcohol, Tobacco, and Firearms. The soil samples contained small quantities of PRM which had not reacted in the explosion. Residues of no other type of explosives were detected.

The tracks in the crater area were examined. No evidence of fire was found on the ties on adjacent tracks, nor was evidence found of an explosion between the rails on track 12, east of the crater area. No PRM residue was observed between the rails or on the ties. The track structure was examined on the east end of the crater; there was no evidence of derailment. However, derailment marks were observed on track 12 west of the crater.

Examination of Car Debris--About 4,000 pieces weighing 3,760 lbs., or 18.8 percent of the inner tank shell, were recovered. (See Figure 4.) The size, shape, and appearance of the pieces varied widely, and included "blued" fragments; clean fragments; fragments with dark residues; hot gouges; cold gouges; collision impact marks; flattened pieces; fragments with missle impact marks and ripple marks; crushed, bent, and torn parts; and parts with splatter-shaped residues. No parts of the car were recovered undamaged.

The inner tank's identifiable parts, which consisted primarily of the tank's lower outlet valve and leg assembly, anchor area, and center

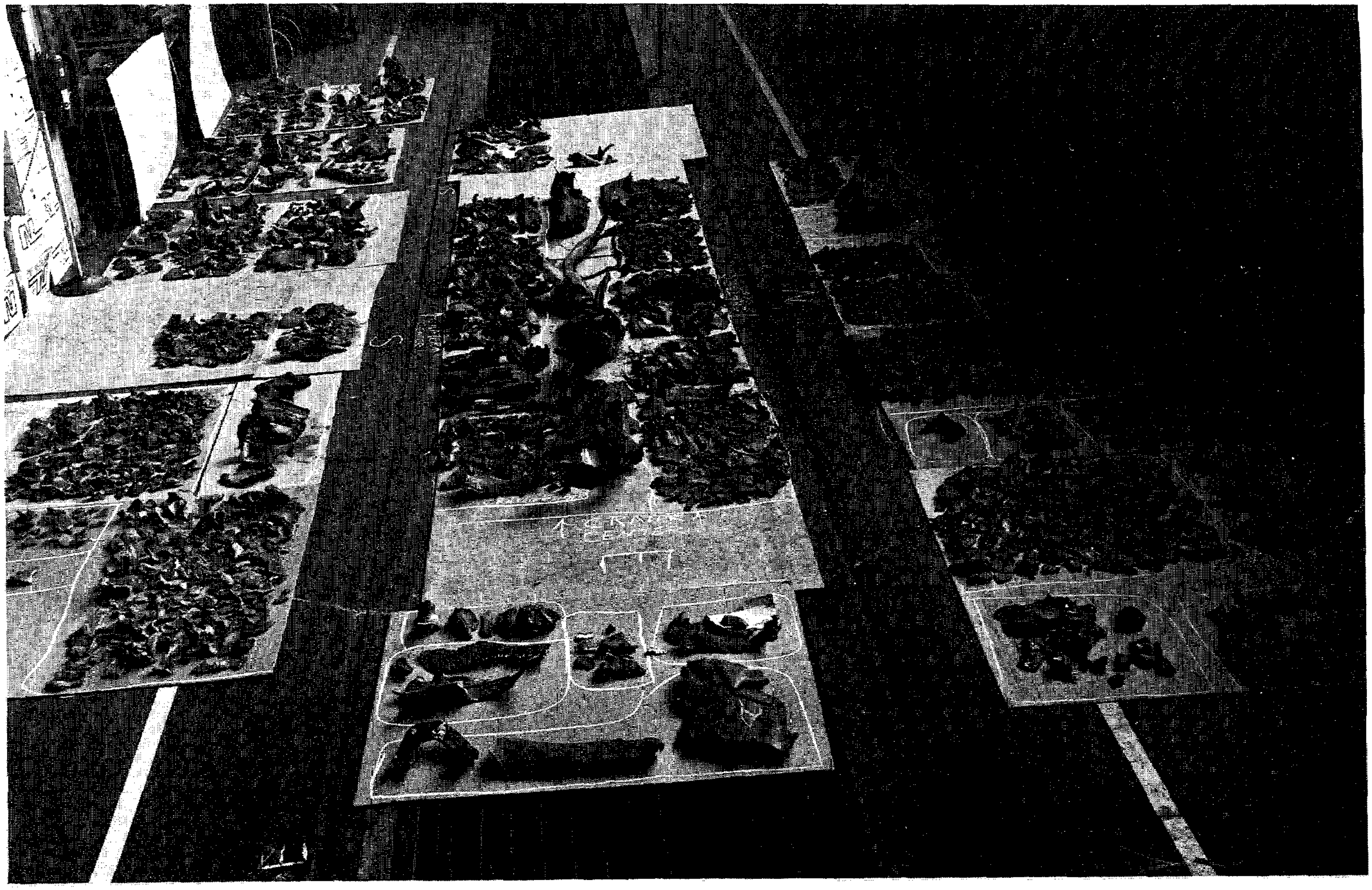


Figure 4. Stainless steel inner tank of DUPX 16009, displayed in accordance with retrieval location.

sill, were reconstructed at the AAR's test center in Chicago. Some parts identified were from the manway entrance area and adjacent valves and attachments. (See Figure 5.)

Parts of the running gear, sill assembly, and couplers were reconstructed from the 12,000 lbs. (38.8 percent) of material recovered from the crater. (See Figure 6.)

The pulling and buffing faces of knuckles on the west end of DUPX 16009 (Car 10) and the adjacent car were examined. Their appearance and the presence of matching marks indicated that they were coupled throughout the explosion. The west coupler of car 9 and parts of the east coupler of car 10 were recovered from the crater. These couplers were examined to determine whether they also were coupled immediately before the explosion occurred. The east coupler of car 10 was fragmented and the west coupler of car 9 was relatively undamaged. Missile marks on the face of the knuckle of car 9 were observed. Missile marks were also found on the front flange of the sliding sill support of car 9 that faced the tank car. Missile marks also were found on other exposed parts. The appearance and location of these marks on car components indicates that they were made before, during, and after structural damage occurred.

Only a small percentage of the inner tank's east tank head of car 10 was recovered. No parts from the outer jacket east tank head area were identified.

Micrometallography techniques were employed on selected samples of the inner tank shell, the heater coil, and the outlet leg assembly parts. Slight stress corrosion cracking was found on a few parts examined.

Microanalyses on selected residue samples taken from tank fragments were conducted. These examinations indicated that the residues were primarily iron.

With the exception of the lower outlet valve and leg assembly, the force of the explosion generally propelled car components away from the central area of the lading in the tank car.

<u>Examination of Other PRM Tank Cars</u>--The three other tank cars that had carried PRM were examined. Two of the three cars--DUPX 16004 and DUPX 16005--were the same type as DUPX 16009. (See Figure 7.) The three cars appeared to be in good condition. However, some of the caulking was missing around the fittings at the top of the tanks, PRM was present inside the annular space and at the tank anchor area, and liquid was dripping from the lower outlet leg on at least one of the cars.

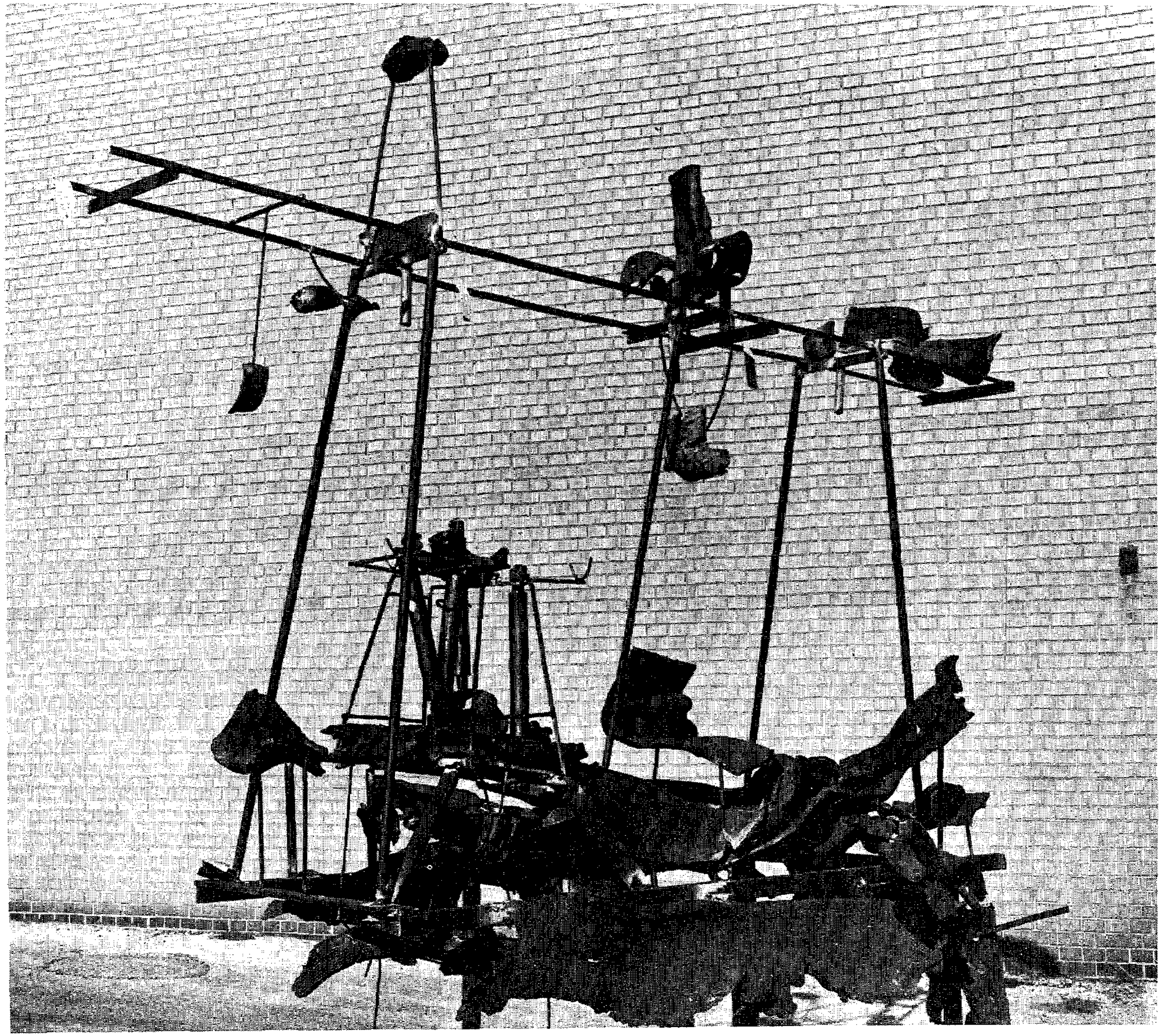
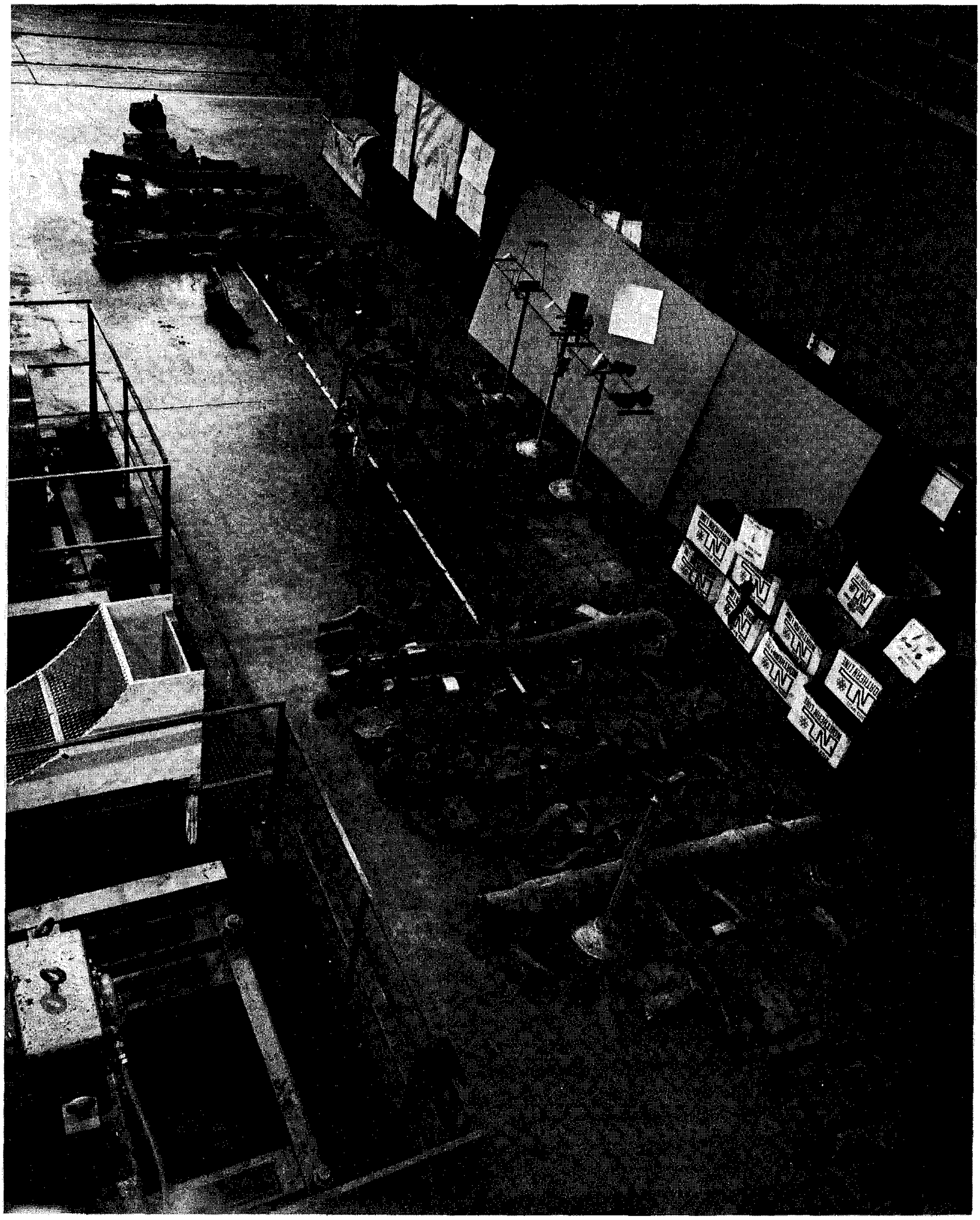


Figure 5. Full-scale reconstruction of the lower central area of the inner tank and adjacent parts of DUPX 16009.



Fegure 6. Reconstructed running gear sill assembly and coupler of DUPX 16009 with reconstructed portions of the inner tank.

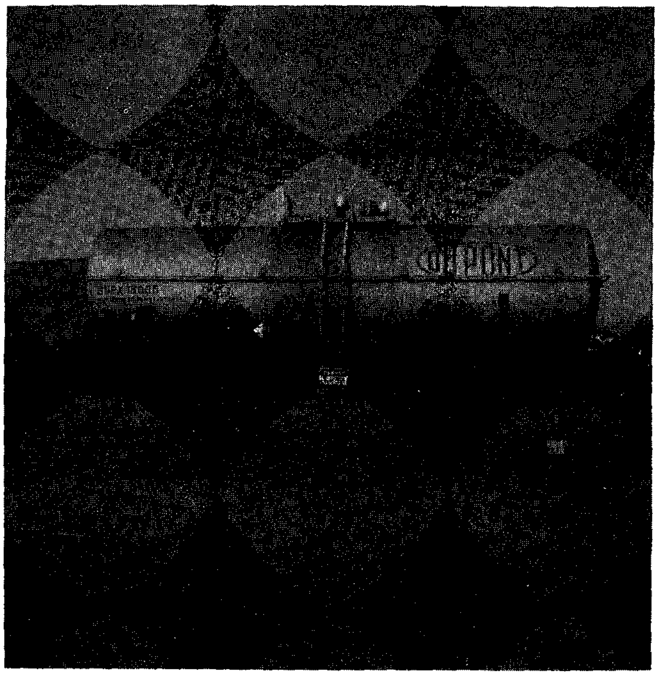


Figure 7. DUPX 16005, similar to DUPX 16009.

DUPX 16004 and DUPX 16005 were disassembled at the General American Transportation Corporation's East Chicago plant to examine their condition. (See Figure 8.)

DUPX 16004 was found to be structurally sound with respect to the insulation, tank, safety valve, and coil. There was a crack in the steam jacket of the eduction pipe, some erosion of the stainless steel eduction pipe guide, and there was no pitting on the heads.

Samples were drawn from the liquid and crystals inside DUPX 16004. An analysis of the liquid indicated that the pH of the liquid was 5.9; the liquid was 64 percent water and 38.4 percent PRM. 2/ Minute traces of solids were removed by filtration. Crystals from inside the car were identified as PRM by X-ray diffraction.

An analysis of samples from the bottom outlet of DUPX 16004 indicated that the pH of the liquid was 6.7; the liquid was 59.1 percent water, 42.2 percent PRM, and 0.08 percent insoluble materials identified as sand, clay, and rust. The crystals consisted of 98.0 percent PRM, 1.7 percent water, and 0.26 percent sand and clay. The crystals had traces of silicone oil and phthalate ester.

2/ Percentages may not total 100 percent because of measurement tolerances.

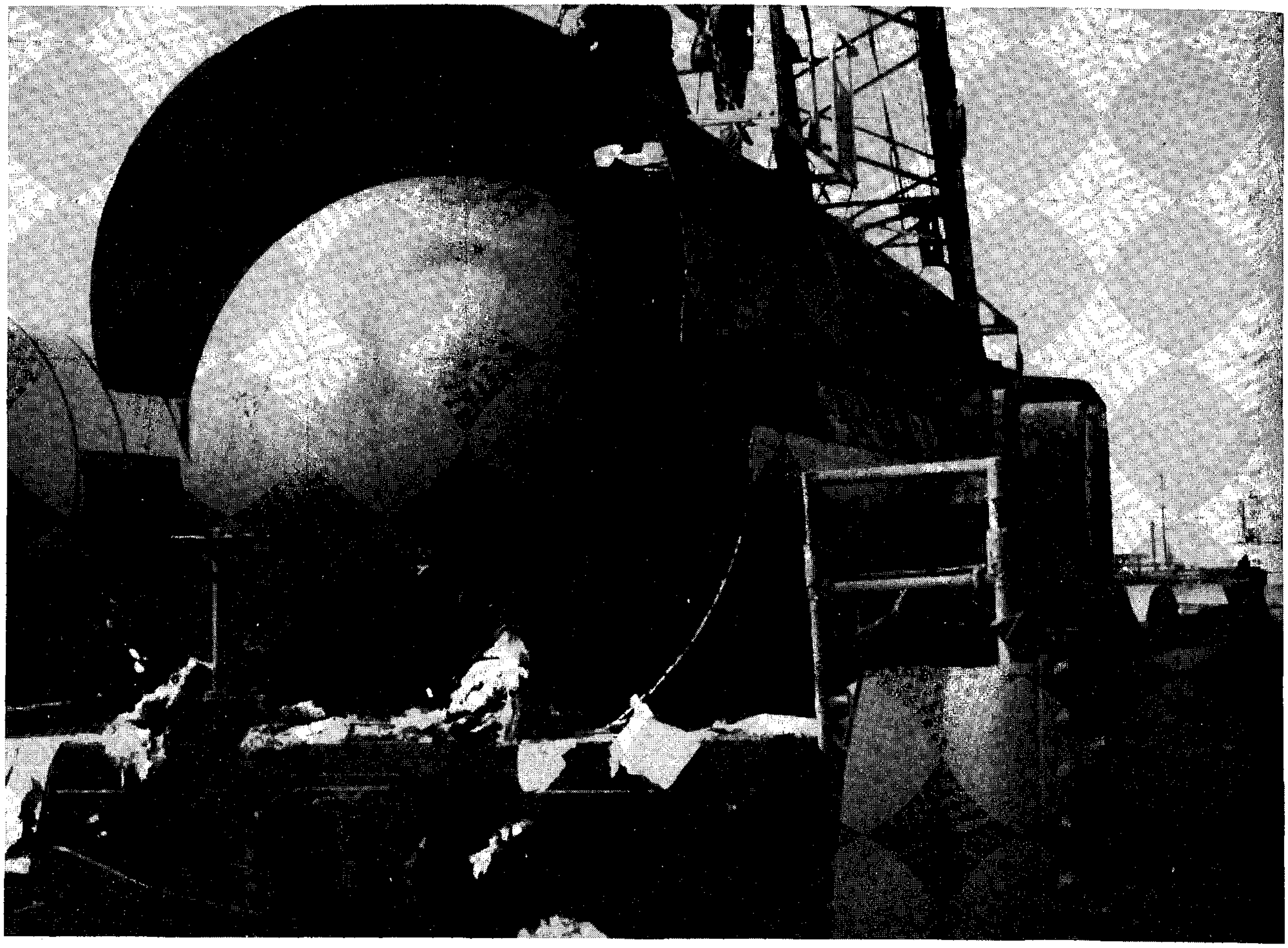


Figure 8. Disassembly and inspection of DUPX 16005.

A sample of glass wool removed from the area near the bottom outlet of DUPX 16004 contained 13.3 percent PRM, sand, a trace of chloride, and 0.24 percent methylene chloride solubles identified as a mixture of hydrocarbon oil, diethyl phthalate, and caprolactam.

DUPX 16005 was inspected and was in sound condition with respect to the insulation, tank, safety valve, and fittings. At 150-psig hydrostatic pressure, a pinhole leak was discovered in the external coil near the center of the car. Small grinding marks were found in the tank. A hydrostatic test of the tank indicated that a gasket on the sight glass leaked at 60 psig.

Liquid and crystal samples were drawn from the inside of DUPX 16005. An analysis indicated the liquid had a pH of 6.3; the liquid was 80 percent

PRM and 20 percent water. Minute traces of solids were removed by filtration. Crystals from the foot valve inside the car were 96.6 percent PRM, 5.1 percent water, and 0.23 percent sand and clay.

Samples from the bottom outlet showed the liquid had a pH of 8.4; it was 74.0 percent PRM, 26.1 percent water, and 1.25 percent sand, clay, rust, and phthalate ester. The crystal samples contained 98.1 percent PRM, 1.80 percent water, and 0.58 percent sand, clay, and rust. They contained traces of silicone oil, hydrocarbon oil, and phthalate ester.

The glass wool near the bottom outlet contained 13.3 percent PRM, a trace of chloride, sand, and 0.24 percent methylene chloride solubles identified as mixtures of hydrocarbon oil, diethyl phthalate, and caprolactam.

Switching Test--In an effort to determine the sequence of events before, during, and after the explosion, Burlington Northern assembled equipment similar to tank car DUPX 16009 and adjacent cars that were on track 12 at the time of the accident. (See Appendix B.) Cars of similar design and load were substituted for cars that were destroyed. The tank car which was substituted for DUPX 16009 was instrumented so that the impact forces, displacement, pressures, and velocities in the car could be determined. The tank car was placed directly over the main crater area. The surviving members of the switch crew involved in the accident were asked to repeat the switch they made on the morning of the accident. Selected data were recorded during nine impact tests.

On the first two runs, when the crew was asked to approximate the move, the five cars switched onto track 12 did not couple with the cars already on that track. During runs 3 through 7, the crew increased the release speeds. On runs 4 through 7, the release speeds ranged from 7.0 mph to 10.5 mph, and consequent impact speeds ranged from 3.3 mph to 9.3 mph. The cars coupled from test 4 to test 10. Coupling dynamometers measured 408.0 to 542.0 kilopounds.

During runs 4 through 7, test tank car DUPX 16007 and the remaining cars in Track 12 moved when they were struck by the cars released by the switch crew. After test 4, brakes were applied on the cars. For tests 4 through 7, the pressure readings inside the tanks ranged from -29 psig to +89 psig. 3/ (See Appendix B.)

3/ Transducer failed during impact on test 7; values reported are maximum before failure.

ANALYSIS

Reconstruction of Accident Events

The events constituting the explosion sequence probably began as the rolling 5-car cut struck the standing cut of cars on track 12. None of the evidence indicates the PRM was reacting before then. This suggests that something occurred during the switching impact to trigger the first reaction of the PRM.

Once triggered, the PRM reaction grew in size rapidly, to the extent that flame and a tall, narrow column of smoke were observed by several distant witnesses. The duration of this visible fire before the detonation is estimated to have been 15 to 20 seconds, based on the approximate times required for the witnesses to take the actions described in their statements. This estimate corresponds roughly with the estimated time between the initial switching impact and the assumed detonation for run 4 of the switching tests, after adjusting the times to compensate for the movement of DUPX 16009 at least 70 feet westward along track 12 after impact. Thus, the initial PRM reaction must have been triggered and escalated almost immediately during the switching impact dynamics into a large fire visible outside the car. The escalation rate must have slowed down for 15 to 20 seconds, while observed burning intensified gradually. Then the lading detonated, as evidenced by the crater, the "blued" fragments, and the nature of the damages in the rail yard and the surrounding community.

The investigation identified several ways that the switching impact might have triggered the initial PRM reaction. Three of these ways are described in the Safety Board's Letter of Recommendation of April 24, 1975, to the Federal Railroad Administrator. (See Appendix C.) Additional ways included mechanical impact of dry or wet crystals or liquid solution, and frictional stresses.

The reaction of dry or wet crystals or liquid solution has been triggered by shock or impact under certain test condition. As the PRM cooled en route, wet crystals probably were present inside the tank and wherever leaking or spilled PRM were present. Dry crystals, reactive enough to be classed as "explosive," could have been present wherever PRM was exposed to the warm, dry, ambient air, just before the accident. The distortions of the car tank and components during the switching tests suggest that switching shock or impacts might have been sufficient to trigger any contaminated PRM solids with reduced decomposition temperatures, and not immersed in liquid. For example, initiation by compression of crystals under the oak insulation spacer block is suggested by tests on the PRM and the condition of DUPX 16005. The impact of the swinging coil cap against dried crystals on the bottom outlet assembly is another possible initiation source.

Initiation of a reaction by frictional stressing in the presence of a gritty substance was demonstrated in tests. Movement at the anchor assembly was noted during switching tests, and the presence of both grit and PRM in the anchor area of DUPX 16005 suggest this initiation mechanism. However, the recovered anchor fragments do not show evidence of such motion on DUPX 16009.

For the initial reaction to grow in size and become visible so quickly, without detonating immediately, certain conditions had to be present. There had to be a delicate relationship among the large amount and condition of the PRM available to react, the dispersion of the heat and gases generated, and the location of these reaction products on the car before the column of smoke could have been produced so quickly. No evidence of burning or crystalline PRM or residues was observed on track 12, east of the crater. Yet the PRM must have been burning vigorously as the car moved over at least the last 20 to 30 feet of track, east of the crater. This suggests that the vigorous deflagration probably was not occurring at the bottom of the tank car.

Deflagration in the insulation space, between the inner tank and outer jacket, might have resulted in the observed smoke and fire. If triggered in this space, the quantity of PRM present would have to have been greater than the quantity found in the dismantled cars, and the time for the heat of the external reaction to penetrate the large tank and trigger the lading seems to have been too short. However, had it occurred at the spacer block near the manway, where a leak caused during the earlier abuse of the car probably would have gone undetected, communication of a reaction into the lading appears possible. The residues on the exterior surface of the manway ring suggest that this mechanism cannot be ruled out.

If the inner tank head was punctured by a coupler override, initiation of the PRM reaction at this breach is considered possible by DuPont. PRM escaping through a small breach could have fed the observed burning without affecting the condition of track 12. While none of the recovered tank head frgments indicated exposure to such burning, not much of the tank head was recovered.

A reaction started inside the inner tank, during successively increasing pressure peaks (See Figure 1, Appendix B.) through the cavitation or adiabatic compression mechanism, might have progressed to detonation as observed. The vapor space above the liquid could have provided room for the internal pressure to increase without detonation, if the gases generated had breached the tank or fittings above the vapor space at relatively low pressure. Such a breach might account for the first of the two explosions reported by some witnesses. Continuing deflagration at that location could have produced enough heat and pressure to trigger the detonation. The appearance of the manway ring debris suggests this possibility cannot be ruled out.

The reaction might also have begun in the halo coil system or in the eduction pipe. The coil system had a reported leak which was not corrected, and the system appeared to have experienced an internal pressure rupture during the accident. The recovered remains of the eduction pipe were damaged at the bottom in a manner that could suggest an internal low-order explosion.

The comparative likelihood of the above possibilities could not be evaluated for several reasons. Any damages to the tank car, produced during the 15- to 20-second interval preceding the detonation, were obscured or obliterated during the detonation. Limitations in the state-of-the-art in interpreting the significance of debris characteristics, residue formation, 4/ and failure modes during detonations of PRM prevent determination of the chronological sequence of events suggested by the debris recovered. Therefore, the reconstruction of the explosion in this accident is incomplete and inconclusive.

Safety Problems Disclosed by the Investigation

The Safety Board's investigation disclosed several ways the accident could have occurred. Each of these possibilities could have been identified before the accident by the methodical application of knowledge existing in the explosive field. Several factors contributed to the existence of these circumstances. They suggest that the processes for assuring safety in transportation of hazardous materials in bulk by rail require reconsideration. The Safety Board identified inadequacies in (1) hazardous materials classification requirements, (2) special permit evaluation practices, (3) shipment quality controls, and (4) assuring compliance with safety requirements.

Hazardous Materials Classification Requirements

When a new product is introduced into commerce, the shipper must determine whether its transportation is subject to safety regulations. This determination is governed by the definitions of the various categories of hazardous materials, contained in 49 CFR 173. These definitions establish the "classes" of hazardous materials. For each class, packaging, marking, billing, and handling requirements are established for shipments under that classification. Thus, the classification selected for a new product largely determines the safety controls established for its transportation.

DuPont was aware that PRM and PRM solutions could detonate; it concluded that some safety precautions were necessary, both in its plants

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4/ Recording of such data, particularly residues formed during the testing of detonable materials, would aid future accident investigations.

and during transportation. PRM is an ingredient of an explosive, and when so used it is intended to function by explosion. Thus, it would appear to meet the general definition of an "explosive" in 49 CFR 173.50. But the PRM solution did not meet the criteria of the tests which further defined liquid explosives. The solution did not detonate under conditions described in 49 CFR 173.50-114, and flash point determinations for flammable liquids under 49 CFR 173.115 were not applicable for this water solution of PRM. Since DuPont believed that PRM required regulation, and since it had to be classified before it could be transported, the "flammable solid" classification was selected. The DOT took no exception to this classification.

Some PRM turns into crystalline form as it cools during transportation. Any spilled or leaking PRM would also form crystals as it cools. When crystals are exposed to hot, dry ambient air in transit, they can become dry. Under 49 CFR 173, these dry crystals fall within the definition of a "Class A Explosive." Thus, some of the "flammable solid" PRM solution can be transformed into a "Class A Explosive" during transportation. Either the dissolved or crystalline form of PRM might have decomposed or detonated in this accident.

This problem in classifying PRM shows that current classification methods are inadequate. Classification tests do not reflect every known way the quantity and form of material being transported may be exploded. Consequently, current classification tests cannot be relied upon to identify all the hazards which must be controlled.

Special Permit Evaluation Practices

The transportation of flammable solids in bulk in tank cars was generally not permitted under the regulations in 1969. Therefore, when the PRM solution was classified as a flammable solid, the shipper had to petition the Department of Transportation for a special permit before it could move the PRM in tank cars. In the handling of this petition, the shipper, the Bureau of Explosives, the Office of Hazardous Materials, and the Federal Railroad Administration scrutinized the petition before movements were authorized by Special Permit 5737. Despite this scrutiny, safeguards were not prescribed against the possible hazards which were identified during the course of this accident investigation.

One of the reasons they were not prescribed is that no system for identifying new hazards or evaluating known or suspected hazards involving detonable materials was required or used in the safety evaluations. The manager who decided to transport the PRM described the extensive safety analyses performed and the documentation done to assure safety in the manufacture of the PRM, but he acknowledged that a comparable safety evaluation program did not exist for the transportation of PRM.

The Bureau of Explosives, to whom the carriers look to represent them in these matters, indicated that safety-analysis techniques are not used to evaluate safety proposals for the use of tank cars. The Federal Railroad Administration, which authorized the tank car movements, does not require or employ methodical safety analysis to identify safety problems during the processing of special permits. The carriers lack the facilities to perform such analyses. Without a structured safety analysis, undiscovered hazards are likely to exist.

This is the concern which prompted the Safety Board's earlier Letter of Recommendation. (See Appendix C.) The approach described in the Federal Railroad Administrator's reply to the recommendation is lengthy and may not identify these hazards.

Sections 107 and 109 of the Hazardous Materials Transportation Act of 1974 address this problem by requiring a safety analysis to justify exemptions to the regulations, and by requiring the Secretary of Transportation to maintain risk evaluation capability. Thus, these problems should be resolved when the Department of Transportation implements the provisions of the legislation.

Control of Shipment Quality

The shipment deviated from the specifications contained in Special Permit No. 5737 in several ways. The PRM solution in DUPX 16009 was stronger than that authorized; this meant that the specific gravity and the freezing point were higher than what was authorized. The presence of iron in the solution, confirmed by residues on the tank debris, may have made the solution more sensitive. The effects of the higher pH of this solution on the tank car, the contaminants, or other car components are unknown. Such deviations from the specifications must have some effect on the sensitivity of the shipment to chemical reactions. Whether these effects are favorable or unfavorable, particularly under stresses encountered in transportation, is unknown. For example, the higher freezing point could have resulted in the presence of solid PRM residues in areas where the solution leaked or was spilled on the car before its arrival at Wenatchee. These deviations from the specifications reflect a possible problem in quality control. Quality deviations were observed by the Safety Board in an earlier hazardous materials accident. 5/

The quality of hazardous materials offered for rail transportation is under the sole control of the party preparing the shipment for transportation. Individual railroads do not have the capability to evaluate the quality of hazardous materials transported by them on a routine basis. The Federal Railroad Administration's inspectors and

5/ National Transportation Safety Board, "Railroad Accident Report--Southern Pacific Transportation Company Freight Trains, 2nd BSM 22 Munitions Explosion, Benson, Arizona, May 24, 1973."

Bureau of Explosives' inspectors visit some shipper facilities, but the number of inspectors, the number of inspections, and the analytical capabilities of these organizations are limited. Consequently, the shipper must take responsibility for quality control.

A few classification descriptions in the regulations of 49 CFR 173 distinguish between concentrations or strengths of certain materials, but they do not consider adequately the quality of the materials. Contaminants from container sources such as prior loadings, leakage, and corrosion products are not covered adequately. If hazardous materials shipments capable of exploding are transported, the control of product quality warrants more stringent treatment under the regulations. It is virtually impossible, because of the destruction in an explosion, to establish by direct evidence whether product quality was causal in accidents. Quality assurance for shipments of detonable materials is needed. The regulation should specify what allowable deviations from intended quality of the materials is acceptable and require procedures to assure that the specifications are achieved. Development of such regulations will require study to determine the most practical method of establishing quality specification ranges and quality control procedures. The Benson, Arizona, and Wenatchee, Washington, accidents suggest that the problem of quality control requires prompt regulatory action.

Compliance with Safety Requirements

The PRM found within the insulation jacket and in the bottom outlet leg suggests another safety problem. The existence in these locations of a material which can react or detonate increases the likelihood of an accidental explosion of the shipments. 49 CFR 171.31(b) (1) requires that "after loading, tanks with bottom outlet valves which permit more than a dropping of the liquid with the outlet caps off...must not be offered for transportation until proper repairs have been made." The dangers involved in permitting the shipment of detonable material in tank cars with small valve leaks apparently were not considered in the type of car selected for PRM and in the special permit process. Since these hazards were not analyzed in the special permit, it made compliance with 49 CFR 171.31(b) (1) difficult both for the shipper and for carrier. They had to make their own interpretations as to when a leaking tank car needed repairs. The degree of leakage which can be tolerated is difficult to convey to operating personnel of the shipper and the carrier. The problem of leakage is further obscured when the caps are in place during loading or in transit, because internal valve leakage is confined in the chamber above the caps.

DUPX 16009 was a private tank car operated by the shipper and moved through the railroad system by the carriers. The responsibility for the quality of the tank when it is offered for shipment is assigned to the shipper by 49 CFR 173.31. In practice, the capability for assuring the quality of such tanks may be very limited, because of heavy personnel workloads, quality of inspection, and the full operational history of tank cars.

In this accident, problems with PRM's classification, with the special permit, with quality control, and with assuring compliance with Federal regulations were observed.

These problems indicate a need for a review of the process by which transportation safety requirements are established and enforced.

CONCLUSIONS

1. PRM was known before its introduction into railroad transportation to be detonable under certain conditions when stimulated by heat, shock, or friction.

2. The PRM solution was classified as a "flammable solid" under the Department of Transportation regulations, although it behaved like a detonating explosive in this accident.

3. In view of classification of PRM as a flammable solid, the shipment did not receive adequate treatment as a material which, in that quantity and form, could explode in transportation. Quantity and form should be considered in the classification process.

4. PRM crystals probably were present in the insulation and bottom outlet leg of DUPX 16009 before the accident.

5. The PRM solution in DUPX 16009 was contaminated with iron in solution accumulated in the car during one or more earlier unloading cycles.

6. The quality of the PRM in DUPX 16009 was not the same as the quality of PRM used by DOT to determine the hazardous material classification and transportation safety requirements or the material in the finished product. This was because of the absence of effective quality control procedures governing the shipper's manufacturing and loading processes.

7. The Federal inspectors and carrier personnel are not likely to detect deviations from the quality of the PRM specified in Special Permit 5737 under existing surveillance practices.

8. Any damages to the tank or components of DUPX 16009 during a train accident which occurred on an earlier trip remained undetected

because the shipper did not know about the accident, because of the nature of the car and lading, and because of the loading and surveillance practices.

9. The explosion of the PRM was triggered during the routine switching impact between the 5-car cut and the standing cut of cars, in a manner that could not be established.

10. Because most of the evidence was destroyed in the explosion, it was impossible to determine the relationship between the escaped PRM, the contaminants, the quality deviations, and the explosion. Nevertheless, these problems require regulatory action.

11. The methods of evaluation which led to the issuance of Special Permit 5737 did not expose safety problems which required safeguards.

PROBABLE CAUSE

The National Transportation Safety Board was unable to determine the probable cause of the accident. A partial list of the possibilities that could not be ruled out completely includes a reaction of dried drystals, a reaction of spilled or leaking crystals in the insulation space, a reaction in one of the tank components, cavitation and recompression of the solution, compression of an air bubble entrained in the solution, a reaction of solution or crystals sensitized by contamination, or the ignition of escaped product by friction. The Safety Board concludes that the classification of monomethylamine nitrate as a "flammable solid" permitted shipment of the chemical without proper safeguards against predictable hazardous conditions.

RECOMMENDATIONS

As a result of the investigation of this accident, the National Transportation Safety Board submitted five recommendations to the Department of Transportation. (See Appendixes C and D.)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

February 2, 1976

APPENDIX A

HAZARDOUS MATERIALS REGULATIONS BOARD
DEPARTMENT OF TRANSPORTATION
2100 2ND STREET, S. W.
WASHINGTON, D. C. 20590

PRIORITY

8/8/74

X

J. R. GROTHE

118-62075

MR. DON BOYD
COMMERCE COUNSEL
E. I. DU PONT DE NEMOURS & CO., INC.
WILMINGTON, DELAWARE 19898

PENDING THE RESULTS OF INVESTIGATION OF RECENT WENATCHEE, WASHINGTON INCIDENT. DOT SPECIAL PERMIT 5737 IS HEREBY SUSPENDED. DURING THIS SUSPENSION NO SHIPMENTS ARE TO BE MADE UNDER THE PERMIT.

/s/ for D. W. Morrison
W. R. Fiste
For the Administrator
Federal Highway Administration

8-8-74
(Date)

/s/ for R. H. Wright
Mac E. Rogers
For the Administrator
Federal Railroad Administration

8 Aug 1974
(Date)

APPENDIX A

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS REGULATIONS BOARD
WASHINGTON, D.C. 20590

SPECIAL PERMIT NO. 5737
FOURTH REVISION
(REINSTATEMENT)

Pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the September 7, 1972 petition by E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.

Special Permit No. 5737 is hereby reinstated and amended by adding paragraph (8a) and changing paragraph (11) to read as follows:

> "8a. Any incident involving loss of contents of the package must be reported to this Board as soon as practicable.
>
> "11. This permit expires September 15, 1974."

All other terms of this permit, as revised, remain unchanged. The complete permit currently in effect consists of the original issue and the First and Fourth Revisions.

Issued at Washington, D.C.:

W. R. Fiste
For the Administrator
Federal Highway Administration

9-22-72
(DATE)

Mac E. Rogers
For the Administrator
Federal Railroad Administration

OCT 2 1972
(DATE)

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U. S. Department of Transportation, Washington, D.C. 20590. Attention: Special Permits.

Dist: a, d, e

APPENDIX A

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS REGULATIONS BOARD
WASHINGTON, D C 20590

SPECIAL PERMIT NO. 5737
THIRD REVISION

Pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the July 29, 1970, petition by E. I. Du Pont De Nemours & Company, Wilmington, Delaware:

Special Permit No. 5737 is hereby amended by extending the expiration date to September 15, 1972.

All other terms of the permit as revised remain unchanged. The complete permit currently in effect consists of the original issue, and the First and Third Revisions.

Issued at Washington, D.C.:

for W. R. Fiste — 26 August 1970 (DATE)
For the Administrator
Federal Highway Administration

Mac E. Rogers — AUG 28 1970 (DATE)
For the Administrator
Federal Railroad Administration

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U.S. Department of Transportation, Washington, D.C. 20590. Attention: Special Permits.

Dist: a, d, e

APPENDIX A

SECOND REVISED SPECIAL PERMIT NO. 5737

Pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the July 24, 1969, petition of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

Special Permit No. 5737 is hereby amended by extending the expiration date to September 15, 1970.

All other terms of the permit as revised remain unchanged. The complete permit currently in effect consists of the original issue, and the First and Second Revisions.

Issued at Washington, D. C.

/s/ for D. W. Morrison — 12 Sept 1969 (Date)
W. R. Fiste
For the Administrator
Federal Highway Administration

/s/ for ______ — 9-10-69 (Date)
Mac E. Rogers
For the Administrator
Federal Railroad Administration

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U. S. Department of Transportation, Washington, D.C. 20590, Attn: Special Permits

Dist: a, d, e, j

Mr. F. J. Lynch, Staff Assistant
Commerce Counsel's Office
E. I. Du Pont De Nemours & Co., Inc.
Wilmington, Delaware 19898

APPENDIX A

REVISED SPECIAL PERMIT NO. 5737

Pursuant to 49 CFR 170.15 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of the June 2, 1969 petition by E. I. du Pont de Nemours and Company, Wilmington, Delaware.

Special Permit No. 5737 is hereby amended by adding DOT Specification 111A100W6 tank car tanks as one of the authorized tank cars under paragraph (1).

All other terms of the permit remain unchanged. The complete permit currently in effect consists of the original issue and this revision.

Issued at Washington, D. C.:

/S/ D. W. Morrison — 8 July, 1969
W. R. Fiste — (Date)
For the Administrator
Federal Highway Administration

/S/ — 7/1/69
Mac E. Rogers — (Date)
For the Administrator
Federal Railroad Administration

Address all inquiries to Secretary, Hazardous Materials Regulations Board, U.S. Department of Transportation, Washington, D. C. 20590. Attention: Special Permits.

Dist: a,d,e,j

Mr. F. J. Lynch, Staff Assistant
Commerce Counsel's Office
E. I. du Pont de Nemours & Company
Wilmington, Delaware 19898

APPENDIX A

DEPARTMENT OF TRANSPORTATION
HAZARDOUS MATERIALS REGULATIONS BOARD
WASHINGTON, D C 20590

SPECIAL PERMIT NO. 5737

This special permit is issued pursuant to 49 CFR 170.13 of the Department of Transportation (DOT) Hazardous Materials Regulations, as amended, and on the basis of your petition of July 8, 1968, as amended August 26 and 28, 1968.

1. E. I. DU PONT DE NEMOURS & COMPANY, INCORPORATED, Wilmington, Delaware, is hereby authorized to ship a materail, classed as a flammable solid, further identified as an 85% to 86% aqueous solution containing PR-M crystals, in DOT Specification 103AL-W and 103-W tank cars, and MC-306, MC-307, and MC-312 cargo tanks. Tanks may be insulated and must be lined unless:

   a. The material of the tank is substantially immune to attack by this product; or,

   b. The material of the tank is thick enough to withstand at least 10 years normal service without being reduced internally below the specification thickness requirements; or;

   c. The chemical reaction between the material of the tank and this product is such as to allow the tank to be properly passivated or neutralized and the tank is not frequently cleaned and not used in the transportation of other commodities.

In addition, cargo tanks approved under BA Number 611 as described in the Bureau of Explosives' document dated August 5, 1966 are authorized for use in the private transportation of this product. This permit is issued only to allow the use of containers not presently authorized under §173.154.

2. Tank pressurization for unloading of tanks is not authorized. Unloading of tanks must be performed by E. I. Du Pont De Nemours & Company, Incorporated personnel.

3. Each shipping paper issued in connection with shipments made under this permit must bear the notation "DOT SPECIAL PERMIT NO. 5737" in connection with the commodity description thereon.

APPENDIX A

Continuation of SP 5737

4. Each railcar and motor vehicle shall bear the appropriate marking or placard in accordance with 49 CFR 177.823 or 174.541, as applicable. In addition, each motor vehicle shall be plainly marked on the right side near the front of the cargo carrying body, in letters at least two inches high on a contrasting background, "DOT SP 5737". In addition, each tank car shall be marked "DOT SP 5737", near the other prescribed markings.

5. A copy of the permit shall be carried aboard the motor vehicle when transporting this product.

6. Cargo tanks shall be reinspected and retested in accordance with the Department of Transportation Regulations as prescribed for the subject DOT Specification cargo tanks. Compliance with 49 CFR 177.824(c)(4) is hereby waived.

7. Shipments are authorized only by motor vehicle and rail freight. Trailer-on-flat-car service is not authorized.

8. The shipper must furnish a record of experience to this Board if any extension or amendment to the permit is requested. This report must include the approximate number of shipments made, and the number of shipments involved in any loss of product. The modes of transportation used must also be shown.

9. This permit does not constitute operating authority such as is required in order to lawfully perform for-hire transportation nor shall it be construed as support for an application seeking such authority.

10. The permit does not relieve the shipper from compliance with any requirement of the DOT regulations, except as specifically provided for herein.

11. This permit shall expire September 15, 1969.

Issued at Washington, D.C., this 3rd day of September 1968.

W. R. Fiste
For the Administrator
Federal Highway Administration

Mac E. Rogers
For the Administrator
Federal Railroad Administration

APPENDIX A

Continuation of SP 5737

Address all inquiries to: Secretary, Hazardous Materials Regulations Board, U. S. Department of Transportation, Washington, D.C. 20590. Attention: Special Permits.

cc:
Bureau of Explosives, AAR
Federal Highway Administration
Federal Railroad Administration

cc: D. Patterson, Jr.
L. D. Petchel

APPENDIX B

December 12, 1974

TO: R. B. BROWN
ESD - LOUVIERS

FROM: B. M. CIOSEK
ESD - ETC

TRANSPORTATION & DISTRIBUTION - WENATCHEE WASHINGTON
END-USE TESTING
TESTING - RAILROAD TANK CAR, DUPX16007

Nine railroad impact test runs were conducted September 27 at Wenatchee, Washington, in the Burlington Northern Railroad Yard. A tank car, DUPX16007, was instrumented to determine impact forces, displacements, pressures, and velocities occurring in car during test coupling operations. Instrument installation and recording equipment arrangement was inspected and approved by L. L. Olson, Manager of Research Projects, AAR. Twenty-five channels of data were recorded for each impact. This memorandum will cover instruments, the instrument setup, and data gathered.

DESCRIPTION

Impact velocity, coupler forces, tank fluid pressures, car displacements, and strains were recorded for each impact by two Midwestern light beam oscillographs. Transducers mounted on the car were connected to the recorder and associated electronics by 200 ft cable. All amplifiers, transducer excitation devices, and recorders were located in a trailer at track side.

All transducers used were physically and electrically calibrated at the Engineering Test Center before leaving for Wenatchee. Each transducer was calibrated using amplifier, connector cables, and recorder channel that was to be used during impact tests. At Wenatchee, each transducer was checked for proper operation before installation on test car. After the impact tests, transducers were again checked for calibration and operation. This work was also inspected and monitored by L. L. Olson, AAR.

Table I has a listing of all transducers including make, model, location, and description of each measurement. Exhibits 1 through 5 show typical transducer locations and test car.

RESULTS OF THE NINE IMPACT RUNS

The first three runs were unsuccessful. The impacting cars rolled to a stop before making a couple with the test car group. Runs 4 through 9 were successful impacts, and the data were recorded during each.

APPENDIX B

December 12, 1974
R. B. Brown

The accelerometer data were not reported due to the poor oscillograph record. During the impact, a large noise signal appears to have been induced on the accelerometer signals, making the data record unreadable.

Transducer L1 was functioning when the unit was installed on the test car, but the post-test calibration indicated the transducer was not operating. The data record shows no displacement during any of the test runs, and it will have to be assumed the transducer did not function during any of the test runs. Transducer L2 appears to have malfunctioned during the seventh run, and the data for runs seven, eight, and nine will not be reported. The data are tabulated in Tables IIA to IIE.

DISCUSSION

Immediately after the impacts were completed, all the pressure transducers were electrically recalibrated. Upon return from Wenatchee, they were checked for normal operation. Three of the transducers were normal, and P1 had failed. The oscillograph record indicates P1 failed during the seventh test run and did not function during the final two runs.

The failed transducer was returned to the factory for repair and their assessment as to the cause of the failure. The Statham Company reported "the transducer failure appears to have been due to an overpressure or mechanical vibration."

During the data reduction, the pressure transducer data appeared to be questionable. The two 0-100 psia transducers, P1 and P2, and the P3 0-1000 psia transducer had an unusual oscillograph record. The output record of the transducers showed pressure spikes and troughs. Figure 1 is a tracing of a typical oscillograph record for transducers P1 and P2. The average frequency of the spikes of transducers P1 and P2 varies between 110 to 160 Hz. Transducer P3 had no regular frequency. The P4 transducer did not exhibit any indication of pressure during any impact runs.

Transducer P1 had positive pressure spikes and negative pressure troughs. The P2 transducer had negative pressure spikes and positive pressure troughs. The negative pressure spikes were lower than absolute zero. Since pressures below absolute zero are impossible, an attempt was made to determine if the P2 battery excitation voltage polarity was reversed accidentally during the test setup. We were unable to make the determination of battery polarity, and the data were reported as recorded.

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A series of tests were conducted at the Engineering Test Center to determine if the spikes could have been initiated by shock or vibration. An electromagnetic shaker was used to vibrate the P2 transducer between 1 and 7000 Hz. The transducer was vibrated parallel and perpendicular to the measuring axis. The transducer did not show any measurable sensitivity to vibration.

A series of shocks were then given to the transducer parallel and perpendicular to the measuring axis. The transducer showed some minor sensitivity, but the oscillograph record did not appear similar to the spikes and troughs on the test record.

Additional testing would be needed to determine the cause of the spikes and troughs.

BMC/dmm
Attach.

TABLE I

WENATCHEE IMPACT TESTS
SEPTEMBER 27, 1974
TRANSDUCERS AND LOCATION

Du Pont Transducer Designation	Location On DUPX16007	Transducer	Measuring
P1	Tank Head-Center "B" End	Statham #PA 731-TC, 0-100 psia	Pressure of liquid
A1	Tank Head-Center "B" End	Columbia Accelerometer, #302-6	Acceleration of exterior tank head
S1	Tank Head-Center "B" End	Micro-Measurements, #EA-06-250BG-120	Strain in tank head
P3	Tank Head-Top "B" End[1]	Statham #PA 822-1M, 0-1000 psi	Pressure of liquid
L3	Tank Head-Top "B" End	Hewlett-Packard LVDT, #24 DCDT-1000, ± 1 in.	Relative motion between tank head and jacket
P2	Tank Head-Center "A" End	Statham #PA 731-TC, 0-100 psia	Pressure of liquid
A2	Tank Head-Center "A" End	Columbia Accelerometer, #302-6	Acceleration of exterior tank head
S6	Tank Head-Center "A" End	Micro-Measurements, #EA-06-250BG-120	Strain in tank head
P4	Tank Head-Top "A" End[1]	Statham #PA 822-1M, 0-1000 psia	Pressure of liquid
L4	Tank Top, Center at Eduction Valve	Hewlett-Packard, 24 DCDT-3000, ± 3 in.	Vertical tank diameter through eduction pipe
B4	Bottom Outlet Valve	Bently-Nevada Proximity Probe, #302-EL-36	Vertical motion of valve plug measured relative to valve seat
S2	Turn Buckle "B" End Westside[2]	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain in web of turn buckle
S8	Turn Buckle "B" End Eastside	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain in web of turn buckle
S5	Turn Buckle "A" End Westside	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain in web of turn buckle

Notes: [1]14 in. down from knuckle

[2]Car orientation, "B" end facing south, "A" end facing north, the river lies east of yard

WENATCHEE IMPACT TESTS
SEPTEMBER 27, 1974
TRANSDUCERS AND LOCATION
(CONT'D)

Du Pont Transducer Designation	Location On DUPX16007	Transducer	Measuring
S7	Turn Buckle "A" End Eastside	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain in web of turn buckle
B1	Tank Bolster "B" End, Westside	Bentley-Nevada Proximity Probe, #308-EL-36	Relative radial motion between tank and bolster top cradle plate, ± .05 in.
B2	Tank Bolster "A" End, Eastside	Bentley-Nevada Proximity Probe, #308-EL-36	Relative radial motion between tank and bolster top cradle plate, ± .05 in.
L1	Tank Bolster "B" End, Westside	Hewlett-Packard, LVDT, 24 DCDT-100, ± .1 in.	Relative longitudinal motion between tank and bolster to cradle plate
L2	Tank Bolster "A" End Eastside	Hewlett-Packard, LVDT, 24 DCDT-250, ± .25 in.	Relative longitudinal motion between tank and bolster to cradle plate
S3	Center Sill-Bottom Surfaces, "B" End	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain on sill between tank anchor and truck
S4	Center Sill-Bottom Surfaces, "B" End	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain on sill between tank anchor and truck
B3	Tank Anchor, Center of Car	Bentley-Nevada Proximity Probe, #308-EL-36	Relative motion longitudinally between tank anchor connection angle and tank jacket
S9	Coupling Dynometer "B" End	General American Transportation Co., E-60	Coupling force
S10	At Base of Dip Tube	Strain Gage, Micro-Measurements, #EA-06-250BG-120	Strain on Dip Tube

BMC:dmm

APPENDIX B

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IIA
RESULTS

Impact Velocity and Coupler Forces

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
V	Velocity at impact timing switches	mph	6.9	6.2	3.1	9.0	-	-
	Radar velocity at impact[1]	mph	7.1	6.5	3.3	9.3	5.1	3.5
	Radar release velocity[1]	mph	8.8	8.5	7.0	10.5	4.5	3.9
S9	Coupling Dynometer	klb	408.0	284.0	120.0	542.0	222.0	133.0
	Time to peak force	sec	0.8	0.5 & 0.8	0.7	0.7	0.5	0.3 & 0.5
	Impact duration	sec	1.2	1.4	2.0	1.3	1.7	1.8

[1] Data furnished by Burlington Northern Railroad

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IIB
RESULTS

Tank Pressures

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
P1	0-100 psia	psig	+78 -16	+66 -12	+ 9 - 5	+89 (1) -11	Trans- ducer	Trans- ducer
	Time to peak pressure	sec	.52	.58	.74	.49	failed	failed
	Average frequency of peaks	Hz	130	115	130	130		
P2	0-100 psia	psig	+ 9 -29	+ 9 -24	+ 4 - 3	+10 -14	+ 6 - 8	+ 4 - 4
	Time to peak pressure	sec	.55	.52	.74	.42	.25	.38
	Average frequency of peaks	Hz	115	125	160	110	130	130
P3	0-1000 psia	psig	+68 -130 (3)	+58 - 8	N.D.P. (2)	+84 -12	+16 - 4	+ 6 - 4
	Time to peak pressure	sec	.59	.50		.56	.29	.35
	Average frequency of peaks	Hz	Irreg.	Irreg.		Irreg.	Irreg.	Irreg.
P4	0-1000 psia	psig	N.D.P.	N.D.P.	N.D.P.	N.D.P.	N.D.P.	N.D.P.

(1) Transducer failed during this impact; values reported are maximum before failure

(2) No detectable pressure

(3) May be an electrical spike

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IIC
RESULTS

Tank Bolster, Radial and Horizontal Displacement

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
B1	Radial displacement "B" end	In.	-.018	-.017	-.011	-.017 (2) +.008	-.013	-.010
L1	Longitudinal displacement "B" end	In.	---------------Transducer Malfunction---------------					
B2	Radial displacement "A" end	In.	+.005	-.001	+.001	-.003 +.004	-.001	-.001
L2	Longitudinal displacement "A" end	In.	N.D.D.	N.D.D.	N.D.D.	(3)	Data quest.	Data quest.

(1) N.D.D. - no detectable displacement

(2) Extreme vibration may be caused by transducer mounting

(3) Data questionable, transducer damage probably occurred during this impact

(4) Minus data - the relative distance between the two measuring points was decreasing

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IID
RESULTS

Tank Head, Top, and Anchor - Bottom Outlet Valve Displacements

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
L3	LVDT - tank head	In.	Vibra. ±.022	Vibra. +.019 -.022	+.066 Vibra. +.004	Vibra. ±.015	Vibra. ±.019	Vibra. ±.004
L4	LVDT - vertical tank diameter	In.	-.09	-.070	-.03	-.16	-.04	-.03
B3	Proximity probe tank anchor	In.	+.017	-.005 +.009	+.003	-.007 +.026	±.004	+.005
B4	Proximity probe bottom outlet valve	In.	-.004	-.002	0	-.004	0	0

Minus data - the relative distance between the two measuring points was decreasing

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IIE
RESULTS

Turn Buckles

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
S2	Strain gage	μ in/in	71	61	25	+50 -114	+14 -50	29
S7	Strain gage	μ in/in	38	19	Noisey, Data Unread-able	+62 -19	+23 -15	±15
S5	Strain gage	μ in/in	38	12	96	+85 -81	19	2
S8	Strain gage	μ in/in	41	31	21	+54 -90	+13 -36	+11 -15

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

SEPTEMBER 27, 1974 - WENATCHEE IMPACTS (DUPX 16007)
TABLE IIF
RESULTS

Tank Heads, Base of Dip Tube, Center Sill Bottom

Du Pont Designation	Transducer	Units	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
S1	Strain gage Tank head	μ in/in	Unread-able	N.D.S.	N.D.S.	+57 -76	N.D.S.	N.D.S.
S6	Strain gage Tank head	μ in/in	100	N.D.S.	N.D.S.	+60 -69	N.D.S.	N.D.S.
S3	Strain gage Sill	μ in/in	455	318	182	636	273	191
S4	Strain gage Sill	μ in/in	514	342	152	648	248	190
S10	Strain gage Dip tube	μ in/in	N.D.S.	N.D.S.	N.D.S.	35	N.D.S.	N.D.S.

N.D.S. - no detectable strain

DATA REPORTED ARE PEAK VALUES UNLESS OTHERWISE NOTED

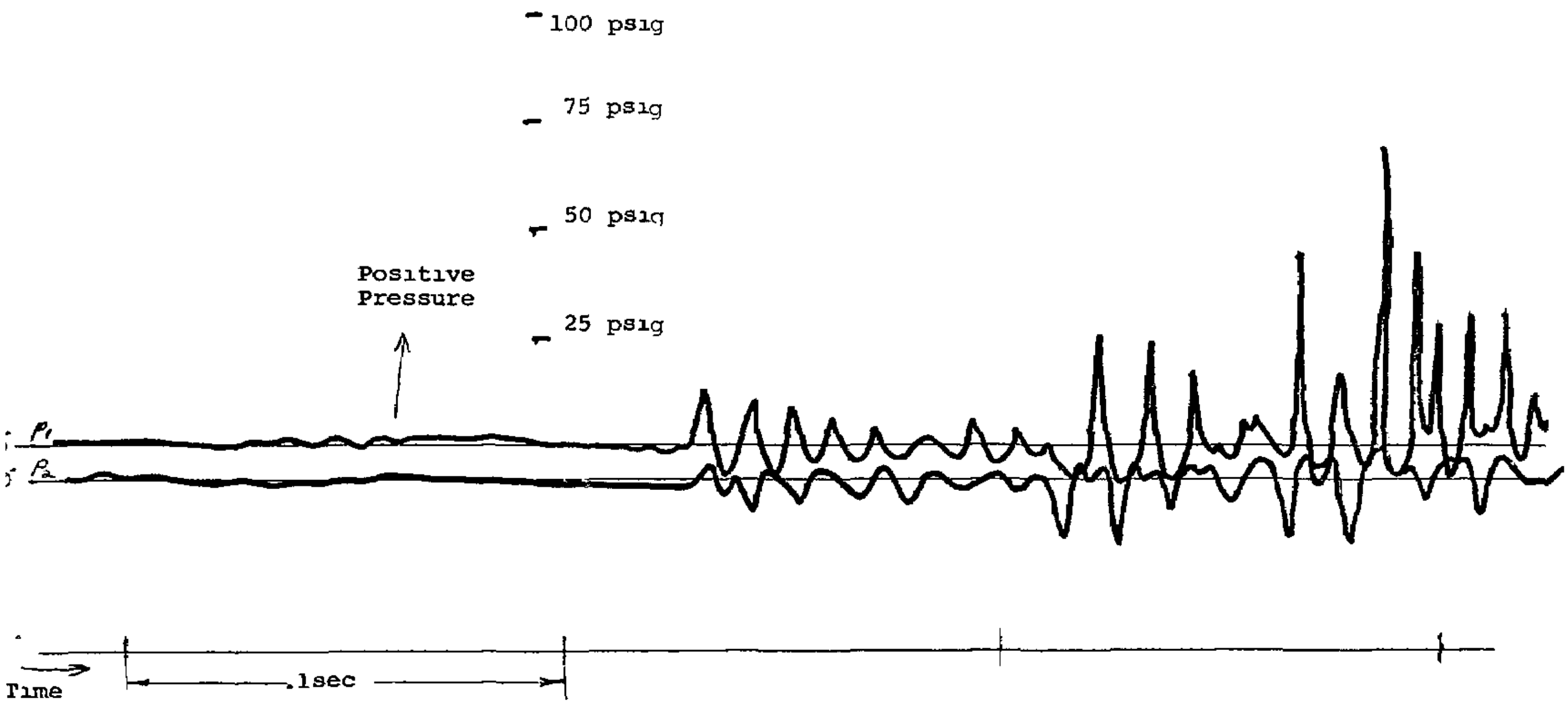
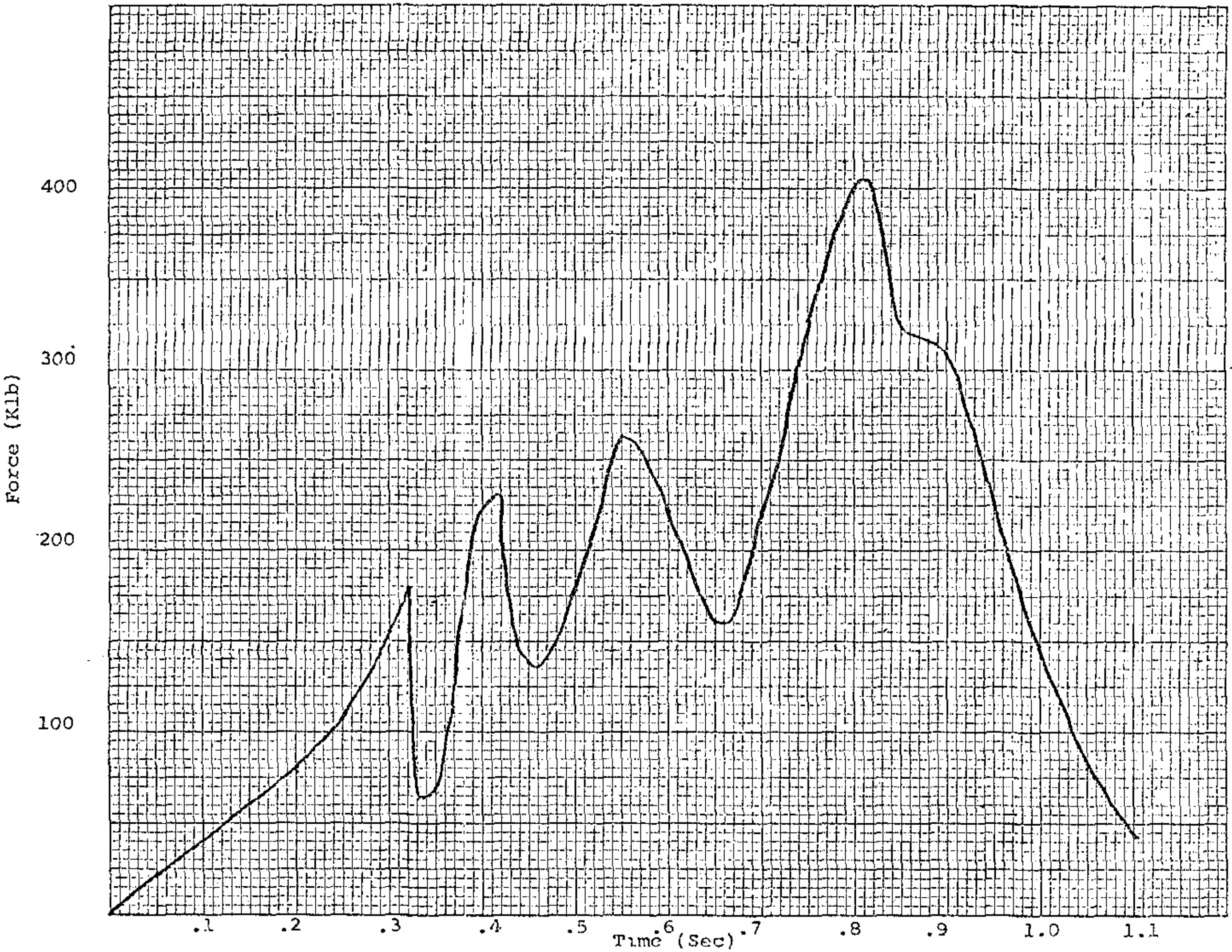


Figure 1

Tracing of Oscillograph Record

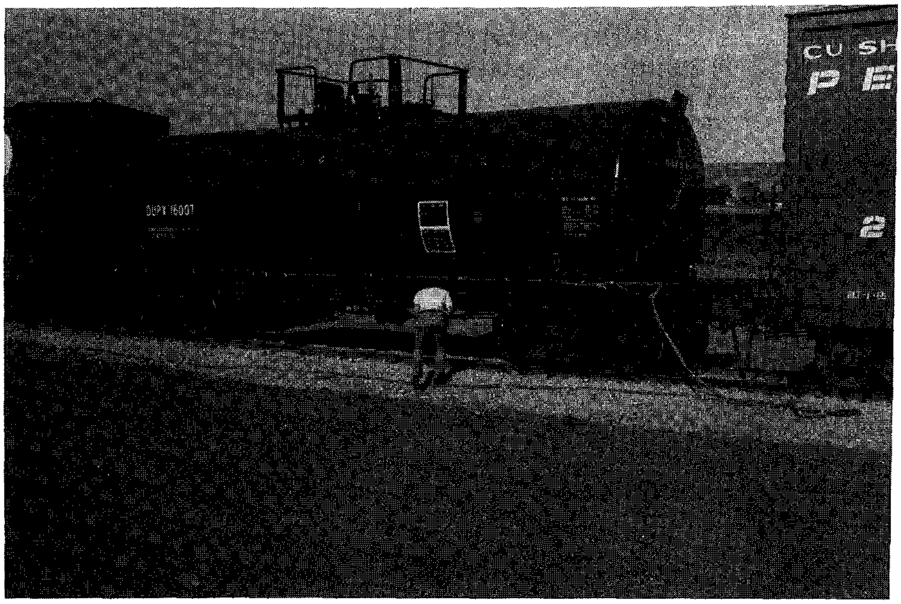
Wenatchee Impacts
Coupler Forces
Run 4

Reenactment September 27, 1974 DUPX 16007 and other cars. Speed of 5 striking cars approx. 7 MPH.

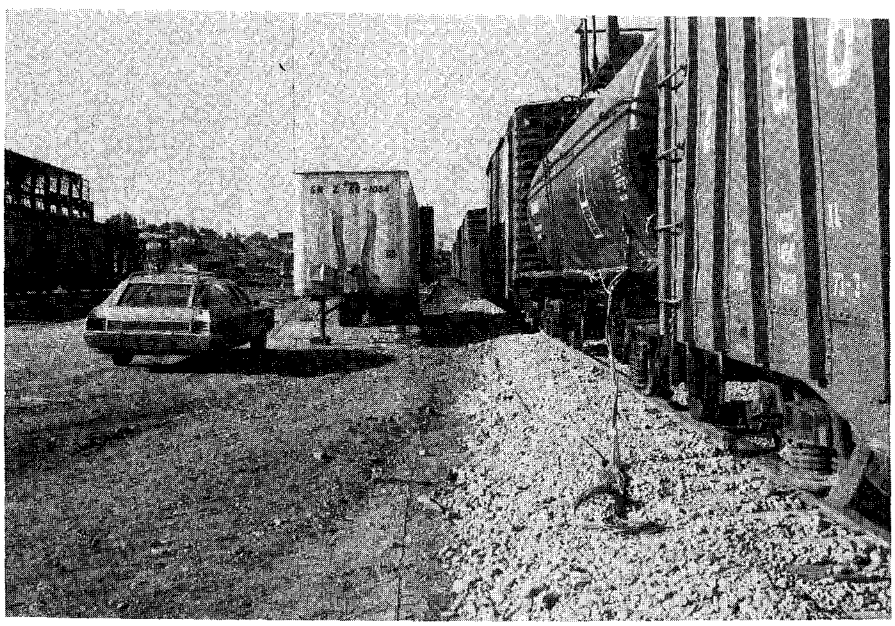


APPENDIX B

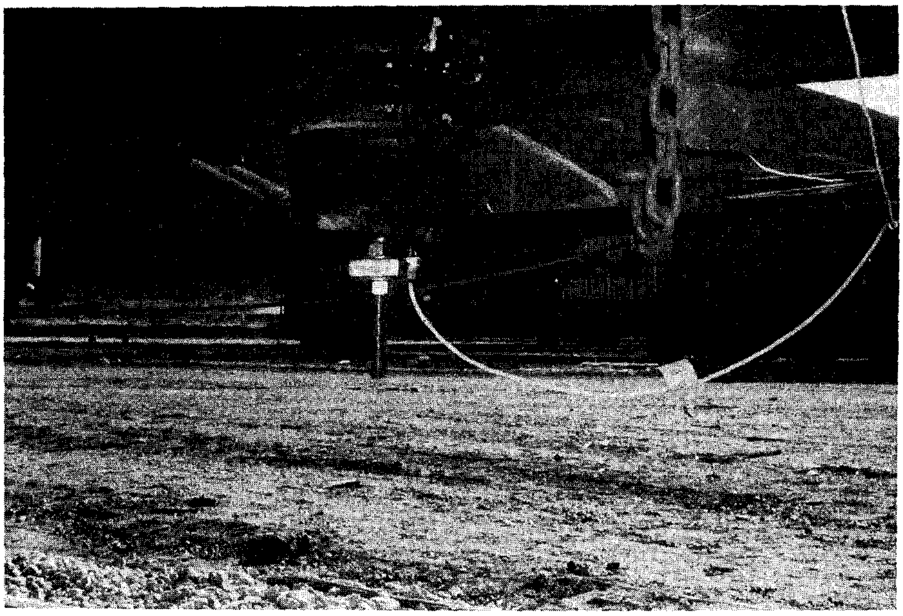
APPENDIX B



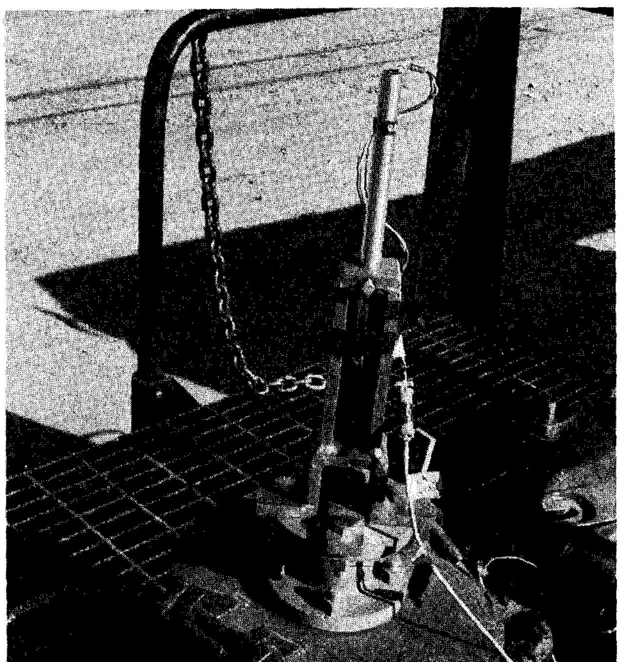
Test Car



Position of Instrument Trailer, and Test Car
Exhibit 1



Bottom Outlet Valve (B4)



Vertical Tank Diameter (L4)
Exhibit 2

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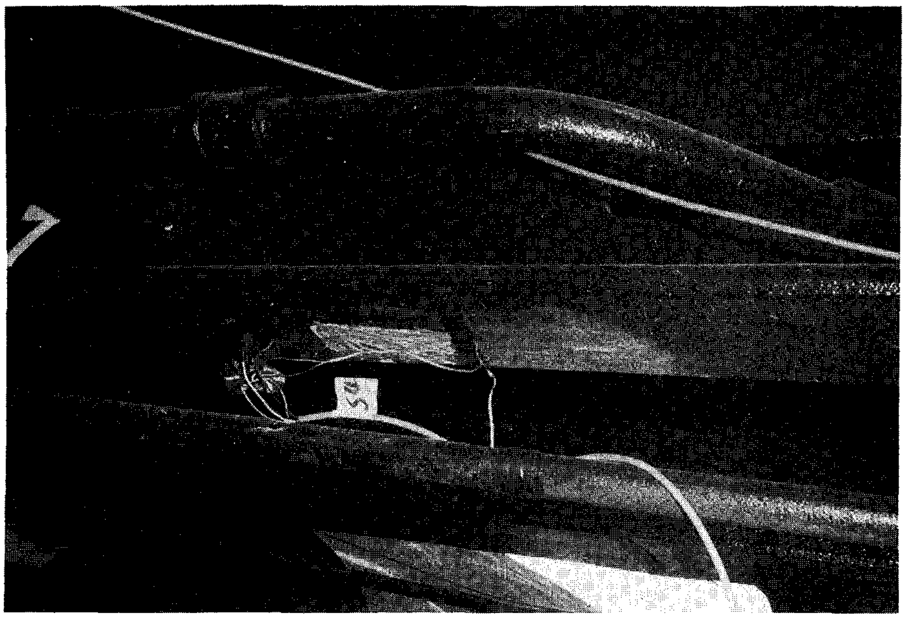
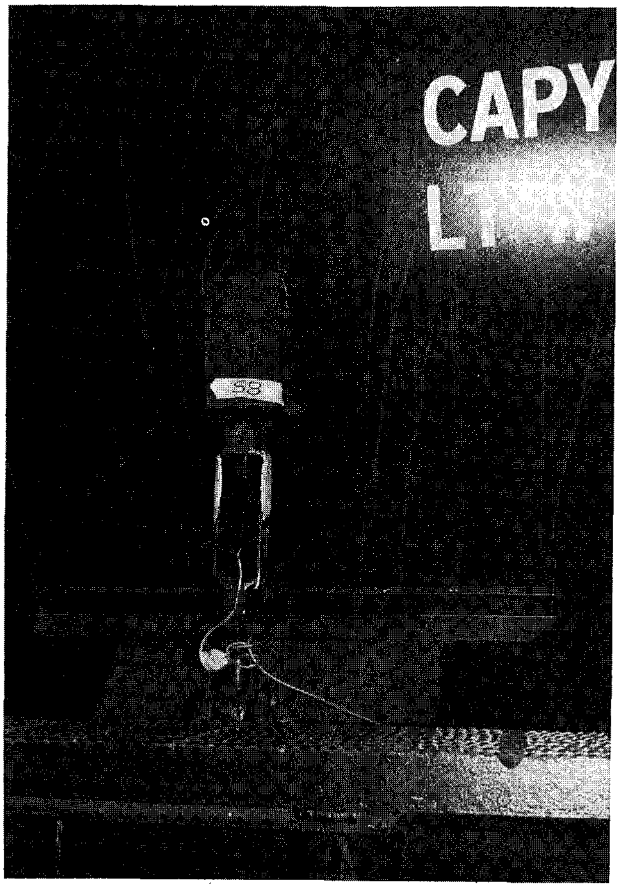
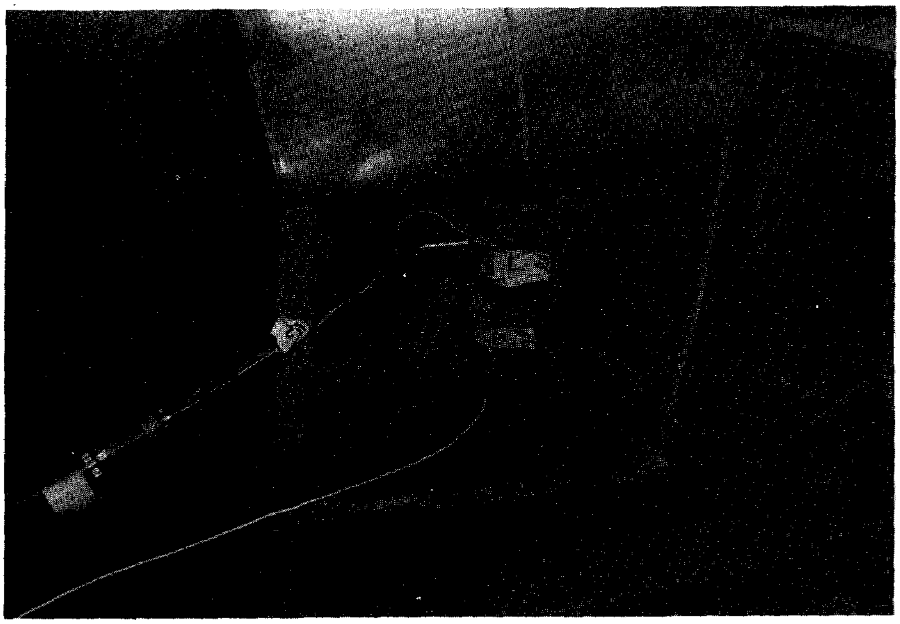


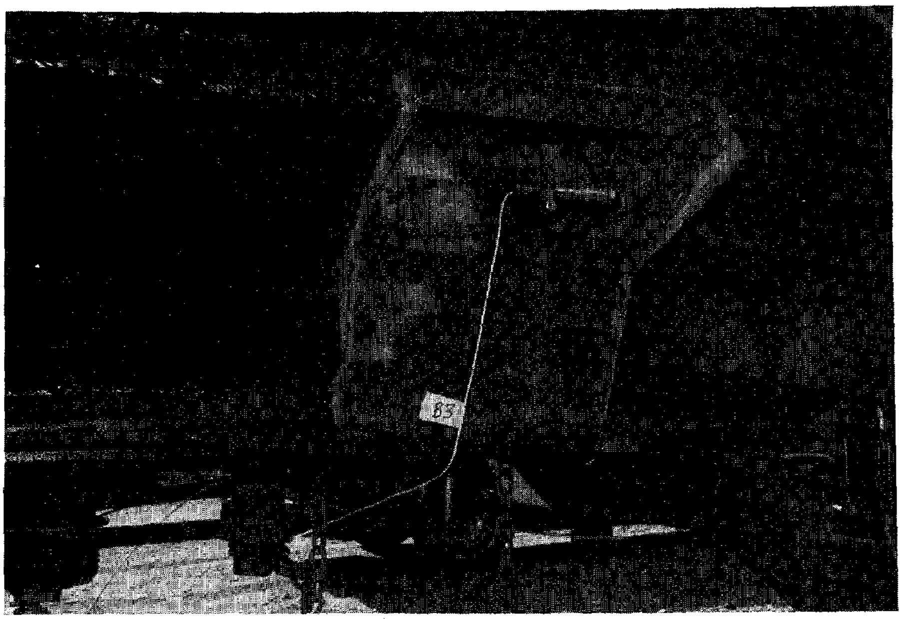
Center Sill Bottom Surface (S4)



Tank Hold-Down Turn Buckle (S8)
Exhibit 3



Tank Bolster (L2, B2)



Tank Anchor, Center (B3)
Exhibit 4

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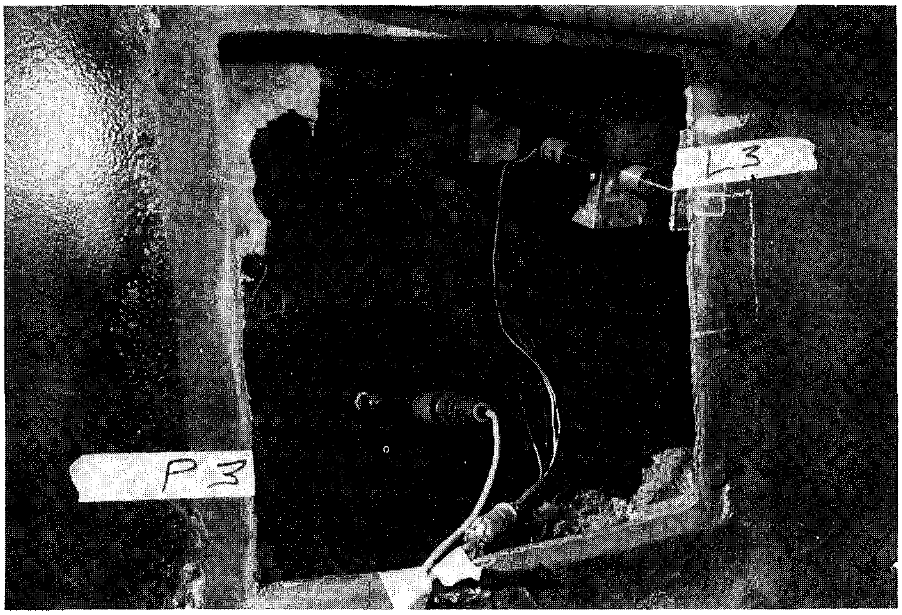
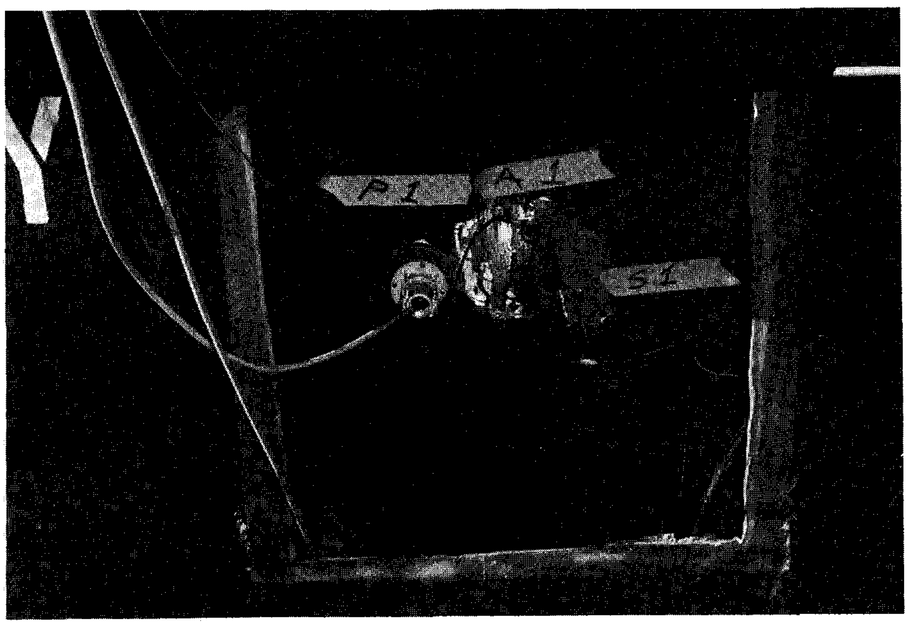


Tank Head, Upper (P3, L3)



Tank Head, Center (A1, P1, S1)
Exhibit 5

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX C

ISSUED: April 24, 1975

Forwarded to:

Honorable Asaph H. Hall
Acting Administrator
Federal Railroad Administration
Washington, D.C. 20590

SAFETY RECOMMENDATION(S)

R-75-16

The National Transportation Safety Board is investigating the explosion of a tank carload of monomethylamine nitrate solution at Wenatchee, Washington, on August 6, 1974. Preliminary evidence indicates that dangerous chemical reactions and explosions are possible when certain materials, capable of detonation, are being transported in tank cars. The Safety Board believes that prompt action is necessary.

The shipper of the monomethylamine nitrate solution (also called PRM), a large chemical manufacturer, reported that a "low-order" or "burning-type" reaction could be initiated in three ways:

"(1) a coupler override which penetrates the tank of PRM,

(2) cavitation followed by recompression within the PRM solution,

(3) compression of an air bubble entrained in the liquid or entrapped in the air space at the top of the tank."

After the reaction begins, it could escalate and the entire lading detonate.

The explosion at Wenatchee, is the third major explosion in which a bulk tank car shipment of a liquid, capable of detonation but not classified or handled as an explosive, did explode. The others, which involved nitromethane, occurred at Buffalo, New York, and Pulaski, Illinois, in 1958.

APPENDIX C

Although the Safety Board has not determined the cause of the Wenatchee explosion, findings concerning the dynamic behavior of liquids in tank cars and the properties of the landing, indicate that an explosion involving this type of shipment could originate in any one of at least three ways. Testimony at the Safety Board's public hearing into the Wenatchee explosion indicated that none of the three explosion-initiating mechanisms described by the shipper had been specifically analyzed by the shipper, the Bureau of Explosives, the carriers, or the Federal Railroad Administration before tank car movements were started under Special Permit 5737, and that currently applicable classification procedures and related regulations do not address such mechanisms.

After the explosion at Wenatchee, tank car shipments of monomethylamine nitrate solutions were terminated when the Federal Railroad Administration suspended Special Permit 5737. After the explosion at Pulaski in 1958, tank car shipments of nitromethane were prohibited by order of the Interstate Commerce Commission; they are presently embargoed under AAR Car Service Division Embargo 7432, due to expire May 29, 1975. Neither material is specifically regulated by name in 49 CFR 170 through 179.

The three mechanisms which can originate a low-order or burning-type reaction are not particularly unusual. Coupler override and tank penetration is a distinct possibility in railroad switching and in several types of accidents. Either cavitation or the compression of air bubble is clearly possible, but operational precautions aimed at the prevention of this behavior are not required.

In view of these findings, the Safety Board is concerned that other liquids with similar dotonation characteristics might move in tank cars, and catastrophic explosions of this type could occur. The risk of such explosions need to be identified, evaluated and adequately controlled. Therefore, the National Transportation Safety Board recommends that the Federal Railroad Administration:

> Identify all liquids now transported in tank cars which are capable of detonation; determine whether detonation or other dangerous chemical reactions can be initiated by conditions and circumstances encountered by those liquids in railroad transportation and issue regulations to control the risks identified.

APPENDIX C

Personnel from our Bureau of Surface Transportation Safety are available if further information or assistance is desired.

by: John H. Reed
Chairman

APPENDIX C

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
WASHINGTON, D C 20591

OFFICE OF
THE ADMINISTRATOR

MAY 21 1975

Notation 1497

Honorable John H. Reed
Chairman
National Transportation Safety Board
800 Independence Avenue Southwest
Washington, D. C. 20591

Dear Mr. Chairman:

This letter replies to your letter of April 18, 1975, transmitting the National Transportation Safety Board's Safety Recommendation R-75-16 stating that the Federal Railroad Administration:

> Identify all liquids now transported in tank cars which are capable of detonation; determine whether detonation or other dangerous chemical reactions can be initiated by conditions and circumstances encountered by those liquids in railroad transportation and issue regulations to control the risks identified.

The Federal Railroad Administration believes that the possible problem of liquids in tanks detonating during transportation is not confined only to tank car transportation but includes transportation by portable tank and cargo tank (and may even involve drum shipments). In order to coordinate evaluation of possible reactive and unstable chemicals and avoid duplicative and redundant effort, the Federal Railroad Administration relies upon the Office of Hazardous Materials to perform initial evaluations and research into behavior that can lead to chemical instability during transportation. The Office of Hazardous Materials' generated information is then given to the Members of the Hazardous Materials

Regulations Board for their guidance in authorizing conditions of transport either by regulation or special permit. Examples of this type of activity are two completed studies:

> "The Thermal Decomposition of Thirty Commercially Available Materials at 300 C (Report No. TES-20-74-1: NOLTR 74-44)"; and

> "An Appraisal of Methods for Estimating Self-Reaction Hazards (Report No. TES-20-74-8: NBSIR 74-551).

I am enclosing a copy of each of these reports for your information.

A further study into the identification of thermal instability is being undertaken under the project title:

> "Correlations between the Thermo Dynamics and Kinetic Properties of Chemical Substances and their Thermal Instability and Hazard Potential."

A copy of the "Work Statement" covering this research is enclosed.

These research efforts are instrumental in enabling the Federal Railroad Administration, the Department and the chemical shippers to gain better understanding into the possible potential hazards of the materials being offered for transportation. As these efforts progress, greater identification of hazard and means of control can be developed by the DOT Operating Administrations.

Your recommendation mentioned that the Association of American Railroads' Car Service Division Embargo 7432 is due to expire on May 29, 1975. The Federal Railroad Administration has been assured by the Association of American Railroads' Car Service Division that this Embargo will be continued in effect until

APPENDIX C

issuance of a final rule in the Hazardous Materials Regulations Board's Docket No. HM-112. Moreover, the Interstate Commerce Commission order prohibiting the shipment of Nitromethane (Laquer Solvent) in bulk, in tank cars, was continued in effect when the statutory authority under which it was issued was transferred to the Department of Transportation. This order will remain in effect until it is superseded by issuance of a final rule in Docket HM-112.

In a Notice of Proposed Rule Making published under that Docket, a section 173.149a entitled "Nitromethane" was proposed to read as follows:

> "Nitromethane must be packaged as specified in section 173.119(b) except that shipment in cargo tanks, tank cars, and portable tanks is prohibited."

This was published in the Federal Register, Volume 39, No. 19 -- Thursday, January 24, 1974, Page 3102. Final resolution of this Notice is expected to be completed by August 1, 1975.

I share your Board's concern that the Department may not be adequately aware of all the hazards associated with the bulk transportation of liquid chemicals. I believe that the efforts of the Hazardous Materials Regulations Board spearheaded by the Office of Hazardous Materials will enable us to better regulate these chemicals when shipped in liquid form whether in bulk or in drums.

I appreciate this opportunity to respond to this National Transportation Safety Board's Safety Recommendation. Please let me know if I can be of further assistance.

Sincerely,

Asaph H. Hall

ASAPH H. HALL
Acting Administrator

APPENDIX C

Attachment #1
(12/4/74)

CORRELATIONS BETWEEN THE THERMODYNAMICS AND KINETIC PROPERTIES OF CHEMICAL SUBSTANCES AND THEIR THERMAL INSTABILITY AND HAZARD POTENTIAL

WORK STATEMENT

A. Introduction

A clear definition and a more complete identification of the property known as thermal instability for chemical substances is needed in various sectors of science, industry, commerce, and defense. In particular, the handling and transport of hazardous commodities by truck, rail, ship and plane require appropriate instructions for packaging and shipping materials as well as proper labeling and placarding so that persons who are confronted with an emergency situation can deal with the problem in the best possible manner.

This work is a continuation of the National Bureau of Standards (NBS) previous efforts, under Interagency Agreement DOT-AS-40028, in which NBS has evaluated methods for estimating self-reaction hazards and has tentatively established those parameters which best exemplify material sensitivity.

B. Evaluation of Test Methods and Test Data

A search of the literature shall be made in which hazard test methods and test data shall be examined and compiled. A preliminary examination of the literature suggests that this body of information is large, scattered, and of unknown utility with respect to the goal of providing test parameters more representative of material sensitivity than those found in the NBS recent study. NBS shall exercise good judgment as far as the extent of the literature search is concerned and shall be judiciously selective with regard to the particular tests and data chosen for compiling. In connection with the literature search and evaluation of the methods and test data, the principal investigator will enlist consultive services of the NBS Center for Fire Research. Whether new methods are required or whether existing methods are adequate to identify self-reaction hazards should result from the evaluation.

C. Predictive Schemes and Correlations

The examination of predictive schemes such as the CHETAH and CRUISE programs shall be continued to seek improvement in their ability to estimate hazard potential. The plan shall be to develop separate schemes which are associated with different reaction mechanisms such as bond breaking processes, molecular eliminations, and polymerization processes. Particular emphasis shall be placed upon identifying the rank of functional groups (nitro, nitramine, nitrate, peroxide, azide, etc.) within each scheme. Empirical rules shall be developed which will give decomposition products closest to the experimentally observed products. Likely parameters, which would be calculated, shall include but not necessarily be limited to the following: enthalpy of decomposition, bond dissociation energy, and activation energy. In conjunction with this effort, the NBS principal investigator will utilize the resources of the Chemical Thermodynamics Data Center and Chemical Kinetics Information Center so that the information employed shall be as current as possible.

The results of the evaluation study on test methods and test data, and the continued examination of the predictive schemes are to determine whether an improved correlation can be obtained between selected test data and selected thermodynamic or kinetic parameters.

D. Period of Performance and Reporting

Within eleven (11) months beginning January 1, 1975, the contractor shall provide the DOT Office of Hazardous Materials with six (6) copies of a draft final report. The contractor will furnish forty (40) copies of a finished final report within thirty (30) days after receipt from DOT/OHM of comments on the draft report. The finished report is to be in accordance with the format requirements of Order DOT-1700.18A (12-8-72).

Progress reports shall be provided on a monthly basis due into DOT/OHM by the 10th of the month following the month being reported.

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Attachment #2
(12/4/74)

COST BREAKDOWN

Project Salaries, 1.0 MY	$ 22,000	
Personnel Benefits	1,800	
Subtotal	$ 23,800	
Bureau Supervision and Services	$ 10,200	
Institute Supervision and Services	1,000	
Division Supervision and Services	7,000	
Subtotal	$ 42,000	
Other Objects:		
(a) Consultative Services with NBS Center for Fire Research	$ 6,000	
(b) Computer Processing, Document purchases, Travel, etc.	2,000	
Subtotal	$ 8,000	
Total Cost		$50,000

APPENDIX C

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
WASHINGTON, D.C. 20590

OFFICE OF
THE ADMINISTRATOR

JUL 11 1975

Honorable John H. Reed
Chairman
National Transportation Safety Board
800 Independence Avenue Southwest
Washington, D. C. 20591

Notation 1497

Dear Mr. Chairman:

In your letter of June 10, 1975, concerning the National Transportation Safety Board's Safety Recommendation R-75-16, you indicated that the research efforts described in my letter of May 21, 1975, did not indicate how the results would be applied to evaluating tank car transportation of chemicals.

One of the objectives of this research effort is to develop indicators (bench marks) of potential adverse behaviors in chemicals, particularly characteristics which could cause severe problems during transportation. The development of this information will give the Department and its Operating Administrations better ability to evaluate bulk liquid shipments including tank car shipments.

Also, specific characteristics of certain chemicals are being studied so as to develop more information on their transportation hazards both during normal and during accident conditions. As this work progresses, the results will be used in safety evaluations of Special Permit requests and in regulatory action. However, it is not possible to state when any specific part of the research effort will result in specific amendments to the regulations. Rather, it is expected that this research will improve our overall knowledge and serve as general reference to future regulatory development.

APPENDIX C

I appreciate your interest in the Department's overall chemical research activities and I will keep you informed of progress.

Sincerely,

ASAPH H. HALL
Acting Administrator

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX D

ISSUED:

Forwarded to:

Honorable William T. Coleman, Jr.
Secretary
Department of Transportation
Washington, D.C. 20590

SAFETY RECOMMENDATION(S)
I-76-1 through I-76-4

At 12:30 p.m. on August 6, 1974, a shipment of monomethylamine nitrate solution (PRM) exploded during routine switching operations in Burlington Northern's Apple Yard in Wenatchee, Washington. The PRM was being transported in tank car DUPX 16009, operated by E.I. DuPont De Nemours & Company, under DOT Special Permit 5737. Two persons died, 113 were injured, and estimated losses exceeded $7,500,000.

PRM was classified as a flammable solid under the Department of Transportation's Hazardous Materials Regulations. The permit to transport the PRM was issued by the Federal Railroad Administration.

A number of ways the accident might have happened were found during the Safety Board's investigation. These possibilities were identified by the methodical application of existing knowledge in the explosive field. Safety requirements established under Special Permit 5737 did not address these possibilities. Efforts to identify such possibilities before the accident, using methodical safety analysis techniques, were not required or used by any of the parties who participated in the evaluation of the proposed transportation before it was authorized. Thus, similar accidents resulting from undiscovered hazards during transportation of detonable materials, authorized under the same evaluation process, could occur in the future.

Cancellation of the Special Permit after the accident indicates that such accidents are considered to be unacceptable risks. Until methodical safety analysis techniques are used to examine large shipments of other materials capable of detonation, similar undetected and unacceptable risks may continue to exist. The Safety Board believes that the need for such examinations should be acted on reasonably soon. One approach to meeting this need is to make guidelines available for the examination effort and to request that those benefiting from such transportation do this work. Prevention of one such accident would more than justify this effort.

The Safety Board found that dry PRM crystals were sufficiently dangerous to require classification as an "explosives Class A, Type 3" hazardous material. During transportation, spilled or leaking solution of PRM could become dry crystals. This would change the required classification of the PRM from a "flammable solid" to an "explosive" if the PRM were exposed to certain high temperatures and low humidities.

The classification as a flammable solid probably resulted in less stringent surveillance and less adherence to precautionary requirements in loading, shipping, and transporting PRM. Testimony given during the Safety Board's public hearing into the facts and circumstances of this accident clearly indicated that current classification regulations are inadequate to prevent similar accidents.

The PRM that exploded differed from the materials on which the classification and the performance tests for quality control were made.

The strength of the solution exceeded the strength of the solution authorized under the special permit. The pH of that solution deviated significantly from the shipper's written specifications. The unloading and handling of the cars permitted the accumulation of an iron contaminant in the cars. While the effects of these deviations in the quality of the PRM could not be established in the investigation, their existence indicates the need for an examination of product quality standards and quality control procedures for transportation of detonable mate.

Therefore, the National Transportation Safety Board recommends that the Secretary of Transportation:

1. Require applicants submitting proposals for transportation of detonable materials to make an examination of the transportation conditions for detonation risks and describe what they found. (I-76-1) ; (Class II, Priority Followup)

APPENDIX D

2. Publish gudelines describing methods available for conducting safety analyses that would facilitate the discovery of detonation risks and standards to be met in preparing the proposal. (I-76-2) (Class II, Priority Followup)

3. Amend 49 CFR 173 to establish appropriate explosives classification definitions and test procedures that address every known way in which detonable materials could explode accidentally in transportation. (I-76-3) (Class II, Priority Followup)

4. Establish regulations for quality specifications and quality control procedures in the manufacture, packaging, and loading of detonable hazardous materials. (I-76-4) (Class III Longer-Term Followup)

REED, Acting Chairman, McADAMS, THAYER, BURGESS, and HALEY, Members, concurred in the above recommendations.

By: John H. Reed
Acting Chairman