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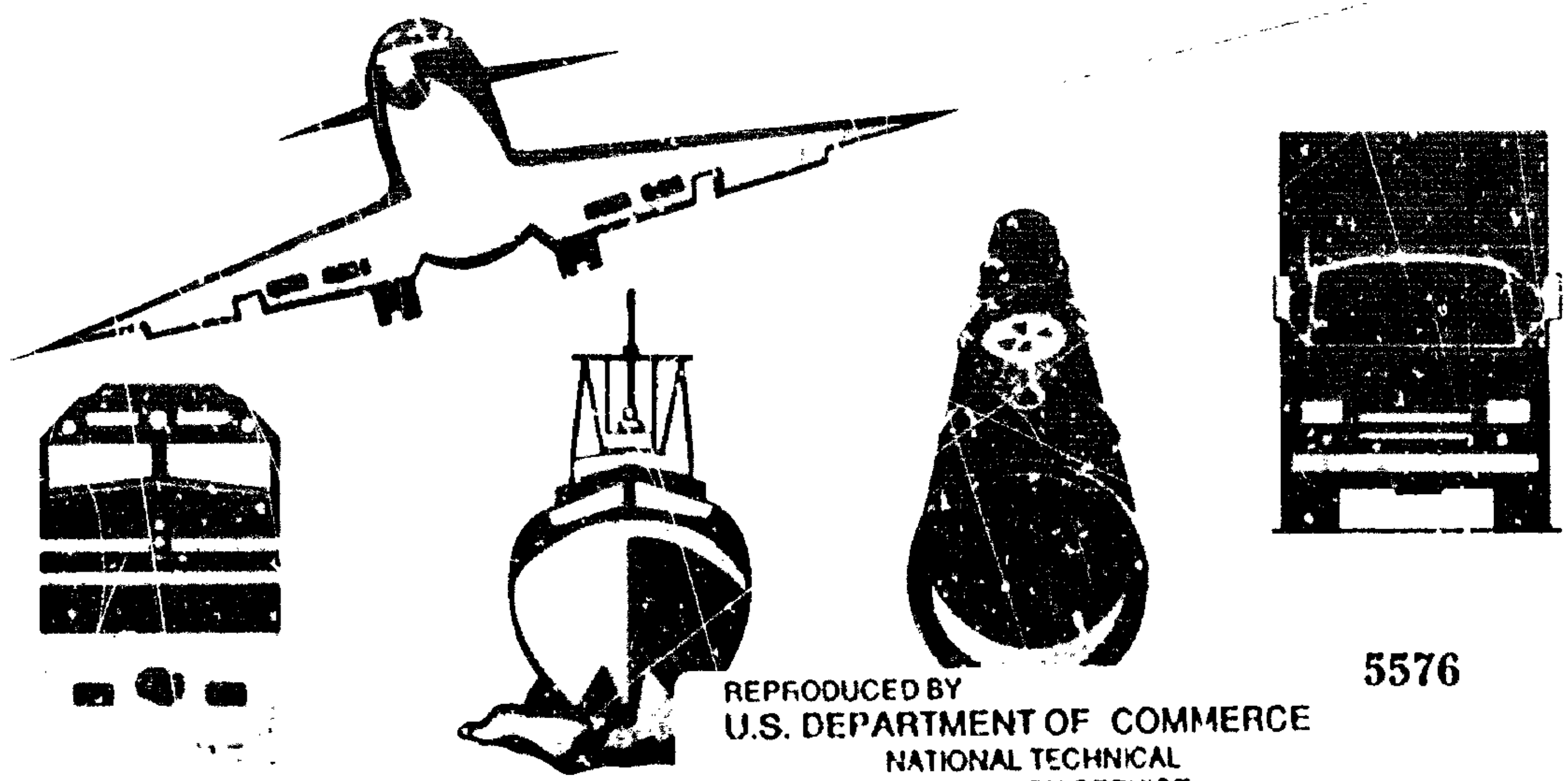
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

FUEL FARM FIRE AT
STAPLETON INTERNATIONAL AIRPORT
DENVER, COLORADO
NOVEMBER 25, 1990



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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AVIATION ACCIDENT REPORT

FUEL FARM FIRE AT STAPLETON INTERNATIONAL AIRPORT DENVER, COLORADO NOVEMBER 25, 1990

ADOPTED: October 1, 1991
NOTATION 5576

Abstract: This report examines a fire that erupted at a fuel storage and dispensing facility at the Stapleton International Airport in Denver, Colorado, on November 25, 1990. The flight operations of one airline were disrupted because of the lack of fuel to prepare aircraft for flight. Airport facilities, other than the fuel farm, were not affected by the fire. The safety issues discussed in the report are the maintenance and inspection of fuel storage facilities on airport property; the training of personnel charged with maintaining and inspecting fuel storage pumping equipment; the safety features for fuel pumping equipment; Federal Aviation Administration inspections of fuel storage facilities on FAA-certificated airport property; and industry contingency plans for responding to large fires on airport property. Safety recommendations concerning these issues were made to the FAA, the operator of the fuel farm, the National Fire Protection Association, the Airport Operators Council International, and the American Association of Airport Executives.

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EXECUTIVE SUMMARY

About 0915 mountain standard time, on Sunday, November 25, 1990, a fire erupted at a fuel storage and dispensing facility about 1.8 miles from the main terminal of Stapleton International Airport at Denver, Colorado. The facility, referred to as a fuel farm, was operated by United Airlines and Continental Airlines. From the time firefighting efforts were initiated immediately after the fire erupted until the fire was extinguished, a total of 634 firefighters, 47 fire units, and 4 contract personnel expended 56 million gallons of water and 28,000 gallons of foam concentrate. The fire burned for about 48 hours. Of the 5,185,000 gallons of fuel stored in tanks at the farm before the fire, about 3 million gallons were either consumed by the fire or lost as a result of leakage from the tanks. Total damage was estimated by United Airlines to have been between $15 and $20 million. No injuries or fatalities occurred as a result of the fire.

United Airlines' flight operations were disrupted because of the lack of fuel to prepare aircraft for flight. Airport facilities, other than the fuel farm, were not affected by the fire. The duration and intensity of the fire, however, raised concerns about the ability of airport and local firefighters to respond to a fuel fire of this magnitude. The origin of the fire also raised concerns about the safety oversight and inspection of fuel farm pumping operations.

The National Transportation Safety Board determines that the probable cause of the fire at the fuel storage facility at Denver's Stapleton International Airport was the failure of AMR Combs to detect loose motor bolts that permitted the motor of motor/pump unit 3 to become misaligned, resulting in damage to the pump and subsequent leakage and ignition of fuel. Contributing to the accident was the failure of AMR Combs to properly train its employees to inspect and maintain the fuel pump equipment and the failure of the city and county of Denver to carry out its certificate holder responsibility to oversee the fuel storage facility in accordance with its airport certification manual. Contributing to the severity and duration of the fire were the lack of storage tank fail-safe control valves and internal fire valves and the location of the control building in the containment area were fuel leaks are likely to occur.

The safety issues discussed in this accident report include:

- maintenance and inspection of fuel storage facilities on airport property;

- training of company personnel charged with maintaining and inspecting fuel storage pumping equipment;

- adequacy of safety features for fuel pumping equipment;

- the responsibility of the Federal Aviation Administration (FAA) for inspection of fuel storage facilities on FAA-certificated airport property; and

- industry contingency plans for responding to fuel farm fires.

As a result of this accident, safety recommendations were issued to the Federal Aviation Administration, AMR Combs--the company that was under contract to operate and maintain United Airlines' portion of the fuel farm, the National Fire Protection Association, the Airport Operators Council International, Inc., and the American Association of Airport Executives.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

FUEL FARM FIRE AT STAPLETON INTERNATIONAL AIRPORT, DENVER, COLORADO NOVEMBER 25, 1990

INVESTIGATION

Fire and Initial Notification

About 0915 mst,[1] on November 25, 1990, a fire erupted at a fuel farm at Stapleton International Airport in Denver, Colorado.[2] The fuel farm, operated by United Airlines, Inc. (United) and Continental Airlines, Inc. (Continental), was located about 1.8 miles from the airport's main terminal. (See figure 1.)

Shortly after 0900, a Sky Chef[3] employee, who was across the street from the fuel farm, noticed "exhaust coming from between two smaller tanks" at the farm. About 0915, the employee and two other Sky Chef employees observed smoke and fire spreading east to west in the vicinity of where the "exhaust" had earlier been spotted. None of these employees, however, reported their observations until after 0922:50, by which time the Denver fire department had already been notified.

About 0921, a Continental security guard, who was also across the street from the fuel farm, witnessed an explosion and fire at the fuel farm and telephoned the local emergency number, 911. About the same time, the air traffic control tower noticed a column of black smoke at the fuel farm and notified airport fire station No. 1. Five aircraft rescue and firefighting (ARFF) trucks were dispatched and arrived at the fuel farm about 0925. Airport fire station No. 2 also responded and arrived at the fuel farm about 0926. While en route from the airport fire department to the fuel farm, the senior fire official requested that the fire dispatcher sound a second alarm, which included four off-airport engine companies and two off-airport fire district chiefs.

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1 All times listed are mountain standard time (mst) based on the 24-hour clock, unless otherwise indicated.

2 "Fuel farm" is an industry term that refers to the fuel storage and dispensing facilities located at airports and used by airlines for fueling their aircraft. Large airports, such as Denver's Stapleton International Airport, typically have several fuel farms operated by the various airlines serving that airport.

3 Sky Chef is a food service company serving the airlines at Denver's airport.

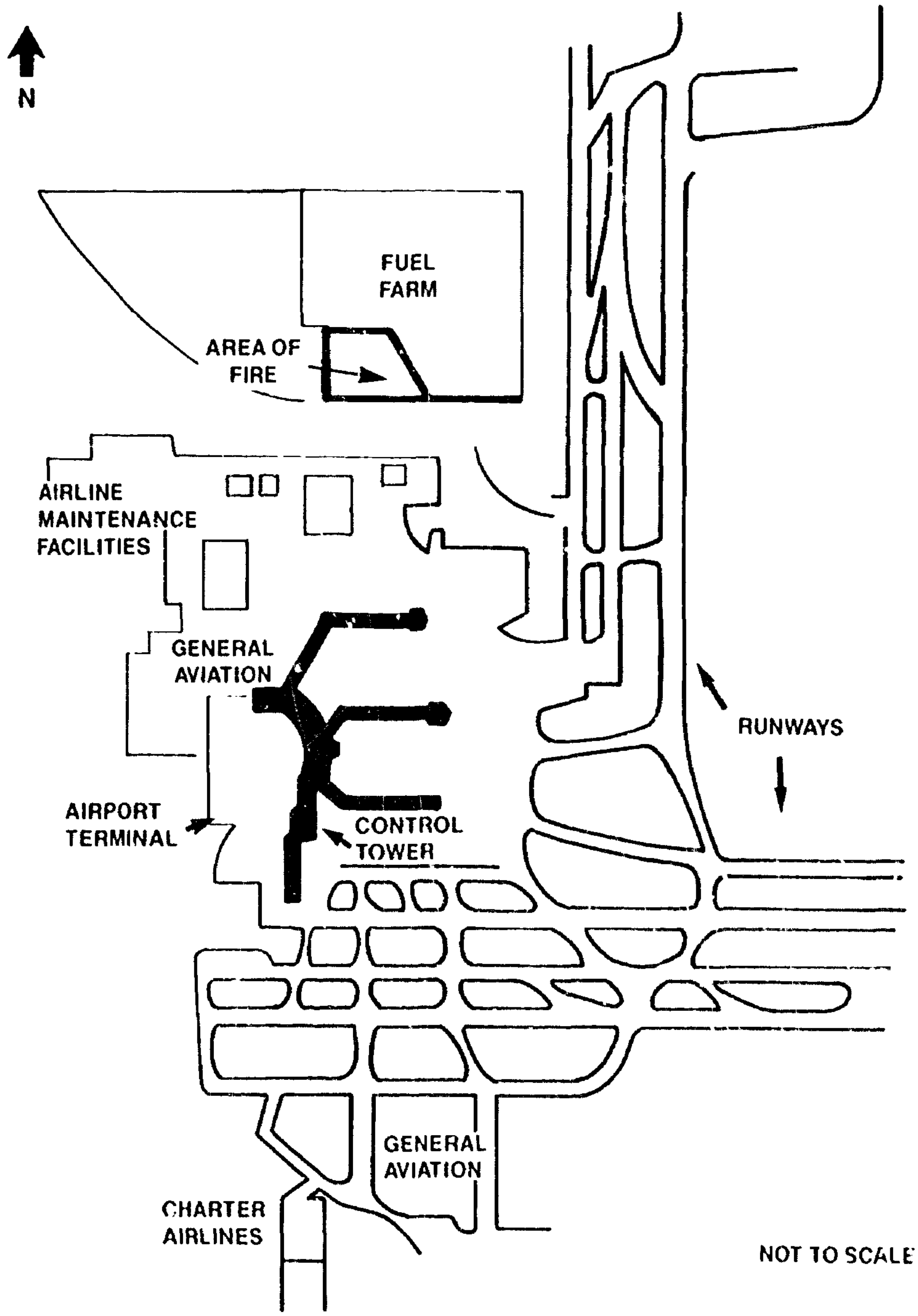

Figure 1.--Fuel farm in relation to airport.

Meanwhile, about 0915, an Ogden Allied[4] employee who was at the company's maintenance shop, about 0.3 miles from the fuel farm, received an alarm on Continental's fuel tank 8 and attempted unsuccessfully to reset the alarm. (The Ogden Allied employee had been at the fuel farm around 0830 and had initiated filling of tank 7, and this tank was being filled at the time of the alarm.) He then exited the maintenance shop, saw smoke coming from the fuel farm, and proceeded toward the fuel farm with another coworker. By the time the Ogden Allied employees arrived at the fuel farm, firefighting officials were already onscene.

Arriving firefighting crews observed a large fire, near United's fuel tanks 3 and 4, in a containment area (pond 1)[5] that contained pipes, pumps, valves, and a control building (see figure 2). Also, burning fuel was spraying from equipment in front of tanks 3 and 4 in "tentacles" 8 to 10 feet long.

At 0933, the Denver fire department called the Public Service Company of Colorado and requested that electrical power to the farm be terminated to eliminate any electrical hazard to the firefighters. According to a power company spokesperson, a company truck was dispatched to the appropriate substation to terminate the power to the fuel farm. The work was completed about 1025; according to the company, it takes about 45 minutes to complete the work.[6]

Response to the Fire

Firefighters on three of the ARFF trucks simultaneously began to discharge fire retarding foam concentrate, mixed with water from a water truck, and extinguished the fire in the containment area within a couple of minutes. However, because of fuel spraying from a rupture in a fuel line in the containment area, the foam layer quickly washed away and the escaping fuel reignited. Within about 3 minutes of initiating their attack, the airport firefighters depleted their water supply and began to replenish it from a nearby hydrant. At the time, other ARFF units returned to station No. 1 to obtain more foam concentrate, which had also been depleted. Because the firefighters were unable to maintain a continuous flow of foam, the fire from the pooling fuel in the containment area continued to intensify before the reserviced ARFF trucks returned.

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[4] Ogden Allied, an independent company under contract with Continental Airlines, maintained and operated Continental's part of the fuel farm. Typically, airlines serving an airport will contract with an independent company that provides the maintenance and operating services. (See additional discussion under "Physical Layout of Fuel Farm.")

[5] "Pond" is the term used to refer to the diked containment area.

[6] An electric clock was found in the control building after the fire was extinguished; the clock was stopped and the time was 1020.

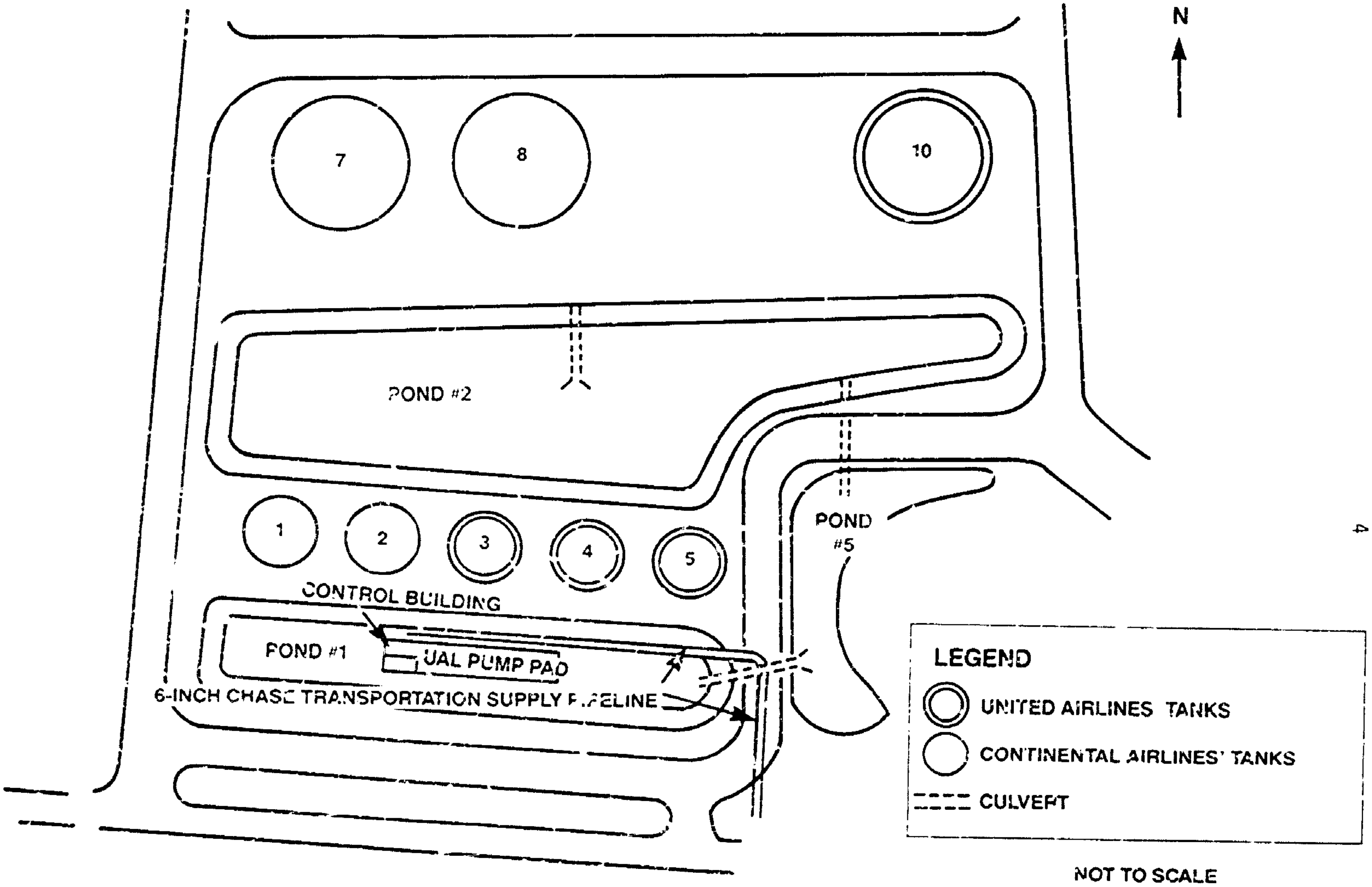

Figure 2.--Portion of the fuel farm involved in the fire.

The first city firefighting units began to arrive about 0925. These units used their equipment to protect exposed fuel tanks by applying hose streams on the tanks. In addition, these units established water supply lines. Although more units arrived and established additional hose lines, the pooling fire continued to intensify and impinged on the piping to tanks 3, 4, and 5. About 1000, firefighters, working with employees from AMR Combs[7] and Ogden Allied, manually closed valves at the base of tanks 1, 2, and 5, to prevent the fire from being fed by head pressure from the tanks. According to the firefighters, because of the intensity of the fire at tanks 3 and 4, they were unable to close the valves to those tanks at that time. Firefighters determined that fuel under pressure was still leaking into the containment area and, with the help of Ogden Allied employees, then manually closed the valves to tanks 7, 8, and 10. About 1015, a Chase Transportation Company employee manually closed a valve that isolated the pipeline that supplied fuel to the farm. (See discussion in "Physical Layout of Fuel Farm.")

By 1500, flames were impinging on tanks 2, 3, 4, and 5. The fire continued to burn and as it grew in intensity, couplings and other valves around tanks 3, 4, and 5 began to fail, allowing more fuel to escape. At one point, burning fuel was spraying into the air to heights of 30 feet in the general vicinity of tanks 3 and 4.

About 2130, a large amount of fuel began to flow into the containment area (pond 1). Firefighters stated that they believed that this increase in fuel was caused from the release of a discharge pipe attached to tank 4. Fuel and water began overflowing pond 1 and flowed into pond 2 via pond 5 (see figure 2). Burning fuel was then impinging on tanks 1 and 10, in addition to tanks 2, 3, 4, and 5. As flames from the burning fuel continued to impinge on tanks 1 and 2, firefighters applied hose streams directly on those tanks to keep them cool and to preclude their rupture.

Firefighting efforts continued throughout the evening of November 25. By 0700, on November 26, tank 3 had partially collapsed. As the fire suppression activities continued, available foam concentrate supplies were depleted, except for the amount reserved to be in compliance with FAA requirements.[8] Initially, additional foam concentrate was received from neighboring communities and other local resources, but those supplies were quickly exhausted. The Denver fire department's requests for additional foam concentrate were acknowledged, and foam concentrate was flown to Denver from fire departments in Seattle, Houston, Philadelphia, and Chicago. As the foam concentrate arrived, firefighters continued to spray the fire. These efforts continued throughout the day. A cold front moved through the area during the

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[7] AMR Combs was the independent contractor that operated and maintained United's part of the fuel farm.

[8] According to the fire department, the amount of foam concentrate required by the Federal Aviation Administration (FAA) for emergencies involving air carrier operations at Stapleton was not used. (See appendix B for FAA requirements.)

day on November 26, and the gusting and changing wind directions in the Denver area at the time repeatedly disrupted the foam blanket and forced firefighters to continually readjust tactics.

On November 27, between 0100 and 0600, a number of recurring explosions were reported to have occurred in tank 5 at half-hour intervals. The fire at tank 3 had been extinguished, and the fire at tank 4 had diminished considerably; however, fires continued to burn at the flanges on piping for tanks 5 and 10.

During the early morning hours on November 27, representatives from Williams, Boots, and Coots, Inc. (WBC), a private company that specializes in extinguishing large-scale fuel fires, arrived at the request of Continental Airlines.[9] Upon arrival, WBC personnel conferred with Continental Airlines and Denver fire department representatives. Although fire suppression activities continued, fire department representatives elected to wait until morning light before attempting to initiate the firefighting tactics outlined by WBC. WBC acquiesced, although WBC expressed concern that waiting might exacerbate the situation.

At daylight, WBC evaluated the fire and tank conditions and concluded that tank 5 would not remain intact much longer. WBC requested and received permission from the Denver fire department to begin to expeditiously attack the fire. From that point on, WBC assumed responsibility for the firefighting operations.

Initially, WBC encountered some difficulty in mating its equipment with fire department hoses. The problem, however, was resolved within an hour with the assistance of Ogden Allied and AMR Combs personnel. About 1 1/2 hours elapsed as personnel installed the foam concentrate/water proportioners and increased the water pressure to sufficient levels for the attack.

WBC attacked the fire first by cooling tank 5 and the piping area near that tank using three foam monitors, two of which had discharge rates of 750 gallons per minute (gpm) and one that discharged at 500 gpm, and two hose lines that were rated at 250 gpm each, for a total application rate of 2,500 gpm. WBC had brought supplies of foam concentrate and equipment that quickly and continuously mixed the foam concentrate and water, allowing for uninterrupted application. As the foam was applied and became effective, fire department dry chemical units were brought forward and used on specifically assigned targets. The flange fires near tank 5 were extinguished, and the contractor used the same technique to extinguish the flange fires near tank 10. After the flames were extinguished, firefighters maintained the hose streams to cool hot surfaces and to reduce the potential

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[9] The communication between WBC and United Airlines, and between the Denver fire department and WBC is unclear. Continental Airlines ultimately arranged and paid for WBC services. Continental became concerned during the course of the events that the fire might impinge on its holding tanks 7 and 8.

for reignition. A total of 45 minutes elapsed from the time WBC began attacking the fire to the time the fire was extinguished.

About 48 hours elapsed from the time the fire erupted until it was extinguished. A total of 634 firefighters, 47 fire units, and 4 contract personnel (WBC) expended 56 million gallons of water and 28,000 gallons of foam concentrate.

Damage

Tanks 3 and 4 were completely destroyed by the fire; tanks 2, 5, 8, and 10 received extensive damage; and tank 1 received smoke damage. In addition, pumps, electrical equipment, and control facilities were extensively damaged (see figures 3 and 4). Of the 5,185,000 gallons of fuel stored in tanks at the farm before the fire, about 3 million gallons were either consumed by the fire or were lost as a result of leakage from the tanks. Total damage was estimated by United Airlines to have been between $15 and $20 million.

Injuries

No injuries or fatalities occurred as a result of the fire.

Meteorological Information

On the morning of November 25, 1990, the temperature at Stapleton International Airport was about 57 °F, and the wind was from the south-southwest at 4 to 10 knots. About 1250 on November 26, a front passed through Denver; the wind began blowing from the north at 12 knots with gusts to 23 knots, the temperature dropped to freezing (32 °F), and snow began to fall. The lowest recorded temperature during the 2 days of the fire was 20 °F around midnight on November 26.

Chemical and Physical Properties of Jet-A Fuel

Jet-A fuel has a specific gravity of 0.82 at 70 °F. The flash point is about 105 °F, and the minimum autoignition is 437 °F. Its lower flammability limit is 0.6 percent and its upper limit is 4.7 percent in air. The National Fire Protection Association classifies Jet-A fuel as a Class II liquid. Class II liquids have flash points at or above 100 °F (37.8 °C) and below 140 °F (60 °C).

Physical Layout of Fuel Farm

The land on which the fuel farm was located was owned by the city and county of Denver, the certificate holder for Stapleton International Airport. The airlines operating the fuel farm leased the land from the city and county. AMR Combs, under contract with United, operated United's part of the fuel farm. Ogden Allied, under contract with Continental, operated Continental's part of the fuel farm. A layout of the fuel farm is provided in figure 2. Fuel storage tanks 1, 2, 7, and 8 were owned by Continental.

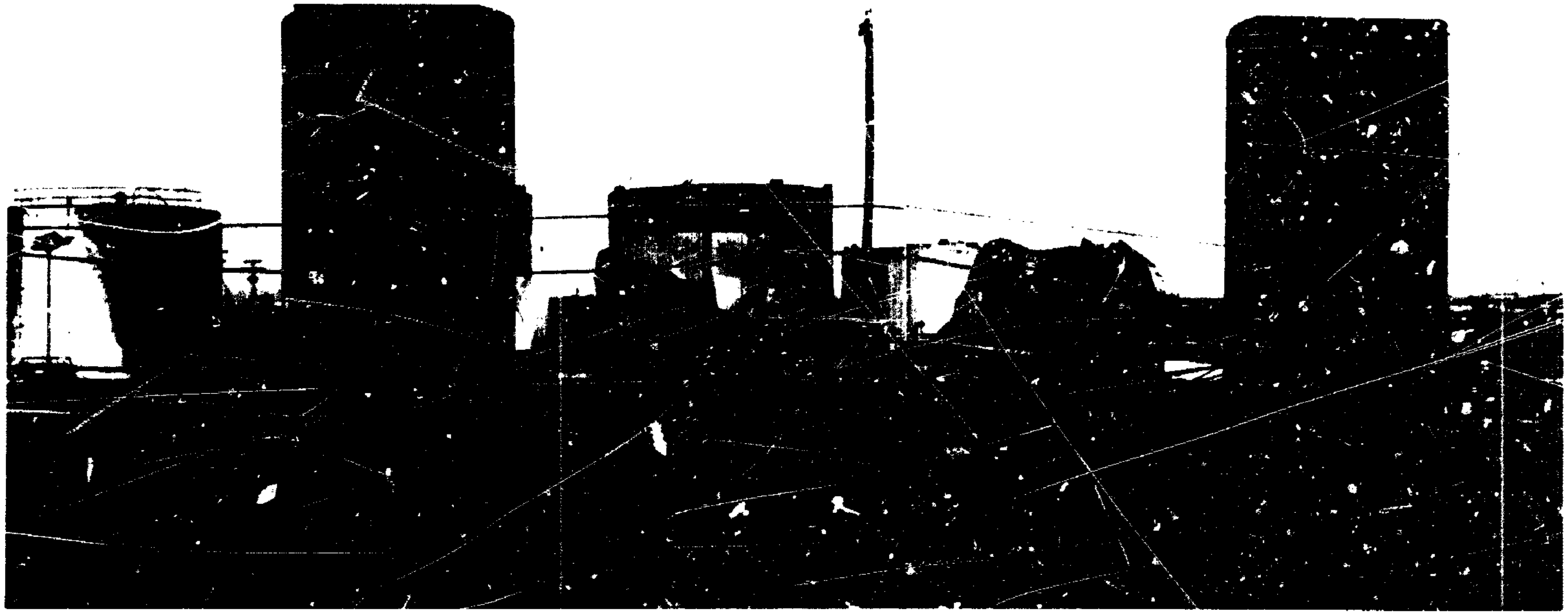
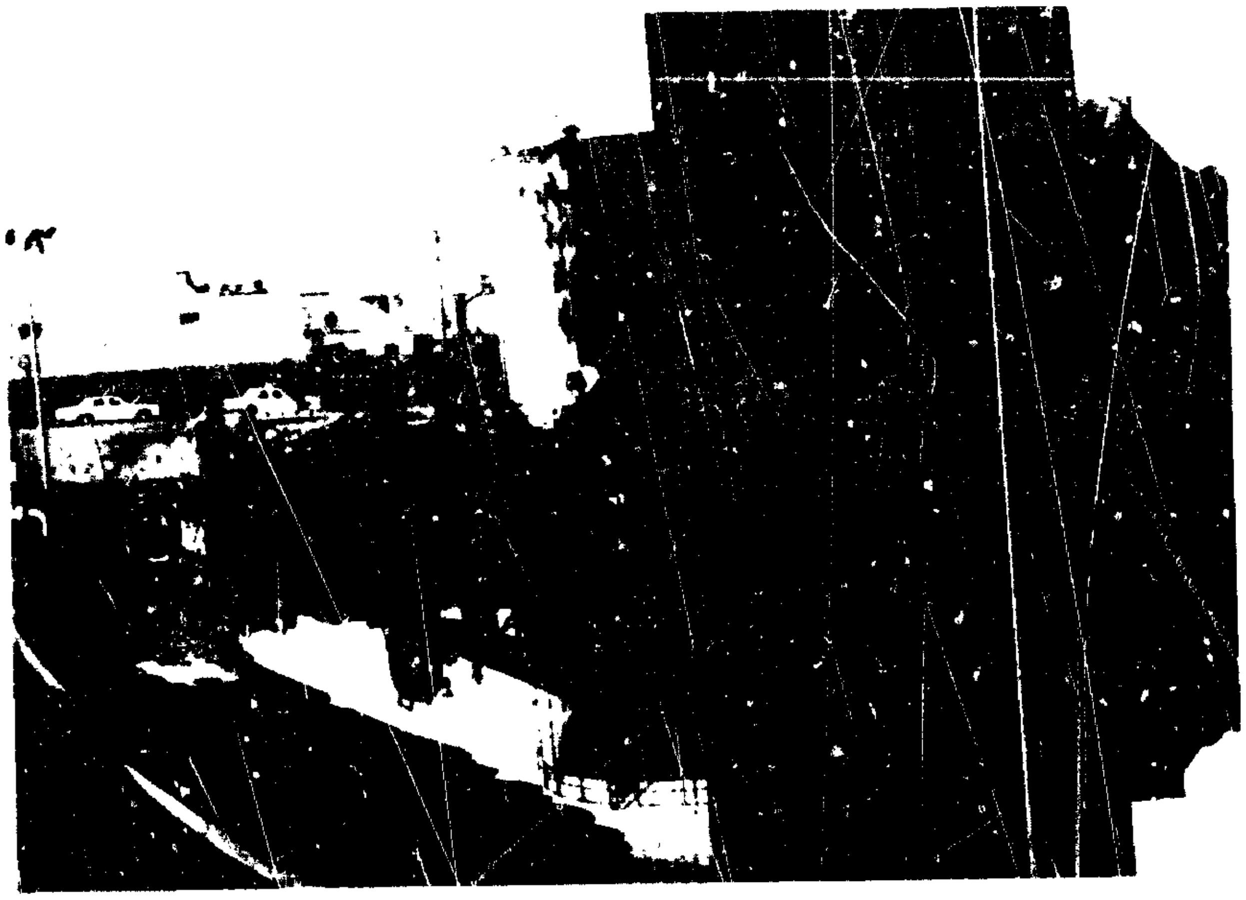


Figure 3.--Damage to fuel farm.



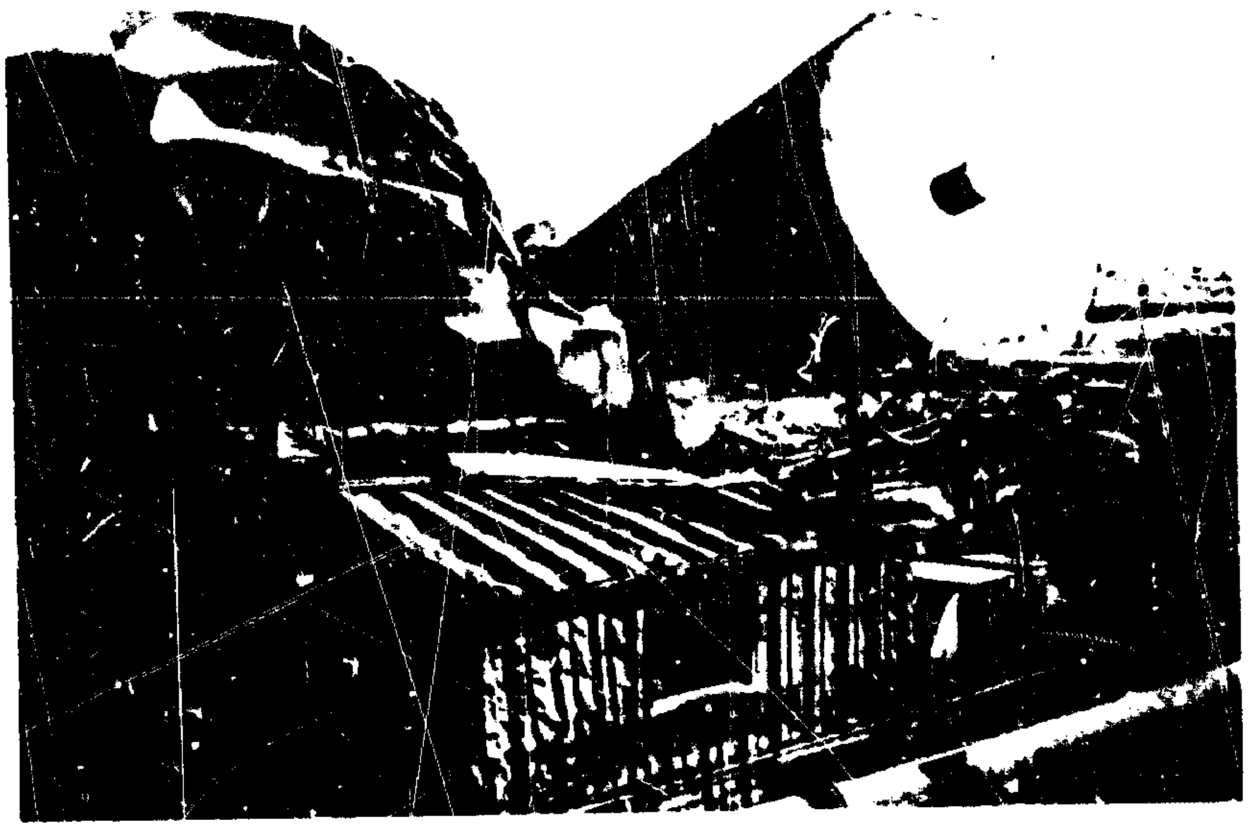


Figure 4.--Fire damage to motor/pump area. Arrows indicate the control building.

Fuel storage tanks 3, 4, 5, and 10 were owned by United. (Tank capacities are listed in appendix G.)

Chase Transportation Company (Chase) provided fuel to the farm from its storage facility at Aurora, Colorado, located about 4.5 miles east of the farm, through an underground 6-inch pipeline. (The elevation of the storage facility at Aurora is about 100 feet above the elevation of the fuel farm at Denver.) After entering the farm, the 6-inch pipeline rose to the surface at which point the line pressure was measured before and after the fuel passed through a filter.[10] At this location, there is a valve that can be manually closed to isolate the 4.5-mile section of pipeline to the Aurora facility. (The foreman on duty at the Aurora facility on the morning of the fire observed smoke at the Stapleton airport and proceeded to the fuel farm and closed this valve at about 1015.) A back pressure valve was installed on the pipeline at a location beyond where the pressure was measured but before the pipeline returned underground. This valve was designed to automatically close when the line pressure fell below 25 psi. The pipeline returned underground, headed north to a point just east and south of tank 5, headed west, and then resurfaced in front of tank 3. The pipeline continued on the surface to the western-most point of a control building, where the pipeline rose and "tee"-ed to the motor operated supply control valves that directed fuel to either United's bulk receiving tank 10 or Continental's bulk receiving tanks 7 and 8. The valves were controlled from the motor/pump control building (see figures 2 and 5) located in front of tanks 2 and 3 in the containment area (pond 1). United's tanks 3, 4, and 5 were routinely filled from tank 10 and these tanks had been filled just before the fire.

The inlet/outlet piping on tanks 1, 2, 3, 4, 5, 7, 8, and 10 had manually operated "butterfly" valves at the base of each tank.[11] (See figure 5.) These fire-rated[12] steel valves were bolted externally onto the tank outlets. According to United, these valves were primarily closed for maintenance purposes, but were otherwise normally left open.

Tank 10 had an internal fire valve with external fusible links that was designed to automatically close when exposed to heat from a fire. This fire valve functioned as designed during the fire. Tanks 1 through 5 did not have, nor were they required to have, this feature.

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[10] These pressure measurements were made to determine when the filter should be changed. Other measurements were made at various locations along the pipeline.

[11] A butterfly valve is a type of valve with a disk turning on a diametrical axis inside a pipe.

[12] National Fire Protection Association (NFPA) Standard 30 (Chapter 3, paragraphs 3.3 and 3.3.1) requires that valves at storage tanks be made of steel or nodular iron or of such material having a fire-resistance rating of not less than 2 hours.

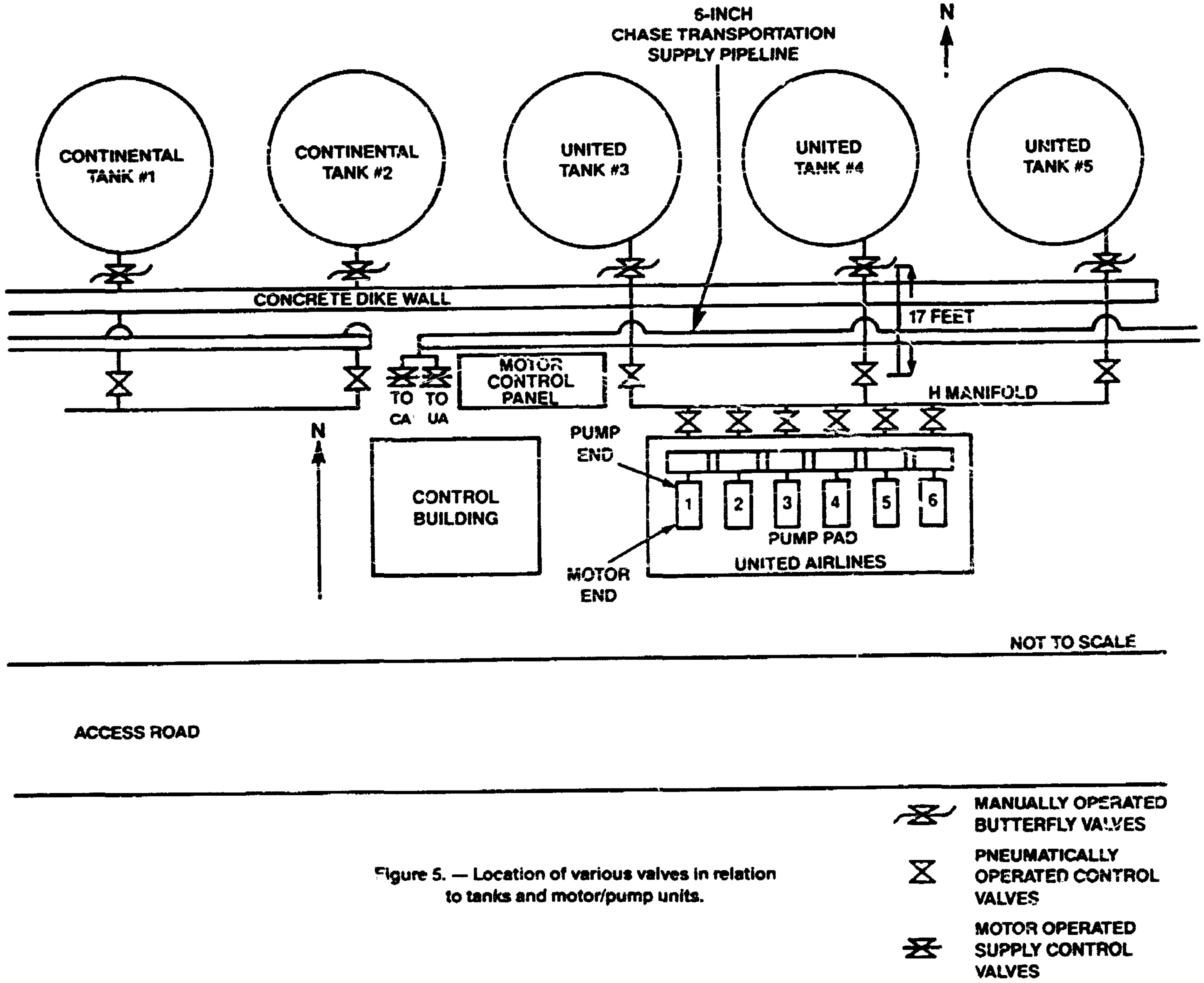

Figure 5. — Location of various valves in relation to tanks and motor/pump units.

Tanks 1 through 5 had pneumatically operated control valves on both the inlet and outlet piping located about 17 feet from the manually operated "butterfly" valves. (See figure 5.) These valves on the piping for tanks 1, 3, and 4 were designed to automatically close if electrical power was lost and air pressure remained on the valve's operating control system. In the event air pressure was also lost, the valves would have to be closed manually. The pneumatically operated control valves on tanks 2 and 5 were fail-safe in the sense that they were designed to automatically close (spring loaded) if either electrical or air pressure was lost. The compressors providing the air supply for operating these valves were located in the control building, which was located in the containment area (pond 1).

Tanks 1 through 5 also had "victaulic" type couplings[13] installed on the 18-inch outlet piping between the manually operated butterfly tank valves and the pneumatically operated control valves.

United Airlines piped fuel from tanks 3, 4, and 5 to six motor/pump units (see figure 5) that discharged fuel into a manifold that was connected to underground pipelines that ran to the airport terminal for fueling aircraft.[14] The number of pumps in operation at any particular time depended on fuel demand, measured by line pressure and fuel flow. Each month a different motor/pump unit was designated as the lead pump; other pumps would automatically be switched on as determined by fuel demand. For the month of November, pump 4 was the lead pump. As demand dictated, pump 3 would be activated after pump 4, followed by pumps 2, 1, 6, and 5. A 24-hour, 2-channel circular paper chart recorder recorded line pressure and fuel flow to the terminal. The chart recorder, the pumping controls, and associated electrical equipment switches for the United fueling system were housed in the control building located in the containment area (pond 1) forward of tanks 2 and 3 (see figure 2).

United's pumps were rated at 1,150 gallons per minute with an output pressure equivalent to 315 feet of head pressure when operated at 3,600 rpm. The pump was divided into two major components: the bearing case and the impeller case, as illustrated in figure 6. Each pump was driven by a 125-hp electric motor, manufactured by General Electric, through a direct gear coupling assembly (C in figure 6). A spacer was bolted to each half of the coupling assembly to facilitate disconnecting the pump from the motor for repairs (item 22 in figure 7). Both the pump and motor were bolted on a machined pedestal--the pump with four 3/4-inch-diameter steel bolts and the motor with four 5/8-inch-diameter steel bolts. The pedestals were welded to a bed plate that was designed with a channel to collect fuel during equipment maintenance and from potential fuel leaks. (See figure 6.)

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[13] Victaulic couplings provide flexibility for pipelines as soil shifts.

[14] An 18-inch and a 24-inch pipeline ran from the fuel farm to United's area at the airport terminal. These pipelines, when filled, as they were on the morning of the fire, contained about 408,000 gallons of fuel.

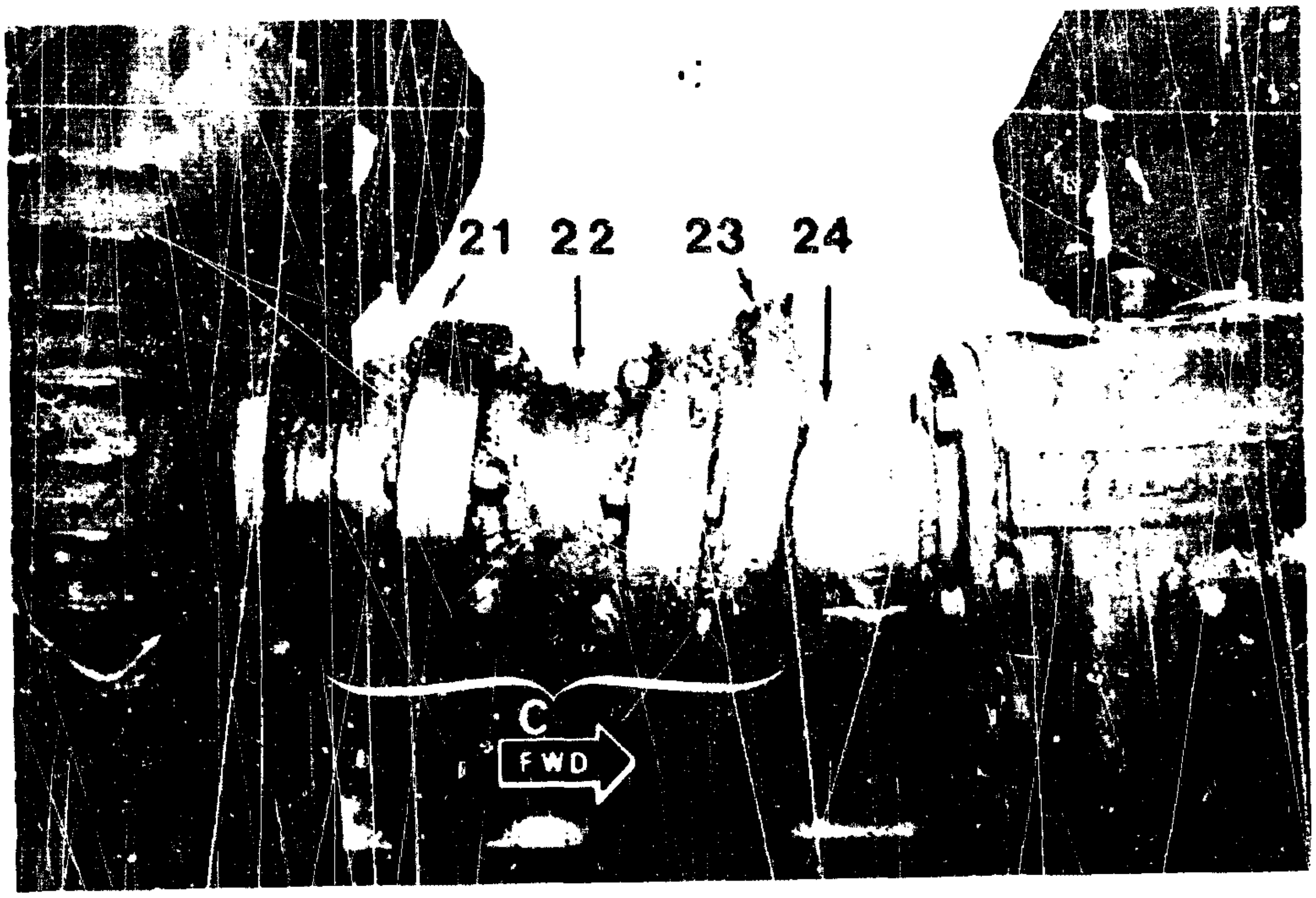

Figure 7.--Damaged coupling assembly of motor/pump unit 3. The coupling gear is denoted by brace C; 21 is the motor shroud; 22 is the coupling spacer; 23 is the pump shroud; and 24 is the separated pump hub.

Design of Fuel Farm

The fuel farm was designed in 1974-75, and construction was completed in 1976. The original design called for the accomodation of five fuel tanks (tanks 1 through 5) on a tract of land of less than 3 acres. According to the designer of the fuel farm, who has also worked on the design of the fuel farm for the new airport at Denver, the primary standard followed for non-military fuel storage facilities is the National Fire Protection Association (NFPA) Standard 30, which has been updated over the years--in 1977, 1981, 1984, 1987, and recently in 1990. According to this designer and another designer, who is also working on the fuel farm at the new Denver airport, neither the NFPA Standard 30 nor any other industry standard specifies (1) the location of pumping control facilities relative to the pumping equipment, (2) the installation of fail-safe control valves, or (3) fire valves on above-ground storage facilities. According to one of the designers, the Denver fire has caused a number of changes in the design of fuel storage facilities, notably in the three areas mentioned above.

Post-Fire Examination of Fuel Farm Equipment

General Information.--After the fire was extinguished and the fuel and water were removed from the containment area (pond 1) in front of fuel storage tanks 1 through 5, various fuel system components were examined. A split was noted on a section of the Chase 6-inch pipeline that travels along the containment area (see figure 8). The butterfly valves on tanks 3 and 4 were found open. Victaulic couplers connecting sections of the 18-inch pipeline that supplied fuel to the pumps from the storage tanks had come apart (see figure 9). Fuel was observed leaking from flanges at other pipe joints and at the check valves in the 18-inch and 24-inch lines that provided fuel to United's terminal.

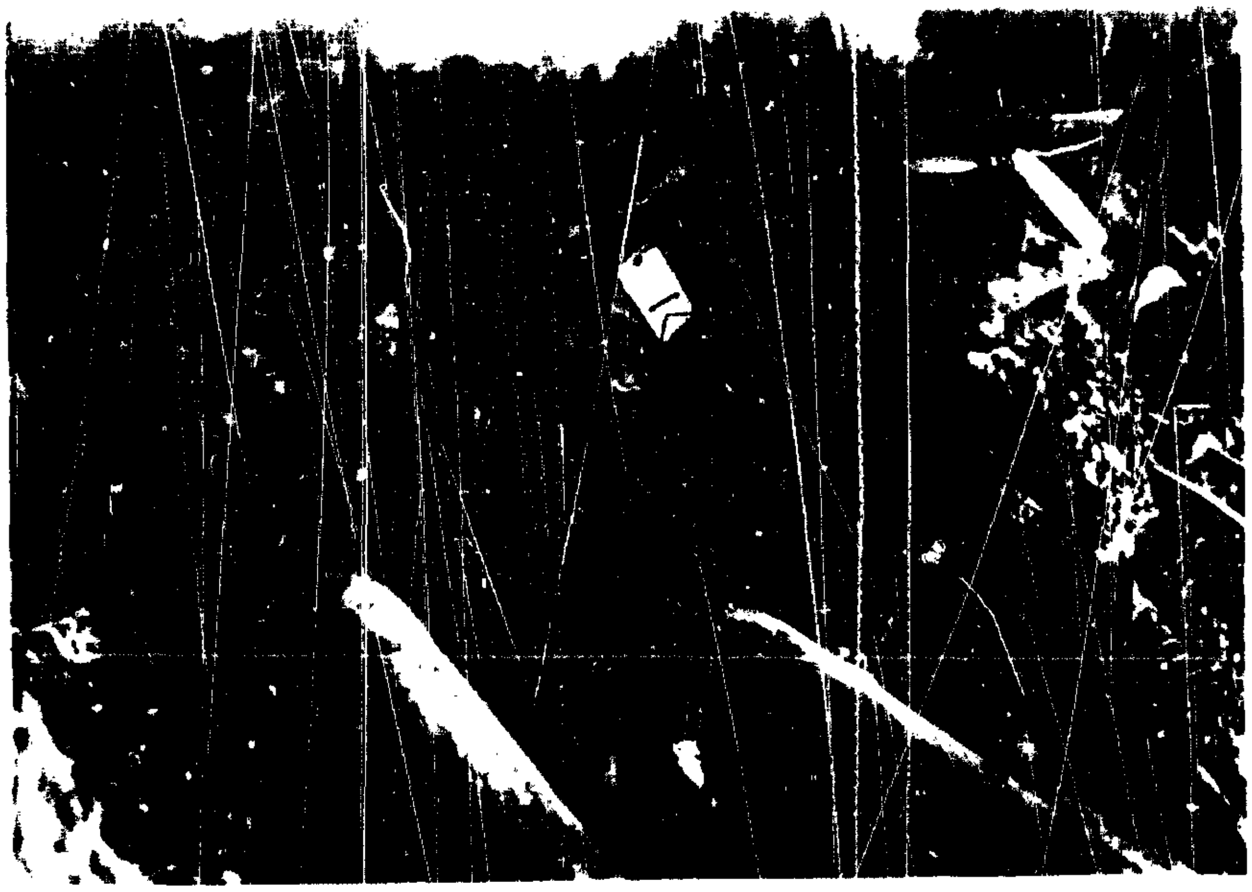

Figure 8. Damaged 6-inch supply pipeline (arrow denotes the split).

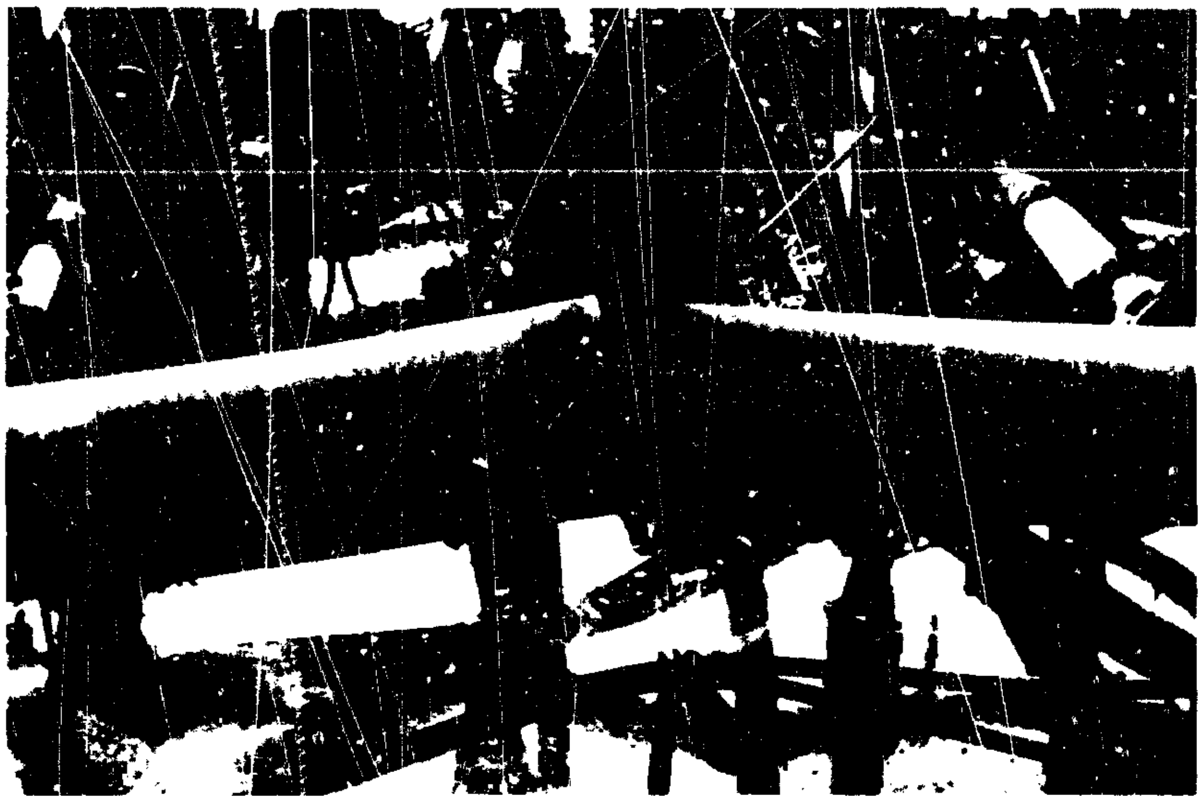

Figure 9.--Failed victaulic coupler.

Preliminary examination of the six motor/pump units indicated anomalies in motor/pump unit 3, including a shifting of the motor relative to the pump by about 3.6 degrees. That unit and motor/pump unit 4, for comparison purposes, were removed from the containment area under the supervision of the Denver fire department.

Examination of Motor/Pump Unit 3.--Motor/pump units 3 and 4 were transported to a facility at Stapleton leased to United Airlines where the pumps were separated from the motors. The coupler and the pump of unit 3 were disassembled and examined in detail at this location. The motor of unit 3 was transported to Reliance Electric Company and disassembled.[15]

The rotor end rings (large, aluminum end pieces on the rotor) had melted into the base of motor 3 during the fire. Consequently, the end caps had to be broken off to remove and inspect the motor bearings and armature shaft. Examination of the bearings after they were removed did not show any unusual wear or damage. The journals were then examined and were also found to be free of wear and damage. Measurements of the motor shaft revealed that the shaft was bowed about 0.240 inches between the forward and rear journals.

All four 5/8-inch-diameter bolts that secured motor 3 to its pedestal were fractured. These fractures occurred in the threaded area (see figure 10). Remnants of all four bolts remained in the threaded holes of the

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[15] Reliance Electric Company had previously overhauled this motor. See section "Fuel Farm Maintenance Records" for further information.

pedestal. The heads of only three bolts were located. The heads of two of these bolts were found on the bed plate; a third head was found on the motor pedestal. The three bolt heads were covered with soot and were heavily oxidized, and the undersides of all three bolt heads were rounded and exhibited deformation in an upward direction.

Two bolt heads used to secure the motor to the pedestal contained permanent markings that indicated they were grade 8.2 bolts, according to SAE J429 specifications.[16] Bolts with this designation are rated with a minimum tensile strength of 150 kilo pounds per square inch (ksi) and have a hardness value of 33 to 39 HRC.[17] A third bolt head contained a permanent marking that indicated the bolt was a grade 5, with a minimum tensile strength of 120 ksi and a required hardness of 25 to 34 HRC.

The three motor bolt sections with heads were examined at the Safety Board's laboratory. This examination revealed that the three bolt sections (labeled A, B, and C in figure 10) had hardness values of 82, 82, and 84 HRB, respectively.[18] Remnants of the bolts that remained in the forward holes of the motor pedestal were also examined. The examination revealed that the bolt remnants that remained in the right and left forward holes of the motor pedestal had hardness values of 85 and 67 HRB, respectively; the corresponding tensile strengths were 82 and 58 ksi, respectively.

Microscopic examination of the fracture surfaces on the three sections of bolts with the heads attached indicated features characteristic of fatigue cracks originating at multiple sites along the thread roots on diametrically opposite sides of the bolts. The remaining fracture surfaces between the fatigued areas revealed features typical of overstress separations. Examination of the fracture surface on the bolt remnant that remained in the left forward hole in the motor pedestal revealed damage consistent with the motor base sliding across the bolt surface.

The sections of the bolts with the heads attached and the remnants that remained in the forward holes of the motor pedestal were cut longitudinally and examined. This examination revealed a microstructure of pearlite and

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[16] The Society of Automotive Engineers' (SAE) document, "Mechanical and Material Requirements for Externally Threaded Fasteners" (SAE J429), lists the bolt grades associated with standard markings.

[1] ardness as measured by the Rockwell C-scale.

[18] The Hardness Rockwell B-scale (HRB) is used to measure the hardness of materials softer than those measured by the C-scale. The B-scale and the C-scale do not overlap. Therefore, the highest reading on the B-scale indicates a softer material than the lowest reading on the C-scale.

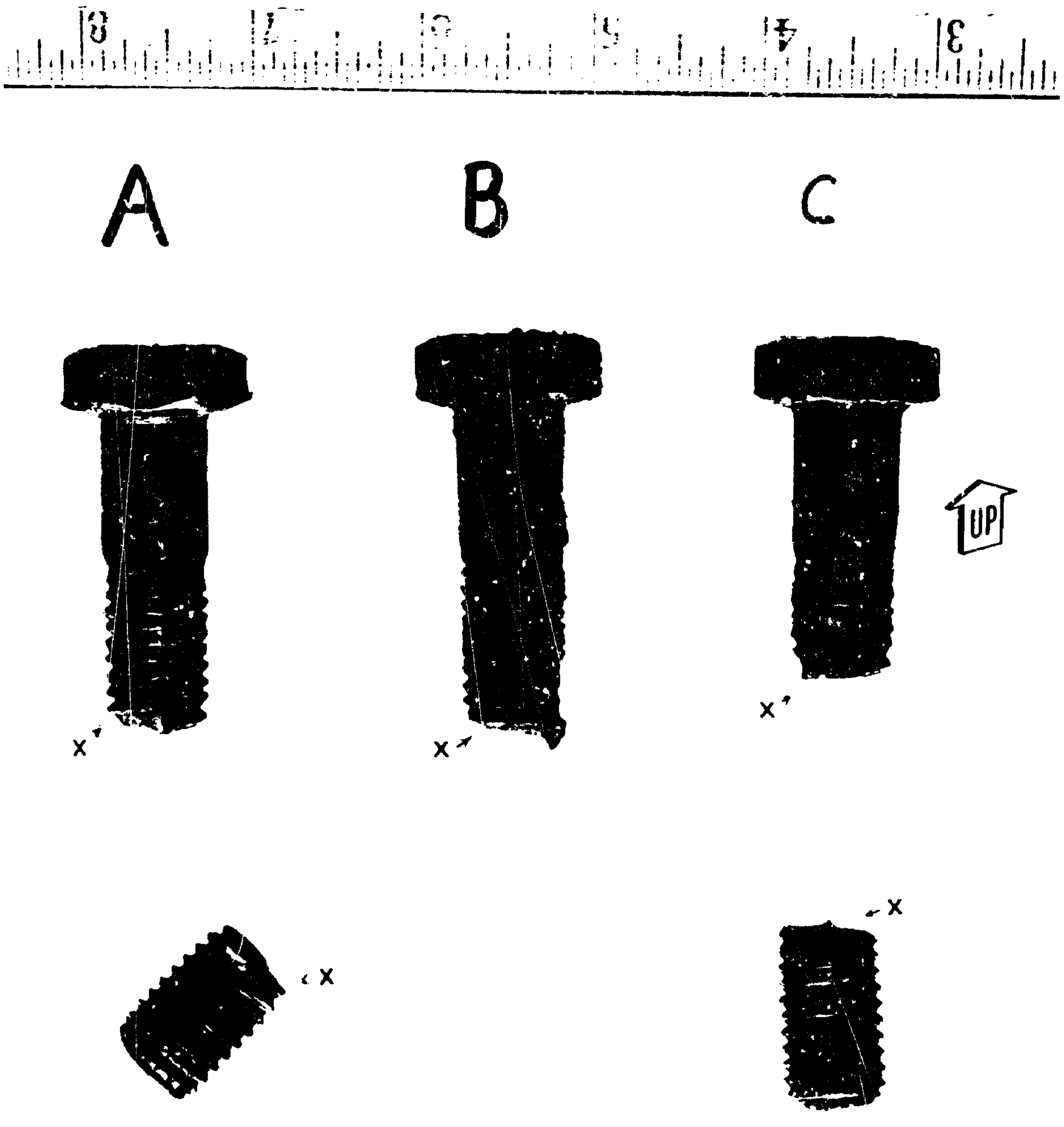

Figure 10.--Failed motor mount bolts of motor/pump unit 3 (x indicates the fractured surface).

ferrite. For high strength steel bolts, the microstructure should be tempered martensite.

Imprint marks around the bolt holes on the motor foot were examined. (See figure 11.) The imprint marks measured 1 1/8 inches from apex to apex and were consistent with the size of the hexagonal bolt heads and lock washers. The imprint around the right rear hole was about 1/8-inch deep and clearly hexagonal. The imprint around the right forward hole was also about 1/8-inch deep, but was more circular with one flat side consistent with the length of one side of the hexagonal bolt head. The imprints around the bolt holes on the left side of the motor foot were about 1/16-inch deep. The imprint around the left rear hole was consistent with a lock washer having been present.

General Electric motor installation instructions, GEI-56128A, provides the following guidelines:

> For base assembly and motor mounting, the bolts must be carefully tightened to prevent changes in alignment and possible damage to the equipment. It is recommended that a washer be used under each nut or bolt head to get a secure hold on the motor foot; or, as an alternative, flanged nuts or bolts may be used. The recommended tightening torques for medium carbon steel bolts, identified by three radial lines at 120 degrees on the head,[19] are: 5/8 inch bolt the minimum torque is 120 ft-lb. and the maximum is 180 ft-lb.

Examination of the guard over the coupling assembly exhibited rotational damage consistent with the rotating coupling assembly pressing against the guard. The coupling assembly was extensively damaged. The pump gear teeth (J in figure 12) were badly worn; the pump hub had been forced forward onto the pump shaft until it was pressed against the bearing case; the corners of the pump hub exhibited circumferential wear damage and gouge marks (Y in figure 12); and the pump shaft, key, and key way exhibited heavy metal smear damage. The pump shroud gear that mates to the pump hub gear (figure 13) was stretched open, and the pump hub gear was badly worn. The teeth in the pump shroud gear were worn or completely gone (area Z in figure 13). Wear marks were also noted in the stretched area; they appear to be consistent with the pump shroud gear wearing against the pump gear and shaft.

Examination of the pump components revealed that the bearing case exhibited cracks where it was attached to the impeller case of the pump (see figure 14). A 2-inch-square piece of metal was dislodged from both the left and right side of the bearing case. The rear of the bearing case was normally fastened to the bed plate by two brackets that are bolted together; the two bolts connecting the brackets were missing (see figure 15).

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[19] Three radial lines 120° apart on the head of the bolt identifies a bolt of 120 ksi.

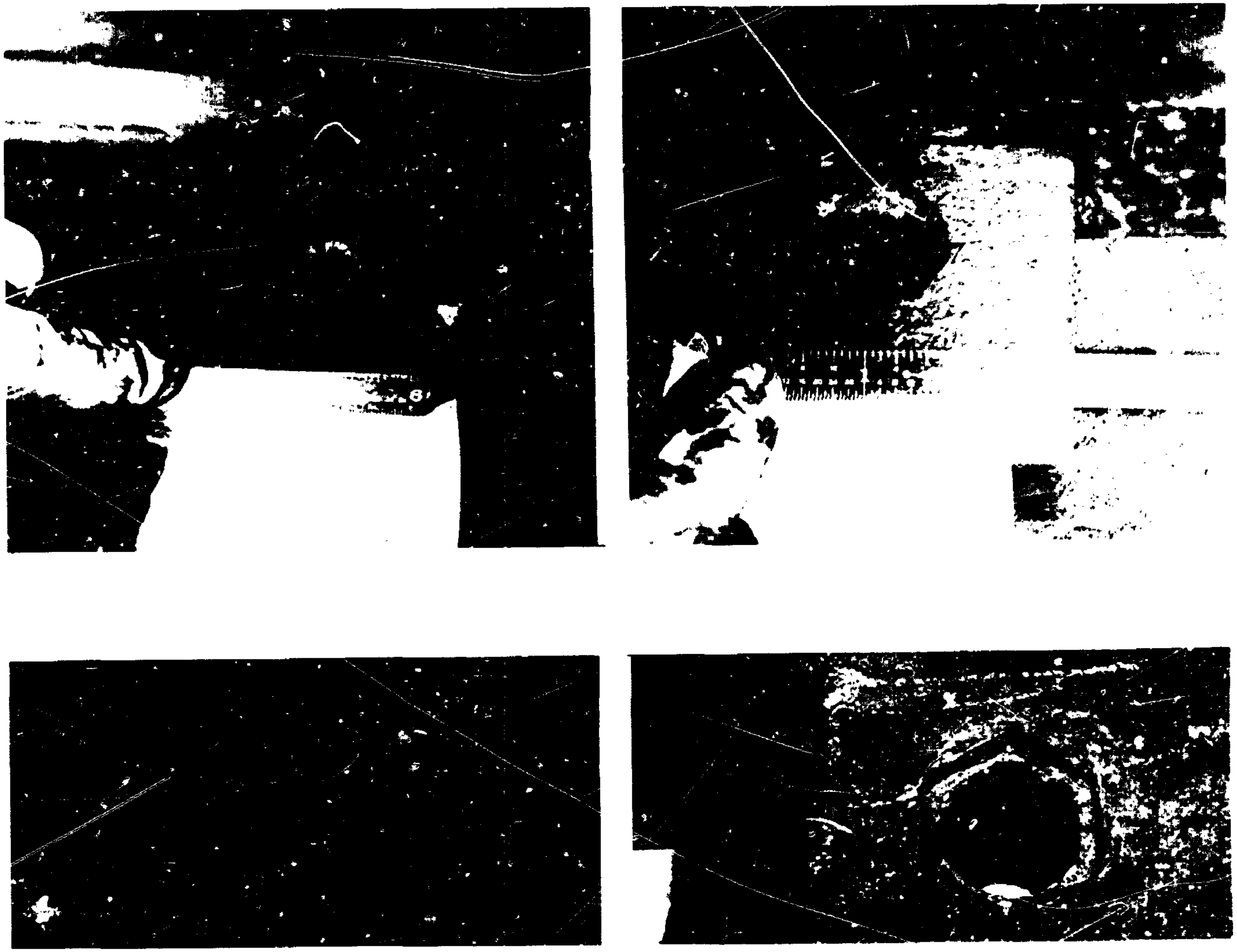

Figure 11.--Imprint marks around bolt holes in motor pedestal of motor/pump unit 3.

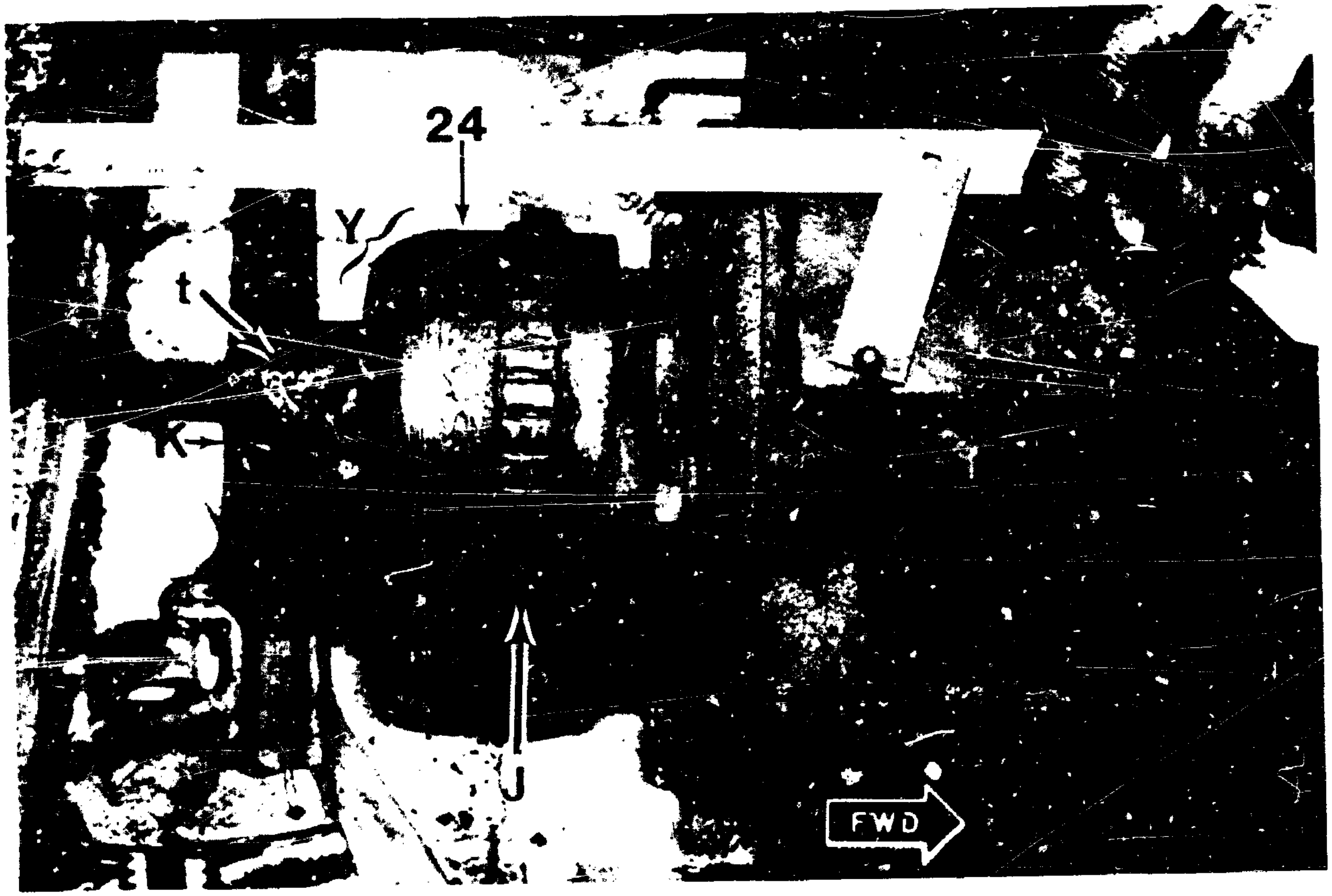

Figure 12.--Pump hub of motor/pump unit 3 (arrow 24 in figure 7) and associated damage. J indicates worn pump gear teeth; K indicates damaged shaft key; t indicates pump shaft damage; and brace Y indicates worn pump hub.

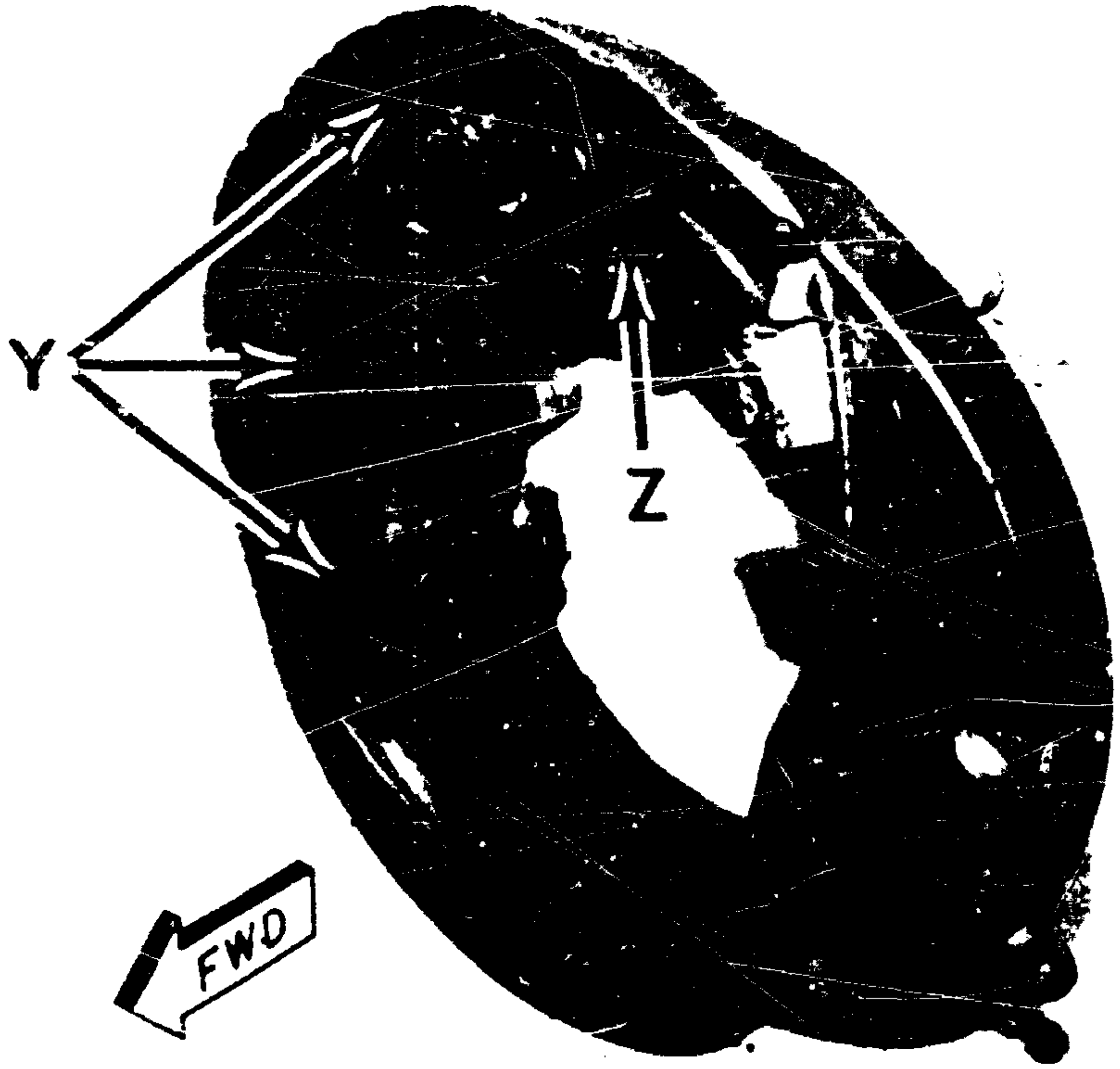

Figure 13.--Disassembled pump shroud of motor/pump unit 3 (arrow 23 in figure 7). Y indicates areas of wear damage and gouge marks; Z indicates area of worn or missing teeth.

Figure 14.--Fractured bearing case of motor/pump unit 3.

Figure 15.--Support brackets (BB in figure 6) for rear of pump unit 3. Arrows indicate missing bolts.

When the bearing case was disassembled from the impeller case, pieces of metal on the bearing case fell off the right and left side. The exposed fracture surfaces on the right side of the case exhibited round globule shaped material that appeared to be solidified from the molten state (see arrows in figure 16). The machined face of one of these fragments was ground, polished, and etched. Metallurgical examination revealed a microstructure consisting of graphite flakes in a matrix of pearlite, which is typical of gray cast iron. No metallurgical anomalies were noted. The examination of the fractured surfaces revealed features consistent with those produced from overstress separation.

The pump is connected to the pump pedestal by four bolts; two on the right side and two on the left side. Both bolts on the left side of the pump were broken; both bolts on the right side were intact. The pump manufacturer specified that the pump mount bolts be made from carbon steel that has a minimum tensile strength of 60 ksi.

Both bolts on the right side were grade 5, according to markings on the heads of the bolts, indicating an equivalent tensile strength of 120 ksi. Post-fire hardness measurements indicated that both of these bolts had a tensile strength of about 77 ksi.

The left rear bolt (as looking forward in figure 6) was separated at the first thread below the hexagonal head (see figure 17). A lock washer was still installed on the bolt head. The remnant of this bolt, a total length of about 18 threads, was found threaded into the pedestal to a depth of about 9 threads. Threads near the top of this remnant (S in figures 17 and 18) were flattened on diametrically opposite sides. The bolt remnant was also bent in the direction of the flattened threads, indicating side loading on the bolt. Secondary cracks were found in the remnant at a location about 7 threads from the top of the remnant. The bolt head, washer, and the top nine threads of the remnant were covered with soot. After electrolytic cleaning, the bolt head, washer, and the top seven threads of the remnant exhibited a copper colored coating. Energy dispersive analysis showed an intense copper spectrum. The bolt was ungraded and had a tensile strength of about 56 ksi, as determined by post-fire hardness measurements.

The hexagonal head of the left forward bolt was not located. The remnant of this bolt (a total length of 18 threads) was found threaded into the pedestal to a depth of 3 threads. These three threads were deformed in a downward direction with circumferential gaping cracks at the base of the crown threads. Threads 6, 7, 8, and 9 (as counted from the bottom of the remnant) were flattened on diametrically opposite sides (brace D in figure 17). Hardness measurements of the remnant indicated a tensile strength of about 50 ksi.

Examination of fracture surfaces (x on figure 17) on both the left rear and forward bolts showed poorly defined features and oxidation from the fire. The fracture surfaces were normal to the longitudinal axes of these two bolts.

Figure 16.--Fractured bearing case of motor/pump unit 3. Arrows point to beads of molten metal.

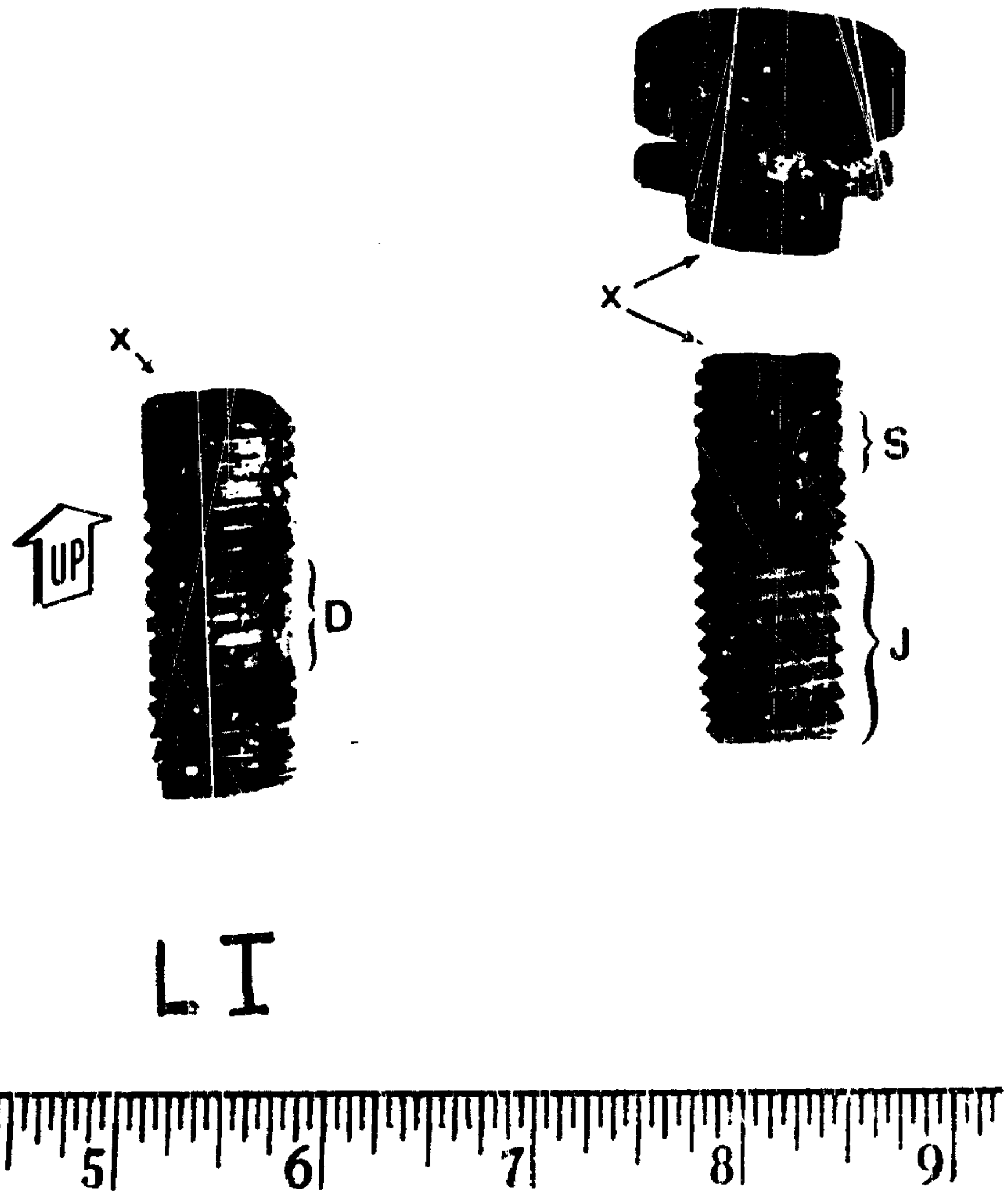

Figure 17.--Fractured left pump bolts of motor/pump unit 3. D and S indicate flattened threads, and x indicates fractured surfaces.

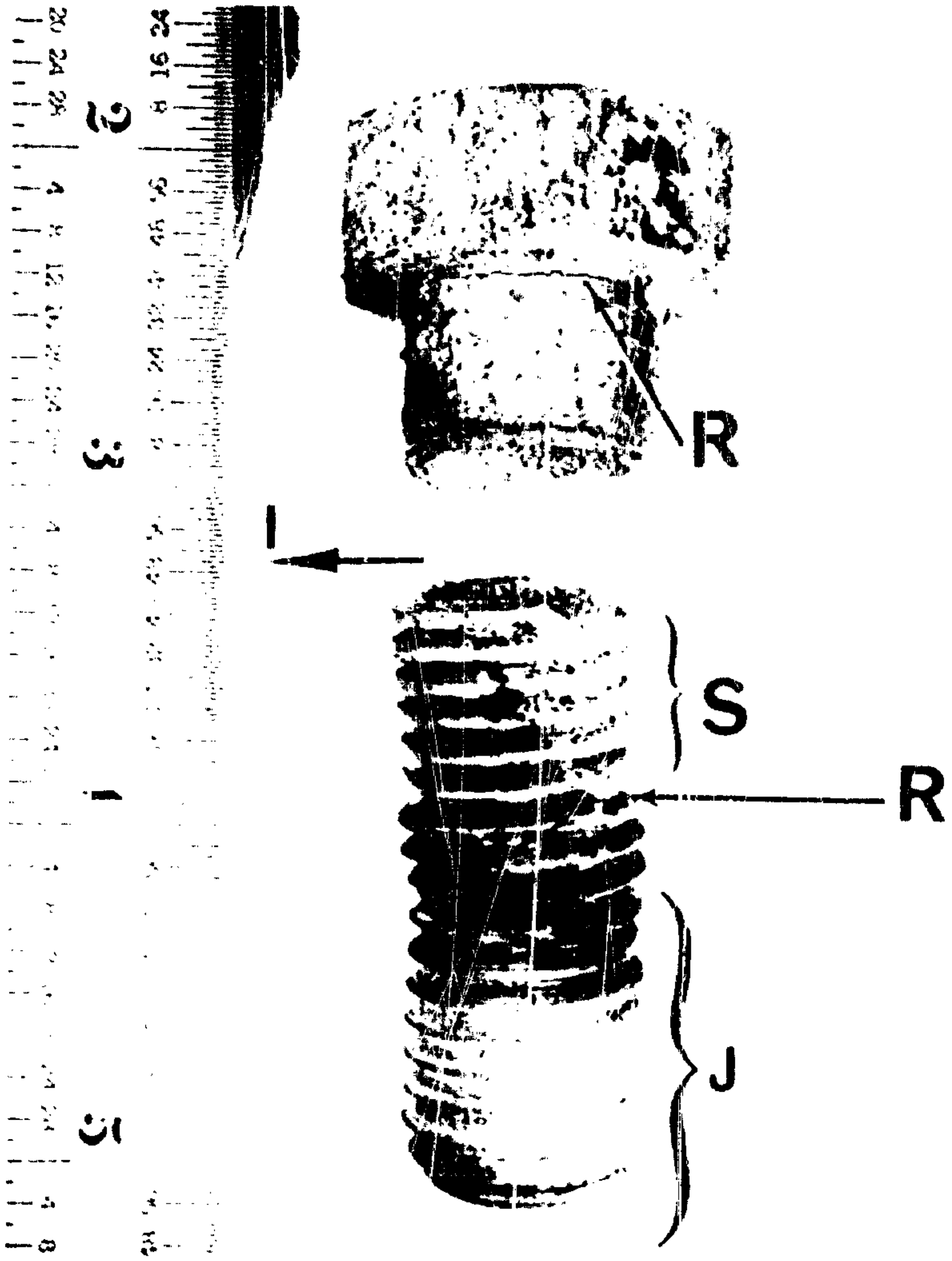

Figure 18.--Fractured pump tolt after electrolytic cleaning. R indicates areas of secondary cracks. S indicates flattened threads.

When pump 3 was disassembled, the surfaces of the pump seal, which prevents fuel from escaping into the atmosphere around the pump, were missing but the "O" rings were present and intact. The pump seal consisted of two mating surfaces: (a) a stationary surface (tungsten carbide, silicon carbide, or some equivalent hard material) held in a steel "gland"; and (b) a carbon rotating disk. The carbon rotating disk is held against the stationary surface with a spring under compression to prevent fuel leaks. A small fuel line (seal flush line) carries fuel from the pump discharge to this seal for lubrication and cooling. Repair records by John Crane, Inc. (see discussion "Fuel Farm Maintenance Records") on pump 3 indicate that the mating surface had been silicon carbide. The gland, which holds the stationary mating surface, was damaged. The gland contained indentation marks on the forward bore surface. The gland exhibited wear damage all around the bore (arrow N in figures 19 and 20). The rotating mechanical sleeve, which holds the carbon rotating disk, exhibited a circumferential worn groove, measuring about 1/32-inch deep, in the area noted by brace Q in figure 20. The location and width of the groove was consistent with the size and position of the worn aft gland bore surface and was also consistent with the rotating seal sleeve having made contact with the stationary gland aft bore surface.

The bearing case was disassembled to examine the bearing and the journals and to determine if the pump shaft was straight. The examination of the bearings and journals revealed that they were undamaged. The pump shaft was bowed about 0.139 inches. The position of the pump shaft was noted before disassembly and using this orientation, the shaft was high in the center between the rear and forward bearings relative to the shaft ends. The oil splash guards in the bearing case were missing. The impeller of the pump was undamaged and there was no evidence of rubbing or unusual wear.

<u>Examination of Other Motor/Pump Units</u>.--At the time motor/pump unit 3 was removed from the containment area, motor/pump unit 4 was also removed to be examined in comparison to motor/pump unit 3. Examination of motor/pump unit 4 revealed that the motor and pump were misaligned. However, all bolts holding the motor and pump in position on the pedestal were intact. One of the bolts holding the pump in position showed damage from extensive shear forces (side loading). The seal on pump 4, which was of a different design than the one on pump 3, was found to be in good condition.

The other four motor/pump units were examined onsite to determine their condition. Examination of motor/pump unit 1 revealed that half of the teeth were missing on the pump part of the coupler gear. Two of the bolts on this coupler were not shoulder bolts as specified by the manufacturer. The coupler gear was installed backward on the motor end of the unit, and the motor was misaligned with respect to the pump. However, no gear damage was noted. The motor and pump on unit 5 were misaligned. The bolts on the pump of unit 6 were loose. The remnants of a fabric were found inside the bearing case on pump 5. The oil deflectors in the pump bearing cases of all units were missing. According to the manufacturer, the oil deflectors were made of neoprene, which would have been destroyed by the fire.

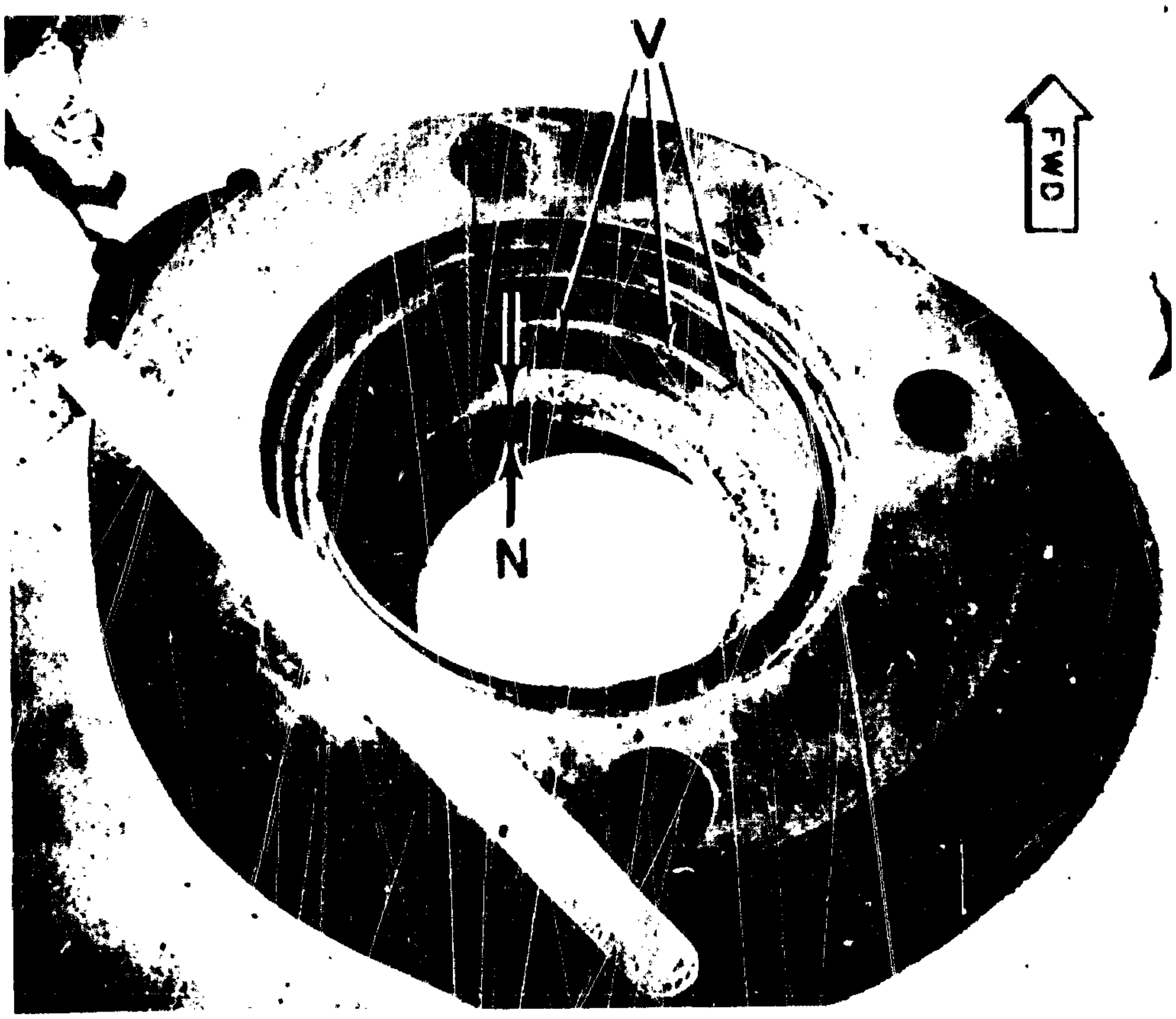

Figure 19.--Gland of pump seal in unit 3 with wear damage (N) around bore and indentation marks (V).

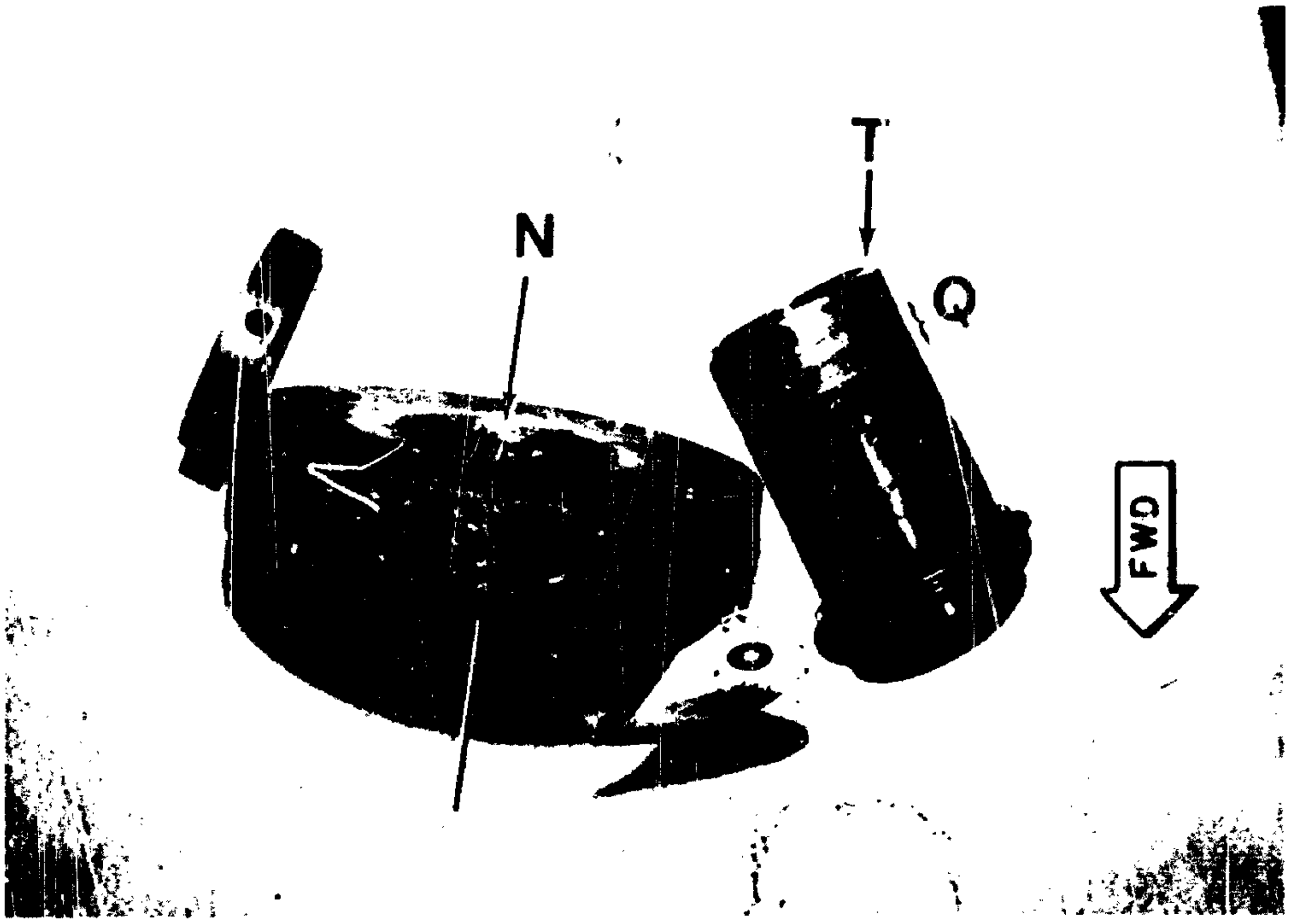

Figure 20.--Mechanical pump seal sleeve of pump unit 3. N indicates damaged gland around the bore, and Q is the area of a worn groove.

Because the bolts in motor/pump unit 3 were fractured and some of the bolts in motor/pump unit 4 showed overstress forces, the bolts from all the motor/pump units were removed and selected bolts were tested for hardness. Some of these bolts had markings on the heads of the bolts indicating that they were grade 5 and others grade 8.2. Most of the bolts had no markings that indicated grade. The tests revealed that none of the bolts with a grade marking had a measured hardness equivalent to the specified tensile strength of the grade. All of the unmarked bolts that were measured for hardness had a hardness value and corresponding tensile strength less than that measured for the graded bolts. The tensile strength of all of the unmarked bolts that were measured was less than 55 ksi. (See appendix E.)

New motor and pump bolts were obtained from the supplier of the motor/pump units and tested for hardness for comparison with the ones that had been removed from the pump area after the fire. (The source of the bolts taken from the fire area could not be determined.) The bolts received from the supplier were unmarked. The motor bolts had an average hardness that corresponded to a tensile strength of about 89 ksi. The tensile strength of the pump bolts was about 115 ksi.

Examination of Debris Found on the Bed Plate of Motor/Pump Unit 3.--Small fragments of material that appeared to be similar to the material used for the stationary part of the seal were found on the bed plate of motor/pump unit 3. These fragments were subjected to energy-dispersive x-ray spectrometry before and after ultrasonic cleaning in acetone. In addition, a fragment of an unused silicon carbide seal was obtained from John Crane, Inc., the company that repaired the seal in pump 3 between April and July, 1989. The energy spectrum from the silicon carbide seal showed a single strong peak of silicon (carbon was not detected). The energy spectrum from the fragments of uncleaned material found on the bed plate also showed a major peak of silicon with smaller peaks from aluminum, titanium, sulfur, calcium, potassium, chloride, and sulfur. After cleaning, the major peak was silicon with minor peaks from aluminum and potassium.

Metallurgical Examination of the Ruptured 6-Inch Supply Pipeline.--A longitudinal rupture about 5 1/2 inches long was found in a section of the 6-inch fuel supply pipeline that was above ground at a location about 25 feet from the inlet piping of motor/pump unit 3. This rupture is identified in figures 8 and 21.

Figure 21.--Ruptured 6-inch supply pipeline (arrow R).

This pipe was reportedly installed in the fuel farm in early 1979. A review of purchase records revealed that a large shipment of 6.625-inch-outside-diameter pipe section with a 0.188-inch wall thickness of either American Institute Petroleum (API) 5LX grade X42 or API 5L grade B specification steel was ordered in early 1979. This pipe was manufactured with a longitudinal seam using electric resistance welding. The measurements of the pipeline in which the rupture occurred corresponded to the measurements of the pipe purchased in 1979.

Isolated areas on the external surface of the fuel supply pipeline were covered with a black coating appearing to resemble fiberglass in a matrix of resin material. The pipe exhibited localized bulging surrounding the rupture, with a maximum diameter of 7.5 inches. The walls along the rupture separation line were reduced and exhibited heavy oxidation. This reduction in pipe wall thickness is characteristic of a ductile overstress separation when the material is hot. Energy-dispersive x-ray spectroscopy analysis of the pipe in an area free of any deformation produced a spectrum that is consistent with the composition of either grade X42 or grade B steel. Further analysis of the seam area revealed an as-manufactured seam typical of an electric resistance weld running through the pipe wall. This seam was flush with the inside and outside walls of the pipe.

Fuel Farm Maintenance Records

Safety Board staff reviewed the contract and supporting documents between United and AMR Combs, dated January 1, 1989. This review indicated that United Airlines, Ogden Allied, and AMR Combs had jointly inspected the fuel farm on December 9, 1988, and that a followup inspection occurred on December 30, 1988.[20] According to the joint inspection documents, 34 discrepancies, many of which were related to fuel system leaks at various valves, were noted during these inspections. The documents also indicated that these discrepancies were corrected by Ogden Allied either before or soon after the contract between United Airlines and AMR Combs was signed.

A discrepancy of particular relevance noted that "hydrant pump motor # 3 has had vibration and noise, sounds like motor bearing is worn out." According to United's records, motor 3 was reconditioned on December 15, 1988, as a result of the discrepancies noted during the December 9 inspections. Reliance Electric Company, a company that specializes in reconditioning motors, was contracted by United Airlines to perform the work. Reliance Electric welded and machined the front bearing journal, repaired the end brackets, and replaced the bearings. Based on records obtained from Reliance, after the repair work was completed, the motor was tested, balanced, and reinstalled on about December 23, 1988. Other United records indicated that the mechanical seal on pump 3 was relapped in September 1988.

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[20] The joint inspection was for the purpose of transitioning from one facility operator to the other.

A review of AMR Combs' fuel system maintenance and operations log indicated that fuel pump 3 was removed on April 4, 1989, and taken to Paramount Equipment Corporation (Paramount) for overhaul. Paramount records indicated that the mechanical seal was replaced by John Crane, Inc., whose documents also indicated that such work was performed. Once this work was completed, AMR Combs personnel placed the pump on its pedestal on July 4, 1989. AMR Combs log indicated that motor/pump unit 3 was aligned and placed back in service on July 6, 1989, by Paramount Equipment Corporation. AMR Combs maintenance staff observed the alignment process as a training exercise.

Fuel Delivery Records

A review of Chase Transportation Company delivery records indicated that on the morning of November 25, 1990, 945 barrels of fuel were delivered to Texaco Aviation at fuel farm D, located about 1/2 mile southwest of the fuel farm where the fire occurred. The rate of delivery from Chase was about 760 barrels per hour. The computer printout of this delivery indicated that the delivery was completed at 0929 central standard time.[21]

The next delivery through the Chase 6-inch pipeline was to Continental's tank 7 at the fuel farm where the fire occurred. At 0920 mst, power to the pumping system at Aurora shut down; 673 barrels had been delivered to tank 7 before the system shut down. According to the Chase terminal foreman, the delivery system shut down as a result of a disruption in communications between the remote transmitter unit, located in the United control building (at the location of the fire), and the pump delivery system at Chase Transportation Company. The delivery system was designed to automatically restart when communications were reestablished.

The computer printout records indicated that at the time the communication interruption occurred during the filling of Continental's tank 7, the pipeline pressure at Aurora was 237 psig and at the fuel farm about 23 psig.

The computer printout indicated that the next delivery was terminated at 0925 mst, after an "estimated" 4 barrels (168 gallons) had been delivered.

At some time, a power failure was noted at the enunciator panel at Chase Transportation Company; however, the time the power failure occurred was not recorded.

Sump Tank Measurements

An underground storage (sump) tank with a 4,000-gallon capacity was located beneath the containment area in front of tank 4. Relatively small

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[21] The computer printout is based on central standard time; the local time was 0829 mst.

amounts of fuel and oily water generated from various sources were dumped or drained into this sump tank. These sources include fuel test samples taken from fuel storage tanks and filters; fuel test samples generated from transport truck deliveries; fuel generated from routine equipment maintenance functions at fuel storage and ramp facilities; and fuel generated to relieve pressure on the Chase supply pipeline. In addition to these sources, fuel that leaked from the pump assemblies was captured in the channel on the motor/pump platform beds (as illustrated in figure 6) and was drained into the sump tank.

According to AMR Combs, measurements were taken daily to determine the amount of fuel and water in the sump tank. The measurements were taken by inserting a dipstick into the sump tank. By referring to a chart, an employee could convert the inches recorded on the dipstick to gallons of fuel. A maximum of 84 inches was shown on the chart.

Records for the month of November were reviewed to determine if the rate at which the sump tank was being filled had increased during the few days before the fire started. The review revealed no significant increase in the rate. Relatively uniform increases were noted daily from November 9 to November 23. The measurement on November 24 indicated a 4-inch decrease from the previous day; however, no fuel was removed on November 23. The sump tank measurements for November 1990 are listed in appendix C.

Fuel Farm Employees

Work Schedules and Employment History.--Work schedules were arranged so that employees were on duty at the AMR Combs facility, which includes the fuel farm, 24 hours a day. At the time of the fire, a fuel supervisor and a fuel technician were scheduled to be on duty. The technician on duty began his shift at 0600; his shift ended at 1430. This fuel technician had been employed by AMR Combs for about 10 years, the last 3 of which were in the fuels department.

The fuel supervisor's shift for November 25, 1990, was to have started at 0900 and to have ended at 1730; however, he was en route to work at the time of the fire. This employee was hired by AMR Combs on January 1, 1989, and became a supervisor that year. He had previously worked as a fuel technician for Ogden Allied.

The night shift for November 24, 1990, included two fuel technicians--one a recent hire and one an experienced employee. The experienced employee's shift was from 2200 on November 24 to 0630 on November 25. The new employee's shift began at 1800 on November 24, and ended at 0230 on November 25. This employee had been hired by AMR Combs on November 21, 1989, and was trained to refuel aircraft. He was transferred to duties at the fuel farm on November 1, 1990.

Training and Duties.--In response to a Safety Board staff request to AMR Combs for a copy of the training program used by the company, AMR Combs personnel provided a "Training and Quality Assurance Manual--Fuel Farm

Operations," another fueling manual, and copies of several employees' training tests. A review of the training materials and the questions on the training tests indicated that most of the material was related to (1) fuel quality (assuring that the fuel was free of impurities), (2) the proper fuels for various aircraft powerplants (aviation gasoline versus jet fuel), and (3) the methods for fueling different types of aircraft. Training did address the safe handling of various fuels in that employees were questioned about flash points, freezing points, types of fire extinguishing agents to be used on different combustibles, ignition sources (including static electricity), and fuel spills. No specific information could be found in the training materials that addressed surveillance and inspection of the fuel pumping system.

In addition, the Training and Quality Assurance Manual lists the items that were to be checked daily, monthly, semiannually, and annually. According to the manual, security, fire, and safety deficiencies were items to be checked for daily. Employees also were to check for fuel leaks daily and report any leaks immediately. The employee performing the daily inspections was required to initial the checklist daily. Both manuals state that "daily checks and inspections should be made at the beginning of each work day including weekends and holidays."

Records obtained from AMR Combs indicated that the recently hired technician, who worked the night shift prior to the time of the fire, had initialed the required daily inspection form during the month of November indicating that all items checked were satisfactory. In fact, items, including pumping systems, had been checked off as satisfactory and the form was initialed through November 26, 1990. (The fire occurred on November 25, 1990.) According to this employee, he would not recognize a problem with the pumping equipment, if there was one, and had not been trained to detect problems with the pumping equipment. He stated that his main responsibility was to determine fuel inventory.

The fuel technician who began his shift at 0600 on the morning of the accident stated that he arrived at the fuel farm about 0645 but did not get out of his truck. He stated that he was not authorized to maintain pumping equipment. He departed the fuel farm shortly before 0700 and went to concourse A and B of the airport terminal where he spent most of his time, as his main responsibility was involved with refueling aircraft.

Discussions with other AMR Combs, Ogden Allied, and United Airlines staff about pumping equipment inspections indicated that inspections included observations of fuel leaks, excessive vibrations (determined by placing a hand on the pump and motor) and changes in the sound of the pumping system. According to the AMR Combs fuel manager, the fuel farm inspections were normally performed during the night shift, as was done during November 1990. However, according to statements made by the fuel farm manager later during the investigation, inspections were performed on each of the three daily shifts. After each shift, the status of the pump system was passed on to the next shift, and the formal signoff was performed by the night shift employee.

Federal Regulations Covering Fuel Storage

Title 14 of the Code of Federal Regulations (CFR) Part 139.321(b) states that,

> Each certificate holder [holder of an airport operating certificate, in this case the city/county of Denver] shall establish and maintain standards acceptable to the Administrator [FAA] for protection against fire and explosion in storing, dispensing, and otherwise handling fuel, lubricants and oxygen on the airport property.

Further, paragraph (d) states that,

> Each certificate holder shall inspect the physical facilities of each airport tenant fueling agent at least once every 3 months for compliance with paragraph (b) of this section and maintain a record of that inspection for at least 12 months.

However, paragraph (h) states that, "The certificate holder need not require an air carrier operating under Part 121 or Part 135 of this chapter to comply with the standards required in this section."

Safety Board staff held extensive discussions with FAA staff to determine (1) the reason for the exemption found at Part 139.321(h) for Part 121 and Part 135 carriers who lease airport property from airport certificate holders and (2) which office within FAA is responsible for inspecting fuel farms operated by Part 121 and Part 135 carriers. Safety Board staff was initially informed by FAA staff that regulations for inspection of fuel farms comparable to those found at Part 139.321 were addressed in Part 121 and Part 135.

Regulations for carriers operating under Part 121 or Part 135 were reviewed to determine whether these regulations contained comparable requirements to that of Part 139.321. Comparable regulations governing the storage of fuel could not be located. Part 121.105 states that,

> Each domestic and flag air carrier must show that competent personnel and adequate facilities and equipment (including spare parts, supplies, and materials) are available at such points along the air carrier's route as are necessary for the proper servicing, maintenance, and preventive maintenance of airplanes and auxiliary equipment.

Part 121.135(b)(18) requires the carrier to develop "procedures for refueling aircraft, eliminating fuel contamination, protection from fire (including electrostatic protection), and supervising and protecting passengers during refueling." Identical language is found at Part 135.23(j).

Based on the review of these regulations, further discussions were held with FAA staff. Safety Board staff was then informed by FAA's Manager of

Airport Safety and Operations Division (a division within the Office of Airport Safety and Standards), that fire standards, training, and inspection for carriers operating under Part 121 and Part 135 are not addressed in Parts 121 and 135, but are required in Order 5280.5A, "Airport Certification Program Handbook." As stated in this document, the order is

> ...designed to provide FAA personnel with the necessary policy guidance and standard procedures for the day-to-day conduct of the Airport Certification Program, to include the inspection, certification, and surveillance of airports and the compliance and enforcement activities required by 14 CFR Part 139, Certification and Operations--Land Airports Serving Certain Air Carriers.

Fuel handling, fire safety, firefighting, and inspections are covered in this Order. The Order states:

> ...at the last revision of Part 139 it was determined that Sections 121.133 and 135.21 required all air carriers to prepare and keep current a manual containing maintenance information and instructions for the use and guidance of ground operations personnel in conducting their operations. The manual must contain procedures for refueling aircraft, eliminating fuel contamination, protection from fire, and supervising and protecting passengers during refueling. For this reason, the Part 139 certificate holder was relieved of the requirements to exercise oversight of the air carrier's refueling operations. This assumes that the air carrier fuels itself with its own employee or has a contract fueler. If the contract fueler fuels others in addition to the air carrier, the certificate holder is required to inspect that operation in accordance with Section 139.321(d).

The Order further states:

> ...if an airport certification inspector observes an airline or airline fueling contractor performing fueling in an unsafe or questionable manner, it should be brought to the attention of the appropriate airport representative and reported to the FAA Flight Standards Office for followup investigation. The provisions in Part 139.321(h) should not preclude the certification inspector from being vigilant to unsafe or questionable fueling practices that go unreported to the appropriate action office.

Section 321 of the Airport Certification Manual for Stapleton International Airport addresses the handling and storing of hazardous substances and materials. With respect to inspection of facilities, the manual states:

> The physical facilities of each airport tenant fueling agent will be inspected at least once every 3 months for compliance with standards and records of these inspections will be kept for at least 12 months. When a vehicle is inspected and is in compliance

with standards, an inspection sticker is issued which is valid for 3 months.

With respect to training of fueling personnel, the manual states:

> SIA [Stapleton International Airport] ARFF personnel will assure that at least one supervisor with each fueling agent has completed an aviation fuel training course in fire safety. Additionally, all other employees who fuel aircraft, accept fuel shipments, or otherwise handle fuel shall receive at least on-the-job training in fire safety from the trained supervisor. Each tenant fueling agent will provide ARFF personnel certification, once a year, that this training has been completed.

The manual also addresses recordkeeping, stating:

> A computer program has been designed specifically to handle all information gathered by ARFF inspections. The program has cross reference capability concerning discrepancies, training, etc. The computer and the program will be used as a management tool to assure compliance with Part 139 requirements concerning handling and storing of hazardous substances and materials.

As a result of the fuel farm fire at Stapleton International Airport, the Office of Airport Safety and Standards issued Program Policy and Guidance #38, "Inspection of Fuel Farms Serving Part 121 or Part 135 Air Carriers" on January 22, 1991. (See Appendix F.) This policy instructs certification inspectors (FAA inspectors within the Office of Airport Safety and Standards) to notify the Flight Standards District Office Managers of an upcoming inspection. The purpose of the notification is to provide the aviation safety inspectors with the opportunity to perform an inspection concurrently with the certification inspector or to inform the certification inspector of problems or situations that should be brought to the attention of airport management. The policy document states, "Consistent with the language in Part 139, the certificate holder will not be violated, if the ACM [airport certification manual] specifically excludes air carrier fueling facilities from airport oversight."

Staff from the Office of Airport Safety and Standards indicated that they have interpreted Policy #38 as giving them the responsibility to inspect all airport fuel storage facilities whether or not they fall under Part 121 or Part 135 operations. One inspector stated, however, that "we clearly do not have the authority to do so." Staff from the Office of Flight Standards stated that "we inspect the fuel from the point at which it comes from out of the ground (pipe connection at the ramp) or from a fueling truck."

In a letter to the FAA, dated June 18, 1991, the Safety Board requested specific information to clarify who within FAA was responsible for the inspection of fuel farms that are on airport property in light of the exemption provided for Part 121 and Part 135 carriers in Part 139.321(h). The response was received on August 9, 1991, but did not clarify or state why the Office of Airport Safety and Standards is conducting the inspections when the Office of Flight Standards is apparently responsible for the inspections.

As a result of its 1984 safety study, "Airport Certification and Operations" (NTSB/SS-84-02), the Safety Board issued several safety recommendations to the FAA, four of which addressed fire safety of fuel storage facilities and fuel handling at airports. Safety Recommendation A-84-29 specifically urged the FAA to:

> Require certificated airports to include fuel storage and dispensing facilities in the self-inspection program prescribed in 14 CFR 139.57 and 139.91, and specify the items, including tank overfill warning devices, which must be checked and approved by airport inspection staff.

The FAA concurred in the recommendation and based on revisions made to the self-inspection program in May 1983, the recommendation was classified as "Closed--Acceptable Action" on March 29, 1990.[22]

At Stapleton International Airport, the fire department of the city and county of Denver was responsible for the self-inspection program; Safety Board staff requested copies of the records for the quarterly self-inspections. Only two inspection records were provided--one dated July 2, 1990, and the other dated October 18, 1990. The inspection dated July 2, 1990, cited the following items: (1) fuel leak at tank 10 fuel pump; (2) more "no smoking" signs needed at the control pit area; (3) emergency shutoff sign needed; (4) fire extinguishers needed at control pit, and at tanks 10 and 17; (5) ground reel needed at tank 17; (6) light bulb needs to be replaced at tank 17; and (7) fire department telephone numbers need to be posted. (Tank 17 was located in another area of the fuel farm, remote from where the fire occurred.) The quarterly self-inspection dated October 18, 1990, cited the need for posting a sign for the main electrical circuit breaker on tank 10, and the need for fire extinguishers.

Records on Stapleton International Airport's annual certification inspections were obtained from the Office of Airport Safety and Standards within the FAA.[23] The "Annual Certification Inspection Letter of Correction" from the FAA, dated June 14 through 22, 1990, noted the following three relevant items regarding Part 139.321 regulations:

> 139.321(b): Certificate holder did not maintain its fueling standards for protecting against fire and explosions in storing and dispensing of fuel on the airport.

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[22] The content and status of the other three recommendations issued in conjunction with the 1984 safety study are discussed in appendix D.

[23] As noted previously, personnel within the Office of Airport Safety and Standards have expressed concern about their legal authority to conduct these inspections; notwithstanding this concern, an annual certification inspection was performed.

139.321(d): Certificate holder did not inspect the physical facilities of each fueling tenant at least every 3 months.

139.321(e): Certificate holder did not obtain certificate once a year from each fueling agent at the airport.

On July 31, 1990, the Denver fire chief responded to the FAA's letter regarding the annual certification inspection noting that "the required quarterly inspections [as mandated by Part 139.321(d)] posed an impossible challenge." The fire chief further noted that following the annual inspection "a program of scheduled inspections was initiated, with inspections for the current calendar quarter completed."

Nine months after the fire, Safety Board staff contacted the Denver fire department inspector to determine the status of quarterly inspections. As a result of this inquiry, another fueling facility at Stapleton operated by AMR Combs was inspected by the Denver fire department inspector. According to information received from the inspector, four nuts without lock washers were loose on the platform holding a motor/pump in position. (The motor/pump unit was examined closely because unusual sounds from excessive vibrations had called attention to the unit.) According to the inspector, inspection and surveillance of the equipment by AMR Combs was still being performed at night, no training was being provided, and no written instructions existed for carrying out the inspection and surveillance activities. Further, the computer program identified in the ACM designed to handle all information gathered as a result of quarterly inspections, including discrepancies and training, to assure compliance with Part 139 was not being used. According to the inspector, he had insufficient time and training to use the program.

Training for Airport Certificate Holder's Inspector

The fire department inspector who performed the quarterly inspections for the certificate holder attended a 1-week course in 1988 on the requirements of Part 139.321. (According to the inspector, he personally paid for the course.) He also obtained an underground storage tank inspector's license as a result of a 3-week course sponsored by the U.S. Environmental Protection Agency. The training was not required by the certificate holder. Part 139.303 requires only that the certificate holder maintain sufficient qualified personnel to comply with the requirements of its airport certification manual.

Immediately after the fire, the inspector was given additional resources for facility inspections, including two temporary employees; but 9 months later, one of the temporary employees left and the other was scheduled to leave in September 1991. In a telephone conversation with the certificate holder, however, Safety Board staff was informed that additional staff would be hired to perform the quarterly inspections.

Aircraft Refueling Operations

On the morning of November 25, 1990, 24 aircraft departed United's gates at the airport terminal between 0840 and 0935. Each had received fuel from the fuel farm hydrant system. United commonly refers to this activity as the "9 o'clock fueling bank," which means that all fueling activities were to be completed on this block of aircraft before 0900. According to United, although records are not maintained reflecting the exact time an aircraft is refueled, fueling of the 0900 bank routinely begins at 0730 and is completed each day between 0850 and 0910. Fueling records and interviews with United fueling personnel reflect that hydrant fuel pressure was available for all 24 aircraft that were refueled from the hydrant system without loss of system pressure.

During the refueling of the 0900 bank of aircraft, 14 hydrant refueling trucks were in use. Records reflect that between about 0755 and 0840, all 24 aircraft from the 0900 bank of departures were on the ground and available for refueling at the same time. About 0730, four of the drivers received assignments to refuel one aircraft each. The other 10 drivers received assignments to refuel two aircraft each. Although records do not indicate exactly when each aircraft was refueled, it is possible that as many as nine aircraft could have been drawing fuel from the hydrant system at any one time between 0755 and 0840. By 0903, all but three of United's aircraft had been pushed away from the gate. If refueling operations continued past 0900, only three aircraft could have been refueling during that time.

According to United, refueling activities routinely began on the next group of departures or refueling bank at 0930. From the time a refueler received an assignment, proceeded to the aircraft, and started pumping, 10 to 15 minutes would normally elapse. Flight 314 was to be the first departure out of the second group of aircraft and was due to depart at 1029. Shortly after arrival at the aircraft, the fueler reported that fuel hydrant system pressure was not available.

Pressure to the United hydrant system was monitored at the Stapleton International Airport Terminal in the United Airlines control center. Controllers recalled that the pressure light went out between 0930 and 0945, indicating that the hydrant system was lost; most controllers believed that it was very close to 0945 when this occurred.

ANALYSIS

As a result of the fuel farm fire at Stapleton International Airport, United Airlines' flight operations were disrupted because of the lack of fuel to prepare aircraft for flight. Airport facilities, other than the fuel farm, were not affected by the fire. The duration and intensity of the fire, however, raised concerns about the ability of airport and local firefighters to respond to a fuel fire of this magnitude. The origin of the fire also raised concerns about the oversight and inspection of fuel farm pumping operations. The Safety Board's investigation, therefore, focused on the origin, duration, and intensity of the fire; the types of valves used on the equipment at the fuel farm; the location of the control building; the inspection and oversight of fuel farm equipment; Federal regulations regarding fuel storage facilities and Federal inspection of these facilities on airport property; and emergency response plans for responding to fuel farm fires.

Fire Origin

Based on witness reports, there is agreement as to the general location of the fire's origin. Shortly after 0900, witnesses observed first "exhaust" and then smoke and fire in front of United's tanks 3 and 4 at the fuel farm operated by United and Continental. Firefighters arriving at the fuel farm shortly after 0925 also observed fire near tanks 3 and 4 in a containment area (pond 1) that contained pipes, pumps, valves, and a control building. Later reports by firefighters described fuel leaking and burning under pressure and coming from an area between motor/pump units 3 and 4. All reports during the early stages of the fire suggest that the fire originated in the general vicinity of motor/pump units 3 and 4.

Based on the observations that fuel was leaking and burning in the general vicinity of tanks 3 and 4, the investigation focused on equipment that could have been the source of the leaking fuel and the possible sources of ignition. The six United motor/pump units located in the general vicinity of tanks 2, 3, and 4 were possible sources of fuel leaks. Minor fuel drips or leaks could be expected to occur on these units during routine maintenance. Also, when seals became worn, minor fuel drips or leaks could be expected. The units were situated on pedestals that incorporated a channel for collecting such fuel leaks, which were drained into a sump tank. Under such conditions, Jet-A fuel leaks would not be expected to be of sufficient size to result in a combustible mixture close to an ignition source, such as an electric motor.

Motor/pump unit 4 was the designated lead pump for the month of November 1990, to supply fuel to United's aircraft at its airport concourse. As demand dictated, the other pumps would be activated, beginning with pump 3. The recorder chart that would indicate the number of pumps in operation before the fire started and at the time of ignition was destroyed by the fire. However, based on United's refueling activity for the morning of

November 25, United maintenance personnel concluded that at least three pumps, if not more, would have been operating during the refueling of the bank of aircraft that were readied for flight between 0730 and 0900. The Safety Board concludes that based on the sequence in which pumps were to be activated, motor/pump unit 3 would have been operating at some time during that period.

Although the duration and intensity of the fire made it difficult to distinguish between pre-fire equipment damage and equipment damage resulting from the fire, inspection of motor/pump unit 3 revealed obvious post-fire damage and pre-fire anomalies. Other equipment, including valves and flanges, did not exhibit damage typical of catastrophic failure before the fire.

The obvious pre-fire anomalies on motor/pump unit 3 included: (1) all four motor mounting bolts were broken, (2) the rear of the motor had shifted to the left by 2.6 inches, which resulted in a misalignment between the motor and pump shaft of 3.6 degrees, (3) the coupler and coupler shield were damaged, (4) the bearing housing cradle was fractured, (5) two pump mounting bolts were broken, and (6) two bolts were missing from the rear of the bearing housing support. The investigation examined the pre-fire anomalies in detail in an effort to reconstruct the sequence of events that led to the failure of pump unit 3 and the subsequent leaking of fuel.

The imprint marks around the bolt holes on the motor pedestal and the deformation of the bolt heads in an upward direction indicate that vertical vibration of the motor occurred over a period of time that resulted in the bolt heads leaving imprints in the motor foot. These vibrations also led to overstress conditions on the bolts which resulted in their failure. The investigation considered various conditions that could have caused the motor to vibrate in such a manner, including: (1) the motor was not balanced at the time of overhaul, (2) the motor and pump shaft were bent before the fire, (3) the motor was not properly aligned with respect to the pump when installed in July 1989, (4) the motor and pump bolts were defective (below the minimum tensile strength) when installed, and (5) the bolts securing the motor to the pedestal had not been properly tightened or had not been tightened with lock washers after the unit was aligned and balanced in July 1989.

Maintenance records indicated that motor 3 was reconditioned in December 1988, and that after the repair work was completed, the motor was tested, properly balanced with vibration measurements taken, and reinstalled. Further, post-fire disassembly of the motor indicated that the bearings and journals were in good condition. Consequently, the Board discounts the possibility that the motor was unbalanced or defective prior to the fire and that an unbalanced motor caused the vibration that led to the failure of the bolts.

The motor shaft was bowed about 0.240 inches. The motor's design clearance between the rotor and stator is about 0.035 inches, which is too small for the motor to have operated with a shaft curvature of 0.240 inches without causing damage to the rotor, the stator, or both. Further, no damage from rotation with insufficient clearance was noted within the motor. The same direction of curvature was noted in the pump's shaft and the pump also showed no internal rotation damage. Consequently, the curvature in both shafts occurred after rotation had ceased and was the result of heat from the fire. Therefore, the motor shaft curvature was not the cause of excessive motor vibration before the fire.

Because motor/pump unit 3 operated for about 1 1/2 years before the failure, gross misalignment of the motor and pump at the time of installation in July 1989 was not considered a cause of motor vibration.

Microhardness measurements of graded motor and pump bolts involved in the fire indicated that all were below the 120 ksi minimum tensile strength required for that grade of bolt. Further, microhardness measurements showed also that all the ungraded bolts had consistently lower tensile strengths than the graded bolts. The use of multiple grade bolts and ungraded bolts indicates various sources for the bolts, and based on maintenance records, they were installed at different times. Consequently, it is not likely that all bolts from various sources and installed at different times would have been defective (below the minimum tensile strength). The Safety Board believes that annealing of the bolts likely occurred as a result of the duration and intensity of the fire. The annealing of the bolts would account for the post-fire lowered tensile strength and the microstructure of pearlite and ferrite rather than tempered martensite also observed after the fire. Further, the bolt heads left well-defined imprint marks in the motor pedestal indicating that the bolts did not fracture early in the vibration sequence, which would be the case if they were of significantly less tensile strength than required. Consequently, the Safety Board believes that the failure of the bolts was not the result of a significantly lower than required tensile strength when installed.

Based on the imprint marks in the motor foot, it could only be conclusively determined that a lock washer was used on the left rear bolt. Based on the imprints on the other three bolt holes, it could not be definitively determined if lock washers were used. However, the hexagonal imprint at the right rear bolt hole on the motor foot suggests that a lock washer was not installed or had broken and come out early from vibrations before impressions of the bolt head were made in the foot. Furthermore, it could not be determined if the bolts were adequately torqued. Regardless of whether the bolts were torqued, forces generated during normal start-up of the motor and acceptable vibration levels during operation could have led to the bolts vibrating loose and eventually "backing out" of the holes. If lock washers were not used or the bolts were not torqued, this process would have been accelerated. Therefore, the Safety Board concludes that as the motor gradually loosened on its pedestal and the looseness went undetected, vibrations increased and caused overstress conditions on the bolts to the point of failure. Metallurgical analysis of the bolt fractures is consistent with this mode of failure.

Operation of the motor, while it was loose and no longer bolted down, resulted in a shifting of the motor with respect to the pump. Post-fire examination indicated that the motor had shifted about 2.6 inches to the left, as viewed from the rear of the unit. The facts that (1) metal from the coupler was smeared (welded) onto the pump shaft, (2) the coupler gear on the pump shaft had moved forward, and (3) the key in the keyway of the pump shaft was damaged indicate that the motor was driving the pump or attempting to drive the pump after serious misalignment had occurred between the pump and motor and that the coupler gear became hot enough to smear the metal. The Safety Board concludes, therefore, that this shifting or angular misalignment resulted in increased vibrations and increased friction that eventually destroyed the coupler.

The investigation revealed that bolts were missing from the brackets supporting the pump bearing case. Because there was little evidence of bolt wear marks on the brackets, it appears likely that the bolts were not installed when the pump was reinstalled or that they were not tightened sufficiently, became loose because of vibration, and eventually fell out during pumping operations.

Without support (as a result of the missing or insufficiently torqued bolts) at the rear of the bearing case, the angular misalignment between the motor and the pump and consequent vibrations would have caused lateral forces on the forward end of the bearing case where it attached to the impeller case. These forces most likely caused the pump shaft to "orbit" about the shaft center line creating lateral and vertical loading. Two fractured pump bolts and the flattened threads on the pump bolts are evidence that excessive lateral loading was present. Based on the pump manufacturer respresentative's statement that he had never experienced a pump failure in which the sealing surfaces had completely disappeared, severe vibrations must have occurred to completely destroy these surfaces. The Safety Board concludes that lateral and vertical loading caused by the pump shaft orbiting about the shaft center line ultimately fractured the pump bearing case and destroyed the pump sealing surfaces.

The stationary part of the seal was silicon carbide, which is very hard, but brittle and easily fractured. Damage to the bore surface of the steel gland that held the silicon carbide indicates that the silicon carbide was ground up and in the process the gland was damaged. Ground-up silicon carbide parts most likely were forced out of the gland onto the bed plate and washed away by the fuel.

The destruction of these pump sealing surfaces would result in a fuel leak, the size of which would depend on the tank head pressure (the height of the fuel in the tanks). In addition, the fracture of the pump case would increase the rate of the leak. Because these tanks had been filled on the morning of the fire, a sizeable fuel leak of 2 to 3 gallons per minute estimated by the manufacturer, would have resulted, accounting for the first arriving firefighters' observations of fuel fire "tentacles" of 8 to 10 feet in length.

Several ignition sources were in the immediate area of the leaking fuel, including the overheated coupler and the motors on units 3 and 4. The metal smearing and deformation indicates that the coupler and pump shaft surfaces reached temperatures of at least 1,000 $^{\circ}F$, the result of the friction from misalignment between the motor and pump. The "exhaust" reported by an early witness probably was vaporized Jet-A fuel or smoke from the fuel hitting the hot coupler or motor. The fins on the top forward end of the motor were burned off at an angle that is consistent with jets of flaming fuel impinging on the motor end cap. The motor end cap, where the fins are located, is cast iron, which melts at about 3,000 °F; the damage indicated that flames similar to a torch impinged on this area. The burn angle of these fins is consistent with fuel under pressure coming from the pump seal area. Motor 3 was the only motor that exhibited this type of fire damage. Both the hot coupler and the motor would have ignited and reignited the fuel until either the coupler cooled down or electrical power to the motor was terminated. However, it could not be determined conclusively whether the coupler or the motor was the initial ignition source.

The damage to the motor and pump, particularly the imprint marks around the bolt holes in the motor pedestal, suggests that the failure of the motor/pump unit 3 occurred over a period of time and not instantaneously. Fuel could have been leaking slowly from pump 3 for a period of time before the complete destruction of the sealing surfaces, which resulted in fuel being sprayed from the pump. In an effort to determine more precisely the period of time during which the failure occurred and if fuel had been leaking for some time before the fire, dipstick records on sump tank 5 were reviewed. The records, which indicate the amount of fuel in the underground sump tank, showed that for about 2 weeks before the fire, there was a uniform increase of between 1.5 and 3 inches of fuel per day in the sump tank. However, fuel from a pressure relief valve in the Chase supply pipeline also emptied into this sump tank. Consequently, it could not be determined whether fuel from this pressure relief valve or leaks from pump 3 were filling the sump tank. Further, the records indicated that there may have been some errors made in the dipstick measurements or the recording of the measurements. For example, the measurement for November 24, 1990, showed a 4-inch decrease over the previous day's reading, even though no fuel was removed from the sump tank. Consequently, the sump tank filling rate provided no insight into the period of time that fuel may have been leaking from pump 3 and, thus, the period of time that the failure of the motor/pump unit 3 may have been occurring.

In summary, although the damage indicates that the failure of motor/pump unit 3 occurred over a period of time, probably days and possibly weeks, the precise time period could not be determined.

The post-fire examination of motor/pump units 1 and 5 indicated that the motor and pumps in these units were also misaligned. However, there were no broken or missing bolts in either the pumps or motors. Consequently, the misalignment was determined to have been the result of warping of the bed plate from the intense heat of the fire.

Duration and Intensity of Fire

Fuel leaking under pressure continued to feed the fire, and, as a result, the fire quickly intensified. The investigation examined the possible sources of the pressurized fuel leaks.

Computer records from Chase Transportation Company indicated that the fuel delivery on November 25, 1990, from its Aurora facility was terminated at 0925. The termination of pumping from Aurora was the result of a communication disruption, which suggests that the fire at the fuel farm damaged part of the communication system that controlled the pump at Aurora. Regardless of the reason for the disruption, the termination of the pumping operation from Aurora indicates that fuel was not being supplied to the fire by the pump in Aurora.

However, when the communication interruption occurred, the pump stopped and a valve closed at the discharge side of the pump in Aurora, maintaining the pressure on the pipeline at about 220 psig. The motor-operated supply valve at the fuel farm that directed fuel to Continental's tank 7 remained open because of the communication interruption. The only other valve at the fuel farm at Denver that would isolate the 6-inch supply pipeline from the Aurora facility automatically is the back pressure valve that closes only when the pressure on the line falls below a preset value of 25 psig. Excessive heat and pressure in the line caused the pipeline to rupture and was the source of burning fuel spraying into the air, which continued until pressure in the line was relieved. Consequently, until the foreman on duty at the Aurora facility arrived at the fuel farm and at about 1015 manually closed a valve where the pipeline enters the fuel farm, fuel under pressure in the 4.5 mile section of pipeline continued to feed the fire. Also, because the manually operated valve to tank 7 was not closed until 1030, fuel from tank 7 would have provided fuel to the fire through the rupture in the 6-inch pipeline.

If the United pumps continued to operate after the fire started, pumping fuel could have continued to feed the fire. The time the pumping system at the fuel farm lost electrical power could not be established with certainty. Because the electrical controls for the pumping system were housed in the containment area, the fire destroyed the records that could have indicated when pressure to the United ramp was lost and, consequently, when the pumps stopped operating. Based on discussions with the Public Service Company of Colorado and a clock located in the control building after the fire, it appears that power to the farm was terminated about 1020. United's records indicate that pressure for refueling aircraft was not available around 0945 when the second bank of aircraft was being readied for flight. Because refueling of the first bank of aircraft normally ended around 0900 and refueling of the second bank did not begin until about 0930, it is possible that the pumps did not operate for very long, if at all, after the fire started, and consequently would not have continued to supply fuel to the fire area.

The pressure heads of the filled tanks was another possible source of fuel that continued to feed the fire. Because the intensity of the fire prevented firefighters from manually closing the valves to tanks 3 and 4, head pressure from these filled tanks caused fuel under pressure to leak from these valves into the fire area.

As the fire intensified, secondary failures of pipe couplings, valves, and other components occurred from thermal stresses. These secondary failures caused fuel to continuously flow into the fire area and intensified the fire, resulting in more failures that provided more fuel.

Fire Safety Features

An analysis of the design and cost benefits of various safety features of the Denver fuel farm or the new fuel storage facility at the new Denver airport was beyond the scope of the Safety Board's investigative role. However, obvious safety deficiencies were noted during the investigation that are not addressed in existing industry standards.

Valves.--The investigation revealed that only tank 10 had an internal fire valve with external fusible links that would automatically close when exposed to heat from a fire. Further, only the control valves on the piping to tanks 2 and 5 were fail-safe--that is, they were designed to automatically close if either electrical power or air pressure was lost. The control valves installed on tanks 1, 3, and 4, were not fail-safe; air pressure had to remain on the valve's control system for the valves to close automatically in the event of an electrical power failure. If the air pressure was lost, the valves had to be closed manually. However, because of the intensity of the fire at tanks 3 and 4, firefighters were unable to manually close the valves to these tanks. The Safety Board concludes that had tanks 3 and 4 been equipped with fail-safe control valves and internal fire valves with fusible links, the amount of fuel that fed the fire would have been significantly reduced, and, consequently, the duration and intensity of the fire lessened. The lack of such valves, therefore, contributed to the severity of this fire. The Safety Board believes that all above-ground fuel storage tanks should be equipped with internal fire valves and that all control valves on above-ground fuel storage tanks should be fail-safe. Consequently, the Safety Board urges the FAA to require that all tanks at fuel storage facilities on airport property be equipped with an internal fire valve and fail-safe control valves. Further, the Safety Board believes that the National Fire Protection Association Standard 30 should require that internal fire valves and fail-safe control valves be installed on all above-ground fuel storage tanks.

Location of Control Building.--The motor/pump equipment was mounted in such a way as to allow for the collection of small, accidental releases of fuel; it is located in the most likely area for fuel leaks to occur. The location of the control building in this same area causes the Safety Board concern. The investigation of the cause of this fire was hampered by the loss of records in the control building that was located in the same area as the motor/pump equipment. The Safety Board is unaware of any valid reason to locate a control building that houses electrical equipment, emergency shutoff switches, and records in an area that is designed to collect fuel leaks. The Safety Board concludes that had the control building been located in an area separate from the motor/pump equipment and outside of the containment area, vital records that could have been helpful to the investigation would not have been lost, emergency response personnel could have accessed emergency shutoff switches and possibly could have remotely closed some of the control valves, thus reducing the amount of fuel that ultimately fed the fire. The placement of the control building adjacent to the motor/pump units in the fuel spill containment area, therefore, contributed to the severity of the accident. Consequently, the Safety Board urges the FAA to require certificate holders to ensure that fuel operators locate fuel farm control systems, one or more emergency shutoff switches, and the recording equipment in an area remote from the pumping equipment and outside a spill containment area.

Monitoring Equipment.--Monitoring equipment, for both temperature and vibration, is available for the type of motor/pump units involved in this fire. The monitoring equipment can be "hardwired" into the control system and will automatically shut down the motor/pump unit in the event of excessive temperature or vibrations. According to the manufacturer, this monitoring equipment can be installed for about $1,200 to $2,000 per motor/pump unit. The cost for a new pump is about $20,000. Had equipment that monitors excessive temperatures and vibrations with automatic shutoff capability been installed on motor/pump unit 3, the equipment would have detected the vibration of the motor on motor/pump unit 3, shut down the unit, and the fire would not have occurred. Therefore, the Safety Board urges the FAA to examine the feasibility of mandating the use of temperature and vibration monitoring equipment on all fuel pumping systems located on airport property.

Inspections of Equipment

The nature of the failure of motor/pump unit 3 over a period of time raises questions about the adequacy of daily inspections conducted by AMR Combs' fuel farm employees and about the concern of AMR Combs' management for adequate inspections. According to training manuals furnished by AMR Combs, the pumping equipment was to have been checked daily and at the beginning of each day. The entries on the daily inspection sheet for the month of November indicate that the pumps were checked daily and were recorded as being satisfactory. The daily inspection forms for the equipment were signed off by the night shift employee, and interviews confirmed that he was performing the inspections. The night shift was the time of lightest fuel demand at the ramp, and little, if any, fueling was done after 2200. Consequently, unless the night shift employee inspected the motor/pump units early in the shift, most of the pumps would have been inspected when they were not operating. Further, it is not likely that all six motor/pump units would be operating during the night shift. Because, according to maintenance staff, inspection of the equipment relied heavily on feeling vibrations and listening for unusual noises in the equipment, only very obvious discrepancies with these pumps could be noted when the equipment is not operating.

The night shift employee had worked at the fuel farm for less than 1 month. Further, his testimony indicates that he had been given no guidance or training by management regarding equipment inspections and that he might not have been able to detect a problem with the equipment if one existed. Inspection of the equipment during nighttime when the equipment was not operating and by an inexperienced and untrained employee could account for the fact that the deteriorating condition of motor/pump unit 3 went undetected. Moreover, the fact that the night shift employee had initialed before the fire the daily inspection sheet for November 26, 1990 (the day after the fire), indicates that the inspections were not conducted properly, if at all, and that the employee may have been merely satisfying paperwork requirements.

According to information received later during the investigation from the fuel farm manager, the equipment was to be inspected during each shift and the formal signoff on the status of the pumping equipment was performed during the night shift. It is difficult to understand how the deteriorating condition of motor/pump unit 3 could have gone undetected if the equipment was inspected during each shift by more experienced personnel and when the equipment was likely to be operating. The Safety Board concludes that adequate inspections were not being performed, and the failure to conduct adequate inspections caused the accident. Further, AMR Combs management failed to train and guide its employees in the inspection and maintenance of its fuel pumping equipment, and this failure contributed to the cause of the accident. The Safety Board believes that pumping equipment at fuel storage facilities on airports should receive detailed inspections when the equipment is operating and also when the equipment is not operating and that these inspections should occur daily. Information received by the Safety Board 9 months after the fire indicates that AMR Combs management has taken no steps to improve its inspection of pumping equipment. Consequently, the Safety Board urges AMR Combs to revise its inspection procedures accordingly.

The Safety Board has not ascertained if inspections and maintenance are adequate at fuel tank farms at other airports. Consequently, the Safety Board urges the Airport Operators Council International, Inc., and the American Association of Airport Executives to inform their members of the circumstances of the fuel farm accident at Denver's Stapleton International Airport and emphasize the importance of providing adequate resources for the inspection and maintenance of fuel tank farm facilities.

Federal Regulations Regarding Fuel Storage Facilities

Although regulations at 14 CFR Part 139.321 address fuel storage, fire protection, training, and inspection, subparagraph (h) exempts the certificate holder (the operator of the airport) from requiring Part 121 and Part 135 air carriers to comply with the requirements of Part 139.321. However, there are no equivalent regulations under Parts 121 and 135 to require air carriers to accomplish what is required under Part 139. The pertinent provisions under Part 121 and 135 appear to address refueling of aircraft only, and not inspection and maintenance of the fuel storage facilities. There also appears to be considerable confusion within the FAA as to which division within FAA has responsibility for inspecting fuel storage facilities on airport property. The FAA's Office of Airport Safety and Standards understands that it has responsibility for inspecting fuel storage facilities operated by fixed-base operators but questions its own legal authority to do so for fuel storage facilites operated by Part 121 and

Part 135 carriers. The FAA's Office of Flight Standards Service has operated in a manner that suggests its responsibility is limited to the refueling of aircraft.

As a result of this fire, the investigation of which highlighted the deficiencies in the regulations, the FAA's Office of Airport Safety and Standards issued a policy memorandum that attempted to resolve the issue and clarify which organization within the FAA has responsibility for inspection and oversight of these fuel storage facilities on FAA-certificated airports. The Safety Board believes, however, that the appropriate course of action would be to clarify the exemption in paragraph (h) of Part 139.321. Further, the FAA should clarify which division within FAA has the responsibility for overseeing inspections of fuel storage facilities on airport property and assure that the inspection responsibility is consistent with regulatory authority.

Although the regulations are not clear as to which division within FAA has oversight with respect to inspections of fuel storage facilities on airport property, the FAA's Office of Airport Safety and Standards did conduct an annual certification inspection of Stapleton International Airport in June 1990. That inspection achieved the intended results, noting that the certificate holder (city/county of Denver) was not in compliance with Part 139.321 nor with requirements outlined in its Airport Certification Manual (ACM); specifically, the certificate holder failed (1) to maintain [adhere to] its fueling standards for protection against fire and explosion in storing and dispensing fuel on airport property, (2) to conduct quarterly inspections of fuel storage facilities, and (3) to maintain yearly training certification of fueling tenants. The failure of the certificate holder to conduct quarterly inspections of the fuel storage facilities and to comply with its ACM certificate represents an inadequate approach to fire safety and, thus, contributed to the cause of the accident. Also of concern to the Safety Board is the apparent lack of followup by the FAA to determine if the certificate holder had resolved the discrepancies noted during the annual certification inspection. Efforts are needed to determine if areas of noncompliance are, in practice, resolved by the certificate holder.

The investigation raised concern that the certificate holder was not allocating sufficient resources to perform thorough quarterly inspections of fuelers on airport property. Although the airport certificate holder inspector cannot be expected to detect all pumping equipment maintenance discrepancies, the Safety Board believes that the certificate holder's inspector should have found that AMR Combs was not properly inspecting and maintaining its equipment. However, only one Denver fire department inspector had been assigned to conduct the quarterly inspections of all fuelers at Stapleton International Airport and he had received only minimal training to conduct these inspections. The Safety Board has not ascertained if the same conditions exist at other airports. The Board believes, however, that the FAA, during the annual certification, should determine if the certificate holders are providing the necessary resources to perform thorough quarterly inspections of fuelers on airport property. Further, the Safety Board believes that training of certificate holder inspectors should be required, particularly because the FAA is relying on the self-inspections to certify that fuel handling is being done safely.

Emergency Response

Airport firefighters and the Denver fire department promptly responded to the fire and immediately began to attack the fire. However, because the firefighters were unable to maintain a continous flow of foam onto the fire, the fire reignited and quickly intensified. Airport and local firefighters did not have, nor could they have been expected to have, a sufficient supply of foam concentrate to fight a fuel fire of this magnitude. However, the Safety Board is concerned that the city of Denver, and the fire department in particular, apparently had not contemplated a fire of this type as no procedures or contingency plans were in place for doing so. Arrangements for Williams, Boots, and Coots to provide onsite expertise were made only after Continental became concerned that the fire would impinge on its holding tanks (7 and 8). The lack of procedures or a contingency plan for responding to a fuel farm fire of this magnitude prolonged the duration of the emergency. The Safety Board believes that this investigation indicates that certificate holders should have contingency plans for fighting very large fires such as fuel farm fires.

CONCLUSIONS

Findings

1. Based on United's refueling activity for the morning of November 25, 1990, and on the sequence in which pumps were to be activated, motor pump unit 3 would have been operating during the refueling of aircraft that were readied for flight between 0730 and 0900 mountain standard time.

2. The motor on unit 3 gradually became loose during normal operations because of inadequately installed or maintained bolts, thus increasing lateral and vertical vibrations that caused overstress conditions on the bolts to the point of failure.

3. Operation of the motor on unit 3 while it was no longer bolted down resulted in a lateral shifting of the motor relative to the pump by about 2.6 inches, which increased vibrations and friction that eventually fractured the pump case and two pump bolts and destroyed the coupler gears and the pump sealing surfaces.

4. The destruction of the pump sealing surfaces and a fractured pump case resulted in a sizeable fuel leak because of the head pressure in the tanks that had been filled on the morning of the fire.

5. Either the hot coupler or the motor on unit 3 provided an ignition source for the leaking fuel.

6. Had tanks 3 and 4 been equipped with fail-safe control valves and internal fire valves with fusible links, the amount of fuel that fed the fire would have been significantly reduced, and, consequently, the duration and intensity of the fire would have been lessened.

7. Had the control building been located in an area separate from the motor/pump equipment and outside of the containment area, vital records that would have been helpful to the investigation would not have been lost, and emergency response personnel could have accessed emergency shutoff switches and possibly could have remotely closed some of the control valves, thus reducing the amount of fuel that ultimately fed the fire.

8. Had equipment that monitors excessive temperatures and vibrations with automatic shutoff capability been installed on motor/pump unit 3, the equipment could have detected the vibration of the motor and shut down the unit, and the fire would not have occurred.

9. The motor/pump equipment was not properly inspected for a substantial period of time before the fire.

10. Management of AMR Combs failed to give proper priority to the task of inspecting and maintaining fuel farm pumping equipment.

11. The airport certificate holder's (city/county of Denver) lack of procedures or a contingency plan for responding to a fire of this magnitude prolonged the duration of the emergency.

12. Federal Aviation Administration (FAA) regulations in 14 CFR Part 139 fail to specify the responsibility for inspection of fuel farms located on airport property, when such fuel installations are operated by Part 121 and Part 135 air carriers. Similarly, FAA regulations in 14 CFR Parts 121 and 135 do not directly address the inspection of fuel farms operated by air carriers.

13. The airport certificate holder did not allocate sufficient resources to perform thorough quarterly inspections of fuelers on airport property.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the fire at the fuel storage facility at Denver's Stapleton International Airport was the failure of AMR Combs to detect loose motor bolts that permitted the motor of motor/pump unit 3 to become misaligned, resulting in damage to the pump and subsequent leakage and ignition of fuel. Contributing to the accident was the failure of AMR Combs to properly train its employees to inspect and maintain the fuel pump equipment and the failure of the city and county of Denver to carry out its certificate holder responsibility to oversee the fuel storage facility in accordance with its airport certification manual. Contributing to the severity and duration of the fire were the lack of storage tank fail-safe control valves and internal fire valves and the location of the control building in the containment area where fuel leaks are likely to occur.

RECOMMENDATIONS

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

--to the Federal Aviation Administration:

Require the airport certificate holder to be responsible for inspections of all fuel tank farms on airport property and to provide the necessary resources, including training of personnel, to perform thorough quarterly inspections of fuel storage facilities on airport property. (Class II, Priority Action) (A-91-95)

Clarify which division within the Federal Aviation Administration has responsibility for overseeing inspections of fuel storage facilities on the property of certificated airports and assure that this inspection responsibility is consistent with regulatory authority. (Class II, Priority Action) (A-91-96)

Require operators of fuel farm facilities on the property of certificated airports to install fail-safe control valves and internal fire valves with fusible links on all above-ground fuel storage tanks. (Class II, Priority Action) (A-91-97)

Require airport certificate holders to ensure that fuel operators locate the fuel farm control systems, one or more emergency shutoff switches, and the recording equipment in an area remote from the pumping equipment and outside a spill containment area. (Class II, Priority Action) (A-91-98)

Examine the feasibility of mandating the use of temperature and vibration monitoring and shutdown equipment on all fuel pumping systems located on the property of certificated airports. (Class II, Priority Action) (A-91-99)

Require airport certificate holders to have contingency plans for responding to very large fires, such as fuel tank farm fires. (Class II, Priority Action) (A-91-100)

--to AMR Combs:

Revise procedures for inspecting airport fuel farm pumping equipment to assure that equipment is inspected daily when the equipment is operating and also when it is not operating. (Class II, Priority Action) (A-91-101)

Provide initial and recurrent training on detailed inspections of airport fuel farm pumping equipment to all fuel farm employees. (Class II, Priority Action) (A-91-102)

--to the National Fire Protection Association:

Revise National Fire Protection Association Standard 30 to require internal fire valves and fail-safe control valves on all above-ground fuel storage tanks. (Class II, Priority Action) (I-91-02)

--to Airport Operators Council International, Inc., and the American Association of Airport Executives:

Inform your members of the circumstances of the fuel farm fire at Denver's Stapleton International Airport on November 25, 1990, and emphasize the importance of providing adequate resources for the inspection and maintenance of fuel tank farm facilities. (Class II, Priority Action) (A-91-103)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES L. KOLSTAD
Chairman

SUSAN M. COUGHLIN
Vice Chairman

JOHN K. LAUBER
Member

CHRISTOPHER A. HART
Member

JOHN A. HAMMERSCHMIDT
Member

Adopted: October 1, 1991

APPENDIX A

INVESTIGATION

The National Transportation Safety Board was notified of the accident on November 25, 1990. An investigative team was dispatched from headquarters in Washington, D.C.

At the request of the city of Denver, the Safety Board assumed responsibility for the investigation. Parties to the investigation included United Airlines, Inc.; AMR Combs, operator of United's fuel farm facilities; Continental Airlines, Inc.; Ogden Allied (which became Ogden Airline Services in 1991), operator of Continental's fuel farm facilities; Chase Transportation Company; Ingersoll-Rand, manufacturer of the pump involved in the fire; and the Denver City Fire Department.

APPENDIX B

PERTINENT FEDERAL REGULATIONS REGARDING MINIMUM AIRPORT REQUIREMENTS FOR RESCUE AND FIREFIGHTING EQUIPMENT AND AGENTS

Part 139.317 Aircraft rescue and firefighting: Equipment and agents

The following rescue and firefighting equipment and agents are the minimum required for the Indexes referred to in Part 139.315:[1]

(a) Index A: One vehicle carrying at least--

(1) 500 pounds of sodium-based dry chemical or halon 1211; or

(2) 450 pounds of potassium-based dry chemical and water with a commensurate quantity of AFFF to total 100 gallons, for simultaneous dry chemical and AFFF foam application.

* * * * *

(d) Index D: Three vehicles--

(1) One vehicle carrying the extinguishing agents as specified in paragraph (a)(1) or (2) of this section; and

(2) Two vehicles carrying an amount of water and the commensurate quantity of AFFF so that the total quantity of water for foam production carried by all three vehicles is at least 4,000 gallons.

---

[1] Denver's Stapleton International Airport falls under the category of Index D.

APPENDIX C

SUMP TANK MEASUREMENTS

November	Fuel (inches)	Water (inches)	Total (gallons)	Total Fuel (gallons)	
1	65.5	12.5			
2	65.5	13			
3	65.5	13			
4	67.5	13	3445	3045	
5	67.75	13	3457	3063	
6	114*	13	4000	3606	
7	79.5	13.5	3917	3507	
8	100*	13.5	4000	3584	(tank pumped)
9	67	13.5	3481	3005	
10	71	13.5	3606	3190	
11	76	13.5	3804	3390	
12	79	13.5	3904	3488	(tank pumped)
13	15.5	13.5	508	92	
14	17	13.5	579	163	
15	20	13.5	730	314	
16	21.5	13.5	808	392	
17	24	13.5	943	527	
18	28.25	13.5	1182	766	
19	31.5	13.5	1370	954	
20	32.5	13.5	1429	1013	
21	33.25	13.5	1473	1057	
22	34.5	13.5	1546	1132	
23	36	13.5	1638	1232	
24	32	13.5	1399	983	
25	(no measurements were recorded for this date)				

* Exceeded level on dipstick

APPENDIX D

STATUS OF PERTINENT SAFETY BOARD SAFETY RECOMMENDATIONS

Safety Recommendation: A-84-27
Date Issued: April 16, 1984
Recipient: FAA
Status: Closed--Acceptable Action
Date Closed: March 29, 1990

Subject:

As an interim measure until a program for certificating fueling personnel can be established, revise the compliance criteria applicable to certificated airports in FAA Order 5280.5, "Handling and Storage of Hazardous Material," to contain specific standards for initial and recurrent training of fueling personnel, which address methods of assuring fuel quality, fire prevention, vehicle inspection and operation, proper fueling techniques, and knowledge of airport operating rules.

Brief Narrative of Status Assignment:

Based on documents provided by the FAA, it appeared that an acceptable action had been taken with respect to the intent of the recommendation, and, consequently, the recommendation was classified as "Closed--Acceptable Action" on March 29, 1990. [The investigation of this fire, however, raises questions regarding the adequacy of action taken by the FAA with respect to the th safety recommendations listed in this appendix.]

Safety Recommendation No.: A-84-28
Date Issued: April 16, 1984
Recipient: FAA
Status: Closed--Acceptable Alternate Action
Date Closed: March 29, 1990

Subject:

Revise the compliance criteria in FAA Order 5280.5, "Handling and Storage of Hazardous Material," to incorporate detailed procedures for fuel storage area inspections and specific facility acceptability criteria.

Brief Narrative of Status Assignment:

Documents provided by the FAA suggested that an alternate approach to the recommendation had been taken and it was so classifed.

Safety Recommendation No.: A-84-30
Date Issued: April 16, 1984
Recipient: FAA
Status: Closed--Acceptable Alternate Action
Date Closed: March 29, 1990

Subject:

Adopt design and construction standards for fuel storage area site selection facilities to be applied uniformly to new airports receiving Federal funds or to currently certificated airports when storage facilities are relocated.

Brief Narrative of Status Assignment:

Documents provided by the FAA suggested that an alternate approach to the recommendation had been taken.

APPENDIX E

TENSILE STRENGTH OF BOLTS BASED ON POST-FIRE MEASUREMENTS

TABLE I

PUMP BOLT MECHANICAL PROPERTIES

BOLT LOCATION	MFG. BRAND, SAE GRADE	RATED TENSILE STRENGTH (KSI)	MEASURED HARDNESS (HRB)	CONVERTED TENSILE STRENGTH (KSI)
P1RI	not marked	--	--	--
P1RC	not marked	--	38	(1)
P2LI	not marked	--	--	--
P2RI	not marked	--	--	--
P2LC	not marked	--	--	--
P2RC	not marked	--	--	--
P3LI*	bolt head was missing	--	60	50
P3RI	C , Grade 5	120	82	77
P3LC*	not marked	--	65	56
P3RC	C , Grade 5	120	82	77
P4LI	not submitted	--	--	--
P4RI	C , not marked	--	--	--
P4LC	not marked	--	--	--
P4RC	not marked	--	--	--
P5LI	not marked	--	--	--
P5RI	not marked	--	--	--
P5LC	not marked	--	36	(1)
P5RC	not marked	--	--	--
P6LI	not marked	--	37	(1)
P6RI	not marked	--	--	--
P6LC	not marked	--	--	--
P6RC	not marked	--	--	--

APPENDIX E

TABLE II

MOTOR BOLT MECHANICAL PROPERTIES

BOLT LOCATION	MFG. BRAND, SAE GRADE	RATED TENSILE STRENGTH (KSI)	MEASURED HARDNESS (HRB)	CONVERTED TENSILE STRENGTH (KSI)
M1LS	not marked	--	--	--
M1RS	not marked	--	--	--
M1LF	not marked	--	--	--
M1RF	not marked	--	53	(1)
M2LS	not marked, Grade 5	120	86	83
M2RS	not marked	--	--	--
M2LF	not marked	--	--	--
M2RF	not marked	--	--	--
M3LS*	S , Grade 5	120	84	81
M3RS*	KS , Grade 8.2	150	82	77
M3LF*	bolt head was missing	--	67	58
M3RF*	KS , Grade 8.2	150	83.5	80.5
M4LS	****, not marked	--	--	--
M4RS	C , not marked	--	--	--
M4LF	C , not marked	--	--	--
M4RF	C , not marked	--	--	--
M5LS	J , Grade 5	120	83	80
M5RS	KY , Grade 5	120	--	--
M5LF	J , Grade 5	120	77	68
M5RF	J , Grade 5	120	--	--
M6LS	not marked	--	--	--
M6RS	not marked	--	--	--
M6LF	not marked	--	52	(1)
M6RF	not marked	--	--	--

NOTES:

(1) Tensile strength was far below 55 ksi.

* These values were also reported in metallurgist factual report No. 91-69 but was reprinted for comparison purposes. Hardness value of M3RF bolt is an average of two values instead of three.

**** The manufacture brand for this bolt is as shown in lower left photo of figure 1 (resembles M combined with D.)

APPENDIX F

FAA POLICY AND GUIDANCE #38

AIRPORT CERTIFICATION PROGRAM - FAR PART 139
PROGRAM POLICY AND GUIDANCE
#38

PART 139.321 (h) JANUARY 22, 1991

INSPECTION OF FUEL FARMS SERVING PART 121 OR PART 135 AIR CARRIERS
SEE ALSO: PROGRAM AND POLICY GUIDANCE LETTER #15

Flight Standards Airworthiness Inspectors (ASIs) are tasked with the inspection of Part 121 and Part 135 air carrier fuel facilities. In their Order 8300.10, Chapter 227 addresses the evaluation of an operator's refueling procedures. Specifically, Section 2, Paragraphs 5A and B on page 227-2 are directed toward reviewing the air carrier's or agent's manual and the inspection of the facility.

In the interest of fueling safety and to insure that all airport fueling operations receive the highest standard of FAA review, we are recommending that Certification inspectors notify Flight Standards District Office Managers of an upcoming inspection to provide the ASIs with the opportunity to accomplish an inspection at the same time or to inform the Airport Certification inspector of problems or situations that should be brought to the attention of airport management. In any event, Certification inspectors will inspect all fuel facilities on the airports. If a discrepancy in a Part 121 or Part 135 facility is noted, the inspector will report said discrepancy, in writing, to the airport and to the FSDO, and will document the discrepancy on the inspection report, if it is a violation of Part 139.

Consistent with the language in Part 139, the certificate holder will not be violated, if the ACM specifically excludes air carrier fueling facilities from airport oversight. However, even in these situations, to ensure airport safety, certification inspectors are requested to encourage actively all certificate holders to exercise sufficient surveillance of air carrier fueling facilities by including them in their ongoing inspection programs.

Richard L. Rodine
Richard L. Rodine, Manager

1-22-91
Date

AIRPORT SAFETY AND OPERATIONS DIVISION AAS-300
POLICY #38

APPENDIX G

TANK CAPACITIES

#	Diameter (feet)	Type of Roof	Contained (gallons)	Capacity (gallons)	Foam Injection	Internal Safety Valve
1	45	Cone	348,000	420,000	No	No
2	45	Floating	693,000	840,000	No	No
3	45	Cone	420,000	420,000	No	No
4	45	Cone	420,000	420,000	No	No
5	45	Floating	830,000	840,000	Yes	No
7	80	Floating	585,000	1,428,000	Yes	Yes
8	80	Floating	1,529	1,428,000	Yes	Yes
10	72	Floating	360,000	2,100,000	Yes	Yes
11	78	Floating	—	—	No	—
12	78	Floating	0	—	No	—
13	78	Floating	0	—	No	—
17	78	Floating	—	—	Yes	Yes

APPENDIX H

SECTION 321 OF AIRPORT CERTIFICATION MANUAL FOR STAPLETON INTERNATIONAL AIRPORT

HANDLING AND STORING OF HAZARDOUS SUBSTANCES AND MATERIALS

CARGO HANDLING

The City and County of Denver at SIA does not act as a cargo handling agent.

FUEL, LUBRICANTS, AND OXYGEN

SIA Operations is responsible for establishing and maintaining standards for protecting against fire and explosions in storing, dispensing, and otherwise handling fuel, lubricants, and oxygen. ARFF personnel assigned full time at SIA are responsible for administering this program. In addition to establishing safety standards, the SIA program includes:

1. Training fueling agents in safe fueling and hazardous materials handling practices.

2. Monitoring the safety practices of fueling agents.

3. Monitoring the storage and replenishing of aircraft oxygen systems.

4. Monitoring the storage, handling and dispensing of lubricants.

5. Inspecting the physical facilities and equipment of fueling agents and the entire fuel system at SIA to ensure compliance with established standards.

6. Investigating and tracking fuel and lubricant spills in order to determine cause factors and taking corrective action aimed at reducing the number of fuel spills.

STANDARDS. Standards for handling fuel, lubricants, and oxygen include all applicable requirements of:

1. SIA Rules and Regulations

2. National Fire Protection Association Publications

3. The Denver Fire Code

4. SIA Managers Bulletin titled "Fuel, Oil, and Chemical Spills."

Following are some specific standards established by the above listed publications:

a. GROUNDING AND BONDING. Grounding and bonding equipment should provide that piping, filters, tanks, and electrical components are electrically bonded together and interconnected to adequate electrical ground. Additional requirements are contained in NFP 407 and 77.

b. PUBLIC PROTECTION. Fueling of aircraft will not take place while passengers are loading or unloading or while passengers remain on the aircraft unless a minimum of two evacuation qualified personnel are positioned on the aircraft at the front and rear and all fire safety equipment is present and operable.

c. CONTROL OF ACCESS TO STORAGE AREAS. All fuel storage areas will:

(1) Be located inside a fenced and signed area to reduce chances of unauthorized entry and/or tampering. Signage must conform to the Denver Fire Code standards.

(2) Be fenced with 6 foot high fence and gates with three strands of barbed wire on top extending outward at a 45 degree angle.

(3) be kept secured at all times. Keys to gate locks will be available only to authorized personnel. Gates will not be left open unless a guard is present.

d. FIRE SAFETY IN MOBILE FUELERS, FUELING PITS, AND FUELING CABINETS. The system should:

(1) Be marked with letters at least 3-inches high on all sides to show danger, flammability, standard hazardous material UN placard, and inside crew compartment (if any) to prohibit smoking.

(2) Be marked with letters at least 3-inches high on all sides and in crew cab to clearly show type or grade of fuel in system.

(3) Contain/dispense only one type or grade of fuel unless the vehicle was specifically designed to contain/dispense multiple grades of fuel. Placarding is required for each type of fuel and individual compartment(s) identified with capacity.

(4) If at fixed locations (e.g., pit or fueling cabinet), be equipped with: (a) at least one boldly marked emergency fuel cutoff placarded at least 7 feet above ground and located so that they can be readily seen from a distance of at least 25 feet; and (b) fire extinguishers as required by NFPA Standard 407.

(5) If a mobile fueler, be equipped with: (a) a system capable of overriding all other controls and stopping, with one physical movement, all fuel flow; and (b) fire extinguishers as prescribed by NFPA Standard 407.

APPENDIX H

(6) Contain no feature which would allow introduction of any foreign material into fuel.

(7) Contain no feature which would allow fuel or concentrated fumes to contact (during normal operations, overfilling or other spill) exhaust system, hot exhaust gasses, or any other ignition source.

(8) If equipped with internal combustion engine, be equipped with air filter/spark arrester and a leak-free exhaust system terminating in a standard baffled (original equipment type) muffler.

INSPECTIONS

The physical facilities of each airport tenant fueling agent will be inspected at least once every 3 months for compliance with standards and records of these inspections will be kept for at least 12 months. When a vehicle is inspected and is in compliance with standards, an inspection sticker is issued which is valid for 3 months.

TRAINING OF FUELING PERSONNEL.

SIA ARFF personnel will assure that at least one supervisor with each fueling agent has completed an aviation fuel training course in fire safety. Additionally, all other employees who fuel aircraft, accept fuel shipments, or otherwise handle fuel shall receive at least on-the-job training in fire safety from the trained supervisor. Each tenant fueling agent will provide ARFF personnel certification, once a year, that this training has been accomplished.

NONCOMPLIANCE WITH STANDARDS

SIA ARFF personnel will require each tenant fueling agent to take immediate corrective action whenever they become aware of noncompliance with a fueling standard. The AOM will be notified immediately when noncompliance is discovered and corrective action cannot be accomplished within a reasonable period of time. The AOM will notify the FAA, Northwest Mountain Region, Airports Division, Seattle, Washington of this situation.

In situations where attempts by ARFF personnel to bring an individual or an organization within compliance with any standard are unsuccessful, ARFF personnel will report the situation to the Deputy Director of Aviation-Operations. The Deputy Director of Aviation-Operations will take appropriate actions to achieve compliance including court actions, if appropriate.

APPENDIX H

RECORD KEEPING

A computer program has been designed specifically to handle all information gathered by ARFF inspections. The program has cross reference capability concerning discrepancies, training, etc. The computer and the program will be used as a management tool to assure compliance with Part 139 requirements concerning handling and storing of hazardous substances and materials.

PARKING AIRCRAFT WITH HAZARDOUS CARGO

The AOM will determine the location for parking aircraft with hazardous cargo depending on operational requirements on the airport at the time. Small aircraft carrying hazardous cargo are generally parked on the small aircraft run up pad at taxiway B-5. Larger aircraft are generally parked on taxiway D-3 between runway 7/25 and taxiway "Z". However, the AOM will determine the location for parking aircraft with hazardous cargo when a special location is required.

Special operations involving Rocky Mountain Arsenal, Rocky Flats, or other agencies will be coordinated by the AOM on an individual basis.