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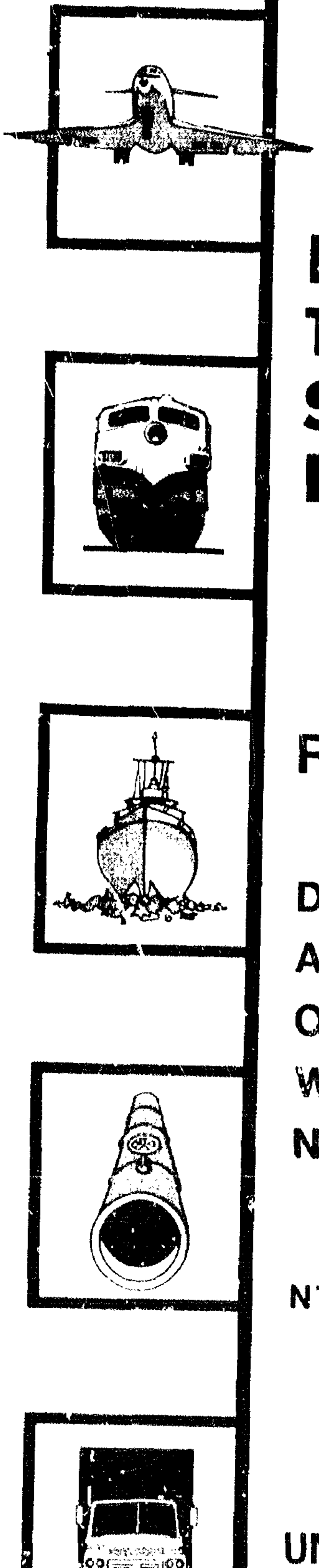

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

DERAILMENT OF AMTRAK TRAIN NO. 21 (THE EAGLE) ON THE MISSOURI PACIFIC RAILROAD WOODLAWN, TEXAS NOVEMBER 12, 1983

NTSB/RAR-85/01

UNITED STATES GOVERNMENT

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16. Abstract About 10:09 a.m. on November 12, 1983, Amtrak train No. 21 (The Eagle), with 162 persons aboard, derailed near Woodlawn, Texas, while traveling at 72 mph on the Missouri Pacific Railroad. The train was traveling westbound on the single main track when it passed over a section of rail that a repair crew had just installed to replace a broken rail. The break had occurred at a field weld in a length of new continuous-welded, 136-lb RE section, chrome-vanadium alloy, high-strength, vacuum-treated rail, which had been installed in the track about 1 month earlier. The temporary repair consisted of removing a length of the outer rail in a curve and replacing it with a 19-foot 6-inch length of rail bolted in place. The repair insert was a section of used, 136-lb RE section, standard-carbon rail. The repair crew used an oxyacetylene torch to cut both the new alloy rail and the used standard-carbon rail during the repair. The accident resulted in 4 passenger fatalities and 72 injuries.

The National Transportation Safety Board determines that the probable cause of this accident was torch-cutting a chrome-vanadium alloy rail in a track curve while making a temporary track repair, precipitating thermal cracks that served as the origin points for a catastrophic rail failure when a high-speed passenger train passed over. Contributing to the accident was the failure of the Missouri Pacific Railroad to train its maintenance-of-way department employees adequately in the requirements necessary to their positions, and of its management to monitor adherence to its maintenance-of-way rules and procedures and Federal regulations regarding minimum track safety standards.

17. Key Words torch-cut rail; alloy rail; thermal crack; web fracture; fracture toughness; notch sensitivity; metallurgy; ductility; brittleness; crack origin; stress raiser; slow-order; procedures; training; overhead baggage; disaster plan.

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Adopted: February 4, 1985

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SYNOPSIS

About 10:09 a.m. on November 12, 1983, Amtrak train No. 21 (The Eagle), with 162 persons aboard, derailed near Woodlawn, Texas, while traveling at 72 mph on the Missouri Pacific Railroad. The train was traveling westbound on the single main track when it passed over a section of rail that a repair crew had just installed to replace a broken rail. The break had occurred at a field weld in a length of new, continuous-welded, 136-lb RE section, chrome-vanadium alloy, high-strength, vacuum-treated rail, which had been installed in the track about 1 month earlier. The temporary repair consisted of removing a length of the outer rail in a curve and replacing it with a 19-foot 6-inch length of rail bolted in place. The repair insert was a section of used, 136-lb RE section, standard-carbon rail. The repair crew used an oxyacetylene torch to cut both the new alloy rail and the used standard-carbon rail during the repair. The accident resulted in 4 passenger fatalities and 72 injuries. Damage was estimated to be more than $2,180,000.

The National Transportation Safety Board determines that the probable cause of this accident was torch-cutting a chrome-vanadium alloy rail in a track curve while making a temporary track repair, precipitating thermal cracks that served as the origin points for a catastrophic rail failure when a high-speed passenger train passed over. Contributing to the accident was the failure of the Missouri Pacific Railroad to train its maintenance-of-way department employees adequately in the requirements necessary to their positions, and of its management to monitor adherence to its maintenance-of-way rules and procedures and Federal regulations regarding minimum track safety standards.

INVESTIGATION

The Accident

On November 12, 1983, a Missouri Pacific (MP) Railroad Company dispatcher instructed a track inspector to inspect the main track at Woodlawn, Texas, because the track light 1/ on his dispatching console was indicating a disruption of the signal circuit through the track. About 6:42 a.m., 2/ the track inspector informed the MP dispatcher by

1/ Track light is a term referring to a track signal circuit detector light on the dispatcher's console.
2/ All times hereinafter are central standard time.

radio of a broken field weld 3/ near milepost 55.6. The track inspector said that there was about a 3 1/2-inch separation between the fracture faces. The broken field weld had resulted in the disruption of the signal circuit. The track inspector immediately ordered the track between Jefferson, Texas, and Woodlawn removed from service and departed for Marshall, Texas, to arrange for repair to the track. (See figure 1.)

While en route to Marshall, the track inspector contacted an on-duty MP welder by radio and instructed the welder to meet him in Marshall. At Marshall, he telephoned the track foreman, who in turn called a track laborer. They gathered the tools to be used to perform the repairs, including oxygen and acetylene tanks and torches; a rail saw was not included because the available saw was broken, according to the track foreman. 4/ The repair crew left Marshall and arrived at the work site shortly before 9 a.m. Between 9 a.m. and 9:30 a.m., the welder, using an oxyacetylene torch, made two torch-cuts in the rail on either side of the broken field weld, leaving a gap in the rail approximately 19 feet 6 inches long. The 136-lb RE section, 5/ chrome-vanadium alloy, high-strength, vacuum-treated rail had been installed as continuous-welded-rail (CWR). The track inspector said that at the time he was not aware whether the alloy rail had characteristics different from those of standard-carbon rail. The welder then torch-cut a section of rail approximately 19 feet 6 inches long from a length of 136-lb RE section, standard-carbon, CWR that was lying along the right-of-way; the length of rail had been left there after it was removed from the track in October 1983 when the alloy rail was installed. The repair crew laid the insert of standard-carbon rail into the gap in the alloy CWR and proceeded to drill bolt holes and apply joint bars.

About 9:13 a.m., while the repair work was still in progress, the track inspector contacted the dispatcher and placed the track back in service. At that time the standard-carbon rail insert was fastened into the alloy CWR with one bolt in each end of the insert and one bolt in each end of the alloy CWR. About 9:30 a.m., a 5,995-foot-long freight train, consisting of 2 six-axle locomotive units, 53 loaded cars, and 45 empty cars, with a trailing tonnage of 6,354 tons, was allowed to pass over the incomplete repair at an unrestricted speed of 50 mph. About 9:40 a.m., the track inspector informed the dispatcher that the freight train had passed and requested that the track be removed from service so that further work on the repair could be completed. The repair crew then drilled one additional hole in each end of the insert and applied a bolt in each hole. At that point, the insert was fastened with two bolts in each end of the insert, and one bolt in each end of the alloy CWR.

About 9:53 a.m., the track inspector contacted the dispatcher and placed the track back in service. An MP roadmaster, who was sent by the MP division superintendent to help expedite train movements through the area, soon arrived at the work site. The roadmaster said that he told the track inspector that the MP had directives concerning cutting rail with a torch, as outlined in instructions issued by the MP's chief engineer's office. The roadmaster said that the track inspector replied that their track saw was broken. The roadmaster said that he and the track inspector discussed placing a slow order on the track at the repair site, but did not do so because they considered the track to be safe.

3/ Field welds are those welds performed at the installation site to connect strings of continuous-welded-rail.

4/ MP officials informed the Safety Board that the rail saw in question was used during track reconstruction after the accident. It was not determined if the rail saw was, in fact, inoperable on the morning of November 12, 1983.

5/ 136-lb RE section refers to rail which nominally weighs 136 pounds per linear yard and is a standard rail section recommended for use by the American Railway Engineering Association.

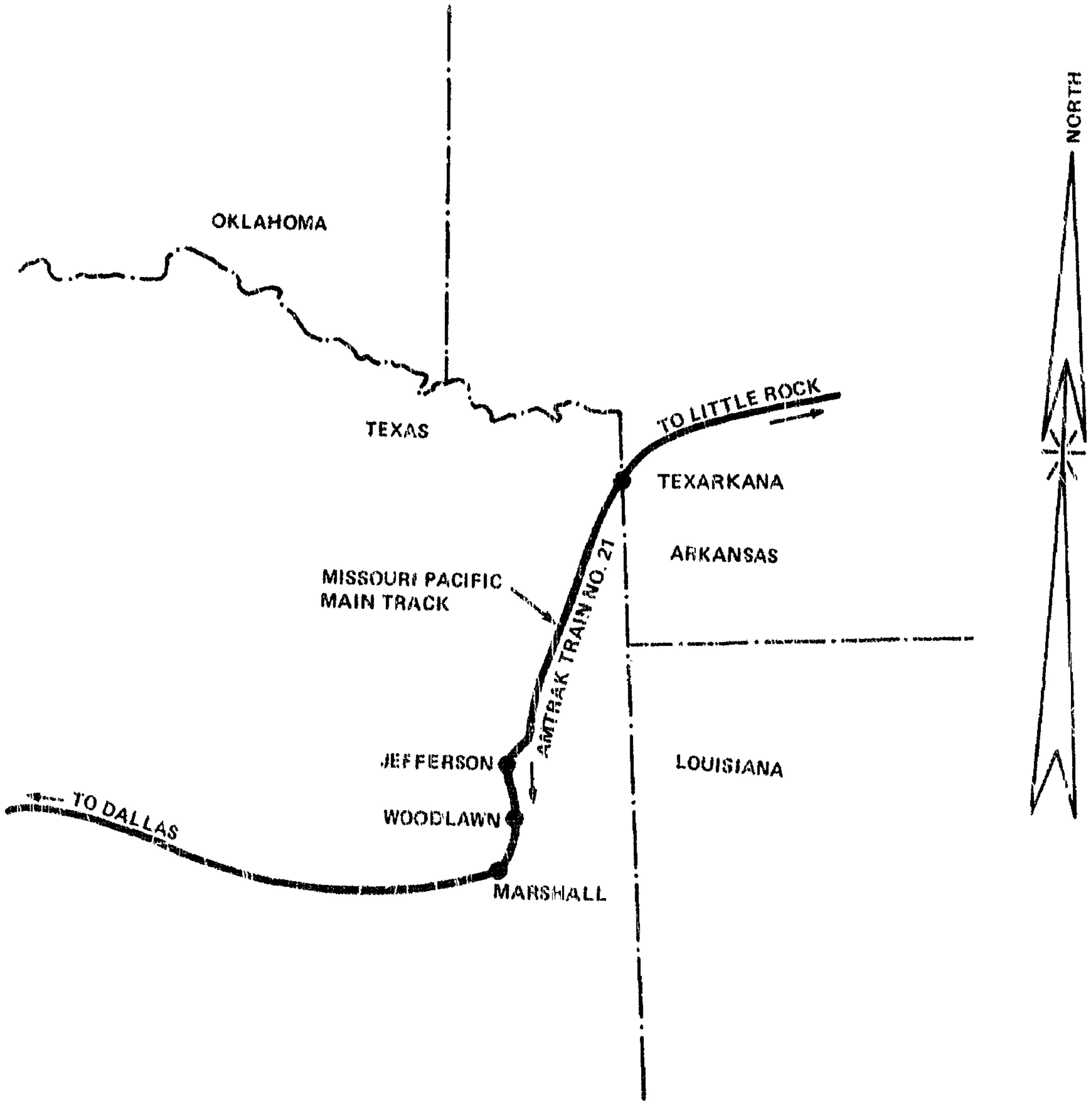

Figure 1.--Route of Amtrak train No. 21.

Meanwhile, National Railroad Passenger Corporation (Amtrak) train No. 21 (The Eagle) had departed Texarkana, Texas, about 9:20 a.m., westbound en route to Dallas, Texas, with 145 passengers and 17 crewmembers onboard. No defective conditions were noted by the crew in the air brake system or equipment upon departure. The train consisted of, in order, two locomotive units, one baggage car, one sleeping car, one dormitory car, one sleeping car, one lounge car, two coach cars, one diner car, and one coach car.

About 10:09 a.m., the train approached the track repair site at milepost 55.6 at a speed of 72 mph (according to the locomotive's speed recorder tape). The fireman, who was also a qualified locomotive engineer, was operating the train, and the engineer was in the fireman's seat. The fireman and engineer said that they saw the members of the track repair crew standing to either side of the track near a wayside signal for eastbound trains. The train was emerging from a 1-degree 24-minute curve to the left and entering onto a 400-foot-long exit spiral from that curve. Immediately after passing a wayside signal, the train's automatic air brake unexpectedly applied in emergency. After the train came to a stop, the crew found that the rear truck of the first sleeping car and the remaining seven cars of the train were derailed. The first coach car was tilted about 30 degrees, and the diner car and the two remaining coach cars were turned on their sides. Although all of the train remained coupled, the cars diverged outward from the track with the degree of divergence being greatest toward the rear of the train. (See figure 2.) The head-end crew and the roadmaster radioed the dispatcher to summon emergency response personnel. Of the 162 persons onboard the train, 4 passengers were killed, and 25 persons were hospitalized.

Injuries to Persons

Injuries	Crewmembers	Passengers	Other	Total
Fatal	0	4	0	4
Hospitalized	2	23	0	25
Minor/None	16	117	0	133
Total	18	144	0	162

Damage

The two locomotive units and the baggage car were undamaged. The rear truck of the first sleeping car received superficial damage. The dormitory car received moderate underside and truck damage, as did the following sleeping car. The lounge car received extensive damage to its underside, trucks, and electrical components, as did the following coach car. The diner car and remaining two coach cars received extensive damage to their undersides, trucks, and electrical components; the sides and roofs of these cars were extensively damaged and the car interiors were moderately damaged as they slid on their sides after overturning. (See figure 3.)

Initial onsite examination of the chrome-vanadium alloy rail indicated the presence of a small crack in the web of the rail at a discontinuity in the torch-cut face near where the alloy rail was bolted to the south end of the standard-carbon insert. The break appeared to extend from that discontinuity through the web a distance of about 6 feet. Within the next 34 feet approximately, the rail was broken into between 50 and 100 pieces of various size.

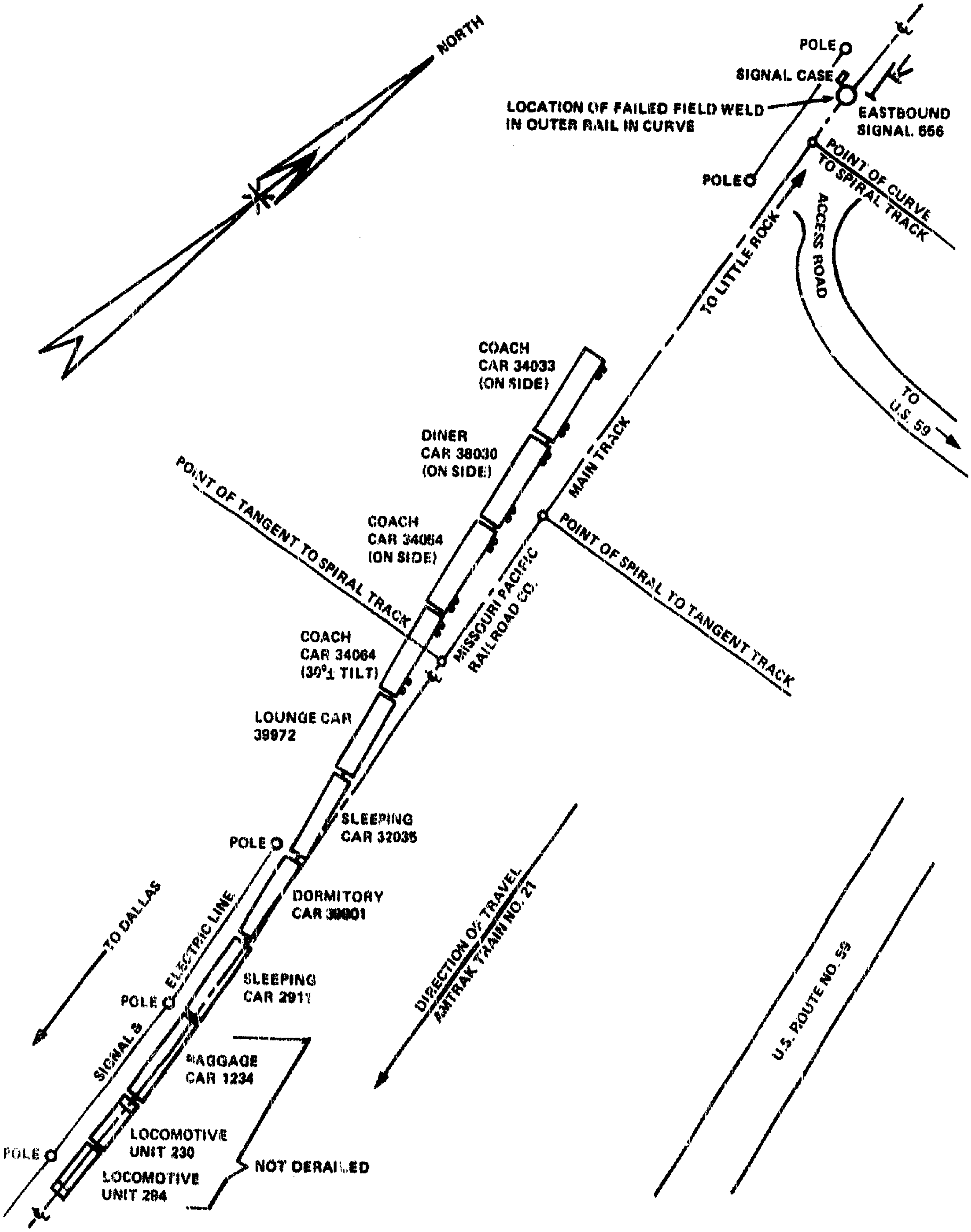

Figure 2.--Plan view of accident site.

Figure 3.--Aerial view of Amtrak train No. 21.

About 700 feet of single main track and roadbed was destroyed in the accident. The signal system track circuit and an adjacent signal and electric pole line were damaged. Damage was estimated to be as follows:

Equipment	$2,111,500
Track	10,500
Signals	200
Wreck clearing	64,082
Total	$2,186,282

Personnel Information

The engineer and fireman of Amtrak train No. 21 were both qualified by the MP as locomotive engineers. The conductor and both brakemen were qualified by the MP for their respective positions. All of the operating crewmembers of Amtrak train No. 21 reported for duty at 8:50 a.m., at Texarkana, to operate the train to Dallas. They were all current on MP operating rules. (See appendix B.)

The site of the broken field weld was part of the track inspector's assigned inspection territory. The track inspector had worked for the MP since 1969 and became a track inspector on September 16, 1983, after attending a 1-week-long MP track inspection school. He stated that it was a common practice to cut rail with a torch on the MP, and that he was unaware of any instructions having been issued regarding that practice. He had not arranged for the presence of a signal maintainer at the work site although the site was signalized.

The site of the broken field weld was not part of the track foreman's and track laborer's assigned maintenance territory. The track inspector called them because they lived closer to the work site than the assigned workers. The track foreman stated that he had been a track foreman for the last 15 years of his 20 years of employment with the MP. The track laborer had been employed by the MP for approximately 29 years. The welder was initially employed by the MP as a track laborer and became a welder in 1979 after attending a 1-week-long MP school for welders.

The roadmaster regularly supervised an adjacent territory. On November 12, 1983, in addition to his own territory, the roadmaster was covering the adjacent territory that included Woodlawn for a roadmaster who was off duty for the weekend. The roadmaster stated that he was informed about 7:05 a.m. of the broken field weld and that a maintenance crew was taking care of the repair. He had been a roadmaster since January 1977 and had attended a 2-week-long MP supervisor school in 1981.

The roadmaster, track inspector, track foreman, and welder were all current on MP regulations for maintenance of way and structures and were qualified for their respective positions in accordance with MP requirements. Testing is performed on a biennial basis by the MP. (See appendix B.) According to MP requirements, it was not necessary for the track laborer to be tested on MP regulations for maintenance of way and structures.

Train Information

The locomotive of Amtrak train No. 21 consisted of two diesel-electric, model F40PH, 3,000-horsepower locomotive units, manufactured by the Electromotive Division of General Motors Corporation. The locomotive units were equipped with operable radio, 26-L air brake system, blended air and dynamic brake, speed indicator, alertness device, and a tape speed recorder. The single-level baggage car and first sleeping car, as well as the remaining bi-level passenger cars, were stainless steel cars manufactured by Pullman Standard, Inc.

The traincrew had operable portable radios which could be used to communicate within the train, between trains, and between the train and the dispatcher or other wayside locations.

Method of Operation

Trains are operated through Woodlawn by timetable, special instructions, train orders, and signal indications of signals of a centralized traffic control (CTC) system. The maximum allowable speed at the accident location was 75 mph for passenger trains and 60 mph for freight trains. According to the MP, 4 passenger trains and 135 freight trains were operated through Woodlawn in the 7-day period preceding the accident.

Passenger trains are operated over the MP by contractual agreement between Amtrak and the MP. According to the MP, the contractual agreement provides for a financial incentive in the form of a bonus for on-time performance. When Safety Board investigators asked the division superintendent after the accident if the MP operations stressed avoiding delays to Amtrak trains, he replied, "I would say that we want to run Amtrak on an on-time basis." On the day of the accident, Amtrak train No. 21 had been scheduled to arrive at Marshall at 9:31 a.m.; the accident site was approximately 10.7 miles from the station at Marshall. The train was approximately 40 minutes behind schedule at this time.

Conditions requiring track to be restricted or removed from service are communicated from the specific site location by track inspectors, track foremen, or roadmasters to the dispatcher by means of radio or wayside telephone locations. A restriction and time limit for correcting the conditions are established, and the dispatcher enters the appropriate restriction to train traffic and the anticipated time limit of the restriction in the dispatching console.

Rule No. 255 of the Rules and Regulations for the Maintenance of Way and Structures of the MP states:

> Notice to Signalmen.--When doing any class of work which may change adjustments, disturb or interfere with the operation of signal apparatus in any manner, Signalman must be advised in advance, if possible, so he can cooperate in the work.

Track Information

The main track through the Woodlawn area was constructed of 136-lb RE section CWR. The rail was laid in double-shouldered tieplates atop 7-inch by 9-inch by 8-foot 6-inch-long, treated, mixed hardwood crossties. The crossties were laid in crushed granite ballast with compacted full tie cribs. 6/ The ballast extended 8 inches below the crosstie bottoms and more than 12 inches beyond the ends of the crossties. The CWR was fastened by two rail-holding and two plate-holding spikes in each tieplate. The CWR normally was anchored on both sides of alternate crossties; where prefabricated bonded

6/ A tie crib is that space between two adjacent crossties in a railroad track.

insulated joint assemblies 7/ were field-welded into the track structure, the CWR was anchored on both sides of each crosstie for a distance of 200 feet on either side of the assembly. The field weld at the south end (geographic direction) of the insulated joint assembly in the outer rail of the curve (geographic west) was the failed field weld which precipitated the repair work being performed on November 12, 1983. Visual inspection of the failed field weld revealed a slag inclusion located at the base of the rail.

The rail in the insulated joint assembly was 133-lb RE section, chrome-molybdenum alloy rail manufactured by Colorado Fuel and Iron Steel Corp. The CWR into which the insulated field joint assembly had been field welded was new, 136-lb RE section, chrome-vanadium alloy, high-strength, vacuum-treated rail manufactured by Krupp Stahl Company, one of a consortium of steel manufacturers located in the Federal Republic of Germany. The new CWR was installed through the Woodlawn area on October 20, 1983, and was adjusted for operational temperature differentials by means of a hydraulic rail stretcher. The chrome-vanadium alloy rail was being installed in curved track locations because, according to the MP,

> . . . the standard AREA [American Railway Engineering Association] specification has been used by the Missouri Pacific for purchasing steel rail. Chrome-molybdenum and chrome-vanadium rail has been used by other railroads successfully to reduce rail wear in curved track. Therefore, the decision was made to use chrome-vanadium from Krupp Steel on our railroad.

The MP's chief engineer stated that the chrome-vanadium alloy rail also was being used for stock rails 8/ in track switches, and that the stock rails were being bent into the necessary curvature to conform to the track switch assembly.

The specifications, including chemical composition, for standard steel rail are set forth in Chapter 4--Rail, Part 2, Specifications For Steel Rails of the AREA Manual for Railway Engineering. With regard to alloy rail, the manual states in Chapter 4, Part 2, Paragraph 3.2, "The chemical composition of alloy high strength rail will be subject to the agreement of the purchaser and manufacturer." Other portions of the specifications for steel rails apply in a generic sense to the alloy rail. (See appendix C). The purchase order for the rail involved in this accident stated that the rail should be manufactured ". . . in accordance with AREA specifications . . ." and directed the supplier to ". . . state the chemical composition . . ." of the rail. (See appendix D.) The information supplied by the manufacturer of the rail, established at the time of manufacture from a test specimen, was as follows for the particular heat 9/ from which the rail involved in the derailment was made:

7/ Those insulated joint bar assemblies in which the joint bars are permanently attached to the rail using high-strength structural adhesives.
8/ A stock rail is the running rail against which the switch point abuts.
9/ A heat is that amount of steel produced from a furnace from one charge of raw material.

Heat	Yieldpoint*	Tensile strength*	Elongation**	Chemical Analysis	Brinell Hardness
80	108,500	174,700	11.0	0.78% Carbon 0.72% Silicon 1.15% Manganese 0.019% Phosphorous 0.023% Sulfur 0.97% Chromium 0.08% Vanadium	343

*expressed in pounds per square inch.
**percentage of elongation in inches per 2-inch gage length; the specification called for a minimum elongation of 9 percent.

The track alignment design through the accident area is a 1-degree 24-minute curve to the left, proceeding into a 400-foot-long exit spiral before a 157.4-foot-long tangent. The track then proceeds into a 2-degree 4-minute curve to the right. At the point of the derailment, the track is on a level grade. The track, other than the immediate portion under repair, met or exceeded the minimum standards of the Federal Railroad Administration (FRA) track safety standards for class 4 10/ track.

Section 213.121(e) of the FRA's track safety standards as set forth in Part 49 of the Code of Federal Regulations (CFR) states:

> In the case of continuous welded rail track, each rail must be bolted with at least two bolts at each joint.

On November 12, 1983, the FRA issued a report of violation of Section 213.121(e) against the MP, because of the lack of a minimum number of track bolts in the repair insert joints.

Section 213.121(g) states:

> No rail or angle bar having a torch cut or burned bolt hole may be used in classes 3 through 6 track.

Instruction No. CE-237-T of the MP's Chief Engineer's Instructions dated May 23, 1978, in effect at the time of the accident, states:

> Rails may be cut with a saw, nicked with a chisel and broken, or cut with a torch. Rails cut by a torch must be re-cut with a saw.
>
> Except in emergencies or under special conditions, all rails will be cut with a saw. Those rails cut with a torch will have a 10 mph slow order until the rails are replaced.
>
> Under no circumstances will the bolt holes be installed with a torch. All bolt holes will be drilled.

10/ According to 49 CFR 213.9, "Classes of track; operating speed limits," Class 4 track prescribes a maximum allowable operating speed of 80 mph for passenger trains and 60 mph for freight trains.

The MP's chief engineer stated to Safety Board investigators that Instruction No. CE-237-T was revised following the accident to prohibit the use of a track chisel to cut rail and to emphasize that a torch should be used to cut rail only in an emergency.

The track inspector, track foreman, and the welder each agreed that it was a standard practice to torch-cut rail on the MP. They said that no one in any of the training schools they attended for the MP had instructed them that the Chief Engineer's Instructions prohibited torch-cutting rail except in emergency situations. They also stated that they were not aware of any requirement to impose a speed restriction when rail was torch-cut or of any requirement to install two bolts in each rail end in the joints. The roadmaster stated that he was aware of the chief engineer's instruction on not cutting rail with a torch, but was unaware of the requirement for a speed restriction.

All of those present at the site just before the accident stated that the new chrome-vanadium alloy CWR exceeded the height of the worn standard-carbon insert at either end of the insert by no more than an eighth of an inch in their estimation; the height differential, however, had not been measured. The insert rail had a protruding lip of flowed rail metal of 1/16 inch on the side of the rail head that was turned to the gage side in the track. To compensate for that protruding lip of rail metal, the welder had removed a tapered section from the gage side of each end of the insert rail. The taper commenced about 2 1/2 inches from the rail end and was about 3/16 inch deep at the rail end.

The MP does not require that all failed field welds or rail failures be retained for inspection or for laboratory analysis.

Meteorological Information

At the time of the accident, visibility was good, the temperature was about 47° F, the relative humidity was about 75 percent, and the winds were from the southeast at about 8 knots. There was no precipitation. The minimum reported morning temperature was 39° F, reported at 5:47 a.m. and 6:47 a.m.

Medical and Pathological Information

Of the 162 passengers and crewmembers on the train, 4 passengers died as a result of injuries received during the derailment. Two of the fatalities occurred in coach car No. 34054, one fatality occurred in the diner car, and one fatality occurred in coach car No. 34033; all of these cars turned on their sides during the derailment. (See figure 2.) Three of the passengers died as a result of blunt trauma injuries, while the other passenger died as a result of injuries sustained when ballast was forced through a broken window in an overturned coach car, burying the passenger.

Twenty-three passengers and 2 crewmembers sustained injuries requiring hospitalization, and 47 persons were treated and released. The injuries consisted of concussions, fractures, lacerations, contusions, and abrasions; all of the serious, and most of the minor injuries occurred in the four rearmost cars of the train. Several of the injured passengers told Safety Board investigators that they were injured by baggage which was thrown about the car interiors during the derailment.

Survival Aspects

At the time of the derailment, the first coach car became tilted about 30 degrees to the west and the following three cars rolled to the west, onto their right sides in the direction of travel. As the three rearmost cars skidded to a stop, large quantities of roadbed earthen fill and crushed rock ballast were scooped into the cars through side doors and windows.

Although the four rearmost cars sustained considerable exterior damage, interior damage was moderate and limited to broken windows, damaged doors, displaced seat and back cushions, and displaced headrests in the coach cars. Baggage was strewn about the car interiors; overhead baggage securement is not provided for in Amtrak passenger cars. The diner car's interior damage consisted of a table torn loose, displaced seat and back cushions, and displaced headrests from several seats.

Many of the passengers and crewmembers were able to exit the train after the accident without assistance. However, most of those persons in the three rearmost overturned cars had to be rescued. The doors and emergency windows on the right sides of these cars were on the roadbed, and the doors and emergency windows on the left sides of these cars were above the car's occupants. Some of the persons in the rearmost car were able to exit through the end door. Before emergency response personnel arrived, MP and Amtrak personnel initiated evacuation and rescue efforts.

Emergency Response

The first rescue units, from the Marshall Fire Department, arrived at the accident scene about 10:25 a.m. and requested assistance from three additional jurisdictions. Many other jurisdictions responded without having been requested to do so after learning of the accident through emergency services radio frequencies and commercial radio stations. Emergency personnel from at least 21 jurisdictions responded to the accident scene. Rescue personnel assisted persons in the overturned cars, initially by hoisting them by hand up to a window, and then by using ladders to facilitate access to the car interiors. All of the passengers and crewmembers were evacuated from the accident site within 1 hour after the emergency response personnel arrived.

Several emergency response personnel, law enforcement officers, and the county civil defense director stated to Safety Board investigators that the lack of a disaster plan and a central dispatching system hampered rescue efforts. Specific problems cited included the lack of a designated on-scene commander, a command post, and a chain of command; lack of a mutual-aid radio frequency for communication among most responding units; and poor crowd control which resulted in the access road to the accident site being clogged with vehicles, including emergency vehicles, and hampering rescue efforts. By about 11 a.m., the main highway and the access road to the railroad had become obstructed with vehicles, severely impeding the flow of traffic. Additional responding emergency personnel continued to head for the accident site even though their services had not been requested; they could not be headed off due to lack of information on their identity. There was no mutual aid agreement among the responding jurisdictions.

The county civil defense director said that he was informed there was no passenger manifest onboard the train which would have stated the number of persons onboard. A passenger manifest was received by the county civil defense director about 4 p.m. About 4:30 p.m., a final search for passengers was begun at the accident site; no additional passengers were discovered.

Tests and Research

Postaccident examination of the track structure revealed no derailment markings to the geographic north of the temporary track repair. Past that location, in the direction

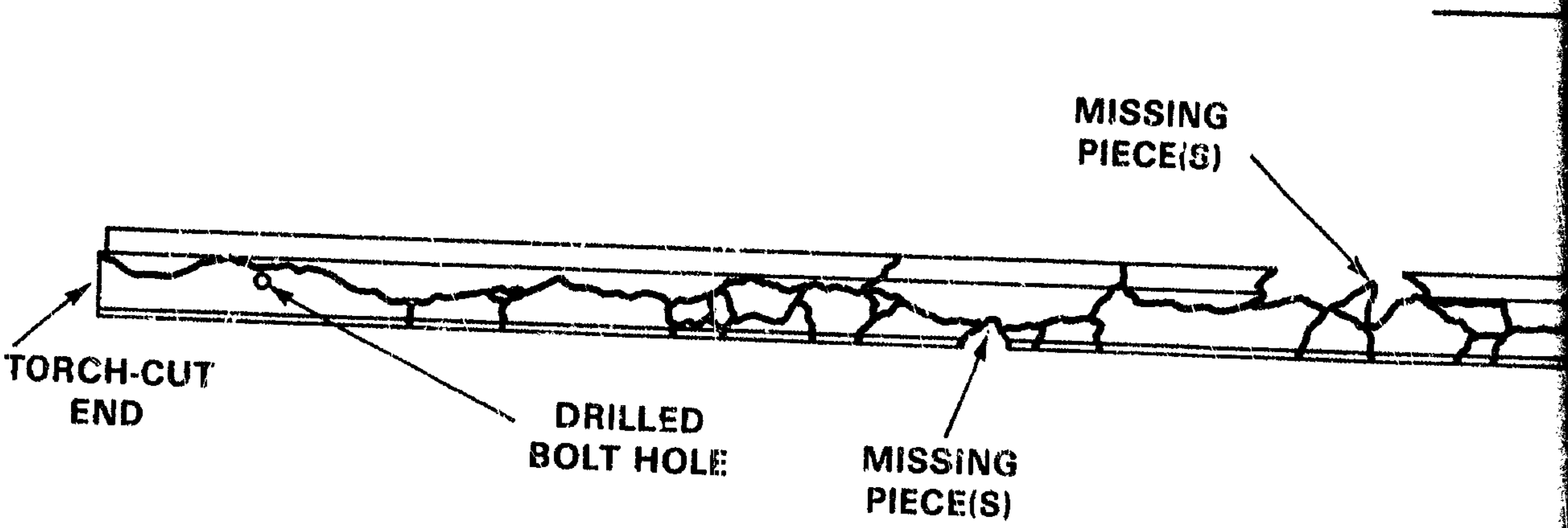
MISSING
PIECE(S)
TORCH-CUT
END
DRILLED
BOLT HOLE
MISSING
PIECE(S)

Figure 4.

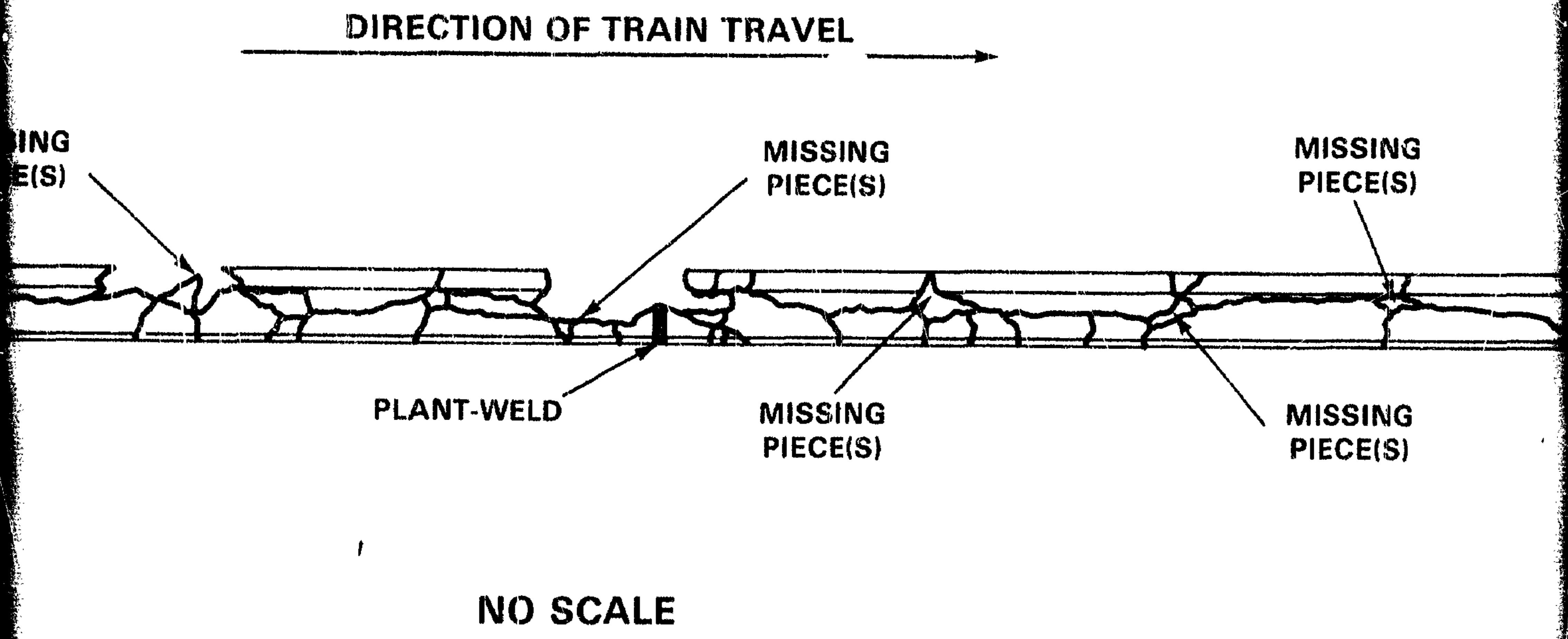

Figure 4.--Rail fracture diagram.

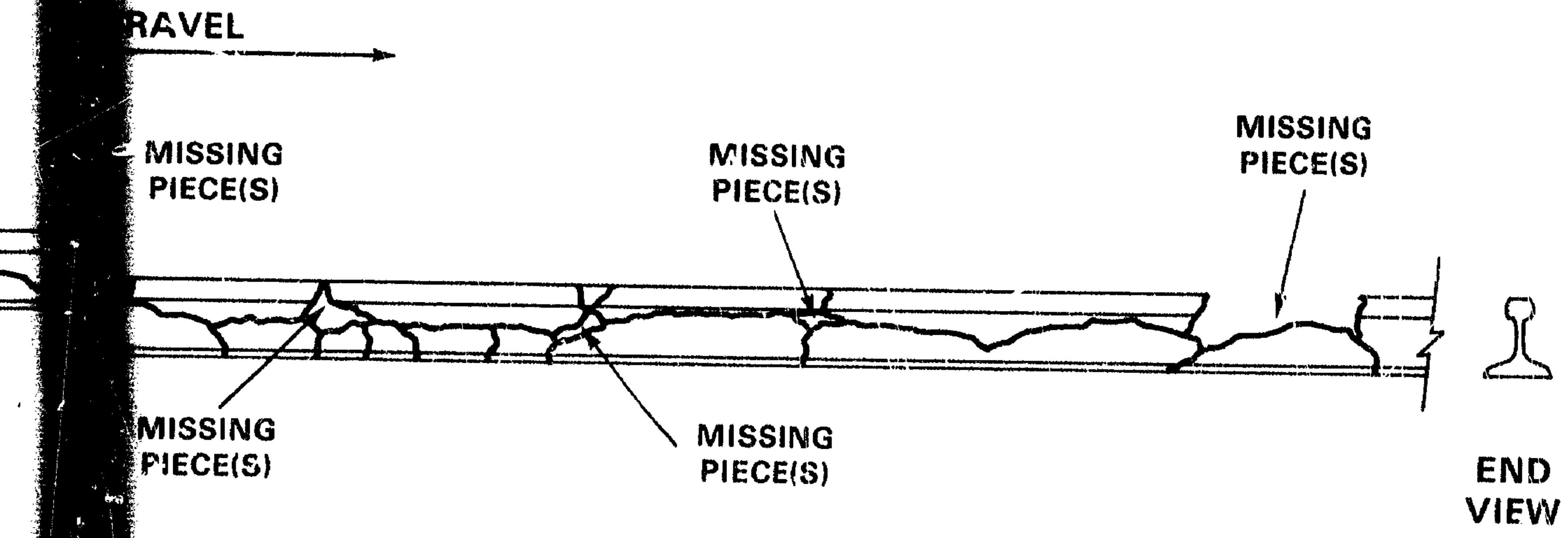

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diagram.

13.6

of travel of Amtrak train No. 21, derailment markings in the form of crosstie damage and ballast displacement led from the location of the temporary track repair to the location where the train came to rest.

Postaccident examination of each of the locomotive units and cars of Amtrak train No. 21 revealed that sleeping car No. 2911, the second car in the train consist, was the first car in the train which displayed derailment-induced markings. The lead wheel on the west side of the car displayed a new gouge mark in the wheel flange. Derailment markings increased in intensity and damage toward the rear of the train. The postaccident examination of the equipment disclosed no mechanical defects or conditions that would have contributed to the accident. However, it was noted that the wet-cell, standby batteries, which provide power for emergency lighting, in the three rearmost cars of the train were damaged to the extent that they did not function. The main electrical power lines between the cars became separated during the derailment.

A section of the chrome-vanadium alloy rail containing numerous fractures, several locations of batterment, and the torch-cut rail end was taken from the accident site and sent by the MP to the Union Pacific (UP) Railroad Company testing facility for metallurgical analysis. 11/ Safety Board investigators present at the testing facility noted that all MP maintenance-of-way personnel who viewed the rail section, as well as the UP lab personnel who viewed the section, stated that the extent and manner of fracturing far exceeded that which any of them had witnessed previously. (See figure 4.) The torch-cut end of the rail displayed mismatched planes of torch-cut surfaces, with the mismatched planes offset by approximately one-eighth inch. (See figure 5.) Examination of the rail revealed that the line of fracture in the rail web intersected the mismatched planes of torch-cutting at the notch located at the juncture of those mismatched planes. Safety Board investigators noted thermal cracks at the intersection of the line of fracture in the rail web and the mismatched torch-cut planes. (See figures 6 and 7.)

The testing performed at the UP laboratory consisted of tensile tests performed on three specimens machined from the rail, hardness tests of the rail surfaces, and chemical analysis of the rail. The director of the UP laboratory reported test results to Safety Board investigators which indicated variations in elongation percentage and chemical composition from the results of tests made at the time of manufacture and furnished by the manufacturer to the MP. After the testing at the UP laboratory, the MP retained a private commercial test facility to conduct further testing on specimens of the chrome-vanadium alloy rail involved in the derailment. The tests were restricted to mechanical testing consisting of tensile tests and impact tests to determine further the rail's characteristics with regard to tensile and yield strengths, ductility, and impact resistance. The test data of the tensile specimens indicated elongation percentages less than the 9 percent specified on the manufacturer's test results.

The Safety Board requested the Fracture and Deformation Division of the National Bureau of Standards (NBS) to perform certain tests on the broken section of chrome-vanadium alloy rail involved in the accident. The tests included tensile tests, impact tests, hardness tests, chemical analysis, and a test for hydrogen content. (See appendix E.) The test results of the tensile specimens revealed tensile and yield strength values comparable to the values set forth by the manufacturer; however, the elongation values of the three specimens were 7.0 percent, 7.0 percent, and 7.2 percent, which were below the values set by the manufacturer. The results of the NBS impact tests were comparable to the test results of the independent testing facility retained by the MP. The

11/ The MP does not maintain its own metallurgical facility but uses the UP facility. The MP and the UP are subsidiary organizations of the Union Pacific System.

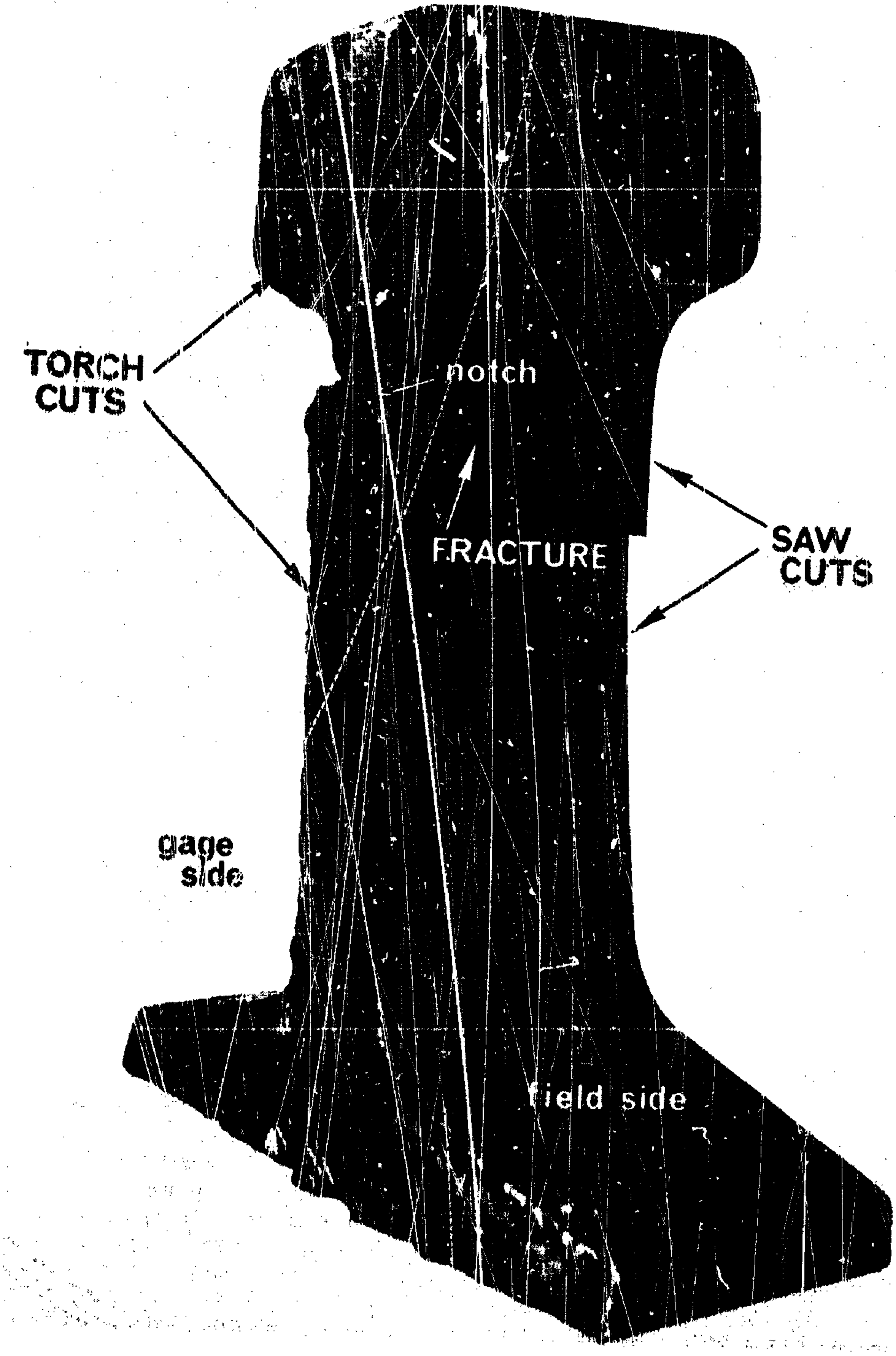


Figure 5.--View of torch-cut rail end of chrome-vanadium alloy rail after the accident. The transverse saw cuts were made after the accident to separate the rail end pieces from the remainder of the rail.

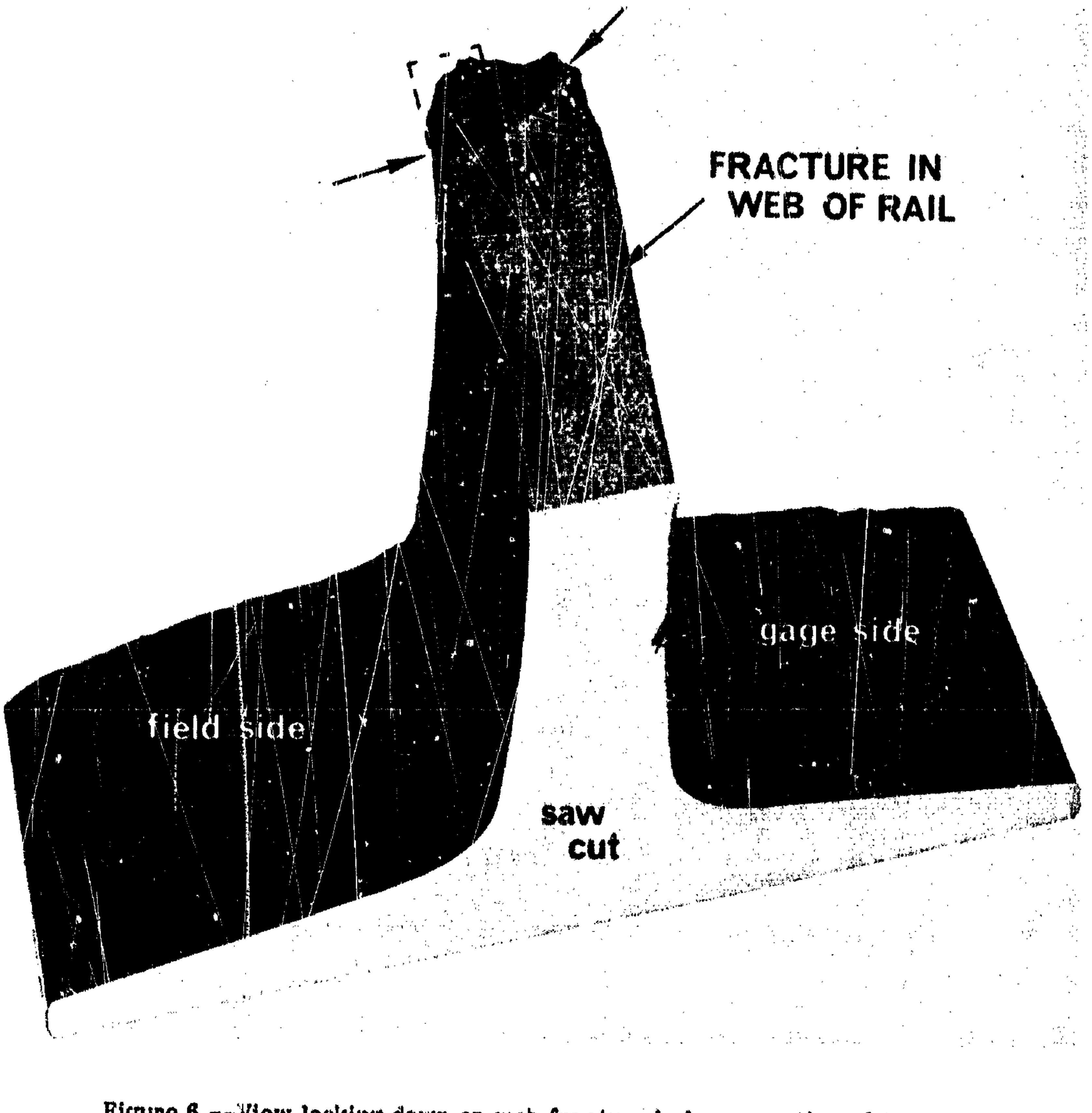


Figure 6.--View looking down on web fracture in lower portion of torch-cut rail end shown in figure 5. The arrows indicate the bottom of the notch created by the torch-cutting. The outlined area is shown in figure 7.

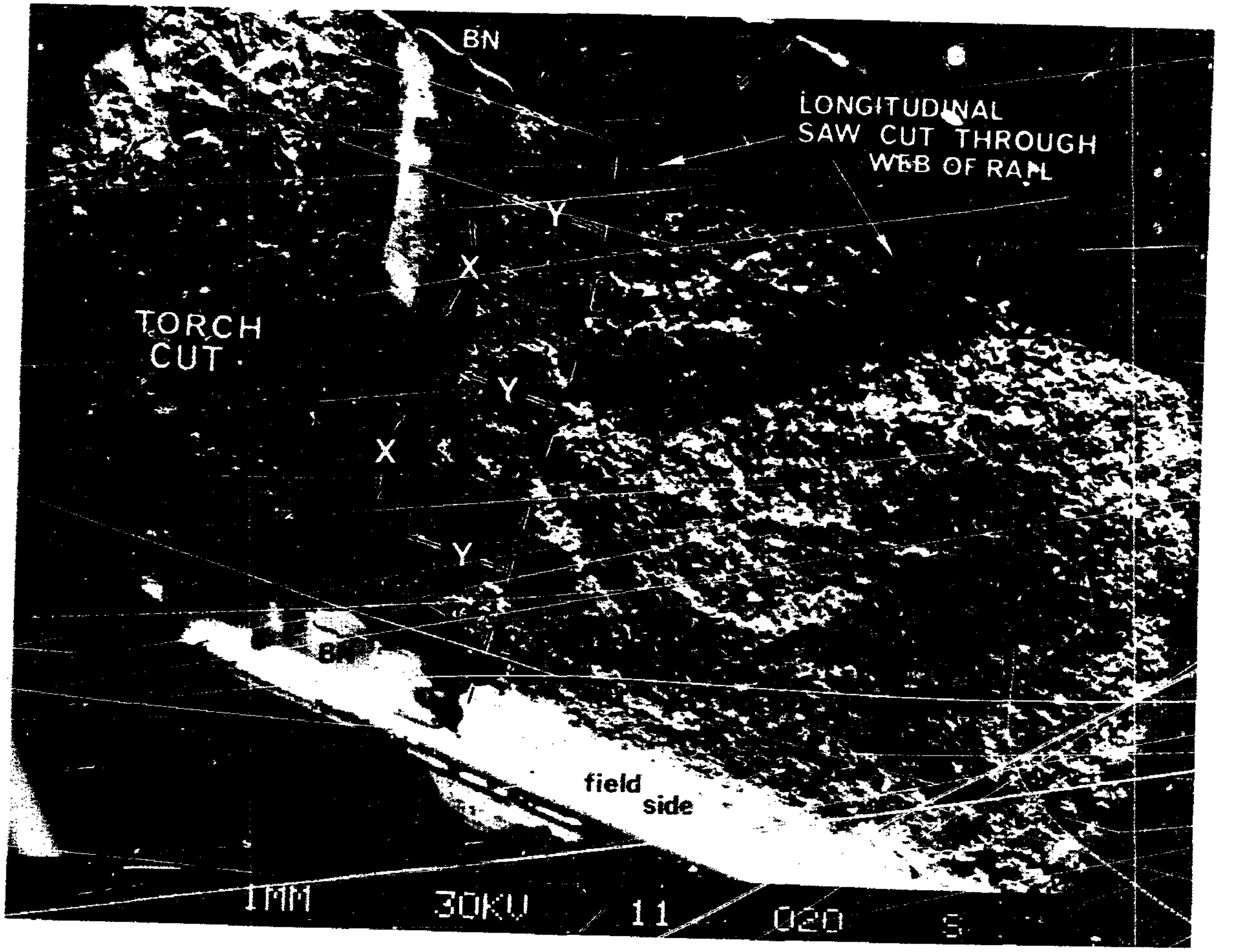


Figure 7.--Scanning electron microscope photograph of the area within dashed line box in figure 6. The bottom of the torch-cut notch is between brackets "BN". Also, two series of thermal cracks are visible in this photograph. One series was unopened and was found in the bottom of the notch, and is indicated by arrows "X". A second series was opened during the fracture process and was found on the side of the notch. The surface of this opened series of thermal cracks was darkly discolored and is indicated by arrows "Y".

NBS test results noted a zero percent shear on the fracture faces. The hardness test readings were comparable to those established in the preceding tests, as were the results of the chemical analysis. The hydrogen analysis revealed readings between 0.05 and 1.22 parts-per-million; 3 parts-per-million or less is the generally accepted upper limit in steel-making procedures. Metallographic examination of the rail revealed no evidence of internal defects.

Testing of chrome-vanadium and other alloy rails, as well as standard-carbon rail, is currently being performed by the Association of American Railroads at its metallurgical testing facility. Preliminary test results indicate that the crack travel characteristics of chrome-vanadium alloy rail are such that cracks travel 4 to 8 times farther before arrest occurs, compared to standard-carbon rail.

Other Information

The FRA commissioned a task force to conduct an evaluation of the rail failure in this accident. Its report 12/ states in part that:

> The trend toward increased usage of alloy rail is likely to continue as the long-term economic benefits are more widely recognized. Therefore, it is essential for the industry to be able to classify alloy rail steels on the basis of fracture toughness and to have specific guidelines for the manufacture, handling, installation, and maintenance of those alloys which are more notch sensitive than plain carbon rail steel.

Fracture toughness is a measure of inherent resistance to fracture initiation, and notch sensitivity is the tendency for a fracture to continue to progress. The report also states that it was ". . . probable that the torch cutting operation left a defect in the rail end, and that this initial defect probably provided the origin for the sudden rail failure" and that the metallurgical examination of the UP testing facility ". . . did not reveal the rail to have any unusual metallurgical characteristics." The report further states that within the railroad industry ". . . no consensus exists on torch cutting practices or on the slow orders to be imposed when a freight or passenger train is travelling over torch-cut rail."

The report made the following recommendations:

- The torch-cutting of rail for temporary jointed repairs should not be a preferred practice.

- If a torch-cut rail end must for any reason be left in a jointed temporary repair, railroads which do so to alloy rail should slow-order such repairs to a speed not exceeding 10 mph.

Also, the report recommended the following long-term actions:

- An industry study should be undertaken to assess quality control procedures to make certain that the manufacturing processes are not introducing excessive residual stresses in the product. Particular attention should be paid to the study of roller-straightening practices.

12/ For more information, see "Task Force Report-Rail Failure Evaluation, May 1984," prepared by U.S. Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts.

- An industry study should be undertaken on the experimental measurement of the fracture toughness of recent formulations of alloy rail steel. Detailed information on fracture toughness and fracture susceptibility, for loading conditions characteristic of normal train operations, would provide a rational basis for the development of recommended procedures for alloy rail installation and maintenance.

- An industry survey should be conducted to ascertain current alloy rail handling, installation, maintenance, and welding practices and produce acceptable practice guidelines since alloy rail may be less tolerant to otherwise similar practices than plain carbon rail.

The Association of American Railroads (AAR) and its engineering division (AREA) have begun tests and studies directed to the fulfillment of the long-term actions recommended by the task force and have indicated that a concerted industry effort will be necessary to achieve those goals.

In an incident at the Burlington Northern (BN) Railroad Company's rail welding facility at Laurel, Montana, on December 6, 1983, during test weld procedures on chrome-vanadium alloy rail, a remnant section of the rail was dropped inadvertently from a height of about 6 feet onto another rail. The remnant section of chrome-vanadium alloy rail had torch cuts at either end, which had been made after test welds were performed on the blank-end rail. The torch cuts were made 3 to 4 feet from each end of the rail section; the remnant rails were designated as scrap, while the welded joints were to be retained for test purposes. The dropped remnant rail section broke through its web and into several pieces. At the time of the incident, the ambient temperature was -12° F. Pieces of the rail were sent to the BN's metallurgical facility for failure analysis. (See appendix F.) The BN attributed the cause of the rail failure to ". . . the expected low toughness of the alloy rail . . . ," and further that, ". . .torch cutting of the alloy rails must be avoided. . . ."

The BN informed the Safety Board that the rail was 132-lb RE section rail, manufactured by Thyssen, another member of the steel manufacturing consortium located in the Federal Republic of Germany. The BN said that the specifications tendered to the manufacturer of the rail were the AREA specifications for steel rail and that the BN was not advised by the manufacturer of any recommended special handling practices.

ANALYSIS

The Accident

The operating crew of Amtrak train No. 21 were properly qualified for their respective positions in accordance with MP requirements. There were no mechanical defects noted in the locomotive units or passenger cars that would have contributed to the accident.

The absence of derailment-induced markings on either of the two locomotive units or the lead baggage car indicates that the ultimate breakup of the rail occurred under the passing passenger train, but behind the locomotive and lead car. The forces generated by the wheels of the two locomotive units and following cars traveling at 72 mph impacting on the chrome-vanadium alloy rail, which was approximately one-eighth of an inch higher than its mating rail, the standard-carbon rail, and also impacting on the offset on the gage sides of the rails in the joint, probably were sufficient to initiate the cracks found in the rail web; the thermal crack at the torch-cut rail end probably served as the crack origin. The freight train which passed at 9:30 a.m. probably negotiated the temporary track repair successfully only because of its slower speed and resultant lower impact forces imposed on the rail joint. Further, recent tests performed by the AAR at its metallurgical testing facility indicate that the crack arrest characteristics of chrome-vanadium alloy rail are such that cracks travel four to eight times farther before arrest occurs, compared to standard carbon rail. It is therefore extremely unlikely that a crack which had initiated under the freight train could have existed without the rail fracturing severely until the passing of the passenger train.

Since the rail breakup occurred in the outer rail of a curved track, the centrifugal force generated by the train resulted in the derailing cars diverging outward from the track, with the three rearmost cars turning onto their sides, and the fourth car from the rear tilting about 30 degrees. The extreme divergence of the four rearmost cars greatly contributed to the extent of the fatalities, injuries, and severity of damage sustained in the accident.

Maintenance-of-Way Training

Although the MP had a stated policy, published in its chief engineer's instructions, of not cutting rail with a torch except in emergencies, it is apparent that the stated policy was not, in fact, a working practice. The actions and statements of the track inspector, track foreman, and welder indicate that torch-cutting of rail, in lieu of using the preferred rail saw, was a routine and common practice, contrary to the MP's published instructions and stated policy. Moreover, it is apparent that the published policy of placing a 10-mph speed restriction on rails cut with a torch in an emergency situation also was not a working practice. The actions and statements of the track inspector, track foreman, welder, and especially the roadmaster indicate a serious deficiency in the training in MP schools about procedures applicable to their respective positions, since none of them was fully cognizant of the procedures. They also apparently were not cognizant of applicable Federal regulations, since they allowed the freight train to pass over the track repair while each of the CWR rail ends had only one bolt--rather than the required two bolts--installed in each of two joints. The Safety Board believes that the actions of the MP maintenance employees involved in the accident indicate that the training and testing of MP maintenance-of-way personnel must be improved.

The Safety Board is particularly concerned with the training and testing given the track inspector and roadmaster who were responsible for the decision that the track was safe for rail traffic. The roadmaster stated that he had been asked by the division superintendent to expedite the train movements, which would have included the Amtrak train movement. From the accident site, Amtrak train No. 21 would have required approximately 9 additional minutes at 72 mph to reach its next scheduled stop at Marshall, which was to have been at 9:31 a.m. Since the accident occurred at 10:09 a.m. approximately 10.7 rail miles from Marshall, the train was running approximately 40 minutes behind schedule. These factors may have influenced the decisions on how the repairs were made and whether to place a slow-order on the track at the work site. In order to comply with applicable Federal regulations and MP instructions, both the freight train and the Amtrak passenger train would have had to be held until the track repair had been completed, with four track bolts (two to each rail end per joint) installed. The leading freight train could then have been allowed to pass over the temporary repair at 10 mph, with the passenger train following the freight train, also at 10 mph, resulting in considerable additional delay to Amtrak train No. 21.

Compliance with the chief engineer's instructions on cutting rail would have necessitated the use of a rail saw. The rail saw assigned to the repair crew reportedly did not function, necessitating cutting the rail with a torch. The decision to cut the rail with a torch may have been affected by the much greater speed by which rail can be cut with a torch as compared to using a rail saw. Similarly, imposition of a slow-order would have further delayed the schedule of Amtrak train No. 21. Moreover, since the site of the temporary repair was within CTC territory with automatic wayside signals, under MP rules, the track inspector should have arranged for a signal maintainer to be at the work site to insure the integrity of the signal system. His failure to do so is a further indication of undue haste in response to directions to expedite train movements.

Indifference to proper maintenance procedures such as cutting rail with a torch, incomplete bolting of joints, omitting prescribed slow orders, and proceeding without essential personnel are situations which should not be tacitly encouraged or condoned by management. The activities preceding this accident suggest that not only are first-line supervisors inadequately instructed on company maintenance-of-way policies, but also that their superiors have not been exercising effective direction and monitoring of routine practices being used on a day-to-day basis.

The Safety Board believes that systematic followup of rail failures in main tracks and other important tracks should be a standard procedure performed by any railroad. If the MP had had a requirement mandating that the failed field weld cut out from the chrome-vanadium alloy rail be retained for inspection or for laboratory analysis, the track repair crew involved in this accident might have been reluctant to use a torch to cut the rail, knowing that the torch cuts would be discovered. The Safety Board notes also that the MP had not requested information on whether the chrome-vanadium alloy rail had any characteristics which would require special installation and maintenance procedures differing from those for standard-carbon rail, even though the MP did not set forth any specifications for the chrome-vanadium alloy rail when that rail was purchased. Moreover, the Safety Board notes that Krupp-Stahl, the manufacturer of the chrome-vanadium alloy rail, did not furnish information to the MP on whether the rail had any such characteristics.

High-Strength Alloy Rail Installation and Maintenance Procedures

The MP, as well as other railroads, have purchased and installed chrome-vanadium alloy rail and other high-strength alloy rail for the purpose of reducing the rate of rail replacement in locations of severe rail wear, such as in curves and track switch stock rails. The task force report on the rail failure in this accident also has indicated that the use of alloy rail, while currently very limited, will increase significantly because of the economic benefits of its wearability. The Safety Board does not question the appropriateness of industry seeking such economic benefit. However, the Board is concerned that indifference to proper methods of rail installation and maintenance which can result in safety hazards in any rail presents acute hazards when using certain high-strength alloy rails, such as chrome-vanadium alloy rail. The Safety Board's concern led to the issuance, during the investigation of this accident, of Safety Recommendation R-84-20 on April 20, 1984, to the AREA, the AAR and its membership, and the American Short Line Railroad Association, which states:

Review and revise, where necessary, procedures for the installation and maintenance of high-strength alloy rails, especially high-strength chrome-vanadium alloy rails, to minimize the possibility of externally induced stress factors in such rails and to implement more stringent internal defect testing programs.

The majority of railroads that have responded to Safety Recommendation R-84-20 have rules and procedures in effect which specifically ban the use of a torch to cut rail except in an emergency situation. All of the railroads that have responded indicate that they have rules and procedures in effect which stipulate that rail cutting with a saw or rail chisel is the preferred method. Although the responses to Safety Recommendation R-84-20 do not comprehensively state the complete policies of all railroads regarding torch-cutting practices, the Safety Board believes they do indicate a consensus that cutting any rail with a torch is an unacceptable practice. Further, the Safety Board notes that although the FRA minimum track safety standards do not address the subject of torch-cutting of rail at present, they do prohibit torch-induced bolt holes.

The Safety Board believes that the thermal cracks found in the chrome-vanadium alloy rail were precipitated by the use of the torch to cut the rail. Metallographic examination of the subject rail did not reveal any other internal defects that could have served as the origin of the rail fracture. Torch-cutting of rail often may introduce flaws at or near the torch-cut surface. The inherently uneven surface of a torch-cut rail has numerous surface discontinuities. These surface discontinuities, in a rail subject to the imposition of dynamic loads from wheels passing over the rail, serve as stress raisers. Stresses most often will occur in their highest intensities at such surface discontinuities. Further, there is a natural propensity for the heat-affected layer of metal adjacent to a torch-cut surface to form thermal cracks upon the cooling of the metal. These thermal cracks probably initiated the severe fracturing of the subject rail as Amtrak train No. 21 passed over it, 45 minutes to 1 hour after the torch cuts were made in the chrome-vanadium alloy rail.

The severity of the fracturing of the chrome-vanadium alloy rail was noted to be unique. The Safety Board believes that the severity of the fracturing may have been due to the very low fracture toughness of the rail. The low values established in the test specimens of the involved rail, in the tensile and impact resistance tests, are indicative of material possessing a low fracture toughness. Such material generally will have a greater tendency to fracture in a brittle manner. Stated in fracture mechanics terms, for a given flaw size, a material with lower elongation and impact resistance values can withstand less stress before failure. The hydrogen content analysis of the rail documented low levels of residual hydrogen, and the chemical analyses of the rail revealed no other anomalies which would account for the low elongation and impact resistance levels. In view of the absence of any specific agent responsible for the low test values, it appears likely that the displayed brittleness of the failed rail may be a characteristic typical of that category of alloy rail and that increased use of this type of rail may be expected to be accompanied by an increased incidence of similar failures.

Rail failure in a track curve or at a track switch often will result in more severe consequences than a rail failure that occurs on a straight (tangent) track. In the case of a track curve, the severe consequences are increased by the centrifugal or outward forces acting upon the equipment negotiating the track curve. In the case of a track switch or other special trackwork, the severe consequences are increased by the extra trackwork appurtenances within the track gage which the equipment must negotiate. In either event, the likely result is a more pronounced dispersal of equipment in the derailment.

Moreover, the greater the extent of rail fracturing at such a location, with a concurrent greater loss of fixed guideway, the greater will be the potential for yet more pronounced dispersal of equipment in the derailment. These factors were present in the accident at Woodlawn and caused an uncommonly severe and lengthy loss of the fixed guideway, allowing the last three cars of the train to overturn. The overturning of the last three cars and the tilting of a car contributed significantly to the severity of injuries sustained by the persons onboard the train. The Safety Board believes that substantive research into this potential problem of catastrophic rail failure is necessary in view of the increased expected use of alloy rail in the industry. While chrome-vanadium alloy rail has been in service in foreign railroad systems for a longer period of time than in United States railroad systems, the knowledge concerning the characteristics of such rail acquired abroad is not totally and directly applicable to the United States railroad system because of differences in operational demands, including heavier axle loads in United States operations as well as differences in maintenance procedures. The Safety Board encourages the FRA to undertake the necessary research and provide the coordination necessary to insure that the task force recommendations are implemented.

Survival Aspects

Although the precise moment the automatic air brake applied in emergency cannot be determined relative to the overturning of the three rearmost cars, the combined effect of the braking and skidding cars resulted in severe decelerative forces in the train. These severe decelerative forces, along with the overturning of the three rearmost cars and the tilting of the fourth rearmost car, resulted in unrestrained baggage and passengers being thrown about inside the cars. All of the fatalities and serious injuries occurred in the four rearmost cars. The Safety Board believes that had those rear cars remained upright and in line, the casualty toll would have been greatly reduced. The baggage and any other items that had been stowed in the open overhead racks became missiles when the cars started to overturn, causing injuries to several of the passengers. If the overhead baggage compartments had been equipped with baggage restraints capable of restraining the stowed items, the injury toll might have been less.

As a result of an accident in Wilmington, Illinois, in 1983, in which the investigation revealed similar problems concerning the lack of baggage restraints, 13/ the Safety Board issued Safety Recommendation R-84-40 on November 29, 1984, recommending that Amtrak:

> Correct the identified design deficiencies in the interior features of existing and new passenger cars, which can cause injuries in accidents, including the baggage retention capabilities of overhead luggage racks, inadequately secured seats, and inadequately secured equipment in food service cars.

Because of the recency of the recommendation, Amtrak has not yet replied.

The underside electrical components of five of the cars involved in the Woodlawn accident were damaged. Although the lack of effective emergency lighting during the evacuation process was not a factor in this accident, the Safety Board has noted the problem of deficient emergency lighting systems in passenger cars in other investigations.

13/ Railroad/Highway Accident Report—"Collision of Amtrak Passenger Train No. 301 on Illinois Central Gulf Railroad with MMS Terminals, Inc., Delivery Truck, Wilmington, Illinois, July 28, 1983" (NTSB/RHR-84/02).

As a result of its investigation of the derailment of a passenger train at Emerson, Iowa in 1982, 14/ the Safety Board issued Safety Recommendation R-83-25 recommending that Amtrak:

> Evaluate and modify, as necessary, emergency lighting systems in passenger-carrying cars to better protect the functioning of emergency lights in emergency situations.

Amtrak replied that, "the emergency lighting systems on Amtrak equipment are designed to provide a minimum of two hours of acceptable illumination when the primary power source is interrupted. Protection is provided by battery power and the circuits are well protected." The recommendation is currently in an "Open--Unacceptable Action" status. As a result of the Wilmington accident, in which emergency lighting system damage was found, the Safety Board issued Safety Recommendation R-84-42 recommending that Amtrak:

> Relocate the battery used in the emergency power system to an area of the car where it is less susceptible to damage in an accident.

Because of the recency of the recommendation, Amtrak has not yet replied.

The circumstances of the Wilmington and Woodlawn accidents demonstrate that the batteries are not protected adequately to insure the availability of emergency lighting in emergency situations. The Safety Board reiterates its concern that progress must be made to remedy the problem of inadequate emergency lighting in passenger-carrying rail cars in emergency situations.

Evacuation of the cars which remained upright was not complicated by any noted obstacles. Evacuation of the fourth car from the rear, which was tilting about 30 degrees, was accomplished using the lower-level window emergency exits and the vestibule door on the right side of the car, through which the car occupants stepped out of the leaning car at or near ground level. Evacuation of the three rearmost cars was seriously complicated because the cars were overturned on their sides. Although rescue workers were able to remove some of the injured from the rearmost car through the rear end door, most of the occupants in that car and in the other two overturned cars had to be removed through the emergency exits on the left sides of those cars. This involved manually lifting the more seriously injured occupants up and out of the cars and assisting the less seriously injured and uninjured on ladders lowered into the cars.

The initial notification and response of the emergency response personnel was timely and effective, as witnessed by the rapid evacuation of passengers and crew from the accident site. The efforts of the emergency response personnel, however, were needlessly hampered by the lack of a disaster contingency plan. Also, the lack of a central dispatching system and mutual aid radio frequency complicated the coordination of the rescue efforts among the 21 jurisdictions which responded to the accident. Had there been an effective disaster contingency plan in place with a county-wide emergency services dispatching system, a commander would have been designated for the emergency response effort who would have been able to tailor the response to the needs of the

14/ Railroad Accident Report--"Derailment of Amtrak Train No. 5 (The San Francisco Zephyr) on the Burlington Northern Railroad, Emerson, Iowa, June 15, 1982" (NTSB/RAR-83/02).

accident and better coordinate those efforts. Moreover, a centralized dispatching system probably would have reduced the on-scene congestion, much of it involving emergency vehicles, which hampered the rescue efforts of the emergency personnel.

CONCLUSIONS

Findings

1. The stated policy of the Missouri Pacific Railroad, as set forth in its chief engineer's instructions, of not cutting rail with a torch except in an emergency, was not, in fact, a working practice.

2. The stated policy of the Missouri Pacific Railroad, as set forth in its chief engineer's instructions, of imposing a 10-mph speed restriction on rail cut with a torch, was not, in fact, a working practice.

3. The track repair crew did not comply with Federal Railroad Administration regulations requiring two track bolts in each rail end in a track joint in continuous-welded-rail on track in service.

4. The track inspector did not arrange for a signal maintainer to be present to insure the integrity of the signal system, as required by Missouri Pacific rules, at the track repair site which was within centralized traffic control territory.

5. The training given the maintenance-of-way department employees by the Missouri Pacific Railroad in its schools was deficient in insuring that the employees were cognizant of the procedures applicable to their positions.

6. Missouri Pacific Railroad management did not exercise effective direction and monitoring of routine maintenance-of-way practices being used on a day-to-day basis.

7. A torch was used to make the cuts in the rail needed to make the temporary track repair because an operable rail saw reportedly was not available; however, the rail saw that was said to be broken was used during track reconstruction efforts immediately after the accident.

8. The use of a torch to cut the rail at the site of the track repair introduced flaws at or near the torch cut surfaces of the rail, precipitating thermal cracks in the rail.

9. The impact forces imparted by the wheels of Amtrak train No. 21 traveling 72 mph onto the failed rail, which was approximately one-eighth of an inch higher than its mating rail in the track joint, probably were sufficient to cause the cracks in the rail web; the thermal cracks at the torch-cut rail end probably served as the crack origin.

10. The freight train that passed over the temporary track repair before Amtrak train No. 21 probably successfully negotiated its passage only because of its slower speed and lower resultant impact forces on the rail joint.

11. The fracturing of the chrome-vanadium alloy rail occurred under the passing Amtrak train No. 21, but to the rear of the two locomotive units and the following baggage car.

12. There were no mechanical defects noted in the locomotive units or passenger cars of Amtrak train No. 21 which would have contributed to the accident.

13. The severity of the fracturing of the chrome-vanadium alloy rail involved in this accident was noted to be uncommon and may have been due to a very low fracture toughness of the rail.

14. Metallurgical testing of the chrome-vanadium alloy rail involved in this accident did not disclose any specific agent responsible for the low test values established for the alloy rail, indicating that the displayed brittleness of the failed rail may be a characteristic typical to that category of alloy rail.

15. The uncommon and catastrophic manner of rail failure of the chrome-vanadium alloy rail involved in this accident contributed to the severity of the accident.

16. Current methods of rail installation and maintenance may be inadequate for certain high-strength alloy rail, such as chrome-vanadium alloy rail.

17. The anticipated increase in the use of alloy rail in the railroad industry due to its improved wear characteristics necessitates that substantive research into the potential of catastrophic rail failure be accomplished quickly.

18. The Missouri Pacific Railroad did not request any information on the need for any specific installation and maintenance procedures for chrome-vanadium alloy rail, even though the Missouri Pacific Railroad did not set forth specifications for the rail when it was purchased.

19. Krupp-Stahl, the rail manufacturer, did not furnish the MP any specific installation or maintenance procedures for the chrome-vanadium alloy rail.

20. Unrestrained items of baggage and other personal belongings that had been stowed in open overhead baggage racks caused injuries during the accident.

21. The tilting and overturning of the four rearmost cars, combined with the severe decelerative forces on the stopping train, increased the injury potential and severity of damage in the accident.

22. Evacuation of the three rearmost cars was seriously complicated by the overturning of those cars.

23. The initial notification and response of the emergency response personnel was timely and effective; however, the efforts of those personnel were needlessly hampered by the lack of a disaster contingency plan.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was torch-cutting a chrome-vanadium alloy rail in a track curve while making a temporary track repair, precipitating thermal cracks that served as the origin points for a catastrophic rail failure when a high-speed passenger train passed over. Contributing to the accident was the failure of the Missouri Pacific Railroad to train its maintenance-of-way department employees adequately in the requirements necessary to their positions, and of its management to monitor adherence to its maintenance-of-way rules and procedures and Federal regulations regarding minimum track safety standards.

RECOMMENDATIONS

As a result of this investigation, the National Transportation Safety Board reiterated the following Safety Recommendations issued to the National Railroad Passenger Corporation (Amtrak) on November 29, 1984:

> Correct the identified design deficiencies in the interior features of existing and new passenger cars, which can cause injuries in accidents, including the baggage retention capabilities of overhead luggage racks, inadequately secured seats, and inadequately secured equipment in food service cars. (R-84-40)
>
> Relocate the battery used in the emergency power system to an area of the car where it is less susceptible to damage in an accident. (R-84-42)

As a result of this investigation, the National Transportation Safety Board made the following recommendations:

--to the Missouri Pacific Railroad:

> Review and revise, where necessary, the curriculum and/or training and testing procedures in its maintenance-of-way training schools to instruct employees in its of the procedures and requirements related to their positions. (Class II, Priority Action) (R-85-1)
>
> Review and revise, where necessary, supervisory procedures for monitoring adherence to Federal regulations regarding minimum track safety standards and Missouri Pacific Railroad maintenance-of-way rules and procedures. (Class II, Priority Action) (R-85-2)
>
> Arrange for metallurgical evaluations of the various heats of chrome-vanadium alloy rail presently in track to establish specific installation, maintenance, and operating procedures for Missouri Pacific Railroad tracks containing chrome-vanadium alloy rail. (Class II, Priority Action) (R-85-3)

--to the Federal Railroad Administration:

> Require that a maximum allowable operating speed not exceeding 10 mph be imposed on any railroad track having a torch-cut rail end in a bolted track joint. (Class II, Priority Action) (R-85-4)

In coordination with the Association of American Railroads and its membership, the American Railway Engineering Association, and the American Short Line Railroad Association, develop a plan to implement the long term recommendations made in the Transportation Systems Center Task Force Report-Rail Failure Evaluation, vis:

- o An industry study should be undertaken to assess quality control procedures to make certain that the manufacturing processes are not introducing excessive residual stresses in the product. Particular attention should be paid to the study of roller-straightening practices.

- o An industry study should be undertaken on the experimental measurement of the fracture toughness of recent formulations of alloy rail steel. Detailed information on fracture toughness and fracture susceptibility, for loading conditions characteristic of normal train operations, would provide a rational basis for the development of recommended procedures for alloy rail installation and maintenance.

- o An industry survey should be conducted to ascertain current alloy rail handling, installation, maintenance, and welding practices and produce acceptab! ; practice guidelines since alloy rail may be less tolerant to other ..ise similar practices than plain carbon rail.

(Class II, Priority Action) (R-85-5)

--to Harrison County, Texas:

Establish a centralized emergency services dispatching system. (Class II, Priority Action) (R-85-6)

In coordination with neighboring jurisdictions, develop and implement a mutual-aid agreement for responding to emergencies which provides for the orderly dispatch of emergency service units in participating jurisdictions on an "as needed" basis. (Class II, Priority Action) (R-85-7)

--to the Association of American Railroads:

Inform its membership of the facts and circumstances of the derailment at Woodlawn, Texas, on November 12, 1983, and urge its member railroads to join with the Federal Railroad Administration in implementing the long-term recommendations made in the Transportation Systems Center Task Force Report-Rail Failure Evaluation. (Class II, Priority Action) (R-85-8)

--to the American Short Line Railroad Association:

Inform its membership of the facts and circumstances of the derailment at Woodlawn, Texas, on November 12, 1983, and urge its member railroads to join with the Federal Railroad Administration in implementing the long-term recommendations made in the Transportation Systems Center Task Force Report-Rail Failure Evaluation. (Class II, Priority Action) (R-85-9)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

February 4, 1985

APPENDIXES

APPENDIX A

INVESTIGATION

The National Transportation Safety Board was notified of the accident at 1:45 p.m. on November 12, 1983. The Safety Board immediately dispatched investigators from its Washington, D.C., headquarters and from its Denver, Colorado, and Fort Worth, Texas, field offices to the site.

Groups were formed to investigate the mechanical, operational, survival factors, and track aspects of the accident. The groups were comprised of personnel from Amtrak, the Missouri Pacific Railroad, the Federal Railroad Administration, and emergency response personnel, and were headed by Safety Board investigators.

A formal deposition proceeding was held in Marshall, Texas, on March 6-7, 1984. Sworn testimony of the facts of the accident was taken from 10 witnesses. Parties to the proceeding were Amtrak, the Missouri Pacific Railroad, the Krupp-Stahl Company, and the Federal Railroad Administration.

APPENDIX B

PERSONNEL INFORMATION

Roadmaster

The roadmaster was employed by the Missouri Pacific (MP) on September 10, 1973, as a track laborer. He was promoted to track foreman in September 1974, and promoted to roadmaster on December 1, 1976. He attended a 2-week MP supervisory school in 1981 and attended a welding seminar in 1981. He was current on the MP rules and regulations for the maintenance-of-way and structures.

Track Inspector

The track inspector was first employed by the MP on November 7, 1969, as a track laborer. He was promoted to track foreman on February 13, 1971, and promoted to track inspector on September 16, 1983. He attended an MP track inspector school in October 1982. He was tested on the MP rules and regulations for the maintenance-of-way and structures on August 16, 1982.

Welder

The welder was employed by the MP on May 19, 1977, as a track laborer. He attended an MP welder's school in 1979 and was promoted to welder on October 16, 1979. He was tested on the MP rules and regulations for the maintenance-of-way and structures on January 28, 1982.

Track Foreman

The track foreman was employed by the MP on March 25, 1963, as a track laborer. He was promoted to assistant track foreman on September 15, 1967, and promoted to track foreman on December 18, 1967. He was tested on the MP rules and regulations for the maintenance-of-way and structures on August 24, 1982.

Track Laborer

The track laborer was employed by the MP on March 3, 1952, as a track laborer. He was not required to be tested on the MP rules and regulations for the maintenance-of-way and structures.

APPENDIX C

EXCERPTS OF AMERICAN RAILWAY ENGINEERING ASSOCIATION SPECIFICATIONS FOR STEEL RAILS

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Part 2

Specifications

[1]SPECIFICATIONS[2] FOR STEEL RAILS

1979

(Reapproved with revisions 1979)

1. Scope

1.1 These specifications cover steel tee rails for use in railway track.

1.2 Supplementary requirements S1 through S4 shall apply only when specified by the purchaser.

2. Manufacture

2.1 The steel shall be made by any of the following processes: open hearth, basic oxygen, or electric furnace.

2.2 The steel shall be cast by a continuous process, in hot topped ingots, or by other methods agreed by purchaser and manufacturer.

2.3 Sufficient discard shall be taken from the bloom or ingot to insure freedom from injurious segregation and pipe.

3. Chemical Composition

3.1 The chemical composition of the standard rail steel, determined as prescribed in 3.3 shall be within the following limits:

	Weight Percent	
	Nominal Weight lb/yd	
	90 to 120	*121 and over*
Carbon	0.67–0.80	0.70–0.82
Manganese	0.70–1.00	0.75–1.05
Phosphorus, Max.	0.035	0.035
Sulfur, Max.	0.040	0.040
Silicon	0.10–0.35	0.10–0.35

3.2 The chemical composition of alloy high strength rail will be subject to the agreement of the purchaser and manufacturer.

3.3 Separate analysis shall be made from ladle samples representing one of the first three and one of the last three ingots or blooms from each heat. Determinations may be made chemically or spectrographically. Only the portion of the heat which meets the conditions of 3.1 may be applied.

3.4 Upon request by the purchaser, samples shall be furnished to verify the analysis as determined in 3.3.

[1] References, Vol. 3, 1902, pp. 204, 208; Vol. 5, 1904, pp. 465, 469; Vol. 6, 1905, pp. 183; Vol. 7, 1906, pp. 549, 573; Vol. 10, 1909, part 1, pp. 374, 393; Vol. 11, 1910, part 1, pp. 237, 255; Vol. 12, 1911, part 1, p. 467; Vol. 12, 1911, part 2, p. 13; Vol. 13, 1912, pp. 853, 1031; Vol. 14, 1913, pp. 181, 1103; Vol. 15, 1914, pp. 158, 375; Vol. 16, 1915, pp. 3117; Vol. 21, 1920, pp. 1070, 1447; Vol. 26, 1925, pp. 619, 1413; Vol. 31, 1930, pp. 1455, 1770; Vol. 32, 1931, pp. 347, 816; Vol. 34, 1933, pp. 606, 821; Vol. 37, 1936, pp. 426, 991; Vol. 38, 1937, pp. 216, 635; Vol. 40, 1939, pp. 396, 738; Vol. 43, 1942, pp. 575, 704; Vol. 47, 1946, pp. 373, 635; Vol. 52, 1951, pp. 396, 826; Vol. 54, 1953, pp. 1177, 1413; Vol. 55, 1954, pp. 775, 1098; Vol. 57, 1956, pp. 786, 1088; Vol. 58, 1957, pp. 962, 1248; Vol. 63, 1957, pp. 501, 768; Vol. 64, 1963, pp. 498, 690; Vol. 65, 1964, pp. 321, 851; Vol. 68, 1967, p. 408; Vol. 69, 1968, p. 356; Vol. 71, 1970, p. 223; Vol. 75, 1974, p. 479; Vol. 80, 1979, p. 82.

[2] *Latest page consist:* 1 (1983), 4, 4 2, 4 3 (1981), 2, 3, 4, 1, 4 4, 4 5 (1979) (Note Page 4-2-6 left intentionally blank)

3.5 The first analysis shall be recorded as the official heat analysis, but the purchaser shall have access to all ladle analyses.

4. Hardness Properties

4.1 Rails shall be produced as specified by the purchaser as one of two levels within the following limits:

	Standard Rail	*High Strength Rail*
Brinell Hardness	248 minimum	321–388

4.2 A Brinell hardness test shall be performed on a rail or a piece of rail at least 6 inches long cut from a rail of each heat of steel.

4.2.1 The test shall be made on the side or top of the rail head, after decarburized material has been removed, to permit an accurate determination of hardness.

4.2.2 The test shall otherwise be conducted in accordance with the American Society for Testing and Materials (ASTM) Standard Method of Test for Brinell Hardness of Metallic Materials E10 latest version.

4.3 If for heat treated rails a test fails to meet the requirements of 4.1, the rails may be retreated, at the option of the manufacturer, and such rails may be retested in accordance with 4.2.

5. Section

5.1 The section of the rails shall conform to the design specified by the purchaser subject to the following tolerances on dimensions:

	Inches (Thousandths)	
	Plus	*Minus*
5.1.1 height of rail (measured 1 ft from each end)	.030	.015
5.1.2 width of the rail head (measured 1 ft from each end)	.040	.040
5.1.3 thickness of web	.040	.020
5.1.4 width of either flange	.040	.040
5.1.5 width of base	.050	.050

5.1.6 No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fishing templet may stand out not to exceed 1/16 in. laterally.

6. Branding and Stamping

6.1 Branding shall be rolled in raised characters on the side of the web of each rail a minimum of every 16 ft in accordance with the following requirements:

6.1.1 The data and order of arrangement of the branding shall be as shown in the following typical brand, the design of letters and numerals to be optional with the manufacturer.

132 (Weight)	RE (Section)	CC (Method of Hydrogen Elimination, if indicated in Brand)	Manufacturer (Mill Brand)	1977 (Year Rolled)	III (Month Rolled)

6.2 The heat number, rail letter, ingot number, and method of Hydrogen Elimination shall be hot stamped into the web of each rail a minimum of every 16 ft on the side opposite the brand.

6.2.1 The data and arrangement shall be as shown in the following typical stamping. The height of the letters and numerals shall be ⅝ inch.

287165 (Heat Number)	ABCDEFGH (Rail Letter)	12 (Ingot Number)	BC (Method of Hydrogen Elimination, if indicated in stamping)

6.2.2 The top rail from each ingot shall normally be hot stamped "A" and succeeding ones "B", "C", "D", "E", etc., consecutively.

6.2.3 Ingots shall be numbered in the order cast.

6.2.4 Alternatively, each rail shall be identified by hot stamping using a numerical and/or alphabetical system or coding. The system employed shall be such as to enable the hot stamp marking to be collated with:

—the position of the rail relative to the top of the ingot or bloom or continuously cast strand

—any other identification of the position of the rail within the cast, as agreed between the purchaser and manufacturer.

7. Hydrogen Elimination

7.1 The rail shall be free from shatter cracks.

7.2 The above shall be accomplished by at least one of the following processes:

Control Cooling of Rails (CC) (See Appendix 1)
Control Cooling of Blooms (BC)
Vacuum Treated (VT)
Such other processes as will meet the conditions of 7.1 (OP)

7.3 The mill brand or stamp shall identify the process used by the initials in parenthesis shown in Section 7.2.

8. Resistance to Impact

8.1 Rail produced by a continuous casting process is not subject to this requirement.

8.2 Resistance to impact shall be determined on a machine which conforms to the requirements of the AREA "Specifications for a Drop Test Machine."

8.3 Test Specimens.

8.3.1 Drop tests shall be made on test specimens of rail not less than 4 ft and not more than 6 ft in length.

8.3.2 The test specimens shall be cut from the top of the top rail from one of the first three, one of the middle three and one of the last three ingots of each heat.

8.3.3 Temperature of the test specimens shall not exceed 100°F.

8.4 Test Procedure.

8.4.1 The distance between support shall be 3 ft for sections under 106 lbs. For sections 106 to 140 lbs. it shall be 4 ft. For sections over 140 lbs. it shall be 4 ft, 8 in.

8.4.2 The test specimens shall be placed head upwards on the supports and subjected to one blow from the tup falling free from the following heights for rails of the nominal weights indicated:

Weight per Yard Pound	*Feet*
90-100	19
101-120	20
121 and over	22

8.5 Test Requirements.

8.5.1 If all three specimens withstand the above drop test without breaking between the supports, all of the rails of the heat will be accepted subject to final inspection for surface, section and finish.

8.5.2 If any specimen breaks in a location other than between the supports, the test shall be disregarded and a retest shall be taken from the top of the rail involved.

8.5.3 If one of the three specimens fails, subject to the requirements of 8.4.2, all of the top rails of the heat shall be rejected.

8.5.4 Specimens shall then be cut from the bottom end of the same top rails or the top end of the "B" rails of the same ingots and tested subject to 8.4.2. If any of these specimens fail, the "B" rails of the heat shall be rejected.

8.5.5 Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails of the same ingots and tested subject to 8.4.2. If none of these specimens fail, the balance of the heat shall be accepted subject to final inspection for surface, section and finish. If any of the specimens fail, the entire heat shall be rejected.

9. Interior Condition

9.1 A test piece representing the top end of the top rail of each ingot of each heat rolled, which has passed the drop test requirement of Section 8, shall be nicked and broken. If the fracture on any test specimen exhibits seams, laminations, cavities, evidence of injurious segregation, or interposed foreign matter, the heat number and ingot number shall be recorded and the top end and bolt holes of the finished rail, so recorded, shall be closely examined for those defects. If the finished rail is clear of the above defects when presented for inspection, it shall be accepted as a No. 1 or No. 2 rail, subject to the requirements of 10. If the finished rail shows defects, it shall be broken or cut back to sound metal and accepted as a short rail, subject to the requirements of 10 and 11.

9.2 Short rails produced under this procedure shall be excluded from consideration in the limitation of 11.2.

9.3 9.1 and 9.2 may be waived if the purchaser requests the application of Supplementary Requirement S.2.

10. Surface Classification

10.1 Rails free from surface imperfections and flaws of all kinds shall be classified No. 1 rails.

10.2 Rails which contain surface imperfections in such number or of such character as will not, in the judgment of the purchaser's inspector, render them unfit for recognized uses shall be accepted as No. 2 rails.

10.3 No. 2 rails to the extent of 5 percent of the total tonnage shall be accepted from each individual order.

11. Length

11.1 The standard length of rails shall be 39 ft when corrected to a temperature of 60°F.

11.2 Up to 9 percent of the total tonnage accepted from each individual order will be accepted in shorter lengths varying by 1 ft from 1 ft shorter than the ordered length to 25 ft.

11.3 A variation of 7/16 in. from the specified length will be permitted.

11.4 Standard length variations other than those set forth in 11.2 and 11.3 may be established by agreement between the purchaser and manufacturer in accordance with Supplementary Requirement S4.

12. Drilling

12.1 The purchaser's order shall specify the amount of right-hand-drilled and left-hand-drilled rails, drilled-both-end rails and undrilled (blank) rails desired. The right-hand or left-hand end of the rail is determined by facing the side of the rail on which the brand (raised characters) appears.

12.1.1 When right-hand and left-hand drilling is specified, at least the minimum quantity of each indicated by the purchaser will be supplied.

12.1.2 Disposition of short-rails which accrue from left-hand-drilled, right-hand-drilled, and undrilled (blank) rail production, and which are acceptable in accordance with 11.2 shall be established by agreement between the purchaser and the manufacturer.

12.2 Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser.

12.2.1 A variation of nothing under and 1/16 in. over in the size of the bolt holes will be permitted.

12.2.2 A variation of 1/32 in. in the location of the holes will be permitted.

12.3 Fins and burrs at the edges of bolt holes shall be eliminated. The drilling process shall be controlled so as not to mechanically or metallurgically damage the rail.

13. Workmanship

13.1 Rails shall be straightened cold in a press or roller machine to remove twists, waves and kinks until they meet the surface and line requirements specified, as determined by visual inspection.

13.2 When placed head up on a horizontal support, rails that have ends higher than the middle will be accepted, if they have a uniform surface upsweep, the maximum ordinate of which does not exceed ⅜ in. in 39 ft is illustrated in Fig. 1.

TOLERANCES FOR INSPECTION OF RAIL

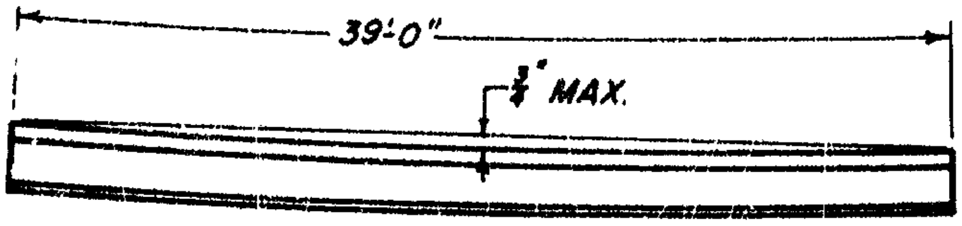


Fig. 1—SIDE ELEVATION OF RAIL
UNIFORM UPSWEEP TOLERANCE PER SECTION 13.2

13.3 The uniform surface upsweep at the rail ends shall not exceed a maximum ordinate of 0.025 in. in 3 ft and the 0.025 in. maximum ordinate shall not occur at a point closer than 18 in. from the rail end as illustrated in Fig. 2.

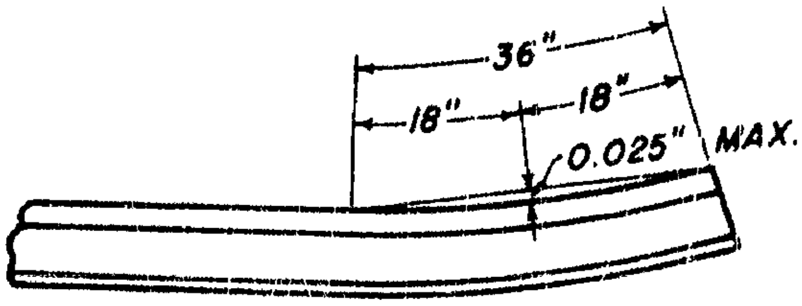


Fig. 2—SIDE ELEVATION OF RAIL
UNIFORM UPSWEEP TOLERANCE AT RAIL ENDS PER SECTION 13.3

13.4 Surface downsweep and droop shall not be acceptable.

13.5 Deviations of the lateral (horizontal) line in either direction at the rail ends shall not exceed a maximum mid-ordinate of 0.030 in. in 3 ft using a straight edge and of 0.023 at the end quarter-point as illustrated in Fig. 3.

13.6 When required, proof of compliance with 13.2 shall be determined by string (wire) lining, and a straightedge and taper gauge shall be used to determine rail end surface and line characteristics specified in 13.3, 13.4, and 13.5.

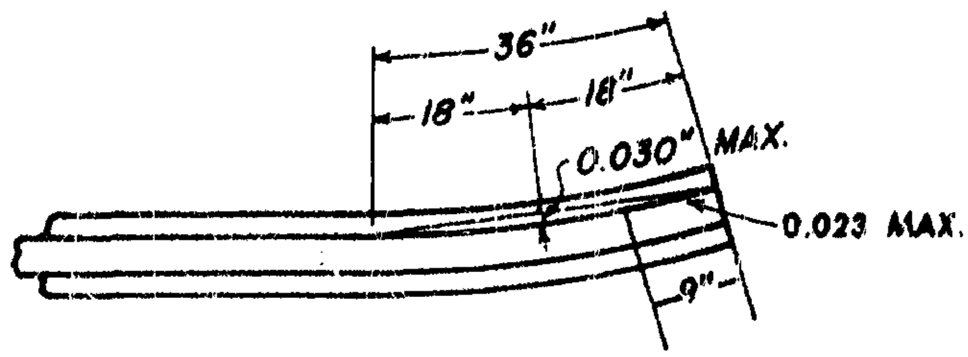


Fig. 3—TOP VIEW OF RAIL
LATERAL (HORIZONTAL) LINE TOLERANCE
AT RAIL ENDS PER SECTION 13.5

13.7 Rails shall be hot sawed, cold sawed, milled, abrasive wheel cut, or ground to length, as specified by purchaser, on purchase order, with a variation in end squareness of not more than 1/32 in. allowed (3/64 for 140 and over). The method of end finishing rails shall be such that the rail end shall not be metallurgically or mechanically damaged.

13.8 Stamping shall be performed in such a manner that will avoid stamping to a nominal depth of less than nominal 1/16 in.

14. Acceptance

14.1 To be accepted, the rails offered must fulfill all the requirements of these specifications.

14.2 Only A-rails produced on the purchaser's order will be accepted.

15. Markings

15.1 High-strength rails shall be marked by either a metal plate permanently attached to the neutral axis, hot stamped, or in the brand which gives the manufacturer, type and/or method of treatment. Heat treated shall be paint-marked orange and alloy rail shall be paint-marked aluminum.

15.2 No. 2 rails shall be paint-marked white.

15.3 "A" rails shall be paint-marked yellow.

15.4 No. 1 rails less than 39 ft long shall be paint-marked green.

15.5 Individual rails shall be paint-marked only one color, according to the order listed above.

15.6 Paint markings will appear on the top of the head at one end only, at least 3 ft. from the end.

16. Loading

16.1 Rails shall be handled carefully to avoid damage and shall be loaded in separate cars, with the branding on all rails facing the same direction, according to the marking, except when the number of rails in a shipment is insufficient to permit separate loading.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, order and contract.

S1. End Hardening

S1.1 The drilled ends may be specified to be end hardened. When so specified, end hardening and chamfering shall be in accordance with S1.1.1 through S1.1.7.

S1.1.1 End-hardened rails may be hot stamped with letters CH in the web of the rail ahead of the heat number.

S1.1.2 Water shall not be used as a quenching medium except in oil-water or polymer-water emulsion process approved by the purchaser.

S1.1.3 Longitudinal and transverse sections showing the typical distribution of the hardness pattern produced by any proposed process shall, upon request of purchaser, be submitted to the purchaser for approval before production on the contract is started.

S1.1.4 The heat-affected zone defined as the region in which the hardness is above that of the parent metal shall cover the full width of the rail head and extend longitudinally a minimum of 1½ in. from the end of the rail. The effective hardness zone ½ in. from the end of the rail shall be at least ¼ in. deep.

S1.1.5 The hardness measured at a spot on the centerline of the head ¼ in. to ½ in. from the end of the rail shall show a Brinell hardness number range of 341 to 401 when decarburized surface has been removed. A report of hardness determination representing the product shall be given to the purchaser or his representative.

S1.1.6 The manufacturer reserves the right to retreat any rails which fail to meet the required Brinell hardness number range.

S1.1.7 Chamfering rail ends shall be done in such a manner as will avoid formation of grinding cracks.

S2. Ultrasonic Testing

S2.1 The rail may be specified to be ultrasonically tested for internal imperfections and pipe by the purchaser or manufacturer.

S3. Calibration and Operation of Instruments

a. The instrument shall be standard ultrasonic testing equipment acceptable to purchaser.

b. Transducer or sensor shall be standard dual transducer of 5 MHz acceptable to purchaser.

c. Test block shall be of purchaser's choice with the following characteristics: Material 4340 AISI Steel/Nickel Plate, manufactured in accordance with ASTM E 127-64. Dimension of test block and flat bottom hole shall also be of purchaser's choice.

d. Calibration of instrument shall be performed every 30 minutes.

e. When search unit is properly coupled to test block or web of rail, a back reflection should appear at full maximum height on the Cathode Ray Tube "Graticule."

f. Couplant shall be distributed over the area to be examined and search unit moved over the entire area in vertical or horizontal sweeps. Any indication above the initial trace line between the initial impulse and the back reflection will be regarded as a flaw, inclusion or void and shall be reason for rejection.

S4. Standard Length Variations

S4.1 Rails may be furnished in miscellaneous lengths between the 1 ft increments established in 11.2. Rails may be applied in the maximum length at which ends can be properly prepared.

S4.2 Under the arrangement of S4.1 the provisions of 11.3 shall be waived for other than the 39 ft length. Lengths 38 ft and under shall be considered as shorts and subject to the specified limitations.

APPENDIX 1

Inasmuch as the controlled cooling of rails has proved a successful method for the elimination of hydrogen, the following procedure is presented as one which will meet the requirements of Section 7.1.

1. All rails shall be cooled on the hot beds or runways until the temperature is between 1000 and 725 deg F and then charged immediately into the containers.

2. The temperature of the rails before charging shall be determined at the head of the rail at least 12 in. from the end.

3. The cover shall be placed on the container immediately after completion of the charge and shall remain in place for at least 10 hours. After removal or raising of the lid of the container, no rail shall be removed until the temperature of the top layer of rails has fallen to 300 deg F or lower.

4. The temperature of an outside rail or between an outside rail and the adjacent rail in the bottom tier of the container, at a location not less than 12 in. nor more than 36 in. from the rail end, shall be recorded. This temperature shall be the control for judging rate of cooling.

5. The container shall be so protected and insulated that the control temperature shall not drop below 300 deg F in 7 hours for rails 100 lb per yd in weight or heavier, from the time that the bottom tier is placed in the container, and 5 hours for rails of less than 100 lb per yd in weight. If this cooling requirement is not met, the rails shall be considered control-cooled, provided that the temperature at a location not less than 12 in. from the end of a rail at approximately the center of the middle tier does not drop below 300 deg F in less than 15 hours.

6. The purchaser shall be furnished a complete record of the process for each container of rails.

APPENDIX D

MISSOURI PACIFIC RAILROAD PURCHASE ORDER FOR CHROME-VANADIUM RAIL

210 N. THIRTEENTH ST.
ST. LOUIS, MISSOURI 63103
AREA CODE 314-622-0123

Page 1 of 2.

PURCHASE ORDER

ALL PACKAGES, INVOICES, BILLS OF LADING, SHIPPING NOTICES AND CORRESPONDENCE

ORDER NUMBER	DATE
F96161-W	7/6/81

3035
VENDOR CODE

FERROSTAAL CORPORATION
50 CALIFORNIA ST #3105
SAN FRANCISCO, CA 94111

THIS ORDER GIVEN PURSUANT TO TERMS AND CONDITIONS AS SET FORTH ON THE REVERSE SIDE AS WELL AS THE FRONT HEREOF.

RENDER EACH INVOICE IN TRIPLICATE TO
MANAGER DISBURSEMENT ACCOUNTING
210 N. THIRTEENTH ST. - RM 712
ST. LOUIS, MISSOURI 63103

SHIP TO:
CARE OF: MISSOURI PACIFIC RAILROAD COMPANY
C D BARTON
ZONE 4, TRACK 14, CYPRESS YARD
KANSAS CITY, MO

ROUTE VIA:

SHIP MATERIAL NOT LATER THAN

SHOW THIS NUMBER ON ALL INVOICES AND PACKING

QUANTITY	DESCRIPTION	STOCK CONTROL NO.	PRICE	
423,529 LF OR 9,600 NT	RAIL 136# RE HIGH STRENGTH RAIL IN ACCORDANCE WITH CURRENT AREA SPECIFICATION FOR STEEL RAILS. No. 2 RAILS WILL BE ACCEPTED IN ACCORDANCE WITH PARAGRAPH 10 - SURFACE CLASSIFICATION. PARAGRAPH 11 - SHORT RAILS UP TO 9% ON THE TOTAL TONNAGE OF THE ORDER WILL BE ACCEPTED IN LENGTHS VARYING BY 1 FT. TO 25 FT. SHORT RAILS ARE TO BE SEGREGATED BY LENGTH. ALL RAILS ARE TO BE LOADED BASE DOWN AND HEAD UP.	LX 571 ~~1361676~~ 1364010	614.40	NT

SUPPLIER TO ADVISE THE FOLLOWING:

1) STATE THE CASTING PROCEDURE TO BE USED IN MANUFACTURE OF THE RAILS.

2) STATE THE CHEMICAL COMPOSITION OF THE STEEL.

3) STATE IF THE RAILS WILL BE ULTRASONICALLY TESTED IN ACCORDANCE WITH SUPPLEMENTARY REQUIREMENT S2 (IF RAIL IS ULTRASONICALLY TESTED, NICK AND BREAK TEST FOR INTERIOR CONDITION WILL BE WAIVED AS PERMITTED UNDER PARAGRAPH 9 - INTERIOR CONDITION).

SHIP MATERIAL NOT LATER THAN

F.O.B.

SHIP QUANTITY ORDERED IN THIS UNIT OF

DEFINITIONS OF UNIT OF MEASURE ABBREVIATIONS

BY

PURCHASING DEPT. COPY

OVER

CORRESPONDENCE PERTAINING TO THIS ORDER SHOULD BE ADDRESSED ...
SEND 1 COPY OF SHIPPING NOTICE TO ...
PACKING LIST MUST ACCOMPANY EACH SHIPMENT.

Page 2 of 2.

210 N. THIRTEENTH ST.
ST. LOUIS, MISSOURI 63103
AREA CODE 314-622-0123

PURCHASE ORDER

3035
VENDOR CODE

FERROSTAAL CORPORATION
50 CALIFORNIA ST #3105
SAN FRANCISCO, CA 94111

ORDER NUMBER	DATE
F96161-W	7/6/81

THIS ORDER GIVEN PURSUANT TO TERMS AND CONDITIONS AS SET FORTH ON THE REVERSE SIDE AS WELL AS THE FRONT HEREOF.

RENDER EACH INVOICE IN TRIPLICATE TO
MANAGER DISBURSEMENT ACCOUNTING
210 N. THIRTEENTH ST - RM 712
ST. LOUIS, MISSOURI 63103

SHIP TO : MISSOURI PACIFIC RAILROAD COMPANY
CARE OF : C D BARTON
ZONE 4, TRACK 14, CYPRESS YARD
KANSAS CITY, MO

ROUTE VIA :

SHIP MATERIAL NOT LATER THAN

SHOW THIS NUMBER ON ALL INVOICES AND PACKING L

QUANTITY	DESCRIPTION		STOCK CONTROL NO.			PRICE	PRICE PER
	4) STATE METHOD TO BE USED FOR HYDROGEN ELIMINATION AS DEFINED IN PARAGRAPH 7 - HYDROGEN ELIMINATION.						
	PRICE IS FIRM FOR THIS SHIPMENT DATE ONLY. SHIPMENT TO ARRIVE IN December, 1981 WITH PAYMENT IN JANUARY, 1982.						

SHIP MATERIAL NOT LATER THAN

SHIP QUANTITY ORDERED IN THIS UNIT OF MEA

F.O.B. 99 FREE ON RAIL CARS AT PORT ALLEN, LA

TERMS NET

DEFINITIONS OF UNIT OF MEASURE ABBREVIATIONS

PURCHASING DEPT. COPY

OVER

BY
H. L. LEGG/PURCHASING AGENT

CORRESPONDENCE PERTAINING TO THIS ORDER SHOULD BE ADDRESSED TO 210
SEND 1 COPY OF SHIPPING NOTICE TO CONSIGNEE & 1 TO SIGNER.
PACKING LIST MUST ACCOMPANY EACH SHIPMENT.

APPENDIX E

NATIONAL BUREAU OF STANDARDS TEST REPORT

September 5, 1984

Memorandum Report to: Dr. Carol A. Roberts
Chief, Laboratory Services Division
National Transportation Safety Board
Washington, D.C. 20594

T.R.Shives DJ

From: T. Robert Shives
Fracture and Deformation Division
Center for Materials Science
National Bureau of Standards
Gaithersburg, Maryland 20899

Subject: Results of tensile tests, Charpy V-notch impact tests, chemical analysis, and Brinell hardness tests of high strength rail involved in a a derailment of Amtrak Train Number 21 which ocurred in Woodlawn, Texas, on November 12, 1983.

In a letter dated April 9, 1984, the National Transportation Safety Board (NTSB) requested the National Bureau of Standards Fracture and Deformation Division to perform tensile tests, Charpy V-notch impact tests, Brinell hardness tests, and a chemical analysis, including hydrogen, on a high strength rail involved in the derailment of Amtrak Train Number 21. Specimen type, location, orientation, and designation was done by Mr. J. Wildey of the NTSB. The tensile and hardness survey specimens were taken from the railhead. The Charpy and chemistry specimens were taken from the web plate. The locations in the rail from which the specimens were taken are shown in Figure 1.

Three tensile specimens were machined in accordance with ASTM Designation E8-82 for standard 0.500 inch round tension test specimens with a two inch gage length. The tensile specimens were tested on a Satec System 25000 Kg capacity testing machine. To record strain, an LVDT extensometer was attached to each specimen and after yield, the extensometer was removed. Cross-head speed was maintained at 0.040 in/min throughout the test. The tensile test results are given in Table 1.

The Charpy V-notch impact specimens were machined and tested in accordance with ASTM Designation E23-82. Tests were run on a 264 ft-lb capacity Tinius-Olson impact machine at temperatures of 40°F, 50°F, and 60°F. These test temperatures were chosen by NTSB. The Charpy V-notch impact test results results are given in Table 2.

A Brinell hardness survey was done on the side of the railhead. After surface grinding to a flat and parallel surface Brinell hardness indentations were taken. The results are shown in Table 3.

A sample from the web of rail was analyzed for chemical composition by a commercial laboratory. The sample was analyzed for Cr, Si, Mn, V, Mo, C, Ni, S and P as requested by NTSB. In addition NTSB requested a hydrogen analysis. The hydrogen analysis was performed at NBS on areas taken from three other samples selected by NTSB. The results of these analyses are given in Table 4.

APPENDIX E

Table 1. Results of Tension Tests

Specimen	Ultimate Tensile Strength[1], psi	Yield Strength[1] 0.2% offset, psi	Elongation[2], % in 2 inches	Reduction[3] of Area %
1	173,000	115,000	7.0	8.5
2	174,000	114,000	7.0	10.0
3	171,000	106,000	7.2	10.0

1. Values given to the nearest 1000 psi in accordance with ASTM Designation E8-82.
2. Values given to the nearest 0.2% in accordance with ASTM Designation E8-82.
3. Values given to the nearest 0.5% in accordance with ASTM Designation E8-82.

Table 2. Results of Charpy V-Notch Impact Tests

Specimen	Test Temperature °F	En. Absorbed Ft-lb	% Shear Fracture	Lateral Expansion, inch
1	59.7	1.5	0	Less than .001
2	49.7	1.5	0	Less than .001
3	39.4	1.25	0	Less than .001

Table 3. Results of Brinell Hardness Tests

Readings	Diameter mm[4]	Brinell Hardness
1	3.30	341
2	3.27	347
3	3.28	345
4	3.28	345

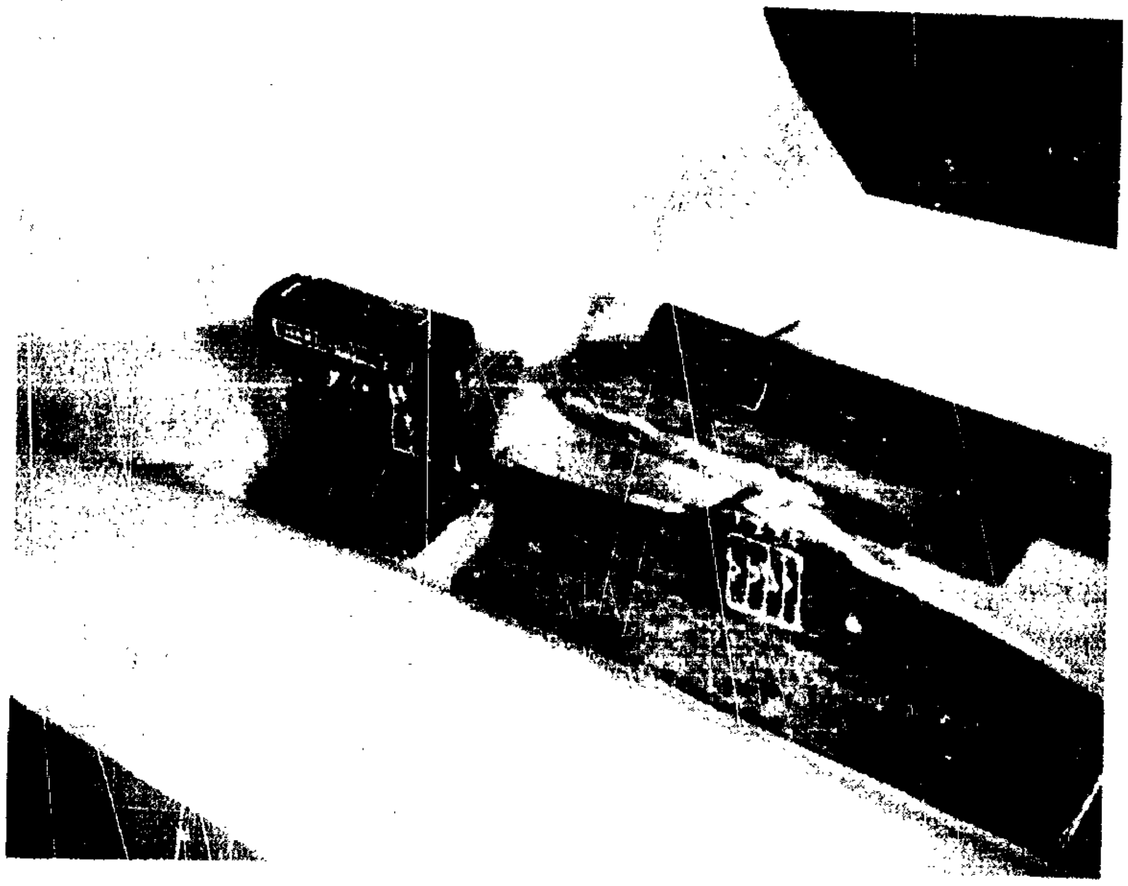
[4] Average of two values

Table 4. Results of Chemical Analysis

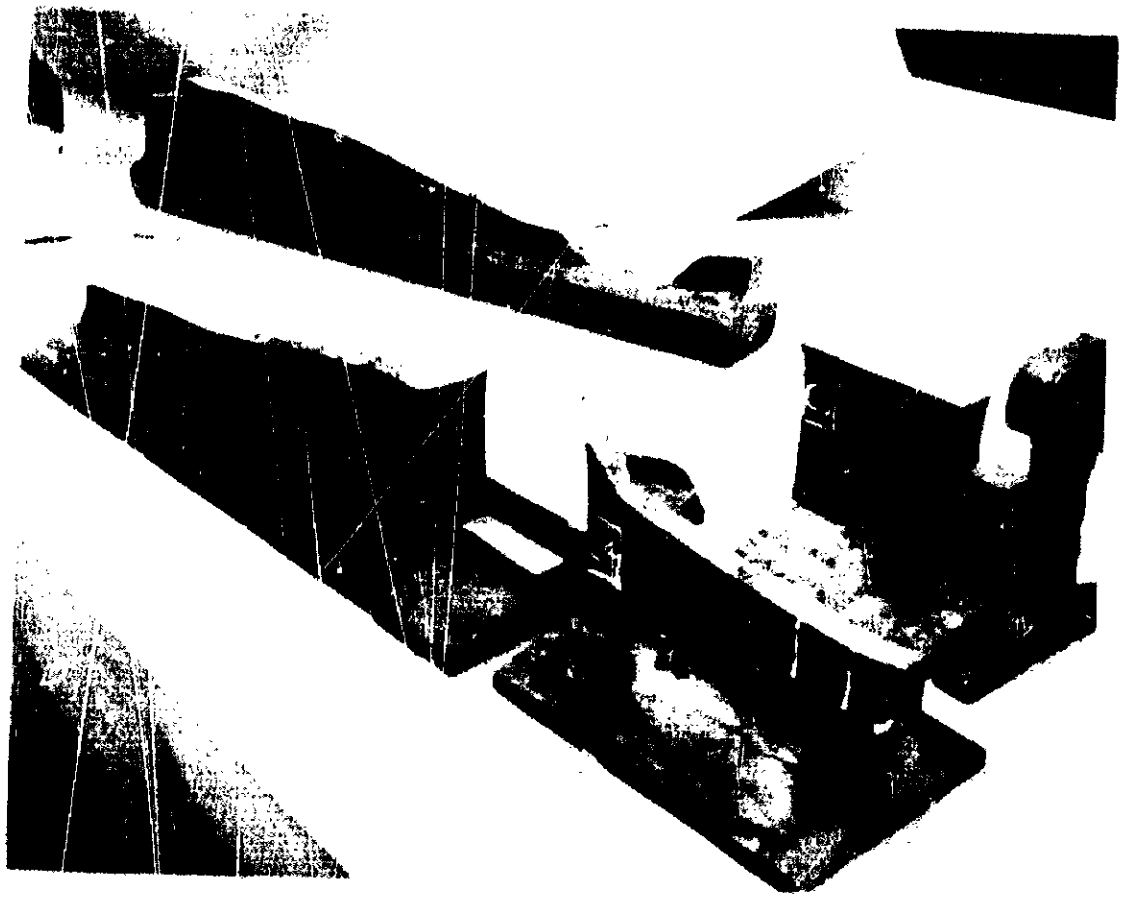
Element	Weight Percent
Carbon, C	0.80
Manganese, Mn	1.10
Phosphorus, P	0.011
Sulfur, S	0.019
Silicon, Si	0.59
Nickel, Ni	0.02
Chromium, Cr	0.89
Molybdenum, Mo	0.01
Vanadium, V	0.042
Copper, Cu	0.03

Hydrogen, H (total ppm)

Sample:	Run 1	Run 2
C1	0.05	0.07
C3	0.20	0.16
C4	1.22	0.98



(a)



(b)

Figure 1. Location of test specimens in rail.
(a) view showing the location of hardness, tensile, impact, and chemistry (general) specimens,
(b) location of specimens used for hydrogen analysis.

APPENDIX F

BURLINGTON NORTHERN RAILROAD
TEST REPORT

July 13, 1984

Mr. Jerry R. Masters
Chief Engineer-Maintenance
Burlington Northern Railroad Company
9401 Indian Creek Parkway
Overland Park, Kansas 66210

Dear Mr. Masters:

This letter is to confirm our conversation of July 12, 1984. The Safety Board is investigating the derailment of Amtrak train No. 21 on the Missouri Pacific Railroad at Woodlawn, Texas, on November 12, 1983. The accident resulted in 4 passenger fatalities and 72 injuries, and damage is estimated to exceed $2,250,000. As a result of this accident, on April 20, 1984, the Safety Board issued recommendation R-84-20 to member railroads of the Association of American Railroads, relative to high-strength alloy rail, including chrome-vanadium alloy rail. A copy of R-84-20 is attached for your information.

As noted during our conversation, it has come to the Safety Board's attention that Burlington Northern (BN) had acquired a quantity of rail for test purposes, similar to the rail involved in the Amtrak/Missouri Pacific accident of November 12, 1983. Further, it has come to the Safety Board's attention that in or about January of 1984, during test welding procedures being conducted on that chrome-vanadium alloy rail reportedly at the BN rail welding facility at Laurel, Montana, a portion of said rail approximately 75 to 78 feet in length was accidently dropped from a height of a few feet, resulting in a breakup of virtually the entire length of the rail.

Due to the apparent similarities of the fracture characteristics of the rail involved in the November 12, 1983 accident and of the rail involved in the test weld procedure incident in or about January 1984, the Safety Board deems it advisable to request from the BN the following information concerning its rail involved in the test weld procedure incident:

1. A statement of the details involving the manner in which the test welds were being performed, and of the incident of the rail breakage.

2. The specifications that were tendered to the manufacturer of the rail.

3. A statement of weight and section of the rail; the branding and stamping information; and the manufacturer.

4. The method of rail straightening employed by the manufacturer.

5. The method of hydrogen elimination employed by the manufacturer.

6. A statement of any recommendations furnished by the manufacturer regarding any special handling procedures for the chrome-vanadium rail.

7. The results of any and all tests performed on the rail broken in the mentioned test weld procedure incident, including copies of photographs of the rail.

Your cooperation in this matter is appreciated. If you have any questions concerning this matter, please feel free to contact me at (202) 382-6846.

Sincerely,

/s/

William G. Zielinski
Investigator-In-Charge

Docket No. DCA-84-RM-002

BURLINGTON NORTHERN RAILROAD

OPERATIONS DEPARTMENT

9401 Indian Creek Pkwy.
Overland Park, Kansas 66210
Telephone (913) 661-4100

July 23, 1984

Mr. William G. Zielinski
National Transportation Safety Board
800 Independence Avenue SW
Washington, DC 20594

Dear Mr. Zielinski:

SUBJECT: Chrome - Vanadium Alloy Rail

Reference to your letter of July 13, concerning the derailment involving an Amtrak train at Woodlawn, Texas, on November 12, 1983, and requesting certain information on chrome-vanadium alloy rail, which has been test welded by the Burlington Northern Railroad.

Following is the information requested:

1. On December 6, 1983, test welding was performed on chrome-vanadium rail to determine the optimum weld procedures for this particular type rail. The test weld procedure included the flash butt welding of two pieces of blank end rail and torch cutting back approximately three to four feet on either side of the completed weld. The two rail were then turned end for end, and a second test weld was performed on the opposite blank ends of the rail. Torch cuts were again made approximately three to four feet back on either side of the completed weld, and the remaining two pieces of rail (torch cut on both ends) were classified as scrap. The incident which involved the breakup of a piece of the chrome-vanadium rail occurred after the welding and torch cutting process was completed and the rail fell from the crane magnet a height of about six feet onto another rail pile. The ambient temperature was approximately -12 degrees F. at the time of the incident.

2. Rail to comply with the AREA specifications covering rail, dated 1979.

3. 132#, RE-VT-Thyssen, 1983, September, AL, 449-D-39.

4. Roller straightening process.

Mr. William G. Zielinski
July 23, 1984
Page 2

5. Vacuum-treated.

6. No special handling procedures for handling the chrome-vanadium rail.

7. Attached Test Report D-1315, dated March 9, 1984.

If we can be of any further assistance, please advise.

Sincerely,

L. F. Woodlock

L. F. Woodlock
Asst. Vice President Engineering

File: 81617

Attachment

3435/j12384073684f17

Burlington Northern Railroad Company
RESEARCH & DEVELOPMENT DEPARTMENT

UPON FUTURE REFERENCE REFER TO REPORT NUMBER

Material ALLOY RAIL Test Report No. D-1315

Manufacturer Thyssen Address

Purchase Order No. Specification

Date Sample Submitted Date Sample Received

Broken pieces of an alloy rail were received at Springfield Laboratory February 13, 1984 for failure analysis. The rail was a CrMnSiV, 132 lb. manufactured by Thyssen of Germany. The rail broke through the web when it fell off the crane magnet, from a height of six feet onto a rail pile. The incident happened on a cold day with a reported temperature of -12°F. to -18°F. Rail identification was reported as 132 RE-VT-Thyssen-1983 September-AL 449-D-39. Photograph G-5578 shows fracture surface of the failed pieces.

Laboratory Examination

1. Visual Inspection - Both pieces received at Springfield and a piece that was sent to G. W. Johnson at St. Paul were visually inspected. All fracture surfaces indicate a sudden break. The torch cut end was not sent for analysis therefore we are not certain whether or not there was a relationship between the torch cut area and the fracture.

2. Chemical Analysis - Except slightly high carbon content the chemistry of the rail steel is normal. Silicon content is in the higher limit of the specification. The analysis is shown below:

Carbon	0.834%
Manganese	1.071
Phosphorus	0.024
Sulfur	0.033
Silicon	0.925
Chromium	1.109
Vanadium	0.108

Brinell Hardness Numbers - Hardness numbers had very uniform distribution with an average of 341 (BHN).

Cause of Failure

The failure is attributed to the expected low toughness of the alloy rail steel. With high strength alloy rails it is necessary to avoid any impact stresses during handling, especially in cold temperature which

MAR 9 1984

Material Date Manager, Springfield Laboratory

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BURLINGTON NORTHERN RAILROAD

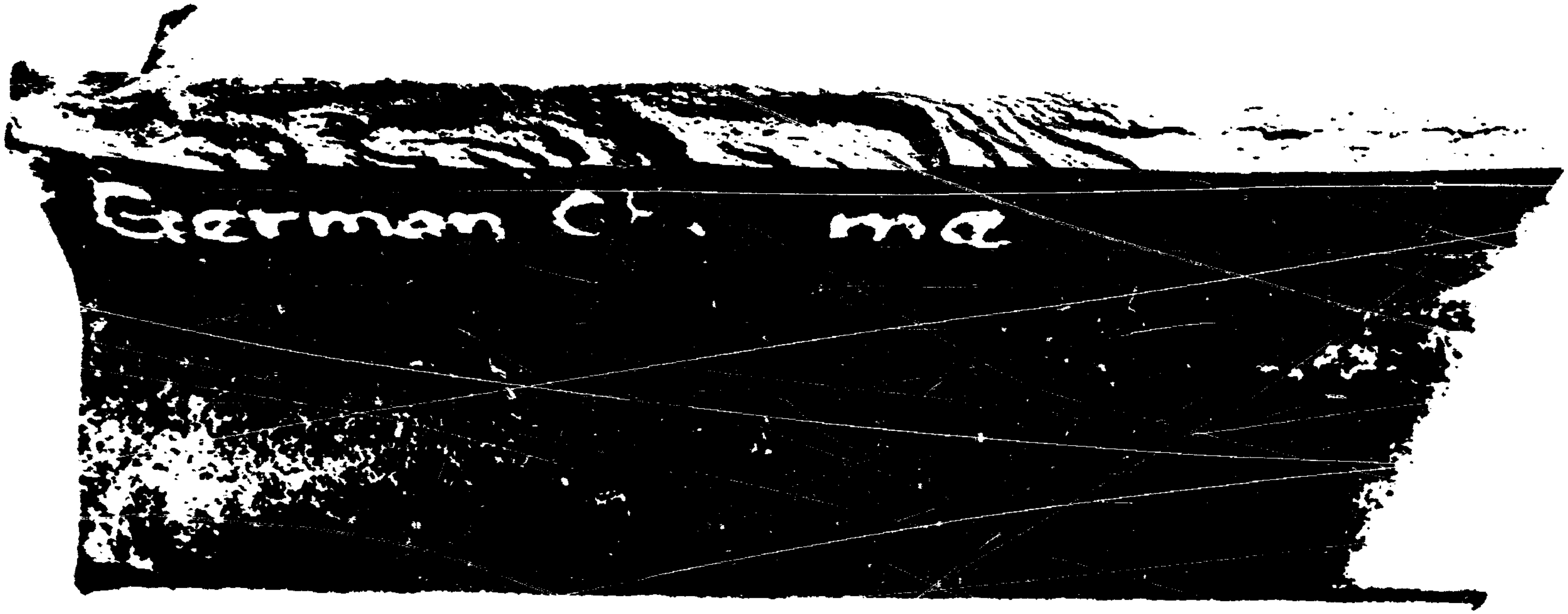
Test Report No. D-1315

Page 2

Material ALLOY RAIL

has adverse effects on the impact strength of the rail. Any dropped alloy rail even with no obvious failure must be rejected. Also, torch cutting of the alloy rails must be avoided since chance of crack initiation is very high upon cooling.

cc: J. R. Masters
R. D. White
T. S. Rochon
M. J. Cronin



Photograph G-5578

Section of broken Thyssen alloy rail which shattered when dropped at Laurel welding plant during sub zero temperatures.

APPENDIX F