AILROAD ACCIDENT REPORT

DERAILMENT OF MISSOURI PACIFIC RAILROAD COMPANY'S TRAIN 94 AT

Houston, Texas
October 19, 1971

TRANSPORTATION SAFETY BOARD

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-RAR-72-6

SS-R-16

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. NTSB-RAR-72-6	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Railroad Accident Report - Derailment of Missouri Pacific Railroad Company's Train 94 at Houston, Texas, October 19, 1971.	5. Report Date December 13, 1972 6. Performing Organization Code
7 Author(s)	8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Surface Transportation Safety Washington, D. C. 20591	10. Work Unit No. 11 Contract or Grant No.
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20591	13. Type of Report and Period Covered Railroad Accident Report October 19, 1971 14. Sponsoring Agency Code

15. Supplementary Notes

This report contains Railroad Safety Recommendations R-72-41 through R-72-45.

16. Abstract

The Missouri Pacific Railroad's freight train 94 was traveling north on track which belongs to the Atchison, Topeka and Santa Fe Railway when 20 of its cars derailed in Houston, Texas, on October 19, 1971, at 1:44 p.m. There were four diesel-electric locomotive units and 82 cars in the train.

Derailed cars included six tank cars containing vinyl chloride monomer and two cars containing other hazardous materials. Two tank cars were punctured in the derailment. The vinyl chloride monomer escaped and ignited. The Houston Fire Department attempted to control the fire. Approximately 45 minutes after the initial derailment, one tank car ruptured violently and another tank car "rocketed" approximately 300 feet from its initial resting place. This sequence of events caused the death of a fireman. Fifty people were injured and there was considerable property damage. Most of the injured were firemen.

The Safety Board determines that the probable cause of this accident was an unexplained emergency brake application which induced lateral forces exceeding the holding capacity of the track fasteners. The severity of the accident was increased by the abrupt rupture of the tank car and the lack of adequate training, information, and documented procedures for identifying and assessing the threats to public safety.

17. Key Words Railroads, Train Accidents, Derailments, Accident Investigations, Hazardous Materials Accident, Firefighting, Emergency Response, Tank Cars, Vinyl Chloride, Freight Train Braking, Trackwork, Explosives, National Fire Protection Association, Transportation Accidents, Railroad Safety.	18. Distribution Statement Released to public; Distribution unlimited.

19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No of Pages 56	22. Price

NTSB Form 1765.2 (11/70)

FOREWORD

This report by the National Transportation Safety Board is based on facts developed in a field investigation and at a public hearing The field investigation was conducted by the Safety Board in cooperation with the Federal Railroad Administration. The public hearing was conducted by the Safety Board in Houston, Texas, on November 30, December 1, 2, and 3, 1971 Representatives of the State of Texas participated in the hearing and the parties to the hearing included the:

- Atchison, Topeka and Santa Fe Railway Company
- Brotherhood of Locomotive Engineers
- City of Houston, Texas
- Congress of Railway Unions
- Dow Chemical Company
- Federal Railroad Administration
- International Association of Fire Fighters
- Missouri Pacific Railroad Company

The data and support these organizations and other witnesses contributed are acknowledged with appreciation by the Safety Board

TABLE OF CONTENTS

TABLE OF CONTENTS–(Continued)

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20591
RAILROAD ACCIDENT REPORT

ADOPTED: December 13, 1972

DERAILMENT OF MISSOURI PACIFIC RAILROAD COMPANY's TRAIN 94 AT HOUSTON, TEXAS OCTOBER 19, 1971

I SYNOPSIS

The Missouri Pacific Railroad's Train 94 was a northbound freight train consisting of four diesel-electric locomotive units and 82 cars On October 19, 1971, at 1:44 p.m., the train was traveling on track which belongs to the Atchison, Topeka and Santa Fe Railway when 20 cars derailed approximately two miles inside the city limits of Houston, Texas.

Derailed cars included six tank cars containing vinyl chloride monomer and two cars containing other hazardous materials. Two of the tank cars were punctured in the derailment The vinyl chloride monomer escaped and ignited. The Houston Fire Department attempted to control the fire. Approximately 45 minutes after the initial derailment, one tank car ruptured violently and another tank car "rocketed" approximately 300 feet from its initial resting place This sequence of events caused the death of a fireman. Fifty people were injured and there was considerable property damage Most of the injured were firemen.

The National Transportation Safety Board determines that the probable cause of this accident was an unexplained emergency brake application which induced lateral forces in the area of the 52d car as the train's slack was taken up These lateral forces exceeded the holding capability of the track fasteners and a rail overturned, which caused the following cars to jackknife Tank cars ESMX 4803 and 4804 were punctured The retardation of the empty cars which preceded the 52d car was greater than the retardation of the more heavily loaded cars which followed. This variation in retardation contributed to the development of high lateral forces

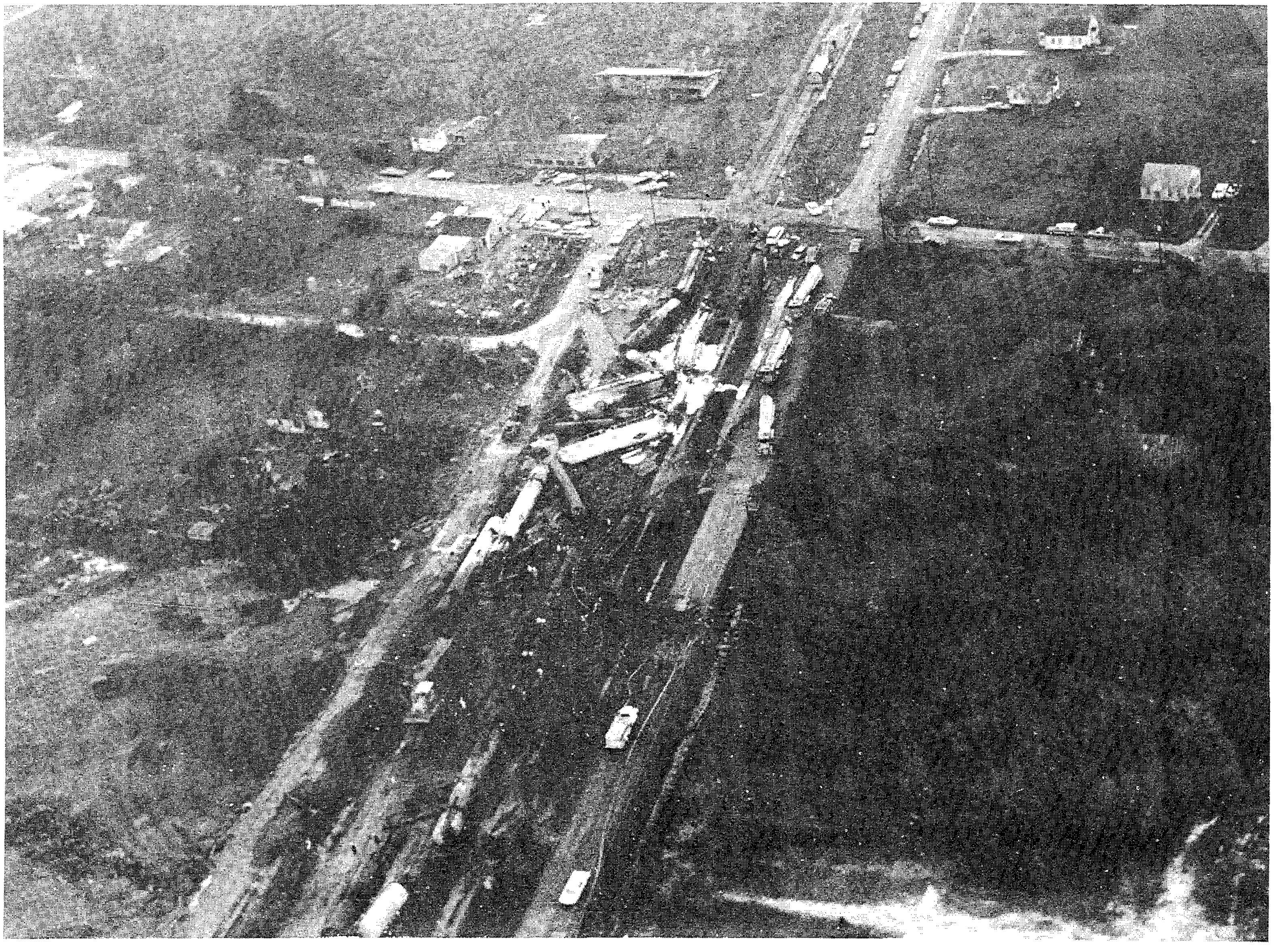
The severity of the accident was increased by the abrupt, violent rupture of the tank car which contained a pressurized, flammable gas; the lack of adequate training, information, and documented procedures for on-scene identification and assessment of the threats to public safety; and firemen's reliance on firefighting recommendations which did not take into account the full range of hazards in such situations

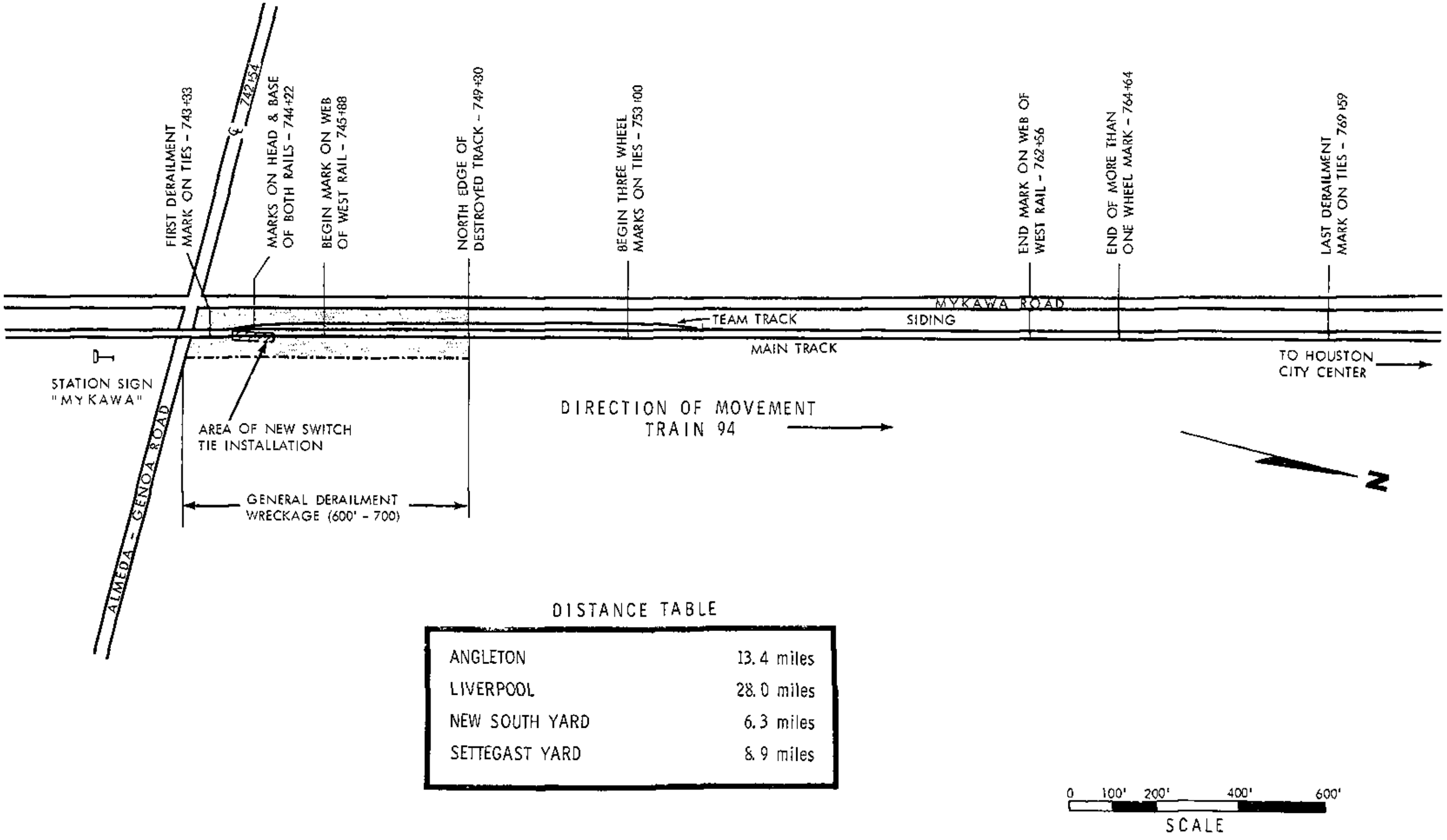
II FACTS

A. Location

The derailment of the Missouri Pacific Railroad's Train 94 occurred at Mykawa Station, which is located on the Santa Fe's connecting line between Houston and Galveston, Texas Mykawa is approximately 2 miles inside the southern city limits of Houston, and 10 miles south of the city center

The population density in this area is light Most of the buildings are adjacent to Almeda-Genoa Road, which intersects the Santa Fe's tracks just south of the accident site Figures 1 and 2 show the general arrangement of tracks, roads, and other pertinent features in the vicinity of Mykawa





DISTANCE TABLE

ANGLETON	13.4 miles
LIVERPOOL	28.0 miles
NEW SOUTH YARD	6.3 miles
SETTEGAST YARD	8.9 miles

Figure 2 - Sketch showing derailment area

B Method of Operation

1. Operating Procedures

The single main track is generally used by Missouri Pacific and Santa Fe trains. To a lesser extent, this track also is used by trains which belong to a third carrier In 1971, before the accident, these railroads ran an average of 18 trains daily on this track

Train movements through this area are directed by a Santa Fe dispatcher through a traffic control system which includes automatic block signals on the main track. Movements onto the siding are made through dual-control, power-operated switches

The Santa Fe's book of rules and timetable apply to the operation of trains belonging to the Santa Fe and the third carrier Missouri Pacific train crews are governed by the railroad's "Uniform Code of Operating Rules" and timetable, which include Santa Fe rules for train operations on the 24-mile portion of Santa Fe track between Houston and Algoa, Texas. When Missouri Pacific employees are operating trains on Santa Fe track, they are subject to efficiency tests by Santa Fe supervisors

For the purpose of this report, geographic directions will be used, and Houston will be the northern extremity of the line in any directional reference.

2. Authorized Train Speeds

The Santa Fe's timetable authorizes a maximum operating speed of 60 m.p h Freight trains which average 85 to 100 tons per car are restricted to 55 m.p.h. Those which average over 100 tons per car, or exceed a total weight of 7,000 tons, are restricted to 45 m p.h. The 55- and 45-m.p.h. speed restrictions were imposed to keep train braking distances within signal intervals.

The Missouri Pacific's timetable authorizes a maximum operating speed of 50 m.p.h except for heavy trains which fall within the Santa Fe's more restrictive 45 m p.h. speed limit The Missouri Pacific's 50-m.p h speed limit prevails for its trains throughout the Gulf District, which includes the accident area.

3. Track Use On the Day of the Accident

Appendix 1 lists the trains that operated in the area on October 19th between 6 a m. and the time of the accident.

Use of the siding by four of the trains was prompted either by conflicting train movements on the main track or by industrial switching in the area

C. Track

1. Alignment and Grade

The track alignment south of the accident site is straight for several miles. About 3,200 feet south of the Almeda-Genoa Road grade crossing, the track has a 0.1-percent upgrade north to the crossing, flattens for approximately 800 feet, and then begins a 0.16-percent downgrade which extends beyond the involved area

2. Structure

The main track consists of 119-pound continuous welded rail, laid in 1961. Rail temperatures at the time of installation were 74°F. for the east rail, and 64°F. for the west rail. There is no record of adjustment of the rails for stress relief after they were laid, but trackwork had been performed in the area.

The continuous welded rail was interrupted in the accident area to accommodate insulated joints for automatic crossing-protection devices at the Almeda-Genoa Road grade crossing. These four insulated joints were located 111 and 108 feet south of the grade crossing's centerline and 69 and 74 feet north of it. To minimize longitudinal rail movement, the rail was box-anchored on every other crosstie. One tension anchor per rail also was installed on alternate crossties between the insulated joints and for

195 feet beyond them However, for approximately 30 feet through the Almeda-Genoa Road crossing, there were no rail anchors.

The crossties were made of creosoted timber spaced 19½-inches from center to center or 3,250 crossties per track mile. The last major replacement of crossties in this area was in 1958 when 545 new crossties were installed in this particular track mile. Since 1950, approximately 1,500 new crossties had been installed About 1,750 crossties had been there over 21 years. A scheduled 1972 crosstie renewal program included 644 crossties for this particular mile The crossties were fully plated with double-shoulder tie plates. The rail was secured to the crossties by two cut spikes per tie plate Two Racor studs anchored each tie plate

The track was laid on slag ballast with a maximum particle diameter of 1-¼ inches The entire track through this area was last surfaced in 1967 and spot-surfaced in 1970

3. General Condition

Federal regulations prescribing standards for track geometry were not in effect at the time of the accident However, standards had been promulgated by the Federal Railroad Administration (FRA) for later effective dates Measurements taken after the accident on 1,426 feet of undisturbed track south of the derailment area indicated that the track geometry conformed to FRA standards for track with a speed limit of 80 m.p.h. This is 20 m.p.h. more than the prevailing speed limit

4 Trackwork

The day before the derailment, workmen had started to install a new set of 71 switch ties to accommodate a No. 10 turnout. The point of switch was 120 feet north of the centerline of the Almeda-Genoa Road crossing. The turnout was to be a right-hand, facing-point for a northward, main track movement.

There were no speed restrictions for trains passing through the construction area The work was being done without mechanized equipment. Directions to the men in charge of the work on October 18 and 19 included instructions to "keep the track safe "

The new switch ties were being installed consecutively in the track Each switch tie was fully plated with double-shoulder tie plates tamped snugly under the rail Alternate switch ties were not spiked, and rail anchors had been removed and not replaced

The construction work disturbed 99 feet of track up to the time of the accident However, it was stated that no switch ties were missing, and alternate switch ties were tamped and spiked as intended when Train 94 passed over them on October 19.

The foreman of the track crew assumed that position for the first time on the day of the accident. He had worked 1¾ years in the track department before he was promoted to foreman 5 months before the accident During the 5 months, he had worked intermittently as foreman. The foreman indicated that he had not been examined on procedures for installing switch ties, but that he had learned them by experience. When installing switch ties previously, however, he had always had a slow order for trains The directive to perform the work without a slow order on October 19 was given by a track supervisor with 5 years of track-related experience Most of the men in the track crew had 20 to 30 years of experience in track construction and maintenance.

5 Track Inspections

The last scheduled inspection of the track in this area was made by the track supervisor on the afternoon of October 18. This inspection included an on-the-ground review of work in progress, and a motorcar trip over the rest of the main track in the vicinity No exceptions were taken to the method of installing the new switch ties or to the condition of the track

Just before the accident, a representative of the Brotherhood of Maintenance of Way Employees arrived at the site He walked across the main track approximately 30 or 40 feet north of the proposed point of switch. This man had 26 years of experience in track work, including 18 years as a track foreman. He took no exceptions to the condition of the track. However, his purpose was not to inspect the track, but to confer with the crew foreman on union business. He indicated that, in his opinion, the track was safe for an operating speed of 60 m.p.h.

D. Missouri Pacific's Train 94

Train 94 operates daily between Kingsville, Texas, and Houston, with local business stops en route. Hazardous materials often comprise a major portion of the train's cargo because the area served includes large chemical plants. At Angleton, Train 94 connects with a train operating from Freeport, and there is a crew change for the 57-mile northward trip to Houston.

The crew that operated Train 94 north of Angleton on the day of the accident reported for work at Settegast Yard in Houston at midnight and operated a train southward to Angleton. The crew consisted of an engineer, a conductor, and two brakemen.

The engineer had been employed by railroads since 1947. His last examination on the rules was in 1970. The conductor assumed his position in 1959 after working 4 years as a brakeman. His last examination on the rules was in 1971. The two brakemen had been employed since 1969, and both men had been examined on the rules within the 2½-year period specified by the Missouri Pacific

The engineer also was required to qualify on the basic, functional mechanics of locomotives and on train airbrakes These are written examinations in contrast to the oral examinations on operating rules. Both the engineer and the conductor were required to be familiar with the procedures of airbrake tests prescribed by Federal regulations.

At Angleton, the crew assembled Train 94 for the journey north to Houston. The lead locomotive unit on the trip south was coupled onto three 1,200-horsepower switching units standing at the head of the 64-car Freeport connection These four locomotive units and 64 cars were backed onto another track holding the cars that had comprised Train 94 en route from Kingsville to Angleton. This connection brought the train's total consist to 82 cars and a caboose. Sixty of these cars were loaded and the total train tonnage, excluding locomotive units, was 7,148 tons. The distribution of loaded and empty cars was not a consideration in assembling the train. Appendix 2 shows the consist of Train 94 upon departure from Angleton.

The lead locomotive road unit was the carbody type, equipped with type 24RL airbrakes, a two-way radio, and a speed indicator, but it did not have a speed-recording tape The three switching units obtained in Angleton were equipped with type 26L airbrakes.

The cupola-type caboose of Train 94 was equipped with a two-way radio, which was inoperative on the day of the accident The train crew did not have portable radios

E. The Northward Train Trip

A Missouri Pacific trainmaster assisted in the assembly of Train 94 at Angleton. Train 94 departed from Angleton at 11:25 a.m. without an airbrake test that conformed to Federal regulations The only airbrake test conducted consisted of checking the release of the brakes on the standing cars after the air was cut in from the lead locomotive unit. Upon departure, the entire crew was located in the control compartment of the locomotive. The consist was reported to the Missouri Pacific's dispatcher as 63 loaded cars and 19 empty cars with a tonnage of 6,410 tons. The crew did not know that the actual tonnage of the train exceeded the 7,000-ton limitation established to control speed on the Santa Fe's tracks.

Several miles north of Angleton, Train 94 was stopped by an emergency brake application initiated by a ruptured air hose on the 69th car. The conductor, the rear brakeman, and the trainmaster, who had followed the train in his automobile, installed a new hose. The trainmaster used a two-way radio in his car to communicate with the locomotive as he directed the application and release of the airbrakes. Then he took the conductor and the rear brakeman back to the locomotive to continue the journey

Both conductor and rear brakeman were riding on the head-end of Train 94 so that a pull-by inspection could be expedited at Liverpool, 13 miles north of Angleton, as required by Missouri Pacific rules. At Liverpool, the conductor and rear brakeman got off the locomotive to observe the train as it moved past them at a speed of approximately 15 m p.h. The rear brakeman boarded the caboose and immediately applied the emergency brakes by using the air valve on the caboose. He said that he applied the brakes because "it looked like something was low" on a large, white tank car. The conductor identified the car as ESMX 4803, the 59th car in the train He instructed the brakeman to notify the dispatcher of the delay, and then he went to look for the low object observed by the brakeman He did not find anything wrong, so he signalled the engineer to proceed and both he and the brakeman boarded the caboose. The air line pressure in the caboose at that time was 69 or 70 pounds per square inch (p s i).

Fourteen miles south of Mykawa, a Santa Fe operator inspected the west side of the train. Four miles from the accident site, a Santa Fe agent observed the east side of the train while a Santa Fe switch engine crew observed the west side No deficiencies were noted at either of these locations.

Train 94 passed the south switch of the Mykawa siding at approximately 1:44 p.m The engineer was operating the locomotive and the front brakeman was seated in the control compartment on the left side of the engine. The engineer stated that the last air pressure observed before the accident was 80 p s i He also said that the throttle of the locomotive was in full power position and that their speed was 40 m p h

The conductor and rear brakeman were in the cupola of the caboose as the train approached the accident site. The train crew had been on duty 13 hours and 44 minutes when the train passed the south switch of the Mykawa siding. The conductor's plan was to tie up the train at New South Yard, which is approximately 6 miles north of Mykawa

The temperature was 83°F at the Houston Intercontinental Airport at 2 p.m., and the humidity was 70 percent A rainfall of 0 15 inches had been recorded at the airport at 11:45 a m.

F Description of the Derailment

The engineer saw the workmen on the track as the train approached Almeda-Genoa Road and he sounded the whistle to alert them The workmen separated and stepped to each side of the main track They were standing about 10 to 20 feet from the track when the train passed

As the locomotive moved north of the crossing, the engineer noticed a "slight dip" but he had observed a dip in this area on previous trips and he was not alarmed. However, he looked back over approximately 25 cars as the train passed the crossing and he observed that these cars seemed to be riding normally

The first indication of anything unusual was an automatic emergency brake application initiated from an unknown source The engineer immediately shut off the throttle and released the brakes on the locomotive, in an attempt to avoid a possible internal collision. The brakeman looked back, saw dust, then fire and smoke As the train came to a halt, the engineer radioed a request to dispatch fire trucks to the scene. The conductor and brakeman in the caboose also were aware of the emergency brake application Then they saw dust, cars derailing and turning over, smoke, an explosion, and fire. They evacuated the caboose before the train stopped and ran from the area.

The track crew and labor union representative saw Train 94 approaching when it was several miles away. As the train came closer, the foreman warned his crew to clear the track. Some of the workmen observed the passing train for defects.

No unusual conditions were noted until a noise attracted the attention of the track crew and labor union representative. They described this noise as "something banging repeatedly," "a type of rattling," "some kind of clicking noise," and "a loud, rough noise like something hanging." The noise appeared to originate from a car that these witnesses described as located anywhere from 30 to 55 cars back of the locomotive. Although several witnesses looked at the undercarriage of the car in question, no defects were observed, and the type of car was not identified.

Several seconds later they observed dust and a derailed car described as located anywhere from 50 to 250 feet north of the area where the new switch ties were installed. One witness heard the sounds of an emergency brake application after the initial derailment. None of the other track personnel recalled hearing an emergency brake application.

When the initial derailment occurred, the track crew and labor union representative moved away from the area quickly. Within seconds, cars started to jackknife. There was an explosion and a fire after a tank car was struck broadside by another derailed car.

Just before the accident occurred, at least two witnesses in automobiles were stopped on the east side of the Almeda-Genoa Road crossing. One witness stated that the first indication to him of anything unusual was a car he saw rocking rather severely. He said the car was square and that liquid splashed off the top. Two or three cars later, a tank car rocked "real severely" and derailed. He stated that the rocking occurred approximately 150 feet north of the crossing, which would have placed it in the area of the new switch ties.

The second witness stated that he heard "kind of a whistling sound," which sounded like an air exhaust. He then saw ties flying and a car leave the track.

The time of the derailment was established as 1:44 p.m.

G. Configuration of Derailed Cars

In all, 20 cars were derailed. Four of the derailed cars–the 38th, 48th, 49th, and 52d remained partially on the rails and continued moving with the front portion of the train. The train separated between the 52d and 53d cars, and the following 16 cars derailed and stopped just north of the Almeda-Genoa Road crossing. Two cars on the adjacent team track derailed when they were struck by jackknifing cars.

Figure 1 and Appendix 4 show the configuration of the wreckage after the derailment. Appendix 3 provides information on the characteristics of the derailed cars and the commodities involved.

H. Response to the Fire

1. The Fire Emergency

Tank cars ESMX 4803 and 4804 were punctured in the derailment. Vinyl chloride contained in these cars was estimated to be at a pressure of approximately 40 p.s.i. just before the derailment. This internal pressure forced about 35,000 gallons of liquefied vinyl chloride through the punctures at a rapid rate. As the escaping vinyl chloride entered the atmosphere, about 8 percent of the liquid turned to gaseous vapors. Each volume of liquid resulted in 300 volumes of gas. These vapors mixed with the surrounding air and formed a flammable mixture which reacted, or ignited, during the derailment.

The two punctured cars came to rest in the area in which vinyl chloride vapors were burning. Great quantities of heat, flame, and dense, black smoke accompanied the fire. The fire enveloped large areas of the tank cars and the heat increased the internal pressure of ESMX 4804's damaged tank. (See Figures 3 and 4.)

Numerous residents reported the fire to the Houston Fire Department at 1:45 p.m. Railroad personnel telephoned the fire department 13

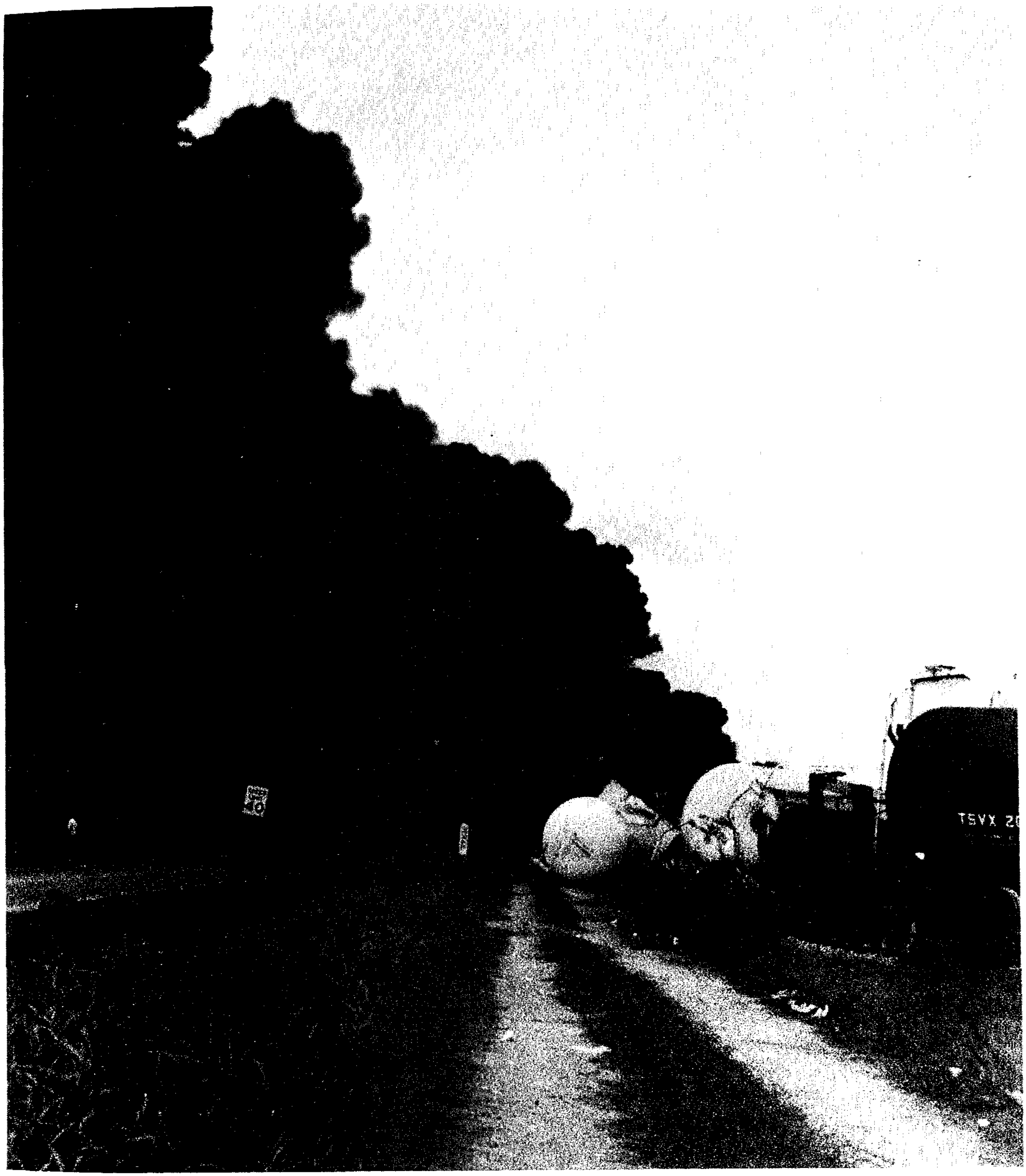


Figure 3 - View from the west side of track, south of the general wreckage prior to 2:30 p.m. on October 19, 1971. Tank car to extreme left is ESMX 4803. Car lettering and position of body bolster indicates car is inverted. Frost line indicates liquid level of contents.

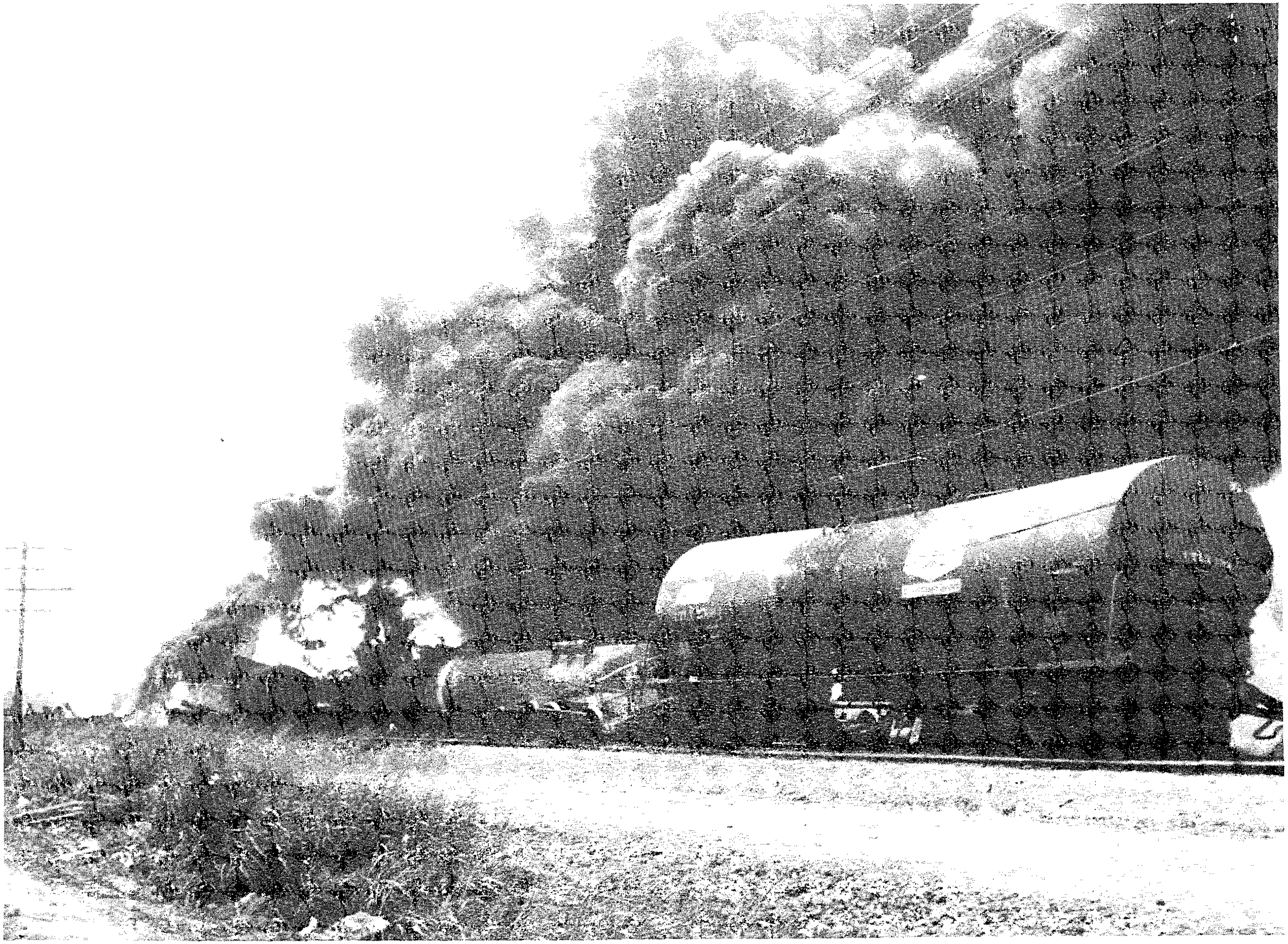


Figure 4 - View from north prior to 2:30 p.m. Tank car to right is the 54th car. Inverted position of tank cars to the left can be detected by the positions of body bolsters. Fireball is emitting from the vicinity of ESMX 4804.

minutes later They did not identify the contents of the tank cars at this time, although the fire department requested this information

2 Activities of the Fire Department

Smoke from the fire was observed from the Houston Fire Department's training academy, less than a mile away One of the first senior fire department officers on the scene was the deputy chief in charge of training. He left his office at the academy within a minute after he observed the fire and proceeded directly to the site. He approached the wreckage on the west side, and immediately went in among the jumbled, derailed tank cars He observed "dangerous" placards marked acetone on car TSVX 2010 and butadiene on GATX 38587. He also observed the vinyl chloride stencil on ESMX 4803, which had overturned, but he did not use his portable radio to transmit this information to other fire department personnel nor did he write down the car numbers or their contents.

The deputy chief was unable to view the fire directly from his vantage point in the wreckage He did not see the car ESMX 4804 at that time. He was not certain what was burning, although he knew that it was a liquefied gas under pressure. The fact that ESMX 4803, which contained vinyl chloride, had rolled over indicated to him that the pressure relief valve was "under the liquid level" He knew that the safety valve in that position could not prevent internal pressures from escalating

The acting district chief arrived on the west side of the accident site, conversed with the deputy chief, and pulled a second alarm. On the east side of the site, firemen already were laying hose lines from water available on that side. The acting district chief instructed firemen operating hand lines to cool the tank cars that were not on fire. Instructions to keep cooling the tank cars that were near the fire were given to the crew of a ladder truck Firemen assigned to this truck were operating a ladder pipe nozzle on the east side of the fire, as shown in Figure 5 They did not know what was burning and they were not sure how to extinguish the fire Meanwhile, additional hose lines were being laid to the fire from the west side of the tracks along Mykawa Road.

Some emergency rescue personnel arriving on the scene, contacted railroad personnel The identity of the burning materials was not discussed during these contacts, and there was no indication that the various people in authority made any effort to contact one another.

At about 2:15 p.m. the assistant chief of the Houston Fire Department arrived at the scene and took command. He inquired about the identity of the burning material and was advised by various firemen that it might be propane, methyl bromide, acetone, caustic acid, butadiene, or methyl chloride. The deputy chief in charge of training informed the assistant chief of the contents he had seen on the placards and car stencil. However, when asked what was burning during a television news interview, the assistant chief said he thought that it was methyl chloride or ethyl chloride The deputy chief also counseled the assistant chief to evacuate citizens in the area, and the assistant chief ordered that this be done The assistant chief's "plan of attack" was to use three hose lines, two from the east side and one from the west side, to cool the tanks in an effort to keep them from exploding and to use a light spray of water to extinguish the fire when it subsided. He testified that if he had known that vinyl chloride was burning he would have withdrawn his truck "a little further", but he noted that "we couldn't have moved much further back and gotten the water coverage that I wanted, so we probably would have acted almost the same, maybe have just given it a little more room." His plan considered the possibility that the ends of the tanks might blow off. Concern also was expressed about the danger of a safety relief valve discharging from the overturned tank However, the assistant chief expected that if the safety relief valve "popped off", it would serve as a warning that the internal pressure was increasing at an excessive rate. He expected that this warning would come in time to permit safe withdrawal.

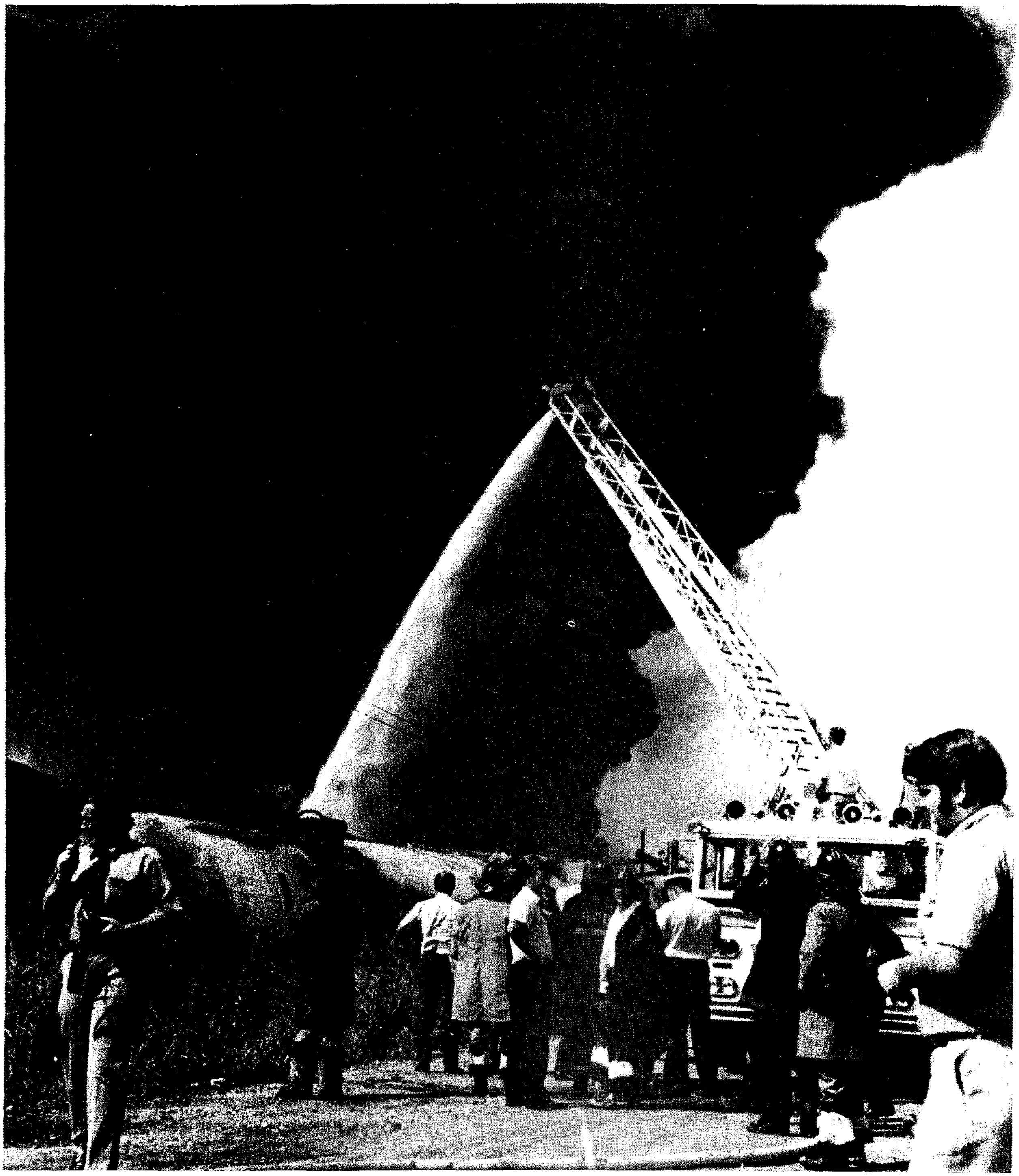


Figure 5 - View looking northwest prior to 2:30 p.m. showing fireman on ladder directing spray of water on burning tank cars.

Some of the decision factors and difficulties in developing the firefighting plan were described at the public hearing. Unknown factors included: the nature and quantity of the fuel in the tanks or escaping from them; the quantity and disposition of heat being produced; the quantity of heat being conducted to the shell of the tank; the length of time the fire had been burning; the materials burning, and consequently the required extinguishing agents; the condition of the tanks exposed to fire; and the rate of pressure buildup inside the tanks. Moreover, the tank cooling capabilities of the fire department's on-scene facilities were unclear. The firefighters were unable to identify railroad crewmen who might have furnished documentation of the contents, or known where such documentation was kept on the train. And the possibility of toxic, combustive products was also suspected.

No documentation of the choices available to the on-scene commander exists for transportation accidents involving hazardous materials, nor are the factors entering into such decisions documented. No publication deals specifically with this overall problem.

The assistant chief was asked why everyone, including fire department personnel, in the sparsely populated area was not evacuated. He replied that he did not believe that this procedure would have been thought of, or followed by any chief of any fire department. He asserted that firefighting is dangerous at the very least, and quite a few precautions were taken. He felt that his overriding responsibility was to try to save the houses in the area.

The assistant chief is very active in emergency response planning activities for the Houston area. He has been with the Houston Fire Department for 39 years, but this was his first encounter with this kind of transportation accident. The assistant chief stated that if he had had a little more time before the explosion, he would have been able to "cool the tanks."

3. Activities of Railroad Personnel

When the head end of Train 94 came to a stop, the engineer remained in his control position, and maintained radio communications with railroad personnel. He was asked if he knew what commodities were involved in the fire and wreckage, and he answered that he did not know.

The front brakeman went back to the second locomotive unit to take part in radio communications. Then he walked back to the north end of the derailment wreckage, inspecting the train and assessing damage en route. He talked with a policeman, some firemen, and some newsmen or photographers near the wreckage. He advised all of them that the derailed cars contained dangerous commodities, but he could not identify the commodities involved. He returned to the locomotive after surveying the situation.

When the rear of the train came to rest and the initial explosion and fire appeared to have stabilized, the conductor and rear brakeman regrouped on the track. The conductor, who was unaware of the radio communications underway in the lead locomotive, instructed the brakeman to advise railroad personnel of the derailment and fire. The brakeman walked to a radio-equipped switch engine 1½ to 2 miles south of the derailment area to carry out the conductor's instructions.

The conductor returned to the caboose to obtain the waybills approximately 12 to 15 minutes after the derailment. He then walked north to the Almeda-Genoa Road grade crossing where he talked to a policeman and a fireman. He identified himself as a member of the train crew and asked the policeman where he could find a telephone. The fireman asked the conductor how to get the rear portion of the train moved off the crossing, but he did not ask him to identify the burning commodities. The conductor answered his question and then went to a tavern approximately one block east of the tracks to report the accident by telephone to the Missouri Pacific's dispatcher.

The track crew fled from the derailment to the southeast and southwest. One of the trackmen proceeded south on Mykawa Road and attempted to flag down northbound automobiles to warn them away from the accident site.

The foreman of the track crew warned one nearby resident to evacuate the area and then he attempted to evacuate his men and the truck assigned to them The truck was blocked by fire department equipment but when he was instructed by a fireman to get out of the area, he and his men complied

I. The Explosion

1 Massive Energy Release

At approximately 2:30 p.m , a violent rupture and massive energy release occurred when the tank of ESMX 4804 suddenly failed. Numerous firemen and bystanders were injured Locations of the firefighters and their equipment when the tank car ruptured are shown in Appendix 4.

The sudden release of approximately 100,000 pounds of vinyl chloride monomer remaining in the tank produced a large fireball Approximately 50,000,000 BTU's of energy were released in less than one second. The reaction of the vinyl chloride was caused by oxidation of the monomer, rather than by its decomposition or polymerization The oxidation of vinyl chloride produces approximately 7,395 BTU's of energy per pound, compared with 435 BTU's per pound associated with its decomposition and 750 BTU's per pound associated with polymerization.

Meanwhile, the damaged tank of ESMX 4803 was propelled to a point adjacent to the grade crossing approximately 300 feet away. The propulsion was caused by the energy produced from the reaction of the vinyl chloride remaining in the tank and the oxygen in the air which had been sucked back through the punctured tank wall during the effort to cool the tanks. The thrust from the gases escaping through the punctures propelled the tank body, intact, onto TSVX 2010 and thence onto the ground near the crossing, while residual, burning, liquefied vinyl chloride spewed from the punctures The safety relief device functioned as designed, but it did not relieve the internal pressure sufficiently to prevent the tank from rupturing.

2. Warning Signals

It was stated that the fire department's plan of attack contemplated a warning prior to the rupture of one of the tank cars. The expected warning would have been the sound of the safety relief device functioning, or an abrupt increase in the quantity of fuel feeding the fire with a resultant flare-up However, the operation of the safety valve was not heard, and the flare-up which preceded the rupture of the tank occurred just moments before the explosion Consequently, none of the danger signals generated by the fire gave firemen time to get far enough away to avoid injury However, the fact that there was some warning was indicated by the location of burns on the backs of firemen One witness reported hearing a loud, metallic, clanging noise immediately before the explosion

3 Injury Producing Events

Appendix 4 shows the location of fire department personnel whose positions at the scene of the fire could be established with a reasonable degree of accuracy. Scorch damage and debris were observed within the broken line on this sketch

The firefighters indicated that they were concerned about the dangers associated with burning, compressed gas. They related the danger zone to those described in one of their training films entitled "Handling LP-Gas Emergencies." This training aid describes two injury-producing mechanisms. It notes that pieces of tanks have been propelled about ½ mile when containers ruptured, but it suggests that a distance of 500 to 1,000 feet is more likely. The film also notes that firefighters have succumbed to radiation burns incurred when they were as far away as 250 feet from very large fire balls It indicates that compressed gas container failures may occur without warning within 10 to 15 minutes of exposure to intense flames

J Postexplosion Events

1 Secondary Fires

After the violent rupture of ESMX 4804, and the propulsion of tank car ESMX 4803, a secondary fire started at the top of tank car TSVX 2010, which contained acetone and which was damaged by the rocketing tank of ESMX 4803 Additional secondary fires started when the remaining contents of ESMX 4803 were discharged through punctures as the tank rocketed toward the grade crossing where it finally came to rest The discharged vinyl chloride burned along a pathway which paralleled its trajectory, and in the process, burned vehicles near the crossing Other combustible materials, including a nearby house, caught on fire The fire department reported that they had extinguished these secondary fires at 6:57 p.m , approximately 5 hours after the derailment. No additional injuries were sustained

2. Postexplosion Response

The abrupt rupture of the tank from ESMX 4804 and the rocketing of the tank from ESMX 4803 injured firemen and bystanders within the danger zone. These events crippled firefighting efforts Firemen and other parties withdrew to about 900 to 1,000 feet from the derailment wreckage. Command was assumed by the Houston fire chief when he arrived a few minutes after the explosion at 2:30 p.m His efforts to identify the burning material were unsuccessful. Several hours later representatives of the Missouri Pacific identified it as acetone.

No prearranged communication procedures existed between the railroads and the fire department. Fire department personnel indicated that they were unable to contact or locate any railroad personnel who had access to the train's consist. By the time firemen learned that the conductor had the waybills, they could not locate him

Meanwhile, the conductor's efforts to inform the dispatcher about the derailment were interrupted when the explosion occurred at 2:30 p m. The conductor's first contact with railroad supervisors on the scene was with Santa Fe officials who were attempting to have the rear portion of the train removed from the danger zone The conductor gave the waybills to a Missouri Pacific supervisor who was involved with rerailing the cars in the forward portion of the train The fire department established contact with this supervisor after 4 p m., and the fire was extinguished after the fire chief learned that the commodity was acetone

K. Firefighting

1 Fire Department Capabilities and Training

A wide variety of materials classified as hazardous materials are produced and transported in the Houston area. The fire department participates in "Channel Industries Mutual Aid" arrangements for emergency fire services which cover a number of industries that produce hazardous materials. Its representative in this group is the assistant chief who was in command part of the time at the scene of this accident.

All new employees take courses at the fire department's training academy. Senior officers at the scene of this accident had not taken the course covering the control of hazardous materials in accidents. However, they were instructed to maintain their proficiency in these matters The course includes instruction in the basic chemistry of hazardous materials, fire service procedures, demonstrations of the hazards of flammable liquids and gases, and how to control flammable liquids in LPG tank truck fires.

The Southern Pacific Transportation Company was the only railroad which provided the Houston Fire Department with training assistance The Bureau of Explosives conducted a seminar in the Houston area several months before the accident, and the deputy chief for training attended some of these sessions. The State of Texas also provided firefighting training services, which focused principally on handling LP gas emergencies.

Federal safety regulations for the transportation of hazardous materials are not included in training courses at the academy. The City of Houston did not participate in formulating these regulations nor does it have any local ordinances to cover the transportation of hazardous materials by rail. However, the city has prescribed some regulations for transporting such materials on highways within the city.

2. National Fire Protection Association (NFPA) Recommended Practices

Local fire departments do not have the resources to develop firefighting recommendations for all the situations they might encounter. Therefore, they rely heavily on outside sources for many recommendations and training aids. The Houston Fire Department relies most heavily on the NFPA, an organization of approximately 25,000 members, organized in 1896. The NFPA's purpose, as stated in its 1971 yearbook, is "to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects, and to secure the cooperation of its members and the public in establishing proper safeguards against loss of life and property by fire." The NFPA holds itself out to develop and publish firefighting recommendations and it sponsors training films which illustrate these recommendations, such as the film entitled "Handling LP-Gas Emergencies." However, the NFPA does not have any publications which specifically apply to handling rail transportation emergencies involving hazardous materials.

The development of NFPA standards or recommendations begins with the establishment of a committee which is appointed by the NFPA Board of Directors. When the committee prepares a proposal addressed to a particular problem, and two-thirds of the committee agree to its content, the proposal is submitted to the association's annual meeting. If the proposal is accepted, it is published as a tentative standard for one year If the committee wants to establish the proposal as a permanent standard, essentially the same process is followed If it is adopted at the next annual meeting, it then becomes a NFPA standard.[1]

The NFPA has adopted regulations governing its technical committees which address a wide variety of procedural and jurisdictional matters. However, these regulations do not contain criteria for quality standards against which committee "products" (recommended practices) can be evaluated, nor does the NFPA publish criteria for technical analysis in developing committee products. The association relies on its procedural requirements, including numerous reviews, to assure the quality of its products.

L. Accident Losses

1. Casualties

A fireman was killed and 50 people were injured in the accident. Thirty-nine of the injured were Houston Fire Department employees Eight others injured were reporters or photographers, and three were spectators. Twenty of the injured were hospitalized.

Most of the injuries were burns. An autopsy was not performed to determine the cause of the fireman's death but he had suffered severe head injuries as well as burns

2. Property Damage

Two of the 22 cars involved in the accident were destroyed. Fourteen cars were damaged extensively, and six were damaged lightly. Fire or contamination destroyed all of the lading in eight cars and 50 percent of the lading in six cars

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[1] For full details see *NFPA 1972 Yearbook and Committee List*

Approximately 600 feet of the main track, 500 feet of the siding, and 400 feet of the team track were demolished in the derailment. One side track turnout also was destroyed and approximately one-quarter mile of main track was damaged moderately

A nearby residence, a fire truck, an automobile, and a railroad motor truck were destroyed in the fire. Several buildings in the area incurred such damages as paint blisters or broken windows

M. Postderailment Inspections and Investigations

1. Train Equipment

The locomotive of Train 94 was inspected after the accident and no conditions were discovered that could have contributed to the derailment. The speedometer of the lead locomotive unit was removed and tested for accuracy The test indicated that it registered a speed 3 m.p.h faster than the actual speed.

The 48 cars that were not derailed in the head portion of the train were inspected on the site by Missouri Pacific personnel This was a cursory inspection to determine whether the train could be moved into Houston No equipment defects were discovered that could have contributed to the accident, and this portion of the train was moved to Houston without further incident.

The front brakeman looked over the first 52 cars of the train when he walked back from the locomotive to the area where the general pileup occurred He discovered that the air hoses between the 47th and 48th cars were uncoupled His testimony was contradicted by another witness, the assistant to the general manager of the Missouri Pacific, who stated that no air hoses were disconnected when he arrived at the scene just after the explosion at 2:30 p.m. The assistant to the general manager indicated that he was responsible for the separation between the 47th and 48th cars as he made a cut at that location during the rerailment activities. He also stated that after he made this cut, the head 47 cars were moved northward approximately two car-lengths or 100 feet. The brakeman indicated that the 47th and 48th cars were coupled when he discovered the disconnected air hoses.

There were four derailed cars in the head 52 cars north of the wreckage. The lead wheels of the trailing trucks of the 38th, 48th, and 49th cars derailed to the west, with the wheels straddling the west rail. The wheels of the leading trucks of these three cars, and also those of the 52d car were on the rails. The trailing truck of the 52d car derailed inside the rails so that the west wheels spread and overturned the rail, while the east wheels were riding on tieplates, ties, and ballast just inside the east rail.

The wheels that were derailed on these four cars were marked and scarred accordingly. Indications that the 48th, 49th, and 52d cars had been subjected to a recent, heavy impact appeared in marks apparently caused by the coupler horns striking the buffer castings or strikers on these cars Similar marks also were discernible on the 38th, 42d, and 54th cars, but these marks could not be identified with certainty as of recent origin. A brake beam on the rear truck of the 52d car had been dislodged and the bottom of the side frame of its rear truck had marks which indicated that it slid along the top of the east rail.

With the exception of the 39th car, the cars that were not derailed in the 52-car front portion of the train were forwarded to their destination without any further detailed inspection. The 39th car, the derailed cars, and the 42nd car, which was delivered to a consignee in the immediate area, were inspected in detail subsequently.

A truck with a loose wheel was discovered in the wreckage, and traced to ESMX 4804, the 56th car, which ruptured violently. The location of the car in the train and subsequent tests indicated that the loose wheel resulted from the derailment

2. Track

An inspection of the track did not reveal any unusual marks on the track structure or on highway grade crossings south of the derailment. The track south of the derailment is shown in Figure 6 There was no indication of longitudinal rail movement south of the wreckage.

The derailment and fire demolished the track for a distance of 607 feet between Santa Fe's Engineering Stations 743 + 23 and 749 + 30. Station 743 + 23 is located 69 feet north of the centerline of the Almeda-Genoa Road crossing (742 + 54) From Station 749 + 30 north to Station 751 + 00 both the east and west rails were spread out and the west rail was overturned From Station 751 + 00 to Station 762 + 56 only the west rail was overturned. The 52 d car was found at Station 762 + 56. The web of the west rail was marked continually from Station 749 + 30 to Station 762 + 56. The outside edge of the head of the east rail was scarred from Station 744 + 22 to 762 + 56 The correlation of the engineering stations with various derailment marks is shown in Figure 2 on page 3

In addition to the spread rails, the crossties were damaged north of the area where the track was demolished. At Station 749 + 30, the first location where the track was not completely destroyed, three fresh marks were found on the crossties between rails (See Figure 7). Two of these marks were generally continuous northward to the location where the 48th and 49th cars came to rest after the derailment. Between Station 749 + 30 and the area of Station 752 + 70, the third mark was intermittent and appeared only on ties that were in poor condition from decay. It was located approximately 3 inches from one of the more distinct, continuous marks on the ties From Station 753 + 00 north to Station 764 + 64, there was clear evidence of three distinct marks (Figure 8). From Station 764 + 64 to Station 769 + 59, where the 38th car came to rest, there was one mark between rails on the crossties (Figure 9).

Because the derailment occurred in the vicinity of trackwork, track conditions were suspected as the cause of the accident. The exact point of the derailment and statements of the track crew on track conditions became key points in determining the cause. After the derailed equipment had been removed and the track had been repaired, the damaged rail and switch ties were reassembled alongside the track.

The welded rail was broken and bent in numerous places, but the various pieces of rail were reconstructed as close as possible to their original positions. Although there were a number of breaks in the rail, they were new breaks without any indication of defects or battered ends, with one exception This exception also was a new break free of defects, but the sharp, angular edges of the broken rail had been battered slightly It was located on the west rail at Station 746 + 18

The scrape mark discernible on the web of the west rail also was apparent on the reassembled rail in the area of the wreckage This mark could be traced back to Station 745 + 88, or 30 feet south of the broken rail discussed above. At that location, the mark on the rail web ended. Just above the end of the mark, the gage side of the west rail head was scored diagonally downward, as viewed from south to north Five feet 6 inches south of this mark, there was another mark on the gage side of the west rail head and still another at Station 744 + 42. This latter mark was scored diagonally upward, as viewed from south to north. The web and base of the west rail also were marked between Stations 744 + 42 and 744 + 22.

The east rail also was marked intermittently throughout the area of the general pileup Scrape marks similar to those noted previously on the outside edge of the rail head were discovered at Station 744 + 22

Efforts to reconstruct the switch ties were less successful than efforts to reassemble the rail The varying lengths of ties and the fact that they were not prebored offered the possibility of establishing the number of switch ties that had been in place or the number of switch ties that had been spiked before the derailment. However, fire and derailment damages hindered this effort. There was evidence that every other tie was spiked for a distance of approximately 50 ties on the south end of the project, but no

Figure 6 - View of tracks south of accident scene. The main track is on the right.

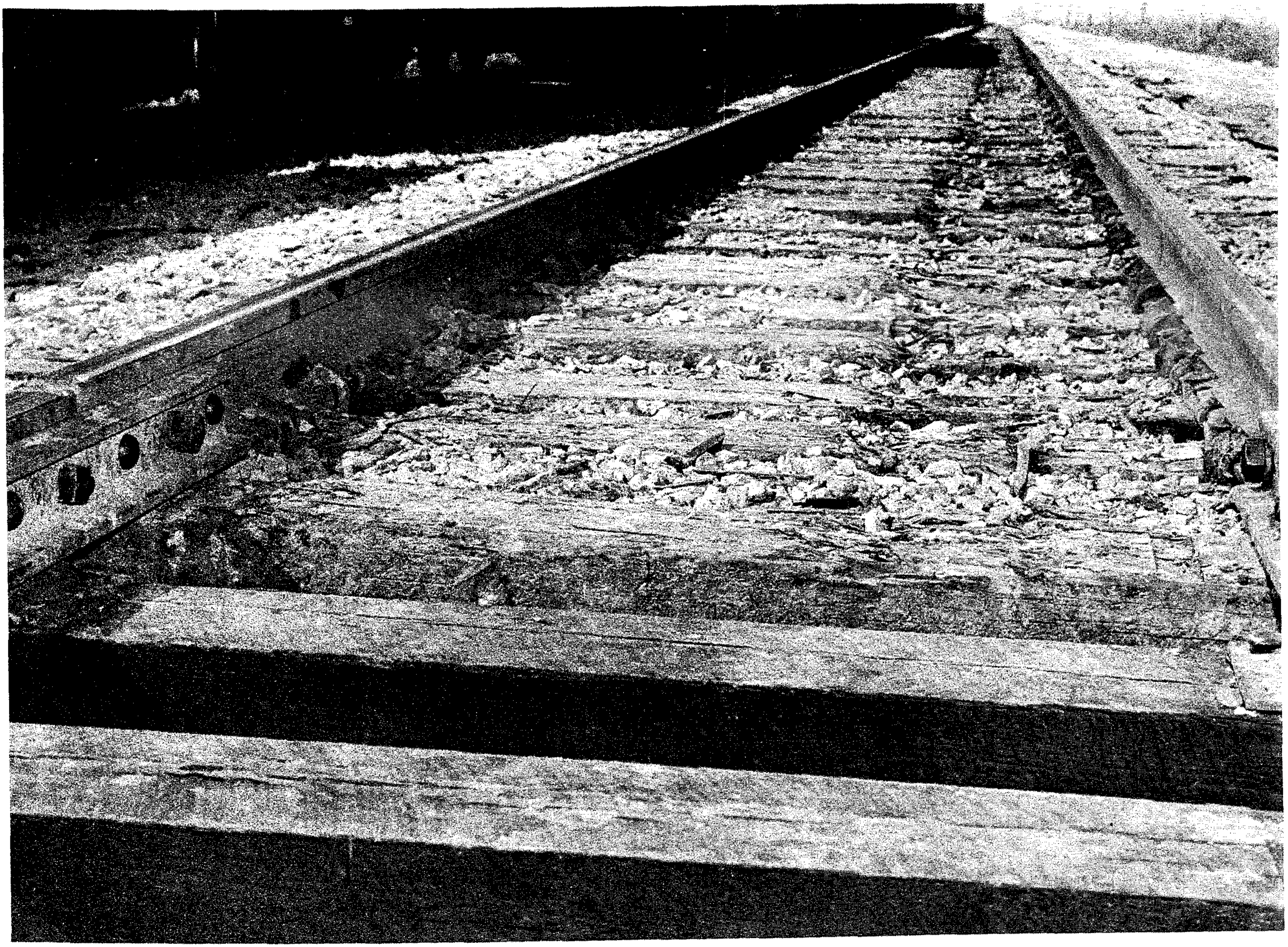

Figure 7 - View of main track at engineering station 749 + 30 showing the marks on crossties north of the area of reconstructed track. The mark on the web of left rail extends between stations 745 + 88 and 762 + 56.

Figure 8 - View of marks on track at engineering station 753 + 17.7 looking north.

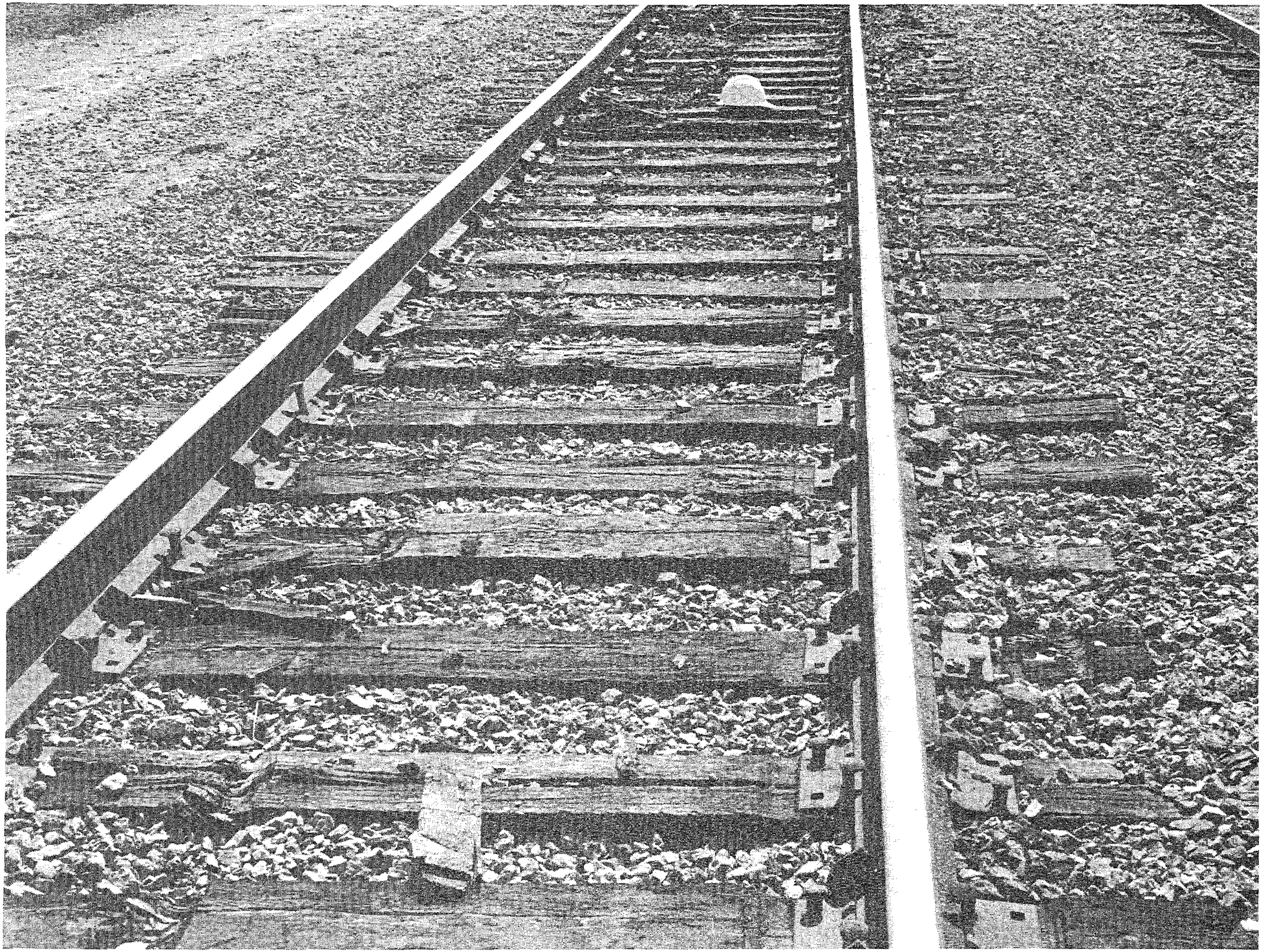

Figure 9 - View of marks on track looking south. Hard hat is located in the vicinity of engineering station 764 + 64.

other condition was substantiated. The condition of the reconstructed switch ties and rail are shown in Figures 10 and 11.

3. Tank Cars

The Railway Progress Institute and the Association of American Railroads (RPI-AAR) currently are engaged in a joint program to research and test the safety of tank cars. A representative of the RPI-AAR group investigated tank car damages in this accident and prepared a report on them. Part III of the RPI-AAR report describes the probable sequence of events (See Appendix 5). These events were reconstructed from photographs and television films of the area before the explosion at 2:30 p.m., from statements of witnesses, and from the condition and position of the equipment after the accident. The Safety Board believes that this report accurately describes the probable post-derailment events.

III. ANALYSIS

A. The Derailment

1. Possible Causes

The evidence suggests a number of possible causes of this derailment. Among them are: (1) dragging or dislodged train equipment, (2) a broken rail, (3) a loose wheel, (4) the "rock and roll" phenomenon, and (5) excessive speed for the tonnage of the train. All of these possibilities were suggested by observations of eyewitnesses or by discoveries made during the investigation.

Dragging or dislodged train equipment was considered as a possibility because of observations made before the accident. The testimony of the rear brakeman concerning a low-hanging object he observed on a tank car during the pull-by inspection at Liverpool and the unusual noises heard by several witnesses as the train passed at Mykawa suggested that something was amiss. However, other considerations indicated that dragging or dislodged equipment did not cause the accident. First, the train had been inspected en route to Mykawa and at the accident site by several individuals who did not see anything dragging. Second, the first 52 cars of the train received a walking inspection just after the accident, and no defects were observed. Third, there were no marks or equipment components on the track structure approaching the accident site that suggested the presence of anything dragging or dislodged. These outweighed any indication that such equipment caused the derailment. However, this determination could have been simplified and reaffirmed by a detailed inspection of the head-end of Train 94 before the cars were dispatched from Houston. This was not done.

The configuration of this derailment was similar to those caused by a broken rail. As noted, the rail was broken, but there was no indication of any rail defects, and all of the breaks were new. It appeared that all of the breaks occurred as a result of the derailment and activities of the wrecking crew. Therefore, a broken rail was dismissed as a causal factor.

As noted, the loose wheel discovered in the wreckage was traced to the 56th car. Because of the car's position in the train, the loose wheel probably was not significant. Moreover, there were no marks on the track structure or grade crossings south of the accident area to indicate that the wheel was loose prior to the derailment. Subsequent disassembly of the truck eliminated the loose wheel theory and indicated that the wheel was dislodged during the derailment or explosions.

One witness testified that before the derailment the cars started to rock back and forth more than they normally do, suggesting that the cars may have rocked off the track. This was not substantiated by other witnesses and it was not consistent with the characteristics of this type of derailment. The condition of the track, the type of train equipment, and the indicated speed of the train did not substantiate the "rock and roll" theory.

Figure 10 - View looking north showing switch ties reassembled after the accident. Tie at the bottom of photograph is the first headblock tie. Rail to the left of switch ties is the east rail repositioned following the accident.

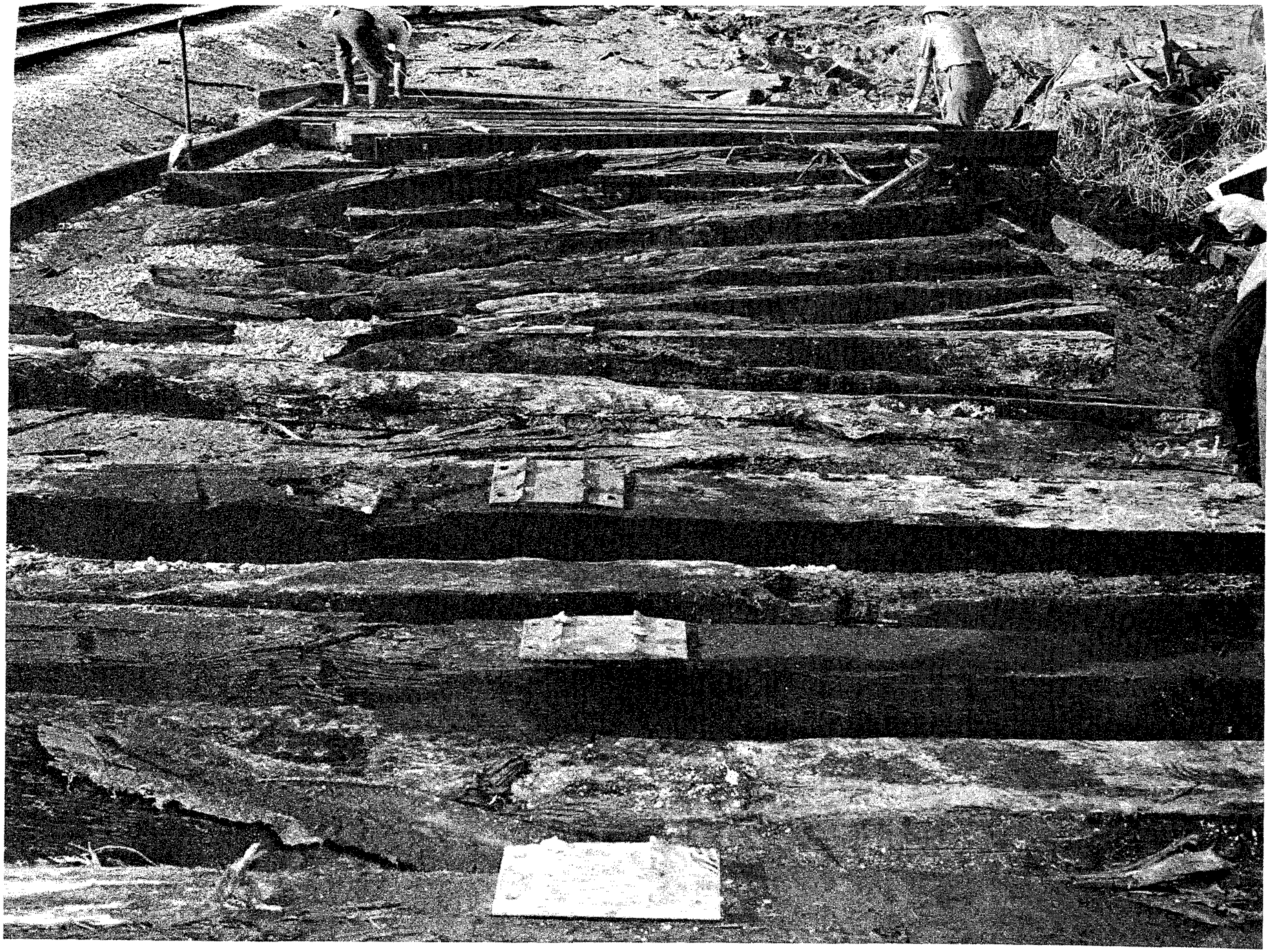

Figure 11 - View looking north showing switch ties reassembled after the accident. First tie at bottom of photograph was positioned as tie No. 42. The switch ties at the top of photo had not been installed at the time of derailment.

The total weight of Train 94's consist exceeded 7,000 tons and, therefore, a maximum speed of 45 m.p.h. was authorized by Santa Fe rules. The engineer and conductor were not aware that their train weighed more than 7,000 tons and, they were operating on the premise that the authorized speed in this area was 50 m.p.h. The speed restriction of 45 m.p.h. was based on signal spacing and not on the ability of the track to sustain the load. The engineer and front brakeman indicated that the train was moving 40 m.p.h. just prior to the accident. A theoretical train speed was calculated for the conditions prevalent on the day of the accident and this speed was consistent with the testimony of the engineer and brakeman. Therefore, the Safety Board did not attribute this derailment to excessive speed. However, the speed of the train undoubtedly influenced the number of cars involved in the accident.

2. The Trackwork

The train proceeded from Angleton to Mykawa without major incident. The one factor at Mykawa that was not present at other locations en route was that a new set of switch ties was being installed. This suggests that the trackwork in progress could have been a contributing cause of the accident.

There is no evidence to contradict the assertion that alternate switch ties were spiked and all switch ties were tamped. If a known deficiency that would endanger the train had existed, the track crew would have retreated hastily from the area when the train approached. However, they merely stepped back from the track and most of the crew watched the train pass by. It seems clear that if a track deficiency existed, the track crew were not aware of it, or they were not afraid of the consequences.

As noted, the foreman had been instructed to install the switch ties without benefit of a slow order but in a manner that would "keep the track safe." However, this was the first time that he had installed a set of switch ties without restricting the speed of trains. Testimony at the hearing indicated that temperature is the main factor considered when decisions are made to conduct such work without speed restrictions. Yet, there were no objective criteria to guide field personnel in making such decisions. The stability of the track had been affected adversely by the removal of all rail anchors, the spiking of only alternate switch ties, and the progression of the work continuously from the head block ties northward. The destressed (stress-free) temperature of the rail was an unknown factor because the rail had been installed 10 years before the accident, and the track had been disturbed since then.

The main track accommodated an average of 18 trains per day at speeds of 60 m.p.h. Commodities transported included considerable amounts of hazardous materials. Equipment included tank cars that were 90 feet 10 inches long with gross weights approximating 500,000 pounds. Although the area was populated sparsely, it was within the corporate limits of one of the nation's largest cities. It would seem that, based upon past practice of the Santa Fe, a prudent course of action might have been to place a slow order, restricting the speed of all trains using this track.

What speed would have been proper? Train 94 was proceeding at approximately 40 m.p.h. rather than the 60 m.p.h. authorized by the Santa Fe for lighter trains. Should the speed have been restricted to 30 m.p.h.? Laurel, Mississippi[2] was partially destroyed when tank cars were derailed in a train estimated to be traveling 28 to 30 m.p.h. A speed of 15 to 20 m.p.h. may be suggested as prudent, but this speed introduces the risk of "rock and roll." The fact that a dilemma exists is clear, but it also is clear that high speeds increase the risks when hazardous materials are involved. Procedures that are safe for accommodating a trainload of coal may not be safe when vinyl chloride or

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[2] NTSB Railroad Accident Report, Southern Railway Train 154, *Derailment with Fire and Explosion, Laurel, Mississippi*, January 25, 1969

other hazardous materials are the commodities being transported through populated areas. The transportation of hazardous material involves extra risks and, therefore, extra safeguards must be taken. In this instance, the stability of the track was reduced by the trackwork in progress but speed restrictions were not imposed.

3. The Cause of the Derailment

Although this accident was witnessed by a number of persons, the exact location of initial derailment was disputed. The track crew and labor union representative indicated that the first derailed cars were some distance (50 to 200 feet) north of the switch ties. Other witnesses indicated that the derailment occurred where the trackwork was underway.

The most northerly marks on the crossties and on the web of the west rail could be definitely attributed to the wheels of certain derailed cars. That is, the places where the 38th, 48th, 49th, and 52d cars stopped after the derailment could be located by relating the marks on the ties and rail to the position of the respective cars in the train and by statements of witnesses as well. There was some movement of the train subsequent to the derailment, but this movement was minimal and inconsequential to the analysis The most northerly marks attributed to the derailed cars were at Stations 769 + 59 for the 38th car, 764 + 64 for the 48th car and 762 + 56 for the 52 d car. (See Figure 2.)

The derailed paths of four cars were evident between Stations 762 + 56 and 753 + 00. Between Stations 753 + 00 and 749 + 30 (the end of the destroyed track), the derailed paths of three cars could be readily recognized. There also were fresh derailment marks adjacent to deeper marks on ties that were soft from decay. The deep marks appeared to result from the flanges of a wheel, and the adjacent marks appeared to result from the wheel treads. This indicates that there could only have been three cars derailed between Stations 749 + 30 and 753 + 00. A fourth car derailed in the vicinity of Station 753 + 00, and the paths of wheel marks indicated that it was the 38th car.

The point at which another car left the rails also could be located with reasonable certainty. The 52d car was rerailed at Station 762 + 56, as indicated by the rerailment mark on the gage side of the west rail head and by the end of the continuous scrape on the web of the west rail. The mark on the rail web could be followed back into the area of the general wreckage. It was determined that this mark originated at Station 745 + 88, where there also was a mark on the gage side of the west rail head, which suggested that the 52d car overturned the rail at that point and derailed. Additional evidence that the 52d car derailed at this location was provided by the mark on the rail head 5 feet 6 inches south of Station 745 + 88, which was the distance between the wheels of the 52d car.

The mark on the web of the west rail at Station 745 + 88 was 1,668 feet from the point where this web mark ended (Station 762 + 56). This would have been the stopping distance for the 52d car after it derailed since the scrape on the rail web was continuous between these extremities. From Stations 753 + 00 to 769 + 59, where the derailment marks for the 38th car began and ended, the distance was 1,659 feet, or the stopping distance for the 38th car after it derailed. This indicated that the derailment of the 38th and 52d cars occurred at nearly the same instant.

How could this have occurred? In this instance, the simultaneous derailment of cars widely separated in the train could result only from an impact within the train caused by an emergency brake application.

What could have caused an emergency brake application? Again, there are several possibilities. The emergency brakes could have been applied by crew members, but their testimony, supported by other evidence dismisses this possibility.

The train was separated between the 52d and the 53d cars and, an emergency brake application could have originated from the separation at this point. But then, an impact sufficient to derail the 38th, 48th, and 49th cars could not occur because the loaded cars which would have provided the required momentum would have been left behind when the train separated.

Another cause of an automatic emergency brake application could have been the separated air hose which the front brakeman said he discovered between the 47th and 48th cars. Another witness contradicted the brakeman's testimony, but the possibility must be considered The initiation of an emergency brake application between the 47th and 48th cars would have resulted in the propagation of braking signals in both directions. As indicated in the consist list (Appendix 2), 13 of the 15 cars immediately preceding the 48th car were empty. The 49th and 54th cars were the only empty cars between the 48th and 72d cars The braking of freight cars is controlled by the weight of empty cars and, thus, the braking of empty cars may be many times more efficient than the braking of loaded cars. Therefore, the conditions induced by an emergency brake application originating between the 47th and 48th cars would have been conducive to a run-in or impact within the train.

The marks at Stations 753 + 00 and 745 + 88 establish the locations of the 38th and 52d cars when they were derailed simultaneously. These locations would be near the area where braking became fully effective. If the brake application was initiated by a separated air hose, it would be useful to know where the train was when the air hose separated. Air is transmitted at a rate of 930 feet per second during an emergency brake application More importantly, a build-up time is required in the brake cylinders before braking becomes effective. This build-up time varies with the brake pipe pressure, but generally it approximates 9 to 10 seconds. There was distance of 333 feet between the rear of the 47th car and the rear of the 52d car, or 0.4 second of propagation time. If the train was travelling 37 m.p.h (54 feet per second), 10 seconds before the 52d car derailed the rear of the 47th car would have been near Station 743 + 81 or 10 feet north of the southern extremity of the new switch ties. At 40 m.p.h (59 feet per second), the trailing end of the 47th car would have been near Station 743 + 31 or south of the new switch ties when the brake propagation occurred In either case, if a separated air hose resulted from the derailment of the rear truck of the 48th car, this derailment would have occurred ahead of the new switch ties. There is no evidence to suggest that this occurred.

The havoc created by the derailment, fire, and explosion prevented a complete examination of the train equipment Nothing was found in the wreckage that suggested an emergency brake application could have originated from the equipment. However, the condition of the equipment was such that it could not be eliminated as a possibility. An emergency brake application initiated from the 53d car or from other derailed cars immediately behind it could have caused an impact within the train Such a brake application would have been initiated before the cars passed the Almeda-Genoa Road crossing if it caused the derailment of the 52d car at Station 745 + 88

Excessive brake pipe leakage also could have caused an emergency brake application. As noted, the brake tests that were conducted on Train 94 before it left Angleton were not in accordance with Federal regulations. The engineer of Train 94 stated that the brake pipe pressure was 80 p.s.i. in the locomotive and the conductor indicated that the gauge in the caboose registered 69 or 70 pounds per square inch. This suggests that excessive brake pipe leakage may have existed However, it was not detected because Federal regulations for conducting brake tests were not observed even though a supervisor was overseeing the train assembly and departure procedures

An emergency brake application caused by excessive brake pipe leakage would have been most conducive to an impact within the train if the brake application had been initiated between the 30th and 60th head cars. In this part of the train, effective braking would have been built up quickly on the block of empty cars and the loaded cars would have been retarded at a slower rate

Sometimes brake-pipe leakage is detectable only when the brake line is in tension. If there was brake pipe leakage in this accident, it may have been in the wrecked equipment There also may have been leaks in the equipment on the head-end of the train that was forwarded to its destination without detailed inspection after the derailment

There were marks on the equipment which suggested that the derailment was caused by an internal collision. The 48th, 49th, and 52d cars showed conclusive evidence of having been subjected to recent, heavy compression or impact. The 38th, 42d, and 54th cars also had marks indicating a recent impact The number of cars so marked implies that this impact had occurred when the cars were part of Train 94's consist.

There were two emergency brake applications before Train 94 arrived at Mykawa. Just north of Angleton, an emergency brake application occurred as the result of a ruptured air hose on the 69th car At Liverpool, the rear brakeman applied the emergency brakes from the caboose when the train was moving at a speed of approximately 15 m.p.h. Neither of these occasions would have induced a severe run-in in the middle of the train, because the brake application was initiated from the rear of the train This would tend to place the middle of the train in tension rather than compression until braking became fully effective

Similarly, if the derailment of the 38th, 48th, 49th, and 52d cars occurred independently at the switch ties without a concurrent emergency brake application, those cars would have been in tension at the time of derailment, because the wheels would have been dragging on the crossties or rails Again, the compressive force great enough to make impact marks would not have been generated without an emergency brake application.

As noted, the marks on the track structure indicated that the 38th car stopped within 1,659 feet and the 52d car stopped within 1,668 feet after the cars derailed The total stopping distance of the 52-car, head-end portion of Train 94 would have been within this range, plus the distance covered during propagation or build-up time. The distances varied because the time to transmit the impact also varied. In this analysis, it was indicated that the train would have traveled from 540 to 590 feet during the propagation and build-up time for effective braking. Thus, the total braking distance would have been 2,199 feet to 2,258 feet. Theoretical braking distances calculated for a train speed of 40 m.p.h. varied from 2,298 to 2,453 feet. However, no allowance for the drag of derailed cars was made

The value of such calculations is that it locates the place where the brakes were applied without the necessity of interpreting the derailment marks on the track The location can be determined from the position of the equipment after the derailment. The critical location was Station 744 + 22 where marks on both the east and west rail may have resulted from the initial derailment of the 52d car Station 744 + 22 was near the center of the newly installed switch ties and it was 1,834 feet south of the point where the 52d car stopped after the derailment. This was 464 feet less than the shortest stopping distance calculated for the head-end of Train 94, which suggests that the brake propagation was initiated south of the Almeda-Genoa Road crossing. These calculations are far from conclusive, however, because there is no exact method of calculating normal train stopping distances, even without the variables introduced by derailed cars.

What is more conclusive is the fact that, regardless of the circumstances considered in the reconstruction of the accident, the propagation of the emergency brakes would have occurred before the 48th and 49th cars passed over the newly installed switch ties This dismissed the switch ties as a causal factor in the initial derailment and directs further attention to the possibility of an inadvertent, emergency brake application.

4. The Derailment Mechanism

The above analysis indicates that the derailment was caused by an emergency brake application which became effective when the 52d car was located near Station 745 + 88, or 119 feet north of the newly installed switch ties. The rail overturned sufficiently at this point to permit the lead wheel of the trailing truck of the 52d car to drop onto the rail web. The wheels of three empty cars ahead of the 52d car derailed at the same time.

The train was made up so that 13 empty cars (the 33d through the 45th cars) were in one block near the center of the train. Immediately after these empty cars there were six loaded and three empty cars (the 49th through the 54th cars) followed by a block of 17 loaded cars (the 55th through the 71st cars), five of which weighed approximately 500,000 pounds each. The consist is listed in Appendix 2.

The train also separated between the 52d and 53d cars. Therefore, this location appears to be a logical point to consider existing circumstances. Of particular interest is the fact that cars 55 through 71 were loaded.

There were 269,000,000 foot-pounds of kinetic energy at a train speed of 40 m.p.h. in the 19 cars immediately following the 52d car. Five of these 19 cars had span-bolster trucks and, therefore, are comparable for braking purposes to 10 cars of conventional design. On this basis, the kinetic energy of the 24 cars that preceded the train separation was computed for comparative purposes. There were 125,000,000 foot-pounds of kinetic energy available in these 24 cars. Thus, at a train speed of 40 m.p.h. there was a difference of 144,000,000 foot-pounds in the kinetic energy between these two portions of the train. This is more than the energy that would be expended if the 24 cars struck a stationary wall while travelling 40 m.p.h.

Railroad freight-car braking pressures generally are controlled by the weights of empty cars as noted. Maximum braking pressures are not based on loaded car weights because these pressures would cause the wheels of empty cars to slide. Freight cars are braked at pressures equal to 50 to 75 percent of their light weight. Assuming that the cars involved in this derailment were braked at 60 percent of their light weight, this particular combination of loaded and empty cars produced variable forces of great magnitude within the train.

The 49th car was an empty car and it weighed 90,800 pounds. The estimated brake shoe pressure for this car would have been 0.60 x 90,800 pounds, or 54,480 pounds. The retarding force per ton of weight was 1,200 pounds. The 55th car was loaded and it weighed 495,770 pounds. The light weight of this car was 154,000 pounds. The estimated brake shoe pressure would have been 0.60 x 154,000 pounds or 92,400 pounds. The retarding force per ton of weight was 372 pounds. Thus, the available retarding force per ton for the empty car was 3.2 times greater than that for the loaded car. Similar ratios would have existed for other cars. It is not difficult to visualize the forces that might have been generated by these variations in retardation, particularly since the cars were grouped in blocks of loaded and empty cars.

When three of the empty cars in the front portion of the train were derailed, the lead wheels of the trailing truck straddled the west rail. Derailment in this manner is consistent with the circumstances of other derailments which have been attributed to impact. However, impact within a train normally does not cause rails to spread or overturn. This usually is caused by the introduction of a lateral force, presumably one of considerable magnitude. Normally, on a straight track the impact forces are believed to be transmitted longitudinally throughout the train without appreciable lateral pressures.

The 53d car in this train was loaded and it weighed 174,500 pounds It was a short car with an overall length between coupler pulling surfaces of 31 feet 9 inches and a distance between truck centers of 18 feet 3 inches. The car was critically located near the transition from a long block of empty cars to a long block of loaded cars. This was the area where a run-in probably would occur during an emergency brake application because of the large discrepancy in the retardation rates of the empty and loaded cars The short distance between truck centers of the 53d car offered a moment arm that was conducive to the development of high lateral forces if a longitudinal impact occurred.

The emergency brake application would have provided the longitudinal impact and the rail was spread sufficiently to allow the wheels of the 52d car to drop inside one rail. This initiated the complete destruction of the track for the 16 cars immediately following the 52d car. The torsional forces created when the derailed wheels overturned the continuous welded rail fractured the west rail The broken rail caused the derailed cars to leave the track structure and jackknife, creating the chaos that followed.

5. The Emergency Braking of Trains

In this instance, an emergency brake application apparently caused an accident that resulted in a fatality and numerous injuries. A similar situation was noted in the Safety Board's investigation of a train accident at Glendora, Mississippi.[3] In that instance, emergency brakes were applied to avoid striking a pedestrian and a derailment resulted that also involved tank cars containing vinyl chloride. Moreover 17,000 to 21,000 people were evacuated from their homes. When safety devices such as train brakes initiate such accidents, a review of their "safety" seems essential.

It also is significant that the emergency brake application on Train 94 at Mykawa was the third such "emergency" in the 57-mile trip from Angleton. This indicates that "emergencies" precipitating brake applications are frequent occurrences in the operation of freight trains. It then would seem that the track should be designed to withstand the forces induced by emergency braking.

The evidence shows that the track failed north of the new switch ties. However, it should be noted that at the time the 52d car was overturning the rail, the 38th, 48th, and 49th cars also were derailing, or were derailed. Thus, even if the track structure had not failed, it appears that in all probability a pile-up would have occurred at the next crossing, switch, or other obstacle in the path of the train.

The exact location of the track failure is academic. The point is that the forces induced by the emergency brake application were an unknown factor, as was the ability of the track to resist such forces. When the characteristics of both the load and the support are unknown, extra safety measures are necessary to prevent emergencies.

The reaction to accidents is to increase the safety factor by increasing the ability of track to carry loads through the use of heavier rail, improved ballast, etc. This, in turn, may result in the use of bigger freight cars and, therefore, the accident cycle continues.

In the above mentioned accident report on the derailment of a freight train at Glendora, Mississippi, the Safety Board called attention to the inconsistencies and hazards of freight-train braking. The FRA and the industry are studying the train/track interface involved. The problem is complex and will take some time to resolve. However, the basic problem in train braking, as indicated by this accident, is the difference in the retardation rates of loaded and empty cars. The problem could be resolved by installing devices that would distinguish between a loaded and an empty car, and adjust braking ratios accordingly during braking operations.

The transportation of hazardous material by rail subjects the public to the risk of exposure to these materials in the event of accidents. Safety devices such as emergency brakes should not escalate these risks. Emergency brakes should forestall accidents – not create them.

B. Threat to Public Safety

In this accident, injuries and property damage resulted from hazardous material in transit. The

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[3] NTSB Railroad Accident Report NTSB-RAR-70-2, Illinois Central Railroad Company, Train Second 76, Derailment at Glendora, Mississippi, September 11, 1969

threat to public safety arose because of the presence of materials capable of enlarging the danger zone or area in which injurious events could occur. Analysis of both the threat and responses to the accident is essential because the public hearing spotlighted significant problems associated with emergency responses which increased losses in this accident.

1. The Massive Energy Release

During the course of the fire, an explosion, or an abrupt release of massive quantities of energy occurred with almost no warning The hazardous material associated with the explosion was vinyl chloride monomer, a chemical capable of reacting violently by combustion in air, by decomposition, or by polymerization This chemical was packaged and transported in a manner which could abruptly release massive quantities of energy. As noted, approximately 50,000,000 BTU's of energy were released in less than one second The fatality and injuries occurred when tank car ESMX 4804 ruptured and tank car ESMX 4803 rocketed. The rapid energy release rate prevented successful evasive actions by people in the danger zone.

2. Parties at Risk

Several categories of people were in the danger zone threatened by the preceding events These categories included carrier personnel, emergency personnel, and bystanders.

Carrier personnel included track maintenance crews and the train crew The track maintenance crew was in danger primarily during the derailment. These workers fled at the first indication of the derailment and they were not injured. The crew on the train was separated from the wreckage by at least 15 car lengths. The conductor and the front brakeman entered the danger zone after the derailment to ascertain the extent of the wreckage However, they were not within the danger zone when the explosion occurred.

Emergency personnel include firemen, policemen, and medical aid personnel. Their first concern is to rescue and remove people who are, or may be injured. There were no injuries when the derailed cars came to rest in this accident. The firemen's secondary concern was to protect property adjacent to the accident scene and they entered the danger zone in an effort to do this

Bystanders included residents, people attracted to the scene by the smoke and fire, and newsmen. In this accident, occupants of dwellings in the immediate vicinity were believed to be in danger and they were evacuated at the direction of fire department personnel.

Other bystanders were in automobiles at the grade crossing waiting for the train to pass. They fled from the accident scene instinctively. But some bystanders were attracted to the scene by dense smoke from the fire which began during the derailment. Their injuries stress the need for controls to keep everyone from danger zones in transportation accidents involving hazardous materials. This problem was observed in the Safety Board's Waco, Georgia, highway accident report.[4]

Eight newsmen and photographers were injured by the explosion at 2:30 p.m These newsmen were bystanders in the sense that they were not attached to the transportation system or trained for emergencies, even though they entered the danger zone in pursuit of their occupation Their photographs of the accident were useful in reconstructing the events and circumstances. However, this does not imply that newsmen should enter the danger zone in any accident to acquire such data

Everyone in the preceding categories was exposed to possible injury during the sequence of accident events, even though all of them were not injured It is significant that everyone who was injured entered the danger zone voluntarily.

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[4] NTSB Highway Accident Report NTSB-HAR-72-5, Automobile-Truck Collision Followed by Fire and Explosion of Dynamite Cargo on U S. Route 78, near Waco, Georgia, on June 4, 1971

3. Identification of Threat

In terms of their capability to identify the threat to public safety, those who sustained injuries in this accident can be further categorized as either trained or untrained in emergency responses.[5] The firemen, policemen, and medical aid personnel were trained for such emergencies, whereas the bystanders and newsmen had no training to assist them in identifying or assessing the threat associated with the burning wreckage. The minimal training of nonsupervisory railroad personnel in handling accidents suggests that they should be classified as untrained.

The firemen's identification and assessment of the threat reflected the information available to them at the scene, and their prior experience and training, which was the most comprehensive of any of the parties The inspection of the cars to determine the contents, the conclusion that a "flammable compressed gas" was burning, the possibility of a tank car explosion, the possible ineffectiveness of the safety valves on overturned cars, the expectation of a warning signal before such an explosion, the decision to try to "cool the tanks," and the "advance and extinguish" tradition are all incorporated in their training materials and instructions The threat perceived by the firemen was the harm that an explosion of ESMX 4803 might cause.

The senior fire department officer functioning as the on-scene commander expressed his concern about personnel injuries which might occur if "the ends (of the tanks) blow" or "if a pop-off valve went off" on an overturned car He also expressed concern for the houses of nearby residents. His responses to these concerns included decisions to "cool the tanks" to keep them from exploding, to position the men who were on the east side of the wreckage upwind behind two overturned cars, to evacuate occupants of threatened houses, and to attack the fire from the least dangerous side.

4. On-scene Information About the Threat

Testimony by firemen indicated that the principle threat perceived was the possibility of mechanically-induced injuries by fragments from a tank car explosion. There were no indications that they considered the possibility of thermally-induced injuries from a fireball if an explosion occurred. Yet most serious injuries were attributed to this injury-producing phenomenon. How could this threat have been identified?

Two tank cars are of principal interest, they are ESMX 4803 which leaked severely and ESMX 4804 which ruptured violently. The name of the contents was marked on the side of ESMX 4803 and this information was discernible to the deputy fire chief. The frostline on the car indicated the liquid level of the flammable material that remained in the car. The position of the markings on the end of the overturned car indicated the position of the safety valve. Tank damages were not visible in the smoke and vapors of the fire (See Figure 3).

ESMX 4804 provided less information to the firemen. (See Figure 4). Residue from the burning vinyl chloride obscured all lettering which could have informed the firemen about its contents, car number, or the position of the safety valve. The placard identifying the contents was attached to the span bolster assembly, or underframe, which was separated from the tank during the derailment. The position of the safety valve only could be inferred from the position of the body bolster assembly at each end of the tank.

If the conductor had identified the contents of the wrecked cars, it probably would not have influenced the firemen's decision to fight the fire and it would have influenced their tactics very little before the explosion at 2:30 p.m. The cars came to rest out of sequence in the wreckage. In the disarray which covered a relatively large area, matching the car tanks with

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[5] See also "A Study of Hazardous Materials Information Needs and Identification Systems for Transportation Purposes" Department of Transportation Report TSA-20-72-4, May 1972

the information on the conductor's consist or waybills would have been difficult and time consuming. More importantly, it would have required entry into the danger zone to read the car numbers. This is not intended to imply that communication between railroad and emergency personnel is unnecessary. However, it suggests that the information which should be communicated requires reexamination.

In this instance, inferences could be - and were - drawn from observable facts at the scene. The flame and velocity characteristics of the fire indicated that the escaping contents of the tank cars were a gas which suggested the possibility of an explosion. However, the observable facts did not provide the full range of information required by the most highly trained personnel at the scene.

It follows that if the most highly trained personnel at the scene experienced difficulties in identifying the threat to their safety, the likelihood that untrained bystanders could do so independently is remote. The consequences are significant because the entry of firemen into the danger zone indicated to bystanders that the wreckage could be approached. Newsmen who were injured entered the danger zone after the firemen did so. This suggests that the presence of emergency personnel close to the source of the threat provided a measure of assurance to bystanders.

C. Emergency Response Actions

Comprehensive documentation of emergency response needs in railroad transportation accidents does not exist. Analysis of the conditions and events of this accident, and other, similar accidents, suggests that emergency personnel approaching the scene of a transportation accident need to determine:

a. whether or not conditions conducive to additional injury-producing events exist (hazard detection);
b. if such conditions exist, how and when injury-producing events could progress (possible injury mechanisms);
c. what choices are available to either remove or control these hazardous conditions (decision options);
d. which alternative is best under the circumstances (response decision).

The Safety Board knows of no prescribed or documented procedures which the firemen might have used to help them decide on the most propitious action.

1. Hazard Detection

Changing or unstable conditions at an accident site indicate the presence of hazards which might lead to additional injury-producing events. In this accident, the raging fire was an unstable condition. The spilled cargo and impingement of fire on an adjacent tank car was another unstable condition. These conditions were recognized as such by the firemen who are trained in such observations. They also were discernible to bystanders at the scene. However, the subsequent injuries demonstrated that the threat these conditions presented was not understood

An unstable condition that was not fully understood was the reaction of the cargo in ESMX 4804. The fire impinged on this tank car and the car ruptured later. The cargo was not identifiable from visual information at the scene. Even if it had been identifiable, the formation of the fireball in the event of a tank rupture would not have been anticipated. This phenomenon was not covered adequately in the publications and training aids available to the firemen. Bystanders had no way of knowing about the possibility of a fireball. Thus, information available at the accident site did not cover all the conditions conducive to additional injury-producing events.

2. Injury Mechanisms

Once the existence of conditions which can cause additional injuries has been recognized, an understanding of how and when injury-producing events could progress is required to devise appropriate responses. In this accident, and in others investigated by the Safety Board, numerous injuries have been sustained because of the lack of knowledge of injury modes associated with hazardous conditions. Consideration of the injury mode in this accident is illuminating.

The firemen considered the injury mode associated with the propulsion of tank heads if an explosion occurred. The nature of the fire and the position of the safety valve made them aware of this possibility. However, the injury-producing mechanism associated with the formation of the fireball at the time the tank ruptured was not anticipated, as noted. If this intense, thermal radiation threat had been anticipated, suitable protective clothing undoubtedly would have been required by the fire department commander.

These circumstances suggest the need for a better understanding of injury-producing events in transportation accidents which involve hazardous materials. In this accident, both thermally-and mechanically-induced injuries occurred. Mechanically-induced injuries resulted from the rocketing tank and from the air overpressure which knocked firemen off their feet. The thermal injury mechanism associated with the fireball apparently involved both direct contact and indirect exposure.

In general, the threat of injury to people and damage to buildings or the environment can be assessed in terms of how and when injury-producing events are likely to progress. When wreckage is jumbled, identification of the threat becomes complex. It is contingent on factors which include the nature and quantity of the hazardous material present, the configuration of the wreckage, the facilities which may be threatened, the duration of the unstable conditions (particularly where there is a fire), the energy likely to be released in the event of an abrupt release of a product or failure of a container, the characteristics of a container failure, the availability of medications or antidotes in the event of injuries, warnings which can be relied on to signal the acceleration of accident events, and even the resources required to remove or control the conditions that are likely to produce additional injuries. The danger zone also is significant, because it determines evacuation needs.

Several of these factors are related solely to the presence of hazardous materials in an accident They include the danger zone, the probable manner in which the container failure affects the release rate of the hazardous material, the susceptibility of the material to ignition or reaction, and the warning of additional accident events.

To date, the approach adopted by regulators for identifying the threat has focused on the commodity, on which all information or requirements are based. The garbled communication of the contents of tank car ESMX 4803 demonstrates the deficiencies of this approach. The legends on placards and warning labels, the signal word "dangerous," and the documents required of shippers all indicate that the current, regulatory warning system is addressed to operating personnel, rather than to emergency personnel. This approach may require reexamination, considering the garbled identification of the tank cars' contents, and the categories of people injured in this and other accidents where hazardous materials were present.

The dependence on placards also may require reconsideration. Markings were obscured by smoke and flames. (See Figure 4.) This indicates the need to devise an alternative warning system whereby data to enable the prompt identification of the threat to public safety can be efficiently and accurately communicated to emergency response personnel.[6] For railroad transportation, it may be impractical to rely solely on container markings. There may be

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[6] The Safety Board previously discussed this problem in NTSB Railroad Accident Report, Pennsylvania Railroad Train PR-11A, Extra 2210 West and Train SW-6, Extra East, Derailment and Collision, Dunreith, Indiana, January 1, 1968

some merit in alternative communicative systems using contacts between carrier and emergency service representatives at established communication points.

A hazard-information system has been proposed by the Hazardous Materials Regulations Board, in its Docket HM-103,[7] to meet the need for immediate response information in a manner that would enable emergency personnel to determine quickly the actions and precautions that should be taken The Houston accident experience suggests that the proposed system is deficient because of inconsistencies in the empirical classification system on which it is based and the limited number of factors available for consideration in assessing the threat to public safety A third, more subtle difficulty stems from the implications of the phrase "conditions normally incident to transportation of hazardous materials "

No single classification theory can be discerned in the current classification system for hazardous materials Classification categories are unrelated, ranging from a description of the physical state of the product to the type and rate of the injury mechanism. To illustrate this deficiency, selected classes of hazardous materials were compared on the basis of the principal criteria for their classification. This comparison is shown in Figure 12. Given this variety of criteria for classifying materials, the difficulties in translating the classifications to corresponding threats in accidents becomes evident. For example, in the case of materials classed as poisons, the nature of the threat to public safety and an initial response (avoid contact) can be inferred from injury mechanisms implied by the word "poison." However, translation of the classification "flammable compressed gas" to identify the threat in such accidents as the one in Houston requires integrating additional inputs such as the container's pressure-relief system, the nature of the material, fire impingement, etc Everyone knows a flammable material burns, but how does this help emergency personnel decide what action is necessary? Is the threat thermal radiation, contamination of life-support systems, weakening of structures, or some other menace?

This is just one problem experienced in using the present classification system for identifying the threat in transportation accidents involving hazardous materials. It suggests that reexamination of the hazardous materials classification scheme is necessary before an effective system can be devised to provide instructive data.

The need for a classification theory was cited previously in a report[8] to the Office of Hazardous Materials prepared by the National Academy of Sciences in 1969. The problem also has been identified in another Safety Board report [9] To date, certain classification definitions have been refined, within the existing scheme, and new definitions are published in HM-103 but no general classification theory has yet been developed.

The second difficulty that would arise in using the proposed hazard identification system concerns the amount of hazardous material and the characteristics of its container. In the Houston accident, this difficulty was illustrated by the sequence of events which produced injuries when the fireball was dissipated and released energies propelled the tank fragments. A smaller amount of vinyl chloride might have burned away before the tank failed or it might have produced a smaller fireball. The quantity of hazardous material affects the range at which life may be in jeopardy, or the time available for emergency personnel to respond successfully. The tendency of containers to rupture abruptly

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[7] Federal Register, Vol 37, No 124 - June 27, 1972

[8] "A Study of Transportation of Hazardous Materials," National Academy of Sciences, National Research Council, Washington, D C , 1969

[9] NTSB Highway Accident Report NTSB-HAR-71-6, Liquefied Oxygen Tank Explosion Followed by Fires in Brooklyn, N Y , May 30, 1970

ANALYSIS OF CURRENT HAZARDOUS MATERIALS CLASSIFICATIONS

PRINCIPAL BASES FOR CLASSIFICATION

SELECTED HAZARDOUS MATERIALS CLASSES	Physical State	Physical property	Chemical Reactivity	Chemical Injury Mechanism	Physiological Injury Mechanism	Intended Use	Nuclear Decay Mechanism	Chemical Reaction Initiation Threshold	Transport Packaging
Explosives			X			X			
Flammable Liquid	X		X					X	
Corrosive Liquid	X			X	X				
Oxidizing Material			X					X	
Compressed Gas	X								X
Flammable Compressed Gas	X	X						X	X
Poison					X				
Radioactive Materials							X		X
Pyrophoric Liquid	X		X					X	
Magnetic Materials		X							
Polymerizable Materials			X						

Figure 12

enhances the danger. The proposed system does not consider these elements of the threat to public safety.

The third difficulty concerns the need to focus on accidents, rather than on normal transportation movements involving hazardous materials. The underlying need for regulations of hazardous material shipments arises largely from the threat to public safety. It is primarily the danger of injuries at an accident site, rather than the characteristics of the commodity during normal transportation conditions, which creates the underlying need for regulations.

These considerations suggest that the system proposed in Docket HM-103 would not have reduced injuries in the Houston accident and that a threat-oriented on-scene information system would be more useful to trained emergency personnel, and to untrained bystanders, than a system based on identification of the product and an inconsistent classification scheme.

At the public hearing, the fire chief and one of his officers testified on the need for better methods of identifying the *threat* in transportation accidents involving hazardous materials. Documentation of firemen's specific needs would seem to merit prompt consideration by leaders in this field.[10] Regulators could then accommodate these needs in a revised threat-identification system.

3. Decision Alternatives

After unstable conditions and possible injury mechanisms have been identified, the alternatives available to anyone approaching an accident site need to be identified and assessed. Whereas the first step relies on observation, and the second step relies on integration of on-scene information, the third step requires the introduction of additional external factors. Alternative decisions available to the firemen in Houston may have included the decision to:

1. Evacuate personnel from the "danger zone."
2. Advance and extinguish any fires.
3. Attempt to control the fire while it burned itself out (as was done.)
4. Let the fire burn and withdraw from the danger zone.
5. Protect personnel and remain within the danger zone to control the secondary effects of fires or explosions.
6. Combine any of the above choices.

The full range of decision alternatives for firemen, who usually are in command at an accident site, is not documented. These choices may be constrained by tradition, by statute, or by other circumstances. Also, the factors which enter into the determination of alternatives are not documented, and may not be known or fully understood. A need for further inquiry into these choices in transportation accidents is indicated by the circumstances of this accident.

4. Response Decisions

The variety of choices indicated above usually is not available in nontransportation fires. These choices (and perhaps others) exist in transportation accidents, because of the variety of circumstances. For example, in the Houston accident homes were in jeopardy, and this factor weighed heavily in the decision made by the fire department commander. However, there was no threat of a catastrophe initially. When a threat can be identified with reasonable certainty, the decision may well be made to sacrifice property rather than to take a "calculated risk" by entering the danger zone and jeopardizing the safety of emergency personnel to protect nearby residences.

In weighing available alternatives for removing or controlling conditions which might result in additional injury-producing events, resources of emergency personnel also must be taken into

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[10] The Safety Board is aware of the NFPA's December 21, 1971, letter to Secretary of Transportation Volpe, which describes these needs in general terms. However, this approach does not resolve the problem of threat-identification needs described herein

consideration. In this accident, for example, the absence of firefighting equipment to cool the tanks with a timely, uniform, protective spray contributed to the injury-producing events. With the resources available, fire men had to enter the danger zone to follow the firefighting procedure recommended in their training materials.

Feasible choices also should be taken into account in the preparation of recommended practices and training for such transportation accident emergencies.

Local fire departments such as the one in Houston do not have the resources to prepare recommended practices and training aids. Therefore, they rely heavily on NFPA publications. In essence, NFPA consensus guidelines or recommendations are prepared by a committee of experts who represent a cross section of organizations concerned with the problem. The review procedures for such recommendations are extensive. However, no quality standards for recommendations have been established within the NFPA. Moreover, it does not require technical analyses in the development of its recommendations. Final recommendations are negotiated, consensus standards, which may or may not incorporate essential factors that could be discovered and documented by rigorous technical analysis.

The relevance of quality standards and requirements for technical analysis of recommendations can be observed in reviewing the circumstances of this accident. For example, the recommendation to "cool the tanks" with water, which may be appropriate in fires involving certain fixed facilities, may be inappropriate in certain transportation accidents. Such circumstances appear predictable, and might have been detected if the recommendation had been subjected to technical analysis with advanced safety-analysis techniques. This suggests that such analysis should be required in procedures by which recommendations of this type are developed in organizations such as NFPA.

A compelling need for such quality standards has been indicated by the large numbers of emergency personnel injured in transportation accidents involving hazardous materials.

IV. CONCLUSIONS

1. Inspections of the train and track before and after the accident did not reveal any apparent cause of the derailment.
2. The rocking tank car observed by one witness, the broken rails, and the loose wheel discovered in the wreckage all resulted from the derailment.
3. The speed of Train 94 was within the Santa Fe's speed limits, even though the train crew did not have the correct information to determine the authorized speed.
4. The speed of Train 94 contributed to the seriousness of the accident because it directly affected the kinetic energy that was dissipated by braking and derailment.
5. When the train approached the accident site, all switch ties were in place and tamped. Alternate switch ties were spiked.
6. The stability of the track had been affected adversely by work in progress on the installation of continuous, new switch ties, which involved the removal of rail anchors, and the spiking of alternate switch ties.
7. The derailment of the 38th car and the 52d car occurred at almost the same instant.
8. The cause of an emergency brake application could not be established, but it was determined that the brake application was propagated before the 48th car passed over the newly installed switch ties.
9. The unusual noise that various witnesses heard just before the derailment may have been the "chattering" associated with a brake application.
10. Federal regulations for testing airbrakes were not observed when Train 94 was

assembled at Angleton, although a Missouri Pacific supervisor was overseeing the work.

11. A block of empty cars preceded a block of heavily loaded cars, and this increased the probability of excessive impact occurring within the train.
12. The location of the 53d car between a series of empty cars and a series of heavily loaded cars, coupled with the short truck spacing of the 53d car, contributed to the development of high lateral forces during the emergency brake application. The track fastenings were not able to withstand these forces, which caused the rails to spread and overturn
13 Railroad personnel were on the scene when the accident occurred, but they did not help control the emergency
14. Everyone who was injured entered the danger zone after the derailment and was exposed to the injury-producing fireball and rocketing tank which followed the abrupt, violent rupture of tank car ESMX 4804.
15. Information was inadequate for on-scene identification and assessment of the hazards, potential injury-producing events and consequent response options
16 If firemen had known the names of the contents in the wrecked cars, it would not have lessened the injuries sustained
17. There were no violations of current, regulatory hazard-information requirements.
18. A commodity-oriented placarding requirement, similar to that proposed in Hazardous Materials Regulation Board Docket HM-103, would not have affected the outcome of this accident.
19 The full range of emergency response alternatives and the information needs of parties at risk in transportation accidents involving hazardous materials have not yet been set forth in a comprehensive document
20. Firemen reacted to the emergency promptly and followed procedures based on their prior experience and training, as well as on current, recommended firefighting practices.
21. The absence of a logical classification theory in the current hazardous materials regulatory system of the Department of Transportation is an underlying problem which contributes to information deficiencies experienced in transportation accidents
22 The number of firemen injured indicates that current, recommended firefighting practices are unsatisfactory in some transportation accidents
23 Recommended firefighting practices, which were not effective in this accident, are consensus recommendations.
24 There are no documented quality standards for such recommendations

V. PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this accident was an unexplained emergency brake application which induced lateral forces in the area of the 52d car as the train's slack was taken up. These lateral forces exceeded the holding capability of the track fasteners and a rail overturned, which caused the following cars to jackknife. Tank cars ESMX 4803 and 4804 were punctured. The retardation of the empty cars which preceded the 52d car was greater than the retardation of the more heavily loaded cars which followed This variation in retardation contributed to the development of high lateral forces.

The severity of the accident was increased by the abrupt, violent rupture of the tank car which contained a pressurized, flammable gas; the lack of adequate training, information, and documented procedures for on-scene identification and assessment of the threats to public safety; and firemen's reliance on firefighting recommendations which did not take into account the full range of hazards in such situations.

VI. RECOMMENDATIONS

The National Transportation Safety Board recommends that:

1 The Missouri Pacific Railroad Company take the necessary action to ensure that affected employees understand and comply with Federal regulations pertaining to the operation of trains. (Recommendation No R-72-41)
2. The Atchison, Topeka and Santa Fe Railway Company and the Missouri Pacific Railroad Company initiate programs to train affected employees in proper procedures to follow at accidents involving hazardous materials. These procedures should include methods for identification of and communication with local emergency service personnel (Recommendation No. R-72-42)
3. The Hazardous Materials Regulations Board hold in abeyance the establishment of a hazard-information system (Docket HM-103) until it develops the criteria which a regulatory threat-information system should address. These criteria should be solicited from and documented by the various parties at risk. (Recommendation No R-72-43)
4 The Secretary of Transportation initiate the development of a logical hazardous materials classification theory which will establish a rational basis for classifying hazardous materials, handled under normal transportation conditions and in transportation emergencies as well (Recommendation No R-72-44)
5. The National Fire Protection Association, and similar standard-setting organizations, establish documented quality standards and quality control procedures for developing recommended practices to combat transportation emergencies which involve hazardous materials. These standards and procedures should include a requirement for a technical safety analysis of their applicability and the risks associated with their use (Recommendation No R-72-45)

The benefits that will be derived through the implementation of Recommendations 3, 4 and 5 will be continuous, but also will require some time to become fully effective. Recognizing this, the Safety Board reiterates and emphasizes the importance of the following recommendations made in previous accident reports:

Railroad Accident Report, Southern Railway Company, Laurel, Mississippi, January 25, 1969

> "5 The Safety Board recommends that the Association of American Railroads and the American Short Line Railroad Association develop plans that will result in the fire chief of each community through which the track of a member road passes knowing where immediate information can be obtained, describing the location and characteristics of all hazardous materials in any train involved in a train accident that affects a community This recommendation can be accomplished in a relatively short time regardless of the level of training which may be achieved later by fire departments." (Recommendation No. R-69-22)

Railroad Accident Report, NTSB-RAR-70-2, Illinois Central Railroad Company, Glendora, Mississippi, September 11, 1969

> "2. The Federal Railroad Administration initiate research and development to provide prototype models of freight train braking systems
>
> (a) capable of providing shorter stopping distances which nearly approach the theoretical limit under all conditions of loading and length of trains;

(b) capable of stopping a train in the emergency applications now required by regulations without internal collisions, train separations, or damage to the train or its lading;

(c) capable of propagating brake application, both service and emergency, throughout the length of a train more expeditiously and surely;

(d) capable of more rapid application of the full intended stopping force to the rails at each car after the application signal is received at each car." (Recommendation No. R-70-16)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

Louis M. Thayer, Member, was not present and did not participate in the adoption of this report.

December 13, 1972.

APPENDIX 1

SANTA FE'S RECORD OF TRAIN MOVEMENTS THROUGH MYKAWA AFTER 6 A.M. ON OCTOBER 19, 1971

Train Designation	Direction	No. of Cars	Tonnage	Track Used	Time by South Siding Switch	Time by North Siding Switch
Missouri Pacific* Dow Turn	Southward	66	3,389	Siding	6.16 a.m.	6:00 a.m.
Missouri Pacific 868	Northward	81	1,860	Main	8:17 a.m.	8:22 a.m.
Santa Fe 2643	Northward	12	928	Main	8.30 a.m.	9:50 a.m.
Missouri Pacific 160	Northward	118	5,390	Siding	9:25 a.m.	9.37 a.m.
Santa Fe 2641-S-1**	Northward	5	244	Siding	9:28 a.m.	9:42 a.m.
Santa Fe 2645-R-1	Northward	83	9,358	Siding	9:49 a.m.	10:32 a.m.
Santa Fe 591-S-1	Southward	37	2,171	Main	10:27 a.m.	10:24 a.m.
Santa Fe 2642-S-1	Southward	9	720	Main	12:48 p.m.	12:26 p.m.
Santa Fe 2649-S-1	Northward	9	901	Main	12:57 p.m.	1:00 p.m.
Missouri Pacific 94	Northward	82	6,410	Main	1:44 p.m.	--------

*Manned by the crew that subsequently operated train Missouri Pacific 94 northward

**Manned by the crew that subsequently operated train Santa Fe 2642-S-1 southward

CONSIST OF MISSOURI PACIFIC TRAIN 94 ON OCTOBER 19, 1971

Car Position	Car Number	Contents	Origin	Gross Weight (lbs)	Car Length (Between Pulling Surfaces)
Locomotive	Unit 922		Houston	235,800	50’8”
Locomotive	Unit 1158		Angleton	247,580	44’5”
Locomotive	Unit 1143		Angleton	248,760	44’5”
Locomotive	Unit 1150		Angleton	248,760	44’5”
1	GTTX 301400	Merchandise	Freeport	170,200	88’5”
2	DOWX 73504	Chemicals	Freeport	169,200	50’9”
3	TP 710531	Sulfur	Freeport	262,100	53’10”
4	MI 714393	Sulfur	Freeport	250,100	58’3”
5	TP 710551	Sulfur	Freeport	254,400	53’10”
6	ACFX 89670	Empty	Freeport	42,200	44’9½”
7	ACFX 63723	Sulfur	Freeport	260,900	45’9”
8	TLDX 7772	Sulfur	Freeport	269,800	50’7”
9	TLDX 7842	Sulfur	Freeport	266,100	50’7”
10	TLDX 7728	Sulfur	Freeport	281,800	50’7”
11	DOWX 4758	Caustic Soda	Freeport	175,300	31’8”
12	DOWX 4772	Caustic Soda	Freeport	176,100	31’8”
13	GATX 13392	Styrene	Freeport	259,504	58’9”
14	PPGX 6911	Caustic Soda	Freeport	196,580	40’2”
15	GATX 11574	Chemicals	Freeport	490,700	67’8”
16	GATX 82097	Chemicals	Freeport	257,280	39’5”
17	GATX 63981	Chemicals	Freeport	197,040	37’3”
18	GATX 75536	Chemicals	Freeport	143,800	42’3”
19	DOWX 4776	Caustic Soda	Freeport	171,700	31’8”
20	RTMX 1018	Acid	Freeport	144,800	38’7”
21	GATX 67750	Fuel Oil	Freeport	136,506	45’9”
22	UTLX 82107	Fuel Oil	Freeport	129,415	46’3”
23	UTLX 82547	LP Gas	Freeport	236,992	66’2½”
24	GATX 77987	Fuel Oil	Freeport	134,506	42’3”
25	UTLX 82127	Fuel Oil	Freeport	127,977	46’3”
26	GATX 72591	Fuel Oil	Freeport	134,018	42’3”
27	GATX 80452	Fuel Oil	Freeport	134,980	42’3”
28	NATX 25019	Empty	Freeport	47,300	40’0”
29	MP 602338	Scrap Metal	Freeport	97,200	48’9”
30	MP 611380	Scrap Metal	Freeport	134,500	56’3”
31	MI 640241	Scrap Metal	Freeport	123,600	56’9”
32	MP 602006	Scrap Metal	Freeport	91,900	48’9”
33	NATX 25018	Empty	Freeport	44,000	40’0”
34	NATX 25020	Empty	Freeport	44,200	40’0”
35	MP 705109	Empty	Freeport	59,800	48’5”
36	MP 705249	Empty	Freeport	59,000	48’5”
37	PC 887283	Empty	Freeport	65,700	55’6”
38	AT 308280	Empty	Freeport	61,900	53’3”
39	TP 710980	Empty	Freeport	62,200	53’10”
40	MP 703350	Empty	Freeport	59,500	48’5”
41	SHPX 1199	Empty	Freeport	55,400	38’6”

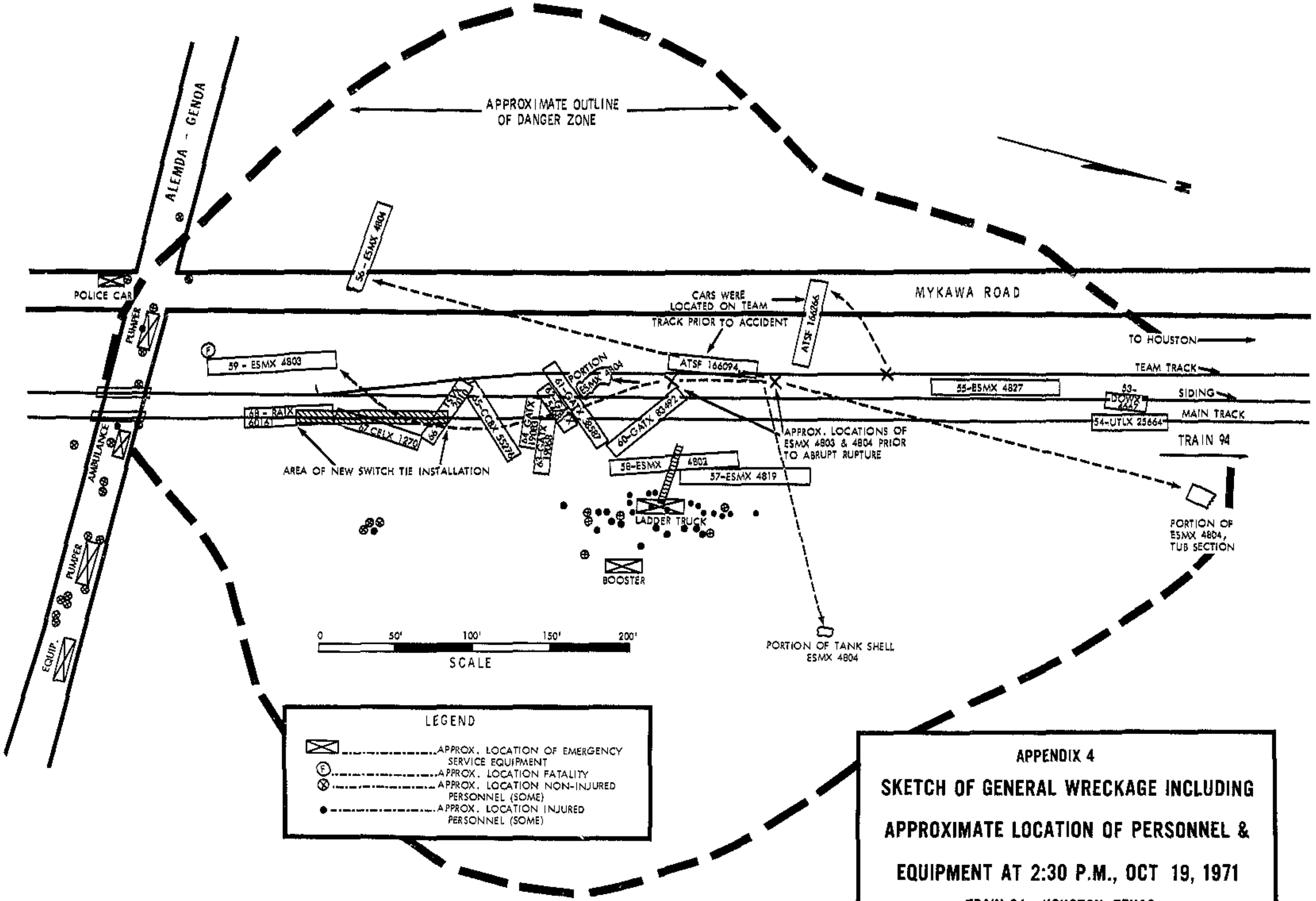
CONSIST OF MISSOURI PACIFIC TRAIN 94 ON OCTOBER 19, 1971

Car Position	Car Number	Contents	Origin	Gross Weight (lbs)	Car Length (Between Pulling Surfaces)
42	CCIX 1158	Empty	Freeport	55,500	31’7”
43	NATX 25015	Empty	Freeport	44,400	40’0”
44	NATX 25024	Empty	Freeport	44,100	40’0”
45	NATX 25017	Empty	Freeport	44,200	40’0”
46	NATX 22791	Fuel Oil	Freeport	212,941	54’10”
47	NATX 22792	Fuel Oil	Freeport	214,103	54’10”
48	UTLX 98255	Empty	Freeport	90,300	67’5½”
49	UTLX 89821	Empty	Freeport	90,800	67’5½”
50	GATX 11057	Styrene	Freeport	259,400	59’4”
51	NKP 81576	Chemicals	Freeport	129,400	57’10”
52	CEI 256545	Chemicals	Freeport	161,300	54’4”
53	DOWX 4667	Caustic Soda	Freeport	174,500	31’9”
54	UTLX 25664	Empty	Freeport	66,600	47’0”
55	ESMX 4827	Vinyl Chloride	Freeport	495,770	90’10”
56	ESMX 4804	Vinyl Chloride	Freeport	497,020	90’10”
57	ESMX 4819	Vinyl Chloride	Freeport	497,480	90’10”
58	ESMX 4802	Vinyl Chloride	Freeport	496,900	90’10”
59	ESMX 4803	Vinyl Chloride	Freeport	497,920	90’10”
60	GATX 83492	Vinyl Chloride	Freeport	239,600	64’8”
61	GATX 38587	Butadiene	Freeport	257,891	65’9”
62	GATX 54681	Fuel Oil	Freeport	98,431	40’3”
63	GATX 19068	Fuel Oil	Freeport	100,459	40’4”
64	GATX 19083	Fuel Oil	Freeport	100,512	40’4”
65	CCBX 55276	Plastic	North Seadrift	246,000	54’8”
66	TSVX 2010	Acetone	Bishop	193,770	50’5”
67	CELX 1270	Formaldehyde	Bishop	257,360	60’11”
68	RAIX 60161	Plastic	North Seadrift	238,400	58’3”
69	DUPX 35475	Plastic	Bloomington	197,400	53’2”
70	GATX 24259	Dichloro Butene	Bloomington	162,500	41’1”
71	GATX 24243	Dichloro Butene	Bloomington	163,800	42’3”
72	NW 297066	Empty	Corpus Christi	81,000	59’4”
73	MP 786199	Empty	Corpus Christi	74,600	59’3”
74	DUPX 21039	Empty	Bloomington	91,300	66’10”
75	JTTX 477154	Plastic	North Seadrift	187,720	88’5”
76	JTTX 100812	Plastic	North Seadrift	176,310	88’5”
77	JTTX 477133	Plastic	North Seadrift	162,320	88’5”
78	JTTX 100810	Plastic	North Seadrift	169,580	88’5”
79	JTTX 100805	Plastic	North Seadrift	154,180	88’5”
80	JTTX 100682	Plastic	North Seadrift	175,560	88’5”
81	CCBX 54015	Plastic	North Seadrift	161,700	47’1”
82	TP 13522	Caboose	Kingsville	52,300	41’7”

DERAILED TANK CARS IN MISSOURI PACIFIC TRAIN 94 ON OCTOBER 19, 1971

Car Position In Train	Car Number	Car Classification	Contents	Capacity (Gallons)	Hazardous Commodity Classification
53	DOWX 4667	111A100W1	Caustic Soda*	10,000	Corrosive
54	UTLX 25664	111A100W3	Empty	20,000	
55	ESMX 4827	114A340W**	Vinyl Chloride*	48,100	Flammable Compressed Gas
56	ESMX 4804	114A340W**	Vinyl Chloride*	48,100	Flammable Compressed Gas
57	ESMX 4819	114A340W**	Vinyl Chloride*	48,100	Flammable Compressed Gas
58	ESMX 4802	114A340W**	Vinyl Chloride*	48,100	Flammable Compressed Gas
59	ESMX 4803	104A340W**	Vinyl Chloride*	48,100	Flammable Compressed Gas
60	GATX 83492	105A300W	Vinyl Chloride*	20,800	Flammable Compressed Gas
61	GATX 38587	112A400W***	Butadiene*	33,500	Flammable Compressed Gas
62	GATX 54681	103W	Fuel Oil	8,100	Not Regulated
63	GATX 19068	111A100W	Fuel Oil	8,000	Not Regulated
64	GATX 19083	111A100W	Fuel Oil	8,000	Not Regulated
66	TSVX 2010	111A100W1	Acetone*	20,800	Flammable Liquid
67	CELX 1270	111A60ALW	Formaldehyde	21,100	Not Regulated

* Car carried "DANGEROUS" placards
** DOT Special Permit 5882
***DOT Special Permit 5745.



APPENDIX 4

SKETCH OF GENERAL WRECKAGE INCLUDING APPROXIMATE LOCATION OF PERSONNEL & EQUIPMENT AT 2:30 P.M., OCT 19, 1971

TRAIN 94 - HOUSTON, TEXAS

The sequence of events described on the following pages are excerpts from a report prepared by Mr. C.E Reedy, a member of the RPI-AAR Railroad Tank Car Safety Research staff. The Safety Board gratefully acknowledges the contributions made by Mr Reedy to this investigation

The entire report of Mr. Reedy's investigation is available from:

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RAILROAD TANK CAR SAFETY RESEARCH AND TEST PROJECT AN RPI-AAR COOPERATIVE PROGRAM

PROJECT DIRECTOR
Earl Phillips

DEPUTY PROJECT DIRECTOR
Lee Olson

RA-01-3-9
Phase 01 Report on
Sequence of Events Following Houston, Texas, Derailment

(10/19/71)

* * * *

III THE SEQUENCE OF EVENTS

The sequence of events is described in the following with reference to the attached sketches.

1:45 p.m. (approximately) SKETCH NO 1

Cars #53 and #54 continued from the point of derailment for a distance of approximately 700 feet At the conclusion of the derailment, car #53 had changed direction of travel and rolled westward 90° blocking the passing track on the west, and one set of trucks stayed on the main track roadbed ahead of car #54 Empty tank car #54 remained in-line and in an upright position on the main line roadbed The action of cars #52 and #54 destroyed the running track for the trailing 14 cars.

The five cars following empty tank car #54 were all class DOT 114A340W, 48,300 gallons capacity, tank cars of 200 ton span bolster design and loaded with vinyl chloride, a flammable liquefied compressed gas.

These five derailed span bolster cars #55 thru #59 traveled in a general straight line paralleling the main tracks and remained in a north-south orientation Separate action of each of the 48,300 gallon cars is tabled below:

Car No Position	Distance Traveled from "Point-of-Derailment"	Car No	Action of Car
55	505 feet	ESMX 4827	Tank rolled 180° westward stopping upside down on its manway between passing and team tracks. No leaks

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*Note: This is an approximate point-of-derailment point since RPI-AAR program is not charged with establishing the exact point of derailment

Car No. Position	Distance Traveled from "Point-of-Derailment"	Car No.	Action of Car
56	410 feet	ESMX 4804	Tank rolled 135° westward over passing track, striking against side of company gondola car ATSF 166266 on team track Tank sustained a small 3½" x 5/16" shell puncture on initial impact. Vinyl chloride was released and a fire started immediately.
57	350 feet	ESMX 4819	Tank rolled 100° eastward of main line tracks into shallow ditch area. "B" head of tank received a blow from tank car #58 causing the tank to roll in a further eastward direction Head dent size was 36" dia. x 8" deep No leaks
58	300 feet	ESMX 4802	Tank rolled 180° eastward and parallel with main tracks, stopping in a shallow ditch area beside tank car #57 Leading "B" head was dented when it struck car #57 Dent in head was near end of tank shell and 18" to 20" wide x 8" deep No leaks.
59	300 feet	ESMX 4803	Tank rolled westward over passing tracks striking south end and side of company gondola ATSF 166094, derailing same. Tank shell and head sustained deep spiral dents ending near center of tank. At the top and bottom of the deep end of the dent the tank plate fractured in two places sufficiently to allow the escape of approximately 35,000 gallons of liquid vinyl chloride in thirty five minutes The greatest quantity was lost after the initial impact before tank pressure was lowered.

The fire ensuing after the derailment involved tank cars #56, #59, and the two parked ATSF gondola cars loaded with company materials.

The other tank cars and two covered hopper cars, #60 thru #68, derailed in the manner shown in the attached sketches. Tank #62 containing petroleum fuel oil distillate was leaking slightly from its dome fittings which were loosened when car #62 rolled 90° into the side of car #61, striking its dome against the car side.

2:20 p.m. (approximately)
Photos by the Houston Chronicle show the fire from car #59 to be nearly under control and probably soon to be extinguished.

2:30 p.m. (approximately SKETCH NO. 2

Flames of the fire from the small shell fracture of car #56 were confined to an area between it and car ATSF 166266 where flame impingement produced a torch like action on the tank shell causing an overheated area.

At a time probably five to eight minutes before 2:30 p.m. the interior of the tank at the torched shell area became exposed to gas vapor just above the receding liquid vinyl chloride wetted surface*. Overheating of the dry surface lowered the steel strength and led to thinning of the steel shell and finally tank rupture. The violent rupture of the tank shell released the remaining more than half tank of liquid vinyl chloride.

Several events happened almost simultaneously in the following order:

(1) Violent rupture of tank car #56 accompanied by a corresponding fireball.

(2) Re-ignition of the vinyl chloride and air mixture in near empty tank #59 (a small pool of cold vinyl chloride still remained in the lower position of shell).

(3) Sudden internal pressure rise of near empty car #59 produced a 180° circumferential rupture of the car tank. Rapid internal burning of the remaining vinyl chloride exhausting flame through the newly created rupture hurled the complete damaged tank into a short trajectory.

(4) A tub section of car #56 was hurled northeastward. A separate shell piece 70" x 90" was also hurled eastward.

(5) The major shell section of car #56 was hurled southwestward. An approximate two sheet shell section was separated adjacent to the tub, opened longitudinally, flattened and projected southward against car #61.

2:30 p.m. plus

Car #59, having descended from its short trajectory, landed on cars #65 and #66. Car #65, a covered hopper car filled with plastic pellets, had its top sheet "B" end torn open exposing product, but no fire resulted. The full impact of descending tank car #59 was received on the top of tank car

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*Note - Calculation of liquid vinyl chloride discharge through a 3½" x 5/16" hole confirms approximately the time of this liquid level recession, see attached calculation sheets 1 and 2.

#66 (TSVX 2010) The "B" head of car #59 dented the entire top shell of car #66 leaving a 100" long gaping hole between the dome fittings and the "B" head Acetone released by this impact tear was ignited from burning vinyl chloride gas in the descending tank #59

Tank #59 turned end over in its continued fall, finally rolling westward over the passing track near Almeda-Genoa road, coming to rest with dome in a 225° rotation. The rotation in degrees relates to the tank in its original 135° position beside company ATSF gondola car 166094 (prior to 2:30 p m)

Respectfully submitted,

/s/ C.E Reedy, Project Engineer

APPROVED:

/s/ Earl A. Phillips
Project Director