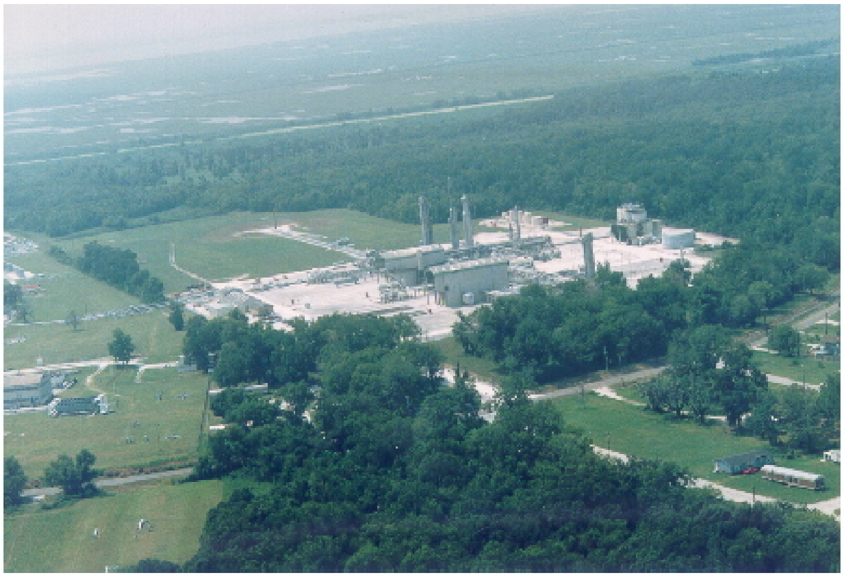
APPENDIX J

GAS DISTRIBUTION



Gas distribution facility

Piece of gas pipeline with external corrosion

Ruptured gas pipeline

GAS DISTRIBUTION

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SUMMARY

The natural gas distribution system includes 2,785,000 km (1,730,000 mi) of relatively small-diameter, low-pressure piping, which is divided into 1,739,000 km (1,080,000 mi) of distribution main and 1,046,000 km (650,000 mi) of services. There are approximately 55 million services in the distribution system. The typical distribution of piping diameters is between 40 mm and 150 mm (1.5 in and 6 in) for main distribution piping and 13 mm to 20 mm (0.5 in to 0.75 in) for service piping. A small percentage of distribution mains and services have a larger diameter pipe, typically for commercial and industrial application. The total cost of corrosion was estimated at approximately 10 percent of the operation and maintenance cost (approximately $5.0 billion).

Several different materials have been used for distribution piping. Historically, distribution mains were primarily made of carbon steel pipe; however, since the 1970s, a large portion of the gas distribution main lines have been made of plastic, mostly polyethylene (PE), sometimes polyvinyl chloride (PVC). A large percentage of mains (57 percent) and services (46 percent) are made of metal (steel, cast iron, or copper). The methods for monitoring corrosion on the lines are the same as those used for transmission pipelines; however, leak detection is widely used.

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SECTOR DESCRIPTION

The Gas Distribution Pipeline sector is a part of the oil and gas industry. Figure 1 illustrates the different components of a natural gas production, transmission, storage, and distribution system. The components include production wells, gathering lines within the production fields, processing plants, transmission pipelines, compressor stations (periodically along the transmission pipelines), storage wells and associated gathering pipelines, metering stations and city gate at distribution centers, distribution piping, and meters at distribution sites (residential or industrial).

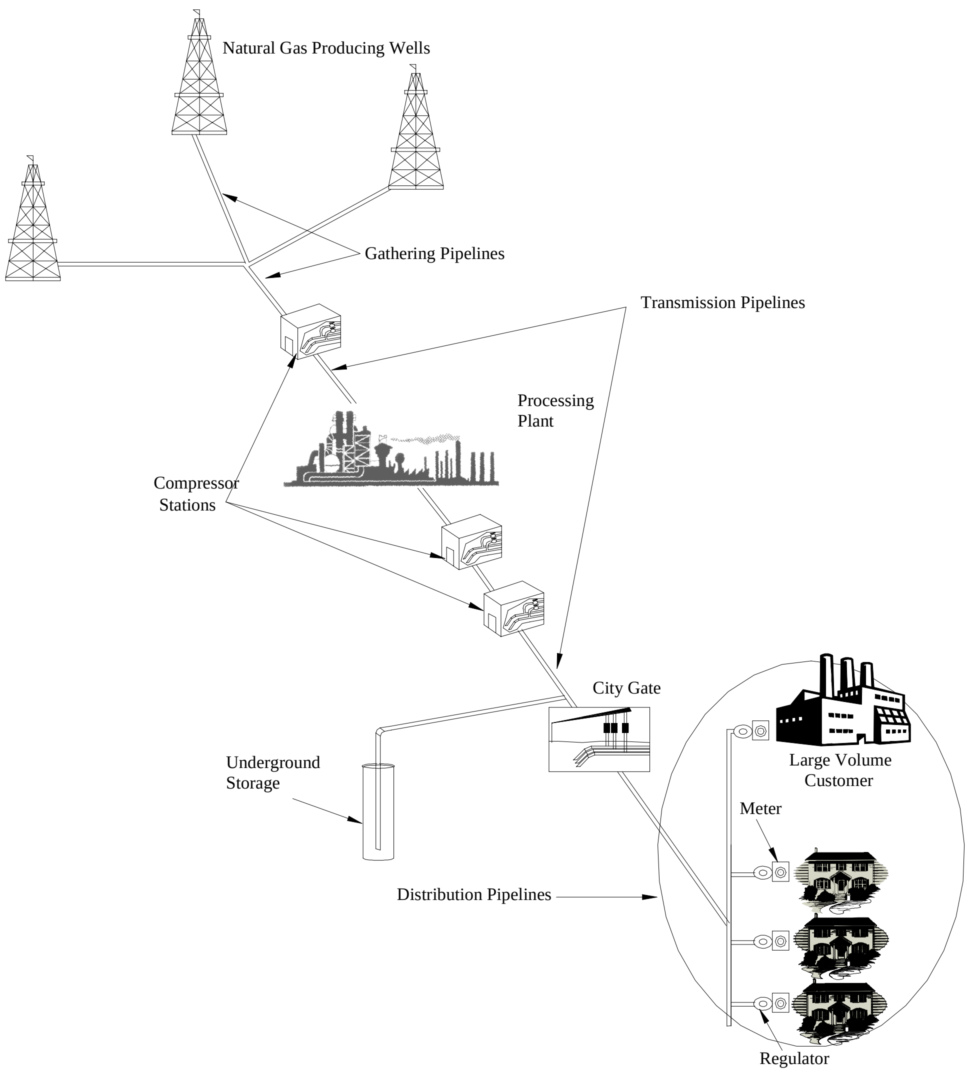

Figure 1. Components of a natural gas production, transmission, and distribution system.

In 1998, the distribution pipeline industry included 2,785,000 km (1,730,000 mi) of relatively small-diameter, low-pressure natural gas distribution piping, which is divided into 1,739,000 km (1,080,000 mi) of distribution main and 1,046,000 km (650,000 mi) of services.[1-2] There are approximately 55,000,000 services in the distribution system. Figure 2 shows the Distribution Pipeline sector in relationship to the oil and gas industry.

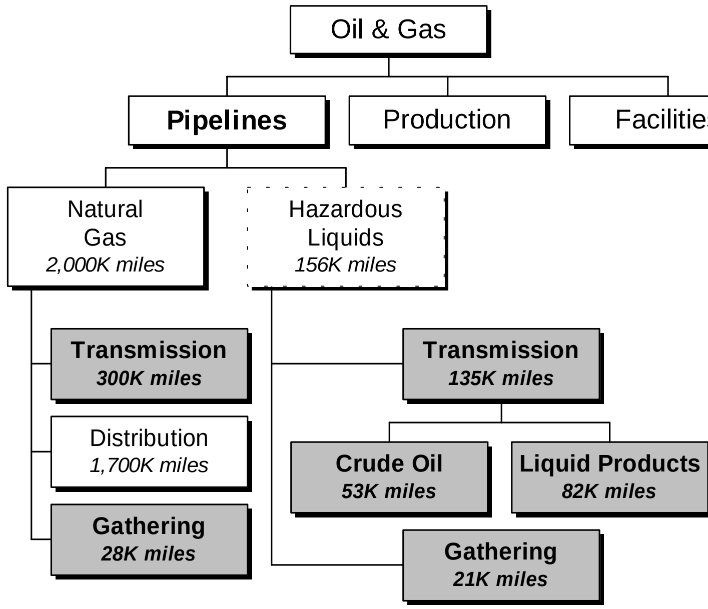

Figure 2. Chart describing the Oil and Gas Distribution Pipeline sector.

BACKGROUND

Several different materials have been used for main and service distribution piping. Historically, distribution mains were primarily carbon steel pipe; however, since the 1970s, a large portion of gas distribution mains have been plastic. Some steel mains are installed in small sections of an existing steel system, in certain "downtown" environments where the use of plastic pipe is restricted, and in some large-diameter [> 150 mm (6 in)] applications. Gas service piping has been constructed primarily of steel and plastic. Essentially, all service piping installed today is made of plastic. Table 1 gives the breakdown of the mains and services by material (1998).(2) Other than steel and plastic, there are some cast iron mains and copper services. The plastic pipe is primarily made of polyethylene, but some PVC piping has also been installed.

Table 1. Summary of miles of gas distribution main and number of services by material.

	STEEL	PLASTIC	CAST IRON	COPPER	OTHER	TOTAL
MILES OF MAINS	569,908	461,433	46,023	52	7,983	**1,085,399**
NUMBER OF SERVICES	23,814,222	28,506,127	51,090	1,497,638	1,099,929	**54,969,006**

1 mi = 1.61 km

Typical distribution piping diameters are between 40 and 150 mm (1.5 and 6 in) for mains and 13 and 20 mm (0.5 and 0.75 in) for services. A small percentage of mains and services is larger diameter pipe, typically for commercial and industrial applications. Tables 2 and 3 give the breakdown of distribution mains and service piping by diameter, respectively (1998).(2)

Table 2. Miles of gas distribution main by material and diameter.

MATERIAL	MILES OF MAIN BY DIAMETER						TOTAL MILES OF MAIN BY MATERIAL
	UNKNOWN	2 in and Less	2 in to 4 in	4 in to 8 in	8 in to 12 in	Greater Than 12 in	
Steel	98	297,246	162,312	93,452	24,632	5,971	583,711
Cast iron	2	1,845	20,030	18,513	3,644	1,989	46,023
Plastic PVC	7	18,572	2,756	189	2	0	21,526
Plastic polyethylene	57	335,691	88,152	15,757	234	16	439,907
Other	0	4,981	1,663	1,121	186	90	8,041
TOTAL BY SIZE	**164**	**658,335**	**274,913**	**129,032**	**28,698**	**8,066**	**1,099,208**

1 in = 25.4 mm, 1 mi = 1.61 km

Table 3. Number of gas distribution services by material and diameter.

MATERIAL	SERVICES BY DIAMETER						TOTAL NUMBER OF SERVICES BY MATERIAL
	Unknown	1 in and Less	1 in to 2 in	2 in to 4 in	4 in to 8 in	Greater Than 8 in	
Steel	534,778	16,620,181	6,420,831	221,997	15,384	1,051	23,814,222
Copper	3	1,012,850	484,366	417	2	0	1,497,638
Plastic PVC	110	1,035,730	160,684	1,459	33	1	1,198,017
Plastic polyethylene	140,429	24,001,942	3,106,968	53,603	5,071	97	27,308,110
Other	93,107	918,691	137,283	1,156	707	75	1,151,019
TOTAL	**768,427**	**43,589,394**	**10,310,132**	**278,632**	**21,197**	**1,224**	**54,969,006**

1 in = 25.4 mm

A large percentage of mains (57 percent) and services (46 percent) are metal (steel, cast iron, or copper) and corrosion is a major issue. For distribution pipe, external corrosion is the primary threat, although internal corrosion has been identified in some instances. The methods of corrosion monitoring on cathodically protected piping are similar to those described in the Transmission Pipeline sector, including pipe-to-soil potential and coating surveys. One difference is that in distribution systems, leak detection is an acceptable method of corrosion monitoring for these pipelines without cathodic protection (approximately 15 percent of the steel mains).(2) For gas distribution piping, corrosion mitigation is primarily sacrificial cathodic protection. Techniques such as in-line inspection are typically not an option for the relatively complex network of distribution mains and services. This makes integrity assessment of the piping difficult.

AREAS OF MAJOR IMPACT

Capital Costs

Because of the vast expanse of distribution piping [992,000 km (616,000 mi)] of metallic main piping and 25,300,000 metallic services], the corrosion-related capital cost of primary interest is the cost of the steel, cast iron, and copper main piping and service lines. The capital cost of the metallic portion of the gas distribution system was not available; making it impossible to calculate a cost of capital related to corrosion.

In order to provide justification for funding for corrosion control in maintaining the existing metallic piping system, a cost is calculated for replacing this infrastructure. The average cost of main replacement (1993 dollars) ranged from $328 per m ($100 per ft) in urban areas to $82 per m ($25 per ft) in developed areas, with an average of $105 per m ($32 per ft). The average cost of a service replacement was $950 per service.(3) It is assumed that the cost of replacement has not significantly increased since 1993 due to improved construction practices. This gives the replacement cost of the metallic gas distribution system as $128 billion [$104 billion for mains (992,000,000 m of metallic main x $105 per m) plus $24 billion for services (25,300,000 metallic services x $950 per service)]. Note that the replacement cost is based on replacement with plastic mains and services, which would be the case in the vast majority of situations.

Pipe Failures

Metal Pipe

Low-pressure gas distribution pipeline failures result in leaks rather than the catastrophic ruptures that may occur in high-pressure natural gas transmission pipelines. The primary concern is that a leak goes undetected and the gas collects in a confined space, eventually igniting and causing an explosion.

Table 4 gives the leak incidence by cause for distribution mains and services.(2) Corrosion was the cause of 40 percent of the leaks repaired on mains and 24 percent of the leaks repaired on services in 1998. The leak incidence as a result of corrosion was 8.4 leaks per 100 km (13.6 leaks per 100 mi) of metal main pipe and 3.9 leaks per 1,000 services. For comparison, the total 1998 leak incidence rate was 12 leaks per 100 km (19.3 leaks per 100 mi) of main pipe and 7.4 leaks per 1,000 services.

Table 4. Leak incidence by cause for distribution mains and services.

	NUMBER OF LEAKS REPAIRED BY CAUSE						**TOTAL LEAKS**
	Corrosion	**Third Party**	**Outside Force**	**Construction Defect**	**Material Defect**	**Other**	
MAINS	83,864	29,566	12,107	6,466	12,835	64,999	**209,837**
SERVICES	99,024	95,555	21,814	20,965	32,356	138,267	**407,981**

The vast majority of the 83,864 corrosion leaks on main pipes and the 99,024 leaks on services are generally detected and repaired without major incidents. Only 26 major incidents caused by corrosion were reported by natural gas distribution pipeline companies for the 5 years from 1994 to 1999 (5.2 incidents per year).(4) These incidents resulted in $4,923,000 in property damage, 4 fatalities, and 16 injuries [see Gas and Liquid Transmission Pipeline sector (Appendix E) for comparison tables and figures between natural gas distribution, natural gas transmission, and hazardous liquid transmission pipelines].

The cost of the 84,000 corrosion leaks on main pipes and the 99,000 leaks on services is significant. For gas mains, the cost of leak repair is estimated at between $1,200 and $2,500 per leak and the cost of service repairs is estimated at between $800 and $1,500 per leak.

The cost of the major incidents are estimated similarly to those for the Transmission Pipeline sector except that the lost product is minimal for low-pressure distribution companies and the legal costs are estimated to be less. Table 5 summarizes the estimated annual costs to gas distribution operators due to corrosion failures. It is estimated that corrosion failures cost the gas distribution operators between $383 million and $667 million annually.

Table 5. Summary of the cost of leaks for gas distribution systems.

	DESCRIPTION	LOW ESTIMATE ($ x million)	HIGH ESTIMATE ($ x million)
Fatalities	One fatality per year @ $1,000,000 to $4,000,000 per occurrence	1.0	4.0
Injuries	3.1 injuries per year @ $500,000 to $1,000,000 per occurrence	1.6	3.2
Added Legal	Legal issues and liability (civil and punitive) @ $50,000,000 to $75,000,000 per fatality and injury (4)	200	300
Property Damage	5.2 incidents per year @ $198,000 per occurrence	0.98	0.98
Non-Reportable Main Leaks	84,000 leaks @ $1,200 to $2,500 per occurrence	100.8	210.0
Non-Reportable Service Leaks	99,000 leaks @ $800 to $1,500 per occurrence	79.2	148.5
TOTAL COST OF GAS DISTRIBUTION PIPELINE FAILURES		**$383.58**	**$666.68**

Plastic Pipe

It is sometimes suggested that plastic pipe is safer than steel pipe due to corrosion of the steel pipe. Although plastic pipe failures are not in the scope of this study, the aging or degradation process of plastics may play an important role in plastic pipe failures and deserve some discussion here. Although degradation of plastic pipe has been studied, degradation processes that lead to plastic pipe failures in operation are not well documented. A recent advisory bulletin from the Research and Special Programs Administration (RSPA), U.S. Department of Transportation (DOT), on the vulnerability of older plastic gas distribution pipe (1960s to mid-1980s) to brittle-like cracking has brought to light the fact that plastic pipe is susceptible to certain aging and degradation processes.[5] The phenomenon of brittle-like cracking in plastic pipe as described in the NTSB report, and generally understood within the plastic pipeline industry, relates to a part-through crack initiation in the pipe wall followed by stable crack growth at stress levels much lower than the stress required for yielding, resulting in a very tight slit-like opening and gas leak. Although significant cracking may occur at points of stress concentration and near improperly designed or installed fittings, small brittle-like cracks may be difficult to detect until a significant amount of gas leaks out of the pipe and potentially migrates into an enclosed space, such as a basement. Premature brittle-like cracking requires relatively high localized stress intensification that may be the result of geometrical discontinuities, excessive bending, improper fitting assemblies, and/or dents and gouges. The report suggests that the combination of more durable plastic pipe materials and more realistic strength testing has improved the reliability of estimates of the long-term hydrostatic strength of modern plastic pipe and fittings. The report also documents that older polyethylene pipe, manufactured from the 1960s through the early 1980s, may fail at lower stresses and after less time than was originally projected.

The number of leaks in plastic (polyethylene) mains in 1993 was 36,948 per year, and in polyethylene services, it was 134,448 per year.[3] This gave a leak incidence of 8.5 leaks per 100 km (13.7 leaks per 100 mi) of polyethylene main and 6.21 leaks per 1,000 polyethylene services. In comparison to above, this suggests that leaks in plastic pipe occur at a similar (slightly less) incidence rate as leaks in distribution piping as a whole.

CORROSION MANAGEMENT

The best way to account for all of the operation and maintenance costs associated with corrosion is to examine the total operating and maintenance budgets for the gas distribution industry. The cost of operation and maintenance for gas distribution piping includes maintenance of both plastic and metallic pipe. The cost of only the metallic piping is being considered in this report. These costs typically include the costs associated with annual test point cathodic protection surveys, leak surveys, cathodic protection maintenance and upgrades (including materials), pipe inspection at excavations, casing and insulator inspection, record-keeping, training, and leak repair. It has been reported that the operation and maintenance budget for distribution pipeline companies is $26.06 billion (1997).[6] It is estimated that 10 percent of the operation and maintenance budget for a typical distribution company represents the cost of corrosion.[7] Therefore, the cost of the operation and maintenance corrosion-related expenditures is estimated at $2.61 billion per year (1997).

Furthermore, the assumption is made that the operation and maintenance cost of corrosion is the same portion of the total cost as calculated for the Gas and Liquid Transmission Pipelines sector (Appendix E) of this report (52 percent). Therefore, the total annual cost of corrosion for natural gas distribution pipelines is $5.0 billion ($2.61 billion = 52% x $5.0 billion).

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