

# **Analysis of DOT Reportable Incidents for Hazardous Liquid Pipelines, 1986 Through 1996**

PUBLICATION 1158  
JANUARY 7, 1999



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# **Analysis of DOT Reportable Incidents for Hazardous Liquid Pipelines, 1986 Through 1996**

**to the U.S. Department of Transportation  
Office of Pipeline Safety and  
The American Petroleum Institute**

**Pipeline Segment**

**PUBLICATION 1158  
JANUARY 7, 1999**

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## EXECUTIVE SUMMARY

This document presents an analysis of incidents reportable to the U.S. Department of Transportation on approximately 160,000 miles of liquid petroleum pipelines in the U.S. during the eleven-year period from 1986 through 1996. During that time period 2262 incidents were reported. These 2262 incidents resulted in 24 fatalities and 215 personal injuries\* and property damages exceeding 280 million dollars. 826,206 barrels (about 35 million gallons) of liquid petroleum products were spilled and not recovered. Compared to the 11 billion tons of refinery and chemical feed stocks, motor fuels, heating oil, and other valuable commodities that were shipped during that time,<sup>(1)</sup> the volume spilled represents roughly 0.001 percent of the volume shipped. The analyses presented herein represent an attempt by both the U.S. Department of Transportation's, Office of Pipeline Safety and the operators of liquid petroleum pipelines through the American Petroleum Institute to better understand the causes and consequences of the incidents, to monitor trends that may indicate the need for action, to use the data to identify potential risks and areas where risk management would be most productive and to identify areas for potential improvement in the data collection process.

In terms of what the analyses showed, about 60 percent of the incidents occurred on buried cross-country or underwater pipelines where less than one half of the fatalities and injuries resulted. The other 40 percent of the incidents occurred on facilities under the control of the pipeline operator such as tank farms, terminals, and pump stations. The latter types of incidents resulted in more than half of the injuries and fatalities.

The leading causes of incidents were "third-party" damage (i.e., incidents where excavation results in a leak or a rupture of a buried or underwater pipeline) and external corrosion where the protective coating and/or cathodic protection system fails to prevent metal loss to the point of leakage or rupture. Third-party damage incidents accounted for 19.9 percent

---

\* The 215 incidents do not include 1851 people examined for smoke inhalation and released without hospitalization after one accident in 1994. The 1851 cases were officially listed as injuries though it is not certain that bodily harm occurred.

of all incidents and 33.0 percent of all "pipeline" incidents. External corrosion incidents accounted for 19.4 percent of all incidents and 32.0 percent of all "pipeline" incidents.

The next-most common causes of incidents were in the category of "miscellaneous and other" where the causes were diverse and difficult to classify, and "incorrect operation" where human error on the part of the operator led to an incident. The "miscellaneous" and "other" incidents account for 10.8 percent of all incidents and 27.3 percent of the "facilities" (i.e. non-pipeline) incidents. Incorrect operations accounted for 8.6 percent of all incidents and 21.7 percent of the "facilities" incidents.

Sixteen other causes contributed to the remainder of the incidents including defective welds; defective pipes and pipe seams; heavy rains and floods; internal corrosion; delayed ruptures of previously damaged pipe; malfunctions of equipment; and failures of gaskets, packing, seals, and ancillary piping components. Among the least frequent causes were: cold weather, lightning, and vandalism. Only 34 of the 2262 incidents occurred offshore; the rest were onshore incidents.

In terms of pipeline infrastructure parameters such as diameters, wall thicknesses, ages of the pipelines, and operating stress levels a few significant findings emerged. Smaller diameters and thinner wall pipes appeared to be slightly more vulnerable to third-party incidents and thinner wall pipes (but not necessarily smaller-diameter pipes) were slightly more vulnerable to delayed rupture from prior damage. However, no conclusions can be drawn without pipeline mileage data with which to normalize these results.

The effects of infrastructure parameters including diameter, wall thickness, stress level, age and others could be better understood if adequate data on the amounts (miles) of pipe in each infrastructure category were available.

Nearly 86 percent of the pipeline incidents, where the stress level was stated, occurred under circumstances where the stress level in the pipe was less than 50 percent of SMYS. The only kinds of incidents which seemed to occur more frequently in pipelines stressed to levels above 40 percent of SMYS were delayed ruptures of previously damaged pipes and pipes containing manufacturing defects in the seams.

The occurrences of most incidents were virtually unrelated to the operating stress level in the pipeline.

The age of the pipeline seemed to be a factor in external corrosion incidents and in incidents caused by manufacturing defects in the pipe body and/or the longitudinal seam. The data indicate that most failures from manufacturing defects occurred in pre-1970 pipe materials. Very few newer materials were implicated in this type of incident

Certain types of incidents were associated with an increased likelihood of significant consequences. Examples are as follows.

- Incidents caused by heavy rains and floods were characterized by high average property damage costs and large spills. The probable reason is that these incidents often resulted in the total separation of the pipeline under conditions where recovery of the spilled commodity is difficult (e.g. breaks in flooding rivers or landslides).
- Incidents caused by manufacturing defects and delayed ruptures of previously damaged pipe also resulted in high average property damage costs and large spills. The probable reason in this case is that these incidents tend to involve more large-opening ruptures than other types of incidents.
- Fatalities and injuries were more frequent in incidents involving pipelines or facilities handling highly volatile liquids (HVL) such as propane, butane, LPG, NGL, etc.

Over the eleven-year period a few trends were evident. These were as follows.

- The frequency of third-party damage incidents is decreasing. The reason may be that the number and quality of "one-call" systems is on the increase.
- The frequency of external corrosion incidents is decreasing. This trend may be attributable to the increasing use of increasingly sophisticated in-line inspection tools and enhanced techniques for monitoring cathodic protection to locate areas of corrosion-caused metal loss or low levels of cathodic protection allowing operators to make repairs before leaks or ruptures can occur.
- The sizes of both gross spills and non-recovered spills have decreased substantially over the eleven-year period. This is most likely the result of pipeline operators having developed better response plans and better equipment to deal with spills.

- Neither the overall frequency of incidents nor the rates of fatalities and injuries have changed. This may be because the apparent gains in reduced frequency of incidents from third-party damage and corrosion were offset by increases in frequency of incidents caused by incorrect operations and miscellaneous and other causes or because of changes in the way operators interpret the reporting criteria.

The analyses of the incident data as done herein can be enhanced if the following steps are taken.

First and foremost, data on the liquid pipeline infrastructure should be gathered.

This could be done and revised every 5 or 10 years since changes would be expected to occur slowly. The data to be gathered should include the mileages of liquid pipelines by diameter, by wall thickness, by grade, by operating stress level, by year of installation, by coating type, by commodity transported, and by other parameters if possible. These data are essential for "normalizing" the incident data, that is, putting them on a "per mile" basis. The normalized data would be expected to provide much better recognition of trends than the tentative comparisons that had to be made herein in the absence of the infrastructure data.

Secondly, the incident reporting should be revised to request more accurate data on the incident.

Specific suggestions have been made and a "model" form is included as Appendix C of this document.

Thirdly, either the appropriate Office of Pipeline Safety personnel or the ASME B31.4 volunteer group that reviews the incidents annually should contact operators who submit incomplete or incomprehensible information on incidents to clarify the data.

Lastly, when an operator obtains subsequent information which would materially alter the information provided initially on an incident, that operator should voluntarily submit a revised incident report to correct the initial data.

The industry's trade organizations should educate their members on the value of having complete and accurate data in the database.

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## INTRODUCTION

This document presents an analysis of "Reportable Incidents" on liquid petroleum pipelines in the U.S. during the 11-year period from 1986 through 1996. Reportable incidents are those which meet at least one of the following criteria and as a result must be reported to the U.S. Department of Transportation (DOT), Office of Pipeline Safety. The criteria for reporting are stated in the Code of Federal Regulations, Title 49 Transportation, Part 195, Paragraph 195.50. A report is required if the incident results in any of the following:

- Explosion or fire not intentionally set by the operator
- Loss of 50 or more barrels of hazardous liquid or carbon dioxide
- Escape to the atmosphere of more than five barrels a day of highly volatile liquids
- Death of any person
- Bodily harm to any person resulting in one or more of the following:
  - (a) Loss of consciousness
  - (b) Necessity to carry the person from the scene
  - (c) Necessity for medical treatment\*
  - (d) Disability which prevents the discharge of normal duties or the pursuit of normal activities beyond the day of the accident
- Estimated property damage, including cost of clean-up and recovery, value of lost product, and damage to the property of the operator or others, or both, exceeding \$50,000.\*\*

The data have been analyzed annually since the mid-1980's by volunteer efforts of members of the ASME B31.4 Section Committee. The 11-year analysis presented in this

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\* This requirement does not appear in Part 192 (gas pipeline regulations)

\*\* This amount was raised from \$5,000 to \$50,000 in 1994.

document is the result of a desire on the part of both the industry (i.e., pipeline operators) and the regulators (i.e., DOT officials) to extract more details from the data. Hence, this expanded effort was funded jointly by the industry and DOT. This report is patterned somewhat after similar reports<sup>2,3</sup> which have been compiled to analyze reportable incidents for natural gas pipelines.

The purposes of this effort are to diagnose potential problems that might be general in nature, to assess the trends as a measure of the effectiveness of both safety regulations and the industry's responses to potential problems, and to provide data for pipeline risk assessment.

The effort involved looking at the causes of incidents and the factors that affect incident frequency and severity.

## **BASES OF THE ANALYSES**

### **Form 7000.1**

The incident data are submitted on a standard form DOT Form 7000.1, a copy of which appears in Appendix A of this document. As seen in Appendix A this form requests data on the time, location, and circumstances of the incident. Pipeline system attributes are requested. The operator is requested to state the number of fatalities and injuries, the amount of property damage, and the amounts of product spilled and recovered. The operator is asked to state the probable cause of the incident and to provide a narrative description of the incident as well as to provide additional technical information related to the incident and the equipment involved.

### **Causes of Incidents**

Each incident is categorized on the basis of what the operator reported. Twenty possible causes were selected on the basis of the judgement of both data analysts and pipeline operating personnel. The following categories have been found to comprise a satisfactory classification system, and they are based on the failure categories utilized in the ASME B31.4/11 annual reports on liquid pipeline accidents.

**Table 1. ASME B31.4 Definitions**

| <b>Symbol</b> | <b>Category</b>                                    |
|---------------|----------------------------------------------------|
| CW            | Cold Weather                                       |
| DFW           | Defective Fabrication Weld                         |
| DGW           | Defective Girth Weld                               |
| DP            | Defective Pipe                                     |
| DPS           | Defective Pipe Seam                                |
| DRW           | Defective Repair Weld                              |
| EC            | Corrosion-Related Failures-External                |
| HRF           | Heavy Rains or Floods                              |
| IC            | Corrosion-Related Failures-Internal                |
| IO            | Incorrect Operation by Carrier Personnel           |
| LIGHT         | Lightning                                          |
| MCRE          | Malfunction of Control or Relief Equipment         |
| MISC          | Miscellaneous                                      |
| O             | Other                                              |
| RLG           | Ruptured or Leaking Gasket or O-ring               |
| RLSPP         | Ruptured or Leaking Seal or Pump Packing           |
| RPDP          | Rupture of Previously Damaged Pipe                 |
| TP            | Third Party Inflicted Damage                       |
| TSBPC         | Threads Stripped, Broken Pipe, or Coupling Failure |
| V             | Vandalism                                          |

The rationale for these categories is largely based on logical considerations and the industry's experience with the types of failures which most often occur.

### **Pipeline Attributes**

Pipeline attributes such as diameter, wall thickness, material strength, operating stress level, location, age, and commodity transported are considered in the analyses herein. Also, considered are non-pipeline components of pipeline systems such as tanks, valves, pumps, fittings, etc. Other factors may also be appropriate, but these are the attributes which were available in the DOT data.

### **Consequences of Incidents**

The consequences of incidents are of great importance in terms of assessing the impact of pipeline safety on the public. The consequences of pipeline failures may be found in the incident reports in terms of fatalities; injuries; property damage from ruptures, fires, and explosions; and the type and amount of commodity released into the environment as a result of each incident.

The extent of environment consequences cannot be well-defined on the basis of the reportable incident date.

### **Pipeline Infrastructure**

To understand the significance of the numbers of incidents and the consequences it is essential to have some idea of the nature and size of the liquid petroleum products pipeline infrastructure in the U.S. The basic “regulated” infrastructure consists of about 160,000 miles of pipelines. These range from 8 to 48 inches in diameter. It is noted that many thousands of miles of liquid pipelines smaller than 8-inches in diameter exist, but many are not covered by the reporting requirements.

The pipelines covered by the reporting requirements carry many kinds of petroleum products. The types of products inferred from the incident reports include:

|                                |     |
|--------------------------------|-----|
| Ammonia (anhydrous)            | (a) |
| Butane                         | (a) |
| Condensate                     | (b) |
| Crude Oil                      |     |
| Diesel                         |     |
| Ethane                         | (a) |
| Ethylene                       | (a) |
| Fuel Oil                       |     |
| Gasoline                       |     |
| Jet Fuel                       |     |
| LPG (liquified petroleum gas)  | (a) |
| NGL (natural gas liquids)      | (a) |
| Other                          | (c) |
| Products                       | (d) |
| Propane                        | (a) |
| Propylene                      | (a) |
| Unknown (not stated in report) |     |
| Xylene                         |     |

- (a) These are highly volatile liquids (HVLs) which are transported in liquid state under pressure. When released to atmospheric pressure they vaporize rapidly leaving no residual liquid.
- (b) Condensate is assumed to be a non-HVL.
- (c) "Other" is believed, to include products such as benzene, toluene and other liquid chemicals.
- (d) "Products" is assumed to mean various refined products such as gasoline, diesel, jet fuel, and fuel oil.

## GENERAL TRENDS

### Number of Incidents by Cause

In the 11-year period from 1986 through 1996, 2262 incidents were reported on liquid petroleum pipelines in U.S. The breakdown of incidents by cause is shown in Table 2 and is presented graphically in Figure 1. The complete data set as compiled by the ASME B31.4

**Table 2. Reportable Incidents on Hazardous Liquid Pipelines, 1986 through 1996**

| <b>ALL INCIDENTS</b>                             |              |                         |
|--------------------------------------------------|--------------|-------------------------|
| <b>Cause as Defined by B31.4 Committee</b>       |              |                         |
| <b>Classification</b>                            | <b>Total</b> | <b>Percent of Total</b> |
| Cold Weather (CW)                                | 25           | 1.11%                   |
| Defective Fabrication Weld (DFW)                 | 13           | 0.57%                   |
| Defective Girth Weld (DGW)                       | 51           | 2.25%                   |
| Defective Pipe (DP)                              | 40           | 1.77%                   |
| Defective Pipe Seam (DPS)                        | 78           | 3.45%                   |
| Defective Repair Weld (DRW)                      | 22           | 0.97%                   |
| External Corrosion (EC)                          | 438          | 19.36%                  |
| Heavy Rains/Floods (HRF)                         | 45           | 1.99%                   |
| Internal Corrosion (IC)                          | 130          | 5.75%                   |
| Incorrect Operation (IO)                         | 194          | 8.58%                   |
| Lightning (LIGHT)                                | 19           | 0.84%                   |
| Malfunction of Control/Relief Equipment (MCRE)   | 114          | 5.04%                   |
| Miscellaneous (MISC) and Other (O)               | 244          | 10.79%                  |
| Ruptured or Leaking Gasket (RLG)                 | 123          | 5.44%                   |
| Ruptured or Leaking Seal or Pump Packing (RLSPP) | 66           | 2.92%                   |
| Rupture of Previously Damaged Pipe (RPDP)        | 113          | 5.00%                   |
| Third Party (TP)                                 | 451          | 19.94%                  |
| Threads Stipped, Broken Pipe Coupling (TSBPC)    | 71           | 3.14%                   |
| Vandalism (V)                                    | 25           | 1.11%                   |
| <b>Total</b>                                     | <b>2262</b>  | <b>100%</b>             |

| <b>PIPE-RELATED INCIDENTS</b>              |              |                         |
|--------------------------------------------|--------------|-------------------------|
| <b>Cause as Defined by B31.4 Committee</b> |              |                         |
| <b>Classification</b>                      | <b>Total</b> | <b>Percent of Total</b> |
| Defective Girth Weld (DGW)                 | 51           | 3.73%                   |
| Defective Pipe (DP)                        | 40           | 2.92%                   |
| Defective Pipe Seam (DPS)                  | 78           | 5.70%                   |
| Defective Repair Weld (DRW)                | 22           | 1.61%                   |
| External Corrosion (EC)                    | 438          | 32.02%                  |
| Heavy Rains/Floods (HRF)                   | 45           | 3.29%                   |
| Internal Corrosion (IC)                    | 130          | 9.50%                   |
| Rupture of Previously Damaged Pipe (RPDP)  | 113          | 8.26%                   |
| Third Party (TP)                           | 451          | 32.97%                  |
| <b>Total</b>                               | <b>1368</b>  | <b>100%</b>             |

| <b>NON-PIPE-RELATED INCIDENTS</b>                |              |                         |
|--------------------------------------------------|--------------|-------------------------|
| <b>Cause as Defined by B31.4 Committee</b>       |              |                         |
| <b>Classification</b>                            | <b>Total</b> | <b>Percent of Total</b> |
| Cold Weather (CW)                                | 25           | 2.80%                   |
| Defective Fabrication Weld (DFW)                 | 13           | 1.45%                   |
| Incorrect Operation (IO)                         | 194          | 21.70%                  |
| Lightning (LIGHT)                                | 19           | 2.13%                   |
| Malfunction of Control/Relief Equipment (MCRE)   | 114          | 12.75%                  |
| Miscellaneous (MISC) and Other (O)               | 244          | 27.29%                  |
| Ruptured or Leaking Gasket (RLG)                 | 123          | 13.76%                  |
| Ruptured or Leaking Seal or Pump Packing (RLSPP) | 66           | 7.38%                   |
| Threads Stipped, Broken Pipe Coupling (TSBPC)    | 71           | 7.94%                   |
| Vandalism (V)                                    | 25           | 2.80%                   |
| <b>Total</b>                                     | <b>894</b>   | <b>100%</b>             |



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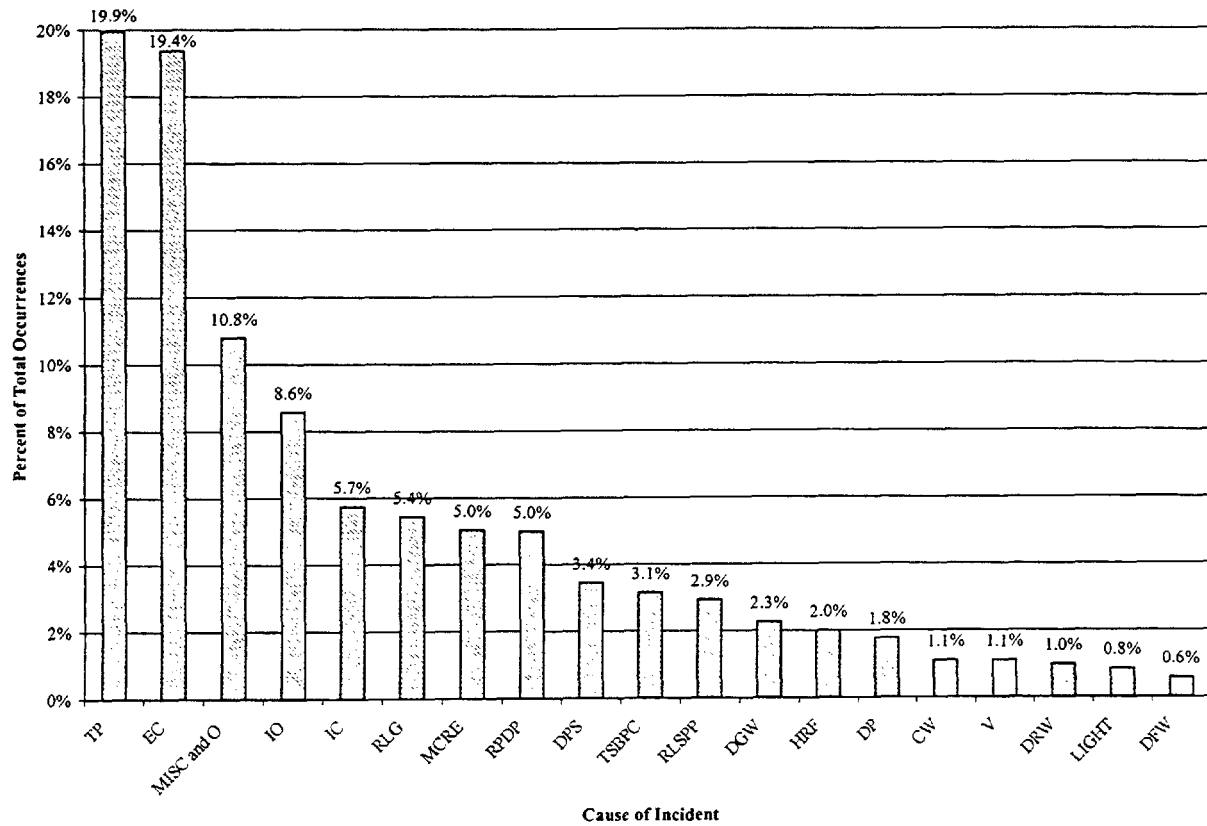


Figure 1a. Distribution of Incidents by Cause

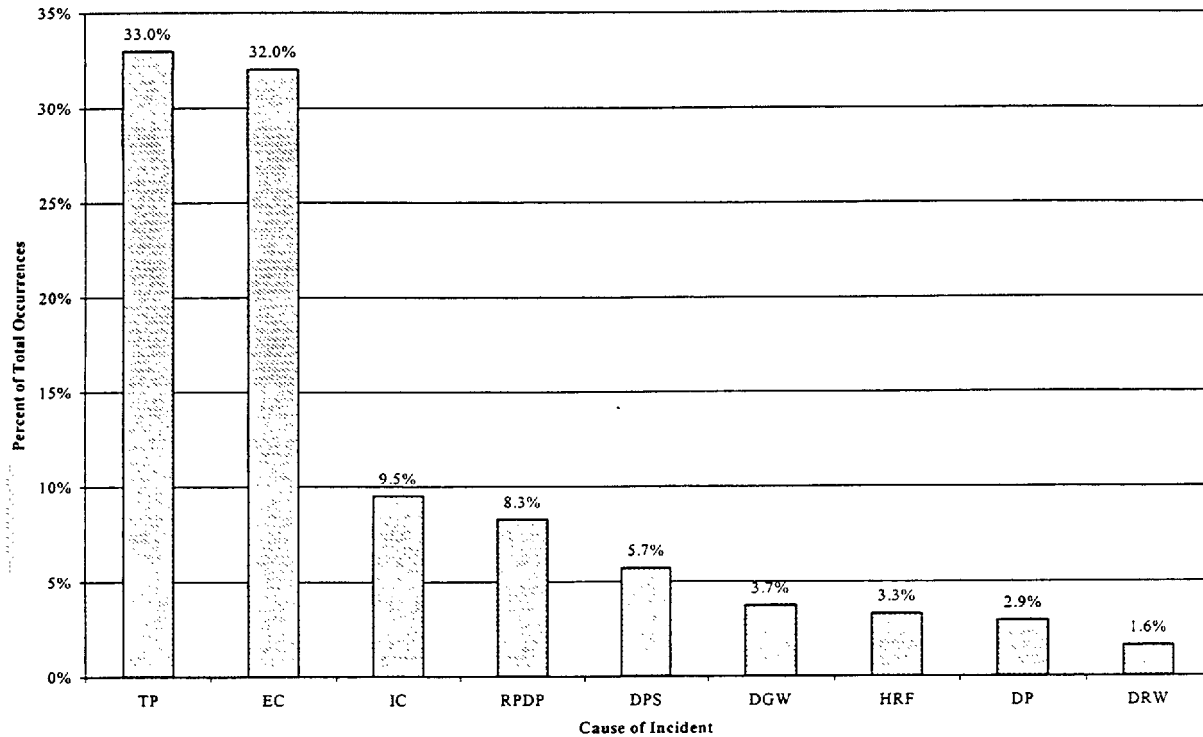


Figure 1b. Distribution of Incidents by Cause for Pipe-Related Incidents

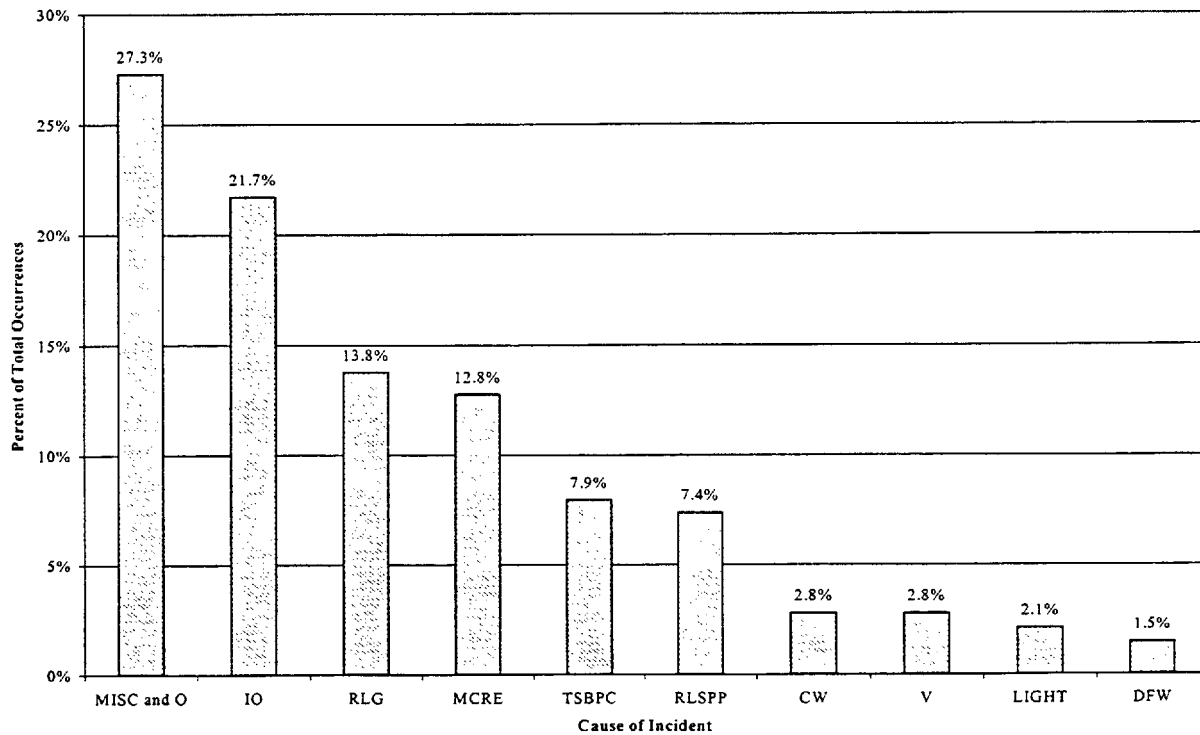


Figure 1c. Distribution of Incidents by Cause of Non-Pipe-Related Incidents

Section Committee is contained on the disk attached to the back cover of this report. A description of the disk and its use is presented in Appendix B.

The leading causes were third party damage (TP) and external corrosion (EC)}.

There were 451 third party incidents accounting for 19.9 percent of all incidents and 438 external corrosion incidents accounting for 19.4 percent of all incidents. The third and fourth most frequent causes were miscellaneous (MISC) accounting for 10.1 percent and incorrect operation (IO) accounting for 8.6 percent. The other sixteen causes accounted for 41.9 percent of the incidents.

Table 2, in addition to presenting all incidents separates the incidents into two classes: pipe-related incidents and non-pipe-related incidents. This separation is useful from the standpoint of possible uses of the data for risk assessment. Pipeline risk assessment models tend to involve pipeline attributes, not the attributes of other facilities such as breakout tanks, pump stations, or metering facilities. As the use of probabilistic risk assessment evolves, the rates of failures associated with pipeline attributes (i.e., pipe-related incidents) will be needed. In addition, parallel risk assessment strategies for other facilities will require the use of non-pipe-related failure rates. The separation was based on the following observations. For certain types of incidents, it was noticed that the diameter of the pipe was almost always stated. For the balance of the types of incidents it was noticed that the diameter of the pipe was usually not stated. These two categories were separated into pipe incidents and non-pipe incidents as shown in Table 3. For each cause we noted the percentage of times diameter was stated. For those causes we have assumed to be mostly pipe-related, the diameter was stated in more the 80 percent of the cases (i.e., the number of cases where the diameter was not stated ranged from zero to 18 percent). In contrast, for those causes we have assumed to be mostly non-pipe-related, diameter was not stated most of the time.

**Table 3. Pipe-Related Vs. Non-Pipe-Related Incidents**

| <b>Categorized as Pipe-Related Incidents<br/>(1368 incidents)</b>    | <b>Percent of Incidents Where Diameter Not<br/>Stated</b>     |
|----------------------------------------------------------------------|---------------------------------------------------------------|
| Defective Girth Weld (DGW)                                           | 4                                                             |
| Defective Pipe (DP)                                                  | 0                                                             |
| Defective Pipe Seam (DPS)                                            | 1                                                             |
| Defective Repair Weld (DRW)                                          | 18                                                            |
| External Corrosion (EC)                                              | 4                                                             |
| Heavy Rains or Floods (HRF)                                          | 13                                                            |
| Internal Corrosion (IC)                                              | 18                                                            |
| Rupture of Previously Damaged Pipe (RPDP)                            | 2                                                             |
| Third Party Damage                                                   | 7                                                             |
| <b>Categorized as Non-Pipe Related Incidents<br/>(894 incidents)</b> | <b>Percent of Incidents<br/>Where Diameter Not<br/>Stated</b> |
| Cold Weather (CW)                                                    | 76                                                            |
| Defective Fabrication Weld (DFW)                                     | 54                                                            |
| Incorrect Operation (IO)                                             | 76                                                            |
| Lightning (LIGHT)                                                    | 68                                                            |
| Malfunction of Control or Relief Equipment (MCRE)                    | 91                                                            |
| Miscellaneous (MISC)                                                 | 71                                                            |
| Other (O)                                                            | 50                                                            |
| Ruptured or Leaking Seal or Pump Packing (RLSPP)                     | 100                                                           |
| Threads Stripped, Broken, Nipple, or Coupling Failure (TSBPF)        | 80                                                            |
| Vandalism                                                            | 40                                                            |

Obviously not all incidents breakdown neatly by cause as being pipe-related or non-pipe-related, but it helps to know when analyzing and using the data which causes are predominantly

pipe-related and which are not. A case-by-case review of the pipe-related incidents revealed that at least 1303 of the 1368 incidents did indeed involve the line pipe material.

A similar review of the 894 non-pipe-related incidents revealed that probably 104 of the incidents involved the line pipe material. This indicates that about 1402 incidents (62 percent) across all causes involved the line pipe material. For analysis purposes, however, we continued to use the number 1368 to represent the number of pipe-related incidents because the 1402 number still represents only a best guess and because it would take a complete reclassification of the incidents to sort strictly by pipe and non-pipe incidents.

Figure 1 is presented in 3 parts (1a, 1b, and 1c) to show the distribution of incidents by cause overall, by pipe-related incidents only and by non-pipe related incidents only.

Third-party incidents and external corrosion incidents accounted for nearly 40 percent of all incidents and 65 percent of the pipe-related incidents as shown in Figure 1b.

Three other pipe-related causes made significant contributions to the pipe-related incident total. Internal corrosion (IC), rupture of previously damaged pipe (RPDP), and defective pipe seam (DPS). As will be shown it makes sense to combine defective pipe (DP) incidents with the defective pipe seam (DPS) incidents. Together the incorrect operations (IO), rupture of previously damaged pipe (RPDP), defective pipe seam (DPS), and defective pipe (DP) incidents accounted for 26 percent of the pipe-related incidents.

The miscellaneous (MISC) and other (O) categories accounted for 23.7 percent of the non-pipe-related incidents. As will be seen the majority of the incidents in these two categories arose from diverse causes which were either difficult to classify or not determinable.

Failure descriptions should be expanded and clarified to reduce the numbers of incidents which end up in these two categories. The cause categories used by ASME B31.4 are adequate, if enough details are provided in the "account of accident section of the reporting form.

Aside from these the other significant causes of non-pipe-related incidents were incorrect operations (IO), malfunctions of control or relief equipment (MCRE), treads stripped, broken

pipe or collar (TSBPC), and ruptured or leaking seals or pump packing (RLSPP), which together account for 42 percent of the non-pipe-related incidents.

### Incidents by Year of Occurrence

Figure 2 shows the incidents by year of occurrence. These data do not reflect any consistent trend.

### Fatalities and Injuries

In the 11-year period there were 24 fatalities and 2066 injuries reported as the result of liquid pipeline incidents. A relatively large number of injuries is associated with one incident in 1994 because of the definition contained in Part 195 of bodily harm which includes necessity of medical treatment. 1851 people were examined for smoke inhalation as the result of burning gasoline on the San Jacinto river after a 40-inch-diameter pipeline was ruptured by a flood. None of these people were hospitalized as a result of the examinations. Except for this incident the number of injuries would have been 215. The relationships of fatalities and injuries to year of occurrence are shown in Figures 3 and 4. It is difficult to discern any trend with year of occurrence.

It would prove useful to provide a more accurate understanding of the consequences of incidents to have a definition of injury similar to the one contained in Part 192 (gas pipeline regulations).

### Property Damage

In the 11-year period, property damage costs totaling \$283,544,369 were associated with the 2262 incidents. The average cost per incident was \$125,400. The costs by causes are shown in Table 4. The average cost for a pipe-related incident was \$156,000, about twice that for the average cost of a non-pipe-related incident (\$78,400). The highest average cost by cause was associated with the heavy rains and floods (HRF) category (\$836,800). In this category two accidents together accounted for \$20,000,000 in costs, so the average number is strongly driven by these two. The highest cost single incident (\$12,000,000) was actually a defective pipe seam incident. It is extremely difficult to draw any conclusions based on property damage since the

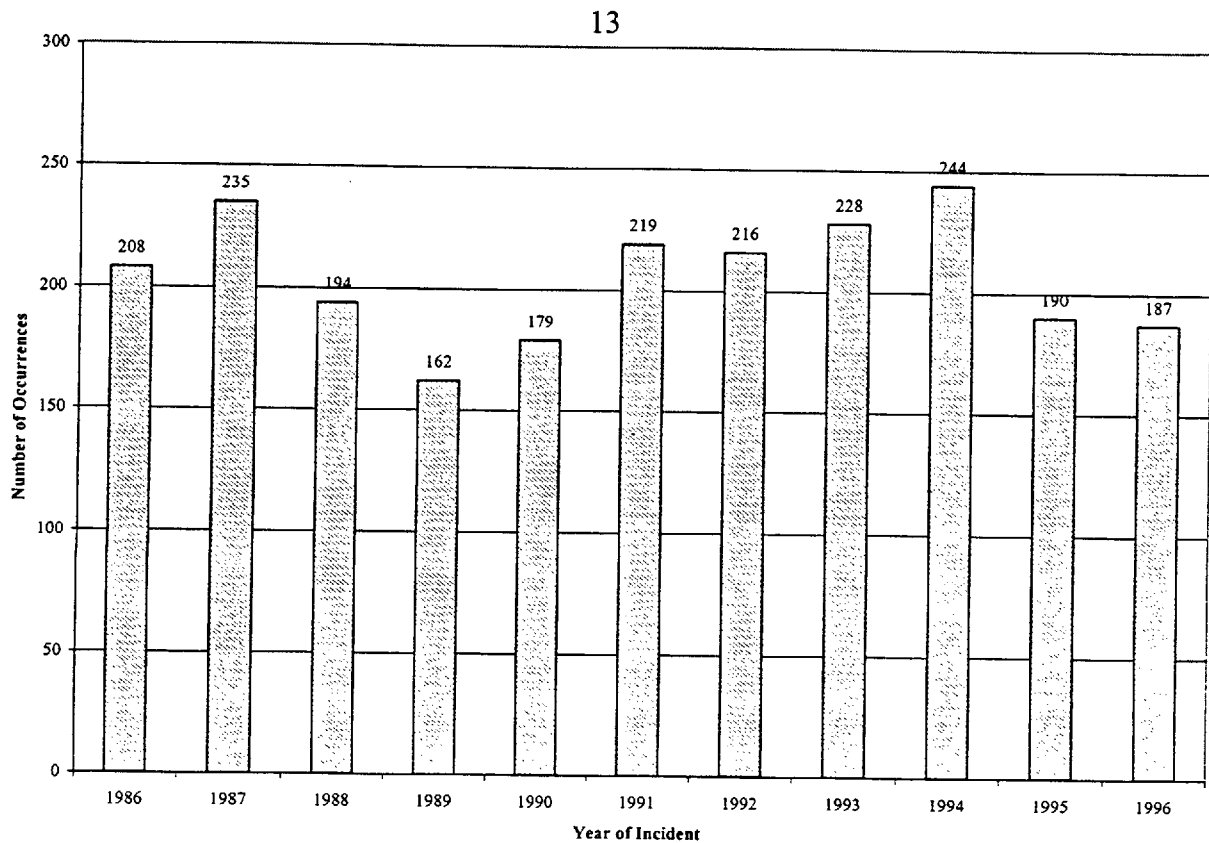


**Figure 2. Incidents by Year of Occurrence**

Table 4. Costs of Incidents

| ALL INCIDENTS                       |                          |                      |
|-------------------------------------|--------------------------|----------------------|
| Cause as Defined by B31.4 Committee |                          |                      |
| Classification                      | Total                    | Average              |
| CW                                  | \$ 2,916,900.00          | \$ 116,676.00        |
| DFW                                 | \$ 1,241,000.00          | \$ 95,461.54         |
| DGW                                 | \$ 13,957,555.00         | \$ 273,677.55        |
| DP                                  | \$ 7,412,183.00          | \$ 185,304.58        |
| DPS                                 | \$ 26,202,775.00         | \$ 335,933.01        |
| DRW                                 | \$ 944,874.00            | \$ 42,948.82         |
| EC                                  | \$ 49,276,657.00         | \$ 112,503.78        |
| HRF                                 | \$ 37,656,091.00         | \$ 836,802.02        |
| IC                                  | \$ 9,532,425.00          | \$ 73,326.35         |
| IO                                  | \$ 15,109,364.00         | \$ 77,883.32         |
| LIGHT                               | \$ 1,872,000.00          | \$ 98,526.32         |
| MCRE                                | \$ 6,784,057.00          | \$ 59,509.27         |
| MISC and O                          | \$ 18,152,046.00         | \$ 74,393.63         |
| RLG                                 | \$ 14,725,660.00         | \$ 119,720.81        |
| RLSPP                               | \$ 3,866,810.00          | \$ 58,588.03         |
| RPDP                                | \$ 27,159,971.00         | \$ 240,353.73        |
| TP                                  | \$ 41,346,006.00         | \$ 91,676.29         |
| TSBPC                               | \$ 4,123,480.00          | \$ 58,077.18         |
| V                                   | \$ 1,264,515.00          | \$ 50,580.60         |
| <b>Total</b>                        | <b>\$ 283,544,369.00</b> | <b>\$ 125,351.18</b> |

| PIPE-RELATED INCIDENTS              |                          |                      |
|-------------------------------------|--------------------------|----------------------|
| Cause as Defined by B31.4 Committee |                          |                      |
| Classification                      | Total                    | Average              |
| DGW                                 | \$ 13,957,555.00         | \$ 273,677.55        |
| DP                                  | \$ 7,412,183.00          | \$ 185,304.58        |
| DPS                                 | \$ 26,202,775.00         | \$ 335,933.01        |
| DRW                                 | \$ 944,874.00            | \$ 42,948.82         |
| EC                                  | \$ 49,276,657.00         | \$ 112,503.78        |
| HRF                                 | \$ 37,656,091.00         | \$ 836,802.02        |
| IC                                  | \$ 9,532,425.00          | \$ 73,326.35         |
| RPDP                                | \$ 27,159,971.00         | \$ 240,353.73        |
| TP                                  | \$ 41,346,006.00         | \$ 91,676.29         |
| <b>Total</b>                        | <b>\$ 213,488,537.00</b> | <b>\$ 156,058.87</b> |

| NON-PIPE-RELATED INCIDENTS          |                         |                     |
|-------------------------------------|-------------------------|---------------------|
| Cause as Defined by B31.4 Committee |                         |                     |
| Classification                      | Total                   | Average             |
| CW                                  | \$ 2,916,900.00         | \$ 116,676.00       |
| DFW                                 | \$ 1,241,000.00         | \$ 95,461.54        |
| IO                                  | \$ 15,109,364.00        | \$ 77,883.32        |
| LIGHT                               | \$ 1,872,000.00         | \$ 98,526.32        |
| MCRE                                | \$ 6,784,057.00         | \$ 59,509.27        |
| MISC and O                          | \$ 18,152,046.00        | \$ 74,393.63        |
| RLG                                 | \$ 14,725,660.00        | \$ 119,720.81       |
| RLSPP                               | \$ 3,866,810.00         | \$ 58,588.03        |
| TSBPC                               | \$ 4,123,480.00         | \$ 58,077.18        |
| V                                   | \$ 1,264,515.00         | \$ 50,580.60        |
| <b>Total</b>                        | <b>\$ 70,055,832.00</b> | <b>\$ 78,362.23</b> |



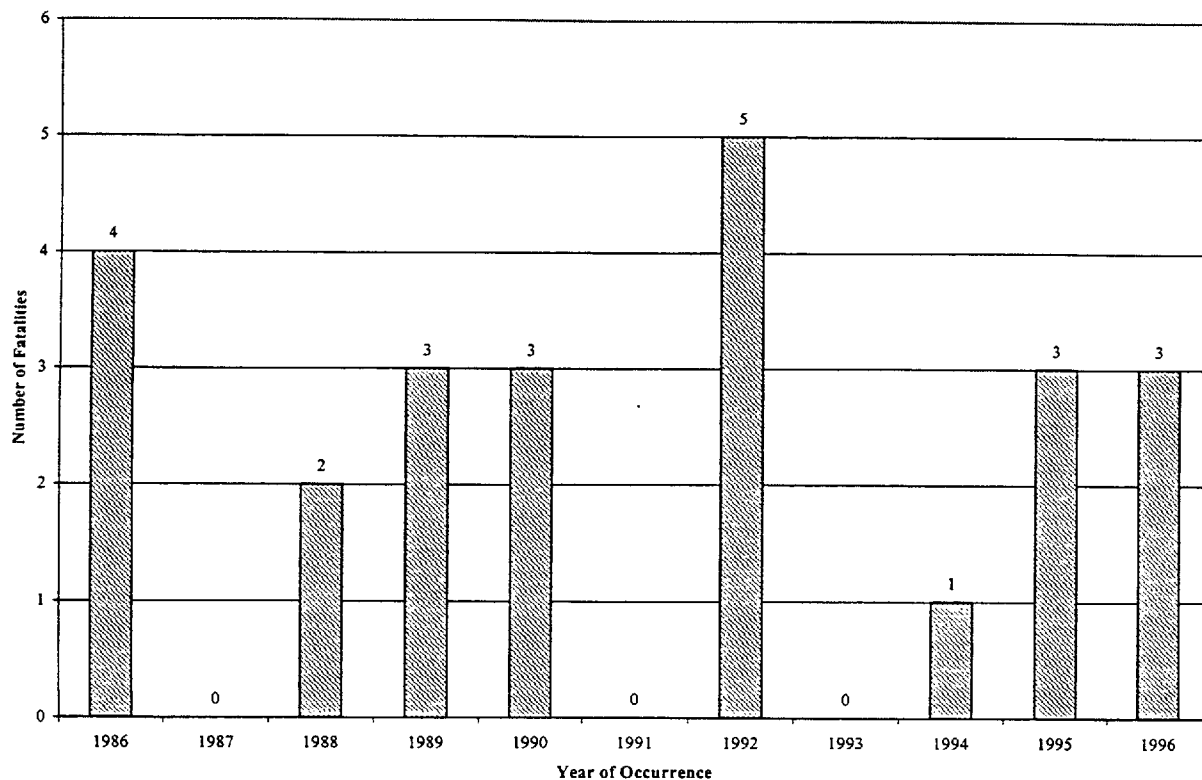


Figure 3. Fatalities by Year of Occurrence

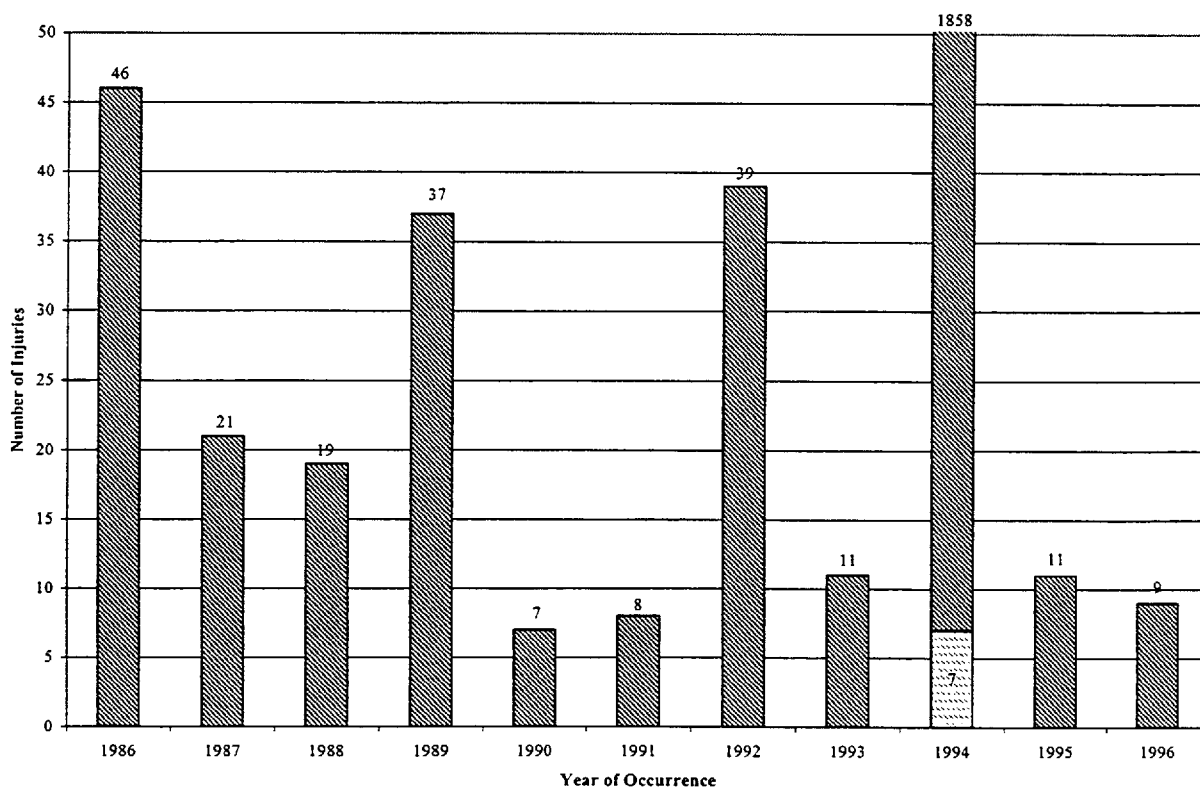


Figure 4. Injuries by Year of Occurrence

cost of an incident is influenced by a variety of factors which are not correlated directly with the consequences of an incident.

### Sizes of Spills

When it comes to spills of the transported commodities, it makes sense to separate the highly-volatile liquids (HVLs) from the non-highly-volatile liquids (non HVLs). This is because the HVLs tend to evaporate completely, are usually not recoverable. Unless they are ignited they seldom do environmental damage (ammonia is an exception, it tends to kill vegetation). Non-HVLs, on the other hand, tend to remain in the liquid state. Since these hydrocarbon liquids are less dense than water, they often can be contained and, to a large extent, recovered and removed from the environment. For the purposes of this report the term "spill" will be used exclusively for non-HVL incidents. The term "release" will be used to describe the amount of commodity lost in an incident involving an HVL. So, when the term "spill" is encountered hereafter in this document it refers to non-HVL commodities only.

During the 11-year period, the 2262 incidents resulted in the loss of 2,146,821 barrels of products, 1,752,436 barrels of which were non HVLs and 394,385 barrels of which were HVLs. Of the non HVLs spilled, 926,229 barrels (53 percent) were recovered. Of the HVLs released only 281 barrels (0.07 percent) were recovered because these commodities tend to vaporize completely. For the 1930 incidents involving non HVLs, the average gross spill size is 908 barrels per incident and the average amount recovered was 480 barrels per incident. For the 332 incidents involving HVLs the average gross release size is 1108 barrels per incident.

The non-HVL spills by incident cause are summarized in Table 5. The highest average gross spill was associated with defective pipe seam (DPS) incidents (2644.7 bbls). The highest average net spill (after recovery) was associated with heavy rain and flood (HRF) incidents (1987.9 bbls). Other causes associated with high average gross spills are HRF incidents (2308.0 bbls), defective pipe (DP) incidents (1518.4 bbls), MISC incidents (1467.8 bbls), and rupture of previously damaged pipe (RPDP) incidents (1441.7 bbls). Other causes associated with high average net spills are DPS incidents (1096.9 bbls), MISC incidents (918.3 bbls), RPDP incidents (746.5 bbls), and lightning strike (LIGHT) incidents (526.9 bbls). It is believed that these types of incidents are associated with larger spills because they are more likely (except for

Table 5. Non-HVL Spills by Incident Cause

| Cause as Defined by B31.4 Committee |                        |                                        |                                          |                                              |             |                        |                                              |
|-------------------------------------|------------------------|----------------------------------------|------------------------------------------|----------------------------------------------|-------------|------------------------|----------------------------------------------|
| B31.4<br>Classification             | Number of<br>Incidents | Total<br>Amount<br>Spilled,<br>Barrels | Total<br>Amount<br>Recovered,<br>Barrels | Total Amount<br>Not<br>Recovered,<br>Barrels | % Recovered | Average<br>Spill, bbls | Average Net<br>Spill After<br>Recovery, bbls |
| CW                                  | 25                     | 16862                                  | 11673                                    | 5189                                         | 69%         | 674                    | 208                                          |
| DFW                                 | 12                     | 4331                                   | 629                                      | 3702                                         | 15%         | 361                    | 309                                          |
| DGW                                 | 36                     | 31267                                  | 16808                                    | 14459                                        | 54%         | 869                    | 402                                          |
| DP                                  | 36                     | 54662                                  | 37204                                    | 17458                                        | 68%         | 1518                   | 485                                          |
| DPS                                 | 67                     | 177193                                 | 103699                                   | 73494                                        | 59%         | 2645                   | 1097                                         |
| DRW                                 | 16                     | 2888                                   | 454                                      | 2434                                         | 16%         | 181                    | 152                                          |
| EC                                  | 382                    | 235576                                 | 130430                                   | 105146                                       | 55%         | 617                    | 275                                          |
| HRF                                 | 40                     | 92320                                  | 12804                                    | 79516                                        | 14%         | 2308                   | 1988                                         |
| IC                                  | 129                    | 87374                                  | 71672                                    | 15701                                        | 82%         | 677                    | 122                                          |
| IO                                  | 169                    | 136118                                 | 102828                                   | 33290                                        | 76%         | 805                    | 197                                          |
| LIGHT                               | 16                     | 8715                                   | 285                                      | 8430                                         | 3%          | 545                    | 527                                          |
| MCRE                                | 95                     | 85083                                  | 67980                                    | 17103                                        | 80%         | 896                    | 180                                          |
| MISC                                | 192                    | 281811                                 | 104863                                   | 176948                                       | 37%         | 1468                   | 922                                          |
| o                                   | 12                     | 10881                                  | 4864                                     | 6017                                         | 45%         | 907                    | 501                                          |
| RLG                                 | 110                    | 49690                                  | 21920                                    | 27770                                        | 44%         | 452                    | 252                                          |
| RLSPP                               | 51                     | 5594                                   | 4230                                     | 1364                                         | 76%         | 110                    | 27                                           |
| RPDP                                | 101                    | 145607                                 | 69962                                    | 75645                                        | 48%         | 1442                   | 749                                          |
| TP                                  | 351                    | 298738                                 | 140783                                   | 157955                                       | 47%         | 851                    | 450                                          |
| TSBPC                               | 68                     | 18231                                  | 13298                                    | 4933                                         | 73%         | 268                    | 73                                           |
| V                                   | 22                     | 9496                                   | 6166                                     | 3330                                         | 65%         | 432                    | 151                                          |
| Total                               | 1930                   | 1752436                                | 922553                                   | 829883                                       | 53%         | 908                    | 430                                          |

lightning) than other types of incidents to involve ruptures (large openings) and because they are more likely than other types of incidents to occur in areas not under the immediate control of the operator.

The best news about spills are the generally downward trends shown in Figures 5 and 6.

Figures 5 and 6 show that both gross spills and net spills have decreased substantially over the 11-year period as viewed both year-by-year and in terms of a 3-year-running average.

These trends undoubtedly result from the regulatory changes and the industry's focus on preventing spills and on rapid responses to spills that do occur, and on utilizing technologically advanced methods for dealing with spills.

### **HVLs Versus Non HVLs from the Standpoint of Fatalities and Injuries**

The 332 incidents (14.7 percent of all incidents) involving releases of HVL resulted in 15 of the 24 fatalities (63 percent) and 87 of the 215 injuries (40 percent excluding the San Jacinto incident with its 1851 reported injuries). The tendency toward a higher probability of death or injury from an HVL incident is believed to be the result of the tendency of the HVLs to form vapor clouds which may be ignited.

### **Offshore Versus Onshore**

Of the 2262 incidents only 34 (1.5 percent) were identified as having occurred offshore. Possibly the low number of reportable incidents offshore is associated with a small amount of offshore pipeline mileage that is covered by the reporting requirements.

The causes of incidents offshore were third party damage (11 incidents); internal corrosion and ruptured or leaking gaskets (5 incidents each); external corrosion (4 incidents); rupture of previously damaged pipe, miscellaneous, and defective girth welds (2 incidents each); and heavy rains and floods, thread stripped or broken pipe, and incorrect operation (1 each). It is noted that the incidents characterized as being caused by heavy rains and floods and by threads tripped or broken pipe actually resulted from mudslides offshore during storms. The one recorded as threads stripped or broken pipe involved the failure of a "breakaway joint: which is

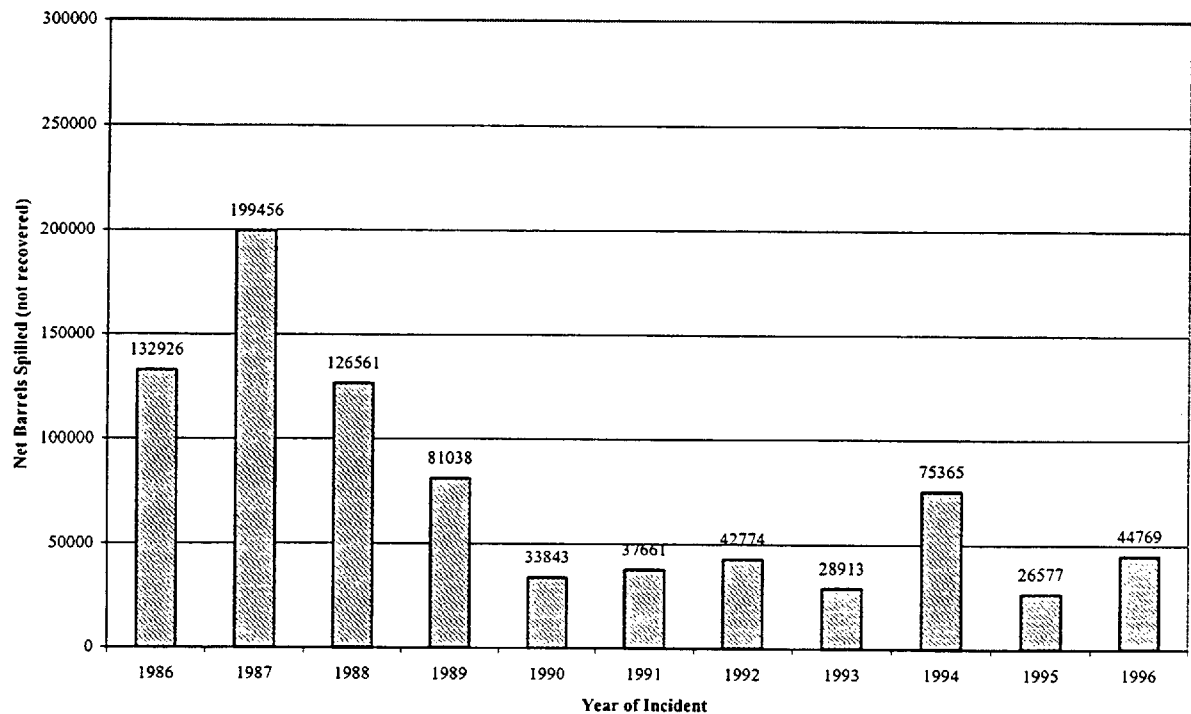
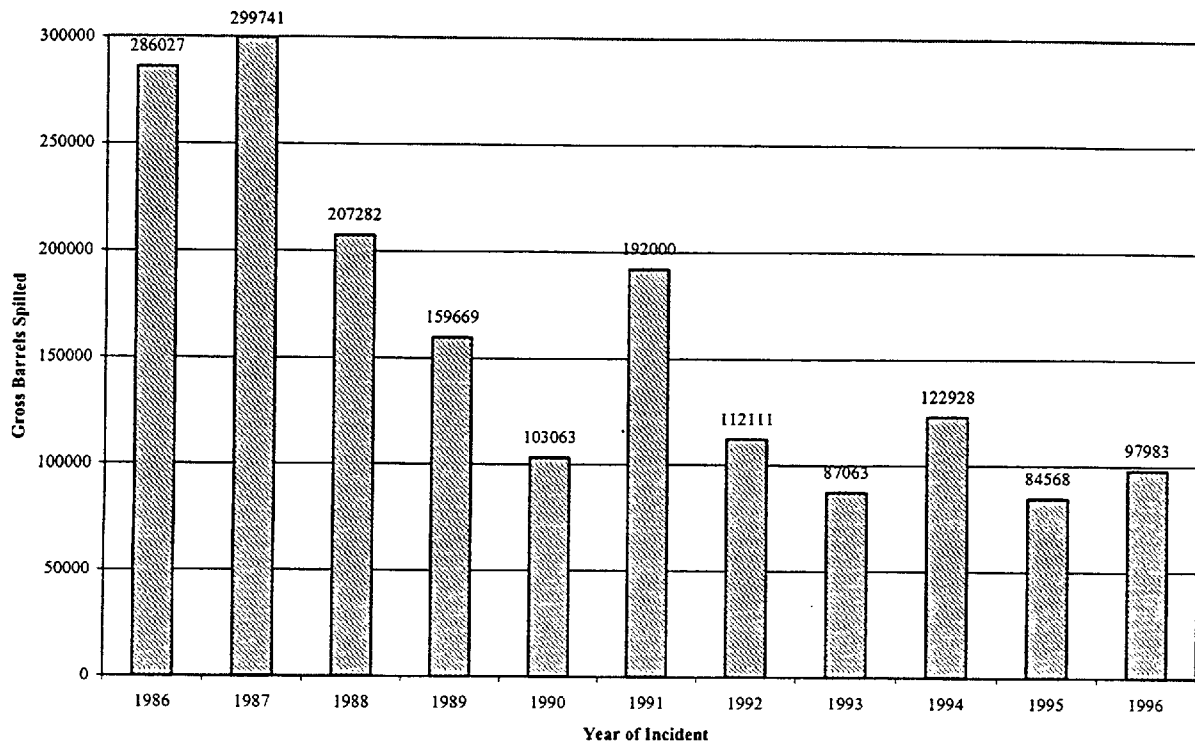


Figure 5. Trends in Gross and Net Spills Over the 11 Year Period from 1986-1996

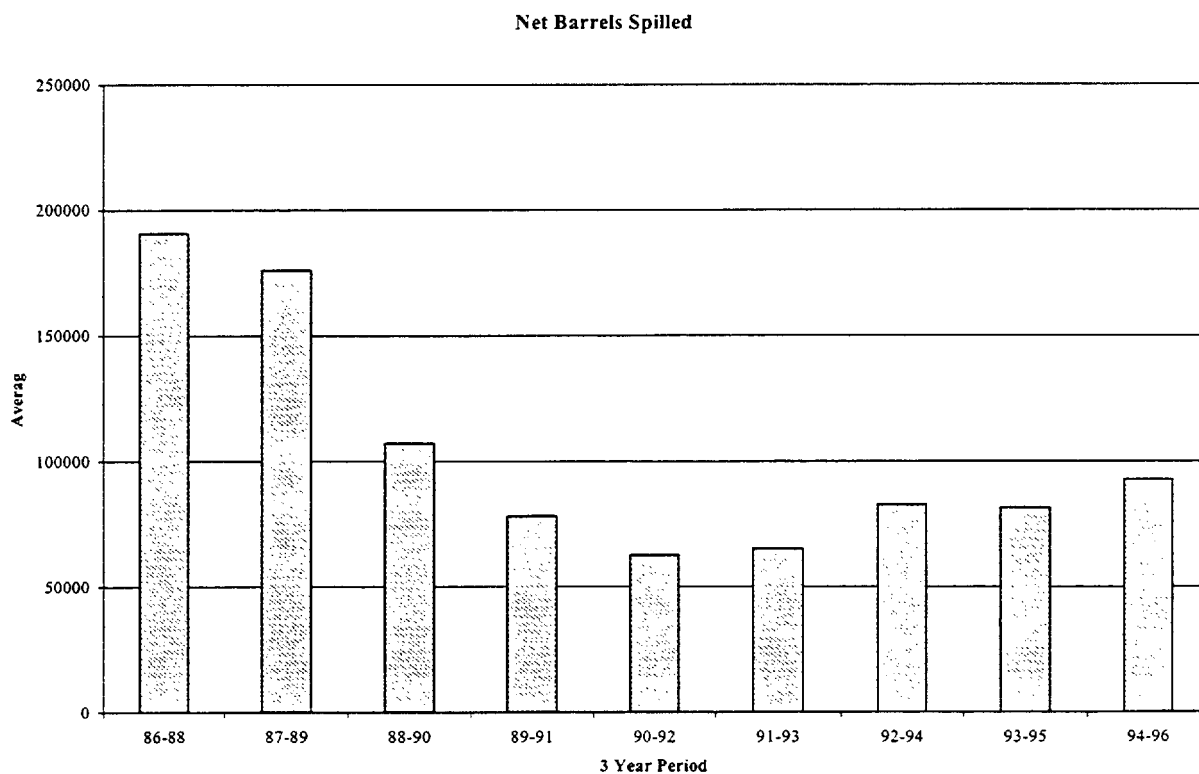
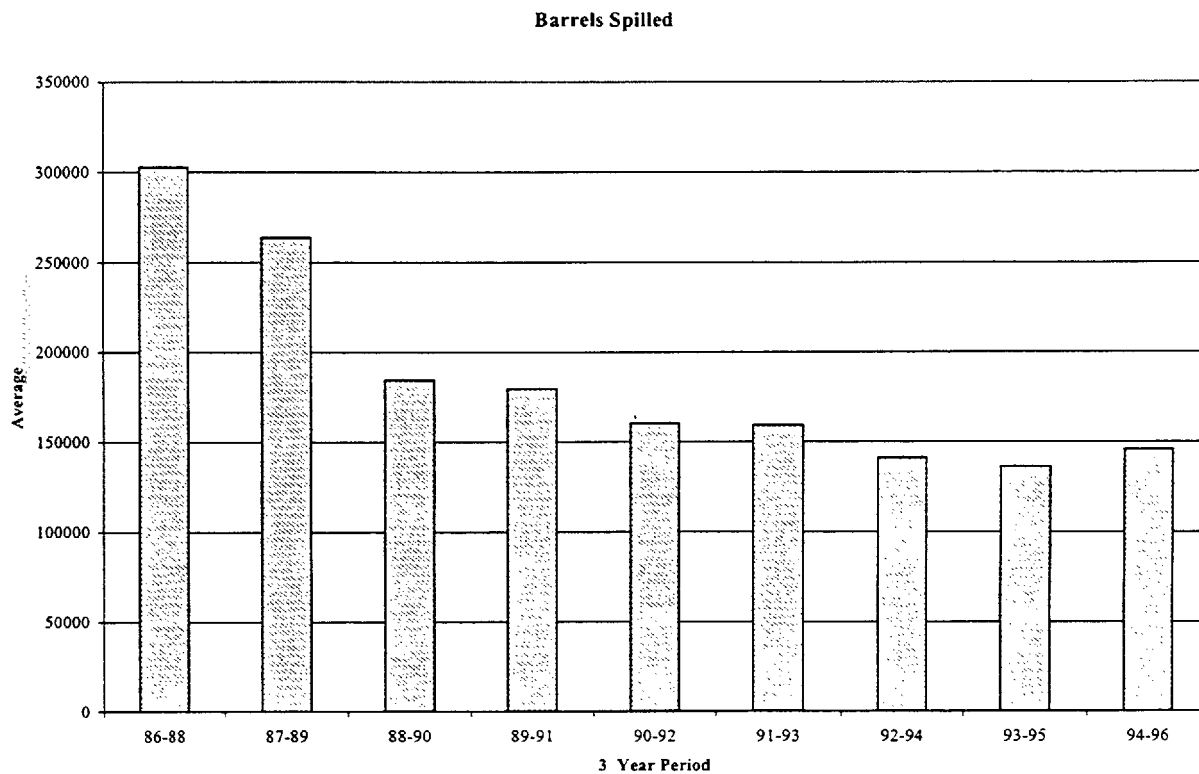


**Figure 6. Spill Sizes Based on Three-Year Running Average**

designed to break in a manner which protects a mainline and prevents a large spill. In this case the joint apparently worked; only 4 barrels of condensate were released.

The products involved in the 34 offshore incidents were condensate (4 incidents) and crude oil (29 incidents). In one incident the product was not stated.

## TRENDS BASED ON ATTRIBUTES

As will be seen, it is useful to consider the rates of pipe-related incidents in terms of various pipeline attributes, in particular, diameter, wall thickness, stress level, and age. These kinds of information will be useful in risk assessments especially when improved infrastructure information becomes available.

### Incidents by Diameter

The distributions of incidents by diameter for each pipe-related incident are listed in Table 6 and are shown for all pipe-related incidents in Figure 7. Two points should be noted in conjunction with these data. First, as noted earlier, many pipelines smaller than 8-inch-diameter do not fall under the accident reporting requirements, and hence, incidents involving these pipelines are not included in these data. Thus, it is not possible to attach much significance to the distributions on incidents involving pipe diameters below 8.625-inch. The relationship of number of occurrences to pipe diameter is inversely proportional to pipe diameter, it is assumed, because the mileage of pipe in service decreases with increasing pipe diameter.

The second point that should be noted with respect to the diameter data is that we have converted all nominal sizes to actual sizes were applicable in order to improve the accuracy of the calculated operating stress levels. Usually the data supplied by the B31.4 group gave only the nominal size.

The number of incidents by diameter would be useful in risk assessment if the mileages by diameter were available.

**Table 6. Incidents by Diameter for Pipe-Related Incidents**

| Cause as Defined by B31.4 Committee |           |           |           |           |            |           |            |            |            |             |
|-------------------------------------|-----------|-----------|-----------|-----------|------------|-----------|------------|------------|------------|-------------|
| Diameter,<br>inches                 | DGW       | DP        | DPS       | DRW       | EC         | HRF       | IC         | RPDP       | TP         | Total       |
| 1                                   |           |           |           |           |            |           | 1          |            |            | 1           |
| 2.375                               |           | 2         |           |           | 2          |           | 3          | 2          | 1          | 10          |
| 3.5                                 |           |           |           |           | 5          |           | 1          |            | 2          | 8           |
| 4.5                                 | 3         |           |           |           | 28         |           | 8          | 3          | 32         | 74          |
| 5.625                               |           |           |           |           | 1          |           |            |            | 2          | 3           |
| 6.625                               | 7         | 2         | 6         | 3         | 78         | 5         | 18         | 18         | 98         | 235         |
| 7                                   |           |           |           |           | 2          |           |            |            |            | 2           |
| 8.625                               | 18        | 9         | 18        | 3         | 118        | 6         | 27         | 31         | 133        | 363         |
| 10.75                               | 8         | 3         | 21        | 9         | 80         | 17        | 11         | 7          | 58         | 214         |
| 12.75                               | 5         | 12        | 9         | 2         | 65         | 2         | 16         | 12         | 37         | 160         |
| 14                                  | 1         | 3         | 2         |           | 7          | 1         |            | 9          | 8          | 31          |
| 16                                  | 1         | 5         | 2         |           | 11         | 2         | 6          | 8          | 15         | 50          |
| 18                                  | 1         |           | 1         |           | 5          | 1         |            | 1          | 8          | 17          |
| 20                                  | 1         | 2         | 3         | 1         | 6          | 2         | 4          | 4          | 13         | 36          |
| 22                                  |           |           | 1         |           | 4          |           |            | 3          | 6          | 14          |
| 24                                  | 2         | 1         |           |           | 1          | 1         | 7          | 2          | 3          | 17          |
| 26                                  |           |           | 2         |           |            |           | 2          | 2          |            | 6           |
| 30                                  | 1         |           | 3         |           | 2          |           | 3          | 2          | 1          | 12          |
| 32                                  |           | 1         |           |           |            |           |            |            | 1          | 2           |
| 34                                  | 1         |           | 9         |           | 2          |           |            |            | 1          | 13          |
| 36                                  |           |           |           |           | 2          | 1         |            | 3          |            | 6           |
| 40                                  |           |           |           |           |            | 1         |            | 4          | 1          | 6           |
| Not Stated                          | 2         |           | 1         | 4         | 19         | 6         | 23         | 2          | 31         | 88          |
| <b>Total</b>                        | <b>51</b> | <b>40</b> | <b>78</b> | <b>22</b> | <b>438</b> | <b>45</b> | <b>130</b> | <b>113</b> | <b>451</b> | <b>1368</b> |

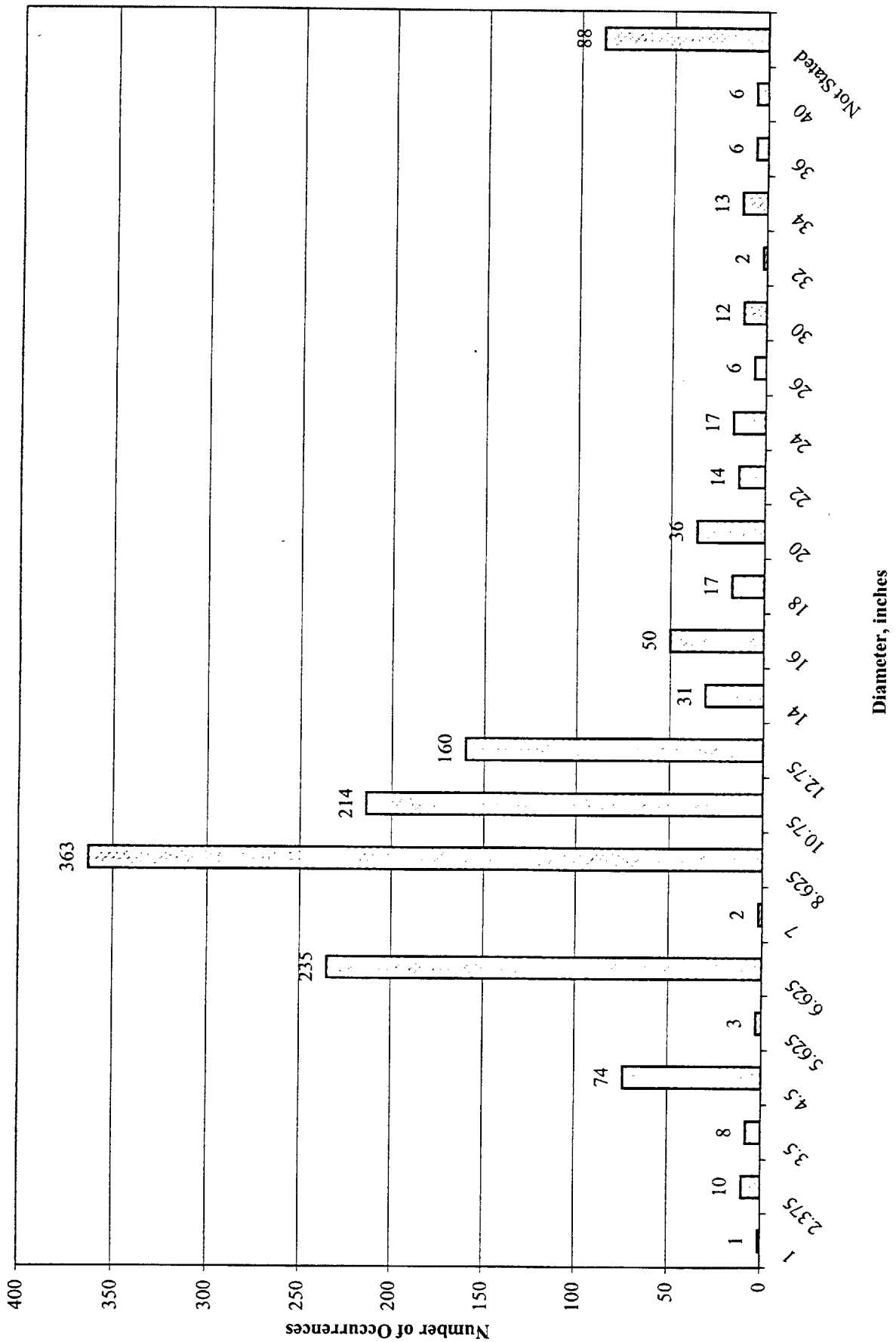


Figure 7. Pipe-Related Incidents by Diameter