PB95-916304
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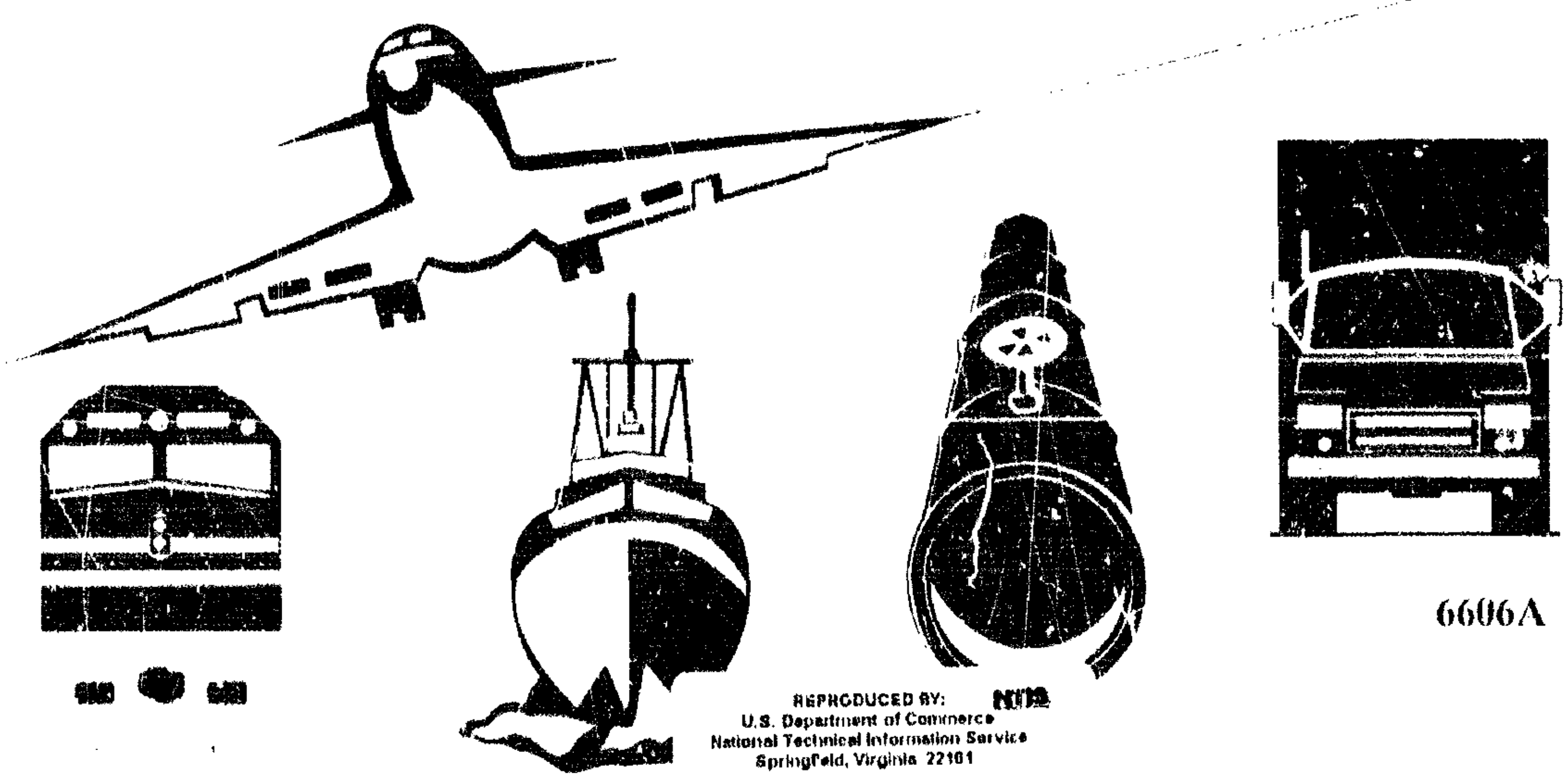
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

REAR-END COLLISION OF ATCHISON, TOPEKA AND SANTA FE RAILWAY FREIGHT TRAIN PBHLA1-10 AND UNION PACIFIC RAILROAD FREIGHT TRAIN CUWLA-10 NEAR CAJON, CALIFORNIA DECEMBER 14, 1994



6606A

Abstract: On December 14, 1994, a westbound Atchison, Topeka and Santa Fe Railway Company intermodal train collided with the rear of a standing Union Pacific Railroad Company coal train near Cajon, California. The two crewmembers from the Santa Fe train were injured when they jumped from the moving train before the collision. Total estimated damages were $4,012,900.

The safety issues discussed in this report are air brake testing in mountain-grade territory; management oversight of train handling practices; feed-valve braking; and two-way end-of-train devices.

As a result of its investigation, the National Transportation Safety Board issued recommendations to the Association of American Railroads, the Federal Railroad Administration, the American Short Line Railroad Association, and all Class I railroads.

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RAILROAD ACCIDENT REPORT

Adopted: November 21, 1995
Notation 6606A

NATIONAL
TRANSPORTATION
SAFETY BOARD

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EXECUTIVE SUMMARY

About 5:12 a.m., Pacific standard time, on December 14, 1994, a westbound Atchison, Topeka and Santa Fe Railway Company (Santa Fe) intermodal[1] train, PBHLA1-10, collided with the rear end of a standing westbound Union Pacific Railroad Company (UP) unit coal train, CUWLA-10, at milepost (MP) 61.55 near Cajon, California, on the Santa Fe's San Bernadino Division's Cajon Subdivision. The two crewmembers from the Santa Fe train were injured when they jumped from the moving train before the collision. Two helper crewmembers on the rear of the UP train detrained before the collision because they had been warned of the impending collision by the Santa Fe crew. As a result of the collision, a fire broke out that burned the two UP helper locomotive units. Four Santa Fe locomotive units and three articulated five-pack double-stack containers were also destroyed. Total estimated damages were $4,012,900.

The National Transportation Safety Board determines that the probable cause of the collision of the Atchison, Topeka and Santa Fe Railway Company train, PBHLA1-10, with the rear of the Union Pacific Railroad train, CUWLA-10, was insufficient available train braking force for the Santa Fe train due to a restriction or blockage in the trainline between the third and fourth articulated cars.

The issues examined in this accident were as follows:

- Air brake testing in mountain-grade territory,
- Management oversight of train handling practices,
- Feed-valve braking, and
- Two-way end of train devices.

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[1] An intermodal train is a merchandise train of single and/or articulated cars that are designed to carry truck trailers and containers.

THE INVESTIGATION

The Accident

About 5:21 a.m., Pacific standard time, on December 14, 1994, a westbound Atchison, Topeka and Santa Fe Railway Company (Santa Fe) intermodal train, PBHLA1-10, collided with the rear end of a standing westbound Union Pacific Railroad Company (UP) unit coal train, CUWLA-10, at milepost (MP) 61.55, near Cajon, California, on the Santa Fe's San Bernadino Division's Cajon Subdivision (see figures 1 and 2).

At the time of the accident, the UP train consisted of 3 diesel-electric locomotive units, 82 loaded coal cars, and 2 diesel-electric locomotive helper units that were on the rear end of the train. The head-end crew consisted of an engineer, a conductor, and a student engineer. The helper crew included an engineer and a brakeman.

The Santa Fe train had originated on the Burlington Northern (BN) Railroad in Birmingham, Alabama, and was destined for Los Angeles, California. The train had 4 diesel-electric locomotive units and 55 loaded freight cars, 13 of which were articulated five-pack double-stack well cars. The train was 5,261 feet long, including the locomotive units, and had 4,882 trailing tons. It had a 1,000-mile air brake test and mechanical inspection, as required by the Federal Railroad Administration's (FRA's) regulations,[1] at Belen, New Mexico.

The last crew change before the accident was at Barstow, California, when a two-man outbound crew, an engineer and a conductor, took over the Santa Fe train. The outbound crew took the four-unit diesel-electric locomotive consist from the "diesel track"[2] and coupled it to the train.[3] The conductor then connected the air brake trainline (brake pipe) between the locomotive and the first car of the train and returned to the lead locomotive unit. The engineer stated that the train brakes were in emergency when the locomotive was coupled to the train because the angle cock[4] on the first car was found fully open and the trainline exhausted. He said it was common practice to set a train's brakes in emergency when removing the locomotive units. (See appendix C for an explanation of how a train's air brake system works and for definitions of *trainline* and *brake pipe*.)

After charging the air brake system, the engineer said he performed a "set and release" air brake test to ensure continuity of the trainline and the braking system according to 49 *Code of Federal Regulations* (CFR) 232.13(c)(1). The test involved making a 20-psi brake-pipe

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[1]The procedure for testing air brakes on road trains at intermediate terminals is described at 49 CFR 232.13.

[2]A servicing area in which locomotive units are fueled, cleaned, and resupplied.

[3]The inbound crew had taken all the inbound locomotive units to the roundhouse, leaving only the cars.

[4]Each car has two angle cocks. An angle cock is a valve that controls air admission to the car's brake pipe.

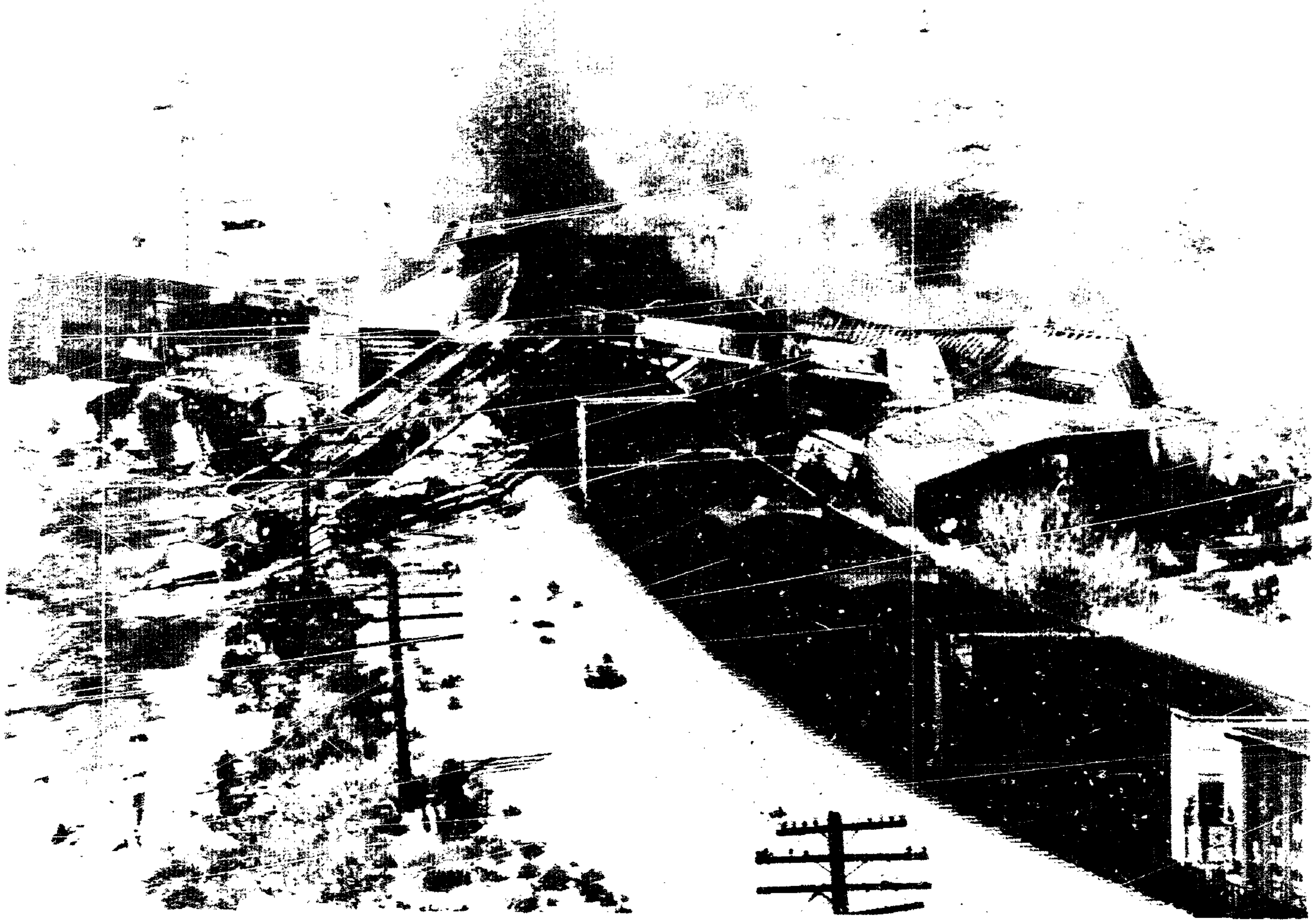

Figure 1 — Aerial view of accident scene, looking east

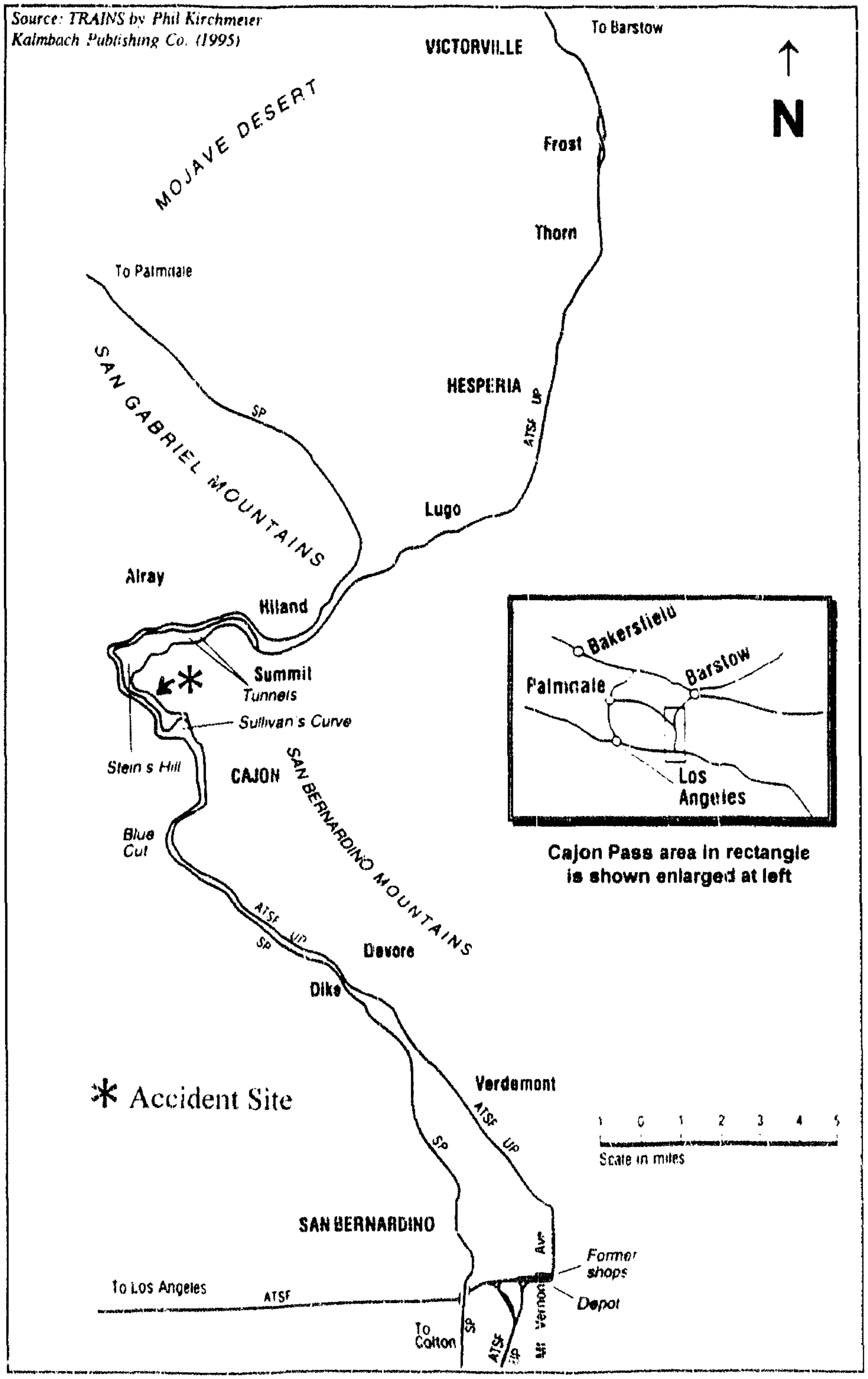

Figure 2 -- Route of tracks through Cajon Pass. SP indicates the track used by Southern Pacific and ATSF UP indicates the track used by Santa Fe and Union Pacific.

reduction after the train's brake pipe was charged to within 15 psi of the regulating-valve[5] setting. The brake pipe of the train was set at 90 psi. The locomotive cab telemetry gauge from the one-way end-of-train (EOT) device[6] (figure 3) was checked to determine that brake-pipe pressure at the rear of the train was being reduced. The reduction was followed several minutes later by a release and another check of the locomotive cab telemetry gauge to ensure that it reflected the brake-pipe pressure on the end of the train which was being restored. This was done at about 3:20 a.m. The Barstow yard tower has an EOT telemetry receiving device so supervisors can monitor air brake tests. Tower personnel monitored the test, but such tests are not recorded. The engineer was satisfied that the train brakes were operating properly, and the train departed Barstow at 3:27 a.m.

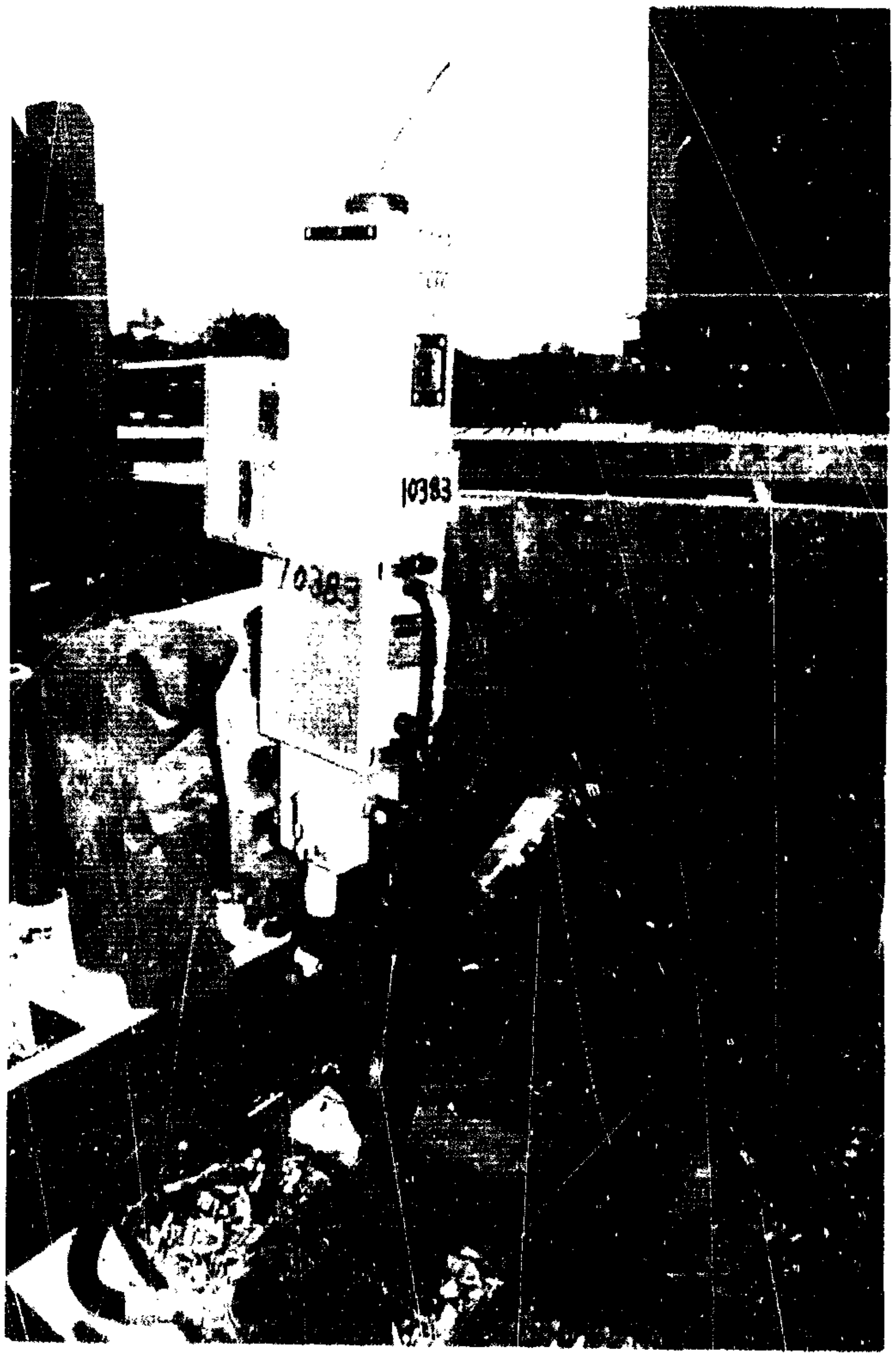

Figure 3 — Typical one-way end-of-train (EOT) telemetry device.

The train arrived at Lugo, MP 50.1, (11 miles from the collision point) about 4:32 a.m., where it stopped to allow an Amtrak train to pass. The Santa Fe engineer stated that he had stopped the train using throttle modulation[7] on a slight upgrade. (See figure 4.) When the train was going about 1/2 mile per hour, he made a 20-pound brake-pipe reduction, stopping the train. He stated that the brakes applied and released normally, without a problem. The train stayed at Lugo for about 17 minutes. According to the event recorder, the train left Lugo about 4:49 a.m.[8]

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[5]The regulating-valve knob is used to set the trainline, or brake-pipe, pressure.

[6]A one-way EOT device provides a required red marker at the end of the train; and via radio signal (telemetry), it provides a receiver in the controlling locomotive cab with trainline pressure on the train end, a movement and direction indicator, and a train distance measurement reading.

[7]Manipulation of the throttle to control train speed and/or train slack.

[8]The Safety Board established all times, throttle movements, and train speeds based on event recorder data..

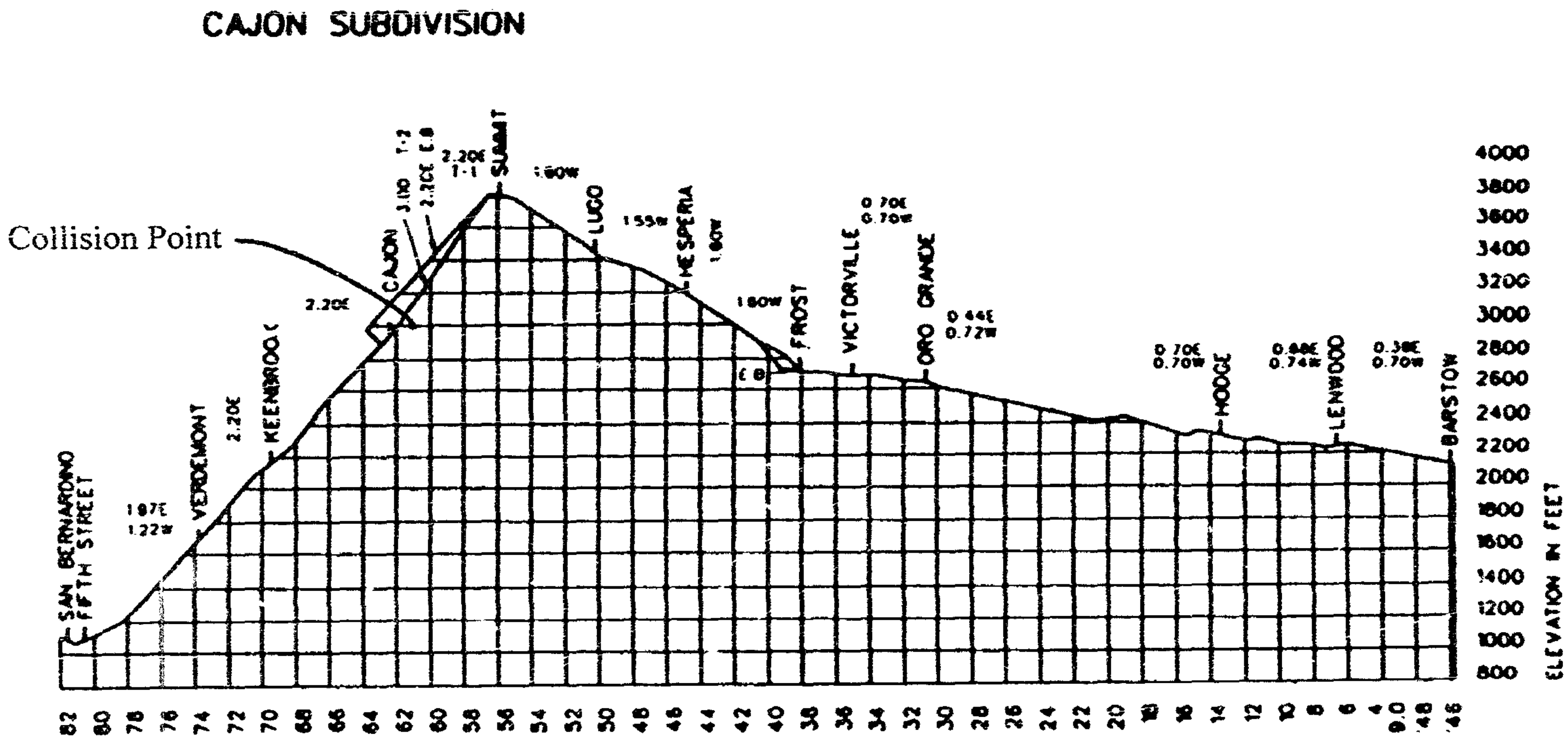

Figure 4 — Track elevations on the Cajon Subdivision

As the train continued west, the engineer maintained a speed between 15 and 18 mph, using various throttle positions to control the speed. About MP 55.9, near the block signal at Summit, he prepared for the descent to Cajon. He used the regulating valve[9] to reduce the brake-pipe pressure by 5 psi and then worked the throttle in position 1, 2, or 3. He later said, "Normally it [the 5-psi brake-pipe reduction] would drag the train down pretty good right there. I didn't notice it really dragging, and mentioned that to [the conductor]."

Up to this point the train had been generally moving upgrade toward Summit, MP 56. There the grade changed and began descending at 0.50 percent to about MP 56.9, where it became steeper, to an average 2.75 percent through Cajon, MP 62.8.

About a minute after the engineer had reduced the trainline pressure by 5 psi, he started using the dynamic brake, which steadily increased in amperage over the next 5 1/2 minutes as dynamic braking increased. About 2 minutes after he had started using the dynamic brake, he was near Campers Point, MP 57.3, and he reduced the brake-pipe pressure by another 3 psi. About a minute later, he reduced it another 2 psi. Both times, he again used the regulating valve, rather than the automatic brake valve, to make the reductions.

The brake-pipe pressure had fallen from 90 to 80 psi, and the dynamic brake amperage had gradually increased to 920 amps. After the engineer had reduced the trainline pressure for the third time, the train's speed increased from 18 to 23 mph in less than a minute.

The train continued to gain speed. The engineer told the conductor "We have problems." The engineer reduced the pressure in the brake pipe by another 15 psi as the train reached 24 mph. Brake-pipe pressure was then 65 psi, and a full-service brake application had been made. The train continued to gather speed steadily, increasing to 28 mph within the next 18 seconds. The conductor and engineer decided that the speed was increasing too rapidly, so the engineer applied the emergency brake from the automatic brake valve.[10] He was at MP 57.9, about 3 1/2 miles from the site of the collision, which happened about 5 minutes later.

After the emergency brake application, the crewmen made a radio call to any train stopped at Cajon. (They had heard that a UP coal train was stopped ahead of them.) The engineer radioed the dispatcher and the UP crewmen and told them that his train was out of control and a collision was imminent.

When the emergency brake was applied, the power control switch activated, and the dynamic brake electrical load was dropped, eliminating the dynamic braking of the locomotives. The locomotive air brakes applied and stayed applied until the collision. The train did

[9] Using the regulating valve to decrease or increase the trainline pressure in order to apply or release the air brakes is called feed-valve braking. For the purposes of this report, the process of manipulating the regulating valve to apply or release the brakes is referred to as feed-valve braking.

[10] The emergency application of brake valves is dependent on the movement of air past a brake valve at a high enough rate to move the valve into an emergency application position. Generally a minimum brake-pipe pressure of 45 psi is required to initiate and propagate an emergency brake application.

not slow, but continued to pick up speed. Neither the conductor nor the engineer could remember whether they had heard air exhaust after the emergency application.

At MP 59, about 2 miles from the point of impact, the engineer spent about 8 seconds trying to reverse the motors, but without effect. By this time the train was moving 44 mph.

Table 1 contains an excerpt from the Cajon dispatcher's tape. There were no corresponding times to the recorded voices. The UP helper crewmembers were not recorded on the transcript. (They had left their train with a hand-held radio shortly before the collision, but the radio could reach only their own train's head-end crew. The helpers' radio could not be picked up by the dispatcher's radio or its recorder.)

Before the collision, the two crewmen from the helper had left their train and followed a dry sandy creek bed north, through scrub brush and woods, to a spot about 50 yards from the track. From there they watched the collision, which occurred at 5:21 a.m. According to the brakeman, almost immediately after leaving the helper units and crossing the tracks toward the mountains, they saw headlights "bearing down," so they ran for cover and watched the Santa Fe train run into the rear of the coal train. The helper engineer said,

> I turned around and saw the Santa Fe unit hit the rear end of my units. And as it did, the lead motor [locomotive unit] went airborne over my power and did a 180-degree turn and come down and lay on its side. The second unit, I believe, was a Santa Fe unit number 144. It also went airborne and did about a 45-degree turn and came to rest on top of the Santa Fe unit. The third unit just went straight into the back end of our train, more like a plowing motion. It didn't go airborne that much. It more or less plowed into it. Then the cars behind the power, they started doing a jack-knifing motion and coming to rest in that fashion.

Table 1 -- Radio transmissions

The Speakers are designated as follows:

SF	The crew on the Santa Fe train
DS	The Cajon dispatcher
UP	The crew on the UP train
3492	Another UP train in the area
877	Another Santa Fe train in the area

SF:	We're in emergency and we're, uh, we're not slowing down. Come in dispatcher.
DS:	Santa Fe Cajon dispatcher. Over.
SF:	Yeah, we're uh...
DS:	Santa Fe Cajon dispatcher. Over.
SF:	Can you move that UP train at Cajon?
DS:	Yeah. You're following the Amtrak right down the hill. Over.
SF:	Well, we are in emergency, and the rear end's not going in the big hole [*Big hole* is railroad slang for an emergency brake application.]
DS:	Is this the coal train? Over.
SF:	No, this is the train behind the coal train.
DS:	Is this the Santa Fe 576 West?
SF:	The 576 West.
DS:	What is your speed right now? Over.
DS:	Santa Fe 576 West, what is your speed right now? Over.
SF:	576 to the Cajon Sub. Over.

continued on next page

The Santa Fe locomotive units and the first three cars were destroyed. The fourth car derailed and was damaged. The rest of the train (cars 5 through 29) stayed on the rail and was undamaged. The two helper locomotive units on the end of the coal train were also destroyed.

The Santa Fe crewmen had jumped from their train before the collision. Both left through the front door on the left side of the locomotive cab. Both were injured in the jump: the conductor sustained minor injuries, the engineer sustained major injuries.

The conductor stated that before he jumped, he had noticed that the air gauge on the head-end monitor indicated that the EOT device was showing 60 psi at the end of the train. The engineer could not recall having observed the device.[11]

After witnessing the collision, the helper crewmen looked for survivors, and they found the Santa Fe conductor about 500 feet back along the Santa Fe train wreckage. He was bloody and showed signs of being in shock. The helper engineer later said, "The weather conditions at the accident site were cold, about 20 or 30 degrees and clear." He gave his jacket to the conductor, left him with the helper brakeman, and looked for the Santa Fe engineer. As he walked east, he saw emergency vehicles by the highway 138 overpass. He went toward an ambulance to get help for the Santa Fe conductor and found the paramedics loading the Santa Fe engineer on a back

Table 1 — Radio transmissions—Cont.

SF:	Come in UP helpers.
SF:	Come in UP helpers.
DS:	Santa Fe Cajon dispatcher to Santa Fe 576 West. Over.
SF:	UP helpers, get off your train.
SF:	Helpers, get off your train. You got a train coming your way.
DS:	Santa Fe Cajon dispatcher to Santa Fe 576 West. Over
SF:	576 West.
DS:	Are you the one that is in emergency? Over.
SF:	Yes, we are.
DS:	What is your speed now? Over.
SF:	40, 40, 45.
SF:	Dispatcher, why don't you let that UP that is at Cajon flag by that red signal at Cajon westbound?
DS:	UP coal train 9450. Over.
UP:	We're coming on out. Let's get up some speed. Let's go.
UP:	Hello helper. Come out with power. Get to going.
[UP helper crew calls UP head-end crew]	
UP:	Coal train.
[UP helper crew tells UP head-end crewmembers of Santa Fe's warning to get off their train]	
UP:	Get off those engines now! Let's go!
UP:	Coal train helpers, get off the power! Get off the power! Coal train is in emergency at Cajon!
DS:	UP coal helpers, did you acknowledge that? Over.
UP:	UP coal train to the dispatcher. Over.
DS:	Go ahead. Over.
UP:	Yes, I have instructed the helpers to get off the power. We are getting off also.
DS:	Is your train stopped?
UP:	Yes sir. They told us to get off the power [before] it was too late.
DS:	All right, are you stopped and you're, uh, abandoning the train? Is that correct?
UP:	Yes sir. I don't have any other choice. The helpers are already off the train. Over.
DS:	All right.
DS:	Cajon UP 3492 East. Over.

continued on next page

[11]Brake-pipe pressures are recorded by the event recorder at the locomotive. No brake-pipe pressures are recorded for the end of the train.

board for evacuation. The conductor was subsequently also evacuated.

When the helper engineer walked past the derailed Santa Fe train, he noticed the wheels were not hot.

> I had a look at the wheels because I was thinking, "These wheels are going to be hot, or smoking, or something." I looked at the wheels and didn't notice anything--they weren't even warm. I did see grease on some of the wheels, you know, how we pick up grease and stuff....and it wasn't burned off, so in my assessment, they never even got warm.

Table 1 — Radio transmissions—Cont.

3492:	We're stopped at the hot box detector.
DS:	All right, thank you. Over.
877:	Santa Fe 877 to the Cajon Sub.
DS:	Cajon Sub.
877:	We're stopped here at Summit. We will wait for your instructions on the south track. Over.
DS:	Okay 877, thank you. Over.
UP:	Emergency! There is a big ball of fire!
DS:	Go ahead. Over.
UP.	Get an emergency person...as soon as you can! They just hit the rear end of this train!
DS:	Is this the head end of the 9450?
UP:	It's the head of 50, and we can see a ball of fire! Get some emergency personnel out here!
DS:	Okay, we got emergency on the way now.

Injuries

Table 2 — Injuries from this accident

Injuries	Santa Fe Crew	UP Crew	Total
Fatal	0	0	0
Serious	1	0	1
Minor	1	0	1
None	0	5	5
Total	2	5	7

Train Damage

The total estimated equipment damage was $3,977,900 for both trains. Table 3 shows the estimates for the locomotives and cars calculated at the replacement value.

Table 3 — Replacement value of both trains

Equipment	Santa Fe	UP
Locomotives	$2,321,900	$1,261,000
Cars	390,000	5,000
Total	$2,711,900	$1,266,000

The collision destroyed about 360 feet of track structure, costing about $30,000. Approximately six spans (600 feet) of pole line, costing about $5,000, were destroyed in the collision area. Total damage was estimated to be $4,012,900.

Personnel Information

Santa Fe Crew — The engineer, who was 50 years old, had been on vacation for 2 weeks, starting in November over the Thanksgiving holiday (11/22/94 to 12/05/94). When he returned, he worked 7 of the next 9 days, for a total of 61.8 hours, before the accident. In an interview with Safety Board investigators, he said that he had felt well rested before going on the accident trip.

During the same period, the conductor, who was 47 years old, had worked a total of 74.6 hours.

The crew went on duty at its away-from-home terminal, Barstow, at 1:45 a.m., on December 14, and had been off duty since 3:15 p.m., December 13, for a total of 10-1/2 hours off duty. Both the conductor and engineer stated that when they went on duty, they felt they had had sufficient sleep and were "well rested."

Under the Hours of Service Act, 49 CFR 228.19, a crewmember may not be on duty unless he has been off duty for at least 8 consecutive hours during the preceding 24 hours. In the 24 hours preceding the accident, the engineer had been off duty for 17.8 hours. The Act also requires that a crewman who has worked for 12 consecutive hours have a break of at least 10 consecutive hours before resuming work. The conductor, whose last trip had lasted more than 13 hours, had had a 10-hour break before starting the accident trip.

Both the engineer and conductor were qualified on operating rules and on the Cajon Subdivision's physical characteristics. The conductor had about 25 operating service years on the Cajon Subdivision. The engineer had 13 engineer service years, having been recertified on December 31, 1992. He had successfully completed an on-board 3-year certification ride on October 25, 1994.

UP Crew — The crew included a conductor, an engineer, and a student engineer. They had gone on duty at Yermo, California, at 11:00 p.m., on December 13. They had been off duty for 21 1/2 hours before the trip.

The helper crew, a conductor and an engineer, had gone on duty at Yermo at 6:15 p.m., on December 13, the day before the accident. They had helped several trains before they coupled onto the rear of the coal train at Victorville, California, at 3:29 a.m., December 14.

Train Information

At the time of the accident, the Santa Fe train had four diesel-electric locomotive units and 55 loaded freight cars, 13 of which were articulated five-pack well cars. The train was 5,261 feet long, including the locomotive, and had 4,882 trailing tons. It had 88.8 tons per operative brake.[12] The train was equipped with a one-way EOT device.

The locomotive units were equipped with 26L schedule brake equipment. The lead Santa Fe locomotive unit brake cut-off valve did not have a "PASS" position for graduated release on passenger trains. The significance of this air brake equipment will be explained later. Cars were equipped with ABD and ABDW control valves.

The train originated in Birmingham, Alabama, on the BN Railroad and was destined for Los Angeles, California. It had a 1,000-mile air brake test and a mechanical inspection at Belen, New Mexico. The train stopped at Barstow for its last crew change before the accident. The inbound crew detached the locomotive consist and took it to the diesel service area. The engineer of the inbound crew, who operated the train from Needles, California, to Barstow, stated that the train had handled normally and that he had had no problems with the air brakes. The outbound crew (accident crew) took a new locomotive consist from the diesel service area and attached it to the train. The consist was not changed in any other way.

The UP train had three diesel-electric locomotive units pulling 82 loaded coal cars. The train had 10,441 trailing tons and, excluding the locomotives, was 4,405 feet long. At the time of the accident, two diesel-electric locomotive units were coupled at the rear of the train to push in helper service. These units were assigned as UP Helper Assignment LZBH-3. The coal was loaded at mines in Utah. The train originated at Provo, Utah, and was destined for the Los Angeles Kaiser Terminal in California.

Track and Signal Information

Track — The railroad was owned, maintained, and dispatched by the Santa Fe, but UP trains operated over the territory between Dagget (Barstow) and West Riverside on a trackage rights agreement.

The track was double main track. By compass direction, the track ran north-south between Barstow and San Bernadino; but by timetable, it was part of a larger east-west route. The MP numbers increased to the west. Near MP 56.5, the tracks split from a single right of-way into two routes; the routes merged again near MP 62.6. The separated tracks were designated as the "south track" and the "north track." The accident happened on the south track.

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[12]The tons per operative brake is the gross trailing tonnage of the train divided by the total number of cars having operative brakes.

The north track MP numbers had an *X* suffix since the routes were separate and since the north track was about 1 1/2 miles longer than the south track. The average gradient of the north track was less than that of the south track (2 percent instead of 2.75 percent).

The Santa Fe maintained and inspected the accident track, the south track, to meet or exceed FRA Class-IV track standards. Approximately 30 freight and two passenger trains used the track daily, totaling about 45 million gross tons annually. The track was inspected once each week day (Monday through Friday).

The south track was constructed of 136-pound RE section continuous welded rail (CWR) rolled in 1979. The CWR was set on concrete ties and fastened with clips. The track structure rested on a foundation of crushed granite and dolomite ballast. The track had been undercut when the concrete cross ties were installed in January 1994. At that time, the existing CWR was reset in place and the track re-surfaced.

Safety Board investigators, accompanied by Santa Fe and FRA officials, inspected the track after the accident. The Safety Board did not observe a defect or visible evidence, such as excessive grease or foreign materials, on the ball of the rail that would have made the rail head slippery or caused a loss of friction between it and the train wheels. Safety Board investigators also reviewed track records to determine whether Santa Fe or FRA inspectors had noted any anomalous conditions during their periodic examinations and whether any noted defect had been repaired. The records show that all identified anomalous conditions had been repaired.

Signals — The train movements on the Santa Fe Cajon Subdivision were controlled by a centralized traffic control[13] (CTC) signal system, which, in turn, was controlled by a computer-assisted dispatching center in Schaumburg, Illinois. The westbound absolute signals[14] (control points) on the south main track were at Summit, MP 55.9, and at Cajon, MP 62.8. Intermediate (automatic) block signals[15] were located between the control points, at MP 58.3 and at MP 60.3.

The recordings of the track and signal system were recovered. They were made from electrical contactor positions integral to the signal system. The following table summarizes the train movements extrapolated by the Safety Board using the recorded signal indications:

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[13]A block signal system within which train movements are authorized by block signals whose indications are monitored and controlled at a central control location.

[14]An absolute signal controls or governs a block or section of track that, if it occupied by one train, cannot be entered by another. If the track is occupied, the absolute signal shows a stop indication, or a red light aspect, requiring the oncoming train to stop until signals tell it to proceed.

[15]These signals were actuated by train movement on the track circuit.

Table 4 — Recorded Train Movements

Time	Signal Location	Event (extrapolated by the Safety Board)
4:20:39	Summit	UP coal train arrives
4:39:23	Summit	UP coal train departs
4:51:30	Cajon	UP coal train arrives
4:53:	Summit	Santa Fe train arrives
4:57:34	Summit	Amtrak train crosses over from south to north track
5:09:33	Summit	Santa Fe train departs
5:15:07	Cajon	Amtrak train crosses over from north to south track
5:16:45	Cajon	Crossover realigns for UP coal train
5:18:26[16]	Cajon	Signal clears to proceed UP coal train
5:21:21	Cajon	Collision

Operations Information

Method of Operation — Train movement over this territory was controlled by operating rules, timetable instructions, and the signal indications of a CTC system.

Since the Santa Fe train exceeded 4,500 trailing tons, its maximum authorized speed down the grade between Summit and Cajon was 15 mph. (The engineer determines the maximum permissible speed according to a logic matrix in the Timetable Special Instruction (E) for the Cajon Subdivision of the Santa Fe System of Timetable No. 4. The matrix is based on the train's weight, grade, and braking capacity.[17] These instructions explain the speed restrictions, dynamic brake requirements, retainer requirements, and the use of helper locomotives for westward trains between Summit and San Bernadino.)

Feed-Valve Braking — According to manufacturers and railroad train-handling rules, the prescribed method of braking is to use the automatic brake-valve handle. *Feed-valve braking* is braking a train by using the regulating valve. The regulating valve is intended for setting the trainline operating pressure, not for applying or releasing brakes. The brakes are designed to be applied and released by the automatic brake-valve handle.

The engineer stated that he used the regulating valve to apply the brakes when the train descended long mountain grades. He stated that doing so was common practice among the engineers who operated over the territory. Santa Fe supervisors stated that they taught feed-valve braking. The Santa Fe manager of train operations confirmed that this was so.

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[16]The dispatcher cleared the signal at the urging of the Santa Fe traincrew. However, by this time it was too late to move the UP train out of the way since the helper crewmembers had left their locomotive units and the wreck was imminent.

[17]*Braking capacity* includes the number and types of locomotive units and their dynamic braking capability.

Rule 305 of the Santa Fe *Air Brake & Train Handling Rules* states:

> B. When applying train brakes, the initial brake-pipe reduction must not be less than 6-8 psi. Under normal operating conditions **the use of the feed or regulating valve to apply and release the train brakes is prohibited.** (Emphasis in the original.)

The Santa Fe manager of train operations stated that going down grade between Summit and Cajon was not operating under "normal operating conditions" and that feed-valve braking was necessary because of the long period of time (50 or 60 minutes) that the train brakes had to be applied.

Traincrew Efficiency Testing and Management Oversight — The Santa Fe Railway's traincrew efficiency testing and management oversight was based on a program accepted by the FRA for engineer certification, rules examinations, check rides, and efficiency testing. Engineer recertification is done every 2 years.

The Santa Fe engineer became an engineer on March 10, 1981. He took his last recertification knowledge examination on October 16, 1992, and scored 85 percent. Passing requires a score of 90 percent or better, and he retook the test that day and scored 97 percent. He was recertified on December 31, 1992. Since the FRA locomotive certification program had begun, the road foreman had given him the following check rides[18] and tape reviews:

Date	Type of Review
01/15/92:	annual event-recorder tape review
06/02/92:	3-year on-board check ride
05/01/93:	annual event-recorder tape review
10/25/94:	3-year on-board check ride

The Santa Fe engineer took his last rules examination on December 8, 1994, and passed with a score of 93. From March 1, 1994, to November 13, 1994, he was observed for efficiency 179 times. He passed each time. He had one rules violation on his record, dated February 20, 1992, for speeding. He was laid off for 35 days, of which 25 were suspended.

Between January 13, 1994, and November 8, 1994, the Santa Fe conductor was observed for efficiency 131 times. He had three failures: two involving Rule #6, which is about complying with form B, a type of train order form that allows a train to run ahead of a superior train, and one involving Rule #20, which is about the proper use of the radio.

[18]When a supervisor rides a train in order to check on how the engineer is handling the train and complying with the rules, the supervisor is taking a check ride.

Meteorological Information

The following weather observations were obtained from a McIDAS[19] at Ontario, California, which is about 18 miles south-southwest of Cajon and the location of the weather station closest to the site of the accident.

- 4:46: Clear skies; visibility 10 miles; temperature 41 degrees F; dew point 38 degrees F; winds calm.

- 5:46: Clear skies; visibility 15 miles; temperature 41 degrees F; dew point 39 degrees F; winds calm.

Medical and Pathological Information

San Bernadino Medical Center took blood and urine samples from each of the two Santa Fe crewmembers. The conductor provided his samples at about noon on the day of the accident (6.5 hours after the collision); the engineer provided his at 12:58 p.m. Part of each sample was shipped to CompuChem Laboratories, Inc., Chapel Hill, North Carolina, for analysis. The samples were screened according to the regulations in 49 CFR 219. The results were negative.

On January 4, 1995, CompuChem Laboratories received permission from the FRA, at the request of the Safety Board, to forward samples to the Center for Human Toxicology at Salt Lake City, Utah, for more testing. CompuChem Laboratories had tested the samples for what is commonly referred to as the NIDA 5, or marijuana, cocaine, phencyclidine, opiates, and amphetamines. (The FRA is not required to test for any substances other than the NIDA 5.) However, drugs other than the NIDA 5, such as some nonprescription cold remedies, may impair an operator's performance.

The conductor's samples were negative. The engineer's blood was positive for pseudoephedrine (92 ng/ml). His urine was positive for phenylpropanolamine (5 ug/ml) and pseudoephedrine (47.8 ug/ml). (Pseudoephedrine and phenylpropanolamine are commonly found in over-the-counter cold medications.) However, the levels reported were not high enough to suggest that the engineer's performance had been affected.

The engineer told Safety Board investigators during a telephone interview that he had bought an antihistamine at a convenience store the night of the accident for a "stuffy nose." He said he couldn't remember the brand and that "the package was burned up in the wreck."

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[19]McIDAS stands for Man Computer Interactive Data Access System, which is administered by the Space and Engineering Center at the University of Wisconsin at Madison.

The UP train employees were not tested for drugs or alcohol after the accident. In the judgment of the railroad officials at the accident site, the coal train was neither causal nor contributory to the accident, and therefore no drug or alcohol testing was warranted.

Survival Factors

Mercy Helicopter No. A-2, with a crew of three (a nurse, an emergency medical technician, and a pilot) was dispatched to the scene at 5:57 a.m. It arrived at 6:08 a.m. and left with the injured crewmen at 6:40 a.m. Both the Santa Fe conductor and the Santa Fe engineer were transported from the accident scene by helicopter to San Bernadino Medical Center, where they were admitted about 6:49 a.m.

The conductor was discharged at 4:50 p.m. the next day. He had sustained closed head trauma, scalp lacerations, and a dislocated right-ring finger.

The engineer was not discharged until 3:40 p.m. on December 21, 1994. He had fractured his right distal radius, his left fifth metacarpal, and his spine (T-7 through T-9). He had also dislocated his right thumb, suffered lacerations to the face, and had several teeth broken.

Emergency Response

The fire-department dispatcher in San Bernardino received the first report of the accident. It came from the Santa Fe dispatcher at 5:25 a.m. The department immediately dispatched five engines and one battalion chief. They arrived at the scene at 5:56. A field command post and treatment area were established at 6 a.m. on the west side of US Route 15. The first units to arrive gave medical aid to the injured and then assessed the situation and reported the conditions back to the incident commander.

Disaster Preparedness

After receiving the initial accident notification from the railroad dispatcher and the first on-scene reports, the incident commander decided that the situation did not warrant implementing the disaster plan. No one had died, no hazardous materials were involved, no one had been evacuated, and the public was not involved.

Tests and Research

Signal Tests — After the wreckage was cleared and the track was repaired, the track and the signal system were restored to service. The first train passed through the collision area about 7:00 a.m. on the day after the accident. At that time, a signal test was conducted between Summit and Cajon of both the control points and automatic signals. A signal sequence test was conducted for a westbound movement. The signal system worked as designed, displaying the proper signal aspects.

Event-Recorder Tests — Three of the four Santa Fe locomotive units had electronic event recorders.[20] Only one recorder, a Pulse solid-state digital recorder on Santa Fe locomotive 144, survived the collision and resulting fire.[21] Because of encroaching fire, Santa Fe mechanical personnel removed the recorder in the presence of an FRA inspector. Under the direction of Safety Board investigators, the Santa Fe personnel then downloaded the recorder to computer disc at the accident site and produced a hard copy of the data so that it could be used immediately. The multi-event recorder sampled at 1-second intervals the following data: date, time, throttle position, direction of movement, brake application, brake pressure, and wheel rotations, which are converted to distance and speed.

At the request of the Safety Board, the Santa Fe mechanical department at Barstow forwarded the event recorder to the Safety Board's laboratory in Washington, D.C. The Safety Board determined that the recorder functioned as designed[22] and made a printout of the event-recorder data. The Safety Board's printout verified a printout made by Santa Fe from the computer disc information that its on-scene personnel had downloaded at the accident site.

Wheel Inspection — On December 20, all the derailed locomotive and car wheels from the Santa Fe train were recovered from the wreckage and arranged at the accident site in the exact order that they were on the train at the time of the accident.[23] The wheels were tread braked with composition brake shoes. All wheels from the locomotives units and from the first three cars showed signs of having been overheated, including blueing (see figure 5), wheel plate discoloration, and/or metal flow. None of the wheels on any of the others cars showed any signs of having been overheated.

The brake shoes on the locomotive units and the first three cars also displayed evidence of having been subjected to extreme heat because of heavy braking. The evidence included heat-checked brake shoes, missing and partially missing brake shoes, and metal flow where the backing plates had contacted the wheel treads. (See figure 6.) None of the brake shoes on any of the other cars showed any signs of having been overheated.

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[20]Locomotive unit 5976 did not have an event recorder.

[21]The Safety Board is currently working with the FRA to improve the capacity of event recorders to survive accidents.

[22]Pulse Air Manifold Number 50029474, Pulse Train Trax Control Box Number 50029490, Axle Alternator Number 13-3-30126, and Pulse Telemetry Device Number 2406.

[23]The order was determined from computer records of wheel serial numbers.

Figure 5 — Metal flow on a wheel tread

Figure 6 — Wheel showing evidence of discoloration, or "blueing"

Postaccident Air Brake Testing

At Accident Site -- On December 19, while the train was still at the collision site, Safety Board investigators observed as Santa Fe and FRA inspectors removed the trainline and air brake hoses of the first three cars. The trainline was cut into 3-foot sections and inspected for a blockage. No blockage, full or partial, or other foreign matter was found in either the trainline or the air brake hoses.

Between 8 and 9 a.m. and before any derailment clearing had been done, Santa Fe and FRA inspectors looked at all cars behind the third articulated car. They inspected the running gear, trucks, and air brake system on each car. At the time, the locomotives were not attached to the train, and there was no air in the trainline.

The inspection revealed that all trainline hoses were connected and that all the trainline angle cocks and all the car cut-out cocks were in the open position. Six cars showed signs of brake-cylinder leakage, as evidenced by the brake-cylinder piston being in full or partial release position.

The investigators looked at the connections between the third and fourth cars. The angle cocks and cut-out cocks were in the open position. No unusual or fresh strike marks on the angle cocks were found to indicate that the angle cocks had been struck and turned from other equipment in the derailment. The inspectors did not find any creases or crimp marks on the air hoses between cars.

About 4:15 p.m., the locomotives were attached at the east end of the 5th through 29th cars (25 cars) for an application-and-release test.[24] This was done to clear the congestion at the accident site and to ensure that it was safe to move the cars. The pressure in the trainline was reduced by 20 psi, and then an emergency application was made, followed by a release. A walk-by inspection of the cars showed that the brakes applied and released sufficiently to allow movement. The cars were then taken to Summit.

At Summit -- The Summit inspectors repositioned the locomotives on the west end of the 5th through 29th cars to simulate the flow of air through the trainline at the time of the accident. They gave the cars an equivalent of the initial terminal air brake test. Using the automatic brake handle, they reduced the pressure in the brake pipe by 20 psi and followed that with an emergency application. They also tested the brake pipe for leakage.

The cars had 4 psi leakage per minute.[25] All air brakes applied and brought the brake shoes against the wheels. The brakes remained applied until released from the locomotive control valve. All the brakes released without fouling. An 11 1/2 inch piston travel was

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[24]All postaccident air brake tests, unless otherwise noted, were performed with a 90-psi brake pipe.

[25]According to 49 CFR 232.12(b)(1), trainline leakage cannot exceed 5 psi per minute.

recorded on TTX 602374, exceeding the FRA maximum allowance of 9 inches for body-mounted brake cylinders.[27]

The inspectors repeated the test, this time reducing the pressure in the brake pipe by using the regulating valve instead of the automatic brake-valve handle. The results were the same.

After the tests, the consist was sent back to Barstow.

At Barstow -- The day after the accident, Safety Board investigators tested the undamaged accident cars at Barstow. They tested the car brakes at a number of air brake pressures to replicate as closely as possible the full range of operating pressures at the time of the accident. In order to test and inspect the cars, the train was divided into five sections. An inspection team from the Safety Board mechanical group, which included at least one Safety Board investigator, was assigned to each section.

The inspection teams performed the first two tests using the automatic brake-valve handle to see whether in-train forces and dynamic conditions had influenced the braking of the train. For the first test, they made a minimum reduction (5 to 7 psi) in the trainline pressure while the train slack was bunched and then stretched. For the second test, they did the same thing, except that they reduced the pressure in the trainline by 20 psi.

A third test involved duplicating the brake applications by using the regulating valve, including timed intervals as dictated by the event-recorder data, while the train was bunched and then stretched to simulate dynamic conditions.

The fourth and fifth tests were done in the same manner, except that the fourth test was done with an 18-psi brake-pipe reduction by the regulating valve, and the fifth test was done with an 18-psi brake-pipe reduction by the automatic brake valve.

The fact that a brake shoe is touching the wheel tread does not necessarily mean that the wheel is being effectively braked. To determine whether the brake shoes had been applied on the accident train with an effective amount of force, carmen using 24-inch-long pry bars tried to pry, or bar, the brake shoes away from the wheel tread. Ten cars had soft set, meaning the brake shoes could be pried away from the wheels. One car's brakes failed to apply during test four, but all brakes applied on test five. Four cars[28] from the group of ten with soft set were selected for a single-car air brake test and were switched out of the train. Two other cars[29] were also switched out for nonbrake-related repairs.

[27]49 CFR part 232.17 (a) (2) (ii)

[28]The following cars were selected for the single-car air brake test: DTTX 64004, 63024, and 54018 and RTTX 601263,.

[29]TTX 602374 and 601922.

The following is a synopsis of the results from the above tests:

Team #1, cars 4 through 7:

All cars had positive brake applications, although cars 5, 6, and 7 appeared to have some soft set.

Team #2, cars 8 through 11:

Cars 8, 10, and 11 performed as designed on all the air brake tests. Car 9, DTTX 64004, did not perform as expected on all air brake tests. The 5/6 and 7/8 wheel sets did not respond for all four tests, including emergency. During the third test, the 3/4, 5/6, and 7/8 wheel sets did not apply with a minimum 3-psi brake-pipe reduction.

Team #3, cars 12 through 15:

Cars 12, 13, and 14 had some soft set. The brakes on car CP 521173 did not apply in emergency. The B-end brakes of car DTTX 720378 were not cut in, and a service portion of the brake control valve of the car had a leak.

Team #4, cars 16 through 22:

The A-end brakes of car TTAX 353539 did not apply. The brake cylinder of KCS 8656 lost pressure on the first test, but not on subsequent tests. TTX 602374 had excessive piston travel (11 1/2 inches).[30] TTX 601263 failed to respond to the second application of the third test until a 12- to 14-psi reduction had been made. All other responses were as designed. Cars 16, 17, 18, 19, 21, and 22 appeared to have soft set.

Team #5, cars 23 through 29:

The brake cylinder of car CN 639265 failed to hold pressure. The brake shoes did not go tight against the wheel tread; however, the brake shoes did not release.

The next day, December 16, the selected four cars received single-car air brake tests and were repaired. The investigators did not find any significant repair-related items.

Car DTTX 64004 remained at Barstow awaiting parts. The other cars were returned to the consist. After the cars were back in the train, a 20-psi brake-pipe reduction was made from an attached locomotive unit, and the cars were checked for soft set, using pry bars. Only one car, TTX 602374, was found with soft set. An initial terminal air brake test was then performed with satisfactory results.

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[30] According to CFR 49 232.17(a)(2)(ii), "Piston travel on a standard body mounted brake cylinder which is less than 7 inches or more than 9 inches must be adjusted to nominally 7 inches."

The train departed Barstow at about 1:30 p.m. for Los Angeles with 24 of the original undamaged 25 cars that had been returned from the accident site. The train was observed in operation from Barstow to Los Angeles. No exceptions were noted with any of the cars. The train slowed normally at each brake application, including the Cajon Pass descent.

On December 21, Santa Fe inspectors in the presence of representatives from the Safety Board and the FRA gave the derailed and damaged fourth car a ball test, which consisted of blowing a 1-inch steel ball through the car's trainline. The test indicates whether there is a blockage in the trainline or air hoses. No blockage or restrictions were found.

At Los Angeles -- Upon arrival at Los Angeles, the train was weighed and unloaded to ensure that its weight, on which the tons-per-operative-brake and train handling were based, was correct and did not cause or contribute to the accident. All weights were found to be correct and corresponded to the weights recorded on the consist lists.

On December 20, five cars were randomly selected for a brake-shoe force test and a single-car air brake test.[31] Of the five, three were five-pack double-stack cars, and two were single-platform cars. Several cars were found to have air brake-cylinder malfunctions despite the fact that they had just been inspected, tested, repaired, and re-tested at Barstow. After disassembling the cylinders on several of the failed five-pack cars, the Safety Board investigators found that the packing cups, which had been replaced at Barstow, had not been lubricated properly, causing them to fold up and fail. The investigators also found that the packing cups were out of date,[32] a fact that they brought to the attention of the Santa Fe management on site. The defective packing cups were subsequently replaced.

The Santa Fe immediately initiated an extensive inventory of rubber air brake parts and removed all components at Los Angeles, Barstow, and Winslow (Arizona) that were found to be out of date. By December 29, the Santa Fe's maintenance team had identified and discarded 121 rubber air brake items with an expired shelf life. By January 12, an electronic alert (e-mail) was sent to all Santa Fe users who had ordered rubber air brake parts with a shelf life. The alert instructed the user to check the expiration dates. Pre-assembled air brake sub-systems that are supplied by contractors were sampled by disassembly and spot checked for out-of-date parts and misapplication. All appropriate mechanical and supply personnel were also given remedial training in the identification and disposal of out-of-date parts.

AAR Standards for Minimum Brake-Shoe Force -- As a result of the accident, the Santa Fe and the UP asked the Safety Board to allow the Association of American Railroads (AAR) to assist in the investigation. The AAR became a party to the investigation and provided air brake experts. The AAR investigators supervised the brake-shoe force tests[33] on the

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[31]DTTX 64004, 63024, and 54018 and TTOX 140315 and 145798.

[32]Railroad air brake rubber parts are required to have an expiration date according to AAR Specifications S-4001, dated March 1, 1993, *Performance Testing of Air Brake Rubber Products*, paragraphs 8.1 and 8.2.

[33]The brake-shoe force test is also called Gym Shoe test or Golden Shoe test.

accident cars at the Santa Fe's Hobart Yard in Los Angeles on December 20. The purpose of the tests was to determine whether the braking system and resulting brake-shoe forces were consistent for the intermodal cars involved in this accident and whether inconsistent and/or ineffective braking may have caused or contributed to the accident.

Five of the cars from the accident train were given the brake-shoe force test. The cars were made by three different car builders.[34] Representatives from the Santa Fe, the AAR, and the three car builders conducted the tests in the presence of representatives from the Safety Board, the FRA, and the California Public Utilities Commission.

The brake-shoe force test involves removing all brake shoes from a car truck and replacing them with sensing devices that indicate the braking force of the brake shoe applied to each wheel. Although the tests revealed the cars consistently braked according to the brake-cylinder pressure, braking adequacy could not be totally determined because there are no minimum brake-shoe force standards. The AAR has proposed an empirically developed minimum standard of 100 pounds force for each brake shoe on a tread-braked wheel. Such a force is considered the minimum that will produce a bench-mark level of effective braking for the wide variety of tread-braked freight cars. As a result of the tests in Los Angeles, the AAR agreed to expedite issuing national standards for minimum brake-shoe forces.

EOT Device -- The EOT device from the Santa Fe was tested to determine whether it was working at the time of the accident and sending proper trainline pressure readings to the controlling locomotive cab. The device was tested at Pulse Laboratories in Rockville, Maryland. It functioned as designed.

Santa Fe Simulations -- After the accident, the Santa Fe performed a number of computer simulations in order to analyze the accident train's performance. Safety Board investigators did not participate in the simulations. Santa Fe compared the simulations of the train's performance to the event recorder's speed graph and other data. The dynamic performance of the train could be duplicated only when a closed angle cock was simulated between the third and fourth cars. According to Santa Fe, simulations using the same train handling as recorded by the event recorder showed that if the train had been in emergency brake application, it would have stopped in less than 2,000 feet, assuming that all the cars had functioning brakes, and in 6,000 feet, assuming that only the first 11 cars had functioning brakes.

Santa Fe created additional simulations to model the train's slow down at Victorville and its stop at Lugo. These simulations revealed that the train demonstrated braking problems after it left Barstow. During the slow down at Victorville, the train's brakes were not fully responsive, and the stop at Lugo took 1/3 of a mile more than it should have had its brake system been fully functioning.

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[34]The three manufacturers were Thrall Car Manufacturing Company, Trinity Industries Incorporated, and Gunderson Incorporated.

Finally, the Santa Fe simulated the train coming into Barstow. These simulation results closely matched the event-recorder data when fully functioning brakes were modeled.

Trainline Blockage and Braking

The air brake system is designed to apply the brakes by intentionally reducing the brake-pipe pressure. (See appendix C.) However, brake-pipe pressure tends to reduce on its own, primarily through small leaks in the trainline at air hose connections between cars.[34] Air is pumped back into the trainline from the locomotive to maintain the set brake-pipe pressure in the trainline against this leakage.[35] The leakage and the air sent back into the trainline create a gradual linear drop in air pressure from the locomotive to the end of the train. This air pressure drop is called *gradient*. Generally the gradient is no more than a 15 psi difference.

The gradient is dependent on the amount of air leaking from the trainline and the distribution and location of the leaks. It is also dependent on air temperature, the brake-pipe pressure, and the length of the train. After the brake-pipe gradient is established, it remains relatively stable unless acted on by a brake application, release, or recharging of the brake system. Thus, even though the brake-pipe pressure set by the regulating valve in the locomotive cab may say 90 psi, the actual brake-pipe pressure throughout the rest of the train will be gradually less toward the end of the train.

Each car's control valve and brake system responds to the brake-pipe pressure it senses, regardless of its particular location in the train along the gradient. When a car's control valve senses a 1-psi or greater drop in brake-pipe pressure, the brakes apply; when a car's control valve senses a 1-psi or greater rise in brake-pipe pressure, the brakes release, notwithstanding the local brake-pipe pressure at that point along the gradient. However, the brake-cylinder pressure of a brake application will diminish somewhat as the brake-pipe pressure drops along the gradient toward the end of the train.

If the trainline is blocked or significantly restricted, no maintaining air can flow to maintain the set brake-pipe pressure and the gradient will no longer be maintained or will remain stable. The trapped brake-pipe air pressure will attempt to equalize throughout the blocked trainline and the air will flow from the higher pressure area at the front of the train to the lower pressure area at the rear of the train. This creates a wave that may alternately apply and then release brakes as it travels to the end of the train, reflects off the end, and heads back towards the front of the train, progressively weakening in energy until the air pressure stabilizes. This phenomenon is affected by the leakage factors previously mentioned and the environmental factors of temperature, train length, etc. Generally, any brakes to the rear of the

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[34]According to 49 CFR 232.12 brake-pipe leakage cannot exceed 5 psi per minute.

[35]The portion of the air brake control valve in the locomotive which does this is called the *maintaining feature*. The maintaining feature functions even when a brake-pipe reduction is made to apply the brakes in order to compensate for leakage and prevent a greater-than-intended reduction of brake pipe pressure.

blockage or restriction will either apply weakly or not at all. The accident train's brakes from the fourth car on back displayed what would be expected of a blockage or restriction: little or no evidence of braking.

ANALYSIS

General

Based on the available evidence, the Safety Board concludes that the weather, the signal and train control system, the track, dispatcher operations, and drugs and alcohol neither caused nor contributed to the collision of the trains. The train crewmembers were rested in accordance with the Hours of Service Act and were qualified to perform their duties in accordance with Santa Fe procedures and accepted practice.

When Safety Board investigators examined the event-recorder data from the Santa Fe train, they took no exception to the engineer's train handling. The engineer's work schedule, his statement that he felt well rested, and the event-recorder data do not suggest that fatigue was a factor in this accident.

Although the blood of the Santa Fe engineer showed traces of phenylpropanolamine and pseudoephedrine, the amounts were consistent with his statement that he had taken an antihistamine the night of the accident. Since pseudoephedrine and phenylpropanolamine are commonly found in over-the-counter cold medications and were found in relatively low amounts in the engineer's blood, the Safety Board believes that drugs did not cause or contribute to the accident.

Investigation

At the accident site, there was evidence of effective braking on only the locomotive units and the first three cars in the consist. These were the only vehicles in the consist with blueing of the wheels and tread metal flow consistent with the expected heat generation of heavy braking and an emergency brake application prior to the collision. Conversely, there was no wheel discoloration (blueing) on any of the remaining cars in the train (cars 4 through 29). Nor was there any other indication of braking force applied to the tread surfaces of any of the wheels of the remaining cars that would be consistent with the heavy braking and emergency brake application prior to the collision. The disparity in braking evidence between the lead vehicles in the train and the rest of the train was so stark as to indicate that no braking effort had been exerted after the third car. Investigators then attempted to determine whether there had been some kind of blockage or restriction in the air brake trainline between the third and fourth cars that would have prevented the brakes from applying on the fourth and all succeeding cars.

The first source examined was the angle cocks at the end of each car, particularly the third and fourth cars, which are designed to block trainline air flow when cars are connected and disconnected. It is known that the train had a complete and open trainline at Barstow because a set-and-release test was done and confirmed by the yard tower supervision. No turned (closed) angle cocks were found by investigators during their initial inspection at the accident site. In order to turn an angle cock, the handle must first be lifted to allow handle and valve rotation. The dynamics of the collision may have returned an angle cock handle to an open position, but such an occurrence would have most likely left strike marks. Since there were no strike marks on the angle cocks, a closed and/or reopened angle cock may imply some form of human intervention. Several previous railroad derailments investigated by the Safety Board have involved turned angle cocks due to theft and vandalism.[37] Investigators did not find any material evidence of vandalism.

If moisture in the trainline had frozen, the ice could have caused a blockage. Although no ice was found, it could have melted and evaporated after the accident. While the formation of ice is more likely in colder and wetter weather and while the temperature at the time of the accident was probably at or near freezing, the train had been traveling through a relatively dry semi-arid region. The engineer said the temperature was "cold, about 20 or 30 degrees (F) and clear." The weather data gathered over 16 miles away at a lower elevation was 41 degrees F and clear. The Santa Fe train had also been traveling through dry cool climates for some time. No evidence of frozen moisture was found.

Finally, a crimp in the air brake hose (the flexible connection of the trainline) at the end of the third or fourth car could have blocked or restricted the trainline. As the train began its descent to Cajon, the slack in the train's couplers and draft gear bunched together and may have bent or crimped an air brake hose, pinching off air flow to the rear of the train. Examination of both the third and fourth cars' air hoses found no weak or damaged air hoses, and no creases were found from bending. Investigators noted that the five-pack double-stack type of cars are not known for intermittent air hose problems.

The Santa Fe performed computer simulations on a train dynamics analyzer based on event-recorder, train-consist, and track data in order to provide some insight into the cause of the accident. The simulations matched the event-recorder data only when an angle cock was closed or a blockage was placed between the third and fourth cars. According to further simulations, even with significant degradation of the braking system and only 11 functioning car brake systems, the train would have stopped short of the collision. These simulations support the physical evidence found on the wheels at the accident site; only the locomotives and first three cars were braked.

Despite the extensive postaccident air brake inspection and testing and numerous minor problems discovered in the testing process, the Safety Board was unable to find any postaccident air brake equipment problems that individually or collectively prevented the train from stopping short of the collision.

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[37]Railroad Accident Report--*Collision and Derailment of Southern Pacific Train at Garnet, California, August 23, 1986* (LAX86FR015), and Railroad Accident Report--*Derailment of Burlington Northern Train at Spokane, Washington, December 24, 1991* (LAX92FR006).

Barring a blockage or restriction of the trainline, the train should have responded to an emergency brake application and stopped before the collision. There was sufficient air pressure in the trainline at the rear (60 psi), according to the Santa Fe conductor, who read the EOT device before leaving the cab, and at the head (65 psi), according to the event recorder, which read the head-end trainline pressure, to cause an emergency propagation of the train's brakes. According to Westinghouse Air Brake Company (WABCO), a minimum trainline pressure of 45 psi is needed to initiate an emergency brake application of the train brakes.

Although the exact cause of a blockage or restriction is not known, postaccident inspection of the train's wheels, simulation of the train's event-recorder speed graph, and postaccident air brake system testing all support the conclusion that there was a restriction or blockage between the third and fourth cars. Therefore, the Safety Board concludes that because of a restriction or blockage, the train had functioning brakes on only the locomotive units and the first three cars and, consequently, was unable to stop in time to avoid the collision.

Two-Way EOT Devices

A two-way EOT device offers a key advantage that a one-way EOT device does not. The two-way device allows the locomotive crew to telemetrically initiate an emergency brake application from the rear of the train forward. This means that the entire train can be braked even if there is a blockage in the trainline. The Safety Board concludes that there would have been no accident had the train had a two-way EOT device.

Two-Way EOTs in Canada -- Since December 14, 1987, Canadian railways have been required to use a two-way EOT device called a TIBS (train information and braking system) with a distance measuring device. The TIBS consists of a sensing braking unit (SBU) with an emergency braking feature located on the rear of the train; a communications logic unit (CLU) in the locomotive that accepts, analyses, and forwards information to the display cab in the locomotive; an input and display unit (IDU) for the engineer; and a communications display unit (CDU) that combines the features of the CLU and the IDU.

Rail safety investigators from the Transportation Safety Board of Canada told Safety Board investigators that the Canadian railway carriers have not experienced any operational problems with the TIBS. The only significant reported problem involves the lack of visibility of the rear marker/light. The original requirement for two-way EOT devices was revoked effective August 9, 1995, at the request of the Railway Association of Canada (RAC) and its constituent railway companies. The basis for their request was that, because all aspects of the original requirement are now covered by the railways' internal documents, collective agreements, or have been replaced by other rules, the requirement had become redundant. Comments by the Canadian Railway Labour Association, the United Transportation Union, and the Brotherhood of Locomotive Engineers supported the RAC's position.

Two-Way EOTs in the United States -- Carriers in the United States are not required to have two-way EOT devices; the Safety Board, however, has a long history of advocating the use of such devices.[38] In 1989, the Safety Board investigated the derailment of a runaway Montana Rail Link freight train in Helena, Montana.[39] One conclusion drawn from that investigation was that a two-way transmitting EOT device would have allowed the train's engineer to initiate an emergency application of the train brakes from the rear of the train. As a result of that investigation, the Safety Board issued Safety Recommendation R-89-82 asking that the FRA:

> Require the use of two-way EOT telemetry devices on all cabooseless trains for the safety of railroad operations.

The FRA has recognized the importance of requiring two-way EOT devices in its proposed changes to the "Power Brake Regulations."[40] The comment period for the proposed changes was extended to April 1, 1995, and the FRA has been evaluating the responses. The Safety Board notes that 6 years after the recommendation was made, the FRA has finally addressed the need for two-way EOT devices.

Some carriers have taken independent action in installing two-way EOT devices, but others have elected to wait until the FRA revises the regulation. The Safety Board believes that until a rule requiring two-way EOT devices is in effect, runaway train accidents like Cajon will continue to happen. Therefore, the Safety Board is superseding Safety Recommendation R-89-82 with a new recommendation asking that the FRA take action outside the current rulemaking process that will result in the immediate requirement that two-way EOTs be used on all cabooseless trains.

Manufacturers have been supplying some railroads with two-way EOT devices for several years in anticipation of new regulations. The two-way units have the capability of being easily retrofitted, and they work with existing one-way units. A new two-way EOT device has a basic cost of about $7,000, versus about $5,000 for a one-way unit. This price could be increased by special requirements of the carrier (such as accelerometers or lead-acid batteries), or decreased as a result of volume production. The Safety Board learned in a discussion with a leading manufacture of two-way EOT devices that the industry would probably not be able to supply enough of the devices within one year to meet the needs of every U.S. railroad.

As a result of the Safety Board's investigation of this accident, the Santa Fe issued the following instructions: any train that does not have a two-way EOT device must have a helper locomotive if the consist runs on the north Cajon track and more than half the cars on the train are five-pack double-stack cars that exceed 100 tons per operative brake or if the consist runs

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[38]EOT devices are regulated under 49 CFR 232.19.

[39]Railroad Accident Report--*Collision and Derailment of Montana Rail Link Freight Train with Locomotive Units and Hazardous Materials Release, Helena, Montana, February 2, 1989* (NTSB-RAR-89-05).

[40]*Federal Register*, Vol. 59, No. 179, Friday, September 16, 1994, "Proposed Rules," page 47678.

on the south Cajon track and more than half the cars on the train are five-pack double-stack cars that exceed 80 tons per operative brake.

The Santa Fe considers a train with more than 100 tons per operative brake to be a "heavy" train and considers it critical that a heavy train have an additional initiation source for an emergency brake application. The additional source can be either an EOT device or a crewman on a helper unit at the end of the train.

Also as a result of the Safety Board's investigation, the Santa Fe has committed itself to requiring that any freight train operating down Cajon Pass, Raton Pass, and the Tehachapi Mountains have a two-way EOT device. The requirement also applies to any UP or Southern Pacific train that operates on Santa Fe track.

Before this accident, the Santa Fe was replacing its conventional one-way EOT devices with two-way EOT devices only on an attrition basis. The company expedited the process after the accident. According to a March 3, 1995, letter to the Safety Board from the Santa Fe Senior Vice President and Chief Operating Officer, the Santa Fe had bought 50 two-way EOT devices at the end of December 1994 and had ordered another 270, of which 37 were received on February 6, 1995. Ten a week will be delivered until the end of the year. As of February 6, 1995, the Santa Fe had installed 59. As of July 1995, the Santa Fe had equipped more than 81 percent of its locomotives with two-way EOTs.

Air Brake Testing

Safety Board investigators examined the possibility that the accident train may have had brake problems before it arrived at Barstow.

The engineer who took the train from Needles to Barstow said that he did not test the air brakes and was not required to do so because the consist had not been changed. After taking control of the train at Needles; he released the brakes, and the train responded as expected. He began moving the train when the EOT device registered a trainline pressure of 77 or 78 psi. He stated that the EOT device showed a trainline pressure of 85 to 86 psi throughout the trip when the brakes were released.

He said that he did not use the regulating valve and that he always made brake applications with the automatic brake handle. He said he used the automatic brake twice at Goffs, MP 609.1, where he took the siding to meet an eastbound train. There he stopped at each end of the siding to align switches. He said he had no problems with the train's braking. After Goffs, he made three or four minimum trainline reductions and noticed nothing unusual.

After the oncoming Santa Fe train crewmembers, who were later involved in the accident, added the new locomotive consist to the train at Barstow, they did a set-and-release test. Had the trainline been blocked at that time, the traincrew and supervisors would have noticed it. The likelihood that they would not notice such a condition is remote. Therefore, the

Safety Board concludes that the blockage or restriction occurred sometime after the set-and-release air brake test at Barstow and, based on the simulation results, sometime before the brakes were first used, at Lugo, where the train stopped to let an Amtrak train pass.

According to the Santa Fe supervisors in the Barstow Yard control tower, the air brake set-and-release test was done at 3:20 a.m., and the Santa Fe train departed Barstow at about 3:27 a.m. It took the train 65 minutes to reach Lugo. During that time an angle cock could have been closed or a blockage could have developed. Either could have interfered with the continuity of the trainline between cars 3 and 4.

Neither the development of a blockage nor the inappropriate closing of an angle cock can be totally prevented. However, the Santa Fe has taken steps as a result of the Safety Board's investigation of this accident to reduce the possibility. On December 20, 1994, the Santa Fe issued instructions that each westbound traincrew do an emergency application of the brakes if the train receives an application-and-release test, an initial terminal test, an intermediate inspection, or more cars at Barstow.

In addition, the Santa Fe issued instructions that all westbound trains operating on the Cajon Subdivision make a running air brake test as prescribed by Santa Fe Air Brake Rule 30.15[41] before descending from Summit to Cajon to ensure that there is trainline continuity and that the brakes are responding.

Feed-Valve Braking

Safety Board investigators examined whether the Santa Fe engineer's use of the regulating valve in feed-valve braking caused or contributed to the accident. Train brake applications are normally made using the automatic brake-valve handle, rather than the regulating valve. Postaccident interviews of Santa Fe operating personnel by Safety Board investigators established that feed-valve braking became a practice in Santa Fe mountain territory in order to compensate for a brake system leakage problem.

This phenomenon is more likely in mountainous areas where brakes are likely to be applied for an hour or more. Other railroads and the AAR agree that the problem is more frequent on railroads with a greater number of extended grades. To cope with the problem, Santa Fe engineers in mountain-grade territory adopted feed-valve braking, or the use of the regulating valve, as standard operating procedure.

A frequently occurring leak in the control stand between the equalizing reservoir[42] and associated piping, such as the equalizing gage, can cause brakes to gradually and continually

[41]Effective April 10, 1994.

[42]The equ[illegible]ing reservoir is a small reference volume that monitors the trainline pressure and maintains that pressure (maintain[illegible] feature) against inherent leakage in the train's trainline even when the trainline pressure has been reduced to apply [illegible] brakes.

apply beyond the set brake application. Under such circumstances, brake-pipe reductions continue past a set reduction by the automatic brake handle until dropping brake-pipe pressure causes the train to bog down and stop, rather than just slow down.

The regulating valve is intended to set the operating brake-pipe pressure; it is not intended to be used to apply or release the brakes. That is the function of the automatic brake-valve handle. Feed-valve braking was allowed under Santa Fe train handling rule 537, but only as an implied exception to normal braking procedures under certain circumstances. Rule 537, *Regulating Valve Braking*, reads:

> Use of the regulating valve to brake a train is not permitted if the brake-pipe pressure maintaining feature is operative, or on 26 brake equipment the brake valve will maintain in the IN FRT or PASS position.

Since a leak between the equalizing reservoir and the associated piping prevents the maintaining feature from maintaining pressure, engineers and first-line supervisors felt free under the rule to use the regulating valve to brake the train. The Santa Fe director of operating practices, who was responsible for training crews, and the managers of train operations (road foremen) explained that over a number of years, the exception had become a train handling norm in mountain-grade territory and was condoned and taught by first-line supervisors, although many upper level managers, including superintendents, were unaware of the practice. The "tradition" was passed from older to younger engineers and, thus, to first-line supervisors, who are often promoted engineers.

According to WABCO, feed-valve braking is not condoned or warranted and is a misuse of a device designed for other purposes. WABCO inserts the following warning on page 17 of its booklet *26-L Locomotive Air Broke Equipment and Devices*, #5071-6, dated January 1988:

> The regulating-valve adjustment screw MUST NOT BE turned once the brake-pipe pressure has leveled off and the brake-pipe leakage test is completed. Any movement of the regulating-valve adjustment screw immediately before the departure of the train and/or while the train is in motion WILL CAUSE unpredictable variation in brake-pipe air pressure and unpredictable degradation of brake-cylinder pressure. Such erratic changes in brake-pipe pressure and/or brake-cylinder pressure could result in a less effective train retardation with possible damage to equipment and/or injury to personnel or by-standers.

WABCO also warns:

> WARNING: An initial "minimum reduction" of less than 5 psi will probably result in undesired pressure waves in the brake pipe which could cause the train brakes to release.

Unintentional brake release may result in equipment damage and/or personal injury and therefore such reduction must not be made.

At the time of the accident, 75 percent of Santa Fe locomotives were equipped with cut-off valves having a passenger, "PASS," position, which is designed for graduated release on passenger trains. Such a position allows engineers to bypass the leak problem described above, but when used on freight trains, has its own inherent danger. If, during a brake application with the cut-out valve in the PASS position, the automatic brake-valve handle is moved, bumped, or vibrates back toward release, all the train's brakes will release, whether desired or not. This situation, if not carefully monitored, can cause an inadvertent release of a train's brakes. Therefore, the Santa Fe had prohibited the use of the PASS position before the Cajon accident. However, several western railroads use the PASS position on locomotives so equipped rather than use feed-valve braking to compensate for leaks at the equalizing reservoir.

As a result of the Cajon accident, the Santa Fe has installed a PASS position cut-out valve on all its locomotives to aid locomotive engineers in braking in the event of a equalizing-reservoir leak. According to Santa Fe, all of its engineers have been instructed verbally about the proper use of the PASS position. They have also been given copies of Superintendent's Notice No. 119, dated January 6, 1995, which repeats the explanation.

The Safety Board believes both feed-valve braking and the use of the PASS position on freight trains are inherently dangerous because either can result in the inadvertent release of the brakes. While the Safety Board acknowledges the Santa Fe's action, the Board views the action as an interim solution without any implied sanction as a final solution. Air brake manufacturers identify both feed-valve braking and use of the PASS position on freight trains as hazardous and as an abrogation of the safe design of the air brake system. The Safety Board believes the difference between air brake practice and design should be reconciled. The Safety Board also believes that the remedial use of feed-valve braking and the PASS position is not unique to the Santa Fe, but is common on many other railroads. Therefore the Safety Board believes that the AAR, in cooperation with the air brake manufacturers, should assess the current methods of braking in mountainous territory and identify safe braking methods for handling a train on an extended downhill grade. In addition, the Safety Board believes the AAR should inform its members that feed-valve braking and any other braking method deemed hazardous should not be used to control trains that are descending mountains.

After interviewing the Santa Fe engineer and conductor, examining and testing the braking systems of the freight cars, and analyzing the train's event-recorder printout, the Safety Board concludes that feed-valve braking neither caused nor contributed to the inability of the Santa Fe train to stop short of the collision. The braking system is designed to propagate an emergency brake application as long as the trainline has at least 45 psi of pressure, independent of the manner of the application.[43] The event-recorder printout shows that the head

[43] WABCO manual 5071-6, page 18.

end of the train went into emergency braking with the trainline at 65 psi, but with little or no effect on the train's speed. Even considering the gradient from trainline leakage throughout the length of the train and the previous reductions by the engineer, there should have been sufficient brake-pipe pressure at the end of the train to propagate an emergency application from the lead locomotive unit.[44] Indeed, the Santa Fe conductor's testimony confirms that there was:

> The only time I remember the reading was after we were in emergency for quite a while, and I don't know how long that was, but it was long enough for the ETD[45] [trainline air gage] to drop to zero; zero, and we still had 60 pounds of air on the rear of the train. That was pretty much there my decision to get off.

The Safety Board determines that the trainline pressure was sufficient to cause an emergency brake application.

As a result of the Safety Board's investigation, the Santa Fe has banned feed-valve braking and has instructed 14 train operations managers to ensure that there is "total and unqualified" compliance with the ban. On December 16, 1994, the Santa Fe prohibited the use of the regulating valve to apply or release a train's brakes. The company sent out notices to confirm that the automatic brake-valve handle is the primary source of braking application for westward freight trains on the Cajon Subdivision. Additionally, managers of train operations from across the Santa Fe system were sent to the Southern California Division to train and observe engineers in order to ensure compliance with the above notices.

Finally, the Santa Fe has added two additional managers of train operations in Barstow and an assistant vice president of operations in San Bernadino with jurisdiction over all California Santa Fe divisions. According to a Santa Fe letter, these managers were added to ensure enforcement of the ban on feed-valve braking.

Brake-Shoe Force

The amount of brake-shoe force affects the ability of the brake system to stop the car. Postaccident testing was done to determine the brake-shoe force against the wheel and to determine the consistency of force throughout the range of brake applications. When investigators barred back the brake shoes, they found that although many brake shoes were making contact with the wheel tread, they could easily be barred away. In order to ensure some level of braking effectiveness and adequacy, there should be a minimum standard for brake-shoe force if the braking system is to properly and efficiently perform the critical job of stopping a train. The AAR has been aware of this need for some time and has empirically

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[44]In order to propagate an emergency application, trainline pressure should be greater than 45 psi.

[45]Same as EOT, end-of-train device.

developed a 100-pound minimum freight-car tread-brake-shoe force. This force serves as a benchmark from which to measure force at the brake shoe to ensure some level of braking effectiveness. Therefore the Safety Board believes the AAR should expedite the issuance of a national standard for minimum brake-shoe forces before 1996.

Santa Fe Postaccident Actions

The Santa Fe Railway cooperated fully with the Safety Board in this investigation. Safety Board investigators suggested a number of ways the Santa Fe could help ensure safe train handling through Cajon Pass. Several of these suggestions were immediately adopted by the Santa Fe management and appear as safety accomplishments in Appendix B of this report. The Safety Board commends the Santa Fe for those actions it has taken and those that it has agreed to take to improve the safety of its operations.

CONCLUSIONS

1. The weather, the signal and train control system, the track, dispatcher operations, and drugs and alcohol neither caused nor contributed to the collision. The train crewmembers were rested in accordance with the Hours of Service Act, and were qualified to perform their duties.

2. Because of a trainline blockage or restriction, the only responsive brakes on the train were on the locomotive units and the first three cars.

3. Had the train been equipped with a two-way EOT device, the collision could have been avoided because the engineer could have initiated an emergency brake application from the end of the train.

4. The blockage or restriction occurred after the locomotive units were added and tested at Barstow.

5. Feed-valve braking neither caused nor contributed to the inability of the train to stop short of the collision.

6. Had there been no blockage or restriction in the trainline, the train would have responded to the emergency brake application and stopped before the collision.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the collision of the Atchison, Topeka and Santa Fe Railway freight train, PBHLA1-10, with the rear of the Union Pacific Railroad freight train, CUWLA-10, was insufficient available train braking force for the Santa Fe train due to an undetermined restriction or blockage in the trainline between the third and fourth articulated cars.

RECOMMENDATIONS

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

--to the Association of American Railroads:

> Pending the adoption of a formal rule by the Federal Railroad Administration, recommend the use of two-way end-of-train telemetry devices on all cabooseless trains by March 31, 1996. (Class II, Priority Action) (R-95-41)
>
> Expedite the issuance of national standards for minimum freight-car tread-brake shoe force before 1996. (Class II, Priority Action) (R-95-42)
>
> In cooperation with the air brake manufacturers, assess the current methods of braking in mountain-grade territory and identify safe braking methods for trains descending extended grades, and inform your membership that feed-valve braking and any other braking method found hazardous should not be condoned as an alternative method of controlling a train that is descending an extended grade. (Class II, Priority Action) (R-95-43)

--to the Federal Railroad Administration:

> Separate the two-way end-of-train requirements from the Power Brake Law notice of proposed rulemaking, and immediately conclude the end-of-train device rulemaking so as to require the use of two-way end-of-train telemetry devices on all cabooseless trains. (Class II, Priority Action) (R-95-44)

--to the American Short Line Railroad Association:

> Pending the adoption of a formal rule by the Federal Railroad Administration, recommend the use of two-way end-of-train telemetry devices on all cabooseless trains by March 31, 1996. (Class II, Priority Action) (R-95-47)

--to all Class I railroads:

Pending the adoption of a formal rule by the Federal Railroad Administration, implement the use of two-way end-of-train telemetry devices on all cabooseless trains by March 31, 1996. (Class II, Priority Action) (R-95-48)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

November 21, 1995

APPENDIX A

Investigation

The Safety Board was notified at 10:17 eastern standard time on December 14, 1994, that a Santa Fe freight train had collided with the rear of a Union Pacific freight train at Cajon Pass, California. An investigator-in-charge and the mechanical-group chairman were assigned from the Los Angeles, California, regional office. Group chairmen for track and signals and operations were assigned from the Chicago, Illinois, regional office. A report writer and additional group chairmen were assigned from Washington, D.C., for survival factors and human performance aspects of the investigation.

The Federal Railroad Administration, the California Public Utilities Commission, the Santa Fe Railway, the Union Pacific Railroad, the Brotherhood of Locomotive Engineers, the Association of American Railroads, Trailer Train, Gunderson Railcar Services, Thrall Car Manufacturing, Trinity Industries (Railcar Division), and the Westinghouse Air Brake Company assisted the Safety Board in this investigation.

The investigation involved interviewing witnesses. No formal deposition proceedings or public hearings were held.

APPENDIX B

Safety Accomplishments

The Santa Fe made the following changes as the result of the Safety Board's investigation of the Cajon rear-end collision. These safety accomplishments have been approved by the National Transportation Safety Board's Safety Proposal Review Board.

1. The Santa Fe issued system-wide instructions prohibiting the use of the feed-valve braking.

2. The Santa Fe expedited the installation and use of two-way EOT devices.

3. The Santa Fe now requires an emergency brake application test for any westbound train that receives an initial terminal, intermediate, or application/release test or has cars added at Barstow.

4. The Santa Fe now requires each westbound train operating on the Cajon Subdivision to make a running air brake test according to the rules before descending Cajon Pass.

5. The Santa Fe has established an additional assistant vice president of operations position and two additional manager of train operations positions to insure compliance with the above train handling and testing rules.

6. The Santa Fe had inventoried all rubber air brake parts for out-of-date components and scrapped all those found with expired dates.

7. The Santa Fe temporarily suspended the operation of five-pack double-stack trains down grades of 3 percent or more.

8. The Santa Fe issued temporary instructions requiring helper locomotives on train consists of more than half five-pack double-stack cars that exceed over 100 tons per operative brake and 250 tons per dynamic brake on the north Cajon track and 80 tons on trains on the south Cajon track.

APPENDIX C

How Air Brakes Work

The air brake system on a train is designed to slow or stop a train through the use of compressed air. The compressed air is used to push a piston within a cylinder. Usually, through a series of rods and levers, the piston's movement forces brake shoes against car or locomotive wheels or discs to slow their rotation through friction. The air is compressed by an air compressor in the locomotive and stored for use in the main reservoirs (large tanks) on the locomotive. (See diagram that follows.)

The compressed air and the brakes are controlled by the engineer using an automatic brake-valve handle on a locomotive control stand. The automatic brake valve controls the train's brakes (including the locomotive) and has three functions: 1) To apply the brakes, 2) To release the brakes, and 3) To charge or recharge the air brake system. Another valve handle, called the independent brake valve, is used by the engineer to independently control only the locomotive's brakes.

Each railroad car has one or more brake-cylinder pistons, a reservoir (storage tank), associated piping, and a control valve. The control valves on cars are designed to respond to signals sent by the engineer. These signals take the form of changes in air pressure through the trainline. The trainline is the physical connection of the locomotive and cars air brake systems through metal pipes and connecting flexible air hoses at the ends of each railroad vehicle.

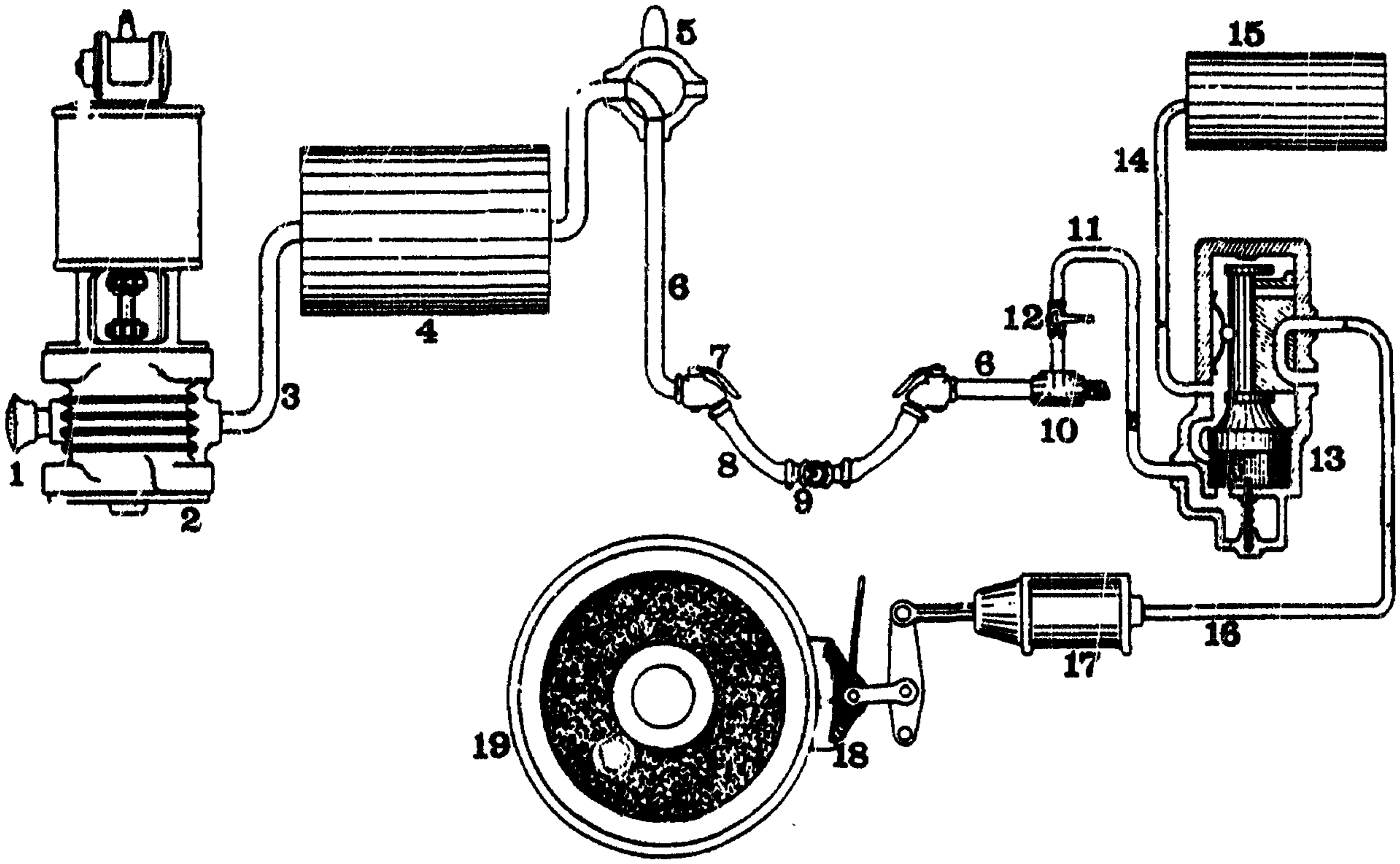
The air pressure within the trainline is called *brake pipe* pressure. When brake-pipe pressure (in the trainline) is reduced by the engineer, each car's control valve senses the drop and applies the brakes by sending some air stored in the car's reservoir to its brake cylinder(s). The amount of air sent to the air brake cylinder is proportional to the drop in brake-pipe pressure. Up to a point, the larger the drop in brake-pipe pressure, the more air the control valve sends from the reservoir to the brake cylinder and the greater the amount of braking force created.

To release the brakes, the engineer lets more air into the trainline from the locomotive main reservoirs, increasing the brake-pipe pressure. Each car's control valve senses this increase in air pressure and exhausts air from the brake cylinder, releasing the brakes. A return spring within the brake cylinder pushes the piston back into the cylinder and the brake shoe backs away from the wheel or disc. At the same time, the car's control valve takes some air from the brake cylinder to replenish the brake pipe and recharge its system.

The initial brake-pipe pressure is determined by the engineer, who turns a knob that sets the regulating or feed valve. The regulating valve reduces the pressurized air from the main reservoir to a determined amount for delivery to the equalizing reservoir, which then dictates brake-pipe pressure. The equalizing reservoir is a small reference volume used to control the much larger train's brake-pipe or trainline volume. The equalizing reservoir allows the engineer to make immediate predetermined changes to the brake-pipe pressure without having to wait for the changes to take place in the train and stabilize, and still be assured that precise changes in pressure will be made.

Since the trainline connections through and between cars are not perfect, some of the compressed air leaks. In order to prevent the car control valves from sensing a drop in air pressure from leakage and inadvertently applying the brakes, the automatic brake valve in the engineer's locomotive control stand has a maintaining feature. The maintaining feature automatically sends just the right amount of air into the brake pipe, regardless of whether the brakes are applied or released, to make up for any trainline system leakage.

Since the maintaining feature is located in the locomotive, there is usually a constant flow of air toward the rear of the train. Trainline leakage progressively draws off air from the brake pipe as it travels toward the rear of the train, dropping air pressure. This gradual drop in brake-pipe pressure is called *gradient*, and represents the difference in brake-pipe pressure between the front of the train and the rear of the train.



1. Air Intake Filter
2. Air Compressor
3. Main Reservoir Pipe
4. Main Reservoir
5. Engineer's Brake Valve
6. Brake Pipe
7. Angle Cock
8. Air Brake Hose
9. Hose Coupling
10. Branch Pipe Tee
11. Branch Pipe
12. Cutout Cock
13. Triple Valve
14. Auxiliary Reservoir Pipe
15. Auxiliary Reservoir
16. Brake Cylinder Pipe
17. Brake Cylinder
18. Brake Shoe
19. Wheel

Components of a train air brake system