NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

**REAR-END COLLISION OF
UNION PACIFIC RAILROAD COMPANY
FREIGHT TRAINS EXTRA 3119 WEST
AND EXTRA 8044 WEST
NEAR KELSO, CALIFORNIA
NOVEMBER 17, 1980**

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UNITED STATES GOVERNMENT

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16. Abstract

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The National Transportation Safety Board determines that the probable cause of this accident was the dispatcher's permitting Extra 3119 West to leave Cima with inadequate braking capability, the inadvertent release of the train's brakes after they were placed in emergency from the caboose, and the UP's inadequate rules and instructions for the management of trains on mountain grades that resulted in the engineer's inability to control the speed of the train. Contributing to the accident were the failure to properly inspect and test Extra 3119 West at Las Vegas, the inadequate maintenance of braking equipment on tie cars used in company service, and the practice of underestimating the weight of loaded tie cars. Contributing to the severity of the accident were the lack of effective direction by the dispatcher and assistant chief train dispatcher and the absence of emergency procedures for train operations on Cima Hill.

17. Key Words Rear-end collision, accelerating, single-main track, fatal, diesel-electric, freight train, brake system, CTC, brake test, dispatching, emergency procedures, train braking, train handling, train inspection, cycle braking, dynamic braking, air brake rules, brakepipe flow indicator, pressure maintaining, descending grade, Federal Power Brake Regulations, enforce regulations.

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WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

Adopted: August 18, 1981

REAR-END COLLISION OF UNION PACIFIC RAILROAD COMPANY FREIGHT TRAINS EXTRA 3119 WEST AND EXTRA 8044 WEST (2-VAN-16) NEAR KELSO, CALIFORNIA NOVEMBER 17, 1980

SYNOPSIS

About 2:29 p.m., P.s.t., on November 17, 1980, Union Pacific Railroad Company (UP) work train Extra 3119 West ran out of control while descending a long 2.20-percent grade, overtook, and struck the rear of UP freight train Extra 8044 West (2 VAN-16) on the UP's single main track near Kelso, California. Three train crewmembers were killed and one crewmember was injured. The locomotive unit of Extra 3119 West, the caboose of Extra 8044 West, and 23 freight cars were destroyed. Total damage was estimated at $1,200,000.

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INVESTIGATION

The Trip From Las Vegas to Cima

At 10:00 a.m., on November 17, 1980, Union Pacific Railroad Company (UP) westbound work train Extra 3119 West, consisting of locomotive unit 3119, 20 specially-fitted bulkhead flatcars loaded with crossties, and a caboose, departed Las Vegas, Nevada, for Yermo, California. (See figure 1.) The clearance form issued to the crew authorized a maximum speed of 50 mph for the train. Extra 3119 West was followed from Las Vegas at 10:20 a.m., by a 73-car loaded grain train, Extra 3135 West (SGT-722), and at 12:05 p.m., by Extra 8044 West (2-VAN-16), a through freight train consisting of 49 loaded automobile and piggyback flatcars and a caboose. The maximum authorized speeds for the grain train and the VAN train were 50 and 70 mph, respectively.

STATION	MILEPOST
Las Vegas	334.3
5.2	
Bracken	329.1
6.6	
Arden	322.5
13.2	
Erie	309.3
8.0	
Jean	301.3
13.7	
Calada	278.6
20.2	
Ivanpah	267.4
13.4	
Cima	254.0
3.6	
Chase	250.4
3.1	
Elora	247.3
4.0	
Dawes	243.3
4.0	
Hayden	239.3
3.9	
Kelso	235.4
4.8	
Point of Collision	230.6
53.1	
Manix	177.5
14.4	
Yermo	163.1

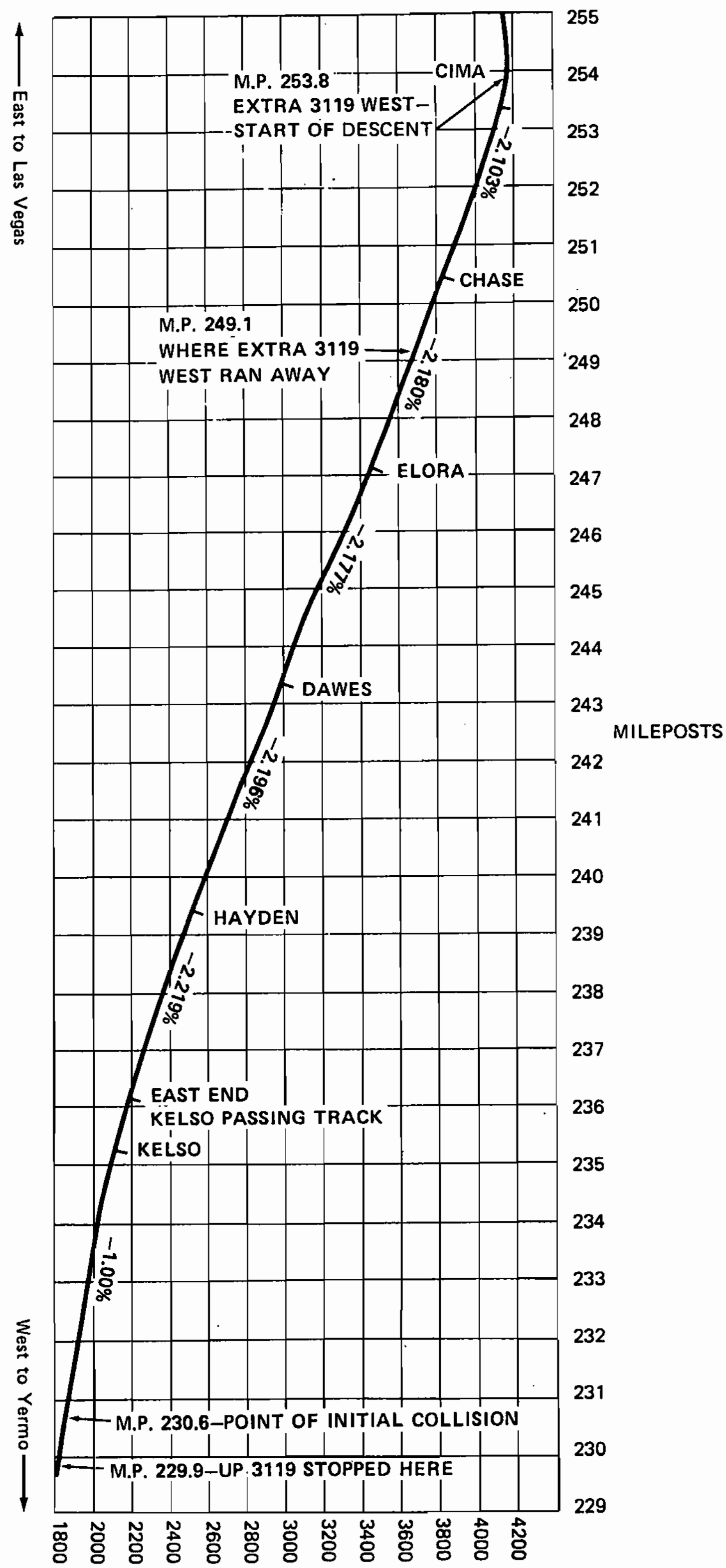

Figure 1.--Profile of Union Pacific Railroad from Cima to Kelso, California, and the point of collision.

About 3 1/2 miles west of Las Vegas, Extra 3119 West stopped briefly while a rail detector car cleared into a passing track at Bracken, Nevada. The train was decelerated quickly from 25 mph on a 0.80-percent ascending grade, but it is not known whether the engineer resorted to braking action to stop the train or to hold it on the grade. From Bracken to Erie, Nevada, Extra 3119 West was on a continuous ascending grade for 20 miles, most of which was at the rate of 1.00 percent. 1/ Speed was maintained at 20 to 22 mph on the grade except at Arden, Nevada, where several miles of lesser gradient permitted the train to briefly accelerate to slightly higher speeds. About this time, the dispatcher at Salt Lake City, Utah, radioed the engineer of Extra 3119 West to find out if his train was moving fast enough to avoid delaying Extra 3135 West. The dispatcher was satisfied with the train's speed and allowed it to continue to run ahead of Extra 3135 West.

After cresting the grade at Erie summit, Extra 3119 West started down a 14-mile section of railroad with varying gradient up to 1.00 percent, all but about 2 miles of which was descending westbound. In the first 3 miles, Extra 3119 West accelerated from 22 to 57 mph on a downgrade of up to 0.68 percent and then slowed to about 49 mph on a half mile of level grade. Thereafter, speed varied between 41 and 57 mph with the fluctuations generally corresponding to changes in the gradient. According to the conductor and rear brakeman, the train brakes were applied after the train passed Erie. During the descent from Erie, the engineer informed the dispatcher that the locomotive had no effective dynamic braking 2/ and that when descending the 17-mile, 2.20-percent grade between Cima and Kelso, California, he would have to use retainers, 3/ restrict speed to 15 mph, and stop the train on the grade at Dawes to cool the wheels--all of which were actions required by timetable special rule 1042(RC). (See appendix C.) The dispatcher acknowledged the engineer's report without comment and he encoded the Traffic Control machine to route Extra 3119 West into the north passing track at Cima, 79 miles west of Las Vegas.

Over the 27 miles of generally 1.00-percent ascending grade to Cima summit, Extra 3119 West maintained a speed of 22 mph except in three short sections of lesser gradient where the speed increased briefly. Extra 3119 West arrived at Cima at 1:29 p.m., pulled into the north passing track, and stopped more or less balanced on the apex of the grade. After the train stopped, the conductor and flagman walked forward from the caboose, setting up the retainers in the high-pressure position. About halfway to the head end, they met the head brakeman who had been setting up the retainers on the forward part of the train. The conductor and flagman then returned to the caboose and the head brakeman worked his way back to the locomotive. The conductor and flagman stated that they observed no defects and heard no air leaks in the rear portion of the

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1/ A 1.00-percent grade denotes a vertical rise or fall of one foot in each 100 feet of horizontal distance.

2/ Dynamic braking results from reversing the field of the locomotive's traction motors thereby changing them into generators and thus causing retardation of the locomotive wheels. This form of braking is independent of the locomotive and train air brake systems. Many, but not all, diesel-electric locomotive units are equipped with this feature.

3/ Freight cars are equipped with retainers (air brake retaining valves) which can be set to retain air pressure in the brake cylinders as a means of controlling speed by continuous braking effort while the engineer releases the automatic air brake in order to restore pressure in the trainline, or brakepipe. Use of retainers permits frequent applications and releases of the train brakes on heavy grades without seriously depleting brakepipe air pressure or braking capability. The technique is commonly referred to as cycle braking.

train. According to the conductor, the head brakeman did not report finding any defect in the forward part of the train. Shortly afterwards, the engineer moved the train ahead to a point about 1,100 feet east of the westbound home signal for the north passing track. According to the conductor, the gauge in the caboose indicated 90 pounds of brakepipe pressure and zero pounds of brake cylinder pressure.

Extra 3135 West (grain train SGT-722) arrived at Cima at about 1:35 p.m. and occupied the south passing track. Because this train weighed more than 132 tons per operative brake, the crew proceeded to set up their train's retainers as required by special rule 1042(RC). (See appendix C.) At 1:46 p.m., Extra 8044 West (2-VAN-16) arrived at Cima, reduced speed to about 13 mph as it passed over the summit, and began descending the grade to Kelso. After the VAN train cleared Cima, the dispatcher asked the engineer of Extra 3119 West if he was ready to leave. When the engineer replied affirmatively, the dispatcher encoded the traffic control machine to route the train from the north passing track to the main track. After the VAN train cleared intermediate signal 2523 4/, the passing track switch automatically reversed and the home signal changed from a red "Stop" aspect to a yellow "Approach" aspect, permitting Extra 3119 West to "Proceed prepared to stop before any part of train or engine passes the next signal. . . ." Extra 3119 West cleared the turnout to the main track at 1:59 p.m., and the dispatcher then encoded his machine to reverse the south passing track turnout. When Extra 3119 West cleared signal 2523, Extra 3135 West moved out of the south passing track on an "Approach" signal aspect.

The Accident

Leaving the north passing track at Cima, Extra 3119 West accelerated to 14 mph in 0.3 mile, slightly more than the distance from its starting point to the turnout, and by the time the caboose entered the main track, speed had reached about 17 mph. The engineer responded by initiating braking action which reduced the train's speed to about 13 mph, but almost immediately Extra 3119 West began to reaccelerate. In an apparent attempt to stabilize speed at 15 mph, the engineer made another brake application at 16 mph, but it was insufficient to prevent reacceleration above 15 mph. According to the conductor and flagman, the brakes had applied on the caboose and at no time were the brakes released.

At 2:09 p.m., Extra 3119 West reached milepost 250.6, midway between the passing track turnouts at Chase and 3 miles west of Cima. By this time, the engineer had made two additional brake applications and each time the speed had reduced to the desired 15 mph only to pick up again within one- or two-tenths of a mile. After making the last brake application, the engineer informed the dispatcher that he was having trouble. The engineer of the VAN train recalled him stating, "I keep setting air and it won't slow down." Also at 2:09, the rear of the VAN train passed the west end of the passing track at Elora, running in full dynamic braking with train brakes applied and speed stabilized at about 25 mph. At this time, the VAN train was 3.9 miles ahead of Extra 3119 West. At the same time, Extra 3135 West cleared the passing track at Cima moving at about 20 mph. The head end was about 2.9 miles behind Extra 3119 West which was fully visible to the engineer of Extra 3135 West. He noticed that Extra 3119 West was smoking heavily as it passed Chase, and he remarked to the head brakeman that this seemed unusual considering the short distance the train had traveled.

4/ Signal 2523 was located 6,705 feet west of the home signal at the west end of the north passing track at Cima.

The engineer of Extra 3119 West was never again able to reduce the speed of the train. At 2:13 p.m., it was accelerating at the rate of 1.6 mph per minute and had attained a speed of 19.5 mph. At this time, the VAN train had reached the east turnout of the Dawes passing track, maintaining 25 mph, and was now separated from Extra 3119 West by about 4.8 miles. As Extra 3135 West approached the signal at the east end of Chase, the engineer observed the signal aspect change from red to yellow and then to green, indicating that Extra 3119 West had rapidly passed both the west end of Chase and the intermediate signal west of Chase. About this time, the engineer of Extra 3135 West heard the engineer of Extra 3119 West state that he had 30 pounds of engine brakes, indicating that he had made a substantial application of the independent brake. About this time, also, the conductor of Extra 3119 West used the caboose valve to apply the train's brakes in emergency. He did not use his radio to inform the engineer that he had done this, but hearing the brakepipe exhaust he assumed the brakes had applied in emergency throughout the train. Almost immediately after making the emergency application, the conductor and flagman went to the forward platform and made a futile effort to uncouple the caboose.

At 2:15 p.m., the engineer of Extra 3119 West called the dispatcher and informed him that he had made a full service application of the brakes, was traveling at 25 mph, and was still accelerating. The dispatcher asked if this meant that he was not going to stop at Dawes to cool the wheels, and the engineer replied that he did not think he would be able to stop. The conversation was heard by the engineer of the VAN train and by the conductor of an eastbound train in the passing track at Kelso. The dispatcher did not comment, nor did he take any action.

By 2:15 p.m., Extra 3119 West was at milepost 248.8 and was approaching the east turnout of the Elora passing track. A minute earlier, the train's speed had stabilized at 20 mph for about three-tenths of a mile, followed by a sudden and dramatic reacceleration at an average rate of 5 mph per minute. Extra 3119 West was running out of control on the downgrade with very little effective retardation. It was, however, about 5 miles behind the VAN train. Recognizing what was happening to Extra 3119 West, the VAN engineer began to accelerate his train by first releasing the train brakes and then by gradually throttling down the dynamic braking to idle, changing to power position, and reopening the throttle. The engineer had asked for and was granted by the dispatcher authority to exceed the 25-mph speed limit for his train.

Extra 3119 West reached milepost 247.8, at 2:17 p.m., making 39 mph just as the VAN train was clearing the west turnout of Dawes passing track at milepost 242.7. At 2:21, Extra 3119 West was at milepost 244.4 between the turnouts at Dawes moving at 62.5 mph, and the VAN train had passed the west end of Hayden passing track at milepost 238.8. The VAN train was now being operated in full throttle and had attained a speed of about 65 mph. The 5-mile gap between the trains was being maintained and the VAN train could accelerate to about 75 mph before the locomotive's overspeed feature became operative. However, Extra 3119 West continued to accelerate at a phenomenal rate. When it reached milepost 241.2 shortly after 2:24 p.m., it was moving at 80 mph, the limit of the locomotive's speed indicator. As Extra 3119 West had moved out of control down the mountain, the engineer repeatedly broadcast the indicated speed of the train, even after actual speed had passed 80 mph. Because the engineer kept broadcasting his speed as being 80 mph, the engineer of the VAN train believed that Extra 3119 West had finally reached maximum velocity and that he still had a chance to outrun it west of Kelso where the downgrade was only 1.00 percent.

When the VAN train reached the east end of Kelso, the locomotive's overspeed feature became operative and caused an immediate loss of power. Although the engineer succeeded in forestalling a penalty brake application, the train had decelerated to about 68 mph before the engineer could restore full power operation and begin reacceleration. In the interim, Extra 3119 West continued to pick up speed at the rate of 6 to 8 mph per minute and it passed through Kelso only a minute behind the rear of the VAN train. As Extra 3119 West passed through Kelso, the locomotive whistle was sounded continuously. The engineer was observed facing forward seated at his post holding the radio microphone in front of his face. He continued to inform the VAN engineer of the rapidly closing distance between the trains. When Extra 3119 West passed the hotbox detector at milepost 233.9, it was moving at 112 mph.

The VAN train again reached the 75-mph mark about 2 1/2 miles west of Kelso. At this point, the head brakeman succeeded in preventing a second operation of the overspeed feature by interrupting the operation of the speed recorder stylus. However, the only remaining hope of avoiding a collision was that Extra 3119 West would derail in the 2°03' curve at milepost 231. Although Extra 3119 West was moving nearly twice the maximum speed for the curve, it did not derail. At 2:29 p.m., Extra 3119 West struck the caboose of the VAN train on tangent track at milepost 230.6. The VAN train and Extra 3119 West were moving at 80 to 85 mph and about 118 mph, respectively, when the collision occurred.

Collision and Derailment

The accident probably consisted of four separate episodes of collision and derailment. The first occurred when Extra 3119 West struck the VAN caboose causing it to separate from the car ahead, derail, and slide down the south embankment on its side. The locomotive then struck, one at a time, the three rear cars of the VAN train which were enclosed tri-level auto rack cars. The first two cars, as with the caboose, did not offer substantial resistance to Extra 3119 West. They, too, separated from the train, turned over to the left, and slid down the south embankment. Although the first three collisions probably heavily damaged the forward superstructure of the locomotive of Extra 3119 West, they did not cause it to derail.

Separation of the caboose from the VAN train had caused the train to go into emergency braking and when Extra 3119 West struck the third rack car, the car overrode the locomotive, destroyed the remaining superstructure, and caused the locomotive to overturn the north rail. The near-instantaneous derailment of the rest of the train followed immediately. The forward 14 or 15 cars were hurtled from the grade over the north embankment with their loads of crossties ejected into the desert at a 90-degree angle to the track. (See figure 2.) The rearmost cars also derailed to the north, but less violently, and the two rear cars and caboose remained coupled. These three cars stopped in an upright position on the track structure. The forward 46 cars and the locomotive units of Extra 8044 West stopped normally as a result of the emergency brake application and did not derail.

The general derailment area began about 500 feet west of the initial collision location and extended for 700 feet farther west. The locomotive unit of Extra 3119 West stayed on the track structure and came to a stop about 2,100 feet west of the original point of collision and 1,900 feet west of the caboose of Extra 3119 West.

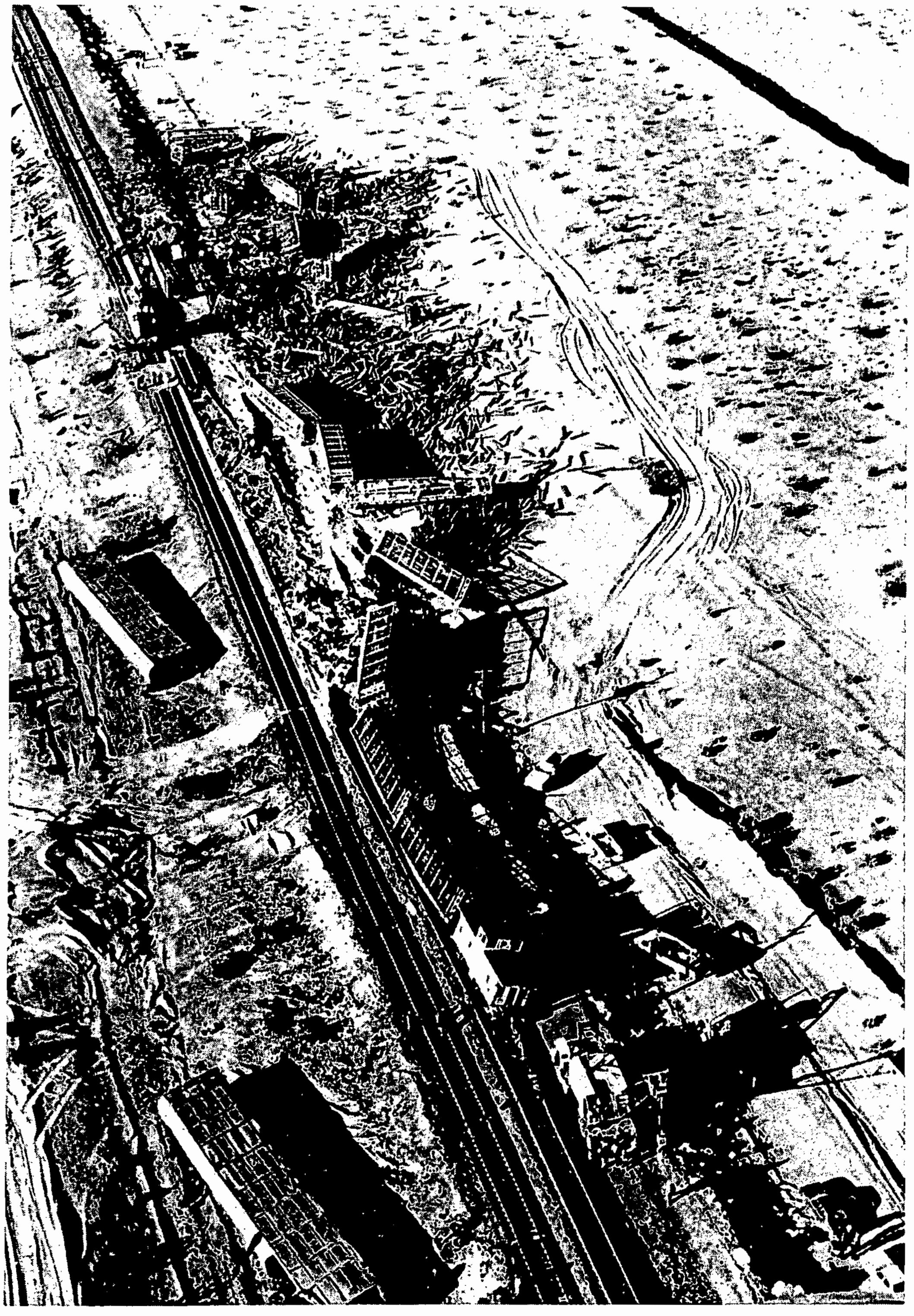

Figure 2.--Aerial view of accident location viewed to the west. The caboose and cars of Extra 3119 West are to the right of the tracks. Derailed auto rack cars of the VAN train are to the left. The left-hand track was constructed after the accident for train operations during wreckage clearing operations.

Injuries to Persons

The engineer and head brakeman were on the locomotive of Extra 3119 West when the collision occurred and both were killed. The conductor and flagman of the VAN train were in the caboose when it was struck. The conductor was killed and the flagman was critically injured.

Injuries	Extra 3119 West (2-VAN-16) Crewmembers	Extra 8044 West Crewmembers	Total
Fatal	2	1	3
Nonfatal	0	1	1
None	2	2	4

Damage to Property

The 20 tie cars and the locomotive of Extra 3119 West were destroyed, and three auto rack cars and the caboose of the VAN train were destroyed. A total of eight other cars were damaged. About 2,400 feet of track had to be replaced and a number of automobiles in the rack cars were destroyed. Damage was estimated as follows:

Train Equipment	$ 689,800
Train Lading	330,000
Track	146,600
Clearing and Salvage	33,600
Total	$1,200,000

Crewmember Information

Each of the trains involved in this accident had a conductor, engineer, and two brakemen. All were qualified under Union Pacific rules without restriction. (See appendix B.)

The crewmembers of Extra 3119 West reported for duty at Las Vegas at 8:05 a.m. on November 17, 1980, and had been on duty 6 hours 24 minutes when the accident occurred. All the crewmembers were assigned to the extra board and had last worked on November 16. During the 4 1/2 months preceding the accident, the engineer handled 27 westbound tonnage trains over the grade between Cima and Kelso. As far as could be determined, he had not encountered any previous difficulty on the grade. He was described as a very capable handler of trains by his supervisors, fellow engineers, and the conductor of Extra 3119 West. He was also known to be a stickler for compliance with rules and instructions. Prior to reporting for duty on November 17, 1980, the engineer and conductor had been off duty for 17 hours 10 minutes, and 21 hours 30 minutes, respectively. The brakemen had been off duty 20 hours 40 minutes.

The crewmembers of Extra 8044 West reported for duty at Las Vegas at 11:20 a.m., on November 17, and had been on duty 3 hours 9 minutes when the accident occurred. The crew was regularly assigned in pool freight service and all crewmembers had been off duty for at least 12 hours prior to reporting on November 17.

Postmortem toxicological screens of the blood of the engineer and head brakeman of Extra 3119 West, and the conductor of Extra 8044 West, were negative for alcohol and barbiturates.

Train Information

Extra 3119 West

Extra 3119 West originated at Las Vegas and consisted of UP diesel-electric locomotive unit 3119, 20 UP bulkhead flatcars loaded with crossties, and a UP caboose. The train's makeup was not altered en route and it had a nominal length of 1,252 feet.

UP 3119 was a General Motors Model SD40 diesel-electric locomotive unit manufactured in 1971. It was rated at 3,000 horsepower and had a working-order weight of 392,000 pounds. The unit had 6-wheel roller-bearing trucks with 40-inch wheels, clasp-type brake rigging with two 16-inch cast-iron brake shoes to each wheel. It was equipped with 26L brake equipment with a pressure-maintaining feature, extended range dynamic braking, an overspeed control set to function at 71 mph, a speed indicator and recorder, a functioning radio, and a floor-mounted pedal-type "deadman" safety device. The unit was not equipped with a brakepipe flow indicator 5/ or with an event recorder.

The caboose was an all-steel cupola type, built in 1967, and weighed about 58,700 pounds. It had 4-wheel roller-bearing trucks with 33-inch wheels and high-phosphorous cast-iron brake shoes. The caboose was equipped with electrically-powered marker lights and interior lighting as well as a radio, powered by a 12-volt battery charged by a belt-driven alternator. However, the electrical system was inoperative and the conductor had been furnished a large pack-type portable radio set. The caboose had a type AB air brake and type A-1 graduated brake valve mounted on the cupola bulkhead. Adjacent to the brake valve was a dual-needle gauge which indicated both brakepipe and brake cylinder air pressure. (See figure 3.) The caboose had end ladders which provided access from the platforms to the roof.

The bulkhead flatcars were built by UP in 1956 (see appendix H) and later modified for hauling crossties by adding steel framing on each side to prevent shifting of the ties while in transit. A total of 55 such cars carried the UP classification F-70-1. (See figure 4.) The cars were 53 feet 6 inches long over the end sills and, as modified, had an average light weight of 79,160 pounds, stenciled load limit varying from 139,000 to 141,700 pounds, and a maximum allowable gross weight of 220,000 pounds. They had cast-steel "fishbelly" type underframes, 4-wheel trucks with 33-inch wheels, 6- by 11-inch plain journals, and high-phosphorous cast-iron brake shoes. All of the tie cars in Extra 3119 West had type AB air brakes and 4-position retaining valves. They had side and end ladders the full height of the bulkhead on the brake ends of the cars.

Extra 8044 West (2-VAN-16)

Extra 8044 West (2-VAN-16) consisted of 5 UP locomotive units, 49 loaded piggyback and automobile rack cars, and a UP caboose with functioning radio. The train's trailing weight was calculated to be 3,625 tons and its nominal length was 4,750 feet. The

5/ The brakepipe flow indicator is a differential pressure gauge designed to give the engineer an indication of the rate of air flow through the automatic brake valve to the brakepipe. The device also has an amber warning light which can be set so that it lights whenever air flow reaches a given level. UP had service-tested the device but had not adopted it as standard equipment on their locomotive units.

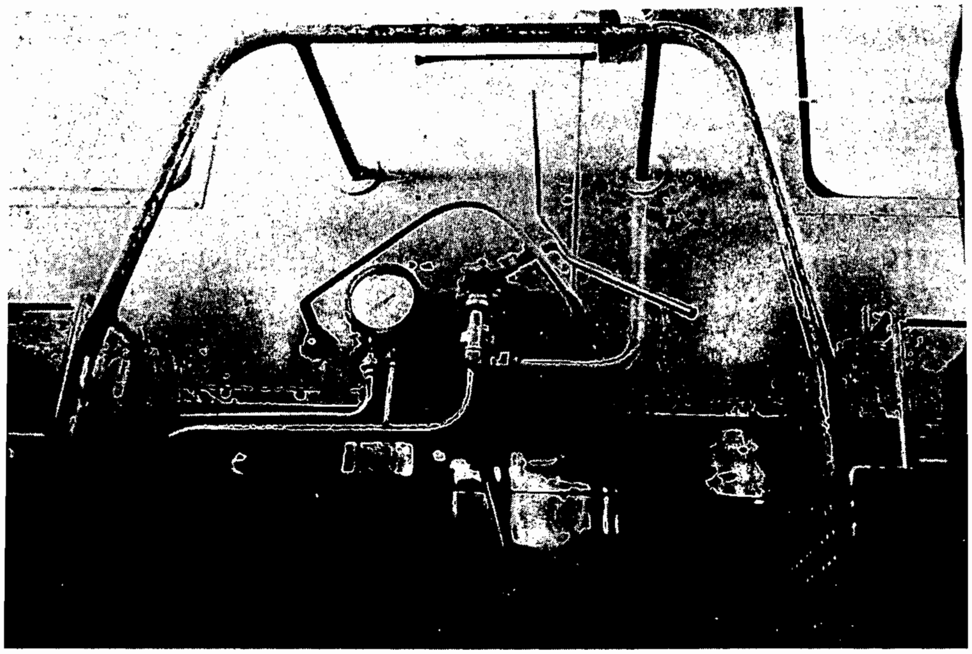

Figure 3.--Interior view of UP 25668, the caboose of Extra 3119 West, showing cupola bulkhead wall with type A-1 graduated caboose brake valve and dual-needle air pressure gauge. Viewed as found at the accident site facing forward or west.

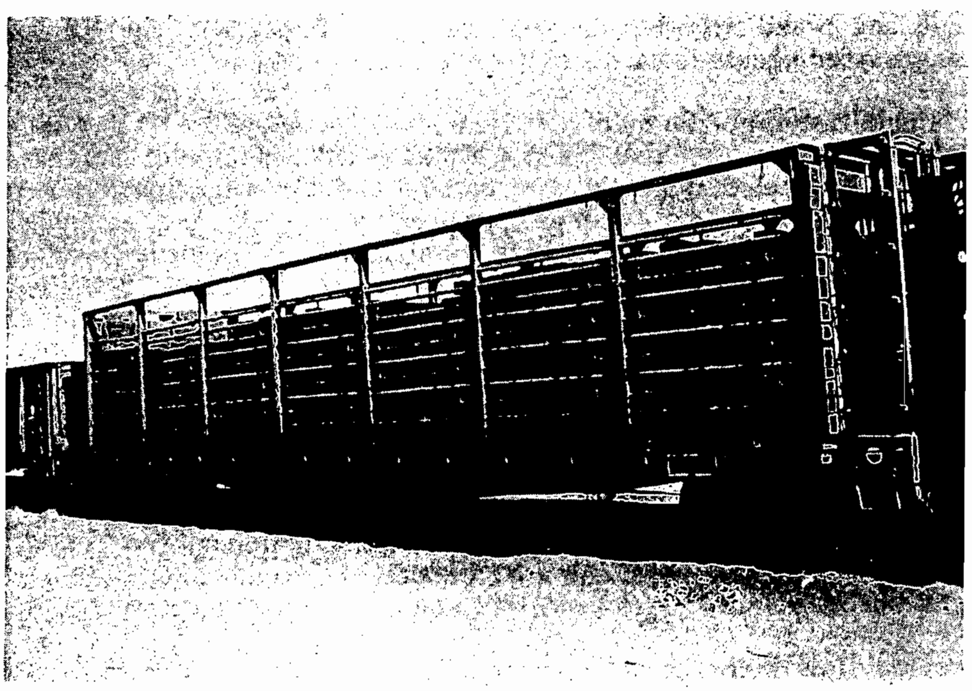

Figure 4.--Partly-loaded UP 913000-series bulkhead flatcar modified for hauling crossties. This car was of the same type and class as the tie cars in Extra 3119 West.

lead locomotive unit was UP 6946, a General Motors model DD40X diesel-electric locomotive unit with 8-wheel trucks and a rating of 6,600 horsepower. This unit had a functioning radio, a speed indicator and recorder, and an overspeed control set to function at 76 mph. UP had removed the cutout cocks by which the overspeed control of its locomotive units could be readily rendered inoperative by the engineer. The other four locomotive units of Extra 8044 West were 3,000-horsepower SD40-2 models. Maximum dynamic braking horsepower that could be developed by the locomotive's 32 axles was 18,600 and the ratio of dynamic braking horsepower to trailing tonnage was more than 5 to 1. According to the engineer of Extra 8044 West, the air brake test performed on his train was initiated by a car inspector from the head end, as in the case of Extra 3119 West.

Makeup and Inspection of Extra 3119 West

The consignment of ties shipped from UP's timber-treatment plant at The Dalles, Oregon, arrived at Las Vegas in a through freight train at 12:55 a.m., November 17. There were 20 cars of 9-foot main track ties and 5 cars of 8-foot yard ties mixed in the head 26 cars of the train. A car loaded with beer separated the 15 forward tie cars from the 10 rear tie cars. It had been decided to run the 20 cars of 9-foot ties to the location of a tie renewal program near Yermo, Califorina, and the incoming crew was instructed to uncouple the 26-car head-end block from their train and set it over against a caboose which had been placed in the No. 5 yard track. Later, a third-shift yard crew uncoupled the block behind the beer car and placed this car and the 5 tie cars ahead of it on the wye track, after which the 10 head tie cars were coupled to the 10 cars that had been left in the No. 5 track with the caboose. Subsequently, UP 3119 was brought from the locomotive servicing facility and placed on the head end of the train. All of the air hoses in the train were coupled and the brakepipe was charged to 90 pounds, the air-brake feed valve setting on the locomotive. The car inspector who later performed the air brake test stated that he observed the caboose gauge indicating 90 pounds brakepipe pressure after the train was initially made up.

At about 7:45 a.m., 20 minutes before the reporting time of the crew of Extra 3119 West, the Las Vegas terminal superintendent was informed that Extra 3119 West contained five cars of 8-foot yard ties which could not be used in the main track and would have to be replaced by the cars that had been switched out with the beer car. The terminal superintendent at first refused to switch the train, stating that "Ties are ties." Later, he directed an 8:00 a.m. yard crew to board the 3119 and pull Extra 3119 West by him so that he could personally determine the location of the cars that had to be switched out. This work was started about 8:20 a.m. The five cars with 8-foot ties were actually the 5th, 6th, 7th, 8th, and 10th cars from the head end and the train was again parted ahead of the rear 10 cars. Apparently due to a mixup of numbers, the 9th head car (UP 913015) was erroneously switched out instead of the 7th head car (UP 913035). All of the switching was done with air in the cars and when the train had been broken, the brakepipe had been left open and allowed to vent on the rear half of the train. After obtaining five cars of 9-foot ties from the wye track, the yard crew coupled these, with unit 3119, on the head end of the train. Air hoses were recoupled and the brakepipe was allowed to recharge. During the various switching operations at Las Vegas, the couplings within 3 blocks of tie cars were never disturbed. These blocks were the rear 10 cars, the head 5 cars, and the 6th through 9th head cars in what ultimately constituted Extra 3119 West.

Of the 20 tie cars in Extra 3119 West, one car was loaded with 586 treated 7- by 9-inch by 8-foot softwood ties intended for use in yard tracks, and the remaining 19 cars contained 10,203 treated 7- by 9-inch by 9-foot main track ties, 8,097 of which were hardwood and the remainder softwood. As far as could be determined, the tie cars were not weighed at the treating plant, en route, or at Las Vegas, where UP had a track scale. However, the waybill for each car had a typewritten estimate of 60,000 pounds for lading. On this basis, the total estimated lading was 1,200,000 pounds, making the trailing weight of Extra 3119 West 1,421.25 tons. However, the conductor was given a form indicating the train's trailing weight was 1,495 tons. Following the accident, the UP mechanical department estimated the train's lading as weighing 2,321,317 pounds, and the train's trailing weight as being 1,981.55 tons. An expert witness engaged by UP gave the average weights for hardwood and softwood ties as being 240 and 160 pounds, respectively. On that basis, the trailing weight of Extra 3119 West would have been 2,002.74 tons.

After the switching was completed, the terminal superintendent informed the engineer that Extra 3119 West was ready and that he should make an air brake test as soon as a car inspector was on hand. The engineer and head brakeman then walked to the locomotive unit, but the conductor and flagman remained in the yard office which was about 1,500 feet from their train. Although it was customary for two car inspectors to inspect and test an outbound train, only one inspector was available. This man stated that he initiated the air brake test from the head end of Extra 3119 West, and after the brakes were applied, he walked to the rear of the train, checking brake shoes, brakepipe angle cocks, and brake cylinder piston travel. The inspector asserted that he crossed over between the cars whenever he could not see a car's brake cylinder because it was on the opposite side of the center sill. He did not, however, inspect the cars' branchpipe cutout cocks. After observing the brakes apply on the cars and having found no defects, the inspector used his portable radio to instruct the engineer to release the brakes. After the caboose brake released, he boarded the caboose and observed that the gauge in the cupola indicated brakepipe pressure of more than 85 pounds. The inspector then returned to the locomotive where he asked the engineer if everything was "O.K." When the engineer replied affirmatively, the inspector assumed this meant that brakepipe leakage had not exceeded the allowable 5 pounds per minute. (See appendix D.) The inspector stated that the brake test was completed at 9:42 a.m. and that he inspected the train from the south side as it pulled by him. The conductor and flagman said they inspected the train from the north side as it pulled by the yard office and then boarded the caboose. No surviving crewmember or other employee witnessed the air brake test or could otherwise corroborate the inspector's statements concerning it.

Meteorological Information

At the time of the accident, there was high overcast with 25 miles visibility in the Cima-Kelso area. Winds were northeasterly at 5 to 10 mph. The temperature was 62° F.

Method of Operation

The accident occurred on the First Subdivision of Union Pacific's California Division, which connects Las Vegas, Nevada, with Yermo, California, a distance of 171 miles. This is a single track railroad and trains are operated by the indications of a centralized traffic control system (CTC). Normally, 22 freight trains and 2 passenger trains are operated daily across the First Subdivision. A dispatcher at Salt Lake City, Utah, supervised operations over the First Subdivision and he was under the direct supervision of an assistant chief train dispatcher, who was also located at Salt Lake City. The dispatcher routed and monitored the movement of trains as they reached and passed control points, represented by lights on the modelboard of his CTC machine. The machine was also equipped with a Traingraph, a recording instrument that tracked the movement of trains by time and location. The dispatcher also used radio to instruct and communicate with the traincrews. There were no means for recording communications traffic to and from the dispatcher.

The dispatcher who was on duty at the time of the accident worked the first, or daylight, shift between 7:00 a.m. and 3:00 p.m. He was a salaried supervisor and had worked as a dispatcher since 1952. He stated that he was thoroughly familiar with the First Subdivision and had ridden the head ends of trains down Cima Hill as part of a continuous effort over the years to familiarize himself with the territory. The dispatcher acknowledged that there had been incidents in the past when engineers had trouble controlling their trains between Cima and Kelso, but these had not actually resulted in accidents. The dispatcher stated that he did not consider Extra 3119 West as being in an emergency situation until the train passed Elora and that, even then, he had no doubt that the VAN train was capable of outrunning Extra 3119 West. At no time did the dispatcher consider routing the VAN train into the passing track at either Dawes or Hayden so that Extra 3119 West could overtake and pass it.

Union Pacific requires dispatchers to keep trains moving in an expeditious and safe manner and they must provide proper protection for all trains in accordance with rules and special instructions. 6/ According to the dispatcher, there were no standing procedures to follow in a runaway emergency on Cima Hill, and when he notified the assistant chief train dispatcher that an emergency appeared to be developing, the assistant chief train dispatcher did not offer advice or instruction.

Cima Hill

Beginning at milepost 253.4, just west of Cima, and ending at milepost 236.1, at the east end of Kelso, the elevation above sea level drops 2,006 feet, requiring a westerly descent at a rate in excess of 2 percent. Union Pacific treats this as a sustained 2.20-percent grade compensated for curvature; the combined resistance of ascending grade and track curvature 7/ is the equivalent of an average of 2.20 percent, or a rise of 116 feet to the mile. However, the grade itself is not uniform.

Between Cima and Kelso, the UP crosses the Mojave Desert on a relatively direct line. The country is open and there are no sharp breaks in the terrain. There are only 17 curves in 17.3 miles and, collectively, the curves and their spirals comprise less than 40 percent of the alignment. The sharpest curves and the least severe fall in elevation per mile in the entire grade are between Cima and Chase. (See table 1.) The tangents are short and curves and their spirals make up more than two-thirds of this section. West of Chase, the fall in elevation becomes progressively more severe and there is progressively less curved track. Straight track comprises more than 6 of the 8 miles between Elora and Hayden and in this section there are tangents of 0.9, 1.4, and 2.3 miles.

Between Cima and Kelso there are four controlled 6,500-foot passing tracks--Chase, Elora, Dawes, and Hayden, from east to west. All were clear at the time of the accident. The distances between the opposing turnouts of these passing tracks are: Cima to Chase, 2.43 miles; Chase to Elora, 1.92 miles; Elora to Dawes, 2.74 miles; Dawes to Hayden, 2.67 miles; Hayden to Kelso, 2.21 miles. The VAN train could have fit into any of the passing tracks with about 1,000 feet to spare between the insulated joints. All of the passing tracks had No. 14 turnouts with a maximum speed of 20 mph

6/ Union Pacific Railroad Company Form 2274, Instructions for Train Dispatchers, effective May 1, 1972.

7/ One degree of curvature offers the same resistance as 0.05 percent grade. (See appendix F.)

Table 1.—Union Pacific track between Chase and East Kelso.

	Distance (miles)	Tangent Track (miles)	Curved Track (miles)	Fall in Elevation (ft)	Average Fall per Mile (ft)	Average Actual Gradient (%)	Grade Equivalent of Curvature (%)	Descending Grade Compensated for Curvature (%)
m.p. 253.4 to Chase (m.p. 250.44)	2.96	0.86	2.10	337	113.8	2.155	0.052	2.103
Chase to Elora (m.p. 247.28)	3.16	1.91	1.25	366	115.8	2.193	0.013	2.180
Elora to Dawes (m.p. 243.27)	4.01	2.78	1.23	464	115.7	2.191	0.014	2.177
Dawes to Hayden (m.p. 239.35)	3.92	3.27	0.65	456	116.3	2.202	0.006	2.196
Hayden to East Kelso (m.p. 236.1)	3.25	1.75	1.50	383	117.8	2.231	0.012	2.219

authorized by the timetable. A maximum of 5 minutes delay had to be allowed from the time the dispatcher encoded his CTC machine to align the turnout to any of the passing tracks to the time the command was actually executed. The turnout could be reversed as soon as the train cleared the insulated joint inside the passing track.

Union Pacific System Timetable No. 4 was in effect on November 17, 1980, (see appendix C) and authorized a 70-mph maximum speed for freight trains between Yermo and Erie, which included the section between Cima and Kelso. This was subject to the maximum authorized speed for a train as noted on the clearance form issued to the train's conductor and engineer, as well as to lesser speeds stipulated in the timetable for westbound trains between Cima and Kelso. These speeds were 35 mph for trains controlled exclusively with dynamic braking, and 25 mph for trains not required to use retainers. California Division Special Rule 1042 (RC) in the timetable stipulated that any train exceeding 3,500 tons could not be controlled exclusively with dynamic brakes. VAN train Extra 8044 West fell under the provisions of this rule and was, hence, restricted to 25 mph. The rule also required that retainers be used on trains between Cima and Kelso when; (1) they exceeded 85 tons per operative brake; (2) they exceeded 80 tons per operative brake and had less than 2-horsepower dynamic braking per trailing ton, or; (3) had less than 1-horsepower effective dynamic braking per trailing ton. UP air brake rule 1042(A), (see appendix D) restricted any train using retaining valves to 20 mph. However, Special Rule 1042(RC) further restricted trains which fell under the 3rd category to 15 mph on Cima Hill and required that they be stopped for 10 minutes at Dawes to cool wheels. Extra 3119 West fell under this category of the rule.

Air Brake Rules

There was no rule or special instruction requiring the determination that a locomotive unit's dynamic braking feature was functional before it was assigned to a train at Las Vegas or elsewhere on the Union Pacific. California Division Special Rule 1042 (RC) required only that westbound trains handled by a locomotive not equipped with a brakepipe pressure maintaining feature had to make a dynamic braking test on the downgrade west of Erie. However, counterparts of this rule on the Utah and Wyoming divisions required this type of testing on all freight trains before they were allowed to descend designated grades. California Division Superintendent's Circular No. 47, issued effective January 2, 1980, instructed engineers that locomotive "units will not be dispatched...without dynamic brakes functioning on lead unit." In the event dynamic brakes failed en route, the circular instructed engineers to contact the train dispatcher and be governed by his instructions. (See appendix E.) The circular was cancelled on August 12, 1980. It could not be determined what may have prompted the issuance of the circular or its subsequent cancellation.

Las Vegas is a designated 500-mile inspection point and all trains leaving there are required to receive the initial terminal air brake inspection and testing prescribed by various UP air brake rules. 8/ (See appendix D.) These rules require that the inspection and testing be initiated after it has been determined that the brakepipe has been charged to within 15 pounds of the feed valve setting on the train's locomotive, as indicated by an accurate gauge connected to the brakepipe at the rear of the train. After a prescribed test has established that brakepipe leakage does not exceed 5 pounds per minute, the train's braking system must be inspected to determine that the brakes on all cars apply and release; that retaining valves and retaining valve pipes are in serviceable condition; that angle cocks, brakepipe end cocks, cut-out-cocks, and retaining valve handles are in

8/ The requirements of these rules generally conform with what is required by the Power Brake Law (49 CFR 232.12) the proper position; that brake rigging is properly secured and does not bind or foul; and that air hoses are serviceable and properly coupled. Body-mounted brake cylinders with piston travel of less than 7 inches or more than 9 inches must be adjusted to nominally 7 inches. UP Air Brake Rule 1058(A) states that when brake cylinder piston travel exceeds 10 inches, the air brakes cannot be considered to be in effective operating condition. After the brakes have been released, inspectors and trainmen must know that air pressure has been restored or is being restored as indicated by the caboose gauge.

UP "Rules and Instructions Governing the Operation of Air Brakes" also included the following rules applicable to the management of trains on mountain grades:

> 1039(A.) Dynamic brake must be supplemented by use of train air brakes to extent necessary to properly control speed of train.
>
> 1043. When starting freight trains from summit of heavy descending grades and pressure maintaining method of braking is to be used, care must be used to avoid making first reduction too heavy as this would reduce speed of train to extent brakes would have to be released.
>
> If first reduction was not sufficient to hold train, further brake pipe reductions of one or two pounds each may be made until amount is reached where train will be held at desired speed.
>
> Equalizing reservoir gauge must be frequently observed and if any increase in pressure is shown on this gauge during time brakes are applied, this pressure should be promptly reduced to the amount indicated by this gauge before increase occurred.
>
> 1043 (A). When starting freight trains from summit of heavy descending grades and "short cycle" method of braking is to be used, first application of brakes must be made as soon as practicable without stalling, to test holding power of brakes while speed is slow and to get the additional aid of retaining valves if their use is required. All subsequent brake applications must be of sufficient amount to hold train at required speed, and when releasing if necessary, "Release" or "Running" position of automatic brake valve must be used until air brake system has recharged and brakes are to be reapplied. Subject to local restrictions, speed must correspond with holding power of brakes and ability to fully recharge, maintaining as nearly as possible a uniform speed. Light applications are best, but must not be so light as to prevent getting a sufficient reduction in speed to insure recharging before again reaching too high a speed. To determine the extent to which pressure in brake system is being recharged, brake pipe pressure as indicated just before releasing must be observed. If pressure is gradually reducing and cannot be regained by slower speed, train must be stopped and air brake system recharged. When retaining valves are being used, it is practical to release at slower speeds.

Union Pacific had no rule, special instruction, or bulletin to indicate to engineers the maximum service brakepipe reduction that could be used safely in an effort to arrest acceleration on a heavy descending grade.

Air Brake Rule 1052 stipulates that the conductor's, or caboose, brake valve must not be used except in an emergency. There is no rule or instruction that requires the conductor to inform the engineer that he has applied the air brakes from the caboose valve. Rule 1052(A) reads, "When conductor's valve or caboose valve is opened while train is moving, under no circumstances must it be closed before the train has stopped." Rule 1053(A) required the engineer to place the automatic brake valve in "Emergency" position in the event an emergency brake application was initiated from any source other than the automatic brake valve. In the event that a service application of the automatic brake was initiated from a source other than the automatic brake valve, the following air brake rule applied:

> 1053. If brakes in train are applied with service application from any source other than from use of automatic brake valve on locomotive while using power, engineer must leave brake valve in "Running" or "Release" position, keep locomotive brake released, and close throttle gradually as speed of train reduces. When train has reached point where it is evident it will stop within next 100 feet, throttle must be closed, rails sanded, and independent brake fully applied as train comes to stop. This procedure must also be followed when not using power except with respect to use of throttle. After stop is completed, engineer must make or observe that not less than a ten (10) pound brake pipe reduction has been made from equalizing reservoir pressure, and must permit this application to equalize throughout train before releasing train brakes.

Union Pacific does not have divisional or regional air brake supervisors, and with the advent of its formal engineer training program, UP discontinued the use of air brake instruction cars to provide local air brake training to supervisors and employees. As a result, there is no provision for training brakemen and conductors on the air brake rules. The conductor and rear brakeman of Extra 3119 West stated that they had never received formal, comprehensive training on air brakes.

Survival Aspects

Locomotive 3119 remained upright and in line with the track but had virtually all of the carbody torn from the frame as a result of being overridden. (See figure 5.) The engineer and head brakeman were ejected from the unit and their bodies were found on the ground south of the main track. The engineer received massive blunt head injuries that were instantly fatal. The head brakeman received massive multiple injuries to the head, chest, abdomen, and extremities that were also instantly fatal.

The VAN train's caboose had both platforms crushed and the rear bulkhead was partly driven in. After derailing, the caboose carbody separated from the trucks, turned over, and slid down the south embankment on its left side. The conductor and rear brakeman were thrown to the floor. The conductor received multiple severe head, chest, and spine injuries which were fatal within minutes. The rear brakeman survived the accident with severe facial and back injuries. He was flown from the accident site to a Las Vegas hospital in a "Flight for Life" rescue helicopter.

Tests and Research

Although the operator compartment of UP 3119 was demolished, it was possible to determine most of the locomotive's control settings after the accident. The throttle was found in "Idle," the reverser was in "Forward," the selector was in "Power," and the brake valve cut-off valve was in "Pass." The independent brake was found fully

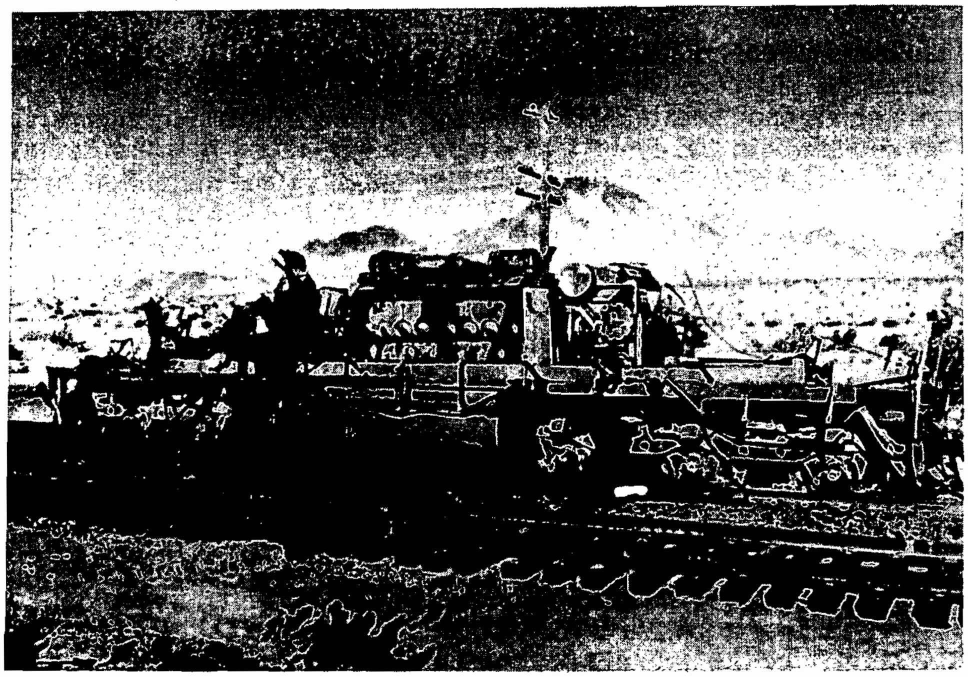

Figure 5.--Locomotive unit of Extra 3119 West where it stopped after the accident.

applied. The automatic brake valve was in release with the handle appearing to have been struck and possibly moved. The unit's brake shoes were all worn away, and all the wheels had discolored rims. Metallurgical examination at UP's laboratory indicated that all the wheels had been uniformly overheated to 900-950° F throughout the full rim section. Post-accident testing of the unit's air brake valve determined that it functioned normally. A legible tape was recovered from the speed recorder of UP 3119 and calibration of the recorder indicated that there was no variation between actual and recorded speeds up to 32 mph and only nominal difference at higher speeds. (See appendix J.) Because the recorder was accurate at lower speeds, the tape was analyzed to determine the time and relative locations of variations which occurred in indicated speed. It was possible to establish that a dramatic increase in acceleration occurred at 20 mph, about 18 1/2 minutes and 4.6 miles into the run. The maximum 79-mph speed that could be recorded was reached 12 1/2 miles west of the starting point at Cima. Analysis of the speed tape indicated that Extra 3119 West attained its maximum rate of retardation during the descent, about 2.5 mph per minute, following the brake application made after the train cleared the passing track at Cima.

The caboose valve was found in the fully open, or emergency position. The hand brakes of the caboose had not been applied. The angle cock on the forward end of the car was open; the angle cock on the rear was closed. The brake cut-out cock was open and the retainer valve was in the direct release position.

Most of the tie cars of Extra 3119 West were thrown from the track with such force that the cars' trucks were completely dismantled and it was impossible to reconstruct them or to ascertain which wheelsets had been under a given car. The brake rigging of most of the cars was destroyed and only 32 of the 160 brake shoes were recovered.

About half of these had more than half the original thickness remaining. Retainer valves were found on 18 cars, and of these, 12 were in the heavy holding position, 2 were broken, 3 were in direct release position, and 1 was in indirect pressure position. Thirteen of the undamaged retainer valves functioned normally under test. Of the tie car brake valves recovered, 11 functioned normally under test, 2 had some leakage but were operable, and 1 leaked due to damage. Branchpipe cut-out cocks were found in the closed, or out, position on the 11th, 15th, and 18th head cars. Brakepipe angle cocks on the rear of the 3rd and 17th head cars were found closed but both had been struck during the derailment. The forward angle cock of the 18th head car was also found closed, half-buried in the sand. During the handling of the tie cars at Las Vegas, these cars had not been uncoupled at the ends where the angle cocks were found closed.

Of 78 tie car wheelsets recovered and sent to UP's laboratory for examination, 25 showed no thermal evidence, 29 showed discoloration indicating heating to less than 400° F, 12 had indications that they were heated to 400-700° F, and 2 appeared to have been heated to 750-800° F. (See appendix I.) Thirteen wheelsets displayed evidence of overheating on only one wheel. The ten remaining wheelsets had thermal evidence, if any, obliterated by rust or corrosion. The UP laboratory report stated that no evidence was found to indicate "any abnormal heating not commonly seen in normal train service." The report also stated that there was no significant evidence of slid flats, tread smear, or deformation apparent in any wheel.

In order to determine the efficiency of the brake rigging of the tie cars, the UP tested an undamaged car of the same class as those in Extra 3119 West. This car had a light weight of 80,000 pounds and a gross allowable weight of 220,000 pounds. Total brake shoe force at 50 pounds brake cylinder pressure was found to be 32,605 pounds which was 40.75 percent of the light weight and 14.8 percent of the gross weight. These compared favorably with the maximums of 53 and 13 percent for light and gross weights, respectively, specified by the Manual of Standard and Recommended Practice of the Association of American Railroads.

Following the accident, UP made up a test train with a SD40 unit similarly equipped to the 3119, a caboose of the same class as that on Extra 3119 West, and 20 serviceable class F-70-1 tie cars similar to the cars in Extra 3119 West. A number of the test train cars were reloaded with ties salvaged from the accident site and all the test cars were weighed after loading. Four cars were only partly loaded and the test train was found to have 9,695 ties on board, more than 1,000 less than had been on Extra 3119 West. The 16 fully-loaded test train cars had an average gross weight of 201,031 pounds and the full trailing weight of the test train was 1,948.25 tons.

The test train cars were inspected and repaired as necessary to meet the requirements of UP air brake rules. Brake cylinder piston travel was adjusted to nominally 7 inches on all of the cars and a total of 18 brake shoes were changed out on 10 cars. Prior to adjustment, piston travel had been in excess of 10 inches on 6 cars and from 9 to 10 inches on 7 cars. The test train included 3 cars that had been switched out of the tie train on November 17. One had 9-inch piston travel and had two brake shoes changed; the second had 9 1/2-inch piston travel and had two brake shoes changed; and the 3rd had 11-inch travel and had one shoe changed.

The test train was first used in static testing at Las Vegas. Employing various reductions of the brakepipe pressure at varying time intervals, it was shown that with pressure maintaining and functioning retainers used in heavy holding position, it was virtually impossible to dissipate the train's brakepipe air supply to the point of no recovery through manipulation of the locomotive brake valve. Road testing was preceded by an inspection and test of the train's air brakes at Cima which revealed that a tie car had developed a cylinder leak that rendered its brakes only partially effective. All other cars had fully effective brakes and the dynamic brake was not used. The test train started from the north passing track at Cima and was operated by an experienced retired UP supervisor with Safety Board investigators observing from both ends of the train. No effort was made to exactly duplicate the speed tape of Extra 3119 West and the caboose valve was not opened during the testing. The train was started by releasing the independent brake, opening the throttle to the No. 1 position, and advancing throttle to the No. 3 position when speed reached 10 mph. When the train had moved about 1,000 feet, but had yet to enter the main track, a 10-pound brake application was made to decelerate from 13 mph. The throttle was then progressively advanced to the No. 5 position accelerating the train to 16 mph by the time it had traveled three-fourths of a mile. Acceleration was arrested by reducing throttle, the brakepipe reduction was increased to 17 pounds at 15 mph, and 15 seconds later the brakes were released against the retainers. Thereafter, speed was cycled between 3 and 18 mph by successive 10-pound applications and releases against retainers, and manipulation of the throttle. The train was stopped from 15 mph by the combination of gradual throttle reduction and a 10-pound brake application at a point 4.7 miles west of Cima--the approximate location where Extra 3119 West had begun uncontrolled acceleration.

Additional static tests were made at Las Vegas to determine the effect of an emergency application initiated from the caboose after the brakepipe had been depleted from a full charge. Tests were made with brakepipe pressures of 64 (full service), 60, 57, 50, and 37 pounds. The emergency application propagated through the train and the locomotive unit only in the case of the full service reduced brakepipe. In each instance where the reduction was beyond full service, the emergency application failed to transmit to the locomotive and the locomotive brake valve's pressure-maintaining feature began restoring brakepipe pressure in less than one minute. This caused a partial release of the brakes throughout the train and further depletion of pressure in the cars' emergency reservoirs. According to UP's director of train operating practices, it would be necessary to quickly place the locomotive brake valve in emergency position in order to nullify the action of the pressure maintaining feature. Even then, restoration of emergency brake cylinder pressure and adequate braking capability could not be achieved as long as the caboose valve remained open. The test results were later confirmed in testing performed for the Safety Board by the Westinghouse Air Brake Company at their Wilmerding, Pennsylvania test rack.

Other Information

Air Brake Association

The Air Brake Association manual Management of Train Operation and Train Handling, 1977 edition, (see appendix F) relates that operating freight trains down grades of any significant length requires an ability to "balance the grade" by achieving zero acceleration, or holding speed steady at safe and practical values, while maintaining an ample safety margin of service brake available to stop normally anywhere on the grade. To hold speed steady on a downgrade, the force of gravity must be balanced by the sum of train resistance and brake retarding force. The heavier, or steeper, the grade, the lower the effect of train resistance and the more braking required. The increase of a few tons in weight per car can also be critical in the ability to balance the grade since there must be a nearly corresponding increase in braking force. Each added ton of train weight on a 2.20-percent descending grade adds 44 pounds to the force of gravity while providing only 4 pounds of added train resistance at 15 mph, according to calculations in the Association's manual. Short trains with high gross weights per car are particularly sensitive to this since a greater workload is imposed on wheels and brake shoes than is the case with longer trains of cars of moderate average weight.

According to the Association, the amount of train brake retarding force used to balance the grade normally should not exceed one-half of the normal full service train brake available if dynamic brake and pressure maintaining are operative. When pressure maintaining is available but dynamic brake is not, the amount of brake required to balance the grade should not exceed one-third of normal full service. (At 90 pounds brakepipe pressure, full service is 26 pounds.) Since speed can get out of control in a very short time on heavy grades, it is stated that the engineer should not hesitate to use an emergency application to stop the train.

The Air Brake Association recommends that when cycle braking against retainers, "The initial application should be started at a point that will prevent speed from becoming excessive as the train moves out onto the grade and before the application becomes effective on the whole train. There is no substitute for good judgment and experience." Additionally, it is recommended that the initial application be held until speed is under the average required before the brakes are released against the retainers. When pressure maintaining is being used, the Association recommends that the engineer be alert for, (1) brakes being applied from the rear end, and (2) bad leakage having developed in the brakepipe. If the locomotive unit is not equipped with a brakepipe flow indicator with indicator light, the engineer can detect the increased flow of air into the brakepipe through the automatic brake valve resulting from either situation by observing main reservoir pressure dropping rapidly and compressors loading repeatedly.

Rules of Other Railroads

The Baltimore and Ohio (B&O), Denver & Rio Grande Western (D&RGW), Burlington Northern (BN), and Southern Pacific (SP) railroads all operate over mainline grades that are at least as long as Cima Hill, descend at sustained rates of at least 2 percent compensated for curvature, and over which trains of bulk commodities are commonly operated. In each instance, these railroads have specific and straightforward air brake rules and/or timetable instructions covering the management of trains on their mountain grades, which go beyond what is provided by UP in their air brake rules. (See appendix G.)

Burlington Northern classifies any extended grade of 1.80 percent or more as a mountain grade and has special rules to cover such operations which include long 2.20-percent grades in the Cascade Range of Washington. The stipulated method of moving all freight trains down these grades is the combination of dynamic braking and a service application of the air brakes of not less than 5 to 7 pounds. Trains which average 100 tons or more per operative brake must carry 100 pounds of pressure in the brakepipe. It is not permitted to reduce brakepipe pressure by more than 18 pounds to balance the grade. Trains averaging 80 to 99 tons per operative brake must carry 90 pounds in the brakepipe and are permitted a maximum service reduction of 15 pounds. At four places in BN's Mountain Grade Rules, this admonition appears in bold type: "AN EMERGENCY BRAKE APPLICATION SHOULD BE MADE WITHOUT HESITATION SHOULD ANY CONDITION OCCUR WHERE THERE IS DOUBT OF ABILITY TO CONTROL TRAIN SPEED."

• Southern Pacific has a number of long 2.00- to 3.00-percent grades in the Cascades of Oregon and Sierra Nevadas of California, as well as the 40-mile, 2.20-percent grade in southern California known as Beaumont Hill. SP rules require engineers of all freight trains to perform a running test of the automatic air brake before descending these heavy grades. Also, SP rules require that a train must be stopped immediately if a reduction of 13 pounds (one-half of full service) is insufficient to balance the grade.

Bulk trains descending Baltimore and Ohio's 2.00-percent Seventeen Mile Grade between Altamont and Piedmont, West Virginia, must slow to 8 mph passing the summit and once acceleration begins, the engineers are required to make a minimum brakepipe reduction of not less than 8 pounds to be followed by application of the dynamic brake. If the grade cannot be balanced by a combination of dynamic braking and a maximum of 15 pounds service reduction, the train must be stopped. The train may not descend the remainder of the grade until retainers have been set up, hand brakes have been applied, and brakepipe pressure fully restored. Continuous use of the automatic brake for more than 2 miles is prohibited in any event.

There are numerous notable grades on the Denver & Rio Grande Western (D&RGW) including the 37-mile, 2.00-percent descent down the front range of the Rocky Mountains from Moffat Tunnel to the suburbs of Denver; the 22-mile 3.00-percent descent from Tennessee Pass to Minturn, Colorado; and the 30-mile, 2.00-percent downgrade from Soldier Summit to Thistle, Utah. Both Colorado grades are characterized by near-constant curvature up to 12 degrees. The Utah grade has 9-degree curves. D&RGW timetable rules define a bulk train as any which averages 80 or more tons per car, which has functioning dynamic brake, and has trailing tonnage in excess of that specified for the various locomotive models. In the case of an SD40 unit, the specified minimum is 1,300 tons. If a bulk train can not balance the grade with the combination of dynamic braking and a maximum of 18 pounds service reduction, the train must be stopped and sufficient retainers set up and hand brakes applied to hold the train on the grade. The crew must then notify the chief dispatcher who, in turn, is advised by the superintendent of air brakes or road foreman of equipment as to what course of action is to be taken. The rules provide that this procedure must also be followed with a bulk train with inoperative dynamic brake <u>before</u> the train begins descending the grade. In actual practice, however, even trains with inoperative dynamic brake which do not qualify as bulk trains are not allowed to start down the grade before receiving instructions from the chief dispatcher.

ANALYSIS

The Makeup and Inspection of Extra 3119 West

Extra 3119 West was not an ordinary work train. In fact, it was as expedited a train as any on UP's California Division on the morning of November 17, 1980. A large mechanized tie gang was on location about 160 miles west of Las Vegas with no ties to install. It had taken only 3 1/2 days to move a consignment of more than 10,000 main track crossties 1,260 miles from UP's timber treating plant in Oregon to Las Vegas. When the tie cars arrived at Las Vegas shortly after midnight, supervisors there had already placed a caboose on the No. 5 yard track and they had the inbound freight crew place the block of cars containing the tie cars against the caboose. An extra board crew was available for Extra 3119 West and, with a timely departure from Las Vegas, the train could have been at the work site well before noon so that most, if not all, of the ties could have been distributed along the right-of-way during daylight hours. However, the only caboose available had an inoperative electrical system and the marker lights could not be illuminated as required between an hour before sunset and an hour after sunrise. As a result, the crew was not called to report for duty until 8:05 a.m., long after the train had been switched.

About 20 minutes before the Extra 3119 West crew was due to report, the Las Vegas terminal superintendent was told that the train included 5 cars of 8-foot yard ties that could not be used in the main track and that these would have to be replaced with cars of 9-foot ties that had been switched out during the night. Although he first refused to allow it, the terminal superintendent saw to it that a yard crew coming on duty was immediately put to work reswitching Extra 3119 West. The terminal superintendent personally directed the switching to assure that it was expedited. Perhaps a good indication of the haste with which the switching was done, was the mixup of numbers that resulted in Extra 3119 West leaving behind one of the cars of main track ties and taking in its place a car of 8-foot yard ties. The Safety Board believes that considering the delays that had been incurred, and the manner in which the switching was done, the subsequent inspection of the train was also hurried in an effort to expedite matters.

Extra 3119 West required thorough inspection and testing, not only because this was dictated by UP's rules and Federal law, but because the train would have to traverse long and heavy grades to reach its destination. Only one car inspector was available and he improperly initiated the brake test from the head end of Extra 3119 West without first determining whether or not there was any air in the brakepipe at the rear of the train. The car inspector stated that he did not make the required check to see if the cars' brakes were cut out and inoperative. He also stated that he did not ask the engineer if there had been any brakepipe leakage, but assumed that leakage had not exceeded the allowable 5 pounds per minute. The car inspector found no defects and he made no adjustments or repairs. According to the inspector, not 1 of the 160 tie car brake shoes needed to be replaced. Since there were no new brake shoes distributed along, or nearby the No. 5 track, the inspector would have had to go a considerable distance to obtain a replacement had one been needed.

Before Extra 3119 West departed from Las Vegas, the conductor was told that 1,495 tons was the trailing weight of his train. This was not the sum of the weights shown on the waybills for the cars, but it was 5 tons less than 1,500 tons which was one-half the dynamic braking horsepower of the locomotive unit. Giving the conductor this incorrect figure authorized the crew of Extra 3119 West to operate their train down Cima Hill at 35 mph without stopping to set up retainers and to cool wheels, thereby avoiding a substantial delay to the train.

The waybills for the tie cars that had been in Extra 3119 West were prepared at UP's The Dalles treating plant and were dated November 13, 1980. The date, destination, consignee, description, and weight of "Est 60,000" were typewritten. The car numbers, and the number and length of ties, were apparently added later to the waybills in handwriting. Inquiries made at the tie plant developed that the estimated 60,000-pound weight was arbitrarily applied to all shipments regardless of the type and number of ties loaded on the cars. No effort was made to estimate the weight on the basis of the individual shipment.

Safety Board investigators established that there were 9,695 9-foot ties on the test train that UP assembled at Las Vegas, compared with the 10,789 ties that had been on board Extra 3119 West. Most of the test train ties were recovered from the accident site and were a mixture of the hardwood and softwood varieties. With the ratio of hardwood to softwood on the test train probably similar to that of the original consignment, about 3 to 1, the average weight per tie on the test train was estimated at 232.55 pounds. Using this as a basis and taking into account the carload of 8-foot yard ties, the total lading weight of Extra 3119 West was conservatively calculated to be 2,456,000 pounds, more than double the total shown on the waybills. The total weight of the train, therefore, including the locomotive, was probably 2,245 tons compared to the 2,198.74-ton estimate based on average tie weights stated by UP's expert witness; and the 2,177.56-ton estimate made by UP's mechanical department.

Crew of Extra 3119 West

Since it was classed as a work train, Extra 3119 West had to be manned by a crew drawn entirely from the newer and less experienced employees who were on the extra board. The crewmembers assigned to Extra 3119 West were qualified under UP rules, but they averaged only 16 months experience in road service out of Las Vegas. The conductor had been promoted 7 months before. He and the brakemen received all of their formal training when they were switchmen on UP's Los Angeles terminal, and this included little on the air brakes that would be of use to them in the management of their train on a mountain grade such as Cima Hill. The engineer was described as an apt and capable graduate of UP's engineer training program and he had successfully handled many conventional trains down the Cima-Kelso grade. However, the investigation failed to disclose any evidence that he had acquired sufficient knowledge and expertise necessary for successfully descending this grade with a short train with high-gross weight per car and grossly inadequate braking capability.

Braking Capability of Extra 3119 West

The engineer of Extra 3119 West had been informed that his train had a trailing weight of only 1,495 tons (71.2 tons per car) and as far as he knew, all of the cars in the train had operative brakes. With pressure maintaining and dynamic braking features of the locomotive in operating condition, the engineer was permitted by the timetable to operate the train from Cima to Kelso at 35 mph. He would not have to stop at Cima to set up retainers, but he would have to reduce speed to 25 mph passing over the crest of the grade at Cima. Had Extra 3119 West weighed 1,495 tons (1,691 tons including locomotive), the downward grade force of gravity, at 44 pounds per ton of train weight, would total 74,404 pounds on the 2.20-percent grade. Nominal train resistance of 7,369 pounds 8/ combined with the 60,000-pound braking force provided by the dynamic braking of the locomotive would very nearly have balanced the gravity force. A light reduction of 7 to 8 pounds brakepipe pressure with the equivalent of 3 to 4 effective car brakes might have been required on the lower half of Cima Hill where the grade was the steepest to augment the dynamic braking and control speed.

Had the engineer been told that the weight of Extra 3119 West, including locomotive, was about 2,245 tons rather than 1,691 tons as supposed, Rule 1042(RC) required that Extra 3119 West would have to be stopped at Cima and retainers set up. Also, a 20-mph maximum speed was imposed by Rule 1042(A). As the descending gradient increased progressively from -1.822 percent to -2.176 percent between Cima and Chase, the grade force of gravity in excess of the train's rolling resistance would increase from 74,543 to 90,437 pounds. Had the dynamic brake been operative, the remaining grade force that would have to be balanced by train braking force would ultimately require the equivalent of 10 fully-operative car brakes while still leaving an adequate reserve of braking capability to stop the train if necessary. (See table 2.)

Without dynamic braking, Extra 3119 West's air brake system had to be relied upon entirely to balance the 90,437-pound grade force at 15 mph by the time the train reached Chase, less than 3 1/2 miles from the starting point. Table 3 indicates that once the train had started down the -1.822-percent compensated grade, it was not possible to balance

8/ Train rolling resistance is calculated here and elsewhere in this report on the basis of the Davis formula. (See appendix F.)

Table 2.—Extra 3119 West--Number of Effective Car Brakes Required With Fully Effective Dynamic Braking Capability to Balance Grade at 20 mph.

Train Weight--4,490,000 lbs.

Pounds Brakepipe Reduction	-1.822% No. of Brakes (13,838 lbs.) Required	-2.102% No. of Brakes (26,410 lbs.) Required	-2.176% No. of Brakes (29,732 lbs.) Required
7	8.1	15.6	17.5
8	7.1	13.6	15.3
9	6.3	12.1	13.6
10	5.7	10.9	12.3
11	5.2	9.9	11.1
12	4.8	9.1	10.2
13	4.4	8.4	9.4

the grade at 15 mph and also retain any margin of brakepipe pressure for stopping if necessary. To balance the -1.822-percent grade, the train would have needed a full-service 26-pound reduction and fully effective brakes on 12 of its 21 cars. Once on the -2.176-percent grade, a minimum of 14.4 effective brakes were required at full service to stabilize speed and there would be no reserve of braking capability other than the locomotive's independent brake.

Table 3.—Extra 3119 West--Number of Effective Car Brakes Required without Effective Dynamic Braking Capability to Balance Grade at 15 mph.

Train Weight--4,490,00 lbs.

Pounds Brakepipe Reduction	-1.822% No. of Brakes (74,543 lbs.) Required	-2.102% No. of Brakes (87,115 lbs.) Required	-2.176% No. of Brakes (90,437 lbs.) Required
15	20.5	----	----
16	19.2	----	----
17	18.1	21.2	----
18	17.1	20.0	20.7
19	16.2	18.9	19.7
20	15.4	18.0	18.7
21	14.7	17.1	17.8
22	14.0	16.4	17.0
23	13.4	15.7	16.2
24	12.8	15.0	15.6
25	12.3	14.4	14.9
26	11.8	13.8	14.4

Postaccident examination indicated that three of the cars of Extra 3119 West probably had their brakes cut out and inoperative. The engineer of Extra 3135 West observed Extra 3119 West smoking heavily as it passed Chase. This indicated that the engineer of Extra 3119 West had made a very heavy application of the train brakes and that actual braking effort was being provided by only a few cars in the train. The laboratory examination of 78 tie car wheelsets revealed no evidence of abnormal heating not commonly seen in ordinary train service. There were no slid flat spots or other deformations which would have probably occurred during a prolonged episode of continuous heavy braking. Little or no thermal evidence was found on 54 wheelsets. Based on the foregoing, the Safety Board concluded that six cars probably had ineffective brakes and another seven cars had only partially effective brakes. Since another 10 wheelsets had arrived at the laboratory in rusted or corroded condition and it was not possible to determine whether they had been overheated, there may have been other cars with less than fully effective brakes.

Twenty of the surviving 35 F-70-1 tie cars were assembled at Las Vegas about 10 days after the accident. The condition of these cars as they were received is also probably indicative of the condition of the cars that were in Extra 3119 West. Six of the cars were found to have ineffective brakes while 10 of the cars had only partially effective brakes. The three cars in the test train which had been in Extra 3119 West as it was first constituted were probably representative of the cars that left Las Vegas in Extra 3119 West. None of these cars had fully effective brakes.

The test train operated by UP was useful in that it revealed that a train composed of 20 loaded tie cars and a caboose with 20 fully effective brakes could be operated without dynamic braking down Cima Hill safely by a veteran engineer and supervisor who was called out of retirement for the demonstration. Extensive precautions were taken, including 2 days of inspecting and repairing the tie cars at Las Vegas and the performance of a complete brake inspection and test before the train left Cima. The test cannot be properly considered as a simulation of the operation of Extra 3119 West since that train was not repaired, inspected, or tested before it descended the grade and the engineer did not have the depth of experience and expertise possessed by the man who operated the test train. Table 4 gives the braking calculations for the test train between Cima and Chase. Interestingly, the test train balanced the grade with the equivalent of about 20 1/2 effective brakes and a total brakepipe reduction of 17 pounds at 15 mph.

The Descent from Cima

Analysis of the speed tape from UP 3119, together with the radio reports attributed to the engineer and statements of surviving crewmembers, give considerable insight into what probably occurred after the train left Cima. Aside from the discovery that the locomotive's dynamic brake was inoperative, nothing untoward appears to have occurred prior to the start down the grade. Erie Hill had not put the train's air brake system to any real test nor had it alerted the engineer to inadequacies in braking capability. The speed tape indicated that the only place on Erie Hill where some form of braking action was taken was on a 3.2-mile section with an average -0.91-percent descent. The braking action was probably taken after the engineer had tried the dynamic brake and found it to be inoperative. Acceleration on the downgrade was arrested at 57 mph and held at that level for 1.4 mile before deceleration began in a long curve. A modest brake application that was effective on some of the cars would have been sufficient to produce that response.

Table 4.—UP Test Train Extra 3114 West--Number of Effective Car Brakes Required to Balance Grade Without Dynamic Braking Capability at 15 mph.

Train Weight--4,288,500 lbs.

Pounds Brakepipe Reduction	-1.822% (71,617 lbs. Required)	-2.102% (83,625 lbs. Required)	-2.176% (86,799 lbs. Required)
14	21.1	----	----
15	19.7	----	----
16	18.5	----	----
17	17.4	20.3	21.1
18	16.4	19.2	19.9
19	15.5	18.1	18.8
20	14.8	17.2	17.9
21	14.1	16.4	17.0
22	13.4	15.7	16.3
23	12.8	15.0	15.6
24	12.3	14.4	14.9
25	11.8	13.8	14.3
26	11.4	13.3	13.8

Table 5.--Movement of Extra 3119 West from Cima to Milepost 248.8 Analyzed from Speed Tape

Milepost Reference	Distance from Start		Speed in MPH	Time in Minutes	Acceleration Rate MPH per Min.	
253.8	0.0	1°30' L.H. curve	0.0	0.00	0.00	
253.7	0.1		8.0	1.50	5.33	
253.6	0.2		12.0	2.10	6.67	End-1.115%
253.5	0.3	Turnout	14.0	2.56	4.33	Begin-1.822%
253.4	0.4	No. Passing Track	16.0	2.96	5.00	End-1.822%
253.3	0.5		17.5	3.32	4.19	Begin-2.102%
253.2	0.6	2° L.H. curve	16.5	3.67	-2.83	
253.1	0.7		15.5	4.05	-2.67	
253.0	0.8		14.0	4.45	-3.69	
252.9	0.9		13.5	4.89	-1.15	
252.8	1.0		14.5	5.32	2.33	
252.7	1.1		15.0	5.73	1.23	
252.6	1.2		15.5	6.12	1.27	
252.5	1.3		16.0	6.50	1.31	
252.4	1.4	2° R.H. curve	16.0	6.88	0.00	
252.3	1.5		15.5	7.26	-1.31	
252.2	1.6		15.0	7.65	-1.27	
252.1	1.7		15.0	8.05	0.00	
252.0	1.8		16.0	8.44	2.58	

Milepost Reference	Distance from Start		Speed in MPH	Time in Minutes	Acceleration Rate MPH per Min.	
251.9	1.9		17.0	8.08	2.75	
251.8	2.0	1° L.H. curve	17.5	9.15	1.44	
251.7	2.1	1° L.H. curve	17.0	9.50	-1.44	
251.6	2.2	1° L.H. curve	16.5	9.85	-1.40	
251.5	2.3	1° L.H. curve	15.5	10.23	-2.67	
251.4	2.4	1° L.H. curve	15.0	10.62	-1.27	
251.3	2.5	1° L.H. curve	15.5	11.02	1.27	
251.2	2.6		16.0	11.40	1.31	
251.1	2.7		16.5	11.77	1.35	Turnout East End Chase Passing Track
251.0	2.8	1° R.H. curve	17.0	12.12	1.40	Turnout East End Chase Passing Track
250.9	2.9	1° R.H. curve	17.0	12.48	0.00	
250.8	3.0	1° R.H. curve	16.5	12.84	-1.40	
250.7	3.1	1° R.H. curve	15.5	13.21	-2.67	
250.6	3.2	1° R.H. curve	15.0	13.60	-1.27	
250.5	3.3	1° R.H. curve	15.0	14.00	0.00	End-2.102%
250.4 Chase	3.4	1° R.H. curve	15.5	14.40	1.27	Begin-2.176%
250.3	3.5	1° R.H. curve	16.0	14.78	1.31	
250.2	3.6	1° R.H. curve	17.0	15.14	2.75	
250.1	3.7	1° R.H. curve	17.5	15.49	1.44	
250.0	3.8	1° R.H. curve	17.5	15.83	0.00	
249.9	3.9		18.0	16.17	1.48	Turnout West End Chase Passing Track
249.8	4.0		18.0	16.50	0.00	Turnout West End Chase Passing Track
249.7	4.1		18.5	16.83	1.52	
249.6	4.2		19.0	17.15	1.56	
249.5	4.3	0°30' R.H. curve	19.5	17.46	1.06	
249.4	4.4	0°30' R.H. curve	20.0	17.77	1.65	
249.3	4.5	0°30' R.H. curve	20.0	18.07	0.00	
249.2	4.6		20.0	18.37	0.00	
249.1	4.7		21.0	18.66	3.42	
249.0	4.8		22.0	18.94	3.58	
248.9	4.9		23.0	19.21	3.75	
248.8	5.0		25.0	19.46	8.00	

If the engineer of Extra 3119 West had any misgivings about the braking capability of the train, he did not express them to the conductor or dispatcher. And if he had any anxiety about his ability to manage the train successfully on Cima Hill, it is doubtful that he would have followed the VAN train from Cima as soon as the passing track home signal aspect changed from "stop" to "approach."

Because the downgrade force of gravity became progressively greater as Extra 3119 West descended from Cima, it was necessary to establish almost immediately that the available braking force was sufficient to balance the grade. It is possible that the engineer understood this and made a minimum brake application before leaving the passing track inasmuch as there was a decrease in the rate of acceleration at milepost 253.6 where the grade steepened to -1.822 percent. The only UP rule that applied in the situation cautioned against making the initial brakepipe reduction too heavy and then instructed the engineer that if the first reduction was not heavy enough, he should make further light reductions until the desired speed could be held. The engineer had probably made the first reduction at 12 mph, desiring to ultimately control speed at the required 15 mph. After entering the main track and reaching the place at milepost 253.4 where the average gradient steepened to -2.102 percent, the engineer made another brakepipe reduction. This began to slow Extra 3119 West with the maximum rate of deceleration being achieved once the entire train was in the first 2-degree curve beginning at milepost 253.2. However, acceleration occurred again while the train was still in the curve. This development must have troubled the engineer and should have caused doubt as to whether or not speed could be controlled. At this point, the engineer might have been able to stop the train, if not with an immediate reduction to full service, then most likely with an emergency application of the brakes. There was still half of the first 2-degree curve to stop in, but the train would soon be running out of curves and onto even steeper gradient. Overheating and overload of the wheels and brake shoes would soon reduce braking efficiency of those cars that had braking capability. However, the UP rules did not tell the engineer to stop his train if there was any doubt that speed could be controlled nor was there any rule or instruction requiring the retention of sufficient brakepipe pressure to be able to do this.

Another partial brakepipe reduction again arrested acceleration and reduced the speed once the entire train was in the second 2-degree curve beginning at milepost 252.4. Thereafter, additional brakepipe reductions resulted in brief episodes of deceleration which always occurred in curves and which were quickly followed by reacceleration. Braking never resulted in reducing speed sufficiently or stabilizing speed long enough to permit the engineer to risk releasing the brakes against the retainers. By the time the train reached Chase, the engineer had the brakes in full service, the independent brake was applied, and the engineer had informed the dispatcher that he was in trouble. This report alarmed the conductor who placed the caboose valve in emergency without communicating with the engineer. Once the valve had been opened, a UP rule required that it be kept open. Although the conductor and rear brakeman tried to uncouple the caboose, they did not think to apply the caboose hand brake or the hand brakes on the cars ahead.

The speed tape analysis (see table 5) shows that there were two last, brief interruptions of acceleration after Extra 3119 West passed Chase. The first was probably achieved by increased application of the independent brake and/or the automatic brake beginning at milepost 250.5. Although the engineer had been taught not to go beyond full service to the "suppression" position, he probably did so in desperation after reporting that he had the independent brake fully applied. The second interruption in acceleration, at milepost 249.9, lasted less than a minute and probably resulted from the emergency application made by the conductor. It was immediately followed by a burst in acceleration which progressively increased at a phenomenal rate. As shown in postaccident testing, the logical explanation for this occurrence was the failure of the emergency application to be transmitted to the locomotive and the resultant partial release of the brakes due to the locomotive pressure-maintaining feature restoring air to the brakepipe. Had the locomotive been equipped with a brakepipe flow indicator, the rush of air through the brake valve would have caused the indicator to light and would have alerted the engineer to what was happening. By placing the brake valve in emergency position, he could have stopped the flow of air to the brakepipe. Without a flow indicator, there was no way the engineer could know that an emergency application had occurred unless told so by someone in the caboose. Even if he had detected the drop in trainline pressure that occurred, the engineer could not have determined that this had been caused by an emergency application instead of a service application. In addition, a rule required him to leave the brake in "Running" or "Release" position and keep the independent brake released when a service application was made from elsewhere in the train. With the brake valve in any position other than the emergency position, the brakes were released in less than a minute and there was no way that braking capability could be recovered as long as the caboose valve remained open. In a very short time, only the independent brake of the locomotive was providing retardation.

Role of Dispatcher

From the time the engineer of Extra 3119 West reported that his dynamic brake was inoperative to the time the engineer of the VAN train reported the collision, the dispatcher failed to properly respond to the situation. In addition, the assistant chief dispatcher said and did nothing after he learned that an emergency was developing. This same apparent detachment and lack of concern that run counter to the traditional role that dispatchers play in the operations of all railroads was cited by the Safety Board in its report on the rear-end collision of two UP trains near Hermosa, Wyoming, on October 16, 1980. 9/ The dispatcher was experienced, had firsthand knowledge of Cima Hill, and was aware of problems westbound trains had encountered descending the grade in the past. He was the immediate supervisor of the traincrews and he should have known that the engineer and other crewmembers of Extra 3119 West were inexperienced. It was the dispatcher's responsibility to provide proper protection for all trains and to guard against dangerous conditions in their movement. He should have known that a short, heavy train without dynamic braking could be hard to handle on the grade even for a seasoned engineer. The dispatcher had the time to consult with other supervisors and to work out a safe solution to the situation before Extra 3119 West was allowed to descend Cima Hill. He could have stopped the VAN train at Cima to exchange one of its trailing units for the 3119. Failing this, he could have had a supervisor with the necessary expertise advise the engineer as to how he should handle Extra 3119 West on the grade. Finally, the dispatcher should have held Extra 3119 West at Cima until the VAN train was well down the hill and out of danger.

When the engineer of Extra 3119 West reported that he was in trouble, the VAN train was about 4 1/2 minutes from the east turnout of Dawes passing track and about 4 miles ahead of Extra 3119 West. The dispatcher probably could have averted the accident by immediately acting to align the turnout at Dawes to the passing track and instructing the VAN train engineer to slow down sufficiently to allow for the time it would take for the CTC command to be executed. Slowing down the VAN train would also have given the men on that train's caboose an opportunity to evacuate it. As it developed, the VAN train would probably have cleared into the passing track 2 or 3 minutes before Extra 3119 West reached Dawes. The UP, however, had no contingency plans that could be followed in the event of an emergency on Cima Hill, and the dispatcher would have had to react immediately to the initial trouble report. Had Extra 3119 West been held at Cima until the VAN train reached Chase, there would have been more than ample time to put the VAN train into the Hayden passing track. As it was, however, the only passing track that could have been used by the VAN train was Dawes. Extra 3119 West closed too fast for the VAN to use Hayden.

Once it became obvious that Extra 3119 West was out of control, the VAN engineer took matters into his own hands. Hearing the engineer of Extra 3119 West repeatedly report his speed as being 80 mph, the VAN engineer believed the other train had reached maximum speed and that he could outrun it. Had he been instructed to do this earlier

9/ "Railroad Accident Report--Rear-End Collision of Union Pacific Railroad Company Freight Trains, near Hermosa, Wyoming, October 16, 1980" (NTSB-RAR-81-3).

by the dispatcher, he might have succeeded in staying ahead of the runaway. The VAN train ultimately failed to stay ahead of Extra 3119 West because its overspeed device caused a power loss and resultant loss of speed. Ironically, this probably prevented the derailment of the VAN train ahead of the collision since it is unlikely that the rigid 8-wheel trucks of the lead locomotive unit could have negotiated the curve west of Kelso at a speed much higher than the VAN train was making. It is doubtful that any crewmember of the VAN train would have survived such a derailment and subsequent ramming by Extra 3119 West.

Adequacy of Current UP Air Brake Rules and Instructions

The Safety Board's investigation revealed that UP made significant changes in the methods of operating westbound freight trains down the Cima-Kelso grade many years after the use of steam locomotives was discontinued and diesel-electric locomotives with dynamic braking were put into service on the First Subdivision. In the past, the crews of all westbound trains had to make a running test of the dynamic brake on Erie Hill and were required to stop at Cima to make a brakepipe air test and inspect their trains before starting down the grade. Westbound trains with inoperative dynamic brake had to be stopped for 10 minutes at both Chase and Dawes, and the crews had to make walking inspections of their trains at both places. No train was allowed to descend Cima Hill with more than 70 tons per operative brake, and empty cars were kept at Cima so that they could be added to trains which exceeded the per brake tonnage limit. At the time of the accident, there was no limit to the allowable tonnage per operative brake; the running dynamic brake test had to be made only by trains with locomotives lacking the pressure-maintaining feature; and the brakepipe test and inspection at Cima were no longer required. Trains with inoperative dynamic braking had to stop only at Dawes, and the crews were no longer required to make a walking inspection of their trains.

In the past, trainmasters and other supervisors spent much of their time observing brake tests and inspections at Yermo and Las Vegas, checking piston-travel at Cima and Kelso, and otherwise ensuring that the rules and instructions were complied with. Supervisors and trainmen, as well as engineers, were given extensive and periodic instruction on the air brakes. The Safety Board's investigation revealed that these practices were no longer being followed at the time of the accident. There is a greater need than ever before for better instructions, safeguards, training, and supervisory oversight due to a very substantial increase in typical axle loadings of freight cars used for bulk commodities, and a major increase in the number of heavy bulk trains moving over UP to west coast ports. Enginemen no longer serve a long apprenticeship before being qualified as engineers. The engineer of Extra 3119 West was trained and qualified in 6 months and he had no prior experience in train service.

As demonstrated by UP Rule 1039(A), the dynamic brake has become UP's primary method of retarding a train on a grade with the train air brakes relegated to a supplementary role when necessary. It is not, however, at all unusual for the dynamic braking feature to become inoperative, and when this occurs, the train must have an air brake system which will function properly. When deprived of their primary means of braking on a grade, enginemen must know what to do and when to do it. Air brake rules and train handling instructions should set forth explicitly the safe procedures to follow when braking power is diminished or other conditions arise which reduce the ability to control speed on steep grades.

The recommendations of the Air Brake Association and the rules of the other railroads cited in this report differ in some respects, but the underlying intent of all is the common desire to prevent the most feared event in railroading--the irrevocable loss of control of trains descending mountain grades. The framers of these rules and the managers who endorsed them recognized that emergencies and failures do occur, that allowances must be made for the less experienced employee, and that the movement of heavy trains down long, steep grades is a difficult and dangerous business under the best conditions. The Safety Board believes that the UP's rules and instructions, as well as the manner in which its operations are conducted, do not adequately take these principles into consideration. This may explain why the runaway and the difficult-to-control train have become a problem relatively unique to the UP in the past few years. 10/

The Safety Board believes that Extra 3119 West was dispatched from Las Vegas with less than half its train brakes in fully effective condition, and as a direct consequence, the engineer was unable to control the train's speed on Cima Hill. The car inspector who performed the required inspection and testing of Extra 3119 West at Las Vegas was experienced. He knew what to look for and he should have discovered the defects. Considering that it required the Las Vegas car department more than 2 days to adjust and repair the 20 tie cars UP later assembled for a test train, it is doubtful that UP's Las Vegas facilities were adequate to quickly and properly dispose of a job of the magnitude represented by Extra 3119 West. Since all 20 cars in the train were urgently needed at the other end of the subdivision and the train had already been substantially delayed, the car inspector probably understood that there was little chance that additional delay would be tolerated.

The manner in which Extra 3119 West was tested and inspected was no isolated aberration brought about by special circumstances. The engineer of the VAN train testified that his train received the same abbreviated attention by a car inspector before it departed from Las Vegas. Written instructions had been issued to car inspectors to take no more than 15 minutes to inspect and test expedited trains. (See figure 6.) There was no way that this could be done properly by one or two inspectors walking a train that might be a mile in length or longer. The Safety Board's investigation has developed that trains have continued to be operated over the California Division First Subdivision without proper inspection and testing. In one documented instance, a trainmaster acting under instructions from an assistant superintendent ordered a crew, under threat of removal from service for insubordination, to take a train from Yermo to Las Vegas after the crew protested that the train's braking system was defective. Upon approaching the yard at Las Vegas, the engineer was unable to stop the train short of a "stop" signal. 11/

10/ "Railroad Accident Report—Derailment of Union Pacific Railroad Freight Train, Granite, Wyoming, July 31, 1979" (NTSB-RAR-79-12). "Railroad Accident Field Investigation--Derailment/Collision of Union Pacific Freight Trains, Granite, Wyoming, October 13, 1979" (NTSB-DEN-80-FR-001). "Railroad Accident Field Investigation--Derailment of Union Pacific Freight Train, Albany, Wyoming, February 11, 1980" (NTSB-DEN-80-FR-013). "Railroad Accident Report—Rear End Collision of Union Pacific Railroad Company Freight Trains, near Hermosa, Wyoming, October 16, 1980" (NTSB-RAR-81-3).

11/ Extra 3493 East (BNSL-14), originated at Yermo on February 14, 1981, destined for Salt Lake City Utah. As formally reported by the Brotherhood of Locomotive Engineers, a party to the NTSB investigation, and confirmed by NTSB investigators. The incident was also the subject of a formal complaint made by the United Transportation Union to the Office of Safety, Federal Railroad Administration on March 24, 1981.

UNION PACIFIC RAILROAD COMPANY
MAILGRAM

Las Vegas - March 16, 1979

Mr. M. Palipkonich
Mr. L. P. Valdez
Mr. E. T. Murdock
Mr. H. H. Stump

Mr. F. H. Adamson
Mr. J. F. Warth, Jr.
Mr. D. L. Hidinger

Trains arriving Las Vegas with the following symbols will have a 500 mile air test only and will not be delayed at Las Vegas for further inspection:

Super Van
Van
SSS
CN
LAX
LAD
SDV
CTT

These trains will depart in 15 minutes or less from arrival time unless cars are added or removed but in any case the Car Department will not delay these trains. J-57

Signed
D. L. Joy

Figure 6.--Written instructions from the Las Vegas general car foreman concerning the testing and inspection of trains by car inspectors. (reproduced by NTSB.)

The Safety Board believes that Las Vegas and Yermo may not be the only points on the Union Pacific system where trains are not receiving the required inspection and testing to assure that they are safe to operate. The cars that constituted Extra 3119 West were required to have been fully tested and inspected at least three times en route from the treating plant to Las Vegas. Many of the tie cars assembled for the test train also arrived in Las Vegas in defective condition. In its report of the investigation of a runaway freight train on Sherman Hill at Granite, Wyoming, on July 31, 1979, 12/ the Safety Board determined that the accident was caused by lack of braking capability resulting from a closed brakepipe angle cock and that the train had not been properly inspected and tested at the point where it was originated.

The Safety Board believes that present UP management policy does not foster compliance with its rules requiring air brake tests nor compliance with the provisions of the Federal Power Brake Regulations regarding the performance of train air brake tests and inspections, and that what has been observed by Safety Board investigators following a number of serious accidents on the UP is a direct reflection of that policy. Following the Granite investigation, the Safety Board recommended on January 10, 1980, that UP "Instruct employees who make train brake tests in the test requirements of the Federal Power Brake Regulations, CFR 49 Part 232, and establish monitoring procedures to insure that the tests are conducted properly." Although more than 1 1/2 years have passed since this recommendation was made, the Safety Board has not received a response from UP management.

The basis of the Federal regulations requiring train air brake tests is the Power Brake Law of 1958 (Public Law 85-375) by which Congress required the Interstate Commerce Commission to place into effect as Federal regulations for the sole purpose of safety, the rules, standards, and instructions of the Association of American Railroads (AAR) for the installation, inspection, maintenance, and repair of all power or train brakes used by common carriers engaged in interstate commerce. Since 1968, the responsibility for enforcing this law has been vested in the Federal Railroad Administration (FRA) which maintains safety inspectors in the field for this purpose. Following the Granite investigation, the Safety Board recommended that FRA "Enforce the requirements for testing train brakes in accordance with the Federal Power Brake Regulations, 49 CFR Part 232, on the Union Pacific Railroad." On April 7, 1980, FRA responded that they had a strong program in effect for the enforcement of the Power Brake Regulations and also favored a policy of permitting the railroads to improve compliance with the law through their own internal training programs. On June 3, 1980, the Safety Board responded to FRA by describing FRA's response as unacceptable and asking for advice as to what FRA had done specifically in the case of Union Pacific to improve compliance with the law. FRA has never answered this letter and there is no indication that FRA has stepped up its enforcement activity on the Union Pacific.

FRA is currently considering the publication of a notice of proposed rulemaking, apparently with the intention of eliminating or modifying some of the provisions of the Federal Power Brake Regulations on the basis that the advent of dynamic braking and other changes in technology have made them obsolete. However, this accident and those which preceded it on the UP have demonstrated that there is still a compelling need for minimal requirements for inspecting and testing the air brake systems of trains at the points where they are assembled. Indeed, as trains become heavier, the requirements should become more comprehensive and enforcement of the requirements must become

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12/ "Railroad Accident Report--Derailment of Union Pacific Railroad Freight Train, Granite, Wyoming, July 31, 1979", NTSB-RAR-79-12.

stricter. FRA should make no modifications to the regulations which will adversely affect the safety of train operations.

CONCLUSIONS

Findings

1. UP wanted Extra 3119 West dispatched expeditiously from Las Vegas to a track work site near Yermo.

2. Extra 3119 West was delayed for about 6 hours at Las Vegas because its caboose had an inoperative electrical system and could be operated only during daylight hours.

3. A last-minute need to switch the train further delayed Extra 3119 West. The work was done hurriedly under the supervision of the Las Vegas terminal superintendent who was accountable for the delay.

4. Extra 3119 West left Las Vegas without receiving a proper and adequate inspection and test of the air brake system.

5. The lading of the 20 tie cars in Extra 3119 West was estimated on the waybills to be 1,200,000 pounds which was less than half the actual weight.

6. It was the practice of UP's timber treating plant at The Dalles, Oregon, to arbitrarily underestimate the weights on the waybills of crosstie shipments from the plant, even though the approximate weights of the various grades and sizes were known.

7. UP's methods of operation on Cima Hill and other mountain grades were predicated on tonnage per operative brake. The traincrews, therefore, should be given figures which accurately reflect the actual tonnage and number of operative brakes in the train.

8. UP had no rule or special instruction limiting the tonnage per car or locomotive unit that a train could have descending Cima Hill.

9. The engineer of Extra 3119 West discovered that the locomotive dynamic brake was inoperative after the train left Las Vegas and he reported the fact to the dispatcher. However, no provisions were made to provide the train with a replacement unit or to determine that the engineer knew how to handle a train down the grade without dynamic brake.

10. The engineer of Extra 3119 West understood the timetable restrictions for his train and he attempted to operate the train accordingly. The investigation did not reveal any evidence to indicate that the engineer and other crewmembers were in other than normal and alert condition at all times.

11. The crew of Extra 3119 West set up the retainers of their cars as required by the timetable instructions. However, the engineer was never able to stabilize the train's speed long enough at the desired level to release the brakes against the retainers.

12. The engineer was considered to be a capable and rules-conscious employee, but the Safety Board believes he lacked the experience and expertise to manage a train with inadequate braking capability on Cima Hill.

13. Because there is less fall in elevation and there are more curves at the top of the Cima-Kelso Grade than at any other part of the grade, a train unable to balance the grade immediately after leaving Cima, would not be able to balance the grade beyond that section.

14. To balance the grade between Cima and Chase with a minimum of 18 pounds brakepipe reduction, Extra 3119 West had to have fully effective brakes on all the cars in the train. The minimal number of effective brakes needed to balance the grade with a full service application of the brakes was 14.4; analysis of the wreckage of Extra 3119 West indicated that at least 13 of the train's 21 cars did not have fully effective brakes. The crew was not aware of this.

15. UP's rules and instructions do not inform an engineer how much brakepipe pressure he may expend attempting to balance a grade nor how much pressure should be retained for stopping ability.

16. UP's rules and instructions do not require that a train be stopped if there is doubt that speed can be controlled with a given amount of braking.

17. The conductor placed the caboose valve in emergency when Extra 3119 West was moving at about 20 mph with the train brakes in full service or beyond. He was not required to tell the engineer he had done this, but he was required to leave the caboose valve open. The emergency application did not transmit to the locomotive.

18. The brakes released following the emergency application because the brake valve pressure-maintaining feature began restoring air to the brakepipe. Since the locomotive did not have a brakepipe flow indicator, there was no way the engineer could tell whether a service or emergency application had been made from the caboose.

19. Had the locomotive been equipped with a brakepipe flow indicator, the engineer probably would have realized that the brakes had been applied in emergency and by quickly placing the locomotive brake valve in emergency position, he could have nullified the action of the pressure-maintaining feature. Having failed to do this, there was no way braking capability could be restored as long as the caboose valve remained open.

20. If the engineer interpreted that the conductor had made a service application, the engineer was obliged by UP Rule 1053 to keep the locomotive brake valve in "running" or "release" position.

21. Although the engineer of Extra 3119 West told the dispatcher that he was in trouble when at or near Chase, the dispatcher took no action of any kind. UP had no contingency or emergency plan for action in the event a train ran away on Cima Hill.

22. The engineer of the VAN train took matters into his own hands and tried to outrun Extra 3119 West but was unable to do so because the locomotive overspeed feature had functioned causing a loss of power. If this had not occurred, the VAN train probably would have derailed in a curve west of Kelso.

23. The test train operated by UP proved that a train composed of 20 loaded cars and a caboose, with 20 fully effective brakes could be operated safely down Cima Hill by an expert engineer without using dynamic braking.

24. Twenty tie cars similar to those in Extra 3119 West were assembled for the test train. Before being repaired, 6 of these cars had ineffective brakes and 10 had only partially effective brakes. This was probably a fair indication of the condition of Extra 3119 West when it descended Cima Hill.

25. The only applicable UP rule instructs enginemen to continue making brakepipe reductions until they are able to control speed at the desired level. There is no recommended or required limit as to how much total reduction an engineer may make in the process.

26. Compared with the recommendations of the Air Brake Association and the rules of other railroads applying to mountain grade operations, the UP rules are inadequate because they do not provide necessary safeguards and safety procedures.

27. The Safety Board believes that UP management policy does not foster compliance with the air brake test rules and Federal Power Brake Regulations; consequently, UP trains are not being inspected and tested properly.

28. The Federal Railroad Administration is not adequately enforcing the Federal Power Brake Law on the Union Pacific Railroad.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the dispatcher's permitting Extra 3119 West to leave Cima with inadequate braking capability, the inadvertent release of the train's brakes after they were placed in emergency from the caboose, and the UP's inadequate rules and instructions for the management of trains on mountain grades that resulted in the engineer's inability to control the speed of the train. Contributing to the accident were the failure to properly inspect and test Extra 3119 West at Las Vegas, the inadequate maintenance of braking equipment on tie cars used in company service, and the practice of underestimating the weight of loaded tie cars. Contributing to the severity of the accident were the lack of effective direction by the dispatcher and assistant chief train dispatcher and the absence of emergency procedures for train operations on Cima Hill.

RECOMMENDATIONS

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

--to the Union Pacific Railroad Company (UP):

Provide traincrews with accurate tonnage figures for their trains at Las Vegas and other locations where operating methods are predicated on tonnage per operative brake. (Class II, Priority Action) (R-81-88)

Require that The Dalles, Oregon, timber treating plant and other UP facilities where material is loaded on cars provide actual weights on waybills where track scales are available. Where scales are not available, require that weights be accurately estimated. (Class II, Priority Action) (R-81-89)

Amend its timetable instruction pertaining to the operation of westbound trains between Cima and Kelso without functioning dynamic braking to provide for:

(1) A maximum tonnage per operative brake that is consistent with the braking force required to balance grade force;

(2) The requirement that a running air brake test be performed in advance of Cima;

(3) Establish the maximum brakepipe reduction that may be made in the effort to balance the grade; and

(4) Caution traincrews that in case there is any doubt of ability to control speed, the train must be stopped immediately, sufficient hand brakes set to hold the grade, and brakepipe fully restored before the train is allowed to proceed. (Class II, Priority Action) (R-81-90)

Issue instructions to the California Division chief train dispatcher that require First Subdivision dispatchers to:

(1) Ascertain that crews of westbound trains without functioning dynamic brakes understand the special timetable provisions applying to their trains between Cima and Kelso;

(2) Determine that engineers of westbound trains at Cima fully understand the proper method of braking on the grade;

(3) Hold westbound trains without functioning dynamic brakes at Cima until the main track is clear to Kelso and not permit the occupancy of the main track east of Kelso by other trains while a train without functioning dynamic brakes is descending the grade. (Class II, Priority Action) (R-81-91)

Require that the dynamic braking feature of the lead locomotive unit on all westbound trains originating at Las Vegas and which are to be operated west of Cima be tested and determined to be functional. (Class II, Priority Action) (R-81-92)

Amend its air brake and train handling rules to:

(1) Require crewmembers to notify the engineer whenever the caboose brake valve is used;

(2) Expand Rule 1043 to include references to the necessity of retaining sufficient brakepipe pressure to stop anywhere on the grade; and

(3) Modify Rules 1053 and 1053(A) to eliminate the possibility of an inadvertent release of the brakes after an open brakepipe occurs and this fails to result in an emergency brake application on the locomotive. (Class II, Priority Action) (R-81-93)

--to the Federal Railroad Administration (FRA):

Conduct a safety review of the Union Pacific Railroad Company to determine that compliance with Federal Power Brake Regulations (49 CFR 232) is enforced effectively at Las Vegas, Nevada, Yermo, California, and other initial terminal points, and provide the Safety Board with a report of the findings. (Class II, Priority Action) (R-81-94)

Retain the minimal requirements of the Federal Power Brake Regulations (49 CFR 232) for the inspection and testing of trains at the points where they are originated. (Class II, Priority Action) (R-81-95)

In addition to these recommendations, the Safety Board reiterates and reemphasizes the importance of the following recommendations which were made as the result of other accidents on the Union Pacific Railroad:

--to the Union Pacific Railroad Company:

Instruct employees who make train brake tests in the test requirements of the Federal Power Brake regulations, CFR 49 Part 323, and establish monitoring procedures to insure that the tests are conducted properly. (Class II, Priority Action) (R-79-78) This recommendation is currently held in "Open" status; no response has been received from UP.

Equip locomotives with brakepipe flow indicators to enable engineers to measure trainline air flow. (Class II, Priority Action) (R-79-81) This recommendation is currently held in "Open--Acceptable Action" status; UP responded on March 4, 1980, that pending results of tests then being conducted by the Association of American Railroads (AAR), UP would withhold further application of flow indicators to their locomotive units. On April 28, 1980, the Safety Board acknowledged this response and requested being advised of the results of the study and UP's ultimate decision in the matter. No further advice has been received from UP.

Amend and clarify rules to require dispatchers and train crewmembers to communicate with each other about conditions affecting the movement of their train. (Class II, Priority Action) (R-81-42) This recommendation is currently held in "Open" status; no response has been received from UP.

--to the Federal Railroad Administration:

Enforce the requirements for testing train brakes in accordance with the Federal Power Brake Regulations, 49 CFR, Part 232, on the Union Pacific Railroad. (Class II, Priority Action) (R-79-82) This recommendation is currently held in "Open—Unacceptable Action" status. FRA responded on April 7, 1980, stating that FRA believes adherence to regulations is best accomplished through the railroad's own training programs and proficiency testing. The Safety Board replied on June 3, 1980, noting that FRA's response did not directly address the recommendation and asking what had been done to improve compliance on UP. No further response has been received from FRA.

Review the monitoring system for rule compliance on the Union Pacific Railroad to insure that their supervisors can adequately enforce the rules to provide a safe and efficient operation. (Class II, Priority Action) (R-79-84) This recommendation is currently held in "Open--Acceptable Action" status. FRA responded on April 7, 1980, stating that FRA's 5-year review of annual operational tests by UP indicated an increase in observed failures of rules, and that the results would be studied and analyzed with NTSB to be informed of the findings by the summer of 1980. The Safety Board acknowledged FRA's response on June 3, 1980, and asked to be kept informed. No further advice has been received from FRA.

Study the feasibility of requiring locomotives to be equipped with brakepipe flow indicators to enable engineers to measure trainline air flow. (Class II, Priority Action) (R-79-85) This recommendation is currently held in "Open--Acceptable Action" status. FRA responded on April 7, 1980, stating that FRA would include the feasibility of requiring brakepipe flow indicators under proposed revisions to Power Brake Regulations. The Safety Board acknowledged FRA's response on June 3, 1980, and asked to be informed when definite action had been taken. No further advice has been received from FRA.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

JAMES B. KING, Chairman, did not participate.

August 18, 1981

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

Investigation

The National Transportation Safety Board was notified of the accident about 5:30 p.m., P.s.t., on November 17, 1980. The Safety Board immediately dispatched an investigator from the Los Angeles Field Office to Kelso and, subsequently sent an investigative team from Washington, D.C. to the scene. Investigative groups were established for operations, vehicle factors, track and signals, and human factors.

Depositions

The Safety Board conducted a 1-day deposition proceeding on February 19, 1981, at Las Vegas, Nevada, as part of its investigation of this accident. Parties to this proceeding included the Union Pacific Railroad Company, the Federal Railroad Administration, the Brotherhood of Locomotive Engineers, and the United Transportation Union. Testimony was taken from eight witnesses.

APPENDIX B

TRAIN CREWMEMBER INFORMATION

EXTRA 3119 WEST

Conductor David Alan Branson

Conductor Branson, 26, was employed by the Union Pacific Railroad as a yard switchman at Los Angeles, California, on October 16, 1973. He transferred to the extra board at Las Vegas, Nevada, on April 20, 1979, and on April 7, 1980, he passed the various examinations for promotion to conductor.

Mr. Branson last passed a company physical examination in July 31, 1978, and he was last examined on the timetable rules and air brake rules at the time of his promotion. He was not restricted in any way.

Engineer David LeRoy Totten

Engineer Totten, 31, was employed by the Union Pacific Railroad as a sectionman on January 30, 1974. On July 17, 1978, he entered UP's formal training program for engineers and he completed the classroom training phase on September 7, 1978. According to UP's director of train operating practices, who was in charge of the engineer training program at the time, Engineer Totten was a "very apt student: very capable," and he scored a mark of more than 96 percent on the final examination. After extended on-the-job training, Mr. Totten was qualified as an engineer on January 17, 1979.

Mr. Totten was not restricted in any way. He had last passed a company physical examination on July 24, 1976; the examination on mechanical rules on August 24, 1978; the examination on the operating rules on or about September 7, 1978; and the air brake rules on May 17, 1979.

Rear Brakeman Thomas Cecil Faucett

Brakeman Faucett, 30, was employed by the Union Pacific Railroad as a switchman at the Los Angeles, California, terminal on June 26, 1978. On February 9, 1980, he transferred from Los Angeles to road service out of Las Vegas. He was not promoted. Mr. Faucett was last examined on the operating rules on April 3, 1980, and he was not restricted.

Head Brakeman Wallace Dean Dastrup

Brakeman Dastrup, 22, was employed by the Union Pacific Railroad as a switchman on May 2, 1979. He worked one tour of duty at Las Vegas, was furloughed, and worked on the Los Angeles terminal until October 16, 1979, when he was transferred to road service at Las Vegas. He was not promoted.

Mr. Dastrup last passed a company physical examination on April 9, 1979, and an examination on the operating rules on November 2, 1979. He was not restricted in any way.

APPENDIX C

EXCERPTS FROM UNION PACIFIC RAILROAD SYSTEM TIMETABLE NO. 4, OCTOBER 26, 1980

CALIFORNIA DIVISION

WESTWARD				FIRST SUBDIVISION (PACIFIC TIME)		EASTWARD		
STATION NUMBER	LENGTH OF SIDINGS FEET	FIRST CLASS 35 DAILY		Timetable No. 4 STATIONS		MILE POST	FIRST CLASS 36 DAILY	RULE 6(B)
9-1479		9.05AM		DN-R LAS VEGAS	5.2	334.3	A7.20PM	FPY
9-1484	5876			BRACKEN	1.7	329.1		P
9-1486	3403			BOULDER JCT.	4.9	327.4		PY
9-1490	6480			ARDEN		322.5		PY
9-1491				BLUE DIAMOND SPUR	7.0	321.8		P
9-1498	5212			SLOAN	5.5	314.8		P
9-1504	5690			ERIE	8.0	309.3		P
9-1512	5730			JEAN	4.9	301.3		P
9-1517	5791			BORAX	8.8	296.4		P
9-1526	6116			CALADA	10.1	287.6		P
9-1535	5774			NIPTON	5.1	277.5		P
9-1541	5769			MOORE	5.0	272.4		P
9-1545	5761			IVANPAH	4.2	267.4		P
9-1550	5760			BRANT	5.3	263.2		P
9-1555	5226			JOSHUA	3.9	257.9		P
9-1559	5088 5272		CTC	CIMA	3.6	254.0		PY
9-1563	5667			CHASE	3.1	250.4		P
9-1566	5723			ELORA	4.0	247.3		P
9-1570	5781			DAWES	4.0	243.3		P
[illegible]1574	5788			HAYDEN	3.9	239.3		P
[illegible]77	9827			KELSO	9.3	235.4		PY
[illegible]587	5757			KERENS	8.5	226.1		P
9-1595	558			SANDS (SPUR-E)	6.0	217.6		P
9-1601	5758			BALCH	8.1	211.6		P
9-1609	5765			CRUCERO	6.5	203.5		P
9-1616	6198			BASIN	5.2	197.0		P
9-1621	640			AFTON (SPUR-E)	4.4	191.8		P
9-1626	6116			DUNN	5.1	187.4		P
9-1631	5718			FIELD	4.8	182.3		P
9-1635	5771			MANIX	9.5	177.5		P
9-1645	5686			TOOMEY	4.9	168.0		P
9-1650				DN-R YERMO		163.1		FPY
				(171.2)				

CALIFORNIA DIVISION
SPEED RESTRICTIONS — FIRST SUBDIVISION

LOCATION	MPH PSGR	MPH FRT
Maximum Speed Between Yermo and Erie	79	70
Between Erie and Las Vegas	79	60
Between Mile Posts — Yermo 162.0 and 162.75	60	60
162.75 and 163.75	20	20
Field 186.1 and 187.1	70	60
Dunn 188.4 and 191.6	55	45
191.8 and 194.1	50	40
194.4 and 196.2	55	45
Flynn 230.9 and 231.2	70	60
Kelso 246.5 and 246.7	45	45
251.3 and 254.4	45	45
Cima to MP 236 Westward freight trains not required to use retainers per Special Rule 1042(RC)		25
Westward freight trains being controlled exclusively with dyanmic brake		35

SPECIAL RULES — FIRST SUBDIVISION and BOULDER CITY BRANCH

1042 (RC). On descending grades from Cima to Kelso and from Blue Diamond to Arden the following applies:

Train exceeding 3500 tons must not be controlled exclusively with dynamic brake.

Retaining valves must be used:

1. On any train exceeding 85 tons per operative brake.
2. On any train exceeding 80 tons per operative brake with less than two horsepower effective dynamic brake per trailing ton.
3. Any train with less than one horsepower effective dynamic brake per trailing ton. Such trains must not exceed 15 MPH Cima to Kelso and must stop and remain standing ten minutes at Dawes to cool wheels.
4. On any train being handled without pressure maintaining. Dynamic brake must be tested between MP 309 and MP 292.

Conductor must advise engineer number of cars in train, total tonnage, and tons per operative brake.

From Cima to Kelso, train not required to use retaining valves may operate at a speed not to exceed 25 MPH provided speed can be controlled with minimum brake pipe reduction (6-8 lbs.). If more than minimum brake pipe reduction (6-8 lbs.) is required to control speed, a speed of 20 MPH must not be exceeded.

Maximum speed of westward trains over crest of grade at Cima must be 10 MPH less than maximum authorized speed Cima to Kelso.

Between Kelso and MP 217.6, westward trains exceeding 75 tons per operative brake and which do not have at least one horsepower effective dynamic brake per trailing ton, must not exceed 30 MPH at any point.

In cases where a train is required to stop between Cima and Kelso, provisions of Air Brake Rule 1044 will govern.

APPENDIX D

EXCERPTS FROM UNION PACIFIC RAILROAD AIR BRAKE RULES, DECEMBER 15, 1974

GENERAL RULES

INSPECTION OF AIR BRAKE EQUIPMENT

1001. Brake and signal equipment on locomotives and cars must be inspected and tested in accordance with Department of Transportation regulations and Association of American Railroads Interchange Rules, requirements of which are covered by these rules and instructions.

INITIAL TERMINAL ROAD TRAIN AIR BRAKE TEST

1022. Except for run-through and unit run-through trains covered under Rule 1031, all trains must be given inspection and test prescribed by Rule 1025 at points —

1. Where train is originally made up.
2. Where train consist is changed other than by adding or removing a solid block of cars, and train air brake system remains charged.
3. Where train is received in interchange.

1025. After the air brake system on a freight train is charged to within fifteen (15) pounds of the setting of the feed valve on locomotive but not less than sixty (60) pounds, and on a passenger train to not less than seventy (70) pounds, as indicated by an accurate gauge connected to the brake pipe at rear end of train, and upon receipt of proper request or signal to apply brakes for test, a fifteen (15) pound brake pipe reduction must be made from pressure indicated by brake pipe gauge on locomotive, and after reduction is completed, wait thirty (30) seconds for brake pipe pressure to equalize and then check of brake pipe leakage for one minute must be made. If leakage does not exceed five (5) pounds per minute a further brake pipe reduction of ten (10) pounds must be made, and on a freight train, one long sound of locomotive whistle must be sounded to indicate brakes are applied for test. On locomotives with 26-L equipment, the equalizing reservoir pressure must be reduced approximately one pound below the brake pipe pressure before moving the brake valve cut-off valve to "Frt" or "Pass" position to avoid unintentional release of train brakes.

Inspection of train brakes must be made to determine that retaining valves and pipes are in condition for service, angle cocks, brake pipe end cocks, cut-out cocks and retaining valve handles are in proper position,and that air hose is properly coupled and in condition for service. It must be determined that brakes are applied on each car, that piston travel is correct, that brake rigging does not bind or foul and that all parts of brake equipment are properly secured.

When inspection of the application of train brakes is completed, and upon receipt of proper request or signal to release brakes, air brakes must be released. On a freight train, two long sounds of locomotive whistle must be sounded to indicate that brakes have been released. Each brake must then be inspected to see that all have released.

1025(A). If brake pipe gauge indicates leakage in excess of five (5) pounds per minute after brake pipe reduction of fifteen (15) pounds has been made for test of brakes, engineer must give one short and one long sound of locomotive whistle and place automatic brake valve in "Running" position to recharge train. Upon receipt of this signal, train must be inspected for leaks and leakage corrected, after which complete test of brakes, as prescribed by Rule 1025, must be made.

1025(B). During terminal air brake test. brakes must not be applied or released until proper signal or request has been received, except in case of excessive brake pipe leakage.

1025(C). Each train must have air brakes on all cars operative before leaving a terminal except on scale test cars which are not equipped with air brakes.

1025(D). Defects which cannot be repaired promptly must be reported to foreman of inspectors or conductor and appropriate action taken for correction.

1025(F). Trainmen must inform engineers of total tonnage and number of cars and location of loads and empties in freight trains if concentrated at either end of train.

1025(G). Before a train departs from a terminal, inspectors and trainmen must know that all hand brakes are released, hoses are properly coupled, retaining valve, angle cock, brake pipe end cock and cut-out cock handles are in proper position, and that pressure is being restored or has been restored as indicated by caboose gauge on freight or other trains so equipped.

1025(I). At initial terminal, piston travel of body-mounted brake cylinders which is less than seven (7) inches or more than nine (9) inches must be adjusted to nominally seven (7) inches.

1039(A). Dynamic brake must be supplemented by use of train air brakes to extent necessary to properly control speed of train.

BRAKE PIPE TEST

1041. Before descending heavy grades designated in Special Rules, freight trains must stop and while train is standing, and with pressure maintaining cut out, engineer must apply brakes with a ten (10) pound brake pipe reduction, and give one long sound of locomotive whistle.

A trainman must observe if brake on rear car applies, and if so, make a further brake pipe reduction by gradually opening angle cock on rear end of rear car sufficiently to register on brake pipe gauge in cab of locomotive.

When engineer observes proper reduction in pressure on brake pipe gauge, two long sounds of locomotive whistle must be given and trainman must close angle cock at rear end of train, give signal to release brakes, and observe that brake on rear car releases. Failure of brake on rear car to release indicates an obstruction in brake pipe, which must be corrected and brake pipe test repeated.

If train does not depart within thirty (30) minutes after this test is completed, test must be repeated before proceeding.

GRADE BRAKING

1043. When starting freight trains from summit of heavy descending grades and pressure maintaining method of braking is to be used, care must be used to avoid making first reduction too heavy as this would reduce speed of train to extent brakes would have to be released.

If first reduction was not sufficient to hold train, further brake pipe reductions of one or two pounds each may be made until amount is reached where train will be held at desired speed.

Equalizing reservoir gauge must be frequently observed and if any increase in pressure is shown on this gauge during time brakes are applied, this pressure should be promptly reduced to the amount indicated by this gauge before increase occurred.

1043(A). When starting freight trains from summit of heavy descending grades and "short cycle" method of braking is to be used, first application of brakes must be made as soon as practicable without stalling, to test holding power of brakes while speed is slow and to get the additional aid of retaining valves if their use is requried. All subsequent brake applications must be of sufficient amount to hold train at required speed, and when releasing if necessary, "Release" or "Running" position of automatic brake valve must be used until air brake system has recharged and brakes are to be reapplied. Subject to local restrictions, speed must correspond with holding power of brakes and ability to fully recharge, maintaining as nearly as possible a uniform speed. Light applications are best, but must not be so light as to prevent getting a sufficient reduction in speed to insure recharging before again reaching too high a speed. To deter-

USE OF CONDUCTOR'S VALVE

1052. Conductor's valve must not be used except in case of an emergency. If an immediate stop is necessary, valve must be opened fully and left open until train has stopped. When a gradual stop is desired, and type of valve will permit, handle must be moved to position No. 1 and after lapse of five (5) seconds it must be moved to position No. 2. If brakes apply with sufficient force, handle must be left in position No. 2 until train is stopped; otherwise, additional braking force can be obtained by moving handle to remaining positions at five-second intervals, leaving handle in position at which desired braking force is obtained until train is stopped. Valve handle must be moved slowly from one position to another.

1052(A). When conductor's valve or caboose valve is opened while train is moving, under no circumstances must it be closed before train has stopped.

OTHER THAN NORMAL STOPS

1053. If brakes in train are applied with service application from any source other than from use of automatic brake valve on locomotive while using power, Engineer must leave brake valve in "Running" or "Release" position, keep locomotive brake released, and close throttle gradually as speed of train reduces. When train has reached point where it is evident it will stop within next 100 feet, throttle must be closed, rails sanded, and independent brake fully applied as train comes to stop. This procedure must also be followed when not using power except with respect to use of throttle. After stop is completed, engineer must make or observe that not less than a ten (10) pound brake pipe reduction has been made from equalizing reservoir pressure, and must permit this application to equalize throughout train before releasing train brakes.

1053(A). If brakes in train are applied in emergency from any source other than by automatic brake valve, brake valve must be moved to "Emergency" position and left in this position until train has stopped and equalizing reservoir pressure has vented to zero. Sufficient brake cylinder pressure must be applied to locomotive to control slack, keeping independent brake valve handle depressed in application zone to prevent sliding or overheating wheels. After brakes are released, brake pipe pressure restored, and train brakes applied with a twenty (20) pound brake pipe reduction, pressure maintaining feature must be cut out. Leakage must then be checked to see if within prescribed limits.

If power was being used at time emergency application occurred, throttle must be moved to "Idle" position.

If dynamic brake was in use at time emergency application occurred, dynamic brake operating lever must be moved to "Off" position.

OPERATIVE BRAKES

1058. Each train must have operative air brakes on all cars, except scale test cars, while running except in case of emergency, but at no time shall the number and position of operative air brakes be less than permitted by Federal requirements.

1058(A). When piston travel is in excess of ten (10) inches, the air brakes cannot be considered in effective operating condition.

APPENDIX E

UNION PACIFIC RAILROAD COMPANY
OFFICE OF SUPERINTENDENT
CALIFORNIA DIVISION

CIRCULAR NO. 47

Los Angeles - January 2, 1980

410-22-D

TO ALL ENGINEMEN

Effective immediately units will not be dispatched on train from mechanical points without speed recorders operating or without speed tapes and units without dynamic brakes functioning on lead unit. If speed recorder or dynamic brakes fail enroute, engineer will contact train dispatcher and be governed by his instructions.

L. D. Nelson
Superintendent

POST: All Circular Notice Books

REMOVE: December 31, 1980

CC: REI AL MWV LDS WET PGW GRT ECB SJJ(10) RLB RCA REM FHB RCK EKS OWP(6) TAW ADM(2) Agents - City of Industry, Riverside, Paramount, Yermo, Fullerton, H. Z. Wagner - Harbor Belt Line

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NTSB NOTE: - Fascimile of UP California Division Superintendent's Circular No. 47

CIRCULAR NO. 108

Los Angeles- August 12, 1980

410-22-D

TO ALL ENGINEMEN:

Effective immediately Circular No. 47, dated January 2, 1980, is hereby canceled and should be removed from Circular Notice Books and Bulletin Boards.

L. D. Nelson,
Superintendent

POST: Circular Notice Books and Bulletin Boards

REMOVE: December 31, 1980

cc - REI AL RCA JES - Salt Lake
LDS WET PGW GRT ECB SJJ(10) RLB HMD WCH ADM MVW NM - Los Angs
REM - Yerm
DRL RCK EKS WSN OWP(6)
Agents - Los Angeles, Yermo(3) Las Vegas(6) City of Industry
Paramount Riverside
H. Z. Wagner - Harbor Belt Line

APPENDIX F

EXCERPTS FROM AIR BRAKE ASSOCIATION MANUAL

Control of air to the train brake system

At the automatic brake valve the pressure of the air delivered from the main reservoirs to the train brake system is reduced by a regulating valve to the brake pipe pressure carried for the particular train service. Brake pipe pressures in common use range between 70 and 110 psi, depending on the railroad and its type of service.

In undergoing this pressure reduction air expands, increasing its ability to carry moisture (or in effect reducing the humidity of the air) so that the relative humidity of the air in the brake pipe commonly ranges between 70 and 80% of saturation.

The 26-C automatic brake valve, shown in Fig. 9, supplies the brake pipe with air which is used for the following purposes:

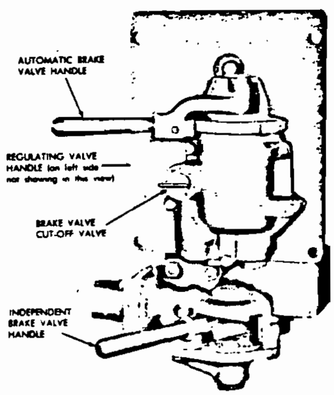


FIG. 9 26-C AUTOMATIC BRAKE VALVE

1. To charge the auxiliary, emergency and supply reservoirs of the car brake equipment and the auxiliary reservoirs of the locomotive equipment.
2. To vary the brake pipe pressure to cause the automatic train brakes to apply and release in service and emergency.

After the train is charged with the automatic brake valve handle in release position, movement to the right will cause a reduction in the equalizing reservoir pressure. This in turn will cause the brake pipe pressure to reduce a corresponding amount. Specific handle positions determine the specific pressure in the equalizing reservoir.

a. That is, leaving the brake valve handle in a position which reduced the equalizing reservoir pressure by, say 10 psi, will cause the brake pipe pressure to reduce 10 psi. Since the 26-C brake valve is of the "pressure maintaining type", the brake pipe pressure reduction of 10 psi will be held or maintained against the effect of the nominal brake pipe leakage.

b. Reducing the brake pipe pressure will cause the locomotive 26-F control valve (Fig. 11) and train brakes to apply.

c. The 26-C automatic brake valve handle positions are shown in Fig. 10 and are:

1. Release-Equalizing reservoir and brake pipe correspond to regulating valve setting, 70 to 110 psi, as required for the particular train service.

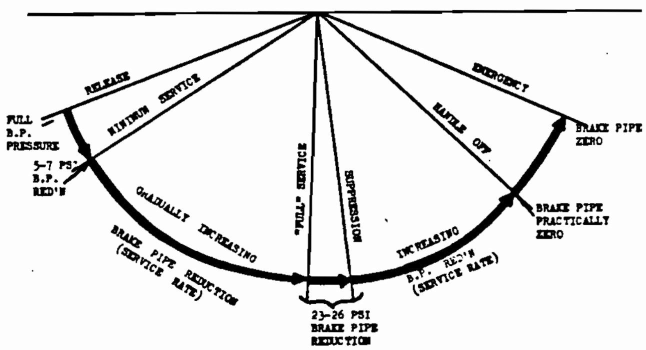


FIG. 10 26-C AUTOMATIC BRAKE VALVE HANDLE POSITIONS

2. Minimum Service Reduction: 5-7 psi reduction in equalizing reservoir and brake pipe pressure. Pressure can be further reduced in steps by moving handle progressively to the right.
3. Full service - 23-26 psi reduction of equalizing reservoir and brake pipe.
4. Suppression - 23-26 psi brake pipe reduction plus air into port #26 or "Suppression Pipe" to permanently suppress safety control or train control. Additional movement to the right toward "Handle Off" will progressively reduce brake pipe at a service rate.
5. Handle off - Brake pipe is further reduced to approximately 10 psi. Equalizing reservoir will be reduced to approximately 0.
6. Emergency - Brake pipe is quickly vented through a large opening to atmosphere and equalizing reservoir vents to atmosphere at normal rate.

Grade Operations

. Operating freight trains down grades of any significant length, requires observance of the following:

a. Balancing the grade, or holding speed steady at safe and practical values.

b. Maintaining ample safety margin, or keeping speed to a value which will allow stopping the train anywhere on the grade within signal spacing or other prescribed limitations.

In order to hold speed steady on a downgrade, the force of gravity must be balanced by the sum of train resistance and brake retarding force. The heavier the grade, the lower the effect of train resistance; and the more brake must be used. Obviously, train resistance will vary with the type of cars, train make-up, and train length and weather. On heavier grades, the majority of the grade retarding force comes from the locomotive dynamic brake and the train air brake. The following conditions apply:

a. The amount of train brake retarding force used to balance the grade normally should not exceed one half (½) of the normal full service train brake available if dynamic brake and pressure maintaining are operative.

b. If pressure maintaining is available but dynamic brake is not operative, the amount of the brake required to balance the grade should not exceed 1/3 of the normal full service available.

c. With neither dynamic brake nor pressure maintaining available, cycling manipulation and use of retainers would probably be required. In this case, the train brakes are alternately applied and released. In order to insure holding an adequate reserve of pressure for stopping, the amount of train brake to balance the grade should not be more than approximately ¼ of the normal full service brake retarding force available.

2. On a grade, gravity acts on each ton of train weight with a force of 20 lb for each per cent grade as shown below:

Per Cent Grade	Down Grade Force of Gravity
1%	20 lb per ton
2%	40 lb per ton
3%	60 lb per ton

The brake retarding force required to balance the down grade gravitation force is the force of gravity less the car or train resistance. In the following examples, assume resistance is equal to approximately 4 lb per ton at speeds of 15 to 30 mph. Obviously, the heavier the car, the more brake retarding force is needed. However, the difference of a few tons in car weight requires considerably more braking. This is illustrated on the tabulation below and Figure 114. It is important for enginemen and trainmen to have an understanding of this.

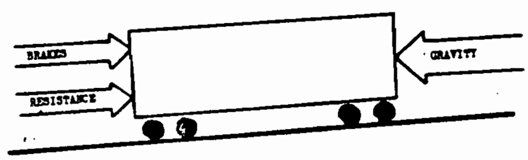


FIG. 114 BALANCING A GRADE

Train With Cars of 80 Tons Average Weight

Descending Grade Per Cent	Gravity Force	Resistance Force*	Required Brake Retarding Force	Approximate Brake Pipe Reduction
1%	1600 lb	320 lb	1280 lb	6 psi
1½%	2400 lb	320 lb	2080 lb	8 psi
2%	3200 lb	320 lb	2880 lb	10 psi
2½%	4000 lb	320 lb	3680 lb	12 psi
3%	4800 lb	320 lb	4480 lb	14 psi

Train With Cars of 100 Tons Average Weight

Descending Grade Per Cent	Gravity Force	Resistance Force	Required Brake Retarding Force	Approximate Brake Pipe Reduction
1%	2000 lb	400 lb	1600 lb	7 psi
1½%	3000 lb	400 lb	2600 lb	10 psi
2%	4000 lb	400 lb	3600 lb	12 psi
2½%	5000 lb	400 lb	4600 lb	14 psi
3%	6000 lb	400 lb	5600 lb	16 psi

Note: If curvature is particularly heavy, train resistance will increase and somewhat less brake will be required.

3. While a difference of 2 psi in brake pipe reduction to balance the grade may not seem too significant, it means quite a bit in stopping ability on the grade. A normal stop on the grade should always be available with the service brake. However, balancing the grade has used up a portion of the service brake. Therefore, a service stop on the grade will be similar to a stop on level territory with a partial service application. For example, if descending a 2% grade with a train of 80-ton cars (80 tons per operative brake) employing a 10-psi reduction to balance and using 70-psi brake pipe pressure:
4. Components of the brake system including brake shoe and wheel have practical limits on the work they can be subjected to, or the braking horsepower they can dissipate. The practical limit is that which will give satisfactory performance of brake shoe and wheel down the complete grade with ample margin for stopping anywhere on the grade.

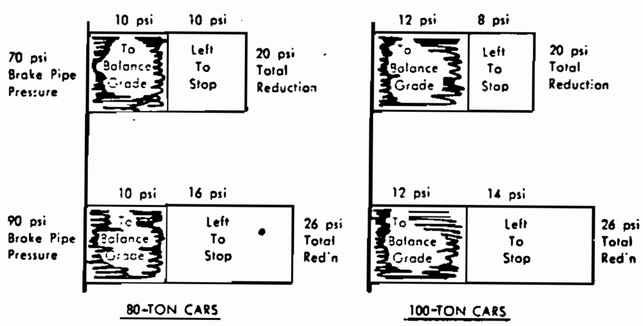


FIG. 116 EFFECT OF BRAKE PIPE PRESSURE ON GRADE BALANCING AND STOPPING

a. Braking horsepower varies directly with speed. For example, if a grade is descended at 30 mph instead of 15 mph, twice as much braking horsepower is required, even though the force of gravity on the train is the same.

b. The braking horsepower required varies directly with the weight of the train. An 8000-ton train takes twice as much braking horsepower as a 4000-ton train. If conditions permit, the lighter train can descend the grade at higher speed and still stay within practical limits of brake shoe and wheel performance. The braking horsepower required is provided by the combination of train air brake horsepower plus dynamic brake horsepower, if available (see section on dynamic brake for more complete information). If dynamic brake is available, it is obvious that the train air brakes do not have to be worked as hard. Higher speeds may be permitted under these conditions. In the opposite case, if dynamic is not available, it is only practical common sense to run under more conservative conditions at lower speeds.

c. Practical limits of continuous braking (work transferred from car brake shoes to car wheels) is in range of 20-25 hp for the 33-in. freight car wheel. Larger wheels can take somewhat more horsepower, generally in proportion to the square of the diameter. Brake shoes are capable of performing satisfactorily within these ranges; however, shoes will wear at a faster rate with higher braking horsepower demand.

d. The effect of high gross car weights on the braking demand per car wheel is important. For example, on a train of 73 cars each weighing 110 tons, or total of 8030 tons, there would be 584 car wheels, not including locomotive or caboose to share the train air brake work load. This might be compared with a train of 146 cars of 55 tons average gross weight totaling 8030 tons as above, but with 1168 wheels to share the train brake work load. Obviously, a greater work load is imposed on wheels and brake shoes with trains of fewer and heavier cars.

5. Cycling brake manipulation: In the event that neither dynamic brake nor pressure maintaining is available, it will be necessary to descend the grade, using cycling manipulation and retainers set up. It is assumed that the required grade balancing brake application is heavier than that obtained with a minimum 6-8 psi brake pipe reduction. At heavier reductions, the brake cylinder pressure even with retainers, may reduce due to minor leakage if on the grade for a considerable period of time. Since the leakage rate varies from car to car, with some cars having very little leakage, compensating for this simply by increasing the brake reduction from time to time, would result in some cars having little brake cylinder pressure and others very high pressure. The brake shoes and wheels on the "low leakage" or "tight" cars may have excessive heat and wear. Therefore, it has proven to be more practical to release and reapply the train brakes from time to time. Hence, the term "cycling" implies that the speed will vary within limits because brakes are alternately applied and released.

a. Cycling manipulation and use of retainers go hand in hand. Retainers should be set up on a sufficient number of cars so they will hold just about enough brake cylinder pressure to balance the grade.

b. General practice is to make the initial brake pipe reduction somewhat heavier than that required to balance the grade, probably 9-12 psi, which is sufficient to fill brake cylinder to 20 psi or more. Timing of the start of this application is important as the train goes over the crest of the grade. The initial application should be started at a point that will prevent speed from becoming excessive as the train moves onto the grade and before the application becomes effective on the whole train. There is no substitute for good judgment and experience. It is better to approach the crest of the grade at a somewhat lower speed than authorized for the train, making the initial application a little on the light side in order to get the feel of the train as it comes over the crest, and then add to it if the train seems to require additional retardation. Hold the initial application so that the speed reduces under the average speed required. Then release the brakes. Retainers should hold the increase in speed during the release to a slow rate which will allow the brake valve handle to remain in release position at least 45 seconds and preferably longer.

c. Start the next application at a speed which will allow brakes to become fully effective before excessive speed is reached. However, since the brake system will not have had time to recharge completely, it will be necessary for the engineman to compensate for this in making the second and all succeeding reductions. Keep track of the brake pipe and equalizing reservoir gages during the release. When the next application is needed, note carefully the brake pipe pressure which may be less than equalizing reservoir (say 76 psi B.P., 80 psi ER). For the succeeding application, subtract the desired reduction from that existing brake pipe pressure and reduce the equalizing reservoir to this value (76—12=64 psi). Another method is to measure the equalizing reservoir pressure reduction from the moment the Service exhaust starts to blow. These methods will produce the desired brake pipe reductions. The cars in the train respond only to the actual (net) brake pipe and reservoir pressure changes effective at that point in the train.

d. Long periods of "short cycling" brake operation usually result in slight but steady lowering of minimum car reservoir pressures. Frequent observations of the train must be made while moving down grade. Pay particular attention to signs of excessive braking heating when using a cycling manipulation. Retainers will develop higher brake cylinder pressures on the head end than those toward the rear. Therefore, the head end cars will do considerably more braking work. Follow local rules in regard to cooling stops and train inspection. Follow local rules regarding stopping on grades. General good practice is to stop at a point where the locomotive independent brake will hold the train thus allowing the train brake system to be fully recharged.

J. Pressure Maintaining

With pressure maintaining, brake pipe pressure is maintained against brake pipe leakage to the level of the pressure in the equalizing reservoir. The normal or natural brake pipe gradient, or "taper" from front to rear will be maintained during service applications.

Pressure maintaining is a basic feature of the 26-L equipment and is an optional feature, although widely applied, on 24-RL. Train brake release action is faster and more positive with pressure maintaining.

f. Attention to the main reservoir pressure and load-unload cycle of the compressors will indicate the relative amount of air flow into the brake pipe, if the locomotive is not equipped with a brake pipe flow indicator. During pressure maintaining operation, if markedly increased air flow into brake pipe becomes evident, be alert for the following procedure:
   1. Brake application being made from the rear end.
   2. Bad leakage has developed in the brake pipe or hoses back in the train.

DYNAMIC BRAKE RETARDING FORCE
3300 HP DYNAMIC BRAKE

	6 motored axles		4 motored axles	
Speed mph	Extended Range Dynamic, lb	Standard Dynamic, lb	Extended Range Dynamic, lb	Standard Dynamic, lb
6	60,000	14,400	40,000	9,600
12	60,000	30,000	40,000	20,000
24	60,000	60,000	40,000	40,000
30	48,600	48,600	32,400	32,400
40	34,000	34,000	24,000	24,000
50	28,800	28,800	19,200	19,200
60	24,000	24,000	16,000	18,000
70	20,400	20,400	13,600	13,600

THE BRAKE PIPE FLOW INDICATOR

The brake pipe flow indicator, Fig. 90, is an instrument which indicates the rate of flow of air through the automatic brake valve to the brake pipe. It may be used with any of the brake equipment presently in use.

This instrument is actually a differential pressure gage which indicates on its dial a difference between two pressures. It also actuates a switch which lights a lamp as an added indication. The lamp switch may be set to light the indicating lamp at any desired reading.

The brake pipe flow indicator is the only indicator which the engineman has which will inform him as to what is taking place in the brake pipe in regard to air flow. In locomotive brake equipment, such as the No. 6 types and the 24-RL, the flow indicator has one of its connections piped to the feed valve pipe and the other connection piped to the brake pipe. In the 26-L equipment, these connections are made across a check valve and choke arrangement known as the A-19 flow indicator adapter, which is placed in the main reservoir pipe to the 26-C brake valve. With the No. 6 and 24-RL types of locomotive brake equipment, the flow indicator indicates the difference in pressure between the feed valve pipe or core and the brake pipe—the greater the differential, the greater the air flow. With 26-L equipment the flow indicator indicates the difference in pressure across the choke orifice in the A-19 flow indicator adapter, Fig. 90-A, and, here also, the greater the difference, the greater the air flow.

The brake pipe flow indicator, because it indicates the rate of flow of air to the brake pipe, may be used to indicate several things.

It can indicate when a train is charged. It can indicate when excessive leakage is present. The indicated reading is not an actual measure of brake pipe leakage, but represents the condition of air flow into the brake pipe. It can indicate when the brakes are being applied from the caboose, an occurrence which does not show on the locomotive brake pipe gage.

In cold weather, the flow indicator can be of assistance, as it can indicate whether difficulty in obtaining sufficient pressure on the rear or caboose is due to leakage, possible freeze-up, restriction in the locomotive brake pipe, or the first few cars of the train.

Referring to the illustration showing the brake pipe flow indicator, it will be noted that there are two pointers. One of these is colored black, and this pointer indicates the brake pipe air flow. The other pointer is colored red and may be set at any point; for example, it might be desirable to indicate a minimum flow at a certain time. To adjust the red hand, the adjusting knob in the center of the cover above the dial is turned. The indicator lamp is shown to the right of the adjusting knob. This lamp shows amber through the lens.

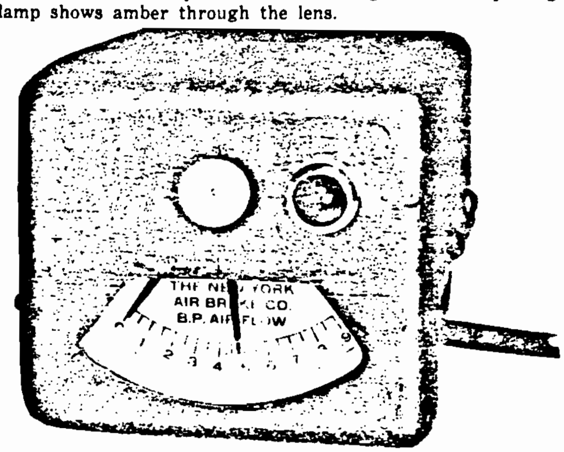


FIG. 90 TYPE B BRAKE PIPE FLOW INDICATOR

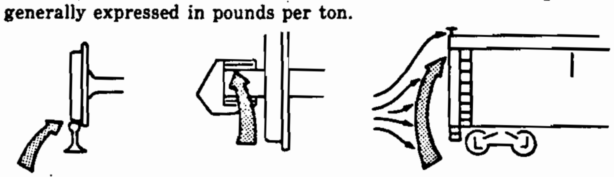
10. Applying Brakes From the Rear End

Conductor valves and back up valves are only for the purpose of stopping trains, and must not be used to apply train brakes in an attempt to control slack. Do not use these unnecessarily as they may cause a light service application from which stuck brakes may result, or may cause an undesired release of a locomotive initiated service application. After the train stops, close the caboose valve, moving the caboose valve handle to extreme left. The engineman should be alert for indications of brakes being applied from the rear, such as:

1. Increased air flow through the automatic brake valve into the brake pipe—Main reservoir gauge changing rapidly, compressors loading more frequently, etc.
2. If the locomotive is equipped with a "B" type flow indicator, the reading will increase rapidly and may light the indicator lamp.
3. Speed may reduce abnormally and amperage, if the locomotive is under power, may also increase.
4. When an application from the rear is detected, the engineman should make a minimum brake pipe reduction of 6 to 8 psi and wait until the brake pipe pressure "settles". Reduce power gradually, making further 2 to 3 psi brake pipe reductions if necessary, until the train stops. When about 200 ft. from the stopping point, open the sanders, close the throttle and apply the independent brake. Make final brake pipe reduction so the exhaust is blowing when train comes to rest.

ROLLING RESISTANCE

The rolling resistance of a train can be determined by formula, but more generally is taken from tables and curves based on formula. The most widely used of such formulae is the Davis Formula. Rolling resistance is generally expressed in pounds per ton.



Flange Resistance + Journal Resistance + Air Resistance = Total Rolling Resistance

Other things being equal, total rolling resistance, expressed in pounds per ton . . .

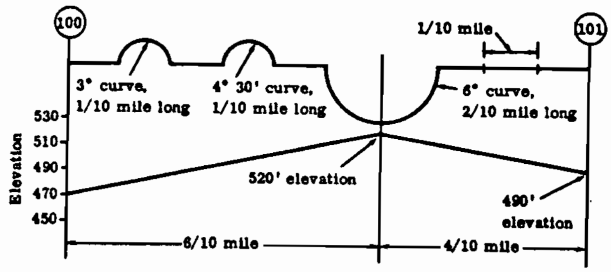
1. ...Increases as speeds increase
2. ...Decreases as car weights increase

ROLLING RESISTANCE
(Lb./Ton)

Speed	20 Ton Car	100 Ton Car
10 MPH	7.5	2.6
60 MPH	16.5	7.0

(Note, however, that when expressed in total pounds, the 100-ton car naturally offers more resistance than the 20-ton car.)

ALLOWANCE FOR CURVATURE



The method for adjusting gradient calculations to allow for the effect of the resistance added by track curvature can be illustrated with the above representation of a one-mile section of track chart and profile:

1. *Determination of gradient*

   From milepost 100 to location 100.6:

$$\frac{\text{Rise x 100}}{\text{Distance}} = \frac{(520\text{ ft.} - 470\text{ ft.}) \times 100}{6\text{ mi.} \times 5280\text{ ft.}} = \frac{5000\text{ ft.}}{3168\text{ ft.}} = 1.58\%$$

2. *Determination of average curvature*

   From milepost 100 to location 100.6:

$$\text{Avg. curve} = \frac{(3^\circ \times .1\text{ mi.}) + (4.5^\circ \times .1\text{ mi.}) + (6 \times .1\text{ mi.})}{.6\text{ mi}} =$$

$$\frac{1.35^\circ\text{ mi}}{.6\text{ mi}} = 2.25^\circ$$

3. *Determination of grade equivalent of 2.25° curve*

   Grade equivalent = 2.25° x 0.05 = .1125%

4. *Determination of effective grade*

   From milepost 100 to location 100.6:

   Effective grade = Actual Grade + Grade Equivalent =
   1.58% + .1125% = 1.69%.

   (Descending, the effective grade = —1.58% + .1125% = —1.47%

DAVIS FORMULA for rolling resistances:

The rolling resistance of locomotives and cars is affected by so many variable factors (weight, speed, size, journal type, configuration, wind, temperature, etc.) that it can be accurately determined only by test. Obviously performance calculations must rely on something more practicable. The most widely known and universally accepted of the several formulae for calculating resistance of a given train is the one developed by W. J. Davis.

$$R = 1.3 + \frac{29}{W} + 0.045^{*}V + \frac{0.0005^{*}AV^2}{Wn}$$

where: R = resistance in lb/ton on level tangent track
W = weight per axle in tons
n = number of axles per car
A = cross section of car in square feet
V = speed in miles per hour

*Factors are for freight cars; other values are substituted for passenger cars and locomotives.

In the formula, the expression $1.3 + \frac{29}{W}$ represents journal resistance; 0.045V represents flange resistance; and $\frac{0.0005\ AV^2}{Wn}$ represents air resistance.

As an example, the rolling resistance (R) of a 40-ton (W=10, n=4) box car of 80 square feet cross section (A=80) at 10 mph (V=10) would be:

$$R = 1.3 + \frac{29}{10} + (0.045 \times 10) + \frac{(0.0005 \times 80 \times 10^2)}{(10 \times 4)} = 4.75 \text{ lb/ton}$$

CURVE RESISTANCE

Because the wheels of railroad rolling stock are fixed to, and therefore rotate with, their axles in rounding a curve there is a tendency for the wheel following the inside track to be skidded — or for the outside wheel to spin. Whether one or the other occurs or whether the tendency is overcome by lateral movement of the axle within its journals, friction (resistance) is created. The "sharper" the curve, the greater this resistance becomes.

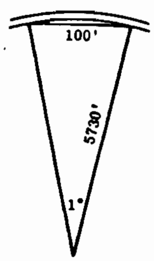


Fig. 155

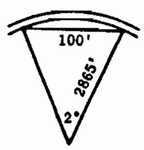


Fig. 156

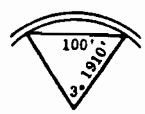


Fig. 157

By definition, a one degree curve is a curve, a 100 ft. chord of which determines a one degree central angle (Fig. 155). It happens that such a curve has a radius of 5730 feet. Given the degree of curvature, radius can be determined by dividing 5730 feet by the degree of curvature. Thus two and three degree curves (Figs. 156 & 157) have respective radii of $\frac{5730 \text{ ft.}}{2}$ and $\frac{5730 \text{ ft.}}{3}$, or 2865 and 1910 feet.

The effect of varying degrees of curvature on train resistance has been determined by test, and most simply stated, indicates that one degree of curvature offers the same resistance to train movement as a 0.05 percent grade, i.e., 1 pound/ton (0.05 x 20) for each degree of curvature.

APPENDIX G

EXCERPTS FROM AIR BRAKE RULES OF OTHER U.S. RAILROADS

Baltimore and Ohio Railroad Company (Chessie System)

D. Operation of Coal Trains—Seventeen Mile Grade—Reduce power to permit the train to pass the summit of the grade just east of the overhead bridge at Altamont at a speed approximately eight miles per hour. As soon as train speed starts to increase, an initial reduction of eight pounds brake pipe pressure will be made and dynamic brake applied. Further reductions of the brake pipe and modulation of the dynamic brake will be used to control speed between 20 and 25 miles per hour, between Altamont and Piedmont.

If the amount of the brake pipe reduction is in excess of fifteen pounds approaching Swanton Flats, the train will be brought to a stop, air brakes inspected and sufficient handbrakes applied before descending the remainder of the grade. The brake pipe must be completely recharged before moving.

At no time will the train be pulled with air brakes applied for a distance greater than 2 miles, or if the brake pipe reduction is greater than 20 pounds.

Before detaching power at Keyser, reduce equalizing reservoir pressure to 80 pounds and comply with CDT-30, Rule 219-C to reduce pressure in air brake system in freight cars.

Coal trains must not exceed 25 miles per hour between Altamont and Piedmont.

E. Operation of Solid Loaded Grain Trains—All solid loaded grain trains must increase to 100 lbs. brake pipe pressure at Hardman and carry to Cumberland Terminal.

Grain trains descending 17 Mile Grade which do not respond to service braking in a normal manner will be stopped between Swanton Road Crossing and Mile Post 219, east of Swanton. After stopping, sufficient hand brakes will be applied to hold the train on the grade. Train will be recharged, then proceed with hand brakes applied. During the remainder of the descent if it becomes necessary to reduce brake pipe pressure more than 25 lbs., stop will be made and brake pipe recharged before further movement.

Denver and Rio Grande Western Railroad Company

Special Time-Table Rules

AIR BRAKE AND RETAINER OPERATION, CAR LIMITS AND INSPECTION STOPS

4. Freight trains will be considered "Bulk" trains if average weight per car is more than 80 actual tons and, in addition, the actual tonnage per road loco. unit with operative dynamic brake exceeds:

GP-9, SD-7, SD-9	600 tons
GP-30, GP-35, GP-40	1000 tons
SD-40, SD-45	1300 tons
Utah Ry 300 Series	600 tons
Utah Ry 400 Series	1200 tons

These trains must not be operated in excess of 40 MPH.

4-A. On "Bulk" trains (see Rule 4) in territories shown below:

Crater to Bond	Monarch Spur
Winter Park to Fraser	Fir to LaVeta
East Portal to Leyden	Sunnyside to M P 6
Tennessee Pass to Minturn	Kyune to Helper
Leadville Branch	Soldier Summit to Thistle

if dynamic brake is inoperative or if use of full dynamic brake and 18 pound brake pipe reduction will not control train at the allowable speed, train must be stopped, retainers on all loads placed in operative position and sufficient hand brakes set to prevent movement. Train must not proceed except as instructed by Chief Dispatcher or other proper authority.

Crater to Bond, Winter Park to Fraser and East Portal to Leyden

4-C. On freight trains if actual tonnage per unit with operative dynamic brake exceeds:

GP-9	1400 tons
GP-30, GP-35, GP-40	2000 tons
SD-7, SD-9, SD-40, SD-45	3000 tons

beginning at head end of train use ten retainers plus one retainer for each additional 50 tons. If dynamic brake is inoperative retainers will be used on all cars.

Tennessee Pass to Minturn

4-D. On freight trains if actual tonnage per unit with operative dynamic brake exceeds:

GP-9	1000 tons
GP-30, GP-35, GP-40	1500 tons
SD-7, SD-9, SD-40, SD-45	2000 tons

beginning at head end of train use ten retainers plus one retainer for each additional 50 tons. If dynamic brake is inoperative retainers will be used on all cars.

Burlington Northern

MOUNTAIN GRADE OPERATION GENERAL RULES

440 A. Mountain Grade Territory is defined as grades of one and eight tenths (1.8) percent or greater.

B. The control of train speed is a key factor in mountain grade operation since the amount of braking required varies directly with speed. Speed can get out of control in a very short time on heavy grades. An EMERGENCY brake application should be made WITHOUT HESITATION should any condition occur where there is doubt of ability to control train speed.

C. The brake pipe pressure maintaining feature must be used when locomotive is so equipped.

D. Train speed must be effectively controlled with no more than a 15 psi brake pipe reduction except as covered under Rule 441 B 5.

E. The train must be observed frequently for any indication of overheated wheels.

F. Before passing summit of heavy descending grades, trainmen on freight trains must note by observation of the caboose gauge that the brake pipe pressure is not less than 75 psi or 85 psi if 100 psi brake pipe being carried. If the pressure is not within this limit, the train must be stopped and the cause of the abnormal condition corrected before proceeding.

G. The speed of passenger trains when passing the summit must not exceed the maximum speed authorized for the descending mountain grade. If a stop is not made by use of train brakes at or closely in advance of the summit, a running brake test, as prescribed by Rule 225 A, must be made before passing the summit.

H. When passing the summit, the speed of freight trains must not exceed the maximum speed authorized for the descending mountain grade. Where helper locomotives are used the engineer of the lead locomotive will be responsible for the method of helper operation as related to train handling.

I. When available, the dynamic brake must be used.

J. In event of failure of dynamic brake, or for any other reason when train speed cannot be properly controlled, engineer must take prompt action to stop the train using an EMERGENCY brake application if necessary and before proceeding take corrective action to permit safe operation of the train.

K. If all locomotives become inoperative on a descending grade, stop must be made immediately. Train and/or locomotive must be secured with hand brakes until condition causing failure has been corrected.

MOUNTAIN GRADE OPERATION TRAIN BRAKING REQUIREMENTS

441 A. Supervisors, dispatchers, locomotive engineers and conductors must consider the status of each train as related to: operative dynamic brake, tons per operative brake and maintaining type brake valves. Requirements contained in the applicable category must then be complied with while descending mountain grades.

B. Trains of 100 Tons or More Per Operative Brake:

1. Locomotives having dynamic brake in effective operating condition must be used on both lead and helper locomotives.

2. Lead locomotive must be equipped with a brake pipe pressure maintaining feature in operative condition.

3. Standard brake pipe pressure will be 100 psi.

4. Not less than a minimum brake pipe reduction (5 to 7 psi) must be used in conjunction with dynamic brakes.

5. Train speed must be effectively controlled with no more than a 18 psi brake pipe reduction.

6. Normally not less than the number of locomotives required on the ascending grade must be used on the descending grade to control speed.

7. Speed must not exceed 30 MPH on the descending grade.

8. AN EMERGENCY BRAKE APPLICATION SHOULD BE MADE WITHOUT HESTIATION SHOULD ANY CONDITION OCCUR WHERE THERE IS DOUBT OF ABILITY TO CONTROL TRAIN SPEED.

C. Trains of 80 to 99 Tons Per Operative Brake:

1. Locomotives having dynamic brake in effective operation condition must be used.

2. Lead locomotive must be equipped with a brake pressure maintaining feature in operative condition.

3. Standard brake pipe pressure will be 90 psi.

4. Not less than a minimum brake pipe reduction (5 to 7 psi) must be used in conjunction with dynamic brakes.

5. Train speed must be controlled with no more than a 15 psi brake pipe reduction.

6. Normally not less than the number of locomotives required on the ascending grade must be used on the descending grade to control speed.

7. AN EMERGENCY BRAKE APPLICATION SHOULD BE MADE WITHOUT HESITATION SHOULD ANY CONDITIONS OCCUR WHERE THERE IS DOUBT OF ABILITY TO CONTROL TRAIN SPEED.

Burlington Northern (Cont.)

D. Trains of Less than 80 Tons Per Operative Brake:

1. Locomotives having dynamic brakes and/or brake pipe pressure maintaining feature in operative condition must be used.

2. Not less than a minimum brake pipe reduction (5 to 7 psi) must be used in conjunction with dynamic brake unless the developed retardation will cause the train to stop.

3. Standard brake pipe pressure will be 90 psi.

4. Train speed must be controlled with not more than a 15 psi brake pipe reduction.

5. AN EMERGENCY BRAKE APPLICATION SHOULD BE MADE WITHOUT HESITATION SHOULD ANY CONDITION OCCUR WHERE THERE IS DOUBT OF ABILITY TO CONTROL TRAIN SPEED.

Trains of Less than 80 Tons Per Operative Brake With Neither Dynamic Brake Nor the Brake Pipe Pressure Maintaining Feature Available.

1. Standard brake pipe pressure will be 90 psi.

2. Train speed must be effectively controlled with not more than 15 psi brake pipe reduction.

3. When required, retaining valves must be set up.

4. The cycle method of braking normally must be used.

5. AN EMERGENCY BRAKE APPLICATION SHOULD BE MADE WITHOUT HESITATION SHOULD ANY CONDITION OCCUR WHERE THERE IS DOUBT OF ABILITY TO CONTROL TRAIN SPEED.

F. Use of Retaining Valves

1. Unless otherwise specified, the use of retaining valves will not be required on trains operated in compliance with Paragraphs B, C, D or E of this Rule or when requested by Engineer.

2. Unless otherwise specified, when train speed cannot be controlled in accordance with brake pipe reduction limitations specified by engineer, retaining valves will be required as follows:

a. Stop must be made immediately and the required number of retainers and/or hand brakes set.

Southern Pacific Transportation Company

Grade Air Brake Test

RULE 25. Summit.

At locations designated by the Timetable, trains must stop before passing summit of grade. An application of brakes must be made to determine that brakes are operative throughout the train and have applied on rear car.

RULE 25-A. Running Test.

At locations designated by the Timetable, running tests must be made as follows:

Head end crew must inform rear end crew that a running test of train air brakes is to be made. After acknowledgment that running test is to be made, engineer must apply brakes with sufficient force to insure air brakes are operating properly. Brake pipe pressure, as indicated by gauge at rear of train, must be observed prior to, and immediately after, the brake pipe reduction to give assurance that a brake pipe reduction was made. It must be known that brakes on rear car of train apply. When the brake pipe pressure is being restored, as indicated by gauge at rear of train, and brakes are released on rear car, trainmen must inform engineer that the running test is complete. If radio communication is not distinct, train must be stopped with the automatic air brakes and comply with Rule 25.

E. Balancing the Grade.

Operating freight trains on descending grades involves:

1. Balancing the grade, or holding speed steady at safe and practical values.

The amount of brake (train) retarding force used to balance the grade normally should not exceed one half (50 percent) of the normal full service train brake available if dynamic brake and pressure maintaining are operative.

In order to hold speed steady on a descending grade, the force of gravity must be balanced by the sum of train resistance and brake retarding force. The heavier the grade, the lower the effect of train resistance; and the more brake must be used. Train resistance will vary with the type of cars, train make-up, and train length and weather. On heavier grades the majority of the grade retarding force comes from the dynamic brake and the train air brake.

2. Maintaining ample safety margin, or keeping speed to a value which will allow stopping the train anywhere on the grade within signal spacing or other prescribed limitations.

a. The braking horsepower required varies directly with the weight of the train. The braking horsepower required is provided by the combination of train air brake horsepower plus dynamic brake horsepower. If dynamic brake is available, the train air brakes do not have to be worked as hard. In the opposite case, if dynamic is not available, train must operate at lower speeds.

Southern Pacific Transportation Company (Cont.)

b. The term "cycle braking" implies that the speed will vary within limits because brakes are alternately applied and released.

It is assumed that the required grade balance brake application is heavier than that obtained with a minimum six to eight psi brake pipe reduction. With heavier reductions the brake cylinder pressure, even with retainers, may reduce due to minor leakage if on the grade for a considerable period of time. Since the leakage rate varies from car to car, with some cars having very little leakage, compensating for this simply by increasing the brake reduction from time to time, would result in some cars having little brake cylinder pressure and others very high pressure. The brake shoes and wheels on the "low leakage" or "tight" cars may have excessive heat and wear.

(1) Cycle braking without retaining valves and without dynamic braking: Use light brake pipe reductions consistent with speed and tonnage of the train. The engine brake may be used to assist in the control of slack, using care to prevent excessive wheel heat.

(3) With retaining valves and without dynamic braking compliance with Rule 17 is required. Make the minimum brake pipe reduction increasing with additional light reductions as required to balance the grade, probably 10-12 psi, which is sufficient to fill brake cylinder to 20 psi or more. Timing of the start of this application is important as the train goes over crest of the grade.

The initial application should be started at a point that will prevent speed from becoming excessive as the train moves onto the grade and before the application becomes effective on the whole train.

Hold initial application so that the speed reduces under the average speed, desired or required, then release the brakes. Retainers should hold the increase in speed, during the release, to a slow rate which will allow the brake valve handle to remain in RELEASE position until just prior to the time required to reapply brakes to preclude exceeding authorized speed.

Start the next application at a speed which will allow brakes to become fully effective before excessive speed is reached. However, since the brake system will not have had time to recharge completely, it will be necessary for the engineer to compensate for this in making the second and all succeeding reductions. The brake pipe and equalizing reservoir pressures must be observed just before the release. At the time for next application, or succeeding applications, the equalizing reservoir must

d. General:

The brake pipe flow indicator provides an indication that a train separation has occurred or the conductor's valve has been opened. This is indicated by the hand moving to the right, generally a sound of air flowing and illumination of the amber light on the flow indicator.

On heavy grades speed can get out of control in a very short time. If use of emergency is indicated, don't hesitate. Service applications usually react too slowly and allow too much speed increase while they are becoming effective.

Even if the addition of 10 psi more brake pipe reduction would eventually balance the grade, at the higher speed, the brake horsepower may be high enough to be excessive for a long grade. Both brake shoes and wheels will probably be overworked.

Again, if dynamic is lost or becomes ineffective for any reason on a heavy grade:

(1) Get the train stopped quickly.

(2) Use emergency application, if required.

(3) Follow safe practice and local rules before again proceeding after such an unplanned stop on the grade.

APPENDIX H

DATA ON TIE CARS IN EXTRA 3119 WEST

Non-revenue No.	Old No.	Lightweight		
909447	15414	79,300*(1)	33"	6x11 Friction
913037	15372	78,600		
913044	15323	79,700		
913017	15400	78,900		
909448	15340	79,700		
913038	15326	79,300		
913029	15376	78,800		
913021	15408	78,300		
913030	15376	78,800		
913046	15341	79,600		
913035	15335	78,600		
913012	15356	80,200		
913013	15357	79,500		
913018	15344	79,300		
913027	15404	79,600		
913008	15382	79,500		
913003	15417	79,100		
913041	15370	78,600		
913026	15375	79,000		
913031	15330	78,800		
Caboose		58,000*(2)		
	TOTAL WT.	1,641,200#		

1,641,200# - 2000#/ton = 820.6 tons

*Approximation

(1) 909447 lightweight shown is average of
909445 - 78800#
909448 - 79300#
909449 - 79700#

237,800 ÷ 3 = 79266#

(2) Nominal lt. wt. 29 ton = 58000#

F - 70 - 1

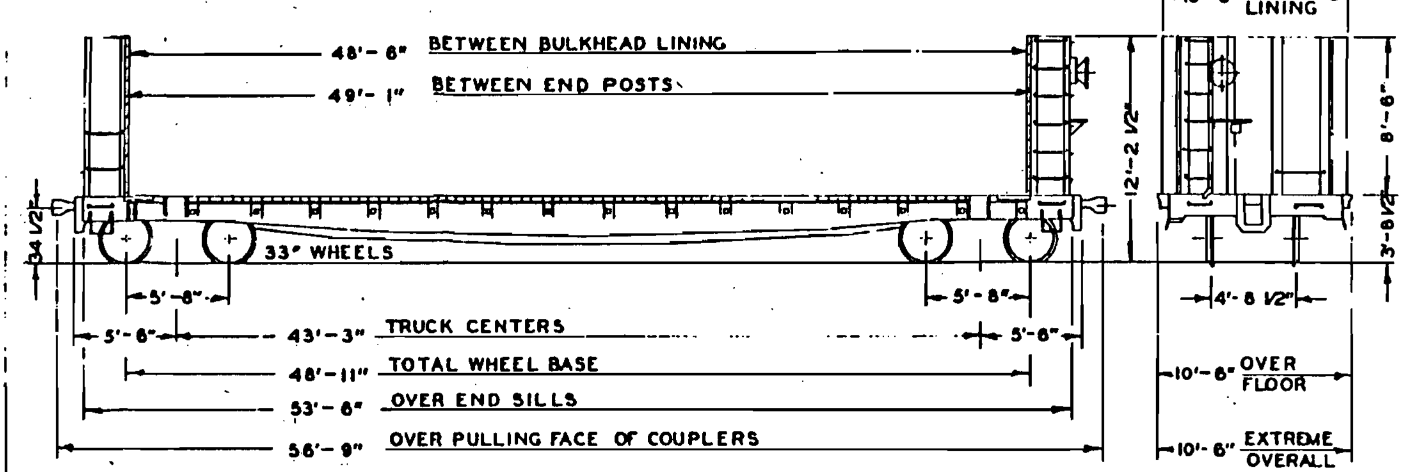
CLASS F-70-1

FLAT CAR

152000 LBS. CAPACITY

FB

CAR NO'S 15320-15424



LENGTH-BETWEEN BULKHEAD LINING	48'-6"
WIDTH - OVER FLOOR	10'-6"
HEIGHT-RAIL TO TOP OF FLOOR	3'-8 1/2"
WT. OF EACH TRUCK A-3	8000 LBS.
LT. WT. OF CAR COMPLETE	67300 LBS.
UNDERFRAME-CAST STEEL-AVERAGE WT. 34980 LBS.	GEN. STL.
BULKHEAD-CAST STEEL	" "

CAR BUILDER	NO. CARS BUILT	YEAR BUILT
OMAHA	105	1956

MIN. CURVE NEGOTIABILITY COUPLED TO BASE CAR 204 FT. RAD.

GENERAL DESIGN	244-C-12753
BRAKE ARRGT.	154-C-12742
TRUCK ARRGT.	423-C-12767
UNDERFRAME ARRGT.	444-C-12757
ALLOCATION OF SPEC.	282-C-12763
PAINT. LETT. & NUM.	303-C-12769
8'-6" CAST STL. BULKH'D	298-C-14266

AIR BRAKES - AB	WABCO
AXLES-6"x11"	BETH.
ANGLE COCK HOLDER	RY. DEVICES
BRAKE BEAMS-NO.18 UNIT	BUFFALO
" CYL. PUSH ROD	SCHAEFER
" LEVER CONN.	"
" ROD JAWS & EYES	"
" PIPE ANCHORS	GUSTIN-BACON
" REGULATOR	UNIVERSAL
" " -AUTO.-	AMER. S.A.B.
" SHOES	ABSCO
COUPLER-TYPE E	ASF
" CENTERING DEV.	SREMCO
" RELEASE RIGGING	"
" YOKES-VERTICAL-	OMA STL WKS
CYL. & FLOATING LEVERS	SHOP MADE
DEFECT CARD HOLDER	WEST RY EQ.
DRAFT GEAR FR-16	WH. MINER
" KEY RETAINER	ILL. RY EQ.
HAND BRAKE-	NATL. BR. EQUIP.CO.

JOURNAL BEARING	MAGNUS
" " WEDGE	SHOP MADE
" BOX LID	SYM. WAYNE
" " LUBRICATORS	AAR APPROVED
LADING ANCHORS-A-30	WINE RY. APP.
SPRINGS-2 1/2" TRAVEL	AMER. LOCO.
TRUCK BOLSTER	ASF
" SIDE FRAME	"
" STABILIZER	"
" LEVERS	SCHAEFER
" SIDE BEARINGS	STUCKI
UNDERFRAME-	GEN. STL.
UNIT SIDE FRAME WEAR PLT.	FLANNERY
WHEELS-CAST STL. AARX-3	GRIFFIN
BULKHEAD	GEN. STL.

PLASTERBOARD LOADING

8'-6" BULKHEAD

UNION PACIFIC RAILROAD CO.
RESEARCH AND
MECHANICAL STANDARDS

9-1-75	3-14-73	15-1-72	DATE	DIAGRAM F-7-24
C	B	A	ISSUE	DRAWN 7-1-60

APPENDIX I

UNION PACIFIC RAILROAD TEST DATA

WHEELS FROM KELSO WORK TRAIN

SPECIMEN NUMBER	1*	2	3*	4	5*	6*	7*	8	x9	10	11x	12x	x13	14*x	15x	16x	17x	18x	19x	20x	21x	22*x	23*
Tread & Flange	1	0	2	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3
Front Fillet	0	0	1	0	4	2	2	0	0	0	2	0	0	2	0	0	0	0	0	2	0	1	0
Back Fillet	0	0	1	0	4	2	2	0	0	0	0	0	0	2	0	0	0	0	0	2	0	1	0
Back Rim	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Severity Index	.25	0	1.0	0	2.0	1.25	1.75	0	0	0	.5	0	0	1.0	0	0	0	0	0	1.5	0	1.25	.75
Phys. Comments	BC	C	AB	BC	B	AB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SPECIMEN NUMBER	24*	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39*	40*	41	42	43	44	45	46*
Tread & Flange	2	0	0	1	1	0	0	0	0	0	3	1	1	1	0	2	0	3	1	0	0	0	0
Front Fillet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	4
Back Fillet	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	2	2	0	0	3
Back Rim	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Severity Index	.5	0	0	.25	.75	0	0	0	0	0	.75	.25	.25	.25	1.0	.5	.5	.75	.75	.5	0	0	1.75
Phys. Comments	-	-	-	A	A	-	-	-	-	-	-	A	A	A	-	A	-	-	-	-	C	-	-

SPECIMEN NUMBER	47	48	49	50	51	52*	53*	54*	55*	56	57	58	59	60	61	62	63*	64*	65*	66	67	68	69
Tread & Flange	0	0	0	0	0	3	2	3	0	0	0	3	1	1	1	0	2	3	2	1	0	0	2
Front Fillet	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Back Fillet	0	0	3	0	0	3	0	0	4	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Back Rim	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Severity Index	0	0	1.75	0	0	2.25	.5	.75	1.0	0	0	.75	.25	.25	.25	0	.5	.75	1.25	.75	0	0	.5
Phys. Comments	-	-	-	-	-	-	-	-	-	-	-	-	A	A	AB	-	A	B	A	A	-	A	-

SPECIMEN NUMBER	70*	71*x	72x	73*	74	75*	76*	77	78	79	80*	81*	82	83	84	85	86	87	88	89	90	91	92
Tread & Flange	2	0	0	2	2	3	2	0	0	0	3	2	Rusted/Corroded Surfaces										
Front Fillet	0	0	0	0	0	0	0	0	0	0	0	0											
Back Fillet	4	3	0	0	2	0	0	0	0	0	0	0											
Back Rim	0	3	0	0	0	0	0	0	0	0	0	0											
Severity Index	1.5	1.5	0	.5	1.0	.75	.5	0	0	0	.75	.5											
Phys. Comments	A	-	-	B	-	B	B	-	-	A	-	B											

0 - Shows no thermal evidence worthy of noting.
1 - Straw to dark straw discoloration or indications of 400°-700°F.
2 - Light blue to blue/purple discoloration or indications of 750°-900°F.
3 - Dark blue to grey/black discoloration or indications of 950°-1000°F.
4 - Evidence of surface decarburization at temperature over 1050°F.
A - Tread shows evidence of rotational skidding or skipping.
B - Thermal evidence apparent on one wheel only.
C - Wheel assembly shows physical damage or breakage.

* Held inside of Laboratory.

x - Roller-bearing wheelset from VAN train

Union Pacific R.R. Brake Efficiency Test Data

Date 11-24-80 Car # 913020 Cyl. Size 10" X 12"

Location OMAHA SHOPS Class F-70-1 Shoe CAST-IRON

ested by: RAC, MRH, RY Lt. Wt. 80,000 G.R.L. 220,000

Comments: [illegible] Hand Brake

Bell Crank

Sheave Whl.

Brake Cyl. Pressure —P.S.I.—	Location								
	R 1	L 1	R 2	L 2	R 3	L 3	R 4	L 4	Total
Hand Brake	2970	3010	2865	3050	2965	2925	3085	2915	
Hand Brake Tapped	3430	3430	3280	3425	3430	3390	3615	3475	
10	535	585	535	550	355	340	390	365	
15	940	1005	955	985	740	710	785	710	
20	1250	1325	1270	1310	1185	1140	1250	1115	
35	2340	2435	2390	2445	2380	2335	2460	2250	
50	3330	3555	3440	3610	3580	3525	3710	3440	
64	4270	4710	4475	4705	4500	4435	4600	4335	36035
Repeat 20	1285	1410	1350	1410	1340	1260	1410	1255	
Tapped 20	1555	1565	1430	1575	1405	1425	1475	1445	
Repeat 50	3505	3865	3695	3925	3580	3600	3700	3325	29195
Tapped 50	4100	4200	3975	4210	3960	3930	4195	4035	32605
Empty Load 50									
Empty Load Tapped 50									

Hand Brake Ratio G.R.L.— Tapped

Brake Ratio G.R.L. at 50 P.S.I. Tapped 14.8

Brake Ratio G.R.L. at 20 P.S.I. Tapped

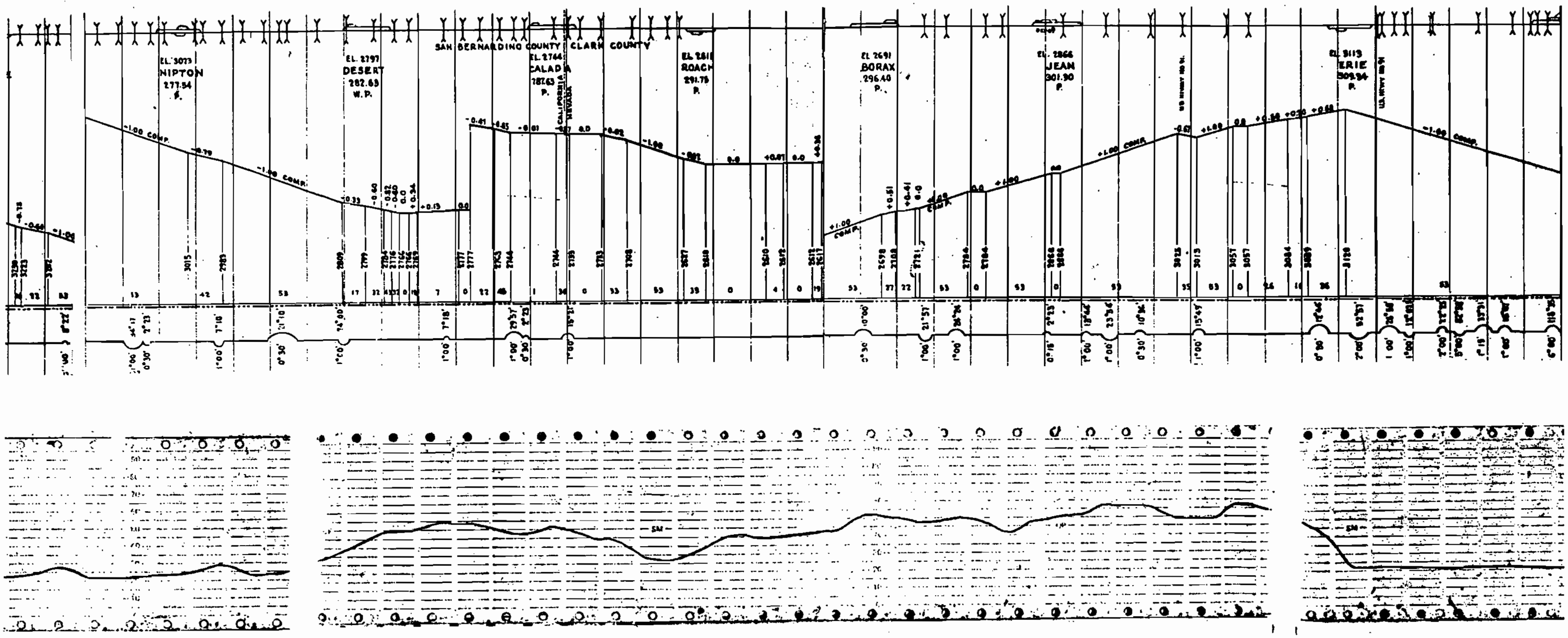
ake Ratio Lt. Wt. at 50 P.S.I. Tapped 40.75

Theor. Brake Force at 50 P.S.I.

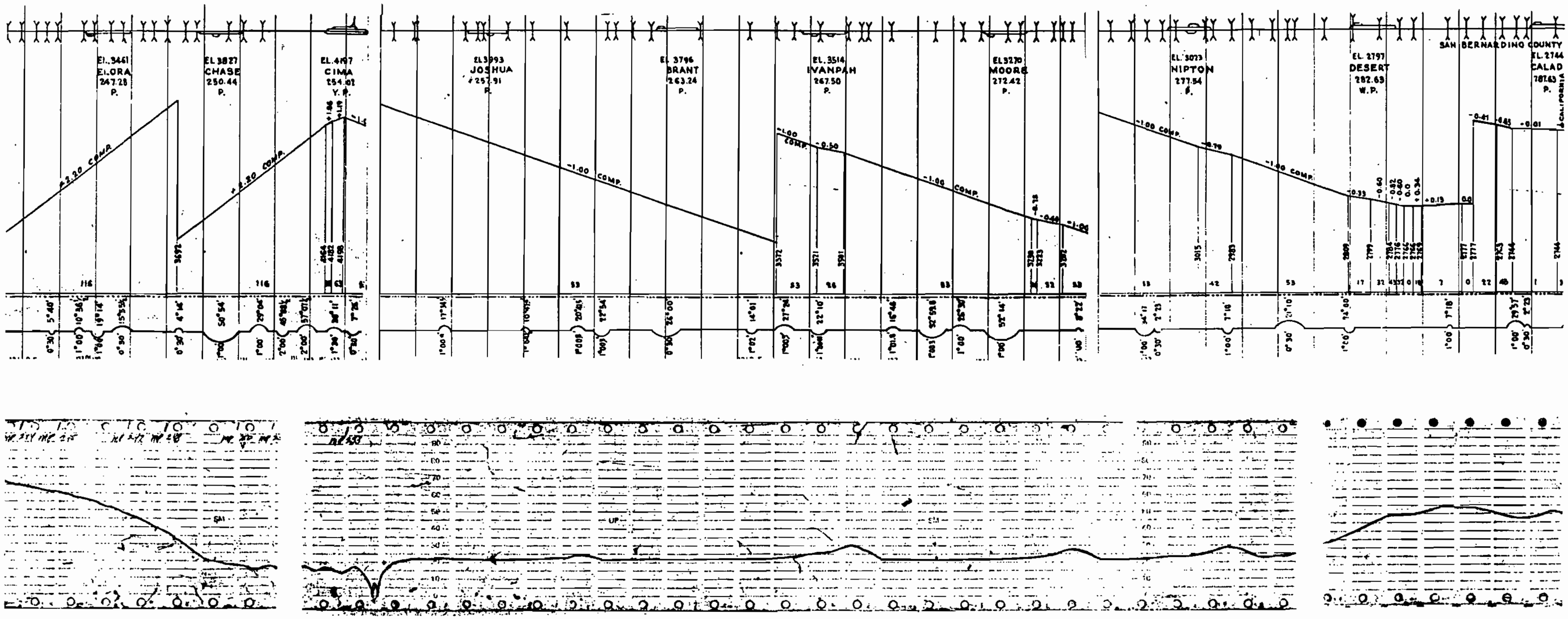
Efficiency at 50 P.S.I. Tapped 86.5

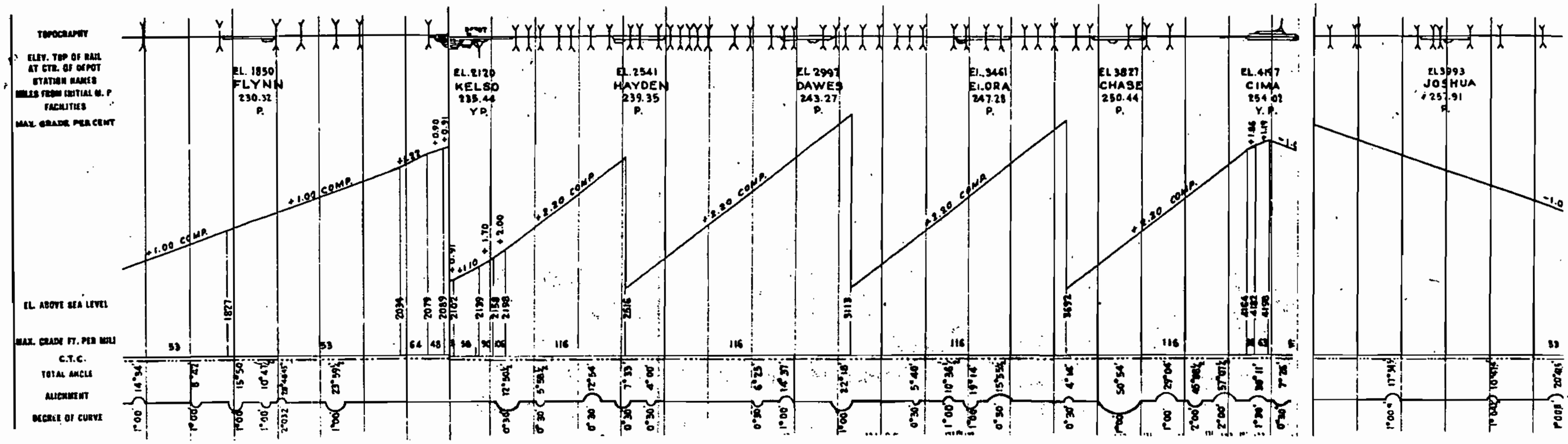
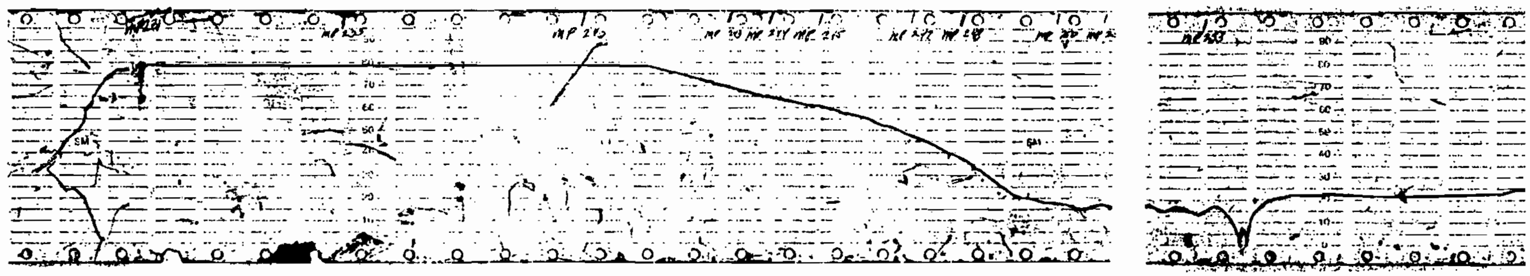
Empty/Load % at 50 PSI Tapped

APPENDIX J. SPEED TAPE OF EXTRA 3119 WEST FROM ERIE TO KELSO AND ACCIDENT LOCATION, ALIGNED WITH CONDENSED PROFILE.



*U.S. GOVERNMENT PRINTING OFFICE : 1981 0-341-828/671


EL. 3461
ELORA
247.28
P.
EL 3827
CHASE
250.44
P.
EL. 4197
CIMA
254.01
Y.P.
+2.20 COMP.
+2.20 COMP.
EL 3993
JOSHUA
257.91
P.
EL 3796
BRANT
263.24
P.
-1.00 COMP.
EL. 3514
IVANPAH
267.50
P.
EL 3270
MOORE
272.42
P.
-1.00 COMP.
EL. 3023
NIPTON
277.54
EL. 2797
DESERT
282.63
W.P.
-1.00 COMP.
SAN BERNARDINO COUNTY
EL. 2744
CALAD
287.63
P.
CALIFORNIA
UP


TOPOGRAPHY
ELEV. TOP OF RAIL AT CTR. OF DEPOT
STATION NAMES
MILES FROM INITIAL M. P.
FACILITIES
MAX. GRADE PER CENT
EL. ABOVE SEA LEVEL
MAX. GRADE FT. PER MILE
C.T.C.
TOTAL ANGLE
ALIGNMENT
DEGREE OF CURVE
EL. 1850 FLYNN 230.32 P.
EL. 2120 KELSO 235.44 Y.P.
EL. 2541 HAYDEN 239.35 P.
EL. 2997 DAWES 243.27 P.
EL. 3461 ELORA 247.28 P.
EL. 3827 CHASE 250.44 P.
EL. 4147 CIMA 254.02 Y.P.
EL. 3993 JOSHUA 257.91 P.
+1.00 COMP.
+1.02 COMP.
+2.20 COMP.
-1.0
1827
2034
2079
2089
2102
2139
2158
2198
2516
3113
3692
4164
4182
4186
53
64
48
116

MP 245
MP 240
MP 250