NATIONAL TRANSPORTATION SAFETY BOARD

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ROAD ACCIDENT REPORT
HICAGO, BURLINGTON, AND UINCY RAILROAD COMPANY TRAIN 64 AND TRAIN 824 DERAILMENT AND COLLISION WITH TANK CAR EXPLOSION CRETE, NEBRASKA FEBRUARY 18, 1969

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-RAR-71-2

SS-R-5

RAILROAD ACCIDENT REPORT

CHICAGO, BURLINGTON, AND
QUINCY RAILROAD COMPANY
TRAIN 64 AND TRAIN 824
DERAILMENT AND COLLISION
WITH TANK CAR EXPLOSION
CRETE, NEBRASKA
FEBRUARY 18, 1969

ADOPTED: FEBRUARY 24, 1971

U.S. NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
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16. Abstract - At about 6:30 a.m., on February 18, 1969, Chicago, Burlington, and Quincy Train No. 64 derailed the 72nd to the 90th cars, inclusive, at a turnout located on the spiral of a 2^{o} curve as the train was entering Crete, Nebraska, at a speed of about 52 miles per hour. The derailed cars struck standing cars on a siding south of the main track and the cars of train 824 standing on a track north of the main track. A tank car in train 824 was completely fractured on impact with the derailed cars which released the lading of 29,200 gallons of anhydrous ammonia into the atmosphere. A gas cloud was formed which blanketed the surrounding area for a considerable time due to the weather conditions. Three trespassers riding on train 64 were killed as a result of the derailment and six people were killed and 53 were injured as a result of exposure to the cloud of ammonia. The Safety Board determined that the derailment was caused by the movement of a rail of the turnout due to lateral forces produced by the locomotive as it moved over track alignment and surface deficiencies of the track. The complete fracture of the tank car on impact was contributed to by the brittleness of the steel of the car caused by the low ambient temperature.

17. Key Words Railroad train accidents, Accident investigation, Railroads, Derailment research; Railroad track conditions; Anhydrous ammonia; Tank cars, Brittle fracture of steel, Trespassers killed, Bystanders killed, Hazardous material, Temperature inversion, Locomotive conditions, Explosion, Track fastenings.

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FOREWORD

This report of facts and circumstances and the determination of probable cause by the National Transportation Safety Board are based on facts developed in an investigation conducted by the Federal Railroad Administration and from observations at the scene of the accident by a Member of the Safety Board and personnel of the Board's Railroad Safety Division. In developing its recommendations, the Safety Board has considered the suggestions of the Federal Railroad Administration made in forwarding the investigatory data. The recommendations made herein, however, are those of the Safety Board.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D. C. 20591
RAILROAD ACCIDENT REPORT

ADOPTED: February 24, 1971

CHICAGO, BURLINGTON, AND QUINCY RAILROAD COMPANY
Train 64 and Train 824
Derailment and Collision with Tank Car Explosion
Crete, Nebraska
February 18, 1969

I. SYNOPSIS

At about 6:30 a.m., on February 18, 1969, Chicago, Burlington, and Quincy (CB&Q) train No. 64 derailed the 72nd to the 90th cars, inclusive at a turnout located on the spiral of a 2° curve as the train was entering Crete, Nebraska, at a speed of about 52 miles per hour. The derailed cars struck standing cars on a siding south of the main track and the cars of train 824 standing on a track north of the main track. A tank car in train 824 was completely fractured by the impact of the derailed cars, and released 29,200 gallons of anhydrous ammonia into the atmosphere. A gas cloud was formed and, due to the weather conditions, blanketed the surrounding area for a considerable time. Three trespassers riding on train 64 were killed as a result of the derailment. Six people were killed, and 53 were injured as a result of exposure to the cloud of ammonia.

The National Transportation Safety Board determines that the derailment was caused by the movement of a rail of the turnout due to lateral forces produced by the locomotive as it moved over track which had alignment and surface deficiencies. The cause of the complete failure of the tank car which released the poisonous gas, following derailment, was a heavy blow delivered to the head of the tank car by the coupler of another car and the brittleness of the tank car steel at the ambient temperature of 4° F.

II. FACTS

A. Location of Accident and Method of Operation

The accident occurred at Crete, Nebraska, 20.1 miles west of Lincoln on the fourth subdivision of the CB&Q's Lincoln Division which extends from Gaines to Lincoln, Nebraska, 98.4 miles. The railroad consists of a single track over which trains are operated in either direction by signal indications of a traffic control system.

A single-track branch line, known as the Wymore Branch connects with the main track at a point 4,016 feet west of the station at Crete. (See Figure 1 page 3.)

At Crete, a siding 3,996 feet in length, known as the Old Wymore Main, parallels the main track on the south. The west switch of the siding is located 3,261 feet west of the station. A siding 4,703 feet in length also parallels the main track on the north. The west switch of this siding is located 3,514 feet west of Crete Station.

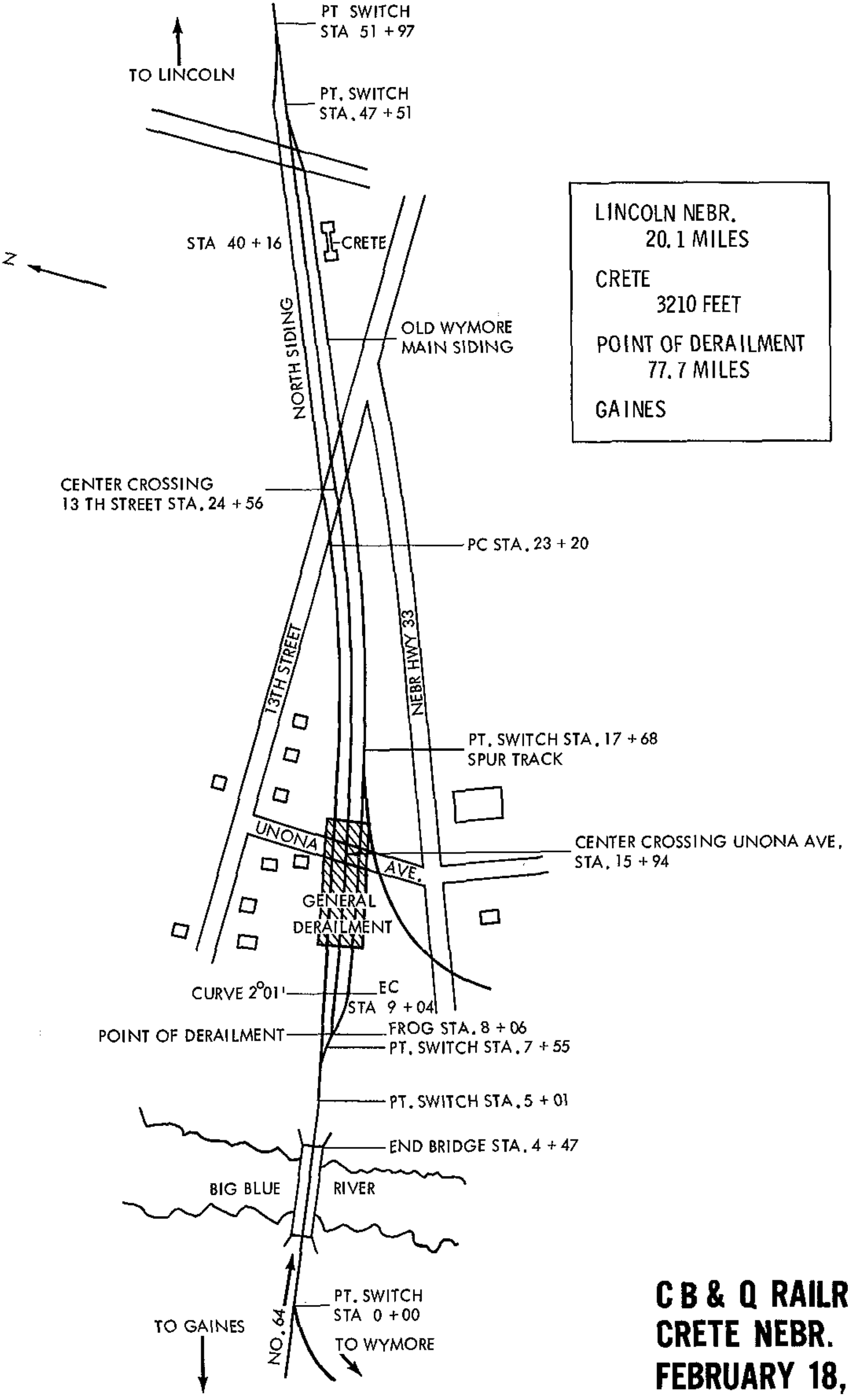
A bridge over the Blue River is located between the switch of the north siding and the switch of the Wymore Branch. The bridge is 382 feet in length and its east end is located 53.7 feet west of the west switch of the north siding.

West of Crete on the main track, there is a 2^{o} curve to the south for 2,106 feet and then straight track for 1,175 feet which extends over the bridge spanning the Blue River to the beginning of the spiral of a 2^{o} 01' curve to the left. The initial derailment occurred 202 feet into the spiral and 99 feet before the beginning of the 2^{o} 01' curve. The 2^{o} 01' curve extends about 600 feet to the area of the general derailment and for 1,214 feet farther eastward. Just west of the derailment site, the grade for eastbound trains is 0.57 percent descending for a distance of about 3.2 miles to a point about 50 feet west of the bridge, and then level to a point 300 feet east of Crete Station.

A residential and light business area is located along each side of the railroad east of the Blue River, as shown in the sketch, Figure 1. In the area of the accident, there are no buildings between the highway and the railroad. Residences are located along each side of Unona Avenue north of the railroad and along both sides of 13th Street.

The maximum authorized speed for freight trains in the vicinity of the accident is 50 miles per hour.

FIGURE 1



C B & Q RAILROAD
CRETE NEBR.
FEBRUARY 18, 1969

B. Description of the Accident

1. Track

The rails of the track structure in the vicinity of the accident were 112-pound, RE rails, 39-feet in length, manufactured by the Illinois Steel Company in 1941 and laid in the track in 1942. Several rails in the west turnout of the south siding were manufactured by the Colorado Fuel and Iron Company in 1937, and laid in the track in 1963. The rails were connected with 24-inch 4-hole joint bars, secured with 1- by 6-inch bolts. The track was fully equipped with 8- by 11-inch double-shoulder, ribbed-bottom tie plates on 7- by 8-inch by 8-foot 6-inch treated ties spaced 24 to each 39-foot rail length. Rails were secured to the ties by two 5/8- by 5½-inch rail-holding spikes per tie plate. No additional rail holding or anchor spikes were provided in curves or turnouts. Sixteen grip-type rail anchors per rail length were provided. The track was ballasted with crushed dolomite rock to a depth of 12 inches below the bottoms of the ties. The subgrade in this area was loam soil.

The No. 11 turnout, at the west end of Old Wymore Main siding, where the initial derailment occurred was provided with 112-pound rails and 16-foot 6-inch switch rails. The switch was operated by a hand-thrown, high-rigid-type switch stand and was protected by an electric facing-point lock. The main track guardrail was 15 feet long with a 6-foot guarding face. The guardrail was secured to the north rail with four 1- by 7-inch heat-treated bolts and two forged steel adjustable guard-rail clamps. Three 3/4- by 7- by 17-inch steel plates and six 3/4- by 7- by 16-inch steel plates fastened to the ties by track spikes were also used to secure the guardrail. The 1-7/8-inch flangeway was maintained with cast iron filler blocks secured with the 1-inch bolts and with the adjustable blocks secured with the guardrail clamps.

2. Trains

About 2 a.m., February 18, train 824, consisting of one diesel-electric locomotive unit and 49 cars, entered the main track from the Wymore Branch and then moved into the north siding. The train was stopped on the siding with three cars of anhydrous ammonia in the vicinity of the Unona Avenue Crossing.

Sometime prior to the accident, 11 box cars were placed on the siding on the south side of the main track. The west end of these cars was about 270 feet east of the west switch.

Train No. 64, operating as Extra 624 East, consisted of seven diesel-electric locomotive units, 92 cars and three cabooses. The train weighed 6,364 tons. Crews were changed at Gaines, and the train was prepared to operate to Lincoln. A red tag had been applied to the control switch of the leading locomotive unit, and it advised that the dynamic brake could not be used, even when this unit was coupled with other locomotive units. The train received an airbrake test, and no exceptions were taken to the condition of the brakes. The train departed from Gaines at 4:55 a.m. and was scheduled to proceed to Lincoln without any intermediate stops. The locomotive was not provided with a speed-recording device but was equipped with a speedometer. No stops were made en route, and the trip was uneventful until train No. 64 approached Crete.

When the speed of the train reached about 60 miles per hour at a point about 4.5 miles west of Crete, the throttle of the locomotive was moved to idle position to reduce power. The throttle was not again advanced to increase power before the accident occurred. The train's speed was reduced to 47 miles per hour by this action but, as it moved eastward on the 0.57 percent descending grade, the speed was increased. The engineer applied and released the independent brake on the locomotive to control the speed of the train when it was about 2 miles west of Blue River. As the locomotive moved over the Blue River Bridge, the train's speed was observed by the engineer to be 52 miles per hour. The engineer made another brake application on the locomotive in the vicinity of the Blue River but, when questioned after the accident, he was not specific as to the location of the train when the brakes were released. The crew advised that there was no noticeable slack action in the train as it approached Crete.

3. Locomotive on Train 64

The locomotive consisted of seven diesel-electric units coupled in multiple-unit control. All but the rear unit were manufactured by the Electro-Motive Division of General Motors Company. The rear unit was manufactured by the General Electric Company. The numbers, type, and weights of the units, beginning with the front unit, were as follows:

Number	Type	Weight (lbs.) Front Truck	Weight (lbs.) Rear Truck	Total Weight (lbs.)
624	GP-40	138,360	137,453	274,813
620	GP-40	138,360	137,453	274,813
183	GP-40	137,027	136,173	273,200
972	GP-30	128,580	128,820	257,400
961	GP-30	128,580	128,820	257,400
513	SD-24	171,953	174,460	346,413
562	U-28C	195,980	195,186	391,166

Diesel-electric locomotive units used in train service are generally provided with flexible type trucks. This type of truck provides better riding and tracking qualities for the locomotive unit than the rigid type used on work switching units. The seven units of the locomotive involved in this accident were all provided with the flexible type trucks, even though they were of different designs. The center plates of many six-wheeled diesel locomotive unit trucks are located at the center of the truck. The center plates on the trucks of the U-28C-type locomotive unit, however, are laterally centered but are off center longitudinally, producing a long and short section of the truck. The trucks are installed so that the long section is towards the center of the unit. The trucks of the rear unit are provided with only coil springs. Friction is depended upon to dampen the harmonic spring action as no mechanical dampening device is provided. The natural frequency of vibration of the locomotive on its springs in the vertical direction was reported by the manufacturer to be 97 cycles per minute.

4. Weather

The weather bureau at Lincoln reported that on the day of the accident there was a high-pressure area over most of the State of Nebraska, including Lincoln and Crete. A ground fog was reported at 6:57 a.m. along with high, thin scattered clouds at 12,000 feet; temperature +4° F., and the wind was calm. A temperature inversion had occurred in the area at this time. Under normal conditions, the warmer air near the earth's surface flows upwards toward the cooler upper air, producing an updraft. If the lower air becomes cooler than the upper air, the draft or upward flow stops; this is referred to as a temperature inversion. When there is no wind, there can be little change of the atmosphere within the area affected by the temperature inversion. This is one of the conditions that can produce smog or air pollution over large cities.

5. Derailment

The engineer first became aware of a problem when an emergency brake application occurred as the locomotive approached a road crossing east of Crete Station about 6:30 a.m. The engineer assumed that the emergency application of the brakes was the result of the train having parted, and he released the locomotive brakes to prevent the front of the train from stopping abruptly. If the front portion stopped abruptly, the rear portion could collide with it. The front of the train came to a stop 5,743 feet east of the station. The engineer was not aware of the derailment until he was advised by the crewmembers on the caboose by radio.

After the train stopped, an inspection by the front brakeman showed that the airhoses had parted between the 14th and 15th cars, and that an outlet pipe had been broken from tank car GATX 1827, the 16th car. He found a piece of rail, about 18 inches in length, wedged under the car on the airbrake valve of the 28th car, GN 6583. He removed the rail, placed it on a car, and continued his inspection. He also found the train had parted at the rear of the 71st car, but he could not see the derailed cars due to the fog.

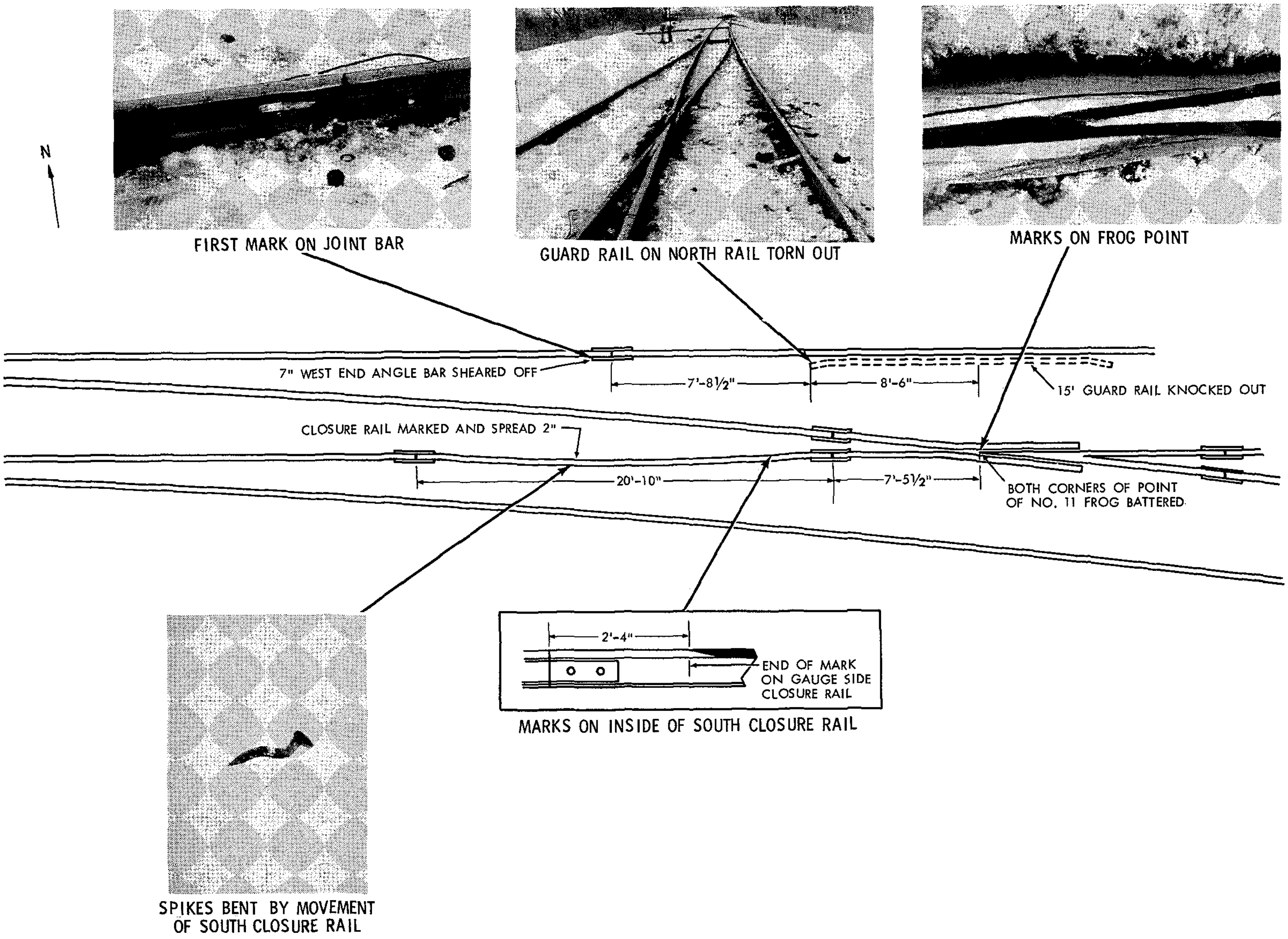
The conductor and flagman on the caboose reported that there was no slack action of the train as it approached Crete. The first knowledge they had of the accident was the fact that the brakes were applied in emergency. The rear of the train came to a smooth stop, and the crewmembers then saw some of the derailed cars. The conductor reported this fact to the engineer by radio. The conductor and flagman saw a dense cloud being formed and saw that it started to move toward the caboose. When they smelled ammonia gas in the air, they immediately departed the caboose and ran westward to escape the gas cloud.

6. Marks of Derailment on Track Structure

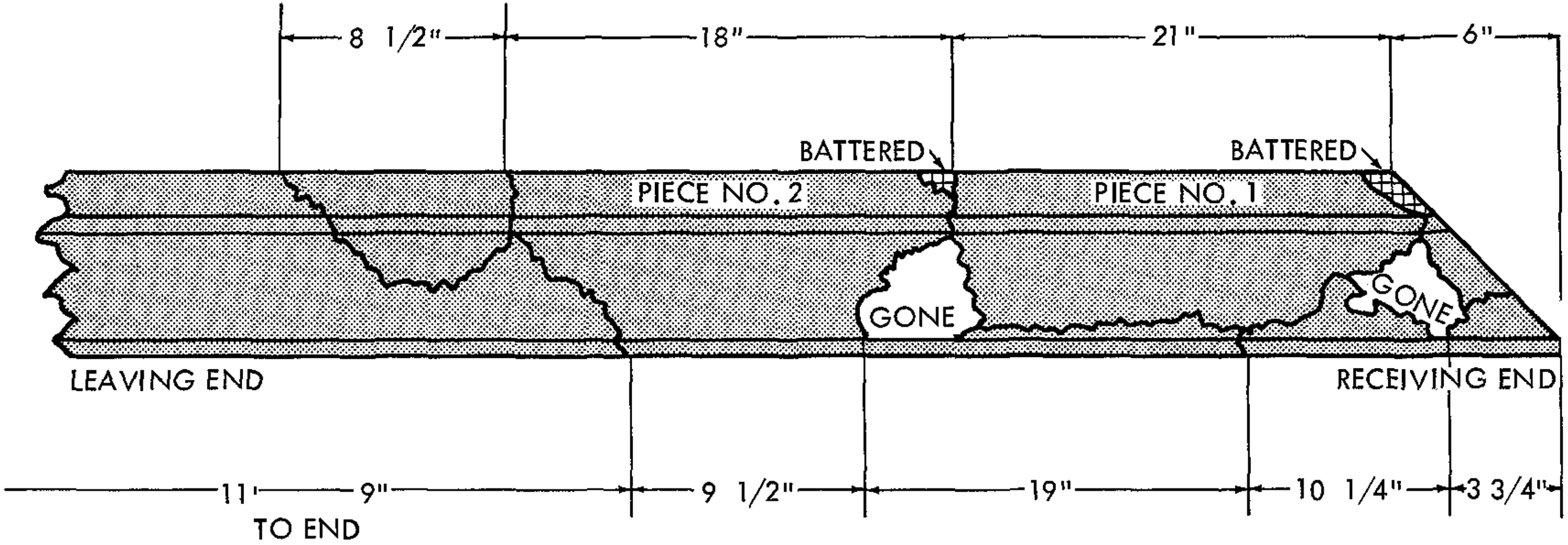
The first mark of the derailment was on a joint bar of the north rail of the turnout leading to the Old Wymore Main siding 7 feet 8½ inches west of the west end of the guardrail. Seven inches of the west end of the inside joint bar were sheared off from contact with the tread of a wheel which dropped inside the rail. Opposite this mark, a 20-foot 10-inch section of the closure rail, which was jointed to the frog, was spread southward about 2 inches. The point of maximum spread was in the center of the section directly opposite the mark on the joint bar. The gage side of the head of the spread closure rail bore a heavy scrape mark which indicated that a wheel was derailed and bore against the side of the rail. This mark ended at a point 2 feet 4 inches from the toe of the frog, indicating that the derailed wheel had rerailed. (See Figure 2 on page 8.) The tie plates were still under the base of the rail, and most of the spikes were still in the tie plate holes. The spikes on the outside of the rail, however, were bent outward at 90° into an "S" shape. Examination of the spikes disclosed that the base of the rail apparently had been raised above the retaining lip of the tie plates and was bearing against the spikes just below the head. This caused the spikes to bend as shown in Figure 2.

The guardrail attached to the inside of the north rail, protecting the frog point was broken and torn out. About 4 feet 5 inches of the west end of the guardrail was broken, as shown in the sketch in Figure 3, page 9. The two larger pieces of the broken portion of the guardrail were battered on their receiving ends. The piece of broken guardrail, marked No. 1 in Figure 3, was the piece found by the brakeman on

FIGURE 2



FIRST MARKS OF DERAILMENT



BROKEN GUARD RAIL

FIGURE 3

the 28th car, GN 6583. The piece of guardrail marked No. 2 was found in the vicinity of the turnout, and the piece of guardrail, which was approximately 11 feet 9 inches long, was found under the caboose of No. 6 about 120 feet east of the point of the frog.

Both sides of the point of the frog were battered by wheels which had struck the surfaces of the point. Wheel marks were found on the ties east of the frog along the south side of the main track. These marks continued to the area of the general derailment.

7. Track Conditions Found Following Derailment

There were no published CB&Q specifications for the maintenance of track. Officials of the carrier relied on the experience of their supervisors to see that the track was maintained in proper condition. Maintenance officials made checks for ride comfort by periodic train rides over the track, supplemented by visual inspections. The visual inspections were not on a scheduled basis.

The turnout at the west end of the Old Wymore Main siding was in the spiral of the 2° 01' curve. Inspections immediately after the accident disclosed a number of irregularities in the track condition.

The track gage varied from the 56½-inch standard between 56¼-inches at a point near the switchpoint to 56 7/8 inches at a point 31 feet east of that point. A rate of change in superelevation of 1 3/8 inches in 31 feet began at a point 17 feet west of the point of switch. The surface varied from the design grade by 2¼ inches within 31 feet eastward of a point 4 feet west of the point of switch. At the same location, the track curvature changed from 0° 15' to the right to 1° 15' to the left in 15.5 feet. Details of the track conditions are found in Appendix 1. These measurements were taken after the spread rail had been returned to its previous position and spiked into the old holes which had been plugged. The frozen-in ties were not displaced by the spreading rail. The track conditions resulted in a variance of the equilibrium speed of the train [2] as it moved around the spiral of the curve. Table No. 18 of Appendix 1 shows the equilibrium speed for each 15.5 foot station from the point of the spiral eastward to the point of the derailment.

8. Condition of Locomotive and Cars Following Derailment

The locomotive and first 71 cars of No. 64, were inspected after the accident at Crete, and a more thorough inspection was made after

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[2] Equilibrium speed is that speed at which the resultant of the weight and centrifugal force is perpendicular to the plane of the track. Therefore, the components of the centrifugal force and the weight in the plane of the track are balanced, and no lateral force is applied to the rails in either direction.

their arrival at Lincoln. No defective conditions or marks of derailment were found on any of the locomotive units. Damage and marks of the derailment were found on the cars.

Some of the cars in the front portion of the train were damaged slightly as a result of the initial derailment and the following general derailment. The defects found on those cars involved were as follows:

> The 14th car, B&M 77924, a loaded boxcar, had a broken coupler yoke on the A, or west, end. The fractured surface contained no evidence of any previous defect. The follower block, a part of the draft gear assembly which is secured by the coupler yoke, fell to the track. The block struck the airhose on the west end of the car, causing a separation of the airhoses between this car and the following car.
>
> The 16th car, GATX 1827, an empty tank, had a broken outlet pipe which fractured at the breakage groove. There were marks on parts of the underframe of the car and in the snow in the middle of the track where the outlet pipe, after it was broken, had bounced repeatedly from the ties to the underside of the car until the safety chain broke. The broken pipe was found along the track in the vicinity of the front portion of the train.
>
> The 18th car, SP 209451, a loaded boxcar, had a broken uncoupling lever, a dent in the body bolster, nicks in the lead axle, and a broken brake lever on the east end.
>
> The 28th car, GN 6583, a loaded boxcar, had a nick in the flange of the R-1 wheel, the leading wheel of the east truck on the north side. The next wheel on the north side at location R-2, had an abraded mark on the outer rim of the wheel about 2½ inches long by one-half inch wide and 1/16 inch deep. A brake beam on the east end was bent upwards. The broken piece of guardrail about 18 inches long, which was found wedged between the airbrake control valve and the bottom of the car, had broken the end cover of the valve. Even though this car was on the track when inspected, the evidence indicated that the wheels had recently been derailed.
>
> GN 6583, was a steel boxcar equipped with Evans D. F. loaders, and was built by the Great Northern Railway in 1953. It was 41 feet 10 inches long over the ends, 10 feet 3½ inches at its extreme width, and 14 feet 7 inches high. The nominal capacity, light weight, and load limit were: 110,000 pounds, 50,000 pounds, and 126,700 pounds, respectively. Truck centers were 30 feet 10 inches, and the axles of each truck were 5 feet 6 inches apart. The car was loaded with lumber at Klamath Falls, Oregon, on February 12,

1969, consigned to Chicago, Illinois. It was routed via the Great Northern, Western Pacific, and Denver and Rio Grande Western railroads to Denver, Colorado, where it was interchanged to the CB&Q and placed in train No. 64 on February 18, 1969. No exceptions were noted during the inspections of the car en route, nor were any repairs made.

GN 6583 was loaded with 75,340 pounds of lumber which was found to be fairly evenly distributed throughout the car. The gross weight of the car on the rails was about 125,300 pounds. After the accident, the car was weighed on a locomotive scale that determined the weight on each wheel, with the following results:

WHEEL LOCATION		LEFT OR SOUTH SIDE	RIGHT OR NORTH SIDE
1		15,460	16,700
2		15,100	17,100
3		14,260	16,500
4		14,340	15,840
	Total	59,160	66,140

The weights indicated that the right or north side of the car was 6,980 pounds heavier than the left side.

C. Results of the Derailment

1. General Derailment of the Train

As No. 64 passed over the turnout leading to the Old Wymore Main siding, the spread closure rail allowed the north wheels of the east trucks of GN 6583, the 28th car, to derail inside the north rail just west of the guardrail. The north wheels struck and broke the guardrail, rerailed at the frog, and continued eastward on the track. There is no evidence that any of the following cars derailed until the 72nd car. ATSF 20820, a loaded boxcar, derailed at the frog of the switch towards the southside of the main track--the direction against which the guardrail, now broken, had provided resistance. The 73rd through 90th cars also were derailed. The derailed cars continued eastward along the southside of the main track and struck the boxcar standing on the Old Wymore Main siding. The first car on the siding was propelled eastward, and the second to the fifth cars, inclusive, were turned on their sides south of the track. The 72nd to the 75th cars, inclusive, of No. 64 came to a stop south of the main track in the area of the general derailment, about 700 feet east of the initial point of the derailment. The 76th car, and several of the following cars, were diverted northward across the main track in the area of the general derailment where they struck the standing cars of No. 824 on the siding, including the three tank cars loaded with anhydrous ammonia. (See Figure 4, on page 13 .)

Figure 4

The 38th car in No. 824, GATX 97076, was derailed and turned on its side across the main track, east of Unona Avenue. The 40th car, GATX 97041, was derailed and turned on its side north of the siding and west of Unona Avenue. These two cars containing anhydrous ammonia did not develop leaks, and at a later time their contents were transferred into other vehicles.

The tank of the 39th car, GATX 18120, shattered after it was struck by the derailed cars. A circumferential fracture which developed just ahead of the manway, located in the center of the tank, divided the tank into two sections. The shorter section also was broken into a number of pieces. The top portion of the shell, about 16 feet in length, was propelled southward about 200 feet over Highway No. 33 and landed in the front yard of a residence. The tank head was broken just above the coupler, and it was broken from the tank in two pieces. The bottom portion of the head, with part of the center sill still attached, was hurled northward about 140 feet, where it landed along Unona Avenue. Other portions of fractured sections of the tank were propelled toward the north side of the track, and came to rest in various positions as shown in Figure 5, page 15. The longer section of the tank, about 30 feet in length, remained intact and came to rest north of the siding and east of Unona Avenue.

Fifteen of the derailed cars in train No. 64 were damaged extensively or destroyed, and four were damaged moderately. Four of the cars on the Old Wymore Main siding were damaged heavily and three were damaged moderately. One of the tank cars on the siding was destroyed, and two were damaged extensively. Two other cars in train 824 were damaged moderately.

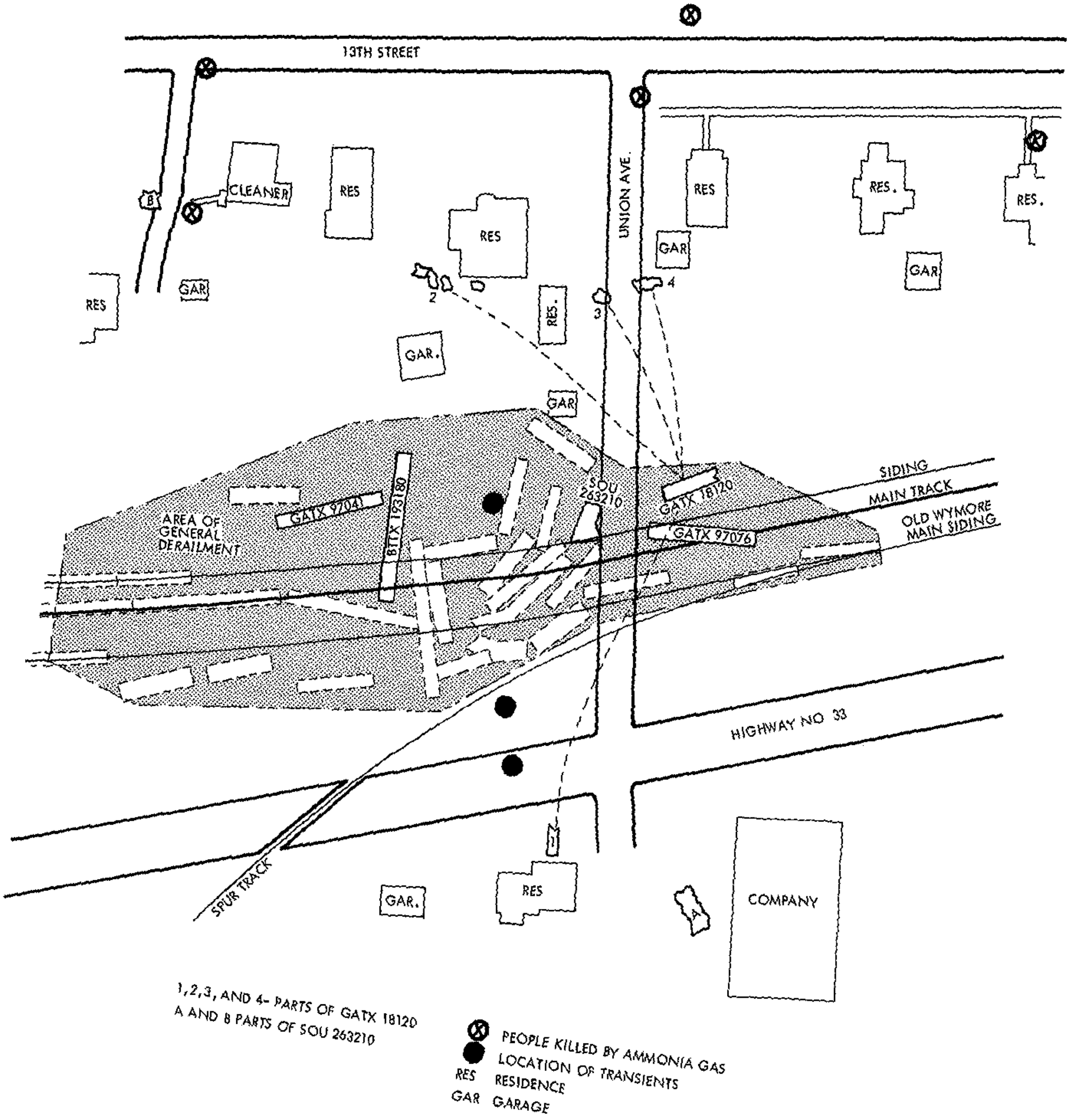
2. Trespassers

Three transients who were riding on one of the derailed cars of train No. 64 were killed in the derailment of No. 64. The bodies of two of the transients were found south of the track near or on Highway No. 33, and the third was found north of the railroad near the derailed cars. (See Figure 5). It could not be determined on which car they were riding when the accident occurred.

3. Ammonia Gas Cloud

Anhydrous ammonia is a liquid which at atmospheric pressure boils at minus 28° F. It will remain in the liquid state when the temperature is above the boiling point if contained in a vessel under pressure. If the pressure is removed when the temperature is above the boiling point, the liquid will be converted rapidly to a gas. When vaporized, one part by volume of the liquid becomes 877 parts by volume of gas. To conserve space, the commodity is loaded and shipped in tank cars as a

FIGURE 5


13TH STREET
UNION AVE.
CLEANER
RES
RES.
GAR
GAR.
B
1
2
3
4
A
AREA OF GENERAL DERAILMENT
GATX 97041
BTTX 193180
SOU 263210
GATX 18120
GATX 97076
SIDING
MAIN TRACK
OLD WYMORE MAIN SIDING
HIGHWAY NO 33
SPUR TRACK
COMPANY
1,2,3, AND 4- PARTS OF GATX 18120
A AND B PARTS OF SOU 263210
⊗ PEOPLE KILLED BY AMMONIA GAS
● LOCATION OF TRANSIENTS
RES RESIDENCE
GAR GARAGE

liquid under pressure. If, after the ammonia is loaded, the temperature rises, some of the liquid will be converted to a gas which increases the pressure within the tank and maintains the remainder of the commodity in the liquid state. When the ambient temperature is plus 4° F., as it was on the day of the accident, the pressure necessary to retain the anhydrous ammonia as a liquid in the tank is about 20 pounds (p.s.i.g.)

When the tank of GATX 18120 was struck and shattered, the pressure within the tank was instantly released. This permitted the liquid anhydrous ammonia to vaporize in very large quantities and in a short period of time. The vapor was released into the atmosphere, and, due to the temperature inversion and lack of wind, a cloud was formed which blanketed the immediate area. The cloud extended westward beyond the Blue River and for several blocks north and south of the railroad. The concentrated cloud of ammonia vapor was retained in the area for a considerable period of time.

The conductor and flagman saw the cloud forming and approaching the caboose. When they smelled the odor of the ammonia, they left the caboose and ran westward. The vapor cloud overtook the conductor and flagman as they started to cross the Blue River Bridge. The conductor dropped from the bridge to the riverbank where he was found later. The flagman continued westward until he reached the highway west of the river where he found rescuers whom he told of the conductor's plight. Both employees were seriously injured by exposure to the ammonia vapor.

The houses of several townspeople, close to the north side of the railroad in the vicinity of Unona Avenue, were damaged by flying parts from the derailed cars and from the bursting tank car. These houses quickly filled with ammonia gas, forcing the people to abandon them and to try to escape. Several other people, after they smelled the ammonia gas and saw the vapor cloud, decided to leave their homes and seek shelter away from the area.

Any person who ventured outside of his house into the vapor cloud without adequate protection was either killed or seriously injured as a result of exposure to the ammonia. Five people were killed immediately by the ammonia, one person died subsequently, and 28 people were injured seriously. Figure 5 shows the locations where the fatalities occurred.

On inhalation, anhydrous ammonia produces chemical injury to the linings of the respiratory tract. Depending on the concentration of the gas in the atmosphere, and in length of time of exposure, results range from irritation of the nose and throat to death due to laryngeal or bronchial spasm and/or severe pulmonary edema.

Within the area where the fatalities occurred, a number of people who stayed in their homes and kept all windows and doors closed tightly until assistance arrived survived with either minor injuries or, in many cases, no injuries.

When interviewed after the accident, one couple who resided near the intersection of Unona Avenue and 13th Street, stated that they heard the noise of the train being wrecked and soon thereafter smelled ammonia. They looked out of the window and saw nothing but the dense fog and decided that the safest place was in their cellar. They immediately went there, taking along a bucket of water and cloths. The couple continually applied wet cloths to their faces until they were rescued about 1 hour later. They were not injured. Other people who ventured into the fringes of the vapor cloud escaped injury by keeping a wet cloth over their faces.

4. Post-Crash Activities

Crete, Nebraska, has a population of about 3,500 people, a seven-man police force, and a 40-man volunteer fire and rescue department. Emergency information is routed through the municipal powerplant where operators are on duty throughout the 24-hour period. Upon receipt of any emergency information, the operators at the powerplant promptly notify the proper authorities.

Many of the townspeople who apparently heard the noise of the derailment of the train and saw the vapor produced by the escaping anhydrous ammonia, flooded the emergency telephone with calls to report the accident. This information was dispatched to the proper officials, the police, and fire departments. Almost all of the personnel so notified promptly reported for duty. Fire department personnel with trucks and equipment were dispatched into the affected area where a house-to-house search was made to effect a complete evacuation. It was necessary for the rescuers to wear gas masks, and to provide masks for the use of the people being evacuated. A shortage of masks soon became evident, but additional ones were promptly obtained from the Crete Mills 3/ and from the National Guard Armory. The vapor cloud became so dense at times that it was necessary to lead the rescue vehicles with a man ahead. Between 200 and 300 people were removed from the area, and the evacuation was completed about 9:30 a.m.

The police department quickly sealed off the area to the best of their ability. The county sheriff and the surrounding communities' police and fire departments were promptly notified, and they supplied

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3/ The Crete flour and grain mills are located along the railroad in the vicinity of the station. Due to the nature of their operations a number of gas masks are maintained by this industry.

valuable assistance. The Crete civil defense organization assisted the various departments with the emergency work, and its director notified the State Police, the National Guard, the Red Cross, and the State Fire and Health Departments. A National Guard unit was mobilized and patrolled the evacuated area to prevent looting and to keep unauthorized persons from entering the area. The Guard also provided emergency radio-telephone facilities which supplemented the overloaded telephone circuits to Crete.

A small hospital with 64 beds, staffed with 21 registered nurses and five doctors, is located in Crete. When the emergency occurred, most of the personnel of the hospital immediately reported for duty. Two inhalation therapists were brought in to assist the staff. The injured people were treated promptly. An emergency plan formulated by the hospital had been rehearsed to the extent that all were thoroughly familiar with its operation. This training was responsible for much of the hospital's success in treating the injured and in handling the emergency.

Many of the people who had been evacuated from the affected area were taken to the firehouse where the Red Cross had made arrangements to feed and care for the people until they could return to their homes.

The evacuees were permitted to return to their homes about 11 a.m. Thursday, February 20th. Each person was given a copy of instructions issued by the State Health Department informing them of the precautions to be taken with food and other material which could have become contaminated by the ammonia gas. 4/

D. Tank Cars on Train 824

1. Loading

The three tank cars of anhydrous ammonia which were damaged in the derailment had been loaded by the Phillips Petroleum Company at its facility in Hoag, Nebraska, 24.6 miles south of Crete on the Wymore Branch. After the accident occurred, representatives of the Department of Transportation made an investigation of the loading procedures at this plant, and no irregularities were noted.

4/ Appendix No. 4--Instructions issued by the Nebraska State Department of Health.

The anhydrous ammonia is stored at a temperature of minus 28° F. When it is to be loaded, it is heated to a temperature of plus 25° F. and loaded in the cars by weight. The three cars involved in the accident were loaded with the following amounts:

GATX 97076	-	159,700 pounds
GATX 18120	-	159,660 pounds
GATX 97041	-	159,520 pounds

GATX 18120, contained 159,660 pounds of anhydrous ammonia, which is equal to 29,188 gallons at a temperature of plus 10° F. Since this car had a capacity of 33,639 gallons, the liquid was within 22-7/8 inches of filling the tank. The tank was not insulated, and it had been loaded a sufficient length of time for the temperature of the liquid to be close to that of the ambient temperature of plus 4° F. when the accident occurred. Thus the tendency of the ammonia to vaporize was somewhat less at the time of the accident than when the car was loaded.

2. Description of the Tank Car

GATX 18120 was a 33,639-gallon tank car, constructed to DOT Specifications 112A340W, for the transportation of certain liquefied gases, including anhydrous ammonia. The tank was 59 feet 11 inches in length, with an inside diameter of 119 inches. The shell was constructed of 5/8-inch steel plate and the ellipsoidal tank heads were constructed of 11/16-inch steel plate. The car was 63 feet 3 inches in length over the ends, with trucks spaced 52 feet 4 inches apart, with short stub-type center sills welded to the tank. The car was equipped with 100-ton trucks, 36-inch wheels, and roller bearings. The estimated light weight was 85,300 pounds, and the permitted total weight on the rail when loaded was 263,000 pounds.

Tank cars were not inspected at the plant by railroad personnel prior to or after being loaded. Employees of the Phillips Petroleum Company, however, checked the cars for damage before loading and for leakage after loading before applying the "Dangerous" placards as required by the Code of Federal Regulations for the shipment of this commodity. No exceptions were taken to the three tank cars by the employees of the shippers.

E. Discussion of Tests Conducted by the Association of American Railroads

1. Metallurgy of Tank of GATX 18120

After the accident, all of the recovered pieces of the broken tank of GATX 18120 were forwarded to the Research Center of the Association of American Railroads in Chicago, Illinois, for testing and analysis. After analyzing the broken surfaces of the tank sheets, and from the positions in which the broken pieces were found, the Research Department came to the conclusion that the initial fracture occurred on the tank head close to where the short center sill was attached. The fracture was caused by a direct impact and progressed rapidly in a number of directions through the sheets of the tank. Two other areas of impact were found; one occurred after the fracture of the tank shell and the other before. The evidence indicated that neither of these areas of impact developed the initial fracture. It was the Research Department's opinion, after analyzing the position of the derailed cars, that the coupler of BTTX 913180, the 87th car of No. 64, loaded with small trailers, struck the tank head on the west end of the tank car and caused the primary fracture which resulted in the shattering of the tank. If this did occur, then the 30-foot portion of the tank was rotated 180° before it came to rest along the north side of the siding.

The report also disclosed that all but a very small number of the tank fractures were of a brittle nature. Tests made of samples taken from the tank head indicated that the nil-ductility transition temperatures (NDTT) were between + 75° F. and + 80° F., which was considerably above the ambient temperatures of +4° F. This means that the metal was brittle at the low temperature. Tests made on samples taken from the side sheets of the tank indicated that in some cases the NDTT was between +20° F. and +40° F. which was also appreciably above the ambient temperature. These tests indicate that, for the temperatures that existed at Crete, the toughness of the steel plate from which the car was fabricated was low, and the impact initiated brittle fractures.

The steel plates from which the tank was manufactured had properties with a few unimportant deviations, as required in the Specifications for DOT 112A340W tank cars. These standards do not, however, include microstructural, or general toughness (e.g., NDTT) specifications.

The initial fracture in the head of the tank started in the weld joining the stub sill reinforcing plate to the tank head. Examination of this area disclosed that there was a gap between the two plates and that a fine crack extended into the weld from this gap. It is not inferred, however, that the failure of the tank was caused by any defect in the welds, as the blow sustained by the head was strong enough to have caused the brittle fractures through the tank regardless of the weld. The propagation of the fractures through the sheets did not follow the welds.

The Research Department of the Association of American Railroads (AAR) in their final report presented the following conclusions and recommendations:

1. The fracture of the Crete tank car was almost entirely of a brittle nature. The steel plates of which the tank car was fabricated were either close to or below their NDTT's (nil-ductility transition temperatures) at the existing ambient temperature of 4 degrees F.

2. The origin of the fracture lay in one tank head of the tank car, specifically at the weld between the tank head and a longitudinal reinforcing plate attached to the stub draft sill arrangement. This weld was of a nature which typically produces a severe stress raiser in the form of a thin gap between the two plates joined by the weld.

3. The metallurgical processing of the tank head led to a microstructure conducive to low toughness and a high NDTT.

4. During the accident, the tank head had received a severe blow, or blows, near the weld in question, resulting in extensive deformation of the head. It was undoubtedly this impact which started the fracture. Though the tank head plate weld served in this instance as the origin of fracture, it is very likely that under the severe impact sustained the fracture would have occurred regardless of the specific nature of the "weak link" at the region of highest stresses.

5. The steel plates of which the fractured tank car was made had properties which met the specifications in the AAR appendix M standards for TC128B plate. These standards do not, however, include microstructural or general toughness (e.g., NDTT) specifications.

6. The welds between the tank car shell plates proper were found to be of satisfactory quality, and no evidence that they were causally involved in the fracture origin or propagation was observed.

7. Photographic evidence exists which suggests that the blow to the tank head of the Crete tank car may have been produced by direct collision with an identifiable car in the derailed Burlington train involved in the accident.

8. NDTT and microstructural tests should be carried out on other tank car plates to check the generality of the conditions found in the plates from this car. If such a generality is discovered, consideration should be given to the desirability of specifying minimum toughness requirements for all tank car

plates used in tanks transporting liquid anhydrous ammonia rather than, as now, only for those tanks to be used for liquid carbon dioxide service. Such requirements should be based on NDTT tests rather than Charpy tests if feasible. If subsequent investigations indicate similar performance of other pressurized tanks at low temperatures, impact requirements should be considered for these cars also.

9. Investigate fabrication procedures for tank heads with the object of providing precise control of thermal conditions for producing improved material properties.

10. Improve construction techniques and design of anchorage of tank shells to stub draft sills because of the possibility of creating undesirable stress raisers in this area of the tank car using current production methods.

11. Study possible stress corrosion effects on tank car plates in contact with liquid anhydrous ammonia. In prior experience with farm equipment tanks containing anhydrous ammonia, stress corrosion cracks occasionally developed particularly on cold formed section.

2. Tests Performed by the AAR of Lateral Forces Produced by Locomotives

As a result of the derailment, the CB&Q Railroad arranged with the AAR to conduct tests of the lateral forces that would be produced by a similar locomotive and train to that of No. 64 on the day of the accident while it moved over similar terrain. The location at Crete was not used because of the possibility of another derailment within the town. A location having similar characteristics to those at Crete was found near Cameron, Missouri. The tests were conducted on April 14, 1969, and were observed by a staff member of the National Transportation Safety Board.

a. Test Site

The location selected for the test was on the east spiral of a 2° 01' curve to the right for westward trains, on a single-track line between Cameron and Osborn, Missouri. The curve had a 4-inch elevation, and a location was selected on the spiral where the elevation was 2-3/4 inches to match the conditions at Crete where the derailment occurred. On the approach to the test site from the east, there ia a 1 percent descending grade for about 1.5 miles, changing to a 0.41 percent descending grade for about 0.5 mile, and then level about 0.25 mile to the test point.

At the test site, four adjoining ties were equipped with roller bearing tie plates to permit lateral forces on both rails to be measured. The four test ties were located at the quarter point of the rails between the rail joints. The rails were then instrumented to measure the lateral forces produced by a passing train.

The track structure in this area consisted of 112-pound rail with bolted joints laid on 7-3/4- by 12-inch double-shoulder tie plates secured with two rail spikes and two hold-down spikes per tie plate on 7-inch by 9-inch by 8-foot 6-inch oak ties spaced 24 per rail length. Grip-type rail anchors were placed on each side of eight ties per rail to restrict movement of the rails in each direction. The ballast was crushed slag, and there was a good ballast section with an adequate shoulder. The alignment of the track at the test site was excellent as indicated in Figure 2 of Appendix 2. [5] In general, the condition of the track structure was good. The conditions did not approximate those at the accident site. The alignment precluded the lateral oscillation and rocking forces which would have been produced at the actual site.

b. Test Train

The test train consisted of seven diesel-electric locomotive units and 94 cars comprising a train of 6,429 tons, 65 tons greater than the train involved in the accident. The locomotive units were similar in design to the ones used on No. 64 on the day of the accident. For the first series of tests, the locomotive units were arranged in the same sequence as to type as those on the derailed train, as follows:

Engine Number	Type
629	EMD GP-40
635	EMD GP-40
187	EMD GP-40
957	EMD GP-30
966	EMD GP-30
501	EMD SD-24
562	GE U28-C

The test train was headed westward so that the curve was to the right rather than to the left, as at the accident site.

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[5] Appendix No. 2 -- Excerpts from AAR Report of "Investigation of Lateral Forces Developed by Diesel Locomotives on the Spiral of a Two Degree Curve on the CB&Q Railroad."

c. Tests

The test train made eight forward test runs at various speeds between 7.9 and 52 miles per hour. Three test runs were made in a reverse direction, and one forward test run was made using full dynamic braking when passing the test point. The location of the locomotive units was then changed to three GP-40 units in the lead, followed by the one U-28-C unit, then two GP-30 units, and the SD-24 unit. Two tests were made in a forward direction with this locomotive at speeds of 49.5 and 52 miles per hour. Two other tests were made with two other trains, one eastbound and the other westbound. 6/

d. Results

The report of the AAR stated that normally the tracking pattern of a locomotive truck on a curve is such that the leading axle exerts a force outward from the center of the truck against both high and low rails. If the locomotive is operating at a speed much less than the equilibrium speed for the track elevation provided, this pattern will be changed. At the point where the lateral force was measured, the curvature of the spiral was just under 1° with the elevation 2-3/4 inches. The equilibrium speed for this curvature and elevation is about 62 miles per hour. As all test runs made were well below the equilibrium speed, the lateral forces exerted on the track were found to be low as expected. The greatest lateral force developed on the outside rail during a forward test run was 4,000 pounds by one of the GP-40 units moving by the test point at a speed of 46 miles per hour.

In some respects, the track conditions at the AAR test location were not the same as those at Crete. At Crete, the spiral and the 2° curve were to the left with a turnout located on the spiral, while at the test site the curve was to the right with no turnout located on the spiral or curve. The alignment of the track at the test site was excellent, and the general condition of the track was good--much better than that at Crete. The tests made by the AAR were conducted during April 1969 when the roadbed supporting the track was not frozen, as it was at Crete on the day of the accident.

The test procedure employed was one that only determined the forces produced at one point on the curve. More lateral forces could have been produced at other points on the spiral.

6/ Appendix No. 2--Tables indicating the results of test runs.

The report concluded that on the test track . . . "no lateral forces applied to the outer rail were measured which were anywhere near large enough to cause the rail to overturn. It can only be concluded that some abnormal condition of the track, equipment, or train action existed at that time to cause the rail to overturn." The rail did not overturn, but moved laterally.

The Board feels that the tests performed by the AAR provided insufficient information to determine the forces produced by the train as it moved over the turnout on which the initial derailment occurred at Crete. About the only definite conclusion that can be drawn from these tests is that a train moving at a speed not exceeding those in the tests, traversing well-maintained track as described, will not develop an excessive lateral force.

III. ANALYSIS

A number of important factors contributed to the derailment of train No. 64 and to the bursting of the tank car, releasing the ammonia gas into the atmosphere. Each of these factors is analyzed and their importance assigned in determining the causal factors of the accident.

A. Maintenance of the Track

The irregularities measured in the track after the accident contributed materially to the development of lateral forces which would tend to move the closure rail outward. Although CB&Q had not published minimum standards, the irregularities in gage, surface, crosslevel, and alignment approaching the derailment point exceeded the standards normally considered acceptable for freight train operation of 50 miles per hour.

The Engineering Division of the AAR has adopted Recommended Standards for Track Maintenance. Some of these standards have been in use on many railroads long before this accident occurred at Crete. The irregularities found in the track at Crete [7] were within one-eighth inch of exceeding the AAR Recommended Standards for track on which trains are to operate at speeds from 46 to 60 miles per hour shown below in section 2.3.3.4 and exceed those shown in section 2.5.3.2 by three-fourths inch in section 2.5.3.2.1 Part 1 and by one-fourth inch in section 2.5.3.2.1 Part 2. The number of spikes were not provided as specified in section 3.5.4.2.1.

2.3.3.4 Corrective or protective action shall be taken when
2.3.3.4.1 alignment of track is found to deviate 1½ inches from uniform alignment on curves for mid-ordinate variation from 62 foot chord.
2.5.3.2 Corrective or protective action shall be taken when individual variations in track surface exceed the following limits on curves:
2.5.3.2.1b (1) Run-off per 31 feet at end of track raise - maximum - 1½ inches.
(2) Variation from uniform profile on either rail - maximum 2 inches.
3.5.4.2 Rail shall be spiked to timber ties on curves over 2 degrees
3.5.4.2.1 to 4 degrees, inclusive, with not less than three spikes per rail per tie including hold-down spikes.

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[7] Appendix 1, Chart No. 1, Track Conditions Following Derailment at Crete

In general, the recommendations of AAR state that the limiting conditions apply to track conditions existing separately. When any of these conditions exist in combination, "judgment" is recommended to be used to determine the extent to which such combination shall be permitted and the corrective action to be taken.

The absence of published CB&Q minimum standards for track maintenance resulted in the reliance on the variable judgments of the supervision of the track maintenance forces. Reliance upon the judgments of supervisors without minimum standards to work from can easily result in the degradation of acceptable levels of maintenance. However, the primary question needed to be answered in this situation is not whether experienced judgment is enough, for reliance has been refuted by previous Board reports. The question is whether and how the irregularities contributed to the derailment and what counteractions might be taken that are better than judgment.

B. Non-Technical Summary of Analysis of Track Condition

When a train moves around a curve, forces are produced from centrifugal force, and these forces vary if the curvature is not uniform. Forces may also be produced if the superelevation varies. These lateral forces have been plotted in Figure 6, page 28 . The plot shows that at points (A) and (B) the wheels of all locomotives were slapped against this outside rail, then at (C) were slapped against the inside rail, and then at (D) against the outside rail. At this point the rail moved outward. This action was rhythmic which could have resulted in an amplification of the force when point (D) was reached.

C. Identification of Abnormal Forces Produced by Rough Track

The fact that the CB&Q-AAR tests of lateral forces did not serve to explain the spreading of a normally fastened rail, led the Safety Board to attempt to find the probable abnormal force by engineering calculations. The Board had requested exact measurements of the track at derailment sites and the measurements were made by the Bureau of Railroad Safety of the Federal Railroad Administration. The measurements were made after the spread rail had been replaced in its former position; however, because the ties in this area were scarcely damaged, the roadbed and ties had been frozen when the accident occurred, and because the existing rail was replaced by spiking in almost exactly the same position as before the accident, it is believed that the measurements are very close to the original condition. As indicated below, it is believed that the source of the abnormal force has been found, even though the exact amount of the force could not be determined. As discussed later, the method of analysis used implies that test instrumentation to perform similar analysis for preventative maintenance might be developed.

FIGURE 6
LATERAL FORCES ON TRACK REAR UNIT

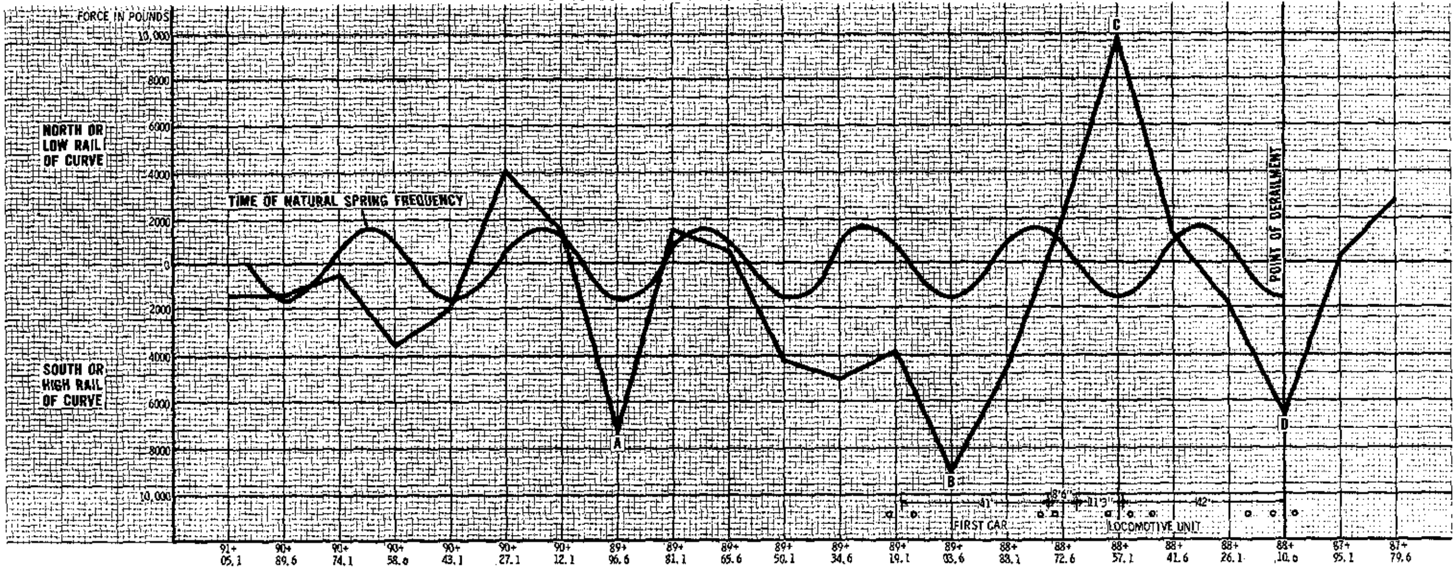
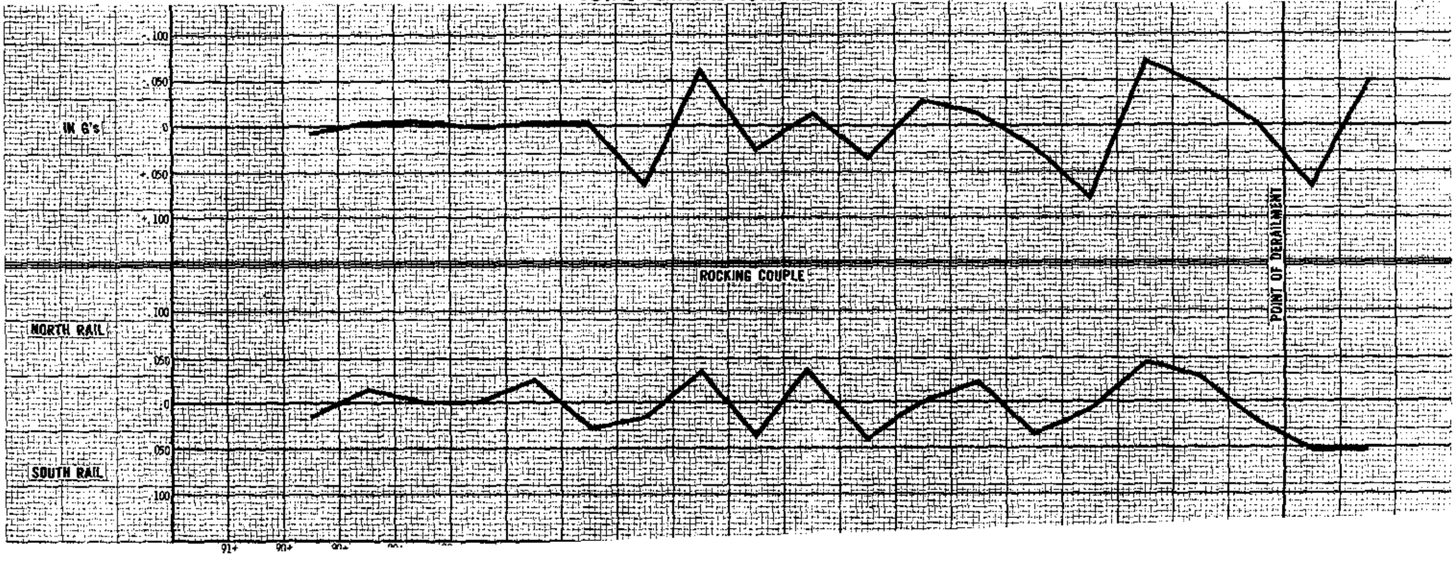


FIGURE 7
TOTAL VERTICAL ACCELERATION



The analysis seeks to determine the effects of track irregularities. It is based upon calculating primary forces on the rails at each rail measurement station along the track near the derailment. The stations were 15.5 feet apart, and the calculations sought to determine the rail force effects for the heaviest locomotive unit in the group.

The forces calculated for each station included:

(1) Lateral force due to centrifugal acceleration, as varying with irregularities of curvature.

(2) Lateral force due to component of locomotive unit train weight and varying superelevation.

(3) Vertical forces, for each rail, due to acceleration produced by irregularities.

(4) Vertical forces, total, due to varying accelerations produced by irregularities.

(5) Rocking couple at gage width and direction due to irregularities.

The most significant forces on the rail, and therefore the corresponding forces on the locomotive trucks, have been consolidated in Figures 6 and 7, page 28. The methods used in these calculations are described in Appendix 1. Figures 6 and 7 show the accelerations and forces produced from about 265 feet before the derailment to about 25 feet after the derailment, traversed by this train in a little more than 3 1/2 seconds.

The total vertical acceleration represents only the up and down accelerations produced by the rising and falling of the track, as separated from the other modes in which the track irregularities act. This acceleration is of the same nature as that which accompanies the rising and falling of an airplane in air currents. The total vertical acceleration was obtained by averaging the sum for both rails. It was varying between about ± .07 g just before the derailment. The vertical acceleration shows an oscillatory movement just before derailment.

The "rocking couple" describes the difference between the acceleration produced by each rail and represents the tendency of the vertical variations to rock the trucks. The chart indicates that each unit was being rocked as it approached the point of derailment. It is very difficult to translate this accurately into a corresponding force, due to the unknown role of the locomotive's suspension, but the direction of the rocking force is indicated. The units were being rocked to the left, as seen from the rear, at the point of derailment.

The most significant force plotted is the lateral force on the track for the north and south rails. This plot represents the sum of the centrifugal force due to the curvature of the rails and the lateral force due to the superelevation of the track. These are the same forces involved in determining the equilibrium speed, but, when the degree of track irregula ity is significant, finding the timing and direction of the forces between train and track is much more important than knowing the equilibrium speed.

In this chart, forces above the line represent a net force against the north rail or low rail inside of the curve, and forces below the line represent forces agains the south rail or high rail. The high rail moves under effects of a force below the line at approximately the point of derailment.

The very significant finding from this chart is that the trucks of the locomotive, and every other car, were being thrown from side to side in the 200 feet before reaching the rail failure point, with sharp, regular peaks in the magnitude of the forces against the trucks before the point in the south rail which failed. At (A), the force against the south rail was 7,000 pounds; at (B), it was about 9,000 pounds; and finally at (D), the point of derailment, the lateral force was about 6,500 pounds. At (C), a force of 10,000 pounds was calculated, which force acted against the north rail and was opposite in direction to the failure.

All of these lateral forces resulting from the irregularities are substantially higher than any forces recorded at running speeds in the AAR-CB&Q tests 8/, although the length for measurement was not the same as the length for calculation. There are no forces recorded in the tables of the AAR-CB&Q tests which approach the forces produced by the irregularities. More importan the timing of the forces indicates an oscillatory pattern in yaw (turning of the cars from side to side) and in vertical movement, so that there was opportunity for resonance to occur. Resonance can greatly increase forces above those which would be calculated.

Plotted adjacent to the lateral forces are (1) the locations of the trucks of locomotive unit U28C and the car immediately to its rear, aligned so that the front truck is opposite the point of derailment, and (2) a wave representing the known natural vibratory frequency of locomotive unit U28C in vertical movement. This latter frequency is 97 cycles per minute, obtained from the manufacturer.

The plot reveals that when the front truck of U28C was being forced to the left and exerting a peak of outward force on the high rail at (D), the rear truck of U28C was being forced strongly to the right and exerting a peak of outward force to the left against the low rail at (C). Similarly, the forces upon the next car to the rear were very similar, but in the opposite direction. These cars, and all others which passed this point were yawed sharply to the right between (B) and (C) and sharply to the left at (C) and (D) in a pattern which coincided very approximately with the length of some of the cars. If the natural vibratory frequency of the locomotive units in yaw happened to

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8/ Appendix 2, Investigation of Lateral Forces Developed by Diesel Locomotives on the Spiral of a Two Degree Curve on the CB&Q Railroad, conducted on April 14, 1969.

be near the frequency of the forced yaw at this speed, the force at (D) could have been increased, excited by the regularity of the yaw which occurred before that point.

The yaw frequency of the locomotive is not known. However, the vertical frequency of the locomotive plotted as a wave, Figure 6, definitely shows that the application of the lateral forces is so timed as to approach a vertical resonance, if there were a coupling between the lateral and vertical forces produced by some factor in the track design.

It is also noted that a vibratory excitation (wavelike variation of forces) existed in the vertical accelerations preceding the point of derailment, and the rocking couple also displayed a longer, but not higher wave in its variations just before the point of derailment.

The peaking of the lateral forces also implies that the forces tending to jackknife the cars due to braking might have been increased. The lateral forces would have produced rolling of the cars at the peaks of lateral force, and would tend to increase and decrease the angle between the center lines of car. The amount of this effect, however, would be difficult to calculate.

D. Ability of High Rail to Withstand Lateral Force

Under the assumed condition that the heaviest locomotive unit would have produced the largest lateral forces, the forces required to be resisted by the rail spikes can be determined.

It is a preculiarity of this type of track-holding arrangement that, although there are holes for five spikes in each tie plate, the lateral outward forces are resisted by only one spike at each tie, and only one spike was bent at each tie. This came about because at the beginning of lateral movement the shoulders of the tie plates were overriden laterally by the base of the rail, so that the laterally resistive contact between the base of the rail and the shoulder was lost. Resistive force was then only from the outside spikes at each tie plate and whatever friction existed between the top of the shoulder of the tie plate and the bottom of the rail. The frictional contact force is significant, but, because vertical working occurs as each wheel passes, the frictional contact is not continuous. It is possible for a rail to be in a lifting portion of its cyclic, vertical movement while the rail is being moved laterally by lateral forces produced at some other part of the rail. If the lifting raises the base above the shoulder of the tie plate, while the rail moves laterally the rail base could come down on top of the shoulder so that the shoulder is no longer engaged. Lifting from some source must have occurred, because lifting was the only mechanism by which the rail base could have overriden the shoulder.

The shoulder, when engaged, has the effect of greatly increasing the lateral resistance to movement, since the tie plate movement is resisted by several spikes. Further, the overriding of the tie plate changes the nature of the force on the spike. The spike must be partially withdrawn in order for the rail to rise above the shoulder of the tie plate. In addition, the point of application of the force on the outside spike rises to the height of the edge of the rail base, so that a large bending moment is established on the spike. If this bending distorts the upper part of the hole in the tie, the spike may lean outward.

The bending of the spike need not be very great, it would appear, to allow continued cyclic application of forces from successive wheels to gradually bend and withdraw the spike. After the spike is angled outward, lateral forces could tend to lift the rail base or allow it to move farther outward during the part of the vertical movement cycle of the rail in which the rail rises.

It is also to be noted that after a little movement of the rail begins, the movement itself produces an increased curvature of the outside rail, increasing the centrifugal force to be resisted by the rail. When lateral movement has progressed sufficiently to allow an inside wheel to drop off a rail, as happened here, a much higher wedging force would be developed. Thus, it is seen that the destructive lateral movement was not instantaneous, but developed in stages. The initial movement occurred well before the first derailment, and it was probably produced by a force just sufficient to produce a lateral shift so that the rail did not drop back behind the shoulder of the tie plate. This applied the lateral forces entirely to the outside spike and greatly reduced the resistive ability of the rail and the sequence proceeded.

This explanation is consistent with the overriding of the tie plates and bending of the partially withdrawn spikes that were observed.

The vertical movement of the rail relative to the ties might have been accentuated by the freezing of the ties into the roadbed. Rail normally rises ahead of a loaded wheel, and the ties work vertically, being depressed or lifted by the downward vertical forces which produce a bending upward movement of other nearby sections. Ties being usually free to follow, the movement occurs between tie and ballast. When the roadbed is frozen, however, the forces of vertical movement could act between rail and tie plate to withdraw spikes. At such a time, the use of only one rail-holding spike outside the rail could be critical, not because two spikes would prevent spike withdrawal, but because the tie plate may not provide enough lateral resistance, and two spikes would increase the lateral resistance.

The calculated lateral forces at the derailment point, Figure 6, for the heaviest locomotive unit indicate lateral loads of the order of 6,739 pounds. This load, if spread over 13 feet of truck length, would have engaged eight spikes. The average force per spike would be 842 pounds.

The average force would have been higher at other points, such as at (C) where the average force would have exceeded 1,256 pounds, or (A) and (B), 900 pounds and 1,131 pounds, respectively. However, as described earlier, the lateral force at (D) could have been considerably increased by the cyclic and periodic nature of the yaws produced by the forces at (A) and (B), and much more strongly by the alternation of (B) and (C) to (D). This yawing would have been felt by every locomotive unit and every car in the train, and the lateral force at (D) was elgible to be increased by resonance in yaw for any car which happened to have the correct yaw frequency.

It cannot be determined whether the vertical resonance of locomotive unit U28C increased the lateral force at (D) because it is not known whether the design of the trucks allowed resonance to result in a horizontal force output. This would normally be avoided in design, if recognized.

It is also possible that resonance in yaw did not occur with any of the locomotive units or cars, but that the location at (D) was, by reason of vertical irregularities of the surface of ties, more subject to vertical wave movements of rails which could have allowed the rail to rise above the shoulders of the tie plates, reducing the lateral restraint.

It cannot be determined whether the calculated average load of 843 pounds per spike at the point of derailment was excessive or was below what a normal spike would be expected to resist. No normal holding power has been established for spikes, so far as the Board can determine. It is also apparent that the average capability of spikes to hold against such loads varies widely, owing to the variation in wood, in the spike itself, in the manner of driving it, and the age of the installation. This inability to determine whether a limit was exceeded derives from the indeterminate nature of the securement of rails by nailing metal to wood and from the absence of a scientific approach in the engineering of track structure.

E. Possible Corrective Measures in Track Design

The tendency of the high rail to become disassembled from the ties under these conditions could have been countered by: (1) the use of an additional rail-holding spike on the outside of the high rail (also needed on the inside, as shown by the 10,700 pound inward force at (C)), (2) the use of a substantially higher shoulder on the tie plate so that the shoulder would not have been overriden and the inner rail-holding spike could have shared the load. It is not known why this shoulder is designed so that it can be overridden with only about a 3/8-inch vertical movement at present.

F. The Broken Guardrail

No marks were found on the wheels of the cars in the front portion of No. 64 with the exception of the 28th car, indicating that the wheels had struck the guardrail. It is evident, however, that this did occur as the receiving end of the second broken piece of the guardrail was battered, indicating that it had been struck a number of times. The conclusions of a metallurgical analysis performed on the guardrail were that it was a good grade of high-strength steel and was free from defects. The failure was due to impact of car wheels against the guardrail which resulted in brittle fractures and the shattering of the rail. With the exception of the piece marked No. 1 in Figure 2, the other pieces of the broken guardrail were found in the vicinity of the turnout. The guardrail continued to be struck until the remaining 10-foot 6-inch piece was finally torn out of the track. This eliminated the protection which insured that wheels passed on the proper side of the frog point. The guardrail was apparently completely torn out, either as the 72nd car was moving over the turnout or by the cars immediately ahead of this car. With nothing to guide the wheels to the proper side of the frog point and with the spread closure rail steering the wheels toward the south side, the flanges of the wheels of the 72nd car passed on the wrong, or south, side of the frog point, permitting the wheels to derail.

G. Train Handling

The dynamic brake on the locomotive was inoperative due to a defective condition on one of the units. When the dynamic brake cannot be used on freight diesel locomotives, the carrier's "Mechanical Instructions for Enginemen" [9/] requires that the automatic train brakes are to be applied to reduce speed on a train but not to come to a stop. Whether or not the independent brake on the locomotive was released or kept applied depended on the condition of the slack in the train. The engineer of No. 64 made an application of the independent brake when the locomotive was in the vicinity of Blue River. He was not specific, however, as to where the brakes were released. When the locomotive was passing over the turnout to the Old Wymore Main siding, all but the head 15 cars in the train were still descending the 0.57 percent grade and pushing the locomotive. The engineer said that the speed of the train was about 52 miles per hour when the locomotive was in the vicinity of the Blue River and that it was about the same when the accident occurred. It can be concluded from the foregoing that the brake on the locomotive was applied as it closely approached the point of derailment and that enough retardation was used to balance the gravity effects of the grade.

[9/] Appendix No. 3--Excerpts from instructions issued by CB&Q titled "Mechanical Instructions for Enginemen."

With the brake applied only on the locomotive to control the speed of the train and with most of the cars of the train still descending the grade, the compressive force was highest between the rear of the locomotive and the first car. A retarding force of about 22,000 pounds would have been required to balance the speed of the train as it approached the derailment point. Some of this longitudinal force would have been transferred laterally as the locomotive moved around the curve. The amount of force transferred would have depended on the angle between the axes of the locomotive and the first car.

As the train moved from the tangent onto the spiral of the 2°01' curve, the angle of the couplers between the locomotive and the first car, if they stayed in alignment with their respective units, would have been no greater than 2°15'. This small amount of angularity would not have transferred laterally any appreciable amount of the longitudinal force, as the lateral force would have been only about 775 pounds. At the points of the extreme forces, as shown in Figure 6, page 28, the lateral force transferred due to the alignment of the couplers would not have exceeded the following percentage of forces produced by the locomotive unit:

At Point	Percentage of Force
A	10
B	8
C	7
D	11

Thus the lateral force from braking did not exceed 11 percent of the force due to the misalignment.

H. The Equipment of No. 64

1. Locomotives

The locomotive consisted of seven diesel-electric units, and it provided sufficient motive power to handle a train of 13,050 tons which was considerably more than was needed to handle No. 64, over the same terrain, on the day of the accident. The seven-unit locomotive not only provided more motive power than a smaller locomotive, but more braking force could be provided when the independent brake was used on the locomotive. In addition to the large number of units, the two rear units of the locomotive consist were the heaviest, and each was provided with six-wheel trucks. The rear unit, a class U-28C, manufactured by the General Electric Company, was considerably heavier than the other units. The six-wheel trucks of this unit differed from other locomotive trucks in the offcenter location of the center plates. This arrangement divided the trucks into a long and short section, with the longer section toward the center of the unit. A question was raised as to whether this arrangement could have contributed to additional forces to the track.

Prior to the time of this accident, the AAR had made several other tests in an attempt to determine why the outside rails of curves were moved laterally, producing wide gage. As a result of one of these tests, it was concluded that, "All-in-all, it seems most likely that the occurrences of 'sudden' wide gage have been due to lateral forces exerted against the high rail as a result of the locomotive jackknifing under dynamic braking." [10/] The method of braking described to control the speed of No. 64 could have developed conditions similar to, if not more severe than, those produced by the use of the dynamic brake.

The AAR in cooperation with CB&Q made tests on April 14, 1969, intended to evaluate possible unknown lateral forces produced by the six-wheel trucks of the U-28C locomotive or by braking. These tests, described beginning on page 22 and in Appendix No. 2, evaluated conditions on a smooth track, curved and superelevated in a manner similar to that at Crete. In the Board's view, the information obtained from the tables, which are in a speed range or braking mode similar to that of the derailment situation, does not give any indication of unusual forces which could explain what happened at Crete.

As indicated on page 31, the Board also made calculations of the possible jackknifing effect due to braking. While these calculations showed negligible lateral force, due to the degree of braking said to have been applied, there is one possibility which ought to be mentioned even though contrary to the evidence.

The braking force necessary to hold the train at constant speed is 22,000 pounds. That force, when generated by seven locomotive units weighing a total of 2,075,000 pounds represents a light brake application--only a little more than .01 g for the locomotive units. About 25 time more forceful braking would be possible before wheels of the locomotive would slide.

The application of brakes on the locomotive was very rapid due to the short distance, only about 400 feet, from front to rear. Thus, if an error had been made in applying the brakes, creating more pressure reduction than intended, the higher retardation and therefore the higher lateral force would have become effective very quickly--certainly before the error could have been corrected. Such an error might have become effective about the time of passing the derailment point. This could have produced a much higher lateral force--

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[10/] AAR Research Department, Report No. ER-68. "Investigation to Determine the Cause of 'Sudden' Wide Gage on the Delaware and Hudson Railroad - October 1966."

perhaps as much as ten times higher than that calculated, depending on the degree of error. Such an increase in force would have made the possible lateral force more than a small fraction of the calculated lateral force, and conceivably could have produced a total lateral force at (D) about twice as high as calculated. However, the lateral force due to braking would still have been of only about the same magnitude as the force due to misalignment and surface deficiencies.

2. First Derailed Car of No. 64

It is apparent from the marks found on the wheels, and the rail, and from the pieces of broken guardrail found wedged under the floor of the car, that the north wheels of the east trucks of GN 6583, the 28th car, derailed just west of the frog of the Old Wymore Main turnout due to the spread closure rail. The wide gage permitted the north wheels to drop inside of the north rail and strike the joint bar and the west end of the guardrail along the north rail. The guardrail was broken and the 18-inch piece lodged in the underframe of the car where it was later.found by the brakeman. The wheels then rerailed at the frog, and the car continued eastward. The other damage found on the car resulted from conditions caused by this derailment.

Although no tests were made to determine the effect of the unequal load in GN 6583, the Safety Board believes that it did not contribute to the spreading of the closure rail or to the temporary derailment of the car.

3. Other Damaged Cars in the Front Portion of Train No. 64

When the emergency application occurred on the front portion of train No. 64, as a result of the derailment, the engineer released the brakes on the locomotive but he permitted the brakes on the cars of the front portion of the train to remain applied. The engineer did this to prevent the rear of the train from colliding with the front portion if the emergency application had been caused by a train separation with no resultant derailment. At that time, he did not know what had caused the emergency application.

With this arrangement, all of the braking effort was being supplied by the cars. Even though power was not being produced by the locomotive, a force was being exerted by the locomotive due to the inertia of the seven diesel-electric units. This force apparently was sufficient to have caused the coupler yoke on the west end of the 14th car, B&M 77924, to break. After this occurred, the steel follower block, which is part of the draft arrangement, fell to the track structure. A number of the following cars ran over the block and several contacted it, which caused the damage to the cars, the parting of the airhoses at the west end of the 14th car, the outlet pipe broken from the 16th (GATX 1827), and the damage to the 18th car (SP 209451). The follower block was found along the track east of the 28th car; therefore, it could not have caused any of the damage to this car.

IV. CONCLUSIONS

1. The track was not maintained to standards normally acceptable for freight train operation at 50 m.p.h. The irregularities in the track contributed to the development of undue lateral forces on the rails.

2. The guardrail protecting the frog of the turnout met specifications, but it was not designed to withstand impacts with the derailed wheels of the cars.

3. The uncentered geometry of the trucks on the U-28C locomotive unit had no significant detectable effect on the lateral forces produced by the trucks in the circumstances of the accident.

4. While No. 64 was moving on the descending grade approaching Crete, the control of the speed by braking was not performed in the manner prescribed by the carrier.

5. The use of the independent brake on the locomotive, in the manner described by the engineer, was shown by calculations to have produced only about 10 percent as much lateral force on the rails as was produced by track irregularities.

6. Train No. 64 slightly exceeded the maximum authorized speed as it approached the accident area, but the excess speed was of little significance.

7. The breaking of the coupler yoke on the west end of B&M 77924, the 14th car, was a result of the derailment, not a cause.

8. Damage to the 14th car, (B&M 77924), the 16th car (GATX 1827), and the 18th car (SP 209451) was the result of the falling of the follower block of the 14th car to the track structure when the coupler yoke broke because of forces resulting from the derailment.

9. Most fractures of the tank were of a brittle nature. At the ambient temperature of +4° F., the steel plates of the tank car were far below their nil-ductility transition temperatures of 75° to 80° F.

10. The original fracture occurred in a defective weld in the tank head where there was a gap between two plates. It could not be determined by the Board whether a complete weld would have prevented the fracture.

11. The steel plates of the tank car met the specification required by DOT 112A340W. These standards do not, however, include microstructural or general toughness (e.g., NDTT) specifications, and thus did not serve to control the low temperature brittleness.

12. The welds between the tank car shell plates were found to be of satisfactory quality and were not causally involved with the propagation of the fractures.

13. Tank cars specified by Federal regulations were used for the loading of the anhydrous ammonia and the loading procedures had nc influence upon the failure of the tank.

14. All persons directly exposed to the cloud of ammonia gas received either fatal or serious chemical injury to the respiratory tract; whereas people within the area of the gas concentration who remained in their homes or who had adequate protection, escaped wi either no injuries or minor injuries.

15. The citizens of Crete were able to cope with the situation because they had developed adequate plans for emergency procedures before the accident occurred.

V. GENERAL CONCLUSIONS

Federal responsibilities are involved in two major areas of this accident. The shattering of about one-half of the tank, which produced rapid vaporization of the ammonia, is a Federal responsibility in that brittleness is now potentially controllable, but was not controlled by the specification for DOT 112A340W tank cars. Control of track irregularities and of the integrity of track construction was not subject to Federal regulation at the time of the accident, but is now subject to such regulation under the Federal Railroad Safety Act of 1970.

The brittleness of the tank car material and the extent of the shattering of the tank in cold weather were surprising findings of great significance for potential hazards. This finding of brittle failure by the AAR was reported to the Federal Railroad Administration by the Association of American Railroads in July 1969. The fact that the deformation which resulted in shattering was not sufficient to have produced a puncture at higher temperatures means that the ability of this tank car to resist accident damage was compromised at the $+4^{0}$ F. temperature to a serious degree. Furthermore, any other tank car employing this same type of steel and metallurgical treatment would be seriously compromised at that low temperature.

No tank cars of the DOT 112A340W class assigned to hauling anhydrous ammonia or liquefied petroleum gas (LPG) have been subjected to control of low-temperature brittleness. This is not the same as saying that all tank cars of this type are subject to low-temperature brittleness. Some of the cars of this class may not exhibit low-temperature brittleness, but if they do not, it would be a result of some significant difference in the metallurgy of the steel employed, as compared to this car. Thus all cars of specification DOT 112A340W assigned in this service must be considered under suspicion of having low-temperature brittleness. These tank cars could potentially fracture in other accidents in the same manner as occurred at Crete, releasing ammonia or other hazardous materials in the same manner.

As of June 1969, there were more than 11,000 cars of this type in service, most of them carrying hazardous materials. Most of these cars are used to ship liquefied petroleum gas. The result of an accident producing a similar large scale failure with LPG in the tank would be sudden release of more than 30,000 gallons (liquid) of flammable gas, probably with fire and rocketing of large tanks similar to the events which have occurred at Laurel, Mississippi, at Crescent City, Illinois, and at other localities. Thus, the implication of the brittleness found in this accident is that, in low-temperature conditions, the consequences of accidents involving some large LPG tank cars are more likely to be catastrophic than in warm weather. Although the very cold-weather accident occurred to a car carrying anhydrous ammonia, a conclusion may properly be drawn that the risk of transporting similar cars carrying LPG is also increased at very low temperature.

In the report of the LPG tank car accident at Laurel, Mississippi, the Safety Board noted that full-scale testing of this type of tank car by fire had not been accomplished prior to approval of the car and that the full-scale testing which disclosed the rocketing phenomenon had been, in effect, performed at Laurel, Mississippi, at very high cost to the public. The accident at Crete was, in effect, a low-temperature crash test which disclosed the need for control of low-temperature brittleness of tank materials. This test was also performed at very high human and economic cost. Both of these tests were performed long after the tank cars had gone into service, and after the pattern of rates and other economics of the use of these cars had been fixed. Under these circumstances, the correction of the existing cars may now be too costly to accomplish. There is also a danger that changes to cars not yet built, which would have seemed reasonable before the economic pattern was establishe may be regarded as costly and profit-reducing, and therefore questionable improvements rather than corrections of an overlooked matter.

The conclusion is inescapable that obtaining knowledge of tank car hazards by analysis and testing, is far less costly to the public than "testing" by service, and would produce more practical corrections. The omission of thorough testing is not only false economy, but an injustice to persons living along the tracks. The "testing" by service use of the Specification 112A340W or 112A400W tanks revealed hazards which in three accidents resulted in 11 fatalities, 152 injuries, including many disfiguring burns, and approximately $5,300,000 in property damage. There is a history of budgetary requests by the Interstate Commerce Commission for research and development funds which might have shown the need for such testing, and testing by manufacturers could have been required by regulation.

This accident again points up the difficulties in attempting to control safety of track and train operation by regulations based upon current track standards concepts. The Safety Board has now found and pointed out the results of vague or absent track maintenance rules and the substitution of "experienced judgment" in three accidents: those at Dunreith, Indiana; Glenn Dale, Maryland; and Franconia, Virginia. In two of these cases, experienced track or engineering personnel of the same railroad gave conflicting testimony of the requirements of track maintenance. In two of the accident cases, Crete and Franconia, experienced railroad personnel could not explain the accident in terms of any existing definitions of track conditions. In the Glenn Dale accident, railroad personnel felt they knew the cause of the track's buckling, but none could say that any corrective measures known to them would prevent a recurrence. Such problems indicate that many of the static and dynamic relationships within the track and train system are genuinely unknown. In the instant accident, even the available track recommendations of AAR would not have controlled this cyclic oscillation that was found. If the relationships are unknown, of course, they cannot be logically controlled.

In this accident analysis, an effort was made to determine analytically which of the various forces could have shifted the rail. The analysis revealed unsuspected sources of cyclic forces in the configuration of the track, and it questioned an impression that a braking action was an important factor. However, the analysis could not positively provide the answers to a comparison between force and ability to resist force. The amount of lateral force capable of being resisted by a railroad spike has never been defined, even though such spikes have been used to hold railroad track together for more than a century. As indicated, the holding power of spikes is highly variable, and this is the probable reason why it has not been defined. The same variability is found in many other aspects of track structure. The freezing of the roadbed having alignment and surface irregularities changed the dynamic behavior of the track, and in ways that are now essentially unpredictable.

The unpredictable and non-analytical approach to track maintenance is thus partially rooted in the present methods of track construction which allow such wide variations. Thus the Crete accident implies again the need for changes in track construction to reduce the number of variables as a step toward objective safety control.

The analytical method of the Board's analysis employed well-known track measurements to produce force indications, thus interrelating the action of train and track on an instantaneous basis. Several assumptions were necessary to compensate for ignorance of some facts. Nevertheless, the method came close to describing the track condition on the basis of what forces the track exerts on the train (and vice versa) rather than on the basis of track dimensional measurements judged on a pass-or-fail basis, which does not reflect forces directly.

It should be pointed out that these calculation methods could be employed on a computerized basis, employing track measurements taken not from laborious hand methods, but from electronic test devices such as the capacitor gage car of the Department of Transportation and those being used by some railroads. Determination of forces and car motions by a fast-moving test car might offer a very definite way of confirming safe alignment and surface conditions.

VI. PROBABLE CAUSE

The National Transportation Safety Board determines that the derailment was caused by the movement of a rail of the turnout due to lateral forces produced by the locomotive as it moved over track which had alignment and surface deficiencies. The cause of the complete failure of the tank car which released the poisonous gas, following derailment, was a heavy blow delivered to the head of the tank car by the coupler of another car and the brittleness of the tank car steel at the ambient temperature of 4° F.

VII. RECOMMENDATIONS

The Safety Board recommends to the Secretary of Transportation that:

1. Because statutory authority has now been conferred by the Railroad Safety Act, the Federal Railroad Administration should establish as soon as possible, objective and enforceable standards for the inspection of condition of track and maintenance of track, such as gage, surface, alignment, and securement. Such standards should be based upon the effects produced upon trains and should rely upon subjective opinion as little as possible. Such standards should consider the effects of roadbed freezing.

2. The Federal Railroad Administration revise the specifications for material for the construction of future tank cars to include transition temperatures for steels so that tank cars hauling hazardous materials will be adequate to operate through the full range of ambient temperatures encountered in service.

3. The Federal Railroad Administration make a study of the steels used to construct existing tank cars to determine the ranges of transition temperatures and the ability of these cars to resist brittle fracture in various temperatures so that the scope of the existing problem can be determined and adequate corrective action taken.

4. The Federal Railroad Administration in cooperation with the Association of American Railroads make a study of the analyses and tests of the forces produced by the various components of a train while traversing track over the full range of operating conditions which would serve as a basis for the design and maintenance of track according to objectively determined requirements.

5. The Office of Hazardous Material in cooperation with Civil Defense and State agencies conduct a study of methods that could be employed rapidly to disperse or absorb clouds of toxic vapors. The study should also determine the suitable and practical means of protecting the public which may be exposed to the hazard on an emergency basis. Arrangements should be formulated for the dissemination of this information.

6. The Safety Board reiterates the recommendation made in its Glenn Dale, Maryland, report of the derailment of Penn Central train 2nd No. 115, issued July 13, 1970, that the: "Federal Railroad Administration, in cooperation with the Association of American Railroads

and the American Railway Engineering Association, conduct studies, including tests, to determine desirable combinations of track and equipment components required to act as a system to keep derailed cars upon and in line with the track structure."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

Isabel A. Burgess, Member, was absent, not voting.

February 24, 1971

APPENDIX NO. 1

This appendix 1 shows in detail the measurements taken of the track approaching the point of the derailment shortly after the accident occurred. It is believed that the measurements in the immediate vicinity of the derailment may not be completely accurate, as some repairs had been made to track to permit the movement of wreck trains over the area. The track approaching the point of derailment had not been changed.

Chart No. 1 shows the actual measurements taken of the track, and in certain instances a comparison is made between the actual measurements and the design standards.

Chart No. 2 contains an analysis of the actual measurements.
Column No. 1 -- Designated stations for each 15.5 feet beginning at a point 294.5 feet west of the point of the derailment.

Column No. 2 -- The elevation in feet of the low, or north, rail of the main track.

Column No. 3A -- First difference--subtract the elevation of the westerly station from that of the next adjacent station to the east.

Column No. 3B -- First difference--divided by time required to move 15.5 feet at 52 m.p.h. (0.203 seconds).

Column No. 4A -- Second difference--in column 3B, subtract the westerly station from the adjacent station to the east.

Column No. 4B -- Second difference--divided by the time required to move 15.5 feet at 52 m.p.h. (0.203 secs.).

Column No. 5 -- Vertical acceleration in g's--Column 4B divided by 32.2 (32.2 feet per second per sec.)

Column No. 6 -- The superelevation in feet of the outside of south rail of the curve.

Column No. 7 -- The elevation, in feet, of the outside or south rail of the curve.

Column No. 8A -- First difference--subtract the elevation of the westerly station from that of the adjacent station to the east.

Column No. 8B -- First difference divided by time required to move 15.5 feet at 52 m.p.h. (0.203 secs.)

Column No. 9A -- Second difference--in column 8B subtract the westerly station from the adjacent station to the east.

Column No. 9B -- Second difference--divided by time required to move 15.5 feet at 52 m.p.h. (0.203 secs.).

Comumn No. 10 -- Vertical acceleration in g's--Column 9B divided by 32.2 (32.2 feet per second per second)

Column No. 11 -- Total vertical acceleration--add Columns 5 and 10, and divide by 2.

Column No. 12 -- Rocking couple--subtract Column 5 from Column 10. Plus figures indicate movement toward the south or outside rail and negative figures indicate movement toward the north or inside rail.

Column No. 13 -- Gage of track in feet--from measurements.

Column No. 14 -- The angle of elevation of high rail above low rail.

Column No. 15 -- The gravity component due to superelevation on curve.

Column No. 16 -- The degree of curvature--taken from measures.

Column No. 17 -- The superelevation of outside or south rail in inches--from measurements.

Column No. 18 -- The equilibrium speed of train around curve.

Column No. 19 -- Estimated centrifugal force produced by train as it moved around the curve

$$C=\frac{W\ V^2}{32.2R}$$

Column No. 20 -- Estimated lateral force produced due to the elevation of the outside or south rail.

$$F = C - \frac{W \times E}{RG}$$

F = Force

C = Centrifugal force

W = Weight in pounds of one end of unit

E = Distance resultant vertical force is off center due to elevation.

RG = Distance of the resultant of the center of gravity of the units due to elevation of curve.

Column No. 21 -- Estimated total lateral force against the outside or south rail--subtract Column 20 from Column 19.

APPENDIX 1

TRACK CONDITIONS FOLLOWING DERAILMENT
AT CRETE, NEBRASKA, FEBRUARY 18, 1969

Engineering Station	Location	Gage	Superelevation or Cross Level				Surface Low Rail		Alignment	
			Design Standard	Measured	Change per 31"	Variance Standard	Elev.	Change	Design Curvature	Measured Curvature
91+14.8	P.S. - NORTH SIDING									
91+05.1	TANGENT TRACK	4'8 1/4"	0	-3/8"		-3/8"	911.99			
90+89.6		4'8 7/8"	0	-3/8"		-3/8"	911.98			
90+74.1		4'8 3/4"	0	-1/8"	+1/4"	-1/8"	911.98	-1/8"	0°	0°
90+58.6		4'8 3/4"	0	-1/8"	+1/4"	-1/8"	911.98	0	0°	0°30'
90+43.1		4'8 3/4"	0	-1/8"	0	-1/8"	911.97	-1/8"	0°	0°15'
90+27.6		4'8 3/4"	0	-1/8"	0	-1/8"	911.97	-1/8"	0°	-0°45'
90+12.1		4'8 3/4"	0	0	+1/8"	0	911.98	+1/8"	0°	-0°15'
90+11.6	POINT OF SPIRAL									
89+96.6		4'8 1/2"	1/4"	+1/8"	+1/4"	-1/8"	911.96	-1/8"	0°10'	+1°15'
89+82.2	HEEL OF FROG									
89+81.1		4'8 3/4"	3/8"	+1/2"	+1/2"	+1/8"	912.02	+1/2"	0°20'	0°
89+65.6		4'8 3/4"	5/8"	+1/4"	+1/8"	-3/8"	912.02	+3/4"	0°30'	0°
89+50.1		4'8 3/4"	7/8"	+5/8"	+1/8"	-1/4"	912.03	+1/8"	0°35'	1°00'
89+34.6		4'8 5/8"	1 1/8"	+3/8"	+1/8"	-3/4"	912.05	+3/8"	0°40'	1°00'
89+19.1		4'8 5/8"	1 1/4"	+7/8"	+1/4"	-3/8"	912.09	+3/4"	0°45'	0°45'
89+03.6		4'8 7/8"	1 1/2"	+1 3/8"	+1"	-1/8"	912.09	+1/2"	0°50'	2°15'
88+88.1		4'8 5/8"	1 3/4"	+1 3/8"	+1/2"	-3/8"	912.10	+1/8"	1°00'	1°30'
88+72.6		4'8 5/8"	2"	+2	+5/8"	0	912.12	+3/8"	1°05'	0°45'
88+61	P.S. - OLD WYMORE MAIN									
88+57.1		4'8 1/4"	2 1/4"	+2 3/4"	+1 3/8"	+1/2"	912.25	+1 7/8"	1°10'	-0°15'
88+41.6		4'8 3/4"	2 1/2"	+2 3/4"	+3/4"	+1/4"	912.31	+2 1/4"	1°20'	1°15'
88+26.1		4'8 7/8"	2 5/8"	+2 1/4"	-1/2"	-3/8"	912.33	+1"	1°25'	1°30'
88+10.6		4'8 3/4"	2 7/8"	+2 1/8"	-5/8"	-3/4"	912.33	+1/4"	1°30'	2°15'
87+95.1	FIRST DERAILMENT MARK	4'8 7/8"	3"	+2 7/8"	+5/8"	-1/8"	912.39	+3/4"	1°35'	1°30'
87+79.6		4'9 1/8"	3 1/4"	+2 3/4"	+5/8"	-1/2"	912.42	+1 1/4"	1°40'	1°00'

APPENDIX NUMBER 1

CHART NUMBER 2

SHEET NO. 1

LOW RAIL							HIGH RAIL					
STATIONS EACH 15.5 FT.	ELEVATION	1ST DIFF	1ST DIFF / SEC/15.5 FT	2ND DIFF	2ND DIFF. / SEC/15.5 FT.	VERT. ACCEL. IN G'S	SUPER ELEV HIGH RAIL	ELEVATION	1ST DIFF	1ST DIFF / SEC/15.5 FT.	2ND DIFF	2ND DIFF. / SEC/15.5 FT.
NO. 1	NO. 2	NO. 3 A	NO. 3 B	NO. 4 A	NO. 4 B	NO. 5	NO. 6	NO. 7	NO. 8 A	NO. 8 B	NO. 9 A	NO. 9 B
	FEET	FEET/SEC.		FEET/SEC.	FEET/SEC^{2}		FEET	FEET	FEET	FEET/SEC	FEET/SEC	FEET/SEC^{2}
91 +05.1	911.99	-					-.03	911.96				
			-.049	-						-.049	-	
90 +89.6	911.98	-.01					-.03	911.95	-.01			
			0	+.049	+ .240	+.007				+.098	+.147	+ .720
90 +74.1	911.98	0					-.01	911.97	+.02			
			0	0	0	0				0	-.098	- 480
90 +58.6	911.98	0					-.01	911.97	0			
			-.049	-.049	- .240	-.007				-.049	-.049	- .240
90 +43.1	911.97	-.01					-.01	911.96	-.01			
			0	+.049	+ .240	+.007				0	+.049	+ .240
90 +27.6	911.97	0					-.01	911.96	0			
			+.049	+.049	+ .240	+.007				-.098	-.098	- 480
90 +12.1	911.98	+.01					0	911.98	-.02			
			-.098	-.147	- .720	-.021				-.049	+.049	+ .240
89 +96.6	911.96	-.02					+.01	911.97	-.01			
			+.294	+.392	+1.921	+.057				+ 441	+ 490	+2.401
89 +81.1	912.02	+.06					+.04	912.06	+.09			
			0	-.294	-1 441	-.043				-.098	-.539	- 2.642
89 +65.6	912.02	0					+.02	912.04	-.02			
			+.049	+.049	+ .240	+.007				+.196	+.294	+ 1.441
89 +50.1	912.03	+.01					+.05	912.08	+.04			
			+.098	+.049	+ .240	+.007				0	- 196	- .960
89 +34.6	912.05	+.02					+.03	912.08	0			
			+.19 6	+.098	+ 480	+.014				+.392	+.392	+ 1.921
89 +19.1	912.09	+.04					+.07	912.16	+.08			
			0	-.196	- .960	-.028				+.196	- 196	- .960
89 +03.6	912.09	0					+ 11	912.20	+.04			
			+.049	+.049	0	0				+.049	- 147	- .720
88 +88.1	912.10	+.01					+ 11	912.21	+.01			
			+.098	+.049	+ .240	+.007				+.343	+.294	+1 441
88 +72.6	912.12	+.02					+ 16	912.28	+.07			
			+.637	+.539	+2.642	+.079				+.931	+.588	+ 2.882
88 +57.1	912.25	+.13					+.22	912.47	+.19			
			+.294	-.343	-1.681	-.050				+.294	-.637	- 3.122
88 +41.6	912.31	+.06					+.22	912.53	+.06			
			+.098	-.196	- .960	-.028				-.098	-.392	- 1.921
88 +26.1	912.33	+.02					+ 18	912.51	-.02			
			0	-.098	- 480	-.014				-.049	+.049	+ .240
88 +10.6	912.33	0					+ 17	912.50	-.01			
			+.294	+.294	+1 441	+.043				+.588	+ 637	+3.122
87 +95.1	912.39	+.06					+.23	912.62	+ 12			
			+.147	-.147	- .720	-.021				+.098	- 490	- 2.401
87 +79.6	912.42	+.03					+.22	912.64	+.02			

APPENDIX NUMBER 1

CHART NUMBER 2

SHEET NO. 2

		SUMMARY											
STATIONS EACH 15.5 FT	VERT. ACCEL. IN G'S	TOTAL VERT. ACCEL.	ROCKING COUPLE	GAGE OF TRACK	ANGLE OF ELEVATION	GRAVITY COMPONENT ON CURVE	ALIGNMENT OF CURVE	SUPER ELEVATION OF HIGH RAIL	EQUILIBRIUM SPEED MPH	CENT. FORCE	FORCE DUE TO ELEV. OF HIGH RAIL	TOTAL FORCE AGAINST THE HIGH RAIL
	NO. 10	NO. 11	NO. 12	NO. 13	NO. 14	NO. 15	NO. 16	(INCHES) NO. 17	NO. 18	NO. 19	NO. 20	NO. 21
		(C5) + (C10) / 2	(C10) - (C5)	FEET						POUNDS	POUNDS	POUNDS
91 + 05.1				4.660	-0° 22'		0	- .37			-1258.4	1258.4
90 + 89.6				4.710	-0° 22'		0	- .37			-1258.4	1258.4
	+.021	+.014	+.014									
90 + 74.1				4.700	-0° 07'		0	- .12			- 385.2	385.2
	-.014	-.007	-.014									
90 + 58.6				4.700	-0° 07'		0° 30'	- .12		3055	- 385.2	3440.2
	-.007	-.007	0									
90 + 43.1				4.700	-0° 07'		0° 15'	- .12		1527	- 385.2	1912.2
	+.007	+.007	0									
90 + 27.6				4.700	-0° 07'		0° 45'	- .12		-4582	- 385.2	-4198.8
	-.014	-.003	-.028									
90 + 12.1 Point of Spiral				4.700	0° 00'		0° 15'	0		-1527	0	-1527.0
	+.007	-.007	+.028									
89 + 96.6				4.680	+0° 07'	.00204	1° 15'	.12	11.7	7637	- 385.2	7251.8
	+.072	+.064	+.015									
89 + 81.1				4.700	+0° 29'	.00844	0°	.50	STA TK	0	1643.7	-1643.7
	-.079	-.061	-.036									
89 + 65.6				4.700	+0° 14'	.00407	0°	.25	STA TK	0	770.5	- 770.5
	+.043	+.025	+.036									
89 + 50.1				4.700	+0° 36'	.01047	1° 00'	.62	29.8	6110	2054.6	4065.4
	-.028	-.011	-.035									
89 + 34.6				4.690	0° 22'	.00640	1° 00'	.37	23.0	6110	1258.4	4851.6
	+.057	+.035	+.043									
89 + 19.1				4.690	0° 50'	.01454	0° 45'	.88	41.0	4582	2824.7	1757.3
	-.028	-.028	0									
89 + 03.6				4.710	1° 21'	.02356	2° 15'	1.37	29 4	13746	4595.9	9150.1
	-.021	-.011	-.021									
88 + 88.1				4.690	1° 21'	.02356	1° 30'	1.37	36.2	9165	4595.9	4569.1
	+.043	+.025	+.036									
88 + 72.6				4.690	1° 57'	.03403	0° 45'	2.00	61.8	4582	6622.6	-2040.6
	+.086	+.082	+.007									
88 + 57.1				4.660	2° 42'	.04711	0° 15'	2.75	REV CURVE	-1527	9209.0	-10736.00
	-.094	-.072	-.044									
88 + 41.6				4.700	2° 41'	.04682	1° 15'	2.75	56.0		9106.4	-1469.4
	-.057	-.043	-.029									
88 + 26.1				4.710	2° 11'	.03810	1° 30'	2.75	46.2	9165	7443.00	1722.0
	+.007	-.003	+.021									
88 + 10.6				4.700	2° 04'	.03606	2° 15'	2.12		13746	7006.7	6739.3
	+.094	+.068	+.051									
87 + 95.1				4.710	2° 48'	.04885	1° 30'	2.87		9165	9542.5	- 377.5
	-.072	-.047	+.051									
87 + 79.6				4.730	2° 40'	.04653	1° 00'	2.75		6110	8979 4	-2869 4

APPENDIX NO. 2

EXCERPTS and TABLES
From the
ASSOCIATION OF AMERICAN RAILROAD'S
REPORT of
INVESTIGATION of LATERAL FORCES
DEVELOPED BY DIESEL LOCOMOTIVES
ON THE SPIRAL OF A TWO DEGREE CURVE
ON THE CB&Q RAILROAD

Conducted on April 14, 1969

FIG. 1

INSTRUMENT LOCATION

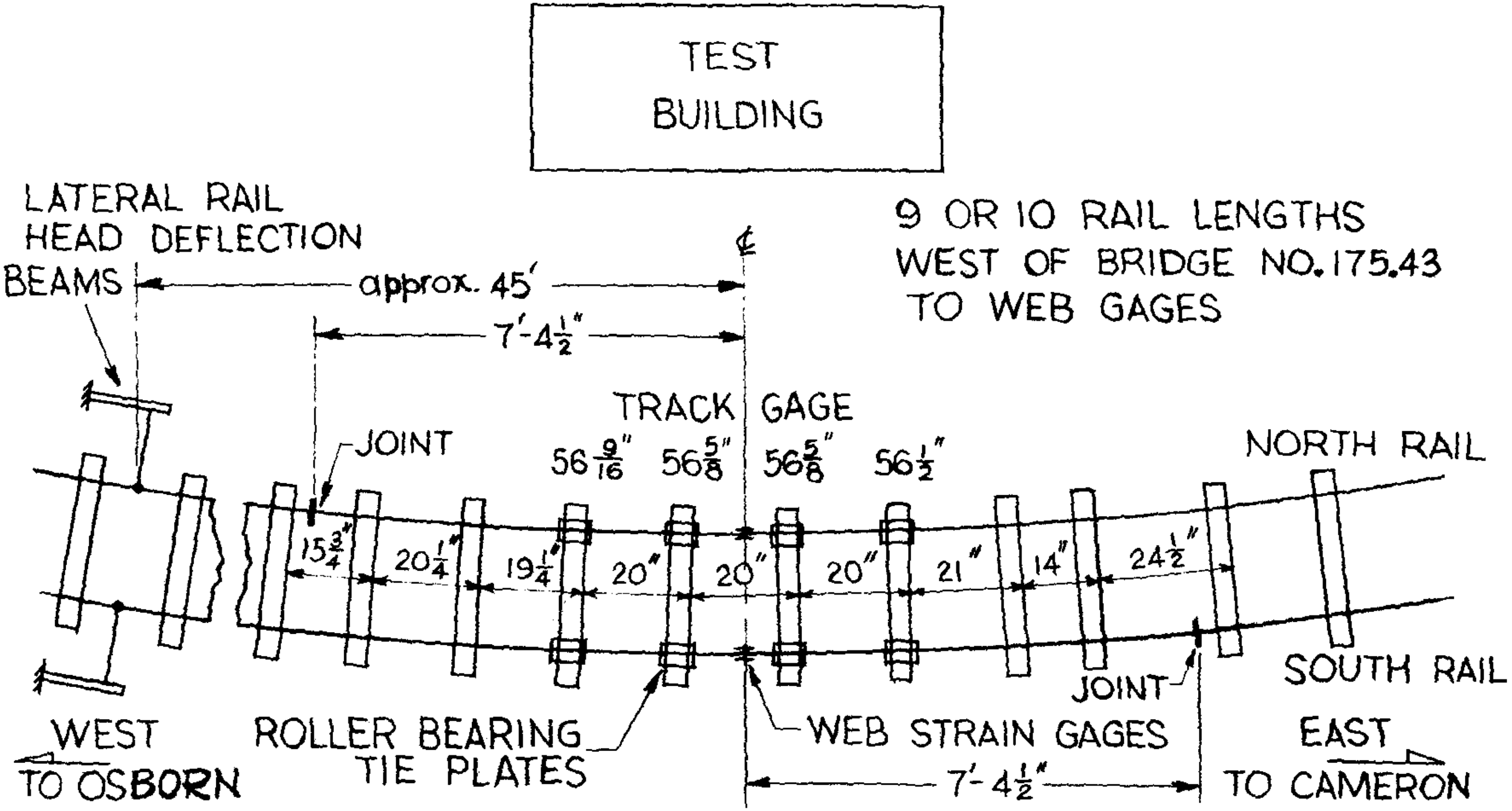
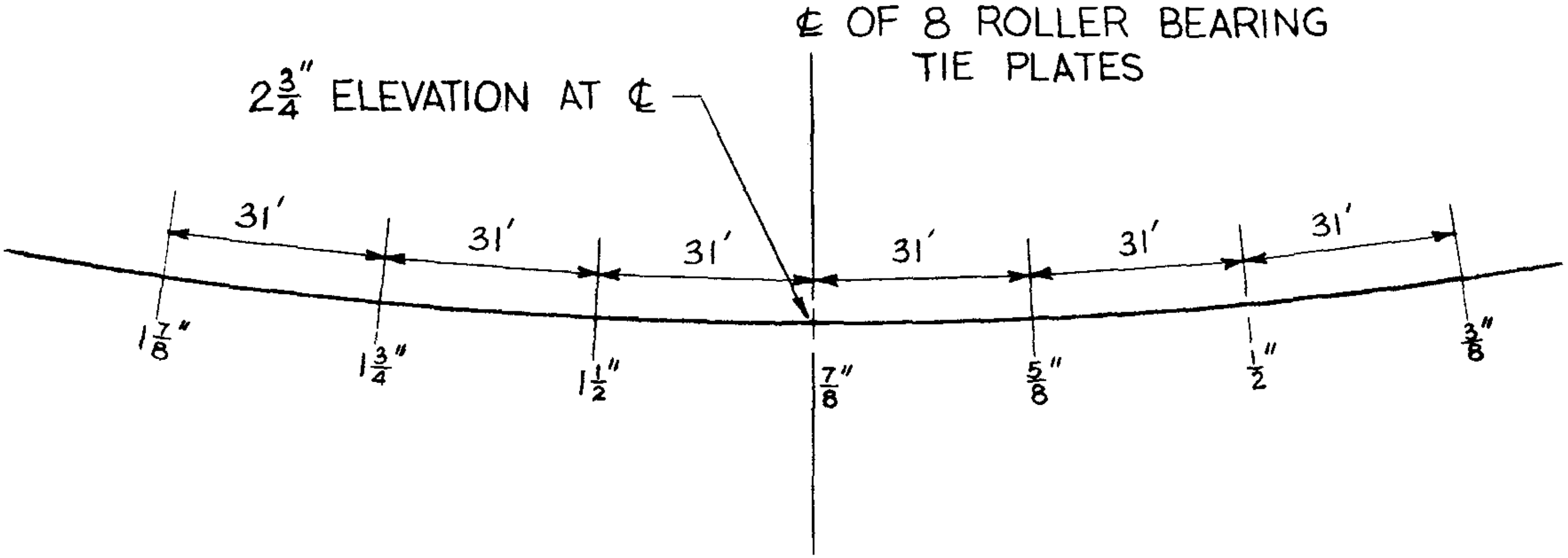


FIG. 2

CURVATURE OF TRACK AT INSTRUMENT LOCATION (MIDORDINATES OF 62 FT. CHORD)



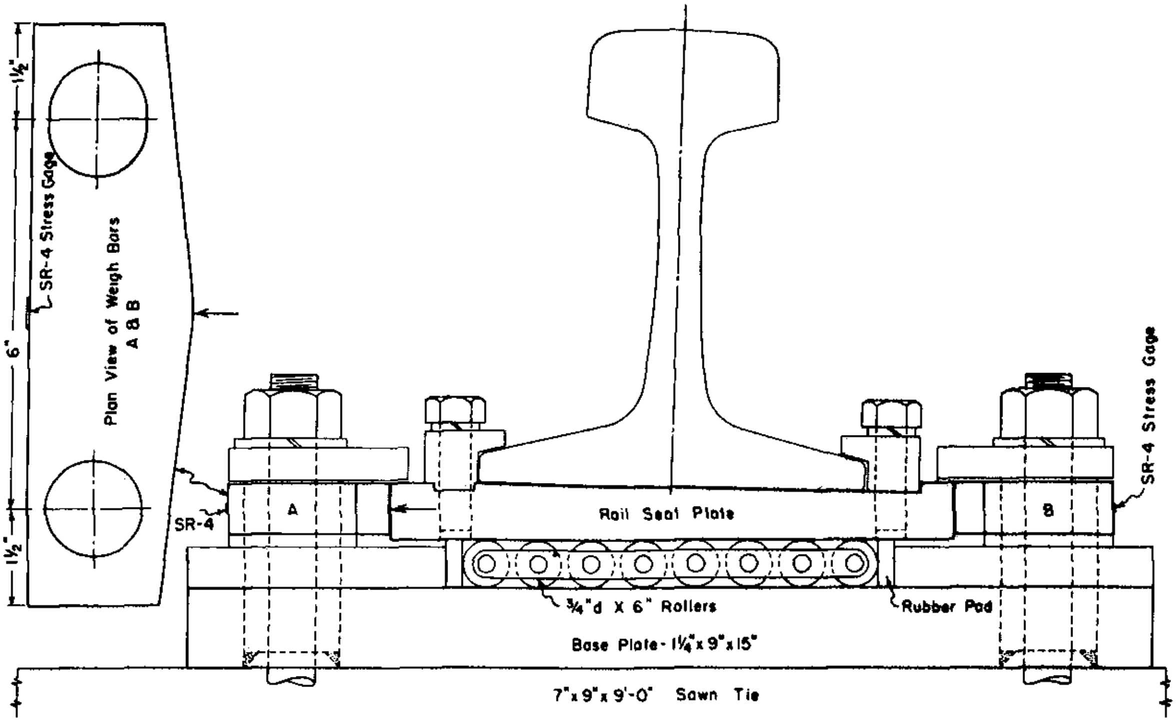


Fig. 3
Section of roller bearing tie plates for measuring lateral force between rail and a tie.

TABLE 1

RAIL FORCES AND DEFLECTIONS
RUN NO. 1 - 7.9 MPH

Locomotive or Car No.	Axle(1) No.	Lateral Force(2)		Vertical Force	Lateral Deflection(2)	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	0	1.2	31		
(GP40)	2	-0.4	3.2	28		
	3	-0.6	2.4	28		
	4	-0.8	1.2	29		
635	1	-0.2	2.4	32		
(GP40)	2	-1.0	2.4	29		
	3	0	2.4	28		
	4	-1.4	2.2	26		
187	1	1.6	3.2	30		
(GP40)	2	-1.0	2.2	28		
	3	-0.6	2.0	28		
	4	-0.8	2.4	25		
957	1	-0.4	1.4	29		
(GP30)	2	-0.6	2.2	26		
	3	-0.2	1.2	28		
	4	-0.4	2.4	26		
966	1	0	1.4	29	-.02 max.	
(GP30)	2	-0.4	2.4	26		
	3	0	1.4	30		
	4	-1.0	2.6	25		
501	1	0.8	2.2	28		
(SD24)	2	0	2.6	27		.04 max.
	3	0	2.4	26		
	4	1.4	2.8	25		
	5	0	1.4	26		
	6	-0.8	2.8	22		
562	1	-0.2	2.0	33		
(U28C)	2	0	2.0	33		
	3	-2.4	3.2	30		
	4	-0.2	2.0	23		
	5	-0.2	2.0	29		
	6	0	1.0	30		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 2

RAIL FORCES AND DEFLECTIONS
RUN NO. 2 - 5.0 MPH - REVERSE MOVEMENT

Locomotive or Car No.	Axle$^{(1)}$ No.	Lateral Force$^{(2)}$		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	-1.2	0.6	31		
(GP40)	2	-1.2	3.2	26		
	3	-1.2	1.4	26		
	4	-1.2	1.8	25		
635	1	-0.4	1.6	31		
(GP40)	2	0.4	4.8	26		.05 max.
	3	-1.4	1.8	28		
	4	-0.6	1.4	25		
187	1	-1.2	2.0	30		
(GP40)	2	-1.0	1.8	26		
	3	-0.6	2.0	26		
	4	-0.4	4.0	28		
957	1	-0.6	0.2	29		
(GP30)	2	-0.4	3.2	23		
	3	-0.2	0.8	26		
	4	-0.2	3.6	24		
966	1	-1.0	1.6	26		
(GP30)	2	-0.8	2.2	24		
	3	1.2	3.4	27		
	4	4.0	6.6	24	.04 max.	
501	1	-0.2	1.4	29		
(SD24)	2	0	3.2	29		
	3	1.4	2.2	25		
	4	0	2.6	25		
	5	0	2.0	25		
	6	0.4	3.2	-		
562	1	-1.6	2.2	31		
(U28C)	2	-0.6	1.8	33		
	3	0	2.4	33		
	4	-	-	-		
	5	-	-	-		
	6	-	-	-		

Note 1. Axles are numbered from head end of train.

Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 3

RAIL FORCES AND DEFLECTIONS
RUN NO. 3 - 29.5 MPH

Locomotive or Car No.	Axle[(1)] No.	Lateral Force[(2)] Outer Rail Klb.	Lateral Force[(2)] Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629	1	0	-	-		
(GP40)	2	0	2.0	31		
	3	-0.6	1.4	31		
	4	-0.4	0.4	33		
635	1	0.6	2.2	33		
(GP40)	2	-0.6	1.2	31		
	3	0.4	2.0	29		
	4	-0.4	0.8	28		
187	1	1.4	2.4	32		.04 max.
(GP40)	2	0	0.8	32		
	3	2.6	4.0	28		
	4	0	1.4	29		
957	1	0	0.6	32		
(GP30)	2	0	0.4	31		
	3	-0.4	1.4	32		
	4	-0.6	1.2	26		
966	1	0	0.8	33		
(GP30)	2	0	0.6	32		
	3	0.6	2.4	30		
	4	0	0.8	29		
501	1	2.0	2.4	28	.02 max	
(SD24)	2	0	2.2	29		
	3	0	2.2	26		
	4	2.8	2.8	28		
	5	0	1.8	26		
	6	0	1.2	24		
562	1	1.4	2.2	36		
(U28C)	2	0	1.4	33		
	3	-0.8	1.2	35		
	4	-0.6	2.0	25		
	5	0	0.8	31		
	6	0	0	29		
CB&Q 23491	1	0	0	15		
	2	0	0	18		
	3	1.2	1.2	14		
	4	0	0	15		
CB&Q 33623	1	0	0	21		
	2	0	0	18		
	3	0	0.8	15		
	4	0	1.0	16		

Note 1. Axles are numbered from head end of train.

Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 4

RAIL FORCES AND DEFLECTIONS
RUN NO. 4 - 38 MPH

Locomotive or Car No.	Axle[1] No.	Lateral Force[2] Outer Rail Klb.	Lateral Force[2] Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629	1	-0.6	-	-	.04 max.	
(GP40)	2	-0.6	-	31		
	3	-0.4	1.8	33		
	4	-0.4	0	31		
635	1	0.6	2.0	32		
(GP40)	2	-0.4	0.6	32		
	3	0.4	2.2	32		
	4	0	0.8	28		
187	1	0.4	2.0	31		
(GP40)	2	0	0.6	31		
	3	3.0	4.0	29		
	4	0	1.4	26		
957	1	0	0.6	33		
(GP30)	2	0	0.4	25		
	3	0	1.2	27		
	4	-0.4	1.8	27		
966	1	0.6	0.4	33		
(GP30)	2	0.2	0	31		
	3	0.6	2.2	28		
	4	0	0.6	31		
501	1	2.8	2.4	30		.04 max
(SD24)	2	0.6	1.8	29		
	3	0	1.4	25		
	4	2.8	2.8	25		
	5	0.4	1.6	22		
	6	0	1.2	-		
562	1	1.6	2.0	33		
(U28C)	2	0	1.4	37		
	3	-0.6	0.8	33		
	4	-0.2	2.0	26		
	5	0	0.6	30		
	6	0.4	-1.0	33		
CB&Q 23491	1	0	0	16		
	2	0	0	17		
	3	0.8	0	13		
	4	0	2.0	16		
CB&Q 33623	1	0	0	18		
	2	0	0	18		
	3	0	0.6	-		
	4	0	0.6	17		

Note 1. Axles are numbered from head end of train.

Note 2 Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 5

RAIL FORCES AND DEFLECTIONS
RUN NO. 5 - 46 MPH

Locomotive or Car No.	Axle(1) No.	Lateral Force(2) Outer Rail Klb.	Lateral Force(2) Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629 (GP40)	1	-0.4	1.2	40	.05 max.	
	2	-1.0	1.2	33		
	3	0	2.0	31		
	4	-0.4	0.6	32		
635 (GP40)	1	1.0	1.8	32		.04 max.
	2	0	1.0	31		
	3	0.8	2.4	30		
	4	0	1.0	29		
187 (GP40)	1	1.2	1.8	35		
	2	0	0.6	33		
	3	4.0	4.6	30		
	4	0	1.2	25		
957 (GP30)	1	0	0.8	35		
	2	0	0.4	30		
	3	0	1.0	23		
	4	-0.4	1.2	27		
966 (GP30)	1	0	0.6	33		
	2	0.6	-1.0	33		
	3	0.6	2.0	31		
	4	0	1.6	26		
501 (SD24)	1	2.0	2.0	34		
	2	0.6	1.4	31		
	3	0	0.4	21		
	4	2.0	2.2	23		
	5	1.0	1.2	-		
	6	0	1.2	25		
562 (U28C)	1	1.4	2.0	35		
	2	0	1.2	34		
	3	-0.4	0.4	34		
	4	-0.2	2.2	26		
	5	-0.2	1.0	29		
	6	0.4	-0.4	-		
CB&Q 23491	1	0	0	17		
	2	0	-0.4	17		
	3	0.4	1.4	13		
	4	0	0	15		
CB&Q 33623	1	0	0	20		
	2	0	0	18		
	3	0	0.6	17		
	4	0	0.2	17		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 6

RAIL FORCES AND DEFLECTIONS
RUN NO. 6 - 50.5 MPH

Locomotive or Car No.	Axle$^{(1)}$ No.	Lateral Force$^{(2)}$ Outer Rail Klb.	Lateral Force$^{(2)}$ Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629 (GP40)	1	-0.2	1.8	34	.05 in.	
	2	-0.8	1.6	32		
	3	-0.6	1.8	31		
	4	-0.2	0.6	35		
635 (GP40)	1	1.0	1.2	34		
	2	0	2.4	36		
	3	0.4	2.4	30		
	4	0	1.8	29		
187 (GP40)	1	1.2	3.0	37		.04 in.
	2	0	1.6	35		
	3	2.0	3.8	31		
	4	0	1.8	28		
957 (GP30)	1	0	0.4	35		
	2	0	2.0	29		
	3	0	0.8	32		
	4	-0.2	1.8	33		
966 (GP30)	1	0	0	35		
	2	-0.2	0	33		
	3	-0.4	1.2	32		
	4	0	0.8	31		
501 (SD24)	1	-2.4	2.0	31		
	2	0.4	1.6	29		
	3	0	1.2	28		
	4	2.0	-	26		
	5	0	-	29		
	6	0	-	25		
562 (U28C)	1	0.8	-	34		
	2	0	-	39		
	3	-0.4	-	39		
	4	-0.6	-	26		
	5	-0.4	-	33		
	6	0.2	-	40		
CB&Q 23491	1	0	0	16		
	2	0	0	18		
	3	0.6	1.0	11		
	4	0	0	16		
CB&Q 33623	1	0	0	21		
	2	0	0	18		
	3	0	0.6	16		
	4	0	0	20		

Note 1. Axles are numbered from head end of train.

Note 2 Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 7

RAIL FORCES AND DEFLECTIONS
RUN NO. 7 - 52 MPH

Locomotive or Car No.	Axle$^{(1)}$ No.	Lateral Force$^{(2)}$ Outer Rail Klb.	Lateral Force$^{(2)}$ Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629	1	-0.4	-3.0	41	No record	.04 max.
(GP40)	2	-0.4	0	34		
	3	-0.6	1.2	28		
	4	-0.6	0	34		
635	1	0.6	-	33		
(GP40)	2	0	-	35		
	3	0.4	-	34		
	4	0	-	30		
187	1	0.6	1.2	36		
(GP40)	2	0	0.6	31		
	3	1.2	3.0	31		
	4	0	1.0	29		
957	1	0	0	35		
(GP30)	2	0	0	30		
	3	0	0.2	31		
	4	0	1.0	30		
966	1	0	0	36		
(GP30)	2	0	-1.0	35		
	3	0.4	2.0	29		
	4	0	1.4	32		
501	1	1.4	1.8	36		
(SD24)	2	1.0	0.8	31		
	3	0	0.6	32		
	4	1.2	2.4	44		
	5	0.4	1.4	27		
	6	0	1.2	24		
562	1	0.6	2.0	35		
(U28C)	2	0	1.0	33		
	3	0	0.4	37		
	4	0	1.0	27		
	5	0	1.0	31		
	6	0	0	44		
CB&Q 23491	1	0	0	17		
	2	0	-0.4	18		
	3	0.4	1.2	12		
	4	0	0	14		
CB&Q 33623	1	0	0	22		
	2	0	0	17		
	3	0	1.0	14		
	4	0	0.8	17		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 8 .

RAIL FORCES AND DEFLECTIONS
RUN NO. 8 - REVERSE MOVEMENT

Locomotive or Car No.	Axle$^{(1)}$ No.	Lateral Force$^{(2)}$		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	-0.6	0.4	31	No record	
(GP40)	2	-1.0	2.2	26		
	3	-0.4	1.2	26		
	4	-0.4	1.4	25		
635	1	-0.4	0.4	31		
(GP40)	2	-0.2	4.0	26		.05 max.
	3	-0.8	1.4	27		
	4	-0.4	1.0	25		
187	1	-0.6	1.4	29		
(GP40)	2	-0.4	1.0	26		
	3	-0.2	1.6	26		
	4	0	3.4	25		
957	1	-0.6	0	29		
(GP30)	2	-0.6	1.6	22		
	3	-0.1	0.6	28		
	4	-0.2	3.8	20		
966	1	-0.2	0	31		
(GP30)	2	-0.2	1.2	23		
	3	2.0	4.0	26		
	4	2.4	6.0	21		
501	1	0	1.6	27		
(SD24)	2	0	2.4	28		
	3	0.4	2.8	24		
	4	0	2.4	25		
	5	0	1.8	24		
	6	0	3.0	20		
562	1	-0.6	3.0	33		
(U28C)	2	1.2	3.2	34		
	3	0.6	3.0	27		
	4	0	0	21		
	5	0	-	26		
	6	1.0	-	29		
CB&Q 23491	1	0	0	16		
	2	0	1.0	13		
	3	0	0	12		
	4	0	2.0	11		
CB&Q 33623	1	0	0.4	18		
	2	0	0.4	18		
	3	-	-	-		
	4	-	-	-		

Note 1. Axles are numbered from head end of train

Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 9

RAIL FORCES AND DEFLECTIONS
RUN NO 9 - 50 MPH

Locomotive or Car No.	Axle(1) No.	Lateral Force(2)		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	0	0.4	35		.04 max.
(GP40)	2	-0.4	0.8	34		
	3	-0.4	1.8	32		
	4	0	0	33		
635	1	0 8	2.0	36		
(GP40)	2	0	0 2	33		
	3	0.6	1.8	32		
	4	0	0	32		
187	1	0 4	2.0	33		
(GP40)	2	0	0.2	33		
	3	2.4	4.0	30		
	4	0	1.6	30		
957	1	0	0	30		
(GP30)	2	0	0.6	29		
	3	0	0.8	27		
	4	0	1.0	27		
966	1	0	0 4	33		
(GP30)	2	0.6	-1.4	33		
	3	0.4	2 0	33		
	4	0	1.0	31		
501	1	0 4	0	32		
(SD24)	2	0.6	0.6	27		
	3	0	0 2	35		
	4	2.0	2 2	29		
	5	0 4	1.0	27		
	6	0	1.0	27		
562	1	0	2 0	31	05 max	
(U28C)	2	0	0 4	38		
	3	0	0.6	35		
	4	0	1.0	26		
	5	0	1 0	27		
	6	0	-0 4	36		
CB&Q 23491	1	0	0	16		
	2	0 2	-0 6	17		
	3	0 8	1.2	11		
	4	0	0	16		
CB&Q 33623	1	0	0	21		
	2	0	0	17		
	3	0	0.8	14		
	4	0	0 2	20		

Note 1. Axles are numbered from head end of train.

Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 10

RAIL FORCES AND DEFLECTIONS
RUN NO. 10 - 48 MPH - FULL DYNAMIC BRAKING

Locomotive or Car No.	Axle(1) No.	Lateral Force(2) Outer Rail Klb.	Lateral Force(2) Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
629	1	0	0	37	04 max.	.04 max.
(GP40)	2	0	2.2	30		
	3	0	0.2	34		
	4	0	0.2	32		
635	1	0.4	1.8	33		
(GP40)	2	0	0	33		
	3	0	1.0	31		
	4	0	0	31		
187	1	0.2	2.0	33		
(GP40)	2	0	0	32		
	3	1.8	4.2	31		
	4	0	0.4	30		
957	1	0	0.2	36		
(GP30)	2	0	0	31		
	3	0	1.0	30		
	4	0	1.0	27		
966	1	0	0.2	33		
(GP30)	2	0.4	-0.6	35		
	3	0.2	1.8	31		
	4	0	1.0	29		
501	1	0	0	32		
(SD24)	2	0.2	2.0	33		
	3	0	1.2	28		
	4	1.2	2.0	26		
	5	0.6	0.4	44		
	6	0	0.6	28		
562	1	0	2.0	34		
(U28C)	2	0	1.0	37		
	3	0	1.0	35		
	4	0	1.4	24		
	5	0	2.0	30		
	6	0	-0.4	39		
CB&Q 23491	1	0.6	0	18		
	2	0.4	-0.6	18		
	3	1.2	1.6	12		
	4	0	0	15		
CB&Q 33623	1	0	0	21		
	2	0	0	19		
	3	0	0.4	15		
	4	0	0.6	17		

Note 1 Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 11

RAIL FORCES AND DEFLECTIONS
RUN NO 11 - REVERSE MOVEMENT - ACCELERATING

Locomotive or Car No.	Axle(1) No.	Lateral Force(2)		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	-1.0	0	38		
(GP40)	2	-0.4	3.0	18		
	3	-1.0	0.8	34		
	4	0	2.8	20		
635	1	-0.4	1.0	39		
(GP40)	2	0.4	4.0	21		
	3	-1.0	2.0	29		
	4	0	2.0	22		
187	1	-2.0	1.0	38		
(GP40)	2	-0.4	1.2	20		
	3	-0.2	2.4	30		
	4	2.0	4.0	23	0.10 max.	.06 max.
957	1	-0.8	0	33		
(GP30)	2	-0.4	1.6	22		
	3	-0.8	3.6	27		
	4	-1.0	2.6	20		
966	1	-0.8	0	33		
(GP30)	2	0	0	22		
	3	0	3.2	32		
	4	2.0	4.2	21		
501	1	-0.6	2.0	31		
(SD24)	2	0	2.4	25		
	3	0.8	2.0	22		
	4	0	1.0	26		
	5	0.2	1.4	26		
	6	0	1.8	21		
562	1	0	4.0	33		
(U28C)	2	2.2	4.4	41		
	3	1.0	2.4	29		
	4	0	0	24		
	5	0	1.6	26		
	6	-0.6	4.0	31		
CB&Q 23491	1	0	0	18		
	2	0	0.6	14		
	3	0	0	12		
	4	0	1.4	12		
CB&Q 33623	1	0	0	21		
	2	0	0	20		
	3	0	0	16		
	4	0	0.4	16		

Note 1. Axles are numbered from head end of train.

Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 12

RAIL FORCES AND DEFLECTIONS
RUN NO 12 - 50 MPH

Locomotive or Car No.	Axle(1) No.	Lateral Force(2)		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	-	-	34	06 max	
(GP40)	2	0	0	33		
	3	0 6	1 6	29		
	4	0	0	33		
635	1	0	0 8	35		
(GP40)	2	0	0	34		
	3	0	2 0	33		
	4	0	0 6	29		
187	1	0	2 0	32		04 max
(GP40)	2	0	0 2	31		
	3	2.0	3 6	28		
	4	0	1 4	29		
957	1	0	0 2	33		
(GP30)	2	0	0	30		
	3	0	0 6	27		
	4	0	1 0	28		
966	1	0	0 2	27		
(GP30)	2	0	-1 0	32		
	3	0	0 8	27		
	4	0	0 8	28		
501	1	0	0	31		
(SD24)	2	1 2	1 4	31		
	3	0	1 0	27		
	4	2 0	1 6	29		
	5	0 6	0	24		
	6	0	1 0	23		
562	1	0	0 8	33		
(U28C)	2	0	0 4	37		
	3	0	0 4	34		
	4	0	0 8	23		
	5	0	0 4	31		
	6	0	-0 8	36		
CB&Q 23491	1	0	0 2	15		
	2	0	0	16		
	3	0 4	1 6	12		
	4	0	0	15		
CB&Q 33623	1	0	0	20		
	2	0	0	15		
	3	0	0	12		
	4	0	0	19		

Note 1 Axles are numbered from head end of train

Note 2 Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 13

RAIL FORCES AND DEFLECTIONS
RUN NO. 13 - 12 MPH - TRAIN NO. 71 - WESTBOUND

Locomotive or Car No.	Axle(1) No.	Lateral Force(2) Outer Rail Klb.	Lateral Force(2) Inner Rail Klb.	Vertical Force Outer Rail Klb.	Lateral Deflection Outer Rail in.	Lateral Deflection Inner Rail in.
188	1	0	1.4	29	.04 max.	
	2	0	1.4	27		
	3	0	1.0	29		
	4	-0.2	2.0	26		
984	1	0	2.6	28		
	2	0	1.4	29		
	3	0	2.2	28		
	4	0	1.4	23		
934	1	0	2.4	27		.04 max.
	2	0	1.8	27		
	3	0	1.8	26		
	4	0	1.4	27		
First Car	1	0	0	16		
	2	0	0.6	14		
	3	0	0.2	9		
	4	0	0.4	10		
Second Car	1	0	1.6	16		
	2	0	0.2	16		
	3	0.4	2.4	8		
	4	0	0	10		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 14

RAIL FORCES AND DEFLECTIONS
RUN NO. 14 - 52 MPH - REVISED LOCOMOTIVE ORDER

Locomotive or Car No.	Axle[1] No.	Lateral Force[2]		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629	1	0	1.0	-	.04 max.	
(GP40)	2	0	0.8	39		
	3	0.6	1.8	29		
	4	0	0	32		
635	1	0.6	1.6	32		
(GP40)	2	0	0	34		
	3	0.2	1.8	29		
	4	0	0	31		
187	1	0.4	1.6	30		
(GP40)	2	0	0	29		
	3	1.0	2.4	28		
	4	0	1.0	28		
562	1	0.4	2.0	30		
(U28C)	2	0	1.4	36		
	3	0	0	38		.04 max
	4	0	1.2	25		
	5	0	1.4	24		
	6	0.2	0	35		
957	1	0	0	33		
(GP30)	2	0	0.2	27		
	3	0	0.4	31		
	4	0	1.6	29		
966	1	0	0	34		
(GP30)	2	0.2	-0.8	35		
	3	0.2	2.6	30		
	4	0	1.2	30		
501	1	0.6	1.6	33		
(SD24)	2	0.6	1.0	26		
	3	0	0.2	29		
	4	1.0	1.6	37		
	5	0	1.0	38		
	6	0	1.0	25		
CB&Q 23491	1	0	0	17		
	2	0	0.4	19		
	3	0.2	1.6	11		
	4	0	0	14		
CB&Q 33623	1	0	0	21		
	2	0	0	17		
	3	0	0	17		
	4	0	0	19		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 15

RAIL FORCES AND DEFLECTIONS
RUN NO. 15 - 49.5 MPH - REVISED LOCOMOTIVE ORDER

Locomotive or Car No.	Axle$^{(1)}$ No.	Lateral Force (2)		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
629 (GP40)	1	0	1.0	35	.04 max	
	2	0	0.4	36		
	3	0.6	1.2	28		
	4	0	0	33		
635 (GP40)	1	1.4	2.0	35		
	2	0	0	32		
	3	0.6	2.0	29		
	4	0	0.2	29		
187 (GP40)	1	0.2	1.2	33		
	2	0	0	29		
	3	2.0	2.8	29		
	4	0	1.4	25		
562 (U28C)	1	0	1.6	31		
	2	0	1.2	38		
	3	0	0	37		
	4	-0.4	1.2	22		
	5	0	1.2	29		
	6	0.2	-0.6	35		
957 (GP30)	1	0	0	-		
	2	0	0	29		
	3	0	0.6	28		
	4	0	1.0	29		
966 (GP30)	1	0	0	30		
	2	0.2	1.4	33		
	3	0.2	2.2	31		
	4	0	1.0	29		
501 (SD24)	1	0.2	0.4	31		.04 max.
	2	0.2	0.8	26		
	3	0	0.4	24		
	4	1.6	1.8	25		
	5	0	1.0	25		
	6	0	1.0	25		
CB&Q 23491	1	0	0	18		
	2	0	0	16		
	3	0.8	1.6	11		
	4	0	0	15		
CB&Q 33623	1	0	0	20		
	2	0	0	17		
	3	0	0	15		
	4	0	0	20		

Note 1 Axles are numbered from head end of train.

Note 2 Negative sign indicates force or lateral deflection acting toward center line of track.

TABLE 16

RAIL FORCES AND DEFLECTIONS
RUN NO. 16 - 46 MPH - TRAIN NO. 72 - EASTBOUND

Locomotive or Car No.	Axle(1) No.	Lateral Force(2)		Vertical Force	Lateral Deflection	
		Outer Rail Klb.	Inner Rail Klb.	Outer Rail Klb.	Outer Rail in.	Inner Rail in.
927	1	-0.8	1.2	24	.02 max.	.02 max.
	2	0	1.2	32		
	3	0	0.4	30		
	4	0	1.2	30		
624	1	0	0	26		
	2	-1.0	1.6	27		
	3	0	0.2	27		
	4	0	1.0	33		
108	1	0	3.4	27		
	2	0	0.6	36		
	3	1.0	3.0	31		
	4	0	1.2	34		
141	1	0	3.0	24		
	2	0	1.4	27		
	3	0	1.4	27		
	4	0	1.4	30		
First Car	1	0	1.8	8		
	2	0	0	9		
	3	0	1.0	11		
	4	0	0	11		
Second Car	1	0	1.0	8		
	2	0	0	8		
	3	0.2	1.4	11		
	4	0	0.6	14		

Note 1. Axles are numbered from head end of train.
Note 2. Negative sign indicates force or lateral deflection acting toward center line of track.

APPENDIX 3

BURLINGTON LINES
MECHANICAL INSTRUCTIONS
FOR
ENGINEMEN

Effective January 1, 1946
Revised Edition
JULY 1, 1954

INTRODUCTION

The instructions and information contained in this book are designed to meet the requirements for the proper care and operation of locomotives.

It is obvious that instructions cannot be made to cover all conditions which will arise unexpectedly, and for which there are no precedents; only good judgment and the application of such principles as may apply to the case will solve such problems; but the usual problems which arise daily can best be solved by following the instructions in this book.

In order that an Engineer or Fireman may perform his duties successfully, he must have a thorough knowledge of the locomotive, both the proper operation and how to successfully meet the unexpected and adverse conditions when they arise.

All Firemen, after six months actual service, may be required to pass a satisfactory examination on the rules and instructions pertaining to his duties.

Before being promoted to the position of Engineer, all Firemen will be required to pass an examination, based on this book, with a grade of not less than 80%.

All Engineers must familiarize themselves with the contents of this book and be prepared to pass a satisfactory examination at any time.

Engineers who have been demoted for a period of two years may be required to pass the regular Mechanical Examination before again being used as Engineers.

Engineers and Firemen will be required to familiarize themselves with all locomotives and locomotive devices in use on their divisions.

The instructions contained in this book supersede all previous instructions which may be in any way contradictory.

Engineers and Firemen must have a copy of this book with them at all times while on duty.

Approved:
S. L. FEE
Vice Pres.-Oper.

H. H. URBACH
Asst. V. P.-Oper. (Mech.)

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(excerpted)

engineer will signal the leading engine to start, with two long blasts of the engine whistle; the leading engineer will then start carefully.

Q.316--If the brakes cannot be applied in service position of the brake valve, what must the engineer do to apply the train brakes?

A.--The valve should be moved to emergency position.

Q.317--How must a train be handled to reduce speed but not stop with steam power? Diesel power, when the Dynamic brake cannot be used?

A.--If possible keep slack stretched by working power. Make a 15 pound split reduction; keep engine brake released. With Diesel passenger locomotives, reduce throttle to No. 5 position, reduce throttle further as speed reduces, to not less than 3 position; if speed is reduced to 30 M. P. H., close throttle to idle, then immediately open to desired position. Release train brakes in running position.

Where dynamic brake cannot be used with freight Diesel locomotives, make a split 15 pound brake pipe reduction, keeping the engine brakes released; as the speed reduces, the throttle and the transition lever must be moved to lower numbered positions, so that the indicator on the transition meter will not move to the right of the red triangle, on the lower scale. Release train brakes in running position.

If the slack cannot be kept stretched, first close the throttle to drifting or idling position, handle the brakes as outlined above except that the engine brakes should be allowed to apply with the train brakes. Keep the engine brakes applied until the train brakes are all released.

When reducing speed with diesel freight locomotives the dynamic brake should be used if possible.

Note: The engine brake on Diesel locomotives MUST NOT BE APPLIED WHILE THE THROTTLE IS IN ANY WORKING POSITION ABOVE NO. 1 OR WHILE THE DYNAMIC BRAKE IS APPLIED. Except as provided in Q.323

Q.318--How should a freight train be handled on short, but steep descending grades not over 3 miles in length where the speed must be kept below 25 M.P.H.?

A.--Work a fairly heavy throttle; keep the engine brakes released; make a 10 lb. brake pipe reduction, in time to have the speed reduced to that desired before reaching the slow track; then put the brake valve in running position one second for each 10 cars

APPENDIX NO. 4

N O T I C E

PERSONS RETURNING TO THEIR HOMES WHICH HAVE BEEN EXPOSED TO AMMONIA SHOULD OBSERVE THESE RULES:

1. Common Sense Test: Sealed food that has no taste or odor of ammonia is reasonably safe to use.
2. Ventilate the rooms well.
3. Use soap and water to thoroughly clean washable clothes, floors, furniture, or other materials which seem to have been wetted by ammonia.
4. Canned goods are safe, but the containers should be washed before being opened.
5. City drinking water is safe.
6. Potatoes and foods which require peeling should be washed before use.
7. Don't use unprotected leafy vegetables.
8. Sealed, wrapped, or frozen foods are safe if odor or taste of ammonia is absent.
9. Only sleep in a well-ventilated room where there is no ammonia odor.
10. DANGER: Avoid skin contact with any wet surface resulting from ammonia.

Nebraska State Department of Health
Lynn W. Thompson, MD
Director of Health

GPO 909-048