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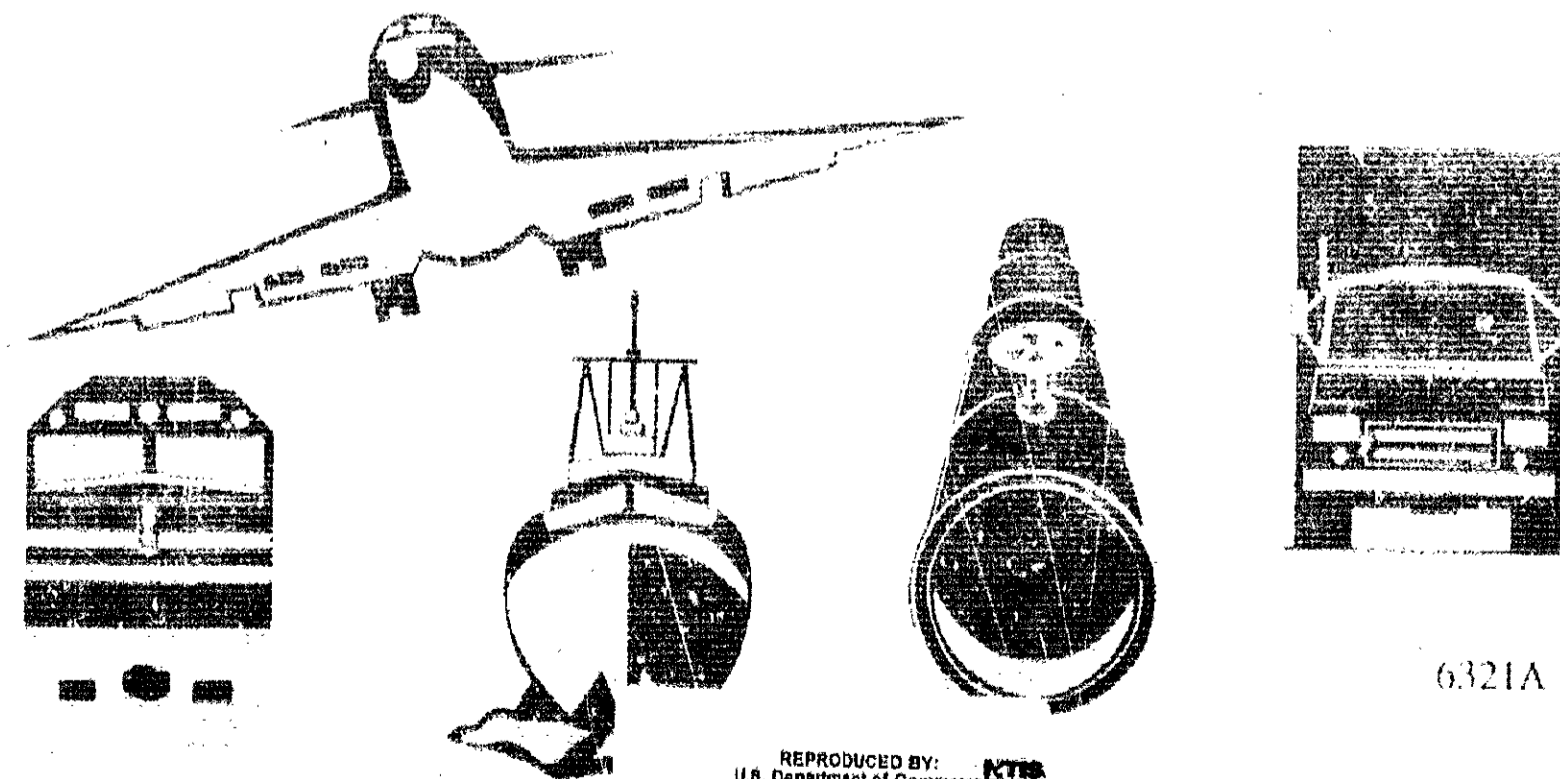


NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

DERAILMENT OF RINGLING BROS. AND
BARNUM & BAILEY CIRCUS BLUE TRAIN
NEAR LAKE LAND, FLORIDA
JANUARY 13, 1994



6321A

REPRODUCED BY:
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Abstract: On January 13, 1994, a northbound Ringling Bros. and Barnum & Bailey Circus (RBB&BC) train derailed about 9:08 a.m., eastern standard time, while passing through Lakeland, Florida, on CSX Transportation railroad en route to Orlando, Florida. A witness observed the train go by and saw two pieces of a wheel fly off a passenger car and land in nearby woods. The train continued 2.7 miles, across five grade crossings, with the broken wheel. When it reached the Park Spur turnout, 15 other passenger cars and 3 freight cars derailed. Of the 16 derailed passenger cars, 5 turned on their sides; the rest remained upright. Two circus employees were killed, and 15 received minor injuries.

The major safety issues discussed in this report are: the safety of straight-plate rim-stamped tread-braked railroad wheels and the securement of interior equipment and appliances on the circus train.

As a result of its investigation of this accident, the Safety Board makes safety recommendations to the Federal Railroad Administration, the Association of American Railroads, the National Railroad Passenger Corporation (Amtrak), the American Association of Private Railroad Car Owners, Inc., the American Short Line Railroad Association, the Association of Railway Museums, the National Passenger Car Alliance, the National Railroad Historical Society, the Tourist Railway Association, Inc., CSX Transportation, and the Ringling Bros. and Barnum & Bailey Circus.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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**DERAILMENT OF RINGLING BROS. AND
BARNUM & BAILEY CIRCUS BLUE TRAIN
NEAR LAKE LAND, FLORIDA
JANUARY 13, 1994**

RAILWAY ACCIDENT REPORT

Adopted: February 14, 1995
Notation 6321A

**NATIONAL
TRANSPORTATION
SAFETY BOARD**

WASHINGTON, D.C. 20594

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EXECUTIVE SUMMARY

On January 13, 1994, a northbound Ringling Bros. and Barnum & Bailey Circus train derailed about 9:08 a.m., eastern standard time, while passing through Lakeland, Florida, on CSX Transportation railroad en route to Orlando, Florida. A witness observed the train go by and saw two pieces of a wheel fly off a passenger car and land in nearby woods. The train continued 2.7 miles, across five grade crossings, with the broken wheel. When it reached the Park Spur turnout, 15 other passenger cars and 3 freight cars derailed. Of the 16 derailed passenger cars, 5 turned on their sides; the rest remained upright. Two circus employees were killed, and 15 received minor injuries.

The National Transportation Safety Board determines that the probable cause of the derailment of the Ringling Bros. and Barnum & Bailey Circus blue train was the fatigue failure of a thermally damaged wheel due to fatigue cracking that initiated at a stress raiser associated with a stamped character on the wheel rim.

The major safety issues discussed in this report are:

- o the safety of straight-plate rim-stamped tread-braked railroad wheels
- o securement of interior equipment and appliances on the circus train

As a result of its investigation of this accident, the Safety Board makes safety recommendations to the Federal Railroad Administration, the Association of American Railroads, the National Railroad Passenger Corporation (Amtrak), the American Association of Private Railroad Car Owners, Inc., the American Short Line Railroad Association, the Association of Railway Museums, the National Passenger Car Alliance, the National Railroad Historical Society, the Tourist Railway Association, Inc., CSX Transportation, and the Ringling Bros. and Barnum & Bailey Circus.

INVESTIGATION

The Accident

The 1994 Ringling Bros. and Barnum & Bailey (RBB&BC) blue train originated in St. Petersburg-Clearwater, Florida, as CSX Transportation (CSXT) train W923 of January 12, 1994, and was destined for Orlando, Florida. It was operated under contract by a CSXT operating crew made up of a locomotive engineer, a conductor, and a brakeman. The train was initially pulled by two CSXT locomotive units. The 53-car train was a "mixed" train of passenger¹ and freight cars. It had 34 passenger cars on the head end followed by 18 TTX-type flat cars loaded with containers, cages, or truck trailers. A bi-level autorack car was on the end. The length of the train, excluding the locomotive units, was 4,702 feet; the cars weighed 3,720 tons.

The RBB&BC trainmaster had given a hand-held portable radio to the locomotive engineer for communication and/or emergency use since the RBB&BC and railroad radios operated on different frequencies. According to the trainmaster, 20 RBB&BC employees, including himself, were authorized to have radios, although not all the employees who had authorized radios were on the train at the time of the accident.

The RBB&BC estimated about 150 of its approximately 250 employees were riding the train. The RBB&BC maintains no trip manifest and does not issue employee train tickets. Performers and employees are expected to be at the performance on time; how they get there is up to them.

When the train arrived in Tampa, CSXT operating crews changed, and the on-coming crew added an additional locomotive unit (CSXT 2682) as the lead unit. It was added because the off-going crew had reported an intermittent wheel-slip problem. The on-coming crew tested the locomotive radio and performed a satisfactory air-brake application and release test on the last car concurrently with a leakage test. Before leaving Tampa, the conductor called the trainmaster to tell him the train was about to leave. The trainmaster told the conductor to give him a wake-up call 1 hour before the train reached Orlando. Later, the conductor called the trainmaster to awaken him when the train got to Plant City.

There were varying degrees of morning fog or mist as the train departed Tampa about 7:30 a.m.; the mist continued up through the time of the accident. The engineer stated that he varied the speed of the train to comply with the train's timetable speed limit of 50 mph, frequently going slower to comply with visibility restrictions in order to see the wayside signals. The railroad was traffic control territory,² maintained to meet or exceed Federal Railroad Administration (FRA) Class IV track standards. Throughout the trip, neither CSXT train crew

¹Passenger cars include observation cars, lounge cars, coaches, sleeping cars, dining/cafe and food-service cars, baggage cars, railway post office cars, and any other cars that are intended to accommodate a passenger or rider.

²In traffic control territory, the dispatcher selects a route for a train, and the signals are set automatically to facilitate movement and to prevent conflicting movement from other trains.

noted anything unusual about the train's handling or performance.³ The engineer at the time of the accident characterized the train's operation as "outstanding."

About 3 miles before Plant City, at Dover, mile post (MP) 864.9, the train passed a defect detector (dragging equipment and hot box). The device automatically reports any detected defects to the passing train by radio synthesized voice. According to the CSXT superintendent of the Florida Business Unit (FBU),⁴ the detector is capable of detecting a hot wheel. No defects were reported, and the train continued on.

Just before Plant City, at the north end of Cherry, MP 861.9, the train passed a working CSXT maintenance-of-way gang that paused to observe the train for any obvious problems as required by CSXT Rule 42:

So far as practicable and as other duties permit, employees must observe passing trains for defects or any other condition that would endanger the train.

The maintenance employees did not note any defects.

About 8:09, a Plant City detective on his way to work turned off Bruton Road and started south on Highway 39. He saw a northbound freight train and smelled a "heavy smell...like brakes burning." He then noticed "that about midway in the train, one of the car wheels appeared to be on fire or smoking very heavily." He called the Plant City police dispatcher to inform CSXT of the smoking wheel.⁵ At 8:17, the Plant City police dispatcher called the CSXT chief dispatcher at the CSXT control center in Jacksonville, Florida.

Yes, this is the Plant City Police Department. I wanted to call and let you know we've got a train northbound on Highway 39 just past St. Allen Road at this time and it's, the wheel on it is smoking and flames are coming out of it.

The chief dispatcher replied,

Oh, boy. Let's see. Going north. Let's see, let me look here a second. I've got a couple different lines through Plant City. About three of them there. I'm trying to figure out which one it's on... I've got four doggone States I got railroads in here, and I can't keep up with all of them. Let's see, there it is. That would be a W92312 [RBB&BC train]. All right, I'll get a hold of them...

³49 *Code of Federal Regulations (CFR)* 213.9 covers Class IV track standards.

⁴*Florida Business Unit*, or *FBU*, is the designation given by CSXT to this portion of the CSXT system and is comparable to a railroad division. Before January 1, 1994, the FBU was called the Fertilizer Business Unit.

⁵The detective had seen CSXT train 800, a phosphate train. A phosphate train is a unit freight train that consists of covered hopper cars and is dedicated to the regular transportation of phosphate.

At 8:15, the phosphate train, which was northbound, crossed through the Plant City interlocking.⁶ At 8:16, the RBB&BC train, which was eastbound, crossed the same interlocking. At 8:18, the CSXT AA⁷ dispatcher called the CSXT operating crewmembers on the RBB&BC train and instructed them to stop and inspect their train.⁸

Dispatcher: Plant City police says you got a car with fire coming out from one of the wheels. You need to stop and inspect your train--over.
Engineer: Alright, any idea where it was on the train?
Dispatcher: No, he didn't say where it was on the train, no sir.
Engineer: Alright.
Dispatcher AA--out.

The CSXT crew stopped the RBB&BC train in the vicinity of Winston Yard, MP 857.2 (see figure 1). According to the conductor, the train stopped "300 feet south of Clark Street." The conductor got off on the left side of the train, and the brakeman got off on the right side (the engineer's side). They positioned themselves about 5 feet away from the train and inspected it as it pulled slowly by them. This "roll-by" procedure was necessary to detect stuck brakes, the suspected cause of the reported problem.

During postaccident interviews, the conductor said, "So we pulled it on down to where we could stop, and we got off and then walked our train, and we didn't find anything wrong with the train."⁹ The conductor also said that he didn't notice any hand brakes on; however, he said, "There was--there seemed to be a flat spot up around 10, about 10 cars deep. But a flat spot on a wheel is--you know, it makes a little thump. It's--you hear them all the time. It's not--not necessarily an unsafe condition." Because of the derailment, the conductor did not file a flat-spot report at Orlando as he was required to do by CSXT Rule 2.5.2, "Flat Spots on Wheels":

When flat spots are indicated by feel or sound, a stop must be made and running gear examined. Engineer will notify train dispatcher or yardmaster at first opportunity of flat spots or any other defective conditions found and include this information on Locomotive Inspection Report.

At completion of trip or tour of duty, written report of occurrence will be promptly made to the Road Foreman of Engines.¹⁰

⁶At this interlocking, two CSXT railroad tracks crossed each other.

⁷An AA dispatcher is subordinate to the chief dispatcher.

⁸At 8:40, the dispatcher called train 800 to tell its crewmembers to stop and inspect their train.

⁹Although the conductor said "walked," this was clarified to be the roll-by inspection.

¹⁰Because of the derailment, no report was filed.

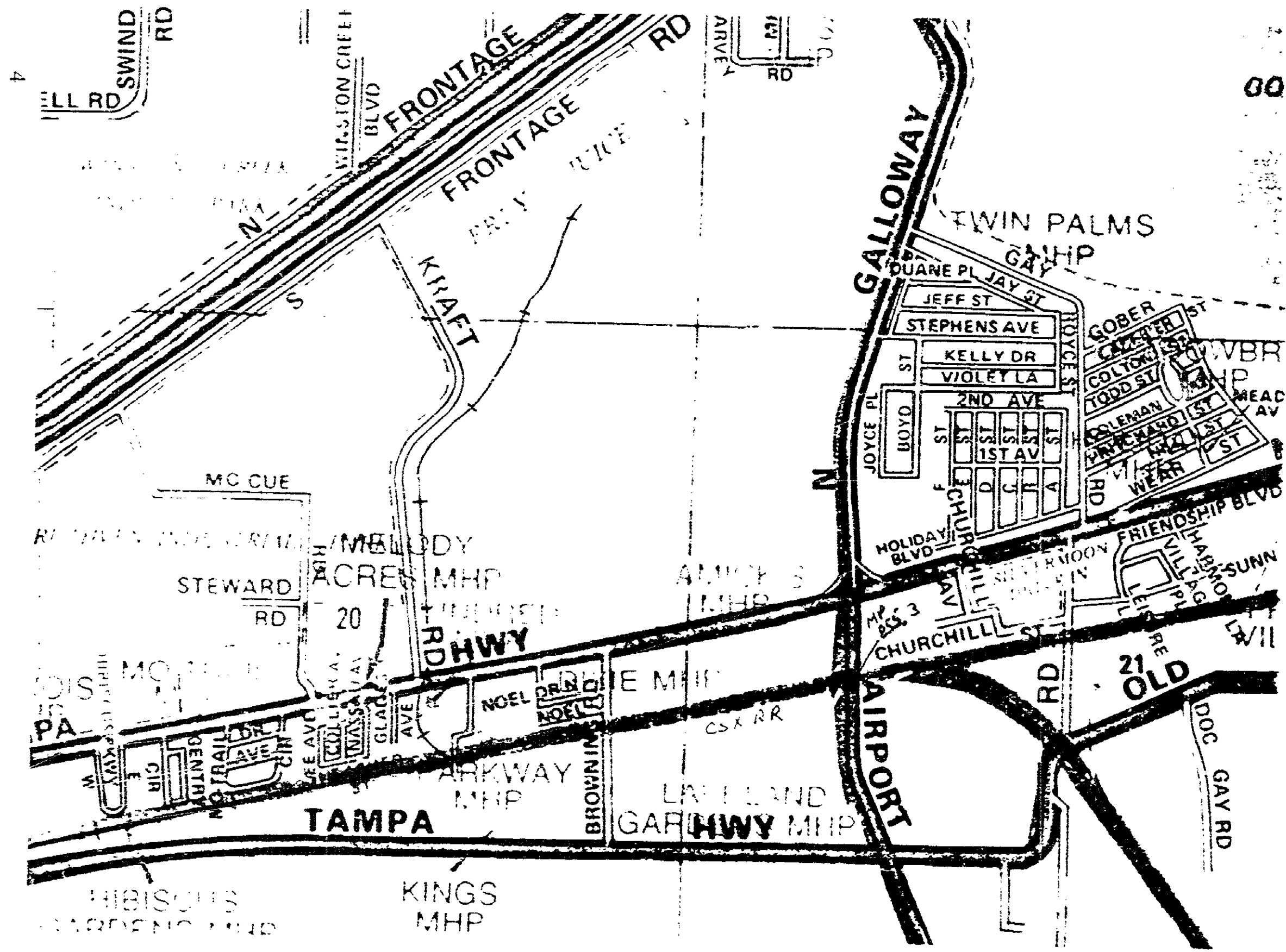


Figure 1.--Map of railroad and Airport Road.

When the brakeman was asked what he saw during the inspection, he said, "No I didn't note anything, and I didn't really hear anything; so I just--after the visual inspection I told my conductor about it, so we went back to the head end. I didn't notice anything."

Once the train pulled completely past, the conductor radioed the engineer to stop, and the lead locomotive came to a stop just short of the Airport Road crossing. The conductor and brakeman then started to walk toward Highway 600, New Tampa Highway, when a pickup truck stopped and gave them a ride back to the lead locomotive unit. At 8:39, the train crewmembers called the CSXT AA dispatcher to report that they had not found anything and to request permission to continue.

The dispatcher had taken the opportunity to run another train, train 601, around the RBB&BC train while it was stopped. He told the RBB&BC train he would move it as soon as train 601 cleared. The dispatcher reported the RBB&BC train to be moving at 8:45. At the Lakeland passenger station, MP 852, the train engineer received a clear signal.

About 8:45, a lawn-service employee who was driving a company van north on Airport Road had come to a stop at the crossing. When he pulled up to the crossing gates, he noticed a train sitting about 50 yards down the track. Believing he would be waiting a while, he shut off the van engine. As he shut it off, he noticed exhaust smoke coming from the train's locomotive units and the train starting to move. He soon realized that the train was no ordinary freight train but the RBB&BC train and listened for the sounds of animals. The first noise he noted was a large diesel generator.¹¹ After the generator noise died away with the passing train, he noted a "very loud clanking noise...like a high-speed train going across a railroad crossing that had loose ties under it."¹² He later said, "As the train car passed me, I lost the sound of the train making the noise, because it went through my door. The windshield came in front of the van and I kind of lost it; it dissipated the sound, and I didn't have the other window down, so it got quiet again." Although he had the driver's window down, the train was on the other side of the van, and the passenger's window was closed. After the clanking noise went by, he heard another large generator pass. The driver described the location of the clanking noise as "midway between the two diesel motors (generators)."

At MP 849.7, about 9:08, an industrial worker was watching the RBB&BC train go by and observed two pieces of a wheel fly off a passenger car and land in nearby woods. This was immediately followed by sparks, a dust cloud, and a "grinding noise." The worker called 911 to report the incident. The wheel was later found to be the L-4 wheel (no. 8 position), the left wheel on the lead axle of the lead truck of car 89, the 23rd car after the locomotive. Where the wheel broke and the associated truck of car 90 derailed was the initial point of the derailment.

Two circus performers¹³ in the vestibule of car 88, adjacent to car 89, had noticed that

¹¹Generators were in the 12th car, car 78, and in the 27th car, car 93.

¹²The driver had had some work experience as a track maintenance worker for a private contractor.

¹³They were professional clowns.

something was wrong with the train. One performer proceeded through the train in an effort to contact the trainmaster. None of the cars had a conductor's (emergency) brake valve (handle) or an intercom system, although some of the 20 RBB&BC employees authorized to have a radio for intra-train communication were on board.

The train continued 2.7 miles across five grade crossings¹⁴ with the broken wheel and derailed truck of car 89. At MP 847, 15 cars derailed (the general derailment) at the Park Spur turnout,¹⁵ starting with the 22nd car, car 88 (see figure 2). Of the 16 derailed cars, five fell on their sides; the rest remained upright (see figures 3 and 4).

At 9:11:55 (CSXT standard time), the Lakeland Police Department dispatcher called the CSXT dispatcher and said, "I have a Ringling Barnum and Bailey Circus train...on Gary Road and one of the wheels is off the track." At 9:12:55 (CSXT standard time), the CSXT dispatcher called to stop the RBB&BC train and was told by the train crew that it was already stopped.

Two RBB&BC employees died in the derailment, including the performer who had gone to find the trainmaster. She died of asphyxiation. She was found underneath a file cabinet in the leading (east) end of car 93, which had rolled on its side. The file cabinet had been attached to the wall with small brackets that had been screwed into the wall. The other employee, an elephant trainer in car 98, died of multiple fractures of the skull and massive head trauma when car 97 intruded into the side of car 98. Fifteen RBB&BC employees received minor injuries. There was no resulting fire, nor were hazardous materials involved. None of the animals were in the derailed cars, and none escaped or were injured.

According to the engineer, the train was moving 47 mph at the time of the accident. The locomotive units were not equipped with speed or event recorders. After the accident, the crewmembers were tox tested according to the FRA rules. The brakeman's test was positive for cocaine and marijuana.

When the train derailed, portions of it fell on top of two pipelines belonging to Central Florida Pipeline Corporation (CFPC), a subsidiary of GATX Terminals Corporation (see figures 5 and 6). (The diameters of the pipelines were 10 inches and 6 inches, respectively.) The wife of the local CFPC field engineer called her husband at work about 10:20, telling him a derailment had been reported on the news. He called the CSXT emergency number to confirm the derailment and location. He then told the pump station operator to shut down both pipelines. The operator was already shutting the lines down in response to an earlier call from the Polk County Utility Coordinator. The field engineer went to the accident site to supervise the integrity, safety, and, later, the inspection and replacement of the pipelines. After the derailed cars were removed, both pipelines were uncovered and inspected. Although they appeared undamaged, sections through the derailment area were replaced as a safety measure.

¹⁴A grade crossing is the spot where a railroad crosses a street, road, or highway.

¹⁵A turnout is a switch location for a diverging route.

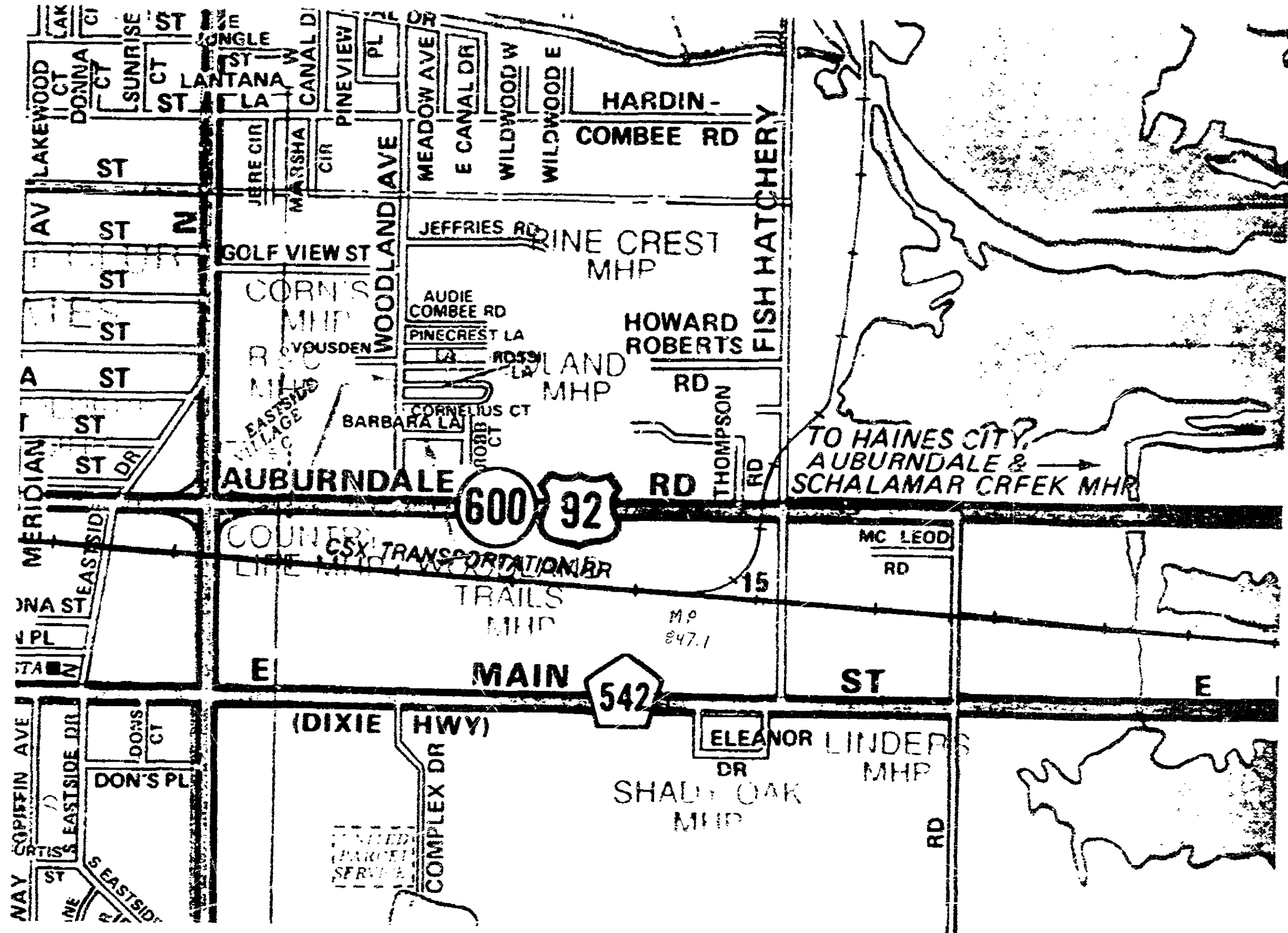


Figure 2.--Map of Park Spur turnout.



Figure 3.--Photograph of cars on their sides.

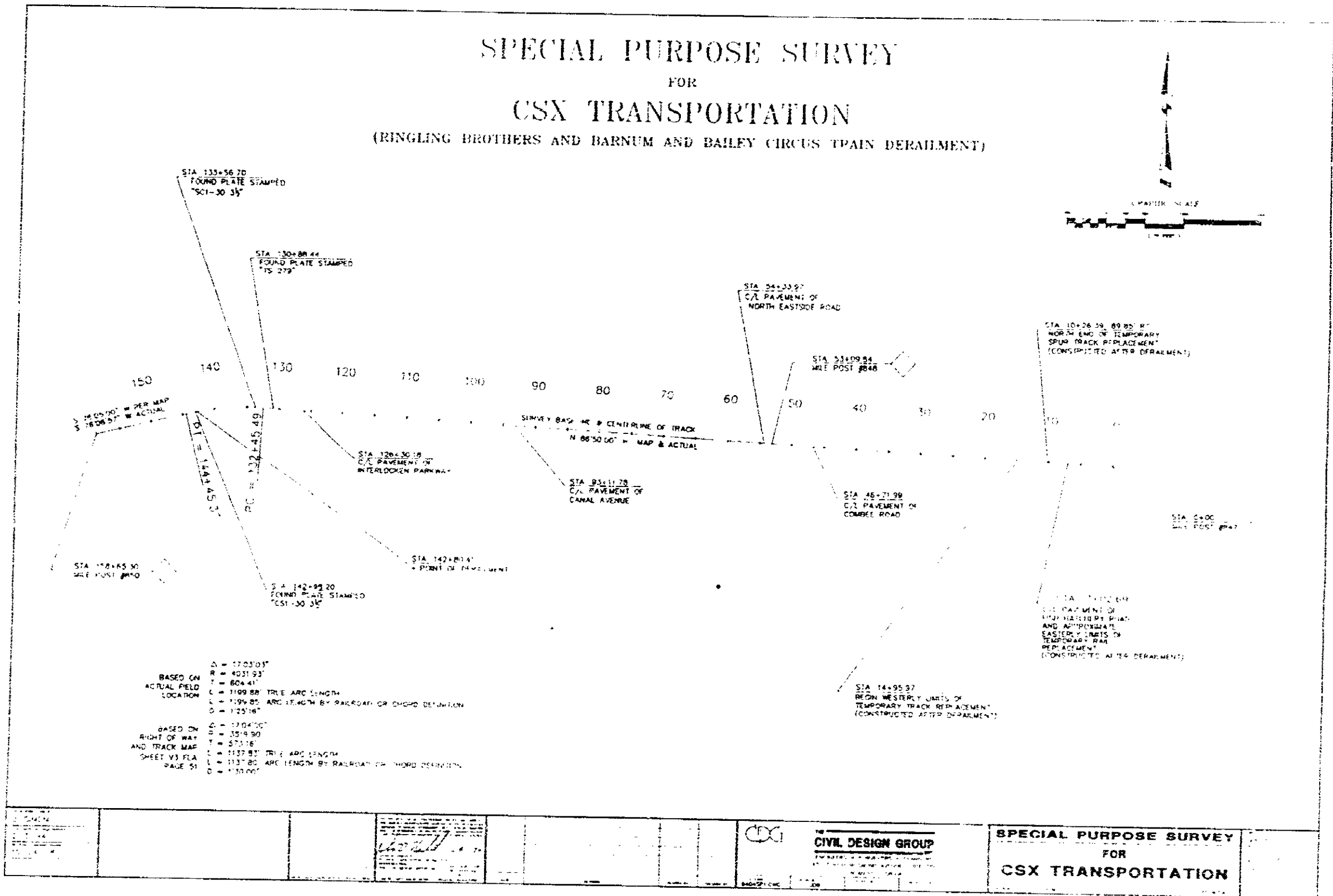


Figure 4.--CSXT survey of accident area.

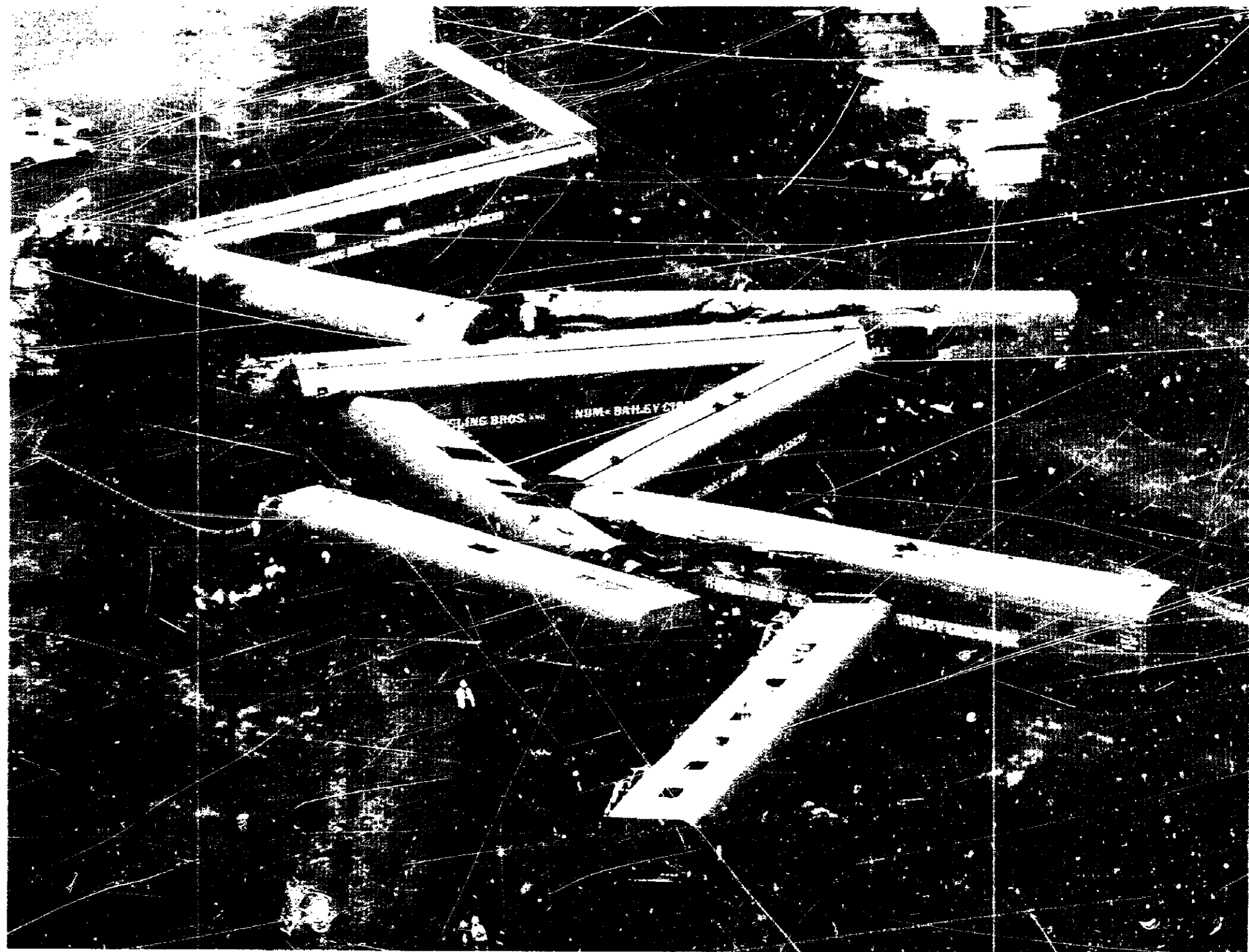


Figure 5.--Photograph of general derailment.

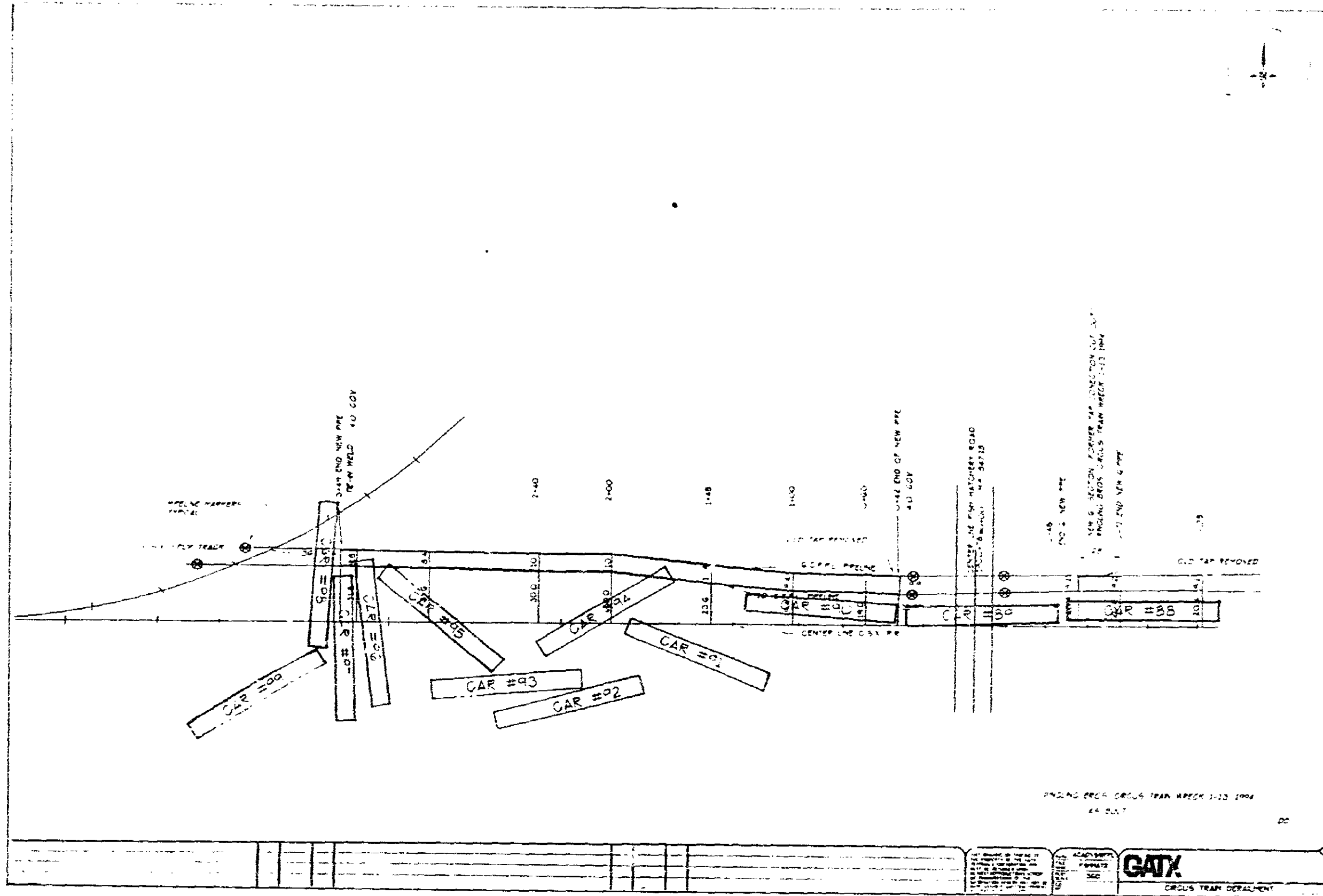


Figure 6.--GATX drawing of derailment disposition.

Injury Table¹⁶

Injuries	Crew	Passengers	Total
Fatal	0	2	2
Serious	0	0	0
Minor	0	15	15
None	3	133	136
Total ¹⁷	3	150	153

Train Damage

The 22nd through the 37th cars derailed. Safety Board investigators examined five cars, 88, 89, 92, 93, and 98, at the derailment site. All five were occupied during the derailment. Although each car was configured differently, overturned major appliances that obstructed passageways and exits were commonplace. Dislodged small appliances, debris, and personal belongings were strewn in occupied areas.

Car 88, a recently remodeled dormitory car, was moderately damaged at the A and B ends. No other damage to the car's structure was noted, although personal belongings and debris were distributed throughout the car.

Car 89, a high occupancy dormitory car, was moderately damaged at the A and B ends. Major appliances in the kitchen area were overturned, obstructing the exit. Personal belongings were scattered throughout the car.

Car 92, a high occupancy dormitory car, received major damage at the A and B ends. Most of the components of the kitchen, at the B-end of the car, were dislodged. The furnishings throughout the car were dislodged and askew.

Car 93 contained two generators, storage for cleaning supplies, and a small office. The interior A-end compartment was destroyed. The B end sustained minor damage. The car's interior components obstructed the end doors.

Car 98 suffered major damage on its right side and was crushed inward on its right side near the midsection. Its interior walls had collapsed, and its appliances and furnishing were

¹⁶The injury table above is based on the injury criteria of the International Civil Aviation Organization, which the Safety Board uses in accident reports for all transportation modes.

¹⁷According to the trainmaster, approximately 150 passengers were on the train at the time of the accident.

displaced or destroyed. Two thirds of the car contained living quarters for a four-member family. The remaining unoccupied 1/3 was under construction as separate living quarters.

Personnel Information

Operating Crew.—The train's operating crew came from CSXT, the host railroad, and consisted of an engineer, a conductor, and a brakeman. All three were qualified and were rested in accordance with the Hours of Service Law before coming on duty. The rules examinations and physicals for all three were current.

The brakeman, 43, was hired by CSXT on March 1, 1971, to work in the maintenance department. He transferred to the transportation department on January 9, 1973. He was a promoted conductor. His last efficiency test was in 1992; he had one failure (Rule 414).¹⁸ His last physical (conducted by a private physician) was in January 1993. As a result of a work-related (wrist) injury in 1985, he periodically took medication to alleviate pain. He had received medical clearance to mark off when he took the medication. He worked as an extra board employee. His last tour of duty was on Sunday, January 9, 3 days before the accident. He went off duty at 2:30 p.m. On the 10th through the 12th, he marked up on the extra board. At 3:30 a.m. on the 13th, he was assigned to the accident train. When the train derailed, he had been awake for approximately 22 hours.

CSXT hired the conductor, 52, on December 24, 1972. He was promoted to conductor in December 1974. His last efficiency test was in 1992. He had one failure (Rule 575).¹⁹ His last physical was in November 1993. His hearing was reportedly adequate although he had problems hearing both high and low notes. He worked as an extra board employee. His last tour of duty was completed on January 7, at approximately 9:00 p.m. On the 3 days before the accident he had stayed at home and received plenty of rest. He had slept for about 4 1/2 hours before his wake-up call at 1:30 a.m. on January 13.

¹⁸CSXT Rule 414 states:

When radios are used in connection with switching, backing, or pushing a train or cars, the employee directing the movement will keep in constant radio contact and give clear and complete instructions to the employee receiving the instructions. These instructions must specify: the distance of the movement to be made in car lengths (50 feet lengths), the position of any switches involved in the move, and that the employee directing the movement is in the clear. Unless additional instructions are received, the movement must be stopped in one-half the specified distance. If there is doubt as to the meaning of the instructions or for whom such instructions are intended, the movement must be stopped and will not resume until an additional job-briefing is conducted and all concerned understand the move to be made.

¹⁹CSXT Rule 575 states:

Conductors must make every effort to start and move their trains expeditiously using the quickest means of communication. Conductors must report delays to the train dispatcher, who may have no previous knowledge of these delays. Reportable information includes, among others, delays caused by air hose failures, sticking brakes, train inspections, and station switching.

The engineer, 61, was hired by CSXT on December 1, 1955. He was promoted to engineer in 1961. He left the railroad in 1964 and returned again in 1967 as a fireman and engineer. His last rules exam was in 1992 (no failures). His last physical was in November 1993. He worked as an extra board employee. His last tour of duty had concluded at 6:30 a.m. on January 11. Prior to his 1:30 a.m. wake-up call on January 13, he had had 6 1/2 hours sleep and later said he had felt well rested. According to his sworn statement, he had had previous experience with RBB&BC trains and "had run a number of them."

Trainmaster. - He was in charge of the overall operation and care of the circus train, including the loading and unloading of the train. He had worked in the mechanical department of a major railroad from 1976 until he came to the RBB&BC in 1985. He had risen from apprentice carman to general foreman of cars and locomotives before coming to the RBB&BC.

in describing the events of the accident, he said that he was in bed when the conductor called to say the train was 1 hour away from Orlando. "I had been in bed when he called me. I sleep with the radio right by my ear. And I was laying on the bed and was mentally going over the--how I was going to yard the train in Orlando." He said it was normal procedure for the CSXT crew to contact him in order to meet at the destination and accompany the railroad personnel on their arrival inspection.

Train Information

RBB&BC blue train. --The RBB&BC had a fleet of about 90 passenger cars and 40 freight cars.²⁰ It had two trains, one designated "red" and one designated "blue." The accident train was the blue one.²¹ Generally each train consist remains the same, particularly the passenger cars. At the start of each season cars may be renumbered and restenciled in consecutive order to facilitate administration. However, the blue train's freight car consist order may be rearranged depending on how the cars are unloaded and loaded at different locations. Most cars are consecutively numbered. The RBB&BC has no motive power of its own but contracts with the host railroads over which it moves to provide operating crews and locomotives. The blue train was not equipped with an end-of-train telemetry device or a caboose but had a required red marker. (See appendix B for the blue train consist list)

The passenger cars on the train were predominately smooth-side streamline cars built between the late 1940s and early 1960s. The RBB&BC bought the cars in the late 1960s and early 1970s as railroads abandoned the passenger business. The RBB&BC converted the cars into living quarters and referred to them as coaches.

Since the RBB&BC cars are not offered for interchange service, they are not registered in the Association of American Railroad's (AAR's) Universal Machine Language Equipment

²⁰Some cars were out of service because they were either in storage or in maintenance.

²¹All RBB&BC cars have the private owner prefix *RBX*.

Register system. The RBB&BC gives train consists to host railroads when the RBB&BC trains are moved.

Air brakes. --All the cars were equipped with ABDW and ABDX-1 freight-brake valves. The train was operated with a brake pipe pressure of 90 pounds. The passenger cars had been converted from passenger car brake valves and associated parts to freight-brake valves and equipment by RBB&BC mechanical personnel from a drawing provided by the New York Air Brake Company. Braking ratios were maintained or adjusted. Consequently, the RBB&BC provided host railroad operating crews with a pamphlet instructing them to place the selector valve in "freight" rather than "passenger," since freight-brake valves are not equipped with graduated release.

According to the RBB&BC, using only freight-brake valves gave the train smoother and more consistent train response than a mix of valves would. Also, since the RBB&BC depended on host freight-railroad train crews for movement, many of which might have had little or no passenger-train experience, freight brakes provided the most familiar train handling response. Logistically, the use of freight brakes also ensured a much more ready source of repair expertise and parts from the railroads if there was an on-the-road problem.

The passenger cars had either tread or disc brakes. Generally, cars from the New York Central System and Baltimore & Ohio Railroad were tread braked; those from the Union Pacific Railroad were disc braked. The cars were not equipped with a conductor's (emergency) brake valve,²² as is customary on public passenger cars, such as commuter cars or Amtrak cars. Due to the multi-national RBB&BC work force and the associated variety of languages, cultural values, and perceptions, the RBB&BC stated, such emergency brake valves posed more of a safety hazard than a safety feature. The RBB&BC also said that it wanted its management to retain control in the event of an emergency.

Passenger-car interior design and construction. --The RBB&BC had a wide variety of passenger-car interior designs and configurations. Most of the passenger cars were converted from railroad coaches to living quarters. In this respect, the RBB&BC passenger cars were markedly different from most railroad passenger cars because the circus cars house their inhabitants for more than a few hours or days at a time. For example, most Amtrak cars are not equipped for full-time living and therefore lack such items found on the RBB&BC cars as electric water heaters for showers or kitchens. The interior designs of the RBB&BC passenger cars were also different from those found on public carriers.

Unlike a public-carrier passenger train, it was not possible to pass through the length of the entire train due to the freight cars, but also due to the lack of corridors in some of the passenger cars. Although vestibules connected the passenger cars to each other, a number of cars had no corridor. Some performers' private living quarters extended the full width of the

²²An air brake valve connected to the train line or brake pipe which can be activated from a caboose or passenger car. Activation of the valve exhausts the brake pipe at an emergency rate, applying the train brakes in emergency.

passenger car. Consequently, continuous passage through the passenger cars was restricted by the necessity of going through private living quarters.

There was no standard passenger-car configuration; generally, each car was unique. Some cars had dormitory-style arrangements with bunk beds, some had a series of small roomettes, and others were for families and had a customized room arrangement. The floor plans were not uniform; the locations of emergency exits, including emergency windows, and emergency lighting varied. The coaches were used as living and sleeping facilities, both en route and during performances. Each coach housed 3 to 20 persons, depending on its interior design. Besides the coaches that were used as living quarters, three baggage cars had been converted to a workshop, generator/diner, and a generator/office. (Several other baggage cars were used to house animals.)

The RBB&BC had a "rebuild" shop in Palmetto, Florida, primarily for the rebuilding or renovating of car interiors according to the needs of contract performers. The shop stripped and rebuilt the interior of the passenger car according to the performer's contract with the RBB&BC, which was generally renegotiated every 2 years. The RBB&BC custom built its car interiors "in a fashion similar to that of recreational vehicles." Some original interior walls and bulkheads remained during rebuilding; however, most walls and partitions were made of paneling that covered two-by-fours nailed to a plywood-and-linoleum-tile covered floor. The nails were ordinary carpentry nails. Each passenger car had one or more domestic electric water heaters. Ceilings were usually made of wood and ceiling tiles. Most windows were not made with FRA glazing, nor was the glazing required since the train was a private one.

Emergency system.--The emergency systems included hand-held fire extinguishers at each end of a car, illuminated exit signs, and an emergency lighting unit like those found in public buildings. The unit was centrally located, usually in the center of the car's corridor if it had one. The train lacked a fixed or hard-wired intercar communication or intercom system. However, 20 circus management employees and the locomotive engineer were equipped with hand-held radios. The train had battery-operated smoke detectors, but when the Safety Board investigators tested the ones in the derailed cars, some did not function.

Wheel.--The L-4 wheel on car 89 had broken into three pieces; one piece had remained attached to the axle. After the derailment, the two broken-off pieces from the wheel were recovered and taken along with the hub part of the wheel set to the local CSXT car shop for a preliminary inspection. The broken wheel and the mate wheel showed no signs of discoloration²³ on the wheel plates or on the tread. During initial examination, investigators noted the presence of what appeared to be "oyster shell" markings²⁴ on the fracture surface of the wheel where the

²³According to the U.S. Department of Transportation *Handbook of Descriptive Technical Terms*, dated February 1983, overheating is defined, under "Hotspot," as "Subjected to excessive temperature usually evidenced by change in color and appearance of part."

²⁴The markings are also known as fatigue, clamshell, beach, and crack-arrest markings. The markings are macroscopic growth lines or bands attributed to either changes in cyclic stress or periods of crack arrest followed by corrosion.

wheel had broken below the deeply stamped 4 of the serial number on the back (inside) of the rim, along the vertical straight line of the number. The oyster-shell pattern is typical of a progressive failure from a fatigue crack.

The back face of the rim of the broken wheel was stamped, indicating that the wheel had been manufactured in September 1972 by the Standard Steel Division, serial number 4617, and was a controlled-cooled passenger-car straight-plate class B wheel that was 36 inches in diameter. The mate wheel was identical except that its serial number was 4611. According to the AAR *Manual of Standards and Recommended Practices*, Section A, Part III, "Passenger Car Requirements," class B wheels are designed for passenger cars in "high speed service with severe braking conditions and heavier wheel loads." The Vice-President of Quality and Technology for Standard Steel said that both the accident and mate wheels were from the same serial set, which was part of an original order of "probably 100 or 150 wheels for the Southern Railway." He further stated that he believed that the two wheels had stayed together since being first mounted on the axle and had never been removed from the axle.

The accident wheel had been "hot stamped," or stamped during the wheel manufacturing process while the metal was still malleable. Cold stamping, which is a post-manufacturing process, is generally a remedial process done when a hot stamping or related area is defective and the wheel has to be turned to remove the hot stamping. Hot stamping is generally much deeper than cold stamping. In this report, the discussions of rim stamping do not include noting whether the stamping is hot or cold. Either type can produce the same undesirable effects when a wheel is thermally damaged.

Further inspection revealed that both the accident and mate wheels had little wear and showed no evidence of flat spots or physical abuse, such as strike marks. Investigators noted that the wheel set was equipped with Timken AP Class BE 6-inch Amtrak roller bearings with locking plates stamped and etched *ASX 12-90 BRX-R*, indicating that the bearings were mounted in December 1990 by the American Railway Wheel Services Shop in Sanford, Florida. (The company, along with its records, no longer exists.) The roller bearings were intact and showed no sign of failure. The axle was stenciled in white paint with *RB136*, and it had a stainless steel band stamped *RB585*. These were identification numbers used by the RBB&BC to keep track of wheel sets and work performed by contractors.

Maintenance. - The blue train was low mileage, accumulating about 18,000 miles a year,²⁵ and did not normally require any heavy repairs or major part replacement. RBB&BC personnel performed servicing, running repairs, and periodic maintenance on the cars. The trainmaster was in charge of train maintenance. As a quality control step, the RBB&BC contracted with an independent contractor to inspect the train for mechanical defects twice a year to ensure that the cars were mechanically sound and that there would be no unforeseen problems during interchange between railroads. The contractor had last inspected the train in July 1993. The train was also inspected at random by State and/or FRA inspectors, during interchange between railroads, and at any applicable test and inspection points as outlined in FRA regulations.

²⁵Amtrak cars frequently average 500,000 miles a year.

The trainmaster had 12 RBB&BC employees directly under his supervision: 5 outside mechanics, 5 porters, and 2 electricians. All 12 helped maintain and service the train's cars. None of the trainmaster's subordinates had had any prior railroad experience or expertise before working for the RBB&BC, although the RBB&BC had sent three of the outside mechanics to a week-long Westinghouse Air Brake School at Wilmerding, Pennsylvania. The same three employees had taken a safety appliance correspondence course from The Railway Educational Bureau. Besides repairs, the outside mechanics were also expected to inspect the train for defects before and/or after movement and loading or unloading. The outside mechanics were described by the trainmaster as "kind of carmen" in the sense that they performed many of the same functions as carmen on a railroad.

The RBB&BC had a limited maintenance history on each car and had only recently started to keep comprehensive car-maintenance history files. The files included wheel records.

Upon completion of the 1993 season, the cars of the blue train arrived in Tampa, on November 24, 1993, at the CSXT railroad Uceta Yard. The train was then split into two blocks. One block consisted of passenger and container cars, which were moved to old Tampa Yard and parked on two adjacent tracks. The other block consisted of 4 animal cars and 17 flat cars, which were moved to the team track ramp and unloaded by RBB&BC personnel. The flat cars were then moved to Uceta Yard for storage. All the RBB&BC cars were placed where RBB&BC personnel could do maintenance and repair work. While the cars were in storage, RBB&BC personnel performed running repairs and periodic maintenance on the cars. The trainmaster supervised repairs and maintenance on the cars.

On January 2, 1994, the passenger and container cars were moved to Yeoman Yard, where CSXT carmen inspected them and did an FRA initial terminal air-brake test.²⁶ Upon the successful completion of the predeparture inspection²⁷ and air-brake test, the cars were moved that day to St. Petersburg, Florida, for the 1994 season opening.

The next day, January 3, the stock and flat cars were moved to the team track ramp and loaded. CSXT carmen then did a predeparture inspection and initial terminal air-brake test. Upon the successful completion of the inspection and test, the cars were moved later that day to St. Petersburg, where the passenger and freight cars were combined to create the 1994 Ringling Bros. and Barnum & Bailey blue train.

When CSXT inspected the cars, no defects were found on either block of cars with the exception of car 109, a TTX-type flat car. One of its brake beams had a worn brake head. The car was repaired and returned to the block of cars in time for movement to St. Petersburg.

According to deposition testimony from the CSXT car foreman in charge of the RBB&BC train inspection, the CSXT inspections consisted of having two car inspectors on each side of

²⁶49 CFR 232.12.

²⁷49 CFR 49 215.13 and appendix D.

a block of cars. The inspectors progressively moved along, inspecting the running gear, safety appliances, and draft gear for defects. Four CSXT carmen were involved in the inspections, two on the passenger and container block on January 2 and another two on the freight equipment on January 3. The foreman stated that it was CSXT policy to repair any FRA or AAR defects found. He also stated that the carmen would have reported any overheated wheels as determined by telltale orange or reddish-orange discoloration on the wheel plate but that no discoloration was found. Before any RBB&BC cars departed for St. Petersburg, the foreman said, the hand brakes were individually checked to ensure that none were applied.

Couplers.--All the passenger cars were equipped with *H* tight lock couplers. The freight cars (flat cars) were equipped with standard *F* couplers without any special features. The train did not have *F* interlocking freight couplers.²⁸

Track and Signal Information

The general derailment occurred at the Park Spur switch. The railroad was single mainline track with 132-pound continuous welded relay rail. The rail, which was made in 1986, rested on treated hardwood ties. The track met or exceeded FRA class IV track safety standards. Timetable speed through the area was held to 50 mph. Track alignment was tangent, with a descending grade of 1.05 percent, to the derailment site from the direction of the train.

The track had last been inspected on January 11, 2 days before the accident. No FRA defects were found in the accident area. The last geometry car inspection was done on December 7, 1993, and did not uncover any defects in the accident area. The last rail defect car inspection was done on September 7, 1993; no defects were found in the accident area.

Train movement through the accident area was governed by colored light wayside signal indication through a traffic control system (TCS).²⁹ Track was signaled in both directions. Postaccident tests of the signal and TCS systems found no defects or anomalies. Computer printouts of track occupancy and signal indications generated by signal contactor positions showed the signal and control systems had worked as designed at the time of the accident.

Operations Information

Method of operation.--Operation of the railroad in the derailment area was governed by the *CSXT Operating Procedures Manual*, which included a section entitled "Operating Rules," effective August 1, 1992, and timetable sections "CSXT Fertilizer Business Unit Timetable No.2, effective January 1, 1993," and "CSXT Atlanta Division Timetable No. 3, effective

²⁸*Interlocking or tightlock* couplers refer to three AAR types of couplers; the *T* (original Tightlock), type *H* (Tightlock), and type *F* (interlocking).

²⁹*Traffic control system, TCS*, is sometimes called CTC. It is a series of interlockings all controlled by the dispatcher. Trains are governed by signal indication, some of which provide movement authority.

January 1, 1993." The derailment occurred on the CSXT system of the FBU, Lakeland subdivision. The Jacksonville CSXT dispatcher controls the subdivision. The CSXT FBU is one of 13 divisions on the CSXT. The Lakeland subdivision has an average of four passenger, four trailer, two automobile, and two miscellaneous trains in a given 24-hour period.

Train crew efficiency testing and management oversight. --For the year preceding the day of the derailment the CSXT operating crew had the following efficiency test report:

	Operating	Safety	Total	Failures
Engineer	12	2	14	0
Conductor	5	8	13	1 (Rule 575)
Brakeman	7	6	13	1 (Rule 414)

Meteorological Information

The following information is based on data gathered and reported by the National Weather Service, the Federal Aviation Administration, and contractors. The data was provided through the Man Computer Interactive Data Access System, which is administered by the Space and Engineering Center at the University of Wisconsin at Madison.

At Lakeland, Florida, Airport:

8:51 a.m. Cloudy skies; fog; visibility 0.2 miles; winds calm; temperature 65 degrees F; dew point 63 degrees F.

9:53 a.m. Cloudy skies; fog; visibility 1.0 miles; winds calm; temperature 66 degrees F; dew point 63 degrees F.

At Bartow, Florida, Airport:

8:48 a.m. Cloudy skies; fog; visibility 0.2 miles; winds 030 degrees at 2 knots, temperature 64 degrees F; dew point 63⁰ F.

9:45 a.m. Cloudy skies; fog; visibility 0.5 miles; winds 140 degrees at 2 knots; temperature 65 degrees F; dew point 63⁰ F.

Medical and Pathological Information

The derailment resulted in two fatalities. The 28-year-old performer died of asphyxiation. She was found underneath a file cabinet in the leading (east) end of car 93. The file cabinet had been attached to the wall with small brackets and sheet metal screws. The 39-year-old elephant

trainer was found in car 98. He was in a hallway between the bedroom and galley and had died of multiple fractures of the skull and massive head trauma inflicted when car 97 intruded into the side of car 98.

Another performer, a man, who had been in the vestibule of car 88 talking with the performer who tried to contact the trainmaster at the time of the derailment, stated that they were alerted by a loud unfamiliar sound in car 89. Before she proceeded rearward in an attempt to notify the trainmaster, they observed that cars 89 and 88 had become misaligned. Upon their arrival between cars 92 and 93, she entered car 93's end door at the time the cars separated. He said that was the last time he saw her.

Fifteen other circus employees received minor injuries, which consisted of bruises, abrasions, and small lacerations. They were capable of exiting the train with little or no assistance. Safety Board investigators were unable to fully document the causes of the injuries. Most of the injured were foreign performers who could speak little English. During postaccident interviews with Safety Board investigators, one employee could not describe how he had lacerated his hand. Other employees thought they were injured when they were thrown about during the derailment. Safety Board investigators sent each of the 15 a questionnaire about the nature and cause of the injuries. Only one was returned.

Toxicology

In compliance with FRA regulations,³⁰ postaccident blood and urine specimens were collected from the engineer, conductor, and brakeman at Lakeland Regional Medical Center. Samples were taken from the engineer 4.5 hours after the accident, from the conductor 5.0 hours after the accident, and from the brakeman 6.5 hours after the accident. The samples were sent to CompuChem Laboratories, Inc., in North Carolina, where they were analyzed. No drugs were found in the blood or urine of the engineer and conductor. The brakeman, however, tested positive for metabolites of marijuana and cocaine. He later reported that he had taken both drugs the night before the accident. The results of his specimen analysis follows:

Marijuana	Urine: THCA 561 ng/ml Blood: THC 2.9 ng/ml; THCA 65 ng/ml
Cocaine	Urine: Benzoylcegonine 5091 ng/ml; cocaine negative Blood: Benzoylcegonine 35 ng/ml; cocaine negative

Upon receiving the toxicological analysis, the CSXT chief medical officer notified the brakeman of the results. The brakeman was subsequently removed from service. Under CSXT policy, an employee who has tested positive for illicit drugs and is a first-time violator may be given the opportunity to complete a drug rehabilitation program. During the program and for an extended period of time thereafter, the employee is monitored and subject to unannounced

³⁰49 CFR Part 219.

drug testing. If he successfully completes the program, CSXT determines if and in what capacity he will return to service. Consistent with the policy, the brakeman, who was a first-time violator, entered and successfully completed the rehabilitation program. He has consistently tested negative for illicit drugs and is currently awaiting CSXT's decision about whether he can return to duty.

Survival Factors

Emergency response.--About 9:08 a.m., a Polk County emergency medical services (EMS) unit radioed the Polk County Communication Center that the RBB&BC train had derailed. Three advanced life support EMS units and one fire-department engine company were dispatched to the scene at 9:14. They arrived at 9:21.

When they arrived, they searched for victims, started triage, and called for assistance. About 9:20, they established a command post on Fish Hatchery Road, north of the railroad crossing. At 9:30, mutual aid fire apparatus responded from the Lakeland, Orange County, and Auburndale fire departments. An emergency services vehicle staging area was also established on the north side of the Fish Hatchery Road crossing behind the livestock pavilion about 9:45. At 10:00, the triage area was moved to the south side of the derailment site on Fish Hatchery Road. There, first aid was administered since most of the injuries were minor.

The RBB&BC bused the employees who had not been hurt to Orlando or to local hotels. By 12:53 p.m., the last of the 15 injured had been taken to Lakeland Regional Hospital; two had been transported by private vehicles. The bodies of the deceased employees were taken to the Polk County medical examiner's office.

The Polk County Sheriff's Department responded, provided perimeter and traffic control, and investigated the deaths. Five fire trucks, one hazmat unit, several command trailers, and one heavy rescue vehicle responded from Lakeland Fire Department, Orange County Fire Department, and Auburndale Fire Department. They were supplemented by 50 police and fire support vehicles. The emergency response agencies in the county had responded previously to two Amtrak rail accidents and other hazardous-materials incidents.

Disaster preparedness.--At 9:15 a.m., the Polk County disaster plan was put into effect. The purpose of the plan is to provide a coordinated response from fire, police, and medical services to emergencies and disasters in the county. The county communications division was performing a communications drill at the time of the accident. The drill was terminated so that the participants could manage the actual disaster.

RBB&BC safety information.--In a letter to the Safety Board dated August 19, 1994, the RBB&BC stated:

Ringling Bros. developed a safety booklet a number of years ago which has been published and distributed ever since. The booklet, which is entitled *Train Rules & Safety Regulations*, is intended to inform Ringling Bros.' traveling personnel

of the proper procedures regarding safety and general conduct when they are on or around the Circus train, both while it is moving and when it is parked. This booklet, a copy of which is enclosed for your reference, was initially written in English and has been translated into nine other languages which cover the spectrum of foreign performers and other workers who are employed by the circus.

A copy of the booklet is given to each person on each traveling unit who travels on the circus train before the unit leaves its rehearsal site for its annual tour. It is also given to all individuals who are hired in the course of the tour and travel on the train.

Of the 25 rules contained in the booklet, five apply to employees while the train is in motion:

1. Riding or walking on top of the train at any time is prohibited.
3. Do not get on or off the train while it is in motion.
5. Platform doors must be closed while the train is in motion.
10. Passageway doors must remain unlocked at all times during movement.
24. Secure all appliances and use caution when using appliances or cooking utensils during train movement.

The RBB&BC further stated in the letter that in late 1993, it had produced a 16-minute video entitled *All Aboard the RBB&BC Train*. The RBB&BC said that the video supplements the booklet and provides examples of safety precautions that employees should take while the train is at performance locations. The video explains how to use the train's emergency windows, how to identify emergency doors, what to do if there is a fire, and how to test and use a fire extinguisher. It also explains security, housekeeping rules, and how to secure small appliances with bungee cords. Each employee and his family members are required to view the video.

Safety Board investigators interviewed eight circus employees about the usefulness of the information in the booklet and video. All said that they had read the booklet; however, some said that they had not seen the video, and others said they did not know whether they had seen it. While some of the interviewed employees said that the information in the booklet was useful in the derailment, others stated that use of the information contained in the booklet was not necessary in their particular situation. Those employees who had seen the video stated that it contained information on fires and derailments. According to the RBB&BC, two children left car 98 after the derailment by opening an emergency exit window according to instructions they had received from the video.

Tests and Research

A Safety Board materials laboratory examination of the fractured accident wheel disclosed that the wheel separation stemmed from a fatigue crack approximately 1.35 inches wide by 0.55

inch deep. This fatigue crack initiated from multiple origins at the base of the serial number character 4 that was stamped on the gage-side face of the rim. Although the mate wheel was not fractured, it also had a hairline crack that was approximately 0.6 inch long, that was located mainly along the bottom of the long leg of the 4. Sectioning through the mate-wheel crack indicated it was about 0.12 inch deep and was filled with high-temperature oxides.

Laboratory sectioning through the fatigue origin disclosed a decarburized zone at the base of the stamping. Decarburization is the loss of carbon from the surface in steel alloys as a result of heating in an oxidizing atmosphere. Hardness testing showed that the decarburized zone was approximately 0.055 inch deep and had an approximate tensile strength that was about 35 percent lower than the remainder of the wheel. Sectioning through the treads of the fractured and intact mate wheels disclosed a microstructure indicative of tread overheating, with some areas representative of being heated above the transformation temperature of the steel (about 1330 degrees F). Away from the treads, the microstructure and hardness of the material not subjected to heat damage were normal for the specified material. Overheating of the tread, such as that found on the accident wheel, has been shown to produce tensile residual stress in the rim of the wheel.

RBB&BC Postaccident Actions

According to a March 11, 1994, letter from the RBB&BC General Manager to the Safety Board, the derailment led the circus management to reevaluate various mechanical considerations, emergency procedures, maintenance scheduling, and interior designs. The RBB&BC said that it intended to implement changes in phases as quickly as possible. Within weeks after the accident, the RBB&BC had:

- o removed all of the straight-plate rim-stamped tread-braked wheel sets. It had also converted all tread-braked passenger-car wheels to disc braked.
- o equipped all staterooms with fire extinguishers, put two crash tool cabinets in each passageway, and reinforced passageway emergency lighting systems so that they can better withstand impact.

The RBB&BC's ultimate goals are to decrease the possibility of an accident, preserve life, and minimize loss. Some of the following changes will be implemented as cars are rebuilt in a complete overhaul similar to the overhaul Amtrak does in its 40-year inspection and repair program.

The RBB&BC has retained a consultant to examine each car for any structural or mechanical problems and to develop rigidly defined procedures that will enhance existing maintenance and repair programs.

The RBB&BC has directed its maintenance contractor to increase its regular independent

mechanical inspections from two to four per year.

The RBB&BC has directed its risk management consultants to increase the number of car-interior inspections from two to four a year and to include inspections of each private stateroom. Inspections will include checking for homemade construction projects, blocked egresses within staterooms, overloaded circuits, and unsecured or inadequately secured property and appliances.

The RBB&BC carpentry department is designing and installing woodwork to eliminate sharp edges. Cabinet handles will be recessed. New mechanisms will be used to ensure that doors and drawers cannot open by accident.

Every car with a passageway will have a minimum of three emergency exit windows, and every stateroom will have a minimum of two emergency exits.

A resident safety officer has been appointed for each coach car and will be given a private-line radio for emergency use. Safety officers will receive additional training in first aid and evacuation procedures.

Conductor's brake valves will be installed in strategic locations throughout occupied cars.

Each passenger car is being equipped with a "push-to-talk" radio system that can be used to make emergency radio announcements over a public address system to all cars.

An integrated fire alarm system will be installed in all new cars and in any car that is renovated or reconstructed. The system includes battery backup lighting in staterooms, panic alarms, commercial-grade hard-wired smoke detectors, remote-activated fire doors, remote-activated HVAC system shutdown, and strategically placed 1-hour interior fire walls.

A February 21, 1995, letter from the Vice President of Circus Operations to the Safety Board described the RBB&BC's progress in implementing the safety improvements outlined in the March 11, 1994, letter. According to the 1995 letter, the RBB&BC has made the following changes:

It has removed all rim-stamped straight-plate tread-braked wheels from its passenger cars and converted all tread-braked passenger cars to disc-brake systems. All straight-plate freight car wheels have been changed to curved-plate wheels. The RBB&BC adds new wheels to passenger cars that it rebuilds, and all the cars that it has received since the accident have totally rebuilt trucks. In addition, a consultant will do a single-car air-brake test on each car in service.

A consultant has inspected each car for safety, structural, and mechanical problems and has given the RBB&BC a comprehensive report that includes specifics for developing a computerized maintenance and inspection program.

Another consultant has evaluated interior safety appliances and "life safety" issues. When a new car is constructed, its doors and cabinets are made to lock automatically, and the appliances are bolted to the floors and walls.

The RBB&BC has started its Amtrak 40-year inspection and repair program on all cars at its repair and recycling shop in Palmetto, Florida. The shop has been equipped with state-of-the-art technology that exceeds Amtrak shop standards. The RBB&BC has retained an Amtrak inspector to review contractor repairs and to verify proper execution of the Amtrak 40-year inspection. Amtrak employees have conducted courses for the RBB&BC shop workers in mechanical repairs, and the Academy of Industrial Training has trained them and RBB&BC mechanical personnel in truck assembly, air brakes, draft systems, and safety appliances.

All circus employees have received a redesigned orientation program that includes a personalized instruction session with a question-and-answer period. Each passenger car has a safety officer, and each safety officer has a two-way emergency radio that allows him to communicate with train managers and railroad crews directly.

Over 140 additional fire extinguishers have been installed on the trains. The framing of rooms in new passenger cars is done with non-combustible construction materials. The new cars also have an integrated fire alarm system that automatically closes ventilation ducts into living areas and notifies managers through the train's radio system of the nature and location of an emergency. An emergency radio system that allows managers to broadcast safety announcements to individual cars or to the entire train is more than half finished.

The RBB&BC is incorporating a 480-volt electrical distribution system and integral safety devices, including an enhanced emergency lighting system. Over 250 additional emergency exit windows have been installed on the passenger cars. Every common passageway now has a minimum of three emergency exit windows. The retrofitting of staterooms with emergency exit windows is almost finished. Finally, the passenger cars have been equipped with crash tool boxes.

ANALYSIS

General

Based on the available evidence, the Safety Board concludes that the weather, the train handling, the signal and train control system, the track, the brakeman's illicit drug use, and dispatcher operations neither caused nor contributed to the derailment of the train. The train crewmembers were qualified to perform their duties in accordance with CSXT procedures and accepted practice.

Weather.--On the morning of January 13, 1994, the weather was cool with intermittent fog, which had little detrimental effect on operating conditions. The engineer maintained a slower-than-authorized train speed in foggy areas.

Train handling.--Although none of the locomotive units had event recorders, the engineer's sworn statements, the observations from witnesses both on and off the train, the signal and detector recordings, and the recorded conversations between the engineer and the dispatcher indicate that the train was handled in a way that was consistent with accepted practices. The engineer had had over 30 years of experience and expressed having previous experience running "a number" of RBB&BC trains.

Track and signals.--Pre- and postaccident signal and track tests and inspections showed no defects or deviations that could have caused or contributed to the accident.

Impairment of brakeman.--Because of the brakeman's use of illicit drugs and his lack of sleep before his shift, it was likely that he was not fit for duty. The brakeman tested positive for marijuana and the principal metabolite of cocaine. Studies have shown the use of marijuana can result in skill deterioration.³¹ At high doses, people may also experience thought disturbances, rapid emotional changes, loss of attention, and a sense of panic.³² Cocaine, which is a stimulant, may increase arousal, cause insomnia, and provide a sense of well being.³³ Although the duration of the effects of cocaine are relatively short, the brakeman had taken the drug the night before the accident, and it may have affected his ability to sleep.³⁴

³¹W. J. Hindrik Robbe and James F. O'Hanlon, *Marijuana and Actual Driving Performance*, Final Report to National Highway Traffic Safety Administration, Contract No. DTNH22-89-X-07722, November 1993.

³²Benjamin, L., Hopkins, J., and Nation, J. *Psychology*. New York: Macmillan Publishing Company, 1987.

³³See previous footnote.

³⁴For a more comprehensive description of the effects of cocaine, see NTSB Aircraft Accident Report, NTSB/AAR-89/01, *Trans-Colorado Airlines, Inc., Flight 2286 Fairchild Metro III, SA227 AC, N68TC Bayfield, Colorado, January 19, 1988*.

Moreover, the brakeman had not slept the night before the accident and had been awake for 22 hours when the accident occurred. He reported that before the start of his shift he was tired. As a result, he might have been fatigued while he performed his duties. Missing a night's sleep, in addition to making one feel sleepier, may cause decrements in decision making, vigilance, reaction time, and mood.³⁵ Consequently, one's ability to monitor and respond to critical events may be impaired. The performance of a trainman who has used drugs and is fatigued may suffer, particularly during tasks that require extended vigilance.

The brakeman was the only crewmember who tested positive for drugs. The Safety Board considered whether his use of drugs might have contributed to the derailment. According to sworn statements from the train crew, during the roll-by inspection for a stuck brake, he was on the right, or south, side of the train, on the side of the train opposite the broken wheel. Thus he was not in position to detect any defects on the other side of the train. Further, according to deposition testimony from railroad wheel experts and according to the Safety Board's metallurgical report, it is highly improbable that the brakeman, impaired or unimpaired, could have detected a wheel defect, such as thermal damage, which is not readily detectable outside of destructive testing. Therefore the Safety Board does not believe he could have detected the thermally damaged wheel or prevented the derailment.

Although his likely impairment from drugs did not cause or contribute to the accident, the Safety Board is concerned that a trainman who was not fit for duty was performing safety-sensitive tasks. The circumstances of this accident suggest that the accident wheel was undetectable by any means available. An impaired trainman may not have been capable of performing his duties adequately. The Board has previously investigated numerous accidents in which a trainman's impaired performance due to drugs contributed to the accident.³⁶ As a result, the Board has consistently stated its position that impairing drugs must be absent from commercial transportation.

According to the results from random drug testing in the U.S. railroad industry in 1993, the number of employees taking drugs declined, as it had in 1991 and 1992. The FRA reported that in 1993, of the more than 42,000 railroad employees in safety-sensitive positions who were randomly tested, only 0.7 percent tested positive. Of the 403 employees tested as the result of an accident, 2 percent (8) had used prohibited drugs or alcohol.

Under new rules that went into effect on January 1, 1995, the Department of Transportation has lowered the required rate of random drug testing from 50 percent per year to 25 percent if the positive rate for an entire industry is less than 1 percent for 2 years. Because the railroad industry has met this criterion, it is now subject to a lower testing rate. The brakeman's use of drugs in this accident, however, should demonstrate that even though the results of

³⁵Brown, I. (1994). Driver fatigue. *Human Factors*, 36(2), 298-314.

³⁶Two recent reports about railroad accidents are *Atchinson, Topeka and Santa Fe Railway Company (ATSF) Freight Trains ATSF 818 and ATSF 891 on the ATSF Railway, Corona, California, November 7, 1990* (NTSB/RAR-91/04); and *Rear-End Collision of Amtrak Passenger Train 94, The Colonial and Consolidated Rail Corporation Freight Train ENS-121, on the Northeast Corridor, Chase, Maryland, January 4, 1987* (NTSB/RAR-88/01).

random testing suggest a low rate of drug use, government and industry must continue to be vigilant in order to help ensure that all operators are fit for duty. The Board continues to be troubled by any drug use in the transportation industry.

Dispatcher Operations.--The Plant City Police Department notified the CSXT dispatcher that a train had a wheel that was "smoking and flames are coming out of it" after a Plant City detective on his way to work had reported his observations of a passing phosphate train. Safety Board investigators examined the communications link between the railroad and local authorities and the propriety of the dispatcher's actions. The conversation between the police and the railroad reveals that both the police and railroad dispatchers probably should have requested and provided more detail. CSXT's dispatcher training program and instruction manuals cover such contingencies. This instance appears to have been handled by the railroad dispatcher in an expedient manner, based on the limited amount of information he was given, the urgency of the situation, and the unknown value of pressing for more information. Since both the phosphate train and the RBB&BC train were within the circuitry of the interlocking block, it was impossible for the dispatcher to know which train the detective had seen. The dispatcher took the prudent and safe course of first calling the RBB&BC train, a mixed train with occupied cars and much greater potential for loss of life, and later calling the phosphate train.

Safety Board investigators explored a possible connection between the flat-spot noise the conductor heard, the "clanking" noise the lawn-service employee at Airport Road heard, and a broken wheel. The conductor reported the flat spot "about 10 cars" from the front of the train. A postaccident examination of the RBB&BC cars failed to reveal any flat spots, although the examination was limited, due to equipment position and wreckage. The wheels from the first 11 cars, which were not derailed, were scrutinized for flat spots with no result. The lawn-service employee said that he heard the clanking noise about midway between the generator cars, the 12th and the 27th cars in the train. The failed wheel was on car 89, the 23rd car in the train, between the generator cars.

According to deposition testimony from the AAR and wheel manufacturers, thermally damaged wheels fail instantaneously. The chance that the wheel was cracked and making noise is extremely remote. Also, such a condition should have been readily apparent to the inspecting conductor.

Both the train crewmen and the lawn-service employee observed the train at nearly the same location. The crewmen, particularly the conductor, were on the ground about 5 feet from the train looking and listening for a stuck brake, which also involves looking at the wheels. Thus the train crew was in a much better position to observe a broken wheel than the lawn-service employee, who was casually watching the train go by from his semi-isolated van with its inherent acoustical irregularities.

The conductor was unconcerned about the sound of the flat spot. When he reported the result of the roll-by inspection to his engineer, he said that nothing had been found. The conductor's interview statements also minimized the significance of his having heard the flat spot. He said, "...it makes a little thump. You hear them all the time. It's not necessarily an unsafe condition." The conductor felt he had heard a routine, insignificant flat spot.

The Safety Board believes that the conductor was probably inaccurate about the position of the flat spot in the train because it was unimportant. The Safety Board also believes that the "clank" the lawn-service employee heard was probably the same flat spot the conductor had heard, and not a broken wheel.

During the accident investigation, the Safety Board focused on the hazard posed by pipelines under a derailed train, the safety of rim-stamped straight-plate tread-braked wheels and the phenomenon of thermal damage, and the securement of interior equipment and appliances in occupied cars.

Underground Pipelines

Many railroad rights-of-way have underground pipelines that carry hazardous materials. The pipelines may carry natural gas, crude oil, or petroleum products, including such highly volatile liquids as propane.

Derailed cars can directly impinge on a pipeline. Loads imposed on a pipeline from a derailed train or from clean-up equipment can cause immediate or future failure.

Several days after the derailment of a Southern Pacific freight train over a Calnev pipeline at San Bernadino, California, the 36-inch high-pressure gasoline pipeline ruptured, engulfing seven nearby homes in fire, setting two more houses on fire, and killing two residents.³⁷ This accident resulted in the Safety Board recommending that the FRA and the Research and Special Programs Administration:

Require railroad operators to coordinate with operators of pipelines located on or adjacent to their railroad rights-of-way the development of plans for handling transportation emergencies that may impact both rail and pipeline systems and then to discuss the plan with affected State and local emergency response agencies. (Class II, Priority Action) (R-90-25)

In response, the FRA in March 1992 added the following notice to its *Hazardous Materials Emergency Response Plan Guidance Document for Railroads*, dated March 1989:

Railroads must actively coordinate their emergency response activities with pipeline operators to assess possible damage due to the incident and to prevent damage during response and cleanup operations. Railroad emergency response plans should include information on underground pipelines which could be damaged by a rail incident. This information should include location, materials carried, and emergency numbers for pipeline operator.

³⁷Railroad Accident Report--Derailment of Southern Pacific Transportation Company Freight Train on May 12, 1989, and Subsequent Rupture of Calnev Pipeline on May 25, 1989, at San Bernadino, California (NTSB/RAR-90/02).

The FRA sent the revised publication to the AAR; however, there is no evidence that the AAR sent the publication to its members or that its members took action.

Following a 1991 derailment in South Carolina,³⁸ the Safety Board recommended that CSXT:

Maintain an up-to-date emergency response telephone list. (Class II, Priority Action) (R-93-20)

The Safety Board believes that CSXT should comply with the FRA's *Hazardous Materials Emergency Response Plan Guidance Document* and that CSXT should include on its emergency response telephone list those operators that have pipelines on or adjacent to its railroad right-of-way that could be damaged by a rail incident.

The Safety Board will address the issues of notification and clean-up coordination between railroad companies and pipeline operators following railroad accidents. It will address the issues in its Intercession City, Florida, accident report, which will be completed later this year.

Wheel Failure

The presence of multiple crack origination sites is consistent with a high stress or stress raiser at the origin. The stamping of the serial number produces a notch in the gage face of the rim that can initiate fatigue cracking. The decarburized layer at the base of the stamping has a significantly lower fatigue resistance than the base wheel material. Overheating of the tread that was found on the accident wheel would produce residual tensile stresses in the rim portion of the wheel. Development of adverse tensile stresses in combination with reduced tensile strength of the material in the areas of decarburization produced favorable conditions for initiation of the fatigue cracking at the stamped character. Bulk residual tensile stresses in the rim would accelerate propagation of the fatigue crack.

The relative size of the fatigue zone as compared to the wheel fractured section indicates a high bulk stress in the wheel that is consistent with a large residual tensile stress at the rim. Based on the fatigue fracture surface pattern, which showed an oxidized surface containing distinct crack arrest positions, the initiation and propagation of the fatigue probably resulted from a combination of cyclic thermal stresses from braking and applied cyclic stresses during normal operation of the wheel. The crack propagated to a critical size, at which time the wheel fractured under normal operating conditions.

Therefore, the Safety Board concludes that the wheel failure and consequent derailment of the train were due to the fatigue failure of the thermally damaged wheel and that fatigue

³⁸*Derailment and Subsequent Collision of Amtrak Train 82 with Rail Cars on Dupont Siding of CSX Transportation Inc. at Lugoff, South Carolina, on July 31, 1991 (NTSB/RAR-93/02).*

cracking initiated at a stress raiser associated with a stamped character on the wheel rim.

Straight-Plate Rim-Stamped Tread-Braked Railroad Wheels

Tread-braked railroad wheels act much like automobile brake drums and therefore are subject to heat. During braking, the brake shoe is pressed against the tread of the wheel, which stops or slows the railroad vehicle through friction. The friction between the tread and the brake shoe creates heat. Some of the heat is transferred to the brake shoe, but most of the heat is absorbed by the wheel. Heat generated during braking is transferred to the rail and to the air flowing by the wheel. However, this process is relatively slow compared to the rate of heat input, resulting in a build-up of heat in the wheel rim. If braking continues for very long, the temperature of the wheel tread and rim increases, but the temperature of the plate and hub of the wheel remains relatively lower. The temperature differential between the rim and the hub depends on the duration and intensity of the brake shoe force. It is the temperature differential that can create residual tensile stresses in the rim that eventually can allow the wheel to initiate a fatigue crack.

The heated rim has a tendency to expand, but is restrained by the cooler plate and hub. Under normal conditions this is not a problem, and the wheel returns to its manufactured condition of circumferential rim compression, which holds the wheel together like a barrel stave. However, if the braking is unusually heavy or prolonged, as it is when the brake is stuck, excessive local overheating occurs, causing the wheel rim to expand and deform plastically. The result is permanent deformation, and the rim is left in a state of residual tensile stresses that no longer want to hold the wheel together, but want to pull away from the wheel plate and hub. The mechanical rolling of the wheel and the forces of weight involved also contribute to the deformation and the creation of residual tensile stresses. The presence of circumferential residual tensile stresses in the rim defines a thermally damaged wheel.

AAR research indicates that the stresses in thermally damaged railroad wheels are greatest on the back face of the wheel rim. Stamping the back of the wheel rim provides a stress concentration point for a crack to start. Consequently, in 1978 the AAR prohibited the manufacture of rim-stamped railroad wheels on interchange freight cars. According to the AAR, few if any rim-stamped wheels are still in use on interchange freight cars, due to the relatively high attrition rate of freight-car wheels. However, some locomotives, transit cars, and private passenger cars still have wheels with stamped rims. Generally the wheels on these types of railroad vehicles are not as subject to thermal damage in normal operation as freight-car wheels are. Also, these types of railroad vehicles are not regularly interchanged as freight cars are.

Straight-plate wheels are more subject to thermal damage resulting in residual tensile stresses in the rim than curved-plate wheels. The curved-plate wheel acts much like a thermal expansion joint, which allows for elastic bending during overheating and consequently is less prone to formation of residual tensile stresses in the rim. Curved-plate wheels were developed primarily, if not exclusively, for interchange freight cars, which have experienced the large majority of thermally damaged wheel failures, particularly in the 1970s before the large-scale

adoption of curved-plate wheels.³⁹ As of January 1, 1994, the AAR prohibited freight-car wheel replacement with straight-plate wheels; all wheels on freight cars must be replaced with appropriate curved-plate wheels. About 90 percent of the 12 million wheels on the interchange freight-car fleet in this country are curved-plate wheels.

Most wheels on locomotives and passenger cars are still straight plate because they are changed infrequently. Locomotive and passenger-car wheel failure resulting from thermal damage to treads and rims is rare because these wheels are inspected more frequently than those on freight cars and because locomotives and passenger cars have better brake control valves. Also, converting from a straight- to a curved-plate wheel would, in many cases, interfere with mounting disk brakes or other running gear. On many passenger and commuter cars, the use of disk rather than tread brakes has eliminated the possibility of overheating the tread and wheel rim, precluding thermal failure on these wheels. Under such circumstances manufacturers are reluctant to invest in the tooling and machinery necessary to manufacture curved-plate passenger-car wheels when the market is very small and the demand questionable.

The straight-plate B36 wheel, the type involved in this accident, was designed to be used on passenger trains, which are relatively short,⁴⁰ have passenger-brake valves, and receive frequent attention. These considerations greatly reduce the possibility of overheating a wheel. The Safety Board has investigated several previous accidents due to wheel failure from overheating. Between December 1978 and March 1979, the Board investigated four New York City Transit Authority Subway train derailments in which misapplied hand brakes caused the thermal failure of B36 wheels. The Board investigated the March 1979 baggage-car wheel derailment on Amtrak's Empire Builder at Lohman, Montana.⁴¹ The wheel was thermally damaged and had failed because of a defective brake valve. The Safety Board also investigated an AutoTrain derailment near Jarratt, Virginia, on May 5, 1976,⁴² which was caused by fatigue failure of a thermally damaged passenger-car wheel. Like the RBB&BC train in this accident, the AutoTrain was a mix of passenger and freight cars and was much longer than a normal passenger train.

The railroads have long understood the criticality of identifying overheated thermally damaged wheels. As a result of experience and compromise, the AAR added a standard of removal to the interchange rules. The standard required the removal of any wheel that had heat-generated discoloration that extended more than 4 inches from the rim. The same standard was

³⁹According to the AAR, in 1978, 163 derailments were caused by thermally damaged wheels. In 1993, there were such 37 derailments, of which 27 involved straight-plate wheels.

⁴⁰Shorter trains and their shorter brake pipes preclude many stuck brake problems from localized pressure conditions which are found more frequently in longer trains like freight trains.

⁴¹Railroad Accident Report--*Derailement of Amtrak Train No. 8, the Empire Builder, on Burlington Northern Track, Lohman, Montana, March 28, 1979* (NTSB/RAR-79/07).

⁴²This accident occurred before Amtrak's operation of AutoTrain on the then Seaboard Coast Line Railroad. See Railroad Accident Report--*Auto-Train Corporation Train Derailement on the Seaboard Coast Line Railroad Near Jarratt, Virginia, May 5, 1976* (NTSB-RAR-76/11).

adopted as a regulation when the FRA was created. However, according to recent AAR research and tests, 60 percent of the thermally damaged wheels involved in derailments had less than 4 inches of discoloration. Because of this, the AAR has abandoned the 4-inch discoloration criterion for removal of thermally damaged wheels. However, the FRA still maintains such a rule in its regulations. This is due to the lack of any other effective practical field inspection criterion to replace it. Title 49 *CFR* 215.103(h) states:

A railroad may not place or continue in service a car, if--(h) A wheel on the car shows signs of having been overheated as evidenced by a reddish brown discoloration, to a substantially equal extent on both the front and back face of the rim, that extends on either face more than 4 inches into the plate area measured from the inner edge of the front or back face of the rim.

It is still practically impossible to detect a thermally damaged wheel outside a laboratory. At the present time, the only reliable methods of determining a thermally damaged wheel are destructive.

Although thermal damage is not detectable, microscopic cracks emanating from the rim stamping may be detectable before they grow to critical size. Visual examination of the mate wheel after the corrosion product was removed easily revealed a small fatigue crack that was estimated to be about half the size of that on the numeral 4. The Safety Board believes that periodic close visual inspections with a low-power hand lens after cleaning the area are capable of detecting fatigue cracking in the stamping area long before the fatigue crack propagates to critical size. Such inspections may be enhanced by other nondestructive testing methods, such as magnetic particle inspections. To help ensure the integrity of these rim-stamped wheels, the Safety Board believes that operators should periodically inspect these wheels in the stamped areas for cracks and remove from service those wheels found to contain cracks.

Recent developments in the railroad industry have made the issue of overheated wheels less important. Wheel overheating and wheel failure on interchange freight cars have been dramatically reduced due to several factors. The new single-car air-brake test is more effective in detecting defective brake valves, which has reduced the number of stuck brakes and thus the number of overheated wheels. The adoption of curved-plate wheels, which are more heat tolerant, has reduced the number of wheels failing as a result of overheating. Finally, the increased use of dynamic braking has also reduced the possibility of overheating wheels by reducing the use of the air-brake system.

Despite the fact that the RBB&BC train

- o was inspected at Tampa by CSXT and RBB&BC personnel,
- o passed a defect detector 18 miles from the derailment point,
- o passed an observant maintenance-of-way gang that paused to inspect the train as it passed by, and
- o was stopped and inspected by the train crew 10 miles from the point of derailment,

the cracked and thermally damaged wheel was not detected before failure. The Safety Board concludes that thermal damage and cracking in the wheel could not be detected by routine railroad field inspection currently in practice.

The investigation could not determine whether the wheel had been thermally damaged before or after it was installed on the accident car. According to sworn testimony from expert witnesses at the Safety Board depositions regarding the accident, the wheel could have already been damaged when it was installed on the car, which happened 2 years before the accident. It is also possible that the wheel was already thermally damaged when it was recontoured on a truing machine one or more times before it was installed on the accident car.

There was no evidence that the wheel was thermally damaged after it left Tampa. Both RBB&BC and railroad employees stated that they inspected the train specifically for applied hand brakes. None of the wayside inspectors or observers noted any telltale smoke or odor of over-applied or misapplied hand brakes. According to the testimony from the senior railroad officials, the hotbox portion of the wayside defect detector would have reported any significant heat generated by a misapplied or sticking brake. Finally, according to expert witness testimony, the train probably had not been in transit long enough (about 1 1/2 hours) to generate the thermal damage from a misapplied or sticking brake found in the broken wheel.⁴³ The Safety Board concludes that the broken wheel was thermally damaged before the train left Tampa.

As a result of the previously mentioned Auto-Train derailment near Jarratt, Virginia, the Safety Board issued several recommendations to the FRA and the AAR regarding railroad wheels. The recommendations address many of the issues involved in the RBB&BC derailment.

The Safety Board recommended that the FRA:

Establish national standards for the inspection of railroad wheels that will insure detection of critical conditions in wheels before in-service failures occur. (R-76-52)

The FRA replied that it had six on-going studies to gather information on wheel failures and the feasibility of detecting critical conditions before failure. These studies were also integral to meeting the requirements of Safety Recommendations R-76-54 and -55. Besides the 49 *CFR* Subpart A 215.3, "Application"; 215.5, "Definitions"; 215.11, "Designation of Qualified Persons"; and 215.13, "Predeparture Inspection," the FRA in partial response to the Board's recommendation adopted Subpart B 215.103, "Defective Wheel," which was discussed earlier and provides the 4-inch discoloration rule for removal. The Board classified the recommendation in June 1980 "Closed---Acceptable Action."

⁴³The train departed Tampa about 7:30 a.m. and reached the derailment point in Lakeland about 48 miles later at 9:08 a.m.

Further, the Safety Board recommended that the FRA:

Review the methods employed in marking wheels and determine if the present method of marking wheel rims is detrimental to the service life of railroad wheels. (Class II--Priority Followup) (R-76-53)

The FRA replied that research confirmed that markings on the wheel rim may themselves be instrumental in the generation of a crack and that in accordance with the procedures established by the AAR, railroad wheels should be marked on the hub. As previously mentioned, the AAR prohibited the rim stamping of railroad wheels used on interchange freight cars in 1978.

In September 1986, the Board classified the recommendation "Closed--Acceptable Action."

The Safety Board also recommended that the FRA:

Develop a method that does not depend on crew observation that will automatically detect when a wheel(s) has failed or derailed. (R-76-54)

The FRA replied that it was working in conjunction with NASA Langley and the AAR to develop an in-track ultrasonic wheel crack detection system (WHEELFAX). However it was only able to detect about 50 percent of the 20 wheel defects defined in the current freight-car safety standards. Despite other efforts to determine nondestructive residual stress measurement techniques for determining stress conditions in railroad wheels and to determine the correlation between wheel discoloration, residual stress, and the probability of failure, a nondestructive reliable means to find a railroad wheel before it fails has yet to be found. The FRA was therefore forced to a default response to this recommendation of more rigorous enforcement of the previously mentioned regulations.

In June 1980, the Board classified the recommendation "Closed--Acceptable Alternate Action."

The Safety Board also recommended that the FRA:

Revise the *CFR* to insure that wheels exposed or suspected of being exposed to critical temperatures are removed from service. (R-76-55)

Detection of thermally damaged wheels continues to be a practical impossibility outside a laboratory. Even in a laboratory, current nondestructive methods of wheel thermal damage detection are unreliable, including magnaflux, tomography, acoustic, ultrasonic, and x-ray. Only the destructive cutting of the wheel rim will reveal if the wheel is thermally damaged, as any cut will quickly propagate into a crack to the hub if the wheel has thermal stress reversal.

This recommendation has been overcome by events in the freight-car interchange fleet. Wheel overheating and wheel failure on interchange freight cars have been largely eliminated

due to a number of factors. The new single-car air-brake test has reduced the number of stuck brakes by more effectively finding defective brake valves, thus reducing the number of overheated wheels. The adoption of curved-plate wheels, which are more heat tolerant, has reduced the number of thermally failed wheels. The increased use of dynamic braking has also reduced the possibility of overheating wheels by reducing the use of the air-brake system. In addition, on passenger and transit cars, the use of disk rather than tread brakes has precluded the possibility of overheating the tread and wheel rim, precluding thermal failure.

In light of the technical problems already discussed with implementing this recommendation, the FRA in partial response to the Board's recommendation adopted Subpart B 215.103 (the 4-inch discoloration rule) as better than nothing. The Board classified the recommendation in September 1986 "Closed--Acceptable Alternate Action."

In addition to these recommendations to the FRA, the report on the Jarratt, Virginia, accident included two safety recommendations to the AAR. These recommendations asked the AAR to:

Establish a system to insure that wheels exposed to critical temperatures are removed from service before in-service failure occurs. (R-76-56)

and

Establish a system to insure that wheels exposed or suspected of being exposed to critical temperatures are reported by railroad employees. (R-76-57)

Between November 1976 and September 1994, representatives of the Safety Board and the AAR exchanged a number of letters and met a number of times to discuss the need to identify and remove wheels that might be prone to failure due to being exposed to critical temperatures. Safety Recommendation R-76-57 was classified "Closed--Reconsidered" on September 13, 1994, with the following statement to the AAR:

Due to the inability to develop a nondestructive method to identify thermally damaged wheels, the Board has classified Safety Recommendation R-76-57 as "Closed--Reconsidered."

Safety Recommendation R-76-56 was classified "Closed--Acceptable Alternate Action" on September 13, 1994, because the AAR had prohibited the use of straight-plate freight-car wheels for replacements in interchange service and because the AAR since 1978 had prohibited the ordering of new straight-plate freight wheels for use in interchange service. Consequently, the population of straight-plate freight-car wheels has fallen below 15 percent, with a corresponding 80-percent drop in accidents attributable to broken wheels.

As previously discussed, these recommendations have been largely met in the freight-car interchange fleet, in which wheel overheating and wheel failure have been largely eliminated due

to the new single-car air-brake test, the adoption of curved-plate wheels,⁴⁴ and the increased use of dynamic braking.

The Safety Board determines that tread-braked rim-stamped straight-plate wheels are more prone to thermal damage and subsequent fatigue cracking. Currently the greatest number of straight-plate rim-stamped tread-braked wheels are found on private (non-Amtrak) passenger cars. Many of these cars are owned and operated by tourist railways, railroad museums, railway excursion operators, private car owners, and historical groups. Most of these organizations are nonprofit and belong to the Tourist Railway Association, Inc. (TRAIN)⁴⁵ and/or the American Association of Private Railroad Car Owners, Inc. (AAPRCO). According to TRAIN, "well over 500 passenger cars were in private hands in 1986." According to a June 1994 letter from AAPRCO, its members have about 140 Amtrak-certified cars and about 300 additional cars in various stages of rebuilding. Almost all railroads also maintain for excursions and inspections a number of business cars that fall into the private category.

Some of the private passenger cars are tread braked, and some are disc braked. Depending on the type and era, a passenger car usually has four or six axles (wheel pairs). Based on inquiries to TRAIN, AAPRCO, and the Association of Railway Museums, Safety Board investigators were able to determine that the owners of operational passenger cars have a total of about 1,000 pairs of straight-plate rim-stamped tread-braked wheels.

In summary, tread braking is a significant source of wheel overheating and thermal damage; straight-plate wheels are vulnerable to thermal damage, and rim stamping provides a stress concentration for crack initiation. Wheels that are particularly susceptible to thermal damage and subsequent fatigue failure are relatively few but have the potential to injure and kill passengers beyond their numbers since most of the problem wheels that are left are on private passenger cars.

In the last 18 years, the Safety Board has investigated only two thermally damaged wheels that resulted in fatigue failure on passenger trains. The Board acknowledges that insisting on the immediate removal of all rim-stamped tread-braked straight-plate wheels would severely damage private passenger-car owners economically. Because private passenger cars employ low speeds and have a good accident history, the Board believes that the wheels could be replaced gradually without significantly jeopardizing public safety. The Safety Board further believes that the FRA should prohibit future wheel replacement with rim-stamped straight-plate wheels on tread-braked cars.

The Safety Board is concerned about straight-plate rim-stamped tread-braked wheels that may remain in service for an extended period of time before requiring change out. Because of the extremely diverse conditions and environments in which private passenger cars operate, the

⁴⁴AAR Standard S-660, low stress wheels.

⁴⁵TRAIN is a nonprofit New York State corporation chartered for the purpose of furthering the aims of its membership. Members include tourist railways, railroad museums, railway excursion operators, private car owners, suppliers, and other groups and people. Many members of TRAIN also belong to AAPRCO.

Safety Board cannot assess the long term safety risk of such cars and their wheels. However, the Safety Board believes that all private railroad car organizations and private car owners should conduct a periodic inspection of their tread-braked rim-stamped straight-plate wheels to find any cracks emanating from the rim stamping and to remove the affected wheels. The Safety Board also believes that the AAR should prohibit the interchange of any tread-braked railroad car with rim-stamped straight-plate wheels unless adequate inspection procedures are developed

Private passenger cars approved or certified by Amtrak are frequently hauled behind Amtrak revenue trains and in Amtrak special trains. These private passenger cars must meet not only all applicable Federal and industrial requirements, but also all of Amtrak's mechanical and safety standards at each Amtrak inspection for each movement. However, based on the above rationale, the Safety Board does not believe that the high speed public carrier operations of Amtrak are an appropriate environment for private passenger cars with rim-stamped straight-plate tread-braked wheels. The Safety Board believes that Amtrak should prohibit the use of such cars.

Safety in Occupied Moving Cars

Securement of interior equipment and appliances on the RBB&BC train.--Only 19 persons, including family members, occupied the three converted coaches that overturned and sustained substantial damage. Apparently because the cars were sparsely occupied, there were few injuries. Safety Board investigators decided from postaccident interviews and the condition of the cars that a few of the injuries were sustained when the occupants were struck by dislodged small appliances and personal property.

The performer who was killed died of asphyxiation. She was found underneath an inadequately secured file cabinet in the leading (east) end of car 93. Had the file cabinet been anchored with larger more appropriate brackets to the floor and/or wall, it might not have broken loose. The Safety Board concludes that had large interior appliances and equipment been secured, she might not have been killed.

After the Suffolk, Virginia, accident,⁴⁶ the Safety Board issued the following safety recommendation to The American Short Line Railroad Association, the AAR, the National Railroad Historical Society, and AAPRCO:

Recommend to its membership that the interior fixtures and appliances of any passenger-carrying car be secure and that the interiors of cars not have injury-producing features identified in the accident involving train Extra 611 West at Suffolk, Virginia, on May 18, 1986. (Class II, Priority Action) (R-87-31).

⁴⁶Railroad Accident Report--*Derailement of Steam Excursion Train Norfolk and Western Railway Company Train Extra 611 West, Suffolk, Virginia, May 18, 1986* (NTSB/RAR-87/05).

In the February 1988 issue of *TRAINLINE*, TRAIN published the recommendations from the Suffolk, Virginia, accident. *TRAINLINE* is the news magazine of TRAIN. Many private car owners received the recommendations through *TRAINLINE*; the RBB&BC joined TRAIN in 1992.

AAPRCO sent its members a March 24, 1988, letter, "Amtrak Mechanical Liaison Officer's Report," that addressed Safety Recommendation R-87-31. Although the recommendation was not quoted, the letter referred to the Suffolk accident and addressed the need to consider interior crashworthiness in the securement of interior equipment and appliances. It also mentioned the need to eliminate protrusions and injury-producing objects.

In a July 25, 1988, letter to the Safety Board Chairman, AAPRCO stated, "The recommendation that interior fixtures and appliances of passenger-carrying cars should be secure, and that they be modified to eliminate, so far as possible, projections which cause injuries...[is] most reasonable." The recommendation to secure objects was made to the membership immediately following our convention in Milwaukee in October 1986. The Safety Board classified Safety Recommendation R-87-31 "Closed--Acceptable Action" in July 1988.

According to the RBB&BC, it has been a member of AAPRCO for about 10 years, and as such, acknowledges having received the above information and correspondence from AAPRCO. As a result, the RBB&BC did have a limited securement policy at the time of the accident. Small objects and appliances were required to be restrained with bungee cords. The use of the cords was demonstrated in the video tape produced by the RBB&BC for its employees. However, large objects like file cabinets, particularly those in unoccupied nonliving areas, were inadequately secured at the time of the accident. Potentially injury-producing interior fixtures and appliances of any passenger-carrying car should be properly and sufficiently secured to prevent injury in the event of derailment.

The rules in the RBB&BC booklet do not state or cover the actions employees should take in the event of a derailment, a collision, or a fire while the train is moving. Although the video covers some contingencies, such as emergency exits and fire, the booklet does not. The Safety Board believes the booklet should cover at least as much material as the video does and that both should be expanded to explain what employees should do after a derailment or collision.

Communication systems and conductor's (emergency) brake valves.--Although 20 RBB&BC employees were authorized to have a hand-held radio for intra-train communications,⁴⁷ some of those people were not on the train when it derailed. About half of the employees, including some of the people who were authorized to have radios, had opted to travel by privately owned vehicle to Orlando; consequently their radios were not available. There was no formal plan or direction about where or how the radios were to be distributed throughout the train, when the radios were required to be on, or how an extended trip involving sleeping radio personnel would be handled. Nor did the employees on the train have an understanding about

⁴⁷The 20 radios do not include the radio provided to the locomotive engineer.

where the closest radio could be found in the event of an emergency, although they did know a radio was in the trainmaster's quarters. The Safety Board concludes that had an accessible intercom or other effective emergency communication system been available, the performer might not have lost her life attempting to reach the trainmaster seven cars away, and the severity of the derailment might have been reduced, if not averted. The same might also be true had she had access to a conductor's brake valve.

The passenger cars were not equipped with conductor's brake valves. These valves are usually at the ends of passenger cars in or near the vestibule and are labeled *For Emergency Only*. The valve was originally designed to allow the conductor to stop the train from wherever he is in the train with a minimum of delay. Of course the conductor's brake valve was designed to be used on passenger trains, which are relatively short compared to freight or mixed trains and are made up of passenger cars that each have a relatively quick acting passenger-type control valve.

The RBB&BC had the conductor's brake valves removed from all passenger cars due to the large number of foreign and non-English speaking performers and employees who, the RBB&BC felt, might endanger the train by activating a valve at the wrong time. Also, since the train was a mix of passenger cars with freight-brake valves and freight cars and since the train was much longer than most passenger trains, the RBB&BC felt that valve activation might endanger the train by introducing excessive in-train forces. Thus the RBB&BC felt such a valve could potentially create more derailment problems than it would solve. The RBB&BC might benefit from using a train dynamics analyzer machine to analyze the consequences of activating a conductor's brake valve. Such an analysis would provide more evidence about the safety benefit of equipping each of the passenger cars with a conductor's brake valve.

Passenger-car interior construction standards and guidelines.--The Safety Board concludes that occupied railroad cars are not subject to minimum interior safety standards. As discussed in the factual portion of this report, there are no Federal regulatory standards for the interior construction or design of railroad passenger cars, let alone of private passenger cars. However, Amtrak has its own standards. RBB&BC interior construction and design standards reflected those found in the domestic housing and recreational vehicle industries. Thus, lacking any other guidance, the RBB&BC did what it could. The derailment of the train revealed that this was not entirely safe or sufficient design and construction for railroad passenger cars. This is particularly true where the passengers not only travel temporarily in the cars, but live in the cars as well, necessitating many extra features like water heaters and kitchens. Thus safe design and construction of the car interiors may be even more imperative where the exposure to a built-in potential hazard is significantly longer if not continuous.

According to the RBB&BC's June 15, 1994, submission to the Board, the RBB&BC custom builds its car interiors "in a fashion similar to that of recreational vehicles." The RBB&BC has stated in private discussions that it would welcome some official guidance about interior design and construction. In lieu of official guidance, the RBB&BC has sought advice from Amtrak and hired consultants in an effort to make its car interiors safer.

Postaccident Actions

The Safety Board concludes State, county, and local fire, police, and emergency-service units reacted quickly and professionally to the tragedy. Their actions exemplify the ideal of fast and effective response.

The Safety Board is gratified by the expeditious response of RBB&BC to the accident. The RBB&BC's letters are statements of a responsible organization and a good faith pledge to improve safety. The Safety Board looks forward to the continued implementation of RBB&BC's pledged improvements.

CONCLUSIONS

Findings

1. The weather, the train handling, the signal and train control system, the track, the brakeman's illicit drug use, and the dispatcher operations neither caused nor contributed to the derailment. The CSX Transportation train crewmembers were qualified to perform their duties in accordance with CSX Transportation procedures and accepted practice.
2. CSX Transportation did not include on its emergency response telephone list those operators that have pipelines on or adjacent to its railroad right-of-way that could be damaged by a rail incident.
3. Failure of the wheel was caused by a fatigue crack initiating at the base of a stamped character that was promoted by decarburization and adverse residual tensile stresses produced by overheating of the wheel tread.
4. The broken wheel was thermally damaged before the train left Tampa.
5. The fact that the wheel was thermally damaged could not be detected by routine railroad field inspection.
6. Tread-braked rim-stamped straight-plate wheels are more prone to fatigue failure when the wheels are thermally damaged.
7. Had large interior appliances and equipment been secured, the female performer might not have been killed.
8. Had an accessible intercom or other effective emergency communication system been available, the female performer may not have lost her life attempting to reach the trainmaster seven cars away, and the severity of the derailment might have been reduced, if not averted.
9. Occupied railroad cars are not subject to minimum interior safety standards.
10. State county, and local fire, police, and emergency-service units reacted quickly and professionally to the tragedy.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the derailment of the Ringling Bros. and Barnum & Bailey Circus blue train was the fatigue failure of a thermally damaged wheel due to fatigue cracking that initiated at a stress raiser associated with a stamped character on the wheel rim.

RECOMMENDATIONS

As a result of its investigation, the National Transportation Safety Board recommends:

--to the Federal Railroad Administration:

Prohibit the replacement of wheels on any tread-braked passenger railroad car with rim-stamped straight-plate wheels. (Class II, Priority Action) (R-95-1)

--to the Association of American Railroads:

Develop and implement safe operating parameters that consider effective interchange inspection procedures and operating speeds for tread-braked passenger cars with rim-stamped straight-plate wheels. Until such a procedure is developed, prohibit the interchange of any tread-braked passenger railroad car equipped with rim-stamped straight-plate wheels. (Class II, Priority Action) (R-95-2)

--to the National Railroad Passenger Train Corporation (Amtrak):

Prohibit tread-braked passenger cars that are equipped with straight-plate rim-stamped wheels in your trains. (Class II, Priority Action) (R-95-3)

--to the American Association of Private Railroad Car Owners, Inc., the American Short Line Railroad Association, the Association of Railway Museums, the National Passenger Car Alliance, the National Railroad Historical Society, and the Tourist Railway Association, Inc.:

Inform your members about the derailment of the Ringling Bros. and Barnum & Bailey Circus blue train at Lakeland, Florida, on January 13, 1994, and request that they prohibit the replacement of wheels on nonstatic tread-braked railroad cars with straight-plate rim-stamped wheels. (Class II, Priority Action) (R-95-4)

Inform your members that all private railroad car organizations and private car owners should conduct a periodic inspection of their tread-braked rim-stamped straight-plate wheels to find any cracks emanating from the rim stamping and to remove the affected wheels. (Class II, Priority Action) (R-95-5)

--to the Ringling Bros. and Barnum & Bailey Circus:

Continue to implement the safety changes and equipment improvements outlined in your March 11, 1994, letter and report to the Safety Board on your progress in developing improved safety policies and inspection procedures and in installing additional safety equipment in your rail cars. (Class II, Priority Action) (R-95-6)

Revise your booklet *Train Rules & Safety Regulations* so that it covers at least as much material as the video *All Aboard the RBB&BC Train*, and expand both so that they explain what employees should do after a derailment or collision. (Class II, Priority Action) (R-95-7)

--to CSX Transportation:

Include on your emergency response telephone list those operators that have pipelines on or adjacent to your right-of-way that could be damaged by a rail incident. (Class II, Priority Action) (R-95-8)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

February 14, 1995

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APPENDIX A Investigation

Investigation

The Safety Board was notified of the accident by the Coast Guard National Response Center at 10:34 a.m. eastern standard time, on January 13, 1994. A major railroad accident investigation team was launched by the National Transportation Safety Board. Board member James Hall went to accident site with the investigation team, accompanied by his assistant and a public affairs representative. Investigative groups were established for operations, track and signal, mechanical, human performance, and survival factors.

The Safety Board was assisted in the investigation by the Federal Railroad Administration, Ringling Bros. Barnum & Bailey Combined Shows, Inc., CSX Transportation, Inc., Brotherhood of Locomotive Engineers, Polk County Florida, General American Transportation Corporation, Standard Steel, and State of Florida Department of Transportation.

Deposition

The Safety Board held a 1-day deposition as part of its investigation at Tampa, Florida, on April 19, 1994. Parties to the depositions included Federal Railroad Administration, Ringling Bros. Barnum & Bailey Combined Shows, Inc., CSX Transportation, Inc., Standard Steel, and State of Florida Department of Transportation. Nine witnesses testified.

APPENDIX B
Consist List
Ringling Bros. Barnum & Bailey Circus Blue Train
 CSXT Designation W923-12

<u>Position in Train</u>	<u>Vehicle Number</u>	<u>Type</u>	<u>Nominal Weight</u>	<u>Axles</u>	<u>Remarks</u>	<u>Previous History</u>		
Loco. Unit	2682	GP38-2	4	EMD		ex-SCL reblt 1979		
Loco. Unit	1938	U18	4	EMD		rebuilt GP-9 in '88		
Loco. Unit	1939	U18	4	EMD		rebuilt GP-9 in '88		
1	RBX 132	Baggage/Stock	100	6	Horses	UP	1962	ACF
2	RBX 133	Baggage/Stock	100	6	Elephants, Buffalo	UP	1961	ACF
3	RBX 131	Baggage/Stock	100	6	Elephants	UP	1961	ACF
4	RBX 130	Baggage/Stock	100	6	Elephants	UP	1961	ACF
5	RBX 71	Baggage	100	6	Workshop	UP	1962	
6	RBX 72	Converted Coach	70	4	Coach-Bunk	C&O	1950	Pullman
7	RBX 73	Converted Coach	70	4	Workingmen	SCL	1955	Budd
8	RBX 74	Converted Coach	70	4	Workingmen	SCL	1955	Budd
9	RBX 75	Converted Coach	70	4	Coach-SF	RFP	1949	Pullman
10	RBX 76	Converted Coach	70	4	Coach SF Qtrs	NJTR	1949	Budd
11	RBX 77	Converted Coach	70	4	Coach S/F Staff	RFP	1949	Pullman
12	RBX 78	Baggage	100	6	Gen./Pie Car	UP	1961	StL Car
13	RBX 79	Converted Coach	70	4	Pie Staff&Boss	SCL	1955	Pullman
14	RBX 80	Converted Coach	70	4	Supervisors	NJTR	1949	Budd
15	RBX 81	Converted Coach	70	4	Workingmen	B&O	1950	Pullman
16	RBX 82	Converted Coach	70	4	Coach-Act	L&N	1953	Pullman
17	RBX 83	Converted Coach	70	4	Performers	NJTR	1949	Budd
18	RBX 84	Converted Coach	70	4	Performers	NJTR	1949	Budd
19	RBX 85	Converted Coach	70	4	Performers	NJTR	1949	Budd
20	RBX 86	Converted Coach	70	4	Coach-Act	UP	1958	StL Car
21	RBX 87	Converted Coach	70	4	Coach-Act	L&N	1953	Pullman
*22	RBX 88	Converted Coach	70	4	Performers	NJTR	1950	Pullman
*23	RBX 89	Converted Coach	70	4	Clown	B&O	1950	Pullman

APPENDIX B

*24	RBX	90	Converted Coach	70	4	Girls Car	NJTR	1950	Pullman
*25	RBX	91	Converted Coach	70	4	Living Quarters	UP	1958	ACF
*26	RBX	92	Converted Coach	70	4	New Chinese BNP	1956	Pullman	
*27	RBX	93	Baggage	100	6	Gen. / Office	UP	1961	ACF
*28	RBX	94	Converted Coach	70	4	Musicians	NJTR	1949	Budd
*29	RBX	95	Converted Coach	70	4	Center Vest	UP	1955	ACF
*30	RBX	96	Converted Coach	70	4	Center Vest	PW	1954	ACF
*31	RBX	97	Converted Coach	70	4	Center Vest	NJTR	1954	ACF
*32	RBX	98	Converted Coach	70	4	Performers	BNP	1956	Pullman
*33	RBX	99	Converted Coach	70	4	Performers	NYC	1949	Pullman
*34	RBX	100	Converted Coach	70	4	Melssen-Cohen	NW	1956	Pullman
*35	RBX	70	Container Flat	70	4	Souvenirs	JTTX	1965	Bethlehem
*36	RBX	69	Container Flat	70	4	Souvenirs	MCLX	1967	Bethlehem
*37	RBX	108	TTX-Type Flat	55	4	Equipment	NIFX	1978	W&K
38	RBX	107	TTX-Type Flat	55	4	Equipment	GTW	1973	Bethlehem
39	RBX	110	TTX-Type Flat	55	4	Equipment	GTW	1967	ACF
40	RBX	105	TTX-Type Flat	55	4	Equipment		1969	ACF
41	RBX	112	TTX-Type Flat	55	4	Equipment	GTW	1967	ACF
42	RBX	114	TTX-Type Flat	55	4	Equipment	GTW	1969	Bethlehem
43	RBX	102	TTX-Type Flat	55	4	Equipment		1969	ACF
44	RBX	111	TTX-Type Flat	55	4	Equipment	GTW	1967	ACF
45	RBX	104	TTX-Type Flat	55	4	Equipment		1969	ACF
46	RBX	101	TTX-Type Flat	55	4	Equipment		1969	ACF
47	RBX	106	TTX-Type Flat	55	4	Equipment	GTW	1969	Bethlehem
48	RBX	113	TTX-Type Flat	55	4	Equipment	GTW		
49	RBX	103	TTX-Type Flat	55	4	Equipment		1969	ACF
50	RBX	109	TTX-Type Flat	55	4	Equipment	NIFX	1967	W&K
51	RBX	116	TTX-Type Flat	55	4	Bears	WC	1969	Maxon
52	RBX	115	TTX-Type Flat	55	4	Lions	WC	1969	Maxon
53	RBX	129	Bi-Autorack	55	4	Autos/Emty Cages	SP	1970	

APPENDIX C
Metallurgist Report

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

March 31, 1994



METALLURGIST'S FACTUAL REPORT

Report No. 94-81

A. ACCIDENT

Place : Lakeland, Florida
Date : January 13, 1994
Vehicle : Ringling Brothers and Barnum & Bailey train car # 89
NTSB No. : DCA 94-M-R 003
Investigator : Robert Lauby, ST-30

B. COMPONENTS EXAMINED

Axle with an intact wheel and a hub portion of the separated wheel, two sections of the separated wheel.

C. DETAILS OF THE EXAMINATION

1. General

The submitted components are shown as received in the two photographs of figure 1. The separated wheel (see arrow "1" in the top photograph of figure 1) was reportedly the L-4 wheel (No. 8 position), the left wheel on the lead axle of the lead truck of passenger car RBX 89. Arrows "f" in this figure denote the fracture face on the hub portion of the wheel. Two broken off pieces of the wheel are shown in the bottom photograph of figure 1 with the fracture faces in the rim aligned together as if intact. Fracture of the wheel originated at the gage side of the rim and propagated radially into the rim, down to the web area, circumferentially around the hub and then up through the rim again. The gage face of the rim contained stamped identification markings "9 72 *S* 4617 B B 36" indicating that the wheel was of class "B", was manufactured in September 1972 by Standard Steel as a serial number 4617, and had an outside diameter of 36 inches.

The character cavities in the identification stamps of the separated and intact wheels were filled with oxides and corrosion deposits. A fluorescent dye-penetrant inspection, performed in the stamped regions of both wheels, revealed no crack indications in any of the characters.

2. Examination of the Separated Wheel

2.1. Fracture Surface Analysis

Visual examination of the mating fracture faces revealed features typical of fatigue cracking emanating from the bottom of the long leg in the stamped number 4 on the gage face of the rim. A close up view of the rim pieces at the fatigue fracture initiation area is shown in figure 2. Angled views of the fracture faces showing the fatigue fracture area (see arrows "F") are displayed in figures 3a and 3b.

A 1-inch-thick section of the rim adjacent to the fracture face shown in figure 3a was cut out with a band saw from the remainder of the wheel piece for further examination. Approximate boundaries of the obtained sections are denoted by the dashed lines in figure 3a. To facilitate handling, the wheel piece was sectioned approximately in half by a plasma torch prior to band saw cutting.

Figure 4 is a low magnification view of the fracture face and figure 5 is a close up view of the fatigue fracture zone on the removed section of the wheel. Examination with the aid of a low power binocular microscope revealed that the fatigue cracking initiated from multiple sites, as indicated by the brackets in figure 5. Examination further revealed that a portion of the fatigue zone adjacent to the fracture origin areas was covered with a dark corrosion product.

The fracture face was cleaned by an electrochemical procedure and then examined at higher magnifications with a scanning electron microscope (SEM). Examination showed that the fatigue fracture zone extended to a depth of 0.55 inch, to the positions indicated by the arrowheads in figure 5. Beyond this position, the fracture features were consistent with an overstress separation. Fine fatigue striations were observed throughout the fatigue fracture zone. The typical striations are shown in the left photograph of figure 6. The overstress fracture zone contained a mixture of cleavage facets and dimples (see right photograph of figure 6).

2.2. Macro- and Microstructural Examinations, Hardness Tests

2.2.1. Section through the Tread

Figure 7 is a photomicrograph of the rough polished and etched section of the rim adjacent to the fracture face. The location of this section is shown in figure 3a. Examination at low magnifications revealed four (4) distinct microstructural zones below the tread surface (see arrows "a", "b", "c", and "d"). A specimen, outlined by the solid lines in this figure, was cut out and prepared metallographically for further examinations at higher magnifications.

Photomicrographs a, b, c, and d in figure 8 denote the typical differing microstructures in the areas of the tread specimen. The base material (see arrow "a" in figure 7) consisted of fine pearlite (dark areas) with some grain boundary ferrite (light areas). In the area denoted by arrow "b" in figure 7 the pearlite was partially spheroidized into carbides. The

microstructure in the area indicated by arrow "c" consisted entirely of spheroidized carbides, and the microstructure in the area indicated by arrow "d" was completely recrystallized with small grains of pearlite and ferrite. Microstructures observed in the areas arrowed "b", "c", and "d" are indicative of various stages of overheating of a steel with the highest temperature being in the areas immediately adjacent to the tread surface.

The specified¹ hardness for the class B wheels is 277 to 341 HB. A Knoop hardness traverse test was performed in the area shown by a dashed line in figure 7, and these hardnesses were converted to HB values using standard hardness conversion tables. The average hardness in the area denoted by arrow "d" was found to be 305 HB (336 HK). The average hardness in the area denoted by arrow "c", was 222 HB (236 HK) and in the area denoted by arrow "b" was 234 HB (245 HK). Average hardness of the base material (see arrow "a") was 295 HB (323 HK). Based on the hardness values, the depth of the overheated region was estimated to be about 0.7 inch.

2.2.2. Microsection through Fatigue Origin Area

A metallographic microsection was prepared through the fatigue origin area as shown by sectional arrows "A-A" in figure 5. Figure 9 is a low magnification photomicrograph of the polished and etched specimen with arrow "O" denoting the fatigue origin. The depth of stamping was measured using an SEM linear measuring unit. Results indicated that at the location shown in figure 9 the depth of the stamped mark was 0.054 inch (1.37 mm). The specified maximum depth of the stamped characters is 3/32 (0.094 inch).

Figure 10 is a composite photomicrograph showing the microstructure of the wheel material underlying the stamp. The location and orientation of this photograph are indicated by a dashed line in figure 9. Metallographic examination revealed that the area adjacent to the stamped surface of the wheel was decarburized. The depth of the decarburization zone as determined by a Knoop hardness traverse test was found to be about 0.055 inch. The results of the test are shown in Table 1 together with a converted Brinell hardness (HB) value and an equivalent approximate tensile strength for each measurement.

2.2.3. Microsection through a Numerical Character "7"

Section of the rim containing the stamped characters **7 B B** was cut out from the remainder of the separated wheel for further examinations. Oxides and corrosion deposits were electrolytically removed from the stamp cavities and the bottom surfaces of the characters were examined with the bench binocular microscope. Magnified optical examination revealed no cracking in these characters.

A specimen for metallographic examination and the measurement of the depth of stamping was also obtained in the circumferential direction of the wheel on a tangent plane across the central portion of the long leg of the numerical character 7. Examination of the

¹ Association of American Railroads, specification No. M-107-70.

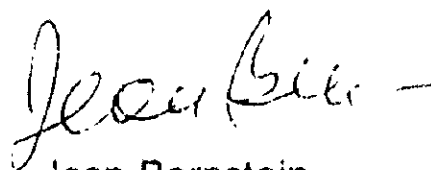
polished and etched specimen revealed a decarburized layer underlying this stamp. The microstructure and depth of the decarburized zone appeared to be similar to that found for the stamped numerical character 4. Figure 11 is an SEM photomicrograph showing that at the measured location the depth of the stamped 7 was 0.045 inch (1.18 mm).

3. Examination of the Intact Wheel

The as received intact wheel (see arrow "2" in the top photograph of figure 1) was uniformly covered with rust and exhibited no evidence of overheating of the tread surface. A radial section (about 1 inch thick) through the rim portion of the wheel was obtained for macroscopic examination. Examination disclosed that a portion of the wheel underlying the tread was overheated. The extent of overheating (depth and microstructural constituents) appeared to be similar to that observed in the separated wheel.

A section of the rim containing a stamped number 4 was cut out from the wheel for further examination. Figure 12 displays a magnified view of this mark after removal of the deposits. Examination with the binocular microscope revealed a hairline crack at the bottom of the long leg, as shown by arrows "c" in this figure. A cross section through the crack was obtained at the location shown by a sectional line "A-A" for microstructural examination.

Examination of the polished and etched specimen revealed that the crack was located in the corner between the bottom and the wall of the stamped mark. The crack was transgranular and the walls of the crack were covered with high temperature (blue) oxides and corrosion deposits. A low magnification micrograph showing the entire length of the crack is displayed in figure 13. The depth of the stamp and the extent of the crack below the surface, as measured with the SEM linear measuring unit, were 0.08 inch (2.04 mm) and 0.122 inch (3.10 mm), respectively. The layer of the wheel material underlying the stamp was decarburized. The depth of the decarburization zone appeared to be similar to that observed in stamps 4 and 7 of the separated wheel.



Jean Bernstein
Metallurgist

APPENDIX C

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TABLE 1.

Distance from the surface, inch	Knoop	Converted to HB	Equivalent Tensile Strength, ksi
0.002	201	185	89
0.005	217	200	96
0.010	217	200	96
0.015	239	228	109
0.020	254	235	110
0.025	263	242	113
0.030	281	258	121
0.035	278	255	120
0.040	283	260	123
0.045	286	262	124
0.050	294	268	128
0.055	308	279 ²	134
0.060	308	279	134
0.065	310	282	135

²277 HB is a minimum hardness specified by the manufacturer.

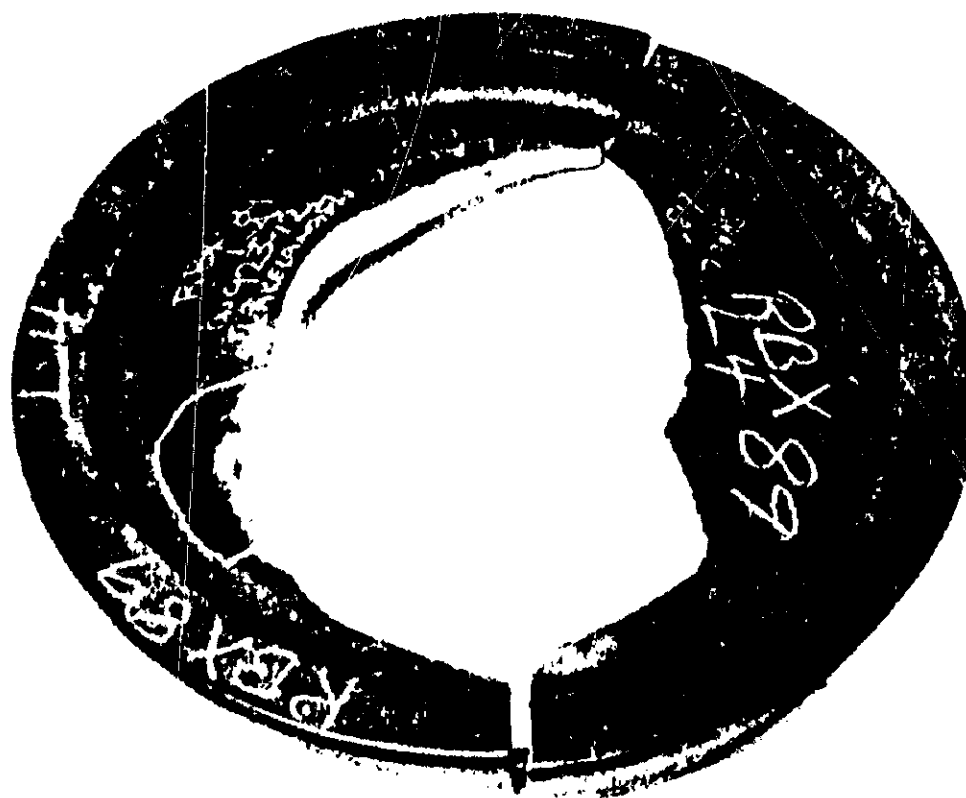
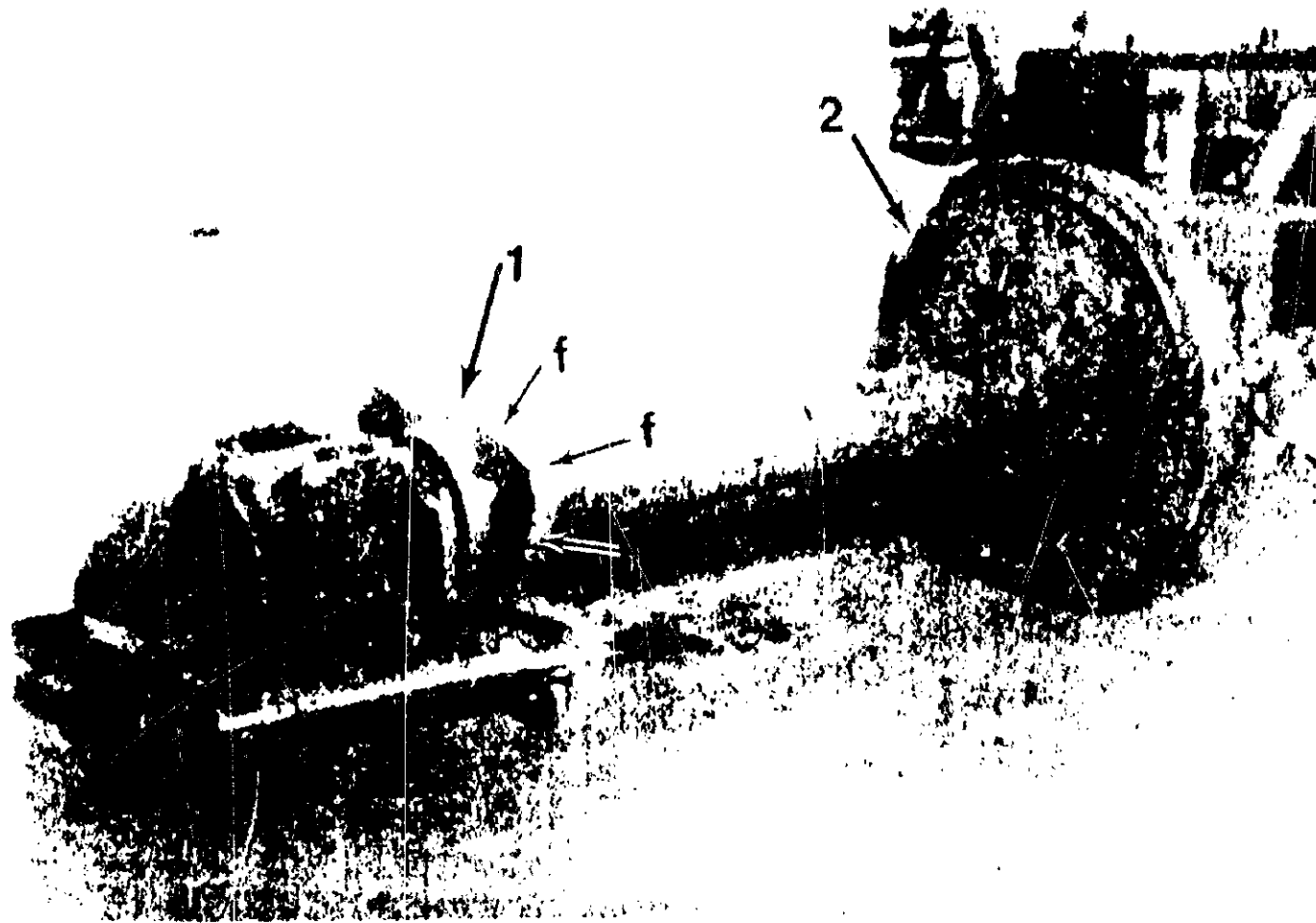


Figure 1. Overall view of the submitted components. Arrows "1" and "2" in the top photograph denote the separated and intact wheels, respectively. The broken off pieces of the wheel are shown in the bottom photograph.

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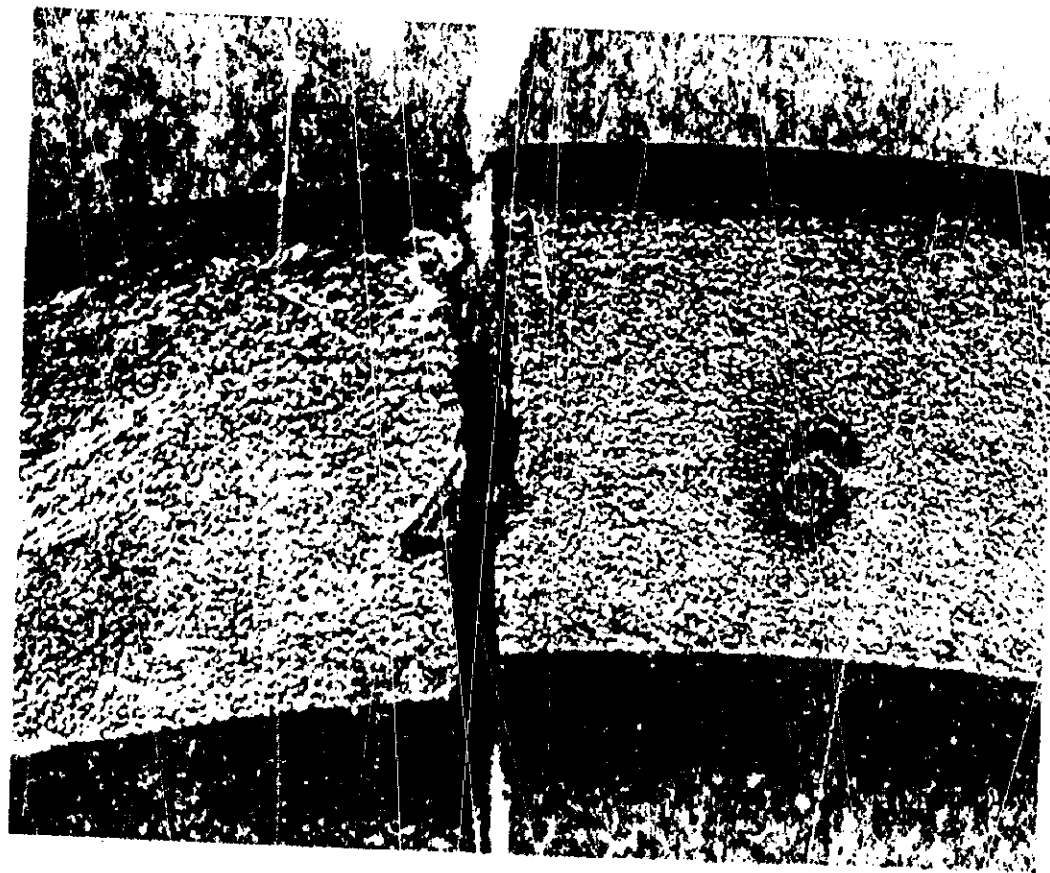


Figure 2. Close up view of the portion of the rim showing the separation through the long leg of the stamped number "4".

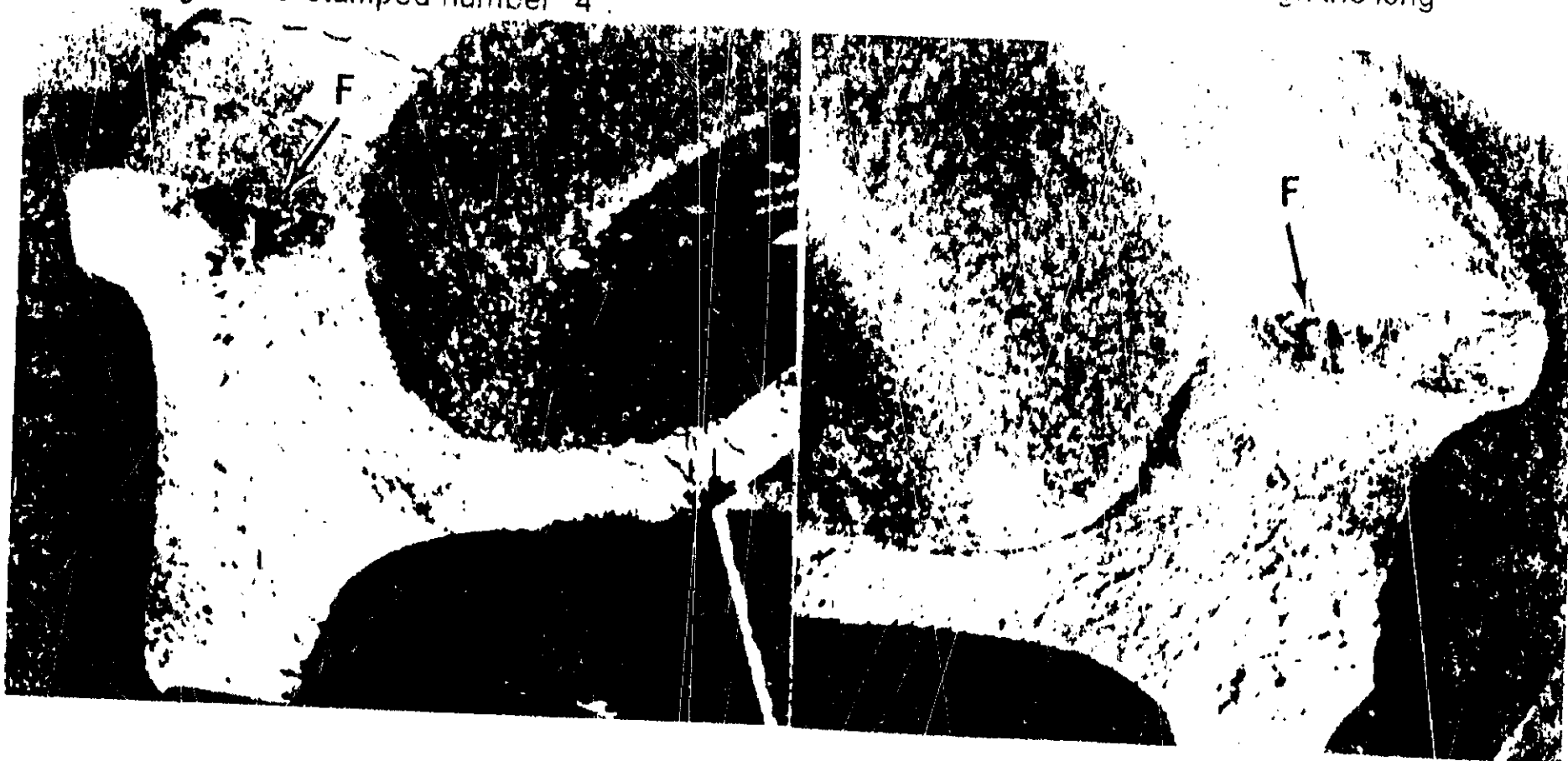


Figure 3. Angled views of the mating fracture faces showing the fatigue fracture area by arrows "F".

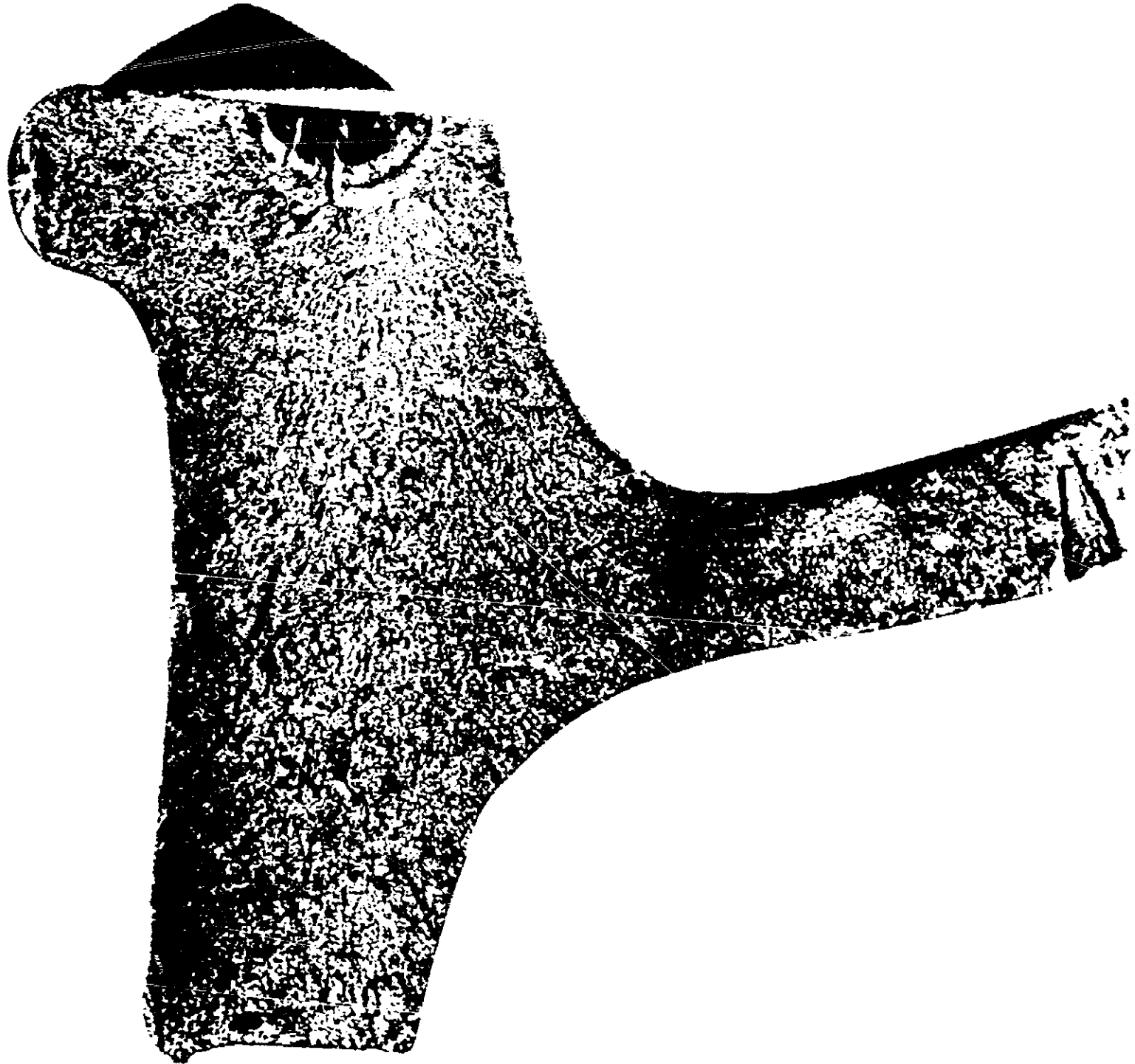
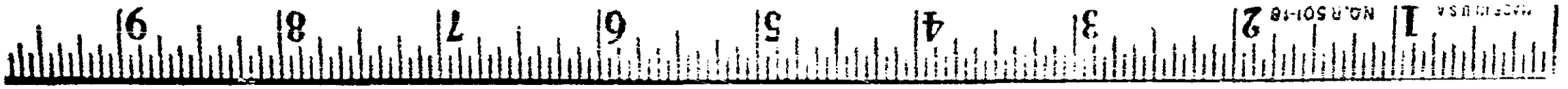


Figure 4. Low magnification direct view of the fracture face shown in figure 3a.

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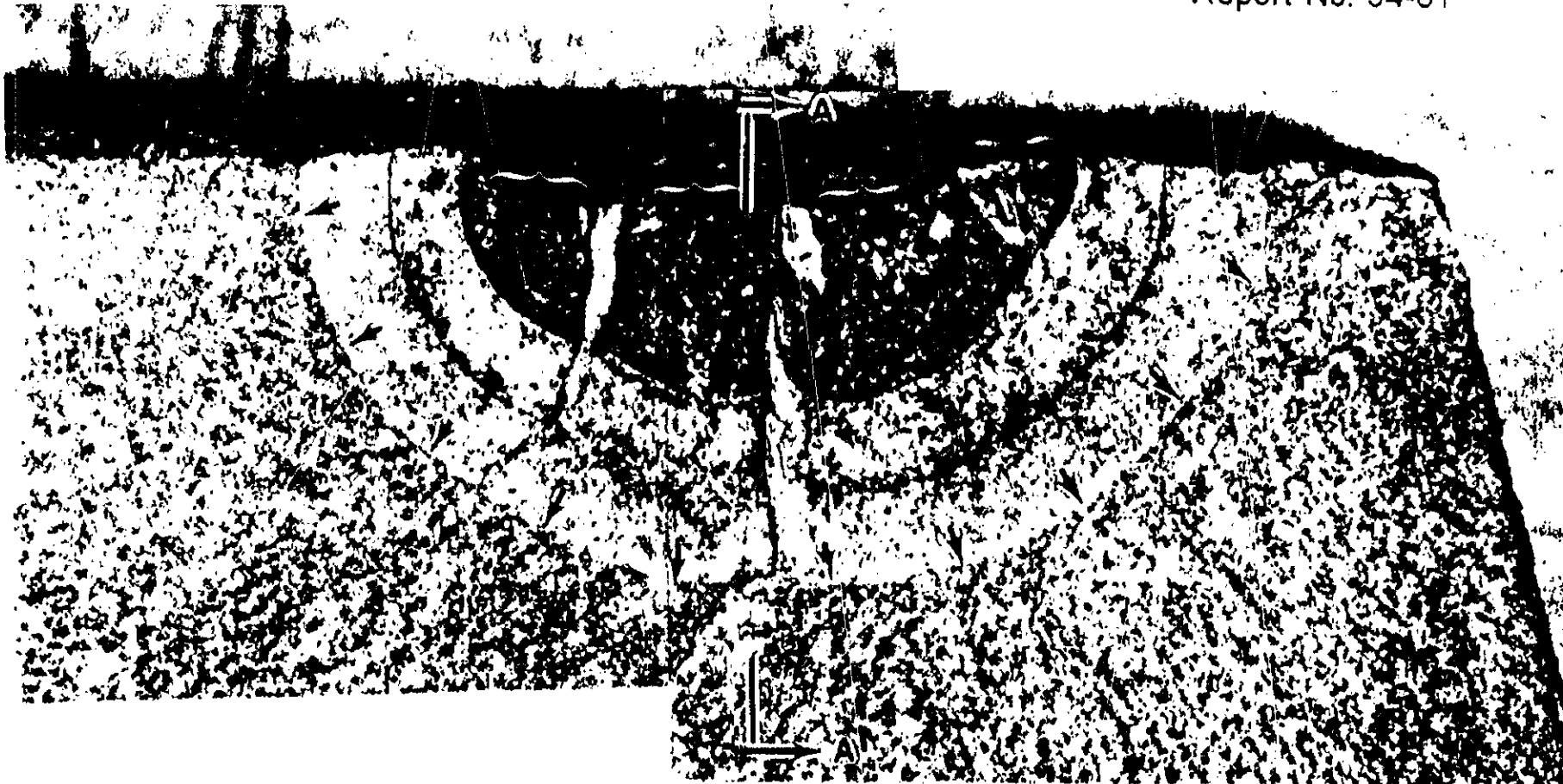


Figure 5. Close up view of the of the fatigue fracture zone. Brackets indicate some of the fatigue origin areas. Extent of the fatigue cracking is denoted by the arrowheads. Location of the metallographic specimen is shown by the sectional arrows "A-A". Magnification 3.5X.

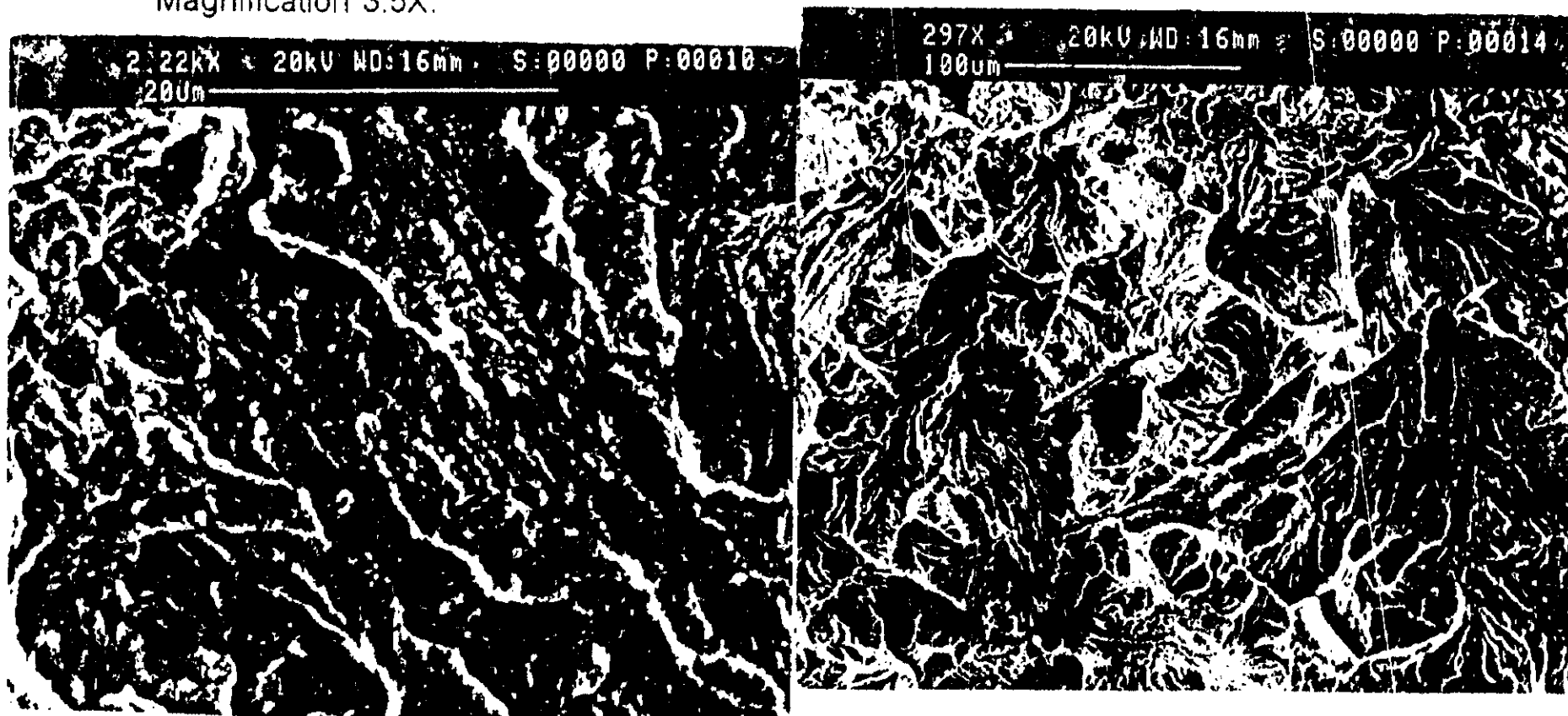


Figure 6. Typical micro-features in the fatigue (left fractograph) and overstress (right fractograph) fracture zones. Magnifications: left - 2,220X, right - 297X.

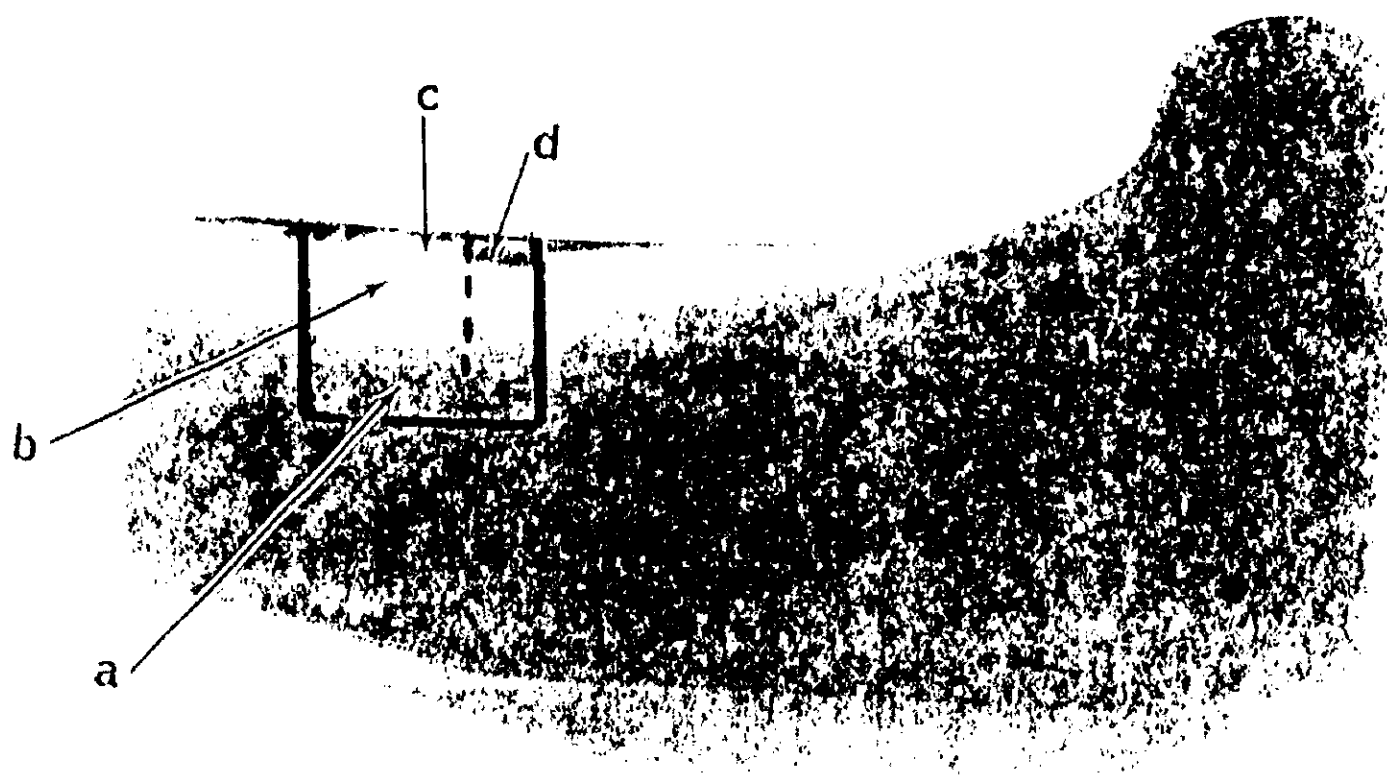


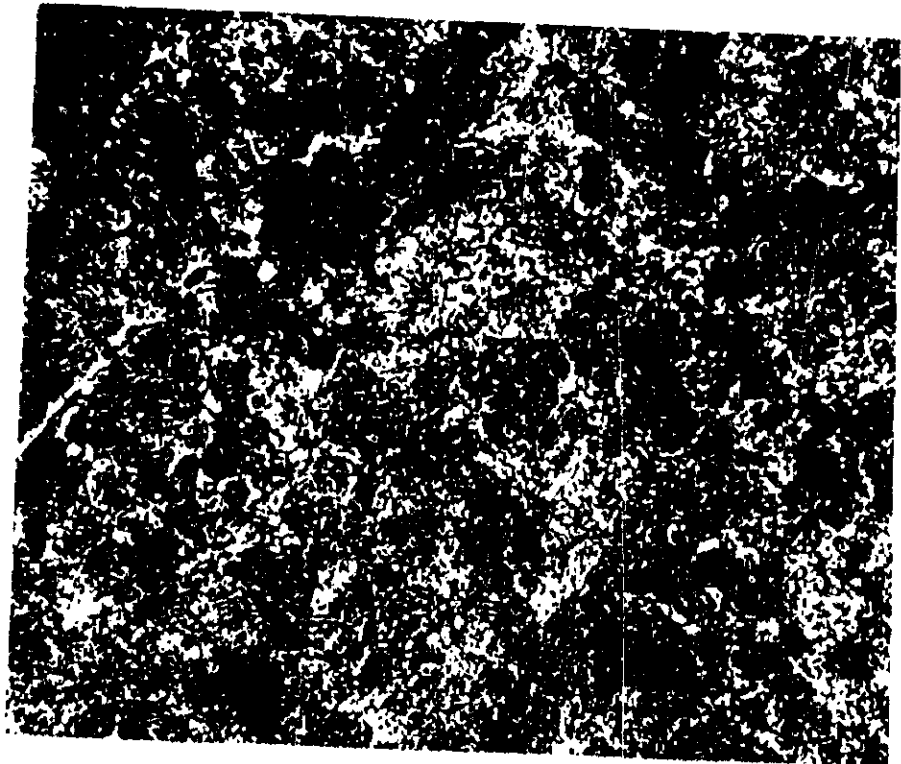
Figure 7. Photomicrograph of the polished and etched section of the rim showing four distinct microstructural zones below the tread surface.

APPENDIX C

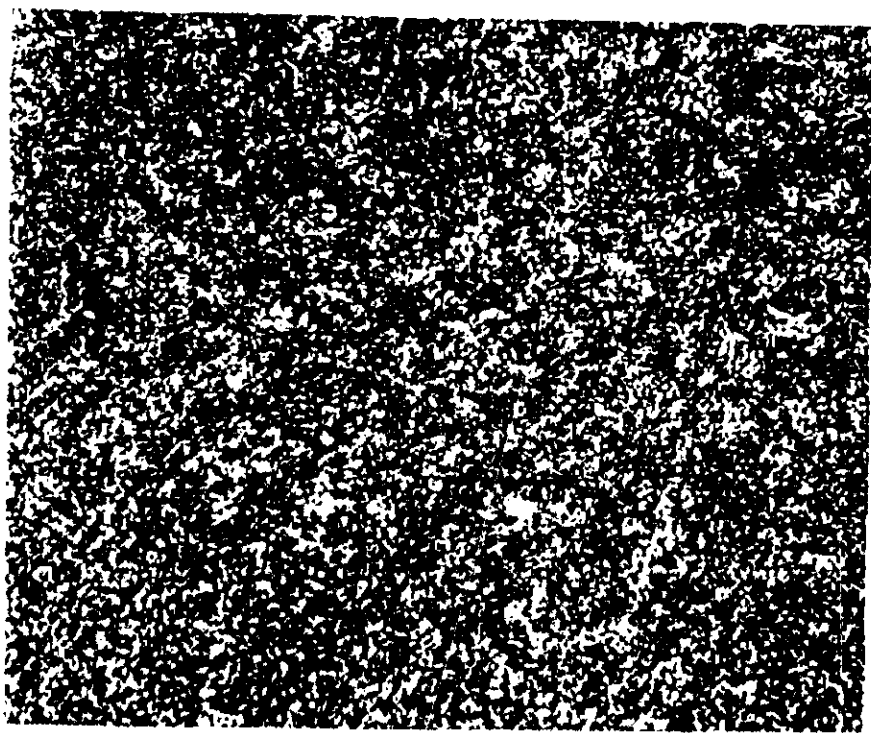
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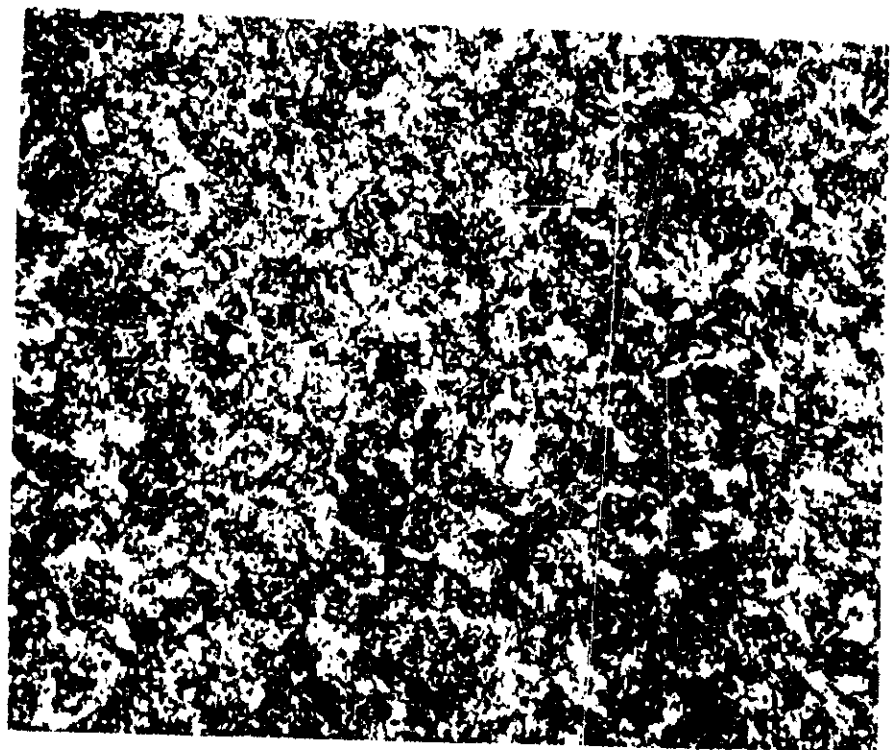
a



b



c



d

Figure 8. Typical microstructures in the areas denoted by arrows "a", "b", "c", and "d" of figure 7. Etch - 2% nital, magnification - 500X.

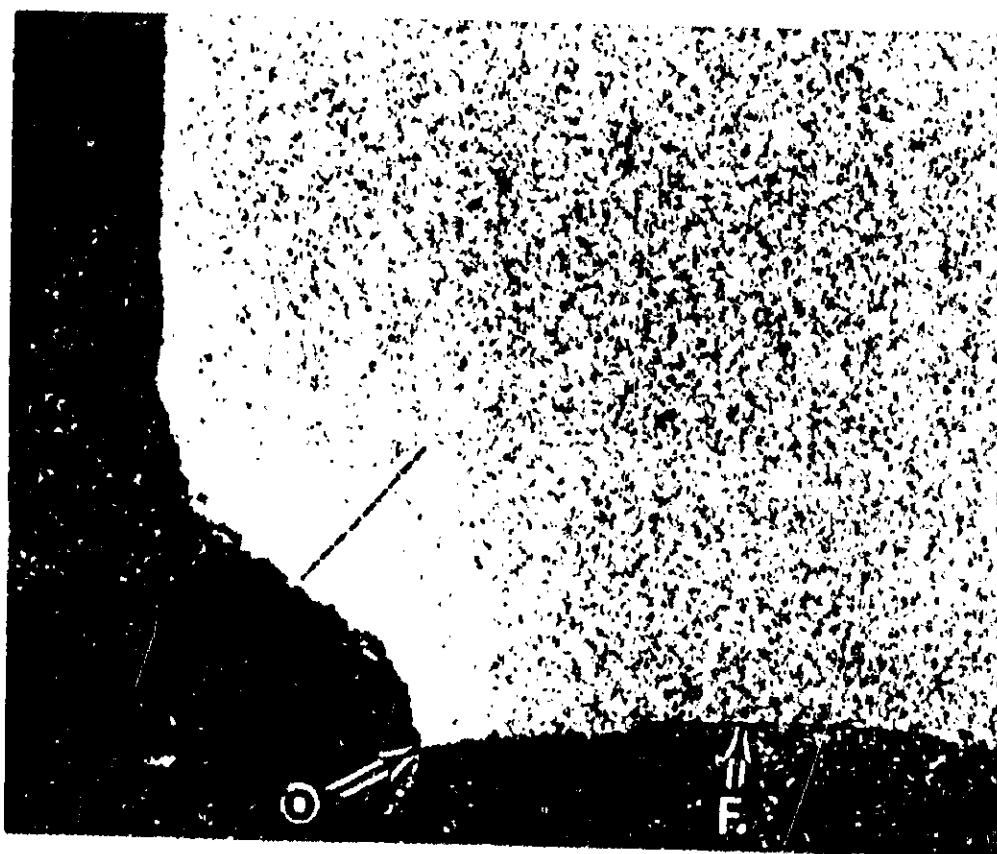


Figure 9. Low magnification photomicrograph of the polished and etched section through the fracture origin area (see sectional arrows "A-A" in figure 5). The fracture origin is indicated by arrow "O" and the fracture is shown in profile at arrow "F". Etch - 2% Nital, magnification - approximately 10X.

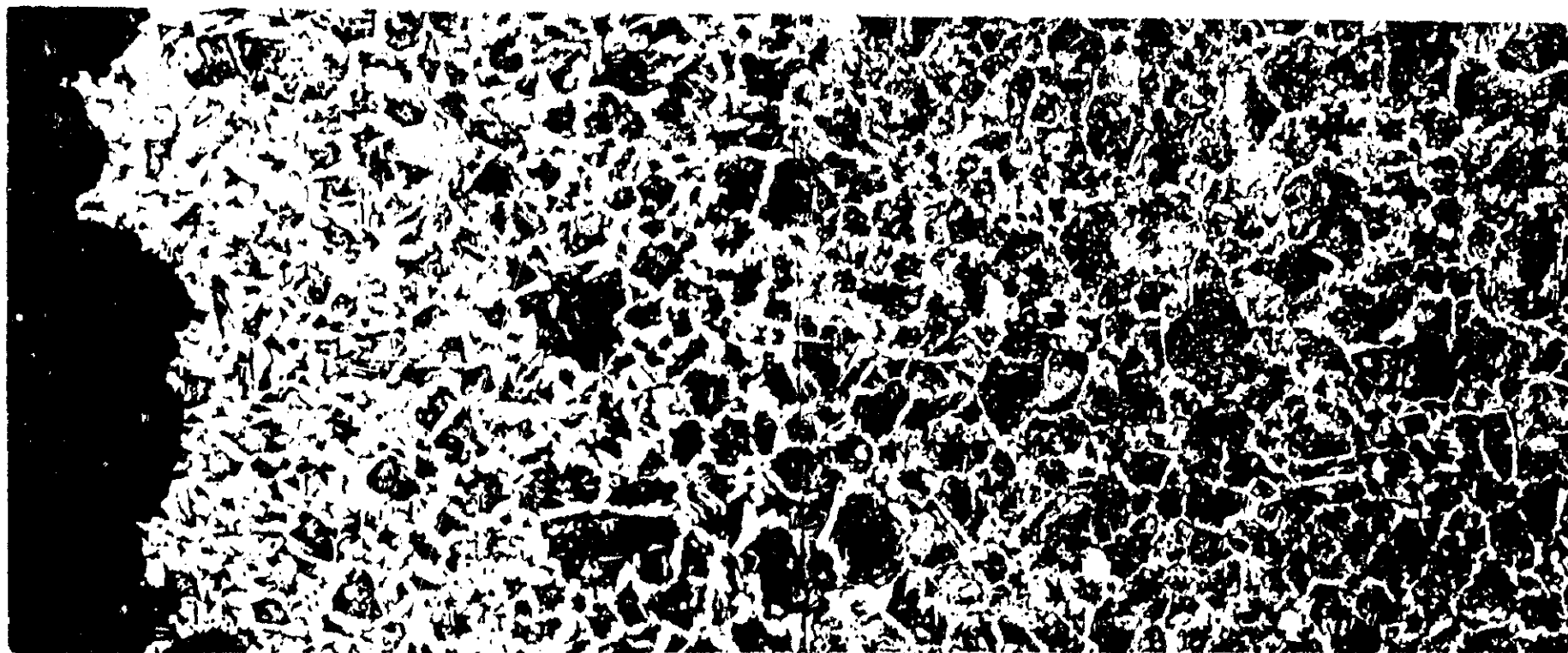


Figure 10. Composite photomicrograph showing the microstructure of the wheel material underlying the stamp at the location shown by the dashed line in figure 9. Etch - 2% Nital, magnification - 200X.

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Report No. 94-81

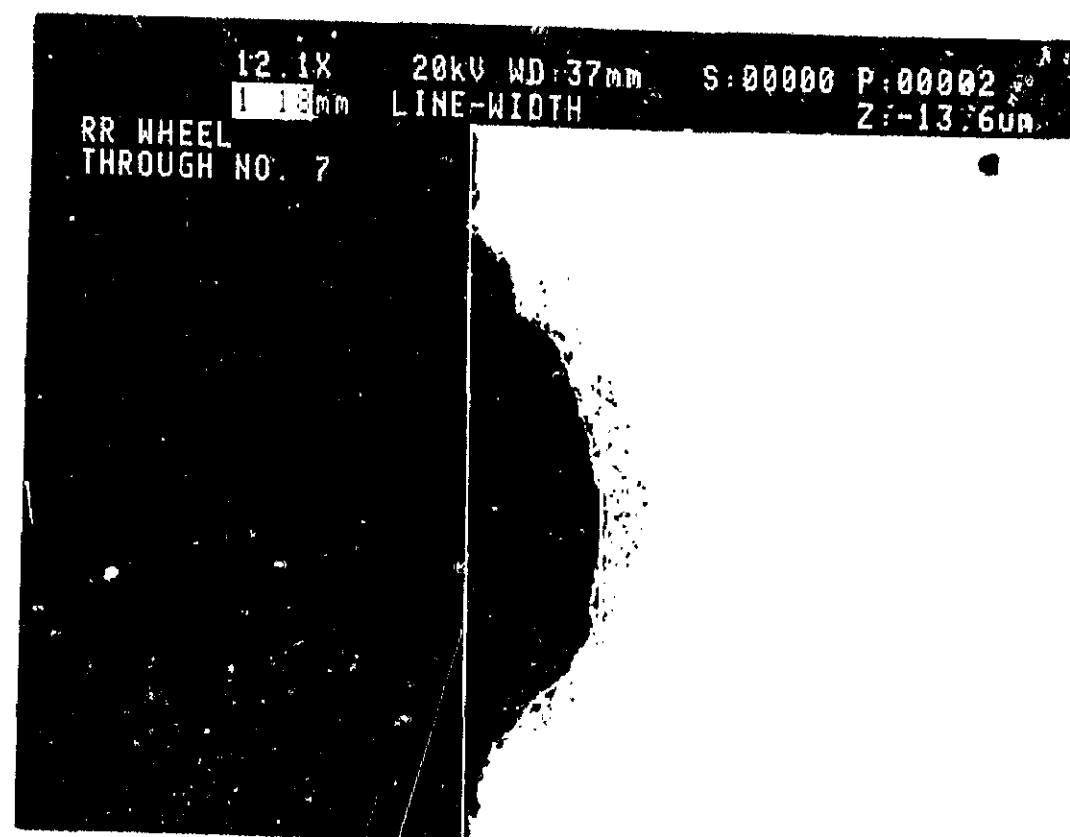


Figure 11. SEM photograph showing the depth of the stamped numerical character "7" in the separated wheel (between the two vertical white lines).

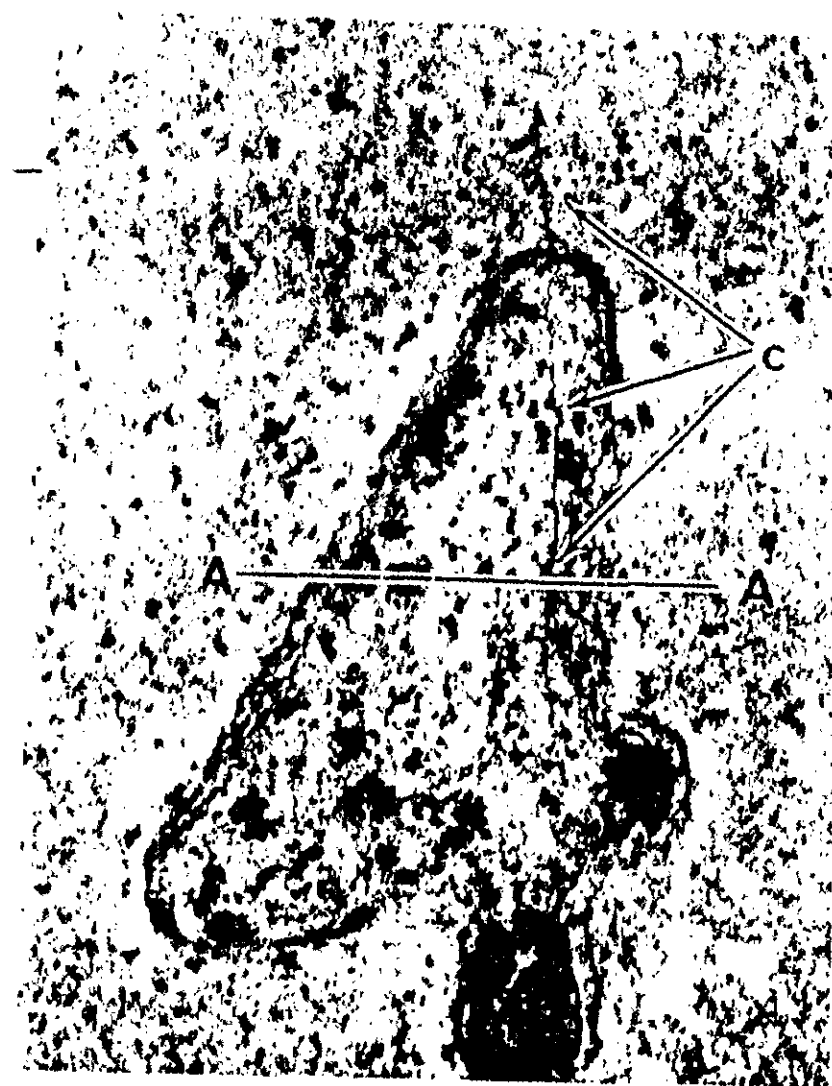


Figure 12. Magnified direct view on the numerical character "4" in the intact wheel showing the crack by arrows "c".

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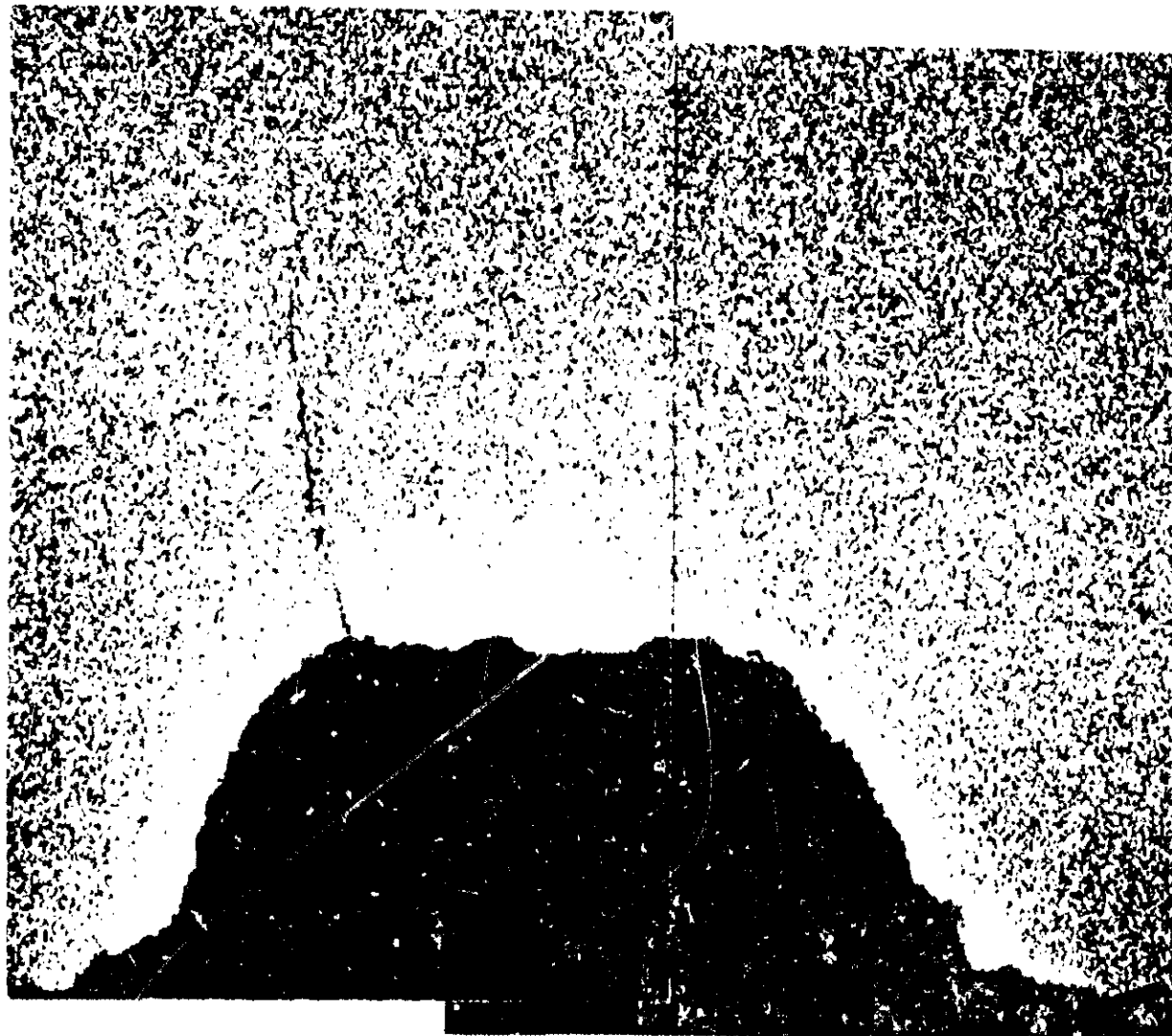
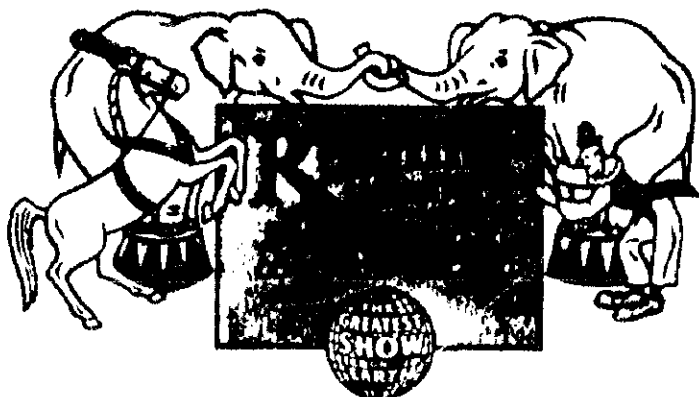


Figure 13. Low magnification micrograph of the section obtained at the location denoted by the sectional line "A-A" in figure 12 showing location of the crack. Etch 2% Nital, magnification - approximately 16X.

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Ringling Bros. Barnum & Bailey Combined Shows, Inc., Letters



Mr. Robert C. Lauby, P. E.
Chief, Railroad Division
National Transportation Safety Board
490 L'Enfant Plaza East, S.W., Rm. 6235
Washington, DC 20594

March 11, 1994

Dear Mr. Lauby:

This is in reference to the derailment of the Ringling Bros. and Barnum & Bailey Circus train in Lakeland, FL on January 13, 1994. I have been assigned by the Circus to undertake a comprehensive safety review of our railroad operations. Since your division of the National Transportation Safety Board is conducting an investigation of the incident and may provide recommendations to prevent a reoccurrence, I wanted to inform you of some of the measures we are taking in this regard.

The derailment was by far the most tragic and serious accident in the company's one hundred plus years on rail. Our internal investigations have led the Circus to reevaluate various mechanical considerations, emergency procedures, maintenance scheduling, and interior design. We are implementing changes in phases as quickly as possible. The ultimate goals are to decrease the possibility of an accident, preserve life, and minimize loss.

The first phase is to retrofit our existing coach cars with modifications and enhancements that will further these goals. Secondly, the Circus is revising its specifications for coach car construction to incorporate new mechanical and interior design criteria.

The Circus has retained the services of a consultant, Passenger Transportation Specialists, Inc. They have been asked to examine every railroad car in our consist for structural/mechanical problems and develop rigidly defined procedures to enhance our existing maintenance and repair program. Pending the results of their study,

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we expect all our coaches to be put on a schedule to undergo a complete overhaul similar to what Amtrak uses for their 40 year inspection and repair program. Passenger Transportation Specialists, Inc. will also analyze our in-house mechanical procedures and personnel. We have requested that they make recommendations on the qualifications, experience, workload, total manpower, facilities, and management of our Palmetto, FL train shop as well as that of our traveling train crews.

The Circus' Human Resources Department is already conducting a recruitment search for a well qualified train mechanical supervisor to be added to the staff of each Circus train crew as soon as possible.

The retention of Transportation Specialists Inc. is separate from and in addition to the regular independent train mechanical inspections made by the Robert W. Hunt Company. The frequency of these inspections has been increased from 2 to 4 per year. Immediately following the derailment, the Hunt Company was also commissioned to inspect all Circus owned railroad wheels throughout the United States and enhance the information data base that documents the wheel maintenance history.

Within weeks after the accident, all but one of the deep rim-stamped on-tread wheel sets had been removed from our coaches. The one wheel set remaining is slated to be changed out as soon as a replacement can be made ready. There are currently 5 on-tread passenger cars still in service. We anticipate changing/converting 3 of these to disc brake before July 1. All passenger cars in service will be disc brake by September 1. In addition, every straight plate wheel set has been replaced on the freight equipment with the new style curved plate wheels.

Prior to the accident, our risk management consultants, Willis-Corroon, conducted semiannual train inspections of our railcars to evaluate interior safety appliances and life safety issues. These reviews will now be made quarterly and include an inspection of each private stateroom. The Circus will more strictly enforce, through monitoring, restrictions against homemade construction projects, blocked egresses within the stateroom, overloaded electrical circuits, unsecured or inadequately secured property and appliances, etc. As problems with unsecured objects are identified in the inspections, they will be repaired by our train crew on a stateroom by stateroom basis.

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Our surveys of the railcar interiors after the derailment have shown that those which were recently rebuilt incurred far less displacement of furniture and appliances than in some of our older designs. We feel that improved construction techniques undertaken in recent years were proven effective. Nevertheless, it's apparent that more must be done to eliminate potential flying objects and other hazards. Our carpentry department is now designing the woodwork to eliminate sharp edges and recessing cabinet handles in all new car construction. Various types of appliance (e.g. refrigerator, stove, etc.) door locks and cabinet door latches are being researched and tested. State of the art mechanisms will soon be utilized to insure that doors and drawers can not inadvertently open. All carpentry, appliances, and other custom designed equipment will be firmly anchored to a structural member. Circus craftsmen are also developing an "E Track" tie down system which will provide a selection of anchor points within the stateroom for use by employees in securing their personal property.

We are now in the process of retrofitting the emergency exits on both trains. Every common passageway will have a minimum of three emergency exit windows, and every stateroom will have a minimum of two exits. This retrofitting project is expected to be finished by July 31, 1994.

A resident Safety Officer has been appointed in each coach car. As a stopgap measure immediately following the accident, each Safety Officer was provided with a private line radio which enables them to transmit emergency information simultaneously to the four senior Circus managers and the Railroad crew. The four managers are in 2 way communication with the Safety Officers and Railroad crew. In the event the Head End doesn't respond, our manager radios are equipped with a key pad to send an alarm tone that directly signals the Railroad crew's radio. The system is tested before and during each train run. Additional training programs and written procedures for the Safety Officers are currently under development.

Conductor's brake valves have been purchased for both trains and will soon be installed in strategic locations throughout the coaches. If all communication systems were to fail in an emergency situation, our managers would be able to initiate a controlled brake application.

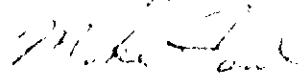
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The long term communication plan is to install an emergency "push-to-talk" radio system in a common area of each occupied railcar. This would be accessible to everyone on board and put them in immediate contact with the 4 senior managers and the Railroad train crew. When the communication plan is completed, managers will also be able to make emergency radio announcements over a public address system to all railcars.

A Willis-Corroon Fire Safety Engineer has surveyed a random sampling of our train cars. Based upon his recommendations we will begin to install an integrated fire alarm system in all new car construction. This includes panic alarms, commercial grade hard wired smoke detectors, remote activated fire doors, remote activated HVAC system shutdowns, and battery back-up lighting in the staterooms. Interior car construction will incorporate several strategically spaced one hour fire walls. Once the integrated fire alarm system has been designed and perfected, cars which are now in use will be retrofitted as part of our ongoing safety program. Within the next 90 days all these cars will be equipped with fire extinguishers in every stateroom and two crash tool cabinets in the passageways. Existing emergency lighting in passageways will be reinforced or replaced to prevent failures in impact situations.

Mr. Lauby, I appreciate your time in reviewing the Circus' plans to upgrade the safety factor on our trains. This letter doesn't fully address many of the improvements we've already accomplished. These include production of a *Train Safety Video* and multilingual *Train Safety Booklet* for employees, a *Circus Train Operating Guide* for Railroad train crews, and conversion to "EE" bearings and "ABDW" brake valves. Ringling Bros. and Barnum & Bailey has a long history of successful railroading. We recognize that safety is an evolutionary process and intend to do everything in our power to continue this railroad tradition with the highest possible standards.

Sincerely,



Michael W. Fauls
General Manager
Ringling Bros. and Barnum & Bailey
Combined Shows, Inc.
8607 Westwood Center, Dr.
Vienna, VA 22182

cc: J. William Misiura, R.B.B.B. Dir. of Transportation

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APPENDIX D



MICHAEL W. FAULS
Vice President
Circus Operations

VIA FACSIMILE AND FEDERAL EXPRESS

February 21, 1995

Mr. Russell G. Quimby
Safety Engineer - Rail
National Transportation Safety Board
490 L'Enfant Plaza East, S.W.
Washington, D.C. 20594

Re: *Derailement of Ringling Bros. and Barnum & Bailey Circus Blue Train Near
Lakeland, Florida, January 13, 1994 (NTSB Accident No. DCA-94-MR-003)*

Dear Mr. Quimby:

I am writing in response to the Safety Board's request for an update on the progress of measures taken by Ringling to enhance train safety, as outlined in my March 11, 1994 letter to Mr. Robert Lauby.

Wheel and Brake Replacement

Ringling has removed all rim-stamped, straight-plate, on-tread braked passenger car wheels from the Circus trains. All on-tread braked passenger cars have been converted to disc brakes. Additionally, all straight-plate freight car wheels have been removed and replaced with curved-plate wheels. All cars rebuilt by Ringling are equipped with new wheels, and all cars delivered to the Units since the derailment have had totally rebuilt trucks.

Ringling retained an outside consultant, Gulf Railear, to conduct a thorough single-car air brake test on each car in service.

Train Inspections

In the March letter, I noted that Ringling had retained the services of a consultant, Passenger Transportation Specialists, Inc., to examine the Circus trains, their operations, and their support facilities from the perspective of optimizing equipment lifespan and insuring the safety of all personnel and animals living on the Units. The assignment encompassed a detailed evaluation of Ringling's entire car fleet, including comprehensive structural and mechanical inspections. PTS also analyzed Ringling's mechanical procedures and personnel, and made recommendations regarding these factors.

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Mr. Russell Quimby
February 21, 1995
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A comprehensive report was prepared by PFS, delineating its findings and recommendations, with a separate section dedicated to developing a scheduled maintenance and inspection program. The report also contained a compendium of car inspection findings, a historical review of all equipment, and an encapsulation of car technical data, all presented on a car-by-car basis.

As noted in the March letter, the formerly semi-annual Robert W. Hunt Company inspections of the trains' running gear, including wheels, trucks, and couplers, are now being conducted quarterly. After the derailment, every railcar wheel was independently inspected and gauged by Hunt, and an information database documenting wheel maintenance history was established. Additionally, Ringling's computerized maintenance record system for mechanical repairs has been enhanced.

Willis-Corroon inspections for evaluating interior safety appliances and life safety issues are being conducted semi-annually. Since the derailment, every private room on both Units has been surveyed twice for safety hazards as part of the regularly-scheduled interior train inspections. The securing of doors, cabinets, and appliances has been enhanced in both private and common areas. New car construction includes automatically locking doors and cabinets, and secure bolting of appliances to floors and walls.

Ringling's Train Repair and Recycling Shop in Palmetto, Florida has begun to implement the Amtrak 40-year inspection and repair program. Each car taken to the Palmetto Shop now undergoes complete inspection and repair based on the Amtrak program. Ringling's Train Repair and Recycling Shop not only meets, but exceeds Amtrak standards, and is fully equipped with state-of-the-art technology and equipment, as well as experienced personnel.

Ringling has also retained an Amtrak inspector to review outside contractor repairs and to verify proper execution of the Amtrak 40-year inspection on cars leaving Ringling's train repair and recycling shop in Palmetto.

Ringling Train Personnel, Mechanical Training, and Employee Orientation

A Safety Officer has been appointed in every passenger car on both the Blue and Red Units. Safety Officers are equipped with two-way emergency radios, for direct communication with the Unit Managers and Railroad crew.

Since the derailment, Amtrak personnel have conducted mechanical repair courses for Ringling's Train Recycling and road personnel. Additionally, Ringling has retained the Academy of Industrial Training to conduct workshops for both the Blue and Red Units on truck assembly, air brakes, draft systems, and safety appliances.

As part of Ringling's efforts to enhance safety aboard its trains, the employee orientation program has been re-engineered to include a personalized instruction session with a question-and-answer period. All new employees are oriented using this program, and re-orientation of current employees is over 60% complete. All employees living on and traveling with the Units will have been oriented under the new program by March 30, 1995.

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Fire Safety

Willis Corroon safety engineers have examined Ringling's railcar construction practices and advised the Circus regarding additional fire prevention measures. Over 140 additional fire extinguishers have been installed on the Circus trains since the Blue Unit derailment.

Additionally, Ringling retained Schirmer Engineering Corporation to evaluate new car construction from a fire safety standpoint. The Circus is now utilizing non-combustible construction materials in framing new car private rooms. New railcar construction also includes a state-of-the-art integrated fire alarm system which, upon activation, automatically closes ventilation ducts into living areas, and automatically notifies the managers and crew of the nature and location of the emergency through the train's radio system.

Electrical System and Emergency Lighting

The Circus' electrical consultant, LTK Engineering Services, issued a report on improving the train's electrical safety and efficiency. As a result of this report, the Circus is now incorporating a 480-volt electrical distribution system, with accompanying safety devices, in all new car construction. Additionally, new cars receive enhanced emergency lighting systems.

On-Board Communications Systems

The Circus retained Bendix-King Company to develop a customized, state-of-the-art emergency communications radio system. The radio system is designed for mounting in an emergency console panel in a public area of each passenger car. A "push-to-talk" button initiates direct, two-way communication with management and the railroad crew. As noted above, in new car construction, the radios are integrated with the fire alarm system, and automatically transmit an emergency signal in the event of fire alarm activation, indicating the origin of the signal. The system also enables managers to broadcast safety announcements to individual railcars, or the entire train. Retrofitting existing cars on the Blue Unit with the system is approximately 60% complete.

Emergency exits

Over 250 additional emergency exit windows have been installed in the Circus Unit trains. Every common passageway in both trains is now equipped with a minimum of three emergency exit windows, and the retrofitting of stateroom exits is approximately 75% complete.

Crash Tool Boxes

Two crash tool boxes were installed in the passageway of each passenger car. Tool boxes have also been installed in or to provided to the residents of private cars not containing a common passageway.

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Conductor's Brake Valves

Pursuant to the NTSB's request, the conductor brake valves that were purchased will not be installed until the Board has had a chance to study the ramifications. Installation of on-board communication systems may obviate the need for conductor brake valves.

Ringling has made significant efforts and taken great strides toward enhancing safety aboard its trains. We have retained the services of a number of consultants in order to modify and develop systems using state-of-the-art equipment and technology, and are continuing to implement changes with the ultimate goal of enhancing the safety of Ringling's Circus trains.

Please do not hesitate to contact me if you have any questions regarding the foregoing, or should you require any additional information.

Sincerely,



Michael W. Fauls
Vice President of Circus Operations
Ringling Bros. and Barnum & Bailey
Combined Shows, Inc.
8607 Westwood Center Dr.
Vienna, VA 22182

APPENDIX E

Amtrak Letter

National Railroad Passenger Corporation, 30th and Market Streets, Philadelphia, PA 19104



December 2, 1994

Mr. Russell G. Quimby
Safety Engineer, Rail
National Transportation Safety Board (ST30)
490 L'Enfant Plaza East, SW
Washington, DC 20594

SUBJECT: Use of Rim Stamped Wheels on Private Cars

Dear Russ,

This is in response to your inquiry concerning the above-referenced matter. Amtrak has not experienced any problems on the private cars that operate on Amtrak trains with wheels that are rim stamped. I believe this is largely due to the strict inspection criteria we use when inspecting cars prior to permitting operation of the cars on Amtrak trains. As you know, we only operate private cars that are registered with Amtrak and are subject to a regular inspection by Amtrak-approved inspectors who follow a standard inspection procedure. Because of our strict observance of these inspection procedures and the relatively low mileage of most of the private cars operating on Amtrak trains, we see no reason to require private car owners to start a wholesale changeout of straight plate, rim stamped wheels at this time.

However, we do agree with the proposed directive that would prohibit the use of straight plate wheels that are rim stamped as a replacement wheelset. Also, we agree that any wheelset that has wheels that have been overheated should be removed and scrapped prior to a trip. Finally, all instructions listed in Rule 41 of the AAR Interchange Rules must apply to private cars as far as defects are concerned.

If you have any question on this subject, please call.

Very truly yours,

A handwritten signature in cursive script that reads "John W. Hutchison".

John W. Hutchison
Assistant Chief Mechanical
Officer