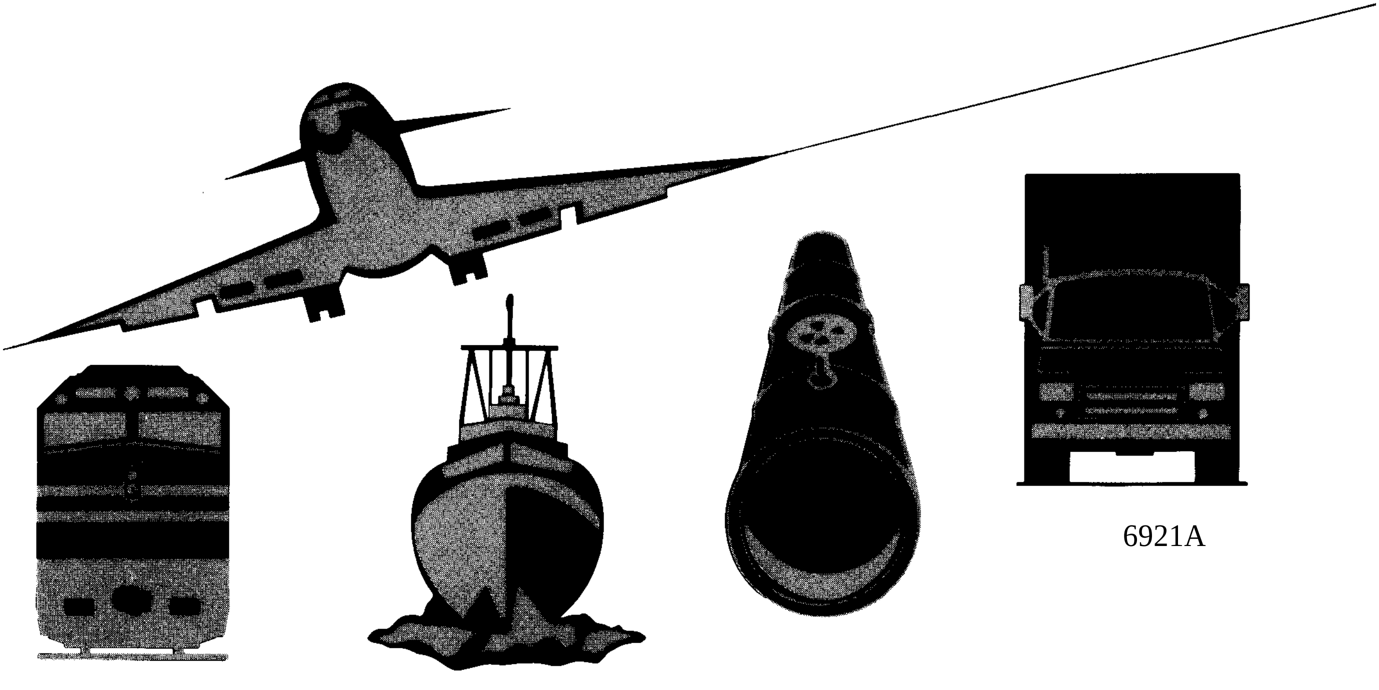
PB98-916301
NTSB/RAR-98/01

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

RAILROAD ACCIDENT REPORT

DERAILMENT OF UNION PACIFIC RAILROAD UNIT FREIGHT TRAIN 6205 WEST NEAR KELSO, CALIFORNIA JANUARY 12, 1997



6921A

Abstract: On January 12, 1997, the Union Pacific Railroad unit freight train 6205 west derailed on the Union Pacific Los Angeles Subdivision, milepost 238.7, near Kelso, California. While descending Cima Hill, the engineer inadvertently activated the multiple-unit engine shutdown switch, which shut down all the locomotive units' diesel engines and eliminated the units' dynamic braking capabilities. The train rapidly became a runaway, eventually reaching a speed of 72 mph, and derailed 68 of its 75 cars while exiting a siding near Kelso. No fatalities or injuries resulted.

The safety issues discussed in this report are the placement of safety-critical locomotive cab controls, adequate train-speed safety margins for steep-grade railroads, and the criticality of dynamic braking systems. The report also discusses accurate car weight reporting, the power brake rulemaking process, and the use of air brake retainers.

As a result of its investigation, the National Transportation Safety Board issued recommendations to the Federal Railroad Administration, the Association of American Railroads, and the Union Pacific Railroad.

DERAILMENT OF UNION PACIFIC RAILROAD UNIT FREIGHT TRAIN 6205 WEST NEAR KELSO, CALIFORNIA, JANUARY 12, 1997

RAILROAD ACCIDENT REPORT

Adopted: February 6, 1998
Notation 6921A

NATIONAL
TRANSPORTATION
SAFETY BOARD

Washington, D.C. 20594

this page intentionally left blank

CONTENTS

EXECUTIVE SUMMARY

On January 12, 1997, about 11:52 a.m. Pacific standard time, the Union Pacific Railroad unit freight train 6205 west derailed 68 cars on the Union Pacific Railroad Los Angeles Subdivision, milepost 238.7, near Kelso, California. The train consisted of 3 locomotive units and 75 loaded covered hopper cars. While descending Cima Hill, the engineer inadvertently activated the multiple-unit engine shutdown switch, which shut down all the locomotive unit diesel engines and eliminated the train's dynamic braking capability. The train rapidly accelerated beyond the 20-mph authorized speed limit despite the engineer's efforts to increase the train's air braking, which the engineer placed in emergency 1 minute and 13 seconds after dynamic braking loss. The train's consist weight was listed at an average of 13 tons per car less than the train actually weighed. The train eventually reached a speed of 72 mph and derailed 68 of its 75 cars while exiting a siding near Kelso, California. No fatalities, injuries, fires, or hazardous materials releases resulted from the accident. The total damage cost was $4,079,152.

The National Transportation Safety Board determines that the probable cause of the derailment was (1) a prolonged pattern of inattention and lack of action by Union Pacific Railroad management to protect effectively or relocate the multiple-unit engine shutdown switch in SD60M locomotives after the switch had repeatedly been recognized as subject to inadvertent activation; and (2) failure of Union Pacific Railroad management to adequately address critical safety issues such as dynamic braking system operational reliance and protection, and authorized maximum train speeds in the event of dynamic braking failure. Contributing to the severity of the accident was the failure of Union Pacific Railroad management to ensure accurate car weight assessment and training for operating personnel on retainer-setting procedures and effects.

The major safety issues discussed in this report are the placement of safety-critical locomotive cab controls, adequate train-speed safety margins for steep-grade railroads, and the criticality of dynamic braking systems. The report also discusses accurate car weight reporting, the power brake rulemaking process, and the use of air brake retainers.

As a result of this accident investigation, the National Transportation Safety Board makes recommendations to the Federal Railroad Administration, the Association of American Railroads, and the Union Pacific Railroad.

this page intentionally left blank

INVESTIGATION

The Accident

Synopsis -- On January 12, 1997, the Union Pacific Railroad (UP)[1] unit freight train 6205 west derailed on the UP Los Angeles Subdivision, milepost (MP) 238.7, near Kelso, California. While descending Cima Hill, the engineer inadvertently activated the multiple-unit (MU) engine shutdown switch, which shut down all the locomotive units' diesel engines and eliminated the units' dynamic braking capabilities. The train rapidly became a runaway, eventually reaching a speed of 72 mph, and derailed 68 of its 75 cars while exiting a siding near Kelso. (See figure 1.) No fatalities or injuries resulted.

Accident Sequence -- The UP unit[2] freight train 6205 west originated in Columbus, Nebraska, on January 3, 1997. The train was destined for a marine terminal near San Francisco, California. Upon its arrival at Salt Lake City, Utah, (on January 11, 1997) the train received a Federal Railroad Administration (FRA) 1,000-mile inspection[3] and then continued west.

When the train reached Las Vegas, Nevada, in the early morning of January 12, 1997, the crew changed. The oncoming engineer went to the lead cab and conducted a locomotive daily inspection.[4] The oncoming conductor moved by crew hauler to the end of the train to renew the end-of-train (EOT) device battery.[5]

[1]See the last page of this document for a list of all acronyms and abbreviations used in this report.

[2]A unit train is dedicated to transporting one commodity from one origin to one destination, generally over a specified route with assigned cars.

[3]See 49 *Code of Federal Regulations* (CFR) Part 232.12(b).

[4]See 49 CFR Part 229.21.

[5]The EOT device is a two-part telemetry mechanism (one part in the lead locomotive cab and one at the end of the train) that informs the engineer of the brake pipe pressure at the end of the train. Batteries power the rear-end part of the device. The batteries are replaced regularly.

After installing the battery, the conductor radioed the engineer to tell him that the battery was installed, that the EOT marker was functioning, and that the trainline air pressure at the rear end of the train was 68 psi. The conductor returned to the train's head end, then went back 10 cars to wait while the pressure in the air brake system built up. Upon the engineer's application of the air brakes, the conductor released the car hand brakes and returned to the lead locomotive.

The train departed Las Vegas, MP 334.3, at 6:05 a.m. on January 12, 1997, with 3 locomotive units on the head end, followed by 75 cars loaded with corn. The train consist showed that the train weighed 9,724 tons[6] and was 4,661 feet long.

According to crew statements, the trip from Las Vegas to Cima was routine. The engineer carried out a running test of the dynamic brakes from Erie, MP 309.3,[7] to Borax, MP 292. He later testified that the dynamic brakes had functioned appropriately. The train made one stop at Brant, MP 263.9, where it took a siding to clear two other trains. Three other trains en route cleared for UP train 6205.

When approaching the crest at Cima, MP 254.6, the engineer made a gradual throttle reduction followed by a minimum application of the air brakes (6- to 8-pound reduction of the brake pipe). The engineer stopped the train with it draped symmetrically over the crest of the grade[8] at Cima.

[6]For reasons that are explained later in this report, the train weight was incorrectly reported to be approximately 975 tons lighter than the train actually weighed.

[7]MPs descend as the train traveled westward.

[8]"Grade" is expressed in percentage of vertical elevation change in feet for a lateral 100 feet. "Mountain," "heavy," or "steep" grade for a train of 4,000 trailing tons or less is a grade of 2 percent or more for a distance of 2 or more miles. For a train with a trailing tonnage of more than 4,000 tons, steep grade is an average of 1 percent or more grade for 3 or more miles.

Figure 1—Derailed UP freight train 6205 west

According to the requirements of *UP System Timetable No. 2*, UP train 6205's maximum speed down Cima Hill would have been 20 mph and retaining valves were to have been set on all cars before descent. The train remained at Cima for 45 minutes, while the conductor set retainers in preparation for the 2.2-percent grade descent in the next 15 miles. The conductor walked down and back up the train, setting its air brake retainer valves to the high pressure position.[9] According to the conductor, when he was about halfway up the train on his return, he radioed the engineer to release the brakes, which he said the engineer did. He set about 15 remaining retainers and returned to the lead unit.

The train started moving down Cima Hill at about 11:18 a.m. The engineer began applying dynamic brakes about 2 1/2 minutes later, with the train traveling at 7 mph. Within 30 seconds, the dynamic braking effort built to 92 amps with the train traveling at 8 mph. Less than 2 minutes later, the dynamic braking effort was 705 amps at 13 mph. The engineer also made a 6- to 8-psi minimum reduction of the brake pipe to apply the train air brakes. The train speed and dynamic brake amperage continued to build slowly over the next 19 minutes, until they reached 843 amps of dynamic braking at 22 mph. The engineer later testified that he had been using most of his locomotive dynamic brake capability and supplementing that braking effort pneumatically with the train's air brake system as necessary to control speed.[10] By about 11:42 a.m., train speed had reached 23 mph and amperage had declined to about 820 amps. (The speed was 3 mph above the maximum authorized speed.)

At 11:42 a.m., the dynamic brake amperage and effort fell to 0 amps within 13 seconds. It later became evident that the engineer had unwittingly depressed the MU engine shutdown switch, which stopped the fuel pumps on all the locomotive units. (The switch provides a means of shutting down the locomotive, regardless of the number of units it comprises.) As the accident unfolded, neither crewmember knew the reason for the shutdown. The traincrew members later testified that they thought only the lead locomotive unit had shut down.

The diesel engine of the lead locomotive stopped, and its alarm bell rang.[11] The engineer moved the dynamic brake lever to maximum without result. He then (within 16 seconds) reduced the brake pipe pressure by 12 to 17 psi, in an attempt to compensate for the loss of the dynamic brakes. The train passed the west switch at Elora, MP 247.9, at 25 mph. Train speed soon increased to 29 mph.[12]

Within the next minute, the engineer continued to increase train air braking in response to the rising train speed, until a full-service application was achieved by the time train speed reached 31 mph. The engineer then made an emergency brake application and notified the dispatcher that the train was a runaway. The engineer noted that the EOT rear-end cab display device showed 0 pressure, indicating to him that the emergency had propagated to the end of the train. The time elapsed between the loss of the dynamic braking until the train was put into emergency was 1 minute, 13 seconds.

For the next 9 1/2 minutes, the train continued to increase speed despite intermittent applications of the independent brakes.[13] The dispatcher had routed the train onto a siding at Hayden, MP 240. The train went into the Hayden turnout at approximately 72 mph. As the train began to exit the Hayden siding at the west-end turnout, MP 238.7, the drawbar between the locomotives and the first car broke, and the cars began to derail. The locomotives, free of the cars, negotiated the turnout onto the

[9]Each freight car is equipped with a retaining valve that, when set in the high pressure position, retains air in the brake cylinder at whatever pressure is dictated by one or more brake applications. Successive applications add to the brake cylinder pressure. From the high pressure position, brakes may only be released by stopping the train and pushing the release rod in or by turning the selector handle on the retainer to another position.

[10]The engineer did not use all the dynamic braking available; he retained some dynamic braking capability "to stop on the hill or if [the train] met another train."

[11]The alarm bell rings when engine shutdown occurs.

[12]It should be noted that upon the failure of one or more units of dynamic braking, UP rules require that maximum authorized speed becomes 15 mph.

[13]Independent brakes apply braking to the locomotives only.

mainline and came to rest 3 miles away. Sixty-eight of the 75 loaded cars derailed at the west-end turnout at approximately 11:52 a.m. (See figure 2 for a map of the accident site.)

Injuries

No injuries resulted from the accident.

Damage

Equipment	$2,886,400
Lading	466,942
Track	236,850
Signal	300,000
Structures	40,000
Clearing and wrecking	148,960
TOTAL	$4,079,152

Personnel Information

Engineer -- The 36-year-old engineer began his employment with the UP as a brakeman on October 5, 1990. In April 1995, he fulfilled the necessary requirements and was certified as a locomotive engineer. On May 5, 1995, he was approved by the UP to operate as a locomotive engineer. He passed his last formal examination on the *General Code of Operating Rules*[14] during July 1996. On December 6, 1996, the UP approved him to operate as a conductor.

The engineer testified that he had been rested in accordance with the Federal Hours of Service Act and that he had felt well rested on the day of the accident. The engineer also said that he had not been formally trained by the UP on setting the retainers. He said he gained his knowledge about retainers during on-the-job training and through experience.

Conductor -- The 54-year-old conductor began his employment with the UP as a brakeman on March 11, 1968. He qualified as a conductor on August 11, 1989. He passed his last formal examination on the *General Code of Operating Rules* during June 1996.

The conductor testified that he had been rested in accordance with the Federal Hours of Service Act. He also stated that he had not been formally trained by the UP on setting the retainers. He said he gained his knowledge about retainers during on-the-job training and through experience.

Track and Signal Information

Track -- The track between Cima, MP 254.6, and Kelso, MP 236.5, consists of a single main track with adjacent siding tracks at Chase, MP 251.1; Elora, MP 247.9; Dawes, MP 243.9; and Hayden, MP 240.0. The general derailment occurred at the west end of the Hayden siding at MP 238.7. The UP designated the track through the accident area as FRA Class 4. Beginning about MP 252, the westbound grade descends at a steady 2.2 percent until MP 237 (15 miles), where the grade decreases through a series of transitions until it is level at MP 217.

Signal -- Train movements on the Los Angeles Subdivision were controlled (in part) by wayside single-lens colored searchlight signals, established through a centralized traffic control (CTC) system[15] controlled from Omaha, Nebraska.

Operations

Train operations through the accident area were controlled by a combination of operating rules, timetable instructions, and CTC system signal indications. According to *UP System Timetable No. 2* (effective October 29, 1995, for the Los Angeles Subdivision), UP engineers must handle trains based on the trailing tons per operative brake and the trailing tons per operative dynamic brake. The tonnage dictates the maximum speed and acceptable methods of braking, including the use of the dynamic brakes and car-retaining valves. The timetable also establishes air brake reduction limits. (See appendix B, "Excerpts from Applicable Operating Rules.")

---

[14]The General Code of Operating Rules governs the operation of railroads, such as the UP, that have adopted it. Railroads are required to file a set of operating rules with the FRA, in accordance with 49 CFR Part 217.7.

[15]A CTC is a remotely controlled system under which train movements are authorized by block signals whose indicators supersede the superiority of trains.

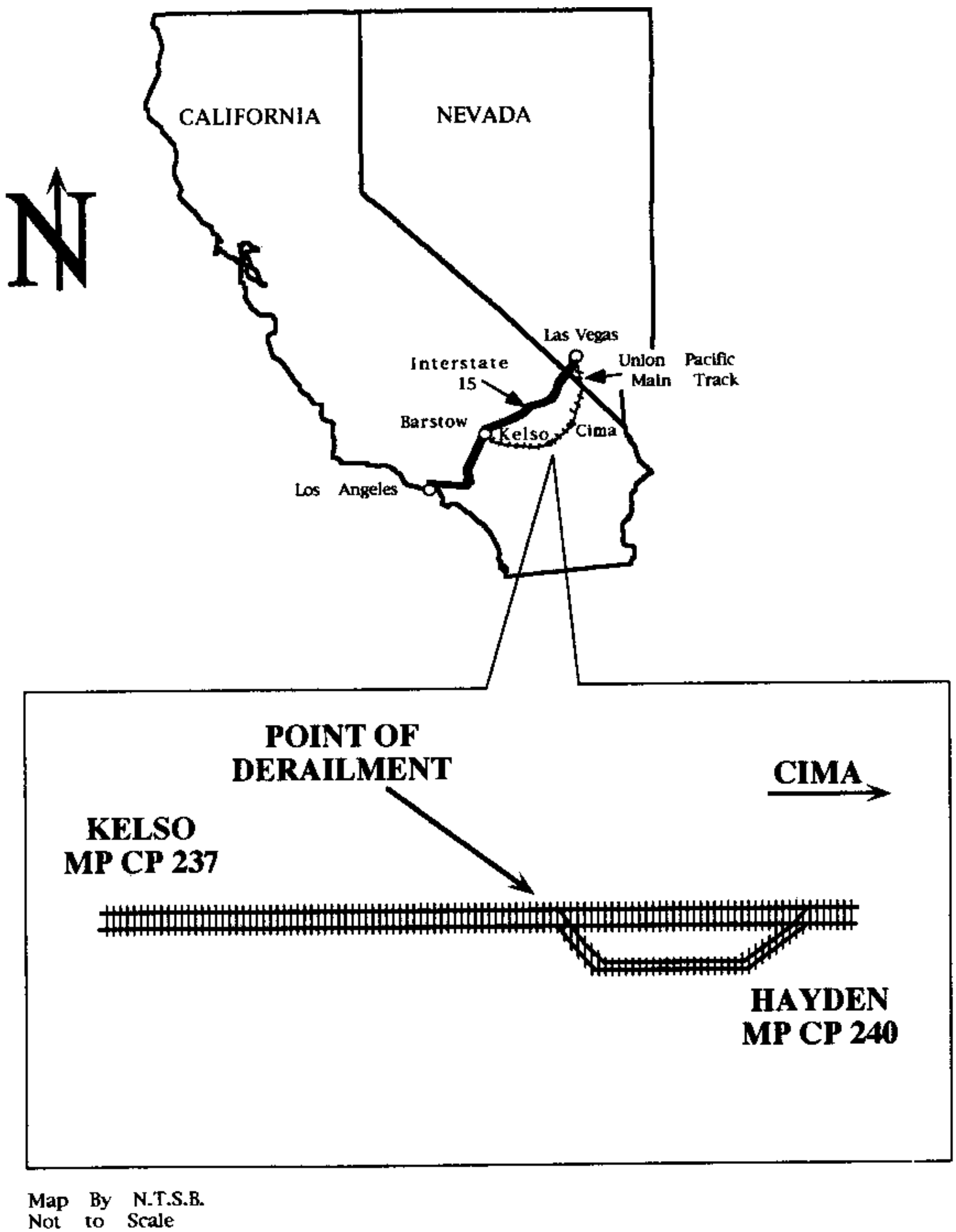


Figure 2 -- Map of the accident site

Before departing Las Vegas, the engineer of UP train 6205 determined, using the car-consist weights, that he had 130 trailing tons per operative brake and 442 trailing tons per operative dynamic brake axle.[16] These determinations dictated that the maximum speed down Cima Hill should be 20 mph and that retaining valves should be set on all cars before descent.

Meteorological Information

The temperature at the time of the accident was 33°F. A mixture of light snow and rain affected the accident area. Both the locomotive engineer and the conductor stated that no significant atmospheric restrictions limited the visibility of wayside signals and passing trains or handicapped their train handling in any way.

Toxicological Information

Blood and urine specimens were collected from the engineer and conductor for postaccident toxicological testing, according to the requirements established by the FRA in 49 CFR Part 219. The results provided by the FRA indicated that no drugs or alcohol was found.

Train and Equipment Information

Train Movement -- The train originated on January 3, 1997, at Columbus, Nebraska, about 88 miles west of Omaha, Nebraska, along the UP's east-west mainline. The train had been assembled from cars collected from the surrounding UP branchline and shortline grain elevators by local trains. Before its departure from Columbus, the train had received an initial terminal inspection in accordance with 49 CFR Part 232.12. Due to track washouts and railroad closures from heavy rains in northern California, the train was rerouted southwest from Salt Lake City, Utah, to Los Angeles, California, and then northward to San Francisco, California.

Car Weight -- The covered hopper cars involved in the accident had a nominal commodity capacity of 200,000 to 221,000 pounds (100 to 110.5 tons).[17] The rated maximum (gross) weight of each car, loaded with commodity, was 286,000 pounds or 143 tons. According to the UP Director of Derailment Prevention, when freight cars first enter UP property, each is identified,[18] entered into the UP train control computer system, and automatically assigned the maximum car-consist weight,[19] which would have been 143 tons per car for UP train 6205.

Shortly before UP train 6205 departed Columbus, Nebraska, a clerk mistakenly replaced the defaulted maximum car-consist weights of UP train 6205 with the freight-car billing weights[20] of 129, 130, or 131 tons for each car and manually entered the billing weights into the UP computer system. The engineer used these weights to determine the maximum speed down Cima Hill. (Since the Kelso accident took place, all loaded car-consist weights are automatically assigned maximum capacity weights by the UP. Billing clerks cannot change the car-consist weights.)

Railcars are generally weighed at or near their points of loading or origin. Bulk-commodity loading points such as grain elevators, mines, and mills usually maintain track scales for this purpose. Railroads also have weigh-in-motion scales near train yards.

[16]These figures are determined by dividing the total trailing tonnage by the number of cars for tons per operative brake and then by the number of traction motors for tons per operative dynamic brake.

[17]Weight and dimension data appear on the left side of each freight car.

[18]This procedure is usually done electronically by an Automatic Equipment Identification (AEI) scanner, which reads a transponder attached to the side of the freight car. Each AEI transponder has information formatted for that particular vehicle, including the equipment type, owner, and number. Car identification must match an entry in the Association of American Railroad's computerized Universal Machine Language Equipment Register before car interchange can take place.

[19]The car-consist weight is used by the engineer to determine appropriate train-handling practices. Freight cars also have a billing weight, which sometimes does not equal the consist weight.

[20]The freight-car billing weight is the "per car rate" agreement between the shipper and the railroad. In this instance, the rate happened to correspond to a nominal tonnage rate for a car of 129 to 131 tons.

Locomotives -- The first and third locomotive units in the train were UP 6205 and UP 6162, respectively. Both were 3,800-hp, SD60M locomotives, built by General Motors Electro-Motive Division (EMD) in 1989. The second locomotive unit was a Southern Pacific Railroad Company (SP) unit, SP 9360, which was a 3,600-hp, SD45-2T locomotive, built by EMD in 1975.

Train Tread Braking -- Freight train air brake systems use compressed air to push a piston within a cylinder that is mounted on a freight car.[21] (See appendix C for additional information on air braking.) Usually, through a series of rods and levers, the piston's movement forces a brake shoe against the tread of each wheel to retard wheel rotation through friction. The application of the brake shoe against the wheel tread is called tread braking.

The effectiveness of tread braking depends upon the resistance to sliding or friction,[22] between the two surfaces. The friction between the brake shoe and the wheel tread results in the creation of heat. Shoe force and wheel speed dictate the amount of friction and the resulting heat generated between the brake shoe and the wheel. The greater the shoe force against the wheel and/or the greater the wheel speed, the greater the frictional heat generated (assuming that the wheel is turning without slipping on the rail).

During tread breaking, the heat generated will migrate away from the surfaces and heat up the wheel and brake shoe. The wheel and brake-shoe temperatures will be warmest at the sliding surfaces, where friction is creating the heat, and progressively cooler away from the wheel tread. At some point during braking, sufficient heat will build in the brake-shoe material and wheel steel to change the molecular and surface characteristics of the materials at the rubbing surfaces. This in turn will change their frictional characteristics (coefficient of friction) and result in a different braking ability. Thus the resistance to sliding between two surfaces changes as the amount of generated frictional heat changes.

Tread braking is most effective soon after initial application of the brakes and actually improves up to some point as the brake shoe and wheel tread surfaces warm up, but soon braking effectiveness begins to degrade as more heat is generated. Generally, the more frictional heat that is generated, the less frictional resistance and retardation or braking ability result. This process is commonly called "heat fade." In order to make up for heat fade, it may become necessary to apply greater brake-shoe force. Although even greater brake-shoe force will result in even greater heat fade and less efficiency,[23] the overall effect will still be more retardation and braking ability than at a lower shoe force.

Depending on the brake-shoe material and the type of wheel steel, heat fade may not be significant at low speeds. At some point during tread braking, the generated heat, which is absorbed by the wheel and (to a lesser extent) the brake shoe, may increase to a certain temperature and remain at that point until the brakes are released. A thermal equilibrium is reached as the wheel and brake shoe act as heat sinks[24] and dissipate the frictional heat as fast as it is generated, resulting in a constant level of frictional resistance and braking retardation.

At higher brake-shoe forces and wheel speeds, heat fade becomes significant. A buildup of heat faster than it can be dissipated will result in diminished braking retardation at an exponential rate. Shoe forces and/or wheel speeds can generate temperatures higher than the wheel and brake-shoe materials can handle, causing their deterioration. Deterioration of brake shoes and changes (melting) in the surface metal of the wheel tread will diminish the frictional resistance between the two materials. In extreme cases, the excessive heat generated will cause metal flow on the surface of the wheel tread, which will act as a lubricant, reducing braking effectiveness and speed retardation.

---

[21]Brake cylinders are usually mounted on the underside of the car body below the floor or on the trucks.

[22]Mathematically, this is quantified as the coefficient of friction.

[23]"Efficiency" refers to the amount of retardation or braking for a given shoe force.

[24]A heat sink is an object that absorbs heat energy.

According to the results of brake tests performed in 1991 by the Association of American Railroads (AAR),[25] an intermodal freight train descending the 2.2-percent grade of Cima Hill with an average braking ratio of 7.5 percent, an initiation speed of 23 mph, and 101.9 tons per operative brake would have been unable to stop on the grade using the air brakes alone. The AAR test results showed that the coefficient of friction is a function of brake-shoe force and wheel temperature. For shoe forces below 1,000 pounds, the coefficient is relatively independent of temperature. At forces above 1,500 pounds, the coefficient decreases as the temperature rises; it decreases at a rate that becomes greater as the shoe force rises. The AAR found that when brake-shoe forces reach such levels, air brake performance declines. The coefficient is lowest when high shoe forces combine with high wheel temperatures.

Air Brake Retainers -- The air brake control valves apply, release, and recharge the train's air brake system. All train locomotives and cars have control valves. Each locomotive control valve receives its commands from the engineer through the trainline, which is a pipe that connects all of the cars to the locomotive. Brakes are applied when air pressure is reduced in the trainline. The degree of braking is proportional to the amount of reduced pressure in the air brakes; the greater the drop in trainline air pressure, the harder the brakes apply. Therefore, the brakes are "fail safe" and designed to apply if the train accidentally breaks in two or becomes uncoupled. Conversely, when trainline air pressure increases, the control valves cause the brakes to release.

The trainline is not perfectly sealed. The trainline may have leaks throughout its length to varying degrees, depending on the seals, ambient temperature, and other factors. In steam engine days, as long as the locomotive's control valve was in the release position, air would continue to flow back through the trainline to continuously recharge the system, making up for any leakage. However, if the brakes were applied, not only would air pressure be reduced in the trainline to apply the brakes, but the leakage would aid in applying the brakes and continue to bleed the trainline pressure down past the level of braking desired by the engineer. Trains being braked down long grades would bog down and stop if the engineer did not release the brakes. Upon release, the train would soon accelerate again and the engineer would have to reapply the brakes. This cycle of application and release down grades is called "cycle braking." If the engineer applied and released his brakes too often, he would use the compressed air faster than the locomotive compressors could make it. The result would be no brakes and a runaway train.

To overcome this problem, retainers were installed on each car. Every freight car's air brake system is equipped with pressure-retaining valves, technically called "release-control retainers." Retainers enabled the engineer to retain air in each car's brake cylinder to brake the train while he placed his locomotive control valve in release to recharge the system. Thus, the retainer allowed the air brake system to do two things at once.

Eventually, locomotive control valves were equipped with a "pressure-maintaining" feature that automatically made up for leakage whenever the brakes were applied and at any level of application. Thus, the brakes would stay applied at any amount of trainline reduction the engineer desired, instead of continuing to leak down which would apply the brakes harder. The pressure-maintaining feature rendered retainers relatively obsolete, but they are still used by some railroads. The development of dynamic brakes, which increased braking capacity, also reduced reliance on retainers.

Retainers are connected to the brake cylinder exhaust and help control the brake cylinder pressure. Retainers enable traincrews to retain a portion of the air pressure in the brake cylinder to help slow trains (particularly on severe downgrades). When the air brakes are applied, the piston within the brake cylinder is forced outward by the compressed air; when the brakes are released, the piston returns to its original position, as release springs take effect.

[25]See the minutes of the AAR Air Brake Association meeting, September 16, 1991, page 36, exhibit 2 – *Summary of Double Stack Stop Distance Tests*.

When the retainer handle is set in position, the retainer will exhaust brake cylinder pressure more slowly and retain or hold a certain amount of pressure in the brake cylinder. This system allows an engineer to make several brake applications and releases in a relatively short time (cycle braking),[26] while still recharging the air brake system. The term “recharging” refers to resupplying the air brake system with pressurized air from the locomotive air compressors. “Precharging” refers to applying the brakes on a car through a set retainer value that may be incrementally increased through further brake applications. Precharging allows the engineer to make more forceful brake applications without increasing the number or magnitude of additional brake applications. Precharging increases the brake-shoe force and may significantly increase wheel temperatures and heat fade. The UP timetable rules do not address precharging.

According to UP timetable rules, retainers are to be set on a train if the tons per operative brake exceed 80 and the tons per operative dynamic brake exceed 300. Because the engineer had determined that UP train 6205 had 130 tons per operative brake and 442 tons per operative dynamic brake, retainers were required to be set on UP train 6205.

Shortly before the Kelso accident, and before descending Cima Hill, the conductor set the retainers on each car. He also unknowingly precharged the brake cylinders by setting most (all but approximately 15) of the retainers while the train brakes were still applied. Postaccident inspection of all the freight cars by Safety Board investigators showed that the retainers of all cars were set in the high pressure position.[27]

Retainers have several pressure-retaining capabilities, which depend on the strength of the springs they contain. Common retainer-pressure values are 10 and 20 pounds, 15 and 30 pounds, 20 and 40 pounds, and 25 and 50 pounds. The retainer pressure values of the accident cars were 10 and 20 pounds.

Dynamic Brakes **--** Each locomotive unit on UP train 6205 was equipped with extended range dynamic brakes.[28] Dynamic brakes apply braking to the locomotives only, not the cars. Dynamic brakes use the kinetic energy of the train to generate electricity through the traction motors, which is then run through resistor grids and dissipated as heat. The kinetic energy used to turn the traction motors retards the movement of the train, causing it to slow or brake.

As long as the dynamic braking system works, total dependence on the air brakes (which are affected by heat fade) can be avoided. Improvements in dynamic braking capacity and reliability have offset the heat-fade limitations of the tread-brake system.

The AAR and some railroads (including the UP) have gone on record with their view that:

> Dynamic brakes are not safety devices but are economical devices and their operation should be governed by the railroads’ operating rules and not Federal regulations…[They] are not the primary brakes and are not used to stop a train...[Dynamic brakes are] optional features used to save fuel and reduce wear and tear on brake equipment.[29]

---

[26] This system depends on a number of factors, including the brake system volume, the brake pipe pressure, and the number and magnitude of brake applications.

[27] Retainers have four handle positions: normal, high pressure, low pressure, and control. Each position causes the brake cylinder to exhaust or release differently. When the handle is pointing straight down, it is in the normal position and allows brake cylinder air to flow unimpeded directly to the atmosphere. In the high pressure position, the handle is turned up at a 45-degree angle. In the high pressure position, both retainer springs must be compressed and double pressure will be retained in the cylinders; the exhaust process at high pressure is also slower than in the low pressure position. The low pressure position, in which the handle is at a 90-degree angle, requires only one spring to be compressed to open the valve to exhaust the brake cylinder pressure. When the exhaust air flow is no longer sufficient to compress the spring, the remainder of the air is trapped and retained in the brake cylinder to provide some level of braking. In the control position, the handle is turned up 135 degrees from the normal position. The control position allows the valves to be bypassed and exhaust brake cylinder air to be directed through a choke to slowly release the brakes.

[28] Extended range dynamic brakes are effective at higher and lower speeds than regular dynamic brakes.

[29] *Federal Register*, Vol. 59, No. 179, September 16, 1994, page 47686.

Regarding dynamic braking use, the FRA has stated[30] that it:

> Views as unfortunate and potentially reckless, the increasing number of train handling and power brake instructions issued by freight railroads that emphasize use of dynamic brakes without including prominent warnings that such systems may not be relied upon to provide the margin of safety necessary to stop short of obstructions and control points or to avoid overspeed operation. Such instructions, while not affirmatively misleading to seasoned locomotive engineers, threaten to overcome the good judgment of safety critics and regulations by leading to excessive reliance on these systems.

In the same *Federal Register* entry, the FRA stated that:

> To the extent significant emphasis is placed on dynamic brakes, […] engineers may in fact be encouraged to make errors in judgment that take them beyond prudent safety margins.

According to the AAR Director of Safety and Operating Rules, many Class 1 railroads emphasize the use of dynamic brakes to control trains in moderate grade territory, to conserve fuel and minimize brake-shoe wear. At 1994 FRA hearing sessions in Newark, New Jersey,[31] several railroad employees testified that dynamic brakes were the first brakes to be used in controlling a train.

Many railroads have train-handling rules that require engineers to use dynamic brakes. The SP's *Air Brake and Train-Handling Rule 56.2, Use of Dynamic Brake to Control Train*, states that "Consistent with good train-handling techniques, dynamic brake must be used as the primary means of reducing and controlling train speed."[32] The Burlington Northern Railroad (BN) *Air Brake and Train-Handling Rule 501B* states that:

> Train handling must be performed in a manner that will be the most fuel efficient consistent with good train handling. Therefore, maximum use must be made of the throttle modulation, throttle reduction and <u>dynamic braking</u> methods for slowing, controlling, and stopping trains. Unless rules specify otherwise, DURING PLANNED BRAKING OPERATION, IF ONE OR MORE DYNAMIC BRAKES ARE AVAILABLE, THE POWER BRAKING METHOD WILL NOT BE USED.[33] [Emphasis appears in original.]

UP rules require that, "On descending grade from Cima to Kelso (California)… freight trains exceeding 3,500 trailing tons must not be controlled exclusively with dynamic brake."

Title 49, CFR Part 229.13 states, "If a dynamic brake or regenerative brake system is in use, that portion of the system in use shall respond to control from the cab of the controlling locomotive." No rule requires that the operational status of the dynamic braking system be determined before use. The FRA has stated that:

> If dynamic brakes] are available, they should be maintained, and engineers should be informed on their safe and proper use and be provided with information regarding the amount of dynamic braking effort that they have available…. The FRA also proposes to require railroads to inform engineers of the total dynamic brake retarding force available on all outbound trains equipped with dynamic brakes.[34]

---

[30]Ibid., page 47687.

[31]The FRA held a public hearing on November 4, 1994, in Newark, New Jersey, regarding proposed changes in the power brake regulations, including the regulations concerning dynamic brakes.

[32]SP *Air Brake and Train-Handling Rules*, April 10, 1994.

[33]Although the SP and the BN had merged with other railroads, each used its own train-handling rules until new rules were written.

[34]*Federal Register*, Vol. 59, No. 179, September 16, 1994, page 47687.

Preaccident Inspections and Actions

Before departing from the Las Vegas station, the engineer carried out an FRA locomotive daily inspection in accordance with 49 CFR Part 229.21, checked the function of the EOT device, and made an application and release test of the air brakes[35] with the assistance of the conductor. The results of all the tests and inspections were satisfactory. The engineer also confirmed that the EOT cab display device reflected his automatic brake pipe changes to ensure trainline continuity.[36]

When the engineer performed the locomotive daily inspection at Las Vegas, he found two "bad order tags"[37] attached to the isolation/run switch located on the back wall of the locomotive cab in the second locomotive unit. One, a red SP tag (form CS78) that was dated December 30, 1996, was torn approximately in half. It indicated a bad order speed indicator, malfunctioning dynamic brakes above the 4th notch, and a bad order alerter reset button. The other tag was a UP noncompliance tag, also dated December 30, 1996, and it cited a bad order speed indicator. The engineer later testified that he noticed the tags. He did not write any comments about them on his engineer's work report, as would have been normal practice according to UP operating procedures.[38] The engineer later said that he had assumed that the dynamic brakes on the second unit worked, even though the bad order tags indicated that they might not. (In fact, postaccident inspections revealed that all the malfunctions cited by the tags had been addressed and resolved.) The UP manager of Operations Practices later testified that it was UP policy for personnel to assume that all equipment worked unless they were specifically told otherwise.

According to the UP's timetable operating rules, the engineer was required to make a running test of his dynamic brakes between MPs 309 and 292. The event recorder from the first locomotive shows that the engineer tested the dynamic brakes from Erie, MP 309.3, to Borax, MP 292. The engineer said that the train was traveling around 45 to 50 mph at the time, the dynamic brakes functioned as required, and the train handled normally. The engineer did not have a device in the locomotive cab that could be used to determine the real-time status of the trailing locomotives' dynamic braking system.[39] (Such devices are not required under current regulations.)

Postaccident Inspections, Tests, and Research

Signals and Track -- The postaccident tests and records review conducted by Safety Board investigators showed that signal and train-control systems in the accident area functioned as designed. Postaccident track inspections revealed no significant track anomalies.

Locomotives -- After the accident, the train's locomotive consist was inspected and tested. A UP mechanical manager from Los Angeles, California, and a California Public Utilities Commission (PUC) inspector found the torn-off half of the bad order tag on the cab floor of the second locomotive unit. Later, during sworn testimony, the UP mechanical manager stated that the company's regular procedure for handling a bad order tag was to remove the tag from the machinery once the repairs had been made. The tag was then to be torn in half and one half was to be filed with the repair report for 1 year. He could not account for the failure to follow proper procedure in this case. He stated that since this accident the UP

[35] An air brake test entails the operation of the brake valve to ensure that the air brake system is operating correctly and could stop the train if necessary.

[36] Trainline continuity is checked (to ensure that all air hoses are connected) by applying and releasing the brakes and then observing, through the EOT device, a corresponding fall and rise in the brake pipe pressure on the last car.

[37] "Bad order" or nonconformance tags are small cardboard markers placed on equipment to notify railroad personnel that the indicated equipment is not functioning properly and is in need of repair.

[38] The work report is a lined blank form that the engineer is required to use to report equipment defects or other problems to mechanical personnel or supervisors.

[39] At least one manufacturer (PULSE Electronics, Inc.) has developed a device that will enable the engineer in the lead locomotive unit to reliably monitor the dynamic braking performance of trailing locomotive units. The device costs about $1,500 per locomotive unit.

has placed greater emphasis on bad order tag system procedures.

The radio in the lead locomotive unit was field tested and found to work as designed. The locomotive consist's air brake, motive power, and dynamic braking systems were also tested. All systems were found to work as designed.

MU Engine Stop Switch -- During postaccident inspections conducted on the day of the accident, California PUC inspectors and UP officers found the MU engine stop switch of the lead locomotive cab (UP 6205) depressed in the "Stop" position. According to the accident crew, the locomotive had been shut down when the train finally stopped. Neither the engineer nor the conductor could account for the locomotive's shutdown. Neither knew that the MU engine stop switch had been activated.

The MU engine stop switch is designed to shut down all locomotive units in the consist simultaneously. Switch activation shuts off electrical power to the fuel pumps, thereby causing engine shutdown. The switch can be considered a safety feature, as it allows the traincrew to shut down all units should a fire or another emergency occur.

Depending on the locomotive make and model, the MU engine stop switch may be located in various places and have one of several designs. The switch in this accident was composed of two rectangular buttons mounted within a 2-inch square, box-like frame that protruded from the wall of the lead locomotive. The top button was black with "Run" imprinted on it in white letters; the bottom button was red with "Stop" imprinted on it in white letters. (See figure 3, below.) The switch was mounted on the lower left panel of the engineer's control console; it was about 18 inches above the locomotive floor and near the cab heater switch and the "attendant call" and "ground reset" buttons.

Figure 3 -- MU engine stop switch (undamaged)

The surrounding frame of the lower lefthand corner of the MU engine stop switch on the lead locomotive had been broken off and was missing. The missing portion would have extended over two-thirds of the bottom of the switch and up about 1/2 inch of its left side. No broken parts remained in the area surrounding the frame, and grime was found on the broken surfaces. (See figure 4.)

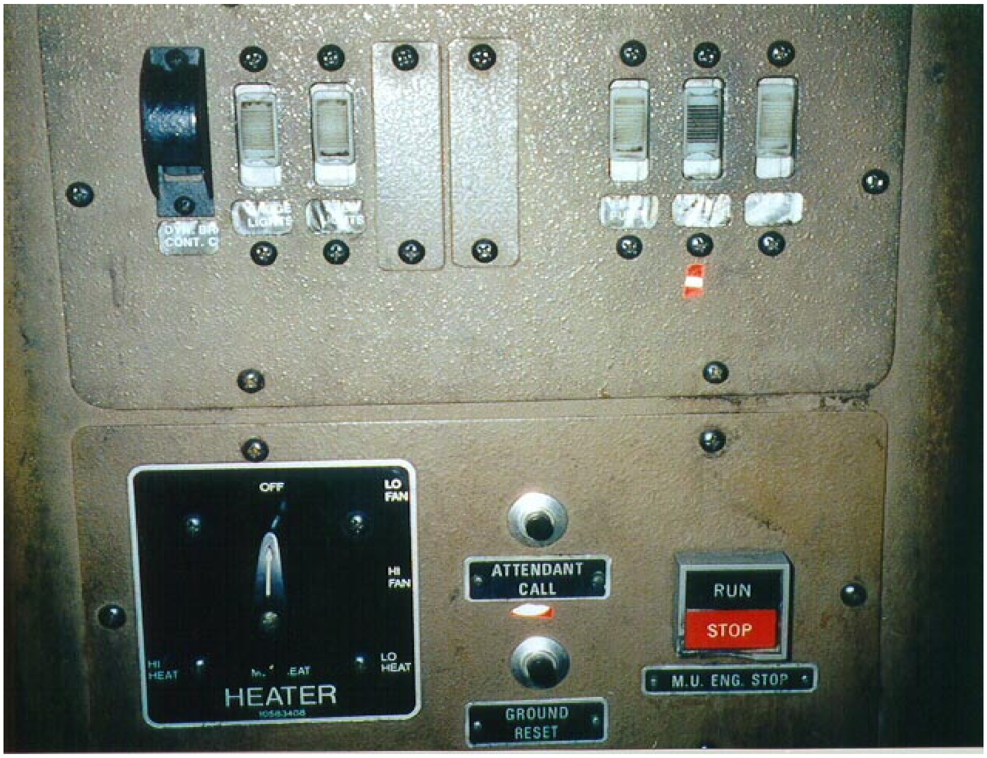


Figure 4 -- Engineer’s control console

Footwear-shaped marks, grease, and dirt were all around the MU stop switch and the sliding light switches located above it. The discolored and dirty area was on the right half of the panel that extended down from the left side of the console. The area appeared to be one in which engineers sitting at the console might have rested their feet when they crossed their legs or leaned back. (See figure 5, next page.)

UP train 6205’s lead locomotive unit, UP 6205, was an SD60M locomotive unit that the UP had ordered from EMD in 1988. In March 1988, development work began on the design of the console cab for the SD60M.[40]

This SD60M was the first EMD production console cab built in the United States. The console cab had been developed in Canada and had already been in use there for some time.[41] The UP requested that space for projected electronics installations be reserved at and above the cab console. Therefore, EMD located the MU stop switch near the bottom of the front left face of the engineer’s control console.

[40]The console cab has a full-width, wide-body design that is commonly called the “North American” cab. Its console is designed to function like a desk or counter for the engineer, rather than like the older-style control stand.

[41]In the early 1970s, the Canadian National Railway and the Montreal Locomotive Works collaborated on a new locomotive cab design to enhance crew safety in case of collision. This resulted in the “safety,” “comfort,” or “wide” cab design, which was used on the M420-model locomotives built between 1973 and 1977.

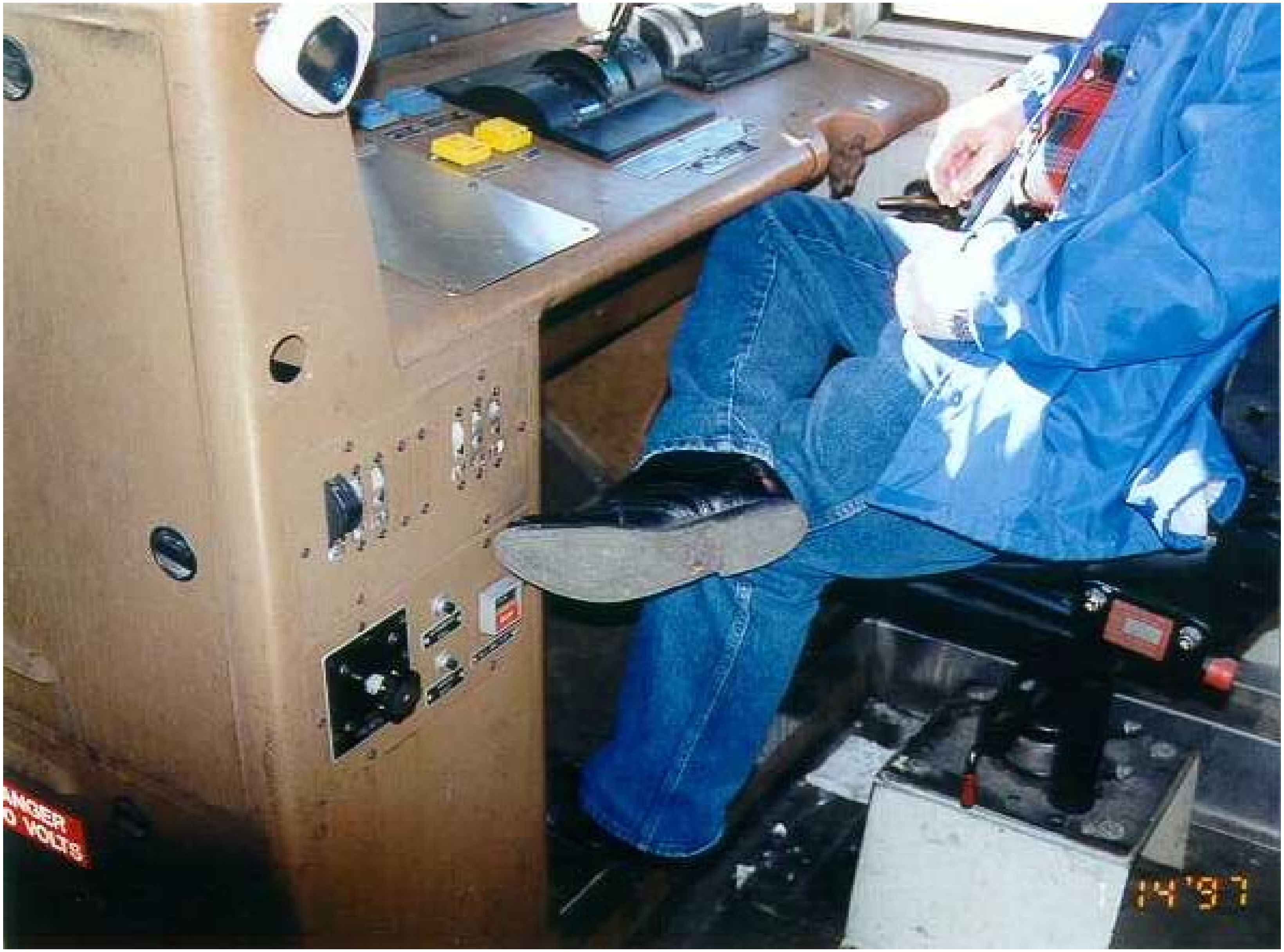


Figure 5 – Proximity of engineer's control panel to seated engineer

A total of 231 SD60M locomotives were built for the UP in 5 successive orders. Changes and improvements were made in the locomotives from order to order, as experience was gained from the units in service. (See details in table 1, below.)

In 1989, within the first year of service of the SD60M locomotives, the UP became aware of a problem with inadvertent activation of the MU engine stop switch. Safety Board investigators' informal postaccident discussions with UP locomotive engineers revealed that inadvertent activations of the switches had been common. The engineers told investigators that once the MU engine stop switch had been activated, it would take 5 to 10 minutes per locomotive unit for a crewmember to reach and then manually restart each engine. The UP requested a "guard" from EMD for the switch.

On January 10, 1990, representatives of the UP and EMD met to discuss open items pertaining to SD60M order 886061; a second meeting followed on January 18, 1990. A January 18 memorandum listed discussion items from the meeting. Item A7 of the memo stated, "The MU engine stop switch shall remain on the lower console but will be provided with a guard to prevent accidental bumping." This guard installation became EMD modification #9133 and took the form of a U-shaped bar to be placed over the Stop button portion of the MU engine stop switch.

Table 1. -- SD60M locomotives built for the UP

Order Number	No. of Units	Remarks
886010	25	Last unit shipped February 1989. Road numbers 6085 through 6109.
886015/023/036	106	Last unit shipped September 1989. Road numbers 6110 through 6215.
886061	52	Last unit shipped November 1990. Road numbers 6216 through 6267. Guard provided for MU engine stop switch.
896050	1	Shipped March 1991. Road number 6268. Included WABCO EPIC air brake system.
906100	47	Last unit shipped December 1991. Road numbers 6269 through 6316. MU engine stop switch relocated to upper console.
TOTAL	231	Of the 231 units, 184 had the MU engine stop switch located on the bottom left portion of the engineer's control console.

On September 5, 1991, an EMD interoffice memo referred to "Retrofit of MU engine stop switch protective bar to first 131 SD60M locomotives. This may also be a service modification." On October 22, 1991, EMD issued the three SD60M customers — the UP, the BN, and the Soo Line (now Canadian Pacific) — an *Engineering Service Release, Subject: MU Engine Stop Switch Guard*. The service release stated:

> Due to the location of the MU engine stop switch on the engineer's control console, it is possible that it can be accidentally activated during normal movement by the crew within the locomotive cab. This switch when activated, shuts down the locomotive consist.

The release included drawings, diagrams, and parts numbers for ordering and installing the bar-type guard. EMD stocked the modification parts, which were provided free to customer railroads upon receipt of a requisition charged to a locomotive unit number. Installation labor was provided and paid for by the railroad.

On November 20, 1991, EMD issued an interorganization memo indicating that 289 locomotive units would be affected by the MU engine stop switch bar-guard modification. Of these units, 184 were operated by the UP, 100 by the BN, and 5 by the Soo Line.

On December 23, 1991, EMD sent the UP a letter outlining the MU engine stop switch bar-guard modification and advised that the modification kit would be available approximately February 1, 1992. On March 10, 1992, the EMD District Engineer notified the UP that "Mod. 9133 - MU Engine Stop Switch Guard…has been entered into your computer system." While arrangements were being made to implement the MU engine stop switch bar-guard modification for in-service locomotives, EMD installed the bar guard on new-production locomotives, beginning with the third UP order, number 886061.

Soon after the first bar-guard units went into service, engine crews began to complain that the bar-guard modification was unsatisfactory. Crewmembers said that they hit their shins against the bar and that its protrusion was a safety hazard. In response to safety concerns regarding the bar guard, EMD developed a clear plastic slide-type guard to fit over the frame of the MU engine stop switch. In April 1992, EMD issued a directive to its field representatives to replace the bar-guard modification with the new plastic slide-type guard. EMD included a manufacturer's drawing of the slide installation with the directive.

On May 24, 1993, EMD sent a letter to the UP concerning a letter it had received from the EMD customer service representative in North Platte, Nebraska.[42] The North Platte representative had referred to the plastic guard modification and had stated that:

> North Platte has just received its first mod kit 9133 since the latest revision. The item received has no locking tabs on it as do the current guards. This will necessitate glue being used to hold these things in place which will not be acceptable to our customer. In addition, this guard has a clear plastic "shield" that must be raised up in order to depress the switch. Given the abuse these units are subjected to, I expect this guard to last one trip before being tossed. In addition, there are sharp corners exposed when this guard is in place which could possibly cause a laceration if hit accidentally. Given these conditions, I strongly recommend we continue to look for other alternatives.

EMD's May 24, 1993, letter reported these concerns regarding the plastic slide guard to the UP. On May 26, 1993, the UP requested that EMD "develop a modification… to relocate the MU engine stop switch to the overhead console location comparable to units 6316 through 6365."

An EMD Modification Status Report dated January 13, 1994, showed that material had been ordered for eight UP units to make

[42] North Platte is a major UP yard and locomotive maintenance facility.

modification #9133 (either the bar or the slide) for the engine shutdown switch. On January 26, 1994, EMD issued an interorganization memo that stated that modification #9133 of the MU engine stop switch "…is now considered closed. The UP has determined this modification to be unsatisfactory and has discontinued its application."

On May 4, 1994, EMD sent the EMD District Engineer who was serving the UP complete information and plans for moving the MU engine stop switch to the upper control console. On June 9, 1994, EMD sent the UP a detailed set of instructions on the step-by-step procedure for relocating the MU engine stop switch to the upper control console. The message included drawings and material lists.

Through postaccident investigation, the Safety Board investigators found that the UP had completed eight switch modifications and no relocations by the time of the accident. The BN and the Soo Line had relocated the switches, at an estimated cost of $5,000 per unit. Safety Board investigators asked UP representatives why the UP had not effected guard modifications or relocated the MU engine stop switches within the 7 years between the first recognition of the switch location problem and the accident. During postaccident interviews, the UP Chief Mechanical Officer (CMO) – Locomotives stated that the UP Mechanical Department had a two-priority system for making equipment modifications. He said that the UP system categorized them as either "safety or operationally critical" modifications or "comfort or convenience" modifications. The CMO stated that the UP would complete the safety or operationally critical modifications on a priority basis. He said that other (comfort or convenience) modifications would be handled as budget and time permitted.

The CMO stated that when the problem of the location of the MU engine shutdown switch was first identified by the UP, it was not considered a safety or operationally critical issue. Changing the location of, or making adjustments to, the switch was therefore not prioritized by the UP as a critical modification. The CMO stated that, until the Kelso accident took place, no UP manager had foreseen direct safety implications involving the switch location, so the switch modifications and relocations were made by the UP as they became convenient.

Event Recorders -- Event recorders were recovered from all three locomotive units. Review of the data revealed that all units had functioned as designed. The recorded information concerning the engineer's train handling was found to reflect his recollection of the accident. Event recorder data generally supported the postaccident statements of the engineer and conductor.[43]

Cars -- After the derailment, the last six cars of UP train 6205 were found to be both undamaged and still on the rail. Two preceding cars had derailed, but they remained relatively undamaged. The UP inspected and tested these eight almost intact cars after the accident as a representative sample of the condition of the cars that had been in the train. The tests and inspections for each car included making a single-car air brake test and air brake inspection, performing a net brake-shoe force test, and weighing the car. These data were later used in a computerized train dynamics analyzer simulation as the basis for determining the car condition for the entire accident train. (See next page's table 2 for the information compiled during the UP postaccident tests and inspections.)

Train Dynamics Analyzer (TDA) Simulations -- At the request of the Safety Board, TDA simulations were conducted after the accident by representatives of the accident investigation parties. The simulations were performed at the New York Air Brake Train Dynamics Simulations Group in Fort Worth, Texas, on February 4 and 5, 1997. They were based on event recorder data recovered from UP train 6205's three locomotive units, postaccident inspection and testing of eight cars from the train, and postaccident interviews.

[43]Event recorder data indicated that the release of the train's air brakes made during the setting of the retaining valves at Cima had taken place earlier than the conductor had remembered.

Table 2. -- UP postaccident test results

Car Number	Gross Car Weight (lbs.)	Gross Car Weight (tons)	Loaded Braking Force (lbs.)	Net Braking Ratio[1] (percentage)	Brake Cylinder Pressure[2] (psi)
NDYX 515956	286,880	143.44	21,415	7.49	52.0
SIRX 515147	288,040	144.02	21,388	7.48	52.0
NAHX 70001	285,080	142.54	19,969	6.98	52.5
GACX 5657	286,300	143.15	21,277	7.44	52.0
UP 91295	286,380	143.19	21,110	7.38	50.0
UP 89336	285,980	142.69	20,434	7.14	50.0
UP 91189	286,076	143.04	20,340	7.11	50.0
UP 90754	286,134	143.07	20,945	7.32	49.0

[1]The net braking ratio is calculated by using the actual brake-shoe force, thus taking into account the rigging efficiency. The braking ratio for freight cars has been traditionally stated at 50 psi brake cylinder pressure.

[2]Brake pipe pressure of 70 psi.

The purpose of the simulations was to determine the maximum accident train speed for descending Cima Hill at which the engineer might have been able to stop the train and what would have occurred had UP train 6205's maximum authorized speed been 5 mph lower. Ultimately, the group found that the TDA simulator did not give a realistic projection of all braking scenarios. The heavy braking and heat fade involved in the accident were not accurately replicated. (Information on the TDA simulations is provided in appendix D.)

Investigators learned that computerized train simulation programs have not yet been developed to realistically replicate the effects of heat fade on train tread brakes. TDA programs cannot accurately predict when heat fade will begin or to what extent it will affect train performance. Statements from industry experts, consultants, and others indicated to Safety Board investigators that the railroad industry considers computerized train performance simulators valuable tools for predicting train dynamic performance but finds their usefulness limited to scenarios that do not involve heavy braking with significant heat generation and heat fade.

UP Braking Tests -- The UP conducted braking tests on Cima Hill with a duplicate of UP train 6205 to investigate the accident and explore alternative operating procedures. The UP test train was composed of 3 SD60M locomotive units, followed by 75 loaded covered hopper cars rated for maximum weights of 286,000 pounds (143 tons) each.

The UP added one car to the duplicate train to provide a means of compiling data. The 16th car from the locomotive was a mobile laboratory car. It was followed by a buffer car and two instrumented cars. The instrumented cars were equipped with ASF Ride Master trucks and TMX brakes. Instrumentation consisted of transducers[44] that measured brake cylinder pressure and thermocouples that measured wheel-tread temperatures. (The differences in configuration from UP train 6205 did not significantly affect braking test results. The braking effort of the four data-gathering cars negated the effect of the additional weight they added to the train.)

The UP made eight test runs westbound down Cima Hill, employing various combinations of the operating parameters, such as use of retainers, initial speed, and speed at the time of the emergency brake application. Runs were made replicating actions taken by the accident crew at the same locations where the actions occurred during the descent of Cima Hill that resulted in the derailment.

The first run replicated the events of the accident as closely as possible, including the use of retainers. The use of dynamic brakes was discontinued at 20 mph, at the same location that this occurred during the accident. As in the accident, an emergency brake application was made when the train speed was 30 mph. The emergency application did not stop the train, and the train speed continued to increase. Wheel temperatures rose to an average of around 650°F during the attempt to stop the train. The train was safely stopped, after it had reached a speed of 36 mph, by reactivating the dynamic brakes. Initially, wheel temperatures rose to an average of 560°F.

Other runs showed that stopping was possible from 25 mph after a descent at 20 mph with some retainers set. The highest average wheel temperature was 650°F during the stop from 25 mph. The stopping distance was 5,700 feet. The stopping distance from 24 mph was 3,000 feet after a descent at 15 mph. Wheel temperature was 575°F during the stop without retainers from 24 mph. The train could be controlled down the hill at 15 mph without dynamic brakes.

The UP's test results confirmed that the effectiveness of the air brakes in controlling train speed depended directly on the coefficient of friction between the shoes and the wheels, which was dependent on the brake-shoe force and the resulting heat generated. The results also confirmed that the heavier the freight car, the greater the brake-shoe force necessary to control its speed.

Brake-shoe forces averaged 1,500 pounds during the tests conducted by the UP between Cima and Kelso. Wheel temperatures were roughly 500°F. Putting the train into emergency raised the shoe forces to almost 4,000 pounds and wheel temperatures to 700°F.

Through the tests, the UP found that heavy cars face three operational consequences in contrast to light cars. First, at a given speed, the wheel temperatures of heavy cars are higher. Second, because the coefficient of friction is less, heavy cars require a greater brake pipe reduction to control their speed. Third, these factors combine to reduce the threshold speed for a runaway train composed of heavy cars by an amount that is more than proportional to the weight increase.

Because the retarding force necessary to brake a vehicle such as a freight car increases with weight, braking horsepower must be higher for heavy cars than for light ones. The greater braking effort requires more brake-shoe force and results in higher wheel temperatures. The same wheel temperature can be maintained for cars of different weights by reducing the speed in proportion to the higher weight, so that the braking horsepower remains constant. For example, to maintain the same wheel temperature, the speed would have to be 8 percent lower for a 286,000-pound car than for a 263,000-pound car. For a 315,000-pound car, the speed would have to be 17 percent lower than for a 263,000-pound car. Because wheel temperatures increase as train speed rises and resistance (the coefficient of friction) decreases, there exists for any train on a descending grade a threshold speed for a given car weight beyond which the car's brakes cannot generate enough retarding force within the limits of the wheel temperature to sufficiently counteract the pull of gravity to stop the train or control its speed.

[44] A transducer is a device that transforms one form of energy into another.

Postaccident Actions

The FRA -- The FRA took action within 1 week of the accident and posted Safety Bulletin 97-1 in the *Federal Register* on January 17, 1997. Safety Bulletin 97-1 applied to railroads nationwide. It issued the following safety precautions to railroads:

1. Inspect all locomotives to determine if the emergency MU fuel line cut-off device is located in such a position in the locomotive cab that it can be inadvertently activated by the engineer. If the device is located in such a position, corrective action must be initiated.

2. Relocate the cut-off device to a location where the device cannot be unintentionally activated, or protect the cut-off device in a housing that prevents unintentional activation.

3. Until the improvements are made, these locomotives must not be operated in the controlling or lead position. If the locomotive cab is occupied while being utilized in a trailing position, the engineer's seat must remain unoccupied to the greatest extent possible. If a trailing locomotive is to be occupied, the conductor must brief all occupants as to the location of the cut-off device and the need to avoid all contact with it.

The UP -- In response to FRA Safety Bulletin 97-1, the UP began relocating its MU engine shutdown switches and restricted SD60M locomotives to trailing positions until the relocation modifications could be made. The Safety Board understands that all modifications were completed by August 24, 1997.

After the Kelso accident, the UP issued General Order No. GO-97-01-18, which stated, in part:

> When operating on descending grades between Cima and Kelso [in addition, the UP specified another 23 steep-grade locations], if train speed reaches 5 mph above authorized speed, stop train immediately, using an emergency brake application if necessary. In all cases, use at least a full-service brake application. Apply a sufficient number of hand brakes to prevent movement. Do not move the train until authorized by a Manager of Operating Practices.

The UP also issued General Order No. GO-97-03-20, which stated, in part, "Do not exceed a speed of 15 mph when retaining valves are set and charged."

At the time of the accident, the UP general director of safety had reported to the vice president of risk management, who reported to the executive vice president of operations, who then reported to the UP president and chief operating officer. In fall 1997, the UP changed its reporting structure such that the UP general director of safety now reports to the executive vice president of operations, who reports directly to the UP president and chief operating officer.

Additional Information

Power Brake Regulations -- The FRA published an Advance Notice of Proposed Rulemaking (ANPRM) concerning the possible revision of the Power Brake Law, 49 CFR Parts 229, 231, and 232 (57 *Federal Register* 62546) on December 31, 1992. The ANPRM included several Safety Board recommendations that were issued following railroad accident investigations. These recommendations dealt with a range of issues, including two-way EOT devices, train brake and equipment inspections, the air-flow method of testing air brakes, monitoring dynamic brakes, and cold-weather and steep-grade air brake testing.

Following publication of the ANPRM, the FRA conducted 4 days of technical workshops in early 1993 to elicit information and opinions. The workshops were held at Kansas City, Missouri, February 17, 1993; Chicago, Illinois, March 2 and 3, 1993; and Newark, New Jersey, March 9, 1993. The workshops in each location addressed different topics.

On September 16, 1994, the FRA published[45] a Notice of Proposed Rulemaking (NPRM) for updating the power brake regulations. It set public hearing dates of October 24 and 25, 1994, in Chicago, Illinois; November 4, 1994, in Newark, New Jersey; and November 9, 1994, in Sacramento, California. During these hearings, the railroads stated that they opposed a provision of the NPRM that concerned the 1,000-mile inspection. The conflict regarding this issue halted action on all the power brake revisions and made continued progress doubtful.

In an effort to complete the revision of the power brake regulation, the FRA established a Railroad Safety Advisory Committee (RSAC). The RSAC was intended to provide a new way of dealing with the industry to collect more information earlier on proposed regulations, to make the regulatory process more responsive, and to identify conflicts before they became entrenched. As part of the RSAC, the FRA set up a Power Brake Working Group to develop a new NPRM for the power brake regulations. During a December 1996 meeting in St. Louis, Missouri, however, the Power Brake Working Group reached an impasse on an issue regarding labor concerns and inspection timing. No further progress on the power brake regulations has since been made.

Car Weight and Train Speed Developments -- As railroad technology has evolved, the sizes and weights of freight cars and the weights and speeds of trains have increased. In the 1890s, the average train was powered by a 1,200-hp steam locomotive pulling a 2,000-foot, 2,000-ton train made up of 20- to 30-ton-capacity freight cars. Train speeds averaged less than 25 mph.

The most recent expansion in car and train capacities began in the early 1960s, with the industry's rapid acceptance of 100-ton-capacity cars and the introduction of the 125-ton car. Increasing demand for coal called for larger and faster trains. Greater use began to be made of welded cars and rails, as well as of larger wheels. By the 1970s, MU diesel-electric locomotives of 10,000 to 16,000 hp were pulling 5,000- to 8,000-foot-long trains that weighed 10,000 to 15,000 tons.[46]

Before the Kelso accident, the UP required that a train be stopped if an 18-psi brake pipe reduction failed to control train speed. Most railroads had similar requirements. Accidents at Tennessee Pass, Colorado,[47] and Cajon Pass, California,[48] in which freight trains became runaways, caused some carriers involved in these accidents to adopt a "plus 5 mph and stop" rule.

The rule states that anytime train speed exceeds by more than 5 mph the maximum authorized speed for that track, the engineer must stop the train immediately (with an emergency application, if necessary). The plus 5 mph and stop rule allows the engineer to quickly recognize when a speed problem exists. The rule is designed to be easy for engineers to interpret, and it can be enforced by the railroad through reviews of information from train event recorders. Railroads using this rule have reported that the policy has been somewhat successful in preventing runaways.

---

[45] *Federal Register,* Vol. 59, No. 179, September 16, 1994, pages 47676-47751.

[46] *Engineering and Design of Railway Brake Systems,* Air Brake Association, 1984.

[47] Railroad Accident Report -- *Derailment and Hazardous Material Release of Freight Train 1 ASRVM-18 Southern Pacific Lines near Tennessee Pass, Colorado, February 21, 1996* (LAX96FR007).

[48] Railroad Accident Report -- *Derailment of Freight Train H-BALTI-31 Atchison, Topeka, and Santa Fe Railway Company near Cajon Junction, California, February 1, 1996* (NTSB/RAR-96/05).

ANALYSIS

General

No evidence found during the investigation indicated that the weather, the signal and train-control systems, or the track conditions caused or contributed to the accident. Postaccident equipment inspections and crew statements showed that no weather-related factors impaired the performance of the traincrew or equipment. Postaccident testing and review of the records showed that signal and train-control systems functioned as designed. Postaccident track inspections revealed no significant track anomalies. The Safety Board concludes that neither the weather, the signal and train-control systems, nor the track conditions were factors in the accident.

No information indicated that fatigue played a part in the accident. Train crewmembers said they were rested in accordance with the Federal Hours of Service Act. They were qualified to perform their duties according to UP procedures and accepted practice. The engineer's work schedule, his statement that he felt well rested, and the event recorder data all suggest that fatigue was not an element in this accident. Drugs and alcohol were also excluded as accident factors. Toxicological tests were performed on the engineer and conductor after the accident, and no drugs or alcohol was found. Therefore, the Safety Board concludes that crewmember fatigue was not a factor in the accident, and drugs or alcohol did not cause or contribute to the accident.

The Accident

The UP unit freight train 6205 west, with 3 locomotive units on the head end, followed by 75 cars loaded with corn, originated in Columbus, Nebraska, on January 3, 1997, destined for a terminal near San Francisco, California. When the train reached Las Vegas, Nevada, in the early morning of January 12, 1997, the crew changed. The oncoming engineer and conductor inspected the train and made an air brake test. The train departed Las Vegas at 6:05 a.m. on January 12, 1997.

On the approach to Cima Hill, while still about 37 miles away, the engineer carried out a running test of the dynamic brakes and found that they responded appropriately. At Cima, the engineer stopped the train with it draped symmetrically over the crest of the grade. By consulting the consist list, the engineer found that the train was reported to weigh 9,724 tons. In fact, the consist weight was incorrect; the train actually weighed 10,699 tons — 975 tons above the consist weight.

UP System Timetable No. 2 established the train's maximum speed down Cima Hill at 20 mph and required that retaining valves be set on all cars before descent. The train remained at Cima for 45 minutes while the conductor set the air brake retainer valves. He set most of the retainers while the air brakes were on, thus precharging all but about 15 of the retainers. As a result, initial movement down the hill required more power to overcome the precharged applied air brakes.

The train started moving down Cima Hill at about 11:18 a.m. The engineer began applying dynamic brakes about 2 1/2 minutes later, with the train traveling at 7 mph. The engineer also made a 6- to 8-psi minimum reduction of the brake pipe to apply the train air brakes. By about 11:42 a.m., the train was traveling at 23 mph and dynamic braking amperage was about 820 amps.

Suddenly, dynamic brake amperage and effort fell to 0 amps within 13 seconds, when the engineer unwittingly depressed the MU engine shutdown switch. Unaware that the shutdown switch had been activated, the engineer tried, without result, to increase the dynamic brake effort. Then, to compensate for the dynamic braking loss with air brakes, he reduced the brake pipe pressure by 12 to 17 psi. The engineer continued to increase train air braking in response to the rising train speed, until a full-service application was achieved by the time train speed reached 31 mph. The engineer then made an emergency brake application and notified the dispatcher that the train was a runaway. The time elapsed between the loss of the dynamic braking until the train was put into emergency was 1 minute, 13 seconds.

For the next 9 1/2 minutes, the train continued to gather speed. It was routed onto a siding and went into the Hayden east-end turnout at approximately 72 mph. As the train began to exit the Hayden siding at the west-end turnout, the drawbar between the locomotives and the first car broke, and the cars began to derail. The locomotives negotiated the turnout onto the mainline, but 68 of the 75 cars derailed at approximately 11:52 a.m.

The Safety Board considered whether the remedial actions taken by the engineer during the accident had been timely and appropriate. First, should the engineer have tried to restart the engines once the MU engine stop switch had been activated? Investigation indicated that, as the engineer was not aware that he had activated the stop switch, he probably did not even know if a restart was achievable. Further, because, without personnel stationed in each locomotive unit, it would have taken 5 to 10 minutes per locomotive unit to manually restart each engine, this action would not have been feasible even if the engineer had immediately realized what had happened. As the accident events demonstrate, even the delay of 1 minute and 13 seconds allowed the train to accelerate beyond the “point of no return.”

Should the engineer have placed the train in emergency sooner? Investigation showed that when he had confirmed that no dynamic braking capability was available, the engineer intuitively applied the air brakes in an increased service application. Seconds later, when he realized that he had no alternative, the engineer made an emergency brake application and notified the dispatcher that the train was a runaway. The Safety Board, appreciating the inherent risks (from in-train forces that could themselves cause a derailment) of placing a train in emergency, found it reasonable that the engineer should have quickly explored other options first. The Safety Board concludes that, given the severity of the grade and the speed of the train, the engineer’s decision to try other options before placing the train in emergency was reasonable.

In its investigation of the accident, the Safety Board identified three major safety issues: the placement of safety-critical locomotive cab controls, adequate train-speed safety margins for steep-grade railroads, and the criticality of dynamic braking systems. The Safety Board also reviewed car weight reporting, the power brake rulemaking process, and the use of air brake retainers.

Placement of Safety-Critical Locomotive Cab Controls

Early in the investigation, it became apparent that the locomotive engineer had inadvertently activated the MU engine stop switch inside the lead locomotive unit. The red Stop button of the MU engine stop switch was found still depressed after the accident. Also, the suddenness with which the engine shutdown occurred indicated that the switch had been struck immediately before the accident. No other reason for the engine shutdown was discovered.

The activation of the MU engine stop switch precipitated the accident. The stop switch activation shut down the diesel engines, resulting in dynamic braking loss. The dynamic brake loss initiated the runaway. Because neither the engineer nor the conductor was aware of what had caused the locomotive units to shut down, they did not take action to reactivate the units or immediately place the train in emergency. (Indeed, the crew thought that only their lead locomotive unit had shut down.) By the time the crewmembers put the train in emergency, it was already in runaway status.

The placement of the MU engine stop switch on the lower left panel of the engineer’s control console made it subject to inadvertent activation. Investigators’ informal postaccident discussions with locomotive engineers revealed that such activations had been common on locomotives equipped with switches in the same location. Sometime after 1989, EMD, the builder of the SD60M locomotive, became aware that inadvertent activation of the MU engine stop switch was a problem. EMD attempted to work with the purchasers of the affected locomotives to correct the poor placement of the switch.

While EMD's attempts to address the problem evidenced some concern over the safety implications of the switch location, the UP management did not consider changing the location a priority modification. Instead, the UP categorized it as a "comfort or convenience" modification. Consequently, the UP did not expedite protection or relocation of the switches. Although EMD had communicated with the UP about this issue as early as January 1990, the UP had taken steps to modify the MU engine stop switches on only 8 of its 184 affected SD60M locomotives by 1996. None of the affected UP locomotives had had their switches relocated.

Correspondence between UP representatives and EMD revealed that some UP representatives and EMD understood that the location of the MU engine shutdown switch had safety implications because crewmembers could, by inadvertently activating the switch, simultaneously shut down all locomotive units. The correspondence indicated concern regarding this possibility. Safety-conscious railroad managers should have foreseen that an unintentional shutdown of all motive power on an operating train could jeopardize train control. This danger should have been particularly conspicuous with respect to trains that traveled on steep grades such as Cima Hill, where dynamic braking has become critical. The Safety Board concludes that the failure of UP management to recognize the MU engine shutdown switch location as a safety hazard and to expedite effective switch protection or relocation created the conditions that led to the accident. The Safety Board believes that the FRA and the AAR should alert locomotive manufacturers and railroad operators about the dangers posed by improperly located safety-significant controls and switches in locomotives. While the Safety Board appreciates that since the Kelso accident the UP has taken action to relocate the MU switches on its locomotives, in the interest of protecting the UP fleet from other possible problems that could arise from poorly located safety controls, the Safety Board believes that the UP should relocate and/or protect all safety-significant controls and switches in its locomotives so they cannot be inadvertently activated or deactivated.

Train-Speed Safety Margins for Steep-Grade Railroads

The rapidity with which the Kelso train engineer was overtaken by events underscores the need for railroads to maintain realistic operating safety margins in case an unexpected failure occurs. Safety margins that were adequate for rail operations 20 years ago are not necessarily adequate today. As time has passed, railroad equipment technology has progressed, and so have the size and weight of freight cars and the weight and speed of trains. These changes have altered the ways trains operate, particularly in steep-grade areas, and have eroded the efficacy of braking safety margins.

Car Weight -- Engineers' determinations of safe maximum train speeds and train-handling methods are made based on the weight of the train (trailing tonnage). The train's tonnage dictates to the engineer the maximum speeds and the braking methods that may be used and indicates whether air brake retainer valves must be set. The accuracy of the engineer's determinations regarding these train-handling limits depends on the accuracy of the figures used to report the weight of each freight car. Unless the engineer is provided with the correct weight or appropriate maximum weight for the train on which to base his determinations, he may be placed in a potentially dangerous situation.

According to the UP, train 6205's cars were initially assigned by computer the default maximum car weight of 143 tons each, which was then mistakenly changed by a clerk to approximately 130 tons each. The engineer used the clerk's weights in making his train-handling decisions. Postaccident car weights were found to be around 143 tons. The additional train weight of 975 tons was unknown to the engineer.

Regardless of whether the engineer knew the actual weight of the train, the maximum authorized train speed down Cima Hill for train 6205 west would have been 20 mph. But beyond the fixed limit of authorized speed, engineers control trains by making experience-based judgments as dictated by conditions. As such, the accident engineer would probably not have significantly altered his braking procedure down the grade had he known the actual train weight, beyond increasing dynamic and pneumatic braking as he felt necessary to control the train. The unknown additional weight, however, eroded any safety margin that had been built into the UP's speed requirements for bringing a train down Cima Hill. Further, the greater weight would have caused the train to speed down the grade faster than it would have at a lower weight and impelled it more quickly beyond the point of no return. Therefore, the Safety Board concludes that, although the unknown additional train weight of 975 tons was not causal to the accident, it contributed to the severity and magnitude of the derailment. Therefore, the Safety Board believes that the FRA should require railroads to ensure that the actual loaded weights of cars in a train are provided to the traincrew or, if the loaded weights are unknown, to implement a method to ensure that the maximum loaded weight is assigned.

As previously noted in this report, following the Kelso derailment, the UP established a procedure to prevent billing clerks from altering the consist weights of cars and trains, thereby intending to prevent inaccurate train weights from being transmitted to engineers. Such a procedure, however, does not prevent cars from being overloaded beyond their design limits.

Since the Kelso accident, the UP experienced another incident that indicated that inaccurate car weight reporting continues to affect the railroad. About 4 p.m. Pacific daylight time, on August 31, 1997, the eastbound UP train CSULA-30 collided with a BN Santa Fe train at Barstow, California. The UP train was a unit train of 72 cars, carrying contaminated soil ("dirty dirt") bound for Utah. At the request of the Safety Board, the California PUC, and the FRA, the UP cars were weighed during the postaccident investigation. The cars were found to weigh, on the average, 5 tons more than the train consist weight of 121 tons per car, which caused the train to be 360 tons heavier than its listed consist weight. Based on these findings, the Safety Board concludes that the issue of accurate car weight assignment has not been adequately addressed by the UP. Therefore, the Safety Board believes that the UP should reexamine its system of car weighing and car-consist weight reporting and take action to ensure that train consist weights reflect actual train weights.

Tread Braking Limits -- Research has shown that train wheels and brake shoes cannot withstand infinite levels of friction-generated heat. Too much heat generated during braking causes brake shoes to wear and deteriorate rapidly, metal to flow on the wheel tread, and trains to lose their stopping ability. In the past, the use of air brake retainer valves (retainers) allowed engineers to control trains down long grades without exceeding the limits of the brake equipment. Then, air brake system air capacity was the limiting factor. Retainers help preserve compressed air capacity and the potential capability to brake a train. Retainers, however, still depend on the same tread-braked system that is subject to heat limitations. With or without retainers, excessive heat at the tread brake can cause the air braking system to become ineffective.

Evidence from the Kelso accident suggests that train weights and speed levels may have reached the physical limitations of the tread-braked freight car. The engineer was attempting to keep the train within the 20-mph speed limit established by the UP for a train of that weight at that location. Retainers had been set. The train's air brakes were functioning properly, and the engineer used the brakes correctly. But even after he had placed the train's tread-braked cars in emergency at 30 mph, the engineer of UP train 6205 could not stop it from running away. The air brakes alone were insufficient to keep the train from experiencing significant acceleration in these circumstances.

Postaccident UP brake tests conducted on Cima Hill showed that the air brakes alone could stop a train similar to UP train 6205 at speeds up to 25 mph but not much beyond that speed. UP train 6205 accelerated to 25 mph within 30 seconds of MU stop switch activation.

UP train 6205, therefore, while it was performing as required by the UP, could not be sufficiently slowed with air brakes alone on the Cima Hill downgrade to ensure safe operation much beyond the maximum authorized speed. The data indicate that the air brakes could not function successfully in this situation because frictional tread-brake heat generation had reached performance-damaging levels. The Safety Board concludes that, due to increases in train weights and speeds, frictional tread-brake heat generation has become a limiting factor for safe train operation, particularly in steep-grade territories.

Dynamic Braking -- While the UP in theory considers dynamic braking a nonessential mechanism, it has in practice relied on the safeguard that, as long as the dynamic braking system works, total dependence on the air brakes (with their heat-fade weaknesses) can be avoided. As the Kelso accident demonstrated, once dynamic braking is lost, a train operating on a steep downgrade can become uncontrollable within seconds, even though the air brake system is fully functional. The Safety Board therefore concludes that the UP's operational reliance on dynamic braking for controlling heavy and fast-moving trains on steep grades, without acknowledging and protecting dynamic braking as a safety-critical system, is imprudent. The fact that the accident occurred because dynamic braking was lost indicates that some railroads may have allowed their margins of safety to erode by maintaining train-handling practices rendered obsolete by the heavier weights and faster speeds of today's trains. The Safety Board therefore believes that the FRA should require railroads to review steep-grade train-handling practices and, if necessary, make changes that will preserve a margin of stopping ability should a dynamic braking system fail.

Operational speeds and train-stopping capability have traditionally been associated with the amount of air pressure that has been reduced from the brake pipe (the level of air braking required). The UP required that a train be stopped after an 18-psi brake pipe pressure reduction failed to control train speed. Other railroads had similar requirements. The Safety Board does not consider that such brake pipe reduction requirements provide timely operational guidance or a sufficient safety margin to traincrews. By the time a dangerous situation is recognized, it may already be too late for crewmembers to take effective corrective action. In the Kelso accident, although the engineer was attempting to abide by the UP's maximum train speed requirement for the area, by the time he realized that a problem existed and initiated a 12- to 17-psi reduction, the train still became a runaway within 73 seconds. The Safety Board therefore concludes that the UP has authorized maximum train speeds that provide insufficient safety margins in the event of dynamic braking failure. To help alleviate this problem, the Safety Board believes that the FRA and the AAR should carry out research, investigation, and analysis to determine maximum authorized train speeds for safe operation of trains of all weights, using speed-based margins of safety that can be easily measured by traincrews.

According to the UP rules in effect for UP train 6205, 20 mph was the maximum safe speed for a train descending from Cima to Kelso with retainers set. After the accident, the UP issued orders that required trains on which retainers had been set to keep speeds at 15 mph or lower. The UP also required its crews operating in specified steep-grade locations, including the descent from Cima to Kelso, to stop trains immediately if speeds rose 5 mph above the authorized speed. While the exact speed at which the engineer might have effectively braked train 6205, given all the variables in this instance, has not been determined by investigators, the Safety Board concludes that some speed-based safeguard might have enabled the engineer to exercise greater control over the Kelso accident train.

The Safety Board considers that the UP's decision to implement the "plus 5 mph and stop" rule specified above is a step in the right direction. Nevertheless, the Safety Board considers that this narrowly defined order may not be sufficient to address the broad range of safety margin issues raised by this accident. Therefore, the Safety Board believes that the UP should reexamine its maximum authorized train speeds for safe operation of trains of all weights to establish new speed-based margins of safety that can be easily used by traincrews.

The railroad industry maintains that dynamic braking is a noncritical feature. Railroads have claimed that dynamic brakes are not required for safety or train control and that the main purposes of dynamic brake use are fuel economy and maintenance reduction. Because regulations require that trains be safely handled with the air brake system alone, railroads do not acknowledge that dynamic brakes have become an important safety and train-handling feature. Actual railroad rules and train-handling routines, however, indicate that, in practice, dynamic brakes have become essential to train handling. During the Kelso accident, the train accelerated beyond its stopping speed very rapidly (within 30 seconds) after dynamic brake loss. Therefore, the Safety Board concludes that railroads are operating trains in situations in which loss of dynamic braking will result in loss of train control.

The Safety Board has a long history of issuing recommendations regarding dynamic brakes. As a result of an investigation of a runaway train accident that occurred near Kelso, California, on November 17, 1980,[49] the Safety Board issued the following recommendation to the UP:

R-81-92

> Require that the dynamic braking feature of the lead locomotive unit on all westbound trains originating at Las Vegas and which are operated west of Cima be tested and determined to be functional.

On December 19, 1981, the UP replied that it had revised its *Special Rule 1042 (RC) #4* to state that, "On any westbound train, dynamic brakes must be tested between MP 309 and MP 292." Because this procedure met the intent of the recommendation, the Safety Board responded on February 16, 1983, that R-81-92 had been classified "Closed -- Acceptable Action."

As a result of the investigation of an accident that took place at San Bernardino, California, in May 1989,[50] the Safety Board recommended that the FRA:

R-90-24

> Revise regulations to require that if a locomotive unit is equipped with dynamic brakes, the dynamic brakes function.

On November 30, 1990, the FRA responded that it was reviewing the issue of regulations pertaining to dynamic brakes on locomotives and specified a range of responses available to the agency. The FRA, however, chose not to make a "definitive response" to the recommendation. On February 21, 1991, the Safety Board responded that the recommendation would remain classified "Open -- Await Response" because of the FRA's lack of commitment to a specific action. Since then, the FRA has taken two actions in response to Safety Recommendation R-90-24, both of which were unsuccessful. First, the FRA issued a proposed rulemaking under the amendment of the Power Brake Law. The rulemaking was ultimately withdrawn. The FRA then placed the recommended action with its RSAC for handling. The RSAC was also unable to develop a satisfactory solution to the problem of providing for functioning dynamic brakes.

Separating high-priority components of needed rulemaking from the routine process and proposing them independently has been a successful strategy in the past, most recently with respect to the two-way EOT device recommendations resulting from the 1996 Cajon, California, derailment. (For accident citation, see footnote 47, page 21.) Because no progress on Safety Recommendation R-90-24 has been achieved in approximately 7 years, the Safety Board concludes that the FRA should separate the dynamic braking function component from the power brake rulemaking process and promulgate regulations to require that, on locomotives equipped with dynamic brakes, the dynamic brakes are functioning properly before trains are dispatched. Therefore, the Safety Board classifies Safety Recommendation R-90-24 "Closed -- Unacceptable Action/Superseded" and believes that the FRA should separate the dynamic brake requirements from the Power Brake Law rulemaking and immediately conclude rulemaking to require railroads to verify that the dynamic braking systems on all locomotives equipped with dynamic brakes are functioning properly before trains are dispatched. The Safety Board also believes that the UP should develop procedures to ensure that, before a train

[49] 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* (NTSB/RAR-81/01).

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

equipped with dynamic brakes is dispatched, all the dynamic brake systems on the locomotives are functioning properly.

In addition, as a result of the San Bernardino accident, the Safety Board made recommendations to both the FRA and the AAR that they should:

> R-90-23 (to the FRA); R-90-26 (to the AAR)
>
> Study in conjunction with the [FRA or AAR, respectively], the feasibility of developing a positive method to indicate to the operating engineer in the cab of the controlling locomotive unit the condition of the dynamic brakes on all units in the train.

The FRA also considered this issue part of the proposed revisions of the Power Brake Law, which, as noted above, have not been successfully advanced. Consequently, the Safety Board classified Safety Recommendation R-90-23 "Open -- Unacceptable Action." Because the AAR performed an independent study on dynamic brakes (the 1991 *Summary of Double Stack Stop Distance Tests*), the AAR recommendation R-90-26 was classified "Closed -- Acceptable Action" on August 10, 1993.

Despite these recommendations, reliable information on the status of a train's dynamic braking is still not available to the engineer. The engineer of the Kelso accident train had reason to question whether the dynamic braking system was operative on his train. Although he apparently did not consider this issue, a bad order tag indicating malfunctioning dynamic brakes had been left on one of the train's locomotives. This bad order tag could have caused the engineer to doubt the reliability of the train's dynamic braking system. He had (in accordance with UP requirements) performed a running dynamic brake test from MP 309.3 to MP 292, and the brakes had responded as expected, although the engineer still could not know whether they functioned as designed. Cima is located a considerable distance (approximately 37 miles) past this checkpoint, at MP 254.6. The engineer made no further dynamic braking tests before reaching Cima and so had no verified information on whether or how the dynamic brakes were functioning as the train neared this significant downgrade.

Although the engineer assumed (in accordance with UP policy) that the brakes were operational, he had no means of checking whether they were, aside from conducting additional tests. No equipment in the lead locomotive provided information on the train's dynamic braking status. The Safety Board therefore concludes that the engineer in the Kelso accident had no practical means of knowing if or how many of his locomotive units were properly working in dynamic braking immediately before the accident or when used.

In recent years, the railroad industry has developed an effective and reliable device to display the real-time dynamic braking performance of trailing locomotive units. Such a display would permit an engineer to modify his train-handling strategy based on the information it provided, before being surprised by the failure of a dynamic braking system that he had depended upon using. The Safety Board concludes that installing a device in the cab of each controlling locomotive to indicate the real-time condition of the dynamic brakes on each locomotive unit in the consist would give valuable information to the engineer on train dynamic braking capability at any given moment. Therefore, because no progress has been made by the FRA on Safety Recommendation R-90-23, which addresses developing a positive method to indicate to the engineer the condition of the locomotives' dynamic brakes, the Safety Board classifies Safety Recommendation R-90-23 "Closed -- Unacceptable Action/Superseded" and believes the FRA should now require railroads to ensure that all locomotives with dynamic braking be equipped with a device in the cab of the controlling locomotive unit to indicate to the operating engineer the real-time condition of the dynamic brakes on each trailing unit. Further, because the engineer of the Kelso accident train had no means in the lead locomotive of determining the real-time condition of the train's dynamic brakes, the Safety Board believes that the UP should equip all lead or controlling locomotive units with real-time displays capable of indicating to the engineer the dynamic brake condition on each trailing locomotive unit in the consist.

Air Brake Retainers

The setting of air brake pressure-retaining valves determines how much, if any, brake cylinder pressure is retained and, therefore, how much braking force can be created. By setting retainers, traincrews retain air capacity in the air brake system. According to UP timetable rules, retainers were to be set if the tons per operative brake exceeded 80 and the tons per operative dynamic brake exceeded 300. Because of its weight and braking capabilities, retainers were required to be set on the Kelso accident train.

Neither the conductor nor the engineer on the Kelso accident train had had any formal training on when or how to set the retainers, even though the practice was common and important to braking safety in steep areas. Both crewmembers said they had gained all the knowledge they had about retainers through on-the-job training and experience.

In this instance, the conductor precharged the brake cylinders by setting most of the retainers while the train brakes were still applied. Investigators were unable to determine with certainty whether this action had any effect upon the unfolding of events in the Kelso accident. Such a precharge may or may not be significant, depending on conditions and future braking actions, because any additional braking will be added to that pressure already in the precharged cylinders. (As previously discussed, brake cylinder pressure directly affects brake-shoe force, frictional retardation of the tread brakes, and braking efficiency.)

The crucial point is that neither the conductor nor the engineer had a well-defined plan about when the retainers should be set or how they should be charged. Neither had a true appreciation of the significance of uncharged or precharged brake cylinders. Further, neither understood the proper use of retainers in controlling train speed through cycle braking. Because the engineer did not release the air brakes on UP train 6205's descent down Cima Hill, the retainers could not function as designed and were rendered effectively useless.

It seems self-evident that any procedure that is important enough to be required by a railroad should be well understood by railroad personnel and included in the railroad's formal training program. The Safety Board concludes that the significance of retainer-setting procedures, proper retainer use, and the various choices involved should be understood by train crewmembers and included in railroad training programs. Therefore, the Safety Board believes that the UP should implement formal training on the proper procedures for setting and using retainers for those traincrews that may be required to do so. The Safety Board further believes that the FRA should require railroads to implement formal training on correct retainer setting and using procedures for traincrew members who may set or use air brake retainer valves.

UP Management of Safety Issues

The Safety Board notes with concern that during this investigation repeated instances of procrastination, inattention, and ineffective action on the part of UP management regarding significant safety issues were uncovered. The 8 years of delay before the poorly placed MU shutdown switches were relocated, the operational reliance on dynamic braking without acknowledging dynamic braking to be a safety component of the braking system, the establishment of maximum train speeds that did not ensure safe operation in all situations, the recurrent misassignment of car weights, and the failure to train personnel responsible for setting and using retainers in correct procedures all indicated to the Safety Board that the UP may not be focusing sufficient corporate attention on operational safety.

The Safety Board understands that the UP has a general director of safety and appreciates that the UP has made organizational changes since the Kelso accident to put this official on a level closer to the UP president and chief operating officer. While the movement of the UP general director of safety one position closer to the president is progressive, the UP general director of safety still reports to, and is under the authority of, the executive vice president of operations. The Safety Board considers that the lead safety officer in the UP's management structure should report directly to the primary managerial authority to avoid possible conflicts of interest between business operations and safety. The potential to subordinate safety to economically expedient operating practices may be too great under such a corporate structure. Subordinating the position of safety officer to an operating officer also implies that safety is secondary to operations. The Safety Board therefore concludes that the UP general director of safety should report directly to the UP president and chief operating officer. The Safety Board believes that the UP should review the functions and responsibilities of the UP general director of safety and make any organizational changes necessary to ensure that this official: (1) reports directly to the UP president and chief operating officer; (2) is involved in all UP operational issues that could affect train, railroad, and personnel safety and; (3) has the authority to take effective safety actions throughout the UP.

CONCLUSIONS

Findings

1. Neither the weather, the signal and train-control systems, nor the track conditions were factors in the accident.

2. Crewmember fatigue was not a factor in the accident, and drugs or alcohol did not cause or contribute to the accident.

3. Given the severity of the grade and the speed of the train, the engineer's decision to try other options before placing the train in emergency was reasonable.

4. The failure of Union Pacific Railroad management to recognize the multiple-unit engine shutdown switch location as a safety hazard and to expedite effective switch protection or relocation created the conditions that led to the accident.

5. Although the unknown additional train weight of 975 tons was not causal to the accident, it contributed to the severity and magnitude of the derailment.

6. The issue of accurate car weight assignment has not been adequately addressed by the Union Pacific Railroad.

7. Due to increases in train weights and speeds, frictional tread-brake heat generation has become a limiting factor for safe train operation, particularly in steep-grade territories.

8. The Union Pacific Railroad's operational reliance on dynamic braking for controlling heavy and fast-moving trains on steep grades, without acknowledging and protecting dynamic braking as a safety-critical system, is imprudent.

9. The Union Pacific Railroad has authorized maximum train speeds that provide insufficient safety margins in the event of dynamic braking failure.

10. Some speed-based safeguard might have enabled the engineer to exercise greater control over the Kelso accident train.

11. Railroads are operating trains in situations in which loss of dynamic braking will result in loss of train control.

12. The Federal Railroad Administration should separate the dynamic braking function component from the power brake rulemaking process and promulgate regulations to require that, on locomotives equipped with dynamic brakes, the dynamic brakes are functioning properly before trains are dispatched.

13. The engineer in the Kelso accident had no practical means of knowing if or how many of his locomotive units were properly working in dynamic braking immediately before the accident or when used.

14. Installing a device in the cab of each controlling locomotive to indicate the real-time condition of the dynamic brakes on each locomotive unit in the consist would give valuable information to the engineer on the train's dynamic braking capability at any given moment.

15. The significance of retainer-setting procedures, proper retainer use, and the various choices involved should be understood by train crewmembers and included in railroad training programs.

16. The Union Pacific Railroad general director of safety should report directly to the Union Pacific Railroad president and chief operating officer.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the derailment was (1) a prolonged pattern of inattention and lack of action by Union Pacific Railroad management to protect effectively or relocate the multiple-unit engine shutdown switch in SD60M locomotives after the switch had repeatedly been recognized as subject to inadvertent activation; and (2) failure of Union Pacific Railroad management to adequately address critical safety issues such as dynamic braking system operational reliance and protection, and authorized maximum train speeds in the event of dynamic braking failure. Contributing to the severity of the accident was the failure of Union Pacific Railroad management to ensure accurate car weight assessment and training for operating personnel on retainer-setting procedures and effects.

RECOMMENDATIONS

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

-- to the Federal Railroad Administration:

Alert locomotive manufacturers and railroad operators about the dangers posed by improperly located safety-significant controls and switches in locomotives. (R-98-1)

Require railroads to ensure that the actual loaded weights of cars in a train are provided to the traincrew or, if the loaded weights are unknown, to implement a method to ensure that the maximum loaded weight is assigned. (R-98-2)

Require railroads to review steep-grade train-handling practices and, if necessary, make changes that will preserve a margin of stopping ability should a dynamic braking system fail. (R-98-3)

Carry out research, investigation, and analysis to determine maximum authorized train speeds for safe operation of trains of all weights, using speed-based margins of safety that can be easily measured by traincrews. (R-98-4)

Separate the dynamic brake requirements from the Power Brake Law rulemaking and immediately conclude rulemaking to require railroads to verify that the dynamic braking systems on all locomotives equipped with dynamic brakes are functioning properly before trains are dispatched. (R-98-5)

Require railroads to ensure that all locomotives with dynamic braking be equipped with a device in the cab of the controlling locomotive unit to indicate to the operating engineer the real-time condition of the dynamic brakes on each trailing unit. (R-98-6)

Require railroads to implement formal training on correct retainer setting and using procedures for traincrew members who may set or use air brake retainer valves. (R-98-7)

-- to the Association of American Railroads:

Alert locomotive manufacturers and railroad operators about the dangers posed by improperly located safety-significant controls and switches in locomotives. (R-98-8)

Carry out research, investigation, and analysis to determine maximum authorized train speeds for safe operation of trains of all weights, using speed-based margins of safety that can be easily measured by traincrews. (R-98-9)

-- to the Union Pacific Railroad:

Relocate and/or protect all safety-significant controls and switches in your locomotives so they cannot be inadvertently activated or deactivated. (R-98-10)

Reexamine your system of car weighing and car-consist weight reporting and take action to ensure that train consist weights reflect actual train weights. (R-98-11)

Reexamine your maximum authorized train speeds for safe operation of trains of all weights to establish new speed-based margins of safety that can be easily used by traincrews. (R-98-12)

Develop procedures to ensure that, before a train equipped with dynamic brakes is dispatched, all the dynamic brake systems on the locomotives are functioning properly. (R-98-13)

Equip all lead or controlling locomotive units with real-time displays capable of indicating to the engineer the dynamic brake condition on each trailing locomotive unit in the consist. (R-98-14)

Implement formal training on the proper procedures for setting and using retainers for those traincrews that may be required to do so. (R-98-15)

Review the functions and responsibilities of the Union Pacific Railroad general director of safety and make any organizational changes necessary to ensure that this official: (1) reports directly to the Union Pacific Railroad president and chief operating officer; (2) is involved in all Union Pacific Railroad operational issues that could affect train, railroad, and personnel safety and; (3) has the authority to take effective safety actions throughout the Union Pacific Railroad. (R-98-16)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

February 6, 1998

APPENDIXES

Appendix A -- Investigation and Sworn Testimony Proceeding

The Kelso railroad accident occurred about 11:52 a.m. Pacific standard time on Sunday, January 12, 1997, and was reported to the U.S. Coast Guard's National Response Center (NRC) in Washington, D.C., about 27 minutes later, at 3:19 p.m. eastern standard time. The NRC incident report number was 372918. The incident report was electronically sent to the Safety Board at 3:34 p.m. the same day. The Safety Board's Western Region Railroad Office was notified to launch at 2 p.m. Pacific standard time and Safety Board investigators arrived on the accident scene about 4 hours later, at 6 p.m. Pacific standard time.

As part of the investigation, a 1-day sworn testimony proceeding was held at the Hilton Flamingo Hotel in Las Vegas, Nevada, on March 7, 1997. Parties to the proceeding included the Union Pacific Railroad, the California Public Utilities Commission, the United Transportation Union, the Brotherhood of Locomotive Engineers, and the Federal Railroad Administration. Five witnesses testified during the proceeding.

this page intentionally left blank

Appendix B -- Excerpts from Applicable Operating Rules

This material was selected from the *UP System Timetable No. 2,* effective 0001 hours, October 29, 1995, for the Los Angeles Subdivision.

- On westward trains, dynamic brakes must be tested between MP 309 and MP 292. The conductor must advise the engineer of the number of cars in the train, the total tonnage, and the tons per operative brake.

- Passenger trains without operative dynamic brakes must not exceed 20 mph [while traveling from] Cima to Kelso.

- On the descending grade from Cima to Kelso, the following items A through G apply:

A. Freight trains exceeding 3,500 trailing tons must not be controlled exclusively with dynamic brake.

B. Retaining valves must be set —

1. On any freight train exceeding 80 tons per operative brake and 300 tons per dynamic brake axle (including helper locomotives). (See note 1.)

   Note 1: The retaining valve requirement does not apply to doublestack trains not exceeding 115 tons per operative brake, not exceeding 9,600 trailing tons, and not exceeding 300 tons per dynamic brake axle (including helper locomotives). These trains may contain up to 4 other intermodal cars (including 4 other multi-platform intermodal cars) if entrained in the rear 5,500 tons of the train.

2. On any freight train exceeding 500 tons per dynamic brake axle (including helper locomotives). Such trains must not exceed 15 mph.

3. On any freight train being handled without pressure maintaining.

C. [For] All freight trains exceeding 80 tons per operative brake and operating without retainers:

1. Anytime a train is stopped with a total brake pipe reduction exceeding 15 pounds, sufficient hand brakes, but not less than 15 pounds, must be applied to hold the train, and the brake system must be recharged before proceeding. (See note 2.)

2. Anytime total brake pipe reduction exceeds 15 pounds to control speed, the train must be stopped and retainers set before releasing the train brakes. The brake system must be recharged before proceeding. If retainers are not sufficient to hold the train while recharging, hand brakes must also be applied. (See note 2.)

   Note 2: Whenever [it is] necessary to apply hand brakes to hold the train on grade, after the air brake system is recharged, reduce the brake pipe pressure not less than 6 pounds to hold the train while hand brakes are released.

D. Freight trains not exceeding 85 tons per operative brake and 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 pounds). If more than minimum brake pipe reduction is required to control speed, a speed of 20 mph must not be exceeded.

E. Freight trains exceeding 85 tons per operative brake must not exceed 20 mph. *EXCEPTION:* Freight trains not exceeding 110 tons per operative brake may operate at a maximum speed of 35 mph, provided the train does not exceed 200 tons per dynamic brake axle, does not exceed 3,500 trailing tons, and is controlled exclusively with dynamic brake.

F. Freight trains authorized to operate at a maximum speed of 35 mph when controlled exclusively with dynamic brake must comply with the provisions of item D shown above when train air brakes are used. These trains may operate at a maximum speed of 35 mph after a running release, provided not more than a 12-pound reduction has been made, or the train has been stopped and the brake system has been recharged.

G. In cases where a train is required to stop, the provisions of *Air Brake Rule 31.1.3* will govern.

Appendix C -- How Air Brakes Work

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

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

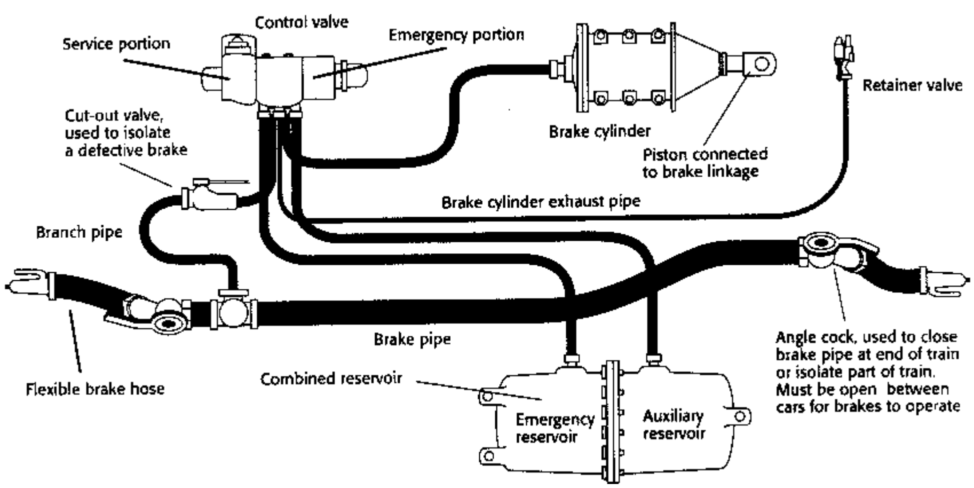


Figure A -- Diagram of freight car air brake system

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

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

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

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

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

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

Appendix D -- Train Dynamics Analyzer Simulations

General -- Train dynamics analyzer simulations were performed at the New York Air Brake Train Dynamics Simulations Group in Fort Worth, Texas, on February 4 and 5, 1997. The simulations were based on event recorder data recovered from UP train 6205's three locomotive units, postaccident inspection and testing of eight cars from the train, and postaccident interviews. The simulations were intended to determine

- the maximum speed while descending Cima Hill at which the engineer might have been able to stop the train, and
- what would have occurred if UP train 6205's maximum authorized speed had been 5 mph less (assuming that the engineer reacted as he did during the accident).

A train dynamics analyzer (TDA) is a computer system connected to a locomotive control stand. A television monitor that displays the behavior of the train on a graph-like track profile is mounted on the control stand. The train on the monitor moves in time along the graph-like track profile past established mileposts (MPs). The monitor display shows corresponding in-train buff and draft forces and trainline air brake pressures as they occur.

Simulation Design -- Before the simulations began, pertinent vehicle and braking information for all the cars and locomotive units in the Kelso accident train consist was loaded into the computer from the Association of American Railroads Universal Machine Language Equipment Register and the manufacturer's locomotive performance data. A complete track profile of the Cima Hill railroad area was also programmed into the TDA.

The group performing the simulations used the data from the lead locomotive unit's event recorder to develop a train-handling sequence that ran from Cima Hill's summit until the engineer placed the train in emergency. The accident engineer handled the simulation accident train for all runs; this was an approach designed to make the simulations as realistic as possible by accounting for unrecorded factors, such as the engineer's dynamic braking routine and technique.

Seven accident scenarios, or runs, were performed. Each of the runs began when the dynamic brakes and engines quit operating at Elora, MP 247.9. Based on the car data from the Union Pacific Railroad, each of the simulation runs used the following parameters: 143 tons per car; 90-psi brake pipe pressure; 100 percent braking efficiency; and 60 (of 75) car air brake retainers set. Starting conditions included a preset 9-psi brake pipe reduction and retainers precharged from a previous 11-psi brake pipe reduction at Cima.

Results Before the Stop Switch was Activated -- The results achieved by the TDA simulations for the period before the engine stop switch was activated confirmed that the nominal braking ratio, based on the average of the actual net braking ratios of eight accident train cars, was not only feasible but probably duplicated the behavior of UP train 6205. Results indicated that two working dynamic brake units could have kept the train speed under control as effectively as three working units, but two units required more amperage to control the train. (The accident engineer said that, judging by the amperage generated during the simulated dynamic braking, he believed that he had three working units, since the lower amperage allowed him to maintain a contingency reserve, as was his practice.)

Results After the Stop Switch was Activated -- Although several nominal braking ratios were found to be realistic for the simulation train before the stop switch was activated, no functional ratio could match UP train 6205's performance after the stop switch had been activated. Nominal braking ratios, which are based on total braking force divided by the car-light (empty) weight, are normally in the 28 to 30 percent range. When testers applied such a realistic ratio, the simulation accident train, in following the train-handling scenario as reported by the event recorder, would stop far short of the actual derailment site. The nominal braking ratio had to be degraded far below that actually found on most freight cars to even approach UP train 6205's performance as detailed by the event recorder.

According to brake tests performed by the AAR in 1991 and documented through a presentation in the minutes of the *Air Brake Association Meeting, Monday Afternoon - September 16, 1991*, a train descending the 2.2-percent grade of Cima Hill with an average braking ratio of 7.5 percent, an initiation speed of 23 mph, and 101.9 tons per operative brake was unable to stop on the grade using the air brakes alone. UP train 6205 was similar to the AAR air brake test train in every important aspect, except that it was 40 percent heavier, at 143 tons per operative brake.

The TDA simulator results, however, demonstrated that UP train 6205 should have stopped far short of the derailment site. Considering this discrepancy and the simulator's inability to realistically match UP train 6205's event recorder speed and time performance, the group performing the tests found that the TDA simulator was unable to give a realistic projection of all braking scenarios.

The group finally determined that the heavy braking and heat fade involved in the accident could not be accurately replicated by the TDA simulator. Therefore, the attempt to fulfill the purposes of the TDA simulations failed, although the exercise provided an overall idea of the kind of braking forces involved, since UP train 6205 behaved on the average like one that had only received a 15-psi brake pipe reduction.

ACRONYMS AND ABBREVIATIONS

AAR	Association of American Railroads
AEI	Automatic Equipment Identification
ANPRM	Advance Notice of Proposed Rulemaking
BN	Burlington Northern Railroad
CFR	*Code of Federal Regulations*
CMO	Chief Mechanical Officer
CTC	centralized traffic control
EMD	General Motors Electro-Motive Division
EOT	end-of-train
FRA	Federal Railroad Administration
MP	milepost
MU	multiple-unit
NPRM	Notice of Proposed Rulemaking
NRC	National Response Center
PUC	Public Utilities Commission
RSAC	Railroad Safety Advisory Committee
SP	Southern Pacific Railroad Company
TDA	Train Dynamics Analyzer
UP	Union Pacific Railroad