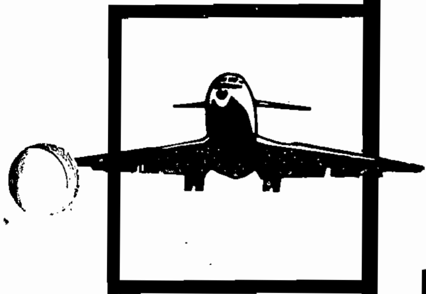

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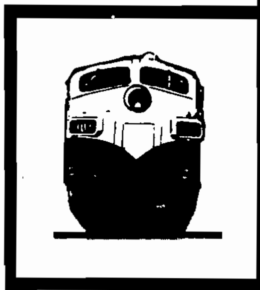

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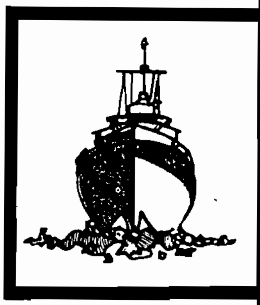
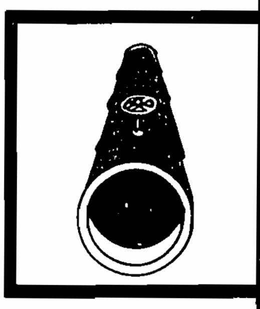


PIPELINE ACCIDENT REPORT

WILLIAMS PIPE LINE COMPANY GASOLINE EXPLOSION AND FIRE ROSEVILLE, MINNESOTA APRIL 16, 1981



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UNITED STATES GOVERNMENT

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16. Abstract
At 4:45 p.m., central standard time, April 16, 1980, gasoline at the Williams Pipe Line Company's Minneapolis terminal in Roseville, Minnesota, sprayed from the fractured cast-iron base of a station booster pump at 72 psig pressure, vaporized, and exploded after it was ignited by the arcing of an electric switch in the mainline pump control room 50 feet downwind of the booster pump. The resulting fire burned for 2 days, fueled by gasoline and fuel oil leaking from many burned-out flange gaskets, from drainage from hundreds of feet of pipe connecting 37 tanks, and from the receiving and loading rack manifolds.

The explosion killed one person. The fire injured three persons and destroyed the receiving manifold piping and valves, pumping equipment, and four vehicles. About 3,500 barrels (147,000 gallons) of petroleum products burned and property damage was estimated at $3 million.

The National Transportation Safety Board determines that the probable cause of the accident was the fracture of the base of a 30-year-old cast-iron pump which had not been hydrostatically tested at its new installation. The failure allowed gasoline under pressure to spray, vaporize, and enter an electric switchgear building 50 feet away. Ignition occurred from an electric arc produced by opening a switch. Contributing to the accident was the failure of the company to (1) utilize explosion-proof equipment in a potentially hazardous vapor area, and (2) fill the gap between the pump and its foundation with grout.

17. Key Words		18. Distribution Statement	
Gasoline explosion; petroleum terminal; storage tanks; mainline pump; centrifugal booster pump; fractured cast-iron base; manifold piping; tank piping; electric switch gear; electric arc ignition; electrically induced explosion and fire; explosion-proof switch gear; hazardous vapors; emergency shutdown system ESD; hydrostatic testing, classification of areas.		This document is available to the public through the National Technical Information Service-Springfield, Virginia 22161 *(Always refer to number listed in item 2)*	
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CONTENTS

SYNOPSIS 1

INVESTIGATION 1
- The Accident 1
- Injuries to Persons 7
- Damage to Facilities 7
- Other Damage 7
- Personnel Information 10
- Pipeline System 10
- Meteorological Information 12
- Fire 12
- Survival Aspects 12
- Tests and Research 14
- Other Information 14
  - Federal Regulations 14
  - Service History of Pump 19
  - Notification of Accident 20
  - Emergency Shutdown Procedures 20

ANALYSIS 20
- Hydrostatic Testing 21
- Grouting the Pump 22
- Explosion-Proof Electrical Equipment 22

CONCLUSIONS 23
- Findings 23
- Probable Cause 24

RECOMMENDATIONS 24

APPENDIXES 27
- Appendix A--Installation, Operation, and Maintenance Instructions for Stuffingboxless Tank Pumps 27
- Appendix B--Purging Procedures 30
- Appendix C--Pump Maintenance 32

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

Adopted: July 22, 1981

WILLIAMS PIPE LINE COMPANY GASOLINE EXPLOSION AND FIRE ROSEVILLE, MINNESOTA APRIL 16, 1980

SYNOPSIS

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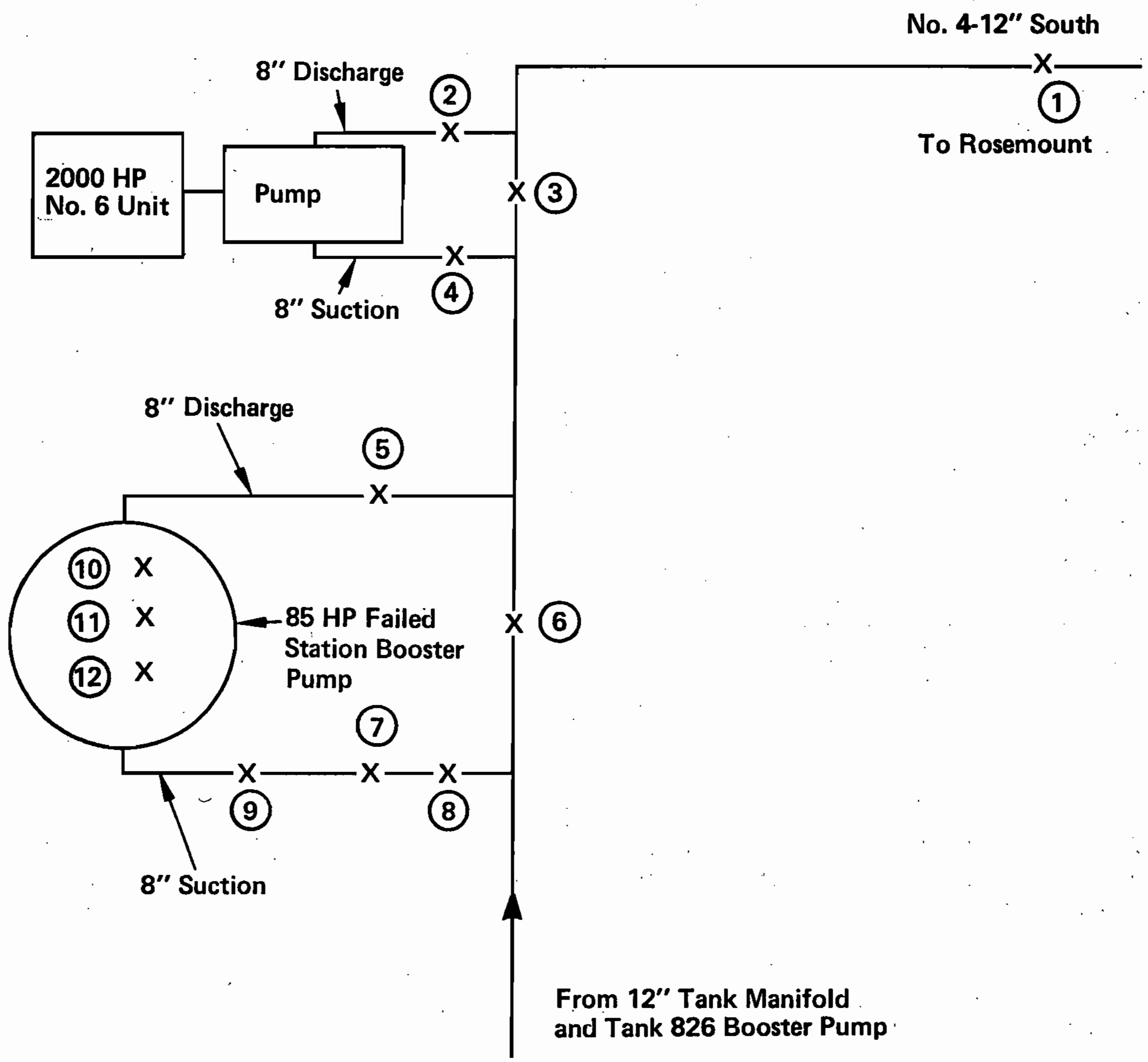
INVESTIGATION

The Accident

On November 20, 1979, at the Williams Pipe Line Company's Roseville Terminal north of Minneapolis, Minnesota, an 85-hp station booster pump was set on a concrete base adjacent to the No. 4 12-inch line, just upstream of the 2,000-hp mainline pump that it was to supply. The motor was removed for inspection and reinstalled, and the pump suction and discharge piping and valves were connected. (See appendix A.) The open ends of the piping were closed with tape to keep out dirt, and the unit was blocked up for support. It was left in this condition until April 1980.

On April 16, 1980, the pump piping was welded into the 12-inch suction line feeding the 2,000-hp mainline pump. (See figure 1.) The pipe for this work had been previously tested; however, the complete assembly, pump, flanges, valves, and welded elbows were not hydrostatically tested as a unit. The pump was placed on its concrete base and held there by four bolts. The pump was then leveled by the use of shims, rectangular pieces of metal 2 1/2 inches wide 3 inches long, and of varying thicknesses. A slot was cut out of each shim so that it would fit snugly around each of the four bolts anchoring the pump to



Valve 1	12"–600# Gate Valve
2	8" –600# Gate Valve
3	12"–600# Gate Valve
4	8" –600# Gate Valve
5	8" –150# Gate Valve
6	12"–150# Gate Valve
7	8" –150# Gate Valve
8	½" Needle Valves 3000#
9	½" Needle Valves 3000#
10	3/8" Needle Valves (Product)3000#
11	3/8" Needle Valves (Lube Oil)#
12	3/8" Needle Valves (Lube Oil)#

Figure 1.—85-horsepower station booster pump.

the concrete base. Because of the shims, the pump did not sit flat on its concrete base, but was separated from it by about 1 inch. (See figures 2 and 3.) Williams Pipe Line Company procedures did not include grouting 1/ this space on small pump installations such as this one. The work was completed about 3 p.m., and shortly after 4 p.m., the pump and piping were filled with gasoline and the air was being purged from the unit. The tank booster pump at tank 826, about 800 feet away, was turned on to supply more pressure for the air purging.

Williams had used its own personnel to install this booster pump; the seven-man work crew consisted of a foremen, two welders, two pipeliners, and two truckdriver/operators. After this crew had completed the pump installation, the foreman and three crewmembers began loading equipment on a truck at the equipment warehouse about 200 feet away from the pump; the other three crewmembers, a pipeliner and two welders, were in the immediate vicinity of the pump gathering tools. A Williams Company Terminal gauger and an electrical technician and a mechanical technician, who had been making final adjustments, were also close to the pump.

At 4:45 p.m., the station booster pump, which was not yet running, had been under 72 psi pressure for about 15 minutes when its cast-iron base failed. Gasoline began to spray from the space beneath the pump mounting flange. The four company employees in the immediate vicinity of the pump--the gauger, the pipeliner, and the two welders--were drenched with gasoline.

The gauger ran to the tank pump control room and turned off the booster tank pump being used to supply pressure during the purging. This pump had a capacity of about 1,800 barrels per hour (75,600 gallons), and the gasoline being pumped continued to escape and spray into the air. The gauger then ran to the mainline pump control room, located 50 feet downwind of the ruptured pump, to attempt to shut down unit No. 1, a 400-hp unit, which was the only mainline pump in operation, in order to eliminate any source of ignition. (See figure 4.)

At the same time, the two technicians ran for the terminal's primary switch-gear facility--the facility that would shut down the entire terminal--located 400 feet upwind (south) of the ruptured pump. On the way, one technician closed the valve in the line in front of the 2,000-hp unit to isolate it from the mainline, and the other technician ran to his van for keys to unlock the gate at the primary switch gear facility. After they entered the gate and just as one technician reached for the switch handle, an explosion occurred in the mainline pump control room. (See figure 5.) Seconds before the gauger had entered the vapor-filled room and disengaged the starter contacts for pump No. 1, the starter contacts arced and ignited the gasoline-air mixture. The gauger was killed by the explosion; the fire flashed back to the ruptured pump and ignited the gasoline soaked clothes of the two welders and the pipeliner.

The technician at the primary switch-gear facility pulled the main switch after the explosion, which shut down the entire terminal electrically. He then ran back to the area to help those injured by the fire. The entire terminal was now shut down electrically. The other technician ran across the road to the AMOCO Oil Company facility to call for help.

Members of the maintenance crew, who had completed their work on the station booster pump installation earlier but were still nearby, helped the injured. They used small handheld dry powder fire extinguishers to extinguish flaming clothing. These

1/ Grouting is a means of filling the gap between a pump and its base with a thin mortar mix.

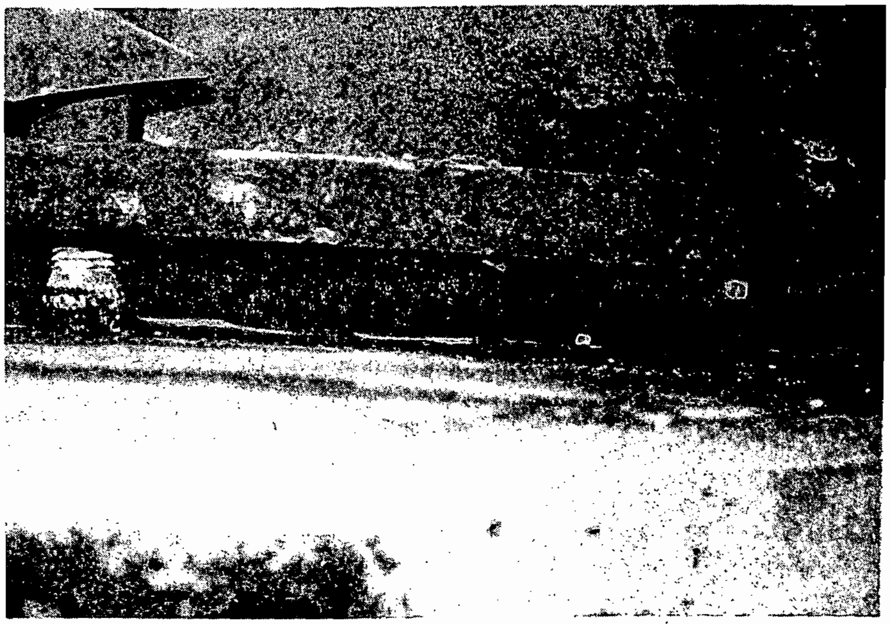


Figure 2.--1-inch space between pump and base.

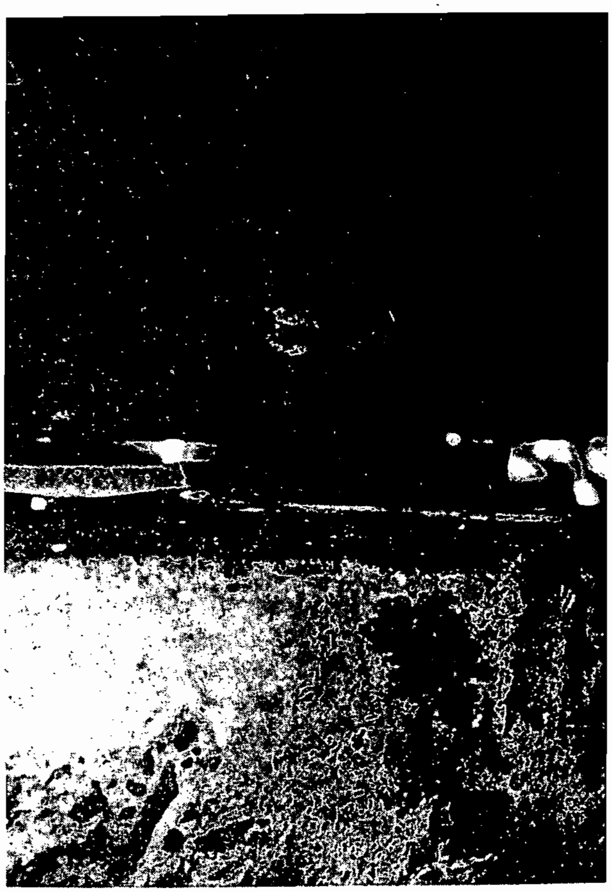
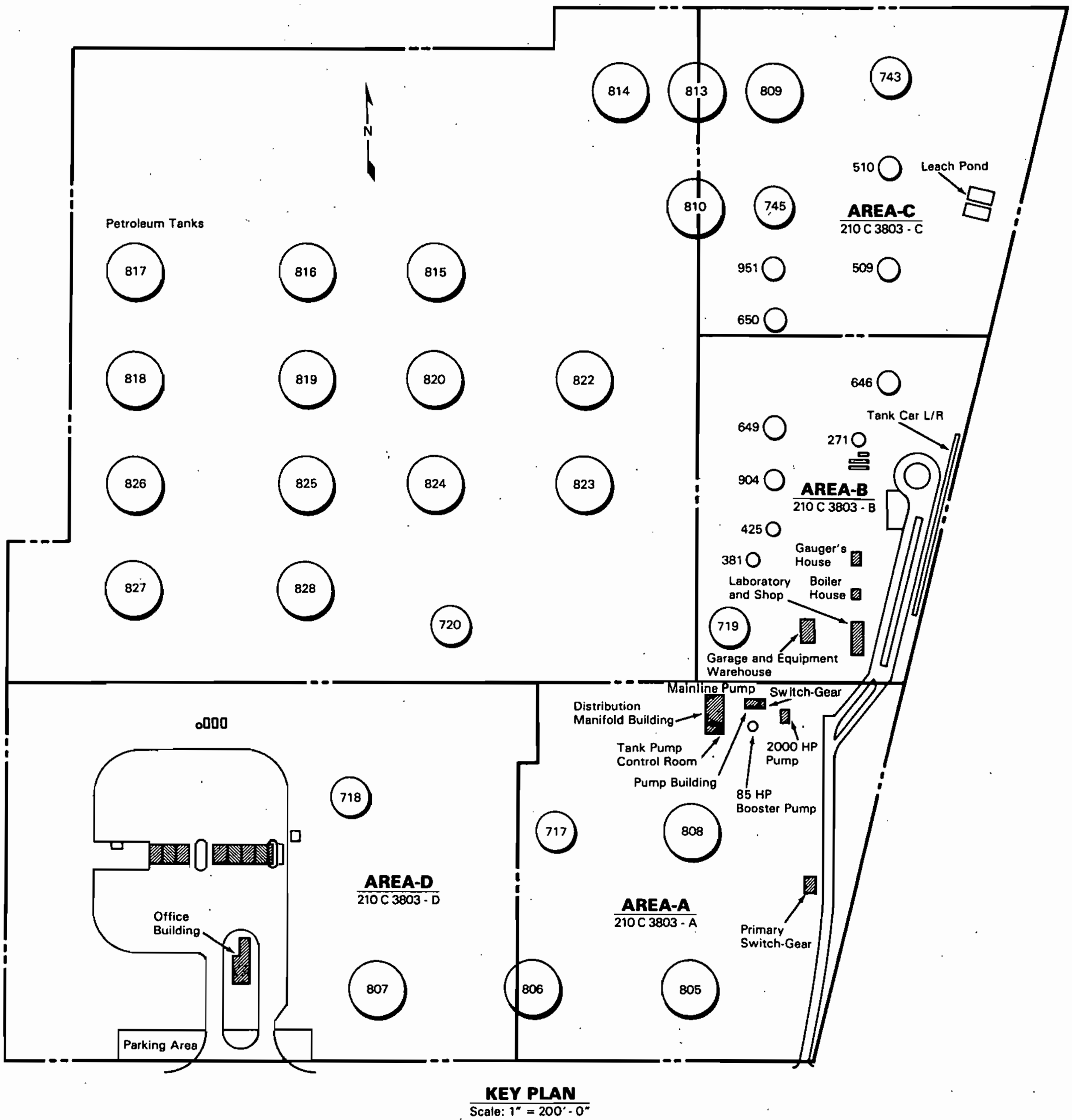


Figure 3.—Pump case failure.



Williams Pipe Line Company
Roseville, Minnesota

Figure 4.--Minneapolis Terminal.

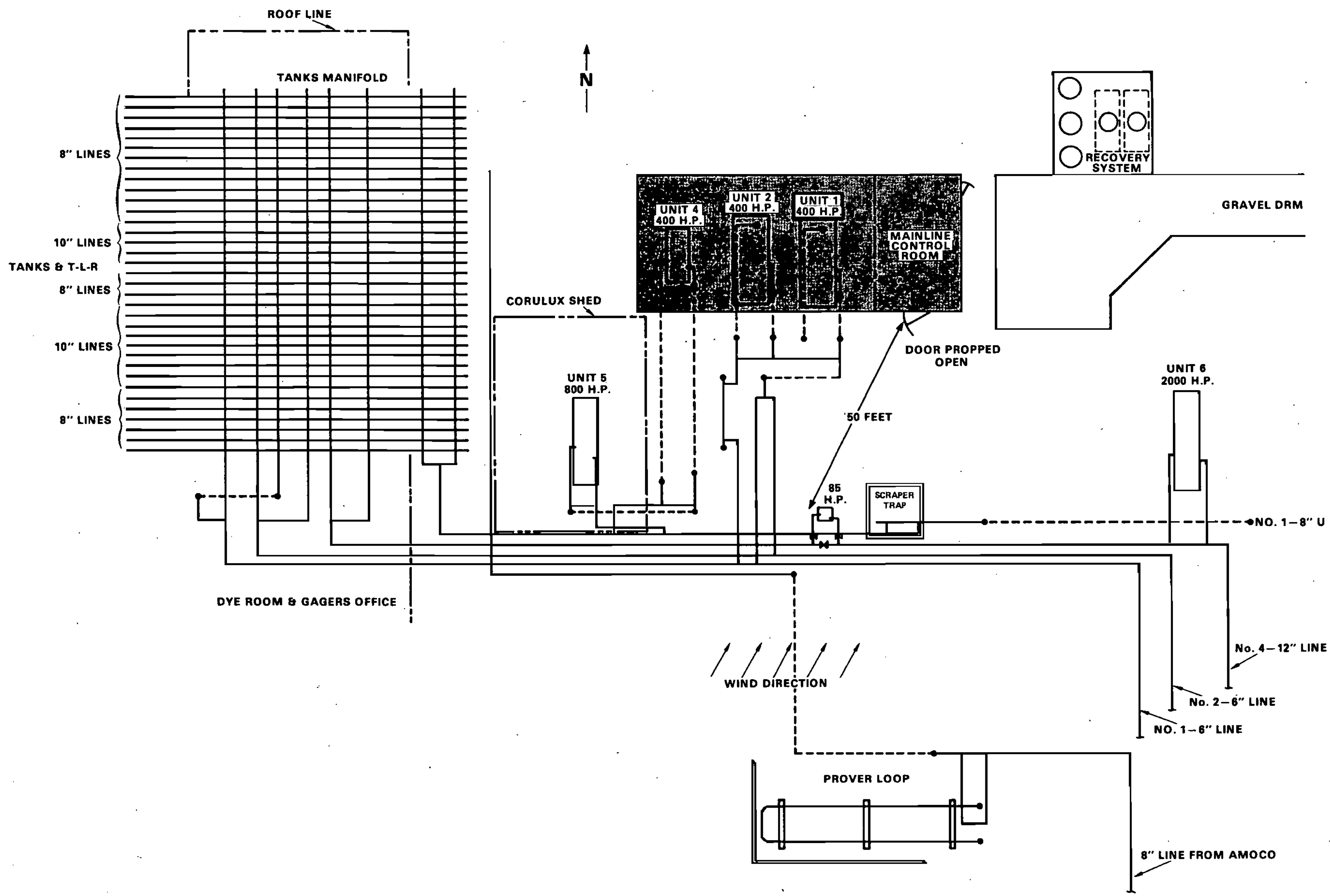


Figure 4B.--Enlargement of the accident area.

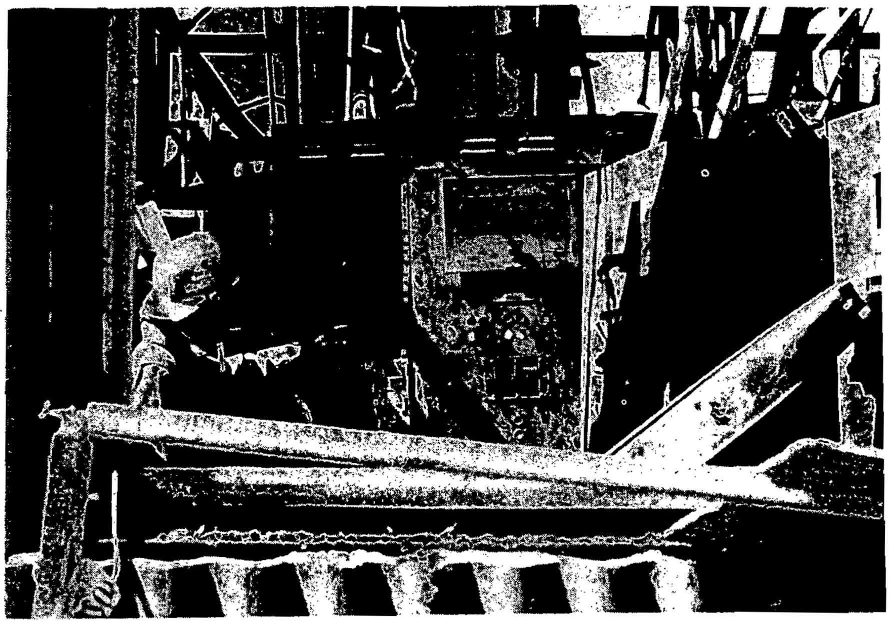


Figure 5.--Mainline pump control equipment.

workers then assisted in closing the terminal's inlet and outlet valves and the valves on those tank lines that were still open. The shutdown was completed within 30 minutes of the explosion; the last valve closed was a gate valve located 10 miles north of the terminal in the 8-inch line coming in from Duluth.

Injuries to Persons

	Operating Personnel	Rescue Personnel	Others	Total
Fatal	1	0	0	1
Nonfatal	3	0	0	3
Total	4	0	0	4

Damage to Facilities

Fire destroyed the receiving manifold piping and valves, four of the mainline pumps, and the station booster pump and its valves. The corrugated metal buildings, housing the gauger's office and the tank pump control room and the mainline pump control room with electric switch-gear, were also destroyed. Nothing remained of the corrugated metal roofs covering the manifold piping and the mainline pumps; their steel support members were distorted and sagging because of the intense heat and flames. (See figures 6 and 7.)

Other Damage

The area damaged by fire covered 20,000 square feet and grass fires extended beyond this area. Although the fire bridged the dikes of several nearby storage tanks, it did not reach the tanks. The largest of the mainline pumps, the 2,000-hp unit, was located only 50 feet southeast of the source of ignition, but winds carried the vapors away from it and prevented damage to it. Two pickup trucks and two vans were destroyed. Total property damage and product loss was estimated at $3 million. Over 147,000 gallons of fuel oil and gasoline were consumed by fire. (See figure 8.)

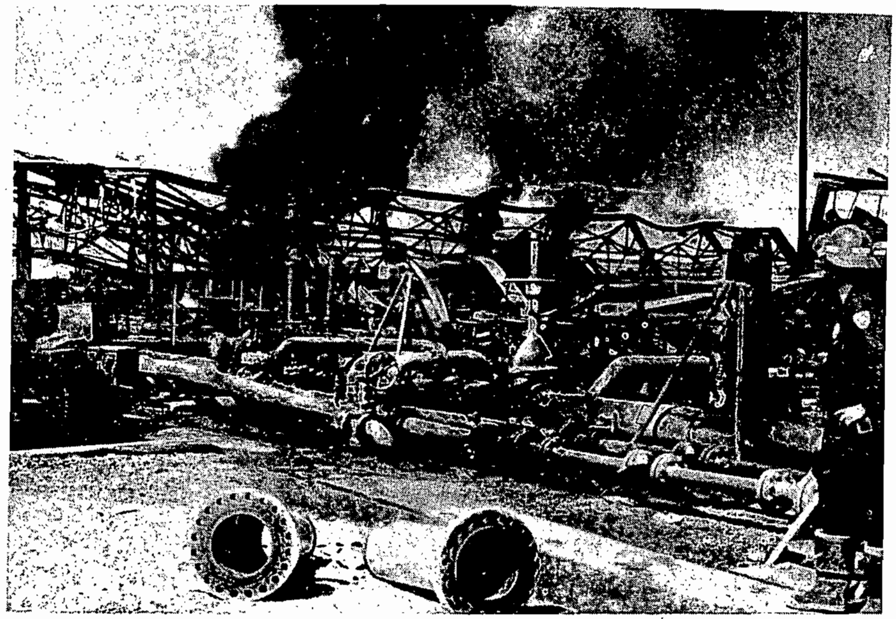


Figure 6.--Booster pump and piping after fire.

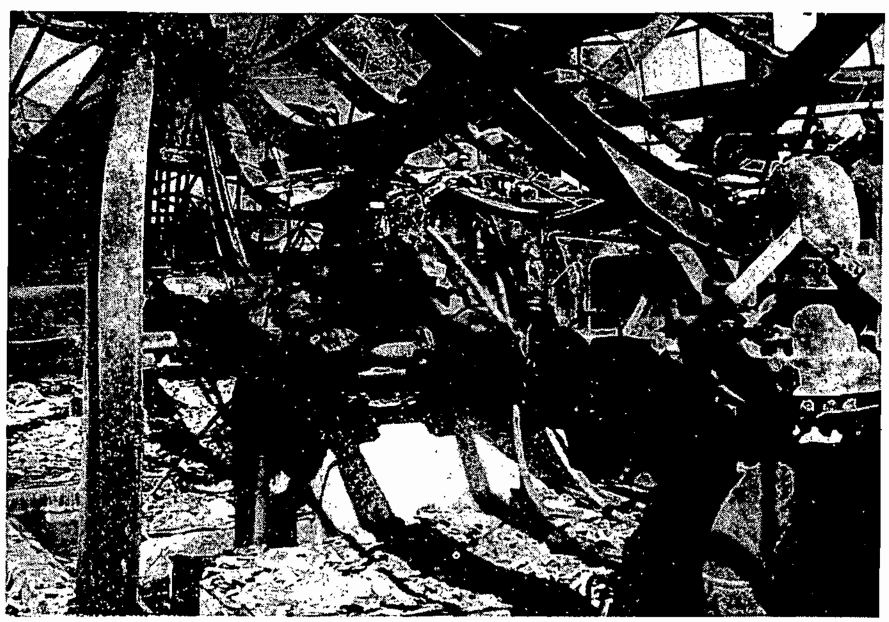


Figure 7.--Mainline pumps and building after fire.

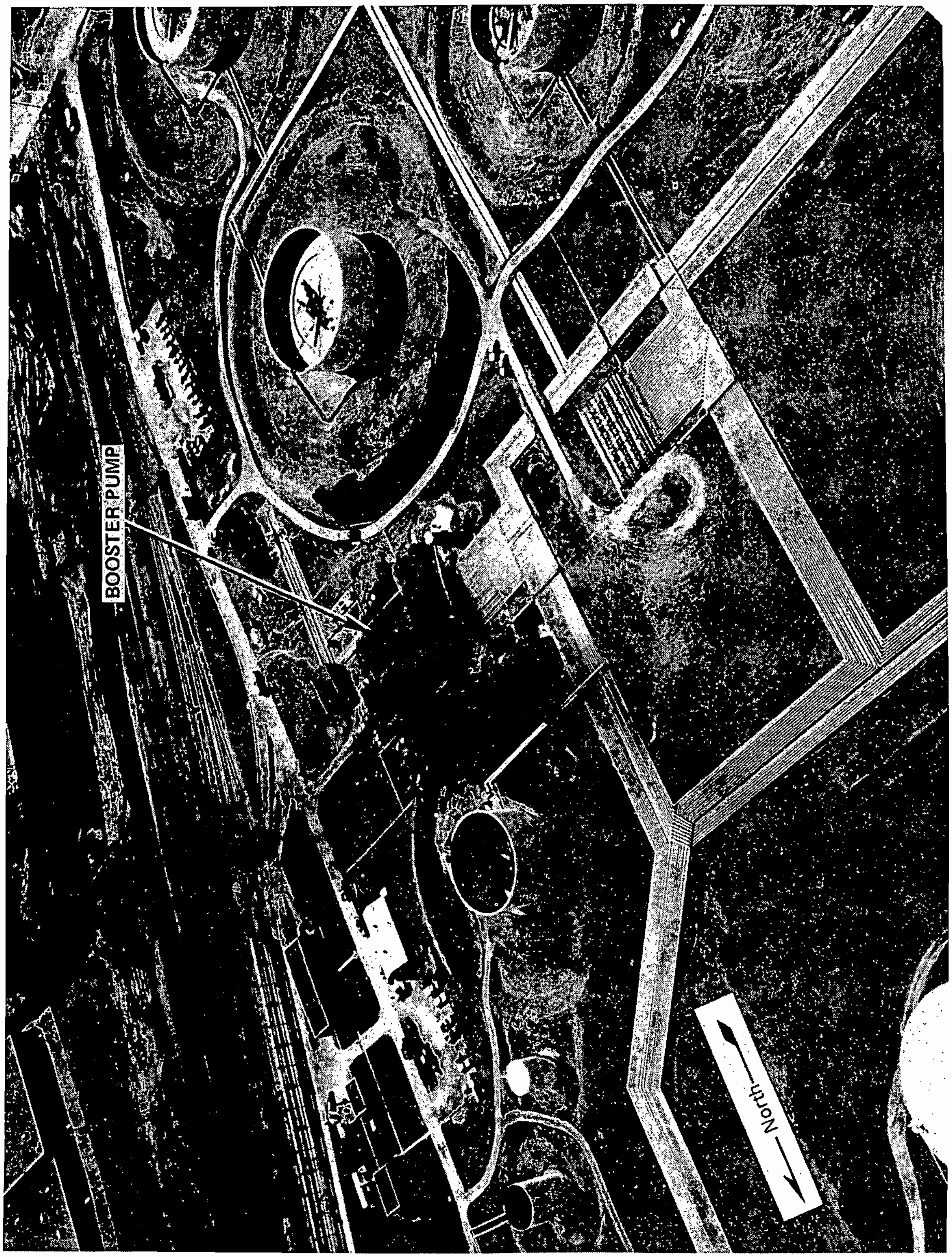


Figure 8.--Roseville terminal showing fire damage.

Personnel Information

The gauger, who was killed, began working for the Williams Pipe Line Company in October 1971; the welders who were burned were employed in 1975. The pipeliner who was burned began his service with the company in January 1978. The two uninjured technicians, who assisted with the pump's installation and the shutdown of facilities, began employment with the company in April 1971 and April 1977.

Pipeline System

The Williams Pipeline Company system serves 12 midwestern States through 8,405 miles of pipeline with 213,905 installed pump horsepower. The system transports more than 170,000,000 barrels per year (7,140,000,000 gallons). (See figure 9.)

Roseville, the Minneapolis Terminal, is the largest in the State of Minnesota. It handles various grades of gasoline and fuel oil, having an annual throughput of some 30 million barrels of product (1,260,000,000 gallons). It has 37 storage tanks with a gross capacity of 1,983,500 barrels (83,307,000 gallons) and a working capacity of 1,750,000 barrels (73,500,000 gallons).

Roseville Terminal was built in 1931 for the Great Lakes Pipeline Company, a common carrier engaged in the pipeline transportation of refined petroleum products. The terminal was modernized from 1950 to 1952, at which time 13 80,000-barrel tanks (3,360,000 gallons) were added, a new office was constructed, a new 14-spot truck loading ramp was installed, and the manifolding was revamped. Williams purchased the Great Lakes System in 1965. Since then, Williams has installed three additional pumps--a 400-hp unit, an 800-hp unit, and a 2,000-hp unit--at the Roseville facility. The 400-and the 800-hp units were installed in the pump house next to the original 400-hp pump. The 2,000-hp pump was installed outside, in the open, away from the pump house.

The 2,000-hp mainline pump had a 3,600-barrel-per-hour (151,200 gallons) capacity with a full tank on its suction side. Under this condition, its discharge pressure was 620 psig; however, this pressure would drop to 580 psig as the tank level fell. Pump capacity would then drop to 2,400 barrels per hour (100,800 gallons). The small tank pumps did not have the capacity to supply the 2,000-hp mainline pump with the 30-psig suction pressure necessary for its designed operating point, and therefore the 2,000-hp unit had to run under reduced operating conditions. The 85-hp station booster pump was being installed to correct this condition and allow the 2,000-hp unit to operate at full capacity.

The mainline pump control electrical switchgear was housed in a 15-foot by 24-foot metal building located 50 feet away from the newly installed 85-hp main station booster pump. It was under the same roof but was separated from the three adjacent 400-hp mainline pumps, units Nos. 1, 2, and 4, by a solid metal wall on the west side. This building also houses the electrical disconnect switches for the three adjacent mainline pumps; these switches were not explosion-proof. 2/ Two windows and a door were located in the east side, and a door and window were located on the south side facing the newly

2/ An explosion-proof apparatus is defined in article 100 of the National Electrical Code (NEC) as an: "Apparatus enclosed in a case that is capable of withstanding an explosion of a specified gas or vapor which may occur within it and of preventing the ignition of a specified gas or vapor surrounding the enclosure by sparks, flashes, or explosion of the gas or vapor within, and which operates at such an external temperature that a surrounding flammable atmosphere will not be ignited thereby."

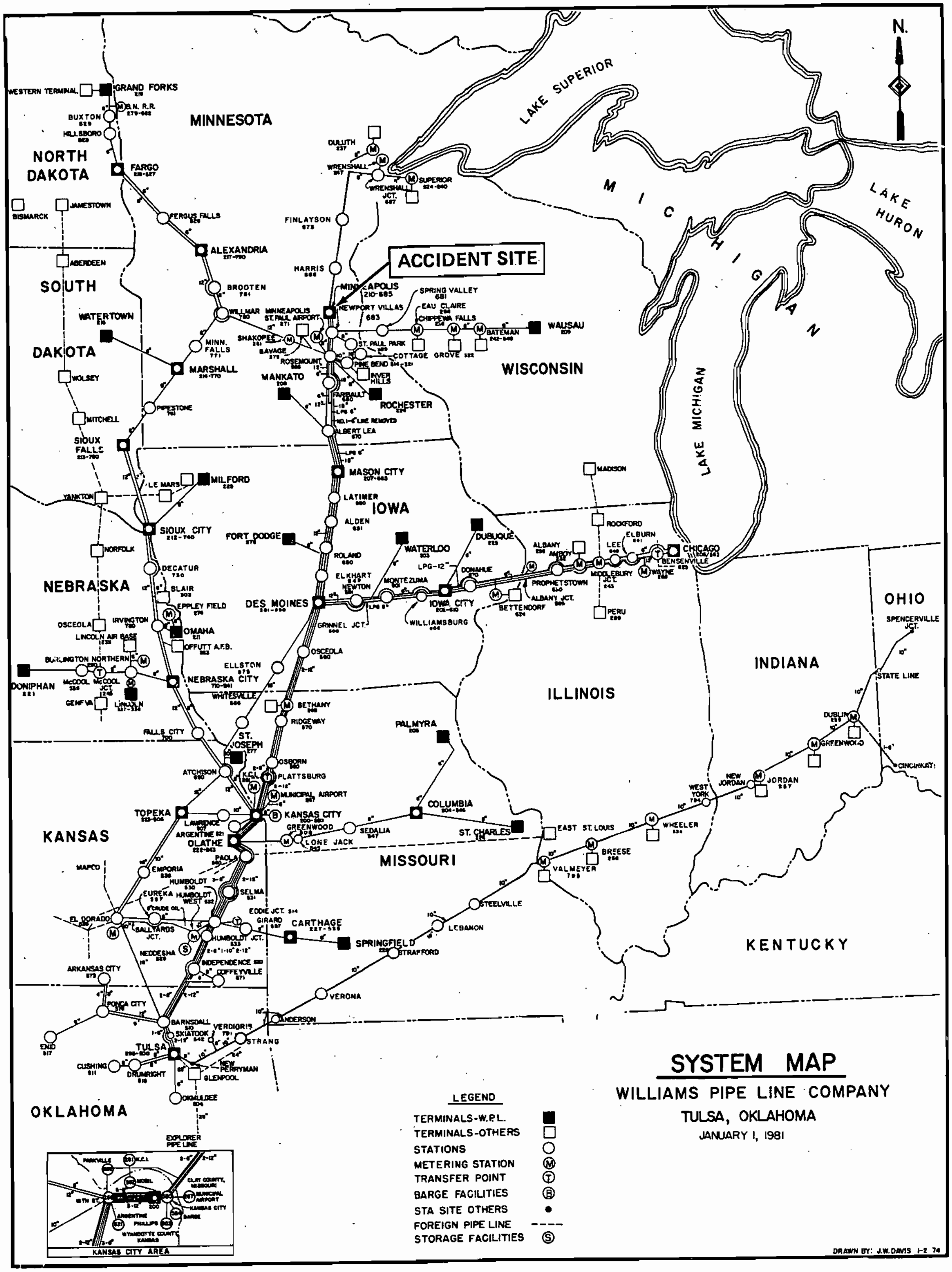


Figure 9.--System Map of Williams Pipe Line Company.

installed main station booster pump. On the day of the accident, the door on the south side had been left propped open.

Meteorological Information

At the time of the accident, the temperature was in the mid-60's, with winds from the south-southwest at 10 mph, gradually subsiding toward evening. The weather was clear and remained so with diminishing winds throughout the 2 days that the fire burned.

Fire

The explosion occurred when flammable vapors, formed by gasoline escaping under pressure from the ruptured cast-iron booster pump, entered the open door of the mainline pump switch gear building and were ignited by a hot electric arc formed when the gauger disengaged the 400-hp motor switch under load. The resulting fire flashed back to the pump and then to the tank manifold area where its heat warped and distorted the manifold piping. This distortion, together with burned out flange gaskets, allowed additional gasoline and fuel oil to leak and supply fuel to the fire. All of the valves at the tanks were closed rapidly.

Communications were established immediately by use of AMOCO's telephone. A Williams Company division engineer, located at an office 3 miles from the terminal, was notified of the accident by the dispatcher in Tulsa, and he maintained a log during the emergency. At 5:45 p.m., the engineer went to the terminal, arriving about 6:00 p.m. Since all phones were inoperative at the incoming end of the terminal because the fire had melted the telephone lines, he maintained communication with the dispatchers in Tulsa from AMOCO's office across the road from the burning terminal. Later, the maintenance foreman's truck with a mobile phone was parked by the primary switch-gear facility, within 400 feet of the fire, and used to maintain communication with the dispatchers in Tulsa from 6:30 p.m. until midnight. Telephone service was restored on a temporary basis thereafter.

Emergency response was excellent. The Roseville Fire Department was on scene within 5 minutes, at 4:50 p.m. after being notified by AMOCO just after the explosion; 68 Roseville volunteers, some of whom were Williams employees, were joined by units of 6 other suburban fire departments. Traffic control and security were provided by the Minnesota State Police, the Ramsey County Sheriff's Department, the Roseville Police Department, and volunteers. The fire was contained by 6:30 p.m., although it was allowed to burn for almost 48 hours under controlled conditions until all of the gasoline from the draining tank lines had burned. (See figures 10 and 11.)

Survival Aspects

The gauger opened the electric switch which arced and ignited the gasoline vapors which had entered the mainline pump control room before him. He was killed by the force of the explosion. The fire then flashed back to the source of the spraying gasoline, the ruptured base of the booster pump. Here, the gasoline-saturated clothing of three other nearby employees caught fire; as a result they suffered second- and third-degree burns before fellow employees, using a handheld fire extinguisher, could help them. Ambulances arrived on the scene within 5 minutes and transported the injured to the hospital for treatment; the ambulances had been called from the AMOCO office adjacent to the terminal.

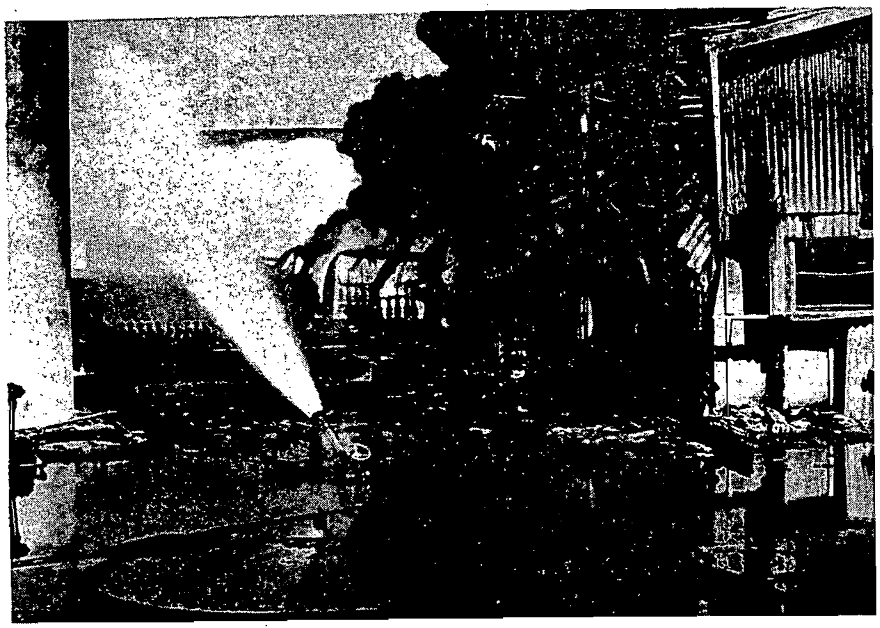


Figure 10.--Fire at the valve manifold.

Figure 11.--Tank lines connecting the valve manifold.

Tests and Research

After the accident, the pump casting was sent to an independent metallurgical laboratory for tests and analysis. In addition, the pump casting was inspected by an independent metallurgist who reported his findings. The Safety Board's metallurgist reviewed both reports and made the following observations:

A review of the . . . reports and an examination of the radiographs and sections taken through the fracture area indicated that the pump may have been underspecification because of the following:

1. The wall thickness of the casting at the measured positions in the fracture varied from a low of 0.350 inch to a high of 0.533 inch. The chaplet size indicates that the design wall thickness of the casting was to be 0.500 inch. 3/

2. Some evidence of porosity (voids in the metal casting) was detected on the casting radiographs and on the sections taken through the fracture area. This porosity may have been caused by free sand in the interior of the mold when the metal was poured.

3. The tensile strength of the cast iron was measured in a sample taken from the smaller of the two fracture pieces from the bottom of the pump casting; it was found to be 36,800 psi. The tensile strength of the cast iron was specified to be 40,000 psi; the 3,200-psi difference indicates an 8-percent reduction in tensile strength.

4. The fracture either initiated at, or progressed through an existing repair made to the casting. The repair had been made by drilling through the leaking area, tapping the drilled hole with threads, and sealing the hole by the insertion of an appropriate size bolt which was then trimmed flush with the casting bottom.

5. Some additional cracks were detected around the bolt holes in the top of the pump case where the motor bolted to the pump. It was not possible to determine whether or not these cracks had occurred when the pump bolts had been damaged before the accident or whether they occurred after the accident as a result of the intense fire.

The failure occurred in the bottom of the pump in its suction stage. (See figures 12a, 12b, and 12c.) The Safety Board's metallurgist concluded that since the pump had been tested successfully to 150 psig in 1950 and had been operating about 18 psig until 1976 with no known operational problems up to that time, the failure must have been caused by additional stresses and damage imposed on the pump after 1976.

Other Information

Federal Regulations.-- The terminal was designed in accordance with industry standards, before the promulgation of Federal standards. The newly installed booster pump was subject to Regulations For The Transportation Of Liquids By Pipeline, 49 CFR 195.

3/ Chaplets are metal forms placed between the mold and the core surfaces, they provide the space between the core and the mold which determines the wall thickness of the casting.

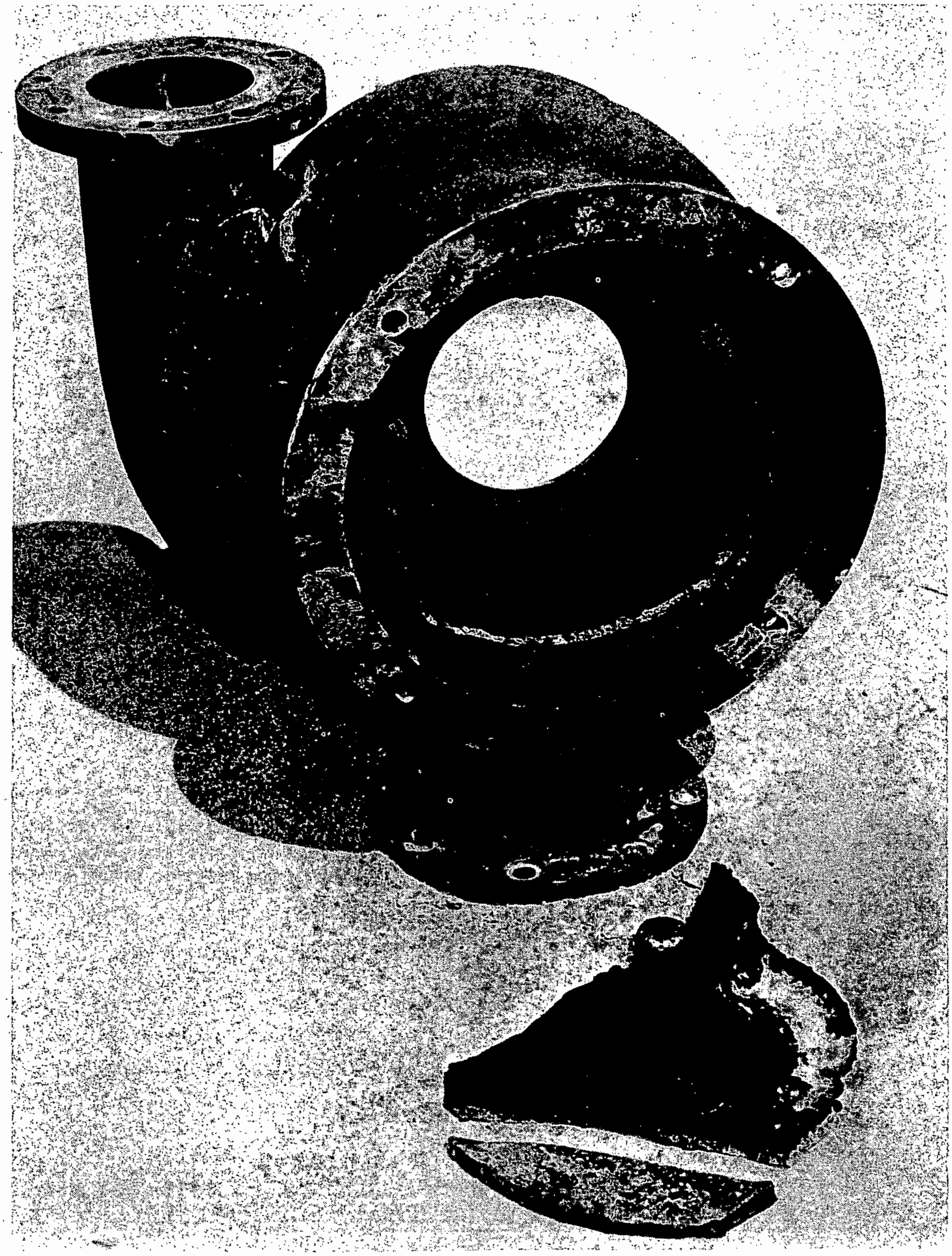


Figure 12A.--Pump case as received for examination.
The pieces in the foreground broke from the bottom of the case.

Figure 12B.--Bottom of case with broken pieces in place. The black arrows indicate what appeared to be chaplets, the white arrow an apparent repair.

Figure 12C.--Pump case from top. The arrow indicates magnetic particle indications of a crack.

Federal regulations relative to this accident follow:

§195.302 General requirements.

(a) Each new pipeline system, each pipeline system in which pipe has been relocated or replaced, or that part of a pipeline system that has been relocated or replaced, must be hydrostatically tested in accordance with this subpart without leakage.

(b) The test pressure for each hydrostatic test conducted under this section must be maintained for at least 24 hours throughout the part of the system that is being tested.

§195.304 Testing of components.

(a) Each hydrostatic test under §195.302 must test all pipe and attached fittings, including components, unless otherwise permitted by paragraph (b) of this section.

(b) A component that is the only item being replaced or added to the pipeline system need not be hydrostatically tested under paragraph (a) of this section if the manufacturer certifies that either--

(1) The component was hydrostatically tested at the factory; or
(2) The component was manufactured under a quality control system that ensures each component is at least equal in strength to a prototype that was hydrostatically tested at the factory.

§195.402 Procedural manual for operations, maintenance, and emergencies.

(a) General. Each carrier shall prepare and follow for each pipeline system a manual of written procedures for conducting normal operations and maintenance activities and handling abnormal operations and emergencies. This manual shall be reviewed annually and appropriate changes made as necessary to insure that the manual is effective. This manual shall be prepared before initial operations of a pipeline system commence and appropriate parts shall be kept at locations where operations and maintenance activities are conducted.

(c) Maintenance and Normal Operations. The manual required by paragraph (a) of this section must include procedures for the following to provide safety during maintenance and normal operations:

(4) Determining on the basis of design, construction, leak history, and other relevant data, which pipeline facilities, operating conditions, installation techniques, and maintenance methods would cause hazards to the safety of the public or system integrity in the event of a malfunction or failure.

(11) Minimizing the likelihood of accidental ignition of vapors in areas near facilities identified under paragraph (c)(4) of this section where the potential exists for the presence of flammable liquids or gases.

The Federal regulations for liquid petroleum pipelines, 49 CFR 195, contain no specific design requirements for the use of explosion-proof equipment in hazardous atmospheres. However, the regulations do reference an industry code, the American Society of Mechanical Engineers, American National Standard Code for Pressure Piping, Liquid Petroleum Transportation Piping Systems, ANSI B31.4, 1966 and 1974. This code, which references the National Electric Code (NEC) and the American Petroleum Institute Recommended Practice for Classification of Areas for Electrical Installations At Petroleum and Gas Pipe Line Transportation Facilities, (API RP 500-C), did not incorporate these references until 1966 when section 434.22 covering electrical installations was added.

Under API RP 500C, a pumping installation transporting gasoline would fall into Group D - "Atmospheres containing gasoline, hexane, naptha, benzine, lacquer solvent, vapors or natural gas." Also under this recommended practice, trunkline pumps in an outdoor area handling volatile liquids would have a hazardous area of a 50-foot radius from the pump.

The NEC, Article 501-Class Locations, 501-3(a) Class 1, Division 1 states:

> In Class 1, Division 1 locations, meters, instruments, and relays, including kilowatt-hour meters, instruments, transformers, resistors, rectifiers, and thermionic tubes, shall be provided with enclosures approved for Class 1, Division 1 locations.
>
> Enclosures approved for Class 1 Division 1 locations include (1) explosion proof enclosures, and (2) purged and pressurized enclosures.

Article 501-3(b) Class 1 Division 2 states:

> In Class 1, Division 2 locations, meters, instruments, and relays shall comply with the following: (1) Contacts, switches, circuit breakers, and make and break contacts of pushbuttons, relays, alarm bells, and horns shall have enclosures approved for Class 1 Division 1 locations in accordance with (a) above.

Service History of Pump.--The station booster pump, a stuffingboxless 85-hp, 1,750-rpm pump, was manufactured by the Byron Jackson Company in 1950. The pump case was made of class 40 (40,000 psi) cast iron and had been tested at the factory from 150 to 180 psig for 30 minutes. After assembly, the entire unit, pump case and 85-hp motor, was tested to 85 psig for 35 minutes. The pump case is a single casting and includes an 8-inch suction and a 6-inch discharge flange. The pump had a capacity of 1,759 gallons per minute at 180 feet of head (56 psig based on gasoline at .73 specific gravity).

The unit consists of an oil-filled induction motor enclosed in a pressure-tight housing directly connected to a centrifugal pump. A single mechanical seal enclosed within the pressure-tight housing serves to separate the oil in the motor from the liquid in the pump. The pump is constructed so that the pump side of the mechanical seal is subjected to suction pressure. During normal operation at 440 volts, 60 cycles, the pump motor will draw 112 amperes current when handling gasoline at a specific gravity of .73.

The Byron Jackson Company's instructions for the pump suction and discharge connections called for the use of suitable flange gaskets and the exercise of care to avoid undue piping strains on the pump. The suction and discharge piping was to be adequately supported to reduce piping strains on the pump.

In 1950, the pump was installed at the Texaco Refinery in Tulsa, Oklahoma, as a tank booster pump in refined petroleum products service. The pump discharge was connected to a line from the Tulsa Pump Station, owned at that time by the Great Lakes Pipeline Company and later purchased by Williams in 1965. As a tank booster pump, the maximum suction pressures to which it was subjected were from 18 to 20 psig. It remained in that service until mid-1976, when it was removed and stored at the Tulsa Station.

About mid-July 1979, the pump and motor were shipped to a machine shop and to an electrical shop for inspection and repairs. The pump was delivered to these shops without skids or packing support. It was cleaned, and running tolerances were checked. Each shop performed some machining operations so that the pump and motor would turn freely. The pump was not subjected to a hydrostatic pressure test at this time. The pump and motor were mounted, as a unit, on wooden skids and shipped from Tulsa by Roadway Motor Freight on September 14, 1979, to the Williams Pipe Line Company's Minneapolis Terminal in Roseville. It was received there on September 21, 1979, where it was unloaded and stored until November 20, when it was set on its foundation at the accident site.

When it was received at Roseville, some of the pump case bolts and nuts were damaged; these bolts and nuts were on the top half of the pump casting where the motor was connected to the pump. In addition, the top projection of the upper bearing housing was broken. It was decided that this would not interfere with its operation. (See appendix C.)

The installation of the pump and equipment by Williams personnel was routine; the company had many similar cast-iron pumps in service as tank booster pumps. The Safety Board's investigator was informed that the pump had not been subjected to any stresses; it had rested on its foundation with the suction and discharge piping supported. The piping used in this installation had been tested previously but the pump which had been hydrostatically tested 30 years before had not been retested. The pressure on the pump was 72 psig at the time of failure; less than half of the factory test pressure but almost four times the pressure that the pump had been exposed to in its 30-year operating history.

Notification of Accident -- The pipeline company reported the accident to the National Response Center (NRC) within an hour; and within an additional 2 hours a followup report was made on the injuries and the fatality. The Safety Board was notified of the accident at 8:00 p.m., 3 1/2 hours after its occurrence.

Emergency Shutdown Procedures -- Williams did not have any written emergency procedures at the time of this accident to deal with this type of situation. As a result of the accident, however, Williams reviewed its procedures at its safety meetings with pump station, terminal, and maintenance personnel. The Safety Board believes that Williams should develop within emergency procedures in order to deal with other similar situations.

ANALYSIS

The cast-iron pump failed in a thin walled area weakened by the earlier leak repair discontinuity. The failure was due to the cumulative effects of stresses and damages imposed on it by moving, handling, installation, and finally by hydraulic pressure almost four times as high as it had been previously subjected to in the past 30 years, although it represented less than half its test pressure.

The Safety Board believes that the accident could have been prevented or its consequences minimized if (1) the pump installation had been hydrostatically tested prior to startup; (2) grout had been placed in the gap underneath the pump; or (3) explosion-proof electrical equipment had been installed.

Hydrostatic Testing

A hydrostatic test using water, rather than a hazardous volatile material, would have safely assessed the strength of the system. Newly installed equipment is tested to a pressure at or below its yield strength, but well above its intended design or operating pressure. Therefore, if the facility passes the test without leaks or failures, it can then be operated safely at the lower operating pressure. On the other hand, if the equipment does not pass the hydrostatic test and ruptures or leaks water, a nonvolatile, nonflammable, nontoxic medium is released with no ill effects.

In the accident case, if the newly installed pump, piping, valves, and fittings had been hydrostatically tested to 150 psig, the original factory test pressure of the pump, the pump base would have failed at 72 psig; water, not gasoline, would have been released, and no explosion, fatality, fire, or property loss would have been experienced.

Federal regulation 49 CFR 195.304, Testing of Components, states that:

> A component that is the only item (emphasis added) being replaced or added to the pipeline system need not be hydrostatically tested under paragraph (a) of this section if the manufacturer certifies that either—
>
> (1) The component was hydrostatically tested at the factory; or
> (2) The component was manufactured under a quality control system that ensures each component is at least equal in strength to a prototype that was hydrostatically tested at the factory.

The intent of this regulation is to avoid long (24-hour) and possibly expensive hydrostatic tests simply because a pipeline company is adding one item or replacing one item in its system. For instance, the replacement of a length of pipe that had been damaged by some outside force and might later fail could be handled by the use of pretested pipe as the replacement and then nondestructively testing the two girth welds required to complete the replacement. This would avoid the need for a hydrostatic test which might require displacing the petroleum products in perhaps miles of pipe, filling the line with water, pressuring the line, holding that pressure for 24 hours, and then dewatering the line and refilling it with the displaced products. All of this would have been done, in this hypothetical case, to test one length (40 feet) of pipe.

On the other hand, this station booster pump was (a) a new installation and not a replacement and (b), it was not "...the only item being replaced or added to the pipeline system...." In this installation, in addition to the pump, the pump suction valve, the pump discharge valve, the division valve, flanges for each valve, and the small needle valves were added and welding of 45° elbows was also involved. None of these valves and fittings were replacements, each was a part of a new installation and should have been hydrostatically tested together as a unit.

Additionally, not only was the pump a used one and 30 years old, but the general condition of the pump when it was received at Roseville before installation--a lug had been broken and the bolts and nuts at the pump/motor mounting had been damaged--should have led Williams to subject the complete installation to a hydrostatic test before operating it. The Safety Board believes that taking the time and expense to hydrostatically test this facility was clearly indicated.

Finally, Federal regulations 49 CFR 195.402(c)(4) require an operator to determine "...on the basis of design, construction, leak history, and other relevant data, which pipeline facilities, operating conditions, installation techniques, and maintenance methods would cause hazards to the safety of the public or system integrity in the event of a malfunction or failure" (emphasis added). In our view, the addition of new pumping equipment requires the reevaluation of potential areas of hazardous vapors, and sources of ignition.

Grouting the Pump

After pumps are positioned on concrete bases and anchored by bolts set in the concrete base, the final positioning--minute adjustments to height or to level--is usually done by shimming under the pump. Following final positioning, nuts are tightened to hold the pump to the base. In good operating practice, though not universally followed, the open space between the pump bottom and the concrete base is filled with grout, by pouring it in, around, and under the pump so that when the grout hardens there are no gaps between the pump and its base. Primarily, grouting prevents water and debris from entering the pump and provides some additional support for the pump. The exclusion of water precludes rusting and eliminates freezing under the pump with its attendant problems of heaving and misalignment.

The pump in this accident had not been grouted after installation, and a 1-inch gap remained between the bottom of the pump and the surface of the base. The gap was large enough to allow the bottom of the pump to fall out after failure, but small enough to restrict the gasoline escaping at 72 psig and to cause it to spray off the flat concrete pump base and vaporize. If grout had been placed in the gap, much less gasoline would have leaked from a smaller crack around the grouted surface of the pump bottom and station personnel might have had an opportunity to shut the pumps down before the gasoline vapors entered the main station control room in sufficient quantities to ignite. Williams was not required by regulation to grout this station booster pump. Some pipeline companies do grout small pumps, others do not.

Explosion-Proof Electrical Equipment

If explosion-proof electrical equipment had been installed in the mainline pump control room, there would have been no electrical arc to ignite the vapors. Both Federal regulations and industry codes adopted by reference in Federal regulations are vague with regard to explosion-proof electrical equipment, and provide minimum guidance about locations where it should be used. (The industry gas piping codes did not cover electrical installations at the time the Roseville facility was constructed; the Federal regulations came into effect later.)

The codes that both the Federal regulations and the ANSI B31.4 reference, the AP IRP 500-C and the NEC, do delineate the area of hazardous vapors and the type of electrical equipment to be used in these areas. APIRP 500-C says that the hazardous area around a pump out in the open is 50 feet in radius and 18-inches in height. NEC says that switchgear within a hazardous area should be explosion-proof. In this case, the switchgear building was located 50 feet away from the pump which might marginally satisfy the code requirements, but in this case the gasoline, spraying under pressure and being blown by a 10-mph wind, covered not only the 50-foot radius referred to by the code, but also sprayed over the tank manifold area and burned in that area. The hazardous vapor area in this accident reached well beyond 50 feet.

Many pipeline companies have more stringent requirements for using explosion-proof electrical equipment than is required by the code. Some companies use explosion-proof equipment exclusively for everything inside the fenced limits of a pump station or a terminal because they believe that, with due consideration to the effects of pressure and wind velocity, everything within those fenced areas could become engulfed by hazardous vapors.

Still other companies achieve the same objective by installing nonexplosion-proof electrical equipment in pressurized buildings. Thus, even if the area becomes filled with volatile vapors, the vapors cannot get into the pressurized building and therefore can not be ignited by electric arc. In one accident 4/ investigated by the Safety Board, a pressurized transformer building blew up, killed one person, and injured others when liquefied natural gas (LNG) which had leaked through an inadequately tightened LNG pump seal, vaporized and migrated through a 3-inch conduit into a substation building where the vaporized LNG/air mixture was ignited by the arcing contacts of a circuit breaker. Thus, even with a pressurized building, vapors can ignite. The use of explosion-proof electrical equipment would have prevented that accident.

CONCLUSIONS

Findings

1. The cast-iron pump failed in a thin walled area weakened by an earlier leak repair. The failure was due to the cumulative effects of stresses and damage by moving, handling, installation, and finally by hydraulic pressure almost four times as high as it had been previously subjected to in the past 30 years.

2. The pump should have been hydrostatically tested after installation, in accordance with 49 CFR 195.302 and 195.304, before it was filled with gasoline.

3. The booster pump failed under a pressure of 72 psig; less than half the test pressure to which it was subjected 30 years previously during manufacture.

4. A hydrostatic test would have safely precipitated the failure and prevented the accident.

5. Gasoline spraying from the pump fracture created a hazardous area downwind of the pump and vapors entered the mainline pump control room.

6. The gauger, in an attempt to shut down unit No. 1--the only mainline pump in operation--disengaged the starter contacts which ignited the gasoline vapors which had entered the control room.

4/ "Pipeline Accident Report: Columbia Liquefied Natural Gas Corporation Explosion and Fire, Cove Point, Maryland, October 6, 1979. (NTSB-PAR-80-8)."

7. The force of the resulting explosion killed the gauger; the ensuing fire injured three other employees and caused extensive damage to terminal facilities.

8. If explosion-proof electrical equipment had been installed in the mainline pump control room, this accident might have been prevented or mitigated.

9. If the gap between the bottom of the pump and its concrete base had been filled with grout, this accident probably would not have occurred, or would have been less severe.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the fracture of the base of a 30-year-old cast-iron pump which had not been hydrostatically tested at its new installation. The failure allowed gasoline under pressure to spray, vaporize, and enter an electric switchgear building 50 feet away. Ignition occurred from an electric arc produced by opening a switch. Contributing to the accident was the failure of the company to (1) utilize explosion-proof equipment in a potentially hazardous vapor area, and (2) fill the gap between the pump and its foundation with grout.

RECOMMENDATIONS

As a result of its investigation of this accident, the National Transportation Safety Board recommended that:

--the Williams Pipe Line Company:

Revise its equipment installation procedures to include hydrostatic tests in accordance with the provisions of 49 CFR 195.302, General Requirements, and 49 CFR 195.304, Testing of Components. (Class II, Priority Action) (P-81-17)

Evaluate its existing facilities to determine the need for explosion-proof electrical equipment. (Class II, Priority Action) (P-81-18)

Provide appropriate written instructions to its employees covering precautionary safety measures to be taken in a hazardous atmosphere, particularly in regard to emergency shutdown procedures. (Class II, Priority Action) (P-81-19)

--the American Petroleum Institute, the American Gas Association, and the Interstate Natural Gas Association of America:

Advise its member companies of the circumstances of this accident and urge that they review the adequacy of their explosion-proof electrical systems and their hydrostatic test procedures. (Class II, Priority Action) (P-81-20)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

July 22, 1981

APPENDIXES

APPENDIX A

BYRON JACKSON

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

FOR

STUFFINGBOXLESS TANK PUMPS

****

FOR GREAT LAKES PIPE LINE CO.

BJ ORDER NOS:
239385
239405

SIZE:	6 X 8 X 17
CAPACITY:	1750 GPM
HEAD:	180 Ft.
H.P.:	85 RPM 1750

Sectional Drawing No.: 1F-2443
Outline Drawing No.: 2A-3146

The Byron Jackson Stuffinboxless Pump consists of an oil filled induction motor enclosed in a pressure tight housing directly connected to a centrifugal pump. A single mechanical seal enclosed within the pressure tight housing serves to separate the oil in the motor from the liquid in the pump. The pump is constructed so that the pump side of the mechanical seal is subjected to suction pressure. Pressure in the motor and consequently the motor side of the mechanical seal is automatically maintained at a fixed differential above suction pressure whatever it may be. This is accomplished by a pressure transmitting system from a point in the pump case to the motor. As the pump liquid is usually soluble in the motor oil and would contaminate it, an isolating tank is used to separate the two liquids. The isolating tank assembly surrounds the motor and consists of inner and outer cylinders closed at each end. The annular space between the cylinders is divided into two equal tanks by two longitudinal plates. A pipe extends from the pump case up through one tank to within 1/2" of the top. This tank is to be filled with a mixture of water and anti-freeze. The other tank contains a pipe from the bottom of the motor up to within 1/2" of the top. of the tank [typo belongs to original copy] This tank is filled with motor oil. The two tanks are connected together by a "U" pipe starting at the bottom of the water tank and leading to the bottom of the oil tank completing the pressure circuit. The pumped liquid enters the isolating tank above the water level and being lighter than water is trapped there. The "U" pipe transmits water from the bottom of the isolating tank to the bottom of the oil tank where it remains because it is heavier than oil. The oil tank has two functions. It receives oil from the rotor as the head developed in the motor causes the oil to expand. This oil returns to the motor when it is not running. Thus the motor is full of oil at all times. The oil tank also supplies oil to the motor to replace the small quantity that is used to lubricate the seal faces. Controls are provided on oil tank to indicate when oil should be added.

INSTALLATION

GENERAL

Before actual installation work is started, we would suggest that sectional and outline drawings be carefully studied and that these drawings be referred to from time to time as installation work progresses. The unit as received will be nearly filled with oil. A small amount was purposely omitted to allow for expansion during transit through varying temperatures. After uncrating, inspect the unit carefully for damage during transit.

FILL MOTOR AND OIL TANK

The motor is filled with oil through the oil tank. It must be completely full of oil to insure rapid transmission of pressure to the motor side of the mechanical seal. Open motor vent valve and oil tank vent valve. Fill through oil tank filler. Close valves when oil flows from them. Replace filler cap. Use Calal Spindle Oil - Engine Oil#5 manufactured by Standard Oil Co. of California or oil equal to following specifications.

Flash Point, CL. °F.	290
I.P.B. °F.	532
Vis. c100 SU	59
Pour Pt. °F.	.60
Sulphur Content, [percent]	.05
Carbon Content, Conradsen	.020
Specification No.	0
Thermal conductivity at 500°F.	66.4
Dielectric strength (volts)	35,000
Odor at normal temp.	Slight refined petroleum odor.
Demulsibility, seconds	46

FILL ISOLATING TANK

Fill isolating tank through isolating tank filler with mixture of water and anti-freeze solution. Open isolating tank vent valve before filling. Close when liquid appears. Replace filler cap.

CONNECT SUCTION and DISCHARGE

Connect suction and discharge piping in the customary manner, using suitable gaskets and exercising care not to impose undue piping strains on the pump. Suction and discharge piping should be adequately supported to reduce strains to a minimum. A suitable valve should be installed in both the suction and discharge lines so that the unit may be isolated in the event dismantling becomes necessary.

CONNECT MOTOR JACKET COOLING LINE

Motor cooling jacket outlet may now be connected to the tank from which the unit takes suction. This must be connected to the tank at a point 45° to 90° from the point at which the unit is located, to assure proper cooling. Size of this line must not be less than 1-1/4" and length must not exceed 100'. It is extremely important that no valve be installed in this line. The motor relies on a flow of fluid through the jacket for cooling. Inadvertantly closing a valve in this line would stop circulation through the motor cooling jacket.

PRIME UNIT

To prime unit before starting, open isolating tank vent valve. This will vent air from pump case.

CHECK ROTATION

Rotation may be checked by starting the unit and measuring discharge pressure. Start unit momentarily. If discharge pressure is approximately 71 psi with suction valve open and discharge valve closed, the motor is rotating correctly. If discharge pressure is approximately 42 psi with the suction valve open and discharge valve closed, the motor is operating incorrectly. Direction of rotation when looking down on top of the unit is counter-clockwise. To reverse rotation, interchange any two leads at power lugs or at source of power. Operation with incorrect rotation will cause no damage, providing the unit has been properly primed.

START UNIT

After starting the unit, carefully check all fill vent and drain plugs, as well as all auxiliary piping connected to the motor for leaks.

CHECK PRESSURE GAUGE ON PUMP DISCHARGE

Immediately after starting unit, check pressure gauge on pump discharge line to be sure that unit has not lost prime and is operating normally with discharge valve fully opened. During normal operation at 440 volts, 60 cycle, the unit will draw 112 Amps, approximately, when handling liquid having a specific gravity of .73. The maximum amperage shall not exceed 120 Amps at 440 volt, when handling distillate. If readings are higher than maximum given, shut the unit down and ascertain cause for overload. The motor furnished with this unit will operate successfully, but not necessarily in accordance with performance guarantee, if:

(a) Frequency is not more than 5% above or below rating.
(b) Voltage is not more than 10% above or below rating.
(c) Combined variation in voltage and frequency is not more than 10%, and providing limits "a" and "b" are not exceeded.

OIL LEVEL INDICATOR

The oil compartment of the isolating tank is fitted with two insulated probes mounted in the top. One extends down 8 inches from the top of the tank and the other 3 inches from the top. The probes are part of a control circuit which will indicate a low oil supply and then shut down the unit if oil is not added. A diagram of the circuit is shown. The control equipment is not supplied as part of the pump. The warning probe indicates that 4 1/2 gallons should be added. The shut down probe indicates that 5 gallons are required to refill the oil tank.

Oil can be added by pumping it in through the motor vent valve provided the pump suction valve is open. Oil added will force water back into isolating tank and pumped liquid back into pump.

APPENDIX B

WILLIAMS PIPE LINE COMPANY
INTER-OFFICE CORRESPONDENCE
May 8, 1980

To: Mr. Larry Lipe

From: J. J. Hagel

In view of possible litigations with respect to the Minneapolis accident on April 16, 1980, I am forwarding the followint information:

Air Purging Procedure for the 85 HP Booster Pump

Step	#1	Initially all 12 valves were closed.
	#2	Valve (1) never opened.
	#3	Valve (2) never opened.
	#4	Valve (4) never opened.
	#5	Valve (8) opened to bleed out air.
	#6	Valve (6) opened.
	#7	Valve (3) was cracked open to allow product in and bleed air out through valve (8).
	#8	After the air and a trickle of product was bled out of valve (8), the pressure was exhausted.
	#9	Valve (3) was then opened all the way.
	#10	Tank pump on tank #286 was turned on and air was bled through valve (8) until product arrived.
	#11	Valve (8) closed.
	#12	Valve (10) opened - product bled on pump.
	#13	Valve (9) opened to bleed air.
	#14	Valve (7) cracked to allow tank pump pressure to booster when air changed to product. Valve (9) and valve (10) were closed.

#15	Valve (11) and valve (12) were cracked to bleed air from oil, and then oil from system to allow adjustment of diaphragm rod to 1/2" in sight glass.
#16	Valve (7) open completely.
#17	Valve (5) opened.
#18	Valve (6) Closed.
#19	Pressure relief tubing reconnected between booster valve (9) and valve (8).
#20	Valve (9) opened.
#21	Valve (8) opened.

JJH:ad

APPENDIX C

DYNMAC CORPORATION

Dynamic Machinery

7925 EAST 40TH STREET TULSA OKLAHOMA 74145

May 29, 1980

APPENDIX C

Dynamic Machinery
7925 EAST 40TH STREET · TULSA OKLAHOMA 74145 (918) 627-0110

May 29, 1980

Williams Pipe Line Company
P. O. Box 3448
Tulsa, Oklahoma

FILE: QR-12594

Attention: Mr. R. G. Keearns
Reference: B-J Stuffingboxless Pump
S/N 239405

Gentlemen:

In accordance with your request, we wish to report as to the work we performed in the repair of the subject pump as covered by your purchase order 09053.

The pump was received in our shop about the middle of July 1979 and was delivered to us un-skidded. We removed the pump volute, impeller and mechanical seal and sent the rest of the unit to A & H Electric to have them check out the motor.

We cleaned up the pump and checked the running clearances and determined that they were satisfactory. There was some type of coating on the inside of the pump volute that had become loose and flaked off in some places. We stripped the rest of the coating from the pump so that it would not work loose when the pump was in service and cause problems. We used a putty knife to assist in removing this coating.

Upon getting the motor case and rotor and shaft assembly back from A & H Electric, we attempted to reassemble the unit. We determined that the rotor would not turn within the stator assembly as the unit was delivered to us by A & H. We could get the rotor to turn but only by loosening the bolts holding the lower bearing housing to the stator assembly. We contacted A & H and advised them of the problem, then returned the stator and rotor assembly to them for further checking. A & H then sent the unit back to us and advised that they had not made any alteration to the motor portion of the unit but still we could not assemble the pump and motor and have the shaft free to turn.

We did determine that the bearings that had been replaced were of the proper size and advised Tom Reed that the unit could not be assembled and it appeared that either the rotor shaft was too long or the stator case too short. Since you do have several of these types of units in service, it was surmised that the unit we had must consist of a rotor assembly and a stator case that originally were in different units.

The decision was made to turn back the shoulder on the shaft that positioned the lower bearing so that we could then assemble the rotor with the stator and have the rotor turn free. This machining was done by A & H. After repositioning the bearing, we then had to relieve some of the threads for the lower bearing lock nut so that they would not interfere with the mechanical seal. This machining was done by Damar Manufacturing.

The next step was to install the impeller on the shaft and assemble the pump case to the motor can. When this was done, we found that the impeller bottomed out against the volute and prevented the shaft from turning free. In order to eliminate this problem, we had the shoulder, on the shaft that positioned the impeller, cut back and we were then able to assemble the entire unit and have it turn free. We mounted the pump on a wooden skid made from four by fours and it was then shipped to the jobsite. There was no hydrostatic pressure test applied to the pump while it was in our shop.

We trust you will find the above complete; however, if you do have additional questions, please do not hesitate to contact us.

Yours very truly

DYNMAC CORPORATION

/S/ Thomas W. Frazee

TWF:bjm

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