TABLE 2.7 ANALYSIS OF REPORTABLE LEAKS IN GAS DISTRIBUTION SYSTEMS FOR TOP 17 STATES, 1970-1975[1]
(cumulative 6-year total)

State	Mileage of Pipeline: Miles[2]	Mileage of Pipeline: Rank	Total Reportable Leaks: I[4]	Total Reportable Leaks: Ratio[3]	Damage by Outside Forces: I[4]	Damage by Outside Forces: % of Total	Damage by Outside Forces: Ratio	Damage by Outside Parties: I[4]	Damage by Outside Parties: % of Total	Damage by Outside Parties: Ratio
1. California (1)	63,848	1	859	0.0135	602	70.1	0.0094	390	45.4	0.0061
2. Michigan (7)	33,497	7	613	0.0183	503	82.1	0.0150	145	23.1	0.0043
3. Texas (3)	49,971	2	426	0.0085	284	66.7	0.0057	186	43.7	0.0037
4. New York (2)	36,156	5	319	0.0088	161	50.5	0.0045	75	23.5	0.0021
5. Illinois (5)	40,152	3	310	0.0077	199	64.2	0.0050	121	39.0	0.0030
6. Pennsylvania (4)	33,639	6	256	0.0076	179	69.9	0.0053	102	39.8	0.0030
7. Arizona (32)	10,148	20	218	0.0215	168	77.1	0.0166	71	32.6	0.0070
8. Alabama (21)	12,486	15	172	0.0138	141	82.0	0.0113	40	23.3	0.0032
9. Ohio (6)	37,757	4	147	0.0039	101	68.7	0.0027	59	40.1	0.0016
10. Indiana (12)	21,074	8	126	0.0060	77	61.1	0.0037	45	35.7	0.0021
11. Louisiana (20)	15,148	13	126	0.0083	101	80.2	0.0067	77	61.1	0.0051
12. Minnesota (19)	11,667	16	121	0.0104	86	71.1	0.0074	50	41.3	0.0043
13. New Jersey (9)	20,768	9	118	0.0057	62	52.5	0.0030	36	30.5	0.0017
14. Wisconsin (16)	17,779	10	113	0.0064	96	85.0	0.0054	70	62.0	0.0039
15. Oklahoma (27)	13,413	14	110	0.0082	81	73.6	0.0060	57	51.8	0.0042
16. Georgia (14)	17,709	11	97	0.0055	72	74.2	0.0041	43	44.3	0.0024
17. Maryland (18)	7,719	27	96	0.0123	71	74.0	0.0091	45	46.9	0.0058
Total and Average	442,991		4,227	0.0095	2,984	70.6	0.0067	1,616	38.2	0.0037
Percent of Nation's Total	68.3%		80.8%		80.6%			79.5%		
Nation's Average				0.0081			0.0057			0.0031

[1] In the order of number of leaks reported to OPSO. Figure in parenthesis after state indicates ranking by population.
[2] 1975 figures, excluding service pipes (from Gas Fact, published by American Gas Association, 1976)
[3] Number of leaks per mile of gas pipeline.
[4] Incidents

TABLE 2.8 ANALYSIS OF REPORTABLE LEAKS IN GAS TRANSMISSION-GATHERING SYSTEMS FOR TOP 15 STATES, 1970-1975[1]
(cumulative 6-year total)

State	Mileage of Pipeline		Total Reportable Leaks		Damage by Outside-Forces			Damage by Outside Parties		
	Miles[2]	Rank	I[4]	Ratio[3]	I[4]	% of Total	Ratio	I[4]	% of Total	Ratio
1. Texas (3)	56,017	1	479	0.0086	276	57.6	0.0049	235	49.1	0.0042
2. Louisiana (20)	23,966	2	213	0.0089	111	52.1	0.0046	71	33.3	0.0030
3. Oklahoma (27)	19,385	4	205	0.0106	143	69.8	0.0074	125	61.0	0.0065
4. West Virginia (34)	14,443	6	169	0.0117	112	66.3	0.0078	29	17.2	0.0020
5. Kansas (30)	22,882	3	139	0.0061	56	40.3	0.0024	32	23.0	0.0014
6. Pennsylvania (4)	17,742	5	132	0.0074	51	38.6	0.0029	28	21.2	0.0016
7. Ohio (6)	13,748	8	126	0.0092	79	62.7	0.0057	45	35.7	0.0033
8. Kentucky (23)	10,488	9	121	0.0115	85	70.2	0.0081	37	30.6	0.0035
9. California (1)	8,645	12	111	0.0128	69	62.2	0.0080	53	47.7	0.0061
10. Arkansas (33)	7,466	15	101	0.0135	88	87.1	0.0118	73	72.3	0.0098
11. Mississippi (29)	9,433	11	59	0.0063	26	44.1	0.0028	21	23.6	0.0022
12. Illinois (5)	10,100	10	54	0.0053	13	24.1	0.0013	7	13.0	0.0007
13. Colorado (28)	8,004	13	48	0.0060	32	66.7	0.0040	23	47.9	0.0029
14. Indiana (12)	6,193	17	47	0.0076	20	42.6	0.0032	13	27.7	0.0021
15. Nebraska (35)	7,469	14	42	0.0056	29	69.1	0.0039	23	54.8	0.0031
Total and Average	235,981		2,046	0.0087	1,190	58.2	0.0050	815	39.8	0.0035
Percent of Nation's Total	71.3%		83.2%		86.0%			85.2%		
Nation's Average				0.0074			0.0042			0.0029

[1] In the order of number of leaks reported to OPSO. Figure in parenthesis after state indicates ranking by population.
[2] 1975 figures (from Gas Fact, published by American Gas Association, 1976).
[3] Number of leaks per mile of gas pipeline.
[4] Incidents

The data in Tables 2.7 and 2.8 also show that the number of outside force and outside party damage incidents for gas pipelines follow closely the same pattern as that of reportable leaks; these states contributed the bulk of the pipeline damage incidents for the nation. Furthermore, the number of reportable leaks that occurred in each of the cited states usually corresponds well with the number of miles of gas pipelines that existed in the states, with only a few exceptions. Arizona ranks seventh in the nation in the number of reportable leaks in the 6-year period, while it ranks only twentieth in the number of miles of gas distribution systems and thirty-second in total population. This fact may be explained by very high migration rates to Arizona (and consequent construction activities) of the past 6 years. New Mexico, although it ranks seventh in the number of miles of gas transmission-gathering systems, has had few reportable leaks possibly because of its low population, low population density, and the extent of its agriculture.

The number of reportable leaks in gas distribution systems for the selected 17 states also correlates reasonably well with the population. This is simply the result of the relationship between population and the number of miles of gas distribution systems; the higher the population the greater will be the number of miles of gas distribution mains and services. The population shows no correlation with the number of reportable leaks in gas transmission-gathering systems because such pipelines are generally located away from population centers. The extent of agriculture appears to be a factor in the number of reportable leaks in gas transmission-gathering systems.

When the data on reportable leaks are computed on the basis of the number of leaks that occurred per mile of gas pipeline, the results vary widely for a few states, indicating that factors characteristic to the states may have played a role in determining the frequency of pipeline damage cases.

The national averages for the number of pipeline accidents per mile of pipeline for the 6-year period are:*

- o <u>Distribution Systems</u>

  Reportable leaks: 0.0081
  Damage by outside forces: 0.0057
  Damage by outside parties: 0.0031

- o <u>Transmission and Gathering Systems</u>

  Reportable leaks: 0.0074
  Damage by outside forces: 0.0042
  Damage by outside parties: 0.0029

If the data in Tables 2.7 and 2.8 are divided by the values for the national averages, the results will show the relative status of the selected states in terms of the frequency of pipeline accidents. Such results are tabulated in Tables 2.9 and 2.10; the states are listed in the order of decreasing frequency of reportable leaks for the 6-year period. Note that the values for reportable leaks, damage by outside forces, and damage by outside parties generally agree well. States having a high frequency of outside party damage to pipelines generally show a high frequency of reportable leaks when the data are examined on the basis of unit distance of pipeline existing in the state. The data in Tables 2.9 and 2.10 show that some states have considerably higher pipeline damage frequencies than others; the frequency could vary by as much as a factor of 10 for outside party damage. Arizona has the highest rate of outside party damage to gas distribution systems, while the state of Arkansas has the highest rate of outside party damage to transmission-gathering systems. Michigan is unusual in its high rate of outside force damage to gas distribution systems, while its share of outside party damage is only average.

* Number of reportable leaks includes those of mains and services for gas distribution systems while the mileage of gas distribution pipelines includes only the mains.

TABLE 2.9 INDEX OF PIPELINE ACCIDENT FREQUENCY FOR SELECTED STATES; GAS DISTRIBUTION SYSTEMS* (1970-1975)

State	All Reportable Leaks	Damage by Outside Forces	Damage By Outside Parties
1. Arizona	2.65	2.91	2.26
2. Michigan	2.26	2.63	1.39
3. Alabama	1.70	1.98	1.03
4. Maryland	1.52	1.60	1.87
5. California	1.42	1.65	1.97
6. Minnesota	1.28	1.30	1.39
7. New York	1.09	0.79	0.68
8. Texas	1.05	1.00	1.19
9. Louisiana	1.02	1.18	1.65
10. Oklahoma	1.01	1.05	1.35
11. Illinois	0.95	0.88	0.97
12. Pennsylvania	0.94	0.93	0.97
13. Wisconsin	0.79	0.95	1.26
14. Indiana	0.74	0.65	0.68
15. New Jersey	0.70	0.53	0.55
16. Georgia	0.68	0.72	0.77
17. Ohio	0.48	0.47	0.52

* Data obtained by dividing the number of leaks per mile of pipeline of each state (Table 2.7) by that of National average.

TABLE 2.10 INDEX OF PIPELINE ACCIDENT FREQUENCY FOR SELECTED STATES; GAS TRANSMISSION-GATHERING SYSTEMS* (1970-1975)

State	All Reportable Leaks	Damage by Outside Forces	Damage by Outside Parties
1. Arkansas	1.82	2.81	3.38
2. California	1.73	1.90	2.10
3. West Virginia	1.58	1.86	0.69
4. Kentucky	1.55	1.93	1.21
5. Oklahoma	1.43	1.76	2.24
6. Ohio	1.24	1.36	1.14
7. Louisiana	1.20	1.10	1.04
8. Texas	1.16	1.17	1.44
9. Indiana	1.03	0.76	0.72
10. Pennsylvania	1.00	0.69	0.55
11. Mississippi	0.85	0.67	0.76
12. Kansas	0.82	0.57	0.48
13. Colorado	0.81	0.95	1.00
14. Nebraska	0.76	0.43	1.07
15. Illinois	0.72	0.31	0.24

* Data obtained by dividing the number of leaks per mile of pipeline of each state (Table 2.8) by that of National average.

The OPSO Annual Report data show that the number of leaks repaired on gas distribution mains has been fairly constant at a rate of about 275,000 per year. The number of leaks repaired on services has been increasing from approximately 300,000 in 1970 to 500,000 annually in 1975.

Due to their relatively low resistance to impact, particularly of plastic services, and shallow depth underground, gas service pipes and components are more likely to be damaged by outside forces than gas mains and their components. On the other hand, more reportable leaks in gas distribution systems were attributed to outside party damage to gas mains than to gas services, as shown in Table 2.11. The data show that more gas mains than services were damaged by outside parties. It is believed that the reverse is true, but many of the damaged services were quickly plugged, shut, and repaired, thus avoiding serious consequences.

TABLE 2.11 PIPE SYSTEMS INVOLVED IN REPORTABLE LEAKS IN GAS DISTRIBUTION SYSTEMS
(OPSO data: 1970-1975, 6-year cumulative total)

	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
Pipe System	I*	% of Total	I*	% of Total	I*	% of Total
1. Mains	2446	46.8	1597	65.3	1100	45.0
2. Services	2575	49.2	1998	77.6	900	35.0
3. Other	196	3.7	105	53.6	30	15.3
4. Not Applicable or Not Specified	13	0.3	4	30.8	3	23.1
Total	5230	100.0	3704	70.8	2033	38.9

* Incidents

The probable reason for the increase in repaired leaks of services is the significant increase in mileage of services and concomitant increase in the number of plastic, thus more vulnerable, services.

A closer examination of the data from Michigan shows that an unusually large portion of outside force damage to gas distribution systems was attributed to the cause factor under "other", particularly in 1974 and 1975. It could not be determined from the OPSO computer data what these other causes are. The raw data may provide the explanation when examined.

The ranking of the states shown in Tables 2.7 and 2.9 is based on OPSO data for reportable leaks and the total mileage of distribution pipeline mains. If the incidents for less than 100,000 customer systems was included, then the ratio of leaks per mile (Table 2.7) would be higher. The particular state position in the ranking might change in Table 2.9.

2.1.3.2 Pipe Systems: It is of interest to consider the reportable leak data as a function of the type of pipe system, distribution mains or services. Table 2.11 shows the breakdown of the reportable leaks as a function of the system type.

2.1.3.3 Pipe Materials: A wide variety of materials are used in constructing gas distribution systems in this country. The OPSO data on repartable leaks were analyzed to determine if correlations exist between materials and outside party damage to pipelines. The results of this analysis are presented in Table 2.12, which shows the highest number of reportable leaks, slightly more than 50 percent, occurred in steel pipes and components during the 6-year period; cast iron, plastic, and copper rank second, third, and fourth. The plastic pipe and components are more prone to damage by outside forces, and particularly by outside parties, as evidenced by the greater portion of the reportable leaks in plastic gas distribution systems that were attributed to outside force and outside party damage. Cast iron pipes were less likely to be damaged by outside parties than other materials. These facts may be explained by:

- Plastic pipe and components are more likely to be ruptured or severed by outside forces because of their comparatively lower impact resistance.

TABLE 2.12 MATERIALS INVOLVED IN REPORTABLE LEAKS IN **GAS** DISTRIBUTION SYSTEMS
(OPSO data: 1970-1975)

Pipe Material	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	Leaks N	% of Total[1]	Leaks	% of Total[1]	Leaks	% of Total[1]
1. Steel	2913	55.7	2091	71.8	1360	46.7
2. Plastic	643	12.3	547	85.1	386	60.0
3. Cast Iron	702	13.4	386	55.0	132	18.8
4. Copper	158	3.0	122	77.2	54	34.2
5. Ductile Iron	38	0.7	28	73.7	8	21.1
6. Wrought Iron	73	1.4	46	63.0	23	31.5
7. Nonmetallic	141	2.7	75	53.2	23	16.3
8. Aluminum	119	2.3	107	89.9	7	5.9
9. Stainless Steel	1	0.0	0	00.0	0	0.0
10. Others	289	5.5	264	91.3	24	8.3
11. Not Applicable	153	3.0	38	24.8	16	10.5
Total	5230	100.0	3704	70.8	2033	38.9

(1) $\% = 100 \times \frac{\text{Leaks}}{N}$

- Underground plastic pipes are more difficult to locate because of their nonmagnetic nature. Conventional magnetic pipe locators can only be used to locate plastic pipes if a trace wire cable was installed with the plastic pipe.*
- Plastic pipes are relatively new to gas distribution systems; thus, more plastic mains and services have been installed in developing areas than in established areas. The developing areas are likely to have more excavation and construction activities.
- The use of plastic pipes for gas distribution has been rising rapidly during the last 6 years. Plastic pipes, in a wide range of sizes are used for both mains and services.
- Cast iron pipes are the material for gas distribution systems of yesteryear. They are found today only in well established parts of cities and towns, where excavation and construction activities are less likely to occur.
- Cast iron pipes in gas distribution systems are of comparatively larger sizes than those of steel or plastic. Their inherent strength renders them less susceptible to damage by outside forces, if they are properly supported.
- Copper has been used primarily in service systems and is not in wide use today.

Figures 2.13, 2.14, and 2.15 present OPSO data on the relation between the material of fabrication and damage cause for reportable leaks. The mileage of mains and services for each material is also presented. The data show that the outside party damage to steel and cast iron systems has shown a slight decrease during the past 6 years. The number of reportable outside party damage incidents for plastic systems has been steadily increasing, except in 1975 when a significant reduction over previous years was registered in spite of a continued increase in plastic pipe mileage. The susceptibility of plastic gas distribution systems to outside party damages could be made more noticeable if the

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* The Federal Gas Pipeline Safety Standard, 49CFR, Part 192, Section 192.321(e) requires that plastic pipe that is not encased must have an electrically conductive wire or other means of locating the underground pipe provided at the time of installation. At least one producer supplies plastic pipe with a stainless steel liner.

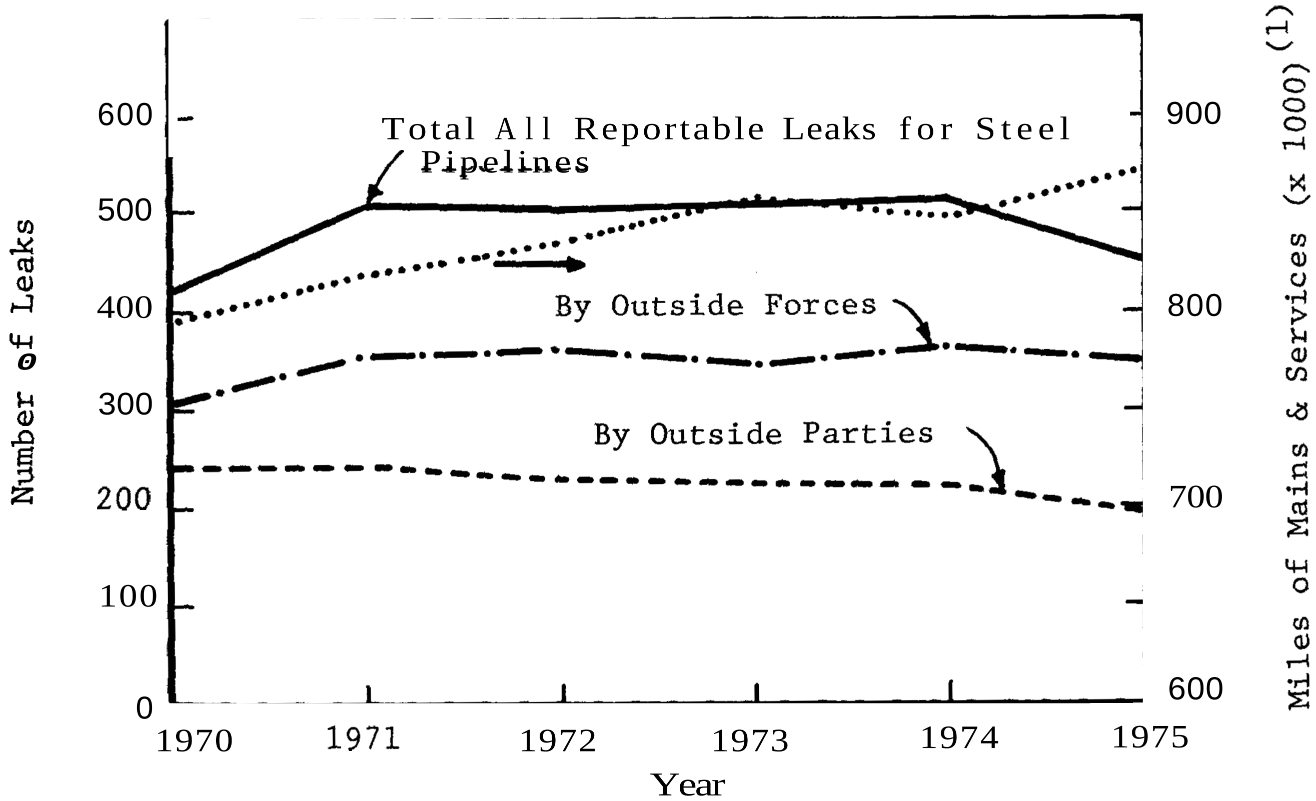

Figure 2.13 Annual Number of Reportable Leaks Involving Steel Gas Distribution Piping Systems (OPSO data: 1970-1975)

(1) Total mileage of all gas distribution pipelines where 50 ft per service is used to estimate service pipe mileage of steel pipelines

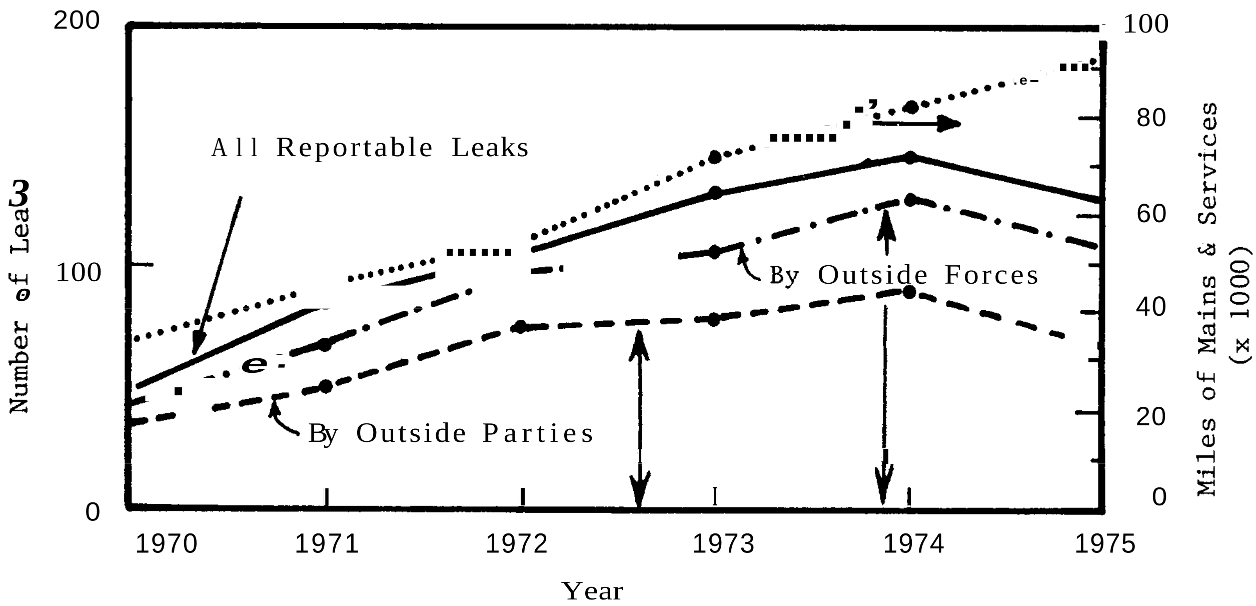

Figure *2.14* **Reportable Leaks Involving Plastic Gas Distribution Piping Systems and Miles** ***of*** **Mains and Services (OPSO data: 1970-1975)**

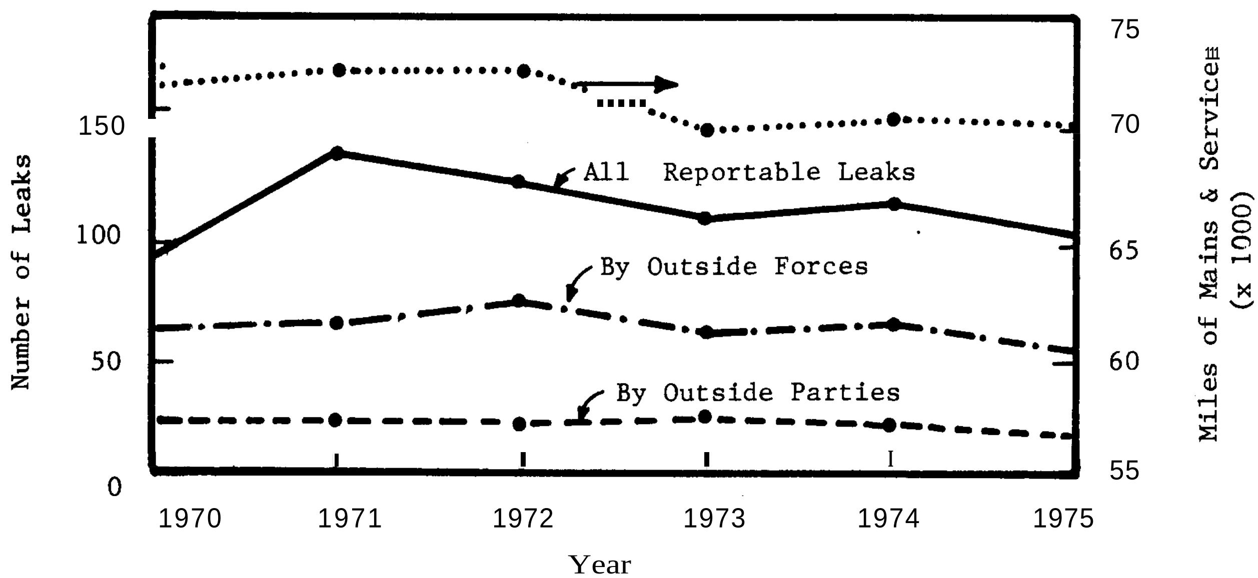

Figure 2.15 Reportable Leaks Involving Cast Iron Gas Distribution Piping Systems and Miles of Mains and Services (OPSO data: 1970-1975)

reportable leaks are computed based on the unit distance of pipeling in service. For example, in 1975 the number of reportable outside party damage per 1000 miles of gas distribution pipeline of various types are steel, 0.23; cast iron, 0.29; and plastic, 0.76. The number of reportable outside party damages per 1000 miles of plastic gas distribution pipelines has been decreasing from 1.42 in 1972, to 1.03 in 1974, and 0.76 in 1975.

2.1.3.4 Pipe Diameter: The relationship between the size of gas pipelines and the reportable leaks was analyzed. Table 2.13 presents a summary of findings from OPSO computer data on reportable leaks. The data show that 16 percent of the reportable leaks in gas distribution systems and about 9 percent of those in gas transmission-gathering systems were associated with pipeline components other than the pipe sections.

In gas distribution pipeline systems, the smallest size of gas pipes, up to 2 inches in diameter, includes the bulk of the gas services plus a substantial amount of gas mains. Thus the 2 inch (and under) diameter pipes have the highest total number of reportable leaks. Because they also have the greatest mileage, the rate of reportable leaks per mile is lower than the rate for the larger diameter pipes. The data are presented in Tables 2.13 and 2.14.

The exact opposite pattern is found in the reportable leak data of gas transmission-gathering systems. The OPSO 1970 to 1975 reportable leak data of gas transmission-gathering pipelines of various sizes are plotted in Figure 2.16 together with the 1975 mileage data of gas pipelines in service. The size distribution of gas transmission-gathering systems did not change much during the 6-year period. These data show that gas transmission-gathering systems of smaller sizes have much higher frequency of reportable leaks than larger ones, particularly in respect to outside force and outside party damage. Furthermore, the group of 4 to 8 inches in diameter exhibits a particularly high frequency of reportable leaks. The reason for this pattern is not clear but may have something to do with the geographical distribution and the population density of the area.

TABLE 2.13 RELATIONSHIP BETWEEN REPORTABLE LEAKS AND DIAMETER OF GAS DISTRIBUTION, AND TRANSMISSION AND GATHERING SYSTEMS
(OPSO data: 1970-1975, 6-year cumulative totals)

Pipe Diameter, inch	Damage to Gas Distribution Systems					Damage to Gas Transmission and Gathering Systems				
	Total	By Outside Forces		By Outside Parties		Total	By Outside Forces		By Outside Parties	
	I[1]	I[1]	% of Total	I[1]	% of Total	I[1]	I[1]	% of Total	I[1]	% of Total
1. 0 to 2	1827	1400	76.6	791	43.3	128	93	72.7	52	40.6
2. 2 to 4	1090	785	72.0	581	53.3	248	192	77.4	158	63.7
3. 4 to 8	824	513	62.3	322	39.1	525	396	75.4	324	61.7
4. 8 to 12	238	131	55.0	93	39.1	474	284	59.9	204	43.0
5. 12 to 18	119	70	58.8	53	44.5	387	197	50.9	129	33.3
6. 18 *to* 24	27	16	59.3	13	48.2	273	119	43.6	45	16.5
7. 24 to 36	12	8	66.7	6	50.0	184	42	22.8	25	13.6
8. 36 and over	6	1	16.7	0	00.0	21	1	4.8	1	4.8
9. Not Applicable or Not Specified[2]	1086	780	71.8	174	16.0	219	60	27.4	19	8.7
Total	5229	3704	70.8	2033	38.9	2459	1384	56.3	957	38.9

[1] Incidents: Reportable Leaks
[2] Components other than pipe sections, i.e., fittings, valves, etc.

TABLE 2.14 FREQUENCY OF REPORTABLE LEAKS OF GAS DISTRIBUTION PIPELINE OF VARIOUS SIZES (OPSO data for 1975)

Pipe Diameter, inch	Approx Miles of Pipelines*	Total Reportable Leaks		By Outside Forces		By Outside Parties	
		I#	Ratio?	I#	Ratiof	I#	Ratio†
1. 0 to 2	706,000	333	0.47	272	0.39	118	0.17
2. 2 to 4	210,000	146	0.70	111	0.53	80	0.38
3. 4 to 8	82,400	119	1.44	77	0.93	51	0.62
4. 8 to 12	36,600	40	1.09	17	0.46	11	0.30
5. 12 and larger	17,200	23	1.34	14	0.81	8	0.47

* Includes gas services by assuming the length of each serv[illegible] to be 50 fe[illegible]

† Number of leaks per 1000 miles of gas pipeline.

Incidents

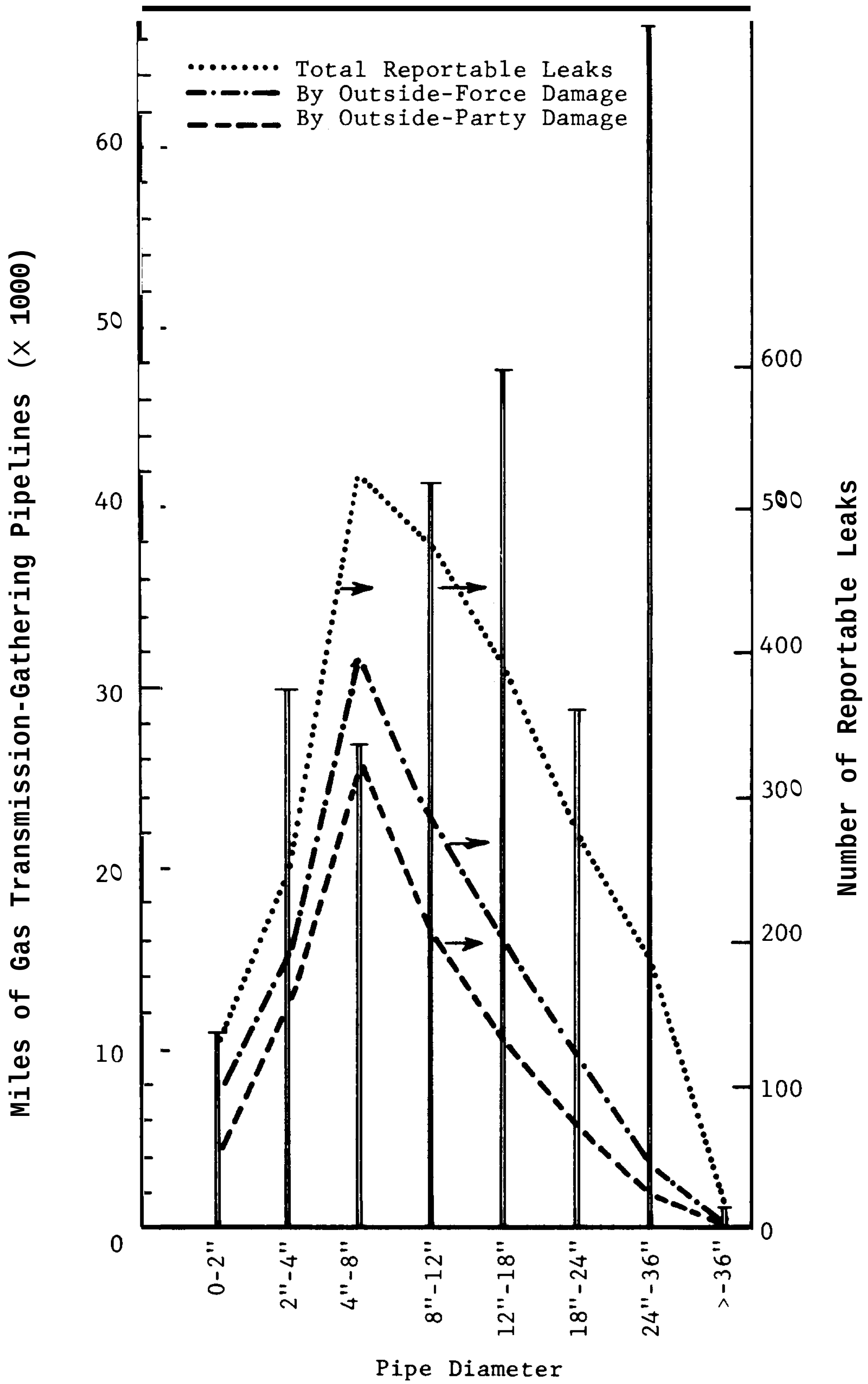

Figure 2.16 Reportable Leaks of Various Diameter Pipe Sizes on Gas Transmission-Gathering Pipeline (OPSO data: 1970-1975, 6-year cumulative totals)

2.1.3.5 Pipe Depth: The relationship between the depth of cover of the gas pipelines and the frequency of outside force and outside party damage was also analyzed. The results of our analysis are summarized in Table 2.15. The data show that, as the depth of pipeline cover is increased, the proportion of reportable leaks attributed to outside force and outside party damage is decreased. The correlation between the depth of cover and the probability of damage by outside forces and outside parties is particularly noticeable in gas transmission-gathering systems.

The data in Table 2.15 indicate that a significant portion of the reportable leaks occurred on components of gas pipeline systems that are not situated underground. These reportable leaks (1269 incidents in distribution systems and 565 incidents in gas transmission-gathering systems) have a somewhat smaller portion of failures from outside party damage because of the aboveground location of the components involved. If this portion of the reportable leaks is excluded from the data, the rest of the data will provide more meaningful information on the severity of outside force and outside party damage to underground gas piping. The results are presented in Table 2.16.

2.1.3.6 Nature of Leak Locations: The OPSO data on reportable leaks in gas pipeline systems classify the locations where leaks occurred into several categories to describe the general conditions of the ground surface. This information was extracted from the computer record and is tabulated in Tables 2.17 and 2.18. As expected, the majority of the reportable leaks in gas distribution systems occurred in residential areas, while the majority of reportable leaks of gas transmission-gathering systems occurred in rural areas because these are the areas where the respective pipe systems are likely to be located. The tabulated data do not show any clear correlation between the nature of the location and the number of reportable leaks, except perhaps that the proportion of outside parties damage attributed to gas distribution systems situated in rural areas is unusually high - particularly, if the density of the pipeline systems is also taken into consideration.

TABLE 2.15 RELATIONSHIP BETWEEN REPORTABLE LEAKS AND DEPTH OF COVER OF GAS DISTRIBUTION, AND TRANSMISSION AND GATHERING SYSTEMS
(OPSO **data:** 1970–1975, **6-year cumulative totals)**

Depth of Cover, inch	Damage to Gas Distribution Systems: Total I[1]	By Outside Forces: I[1]	By Outside Forces: % of Total	By Outside Parties: I[1]	By Outside Parties: % of Total	Damage to Gas Transmission and Gathering Systems: Total I[1]	By Outside Forces: I[1]	By Outside Forces: % of Total	By Outside Parties: I[1]	By Outside Parties: % of Total
1. 0 to 12	95	75	79.0	56	59.0	154	154	100.0	138	89.6
2. 12 to 18	150	118	78.7	80	53.3	118	109	92.4	100	84.8
3. 18 to 24	335	256	76.4	179	53.4	142	123	86.7	94	66.2
4. 24 to 36	1577	1112	70.5	810	51.4	585	351	60.0	239	40.9
5. 36 and over	1739	1113	64.0	713	41.0	938	428	45.6	287	30.6
6. Not Applicable or Not Specified*	1334	1030	77.2	195	14.6	514	218	42.4	98	19.1
Total	5230	3704	70.8	2033	38.9	2451	1383	56.4	956	38.9
* Aboveground	814	699	85.9	109	13.4	335	171	51.0	81	24.2
Within building	393	297	75.6	72	18.3	104	11	10.6	0	00.0
Below water	11	7	63.6	5	45.5	105	64	61.0	29	27.6
Below building	1	0	00.0	0	00.0	0	0	00.0	0	00.0
Not applicable	50	24	48.0	13	26.0	21	10	47.6	8	38.1
Total	1269	1027	80.9	199	15.7	565	256	45.3	118	20.9

[1] Incidents

A more detailed or meaningful analysis will require a breakdown of the distribution of gas pipelines into various types of areas. It is not known if such tendencies occur because the conditions of the ground surface change with time; rural areas can become residential areas in a very short time. Thus, the data would have to be reevaluated periodically.

TABLE 2.16 EXTENT OF OUTSIDE FORCE AND OUTSIDE PARTY DAMAGE TO UNDERGROUND GAS PIPELINES
(OPSO data: 1970-1975, 6-year cumulative totals)

Pipe System	Total Reportable Leaks*	By Outside Forces		By Outside Parties	
		I†	% of Total	I†	% of Total
1. Distribution Systems	3896	2674	68.6	1838	47.2
2. Transmission–Gathering Systems	1942	1165	60.0	858	44.2

* Underground pipe and pipe components only.
† Incidents

2.1.3.7 Reporting of Leaks: OPSO data on reportable leaks in gas distribution systems were analyzed to identify the parties involved in leak reporting. This effort is summarized in Tables 2.19 and 2.20. The data show that the great majority of the reportable leaks were reported to the pipeline operators by partfes other than the personnel of the pipeline operator, indicating that either these leaks were not located during the routine leak surveys or they happened suddenly. The data also show that a large number of outside party damages to gas distribution systems were not reported by the parties that caused the damage. Although these damages are "reportable" in nature and had some serious consequences, only 65.5 percent of the cases were reported by the outside parties who supposedly caused the damage during the 6-year period. The data in Table 2.20 show that the percentage of outside party damage reported by the parties that caused the damage fluctuates between 60 percent and 70 percent, in each of the 6 years.

TABLE 2.17 NATURE OF LOCATIONS WHERE REPORTABLE LEAKS OCCURRED IN GAS DISTRIBUTION PIPELINE SYSTEMS (OPSO data: 1970-1975, 6-year cumulative totals)

Area of Accident	Total Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	I'	% of Total	I'	% of Total	I'	% of Total
1. Commercial	1193	22.8	813	68.1	483	40.5
2. Industrial	243	4.7	167	68.7	115	47.3
3. Residential	3401	65.0	2404	70.7	1233	36.3
4. Rural	350	6.7	290	82.9	179	51.1
5. Unknown	0	0.0	0	00.0	0	00.0
6. Other	31	0.6	24	77.4	20	64.5
7. Not Applicable or Not Specified	12	0.2	6	50.0	3	25.0
Total	5230	100.0	3704	70.8	2033	38.9

* Incidents

TABLE 2.18 NATURE OF LOCATIONS WHERE REPORTABLE LEAKS OCCURRED IN GAS TRANSMISSION AND GATHERING PIPELINE SYSTEMS (OPSO data: 1970-1975, 6-year cumulative totals)

Area of Accident	Total Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	I'	% of Total	I*	% of Total	I'	% of Total
1. Commercial	73	3.0	37	50.7	27	37.0
2. Industrial	116	4.7	64	55.2	48	41.4
3. Residential	201	8.2	124	61.7	86	42.8
4. Rural	1705	69.3	964	36.5	682	40.0
5. Undeveloped	265	10.8	139	52.5	83	31.3
6. Marine	54	2.2	31	57.4	13	24.1
7. Other	35	1.4	22	62.9	15	42.9
8. Not Applicable or Not Specified	10	0.4	3	30.0	3	30.0
Total	2459	100.0	1384	56.3	957	38.9

* Incidents

TABLE 2.19 PARTIES THAT REPORTED LEAKS IN GAS DISTRIBUTION PIPELINE SYSTEMS TO THE PIPELINE OPERATORS
(OPSO data: 1970-1975, 6-year cumulative totals)

	Total Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
Reported by	Leaks	% of Total'	Leaks	% of Total'	Leaks	% of Total'
1. Pipeline Operator Personnel	483	9.2	217	4.1	84	5.9
2. Agency Causing Damage	1500	28.7	1466	65.5	1331	39.6
3. Customer	1023	19.6	615	10.3	209	16.6
4. Police	553	10.6	353	5.0	101	9.5
5. Public	340	6.5	191	3.5	72	5.2
6. Utility Company	123	2.3	54	1.1	23	1.4
7. Fire Department	1110	21.2	755	9.0	182	20.4
8. Other	79	1.5	44	1.3	27	1.2
9. Not Applicable or Not Specified	19	0.4	9	0.2	4	0.2
Total	5230	100.0	3704	100.0	2033	100.0

* The percentage is calculated on the basis of total outside force and outside party damages to show how frequent damages were reported to pipeline operators by the parties causing the damage.

TABLE 2.20 PERCENT OF OUTSIDE PARTY DAMAGE TO GAS DISTRIBUTION PIPELINE SYSTEMS REPORTED BY PARTIES CAUSING DAMAGE
(OPSO data: 1970-1975, 6-year cumulative totals)

	1970	1971	1972	1973	1974	1975	Total
1. Number of Damages Occurred	330	345	349	348	357	304	2033
2. Number of Damages Reported	223	208	246	223	240	191	1331
3. Percentage	72.7	60.3	70.5	64.1	67.2	62.8	65.5

2.1.3.8 Prior Notification: The OPSO data show that the majority of the reportable leaks in gas pipelines caused by outside parties had no prior notification of activity from the outside parties as shown by the summarized data presented in Table 2.21. In only 38.6 percent of the outside party damage incidents to gas distribution systems and 13.2 percent of the outside party damage incidents to gas transmission-gathering systems did prior notification from the outside parties exist.

TABLE 2.21 STATUS OF NOTIFICATION OF OUTSIDE PARTY DAMAGE TO GAS PIPELINES (OPSO data: *1970-1975*, 6-year cumulative totals)

Prior Notification to Pipeline Operators	Distribution Systems I*	% of Total	Trans. & Gathering Systems I*	% of Total
1. Yes	785	38.6	126	13.2
2. No	1161	57.1	811	84.7
3. Not Applicable or Not Specified	87	4.3	20	2.1
Total	2033	100.0	957	100.0

* Incidents

The very low figure of prior notification of outside party damage to gas transmission-gathering systems clearly indicates the lack of such practice in rural areas, where most of the gas transmission-gathering pipelines are located. When the data are examined on a yearly basis, the percentage of outside party damage to gas pipelines that involved prior notification by outside parties remained relatively constant during the 6-year period, as shown in Figure 2.17. Both distribution and transmission systems experienced a somewhat similar history in that there was not a great deal of change in notification during the 6-year period. The transmission-gathering systems were notified prior to excavation from 10 to 20 percent of the time. The gas distribution systems were notified from 35 to 45 percent of the time.

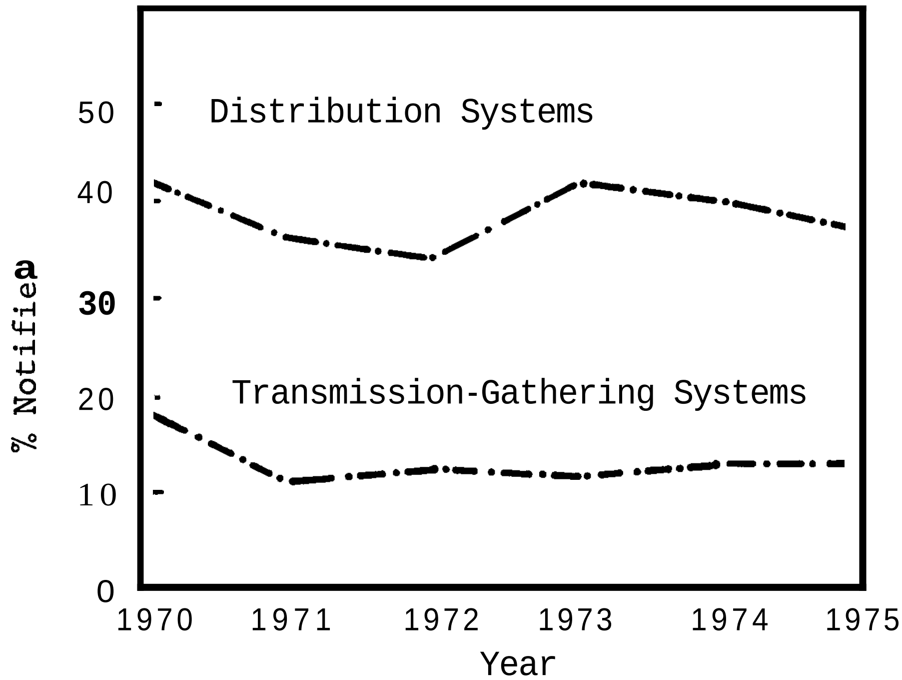

Figure 2.17 Percentage of Outside Party Reportable Leaks on Gas Pipelines Involving Prior Notification

The relationship between the outside party damage to gas pipelines and the existence of prior notification can be further illustrated by gas pipeline damage data from the ICC presented in Table 2.22. The data show that the practice of prior notification among contractors has increased between 1972 and 1976, and resulted in fewer number of hits on gas pipelines. The reduction in number of hits was somewhat low and the percentage of hits having no prior notification was not improved. In fact, the probability that jobs having no prior notification result in damaging gas pipelines has worsened between 1972 and 1976. The exact reason for this development is not clear but could result from the increased congestion of gas pipelines in areas having a high frequency of construction and excavation activities.

TABLE 2.22 OUTSIDE PARTY DAMAGE TO GAS PIPELINES SUFFERED BY NINE ILLINOIS GAS COMPANIES (Illinois Commerce Commission data)

	October 1, 1971 to December 31, 1972(1)	September 1, 1975 to August 31, 1976(2)
1. Estimated total number of jobs occurring near under-ground facilities	180,854	157,920
2. Number of jobs having prior notification	120,221	144,780
Percent of total jobs	66.5	91.7
3. Number of hits reported	4,807	3,334
Percent of total jobs	2.7	2.1
4. Number of hits having no prior notification	2,083	1,674
Percent of total jobs	43.3	50.2
5. Number of unreported hits discovered after completion of jobs	———	78
6. Number of hits per 100 jobs having no prior notification	3.4	12.7
7. Number of hits per 100 jobs having prior notification	2.3	1.1

(1) 15 months, (2) 12 months

2.1.3.9 Pipeline Marking: The OPSO data on reportable leaks caused by outside party damage indicate that about one-half of the gas distribution system incidents and about 82 percent of the gas transmission-gathering system incidents had markers installed indicating the location of pipelines, as shown by the data summarized in Table 2.23. It is fair to assume that, in the case of gas distribution systems, the pipeline markers were mostly of a temporary nature, provided for the outside parties by the pipeline operators, and such markers were provided as a result of prior notification of the pending outside party activities. The markers for gas transmission-gathering systems were presumably permanent types installed at strategic locations (mostly at roadsides) along the pipeline route. The types of markers used by pipeline operators to identify the location of underground gas pipelines are listed in Table 2.24. About one-half of the cases in gas distribution systems were under the category of "not applicable or not specified" because prior notification was absent, and there were a substantial number of cases involving aboveground pipeline components.

TABLE 2.23 STATUS OF PIPELINE MARKERS IN INCIDENTS OF OUTSIDE PARTY DAMAGE TO GAS PIPELINES
(OPSO data: 1970-1975, 6-year cumulative totals)

Provision or Existence of Pipeline Markers	Distribution Systems		Trans. & Gathering Systems	
	I*	% of Total	I*	% of Total
1. Yes	966	47.5	787	82.2
2. No	949	46.[illegible]	148	15.5
3. Not Applicable or Not Specified	118	5.8	22	2.3
Total	2033	100.0	957	100.0

* Incidents

TABLE 2.24 METHOD OF MARKING PIPELINE LOCATION INVOLVED IN OUTSIDE PARTY DAMAGE INCIDENTS
(OPSO data: 1970-1975, 6-year cumulative totals)

Type of Marking Method	Gas Distribution Systems		Trans. & Gathering Systems	
	I*	% of Total	I*	% of Total
1. Permanent Markers	71	3.5	534	55.8
2. Pipeline Map Furnished	102	5.0	12	1.3
3. Temporary Stakes	224	11.0	79	8.2
4. Painted Markers	238	11.7	16	1.7
5. Excavation Provided	49	2.4	5	0.5
6. On-Site Observation	219	10.8	85	8.9
7. Other	89	4.4	61	6.4
8. Not Applicable or Not Specified	1041	51.2	165	17.2
Total	2033	100.0	957	100.0

* Incidents

After examining the data, one logical question to ask is why damages occurred in incidents where the locations of the pipelines were made known to outside parties? The answer to this question could be related to the following factors:

- Accuracy of record on pipeline location
- Effectiveness of pipeline locating equipment and techniques
- The effectiveness of markers
- Carelessness of the outside parties
- Competence of the equipment operators
- Faulty equipment or operating procedures
- Inadvertent actions of equipment operators
- Deliberate actions of outside parties or equipment operators.

The available data do not allow one to determine the contribution to the outside party damage problem of these factors.

The requirement to mark the location of underground lines is not widely practiced. Marking techniques vary from one utility to another though work is now in progress (in particular see APWA-Utility Location Coordination Council (ULCC) efforts) to standardize techniques for temporary marking. The effectiveness of permanent pipeline markers depends to some extent on age of the marker. If the surface of the earth has been changed between the time of permanent installation and the time of excavation an excellent marker together with on-site observation may not prevent a dig-up. Statute requirement of pipeline marking does not by itself prevent dig-ups (see Table 2.25).

TABLE 2.25 PERCENTAGE OF REPORTABLE LEAKS IN GAS PIPELINES CAUSED BY OUTSIDE PARTY DAMAGE WHERE A STATUTE REQUIRING THE MARKING OF PIPELINE LOCATIONS EXISTED
(OPSO data: 1970-1975, 6-year cumulative totals)

Pipeline System	1970	1971	1972	1973	1974	1975	Average
Distribution Systems	27.0	25.6	20.9	22.7	35.2	38.4	28.1
Transmission-Gathering Systems	5.8	3.0	12.6	8.7	14.5	12.5	9.8

2.1.3.10 Consequences of Reportable Leaks: The OPSO data on reportable leaks in gas pipeline systems were also analyzed to determine the nature of some of the consequences. Table 2.26 presents a summary of what happened to the pipeline and the gas when reportable leaks in gas distribution systems occurred. Table 2.27 presents the counterpart for gas transmission-gathering systems. The data show that the percentage of reportable leaks that resulted in the rupture of pipe, ignition of gas, explosion, or secondary explosion, is much hig[illegible] gas distribution systems than in gas transmission-gathering systems. This fact may be explained by the difference in some characteristics of the two pipeline systems:

- Transmission-gathering systems traverse rural areas where there is much less general construction activity thus there is less likelihood of pipe rupture.
- Ignition sources are less likely to be found in areas where gas transmission-gathering systems are found (sources for explosion and secondary explosions).

Further analysis of the data shown in Tables 2.26 and 2.27 was made and summarized in Table 2.28. Outside force damage causes 70.8 percent of the reportable leaks in gas distribution systems but 85.5 percent of the pipe ruptures. In gas transmission and gathering systems outside force damage causes 56.3 percent of the reportable leaks and 57.2 percent of the pipe ruptures.

In terms of personnel injuries and fatalities resulting from reportable leaks of gas pipeline systems, the OPSQ data show that the probability of injuries to personnel and fatalities is considerably higher in gas distribution operations than in gas transmission-gathering operations. This is shown in data presented in Tables 2.29 and 2.30.

TABLE 2.26 CONSEQUENCES OF REPORTABLE LEAKS - GAS DISTRIBUTION SYSTEMS
(OPSO data: 1970–1975, **6-year** cumulative totals)

Consequence of Leak	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	I*	% of Total	I*	% of Total	I*	% of Total
1. Rupture of Pipe						
Yes	2532	48.4	2164	58.4	1273	62.6
No	2609	49.9	1501	40.5	744	36.6
Not Applicable	89	1.7	39	1.1	16	0.8
2. Ignition of Gas						
Yes	2846	54.4	1856	50.1	722	35.5
No	2336	44.7	1824	49.2	1301	64.0
Not Applicable	48	0.9	24	0.7	10	0.5
3. Explosion						
Yes	829	15.9	389	10.5	181	8.9
No	4334	82.9	3275	88.4	1834	90.2
Not Applicable	67	1.2	40	1.1	18	0.9
4. Secondary Explosion						
Yes	568	10.9	405	10.9	157	7.7
No	4596	87.9	3265	88.2	1859	91.5
Not Applicable	66	1.2	34	0.9	17	0.8

* Incidents N = 5230 N_1 = 3704 N_2 = 2033

TABLE 2.27 CONSEQUENCES OF REPORTABLE LEAKS - GAS TRANSMISSION AND GATHERING SYSTEMS
(OPSO data: 1970-1975, 6-year cumulative totals)

Consequence of Leak	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	I*	% of Total	I*	% of Total	I*	% of Total
1. Rupture of Pipe						
Yes	824	33.5	471	34.0	344	35.9
No	1599	65.0	906	65.5	609	63.7
Not Applicable	36	1.5	7	0.5	4	0.4
2. Ignition of Gas						
Yes	270	11.0	85	6.1	28	2.9
No	2158	87.8	1289	93.1	920	96.1
Not Applicable	31	1.2	10	0.8	9	1.0
3. Explosion						
Pes	67	2.7	12	0.9	5	0.5
No	2353	95.7	1359	98.2	942	98.4
Not Applicable	39	1.6	13	0.9	10	1.1
4. Secondary Explosion						
Yes	58	2.4	20	1.4	13	1.4
No	2360	96.0	1352	97.7	938	98.0
Not Applicable	41	1.6	12	0.9	6	0.6

* Incidents $N = 2459$ $N_1 = 1384$ $N_2 = 957$

TABLE 2.28 PERCENTAGE OF CONTRIBUTION TO VARIOUS CONSEQUENCES OF PIPELINE FAILURES BY OUTSIDE FORCE AND OUTSIDE PARTY DAMAGE (OPSO data: 1970–1975, 6-year cumulative totals)

Consequence	Incidents	Gas Distribution Systems: Outside Force	Others[1]	Outside Party[2]
		%		
1. Reportable Leaks	5230	70.8	29.2	38.9
2. Rupture of Pipe	2532	85.5	14.5	50.3
3. Ignition of Gas	2846	65.2	34.8	25.4
4. Explosion	829	46.9	53.1	21.8
5. Secondary Explosion	568	71.3	28.7	27.6

Consequence	Incidents	Gas Transmission–Gathering Systems: Outside Force	Others[1]	Outside Party[2]
		%		
1. Reportable Leaks	2459	56.3	43.7	38.9
2. Rupture of Pipe	824	57.2	42.8	41.8
3. Ignition of Gas	270	31.5	68.5	10.4
4. Explosion	67	17.9	82.1	7.5
5. Secondary Explosion	58	34.5	65.5	22.4

1. Causes of reportable leaks other than outside force damage.
2. Outside party damage is a part of outside force damage.

TABLE 2.29 PERSONNEL FATALITIES AND INJURIES RESULTING FROM REPORTABLE PIPELINE LEAKS IN GAS DISTRIBUTION SYSTEMS (OPSO data: 1970-1975, 6-year cumulative totals)

	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	Incidents (N)	Probability (N/5230)	Incidents (N_1)	Probability (N_1/3704)	Incidents (N_2)	Probability (N_2/2033)
1. Employee Fatalities	12	0.00229	3	0.00081	2	0.00098
2. Employee Injuries	202	0.03862	64	0.01728	36	0.01771
3. Nonemployee Fatalities	130	0.02486	69	0.01863	30	0.01476
4. Nonemployee Injuries	1470	0.28107	765	0.20653	348	0.17118
Total	1814	0.34684	901	0.24325	416	0.20463

TABLE 2.30 PERSONNEL FATALITIES AND INJURIES RESULTING FROM REPORTABLE PIPELINE LEAKS IN GAS TRANSMISSION AND GATHERING SYSTEMS (OPSO data: 1970-1975, 6-year cumulative totals)

	All Reportable Leaks		Damage by Outside Forces		Damage by Outside Parties	
	Incidents (N)	Probability (N/2459)	Incidents (N_1)	Probability (N_1/1384)	Incidents (N_2)	Probability (N_2/957)
1. Employee Fatalities	13	0.00529	0	0.00000	0	0.00000
2. Employee Injuries	65	0.02643	10	0.00723	7	0.00732
3. Nonemployee Fatalities	10	0.00407	1	0.00072	1	0.00105
4. Nonemployee Injuries	69	0.02806	45	0.03252	34	0.03553
Total	157	0.06385	56	0.04047	42	0.04390

2.2 Damage to Liquid Pipelines

2.2.1 Petroleum Pipelines – The largest group of liquid pipelines in the United States is the petroleum pipeline system used to transport crude oil and refined petroleum products, such as gasoline, propane, butane, jet fuel, and heating oil. Petroleum pipelines are commonly classed as trunk lines or gathering lines, depending upon the function of the pipelines. Trunk lines are further divided into crude and product lines, according to the materials being transported. The mileage of petroleum pipelines in the United States as of January 1, 1974, is:

Trunk Lines	
Crude Lines	76,251 miles
Product Lines	76,839 miles
Gathering Lines	69,266 miles
Total	222,356 miles

2.2.1.1 Pipeline and Damage Data: Since crude and gathering lines are used to transport crude oil from wellheads to refineries, they are located in oil producing states, plus the major cross-country trunk lines that link oil fields to distant refineries or ports. The product lines transport refined petroleum products from refineries to market areas; and they are distributed more widely throughout the country. If the petroleum pipelines are combined into a single category, their distribution in the continental 49 states is still very uneven; the bulk of the petroleum pipelines are concentrated in Texas, Oklahoma, Kansas, Illinois, California, Louisiana, and Pennsylvania, as shown in Table 2.31. The offshore crude pipelines are located primarily off the costs of Louisiana and California. Therefore, the states that have high mileage of gas pipelines (see Tables 2.7 and 2.8) generally have high mileage of petroleum pipelines also.

Similar to gas transmission and gathering pipelines, petroleum pipelines also develop leaks and are subjected to damage by outside forces and by outside parties. The nation's interstate petroleum pipeline operators are required by law to submit

TABLE 2.31 ACTIVE PETROLEUM PIPELINES IN THE UNITED STATES
(as of January 1, 1974)

State	Total in Place Jan. 1, 1971 (Miles)	Pipe Laid (Miles) New	Pipe Laid (Miles) Second-hand	Pipe Taken Up (Miles)	Total in Place Jan. 1, 1974 (Miles)
Alabama	1,237	421	101	-	1,759
Alaska	87	35	4	2	124
Arizona	1,071	272	9	-	1,352
Arkansas	2,397	565	408	373	2,997
California	9,858	717	760	1,152	10,183
Colorado	1,756	275	236	87	2,180
Connecticut	92	-	-	-	92
Delaware	3	-	3	-	6
Florida	87	213	-	27	273
Georgia	1,728	184	4	30	1,886
Idaho	640	6	-	13	633
Illinois	11,096	1,254	817	1,762	11,405
Indiana	4,495	283	72	221	4,629
Iowa	3,889	376	-	314	3,951
Kansas	16,013	500	635	1,241	15,907
Kentucky	2,511	8	1,310	1,503	2,326
Louisiana	7,956	1,296	834	1,295	8,791
Maine	353	-	1	-	354
Maryland and District of Columbia	219	-	1	-	220
Massachusetts	242	94	11	-	347
Michigan	3,744	156	297	268	3,929
Minnesota	2,955	107	106	69	3,099
Mississippi	3,058	435	78	182	3,389
Missouri	6,295	562	336	265	6,928
Montana	3,054	127	188	563	2,806
Nebraska	3,341	149	182	389	3,283
Nevada	328	189	2	321	198
New Hampshire	108	-	38	38	108
New Jersey	568	2	1	99	472
New Mexico	5,941	1,139	223	1,376	5,927
New York	1,673	74	247	55	1,939
North Carolina	834	70	-	4	900
North Dakota	1,664	63	113	99	1,741
Ohio	6,909	420	123	487	6,965
Oklahoma	22,308	1,401	292	3,454	20,547
Oregan	689	11	12	39	673
Pennsylvania	8,291	87	162	502	8,038
Rhode Island	17	-	-	-	17
South Carolina	635	71	-	37	669
South Dakota	640	-	37	35	642
Tennessee	629	78	1	1	707
Texas	65,259	1,436	3,429	4,652	65,472
Utah	1,042	39	504	244	1,341
Vermont	177	-	-	-	177
Virginia	822	8	11	7	834
Washington	762	129	3	134	760
West Virginia	3,612	41	548	661	3,540
Wisconsin	942	-	1	1	942
Wyoming	6,644	664	186	597	6,897
Total	218,671	13,957	12,326	22,599	222,355

Crude-Oil and Refined Products Pipeline Mileage in the United States, Bureau of Mines, January 1, 1974.

reports to the DOT on pipeline accidents that involve fatalities, injuries, or substantial property and/or commodity losses. The report form (DOT Form 7000-1) must be used for reporting accidents on liquid pipelines. The form is simpler than that used for reportable leaks of gas pipelines and it also identifies the cause of accident, including corrosion (external or internal), equipment ruptured line, defective pipe seam, incorrect operation, rupture of previously damaged pipe, and others. These cause factors can be grouped, similar to reportable leaks of gas pipelines, into four major categories: corrosion, damage by outside forces, construction defects or material failure, and others. A graphical presentation of these causes of liquid pipeline accidents in the United States is presented in Figure 2.18.

The data in Figure 2.18 show that the total number of accidents occurring annually on the nation's liquid pipelines has been decreasing from 500 in 1968 to 260 in 1975. When these data are compared to the leak repair and reportable leak data of gas transmission-gathering systems (Figures 2.11 and 2.12) it will seem that they correlate very well. In all cases, the number of pipeline accidents caused by corrosion has been decreasing while the number of pipeline accidents caused by outside forces or outside parties has been nearly constant during the 8-year period. As a result, the outside force damage to the nation's liquid pipelines in 1975 was about 40 percent of the total number of accidents.

The damage statistics, in terms of number of accidents per mile of pipeline per year, are also similar between the liquid pipelines and the gas transmission-gathering systems. If we assume that the liquid pipelines consist solely of petroleum pipelines, the pipeline accident rate in 1975 was estimated to be 1.2 incidents per 1000 miles. The reportable leak rate of gas transmission-gathering pipelines in 1975 was 1.1 incidents per 1000 miles. In respect to the rate of outside party damage, the figures of liquid pipeline systems are also quite close to that of gas transmission-gathering pipeline systems.

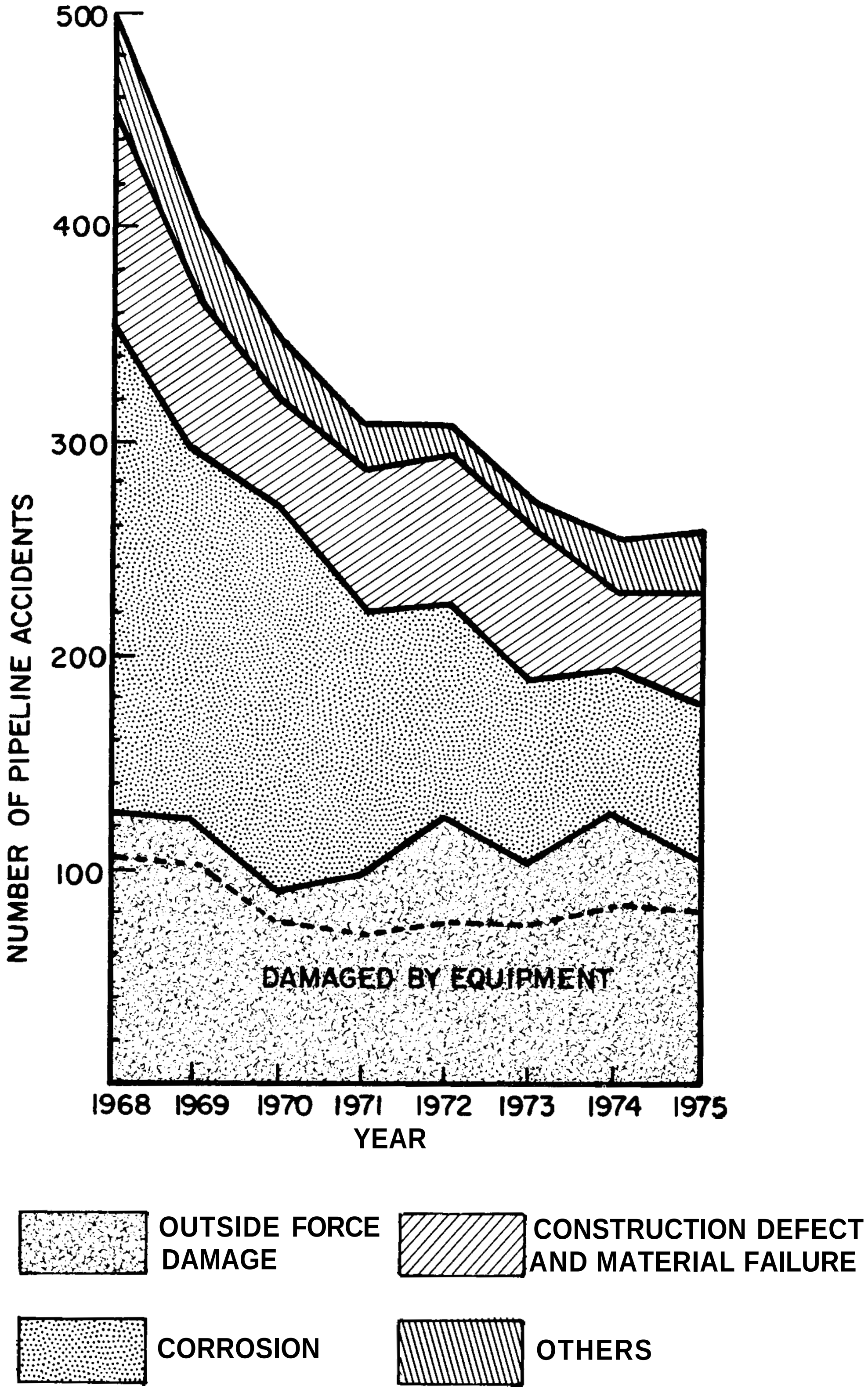

Figure 2.18 Breakdown of Causes of Liquid Pipeline Accidents In the United States (OPSO data: 1968-1975)

The consequences of the accidents occurring on liquid pipelines during the 8-year period (1968 to 1975) are summarized in Table 2.32. The figures on property damage and commodity losses were estimates submitted to OPSO by pipeline operators. These figures are believed to be on the low side due to the fact that the labor costs for repairing damage, settlement from law suits, and damage to environment were not included.

TABLE 2.32 CONSEQUENCES OF LIQUID PIPELINE ACCIDENTS
(OPSO data: 1968-1975, 8-year cumulative totals)

Causal Factor	Personnel Losses Fatalities	Personnel Losses Injuries	Property Losses, $1000	Commodity Losses, 1000 Barrels
1. Damage by Outside Forces	24	57	6,780	1,114
2. Corrosion	2	27	879	446
3. Construction Defects & Material Failure	22	16	2,126	803
4. Others	5	18	3,865	498
Total	53	118	13,650	2,861

It was observed that the geographical distribution of outside party damage to national liquid pipelines is very much in accordance with the distribution of the pipelines, similar to the case of gas transmission-gathering systems. For example, there were 67 cases of rupture by equipment damage to liquid pipelines in 1973. An illustration of these incidents among the states is shown in Table 2.33, with Texas, Oklahoma and Louisiana, all large producers, leading the list - similar to that of reportable leaks of gas transmission-gathering systems. The types of commodity involved in these liquid pipeline damages are listed in Table 2.34, with crude oil and gasoline leading the list of materials.

TABLE 2.33 GEOGRAPHICAL DISTRIBUTION OF OUTSIDE PARTY DAMAGE TO LIQUID PIPELINES THAT OCCURRED IN 1973 (OPSO data)

State	Incidents	State	Incidents
Texas	15	New York	2
Oklahoma	8	Iowa	2
Louisiana	6	Ohio	2
Kansas	5	Washington	1
Missouri	5	Indiana	1
Arkansas	3	California	1
New Mexico	3	Nebraska	1
Pennsylvania	3	Virginia	1
Illinois	3	Montana	1
Minnesota	3	Wyoming	1

TABLE 2.34 COMMODITIES INVOLVED IN OUTSIDE PARTY DAMAGE ACCIDENTS ON LIQUID PIPELINES IN 1973 (OPSO data)

Type of Commodity	Incidents
Crude Oil	31
Gasoline	21
Propane	4
Fuel Oil	3
Jet Fuel	3
LPG	1
Condensate	1
Turbine Fuel	1
Diesel Fuel	1
Propylene	1
Total	67

2.2.1.2 Analysis of Cause Factors: Since the OPSO data on accidents occurring on liquid pipelines have not been computerized, a complete analysis of these accidents would require that individual reports be studied. Such effort was not permitted by the scope of this program so a group of 109 individual accident reports was selected from the OPSO file and reviewed in detail. These reports were selected based upon a description of or comment on the accident which was part of the report. Out of these 109 reports, 107 of them were of the nature of outside force damage and of these 88 were indidents involving rupture of pipelines by equipment. The 88 accidents were distributed among 25 states with

Texas and Oklahoma leading the list, and involved 13 different types of commodities with crude oil, gasoline, propane, and fuel oil leading the list of materials (except in one incident, which involved ammonia, the rest were all crude oil or petroleum products).

These 88 reports were examined in detail to determine how and why the accidents occurred. The findings are summarized as follows:

- The majority of these accidents were caused by earth-moving equipment such as bulldozers, backhoes, and loaders. A few incidents involved trenchers, graders, plows, and boring machines.

- The types of parties responsible for the damage and the number of damage incidents each was responsible for are:

Contractor - utility system	12
Pipeline crew or contractors	10
Contractor - road construction	5
Other contractors	27
Municipal agencies	5
Private citizen	8
Not specified or identified	14

- The activities the responsible parties were engaged in when the accident occurred vary widely. A list of these activities and the number of damage incidents that occurred are:

Pipeline construction	17
Land clearing and grading	11
Excavation and soil removal	10
Road construction and improvement	9
Installation of sewer, drain, or water	7
Ditching or ditch cleaning	6
Quarry or sand pit operation	4
Creek deepening or widening	3
Plowing-in cable or pipe	2
Boring or anchoring or polesetting	2
Marine vessels	3
Not specified	12

Many of the accidents involved in pipeline construction were inflicted upon the pipeline by contractors or crews of another pipeline operator. Most of these incidents were the result of the negligence of equipment operators.

- Except in a few instances, the majority of the 88 accident reports failed to indicate if there were any communications between the users of the construction equipment and the pipeline operators. Judging from the contents of these reports, it is our opinion that such communication was inadequate.
- The accident reports indicate that neither the size of the pipelines nor the depth of cover seem to have any bearing on the probability of pipelines being damaged by the earthmoving equipment. The size of data sample must be considered.
- The majority of the 88 accidents occurred on rural, farm, and uncultivated land. In most of these incidents, signs or markers indicating the presence of underground pipeline existed within a distance of 500 feet or less from the site of the accidents. In some cases, the markers were within sight. These markers are the typical vertical poles marked with the name and telephone number of the carrier and planted at strategic locations. These markers do not, however, show the path or depth of the underground pipeline.
- In most of these accidents, the location of underground pipelines was not known to the equipment operators. However, in some cases the equipment was used in pipeline rights-of-way and the existence of other pipelines in the area should have been made known or was known to the equipment operators. Thus the occurrence of accidents in these cases was certainly the indication of human negligence.

2.2.2 Water and Sewer Pipelines – Detailed statistics on the extent of water and sewer pipeline systems in the United States are not available.

2.2.2.1 Extent of Facilities: According to a 1970 survey of 768 water utilities with population areas of 50,000,000 or more, made by the American Water Works Association, the mileage of water mains was estimated at 220,000 miles. The U.S. Department of Commerce, Water Resources and Engineering Services, provided a figure of 500,000 miles of underground sewer pipes in the United States.

The City of Chicago had a total of 4160 miles of water mains between 6 and 60 inches in diameter (by the end of 1975); plus 504,600 services, and 4160 miles of sewers (in sizes of 10 inches in diameter to 21.5 feet x 19.3 feet concrete sewers). These facilities serve a total population of 4.647 million. If these figures are used to scale-up the statistics of water service pipelines in the country, there will be a total of about 20 million services (equivalent to about 190,000 miles of services if the average length of services is assumed to be 50 feet in length). Thus, the magnitude of underground water mains and services in this country is fairly close to that of gas distribution systems.

2.2.2.2 Damage Status: It has been discovered that the statistics on the damage of underground water and sewer systems in the United States are very scarce. Many water utilities do not maintain any damage records. Some retain work reports on maintenance jobs that define tasks in ways that figures on damage by outside forces could not be extracted. Others do record damage data but such data have been stored together with other job records; extracting damage records will require laborious sorting of files. This observation led us to believe that either the outside force or outside party damage to water and sewer systems has not been a serious problem to the system operators or it has been a problem that received little attention due to the non-hazardous nature of water. It has been reported that the non-hazardous nature of water has been used as an excuse by some water and sewer system operators for not joining underground utility damage programs. Further analysis will show that such an attitude is not justifiable because of the interactions of the various underground utility systems. A water leak can erode supports to other utilities, thus the water itself is not hazardous but its effects could be serious.

Data were obtained on damage to water pipeline systems from the Illinois Commerce Commission (ICC) that showed the number of hits (outside party damage) which occurred on water pipeline systems of privately owned utilities in the state. The ICC has no jurisdiction over municipally owned utility systems. These data, covering a period from September 1975 to August 1976, are presented in Table 2.35.

TABLE 2.35 OUTSIDE PARTY DAMAGE TO UNDERGROUND WATER UTILITY SYSTEMS IN ILLINOIS SEPTEMBER 1975-AUGUST 1976 (Illinois Commerce Commission Data)

Section 1 Notice of Excavation	
1. Estimated total number of jobs occurring near underground facilities	2,647
2. Number of jobs for which notice was received	1,869
(a) Number of notices that were less than one (1) hour prior to excavation	957
(b) Number of notices that were one (1) hour but less than 24 hours	668
(c) Number of notices that were 24 hours but less than 48 hours	159
(d) Number of notices that were 48 hours or more	85
3. Number of jobs discovered for which no notice was received	199
Section 2 Hits by Outside Forces	
1. Total number of hits reported	135
(a) Number of hits, no notice given prior to excavation	72
(b) Number of hits, less than one (1) hour notice given	11
(c) Number of hits, notice of one (1) hour, but less than 24 hours notice	24
(d) Number of hits, notice of 24 hours, but less than 48 hours	8
(e) Number of hits, notice of 48 hours or more	20
2. Number of unreported hits discovered subsequent to completion of construction	44
3. Estimate of total damage caused by hits	
(a) Utility facilities	$ 16,608
(b) Nonutility facilities	$ 1,242
Section 3 Marking of Facilities Following Notice	
1. Number of hits on accurately marked facilities	39
2. Number of hits on facilities not accurately marked, or inadequately marked	12
3. Total number of hits on facilities not marked prior to excavation	24
(a) Number of hits on facilities not marked, but notices were less than 24 hours	10
(b) Number of hits on facilities not marked, with notice of 24 hours, but less than 48 hours	0
(c) Number of hits on facilities not marked, with notice of more than 48 hours	1

The data in Table 2.35 show that a toal of 135 hits occurred on water pipelines of ICC utilities during the l-year reporting period. This is substantially lower than the number of hits that occurred on other utilities. However, in terms of number of hits per 1000 jobs, the water utilities were the highest among various ICC utilities, as shown in Table 2.36 . Note that this was obtained from a number of small water utilities. Considering the common depth of water mains, it is conceivable that most of the hits on water pipeline systems were on services.

TABLE 2.36 OUTSIDE PARTY DAMAGE TO UNDERGROUND UTILITY SYSTEMS IN ILLINOIS SEPTEMBER 1975-AUGUST 1976 (Illinois Commerce Commission Data)

	Water	Gas	Telephone	Electricity
1. Estimated number of jobs occurred near facilities	2,647	157,920	189,746	124,190
2. Number of jobs for which notice was received	1,869	144,780	173,489	112,595
3. Total number of hits	135	3,334	6,122	1,350
4. Probability of hits (number of hits per 1000 jobs)	51	21	32	11
5. Number of hits, no prior notification of jobs	72	1,674	4,691	1,003
6. Percent of hits without prior notification of jobs	53.3	50.2	76.6	74.3

The interactions in damage to underground utility systems of various system operators can be illustrated by the data compiled by the Chicago Utilities Alert Network (CUAN), as shown in Table 2.37. These data show that utility system operators caused three times as many hits as the private contractors. All of the City of Chicago water pipeline excavation is done by city employees; the City also does much of its own sewer excavating.

TABLE 2.37 DAMAGE TO UNDERGROUND UTILITY SYSTEMS IN THE CITY OF CHICAGO IN 1976
(Chicago Utility Alert Network Data)

Utility Owner	Excavator								Notification							Remarks
									Yes	No	More than (t) hrs before damage occurred					
	1	2	3	4	5	6	PC	E			48	16	1	0	(-)	
1	-	12	1	1	-	-	19	33	8	24	3	1	1	1	1	
2	18	-	-	-	-	-	--	18	16	1	1	9	2	2	1	Notified After Damage
3	48	-	-	-	-	-	--	48	38	4	1	5	21	8	3	Notified After Damage
4	2	-	-	-	-	-	1	3	1	2	-	-	--	-	-	
5	6	2	1	1	-	1	3	14	7	5	1	2	1	-	-	
6	-	2	-	-	-	-	1	3	2	1	-	-	--	-	-	
E	74	16	2	2	-	1	24	119								

1 Gas Utility
2 Water and Sewer Distribution
3 Bureau of Electricity
4 Electric Utility
5 Telephone Utility
6 Miscellaneous Utilities
PC Private Contractors

The gas utility, in particular, was responsible for more than half of the hits that were reported in 1976. The telephone company caused and received few damages. The water-sewer operator and the gas company have been exchanging damages to each others systems.

The CUAN has been active since 1975. The collection and evaluation of utility systems damage data have not been an important task insofar as most Chicago utilities are concerned, except AT&T. Chicago traditionally has had a strong city government and the use of the building permit has kept the private contractors alert to underground utilities. City Hall estimates that about 80 percent of excavations are controlled to some degree through the CUAN. However, a quote from a damage report dated June 1976 provides an unofficial view of the system, "Water Distribution Division does not keep records of damaged services. Damage was settled in field and did not think report or permit necessary".

There are a number of reasons why the outside party damage to the underground facilities are much lower in Chicago than in the surrounding area. Chicago is an old built-up city thus construction activity is relatively low, all of the utilities including the municipal utilities are actively practicing damage prevention through the CUAN; the Board of Underground is effective in communication and correlation of construction activities, and the city building permit offices exercise effective control over private contractors. CUAN is the one-call system serving the City of Chicago.

One of the significant causes of damages is that due to contractors who "rip and pay". The contractor obviously has a cost benefit situation if he uses his mechanical equipment as much as he can. A backhoe or trencher sitting idle on the excavation site is a contractor's major source of loss.

All of the utilities, gas, water, electric, and telephone agreed that this type of contractor was a serious cause of damage incidents. Essentially all of the privately owned utilities believed that there was not much that they could do. This was not the reaction of the City of Chicago Water Division representatives. A contractor "Y" was specifically pointed out by a local private utility, as one who had political connections and who used the rip and pay approach. When the Chicago Water Division personnel were interviewed they were asked whether or not the rip and pay attitude was a problem. They gave us an example contractor "X", who had to be brought into line during 1975. They were questioned about contractor "Y" and stated that he had been brought under control during previous years.

The water and sewer lines are generally buried deeper than other utility systems. Thus, in a congested area the maintenance work on water and sewer systems can put other utility systems in jeopardy. If the municipally owned water and sewer utilities do not in some way participate in the effort to reduce underground utility damage, the effectiveness of any damage prevention programs will be significantly reduced.

2.2.2.3 Water and Sewer Pipeline Resume: Consideration should be given to effects of the utility size. A large utility like Chicago Water and Sewer Division must have significant resources on hand in order to function. They must have standby crews ready for emergencies. When a large utility interfaces with any contractor it has plenty of clout without calling on the city government.

A common complaint by all of the utility representatives was concerned with a particular type of private contractor. This type of contractor excavates as fast as possible. His attitude after hitting a pipeline is expressed by the utility spokesmen as "Too bad, we'll pay for any damage". The Chicago Water representatives thought that type of private contractor was the worst offender. However, unlike the private utilities, specifically gas and telephone, the Chicago Water utility was quite confident that they could continue to have control over the contractors.

2.3 Damage to Other Utility Systems

The outside force and outside party damage to underground facilities, such as telephone, electricity, cable television and other communication networks, usually does not present immediate hazards to the general public. However, the economics involved in maintaining service can be a strong incentive for these system operators to be interested in the prevention of damages. For example, the economic penalty for failure in transmitting television signals could be on the order of thousands of dollars per second in some cases. Maintaining uninterrupted service is, therefore of great importance.

2.3.1 Telephone — As indicated in Table 2.37, the telephone system operator in the City of Chicago suffered very little damage to underground facilities in 1976. However, in the State of Illinois as a whole, the situation of damage to underground telephone cables is considerably different, as shown in Table 2.36; a total of 6122 hits were recorded during a 12 month period during 1975 and 1976. Of these hits, 76.6 percent of them had no prior notifications.

A significant problem is the dig-ins that affect accurately marked cables where the excavator made a location request (LR). In the ICC survey there were 1080 dig-ins on jobs where the LR resulted in accurate line marking. There were 401 hits on inaccurately marked lines and 916 hits on lines which had not been marked; in both cases an LR had been made. Thus out of the total. 2397 hits (1080 + 401 + 916) that occurred after an LR, 45 percent of them occurred on accurately marked lines.

Since the total estimated number of jobs that occurred near underground facilities was 189,746 and the number of jobs that had prior notification of activity was 173,489, the number of jobs that had no prior notification was 16,257. Out of these jobs, a total of 4691 hits occurred or 28.9 percent of these jobs where there was not prior notification resulted in damage to telephone cables. This figure is considerably higher than that for gas, electricity, and water-sewer systems, indicating the vulnerability of telephone cables to outside party damage. The 32 hits per 1000 jobs which occurred on Underground telephone facilities (Table 2.36) also indicate that telephone cables may be more prone to outside party damage than gas pipelines and electricity systems, at least in this Illinois experience.

Figure 2.19 presents the damage frequency of AT&T underground facilities during the period of 1967 to 1975. The damage frequencies are in terms of "service affecting troubles", which include cuts (outside force or outside party damage) and water leakage (due to a variety of causes). These data show that AT&T underground cables have been having about 20 repairs per 100 miles of cables per year, placing it below the leak repair frequency of the natural gas distribution system but substantially higher than that of nation's gas transmission-gathering systems. The data in Figure 2.19 also show that pressurized telephone cable systems suffer less troubles than the nonpressurized (sheath type) systems This probably is due to the presence of protective conduit in the pressurized cable systems that constitutes a first barrier to outside party damages, and the pressure of the gas in the protective conduit keeps the water from leaking into the cable system.

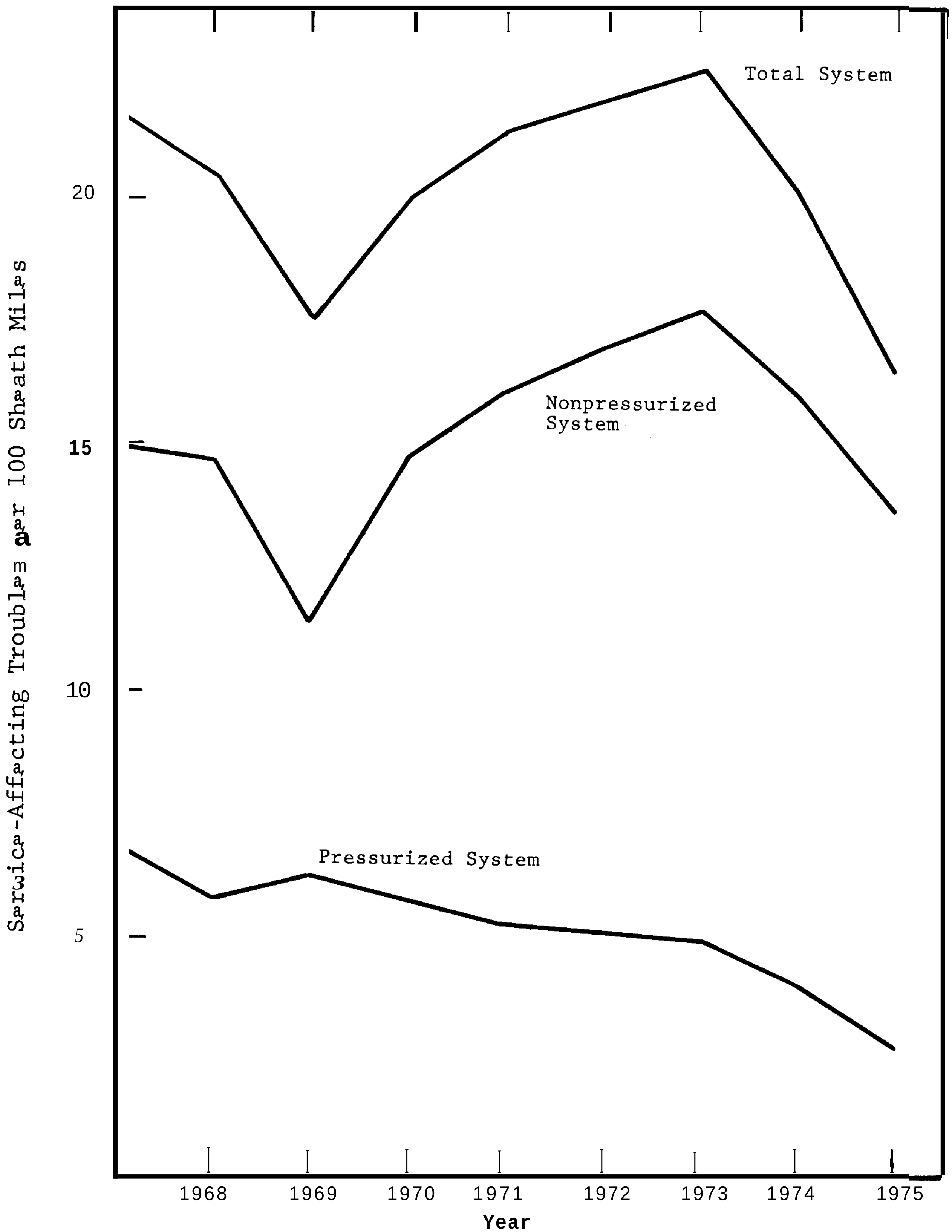

Figure 2.19 Damage Incidents to AT&T Underground Facilities

2.3.2 Electricity and Other Systems — The electric utility underground facilities are by far the largest of this "other underground utility" grouping. The cable television and other communication systems along with some central-city heating piping are a very small percentage of such utility facilities. The total mileage of national underground electrical transmission and distribution systems is not known, but certainly it must be in tens of thousand miles. When the mileage of municipally owned electrical distribution systems for street lighting and traffic control is added to the figure, it is conceivable that the total sheath mileage of electric cable systems may be comparable to that of the telephone systems but less than that of gas distribution systems due to the fact that overhead electric distribution systems are still common in some parts of the country.

The magnitude of outside party damage to underground electric facilities can be illustrated by the data presented previously in Table 2.36. The total number of hits on Illinois electric utility underground facilities in the 12-month period during 1975 and 1976 was 1350, or 11 hits per 1000 jobs occurred near the facilities. These figures are, although smaller than the counterparts of gas and telephone systems, still substantial. Furthermore, the ICC data do not include the damage inflicted upon municipally owned electric distribution systems. The extent of damage suffered by electric distribution cables for street illumination and traffic control can be illustrated by the data presented in Table 2.37, which show that the Chicago Bureau of Electricity facilities suffered the higher number of damages in 1976 than any other utility systems, and all the damages indicated were caused by other utilities.

The damage frequency of national underground electric facilities is not clearly known. The Edison Electric Institute is collecting information from the electric utilities through its Transmission and Distribution Committee. In 1973, this committee released a summary on cable operations, as shown in Table 2.38.

This committee is still in the process of defining the method to be used by electric utilities to collect the damage data. Thus, it has been recommended that the data in Table 2.38 should be used only with considerable caution. The dig-in rate of 2.05 per 100 miles of underground facilities per year reported by the electric utilities seems to be "in the right ballpark", placing it near that of gas distribution and telephone systems (see also Table 2.36).

TABLE 2.38 OUTSIDE PARTY DAMAGE TO UNDERGROUND ELECTRIC POWER CABLE, JOINTS, AND TERMINATIONS*

CABLE OPERATION - 1973

SUMMARY

This report covers 1973 operating experience with power cable, joints, and terminations

Number of companies reporting	22
Total cable miles by end of year	51,318
Total cable trouble rate per 100 miles	3.84
Total joint trouble rate per 1000 joints	1.18
Total terminal trouble rate per 1000 terminals	1.34
Total dig-in rate per 100 miles	2.05

* Cable Operation - 1973. Information contact D. Mastrian, Baltimore Gas and Electric

2.4 Damage Costs

The total damage that could result from hits on underground utility systems varies among the systems. In the case of gas and petroleum pipelines, uncontrolled release of the commodities from outside party damages could have these consequences:

- Damaged pipeline or pipeline components
- Loss of commodities
- Personnel injuries and fatalities
- Loss of properties owned by people other than pipeline operators
- Damage to environment

Costs associated with the repair of damaged pipe and pipe components could be estimated with some degree of accuracy. The costs associated with personnel injuries and fatalities, and environmental damage, are difficult to estimate. Costs resulting from the loss of commodities often are also difficult to estimate; only the loss of crude oil and liquid petroleum products can be readily measured.

In the case of telephone, electric, water, and sewer systems, the major costs that could result from outside party damages are the repair coats for restoring service and the cost of service interruption. Personnel injuries and fatalities are relatively rare in these cases. The economic penalty associated with the interruption of a television cable may be severe.

Discussion of damage costs would be more fruitful if they were based on industry statistics. As has been mentioned previously damage data and the associated cost statistics are not extensive for most of the utilities. Pieces of data can be put together from data sources such as OPSO, ICC, AT&T, and a few individual utilities. In lieu of definitive data, extrapolations can be made which will at least give an approximation of the damage costs.

2.4.1 Gas Pipelines – Table *2.39* presents the property damage figures for gas pipelines extracted from the OPSO data. Data show that the leaks which occurred on natural gas transmission-gathering systems caused considerably greater property damage per incident than those occurring on gas distribution systems. In both cases, the reportable leaks resulted in much higher property damage than did the repaired leaks.

Figure 2.20 presents outside party damage incidents and damage costs for a large western utility. The data of OPSO (Table 2.39), the ICC (Table 2.36), and the data shown in Figure 2.20 can be evaluated and an estimate of the average outside party damage repair costs of $125.00 per hit can be made. The number of hits annually is estimated to be more than 65,000 and less than 125,000. An estimate of *95,000* hits per year is taken as the probable number.

TABLE 2.39 ESTIMATED PROPERTY **DAMAGE** RESULTING FROM GAS PIPELINE LEAKS
(OPSO data)

	1970	1971	1972	1973	1974	1975
Gas Distribution Systems	$	$	$	$	$	$
1. Property Damage - Pipeline Operators	5,511,634	10,903,179	14,787,933	32,747,880	64,596,594	90,470,220
2. Property Damage - Others	3,496,791	7,601,415	3,528,104	12,344,006	3,993,288	5,674,892
3. Total Property Damage	9,008,425	18,504,594	18,316,037	45,091,886	68,589,882	96,145,112
4. Number of Leaks Repaired	559,541	680,114	701,580	768,881	759,446	769,353
5. $/Leak Repaired	16.1	27.2	26.1	58.6	90.3	125.0
6. $/Reportable Leak Repaired	290.9	339.6	649.5	582.0	459.5	512.0
Gas Transmission–Gathering Systems						
1. Property Damage - Pipeline Operators	3,171,225	7,628,539	5,200,327	12,947,974	11,467,796	11,383,764
2. Property Damage - Others	57,160	565,912	168,505	250,722	796,656	482,885
3. Total Property Damage	3,228,385	8,194,451	5,368,832	13,198,696	12,264,452	11,866,649
4. Number of Leaks Repaired	32,418	26,668	25,217	23,049	21,886	15,013
5. $/Leak Repaired	99.6	307.3	212.9	572.6	560.4	790.4
6. $/Reportable Leak Repaired	8,229.6	694.4	5,928.5	13,342.0	17,043.7	12,310.1

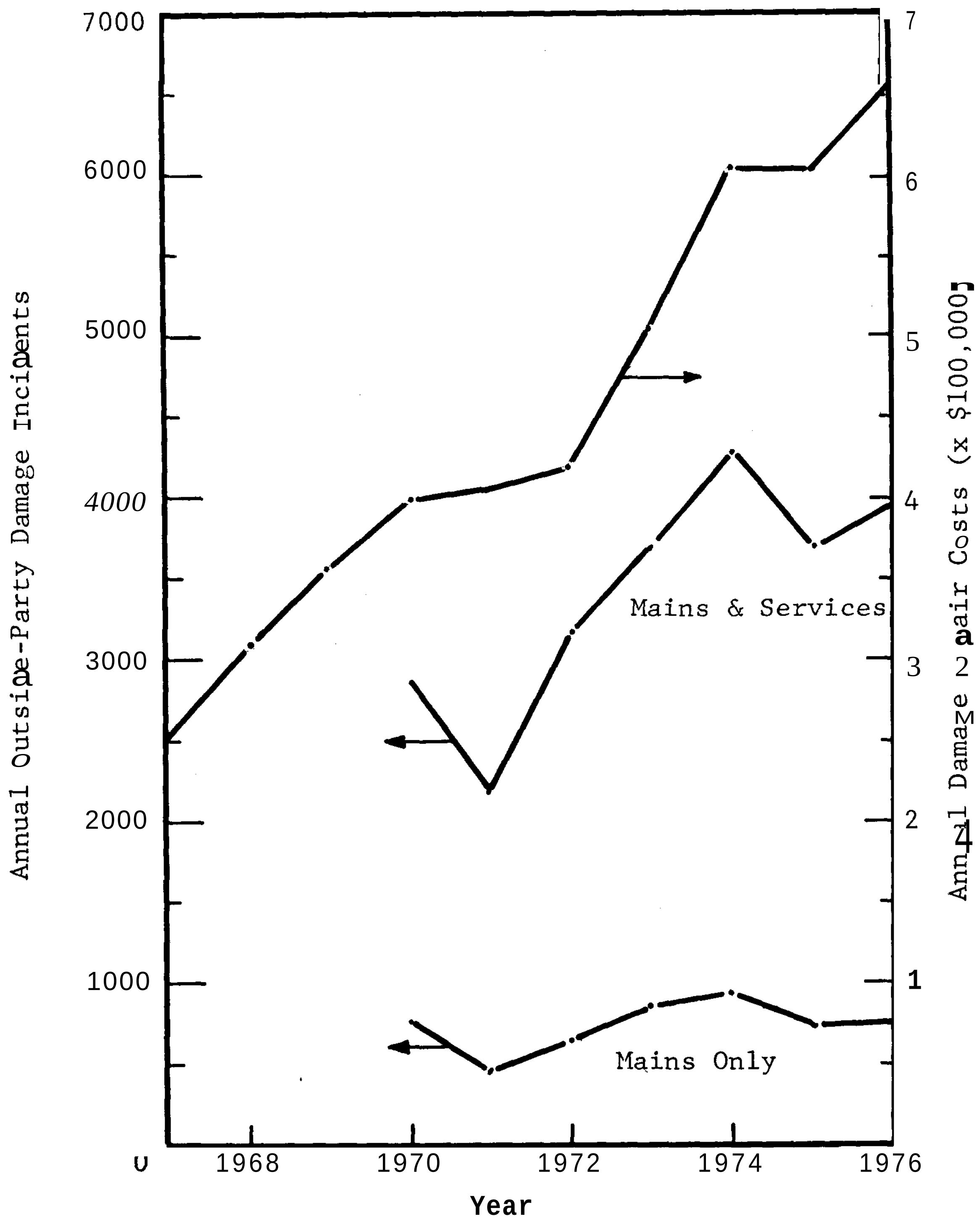

Figure 2.20 **Outside Party Damage Summary of a Western State Gas Utility**

The gas utility companies recover more than 50 percent of the damage repair costs. The national total outside party damage repair costs figure is estimated as; n x C x 50% or 95,000 x $125.00 x 0.5 = $5,900,000.

In a manner similar to that used for gas distribution systems an estimate (based on Table 2.39, OPSO data) that $2,200,000 for outside party damage repairs was spent in 1975 for the transmission-gathering systems.

2.4.2 Petroleum Pipelines — On the basis of the damage reports submitted to OPSO by national liquid pipeline operators, a total of 80 outside party damages occurred in 1975 which resulted in total estimated property damage of $2,018,816 and commodity loss of 154,248 barrels. These 80 leaks were all reportable in nature, similar to those reportable leaks of gas transmission-gathering systems. It is not known how many outside party damages occurred in 1975 that were not reported to OPSO.

The estimated loss of 154,248 barrels of commodities through the reportable outside party damage to liquid pipelines in 1975 could be on the conservative side. Assuming that all the lost commodities were crude oil, which has the lowest case value among petroleum products, the lost commodities represent a loss of about $2,000,000 to the pipeline operators.

2.4.3 Telephone — The repair costs for outside party damages to underground telephone cables has been developed from two sources; the ICC and from AT&T data.

According to the ICC data collected from 21 telephone companies serving the State of Illinois, there were a total of 6122 hits on underground telephone facilities from September 1975 to August 1976. These hits resulted in damage to telephone facilities totaling $858,935, or $140 per hit. Illinois makes up approximately 5 percent of the nation's underground phone system. Thus based on the ICC data extrapolated to the national system the outside party damage repair costs would be $17,200,000.

AT&T data (AT&T Form E-3626A-1976) show that there were 154,000 underground sheath breaks during 1976. From a base of 278 damages sampled the average sheath repair cost was estimated to be $543. Thus the total repair cost for AT&T systems would be projected to be $77,000,000. The AT&T system covers about one-half of the United States area but more than one-half of the underground cables. However the difference of major significance between the ICC data and the AT&T data is the cost of each damage repair; $140 per hit (ICC) versus $543 per hit (ATGT). A broadly defined estimate of outside party damage repair costs between $17,000,000 and $100,000,000 sharply points out the state of the data available.

2.4.4 Electric Utilities – The ICC data indicate that there were 1350 hits on underground electric utilities serving the State of Illinois during September 1975 and August 1976. These hits resulted in $463,746 damage to electric facilities and $19,666 to other facilities, totaling $483,412 or $358 per hit. Based on the Illinois population (11,000,000) served by the utilities and the total United States population (212,000,000) a multiplier of 19 could be used to extrapolate from Illinois damage incidents and damage incident costs to estimate nationwide damages,

2.4.5 Water and Sewer Systems – The ICC data show that a group of nonmunicipally owned water utilities in the State of Illinois suffered a total 135 hits during the l-year period of September 1975 to August 1976. These hits resulted in property damage totaling $17,850. This group of water utilities serves a population of 343,000.

There are no available data that indicate the outside party damage suffered by national sewer systems. Considering the usual burial depth of sewer and drain pipe, it is suspected that the outside party damage to sewer system mains is substantially less severe than that of other utility systems.

2.4.6 Insurance Rates – Another cost associated with the outside party damage is the insurance premiums that private construction contractors have to pay to cover damages that they may inflict upon underground facilities. The underground utility operators also have to pay to insure that the damage on their systems will be compensated for and the property damages resulting from the system damage incidents will be covered.

The ICC data presented an estimate that 477,000 excavation jobs occurred at or nearby underground facilities of privately owned utilities in Illinois. Except for the water and sewer lines the private utilities own the bulk of the underground facilities. Thus for the telephone, the electrical and the natural gas utilities these private utilities serve nearly the entire Illinois population of 11,000,000. The private sewer and water utilities serve a small portion of the Illinois population, i.e., approximately 340,000. Table 2.40 presents an estimate of the number of excavations on or nearby utility underground facilities.

TABLE 2.40 EXCAVATION JOBS IN THE UNITED STATES, 1975

Utility	Number of Excavations in Illinois	Multiplier	Nationwide Number of Jobs Estimated
Telephone	189,746	17.3	3,280,000
Electric	124,190	18.3	2,270,000
Natural Gas	157,920	13.5	2,130,000
Sewer	2,647	370	979,000
Water	2,647	370	979,000
Total (estimated)	477,000	——	9,638,000

The number of excavations in Illinois (Table 2.40) is taken from Table 2.36. The multipliers (column 3) were determined by assuming that Illinois is more completely covered by the respective utilities than the national average, i.e., telephone 0.9, electricity 0.95, natural gas 0.7, sewer and water 0.6. The multiplier thus is determined from Multiplier = (U.S. population) ÷ (Illinois population) x (Ratio).

The multiplier for the water utilities is

$$M = \frac{212,000,000}{340,000} \times 0.6 = 370$$

The multiplier used in Table 2.40 is based on an estimate of the fraction of the United States population served by the particular utility. Since the Illinois privately owned water and sewer utilities make up a small fraction of the state population the extrapolation to the national population is even more uncertain. The number of excavations estimated is based on the data supplied by the utilities to ICC. If every excavation was reported by each of the five utilities, then the total number of excavations nationwide would be approximately 2,000,000.

Larger utilities have had a practice of collecting for damages done to their underground facilities. This collection policy is followed for two reasons; the obvious one of cost efficiency, the other reason is to use collection claims as a disciplinary tool with private contractors. Many utilities repair damage without billing one another. The basic assumption is that each utility inflicts and suffers approximately equal amounts of damage to and from the other utility. If they do not bill one another they defray the cost of paperwork.

The contractors repair a considerable portion of their own damage. The utilities also repair their own damage so that a realistic estimate of a repair cost per job is not made. Also they do not have data or public information that this report could evaluate.

In this greater Chicago area insurance companies do not use premiums to discipline private contractors. They have not been approached by utilities for this purpose. In other areas insurance companies have been approached for this purpose but with little success. Total damage costs for the nation are not insignificant; probably between $300,000,000 and $400,000,000. However for an estimated 9,000,000 excavations per year the cost per excavation is around $40.

2.5 Outside Party Damage Correlations

A summary on the status of the outside party damage problem of national underground utility systems is represented herein. There are two key questions that must be answered:

- Has the magnitude of this problem been increasing or decreasing?
- why?

As previously mentioned, the natural gas transmission-gathering pipelines have been showing a steady decline in the total number of leaks repaired annually (Figure 2.4). This decline in number of leaks repaired probably is due to the reduced occurrence of corrosion leaks which is the result of improved anticorrosion technology and increased use of such technology. A closer look at these data showed that the number of leaks caused by outside party damage to gas transmission-gathering systems has remained very consistent during the 6-year period.

The gas distribution systems, on the other hand, showed no clear decline in the number of leaks repaired annually during the same period (Figure 2.3). The significant decline in the number of corrosion leaks repaired on gas transmission-gathering systems does not follow for gas distribution systems possibly because of the less complete application of cathodic protection on gas distribution pipeline networks. The outside party damage incidents also remained fairly constant during the 6-year period.

when the data on reportable leaks are examined, the results are less encouraging. There has been a steady increase, except recently, in the number of reportable leaks in both gas distribution and gas transmission-gathering systems (Figures 2.5 and 2.6). One of the reasons for the observed pattern is the relatively heavy contribution to reportable leaks by the outside party damages. Unless the number of outside party damages is reduced, the total number of reportable leaks is not likely to decline. This is particularly obvious if the local data on outside party damages are examined. For instance, the data of a western state gas utility (Figure 2.20) show that the outside party damage to gas distribution mains and services has been increasing steadily at a rate much faster than the national average. The reportable leak data of several key states presented in Figures 2.21 and 2.22 also show the same general trend. Our analysis of selected data further show that the outside party damage trends on gas pipelines is particularly troublesome in key states. A significant reduction in the number of damages in these states is required for lowering the nation's total. In gas distribution systems, California, Texas, and Michigan are the leaders in the number of outside party damages per year. In gas transmission-gathering systems, Texas by far contributed the largest number of reportable outside party leaks. Thus, the strengthening of damage prevention programs is particularly necessary in these states.

The accident data of national liquid pipelines (Figure 2.19) showed essentially the same pattern as that of reportable leaks of gas pipelines. As cathodic protection was more widely practiced, the number of liquid pipeline accidents due to corrosion was gradually reduced. The number of outside party damages remained essentially the same during the last 6 years.

When other underground utility systems are considered, the overall situation of outside party damage in this country during the last 6 to 7 years remains essentially the same as that for gas pipelines. For example, the status of outside party damage to underground utility systems in Ohio during a recent 3-year period (Figure 2.23) shows that only the gas distribution systems exhibited a consistent decline in the number of dig-ins. This 3-year period covers a time span since the one-call system has been put into practice.

Figure 2.24 presents the data on outside party damage to underground utility systems collected by the UFPO, Rochester, New York. In this figure, the term dig-ups is synonymous to dig-ins, i.e., outside party damages. An LR is the same as notification of activities.

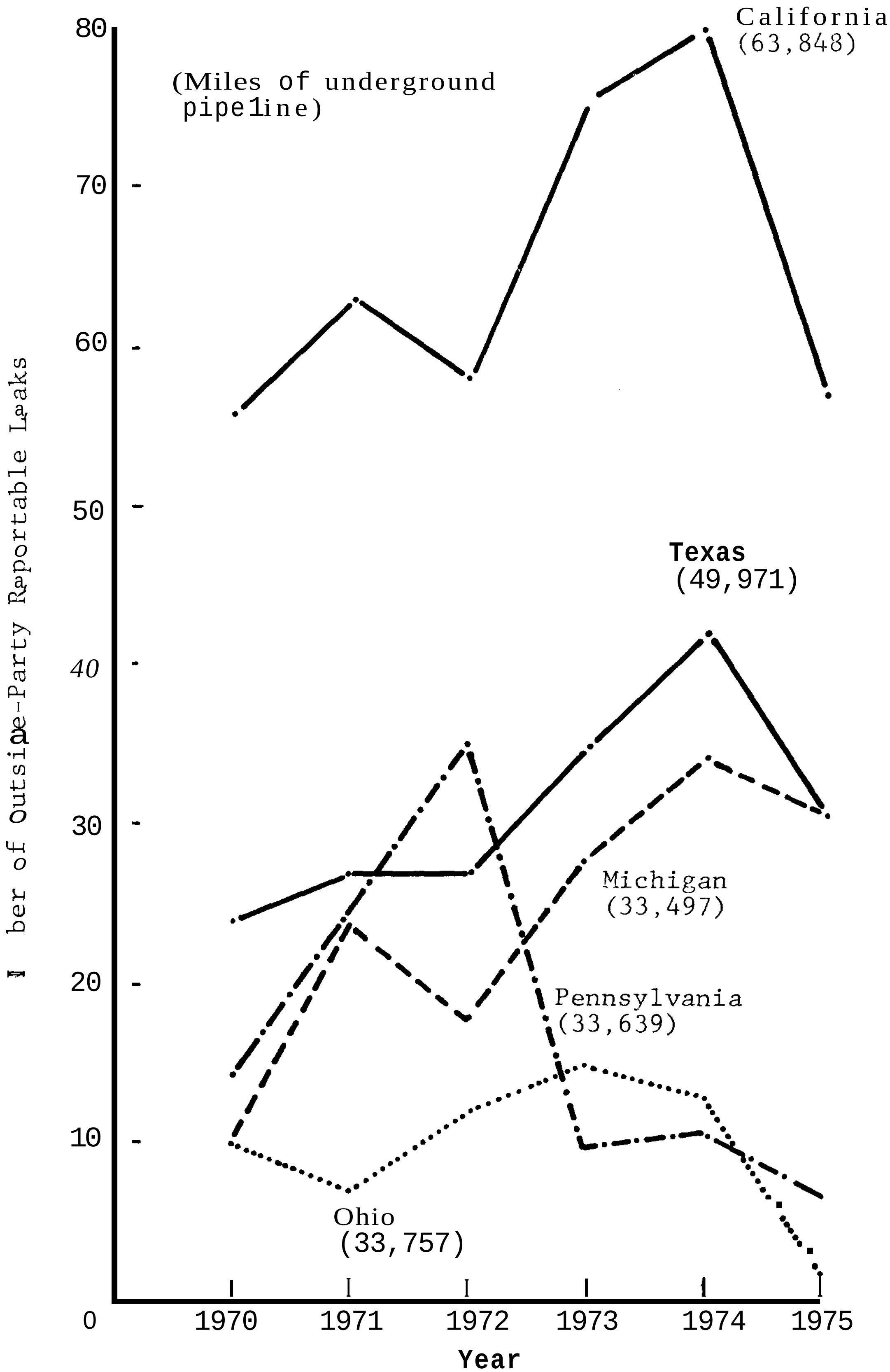

Figure 2.21 **Reportable Outside Party Damage to Gas Distribution Systems in Five Key States**

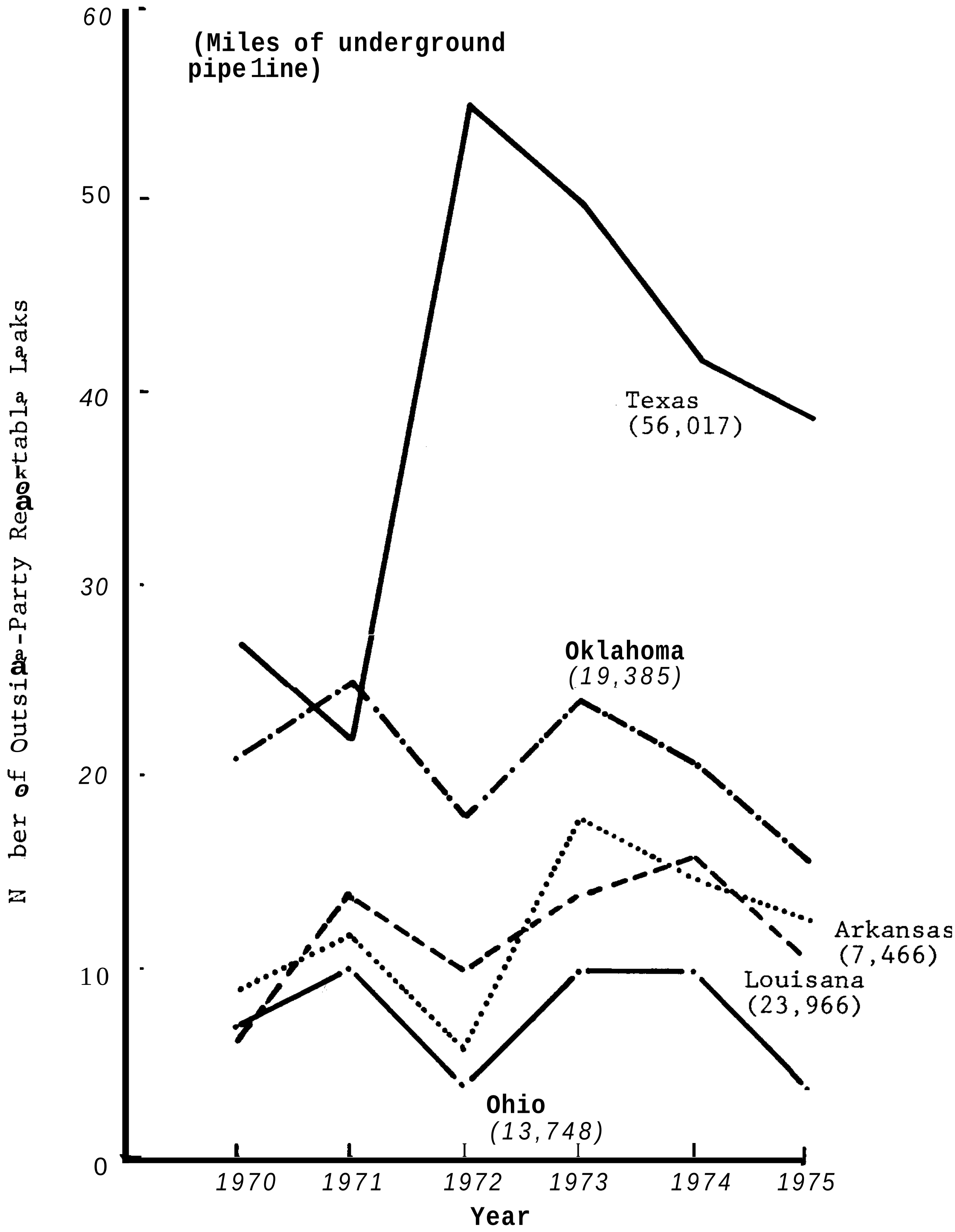

Figure *2.22* **Reportable Outside Party Damage to Gas Transmission-Gathering Systems in Five Key States**

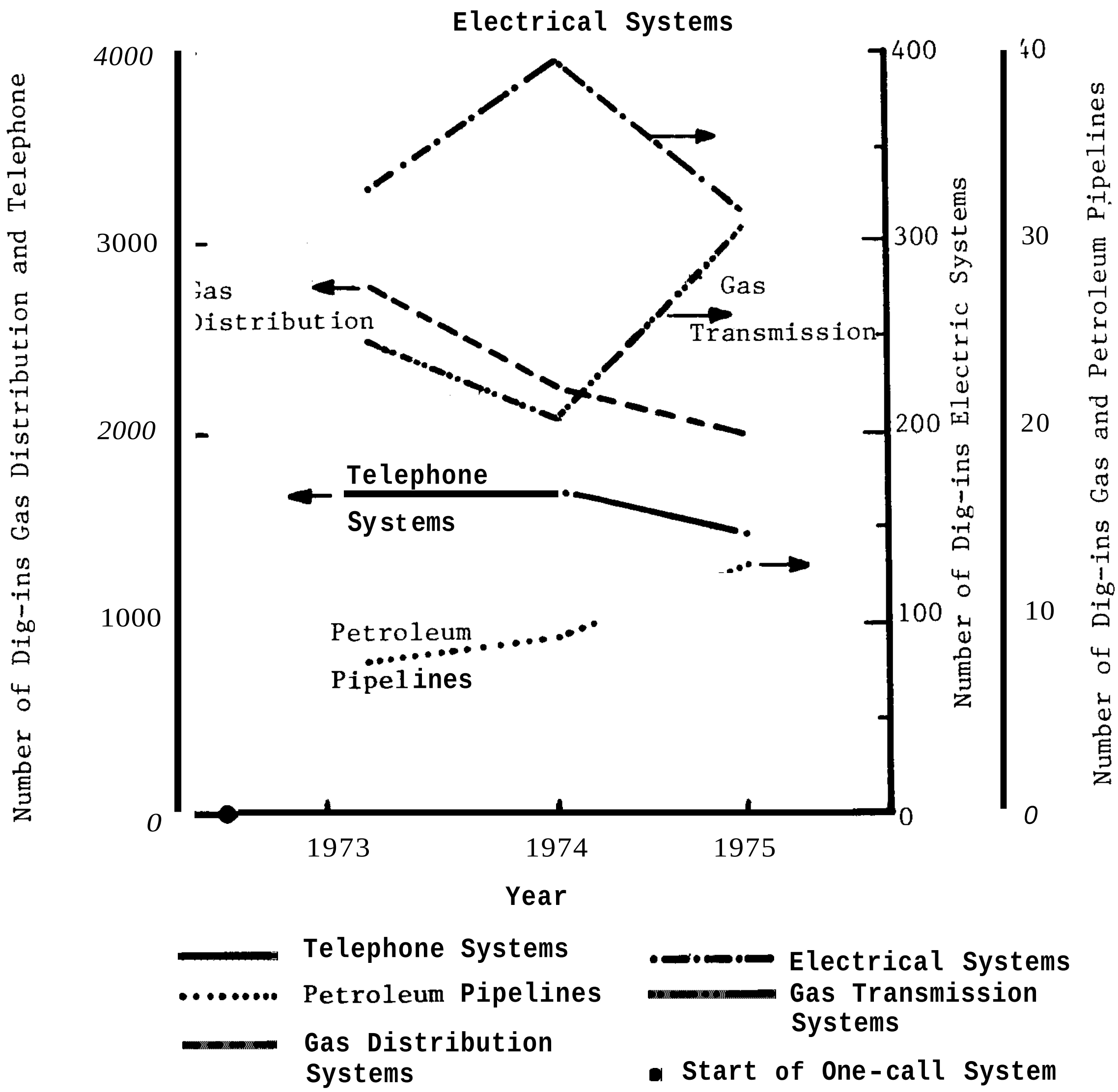

Figure 2.23 Outside Party Damage Incidents on Ohio Utility Systems

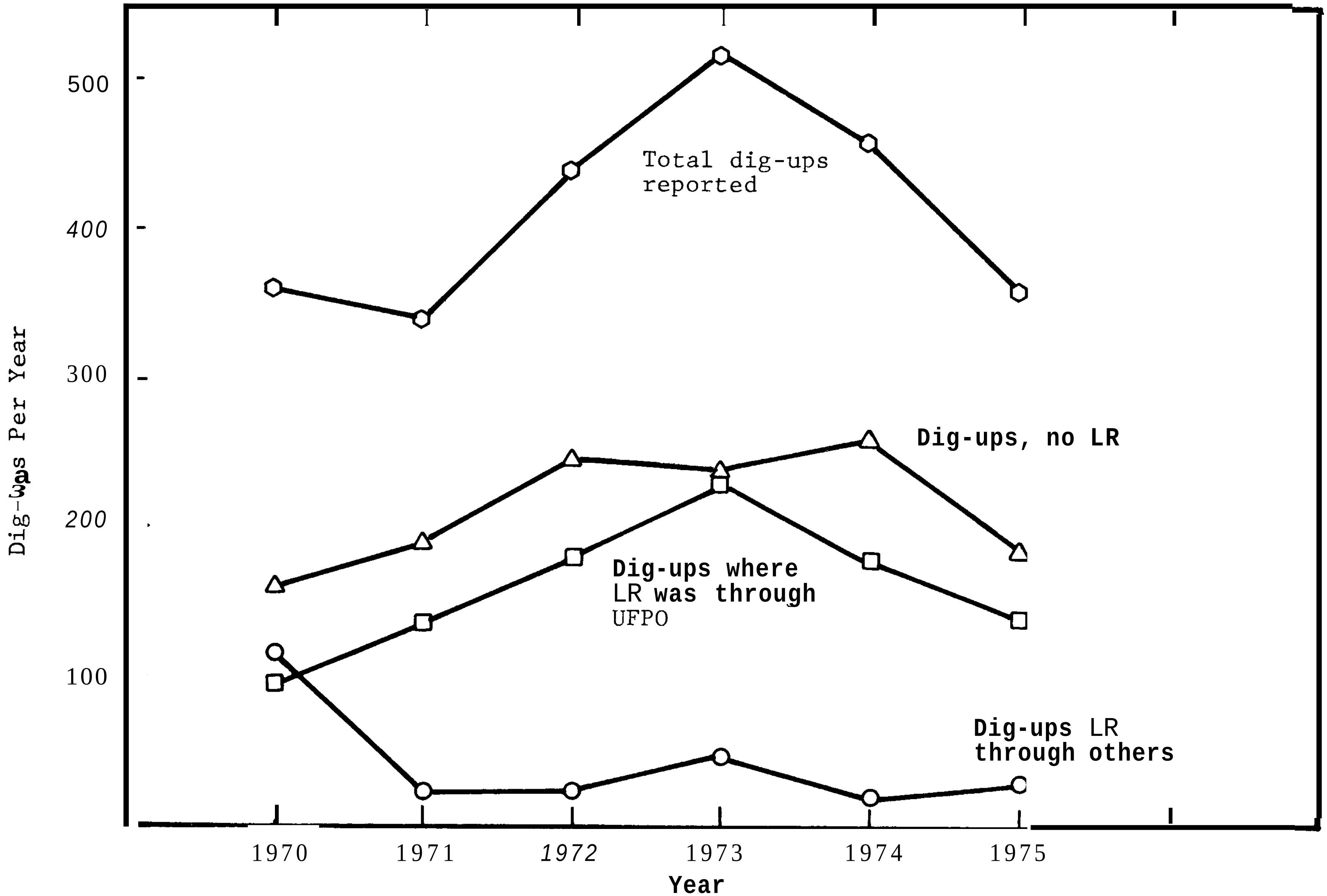

Figure *2.24* **Outside Party Damage to Underground Utility Systems in the Area of Rochester, New York**

These data show that the total number of outside party damages to underground utility systems follows the same general pattern of that of OPSO data on reportable leaks. These data also show that about 50 percent of the damages that occurred in each 6-year period had no prior notifications. A similar situation was also found in the data collected by the ICC.

The data in Figure 2.24 also show that the other 50 percent of dig-ups had prior notifications. Since the total number of jobs (or LR) that occurred in the Rochester area during each 6-year period is not known, the number of hits per 1000 jobs for both with and without LR cannot be computed. However the trend of dig-ups is favorable and without a doubt this trend is reinforced by the policy of LR. The ICC data for the Illinois underground utilities collected during October 1971 to December 1972 and from September 1975 to August 1976 show that the hit rate has substantially reduced in incidents having prior notifications and substantially increased in incidents having no prior notifications, as shown in Table 2.41. As a result, the number of dig-ins of underground utility systems in Illinois has kept up with the increase in the construction activities.

TABLE 2.41 OUTSIDE PARTY DAMAGE TO UNDERGROUND UTILITY SYSTEMS IN ILLINOIS
(Illinois Commerce Commission data)

	October 1971 to December 1972	September 1975 to August 1976
1. Dig-in rate, number of hits/1000 jobs		
with prior notification	22	8.1
without prior notification	34	178
2. Total number of hits	4,807	10,941
3. Total number of jobs	180,854	474,503

The situation of outside party damage to the nation's underground utility systems can be further illustrated by some regional damage data. Figure 2.25 presents the outside party damage data of various utilities located in different parts of the country. These utilities are designated by numbers and the dates when the respective one-call systems were put into practice are represented by black dots. The collection of some of these data did not begin until after the start of the one-call system.

The data in Figure 2.25 show that during the period of 1970 to 1975 some utilities have shown a reduction in the annual outside party damage counts, some showed no changes, and a few showed increases. In other words, the results of putting one-call systems into practice have not been even.

As indicated earlier in Figures 2.3 and 2.4, the number of reportable and repaired leaks of gas distribution systems caused by outside force damage have held a relatively constant ratio through the years. Thus, a significant reduction in dig-ins to gas distribution systems should result in proportional reduction of reportable outside party damages. The data of utility number 2, for example, agree well with the data of reportable outside party damage to gas distribution systems of the state in which this utility is located.

The data on outside party damage to underground utilities collected in this program demonstrate that the situation of the damage problem varies among geographical regions, states, cities, and utility companies. It is difficult, if not impossible, to set a minimum "acceptable" level of damage because of factors that could not be controlled. Far example, a portion of outside party damages were purely accidental. Except for the excavation contractors, all of the representatives of the various segments of the industry claimed that some excavators were content to pay for damages in the economic interest of rapid excavation.

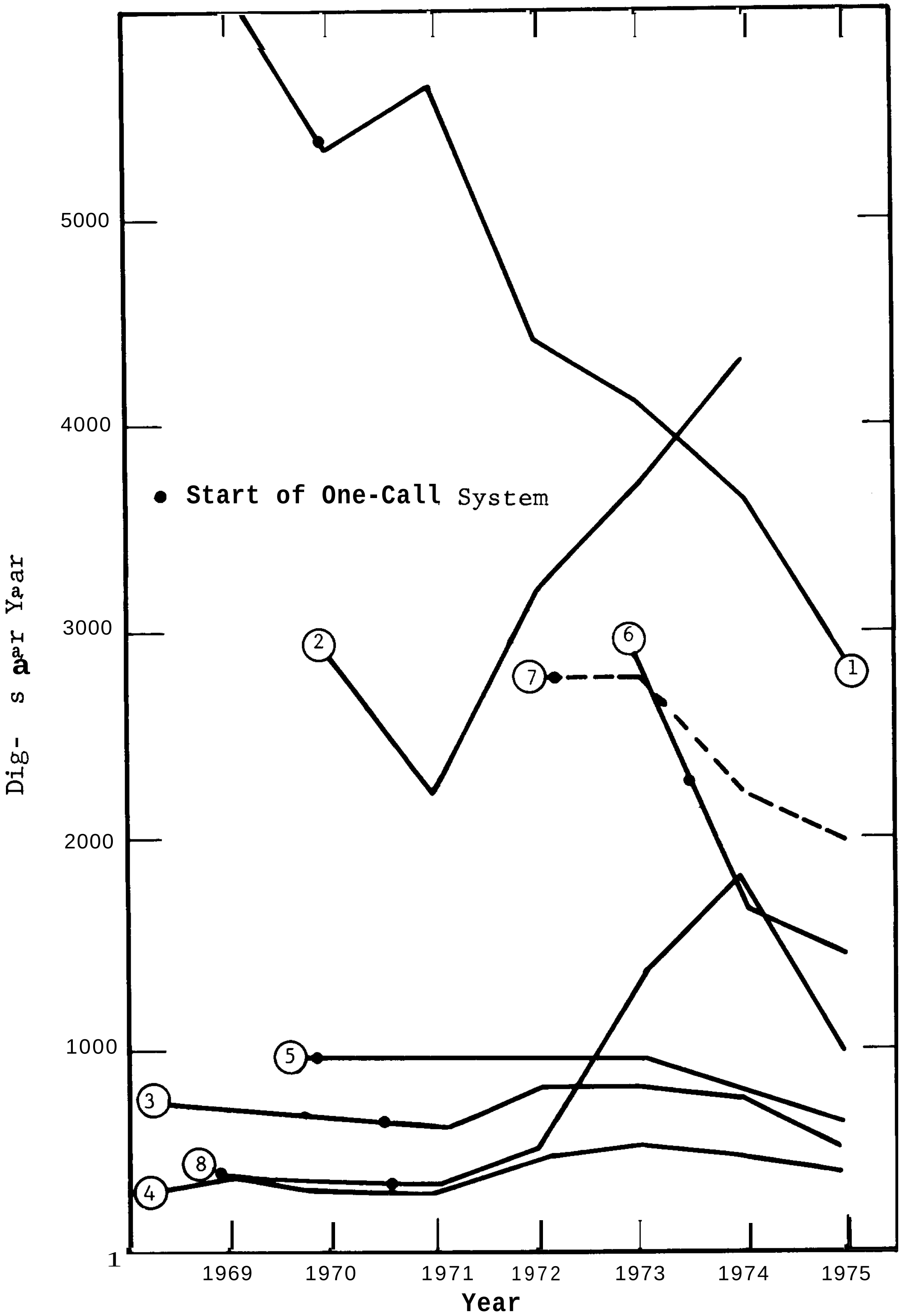

Figure 2.25 Annual Damages to Eight Gas Distribution Operators, Start of One-Call System

At present, it is not possible to determine, on the basis of available data, the statistical level of risk associated with the underground utility systems in regard to excavation and construction activities. The available data do show, however, that in some states and in some utility systems, the level of damage to underground utility systems is kept substantially lower than in others. This relative comparison of data from various utility systems and from various regions in this country clearly show that there is room for improvement.

Also investigated in this program was the reason for the ups and downs of the number of dig-ins of underground utility systems. When this point was brought to the attention of utility officials who were contacted in this program, the answer was invariably the "building activity". As a result, a search of data was made to see if there are any correlations between construction activities and outside party damage to utility systems.

Figure 2.26 presents the number of housing starts in this country between 1969 and 1976 including the number of housing starts in four regions of the United States. Except for minor perturbations, the overall pattern of the housing starts agrees surprisingly well with the OPSO data on reportable leaks of gas pipelines (Figures 2.5 and 2.6). This same overall pattern is also shared by other construction activities. Figure 2.27 shows the dollar value of new constructions undertaken by the national utility system operators during the period of 1967 and 1974.

These data show that the construction activities have been, since the late 60's, building up and reached a peak around 1973 and then declined to a low in 1975. This overall pattern is shared by OPSO data on reportable leaks of gas pipelines. When some regional data are examined, for example that of Atlanta, Georgia and Phoenix, Arizona, the same correlation was observed. Therefore, the relationship between outside party damage to underground utility systems and construction activities has been shown to be essentially valid. It is thus our belief that when the information on construction activities in a given area is combined

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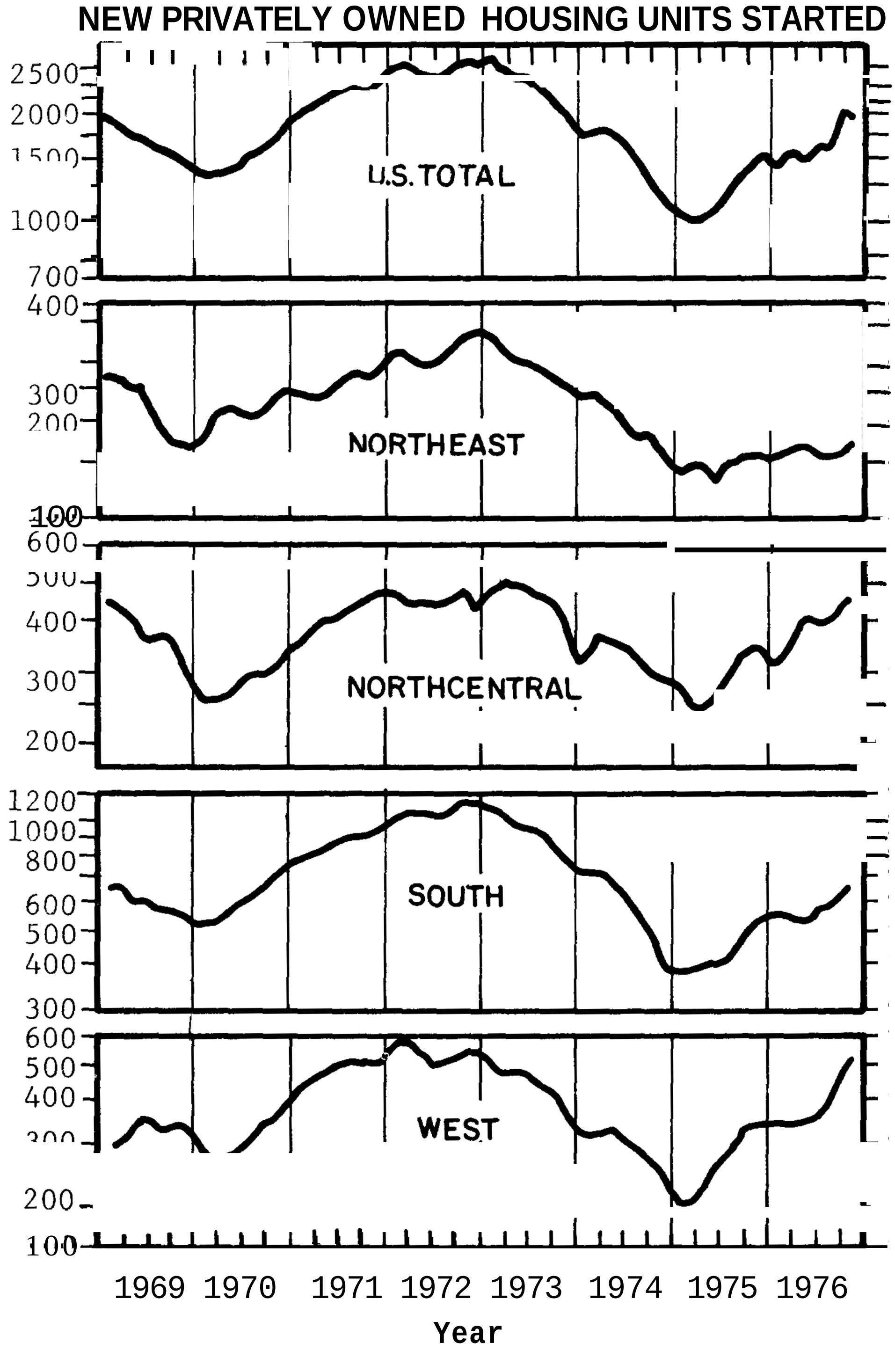

Figure 2.26 **Housing Starts in the United States** 1969-1976
(From: "Construction Review" October 1976
U.S. **Department** of **Commerce)**

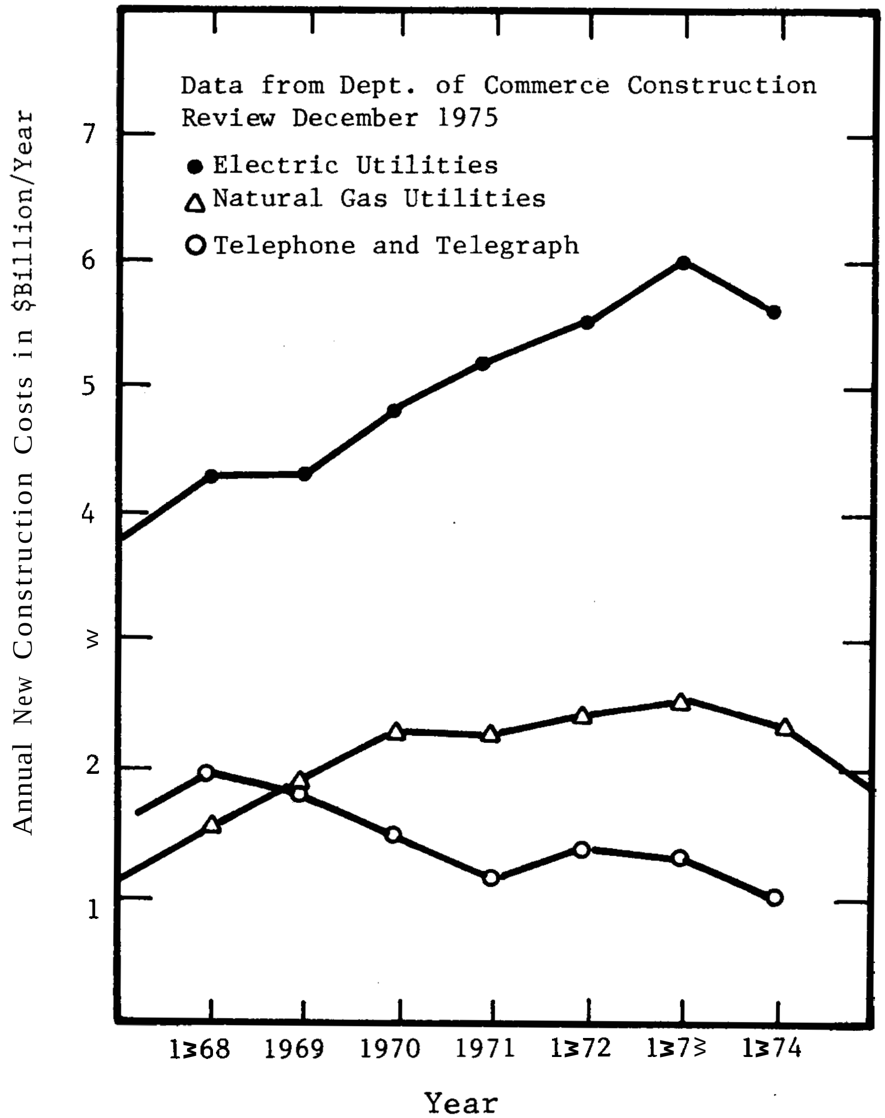

Figure 2.27 Utility Construction Costs in 1967 Constant Dollars

with the statistics of the extent of underground utility systems in this area, one can predict the level of outside party damages with good accuracy.

2.6 Interutility Comparisons

When a decision has to be made it is preferable to have a firm data base. However if sufficient data do not exist then available data must be carefully scrutinized.

New York and California, both large states, have a mixture of active industrial, farming, and transportation networks. Their terrain is similar in that the utilities must frequently resort to blasting through rock to lay pipelines. In the gas distribution system, California has 63,848 miles of mains while New York has 36,156 miles of mains. During 1975 California experienced 0.0135 reportable leaks per mile of pipe; 1.5 times as much as New York which experienced 0.0088 leaks per mile. Insofar as outside party damages are concerned California with a ratio of 0.0061 was hit nearly three times as often as New York with a ratio of 0.0021.

Consider two midwestern states, Illinois and Indiana, with 40,152 miles of gas distribution mains and 21,074 miles respectively. Reportable leak data show that Illinois had 0.0077 leaks per mile and Indiana has 0.0060 leaks per mile; Illinois had an outside party damage ratio of 0.0030 and Indiana had a ratio of 0.0021. Illinois experienced 1.28 times as many reportable leaks per mile as Indiana, and Illinois experienced 1.43 times as much dig-in damage as Indiana (allowing for the differences in the sizes of their systems).

Both Michigan and Arizona have one-call systems that have developed favorable performance data. Consider Michigan reportable leak data: 33,497 miles of gas distribution mains; 0.0183 reportable leaks per mile, the second highest and an outside party damage ratio of 0.0043, the fifth highest in the nation. Also note Arizona: 10,148 miles of gas distribution mains; 0.0215 reportable leaks per mile, the nation's highest; an outside party damage ratio of 0.0070 the nation's highest. Thus, many LR do not always prevent the occurrence of damage incidents resulting from outside forces.