APPENDIX A

Technical Note
Safety and Reliability Performance
of
Natural Gas Distribution Pipeline Systems
1985 – 2002

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EXHIBITS

TECHNICAL NOTE: SAFETY PERFORMANCE OF Natural Gas Distribution Pipeline Systems 1985 – 2002

1.0 Summary

This technical note examines the safety and reliability performance record of natural gas distribution pipeline systems for the period from 1985 through 2002. It excludes transmission lines owned by distribution companies. The performance record is examined based on reportable incidents in the federal Office of Pipeline Safety (OPS) natural gas pipeline incident database (Ref. 1). This current work reviewed several previous studies prepared by others and added some additional analysis based on the OPS data. The relative importance of various parts of the distribution pipeline systems and threats to the systems are examined.

The data show how incident occurrences are apportioned by parts of the distribution infrastructure, cause, and materials of construction. Further analysis of these and other factors might be beneficial in developing the most effective strategy for improvements in safety performance.

Outside forces is the dominant threat category to the systems, comprising about 64% of the mains incidents and 71% of the services incidents. The leading subcategories within this category are third party damage and earth movement. The relative importance of these threats varies with the part of the system and material of construction.

Third party damage and to a lesser extent other forms of outside force damage are due to a variety of factors, many of which are outside direct control of the gas operator. The efforts of the Common Ground Alliance in excavation damage data collection should thus be considered and perhaps further examined for areas that might be key to excavation damage avoidance.

Corrosion is a greater threat to steel pipe bodies than to other parts of a distribution system. Outside forces comprise a greater proportion of causes for polyethylene piping system incidents than for steel piping, 84% to 64%. Corrosion is not applicable to polyethylene (although the analog of other material degradation mechanisms may be; no incidents attributable to any such mechanisms are in evidence from the OPS data).

2.0 Background and Purpose

The function of natural gas distribution systems is to deliver gas safely and reliably. With about 2 million miles of distribution mains and services, the distribution infrastructure exceeds that of transmission pipelines by a factor of about six. This analysis is based on reportable incidents data collected and retained by the federal Office of Pipeline Safety (OPS) (Ref. 1).

The purpose of this technical note is to review the safety performance of the distribution pipeline system based on previously reported analyses and additional analyses performed as part of the current effort focused on normalizing the incident data per mile of system for mains and services and examining incidents by part of system and by major threats.

2.1 Distribution System Characteristics

Natural gas pipeline distribution systems are a significant part of the nation's energy infrastructure. These are the final stage of gas delivery to the nation's natural gas commercial, industrial and residential customers. The nation's distribution system comprises approximately 1.9 million miles of piping, which in 2002 included approximately 1.1 million miles of mains and 0.8 million miles of service lines with about 62 million connections to customer facilities (See Table 2-1). These systems are subject to the federal pipeline safety regulations under Title 49, Code of Federal Regulations, Part 192, with jurisdiction and administration of the regulations by the individual states. However, the U.S. Department of Transportation, Research and Special Projects Administration (RSPA), Office of Pipeline Safety (OPS), maintains certain basic statistics on these systems through annual reporting requirements of the pipeline operators, such as overall mileage on these systems as shown in Table 2-1.

The OPS also maintains a database of pipeline incidents that meet one or more of the following criteria: the incident resulted in a fatality or injury; the damage was $50,000 or more; the operator determined that the incident was important enough to report. This database is the primary publicly available database of pipeline incident failure statistics and records causes and consequence data from operator incident reports.

Table 2-1. Office Of Pipeline Safety, Natural Gas Pipeline Operator, Incident and Distribution Mileage Counts by Year 1/1/1985 - 12/31/2002

Year	No. of Operators*	No. of Incidents**	Distribution Main Mileage	Distribution Number of Services	Distribution Estimated Service Mileage
1985	1,610	205	784,852	44,309,528	498,697
1986	1,562	142	780,401	45,036,343	472,555
1987	1,542	163	802,335	45,848,965	512,360
1988	1,590	201	866,639	48,246,973	504,981
1989	1,558	177	838,237	47,591,804	544,450
1990	1,504	109	945,964	48,755,074	566,763
1991	1,569	162	890,876	52,665,539	589,345
1992	1,545	103	891,984	50,103,974	594,105
1993	1,570	121	951,750	52,009,967	590,917
1994	1,586	141	1,002,669	56,816,569	685,161
1995	1,524	97	1,003,798	55,518,341	669,853
1996	1,481	110	992,860	54,644,300	651,437
1997	1,465	102	1,002,896	54,863,439	640,824
1998	1,456	137	1,040,424	55,735,215	666,506
1999	1,469	118	1,035,946	56,538,415	697,602
2000	1,445	154	1,050,756	57,688,700	675,059
2001	1,427	123	1,100,859	58,465,594	720,391
2002	1,379	102	1,144,407	61,743,320	778,970

* This is the number of operator identification numbers, OPIDs.
** Historical totals may change for any year as OPS receives supplemental information on incidents. The total number of all incidents for 1985 – 2002 is 2467.
Source: www.rspa.dot.com, Oct. 2003. See Exhibit A for original download results.

2.2 Previous Analyses

Three previous studies that examined reliability and safety performance, based on OPS data, appear to be most relevant to the current work (Ref. 2,3,5).

A study for AGA, around 1996, examined the overall characteristics of the distribution pipeline sector of the gas pipeline industry (Ref. 2). This earlier study examined the OPS incident reports for the period 1984 through April 1994 to identify causes of incidents, their relative frequency and their implications for pipeline safety initiatives. The overall conclusion of this work was that the OPS cause category of outside force was the greatest threat to distribution systems, followed by other threats, with corrosion, operator error, material and construction defects contributing less. This pattern has persisted in the current analysis of the OPS data.

The Allegro Energy Group conducted a more recent summary study in 2000 (Ref. 3). The Allegro study provided summaries of distribution system incident data from several perspectives over the period 1985 through 1999. It examined, for the period of 1985 through 1999, the year-by-year profile in incident counts and the change between the beginning and end of the period; the overall profile of threats or causes of incidents; and the profile of incidents by parts of the system and materials of construction. It drew directly on OPS and material in an earlier study by Kiefner and Associates for gas transmission and gathering systems that classified the causes of incidents and defined 22 separate types of causes (Ref. 5).

The Allegro report made various data comparisons. It first examined numbers of incidents by year for the overall system for the period 1985 through 1999. The Allegro report asserted that the counts showed annual variations upward and downward around an overall downward trend. The report examined the data on the basis of a three-year moving average showed that reportable incidents, per unit of gas transported, declined by 45% based on a comparison of the moving averages for the beginning period of 1985-87 and the end period of 1997-99. The number of incidents per trillion cubic feet (TCF) of gas transported fell from 11.0 to 6.0 per TCF (Ref. 3). Based on raw incident count the two-year moving averages were respectively 170 and 119 per year for a decline of 30%. However, the arbitrary comparison of two moving averages from the beginning and end of a period does not indicate a trend. Further analysis would be needed, with supporting statistical tests, to further examine the incident record as a performance indicator.

The above statistics are for distribution systems as a whole. It is also useful to examine incident by parts of the system to identify where the greatest threats lie. The OPS classifies the parts of distribution systems in a hierarchy arranged, in this report, as follows:

Mains	**Service Lines**
Pipe body	Pipe Body
Other parts	Other parts
Fittings	Fittings
Joints	Joints
Meter/regulators	Meter/regulators
Valves	Valves
Welds	Welds
Other	Other
Meter Set Assemblies	
Regulator / meter	
Other parts	

The Allegro study reported on the occurrence of incidents by parts of the overall pipeline system as shown in Table 2-2. Most incidents were found to be associated with the distribution mains followed by the service lines. Other parts of the system and meter set assemblies comprise the next two largest categories, and unknowns make up the rest.

Table 2-2. Incidents by part of system as reported by ref. 3 (Allegro)

SYSTEM PART	**No. of Incidents (1985 – 1999)**	**Percent of Incidents (1985 – 1999)**
MAINS	845	41
SERVICE LINES	508	24
OTHER PARTS	375	18
METER SET ASSEMBLIES	289	14
UNKNOWN	69	3
TOTAL	**2086**	**100**

The Allegro study also examined system mileage and materials of construction as shown in Table 2-3.

2.3 The Current Study

The current analysis begins by reviewing some results of earlier studies, cited above. This technical note examines the safety performance of the distribution piping system infrastructure based on these and updated data and system threats that have been identified by experience. Performance is measured in terms of incident rates and the characteristics of those incidents. An important parameter used in system and equipment engineering reliability and safety work is the frequency of incidents per asset unit. For pipeline systems, the common asset unit is usually taken as some multiple of pipeline mileage. In this analysis, 100,000 miles of pipe was selected as the normalization parameter in the current study. This differed from the previous work, which examined either total event counts or normalized the data by total volume of product transported, used as surrogate for increased infrastructure capacity.

Table 2-3. Mileage Profile For Mains And Services By Material As Of 1999 As Reported By Ref. 3 (Allegro)

	MAINS (% of miles)	**SERVICES** (% of count)
STEEL	54	42
POLYETHYLENE	39	52
CAST IRON	5	--
PVC	2	<1
COPPER	-	3
OTHER	1	2

Source: Ref. 3The AGA study, previously cited, presented the mileage by material and line size as shown in Tables 2-4 and 2-5 (Ref.2).

Table 2-4. Miles Of Gas Distribution Mains By Material And Diameter As Reported By Ref. 2

Material	Miles of Main by Diameter						Total Miles of Main by Material
	Unknown	2 in and Less	Greater than 2 in to 4in	Greater than 4 in to 8 in	Greater than 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
PVC plastic	7	18,572	2,756	189	2	0	21,526
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	**164**	**658,335**	**274,913**	**129,032**	**28,698**	**8,066**	**1,099,208**

Source: Ref. 2 (Source did not specify date. Based in report date of 1996, probable time frame inferred as 1994 - 1996.

Table 2-5. Number Of Gas Distribution Services By Material And Diameter As Reported By Ref. 2

Material	Number of Services by Diameter						Total Number of Services by Material
	Unknown	2 in and Less	Greater than 2 in to 4 in	Greater than 4 in to 8 in	Greater than 8 in to 12 in	Greater Than 12 in	
Steel	534,778	16,620,181	6,420,831	221,997	15,384	1,051	23,814,222
Cast iron	3	1,012,850	484,366	417	2	0	1,497,638
PVC plastic	110	1,035,730	160,684	1,459	33	1	1,198,017
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
1.1.1 Total	**768,427**	**43,589,394**	**10,310,132**	**278,632**	**21,197**	**1,224**	**54,969,006**

Source: Ref. 2 *(Source did not specify date. Based in report date of 1996, probable time frame inferred as 1994 - 1996.)*

The data show how performance varies by threat and various system characteristics. This differentiation is important because it reflects characteristics of distribution piping systems that differ from transmission systems. The characteristics of these systems may suggest approaches, specific to the distribution pipeline industry sector, for the most effective integrity management. Consistent with the scope of the current study, only the most important threats have been examined. This is consistent with rational integrity management where the greatest threats should be addressed first. Some the analyses in this technical note and some additional analyses may be incorporated into a final report.

The major threats to pipeline systems are defined through the cause categories reported in the OPS database. The OPS data are organized in a hierarchy of causes beginning with the broad categories defined in the Research and Special Projects Administration Form 7100.1 for reporting gas pipeline incidents. These categories are:

- Accidentally Caused by Operator
- Construction or Operator Error
- Corrosion
- Damage by Outside Force
- Other

Kiefner and Associates provided a detailed analysis of these data for transmission and gathering lines in a 1996 study (Ref. 5). That report defined twenty-two major cause categories, which can be arranged as subcategories of the major OPS categories listed above. The Allegro report (Ref. 3) examined distribution system data in terms of these categories.

The original classification was developed for the steel lines of transmission and gathering systems, and includes threats for both the pipeline components as well as compressor stations. For the current study, a slight modification was implemented, specific to distribution systems, as shown in Table 2-6. The original Kiefner list is shown along with a suggested modification specific to distribution systems. Only a few of the subcategories have changed, many of which reflect the additional piping materials found in distribution systems.

The Allegro study concluded that the threats and their relative importance will be somewhat different for distribution systems compared with transmission systems, because of fundamental differences in the types of systems. For example, outside force, in general, and third party damage (TPD), in particular, is noted as the largest threat category for both transmission and distribution systems. The Allegro study reports that TPD comprises about 60% or more of incidents in distribution systems while only about 35% in transmission and gathering systems (Ref. 3). Corrosion is a much more important as a threat in transmission and gathering systems than distribution systems, overall, contributing about 23% of the incidents for transmission and gathering systems compared with the 3% to 4% for distribution systems (Ref. 3).

This probably reflects two things: distribution systems contain a higher proportion of non-steel components that are not subject to corrosion; and, distribution assets are mostly in Class 3 and Class 4 areas, where construction activity and maintenance activities associated with other underground assets are higher than in Class 1 and Class 2 areas where most transmission and gathering system assets are located.

In addition to TPD, outside forces include various types of earth movement and other natural events such lightning, external fires, and flooding (sometimes referred to as washout and included along with erosion as "earth movement"). Threats classified as earth movement include subsidence, frost heave, landslide, and seismic movement (earthquakes). The particular threat's significance can depend on the material of construction, among other factors. For example, in cold climates, frost heave is a particular concern for cast iron pipe, most likely because it is less ductile relative to steel or plastic pipe.

Third party damage is also more than just excavation damage, with which is commonly associated. The Allegro report noted a distinction between "traditional" and "non-traditional" TPD. It concluded that "traditional" TPD comprises 35% of TPD incidents and includes:

- Excavation;
- Construction;
- Digging; and
- Drilling.

It concluded that "non-traditional" TPD includes:

- Unrelated fires (fires unrelated to a gas release)
- Vehicle accidents
- Crime

The Allegro and Kiefner reports list some additional third party threats that include: customer equipment failure (downstream of the service meter); electrical failures; vandalism; and damage from vegetation roots. It is not clear why some of these items, not on jurisdictional components of the system, have entered the reportable incident database. It is also known that the list of "unusual" and very specific cases of threats might be extended. Some of these more unusual and rare threats could account for some of the unknown reportable incidents listed among the OPS data.

Table 2-6. Major Threats To Pipeline Systems

OPS Category	Sub-Categories by Kiefner List	Modified Subcategory List for Distribution Systems
Outside Force Damage	Third party excavation Vandalism Earth movement Heavy rains / floods Previously damaged pipe Lightning Cold weather	Third party excavation Vandalism Earth movement (e.g., frost heave, subsidence, landslide, seismic movement, etc.) Heavy rains / floods Previously damaged pipe Lightning Cold weather
Corrosion	External corrosion Internal corrosion Stress corrosion cracking	External corrosion (steel pipe) Internal corrosion (steel pipe) **Other degradation mechanisms** (e.g., cast iron graphitization)
Construction Errors	Defective fabrication weld Defective girth weld Construction damage	Defective fabrication weld (steel pipe only) Defective girth joint (metallic weld for steel, other joining methods for plastic and cast iron) Construction damage
Material Defects	Defective pipe Defective pipe seam Stripped threads / broken coupling Gasket / o-ring failure Seal / packing failure	Defective pipe Defective pipe seam (steel only) <u>For parts of system other than pipe body:</u> Stripped threads / broken coupling Gasket / o-ring failure (e.g. on meters, valves, regulators, etc.) Seal failure
Operator Error	Incorrect operation	Incorrect operation
Equipment Malfunction	Malfunction of control / relief equipment	Malfunction of control / relief equipment
Miscellaneous / Other	Miscellaneous Unknown	Miscellaneous Unknown

These detailed distinctions could not be confirmed from the OPS database in the current study and may require direct review of individual incident reports on file with OPS in Washington, outside the scope of the present study.

The contribution of outside forces as a threat varies with the parts of the system. For main lines, service lines, and meter set assemblies, Allegro reported the following percentages (Ref.3):

- Main lines 64%
- Service lines 72%
- Meter Set Assemblies 74%

In terms of the consequences of incidents, the Allegro report stated that more than 75% of fatalities and more than 50% of injuries occur on parts of the system other than mains. It also notes that, between 1996-1999, that 73% of fatalities and 57% of injuries were caused by third party damage. The Allegro study also concluded that many incidents are caused by others' actions or on customer property, "outside control of the operator."

These and other threats have been further examined in the current study to further clarify their significance and determine how they vary with parts of the system and other factors. This technical note presents what are believed to be some of the additional analyses, out of a spectrum of the possible analyses that could be done on distribution system threats. They have been selected based on their significance in properly characterizing safety and reliability performance for the distribution system infrastructure, beginning first with the most important indicators and likely stakeholder concerns.

2.4 New Analyses

The analysis of threats discussed above has been extended in some new analyses and updated through 2002. Some of these threats have been examined further using data from the earlier studies as well as new data from the OPS database. The earlier work examined data in terms of incident counts. The current analysis examines the data in terms of frequencies by normalizing data for the study period and in terms of 100,000 pipeline miles for the total distribution infrastructure, mains, and services, as appropriate for the specific data set. This accounts for changes in mileage from year to year and generates incident frequency values that can be used to benchmark distribution system performance against other industrial assets handling chemical materials and parts of the distribution system against each other. Comparisons are important in putting the industry's performance into a broader societal perspective. This provides a clearer picture of the contributions of threats to performance over time.

The analysis proceeds with a systematic methodology that examines data normalized by mileage or services counts by parts of the system, by materials of construction, and by threats. Consequences of incidents are also examined, but in less detail.

The analysis proceeds according to a specific hierarchy that reflects analysis by OPS reportable incidents, parts of the system, threats or causes of the incidents, and differences based on material construction and a selection of other relevant factors.

The examination of the data is divided into two distinct parts for the period 1985 through 2002 with presentation of data by:

- Parts of the system affected, incident counts, frequencies;
- Threat or cause of the incident, incident counts and frequencies;
- The consequences of the incidents by parts of the system; and
- The consequences by cause of the incident.

The scope of these analyses has been limited to selected, high priority parts of the systems and of the threats according to the rankings appearing as each part of the data set was examined according to the following analysis hierarchies:

The hierarchy for incident consequences analysis follows a similar pattern.

The data are presented in terms of percentage profiles and in terms of frequencies based on the mileage in each category of pipe: mains and service lines, respective parts of these systems, and material of construction for each for the piping component. From these analyses, a commentary was developed on what the results reveal about safety performance.

Hierarchy for Incidents Analysis by Parts of System

- **Mains**
  - **Pipe body**
    - **Cast iron**
    - **Steel**
    - **Polyethylene**
  - **Other parts of system**
- **Service lines**
  - **Pipe body**
    - **Steel**
    - **Polyethylene**
    - **Other**
  - **Other parts of system**
- **Meter Set Assemblies**
  - **Regulator / meter**
  - **Other parts of system**

Hierarchy for Incidents Analysis by Threats or Causes

- **Mains**
  - **Causes**
    - **Parts**
    - **Materials**
- **Service lines**
  - **Causes**
    - **Parts**
    - **Materials**
- **Meter set assemblies**
  - **Causes**
    - **Parts**
    - **Materials**

3.0 Distribution Mains

The analyses include both the distribution of incidents by system and threats from 1985 through 2002.

3.1 Incident Counts and Frequencies

The Allegro report examined data for the distribution infrastructure as a whole, both in terms of total incidents and normalized by quantity of gas transported per year (Ref. 3). In examining the integrity performance of the assets, the important parameter used in system and equipment engineering reliability and safety work is the frequency of incidents per asset unit rather than the productive capacity (in this case, transportation capacity) of the system. For pipeline systems, the common asset unit is usually taken as a mile of pipe. This normalization parameter has been adopted in the current study.

Table 3-1 shows the year-by-year counts and incident frequencies, based on mileage, for mains.

Table 3-1. Incident Count and Frequencies for Mains Systems (All Parts) by Year (1985 – 2002)

Year	Incidents	Mains Miles	Incidents per 100K Mile-Yr
1985	96	784,852	12.2
1986	53	780,401	6.8
1987	55	802,335	6.8
1988	69	866,639	8.0
1989	69	838,237	8.2
1990	48	945,964	5.1
1991	74	890,876	8.3
1992	42	891,984	4.2
1993	56	951,750	5.9
1994	68	1,002,669	6.8
1995	40	1,003,798	4.0
1996	41	992,860	4.1
1997	34	1,002,896	3.4
1998	54	1,040,424	5.2
1999	48	1,035,946	4.6
2000	69	1,050,756	6.6
2001	49	1,100,859	4.4
2002	26	1,144,407*	2.3
Total	**991**		
Average		**951,536**	**5.8**

Source: Incidents from OPS, Ref.1. Mileage and services counts for years 1985-2002 from www.rspa.dot.gov, October 2003.

* Data from the OPS Annual Reports Database, May 4, 2004, says 1,107,406, a value 3.2% lower. See Exhibit A for results of original download.

Incident Counts and Frequencies by Part of System

The current analysis reveals the results in Table 3-2 for parts of the mains system.

Table 3-2. Incident Frequencies By Primary Parts Of Distribution Mains System (1985 – 2002)

System Part	No. of Incidents	Percent of Incidents	Incident Rate Per Mains 100k Mile-Yr[a]
PIPE BODY	651	65.7	3.8
OTHER PARTS	274	27.7	1.6
NO DATA	66	6.6	0.4
TOTAL OR AVERAGE	**991**	**100**	**5.8 (AVG. FROM TABLE 3-1)**

[A] based on total category incident count for the period divided by the average of 951,536 of mains miles and category average incidents for the period.
Source: ops, ref. 1. See Exhibit B.

The mains pipe body data have been normalized by mileage. The parts other than main line pipe have also been normalized by miles, because on the average, it would be expected that the number of distribution system components would be proportional to the miles of mains. However, if data on the actual counts of these components in the distribution infrastructure are available, these numbers could be converted to component unit basis.

The parts of the system other than the pipe body, as classified by the OPS, are fittings, joints, valves, welds, regulator/meters, and other. Where no data were available from the incident report, the database record designates the part as “no data”.

Incidents by Material of Construction

Analysis of the incidents for the main line pipe body, by material of construction, is of value as an indicator of performance for the primary part involved in incidents for the main lines. Table 3-3 presents the pipe body data on a year-by-year basis for all materials of construction. Table 3-4 presents the data for individual materials for selected years in the 1985-2002 period, obtained from the OPS Annual Reports Database. Mileage by material was from the OPS Annual Report data. The total miles for the years 1998 and 2002 did not match between the values reported on the OPS website (See Appendix A) and those obtained from the Annual Reports database, directly from OPS. The years 1985, 1990, and 1994 differed slightly.

Table 3-3. Incident Count and Frequencies for Mains Pipe Body, All Materials of Construction (1985 – 2002)

Year	Mains Pipe Body Incidents	Mains Miles	Incidents per 100K Mile-Yr
1985	66	784,852	8.4
1986	38	780,401	4.9
1987	36	802,335	4.5
1988	46	866,639	5.3
1989	40	838,237	4.8
1990	29	945,964	3.2
1991	42	890,876	4.7
1992	26	891,984	2.9
1993	31	951,750	3.3
1994	47	1,002,669	4.7
1995	28	1,003,798	2.8
1996	29	992,860	2.9
1997	22	1,002,896	2.2
1998	41	1,040,424	3.9
1999	30	1,035,946	2.9
2000	46	1,050,756	4.4
2001	36	1,100,859	3.3
2002	18	1,144,407*	1.6
Total	**651**		
Average		**951,536 (from Table 3-1)**	**3.9**

Source: Incidents from OPS, Ref.1. Mileage and services counts for years 1985-2002 from www.rspa.dot.gov, October 2003.

* Data from the OPS Annual Reports Database, May 4. 2004, says 1,107,406, a value 3.2% lower. See Exhibit A for results of original download.

Table 3-4. Mains Pipe Body Incident Count and Frequency by Material of Construction (1985 – 2002)

Year	Incidents				Mains Miles				Incidents per 100K Mile-Yr			
	Steel	Polyethylene	Cast Iron	Other	Steel	Plastic *	Cast Iron	Other	Steel	Polyethylene	Cast Iron	Other
1985	31	13	19	3	568,645	149,840	63,185	3,182	5.5	8.7	30.2	94
1990	10	6	12	1	574,479	311,386	58,292	1,807	1.7	1.9	20.6	55
1994	20	7	19	1	608,525	333,689	58,148	2,307	3.3	2.1	32.7	43
1998	14	17	5	3	580,941	409,966	47,271	2,246	2.4	4.1	10.6	134
2002	5	9	3	2	552,449	509,826	42,025	3,106	0.9	1.8	7.1	64
Other**	193	129	108	21	--	--	--	--	--	--	--	--
Total	273	181	166	31	--	--	--	--	--	--	--	--
Average	--	--	--		577,008	342,941	53,784	2,530	2.8	3.7	20	78

Source: Incidents from OPS, Ref. 1. Mileage from OPS Annual Reports Database, May 2004.

* The total miles for all plastic pipe was used as a surrogate for polyethylene pipe. Only the total plastic pipe mileage data were available from the OPS Annual Reports Database. Other plastic use is so small as to be a negligible portion of the total, so that the total plastic pipe mileage is overwhelmingly polyethylene.

** Incidents for the years between 1985 and 2002 for which actual mileage data was not obtained.

One of the incident reporting criteria is the monetary value of property damage. The threshold quantity has not changed between 1985 and 2002. Therefore, over time, the number of incidents that become reportable by exceeding the monetary threshold for reporting has increased because of inflation. This inflation-based "reportables creep" will artificially inflate the apparent incident rate over time. Not accounting for this effect will lead to more conservative estimates of the true incident rates and reduce the apparent improvements in performance or exaggerate any increases incident rates over time. Corrections for these effects were outside the scope of the present study but are noted to call attention to the fact that the actual numerical rates of improvement in performance based on reportable incidents actually exceed the rates of improvement as reported in this study. This leads to the suggestion that a worthwhile effort for future investigation would be the adjustment in reported rates to account for the inflationary effect.

3.2 Threats or Incident Causes

Threats or incident causes are examined in this section. They are examined by part of the system and by materials of construction for the main pipe body. Outside-force damage, as the dominant threat, is examined for by all pipe body incidents and pipe body incidents by material of construction.

Threats or Causes by Part of System

Table 3-5 presents the threats for the all main line components of the distribution system as a whole and the main line pipe body.

Table 3-5. Threats for main line system by parts (1985 – 2002)

	Threat						
System Part	**Outside-force**	**Corrosion**	**Operator Action**	**Construction/ Operating Error**	**Other & No Data**	**Total**	**Percent of Mains Incidents**
Pipe body	486	43	24	16	82	651	65.7
Other & no data	151	10	38	68	73	340	34.3
Total	637	53	62	84	155	991	100
% of incidents	64.3	5.3	6.3	8.5	15.6	100	--

Source: OPS, Ref. 1. See Exhibit B.

Outside-force damage is the single largest threat to main line systems at 64.3% of incidents overall. For the pipe body, it contributes to 486 out of 651 total pipe body incidents or 74.6% of the pipe body incidents. It contributes to 151 out of 340 incidents for other parts of the system, or 44.4%.

Outside-force Damage

Because of its significance as the major threat to distribution piping, incident frequency for outside-force damage and the third party damage (Tpd) subcategory, based on material for main line pipe, was also examined as shown in Table 3-6. From 1985 through 2002, Tpd Represented 74% (361 out of 486 incidents) of the total outside-force contribution, the largest single factor. Earth movement, lightning, external fire, and operator actions were the other main subcategories, noted in the OPS incidents database.

Table 3-6. Outside-force and Third Party Damage Mains Pipe Body by Material (1985 – 2002)

MATERIAL	All Outside-force Incidents	TPD Incidents (subset of outside force)	Total Incidents by Material & Pipe Body	Percent Outside-Force by Material & Pipe Body	Percent TPD by Material & Pipe Body
Cast Iron	109	26	166	65.7	15.7
Steel	207	183	273	82.4	67.0
Polyethylene	151	140	181	83.4	77.3
Other & no data	19	12	31	61.3	38.7
Total	**486**	**361**	**651**	68.7	**55.4**

Source: OPS, Ref. 1. See Appendix B.

Because of the attention focused on outside force, and third party damage in particular, through initiatives such as the Common Ground Alliance, third party damage alone was examined for mains pipe on a year-by-year basis for the study period.

The above table is another example that shows the importance of normalizing performance data by examining the incident data parts of the system and by materials of construction. For cast iron pipe, the profile of threats within the outside force category is distinctly different than for steel or polyethylene pipe. Third party damage is of lesser significance. Further examination of the outside force threat for cast iron pipe revealed that land movement is the primary cause of outside force damage followed by third party damage, as shown in Table 3-7.

Table 3-7. Outside Force Contributions to Cast Iron Pipe Failures

Type of Outside Force	Incidents	Percent of Outside Force Incidents
Frost heave	34	31.2
Subsidence	22	20.2
Landslide/washout	1	0.9
Subtotal, "land movement"	**57**	**52.3**
Third party damage	26	23.8
Other	18	16.5
Operator actions	1	0.9
No data/unknown	7	6.4
Subtotal, not land movement	**52**	**47.6**
Total Outside Forces	**109**	**100**

Source: OPS, Ref. 1. See Exhibit B.

4.0 Distribution Service Lines

The analyses include both the distribution of incidents by parts of system and by threats.

4.1 Incident Counts and Frequencies

Data for service lines was examined in the same manner as the main's data in Section 3. Table 4-1 presents the incident count and frequencies year by year from 1985 through 2002.

Table 4-1. Incident Count and Frequencies for Services Systems (All Parts) by Year (1985 – 2002)

Year	Incidents	No. of Services[a]	Incidents per Million Services	Services Miles	Incidents per 100K Miles
1985	49	44,309,528	1.11	498,697	9.8
1986	39	45,036,343	0.87	472,555	8.3
1987	30	45,848,965	0.65	512,360	5.9
1988	60	48,246,973	1.24	504,981	1.2
1989	39	47,591,804	0.82	544,450	7.2
1990	31	48,755,074	0.64	566,763	5.5
1991	34	52,665,539	0.65	589,345	5.8
1992	23	50,103,974	0.46	594,105	3.9
1993	21	52,009,967	0.40	590,917	3.6
1994	30	56,816,569	0.53	685,161	4.4
1995	26	55,518,341	0.47	669,853	3.9
1996	28	54,644,300	0.51	651,437	4.3
1997	27	54,863,439	0.49	640,824	4.2
1998	41	55,735,215	0.74	666,506	6.2
1999	32	56,538,415	0.57	697,602	4.6
2000	33	57,688,700	0.57	675,059	4.9
2001	34	58,465,594	0.58	720,391	4.7
2002	27	61,743,320*	0.44	778,970	3.5
Total	**604**				
Average		**52,587,892**	**0.65**	**614,443**	**5.7**

Source: Incidents from OPS, Ref.1. Mileage and services counts for years 1985-2002 from www.rspa.dot.gov, October 2003.

* Data from the OPS Annual Reports Database, May 4. 2004, says 59,658,747, a value 3.5% lower. See Exhibit A for original download results.

Incident Counts and Frequencies by Part of System

For distribution services, using the total estimated mileage with the incident counts, the results in the incident frequencies per mile between 1985 and 2002 is shown in Table 4-2.

Table 4-2. Incident Counts and Frequencies By Part Of Service Systems (1985-2002)

SYSTEM PART	No. of Incidents*	Percent of Incidents	Incident Rate per Service 100K Mile-Year
PIPE BODY	234	38.7	2.2
OTHER	313	51.8	3.0
NO DATA	57	9.4	0.5
TOTAL OR AVERAGE	**604**	**100**	**5.7**

*Source: OPS, Ref. 1. See Exhibit B.

In contrast with the mains, where the largest single grouping of incidents involves the pipe body (66%), the majority of incidents with service systems involve parts of the system other than the pipe body (52%), as shown in the table. The pipe body contributes 39%.

Incidents by Material of Construction

Table 4-3. Incident Frequencies for Service Line Pipe Body, All Materials of Construction (1985 – 2002)

Year	Body Incidents	Number of Services	Incidents per 1MM Services-Year	Service Miles	Incidents per 100K Mile-Year
1985	21	44,309,528	0.47	498,697	4.2
1986	9	45,036,343	0.20	472,555	1.9
1987	9	45,848,965	0.20	512,360	1.8
1988	22	48,246,973	0.46	504,981	4.4
1989	21	47,591,804	0.44	544,450	3.9
1990	10	48,755,074	0.21	566,763	1.8
1991	13	52,665,539	0.25	589,345	2.2
1992	12	50,103,974	0.24	594,105	2.0
1993	9	52,009,967	0.17	590,917	1.5
1994	11	56,816,569	0.19	685,161	1.6
1995	15	55,518,341	0.27	669,853	2.2
1996	10	54,644,300	0.18	651,437	1.5
1997	6	54,863,439	0.11	640,824	0.9
1998	12	55,735,215	0.22	666,506	1.8
1999	17	56,538,415	0.30	697,602	2.4
2000	15	57,688,700	0.26	675,059	2.2
2001	12	58,465,594	0.21	720,391	1.7
2002	10	61,743,320*	0.16	778,970	1.3
Total	**234**				
Average		**52,587,892**	**0.25**	**614,443**	**2.2**

Source: Incidents from OPS, Ref.1. Mileage and services counts for years 1985-2002 from www.rspa.dot.gov, October 2003.

* Data from the OPS Annual Reports Database, May 4. 2004, says 59,658,747, a value 3.5% lower. See Exhibit A for results of original download.

Table 4-4. Services Pipe Body Count and Incident Frequency by Material of Construction (1985 – 2002)

Year	Incidents				Services				Incidents per Million Services – Year			
	Steel	Poly ethylene	Cast Iron	Other	Steel	Plastic*	Cast Iron	Other	Steel	PE	Cast Iron	Other
1985	15	5	0	1	29,815,401	11,773,890	214,985	2,505,252	0.50	0.42	0	0.4
1990	4	4	0	2	27,415,107	18,879,865	71,322	2,388,780	0.15	0.21	0	0.8
1994	3	4	0	4	28,049,775	25,112,436	61,831	3,592,527	0.11	0.16	0	1.1
1998	4	4	0	4	24,230,031	29,144,839	58,790	2,304,991	0.16	0.14	0	1.7
2002	4	5	0	1	22,764,950	34,487,405	77,895	2,328,497	0.18	0.14	0	0.4
Other**	61	84	1	24	--	--	--	--	--	--	--	--
Total	91	106	1	36	--	--	--	--	--	--	--	--
Average	--	--	--	--	26,455,053	23,879,687	96,965	2,122,959	0.23	0.21	--	0.9

Source: Incident counts, OPS, Ref.1. Services counts, OPS Annual Reports Database, May 4, 2002.

* The total services counts for all plastic pipe was used as a surrogate for polyethylene (PE) pipe. Only the total plastic pipe counts data were available from the OPS Annual Reports Database. Other plastic use is so small as to be a negligible portion of the total, so that the total plastic-pipe services count is overwhelmingly polyethylene.

** Years between 1985 and 2002 for which actual service counts data not obtained.

Threats or Causes

Threats or incident causes are examined in this section. They are examined by part of the system and by materials of construction for the dominant part of the system the service pipe body. Outside-force damage, as the dominant threat, is examined for the pipe body by material of construction.

Table 4-5 presents the threats for the service line part of the system as a whole and the pipe body.

Table 4-5. Service Line System Threats By Parts (1985 – 2002)

System Part	Threat						
	Outside-force	Corrosion	Operator Action	Construction/ Operating Error	Other	Total	Percent of Total
Pipe body	168	27	4	9	26	234	**38.7**
Other	263	9	23	24	51	370	**61.3**
Total (604)	**431**	**36**	**27**	**33**	**77**	**604**	**100**
% of Total	**71.4**	**6.0**	**4.5**	**5.5**	**12.7**	**100**	**--**

Source: OPS, Ref. 1. See Appendix B.

Outside-force is the largest contributor to service line system incidents with 71.4% of the total. Other, miscellaneous causes, in aggregate, is the next largest category with 12.7%, and corrosion, applicable only to steel lines, is third with 6.0%.

Outside-force Damage

Because of its significance as the major threat to distribution service systems, outside-force damage and the TPD incident frequency, the major contributor to outside-force damage, was examined further for the service pipe, as shown in Table 4-6. From 1985 through 2002, outside force contributed to 71.8% of service pipe body incidents and TPD represented 76.2% of the outside-force contribution resulting in a TPD contribution of 54.7% to all service pipe body incidents. The next largest contributor after TPD was earth movement.

Table 4-6. Outside-force and Third Party Damage for Service Pipe Body by Material (1985 – 2002)

Material	All Outside-Force Incidents	TPD Incidents (subset of outside forces)	Total Incidents by Material &Pipe Body	Percent Outside-force by Material & Pipe Body	Percent TPD by Material & Pipe Body
Steel	59	44	91	64.8	48.4
Polyethylene	89	73	106	84.0	68.9
Other	20	11	37	54.0	29.7
Total all materials	168	128	234	71.8	54.7
% of total pipe body incidents	71.8	54.7	100	--	--

Source: OPS, Ref. 1. See Appendix B.

5.0 Meter Set Assemblies

The third major OPS classification for the part of the system where the incident occurred is the "meter set assembly". Based on the OPS classification, these do not appear to be associated with customer meters. As this part of the overall distribution system is less likely to fail than the mains or services components, the analysis is less detailed than for mains or service piping. Data for meter set assemblies have not been normalized since the count is unknown.

5.1 Incident Counts

Incidents by Part of Meter Set Assembly

Incidents for all parts of the meter set system are presented in Table 5-1. The listing of meter set assembly parts follows the breakdown for reportable incidents for the meter set assembly portion of distribution systems given in the OPS database. The "other" category comprises mostly a group of minor equipment items as well as additional unknowns not otherwise classified as incidents with no data. All of these subcomponents of meter systems are as they are reported in the OPS database.

Table 5-1. Incident frequencies by part of meter set assemblies (1985 – 2002)

SYSTEM PART	No. of Incidents	Percent of Meter Set Assembly Incidents
REGULATOR / METER	142	40.2
OTHER	70	19.8
NO DATA (UNKNOWN)	25	7.08
DRIP RISER	33	9.35
FITTING	28	7.93
PIPE BODY	21	5.95
JOINT	17	4.82
VALVE	15	4.25
WELD	2	0.57
TOTAL METER SET ASSEMBLY	**353**	**100**

Source: OPS, Ref. 1. See Exhibit B.

Incident Count by Year

The incident count by year is presented in Table 5-2. Incidents for meters show less change over time than for either the mains or services lines examined in the preceding sections of this report.

Table 5-2. Incident Count by Year for Meter Set Assemblies All Parts (1985 – 2002)

Year	Incidents
1985	26
1986	19
1987	24
1988	18
1989	20
1990	14
1991	20
1992	21
1993	23
1994	15
1995	14
1996	22
1997	17
1998	21
1999	15
2000	14
2001	24
2002	26
Total	**353**

Source: OPS, Ref. 1. See Appendix B.

Threats or Causes by Part of System

The threats by part of the system are presented in Table 5-3.

Table 5-3. Meter Set Assembly Threats by Parts (1985 – 2002)

	Threat						
System Part	**Outside-force**	**Corrosion**	**Operator Action**	**Construction /Operating Error**	**Other**	**Total**	**Percent of Incidents**
Regulator / meter	141	0	1	0	0	142	40.2
All other	207	4	0	0	0	211	59.8
Total	**348**	**4**	**1**	**0**	**0**	**353**	**100**
% of incidents	**98.6**	**1.13**	**0.28**	**0**	**0**	**100**	**--**

Source: OPS, Ref. 1. See Exhibit B.

Outside-force is overwhelmingly the greatest contributor to meter set assembly incidents at nearly 99%. By part of system, the regulator/meter incidents account for about 40% of the total. The remaining 60% is associated with other components listed previously in Table 5-1.

6.0 Consequences

In the OPS database, the consequences of incidents are reported in terms of fatalities, injuries, and the cost of property damage. The fatality and injury components of consequences are briefly examined here for the three primary parts of distributions systems: mains, services, and meter set assemblies. For each the primary, associated incident cause is also presented.

6.1 Consequences by Part of System

Table 6-1 shows harm to persons and property damage for the three primary parts of the distribution system.

Table 6-1. Fatalities and Injuries by Part of System (1985 – 2002)

Part of System	Incidents	Fatalities		Injuries		Fatality/100 Incidents	Injury/100 Incidents
		No.	&	No.	%		
Mains	991	62	34	600	56	6.3	60.5
Service lines	604	94	51	393	37	15.6	65.1
Meter set assemblies	353	28	15	69	6.4	7.9	19.5
Total	1948	184	100	1062	100	9.4	54.5

Source: OPS, Ref. 1. See Exhibit B. Injuries and fatalities do not add to total incidents because some incidents only involve property damage and some incidents involve more than one fatality or injury. Additional incidents are reported for other parts and unknown parts of distribution systems, which were not analyzed in this study. The study focused on the three main modules of distributions systems that are listed in the table.

These data show that the ratio of harm to people per incident is higher for service lines than for other parts of the system. This may reflect the higher proportion of third party damage incidents for this part of the system. Corresponding fatality and injury frequencies are presented in Table 6-2, over the study period, based on the average mileage for mains and services over that period.

Table 6-2. Fatalities And Injury Frequencies By Part Of System, Based On Average Mileage For Period (1985 – 2002)

Part of System	Incidents	Fatalities	Injuries	Average Mileage	Fatalities / 100K Mile-Year*	Injuries / 100K Mile-Year*
Mains	991	62	600	951,536	0.36	3.5
Service lines	604	94	393	614,443	0.85	3.6

Source: OPS, Ref. 1. See Exhibit B.
* [events] / [(miles)(18 years)]

6.2 Consequences by Threat

Table 6-3 presents consequences of service line system incidents by major threat category for mains and services.

Table 6-3. Consequences By Threat Category (1985 – 2002)

Threat	Incidents		Fatalities		Injuries	
	No.	% by Threat	No.	% by Threat	No.	% by Threat
Mains						
Operator Action	62	6.2	3	4.8	21	3.5
Construction Error	84	8.5	15	24.2	61	10.2
Corrosion	53	5.3	3	4.8	52	8.7
Outside-forces	637	64.3	34	54.8	401	66.8
Other	155	15.6	7	11.3	65	10.8
Total	**991**	**100**	**62**	**100**	**600**	**100**
Services						
Operator Action	27	4.5	1	1.1	30	7.6
Construction Error	33	5.5	4	4.3	14	3.6
Corrosion	36	6.0	9	9.6	35	8.9
Outside-forces	431	71.4	68	72.3	254	64.6
Other	77	12.7	12	12.8	60	15.3
Total	**604**	**100**	**94**	**100**	**393**	**100**

Source: OPS, Ref. 1. See Exhibit B.

Clearly, outside-forces again present the greatest threat. Outside forces account for the majority of the fatality and injury incidents. For mains, the percentage is about 55% and 67%, respectively; for services, it is 72% and 65%. This is not unexpected if one considers that excavators, other workers at the scene are at risk at the time of the incident.

These data could be further developed to examine differences between parts of the system, but the scope has been limited to the current analysis. Of note is that data from the Allegro study (Ref. 3) concluded that that for the non-main pipe parts of the distribution system, 36% of fatalities and injuries occur on the operator easement or right-of-way and 64% on customer property. Whether the “customer property” designation is upstream or downstream of the meter was not clear from the study. It is known that the reportable incident data base includes a number of incidents that do involve a number of items within customer building such as furnaces, stoves, other gas fired equipment and associated piping, connectors and appurtenances that are not jurisdictional under OPS regulations.

Further analysis of consequences and alignments with specific threats may be useful in setting the most effective priorities for further safety enhancements.

7.0 Conclusions

1) The threat profile varies with the parts of the system and materials of construction. For example, outside forces comprise 64% of mains incidents and 71% of services incidents (Table 6-3). Outside force comprises 89% of polyethylene pipe incidents and 59% of steel pipe incidents (Table 4-6).

2) Several dominant threats account for most incidents. Outside forces and the subsets of third party damage and earth movement account for most incidents. This is noted above. However, there are many potential threats, which are driven by local circumstances, so that for a particular section of pipe, the overall average may not be the dominant threat. For example, while on the average third party damage may be a threat to a line, if it is cast iron, earth movement may be a bigger threat at a certain location.

3) Third party damage and to a lesser extent, other forms of outside force damage are due to a variety of factors, many of which are outside direct control of the gas operator. The efforts of the Common Ground Alliance, in dealing with most of the stakeholders involved with underground facilities, is an example of how interactions between operators and others can be enhanced. In particular, the Alliance's efforts in excavation damage data collection could thus be further examined for areas that might be key to excavation damage avoidance.

4) The subcategories of outside forces vary significantly with the parts of the overall distribution pipeline system and with materials of construction. For example, most outside force damage associated with cast iron pipe is from earth movement. For steel and polyethylene pipe it is third party damage.

5) According to previous studies, a significant number of reportable incidents occur on the property of others downstream of the customer meter, which is non-jurisdictional. Such incidents should be removed from the total counts when evaluating the safety performance of the industry from a pipeline operational and regulatory perspective.

6) Further analysis of the OPS data, combined with results of an operator survey may be beneficial in further defining and focusing on the major threats to distribution piping and directly related components in distribution pipeline systems. There are other parameters that could be examined further, if needed, to fine-tune the focus on specific threats and their mitigation. For example, examination of the data in terms of age at failure and geographical differences in threat profiles were not included in the present study.

Starting in 2004, operators will begin reporting distribution incident data using a revised DOT report format. This will collect added data on incidents and contribute to new opportunities for additional analyses for enhancing knowledge of incident behavior.

7) There are opportunities for improving the completeness of incident reporting without changing the current reporting format, which already provides a rich source of useful information. The industry needs to increase its efforts to develop consistency and more attention to detail in reporting incidents to enhance the utility of the incident database in evaluating performance. For example, there are cases in the OPS database where items such as third party damage incident might be reported as "other" rather than in the "outside forces" category. These types of inconsistencies, isolated, may mask certain pieces of data that could further enlighten if the incidents were recorded correctly or with more attention to detail.

8) Further analysis of the "other" categories assigned to some incidents might be warranted by direct analysis of the corresponding incident reports or follow-ups with individual operators to close some of the existing data gaps.

9) There are opportunities for analyses of additional combinations of key variables to further clarify the leading threats and leading system components involved in incidents, using the results of this study for set priorities for such analyses. For example, pipe size is often cited as a variable that might correlate with incident rates. However, pipe size may also be associated with the age, location, and construction material of the pipe. Further understanding of some of the interactions of factors might be worthy of a closer look.

10) The characteristics of the systems themselves, the variability of the performance data from year to year, and the continual changes in practices over time, suggests that more formal statistical techniques might be of benefit in enhancing the understanding of these data and further clarifying the major factors affecting performance.

References

1. U.S. Department of Transportation, Research and Special Projects Administration, Office of Pipeline Safety, Natural Gas Distribution Incident Data, 1984 – Present, www.rspa.dot.gov.

2. Erickson, J., "Twenty-Five Years of natural Gas Pipeline Safety, An Analysis of the Causes and Costs of Accidents", Safety and Compliance Evaluation, Inc., Herndon, VA, undated. (Citations in the report suggest approximately 1996).

3. Allegro Energy Group, The Safety Performance of Natural Gas Distribution Systems, Gas Research Institute, Chicago, IL, February 2001, GRI-01/0041.

4. URS Files, "Appendix J Information", 2003.

5. Vieth, P., Roymna, I., Meloh, R. and Kiefner, J., (Kiefner and Associates), Analysis of DOT Reportable Incidents for Gas Transmission and Gathering Pipelines – January 1, 1985 through December 31, 1994, PRC International and American Gas Association, May 1, 1996.

EXHIBITS

EXHIBIT A

Distribution Mileage and Services Counts Data from OPS Website, October 2003

Natural Gas Distribution Pipeline Annual Miles

Year	No. of Records	Distribution Main Mileage	Distribution Number of Services	Distribution Estimated Service Mileage
1985	1,610	784,852	44,309,528	498,697
1986	1,562	780,401	45,036,343	472,555
1987	1,542	802,335	45,848,965	512,360
1988	1,590	866,639	48,246,973	504,981
1989	1,558	838,237	47,591,804	544,450
1990	1,504	945,964	48,755,074	566,763
1991	1,569	890,876	52,665,539	589,345
1992	1,545	891,984	50,103,974	594,105
1993	1,570	951,750	52,009,967	590,917
1994	1,586	1,002,669	56,816,569	685,161
1995	1,524	1,003,798	55,518,341	669,853
1996	1,481	992,860	54,644,300	651,437
1997	1,465	1,002,896	54,863,439	640,824
1998	1,456	1,040,424	55,735,215	666,506
1999	1,469	1,035,946	56,538,415	697,602
2000	1,445	1,050,756	57,688,700	675,059
2001	1,427	1,100,859	58,465,594	720,391
2002	1,379	1,144,407	61,743,320	778,970

Source: www.rspa.dot.gov.
Note: The original source also listed 1984 data, which was outside the study period and excluded in the above table.

EXHIBIT B

Example Partial OPS Incident Database/Excel Spreadsheet Used For Sorting And Data Incident Data Analysis

IDATE	CLASS	FAT	INJ	PRPTY	CAUSE	PRTLK	PRTFL	MLKD	LOCLK	CAULK
19850103	3	0	0	100000	DAMAGE BY OUTSIDE FORCES	METER SET ASSEMBLY	JOINT	STEEL	ABOVE GROUND	OUTSIDE/THIRD PARTY
19850104	3	0	0	5000	OTHER	METER SET ASSEMBLY	REGULATOR/METER	STEEL	WITHIN/UNDER BUILDING	NO DATA
19850108	3	0	3	500000	OTHER	MAIN	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	NO DATA
19850108	3	0	0	6000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	BODY OF PIPE	STEEL	UNDER PAVEMENT	OUTSIDE/THIRD PARTY
19850108	3	0	0	2000	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	POLYETHYLENE PLASTIC	UNDER GROUND OR UNDER WATER	OPERATOR ACTION
19850109	3	0	0	5000	OTHER	MAIN	WELD	STEEL	OTHER	NO DATA
19850110	2	1	1	3500	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	CAST IRON	UNDER GROUND OR UNDER WATER	EARTH MOVEMENT: OTHER
19850111	2	0	0	3000	DAMAGE BY OUTSIDE FORCES	METER SET ASSEMBLY	REGULATOR/METER	STEEL	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850111	3	0	0	5000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	BODY OF PIPE	POLYETHYLENE PLASTIC	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850111	2	0	0	933	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	POLYETHYLENE PLASTIC	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850115	1	0	2	900	CORROSION	MAIN	BODY OF PIPE	STEEL	UNDER PAVEMENT	NO DATA
19850116	3	0	0	400	CONSTRUCTION/OPERATING ERR	MAIN	BODY OF PIPE	CAST IRON	UNDER PAVEMENT	NO DATA
19850119	3	0	0	1800	DAMAGE BY OUTSIDE FORCES	OTHER	REGULATOR/METER	NO DATA	ABOVE GROUND	OUTSIDE/THIRD PARTY
19850121	3	0	2	0	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	CAST IRON	UNDER PAVEMENT	EARTH MOVEMENT: FROST
19850122	2	0	1	200	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	NO DATA	STEEL	ABOVE GROUND	OUTSIDE/THIRD PARTY
19850122	3	0	0	5000	OTHER	SERVICE LINE	OTHER	STEEL	WITHIN/UNDER BUILDING	NO DATA
19850122	3	0	0	500	DAMAGE BY OUTSIDE FORCES	MAIN	VALVE	STEEL	UNDER PAVEMENT	EARTH MOVEMENT: SUBSIDENCE
19850123	3	0	0	103000	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	POLYETHYLENE PLASTIC	UNDER PAVEMENT	OUTSIDE/THIRD PARTY
19850124	4	0	0	75000	DAMAGE BY OUTSIDE FORCES	MAIN	JOINT	STEEL	UNDER PAVEMENT	EARTH MOVEMENT: FROST
19850124	3	0	0	7800	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850125	3	0	0	100000	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850128	3	0	1	0	ACCIDENTALLY CAUSED BY OPER	OTHER	OTHER	NO DATA	OTHER	NO DATA
19850128	2	0	0	0	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	CAST IRON	UNDER GROUND OR UNDER WATER	EARTH MOVEMENT: FROST
19850129	3	0	0	540	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850129	1	0	2	0	OTHER	MAIN	BODY OF PIPE	CAST IRON	UNDER PAVEMENT	NO DATA
19850131	3	0	0	35000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	JOINT	STEEL	UNDER GROUND OR UNDER WATER	EARTH MOVEMENT: FROST
19850201	4	0	0	85000	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	CAST IRON	UNDER PAVEMENT	EARTH MOVEMENT: FROST
19850201	3	0	1	89000	DAMAGE BY OUTSIDE FORCES	MAIN	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	EARTH MOVEMENT: FROST
19850201	3	0	0	50000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	OTHER	STEEL	OTHER	OUTSIDE/THIRD PARTY
19850202	3	0	0	500	OTHER	MAIN	BODY OF PIPE	STEEL	UNDER PAVEMENT	NO DATA
19850203	3	0	0	600	OTHER	MAIN	BODY OF PIPE	CAST IRON	OTHER	NO DATA
19850203	3	0	0	300000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	BODY OF PIPE	STEEL	UNDER GROUND OR UNDER WATER	OUTSIDE/THIRD PARTY
19850203	2	0	0	200000	DAMAGE BY OUTSIDE FORCES	SERVICE LINE	JOINT	OTHER	UNDER PAVEMENT	EARTH MOVEMENT: SUBSIDENCE
19850205	3	0	0	5000	DAMAGE BY OUTSIDE FORCES	METER SET ASSEMBLY	BODY OF PIPE	STEEL	ABOVE GROUND	OUTSIDE/THIRD PARTY

(One of 67 Excel spreadsheet pages for distribution sector incidents data for 1985 through 2002. Only selected data fields (columns) are shown and all data records (rows) for 1985 are not shown. All 67 pages are expected to be included in final report appendices along with other, selected, sorted analysis sheets.)