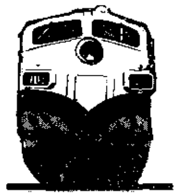
PB84-916303

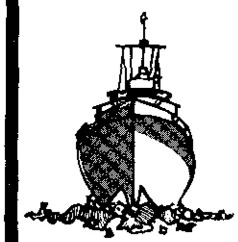
# NATIONAL TRANSPORTATION SAFETY BOARD





WASHINGTON, D.C. 20594

## RAILROAD ACCIDENT REPORT



## DERAILMENT OF AUTO-TRAIN NO. 4 ON SEABOARD COAST LINE RAILROAD FLORENCE, SOUTH CAROLINA FEBRUARY 24, 1978

NTSB/RAR-84/03
(SUPERSEDES--NTSB-RAR-78-6)

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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| 15. Supplementary Notes | | |



16. Abstract

About 2:10 a.m., on February 24, 1978, 19 cars and a locomotive unit of Auto-Train No. 4 derailed on Seaboard Coast Line Railroad trackage at Florence, South Carolina. Twenty-four of the 503 passengers were injured. The total accident damage was estimated to be $774,029.

On September 21, 1978, the National Transportation Safety Board adopted the accident report and probable cause of the accident. On April 25, 1983, the Bethlehem Steel Corporation submitted a petition for reconsideration of probable cause of the probable cause that was adopted in the original report. As a result of Bethlehem Steel Corporation's petition, the accident report and the probable cause have been revised.

The Safety Board determines that the probable cause of the accident was a locomotive unit axle failure that originated from an overheated traction motor suspension bearing on the second unit of the two-unit locomotive consist. Contributing to the cause of the accident was the lack of an onboard system for detecting a bearing failure independent of crewmembers' inspection.

| | | | |
|---|---|---|---|
| 17. Key Words Auto-Train; locomotive axle; void; discontinuity; traction motor suspension bearing; fracture; heat. | | 18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161 | |
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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

**Adopted: June 27, 1984**

# DERAILMENT OF AUTO-TRAIN NO. 4 ON THE SEABOARD COAST LINE RAILROAD AT FLORENCE, SOUTH CAROLINA, ON FEBRUARY 24, 1978

## SYNOPSIS

About 2:10 a.m., on February 24, 1978, 19 cars and a locomotive unit of Auto-Train No. 4 derailed on Seaboard Coast Line Railroad trackage at Florence, South Carolina. Twenty-four of the 503 passengers were injured. The total accident damage was estimated to be $774,029.

The Safety Board determines that the probable cause of the accident was a locomotive unit axle failure that originated from an overheated traction motor suspension bearing on the second unit of the two-unit locomotive consist. Contributing to the cause of the accident was the lack of an onboard system for detecting a bearing failure independent of crewmembers' inspection.

## INVESTIGATION

### The Accident

On February 23, 1978, Auto-Train Corporation (Auto-Train) train No. 4 departed Sanford, Florida, at 4:40 p.m., for Lorton, Virginia. The train consisted of 2 Auto-Train diesel-electric locomotive units and 43 cars. Airbrake tests and inspection of the train before it departed Sanford disclosed no defects. The train was being operated over Seaboard Coast Line Railroad (SCL) trackage by an SCL crew. At 10:48 p.m., the train departed from Savannah, Georgia, for Florence, South Carolina, where the crew was to be changed.

The engineer was operating the train from the seat on the right side of the lead locomotive unit. The fireman and a brakeman were seated on the left side of the lead locomotive unit. The conductor was in a dining car, and the flagman was in the caboose. The crewmembers had observed the train en route and took no exceptions to the train's condition. The locomotive units were not equipped with rearview mirrors to assist crewmembers in observing their train for defects. The train had passed a hot box and dragging equipment detector at Scranton, South Carolina, 20 miles south of the accident site. Crewmembers at both ends of the train had received "no defect" indications as they passed the detector.

An automatic signal, 2 miles south of the National Cemetery road crossing in Florence, displayed an "approach slow" aspect on the northbound track as the train approached the crossing. This required the engineer to promptly reduce the train's speed to 40 mph and to not exceed 20 mph at the next signal. He reduced the throttle position and made a brake application, reducing the train's speed from 70 mph to about 45 mph as the locomotive passed over the crossing. As the locomotive approached the crossing, the wheel-slip indicator light was activated, so the engineer reduced the throttle and actuated the sanders to correct the slippage. The only other wheel-slip actuation had occurred at the Santee River, about 52 miles south of the crossing.

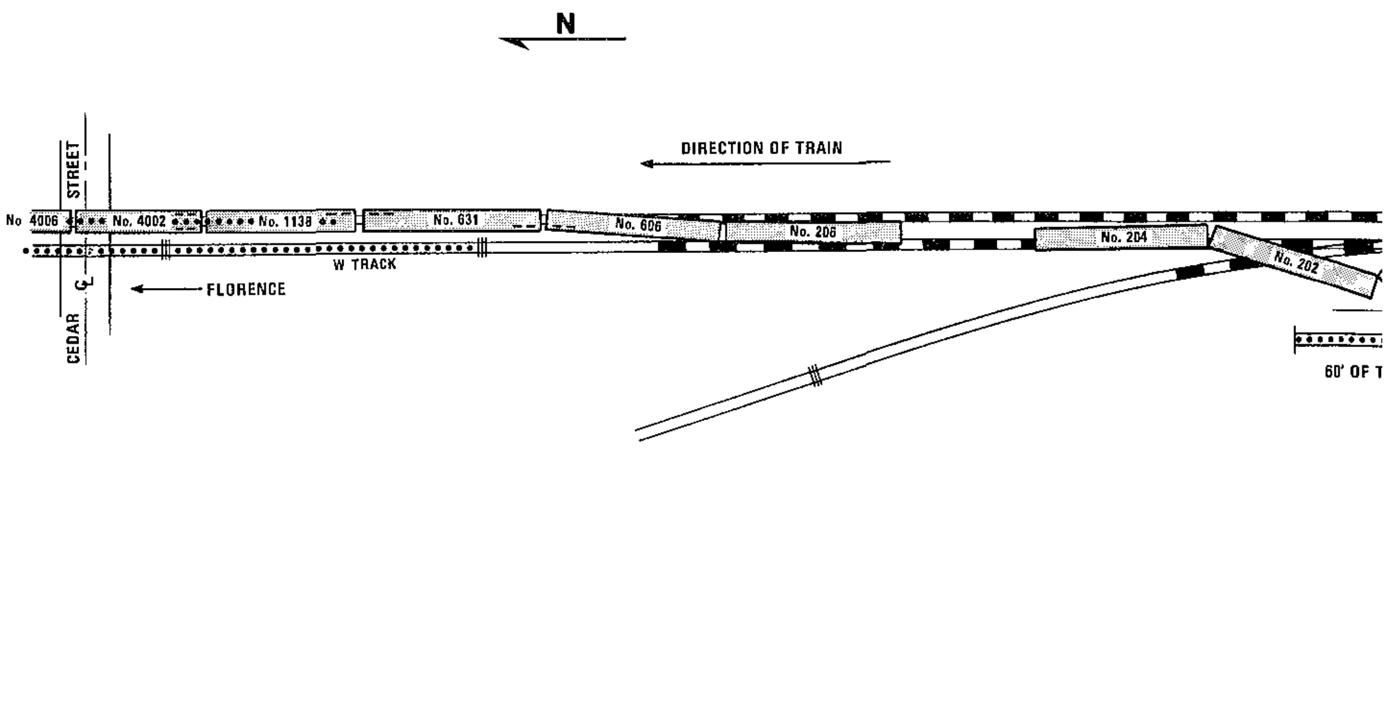
When the locomotive was about 80 feet past the crossing, the fireman looked to the rear, saw fire near the first car, and shouted a warning to the engineer to apply the train brakes in emergency. The engineer responded to this by placing the automatic brake valve in the emergency position and letting the brakes apply on the locomotive. During previous brake applications, the engineer used the independent brake valve to keep the brakes of the locomotive released. The prescribed method of service braking is to keep the locomotive brakes released.

Almost immediately following the emergency brake application at 2:10 a.m., the second locomotive unit and 19 cars derailed. After the locomotive came to rest, the fireman immediately disembarked from the left side of the lead unit. He found the trailing truck of the second unit derailed and saw a fire in the suspension bearing on the gear side of the No. 2 traction motor. As soon as it was determined that emergency forces were coming and no passengers or crewmembers were seriously injured, his attention was directed to extinguishing the fire. Maintenance personnel arrived and removed the axle cap inspection cover. The axle was broken near midpoint of the bearing area. The truck side frames were grooved at the right and left No. 2 wheel, indicating they had contacted the wheel rim faces. As soon as practical, the portion of the train that did not derail was rerouted northward.

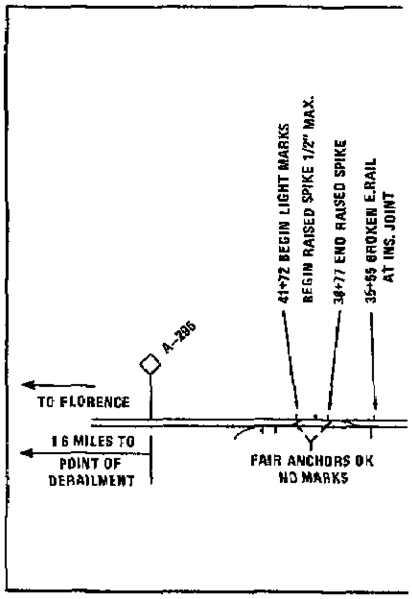
At the accident site, the northbound track was paralleled on the west by the southbound track and on the east by a stub-ended industrial siding. (See Figure 1.) The switch to the siding was located at its north end. Approaching the accident point from the south, the grade ascends 0.56 percent, and the track alignment is straight.

**Injuries to Persons**

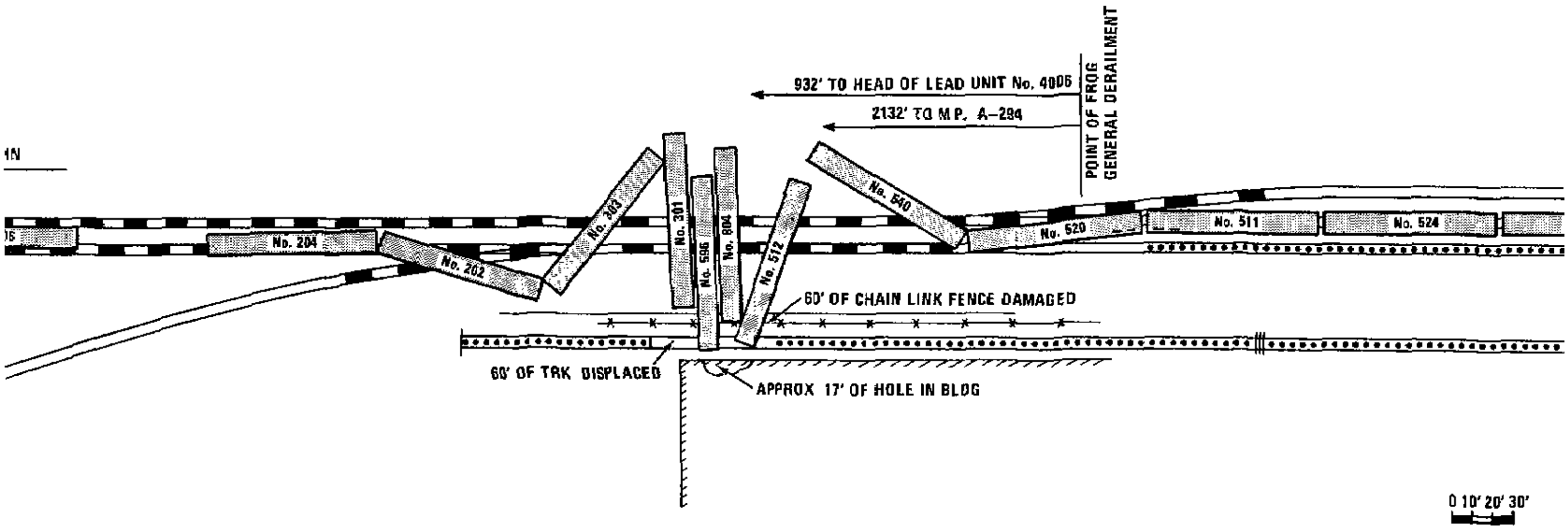
| Injuries | Crewmembers | Passengers | Others |
|---|---|---|---|
| Fatal | 0 | 0 | 0 |
| Nonfatal | 1 | 24 | 0 |
| None | 30 | 479 | 0 |



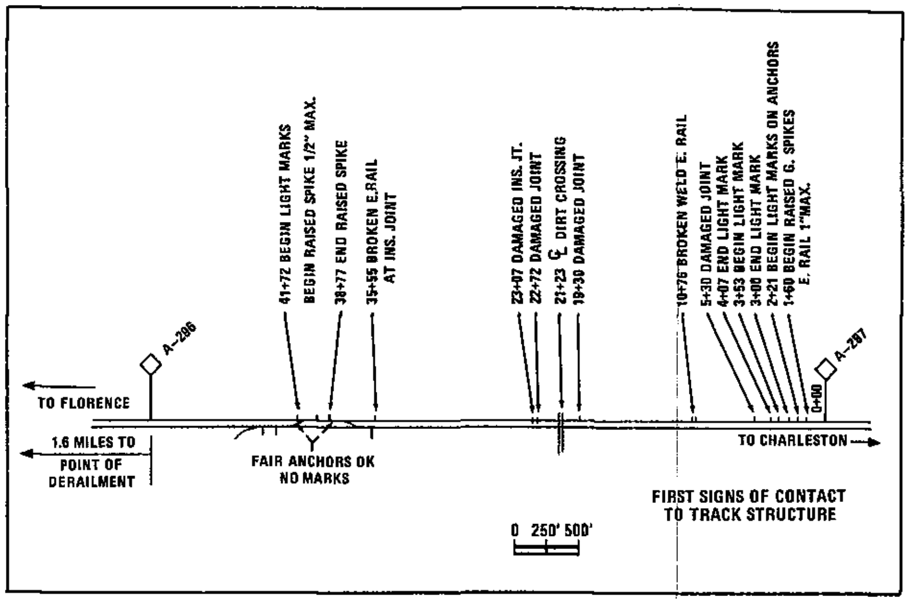
N
DIRECTION OF TRAIN
CEDAR STREET
No 4006
No. 4002
No. 1138
No. 631
No. 606
No. 206
No. 204
No. 202
W TRACK
FLORENCE
60' OF T



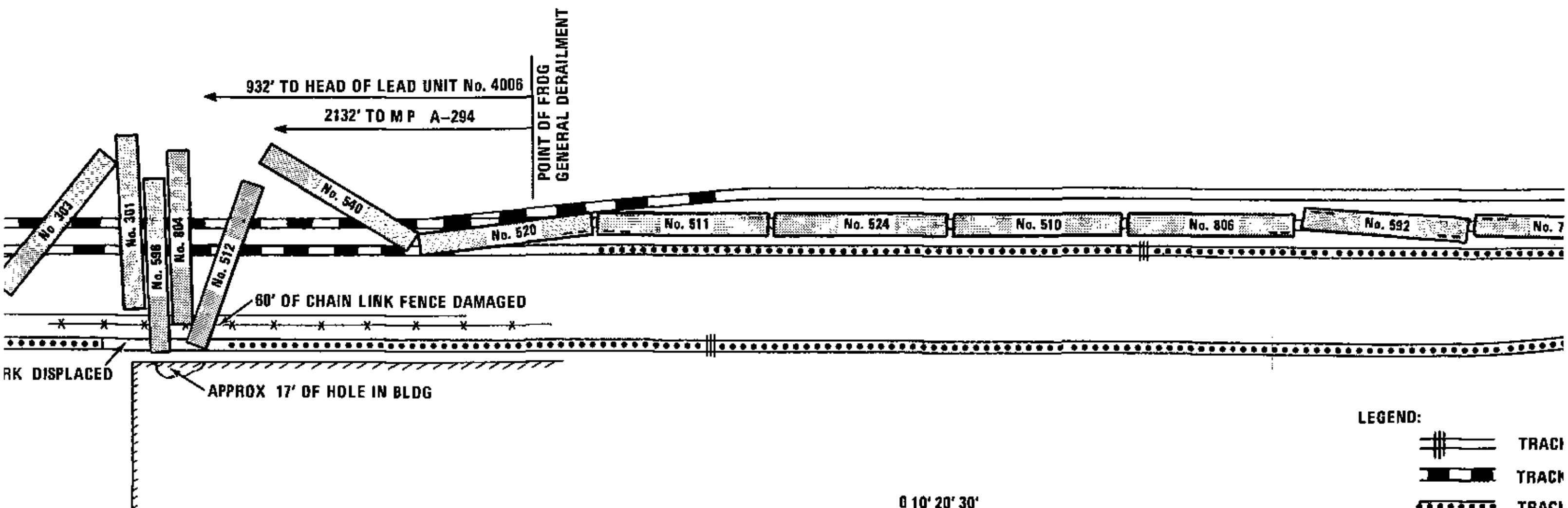
41+72 BEGIN LIGHT MARKS
BEGIN RAISED SPIKE 1/2" MAX.
38+77 END RAISED SPIKE
35+55 BROKEN E.RAIL AT INS. JOINT
A-295
TO FLORENCE
1 6 MILES TO POINT OF DERAILMENT
FAIR ANCHORS OK NO MARKS

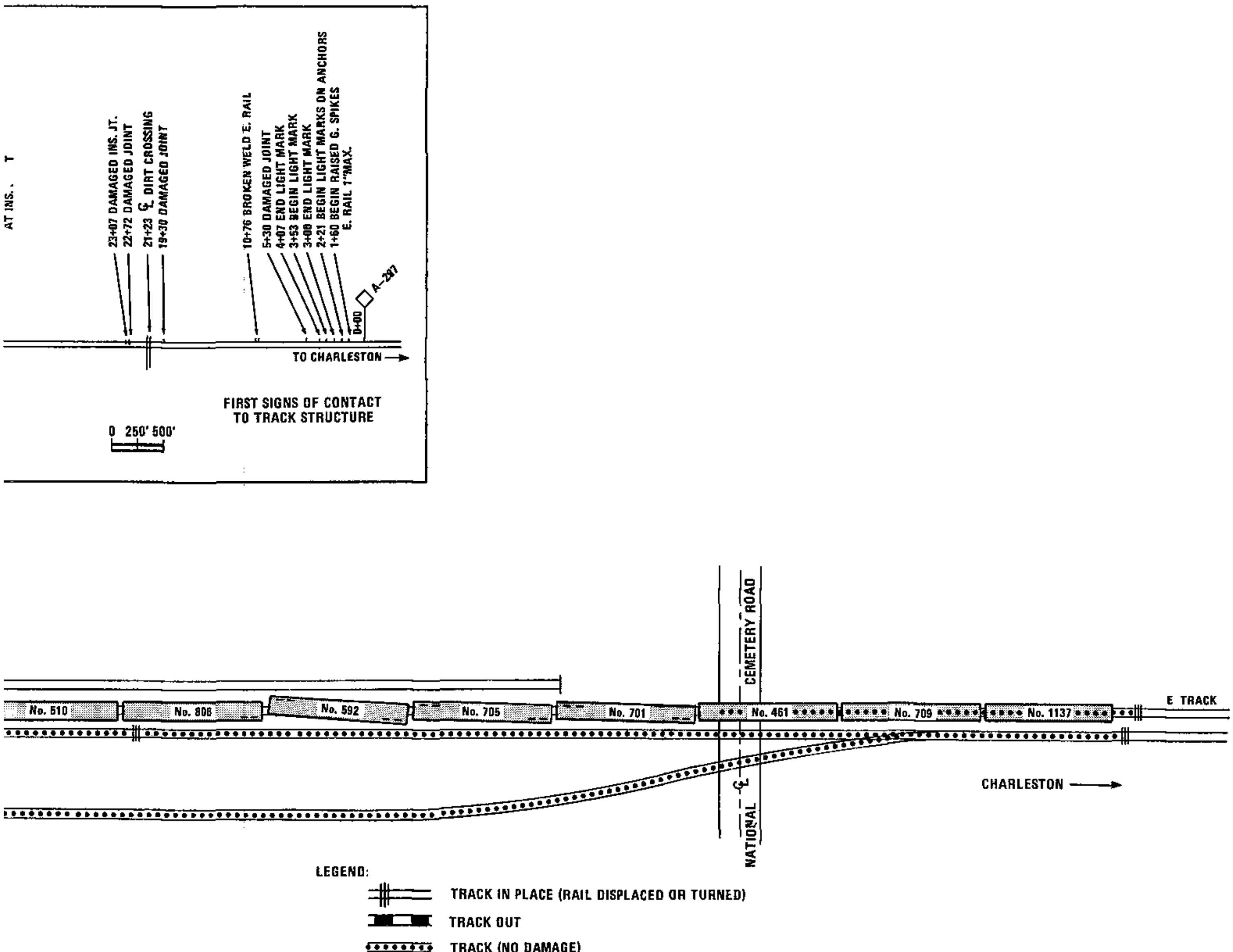
932' TO HEAD OF LEAD UNIT No. 4006
2132' TO M.P. A-294
POINT OF FROG
GENERAL DERAILMENT
No. 204
No. 262
No. 303
No. 301
No. 596
No. 604
No. 512
No. 640
No. 520
No. 511
No. 524
60' OF CHAIN LINK FENCE DAMAGED
60' OF TRK DISPLACED
APPROX 17' OF HOLE IN BLDG
0 10' 20' 30'



41+72 BEGIN LIGHT MARKS
BEGIN RAISED SPIKE 1/2" MAX.
38+77 END RAISED SPIKE
35+55 BROKEN E.RAIL AT INS. JOINT
23+07 DAMAGED INS. JT.
22+72 DAMAGED JOINT
21+23 ℄ DIRT CROSSING
19+30 DAMAGED JOINT
10+76 BROKEN WELD E. RAIL
5+30 DAMAGED JOINT
4+07 END LIGHT MARK
3+53 BEGIN LIGHT MARK
3+00 END LIGHT MARK
2+21 BEGIN LIGHT MARKS ON ANCHORS
1+60 BEGIN RAISED G. SPIKES E. RAIL 1"MAX.
A-296
A-297
0+00
TO FLORENCE
1.6 MILES TO POINT OF DERAILMENT
FAIR ANCHORS OK NO MARKS
TO CHARLESTON
FIRST SIGNS OF CONTACT TO TRACK STRUCTURE
0 250' 500'

POINT OF FROG GENERAL DERAILMENT
932' TO HEAD OF LEAD UNIT No. 4006
2132' TO M P A–294
No. 303
No. 301
No. 596
No. 804
No. 512
No. 540
No. 520
No. 511
No. 524
No. 510
No. 806
No. 592
No. 7
60' OF CHAIN LINK FENCE DAMAGED
RK DISPLACED
APPROX 17' OF HOLE IN BLDG
LEGEND:
TRACK
TRACK
TRACK
0 10' 20' 30'




# FIGURE 1

**SEABOARD COAST LINE RAILROAD**
FLORENCE DIVISION

**AUTO—TRAIN DERAILMENT**
ON FEB. 24, 1978
FLORENCE, S.C.

## Damage

One passenger car was destroyed; two were heavily damaged; six were moderately damaged, and the other derailed cars were slightly damaged. About 1,380 feet of track, including one turnout, were destroyed.

The lead locomotive unit did not derail. The trailing (No. 1) truck on the second unit derailed. The 1st through 14th cars including the steam car, dormitory car, six sleepers, two diners, three coaches, and one nightclub car, were derailed. The 14th car, a coach, was derailed on the north end. The next two cars, both coaches, were not derailed. The 17th car, a diner, and the following three coaches were completely derailed. Only the lead west wheel of the lead truck of the 21st car, a coach, derailed. The first five derailed cars stayed in line with the track; the 6th through 11th cars derailed to the west and stopped perpendicular to the track. The 6th and 7th cars, the 8th and 9th cars, and the 11th and 12th cars jackknifed. The other derailed cars stayed in line with the track. Some of the derailed cars were deformed severely; however, this did not hinder passenger evacuation.

The cost of the derailment damages was estimated to be:

| | |
|---|---|
| Track | $ 95,000 |
| Signal and Appurtenances | 15,000 |
| Nonrailroad | 4,000 |
| Equipment | 660,029 |
| Total | $774,029 |

## Train Information

The two class U36B diesel-electric locomotive units were manufactured to Auto-Train specifications in 1971 and 1972 by the General Electric Company (GE). They were equipped with dynamic brakes and a 26L-type air airbrake. Instead of the GE-designed truck, Auto-Train requested a truck manufactured by the Electro-Motive Division (EMD) of the General Motors Corporation. GE modified the EMD truck to accept a GE No. 752 traction motor. Each locomotive unit had two trucks, each of which contained two traction motor-wheel-axle assemblies. The traction motor mounted on each axle was supported by two friction-type motor-suspension bearings and on the truck frame by a nose support. Oil for each axle bearing was conducted to the axle and suspension bearings through a felt-wick lubricator. A pinion gear on the traction motor armature shaft meshed with the axle ring gear for propulsion. The axle ring gear had 79 teeth, and the pinion gear had 24 teeth.

GE first mounted the axle, wheels, and traction motor on the EMD truck in January 1973. The truck initially was placed in service on another locomotive unit--one not involved in this derailment. In April 1975, the axle was removed to have new wheels applied and was returned to service on the same unit. In November 1976, the wheel assembly was removed to have the wheels turned, and in December 1976, the assembly was installed in the No. 2 position of the locomotive unit that derailed at Florence. At the time of the failure, the axle, traction motor suspension bearings had been in service more than 298,000 miles.

Since June 1972, Auto-Train had experienced 14 suspension bearing failures, some of which resulted in axle failures on locomotive units, and had instituted new maintenance procedures to combat the problem. These measures included a new style suspension bearing, sealing of the dust guard with silicone, changing the suspension bearing oil every 90 days, and checking the wicks every 90 days. Suspension bearings and wicks were replaced each time the traction motors were removed for servicing.

When this assembly, which subsequently failed, was placed in the second locomotive unit, new journal boxes were installed, and new suspension bearings and wicks were applied in accordance with the new instructions. In January 1978, the traction motor brushes were changed, and new pedestal liners and rubber rust absorbers were applied. In February 1978, new swing-hanger bushings and pins were applied. The wheel work done in 1975 and 1976 was performed by the SCL maintenance shop in Rocky Mount, North Carolina, and both times the axle was checked for visible defects. The axle was tested by the magnetic particle method prescribed by the Association of American Railroads (AAR). This type of test is prescribed for an axle to be reconditioned or reworked. The axle was found to be in condition to be returned to service.

GE provided Auto-Train with its specification for maintaining the locomotive and its appurtenances. Auto-Train indicated that it complied with these specifications and requirements. Auto-Train had performed the periodic inspections on the locomotive unit required by the Federal Railroad Administration (FRA). The last examination was on February 23, 1978, and the last 30-day inspection was on February 27, 1978. No exceptions were taken during either of these inspections. The last annual examination was made on August 24, 1977.

The fracture in the axle was located 30 1/4 inches from the left end, at a point where the axle diameter was 8 7/8 inches. The fracture was about midway under the bearing on the drive side of the axle. The fractured axle had a journal size of 6 1/2 by 12 inches, was of grade F steel, and was manufactured by the Bethlehem Steel Corporation (Bethlehem) in May 1972. Specification listed in the AAR Manual of Standards and Recommended Practices were used in the manufacturing process. Specification M-101 prescribes manufacturing procedures, chemical requirements, and mechanical properties and tests. Bethlehem certified to GE that the axle complied with the requirements of M-101, including ultrasonic inspection. (See Appendix A.)

## Method of Operation

Trains operating in the accident territory are governed by a traffic control system. The maximum authorized speeds between Savannah and Florence are 79 mph for passenger trains and 70 mph for Auto-Trains. Normal northbound daily traffic consists of eight trains, including one Auto-Train and two passenger trains.

## Meteorological Information

At the time of the accident, the temperature was 31° F, and surface visibility was 7 miles. The sky was clear with a northeast wind of about 7 mph. There had been no precipitation.

## Survival Aspects

Even though many of the passenger cars were badly deformed in the derailment, only 24 of the 503 passengers and 1 of the 31 crewmembers received minor injuries. One passenger was hospitalized. A significant factor in the relatively low number of injuries was the time of the accident -- 2:10 a.m. Most of the passengers were in berths or seated.

## Tests and Research

An inspection of the northbound track disclosed flange marks on the flange boards of a highway grade crossing located 17.5 miles south of the accident site. Markings were found at each road crossing from this point of derailment. Wheel markings were found on the flared portion of the guardrail of a facing point left-hand turnout, adjacent to the east rail, and on the frog 1/ point on the west rail at Coward, South Carolina, 15 miles from the accident point.

Marks on the heel of the frog of the turnout to the siding at the accident site indicated that the derailed left No. 2 wheel of the trailing truck on the second locomotive unit struck the frog and was diverted to the west. The left wheels on the following cars struck the frog and derailed

The failed wheel axle assembly with its traction motor was shipped to the Sanford shop of Auto-Train, where it was disassembled for inspection on March 3, 1978. All components were examined as they were separated from the assembly. However, since the surfaces of the failed area had been subjected to severe heat and friction, it was not possible to visually determine the sequence of events that led to the axle/bearing failure. Selected sections of the failed surface were forwarded to a laboratory for analysis.

---

1/ A track structure used at the intersection of two running rails to provide support for wheels and passageways for their flanges, thus permitting wheels on either rail to cross the other.

Much of the bearing has been melted and fused to the outer surface of the turning axle due to the intense heat generated in this area. The heat and pressure between the ˙roken sections of the axle were so intense that the outer contour of the axle was changed. Differences in the surface color of the axle steel indicated that the heat originated in the same area as the axle fracture. The axle color spectrum ranged from black to yellow (500° - 800°F).

Chemical analysis below the axle surface disclosed evidence of diffusion of the bronze bearing material into the steel axle. When a bearing is in the process of failing, frictional forces generate heat at the interface of the two dissimilar materials. This heat can diffuse the bearing metal into the steel. There were also several voids and cracks in the fracture ends of the axle.

The felt-wick lubricators of the outer axle suspension bearings were inspected and found to be satisfactory. The wheel-slip control circuitry on the locomotive units was tested and found to perform as intended.

**Other Information**

The FRA does not have regulations pertaining to the manufacture of locomotive unit axles; however, FRA does have rules for the removal of in-service axles. (See Appendix C.)

## ANALYSIS

The flange markings on the highway grade crossings indicated that the axle broke about 17 miles south of the derailment site. The wheel-slip control system did not indicate the failure because the gears still meshed and no voltage differential between the wheels of the unit was established. The broken axle permitted the wheels to move inward sufficiently for the flanges to strike the paved surface of the highway crossings, but not enough to derail. The broken ends of the axle were kept in line by the suspension bearing, and the wheels were kept upright by the truck sides and other parts of the track. The rubbing of the wheels on the truck sides caused the grooving on the locomotive truck frame. This action continued until the wheel struck the frog of the turnout to the siding at the accident site and caused the frog to become misaligned. As other wheels struck the frog, the cars derailed.

The metallurgical examination of the broken axle indicated that the axle probably broke after the bearing had failed. The surfaces of the broken axle had been distorted by rubbing against each other for 17 miles and by the heat produced by this friction. Although this distortion prevented examination of the fractured surface, the penetration of bearing metal along the grain boundaries of the axle indicates that the bearing overheated prior to axle failure. Bearing metal penetration occurs when: (a) the axle surface is heated; (b) residual tensile stresses are present in the axle at the point of penetration; and (c) liquid bearing metal is in contact with the heated steel surface long enough for penetration. If the axle had broken before the bearing overheated, tensile stresses would not have been present in the region under the bearing and penetration could not have resulted. All cracks and voids in the area of the fracture were the result of torsional stresses in the overheated axle during the failure process.

As a result of this accident investigation, the Safety Board found that Auto-Train had experienced other axle failures due to overheated bearings. Auto-Train had modified its maintenance practices in order to cope with these failures, but, at least in this case, the new maintenance practices did not prevent bearing failure.

The lack of serious injuries was probably due to the time of the accident, because most passengers were in their seats or berths. If the accident had occurred at mealtime when the passengers were moving from their cars to the dining cars, or at a time when the entertainment car was open, the probability of deaths or serious injuries would have been greater. Even though many of the passenger-carrying cars sustained considerable damage, passenger evacuation was not impeded.

The Auto-Train locomotive units were not provided with rearview mirrors to assist the crewmembers in observing their train en route. Intermittent sparking was produced during the axle failure prior to the derailment, and the use of a rearview mirror might have alerted a crewmember who could have taken preventive action to avoid the general derailment. The crew had observed the train for defects; however, the sparking might not have been discernible from the vantage point from which their observations were made.

## CONCLUSIONS

### Findings

1. The traction motor support bearing on the No. 2 axle of the second Auto-Train locomotive failed prior to the axle failure.

2. The axle failed at least 17 miles before the train derailed.

3. The crewmembers did not perceive the failed axle in time to avoid the accident.

4. The No. 2 wheel and axle assembly had been used more than 298,000 miles before it failed.

5. Metallurgical tests and chemical analysis were necessary to determine the failure sequence.

6. The wear pattern of the wheel rim on the truck frame indicated that the back-to-back wheel measurement was out of gage.

7. The ultrasonic inspection by the manufacurer did not detect any internal axle defects which were present when it was manufactured.

8. At the time the axle was remounted, SLC employees, using AAR specifications for remounting used axles, did not detect any defects.

9. Metallurgical tests disclosed the presence of bearing metal along the grain boundaries of the locomotive axle in the area of the axle failure.

### Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was a locomotive unit axle fracture that originated from an overheated traction motor suspension bearing on the second unit of the two-unit locomotive consist. Contributing to the cause of the accident was the lack of an onboard system for detecting an axle failure independent of crewmembers' inspection.

## RECOMMENDATIONS

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

--to the Association of American Railroads:

"Amend the procedures for testing and inspecting used locomotive unit axles before they are remounted to insure that internal defects can be detected. (Class II, Priority Action) (R-78-53)"

--to the Federal Railroad Administration:

"Revise 49 CFR 230.213, Axles, to establish specification for the manufacturing and testing of locomotive axles to insure the discovery of internal defects before they are placed in service. (Class II, Priority Action) (R-78-54)"

"Develop a method that will automatically detect the failure of a locomotive unit truck or any of its components, independent of crew observation. (Class II, Priority Action) (R-78-56)"

**REVISED REPORT ADOPTED
BY THE NATIONAL TRANSPORTATION SAFETY BOARD***

/s/ JIM BURNETT
Acting Chairman

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

/s/ VERNON L. GROSE
Member

June 27, 1984

The original report was adopted on September 21, 1978, by the following members of the National Transportation Safety Board: James B. King, Chairman; Francis A. McAdams, Philip A. Hogue, and Elwood T. Driver, Members.

# APPENDIX A

## REPORT OF PHYSICAL TESTS AND/OR CHEMICAL ANALYSIS BY BETHLEHEM STEEL CORPORATION

BETHLEHEM, PA 18016

SHIPT. NO. 603-2035-1/2

SALE ORD. TF 91940

3-103160-1 10/18/71

45325-00 | 301 | 9 | 24 | 3725 | 430 | | | X2 | X576

| Q | 3GS | SHIP TO | H | CAR | 6 | | COLLECT

SOLD TO:
0576
GENERAL ELECTRIC CO
TRANSPORTATION SYSTEMS DIV
2901 EAST LAKE ROAD
ERIE PA 16501

SHIP TO:
GENERAL ELECTRIC CO
TRANSPORTATION SYSTEMS DIV
3410 MAIN AVE FOR ECY 10
ERIE PA 16501

DATE SHPD 9/1/72 SHPD FROM JOHNSTOWN PA FOB

ROUTE W C MCQUAIDE

| CAR OR VEHICLE NO | NO. PCS OR PKGS | KIND OF PACKAGE, DESCRIPTION OF ARTICLES, SPECIAL MARKS AND EXCEPTIONS | WEIGHT POUNDS |
|---|---|---|---|
| TRL TC61495 | 22 | AXLES W/O BRGS GEARS KNUCKLES OR POWER ATCHMTS | 34300 |

| CUSTOMER & ISC ORDER NOS. | UNITS | DESCRIPTION AND SIZE | WEIGHT |
|---|---|---|---|
| 20-0792 | | | |
| | PCS | | |

INSP: 3 CERT TESTS TO LOCO QUAL CONTROL SUPVR BLDG
14-3 2901 E LAKE RD ERIE PA 16501
SPEC: AAR M101-68 GRADE F DN&T MICRO TEST REQUIRED
BTAO STD 60 DEG CENTERS ULTRASONICALLY INSPECTED
TO AAR SPEC M101A-70 LOCO AXLES DWG 41C612095-P3
REV 8

(2353-155-481)

20 32200

| HT | SER | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3-662H534 | 25 | 30 | 64 | | | | | |
| 6-654H497 | 6 | 32 | 34 | 66 | 67 | 68 | | |
| 11-658H505 | 8 | 20 | 21 | 23 | 35 | 36 | 38 | 39 |
| | 43 | 53 | 58 | | | | | |

| | Yield | Tensile | El. 2" | Red.A. | Micro | C | Mn | P | S | Si |
|---|---|---|---|---|---|---|---|---|---|---|
| 662H534 | 53920 | 97850 | 25.0 | 47.2 | OK | 51 | 84 | 012 | 039 | 23 |
| | 54420 | 99350 | 23.5 | 46.3 | OK | | | | | |
| 654H497 | 54420 | 100850 | 25.0 | 45.4 | OK | 55 | 80 | 010 | 027 | 21 |
| | 54920 | 100850 | 24.0 | 44.0 | OK | | | | | |
| 658H505 | 51630 | 99000 | 26.0 | 46.1 | OK | 56 | 79 | 010 | 023 | 20 |
| | 51920 | 97850 | 25.0 | 46.0 | OK | | | | | |

REPORT OF PHYSICAL TESTS AND/OR
CHEMICAL ANALYSES

I CERTIFY THE ABOVE RESULTS OF TESTS AND/OR ANALYSES TO BE CORRECT AS CONTAINED IN THE RECORDS OF THE BETHLEHEM STEEL CORPORATION.

Chief Metallurgist

# APPENDIX B

## EXCERPTS FROM CODE OF FEDERAL REGULATIONS

**§ 230 200a Responsibility for design, construction, inspection, and repair.**

The railroad company is held responsible for the general design construction, inspection, and repair of all locomotives used or permitted to be used on its line. It must know that all inspections, tests, and repairs are made and reports made and filed as required, and that all parts and appurtenances of every locomotive used are maintained in condition to meet the requirements of the law and the rules and instructions in this subpart. Nothing contained in the rules and instructions in this subpart, however, shall be construed as prohibiting any carrier from enforcing additional rules and instructions not inconsistent with those in this subpart contained, tending to a greater degree of precaution against accidents

RUNNING GEAR

**§ 230 213 Axles**

(a) *Defects* Driving and truck axles with any of the following defects shall not be continued in service: Cracked or bent axles; cut journals that cannot be made to run cool without turning; seamy journals in steel axles; transverse seams in iron axles, or any seams in iron axles causing journals to run hot; unsafe on account of usage, accident, or derailment, nor driving or truck axles more than one-half inch under original diameter, except for locomotives having all driving axles of the same diameter, when other than main driving axles, may be worn three-fourths inch below the original diameter

(b) *Stamping* The date applied, the original diameter of the journal, and the kind of material, shall be legibly stamped on each driving axle and truck axle applied after January 1, 1926.

(c) *Abbreviations* The following abbreviations shall be used in stamping "kind of material" on driving axles, truck axles, and crank pins I —iron, S —steel; H T S —heat-treated steel, Chr.—chrome; Van —vanadium; Nkl —nickel, Nik —nikrome; Cof Proc —Coffin process; Cam Spec —Cambria special; Tay. I —Taylor iron.

## APPENDIX C

### BETHLEHEM STEEL CORPORATION'S PETITION FOR RECONSIDERATION OF PROBABLE CAUSE

# *Bethlehem Steel Corporation*

BETHLEHEM PA 18016

LAW DEPARTMENT



April 25, 1983

Mr. Harold Storey
Chief - Railroad Accident Division
National Transportation Board
800 Independence Avenue, S.W.
Washington, D. C. 20594

Re: Report No. NTSB-RAR-78-6
Derailment of Auto-Train No. 4
on Seaboard Coast Line Railroad
Florence, South Carolina
<u>February 24, 1978</u>

Dear Sir:

This will serve to confirm that Bethlehem wishes to formally petition the National Transportation Safety Board for modification of the above report. As was discussed at our meeting on February 2, 1983, Bethlehem did not participate in or observe the original metallurgical investigation upon which the report was based or any of the meetings preceding the investigation. As was also discussed at the meeting, and as noted in my letter of January 18, 1983, Bethlehem was subsequently prevented from commenting in detail on the report or from seeking its modification pending its own investigation and the resolution of litigation arising from the subject derailment. With the successful resolution of that litigation, Bethlehem is now free to discuss the factual findings of its own investigation and hereby petitions for a modification of the report based upon those findings.

As you are aware, Bethlehem's investigation was conducted jointly with Dr. L. Leonard of the Franklin Institute in Philadelphia and the principal findings of the investigation were concurred in by another metallurgical expert retained by Auto-Train, Dr. C. Laird of the University of Pennsylvania. In short, there were two principal factual findings which would dictate modification of the report:

1. Examination of numerous samples from along the axle surface beneath the bearing disclosed extensive penetration of bearing metal along the grain boundaries in every sample. Since such penetration can only occur where the bearing becomes overheated while the axle is still intact and under tension, the bearing failure here necessarily preceded and caused the axle failure.

2. All voids present in the axle metal were confirmed, through the analysis of the orientation of inclusions in the steel, to have been caused by the torsional stresses resulting from the twisting of the partially fractured axle prior to total failure. Oxidation observed on the void surface could only have formed after those surfaces were exposed to the atmosphere by liquid metal embrittlement cracking and not during the manufacturing of the axle. Moreover, there is no plausible manufacturing process problem that could produce such voids. Additionally, Bethlehem performs both the required axial ultrasonic examination and peripheral inspection, as well. Such testing would readily disclose any such voids, assuming they could exist. Obviously, no such voids were detected during Bethlehem's ultrasonic examination.

Based upon the findings of its own investigation, confirmed by the other individuals noted above, Bethlehem would offer these additional specific comments with reference to specific portions of the report:

1. Abstract, second paragraph:

The axle did not fail due to voids not detected during axle manufacture. The failure was due to overheating of the friction bearing on the drive-wheel (gear) side of the axle. Overheating melted the bronze backing of the bearing in contact with the axle producing infiltration of liquid bronze metal into the axle (liquid metal embrittlement) which caused the axle fracture. All voids present were due to twisting of the partially fractured axle which opened voids at austenite grain boundaries where liquid copper was present.

2. Tests and Research, p. 8, second paragraph:

The cracks and voids in the axle were not present before the incident; all occurred as a result of penetration of molten bearing material into the axle. The oxidation observed on the crack surfaces was not present before the accident; all oxidation occurred after torsional stresses opened the liquid metal embrittlement cracks to the atmosphere. The LETCo. chemistry checks of the axle composition were performed using an electron microprobe. This is not a preferred analytical tool for determining bulk chemical analysis.

3. Tests and Research, p. 8, third paragraph:

Examination at Bethlehem of samples from the axle along the axle surface beneath the bearing, disclosed extensive penetration of bearing metal in every sample. This was verified by Dr. L. Leonard of the Franklin Research Center and by Dr. C. Laird (University of Pennsylvania), an expert contracted by Auto-Train's counsel to evaluate the LETCo work. Such penetration can only occur if the bearing overheated when the axle was solid, that is, penetration of bearing metal cannot occur after the axle fracture, only before the fracture.

4. Analysis, p. 9, first paragraph:

The axle broke because the bearing overheated. Penetration of liquid bearing metal was present in the axle. This can only occur when: (a) the axle surface is heated high enough to transform the ferritic structure to austenite, (b) residual tensile stresses are present in the axle at the point of penetration; and, (c) liquid copper is in contact with the heated steel surface long enough for penetration. If the axle broke before the bearing, tensile stresses of the required magnitude would not be present in the region under the bearing and penetration would not result. All of the voids in the axle were opened as a result of the torsional stresses during rupture to failure.

5. Analysis, p. 9, second paragraph:

None of the voids was present in the axle when manufactured for the reasons stated under 1, 2 and 4. There is no plausible manufacturing process problem that could produce such defects. Additionally, Bethlehem performs not only the required axial ultrasonic examination but also peripheral inspection. Any such defects, even if they could exist, would be detected easily. No defects, however, were detected during Bethlehem's ultrasonic examination.

6. Analysis, p. 9, fourth paragraph:

The present inspection program for new axles during manufacture is adequate and needs no changes.

7. Findings, p. 10, point No. 1:

The axle did not fail before the motor support bearing failed. The bearing overheated causing liquid metal penetration and failure as outlined in 1, 3 and 4 above.

8. <u>Findings</u>, p. 10, point No. 5:

The tests performed by LETCo did not prove that defects were present in the axle when manufactured nor did they determine the failure sequence. The LETCo investigator failed to observe the penetrated bearing metal subsequently detected by all other examiners (see no. 3, above).

9. <u>Findings</u>, p. 10, point no. 7

The presence of internal defects at the time of manufacture was not proven. None were present in the axle prior to the accident (see 1, 2 and 5).

10. <u>Findings</u>, p. 10, point nos. 9 and 10.

The existing specifications for locomotive axle manufacture are adequate.

11. <u>Recommendations</u>, p. 11:

Current specifications and inspection procedures for newly manufactured axles are adequate and require no changes.

12. <u>Appendix B</u>, p. 14, "Grain Size Determinations":

The grain size evaluated was not that present in the axle as manufactured. The areas examined were heated during failure into the austenitic region producing a coarser transformation structure upon cooling. Hence, the stated results bear no relationship to the as-manufactured grain size.

13. <u>Appendix B</u>, p. 14, "Cleanliness Ratings and Discontinuities":

AAR M-101 does not require inclusion ratings. The LETCo metallographic preparation was of inadequate quality for such a rating. Such ratings are never conducted on transversely oriented samples. The test was not properly conducted; the data is incorrect.

None of the voids observed were present before the bearing overheated for the reasons outlined in 1, 2 and 4. The difference in void appearance depended on the temperature at the void. If the steel around the void was heated into the austenitic region, upon cooling an undistorted coarse ferrite-pearlite structure would result.

14. Appendix B, p. 15, "Diffusion Studies":

Copper penetration does not occur by diffusion but by liquid metal embrittlement, i.e., bulk penetration of liquid copper in the austenite grain boundaries. We assume that inadequate metallographic sample penetration prevented LETCo from detecting the grain-boundary copper films. Copper penetration was extensive and was detected by others (see item 3 above) after proper sample preparation.

15. Appendix B, p. 15, "Surface Studies in Void Walls":

The so-called "free-surface" voids were not manufacturing defects but occurred after copper penetration as described in 1, 2, 4 and 13. The surfaces were oxidized by air from the atmosphere entering along the crack pattern connecting the voids to the axle surface.

16. Appendix, p. 15, "Mechanical Properties":

The mechanical tests were not taken at the official test prolong location and, hence, may be slightly different than the official test results.

17. Appendix B, p. 15, "Rockwell B Scale"; second paragraph:

AAR M101 does not require Charpy V-notch impact testing. Such testing is irrelevant as an axle is not subject to impact loading.

18. Appendix B, p. 16, "Chemical Analyses":

Chemical analyses was performed by electron microprobe analysis, a method not ideally suited for determination of bulk chemical composition. While a number of measurements were made, only two were reported.

19. Appendix B, p. 16, "Conclusions and Discussion":

The LETCo study did not reveal voids at the fracture surface and did not reveal growth of the voids. All voids were produced after copper penetration as discussed in 1, 2 and 4, and were well away from the fracture surface. The so-called "free-surface" voids were those in areas heated above the upper critical temperature, as discussed in 13.

The bearing was assumed to fail after the axle because LETCo did not observe "diffused" bearing elements. As discussed in 3 and 14, bearing element (austenite) grain-boundary penetration was present.

The tensile data and Charpy V-notch impact data are not relevant to the failure as discussed in 15 and 16.

The axle remnant, laboratory samples and photographs have been preserved and are available for your further inspection, if necessary. If you have any questions or if any further information is required in this regard, please do not hesitate to contact me. Otherwise, we thank you for your attention and consideration in this matter and will look forward to hearing from you regarding this petition.

Very truly yours,

William H. Graham

WHG:ev

## APPENDIX D

## NTSB'S RESPONSE TO BETHELEM'S PETITION FOR RECONSIDERATION

**National Transportation Safety Board**

Washington, D C 20594

June 27, 1984

Bethlehem Steel Corporation
Petition for Reconsideration of
Probable Cause
Railroad Accident--Derailment of Auto-Train No. 4 on
Seaboard Coast Line Railroad, Florence, South Carolina, February 24, 1978
(NTSB-RAR-78-6)

RESPONSE TO PETITION FOR RECONSIDERATION

In accordance with the Safety Board's rules of practice (49 CFR Part 845), the Safety Board has entertained a Petition for Reconsideration of its analysis, findings, and probable cause of the railroad accident, "Derailment of Auto-Train No. 4, Seaboard Coast Line, Florence, South Carolina" (NTSB-RAR-78-6).

Based on its review of the Bethlehem Steel Corporation's April 25, 1983, Petition for Reconsideration, the National Transportation Safety Board has granted the Petition in its entirety. Items 1 through 11 in the Petition addressed revisions in the text of the accident report. Items 12 and 13 resulted in the deletion of appendix B from the report.

The accident occurred about 2:10 a.m., on February 24, 1978. Nineteen cars and a locomotive unit of Auto-Train No. 4 derailed on Seaboard Coast Line Railroad trackage at Florence, South Carolina. Twenty-four of the 503 passengers were injured. The total accident damage was estimated at $774,029. On September 21, 1978, the Safety Board determined that the probable cause of the accident was a locomotive unit axle fracture originating in an undetected void which had developed during manufacture of the axle.

New evidence, as presented in the Petition, alleges that prior tests failed to detect penetration of bearing metal along the grain boundaries of the locomotive axle in the area of the traction motor support bearing where the axle fracture occurred. Additionally, the Petition alleges there were errors in the Safety Board's analysis of the significance of voids found during its metallurgical examination of the axle.

The Safety Board had determined that the voids had existed since the manufacture of the axle and that one of the voids was an origin of fatigue failure. The Board's analysis was based upon a metallurgical report prepared by a consultant. The consultant's report stated that there had been no bearing metal penetration of the failed axle. The Board's original findings were predicated upon that evidence.

With regard to the penetration of bearing metal along the grain boundaries in the fracture area, the Safety Board has reviewed the April 10, 1978, metallurgical report by its consultant and compared the results with the March 22, 1982, Bethlehem Steel Corporation report entitled, "Investigation of the Auto-Train Locomotive Axle Failure." The latter report states that bearing metal penetration was evident in the metallurgical samples examined by Bethlehem Steel Corporation. Similar penetration was not found when samples from the same area were examined by the Board's consultant. The Board

APPENDIX D



now concludes that the consultant's test procedures were inadequate and agrees with the Bethlehem Steel report as to the presence of bearing metal along the grain boundaries and as to the conclusion that the axle was intact until after the bearing failed and that the axle failed from loss of strength due to overheating. The Board now believes that the voids in the body of the axle near the fracture surface most likely were generated by the twisting action that occurred during the fracture sequence when the overheated axle was in a plastic condition. As a result, the Safety Board concludes that the voids in the axle were generated during the axle failure sequence and that they were not defects which originated during the manufacturing process. Thus, the Safety Board will change the report to reflect the new evidence presented by Bethlehem Steel.

With regard to the probable cause, the Safety Board has reexamined the evidence in the original docket and has considered the new evidence presented by Bethlehem Steel. As a result of this reexamination, the Safety Board concludes that the probable cause of the accident stated in its report on the Auto-Train derailment at Florence, South Carolina, on February 24, 1978, was incorrect and it is revised as follows:

The Safety Board determines that the probable cause of the accident was a locomotive unit axle failure that originated from an overheated traction motor suspension bearing on the second unit of the two-unit locomotive consist. Contributing to the cause of the accident was the lack of an onboard system for detecting a bearing failure independent of crewmember's inspection.

The Safety Board appreciates the thoroughness of the documentation the Bethlehem Steel Corporation presented in its Petition and its interest in railroad safety.

ACCORDINGLY,

Petitioner's petition for reconsideration of probable cause is hereby granted, in its entirety, and the Board's original report is revised, reprinted, and reissued. Petitioner's Petition and this response have been appended to the revised report.

JIM BURNETT, Chairman, PATRICIA A. GOLDMAN, Vice Chairman, and G. H. PATRICK BURSLEY and VERNON L. GROSE, Members, concurred in the disposition of this Petition for Reconsideration.

*U S GOVERNMENT PRINTING OFFICE : 1984 0-421-828/10019