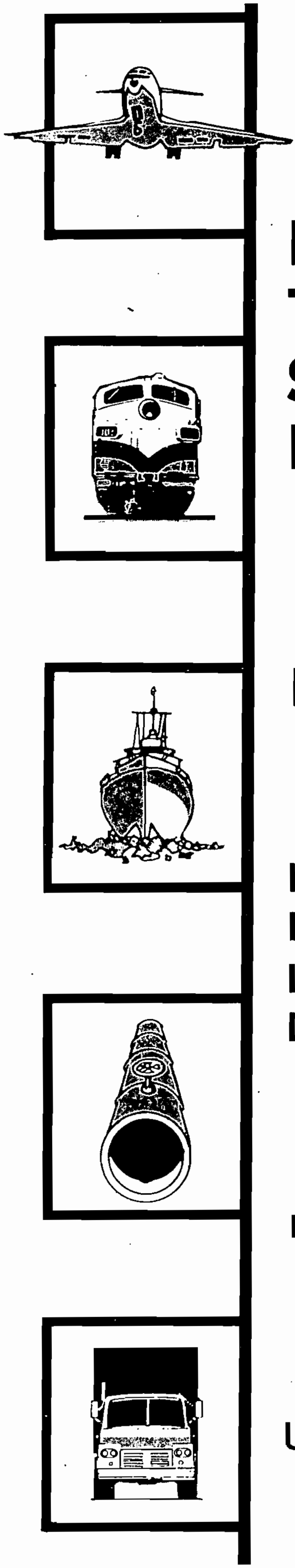

# NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

## PIPELINE ACCIDENT REPORT

**KANSAS PUBLIC SERVICE COMPANY, INC.
EXPLOSION AND FIRE
LAWRENCE, KANSAS
DECEMBER 15, 1977**

REPORT NUMBER: NTSB-PAR-78-4

UNITED STATES GOVERNMENT

**TECHNICAL REPORT DOCUMENTATION PAGE**

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16. Abstract


At 12:50 a.m., c.s.t., on December 15, 1977, a 2-inch plastic gas main under an alley in downtown Lawrence, Kansas, pulled out of a compression coupling which joined it to a steel gas main. Natural gas escaped from the main and migrated through the stone foundation walls of two nearby buildings. At 1:20 a.m., the accumulations of gas in the two buildings ignited. The resulting explosion and fire destroyed one building, severely damaged the other building, and broke nearby windows. Two persons were killed and three persons were injured.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the gas company to properly design, install, test, inspect, and anchor the installation of a 394-foot-long polyethylene plastic gas main that had been inserted in a casing and connected to a steel gas main with a compression coupling. The 2 1/2-year-old unrestrained plastic gas main contracted 3 1/2 inches because of cold temperatures and pulled out of the compression coupling, the resistance of which had decreased with age.


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PIPELINE ACCIDENT REPORT

Adopted: July 5, 1978

# KANSAS PUBLIC SERVICE COMPANY, INC.
# EXPLOSION AND FIRE
# LAWRENCE, KANSAS
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## SYNOPSIS


At 12:50 a.m., c.s.t., on December 15, 1977, a 2-inch, plastic gas main under an alley in downtown Lawrence, Kansas, pulled out of a compression coupling which joined it to a steel gas main. Natural gas escaped from the main and migrated through the stone foundation walls of two nearby buildings. At 1:20 a.m., the accumulations of gas in the two buildings ignited. The resulting explosion and fire destroyed one building, severely damaged the other building, and broke nearby windows. Two persons were killed and three persons were injured.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the gas company to properly design, install, test, inspect and anchor the installation of a 394-foot-long polyethylene plastic gas main that had been inserted in a casing and connected to a steel gas main with a compression coupling. The 2 1/2-year-old unrestrained plastic gas main contracted 3 1/2 inches because of cold temperatures and pulled out of the compression coupling, the resistance of which had decreased with age.


## INVESTIGATION

### The Accident

In 1975 the Kansas Public Service Company, Inc., (gas company) inserted 394 feet of 2-inch, polyethylene plastic pipe in an abandoned 3-inch, steel gas main in Lawrence, Kansas. The pipe was connected to the steel distribution system with boltless, 2-inch-diameter, standard compression couplings. The main was located 3 feet under a 16-foot-wide, concrete-paved alley which connected 7th and 8th Streets between Massachusetts and Vermont Streets in downtown Lawrence.

At 12:50 a.m., c.s.t., on December 15, 1977, the inserted plastic pipe pulled out of one of its compression couplings. The concrete surface of the alley restricted the upward movement of the gas, which was escaping at 30-psig pressure; the gas migrated, via a sand backfill, 5 feet to the rear of a three-story brick building at 747 Massachusetts Street. The gas entered the building through an old stone foundation wall. Gas also entered an adjoining bakery at 745 Massachusetts Street through openings in the mortar of its stone foundation wall.

Sometime between 1:05 a.m. and 1:10 a.m., an employee entered the bakery through its rear entrance. She smelled a gas odor which was stronger than she previously had smelled when the gas pilot light under a nearby gas grill went out. Later, she said that she had called the gas company six times in 7 years for other gas odors, but did not call this time.

At 1:20 a.m., the gas that had accumulated in the two buildings was ignited by a gas pilot light on a water heater in the rear of the bakery. The employee in the bakery was injured and was hurled 20 feet by the force of the explosion. There was a simultaneous explosion and fire in the rear of the adjacent three-story building. Two residents in the building's second- and third-floor rear apartments were killed; two persons in the front second-floor apartment were not seriously injured when plaster fell from the ceiling from the force of the explosion.

Police and firemen heard the explosion 400 feet away at their station at 8th and Vermont Streets. The entire three-story building was engulfed in flames and burning out of control shortly after they arrived at 1:23 a.m. (See figure 1.) At 1:27 a.m., an ambulance arrived on the scene and transported the three injured persons to the hospital.

At 1:30 a.m., the police department telephoned the first of four gas company employees, who are listed as emergency response personnel in the telephone book, and informed him of the explosion and fire. He arrived at 1:40 a.m. and saw gas flames burning through cracks in the pavement in the alley. A second gas company employee arrived at 1:45 a.m. A shutoff valve located at the intersection of the alley and 8th Street was inaccessible to the gasmen because of the intense flames. The gas company did not have sectionalizing valves designated as emergency shutoff valves and shown on prints provided to all emergency response personnel; however, one of the gasmen knew the location of two sectionalizing valves in 8th Street that would isolate the fire, and he closed these valves at 2:05 a.m. (See figure 2.) The gas-fed flames at the rear of the building receded shortly thereafter. Gas service to eight customers was interrupted by the closing of these valves.

Two other gas company employees arrived and assisted the firemen in checking nearby buildings for the odor of gas. Combustible gas indicators (CGI) were not used. The gasmen used their sense of smell to determine that nearby buildings where gas odors were reported by residents were safe. The buildings were not evacuated and bystanders were not warned

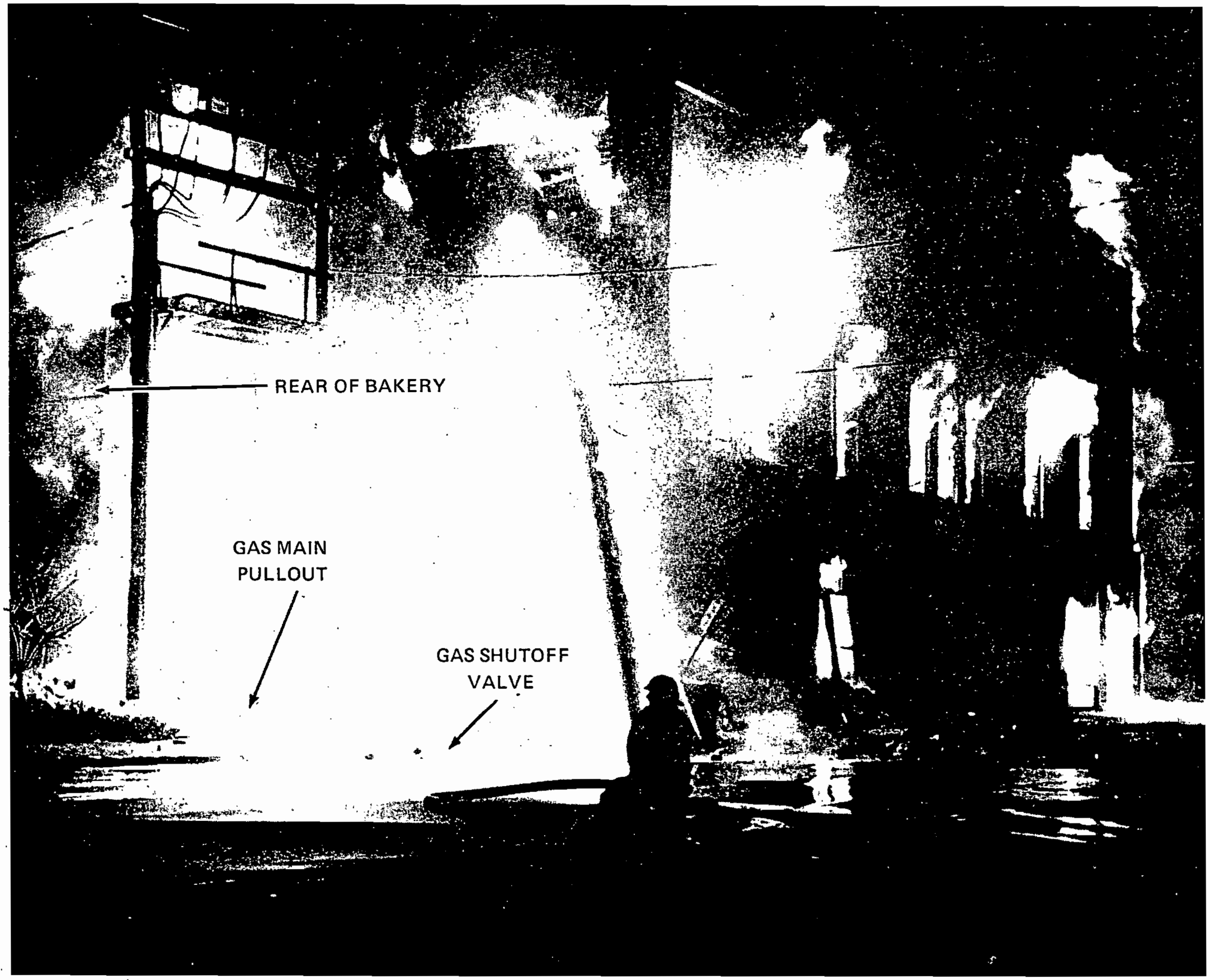


Figure 1. Rears of 745 and 747 Massachusetts Street after explosion.

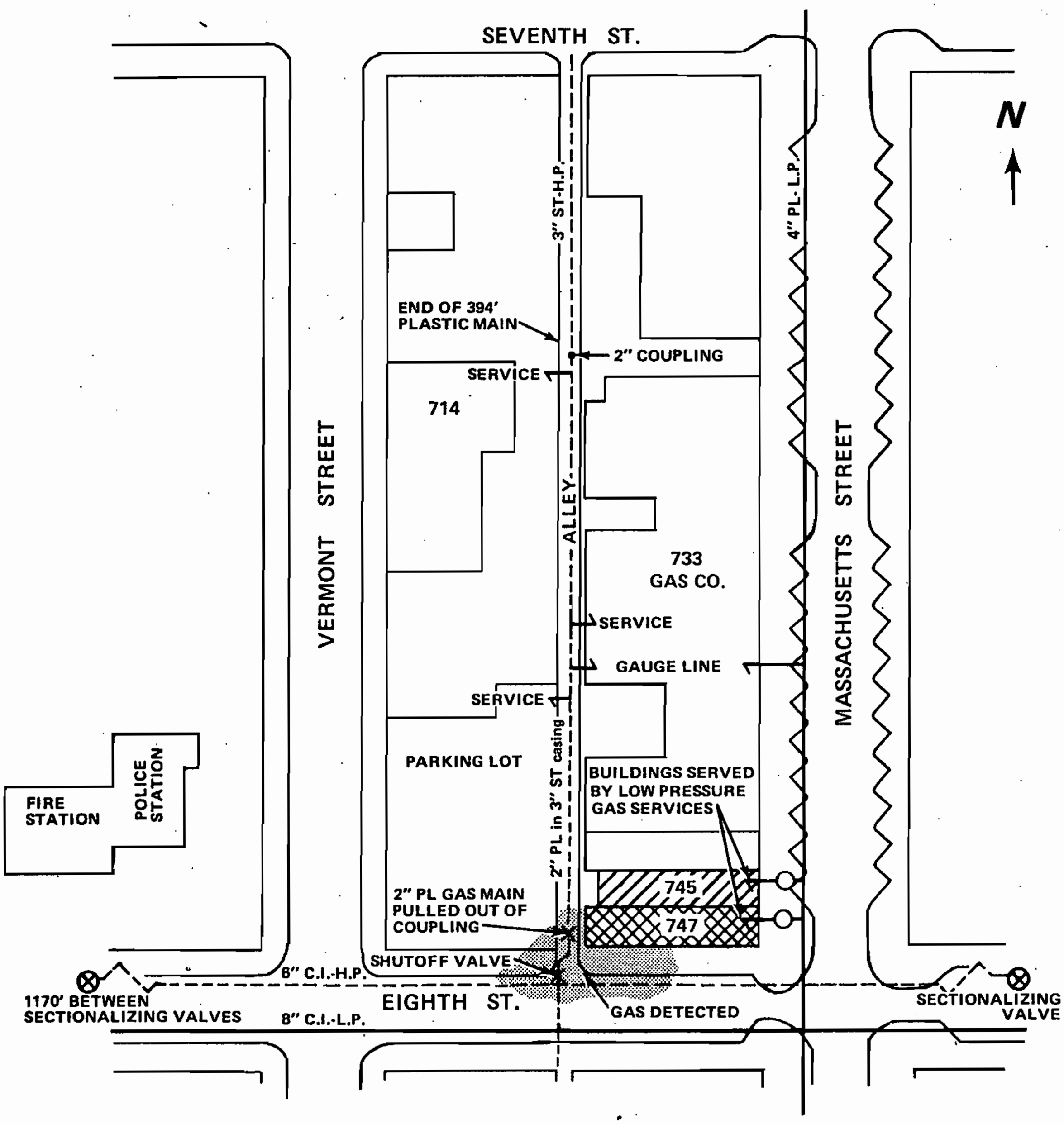


Figure 2. Plan of accident site.

of the possibility of other explosions. The gas company did not have a written procedure to guide their emergency response personnel as to what their responses to this type of emergency should be, or what liaison activities should be carried out with the fire department. The atmosphere of the buildings were not checked with CGI's until later in the day when the company's regular day crews reported for work. The gasmen also shut off the low-pressure gas supply to the burning buildings at curb boxes in Massachusetts Street. The two buildings that were destroyed by the high-pressure gas leak were not served by the high-pressure gas main in the alley. (See figure 2.)

Injuries to Persons

| Injuries | Operating Personnel | Rescue Personnel | Other |
|---|---|---|---|
| Fatal | 0 | 0 | 2 |
| Nonfatal | 0 | 0 | 3 |

Damage to Pipeline

The day after the fire, the gas main in the alley was excavated near where the flames had been the most intense. The plastic pipe was found to have pulled 1/2 inch out of a compression coupling which had been designed as a gas seal only, at the south tie-in location. (See figure 3.) The 11 inches of plastic pipe that extended from the 3-inch casing was bowed 1 inch to one side. The plastic pipe appeared to have taken a slight circular "set" because it had been coiled into a 500-foot-long roll with an average diameter of 5 feet. 1/ The south tie-in location was 3 feet north of the north lot line of 8th Street and 162 feet south of the first service line takeoff. There was no pipe movement 394 feet away at the north tie-in of the main. The north tie-in was anchored by a 2-inch service line takeoff, 2 feet away, and was 2 1/2 feet from the north end of the 3-inch casing.

There were 10 discernible marks on the east side of the plastic pipe around one-quarter of the outer circumference of the plastic pipe. The marks appeared to have been made by side forces such as the bowing of the pipe would have created. The pipe end appeared to have been cut with a saw. It had been cut on a 1/4-inch bias. (See figure 4.)

The only other apparent damage to the pipeline was a torn section in the coal tar-impregnated, fiberglass wrapping material where the plastic pipe entered the coupling. The tear probably was caused by the contraction of the plastic pipe and did not affect this accident.

1/ The technical definition of "set" is the strain remaining after complete release of the force producing the deformation.

Figure 3. Plastic pipe shown 1/2 inch from coupling.

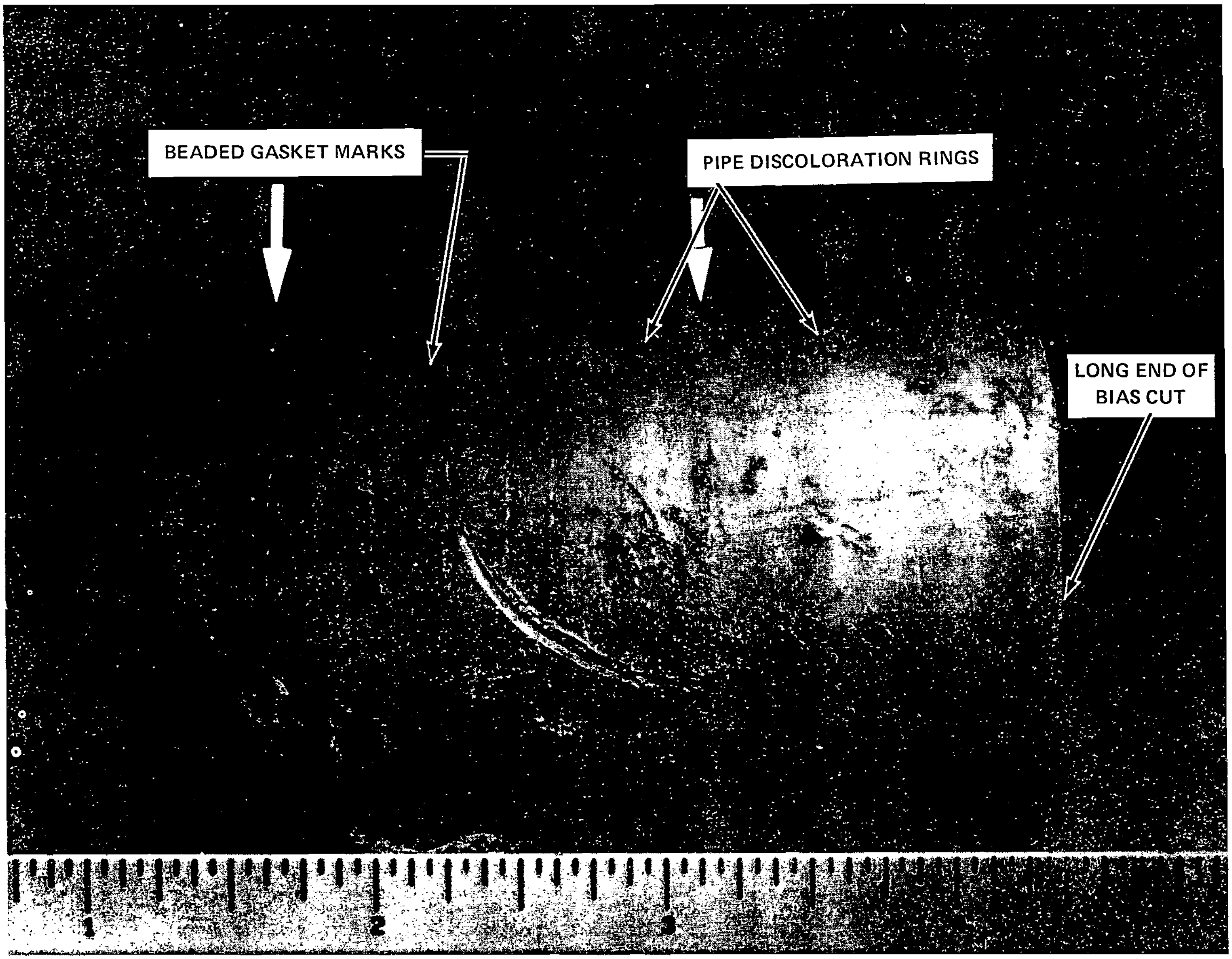


Figure 4. Pipe end that pulled from coupling.

Other Damage

The 26-foot-wide by 27-foot-long rear apartments in the building at 747 Massachusetts Street were completely destroyed by the explosion. Fire destroyed the store and the two apartments in the front of the building.

The adjoining building occupied by the bakery at 745 Massachusetts Street was extensively damaged by the explosion and fire. The city's arson squad determined that the initial explosion occurred at the rear of the bakery near a water heater. The force of the explosion knocked down partition walls and blew out the front plate glass window. It was determined that gas had entered the basement of the bakery through holes in a rock foundation wall which adjoined 747 Massachusetts Street. The mortar in the 87-year-old rock wall had deteriorated, leaving many openings. After the fire was extinguished, residue gas readings were obtained with a CGI by probing through the openings in the wall into the ground beneath the 24-inch crawl space under the rear of 747 Massachusetts Street.

Several windows in nearby buildings were broken by flying debris from the gas explosion. There were also three or four small, secondary explosions when overhead electrical transformers exploded as a result of the gas-fed fires. Several cars were damaged or destroyed by either the explosion or the fire.

Pipeline System

On June 2, 1975, the 394 feet of 2-inch, Du Pont ALDYL "A" polyethylene plastic pipe was inserted in the existing 3-inch, bare steel gas main under the alley between Massachusetts and Vermont Streets. The plastic pipe was part of a 500-foot roll of medium-density PE 2306 pipe that had been manufactured in accordance with the American Society for Testing and Materials (ASTM) specification D2513. The pipe's wall thickness was 0.216 inch, which provided a 2-inch standard-dimension-ratio (SDR) of 11; therefore, the 2.375-inch outside diameter was 11 times the wall thickness. According to 49 CFR 192.121, the formula requires that the design pressure of a 2-inch, SDR 11, polyethylene main is not to exceed 50 psig for a downtown Class 4 location. The operating pressure at the time of the accident was only 30 psig. The thermal coefficient of expansion (or contraction) of the plastic resin used to manufacture the pipe was $9 \times 10^{-5}$ in./in./° F, which is approximately 15 times greater than the coefficient of expansion of steel.

On the day the plastic pipe was inserted, the high temperature was 78° F and the low temperature was 49° F. The average temperature during the pipe installation was about 72° F. The minimum ground temperature at the 3-foot depth of the gas main was interpolated from an engineering handbook to be about 62° F.

The plastic pipe was inserted into the existing main from the north end about 10 a.m. and tested with 60-psig compressor air pressure according to the installation crew. Because most of the crew was at the north insertion opening, they had the only set of special plastic pipe cutter wheels that would assure square cuts on plastic pipe. About 1 or 2 hours after insertion, the crew at the north end cut the pipe with the special cutter and the worker at the south end of the casing simultaneously cut his end of the plastic pipe on a 1/4-inch bias with a hacksaw. They then connected the two ends of the plastic pipe to the steel pipe with Dresser (Manufacturing Company) Style 90 compression couplings. They used 5-inch-long, smooth steel stiffeners, not of the coupling manufacturer's design, inside the ends of the plastic pipe so that the pipe would not collapse when the compression couplings were tightened. (See figure 5.)

The plastic pipe ends were not anchored to the steel casing, or provided with other means of restraint. However, there were service line takeoffs on the plastic pipeline 2 feet from the north compression coupling and 162 feet from the south compression coupling.

The gas company had started installing plastic pipe gas mains in 1971 and had installed 29 miles of new plastic mains by the end of 1976. The company installed an average of 5 miles of new gas mains with its own work force each year. Du Pont ALDYL "A" pipe in the 2-inch through 4-inch sizes was used almost exclusively for the company's new and replacement gas mains in the 1970's. The small gas company has only 12,000 services and 227 miles of gas mains ranging in size from 1 inch to 8 inches in diameter.

The gas company construction crews consisted of 13 men whose combined number of years of service exceeded 200; each man averaged more than 15 years of service. Most of the men had been employed since 1971 when plastic pipe was first used by the company and were experienced in installing more than 20 miles of plastic pipe before 1975. They all had attended training sessions on installing plastic pipe conducted by the manufacturer's technical representative. An estimated 24 insertion projects had been completed before the accident. The gas company does not employ an engineer to design pipelines, write installation procedures, or inspect completed jobs.

The gas company owned only one small warehouse which was not large enough to be used as a testing laboratory. The company also did not have any engineers or personnel experienced in laboratory testing procedures. Therefore, tests on plastic pipe joints were not conducted by the company. The gas company said it purchased the "standard" compression coupling of the short-barrel (5-inch-long) type rather than the long-barrel (10-inch-long) type, mainly because it thought the 5-inch-long internal stiffeners purchased from Du Pont would fit only the short-barrel coupling.

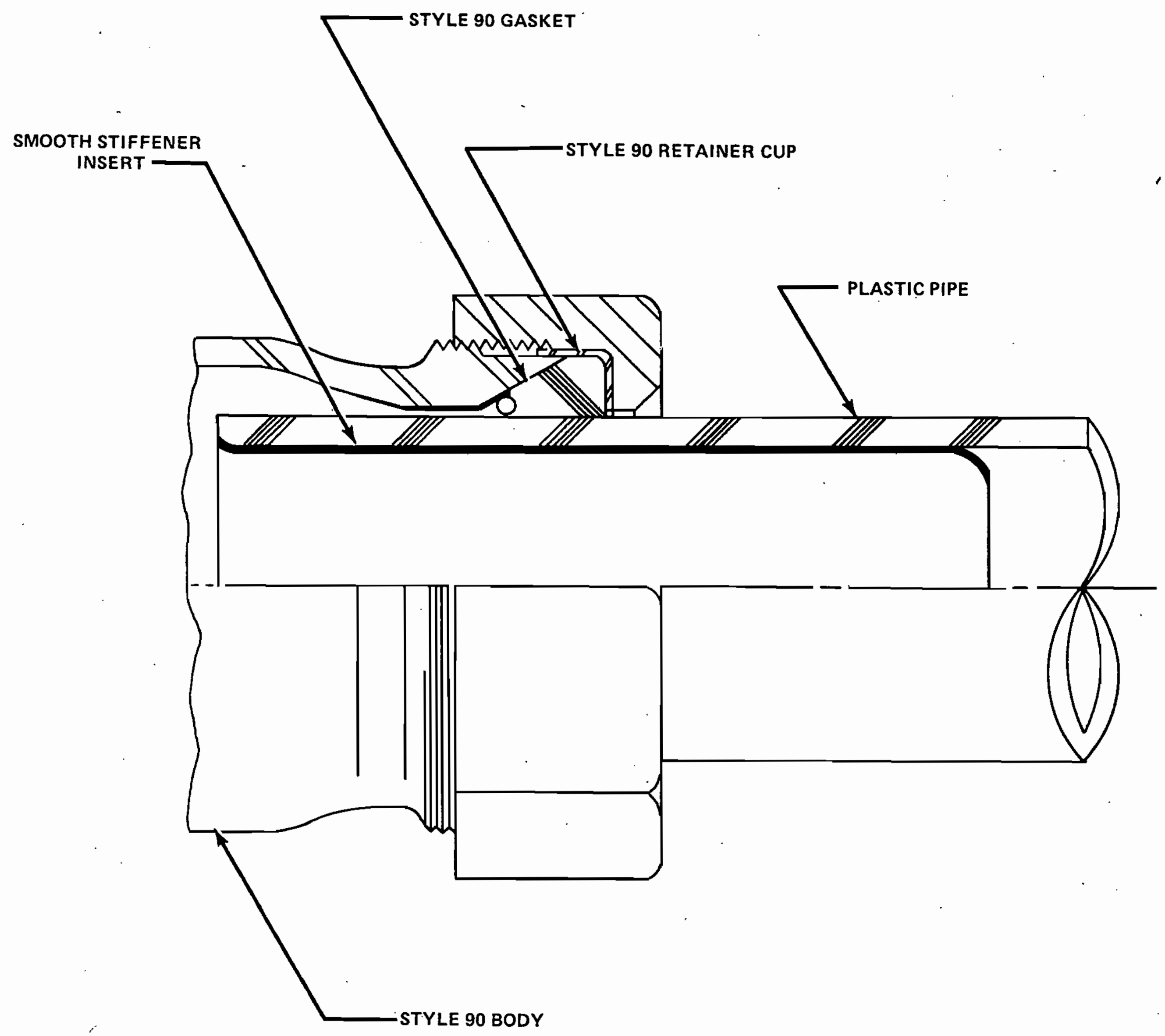


Figure 5. Dresser Style 90 coupling with smooth stiffener insert.

Dresser indicated that it furnished installation instructions for its Style 90 couplings in each box of fittings shipped, which provided torque recommendations and the following small warning note: "When pipe movement out of the coupling might occur, proper anchorage of the pipe must be provided." (See appendix A.) The gas company did not remember receiving this information. On October 23, 1973, Dresser sent a brochure to all gas companies on its mailing list, which it indicated should have included the Kansas Public Service Company, describing its new Style "700" POSI-HOLD transition coupling which Dresser claimed had "Safe, positive holding strength - Meets D.O.T. Regulation 192 in all respects." (See appendix B.) The gas company did not remember receiving this information at that time.

On January 10, 1976, 20 persons were killed in a pipeline explosion at a hotel in Fremont, Nebraska. Investigators found evidence that a similar 2-inch, polyethylene plastic main, 348 feet long, had pulled out of one of its standard compression couplings. On February 24, 1976, the Safety Board issued two urgent safety recommendations--P-76-3 and 4--to the Nebraska Natural Gas Company concerning this safety problem. On February 27, 1976, Du Pont sent an information letter to all gas companies that used its plastic pipe concerning thermal contraction and pullout from compression couplings. (See appendix C.) This was reportedly the first written information that the Kansas Public Service Company had received from the manufacturer concerning a problem in the use of standard compression couplings on polyethylene plastic.

The gas company heeded the letter's advice and asked Du Pont and Dresser field representatives in 1976 about how it could make installation procedures safer. The two manufacturers recommended that the gas company change its joining procedure; the Dresser representative recommended that the gas company purchase and use the Style "700" POSI-HOLD coupling for this application since it both seals and restrains the plastic pipe from pulling out. The gas company purchased POSI-HOLD installation equipment in 1976, and started using these fittings exclusively for tie-in purposes in February 1977.

On May 11, 1976, Du Pont furnished the gas company a technical report that included guidelines for gas distribution engineering concerning pull-out forces on joints in polyethylene pipe systems. (See appendix D.)

Since the accident, the gas company has been excavating locations where standard compression couplings might have been used to join inserted plastic pipe to steel pipe. The standard compression couplings found are replaced with the POSI-HOLD couplings.

## Meteorological Information

The weather was clear and there had been no precipitation in the previous 24 hours. The temperature at the time of the accident was 48° F; however, it had been colder before the accident. The wind was from the northwest at 1 mph.

## Fire

The fire was very intense and spread rapidly because it was fed by high-pressure gas at 30-psig pressure. It was calculated that approximately 200,000 cubic feet of gas was consumed by the fire.

Equipment from the nearby fire station could not drive past the fire and debris on 8th Street so firemen had to fight the fire from the rear of the building. When equipment from another fire station arrived a few minutes later, flames were already at the front of the building.

The fire in the basement of 745 Massachusetts Street was not gas-fed after the initial explosion. It burned in a small area in the west end of the building and then traveled up the elevator shaft to the second floor.

The gas pressure, as recorded on the pressure gauge in the gas company office at 733 Massachusetts Street, dropped to zero at 2:25 a.m., 20 minutes after the sectionalizing valves were closed. The fires were extinguished shortly thereafter.

## Medical and Pathological Information

Autopsy reports indicated that the cause of each death was heat and smoke inhalation and was not the direct result of the explosion. The injured bakery employee suffered burns to the right side of her body.

## Survival Aspects

The bodies of the two deceased were found in the rubble directly under where their bedrooms had been located on the second and third floors. The gas-fed fire was too intense for the firemen to approach the area and attempt a rescue.

Plaster from the ceiling fell on, but did not seriously injure, the two persons who had been asleep in the second-floor front apartment. They found the only second-floor stairway inaccessible because of the explosion and intense flames, so they used the fire escape ladder on the south side of the building. They were injured when they jumped from the lower rungs of the fire escape ladder and escaped through the debris in the street.

The person in the bakery sustained burns from the heat of the explosion. The front door of the bakery was locked but the burn victim was able to escape the flames by stepping over the window sill of the blown-out plate glass window.

## Tests and Research

As a result of this accident the Safety Board was issued a temporary restraining order which initially prevented the Pipeline Accident Division from obtaining the pipe and coupling involved in this accident for tests and analysis. However, the United States District Court for the District of Kansas then directed the pipeline operator to deliver the pipe and coupling to the Safety Board for tests and analysis by the National Bureau of Standards (NBS).

Because the size, type, and manufacturer of the plastic pipe involved in this accident were identical to the pipe involved in the Fremont accident, tensile tests similar to those that were made during the Fremont investigation were rerun. (See appendix E.) It was expected that these similar tests would determine how the two different makes of couplings involved in these two accidents affected the failures.

The test sections of plastic were cut into lengths of 18 inches each. The test sections were each bowed about 0.3 inch because the pipe had been coiled during manufacture, and had retained some of this initial "set." (See figure 6.)

The pipe wall thickness averaged about 0.23 inch, which was within the allowable dimensional tolerances specified in ASTM D 2513. In addition to being bowed, all of the sections of pipe were somewhat flattened and out-of-round; however, the average values were sufficient to indicate that the pipe probably met the required nominal dimension of 2.375 inches at the time of manufacture. For "roundable" plastic pipe, the specific tolerances for out-of-round are required to be met only at the point of manufacture. This variation in the pipe diameter was attributable in part to the fact that it had been coiled.

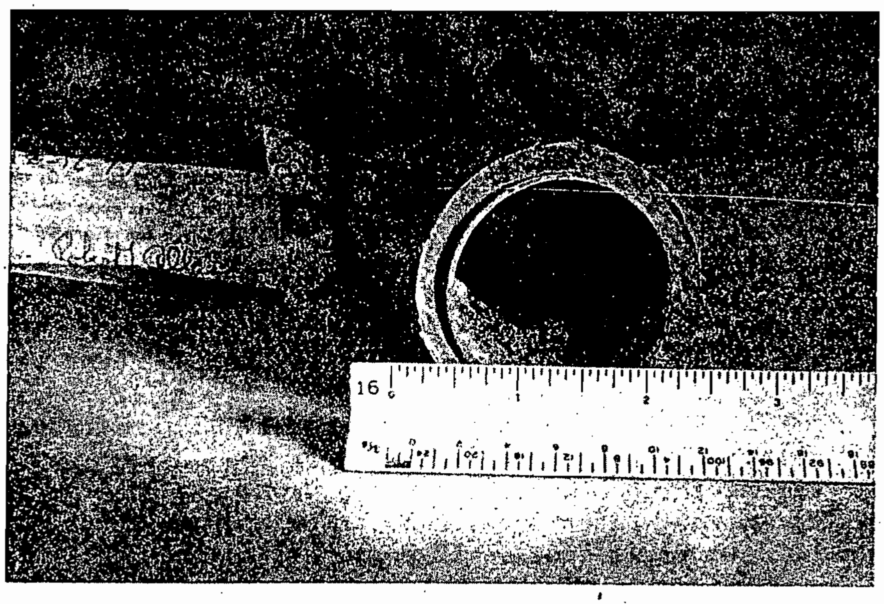

Figure 6. End view of plastic pipe showing bow, bias cut, and metal stiffener.

Outside diameter measurements were made on the section of pipe that had pulled out of the coupling at the accident site, in the area where the gasket and compression nut appeared to have been originally located. The difference between the minimum and maximum values measured was not as great as that in other sections of the pipe. Therefore, it appeared that the compressive forces exerted on the pipe when first installed had had the effect of rounding the pipe. However, it could not be determined whether these forces had resulted in any permanent compressive set in the plastic, primarily because of the tendency for the pipe to be out-of-round. A single test using a new gasket in the coupling from the accident site was conducted to determine if a new and resilient gasket could locate any compressive set in the plastic pipe from the accident site by a reduction in its resistance to pullout.

Microscopic examination of the pipe that failed revealed that eight of the marks found on the east side were due to the gouging of the plastic and the cold flow of the plastic toward the end of the pipe and probably were made by the metal gasket retaining ring. The two other marks resulted from indentation; one of these was probably made by the metal bead of the armored gasket.

The pipe was tri-colored where it had been inserted in the coupling. The end 0.8 inch was the original tan color, the next 0.65 inch was slightly discolored or mottled, and the rest of the pipe had a darker discoloration up to the point where it entered the casing and was again the original tan color. The discoloration was greatest on the top of the pipe and appeared to be strictly a surface phenomenon.

Pressurized and unpressurized tensile tests to determine pullout resistance were conducted. A similar Dresser Style 90 coupling was used for most of the tests with new gaskets installed for each test. However, tests were also conducted on the actual coupling and pipe that had failed in the Lawrence accident. The tests were conducted at pull rates of 0.2 in./min, 1 in./min, and 2 in./min with insertion lengths of 1 inch and 3 inches. All tests were made with the compression nut on the coupling torqued to 150 ft-lbs; the manufacturer recommends a minimum of 75 pounds of force on a 24-inch wrench for 2-inch, boltless, Style 90 couplings.

In the six unpressurized tensile tests, at room temperature, the average torque after 15 minutes relaxed from 150 ft-lbs to 118 ft-lbs--a 21.3 percent reduction. The Fremont tests had established, based on only two tests, that the greater the torque, the greater the pullout resistance. Because the 21.3-percent torque reduction in the Lawrence tests was greater than the 16.1-percent torque reduction found in the Fremont tests, it was expected that the pullout resistance would be less than the maximum pullout force of 700 pounds attained in the Fremont tests. However, in four of the unpressurized tensile tests with the Dresser coupling, the pullout resistance ranged from 780 pounds up to a maximum of 1,200 pounds.

In three unpressurized tensile tests involving a temperature reduction to 32° F, there was no significant reduction in pullout resistance which ranged from 625 pounds up to 1,245 pounds. However, in one of the tests where the pipe and coupling were cooled twice to 32° F over a 4-day period (ASTM specifications call for a 40-hour cooling period), the torque relaxed 41.4 percent--from 150 ft-lbs to 88 ft-lbs.

The previous Fremont investigation determined that for the joint strength to exceed the pipe strength, the pullout resistance probably would have to exceed 5,000 pounds. In all of the tests made on the pipe involved in the Lawrence accident, the joint failed by pullout well before the plastic pipe started to yield. The tensile forces or machine loadings required for pullout in all of the tests ranged from a minimum of 300 pounds to a maximum of 1,245 pounds.

In one of the tensile tests simulating actual field conditions, the nut on the coupling was torqued to 150 ft-lbs; however, the nut was not retorqued after 15 minutes as in the other tests and the coupling was immediately pressurized to 50 psig instead. In this test, using a new gasket in a coupling similar to the one from the accident site, the torque relaxed 46.7 percent--down to 80 ft-lbs--after 15 minutes. The pipe started to move with 515 pounds of force and it required 700 pounds of axial loading to keep the pipe moving at 2 in./min. After 1 minute, the pipe had moved 2 inches to the point where the gasket was near the end of the pipe. In the next 3/8 inch of movement, the load required for pullout increased 125 pounds--from 700 pounds to 825 pounds--and the pipe pulled out. (See curve B, figure 7.)

The coupling, its gasket, and the section of pipe that was attached to it at the time of the accident were tested in this same manner, but the results of this test were different. After 15 minutes, at an internal pressure loading of 50 psig, the original 150 ft-lbs of torque on the coupling's compression nut did not relax. The pipe started to move with 180 pounds of force and then continued to move for 2 inches under 175 pounds of axial loading. In the next 3/8 inch of movement, the load required for pullout increased 125 pounds--from 175 pounds to 300 pounds--and the pipe pulled out. (See curve A, figure 7.) The force diagram curve for the 1 1/2-year-old Fremont coupling and pipe was greater than this curve, and pullout occurred at 480 pounds. (See appendix E.).

Because a comparison of these test results showed that the pullout resistance for the coupling and pipe that had been joined together in the ground for 2 1/2 years decreased about two-thirds from the pullout resistance of the previously unjoined pipe and new coupling, two additional tests were conducted to determine if a "set" had taken place in either the pipe or the gasket, or both. The gasket, which was 0.75 inch in

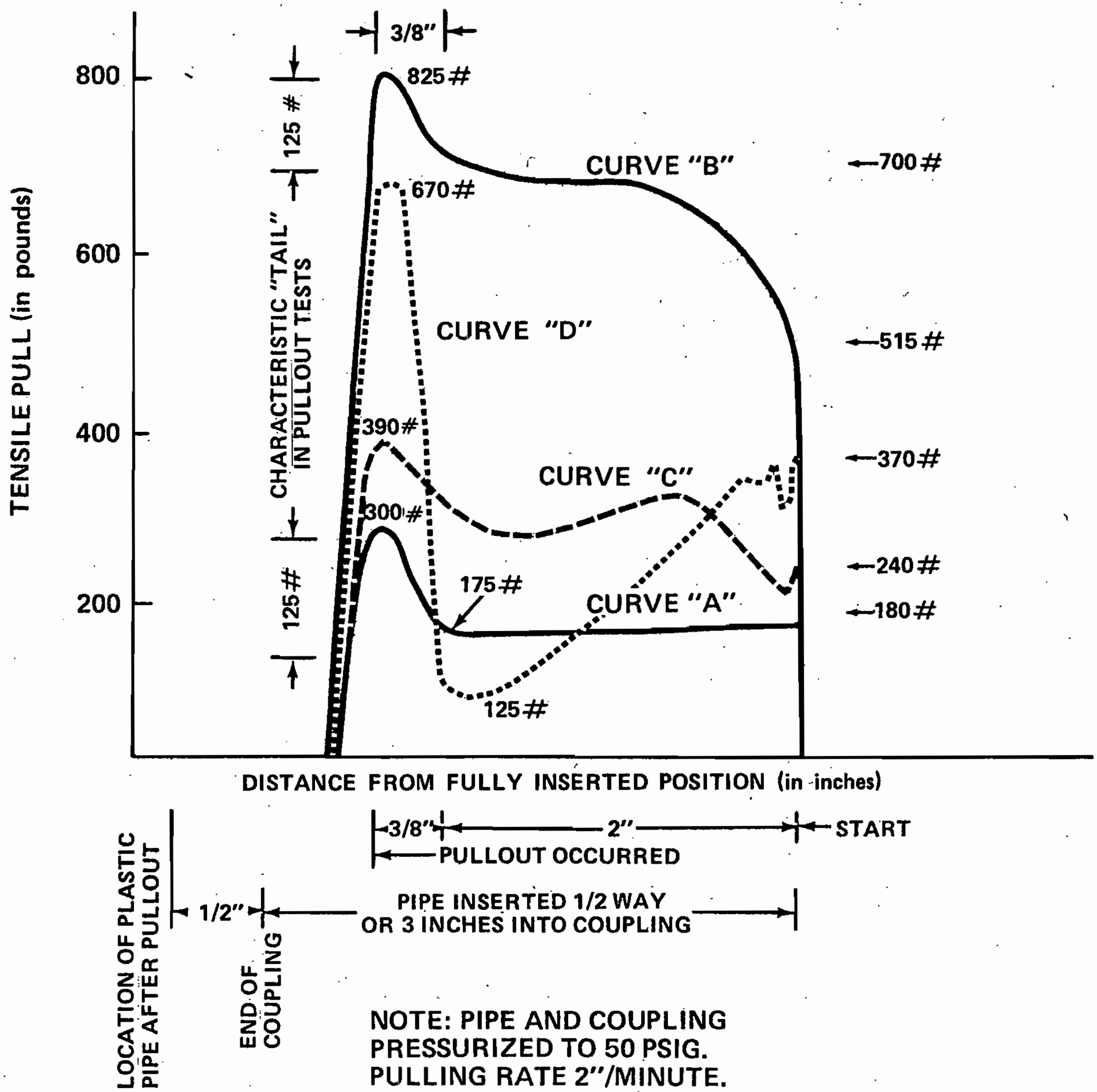


Figure 7. Diagram showing tensile forces at various pipe locations within couplings. Curve B--uncompressed pipe in new gasket. Curve A--previously compressed pipe and old gasket from accident site. Curve C--uncompressed pipe and old gasket in coupling from accident site. Curve D--previously compressed pipe and coupling from accident site with new gasket.

length, exhibited evidence of permanen t compressive deformation on its outer circumference at approximately 0.19 to 0.25 inch from the outer face, i.e., in the area where the gasket appeared to have been in contact with the outer rim of the coupling barrel. The first test using the 2 1/2-year-old coupling and gasket with a piece of previously uncompressed plastic pipe indicated that the tensile forces necessary to keep the pipe moving at 2 in./min ranged between 220 and 390 pounds. There was no torque relaxation from 150 ft-lbs in this test either. (See curve C, figure 7.)

In the second test using the same pipe and coupling, but with a new gasket, the 150-ft-lb torque did not relax after 15 minutes. The results of this test were erratic. The pipe started to move with about 370 pounds of force. At a certain point, the axial loading necessary to keep the pipe moving at 2 in./min dropped down to 125 pounds. About 3/4 inch from pullout, the tensile force increased by more than 500 pounds, to 670 pounds of axial loading for pullout. (See curve D, figure 7.)

The last test conducted to determine pullout resistance was a "destructive burst" test. A closed-end, 3-foot section of plastic pipe was inserted 3 inches within the compression coupling. A nitrogen pressure source was connected to the other closed end of the test coupling. The pipe was pressurized to 50 psig, and the pressure was maintained for 1 hour; the pressure then was increased 5 psig at 1 minute increments. At 150 psig, the pipe started to move in the coupling. Twenty minutes later, at 250-psig pressure, the plastic pipe pulled completely out of the coupling.

The thermal coefficient (C) of expansion (which is the same for contraction) for the pipe involved in the accident was tested to $8.9 \times 10^{-5}$ in./in./° F and $9.1 \times 10^{-5}$ in./in./° F, and averaged the $9 \times 10^{-5}$ in./in./° F which was Du Pont's published "C" value for its ALDYL "A" pipe. Using this average, the Safety Board calculated the contractive forces that would be developed in 400 feet of the 2-inch SDR 11 Du Pont ALDYL "A" polyethylene (PE-2306) plastic pipe under certain conditions. $C = 9 \times 10^{-5}$ in./in./° F = 1.08 in./100 ft/10° F; therefore, in 400 feet, contraction would be 0.432 inch per degree (F) of temperature change.

At an ambient air temperature of 72° F, the pipe length before insertion would be 400 ft 4 1/3 in. At an ambient ground temperature of 62° F, the pipe length, after insertion and being allowed to cool to ground temperature, would be 400 ft. During its first winter, assuming an average ambient ground temperature or gas temperature of 32° F, the pipe length, if not restrained by the couplings or service connections, would be 398 ft 11 in.

The thermal stress and maximum instantaneous force that could be developed using the above conditions are: $S = E \times C \times T$, wherein S=thermal stress; E=modulus elasticity, psi; C-coefficient of expansion in./in./° F, and T=temperature difference ° F. S = 145,000 x 0.00009 x 30, the thermal stress would be 391.5 psi. 2/ The maximum force that could be developed is F = S x A, wherein A=cross-sectional area of the pipe wall, sq. in. (A = 1.56), the force developed would be 391.5 x 1.56, or 611 pounds. If stress relation is taken into account as illustrated by the calculations in appendix D, the thermal force would be 0.44 of the instantaneous force of 611 pounds or 269 pounds.

At the 52° F measured ground temperature on December 15, 1977, the pipe length would have been 399 ft 7 2/3 in. The thermal stress would have been S = 123,000 x 0.00009 x 10 = 110.7 psi, and the force developed would have been F = 110.7 x 1.56 = 173 pounds. 3/ If the 0.44 factor for stress relaxation is taken into account, the reduced thermal force would be 76 pounds.

In addition to the estimated force from temperature change, there would be an additional force from gas pressure on the pipe end. The maximum force from gas pressure is 47 pounds, which is obtained by multiplying the system pressure (30 psig) times the cross-section area (1.56 sq. in.) of the wall of the pipe end exposed.

## Other Information

Storage of plastic pipe.--The lot number stenciled on the ALDYL "A" polyethylene pipe was T0307J33. It was established that the pipe had been shipped from the Du Pont Tulsa Plant on April 30, 1974, about 2 months after it was manufactured. The pipe was then stored in the small yard of the gas company warehouse without any covering or protection. The location of the 500-foot roll of 2-inch plastic pipe in the pipe stack could not be determined. However, it is probable that the roll was at the bottom of a stack because it was not installed in 1974. The unknown stacking height possibly could have caused some pipe out-of-roundness; however, storage outside for more than a year also could possibly have had some adverse effects on the plastic pipe. The new AGA Plastic Pipe Manual for Gas Service dated November 1977 states that: "As a rule of thumb, if the pipe is to be stored outdoors for more than 6 months in a pipe storage or holding area, it should be placed inside or covered to protect it from exposure to direct sunlight. In some localities, pipe that is stored in direct sunlight for longer periods, in both manufacturer's or customer's yards, should be tested to determine that it is still satisfactory." It was determined that, at some time, approximately 100 feet of pipe was cut from the roll because almost all of the pipe remaining on the roll was used in the 394-foot insertion, and because the pipe end that was inserted in the the coupling was more curved than the normally straight end of the pipe coil.

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2/ The 145,000 modulus of elasticity was obtained from Table II of appendix D.

3/ The 123,000 modulus was obtained from the curve from which Table II of appendix D was derived.

The plastic pipe that was removed for testing was "out-of-round" twice as much as was allowed in the manufacturing quality control program. This "egging" of the pipe probably occurred in the coiling operation shortly after it was extruded in the manufacturing process and was still warm or during the stacking operation. It also was noted in testing that when an 18-inch-long segment of plastic pipe was cooled, a more pronounced bow became evident in the pipe as if the "memory" in the plastic was trying to recoil the pipe into its original 5-foot-diameter coil. The combination of egging and bowing made it difficult to insert the 5-inch-long metal internal stiffener during tests unless it was pounded in. The installation guides indicate that the stiffener should not be pounded into the pipe.

Federal Regulations--In May 1974, when the plastic insertion was made, the following Parts of 49 CFR should have applied to the installation:

192.161(e) Anchors: Each underground pipeline that is connected to a relatively unyielding line or other fixed object must have enough flexibility to provide for possible movement, or it must have an anchor that will limit the movement of the pipeline.

192.273(a) Joining of materials other than by welding - General: The pipeline must be designed and installed so that each joint will sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.

192.273(c) General (continued): Each joint must be inspected to insure compliance with this subpart.

192.281(a) Joining of materials other than by welding - Plastic Pipe - General: Each plastic pipe joint must be made in accordance with written procedures that have been proven by destructive burst test to produce joints at least as strong as the pipe being joined.

* * * * *

192.281(e) Mechanical Joints: Each compression type mechanical joint on plastic pipe must comply with the following;

(1) The gasket material in the coupling must be compatible with the plastic.

(2) A rigid internal tubular stiffener other than a split tubular stiffner (sic) must be use in conjection (sic) with the coupling.

192.615 Emergency Plans: Each operator shall have written emergency procedures.

* * * * *

Notification of Accident--In December 1977, at the time of the accident, the following Federal regulation was the requirement for reporting the accident:

> 191.5 Telephonic notice of certain leaks. (a) At the earliest practicable movement following discovery, each operator shall give notice in accordance with paragraph (b) of this section of any leaks that--(1) caused a death or a personal injury requiring hospitalization;

* * * * *

In this particular instance, two persons were missing and presumed dead and three persons had been hospitalized. Other criteria, such as ignition and over $5,000 property damage, were also obvious in this accident. The gas company waited until its office, a few doors away from the accident site, opened for regular business hours, before placing the required notification of accident call. The Safety Board was not notified until more than 8 hours after the accident. This prevented the timely arrival of the Safety Board's pipeline safety specialist at the accident site.

Sealing of Compression Couplings on Polyethylene Pipe.--A report on the results of coupling tests by Dresser, "Comparison of Long-Term Sealing Characteristics of Compression Type Couplings on Steel and Polyethylene Pipe," concluded that: "...compression couplings of the type tested, where properly installed on supported Aldyl "A" pipe, will give a reliable seal equal throughout the lifetime of the system." (See appendix G.)

The coupling type used in these tests was the Style 38 coupling, which is a bolted compression coupling, and the extrapolation of the gasket pressure, in psi, on a 4-inch polyethylene pipe from the 10,000-hour test period to $10^6$ hours shows the remaining gasket pressure to be 63 percent of its original value. This remaining pressure is sufficient to give a reliable gas seal.

The same 4-inch polyethylene pipe and Style 38 coupling shown on figure 6 of appendix G has an initial gasket pressure of 1,260 psi. After 1 hour there was a 9-percent reduction in gasket pressure to 1,150 psi. After 10,000 hours (a little over 1 year) there was a 26 percent reduction in gasket pressure from its initial pressure to 930 psi.

There has been no similar testing of the gasket pressure of boltless Style 90 coupling on 2-inch polyethylene plastic pipe, but the reduction in gasket pressure and in pullout resistance is expected to be substantial.

## ANALYSIS

The test finding that the pullout resistance of plastic pipe in a standard compression coupling decreases with time is significant. It indicates that more accidents of this type could occur involving the thousands of feet of inserted polyethylene plastic pipes that have been installed since the early 1970's and connected with standard compression couplings. This "aging" phenomenon of joints was first evidenced in the Fremont tests where the pull resistance of the 1 1/2-year-old coupling and gasket from that accident site, when tested with new pipe, was observed to be less than that using a new coupling and gasket.

When the 2 1/2-year-old coupling and gasket from the Lawrence accident were tested with a previously uncompressed piece of plastic pipe, the results were similar to the Fremont test results, except that the final pullout load was 480 pounds in the Fremont test and only 390 pounds in the Lawrence test. However, in the Lawrence piping test the coupling was pressurized to 50 psig; this force acted on the 1.56 sq. in. (wall area) of the plastic pipe end and added 78 pounds of force, which although unrecorded would have assisted in pulling the pipe out of the coupling. Therefore, the results were about the same for the two different brands of standard compression couplings. Each had a significant reduction in pullout resistance after being in service for more than 1 year.

When the Lawrence coupling and the actual piece of pipe it was attached to at the time of the accident were tested, the results were even more significant. The plastic pipe started moving at 180 pounds and pullout occurred at 300 pounds (curve A in figure 7). This was approximately one-third the value of 825 pounds determined in the control test which was conducted with all new components (curve B in figure 7).

From the above, the Safety Board concludes that the coupling gasket and the plastic pipe each took on a "permanent set" over a period of time, although they looked nearly normal to visual examinations. The differences resulted in the erratic test results obtained when the two additional tests were conducted to determine if a "set" had taken place. In the test with the pipe and coupling from the accident site, but with a new gasket, the decrease in load from 370 pounds to 125 pounds probably indicated that the circumference of the plastic pipe was smallest where the gasket had compressed the pipe for a long time. The rapid increase from 125 pounds to 670 pounds occurred when the armor of the gasket dug into the end of the plastic pipe (curve D in figure 7).

In the test with the old gasket and coupling from the accident site, but with a previously uncompressed piece of plastic pipe (curve C in figure 7), the resistance to pullout was about one-half of the value obtained using previously uncompressed pipe and a new gasket and coupling (curve B in figure 7). This was probably because the gasket had taken a permanent set in the 2 1/2 years that it had been installed and did not adequately transfer the gasket loading pressure from the compression nut to the plastic pipe. Based on the tests conducted by Dresser on Style 38 bolted couplings on 4-inch polyethylene plastic pipe, a gasket relaxation of 26 percent occurred in a little over 1 year. It was thought that machining and design differences between the boltless and the bolted style couplings could account for some of the above differences. However, it should be noted that the Dresser tests were on gasket relaxation, but the NBS tests were on pullout resistance --two different tests.

Because the time constraint under the District Court order did not permit additional testing to conclusively determine the exact cause of the reduced pullout resistance of the 2 1/2-year-old joint, the Safety Board is recommending that the American Gas Association continue this testing program to determine the cause of the decrease in pullout resistance with time for joints made with standard compression couplings and polyethylene plastic pipe.

The emphasis in the gas industry is to torque standard boltless compression couplings as much as possible without damaging the pipe. Some tests have indicated that pullout resistance increases with additional torque. However, torque is a very poor criterion of pullout resistance with plastic pipe because the friction coefficient and cold flow of different plastics vary. More importantly, additional variables can be introduced in the manufacturing of couplings, such as machined roughness in the mating threads between the body and nut of the coupling, that can affect torque. This one example is the reason that Dresser will not guarantee its standard Style 90 coupling for anything more than zero pullout resistance.

It had been thought that there was an interaction between the polyethylene pipe and the rubber gasket of the coupling which affected the torque relaxation and subsequent pullout resistance. Although the unpressurized tensile tests showed a 21.3-percent torque relaxation in 15 minutes using new gaskets and previously uncompressed pipes, there was more than twice as much torque relaxation when the pipe and coupling was pressurized or cooled. However, the pullout resistance was not significantly different. Unfortunately, long term tests could not be conducted for this report. It is suspected that long term tests may have shown a relationship between torque relaxation and pullout resistance. The Safety Board concludes that there is a need for further study to determine the effects of time on both torque relaxation and pullout resistance.

The tests made on the pipe and coupling removed from the accident site established that torque relaxation alone had little effect on pullout resistance. This was illustrated when the pullout resistance measured 825 pounds in the pressurized pipe test (which had the 46.7-percent torque relaxation), whereas, in the test with the actual coupling and pipe that failed, the pullout resistance measured only 300 pounds even though there was no torque relaxation when the coupling was pressurized. (It did not have to be retorqued to achieve the required 150 ft-lbs.) Although it was surprising that a torque relaxation of 46.7 percent occurred in the first 15 minutes after the pipe was pressurized, it was a greater revelation that even if the coupling could be dug up and retorqued to 150 ft-lbs 2 1/2 years later, the pullout resistance would still be only one-third of the original value. (See figure 7.) Gas companies should realize that there is more to insuring a safe inserted plastic pipeline than just digging up standard compression couplings that have been in the ground for a few years and retorquing them to the manufacturer's recommended values. If an old joint has been excavated for inspection, some method of anchoring the pipe against pullout also should be provided in addition to retorquing even if it appears that the pipe has not pulled out at the time of inspection. Alternatively, an improved-design mechanical joint could be substituted for the original compression coupling.

In the destructive burst tests, the pipe started to move at 150-psig pressure; this pressure multiplied by the pipeline end area of 4.428 sq. in. gives an internal pullout force of 664 pounds. When the plastic pipe pulled out of the coupling at 250 psig, the internal pullout force, calculated likewise, would have been 1,107 pounds. The approximate 300-pound pullout difference between this destructive burst test and the tensile test results of 825 pounds indicates that these joint pullout values should not be used as absolute values in engineering calculations using thermal contraction forces.

It was expected that a temperature reduction might have an adverse effect on pullout resistance. However, this was not the case in the three unpressurized tensile tests where the temperature was lowered to 32° F, even though the torque relaxation of 41.4 percent was similar to the 46.7 percent of the pressurized pullout tests. These tests indicated that temperature reduction and torque relaxation alone are not the primary factors in compression coupling joining failures. (However, temperature reduction is still the primary factor in generating pullout stresses in the plastic pipe.)

In all of the tests on the plastic pipe, there was a characteristic "tail" shown on the testing charts where the axial loading increased by approximately 125 pounds in the last 3/8 inch of travel before pullout occurred. The same phenomenon occurred when testing the pipe in the Fremont accident: The pipe pulled out in extreme winter weather until the end of the pipe was near the gasket where it stopped, presumably because 125 pounds of resistance was added at this point from an interaction between the armor of the gasket, the pipe, and the flared stiffener at the end of the plastic pipe. It was not the purpose of these tests to determine what effect the bias sawcut had on the pullout resistance either; however, logically it had to be detrimental because it reduced the effective insertion length by more than 10 percent.

From the location of the movement marks on the pipe and the two discoloration ring marks near the end of the plastic pipe, the Safety Board concludes that the pipe moved slightly either shortly after installation or during the 1974-75 winter. The pipe then moved about 1 inch more during the 1975-76 winter in increments of about 3/16 inch. In the winter of 1976-77, the pipe probably would have pulled completely out of the coupling, but when the armored edge of the gasket approached the end of the pipe, the pullout resistance increased by approximately 125 pounds and the pipe stopped moving. By the next winter, however, the plastic pipe or the rubber gasket had relaxed so that there would not be a second 125-pound buildup, as established by the Fremont report, and the plastic pipe pulled out completely.

The 1 to 2 hours that the plastic pipe was allowed to equalize to the ground temperature of 62° F during installation was not adequate. The ASTM specifications for the test specimens of this thickness calls for a 40-hour cooling period. Therefore, the temperature differential probably exceeded 30° F during the first season, and the contractive force generated probably exceeded the calculated maximum of 611 pounds.

Referring to curve B of figure 7 and the calculations for a 30° F temperature differential which simulates the installation conditions, the pipe would have pulled partly out of the coupling, shortly after installation or during the first winter and then stopped because only 611 pounds of tensile force was generated by the thermal stress (plus 47 pounds of pullout force created by the 30-psig gas pressure). From the marks on the plastic pipe it is believed that more movement took place the following winter. In the 1976-1977 winter the pipe pulled until the end of the pipe approached the armored gasket and then stopped when the characteristic 125 pounds of additional pullout resistance was encountered.

Assuming that there was no loss in the initial modulus because one end of the pipe was free to move within the coupling, or that the initial installation temperature was higher, the force developed on the day of the accident with only a 10° F temperature differential would have been 173 pounds (plus 47 pounds of pullout force created by the 30-psig gas pressure); this would have been adequate to pull the pipe out of the coupling because the plastic pipe had been allowed to relax for a year (curve A of figure 7.) It is suspected that the actual modulus was probably somewhere between the initial modulus (if the pipe was completely free to move within the coupling) and the theoretical apparent modulus (if the pipe was completely restrained by the two couplings and stretched during contraction).

If the plastic pipe had been completely restrained by the two couplings instead of being allowed to move in one coupling, there would have been stress relaxation, and the calculated thermal forces would have been between 76 to 269 pounds. If this were the case, the workmanship on the joint would be questioned as to whether or not the 150 ft-lbs of torque was applied during installation.

As shown in the Fremont tests, there is a relaxation in either the plastic or the gasket over a summer period so that the 125 pounds characteristic resistance forces is not built up a second time when the gasket is already near the end of the plastic pipe. (See appendix E.)

Although the above theory is supported by the calculations and tests, there are undoubtedly other factors, such as the possible effect of torque relaxation, that may also have assisted in encouraging this pullout (the internal pressure of 30 psig would also provide 47 pounds of pullout force.) The fact remains, however, that pullout did occur and that the limited number of NBS tests indicated that there may be a reduction of pullout resistance with time. If this trend is common to other polyethylene pipe and compression coupling joints that have been installed generally for the first time in the last decade, it is a serious safety problem.

Long term tests by Dresser with another type of coupling (Style 38) on plastic pipe indicated that although there was a reduction of gasket pressure with time, there was no danger of the gasket failing to seal against gas pressure. The Style 38 coupling, like the Style 90 coupling is recommended by Dresser for sealing against gas pressure only -- its pullout resistance is rated as zero pounds by Dresser.

In the Fremont report, the Safety Board recommended that the U.S. Department of Transportation, "Determine if there are locations or circumstances where standard compression couplings are unsafe, and amend 49 CFR 192 accordingly to prohibit their use for such applications. (P-76-45)" In a response to this recommendation dated March 2, 1977, the Materials Transportation Bureau 4/ stated: "We believe that a properly installed compression coupling can be utilized in virtually all locations or circumstances. At this time, we have no evidence to indicate that the use of compression couplings must be predicated on the location or other circumstances. Furthermore, there are many situations where the flexibility offered by the use of a mechanical coupling is an added safety factor. A special study to define where mechanical joints should or should not be used will require considerable staff time which, in our opinion, would result in a comparatively minor improvement in safety."

The Safety Board does not agree with DOT's opinion. The Board suspects that DOT's reporting forms do not show the actual number of accidents of this type that happen every year. The Safety Board hears about other pullout accidents each year that do not result in fatalities but are still hazardous. This accident, however, is further evidence to illustrate to DOT that this type of pipeline accident can and will happen again unless DOT acts to amend its pipeline regulations or the gas industry continues to make the necessary changes on its own initiative.

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4/ The Materials Transportation Bureau of the U.S. Department of Transportation (DOT) is the Bureau that directs the activities of the Office of Pipeline Safety Operations (OPSO).

The Safety Board is not of the same opinion as DOT that this is a "minor" safety problem. The Board believes this to be a major safety problem for the following reasons:

(1) The Board tests on the Lawrence and Fremont joints that had been installed for 2 1/2 years and 1 1/2 years, respectively, indicated that there is a reduction of pullout resistance with time.

(2) These plastic insertions are generally installed in downtown streets where the safer, open-cut installations cannot be considered for economic and other reasons.

(3) In this type of accident, the plastic pipe pulls completely out of the compression coupling, thereby venting large amounts of gas.

(4) The gas is generally under high pressure because this enables the use of smaller diameter plastic pipe in the insertion.

(5) The failure always occurs in the winter when thermal contraction is the greatest.

(6) The ground is always frozen or solidly paved, or both, up to building foundations in these downtown areas so that the large amounts of high-pressure gas released has to migrate to nearby foundations and into buildings.

Based on the above factors the Safety Board concludes that standard compression couplings with smooth stiffeners used on plastic main inserts more than 100 feet long are unsafe unless the pipeline is securely anchored. The Safety Board also continues to believe that a standard compression coupling that is capable of pullout should not be installed at locations such as this--in a narrow paved alley within 5 feet of a building foundation wall. Until this problem is eliminated, accidents such as these could happen again anywhere in the northern United States with similar tragic consequences.

Part of the problem in Lawrence was that the small gas company did not have any engineers or enough technically trained personnel to understand and apply the various Federal code provisions to this coupling installation. This is a problem with many small gas companies and is not especially unique to the one in Lawrence. Small gas companies seemingly cannot afford to hire an adequate number of engineers or highly qualified technicians, and there are not enough large gas companies to train the number of technicians required by the industry, as shown by the statistics on the following table.

Number of Distribution Companies by Size

| Number | Percent of Total | Number of Meters |
|---|---|---|
| 760 | 49 | Less than 1,000 meters |
| 540 | 35 | Between 1,000 and 10,000 |
| 160 | 10 | Between 10,000 and 100,000 |
| 90 | 6 | Over 100,000 |
| 1,550 | Total 100 | |

The Kansas Public Service Company, Inc., with its 12,000 services (there is generally one, and sometimes more, meters for each service) is by industry standards considered a small gas company, but is actually ranked somewhere in the upper 16 percent of the gas companies when taking number of meters as a size determinant. This would indicate that 84 percent of the gas companies in the country are smaller than the "small" Kansas Public Service Company, Inc., and presumably may have less technical capabilities if number of technical personnel is proportional to size of company.

There have been no studies to determine if small gas companies with their presumably limited financial and technical resources can be operated safely. The Safety Board is not a regulatory agency and consequently gas company operators are not required by law to supply statistics on the safety of their system and the number of people they have operating it. However, based on its investigation of fatal accidents, the Board is considering that there may be a link between the size and resources of the company and the safety of the system.

Although the gas superintendents in charge of this work had ample experience in the gas industry, they only recently were introduced to the characteristics of plastic pipe. They relied heavily on the advice of the sales representatives of the manufacturers. The sales representatives do not necessarily have to be engineers, but even if they were and knew their product well, it is doubtful if they would have the background, expertise, or inclination to recommend another manufacturer's product that would unquestionably be compatible for use with their product. This is another reason for the gas company to have its own in-house technical expertise.

The Dresser installation instructions for Style 90 couplings, which presumably were shipped with the couplings, stated that: " -- proper anchorage of the pipe must be provided." However, the field personnel receiving the notice either did not know that 49 CFR 192.161(e) regarding anchors existed, or, without an engineer to assist them, did not have the technical expertise necessary to recognize the need for anchors on plastic pipe and to design them and install them.

The Safety Board concludes that stronger warnings should be issued with each box of fittings. The standard Dresser Style 90 instructions could, for example, read:

> WARNING! THIS STANDARD 2-INCH STYLE 90 COUPLING IS NOT RECOMMENDED FOR ANCHORING STEEL OR PLASTIC PIPE. THE USE OF A SPECIAL PLASTIC PIPE LOCK INSERT STYLE 90 OR "700" POSI-HOLD TRANSITION COUPLING IS RECOMMENDED FOR JOINING INSERTED PLASTIC PIPELINES MORE THAN 75 FEET IN LENGTH. CONSULT WITH YOUR ENGINEERING DEPARTMENT OR YOUR DRESSER REPRESENTATIVE IF YOU HAVE ANY QUESTIONS.

The Du Pont stiffener box could also contain a similar warning for inserted lengths of plastic pipe more than 75 feet long. Of course, a recommendation that purchasers see their manufacturer's technical representatives if they have any question or need training should be volunteered by their suppliers.

Lacking a pipeline engineer or written installation procedures based on consulting engineer's design for the plastic pipe, the gas company also did not comply with 49 CFR 192.273(a), which requires that each joint be designed and installed to sustain the longitudinal pullout forces caused by contraction or expansion.

Title 49 CFR 192.281(a) requires that a joint be made in accordance with written procedures that have been proven by destructive burst testing to produce joints at least as strong as the pipe being joined. The NBS destructive burst test proved that the joint was not as strong as the plastic pipe being joined. The gas company did not have any testing facilities but if the gas company had tested the joint at an outside testing laboratory, it would have known that the Dresser Style 90 coupling with a Du Pont smooth stiffener would not be as strong as the pipe being joined. The Dresser "700" POSI-HOLD coupling, which the gas company adopted as a standard in 1977, was available at the time of this installation, and, according to the manufacturer's tests, would have been as strong as the plastic pipe being joined.

The manufacturer also has more recently redesigned its Style 90 coupling with a serrated, "locking type" stiffener which, according to some of the manufacturer's tests, has held this particular brand plastic pipe to failure. However, to insure safety, an operator should verify these test results by tests of its own, receive certified copies of test results by manufacturers, or document the witnessing of tests by independent laboratories.

If the gas company had had written installation procedures, as required by Federal regulations, the worker making the joint would have have had additional training and a reference guide as to how to make a correct installation and probably would not have hurried the installation. He would have allowed the inserted plastic a certain specified minimum time to relax and cool to the ground temperature before the joint was made. He would have had time to walk the 400 feet to where the other tie-in had just been made and obtain the pipe cutters to make a square cut as recommended by the pipe manufacturer.

It could not be determined precisely what effect the 1/4-inch bias saw cut and the short 2-hour temperature stabilization time had on the installation, but it was certainly detrimental to the integrity of the south joint. However, the location of the two end services probably also affected the pullout resistance. The service takeoff 2 feet from the north coupling that did not pull out was possibly an adequate anchor, but the service takeoff 162 feet from the south coupling that pulled out probably had a negligible anchoring effect.

If the joint had been inspected in accordance with 49 CFR 192.273(c) the inspector might have discovered these shortcomings. More importantly, the Safety Board's tests have revealed that a torque relaxation of almost 50 percent occurs at the compression nut when new plastic pipe and gaskets are installed and after the pipeline has been pressurized. The written procedures could have required an inspector to check on the tightness of the compression nut. The 2-inch coupling could have been retorqued by using the 24-inch pipe wrenches recommended by the manufacturers or a torque wrench as used by some gas companies. Some gas companies or their inspectors might consider tightening a nut on a "hot" gas main a dangerous activity. A gas company could use some other type of mechanical joint if it believed that the standard 2-inch compression coupling joint was too fragile to be worked on by 24-inch pipe wrenches or torque wrenches.

The gas company conformed to 49 CFR 192.281(e)(1) and (2) in that it ordered a coupling that had a rubber gasket that was compatible to the plastic pipe being used and used a solid stiffener as also required by code. The Safety Board concluded in the Fremont accident report that the code requirement of a solid stiffener was not enough and recommended to OPSO "that stiffeners be designed to be compatible with compression couplings so that pipes cannot pull out of the coupling". 5/

The standard Dresser Style 90 will not "hold" the plastic pipe to failure as shown by the tests, mainly because it was never designed for that purpose. The new and proprietary Dresser Style 90 has an internal stiffener that has been shown by the Dresser tests to hold this type of polyethylene pipe to failure. This is mainly due to the fact that the serrated stiffener used inside the plastic was designed as an integral part of the coupling to be compatible with the redesigned coupling body. (See appendix F.) Dresser's "700" POSI-HOLD coupling

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5/ Safety Recommendation P-76-44, "Pipeline Accident Report -- Nebraska Natural Gas Company, Pathfinder Hotel Explosion and Fire Fremont, Nebraska, January 10, 1976."

also has an internal stiffener that has been designed for this particular type of transition joint and it too, according to Dresser, will hold this kind of plastic pipe to failure.

With stiffeners that are compatible with couplings which are available from Dresser and other manufacturers, it is inconceivable why any gas company would use a standard compression coupling from one manufacturer and an internal stiffener from another manufacturer for use on plastic pipe without thoroughly testing the combination for compatability.

Du Pont's technical report mailed on May 11, 1976, indicated that a 2-inch, 400-foot-long pipeline could be shortened by 4.32 inches by a 10° F temperature change and by 12.96 inches by a 30° F temperature change. Either of these contractions would be sufficient to pull the plastic pipe all of the way out of a short-barrel compression coupling. However, without an engineer to interpret the technical data in the letter and heed the warning that there might have been potentially dangerous installations made in the past, the gas company did not attempt any corrective action or attempt a review of this installation which had been made almost a year earlier.

One of the first gasmen called to the scene knew where the two sectionalizing valves in 8th Street were located and closed them. Even though the gas shutdown was effective in this instance, it might not have been if one of the other three gasmen listed in the telephone book had been called first and did not know the valving system. The gasmen did not have system maps showing emergency valve locations. The gas company should have this information recorded so that emergency response personnel will not have to rely solely on their memory. Emergency shutoff valves should be designated, and a locating means provided to all personnel on emergency call status.

The gas company also did not have a written emergency plan as required by 49 CFR 192.615. Although the potential consequences did not occur in this accident because the sectionalizing valves were shut off rapidly and stopped the migration of gas to other buildings, an emergency plan in future accidents of this magnitude might be essential for public safety. Not only did the gas company fail to evacuate nearby buildings and warn bystanders of the consequences of further explosions, but they also did not use CGI's to check reports of gas odors until later in the day. A written emergency plan would have contained procedures for emergency response personnel to have and use CGI's and evacuate persons if, in fact, there were gas indications in these nearby buildings.

A written emergency plan should also contain the telephone number and response time for calling OPSO to report an accident. The 8-hour delay in reporting the accident was partially caused by waiting for business offices to open before the call was made. The OPSO emergency number is a 24-hour number and is answered at all hours by someone trained to evaluate the seriousness of the accident. In an accident of this magnitude a delay of no more than 2 hours would be expected.

## CONCLUSIONS

### Findings

1. Beginning shortly after its installation, and during the three winters, thermal contraction caused one end of the polyethylene plastic main to contract eight times and eventually its length was shortened by 3 1/2 inches.

2. The pipeline had not been designed or constructed so that the tie-in compression coupling could contain the longitudinal forces created by thermal contraction of the plastic pipe within its 3-inch steel casing as required by 49 CFR 192.273(a).

3. The plastic pipe had not been anchored to prevent it from pulling out of the coupling as required by 49 CFR 192.161(e).

4. The compression coupling and smooth steel stiffeners were manufactured by different companies and although they individually met code requirements, the resulting combination produced a joint that was weaker than the plastic pipe that was being joined and therefore the joint was in violation of 49 CFR 192.281(a).

5. The plastic pipe joint was not made in accordance with written procedures that had been proven by destructive burst tests to produce a joint that was as strong as the pipe being joined, as required by 49 CFR 192.281(a).

6. When the contracting pipe pulled out of the compression coupling, the leaking gas was sealed by a concrete alley and migrated into the building foundation 5 feet away.

7. The pipe was not installed in accordance with the manufacturer's recommendation to use special plastic pipe cutters. The end of the pipe cut squarely using the special pipe cutters did not pull out, whereas the end of the pipe cut on a bias using a hacksaw did pull out.

8. The gas company did not have an inspector to assure that the joint was properly made and complied with the code, as required by 49 CFR 192.273(c).

9. When the pipe and coupling were pressurized, the torque relaxed 46.7 percent. An inspector could have directed the retorquing of the coupling nut to 100 percent, 15 to 30 minutes after the makeup of the coupling.

10. Test results indicated that torque relaxation, internal pressure, temperature reduction, or pull rate were not the most significant factors in the pullout resistance of the pipe from the compression coupling. Pullout occurred in each of the above tests which proved that the joint was not as strong as the plastic pipe that was being joined.

11. Testing indicated a reduced pullout resistance by approximately two-thirds from 825 pounds to 300 pounds in the 2 1/2-year-old test specimens.

12. In all of the tensile tests there was an increase in axial loading of approximately 125 pounds in the last 3/8 inch of travel before pullout occurred. This "tail phenomenon" was first reported by the Safety Board in its Fremont, Nebraska, pipeline accident report. This 125-pound increase is due to the flared stiffener and is the reason the plastic pipe pulls almost all the way out of the coupling during extremely cold weather. After being allowed to relax over the next summer, the plastic will no longer require the 125-pound additional force for pullout and can pull out of the coupling the following winter when the soil temperature again drops below the installation temperature by 10° F or more.

13. There was an unnecessary 8-hour delay in reporting this accident which was partially caused by waiting for business offices to open before the call was made.

14. The gas company in Lawrence did not have any engineers or enough technically trained personnel to understand and apply the various Federal code provisions to this coupling installation.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the gas company to properly design, install, test, inspect, and anchor the installation of a 394-foot-long polyethylene plastic gas main that had been inserted in a casing and connected to a steel gas main with a compression coupling. The 2 1/2-year-old unrestrained plastic gas main contracted 3 1/2 inches because of cold temperatures and pulled out of the compression coupling, the resistance of which had decreased with age.

## RECOMMENDATIONS

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

--to the Kansas Public Service Company, Inc:

"Complete the review of its plastic pipe systems before the 1978-79 winter season for other unanchored insertions more than 100 feet long, and rectify any potentially hazardous conditions found. (Class II, Priority Action)(P-78-25)

"Require an engineer or engineering consultant firm to review the design of its plastic pipeline system, including the design of anchors, so there are safeguards to prevent pullout at the mechanical joint for each pipe size and insertion length. (Class II, Priority Action)(P-78-26)

"Conduct destructive burst tests on each type of joint by which a plastic pipeline is connected to insure that the joint is as strong as the pipe being joined. (Class II, Priority Action)(P-78-27)

"Write installation procedures on how to make up each type of plastic pipe joint based on tests that have proven that the joint is as strong as the pipe being joined, and test employees on compliance and proficiency. (Class II, Priority Action)(P-78-28)

"Designate emergency shutoff valves on system maps and provide these maps to personnel on emergency call status. (Class II, Priority Action)(P-78-29)

"Issue an emergency plan that conforms to 49 CFR 192.615 and train emergency response personnel to insure that they are knowledgable of the emergency procedures, including the evacuation procedures and the emergency shutdown of the system. (Class II, Priority Action)(P-78-30)

"Train an installation inspector on the various code provisions and have him inspect each joint for code compliance. The time required for temperature stabilization of inserted plastic pipe and the torque requirements of compression couplings should especially be inspected. (Class III, Longer Term Action)(P-78-31)

"Include in its emergency plans the after-hours telephone numbers of the various agencies to which accidents must be reported, and instruct emergency response personnel to notify the appropriate officials at the earliest possible opportunity after hazards to life and property have been eliminated. (Class II, Priority Action)(P-78-32)"

--to the Materials Transportation Bureau of the U.S. Department of Transportation:

"Reconsider its responses to safety recommendations P-76-44 and P-76-45 in light of this and other accidents that have occurred with plastic pipe and 'standard' compression couplings since 1977. (Class I, Urgent Action) (P-78-33)"

--to the American Gas Association:

"Conduct tests to determine the effect of time on the pullout resistance of standard compression couplings and polyethylene plastic pipe. (Class III, Longer Term Action)(P-78-34)

"Conduct tests on the more common types of mechanical joints used on plastic pipe. Publish the results of these tests to member companies along with the recommendations of the manufacturers regarding whether the joint should be used for gastightness only or also for pullout resistance. (Class III, Longer Term Action) (P-78-35)

"Conduct tests on the more common internal stiffeners used to reinforce plastic pipe. Determine what style of compression coupling is compatible with each stiffener. (Class III, Longer Term Action)(P-78-36)

"Determine the effect of polymer aging, outdoor exposure, and stacking of coiled plastic pipe on its ultimate use. Specify to the natural gas industry what tests should be conducted on the pipe to prove its integrity if excessive storage is found to be detrimental. (Class III, Longer Term Action)(P-78-37)"

--to the Dresser Manufacturing Company:

"Enclose strongly worded warning literature in each box of Style 90 couplings shipped indicating that this standard compression coupling is NOT recommended for connecting long lengths of inserted plastic pipes or the anchoring of plastic pipe. (Class II, Priority Action)(P-78-38)

"Provide test data to the American Gas Association and make recommendations to them as to what the safe application should be for each fitting that Dresser manufactures to join plastic pipe. (Class III, Longer Term Action)(P-78-39)

"Investigate the possibility of setting up a testing laboratory where customers can send in samples of plastic pipe and inserts to be tested with couplings and then be provided certified results of the tests and application recommendations. (Class III, Longer Term Action)(P-78-40)"

--to the E.I. du Pont de Nemours & Company:

> "Enclose warning literature and installation instructions in each carton of internal stiffeners indicating that the stiffeners do not provide any anchoring properties, and that it is the gas company's responsibility to properly design and install plastic pipelines in accordance with the applicable provisions of 49 CFR 192. (Class II, Priority Action)(P-78-41)
>
> "Work with the American Gas Association and the Society of the Plastic Industry, Inc., to conduct tests to determine the effect of time on the pullout resistance of polyethylene plastic pipe and standard compression couplings. (Class III, Longer Term Action)(P-78-42)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

/s/ ELWOOD T. DRIVER
Member

July 5, 1978

# APPENDIX A

## Installation Instructions for Dresser Style 65, 88, and 90 Couplings & Fittings.

**DRESSER** **INSTALLATION INSTRUCTIONS for STYLE 65, 88 and 90 COUPLINGS & FITTINGS**

1. Clean pipe surface for a distance of four inches from the pipe ends (for 10" long bodies—seven inches).
2. Loosen nuts about one-quarter turn and make sure gasket is loose.
3. Apply soap-water to gaskets (alcohol may be added in freezing weather).
4. Stab pipe ends into coupling or fitting. Center coupling over joint.
5. Tighten nuts. See table for wrench size and required pull.

| TORQUE AND RECOMMENDED WRENCH SIZES | Nominal Steel Pipe Size (I.D.) | Recommended Wrench Size |
|---|---|---|
| For use with Dresser Compression Fittings | 3/8" | 10" |
| | 1/2" | 14" |
| | 3/4" | 14" |
| | 1" | 18" |
| | 1-1/4" | 18" |
| | 1-1/2" | 24" |
| | 2" | 24" |

In each case, a pull of about 75 pounds should be applied to the end of the wrench.

The Style 65 & Style 88 couplings and fittings are recommended for maximum line operating temperature of 150°F., Style 90–212°F.

When fixed lock insert is used, see installation instructions on reverse side.

When pipe movement out of the coupling or fitting might occur, proper anchorage of the pipe must be provided.

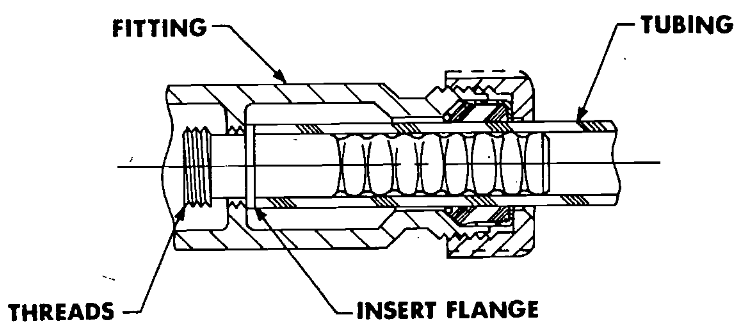
0001–0046–999 1–74

dmd DRESSER
DRESSER MANUFACTURING DIVISION
DRESSER INDUSTRIES, INC.
Bradford, Pennsylvania 16701

**INSTALLATION INSTRUCTIONS**

FIXED LOCK INSERT ASSEMBLED IN FITTING

Stab tubing until tubing comes in contact with flange on insert, and tighten nut to recommended torque.




NOTE: Fixed lock insert may be changed to accommodate various tubing wall thicknesses. To remove insert, unscrew counterclockwise and replace with proper size (O.D. size and wall thickness marked on insert).

DO NOT LUBRICATE GASKET.

See applicable installation instructions for fitting installed.

In event zinc die-cast insert is used with weld-end adapter, insert and gasket must be removed prior to welding.

1–73

APPENDIX B

Form letter and excerpt of brochure from Dresser Manufacturing Company describing Dresser "700" POSI-HOLD Transition Couplings.

dmd DRESSER

DRESSER MANUFACTURING DIVISION

DRESSER INDUSTRIES, INC.

BRADFORD, PENNSYLVANIA 16701

TEL: (814) 368-3131
TWX: 510-695-5171

Thank you for your inquiry on the new Dresser "700" POSI-HOLD Transition Couplings. A brochure describing the products is attached.

With the increasing use of main-size polyethylene pipe by gas utilities, the need for a gas-tight, "lock" type connection between existing steel pipe and the plastic pipe was evident. The Dresser "700" POSI-HOLD Transition Couplings fill this need -- with easy, fast installation and excellent resistance to pull-out of connected pipes.

Many gas companies have also found Dresser Transition Couplings the best answer for joining polyethylene pipe to polyethylene pipe, as well. The gas-tight security of the Dresser joint is welcomed, particularly where unfavorable operating conditions might lead to unsatisfactory or expensive fusion of the plastic pipe joint.

"700" POSI-HOLD Transition Couplings complement the already established line of POSI-HOLD couplings and fittings for steel pipe, which already have several years of proved field experience and excellent performance. The same installation tools are used for installing both the "700" POSI-HOLD and the "700" POSI-HOLD Transition products, providing cost-saving standardization of practices for all your steel and plastic mains.

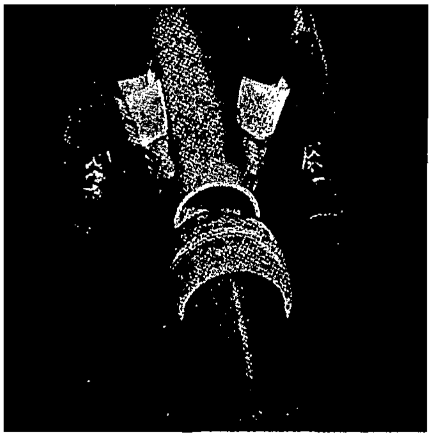
Your Dresser field representative will be happy to demonstrate the advantages of the complete Dresser POSI-HOLD system for pipe joining at your convenience. Or, if we can be of further service, please let us know.

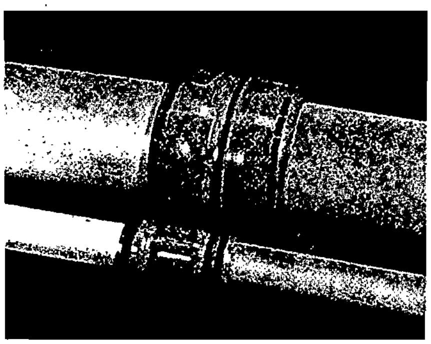
Yours very truly,

DRESSER MANUFACTURING DIVISION

Herman M. Pickles
Market Manager
Gas Industry Sales

# *New, Easier, Safer way to connect polyethylene pipe to existing steel pipe*





Dresser "700" POSI-HOLD TRANSITION Couplings can also be utilized to connect polyethylene pipe to polyethylene pipe.

Now you can make the transition from steel pipe to polyethylene pipe, (or polyethylene pipe to polyethylene pipe), safely and economically. The new Dresser "700" POSI-HOLD® TRANSITION Couplings provide a line of specially designed products for joining 1¼" IPS, 2" IPS, 4" IPS and 6" IPS pipe. These products meet all the requirements of D. O. T. Regulation #192, since the joint will restrain pull-out until the pipe fails outside the coupling or fitting. Special gaskets "lock" the coupling and the pipe together, preventing pull-out.

The new TRANSITION couplings utilize the time and field-proved advantages and gas-tight sealing of regular Dresser "700" POSI-HOLD couplings. The same installation equipment may be used as for the regular POSI-HOLD couplings and fittings. No welders or special fusion equipment are required. Your own crew or your contractor's crew can make the joints in less than five minutes, above or in the ditch.

**Check these advantages of the new Dresser TRANSITION Couplings:**

1. **Proved principle for joining pipe - Five years field experience with regular POSI-HOLD couplings and fittings.**
2. **Safe, positive holding strength - Meets D. O. T. Regulation #192 in all respects.**
3. **Easily installed in any weather - no welders required. Existing "700" field tools can be used for installation.**
4. **Economical - Fast assembly.**
5. **No exact pipe fitting.**
6. **Gas-tight permanent joints.**
7. **Working pressure same as the polyethylene pipe.**
8. **Install from top—no need for large bell-holes.**
9. **Low profile—easy to coat or wrap.**
10. **Steel insert supplied with each coupling.**

Why not start realizing all the benefits of this safe, efficient method every time you connect polyethylene pipe to existing steel pipe, or polyethylene pipe to polyethylene pipe? Your Dresser field representative will give you full details not only about the new Dresser TRANSITION Couplings, but also the many other products Dresser offers for use with polyethylene pipe and tubing. Ask him today.

APPENDIX C

Du Pont information letter re ALDYL "A" pipe, of February 27, 1976.

Z-189 REV. 12-75

ESTABLISHED 1802

E. I. du Pont de Nemours & Company
INCORPORATED
Wilmington, Delaware 19898

PLASTIC PRODUCTS AND RESINS DEPARTMENT

February 27, 1976

Dear Sir:

I am certain that you are aware of the natural gas explosion, which occurred in the Pathfinder Hotel in Fremont, Nebraska, on January 10, and the tragic consequences in loss of life and property. The pipe involved in the incident was Du Pont ALDYL® "A" pipe, and as a user of our products, we felt a report to you on what has happened is appropriate.

The gas leak that caused the explosion and fire occurred because a compression coupling which joined an inserted length of ALDYL "A" pipe with an existing steel gas line failed to hold the pipe. There was no failure of plastic pipe. The pipe contracted because of low temperatures and pulled out of the compression coupling. The gas line was installed June 26, 1974.

The National Transportation Safety Board issued an interim report, February 24, 1976, which stated --

..."The National Transportation Safety Board's investigation disclosed that a two-inch plastic gas main had pulled out of its compression coupling at the intersection of Sixth and Broad Streets, about 15 feet from the northwest corner of the hotel basement. The pipe had pulled out of its six-inch long compression coupling after the pipe had contracted in length 2-1/2 inches. Natural gas, leaking from the pipe at 13 psig pressure, and capped above by frozen earth and the concrete road surface, seeped into the hotel basement.

..."In its installation handbook, the manufacturer of the plastic pipe states: 'Since inserted pipe is not restricted in linear movement as in direct burial, the effect of expansion and contraction (one inch per hundred feet per 10 degrees F. change) must be considered when using compression-type fittings'. The manufacturer further states: 'In relatively short service runs (100 feet) properly tightened fittings will hold over a normal temperature range. However, in longer runs, positive transition fittings may be required to prevent pull-out'."

The Du Pont Company agrees with the findings of the NTSB report and the fact that plastic pipe was not cited as the cause of failure.

Expansion and contraction with changes in temperature is a known property of all piping materials. The changes in length, especially in long runs, can be substantial and, as pointed out in our literature must be considered in insertion installations, particularly when using compression-type fittings. Because of the seriousness of this incident, we felt it important to correspond directly with you to suggest that you review the installation procedures within your company on the use of compression fittings with polyethylene pipe. Du Pont has outlined suggestions in its product literature since 1966 on precautions to be taken on the use of compression fittings with ALDYL "A" pipe when used in insertion work. This information can be found in Du Pont Bulletin No. 680 Technical Data Sheet and Installation Bulletin Nos. 100 and 106.

Your Du Pont field representative who is technically trained to assist you in the use of Du Pont ALDYL "A" products, will be glad to cooperate with your engineering group in review of your company's standards as they pertain to the use of compression fittings. We would also strongly recommend that you review with your supplier of compression fittings his recommendations on use of these fittings with polyethylene pipe.

The ALDYL system is an experience proven system. It has been in commercial use, and has performed satisfactorily in the ground for 11 years. This experience has demonstrated that the ALDYL system, when properly installed, will provide you with a safe, economical and trouble free gas distribution system for many years.

Sincerely yours,

S. Selman

S. Selman
Marketing Manager
ALDYL Piping Systems

SS:ehc

APPENDIX D

Du Pont information letter of May 11, 1976, and report entitled, "Pull-Out Forces on Joints in Polyethylene Pipe Systems."

Z-189 REV. 12-75

ESTABLISHED 1802

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE 19898

PLASTIC PRODUCTS AND RESINS DEPARTMENT

May 11, 1976

Dear Sir:

In my letter to you of February 27, 1976, I recommended that you review the adequacy of your standards and procedures for installation of PE pipe in conjunction with compression fittings. While our product literature (Bulletins 100 and 106) contains sufficient information needed for such a review, we have had several requests for additional, more detailed information on potential pull-out forces on installed PE (polyethylene) pipe systems. The attached report provides this additional information.

We recognize the responsibility which the utilities have for the installation of systems in accordance with Department of Transportation, Office of Pipeline Safety minimum federal standards. We hope the technical report will be of value to your engineering personnel in carrying out this responsibility and may be of use in establishing improved industry standards for polyethylene gas distribution systems.

Because maximum utilization of the benefits of polyethylene systems is important to its continued use in providing safe, reliable distribution of natural gas to the consumer at reasonable cost, Du Pont will continue to include in the price for the ALDYL* Piping Systems, not only pipe, fittings, and tools, but reliable quality assurance and technical service such as this attached report. Your support of this effort through past purchases of ALDYL "A" is appreciated.

Sincerely yours,

S. Selman

S. Selman
Marketing Manager
ALDYL Piping Systems

SS:sak
Attachment

*Reg. U.S. Pat. & Tm. Off. for Du Pont's polyethylene pipe and fittings.

# PULL-OUT FORCES ON JOINTS IN POLYETHYLENE PIPE SYSTEMS

*A Guideline for Gas Distribution Engineering*

April 30, 1976

J. L. Husted

D. M. Thompson

CONTENTS



E. I. du Pont de Nemours & Co. (Inc.)

ALDYL* Piping Systems

# PULL-OUT FORCES ON JOINTS IN PE (POLYETHYLENE) PIPE SYSTEMS

## I. INTRODUCTION

The minimum Federal Standards, Title 49, regulating natural gas distribution, requires the utility to properly design and install pipeline joints as stated in paragraph 192.273, following:

*Subpart F* – Joining of Materials Other Than by Welding 192.273 General

(a) The pipeline must be designed and installed so that each joint will sustain the longitudinal pull-out or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.

(b) Each joint must be made in accordance with written procedures that have been proven by test or experience to produce strong gastight joints.

(c) Each joint must be inspected to insure compliance with this subpart.

In an effort to aid the utility gas distribution engineer in establishing meaningful company standards to comply with Federal Regulations, this write-up presents information and specific examples of practical field application concerning pull-out forces to which PE (polyethylene) systems are subjected.

This information is an extension of the information outlined in DuPont Installation Bulletin Nos. 100 and 106, and Technical Data Bulletin No. 200. Although this write-up deals with the subject of pull-out, there are, of course, other considerations to be included in design and installation of a PE piping system; a reminder is directed in particular to bending limits for pipe and pipe with fittings as covered in Bulletin 100.

## II. PULL-OUT FORCES

Forces which can act on polyethylene system joints are a combination of the following:

- Thermal contraction force,
- Internal pressure force (free ended pipe),
- External forces such as earth movement or "hit" by excavation equipment.

### A. Thermal Contraction

Determining the magnitude of this force is relatively simple. Unrestrained pipe will contract 1.08" per 100 feet for every 10°F of temperature drop. If, however, the pipe were restrained only at the ends (i.e., no earth friction or interference forces), the initial force at the restraint, resulting from a 10° instantaneous temperature drop, is the same as if the pipe were stretched back 1.08" to the original 100 foot length. In the case of 2" pipe with a temperature drop from 45° to 35°F, this would be 208 lbs. An instantaneous 20°F temperature drop from 55°F to 35°F would produce twice the contraction force. If the pipe had twice the wall area, the force would be doubled. However, temperature change underground is seldom instantaneous, and plastic pipe has a valuable property known as stress relaxation. These items interrelate to produce a real force less than that calculated above for instantaneous temperature change without benefit of stress relaxation. The real force on 2" pipe undergoing a gradual 10°F earth temperature change down to 35°F would be more nearly 93 lbs. Attachment "A" illustrates these calculations. Also attached is stress relaxation and modulus of elasticity information for various temperatures (Tables II & III). Table I provides contractive force information for various sizes of ALDYL "A" pipe undergoing an *instantaneous* 30°F temperature drop from 65° to 35°F. Remember these listed forces are higher than actual. In normal situations where temperature changes are gradual, the calculated forces are less than half of those of an instantaneous situation (refer to Attachment "A").

### B. Force Caused by Internal Pressure

This is the force acting on a joint in an unrestrained end of line, and is the product of pipe area times psi of gas. A 2" pipe operating at 60 psi would have a force of 265 lbs. acting on a joint where the connecting fitting was secured to the pipe O.D. Note, this force is present only in that portion of a free-ended line having a closed end. It would be additive to other forces acting to pull-out. Table I contains forces with O.D. secured fittings for various diameters of ALDYL "A" pipe at 60 psi pressure.

One example of this situation is in pressure testing at the line end. Since testing is normally done at 1.5 times system rating, the Table I forces would be 50% higher (at 90 psi). This illustrates the need for adequate provision to secure test caps.

### C. External Forces

The utility must assess the likelihood and magnitude of forces imposed on the pipeline from earth movement or third party mechanical equipment contact. These forces can be transmitted by the pipe to the system joints; the maximum potential force being equal to pipe strength. Table I lists yield strengths for various sizes of ALDYL "A" pipe.

## III. RESISTANCE TO PULL-OUT FORCES

Having arrived at a summation of pull-out forces, the natural restraints to these forces can also be estimated:

### A. Earth Friction

While it is apparent that soil, pressing against the pipe surface, will provide some resistance to movement, the amount of such drag is difficult to quantify since it is dependent on installation conditions. A well compacted soil, having a "tooth" or abrasive character, would be expected to provide more friction against the pipe than a loose soil of a mucky nature. Consider also that the original soil holding force could be diminished if contact with the pipe is reduced because of pipe shrink-away from the earth, due to diameter reduction with temperature, or soil pull-away due to other causes. A practical way to assess magnitude of earth friction forces peculiar to local conditions would be to bury a length of line according to standard practice, and then measure the drag force necessary to cause movement. To obtain conservative design information, the test could be done under burial conditions which the utility considers as the minimum (poorest) likely to be encountered in actual installation.

### B. Earth Interference

Changes of direction of a gas line (90° ell or more gradual curves) and lateral projections (couplings, tees, branch saddles) serve to restrain movement. If movement were to occur, then earth would have to be sheared and compacted as either the lateral projection was forced through the soil, or the curved line was straightened. Although these interferences could be expected to provide considerably more restraint than soil friction on plain pipe, the resistance effect is again difficult to quantify. The utility could determine some measure of drag resistance by test such as suggested in the previous paragraph.

## IV. FITTING STRENGTH vs. PULL-OUT FORCES

In practice, the best guide of the effect that pull-out forces have on joints is to compare the joint strength to pipe strength, since the pipe strength limits the force that can be transmitted to the joint.

The joints made with ALDYL "A" pipe and fittings are rated in axial strength as follows:

| ALDYL "A" Joint Type | Joint Strength vs. Pipe Strength |
|---|---|
| Socket Fused | Equal or Greater |
| Butt Fused | Equal or Greater |
| Transition Fitting | Equal or Greater |
| Compression Fitting – ½" to 1" | Equal or Greater* |
| Compression Fitting – larger than 1" | Less* |

*See Note and Reference on top of Page 4

*Note:* Reports on industry experience with compression fittings indicate that the pull-out resistance of properly installed compression fittings on service sizes is generally considered equal or greater than the pipe strength. For larger sizes, the pull-out resistance becomes less than pipe strength. In all cases, the individual compression fitting manufacturer must be consulted on pull-out strength, recommended installation procedures, and fitting use.

*Reference:* "Comparison of Long-Term Sealing Characteristics of Compression Type Couplings on Steel and PE Pipe" By T. F. Rothwell, Dresser Industries, Inc. – a paper presented at the November 1972 AGA Plastic Pipe Symposium.

## V. COMPRESSION FITTINGS – SPECIAL CONSIDERATION

Compression fittings, properly installed according to the manufacturer's recommended procedures, have given reliable performance in gas distribution with cast iron, steel, and plastic pipe. The fact that compression fittings generally are not designed to resist pull-out with any material has always been recognized by the industry. DOT Minimum Federal Standards, paragraph 192.367 states, for example:

> "Each compression-type service line-to-main connection must be designed and installed to effectively sustain the longitudinal pull-out or thrust forces caused by contraction or expansion of piping, or by anticipated external or internal loading."

With plastic piping systems, the utility must estimate and evaluate the following:

1. Pull-out forces (Section II).
2. Resistance to pull-out forces (Section III).
3. Compression fitting pull-out resistance to be obtained from the fitting manufacturer.

General industry experience indicates that properly installed *service* line compression fittings perform well both in direct buried and in insertion renewal use where the pipe length does not exceed 100 feet.

In *main* sizes, pull-out resistance can be expected to be less than the pipe strength. Although earth restraint in buried systems can usually provide adequate resistance to pull-out forces, pull-out of pipe from fittings in main sizes can occur. In insertion, there is no external resistance to pull-out. Pull-out is much more likely in the absence of proper precautions to avoid it.

If the estimate of the pull-out forces exceeds the fittings manufacturer's pull-out rating of the compression joint, then to prevent pull-out you must:

1. Use a fitting with pull-out resistance which is equal to or greater than the pipe strength such as an ALDYL "A" transition fitting, or
2. Anchor the pipe to ensure elimination of axial load on the compression joint.

*Note:* as recommended in previous DuPont literature, the above should be followed in all cases except for *service* sizes where run length is 100 ft. or less and fittings are properly installed.

### Anchoring

Where the expected pull-out forces at a pipe-to-compression fitting juncture are greater than the inherent restraint in the juncture vicinity, some sort of anchor should be provided to isolate the joint from the axial load.

Such anchors can be in the form of a harness secured at one end by a metal collar placed behind projections fused into the ALDYL "A" line (coupling or saddle fittings), then connected by straps across the compression fitting and welded to the terminating steel pipe. Concrete footings set into undisturbed soil and cast around projections in the ALDYL "A" line (coupling or saddles) provide another method. If saddle fittings are used in anchor projections, at least two should be fused to the line 180° apart to minimize bending stresses at the anchor point. Where a harness arrangement is used, the make-up must be such that the resisting load is evenly carried by all the projecting fittings. In the case of saddles, there must be sufficient number used so that the saddle fusion area is at least three times that of pipe wall area in the line being anchored.

### Existing Systems

With regard to compression fitting joints already in the ground where pull-out forces could exceed fitting pull-out resistance, the utility could consider the following action:

- Examine fitting connections in representative portions of the system where pull-out forces are expected to have been high, or restraint is expected to have been low.
- If evidence is found of pipe movement, then take steps to provide additional restraint adjacent to compression fittings (i.e. anchor, as discussed earlier).

TABLE I

DIMENSION AND LOAD INFORMATION FOR ALDYL® "A" P.E. PIPE

| Nominal Size (in.) | SDR | O.D. (in.) | Wall Thickness (in.) | Total End Area[1] (to nominal O.D.) (sq. in.) | Max. Wall Area (sq. in.) | Min. Wall Area (sq. in.) | Pipe Yield Force at 35° F[2] Max. Wall Area (lbs.) | Pipe Yield Force at 35° F[2] Min. Wall Area (lbs.) | End Thrust[3] at 60 psi (lbs.) | Thermal Contractive[4] Force at 35° F from 65° F (Δ 30° F) (max. lbs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Iron Pipe Size** | | | | | | | | | | |
| ½" | 9.3 | .840±.004 | $.090^{+.020}_{-.000}$ | .554 | .253 | .211 | 918 | 765 | 33 | 97 |
| ¾" | 11.0 | 1.050±.004 | $.095^{+.020}_{-.000}$ | .865 | .342 | .284 | 1,241 | 1,030 | 52 | 131 |
| ¾" | 9.3 | 1.050±.004 | $.113^{+.021}_{-.000}$ | .865 | .387 | .331 | 1,404 | 1,201 | 52 | 148 |
| 1" | 11.0 | 1.315±.005 | $.119^{+.026}_{-.000}$ | 1.357 | .535 | .445 | 1,942 | 1,615 | 81 | 205 |
| 1" | 9.3 | 1.315±.005 | $.141^{+.026}_{-.000}$ | 1.357 | .605 | .518 | 2,196 | 1,880 | 81 | 232 |
| 1¼" | 10.0 | 1.660±.005 | $.166^{+.026}_{-.000}$ | 2.163 | .887 | .776 | 3,219 | 2,816 | 130 | 340 |
| 1¼" | 9.3 | 1.660±.005 | $.178^{+.026}_{-.000}$ | 2.163 | .936 | .826 | 3,397 | 2,998 | 130 | 359 |
| 1½" | 11.0 | 1.900±.006 | $.173^{+.026}_{-.000}$ | 2.834 | 1.067 | .935 | 3,873 | 3,394 | 170 | 409 |
| 2" | 11.0 | 2.375±.006 | $.216^{+.026}_{-.000}$ | 4.428 | 1.625 | 1.460 | 5,898 | 5,299 | 265 | 623 |
| 2" | 9.3 | 2.375±.006 | $.255^{+.030}_{-.000}$ | 4.428 | 1.876 | 1.693 | 6,809 | 6,145 | 265 | 719 |
| 3" | 11.5 | 3.500±.008 | $.307^{+.035}_{-.000}$ | 9.616 | 3.399 | 3.070 | 12,338 | 11,144 | 577 | 1,303 |
| 3" | 9.3 | 3.500±.008 | $.376^{+.044}_{-.000}$ | 9.616 | 4.072 | 3.679 | 14,781 | 13,354 | 577 | 1,561 |
| 4" | 11.5 | 4.500±.009 | $.395^{+.040}_{-.000}$ | 15.896 | 5.565 | 5.080 | 20,200 | 18,440 | 954 | 2,134 |
| 4" | 9.3 | 4.500±.009 | $.483^{+.057}_{-.000}$ | 15.896 | 6.729 | 6.079 | 24,426 | 22,066 | 954 | 2,580 |
| 6" | 21.0 | 6.625±.011 | $.316^{+.038}_{-.000}$ | 34.454 | 6.982 | 6.249 | 25,344 | 22,683 | 2,067 | 2,677 |
| 6" | 11.5 | 6.625±.011 | $.576^{+.069}_{-.000}$ | 34.454 | 12.133 | 10.920 | 44,042 | 39,639 | 2,067 | 4,652 |
| 6" | 9.3 | 6.625±.011 | $.713^{+.086}_{-.000}$ | 34.454 | 14.644 | 13.211 | 53,157 | 47,955 | 2,067 | 5,615 |
| 8" | 21.0 | 8.625±0.13 | $.410^{+.049}_{-.000}$ | 58.397 | 11.788 | 10.559 | 42,790 | 38,329 | 3,503 | 4,520 |
| 8" | 11.0 | 8.625±.013 | $.785^{+.094}_{-.000}$ | 58.397 | 21.415 | 19.293 | 77,736 | 70,033 | 3,503 | 8,211 |
| **Copper Tube Size** | | | | | | | | | | |
| ½"(⅝" I.D.) | 7.0 | .625±.004 | $.090^{+.006}_{-.000}$ | .306 | .161 | .150 | 584 | 544 | 18 | 62 |
| 1"(⅞"O.D.) | 11.5 | 1.125±.005 | $.099^{+.008}_{-.000}$ | .994 | .344 | .317 | 1,248 | 1,150 | 60 | 132 |
| 1"(⅞"O.D.) | 9.3 | 1.125±.005 | $.121^{+.008}_{-.000}$ | .994 | .405 | .379 | 1,470 | 1,375 | 60 | 155 |

[1] Nominal O.D.$^2$ x $\frac{3.14}{4}$; this is the area which internal gas pressure acts against in an attempt to push unrestrained pipe out of fitting.

[2] Yield stress at 35° F is 3630 psi.

[3] The product of (1) times 60 psi, acting on unrestrained pipe.

[4] This is calculated force for instantaneous temperature change of 30° F. See Attachment A for calculation details.

## VI. SUMMARY

Pull-out force on joints in PE pipe systems is a practical engineering consideration. The ALDYL "A" system, which includes transition fittings, is designed to provide all joints which are equal to or stronger than the pipe. This system will provide long service in gas distribution use when installed using good general practice within the design constraints outlined for bending. With compression fittings, where the pull-out resistance may not equal pipe strength, special considerations are required. This report is designed to provide you with the technical approach and design information on pull-out forces on PE system joints as a basis for developing sound installation standards and assessment of expected performance in existing installations.

TABLE II

**PROPERTIES OF ALDYL® "A" PE PIPE**

| Temperature | −20° F | 0° F | 32° F | 73° F | 100° F |
|---|---|---|---|---|---|
| Short Term | | | | | |
| Yield strength (tensile), psi | 4,800 | 4,400 | 3,700 | 2,800 | 2,200 |
| Elongation at yield, % | 10 | 11 | 11 | 12 | 13 |
| Ultimate strength (tensile), psi | | | | 5,000 | |
| Ultimate elongation, % | | | | >800 | |
| Modulus of elasticity, psi | 210,000 | 180,000 | 145,000 | 100,000 | 80,000 |
| Coefficient of thermal expansion | | | | | |
| in/in/° F | | | | $9 \times 10^{-5}$ | |
| in/100ft/10° F | | | | 1.08 | |

TABLE III

**APPARENT MODULUS OF ALDYL® "A" PE PIPE**

| Time | | Modulus as % of Initial (Instantaneous) Modulus |
|---|---|---|
| 6 min. | 0.1 hr. | 100% |
| – | 1.0 hr. | 80% |
| – | 10 hr. | 67% |
| 4 days | 100 hr. | 51% |
| 1½ months | 1,000 hr. | 39% |
| 1.1 yrs. | 10,000 hr. | 30% |
| *11 yrs. | 100,000 hr. | 24% |
| *50 yrs. | 438,000 hr. | 21% |

*Projected

Note 1: Apparent modulus is the modulus that takes into effect the creep (strain increases with time when stress is constant) and stress relaxation (stress decreases with time when strain is constant) in plastics at use temperatures.

ATTACHMENT A

# DETERMINATION OF THERMAL CONTRACTION FORCES ACTING ON ALDYL®"A" POLYETHYLENE PIPE

## I. INTRODUCTION

This attachment presents two situations of temperature change and resultant longitudinal forces acting on P.E. (polyethylene) pipe due to thermal contraction. In the first situation, Section V, the forces are calculated based on *instantaneous* temperature drops. This does not represent a normal field situation where temperature changes in the earth are usually very gradual.

The second situation, Section VI, illustrates the smaller force present with *gradual* temperature drop. This case represents an actual field situation where the highest to lowest earth temperature change (assumed same for pipe) took place over a 5-6 month period; thus the opportunity for stress relaxation and smaller increments of temperature change (with more favorable modulus, rather than a larger, final temperature modulus) combine to reduce the stress due to thermal contraction. Except for the speed of temperature change, conditions for two situations are the same.

Note in the actual field situation, the force calculated as acting on 4" polyethylene pipe due to a gradual 29°F temperature drop is 930 lbs., whereas the calculated force associated with an instantaneous 29° temperature drop is 2100 lbs.

## II. CONDITIONS

1. 4" SDR 11.5 ALDYL "A" PE (polyethylene) pipe inserted into 6" metal pipe.
2. Length: 100 ft. and 400 ft.
3. Temperature of air: 100°F on day of installation.
4. Temperature of pipe wall before insertion: 100°F.
5. Temperature of pipe wall at tie-in: 65°F. [See Note (A). i.e. soil temp. 65°F.]
6. Temperature of pipe wall during next 12 months: Per Graph I.
7. Ultimate temperature of pipe wall same as soil temperature.
8. Pipe not put into compression or "snaked" within 6" casing (metal pipe), i.e. at final tie-in, as in (5) above, PE pipe is "at rest" and straight.
9. ALDYL "A" pipe restrained only at ends.

*Note (A)* Assuming gas company has allowed pipe to cool to soil temperature. (estimated 1 to 2 hours to make final tie-in).

## III. PROBLEM

Find longitudinal forces acting on a joint caused by temperature changes in PE pipe wall.

## IV. TERMS AND EQUATIONS USED IN CALCULATIONS

| Term (Units) | Definition |
|---|---|
| $\Delta T$ (°F) | Change in Temperature |
| $E_t$ (psi) | Apparent modulus at end of time period |
| Stress (psi) | Fiber Stress |
| Strain (in/in) | Elongation per inch |
| $E = \frac{\text{stress}}{\text{strain}}$ | |
| $\text{Stress} = \frac{F}{A}$ | F = Force (lbs.) – Total<br>A = Area (sq. in.) – Total |
| $\text{Strain} = \frac{\Delta L}{L}$ | $\Delta L$ = Total Elongation (in)<br>L = Total Length (in) |
| Coefficient of Thermal Expansion | $9 \times 10^{-5}$ in/in/°F<br>1.08 in/100 ft/10°F |
| Wall Area 4" Pipe = | 5.08 sq. in (min)<br>5.57 sq. in (max) |

## V. INSTANTANEOUS CONDITIONS (Maximum Potential force)

This shows potential forces that could be caused if the temperature change were instantaneous. This is not representative of actual conditions.

| Temperature Drop | | Forced Developed |
|---|---|---|
| a. 100°F to 65°F | (35°$\Delta$T) | 1950 lbs. |
| b. 65°F to 36°F | (29°$\Delta$T) | 2100 lbs. |
| c. 100°F to 36°F | (64°$\Delta$T) | 4500 lbs. |

CALCULATIONS FOR ITEMS a., b., c.

**a. 35°$\Delta$T, to 65°F**

*Length Change* (1.08 in/100 ft/10°F)

for 100 ft. = 1.08 x 1 x 3.5 = 3.8 inches

for 400 ft. = 1.08 x 4 x 3.5 = 15.2 inches

*Strain*

for 100 ft. $= \frac{3.8 \text{ in.}}{1200 \text{ in.}} = .0032$ in/in.

for 400 ft. $= \frac{15.2 \text{ in.}}{4800 \text{ in.}} = .0032$ in/in.

*Stress*

stress = strain x E (modulus)
= .0032 in/in. x 110,000
(instantaneous modulus at lower temperature, 65°F)
= 350 psi

*Force*

force = stress x area
= 350 psi x 5.57 in.$^2$
(max. wall area 4" SDR 11.5)
= 1950 lbs.

**b. 29°ΔT, to 36°F**

Calculation method per a., using modulus at 36°F.
force = 2100 lbs.

**c. 64°ΔT, to 36°F**

Calculation method per a., using modulus at 36°F.
force = 4500 lbs.

## VI. ACTUAL FIELD CONDITIONS

This shows the effect of actual field conditions of:

- Cooling to 65°F before tie-in.
- Gradual temperature changes in the soil.
- The effect of stress relaxation of polyethylene pipe.

It is realistically assumed that after the pipe is placed in the ditch or inserted, enough time passes (1 to 2 hours) before final tie-in to allow it to reach the ground temperature (65°F) before it is restrained at both ends. In the attached Graph I, this is the warmest ground temperature in Wilmington, Delaware and occurs in July, August, and September. We are then concerned about thermal contractive forces due to decreases in soil temperature through the winter months. These take place gradually and allow stress relaxation to take place in the pipe.

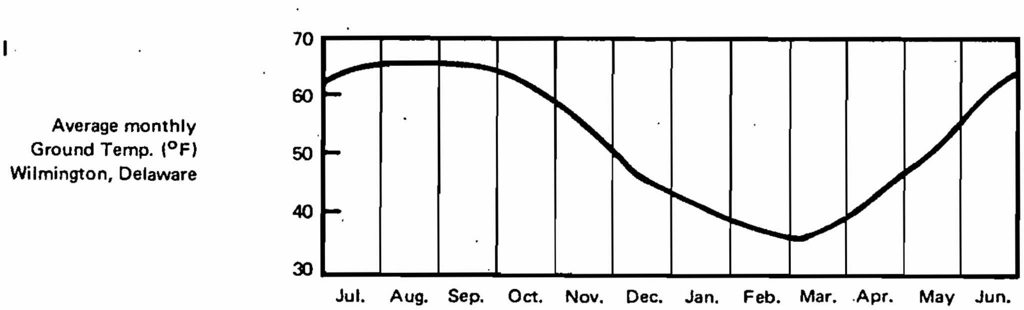
*Note:* Steel pipe does not show this same characteristic of stress relaxation at these temperatures.

### Resultant Force

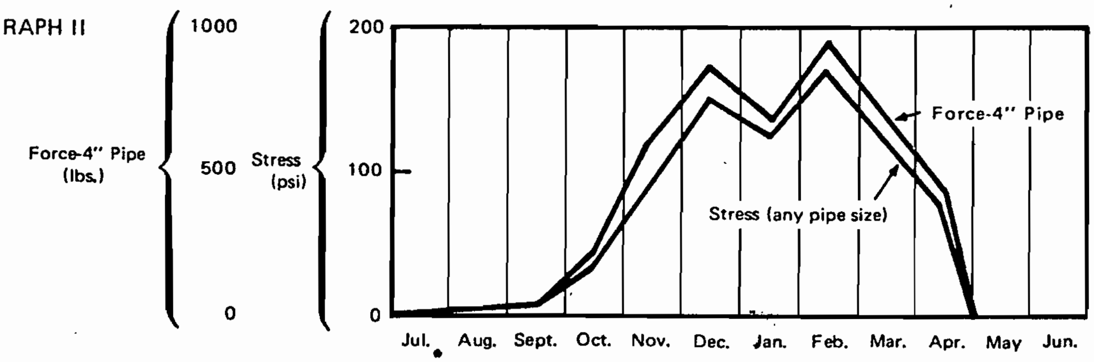
Based on the above, the maximum force developed on 4" SDR 11.5 pipe is 930 lbs. in January and February. This is less than half the force calculated in the unrealistic instantaneous conditions of V.b.

Graph II shows the realistic stresses developed in polyethylene pipe during the year based on the average ground temperature in Graph I. This when multiplied times the cross sectional area of the pipe gives the force tending to contract the pipe. The example of 4" pipe is included in the graph. The information on Graph II was developed by month-to-month calculation which is the summation of the incremental stress change for the current month (using the incremental temperature change and associated modulus at new temperature), and the adjusted stress (relaxed) accumulated from previous months.

GRAPH I




GRAPH II



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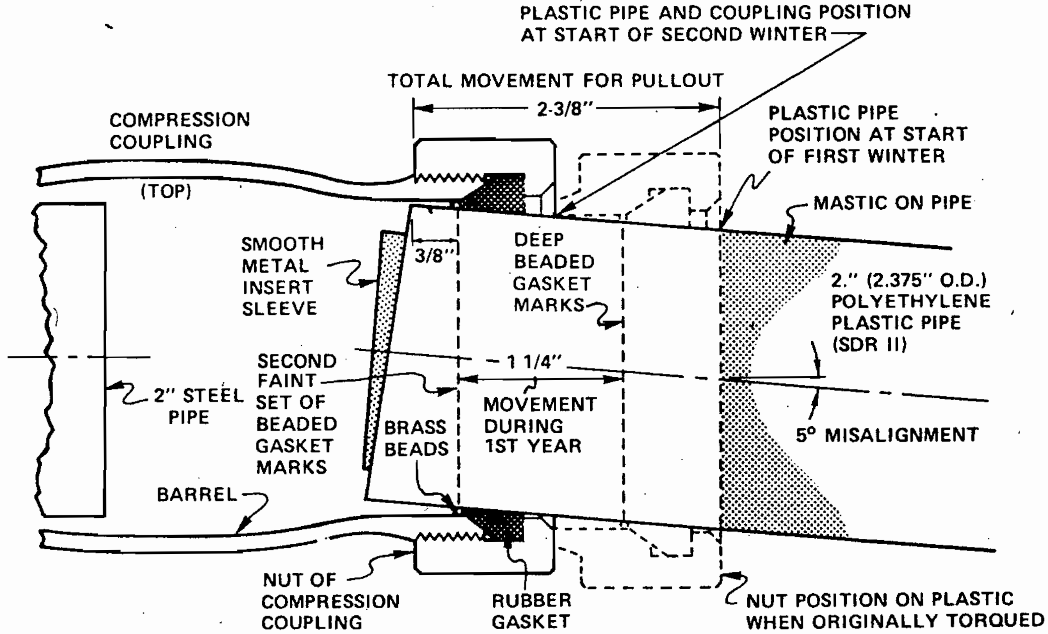
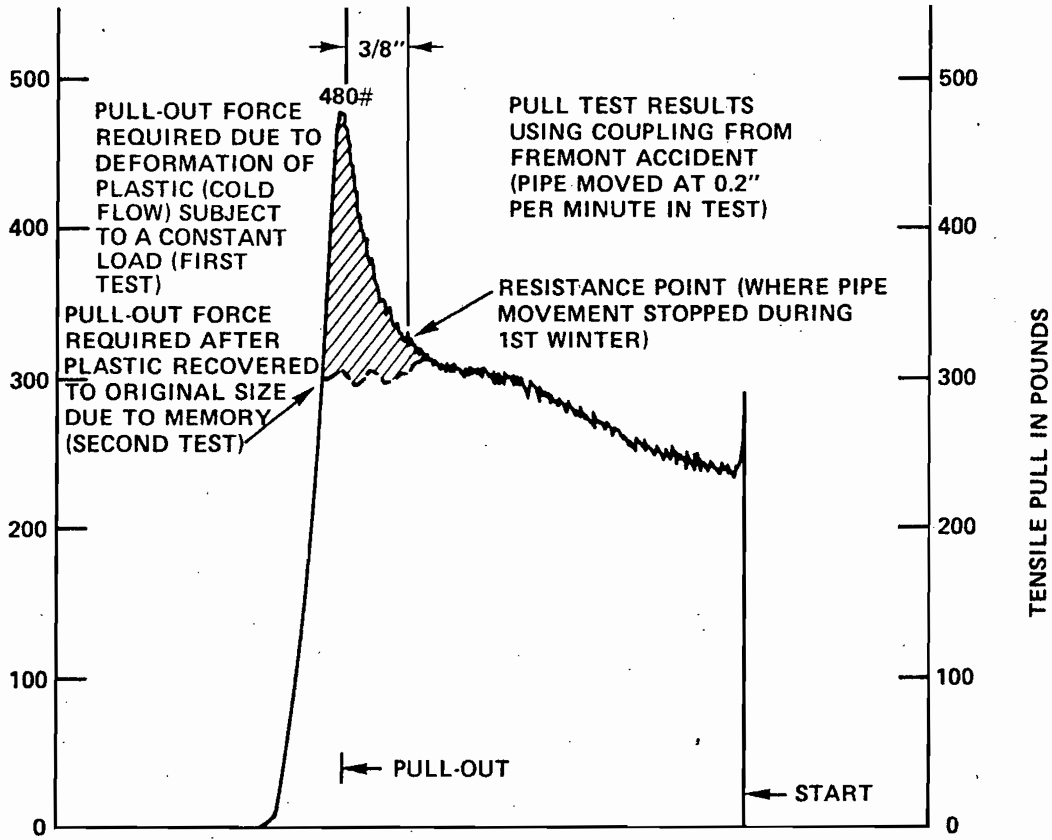
APPENDIX E

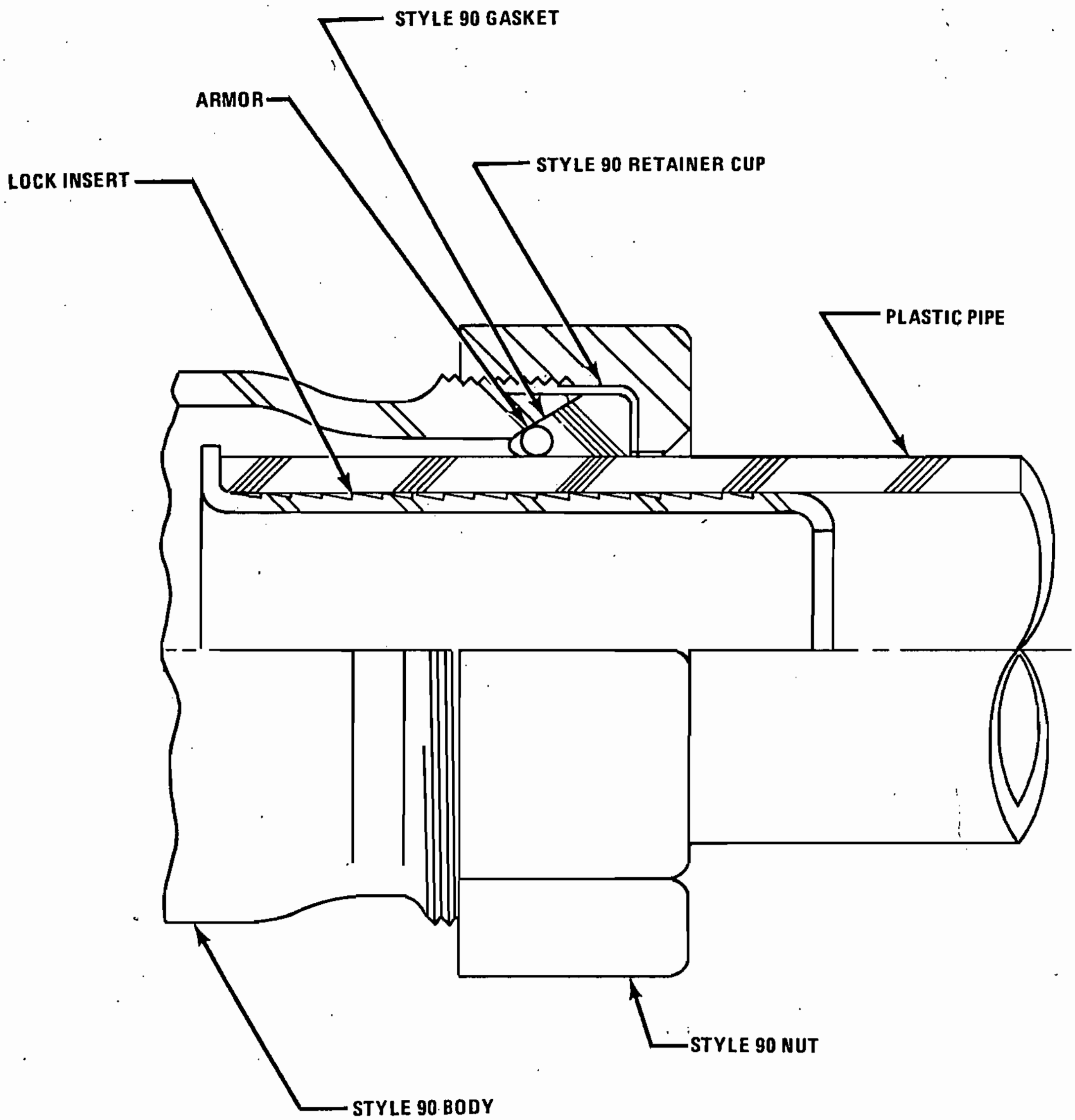
Cross-section of plastic pipe, from Fremont, Nebraska, accident, within compression coupling, and force diagram.



APPENDIX F

New Dresser Style 90 compression coupling redesigned for Dresser lock insert.



APPENDIX G

Excerpt from Proceedings of Fourth A.G.A. Plastic Pipe Symposium.

# Comparison of Long-Term Sealing Characteristics of Compression Type Couplings on Steel & Polyethylene Pipe

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## Background

Compression type elastomeric sealed couplings have been used successfully in joining gas pipe for over 80 years. The predominance of usage has been on rigid metallic pipe and tubing. In the last two decades, plastic piping materials have become more and more common in gas distribution systems. The first usage was primarily in sizes under 2" IPS for service connections–generally CAB and ABS tubing. The need to connect these small sizes to the main and meter set was handled by many users by direct substitution of mechanical compression couplings from the metal-to-metal connections used in the past to the new plastic-to-metal junction.

Fig. 1 shows a typical joint of this type now in common usage and differing from the earliest installations on plastic pipe only in the type of insert.

Changes in material types have taken place since the introduction of plastic as a piping material until, today, the polyethylene materials predominate in current usage. The mechanical coupling (Fig. 1) with an insert specifically designed for polyethylene pipe (tubing) has been used over the past six years in well over a million connections with no reported failures on a properly made installation.

The growth of plastic in the gas industry has resulted in the expansion of usage to distribution mains with attendant increase in sizes. This increase in usage of larger sizes has produced the need for a coupling capable of making the transition joint from existing steel to plastic, joining plastics of two different types, and plastic of the same type from two different sources. The larger-size piping precludes the practical use of a locking insert of the type shown in Fig. 1. The larger clearances caused by increased manufacturing tolerances of both pipe and coupling parts and the heavier pipe walls would require extremely large forces to deform the plastic material into intimate confined contact with this type of shaped insert. Conformity of the pipe to the shaped insert and a confinement of the gasket and pipe material in the area of the seal are the largest contributing factors to the success of this type of joint for both seal and pipe pull-out resistance. The successful use of the smaller boltless mechanical couplings (Fig. 1) bears this out.

In our company, a new coupling mechanical design was initiated to develop a mechanical joint for polyethylene pipe in sizes 1-¼" thru 6" used in the distribution mains. Requirements were obviously long-term reliable sealing ability ("long-term"–equal to the life span of the piping material) and a joint locking strength equal to the longitudinal strength of the plastic pipe being joined, as required by (our interpretation) the D.O.T. regulations Vol. 35, number 161, paragraph 192.773 (a).

With almost a century of experience in the manufacture of highly loaded elastomeric seal mechanical couplings, there was no question in our minds as to the type of sealing mechanism to be used.

We are aware of the recurring questions in the industry concerning the probable deleterious effects on mechanical coupling seals when the elastomer must work in conjunction with a flexible plastic pipe material (PE) having stress relaxation properties similar in form (when viewed from long-term curves) to the rubber seal.

Data are unavailable from the smaller-size couplings (ref. Fig. 1) as to the actual value of relaxation of gasket pressure caused by cold flow of the rubber and/or plastic, although usage history indicates that the plastic-elastomer creep is not of sufficient magnitude to affect the long-term sealing reliability. Attempts were made to develop gasket-pipe relaxation by assembling these smaller-size couplings on plastic tubing in which polished steel rod had been inserted. Gasket pressures and induced loads on the tubing were then calculated using the force to withdraw the rod and the coefficient of friction between the tubing material and the polished steel surface. Gasket pressures calculated in this manner at the time of initial setup ranged from 1,000 to 1,600 psi. Time tests with this method gave inconclusive results.

## Test Methods & Derived Data

In view of the large number of installations of our Style 38 coupling by gas utilities on PE distribution piping and in order to develop sealing data for the proposed transition coupling design, we elected to use the arrangement shown in Fig. 2 to measure seal pressure relaxation with time. Gasket pressure in the bolted compression coupling is a direct linear function of the load imposed on the gasket by bolt torque. Measuring the bolt strain using strain gages so mounted on the bolts as to cancel bending stresses, it is possible to monitor the gasket relaxation through reduction in bolt strain. A series of tests were conducted using bolted compression couplings installed on du Pont's Aldyl "A" medium-density polyethylene pipe. As a bench mark, a similar number of couplings were installed on Schedule 40 steel pipe with equipment to monitor the stress relaxation of the gasket.

The curves shown in Fig. 3 represent stress relaxation of the gasket on steel pipe and gasket-pipe combination on the PE pipe carried through 10,000 hours to date. Of

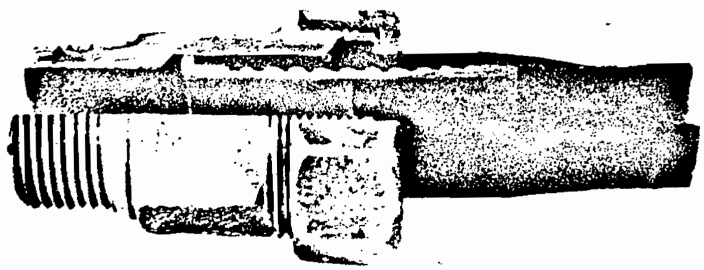

Figure 1

BOLTED COMPRESSION COUPLING

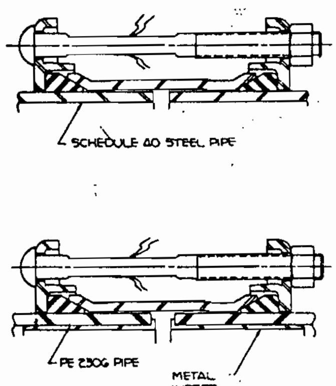


Figure 2

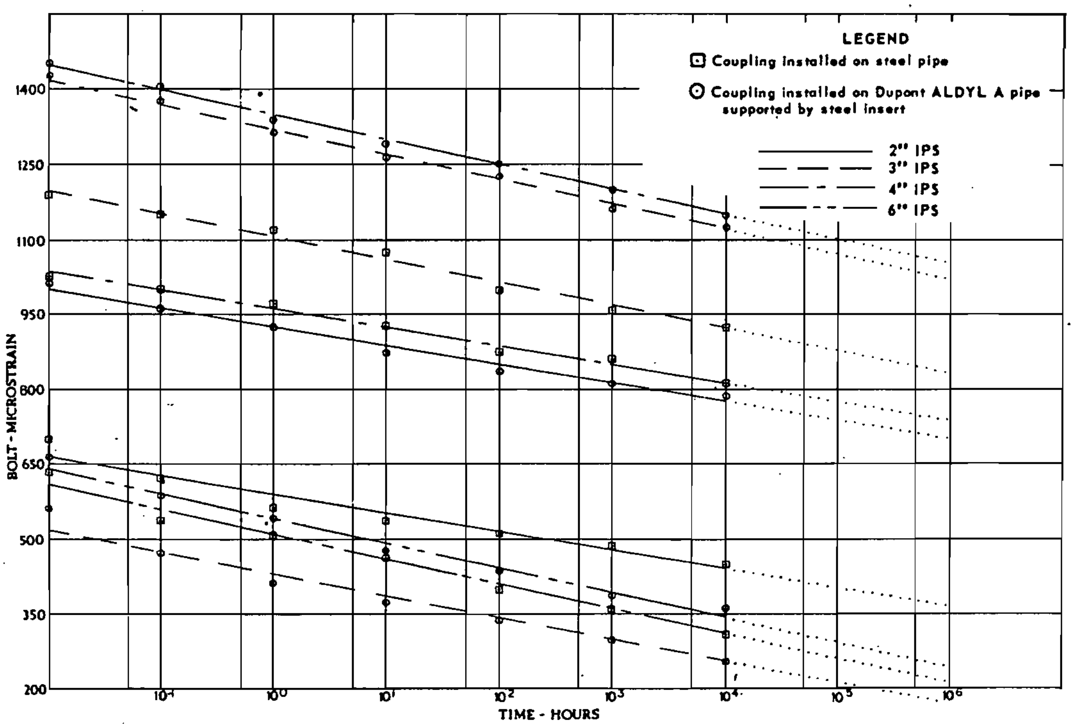


**Figure 3. Comparison. DRESSER® Style 38 Coupling Installed on Schedule 40 Steel Pipe and on Dupont ALDYL® A Pipe Supported by Steel Insert.**

interest is the high degree of parallelism between the curves, indicating the same order of magnitude of relaxation between the elastomer bearing on steel pipe and on internally supported polyethylene pipe. The difference between the two pipe materials as they affect the performance of the gasket seal appears from Fig. 3 to be negligible, and it is apparent that the higher the initial gasket loading, the more reliable will be the seal in terms of remaining gasket pressure after extended periods of time. These relaxation curves were derived from a time-bolt strain relationship which must, of course, bring up the question of the actual gasket pressure.

The second series of tests were conducted using a different method of measuring gasket pressure–both to double-check the curves in Fig. 3 and to determine as close as practical the actual gasket pressure.

Fig. 4 shows the hydraulic transducer whereby data could be derived using actual pressure readings on the pipe surface developed by a compressed gasket. An accurately machined cylinder was instrumented with strain gages series-connected around the internal circumference. The series connection of the strain gages will read the average strain developed on the inside of the cylinder resulting from a uniform external compressive loading. As may be seen from Fig. 4, the outer "O" ring sealed cylinder was placed over the instrumented pipe section and hydraulic pressure introduced into the seal chamber. The relationship between strain gage readings and incremental hydraulic pressure applied to the outside of the cylinder was graphed to give a strain versus external loading in pounds per square inch.

The separately instrumented cylinders were used as pipe ends and internal supporting inserts for PE pipe on which were installed bolted compression type couplings (Fig. 5). The graph (Fig. 6) shows the result of the 10,000 hour test whereby stress relaxation is plotted against gasket pressure. The results here are similar to those shown in Fig. 3, indicating no appreciable difference between the gasket relaxation of the bolted coupling installed on du Pont Aldyl "A" PE pipe compared to a similar installation on steel pipe.

In the near future, we will introduce a locking boltless transition coupling ("700" Posi-Hold) to be used on plastic pipe of the sizes commonly found in gas distribution

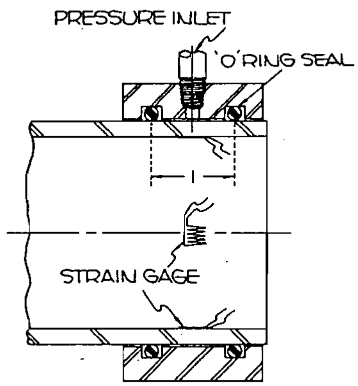


Figure 4.

BOLTED COMPRESSION COUPLING

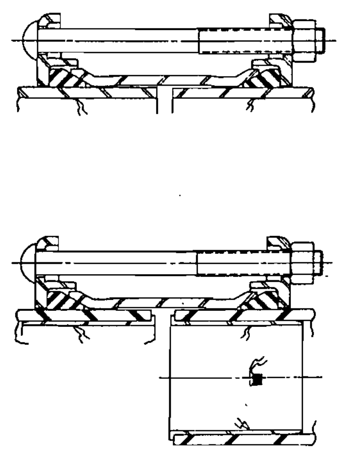

Figure 5.

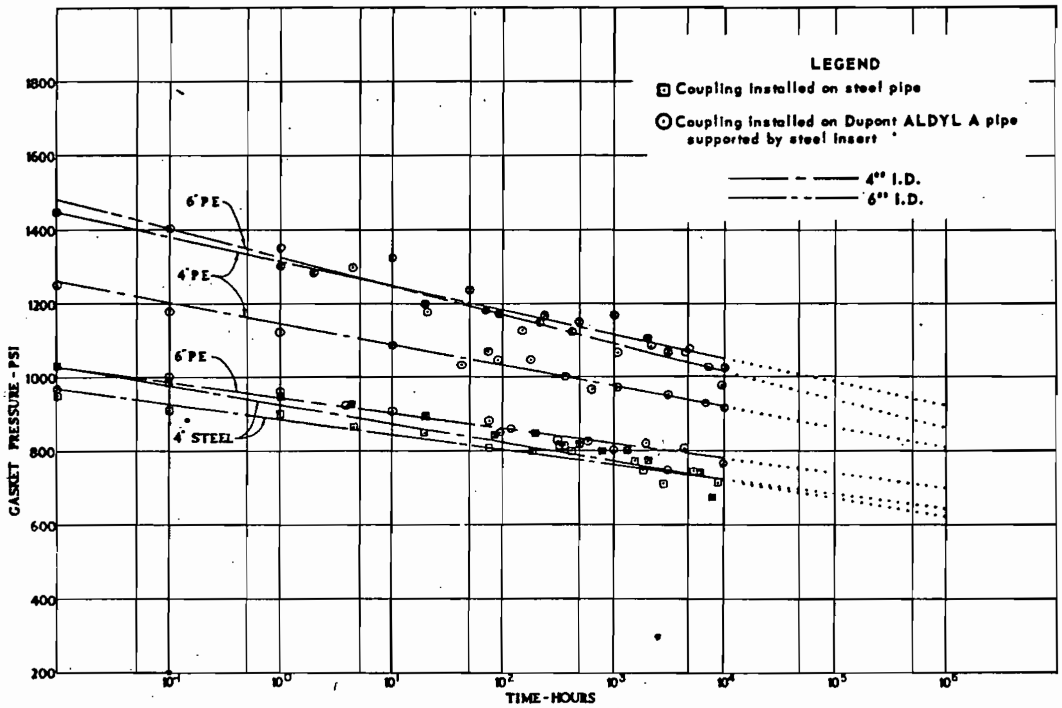


**Figure 6.** Comparison. DRESSER® Style 38 Coupling Installed on Steel Pipe and on Dupont ALDYL® A Pipe Supported by Steel Insert.

BOLTLESS COMPRESSION COUPLING

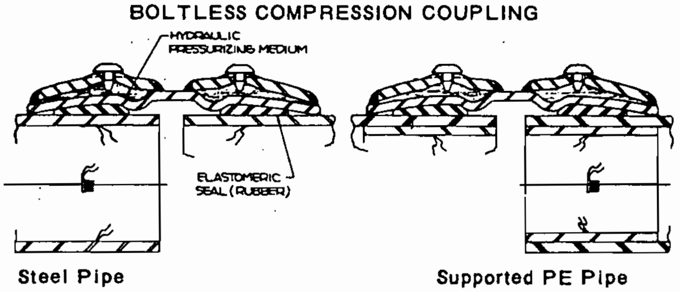


**Figure 7**

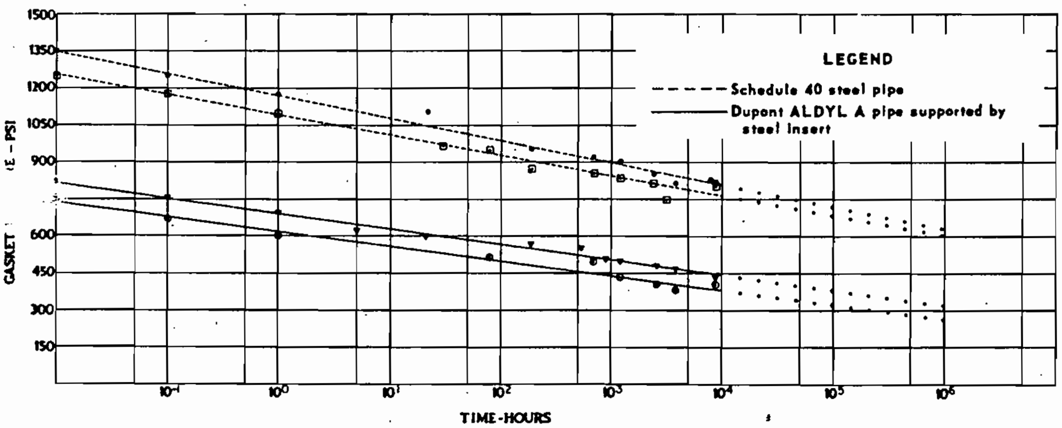


**Figure 8.** Comparison, Dresser POSI-HOLD® 700 Coupling Installed on Schedule 40 Steel Pipe and on Dupont ALDYL® A Pipe Supported by Steel Insert.

mains. This coupling will use as its sealing mechanism a highly loaded elastomeric seal. Fig. 7 shows a cross section of this mechanical coupling without the locking feature. Initial loading of the gasket is accomplished by introducing hydraulic pressure in the annular space between the two coupling shell halves, which deforms the inner shell, bringing the gasket into highly loaded contact with the coupling body and pipe. Using the strain gage calibrated transducer, this coupling was set up and tested over a 10,000 hour period on both steel pipe and internally reinforced polyethylene pipe. The results for this 10,000 hour test are plotted on Fig. 8. We find here that these results confirm the two previously conducted tests in that the difference in gasket relaxation varies only insignificantly between a coupling installed on steel pipe and one installed on the Aldyl "A" material.

Extrapolation of the curves to $10^6$ hours shows the remaining gasket pressure after this time interval in excess of 60% of its original value. Considering that the couplings of this type in size ranges 2"-6" can be hydraulically tested without leakage with pressure in excess of 1,500 psi, the long-term ($10^6$) residual pressure is more than adequate for the pressures used in gas distribution systems.

### Conclusions

Based on known long-term reliability of Style 38 mechanical couplings on steel pipe and the proven performance of Aldyl "A" PE pipe in the gas industry, along with the data presented in this report, it has been concluded that compression couplings of the type tested, where properly installed on supported Aldyl "A" pipe, will give a reliable seal equal throughout the lifetime of the system.

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