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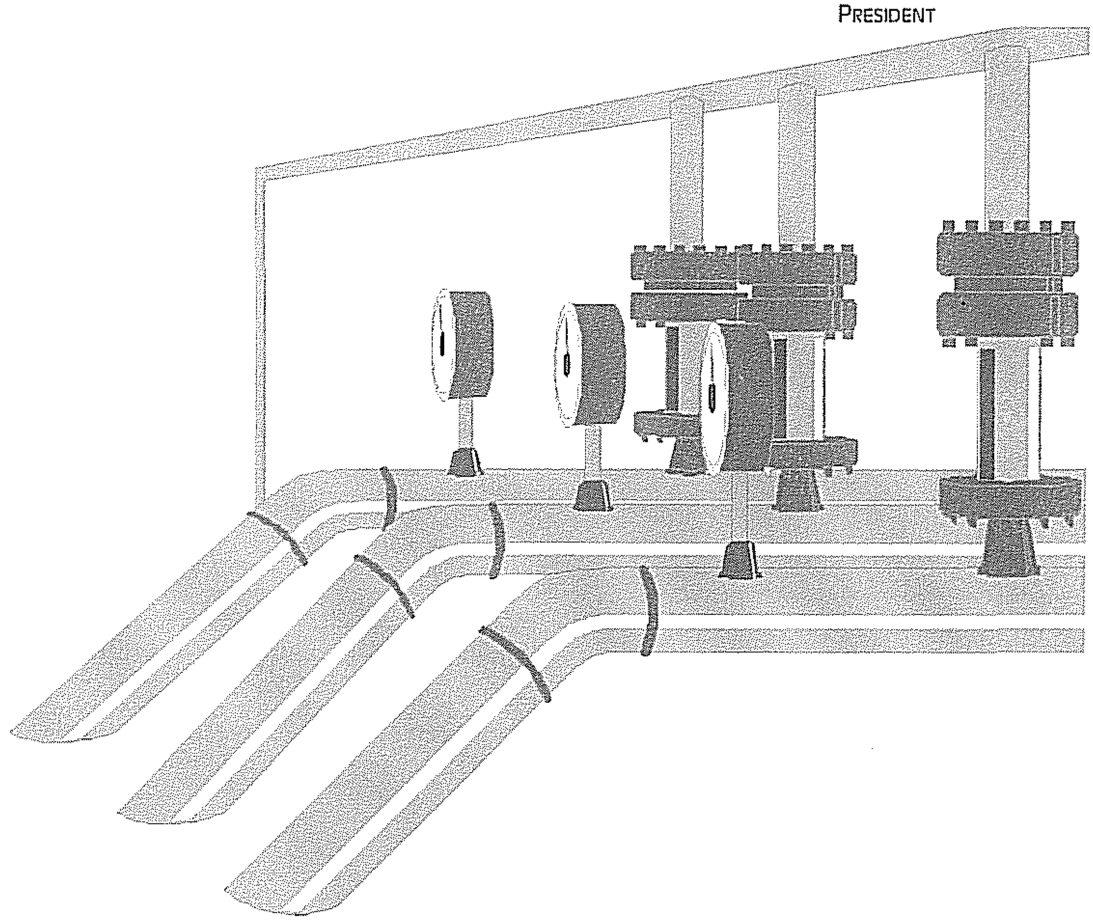

The U.S. Oil Pipeline Industry's Safety Performance

A report prepared for the
Association of Oil Pipe Lines
and the American Petroleum Institute's Pipeline Committee

February 2003

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Introduction and Summary

Background to Study

Update of two earlier studies

This report incorporates new data for 2001 to update the findings of a report of the same name published in March 2002, itself an update of a report published in May 1999. Like the two earlier versions, this report was co-sponsored by the Association of Oil Pipe Lines and the American Petroleum Institute's Pipeline Committee as part of their Environmental and Safety Initiative. First begun in 1998, the Initiative's overall goal is to facilitate improvement in the industry's safety record. The steps to achieve that goal include: developing a better understanding of the safety record, including how it has changed and why and what that implies for further improvement; ensuring that the reporting of incidents provides the information needed; and developing materials that the associations and their members can use as they answer inquiries from legislative bodies, regulatory agencies, the press and the public.

Focus is the pipeline industry's environmental and safety record

Primarily, the report reviews data available from the Department of Transportation's Office of Pipeline Safety on the pipeline industry's oil spills and reportable safety incidents. It also compares the record for pipelines to the record for competing modes of oil transportation. (Reports on other issues and pipeline operation in general are available on the Association of Oil Pipe Lines' website, http://www.aopl.org/, and at http://www.pipeline101.com/.)

It is important to note that the environmental and safety records of all modes of oil transportation, including pipelines, are excellent, resulting in oil transportation being a relatively small source of oil released to the environment. For instance, according to the Environmental Protection Agency, about *185 million gallons* of used motor oil are improperly disposed of each year – dumped on the ground, tossed in the trash (and hence to landfills) or poured down storm sewers and drains. That means that dumped motor oil puts 25 times more oil into the environment than spills from all modes of oil transportation combined.[1]

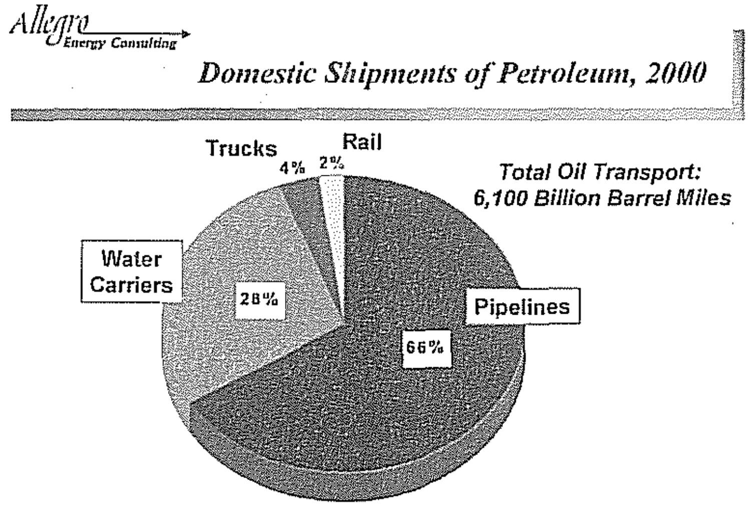
[1] Although this dumped oil is not the industry's responsibility, the size of the problem prompted the American Petroleum Institute to implement a public awareness and recycling campaign to combat this improper consumer disposal of motor oil.

The Role of Oil Pipelines

The oil pipeline system, born in World War II, is by far the most important mode of oil transportation

The development of large diameter pipe during World War II opened the door to the development of the nation's petroleum pipeline system during the post-War boom. By 2000, there were more than 150,000 miles of oil pipelines in the United States under Federal Energy Regulatory Commission rate jurisdiction (hence excluding intra-state and small gathering lines), moving about 14.5 billion barrels[2] of crude oil and refined petroleum products, more than <u>twice</u> the volume finally consumed.

Pipelines are by far the most important mode of petroleum transportation in the United States. In 2000, pipelines carried 66% of all of the oil transported in the United States, as measured in barrel-miles (one barrel transported one mile equals one barrel-mile), while marine transportation accounted for about 28%, trucks 4% and rail 2%.



Source: Estimated from Association of Oil Pipe Lines, *Shifts in Petroleum Transportation*, 2002

More broadly, oil pipelines in 1999 accounted for 17% of the ton-miles in inter-city freight transportation at only 2% of the total cost, according to Eno Transportation Foundation Inc.'s *"Transportation in America, 2000."*

Pipelines are the safest and generally the cheapest way to move oil

Pipeline systems are recognized as the safest and most economical way to distribute vast quantities of oil from production fields to refineries to consumers. For instance, the cost to transport refined petroleum from Houston to the New York Harbor area via pipeline is about $1.20/barrel or 3 cents/gallon -- only 3% of even the lowest national average monthly retail price for gasoline in the last five years.

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[2] There are 42 gallons in a barrel.

Oil pipelines are usually also the only realistic transportation option for moving significant volumes of petroleum by land over long distances. Replacing a relatively modest 150,000-barrel per day pipeline with a fleet of trucks, each holding 200 barrels or 8,400 gallons, would require some 750 trucks each day, or one arriving and unloading every 2 minutes. Replacing the same pipeline with a unit train of 2000-barrel tank cars would require a 75-car train to arrive and be unloaded every day. Pipelines do sometimes face competition from barges for shipments in intermediate distances along the coast or near major waterways. However, U.S. coastal shipments by ocean-going tank ships, the preferred alternative for most international long distance moves, are limited by the high costs imposed by the Jones Act (legislation that requires all shipments between U.S. ports to be in vessels that are U.S.-built, -operated and -crewed).

Summary of Key Findings

Over the long term, oil spills from the pipeline system have become fewer and smaller, especially from line pipe

The oil pipeline industry's spill record has improved substantially over the last 34 years, with both the annual number of spills or other safety incidents and the volume of oil spilled decreasing by about 60%, despite a 42% increase in the amount of oil transported. In the five years from 1968 (the year that data collection began) through 1972, the pipeline system experienced 377 incidents per year that were reportable to the Office of Pipeline Safety (OPS), resulting in an average annual volume of oil spilled of 366,000 barrels. The averages for the most recent five years, 1997-2001, have been reduced to 154 incidents and 144,000 barrels spilled per year.

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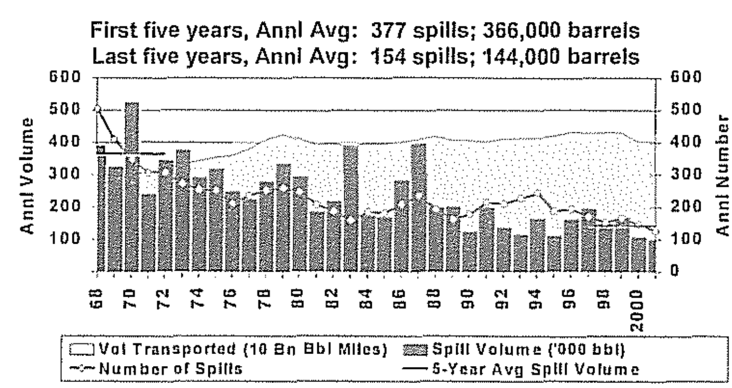
Oil Spill History: An Improving Record, 1968-2001



Source: RSPA 7000-1

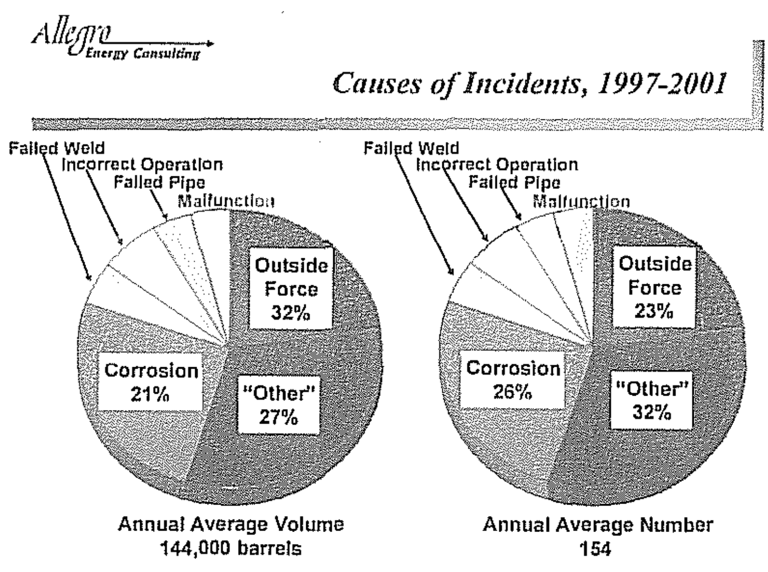
Furthermore, the volume spilled from line pipe has fallen more rapidly than that from other parts of the system such as tank farms and pump stations. (Spills from line pipe are more likely to be disruptive to the surrounding community, while tank farms and pump stations are generally on company property, with barriers to protect non-company property.)

Around half of all oil spills involve crude oil; line pipe spills are more important for the other commodities

Crude oil plays a greater role in oil spills than any other commodity. Based on the OPS data for 1997-2001, crude oil accounted for approximately half of the spill incidents and of the volume of oil spilled, with slightly over half of the latter released from line pipe. In contrast, refined petroleum products[3] accounted for just over one-fifth of the volume spilled, with almost two-thirds of that from line pipe, and liquefied petroleum gases and natural gas liquids accounted for another fifth, with over 90% of it from line pipe. (The latter pair of products is in a special category called "highly volatile liquids," which are generally gaseous at atmospheric temperature and pressure. They leave little, if any, liquid behind after a release.)

Outside Force Damage is the most important cause of spilled oil

The most important cause of spilled oil is Outside Force Damage. Based on 1997-2001, Outside Force Damage accounts for almost one-third of the overall volume of oil spilled. After that, the catchall category "Other" accounts for over one-quarter and the only other important named category, Corrosion, for 21%. Although the number of incidents has a slightly different distribution of causes, the same three categories dominate, again with a combined share of 80%.



[3] The main refined petroleum products transported by pipeline are gasoline, jet fuel, diesel, and home heating oil.

More detailed examination confirms the role of Third Party Damage

More detailed examination of the data provides more specific spill causes. The significant ones ranked: Damage by Third Parties, first; Corrosion, second; and Equipment-related Failures, third. A committee of the American Society of Mechanical Engineers (ASME) annually audits and re-categorizes the OPS data with an eye to future prevention. Its compilation confirms the importance of limiting both Corrosion and Third Party Damage, especially to line pipe: Third Party Damage – that caused by excavation, farming or other digging/boring activities – is responsible for 41% of volume spilled from 1996 through 2000. In addition, the audit reclassifies a number of spills into several ASME categories that, along with Malfunction of Control or Relief Equipment, can be broadly characterized as Equipment-related Failures. As a result, Equipment-related Failure becomes the third-ranked cause (18% of volumes) of all spills and the leading cause (45%) of those at tank farms and pump stations.

If spills do occur, initial clean-up efforts recover half the oil, and remediation pushes this toward 100%

The impact on the environment is significantly less than the spill volumes of this report might indicate, because a large proportion of the barrels included here are later recovered through operator clean up efforts. Spill data in this report show that, over the 1997-2001 period, pipelines recovered 53% of the oil spilled from their systems in total, and 67% of that spilled at tank farms and pump stations. (These calculations exclude spill volumes for so-called "highly volatile liquids" or HVLs because, on release, HVLs return almost entirely to a gaseous state, leaving minimal, if any, liquid for clean-up or recovery from soils or waters.) The Office of Pipeline Safety's data on recovery are limited to estimates of liquids recovered directly. They exclude remediation and other recovery techniques that may take longer to complete. However, today's environmental standards normally result in the removal or treatment of most, if not all, of the rest of the spilled petroleum, raising ultimate recovery rates toward 100%.

Trucks have a 70% worse spill record than pipelines, but all modes of oil transport have low loss rates

The initial losses from line pipe discussed above (i.e. not counting recovered volumes) amount to about 1 gallon per million barrel-miles. In household terms, this is less than 1 teaspoon per thousand barrel miles. The loss rate from barges and trains when they are transporting oil is similarly modest. However, the spill rate from trucks was more than 70% higher than from line pipe over 1997-2001, even when adjusted for different reporting thresholds in the data sources.

If the deciding factor is safety, pipelines are the best option for moving oil

Pipelines have a better safety record (deaths, injuries, fires/explosions) than other modes of oil transportation. This is especially true relative to trucks. Over 1997-2001, truck incidents resulted in over 100 times more deaths, over 30 times more injuries, and over 45 times more fires and/or explosions than pipeline incidents did, based on rates per ton-mile of oil moved.

The Pipeline Oil Spill Record

Data Sources

Office of Pipeline Safety Data

Pipelines must report safety or spill incidents to the Office of Pipeline Safety

The primary source for pipeline spill data is the Office of Pipeline Safety (OPS), part of the Department of Transportation's Research and Special Programs Administration. OPS requires pipeline systems to use RSPA Form 7000-1 to report spills and other incidents that occur in connection with pipeline operations. Most of the discussion on the pipeline industry's record uses data for incidents that occurred from 1997 to 2001. Over that period, the reporting criteria were:

1) Explosion or fire

2) Loss of 50 or more barrels of hazardous liquid or carbon dioxide

3) Escape to the atmosphere of more than five barrels a day of highly volatile liquids[4]

4) Death

5) Bodily harm, such as loss of consciousness or the necessity for medical treatment

6) Estimated property damage exceeding $50,000.

Full incident details are published on the Internet

The Office of Pipeline Safety publishes the spill data, incident-by-incident, on the Internet at http://ops.dot.gov/. The published data provide details on who, what, when, where, how or why, including:

- Operator's name, address, phone number
- Location, date and time of the incident
- Injuries, fatalities, damage, fires
- Volume lost
- Volume recovered
- Commodity
- Cause

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[4] Highly volatile liquids, or HVLs, are gaseous at atmospheric temperature and pressure. They are transported in a liquid state, under pressure. Liquefied petroleum gases -- propane, for instance -- and natural gas liquids are examples of HVLs.

- Location in the system: line pipe, pump station or tank farm; above/below ground
- Pipe characteristics: nominal diameter, thickness, year installed

The core of the information on pipeline spills presented here utilizes data available from the Department of Transportation as of July 2002.

OPS has lowered its spill reporting threshold by over 99%, to 5 gallons...

The OPS adopted a new Form 7000-1 at the beginning of 2002. The revised form has a much lower spill volume reporting threshold – 5 gallons rather than the previous 2,100 gallons (50 barrels) – and, for spills of 210 gallons (5 barrels) and larger, an expanded range of required detail on causes and consequences. In addition, the reporting criterion for bodily harm has been modified to "personal injury requiring hospitalization," aligning it with that for natural gas pipelines.

...coming into line with the industry's voluntary Pipeline Performance Tracking System

The new OPS Form 7000-1 parallels much of the structure and reporting detail established in the oil pipeline industry's voluntary reporting initiative, the Pipeline Performance Tracking System (PPTS). This voluntary effort, which began receiving data in 1999, is another facet of the industry's Environmental and Safety Initiative. The industry's stated goal in implementing the reporting regime was to "provide high quality, accurate data and analyses to the pipeline industry to improve safety performance, reduce operational errors and achieve 0 spills." The PPTS incident reporting form was designed to reflect risk factors to the extent possible, making it easier to assess the implications for operations and the impacts of incidents, as well as to prioritize risk mitigation strategies. By paralleling the PPTS form, the new OPS Form 7000-1 will provide additional insights for improving operations to prevent incidents.

Other Data Sources

OPS data are the most comprehensive available

Pipeline companies also report incidents to other agencies and jurisdictions. The National Response Center (NRC) must be notified by telephone of any spills into water (including a sheen), and these may be investigated by the Coast Guard and/or the Environmental Protection Agency. (The OPS also utilizes NRC reports as a notification system for its own oversight activities.) The NRC data, however, have a variety of shortcomings: their coverage of spills on land is incomplete; they often include multiple notifications of the same incident; and, by their nature, they include only the most preliminary volume estimates. Thus, neither the number of incidents nor the volume released is accurately represented. The Coast Guard does have highly accurate data, because it only completes its data records after careful investigation of any incident, but its database also does not cover spills that occur exclusively on land.

Additionally, pipeline companies are also frequently required by state statute or regulation to report spills to a state environmental agency. However, the reporting detail is not standardized, its collection is often by phone or onsite oversight, not in writing, and it is frequently not accessible in a database or table format. Thus, we have relied on the OPS data for this report.

Data Quality

Comparability over the Period

No material impact on OPS data from changes in reporting criteria

Most of the discussion of pipeline data in this report covers the period from 1997-2001, during which time the OPS made no changes at all to its reporting requirements. However, some of the data used extend back to 1968, and therefore encompass two OPS changes. Neither materially impacts the results.

In 1994, the OPS raised the reporting threshold for damage to $50,000 from $5,000, bringing the damage reporting criterion for liquid pipelines into line with that imposed on natural gas pipelines. It also matches the $50,000 damage threshold imposed by the Hazardous Materials (HazMat) Incident Reporting System for truck and rail incidents.

OPS' 1994 increase in property damage threshold to $50,000 excluded <1% of spill volumes

This change had some modest impact on the number of reported incidents, since the number of spills with a volume of 50 barrels or less went from 38% of the total in 1990-93, the four years immediately preceding the change, to 33% of the total in 1995-98, the four years following the change. However, much more importantly, the impact on total spill volume is negligible. Since all other reporting criteria remained the same, the only spill volumes excluded from the OPS database due to the increase in the damage threshold are those for incidents where the spill is less than 50 barrels and the damage falls between $5,000 and $50,000. As the volumes in incidents less than 50 barrels have never reached even 1% of the total volume spilled in any year either before or after the change, the volume excluded must be *de minimis.*

In 1985, OPS substantially re-designed its reporting form, in response to the Paperwork Reduction Act. However, because it made no changes to the reporting criteria, pre- and post-1985 data are consistent. Thus, as with the 1994 OPS change, concern about a lack of comparability between data from different years is unfounded.

Data Limitations

It takes constant vigilance to maintain a database like the Office of Pipeline Safety's. Even so, errors can occur. Some are unimportant and readily visible: a pipeline thickness entered with a misplaced decimal point. Others, such as the brief availability of a database file that included double-counted volumes, are very important but less visible. OPS has quickly corrected such errors discovered by its staff or outside users. OPS, however, does not edit company reports, even where data are clearly incorrect or missing. For some questionable entries, the agency communicates with the operator to request a resubmission of information. Operators are also required to resubmit a Form 7000-1 when additional information comes to light, including changes in volume lost, incident causes, and property damage payments.[5]

OPS uses seven categories of causes for classifying incidents

The OPS Form 7000-1 in use through 2001 used seven causes of incidents: Corrosion, Failed Pipe, Failed Weld, Incorrect Operation by Operator Personnel, Malfunction of Control or Relief Equipment, "Other," and Outside Force Damage. The OPS data can be frustrating for the analyst, because of both the breadth of the categories and inconsistencies in how reporting companies classify incidents. Outside Force Damage, for instance, included both damage from third party excavators and farm equipment, as well as incidents caused by weather extremes. The category "Other," as in any database, is a catchall. Some descriptions of incidents classified as Other: leaking gasket; stress induced seam failure; structural failure; loose flange; block valve leak, suggest that Other also contains incidents that should have been reported under another category.

The ASME audits the OPS data annually, reclassifying as necessary

It is well beyond the scope of this report to audit and re-classify OPS incident records. However, a committee of the American Society of Mechanical Engineers (ASME) re-examines and re-classifies the submissions on Form 7000-1 each year, driven by the need to glean as much information as possible about operating realities so as to assess whether amendments are needed to ASME standards. Later in this report, we examine the ASME Committee's results in more detail.

The OPS data do not allow calculations of relative rates of release

The biggest frustration for the analyst has been well outside the control of the OPS: a lack of data about the pipeline infrastructure that would allow the calculation of *rates* of releases. For example, the OPS incident data include the year the pipeline was installed. Without data on the vintage of all pipe, however, we cannot draw robust conclusions about the impact of age on the likelihood of a spill. Similarly, we

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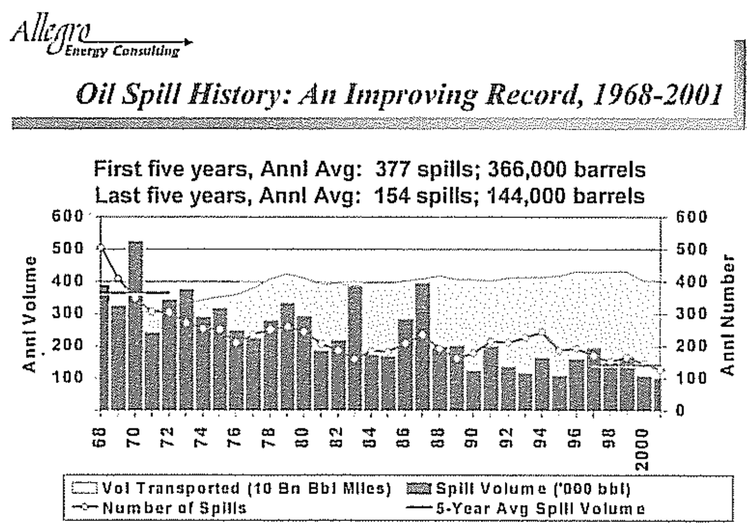
[5] In conjunction with the new expanded reporting form, OPS has instituted a new incident-by-incident review procedure to be carried out by OPS regional offices.

know the diameter of those pipelines that have had an environmental or safety event that required them to report to OPS, but we have no information about the remaining, incident-free, pipelines. Furthermore, we have not had information on miles of pipe or barrel-miles shipped for subsets of the pipeline infrastructure. Thus, for instance, we can conclude from OPS data that crude oil spills in greater volume than refined petroleum product, but since we do not know how much crude oil is shipped relative to refined products, we cannot determine whether it spills at a greater *rate*, i.e. more frequently *per barrel shipped.* These data shortcomings are among those addressed by the industry's PPTS, in this case in its survey of pipeline mileage and volumes transported.[6]

Historical Trends, 1968-2001

There has been a substantial, long-term improvement in the safety record of oil pipelines

The spill record of oil pipeline systems has improved substantially over the 34 years that OPS has been collecting data. In the five years from 1968 through 1972, the pipeline system on average experienced 377 reportable incidents per year, with an annual volume spilled of 366,000 barrels. In the most recent five years, 1997 through 2001, the average number of incidents per year and the average annual volume spilled were both approximately 60% lower, at 154 incidents and 144,000 barrels respectively.



Source: RSPA 7000-1

As the amount of oil transported by pipeline increased by 42% between these two periods, from just under 3,000 billion barrel-miles

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[6] OPS has also recently issued a Notice of Proposed Rulemaking that would collect annual information on mileage and other system characteristics.

per year to over 4,200 billion, the volume spilled per barrel-mile fell even more dramatically, by over 70%. (These are original spill volumes, unadjusted for recovered oil. As discussed later, half the oil spilled in incidents during 1997-2001 was immediately recovered, according to OPS data.)

Further improvement seems increasingly likely

A projection of yet further improvement in the oil pipelines' safety record seems increasingly likely. In 2001, for the second year in a row, both the number of incidents and the annual volume of oil spilled set record lows. At 129 incidents and 97,000 barrels spilled, these 2001 statistics were 16% and 32% respectively below even their most recent 5-year averages. In addition, the volume of oil spilled in 1997 was the highest since 1991 and 50% more than the annual average for the four succeeding years. Therefore, when adjusted for the changes in reporting criteria, the next 5-year average (1998-2002) will almost certainly show a further decline for volume spilled. (Without adjusting to make the data consistent before and after the 2002 changes in reporting thresholds, the new reporting threshold will have a sharp impact on the number of reported incidents, but only a small impact on the volume. The industry's voluntary system, PPTS, has already demonstrated this point – that the old OPS reports were already capturing 95% of the volume.)

Spill volume peaks are due to a few large spills, not a surge in total spills.

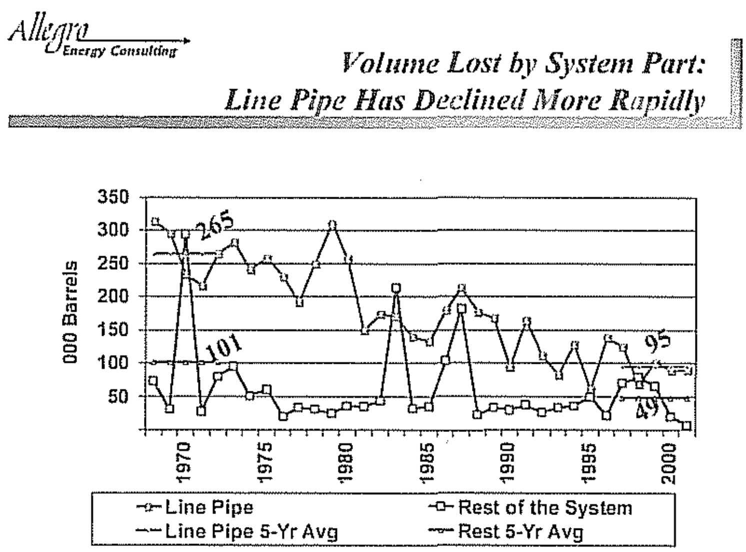
In each of the three years that stand out as spill volume peaks, one or two extremely large spills pushed volumes higher. The largest spill in the database, for instance, occurred in 1970 at a pipeline company's tank farm, where it damaged no property beyond company property. That one spill of 223,000 barrels accounted for more than 40% of the industry total that year. There was also one spill of over 120,000 barrels in 1987, accounting for about 30% of the annual total, and two totaling over 190,000 barrel in 1983, accounting for almost 50% of the year's volume. There have been no such extremely large spills recently. In the last five years, the size of the single largest spill has been only 27% of 1987's largest spill and just 15% of the 1970 record.

Both the largest spills and spills in general are getting smaller.

The largest spill in 2001 was 28,000 barrels – just 12% of the 1970 record, yet it accounted for 28% of the year's total spill volume. (This spill involved HVLs, which are generally gaseous at atmospheric temperature and pressure and so leave little, if any, liquid behind after a release.) This spill was one of the ten largest in the database. The fact that the overall spill volume was at a record low in the year that such a large spill occurred is another clear indication of the industry's overall improving record. Improvement is also evident in examining the median spill size (half of the spills are smaller, and half are larger than the median size). The industry is not just reducing the number of spills and avoiding or reducing the size of the infrequent large spills, but its spills are in general getting smaller. By 2001, the median spill size was only 75 barrels, one-fifth of the peak and the second lowest level ever. The decline is underscored by the changes in the 5-year median spill volume for incidents in the OPS database. This was 300 barrels or higher from 1968-73 to 1981-86 but then dropped sharply, and has remained under 150 barrels since 1989-93.

Spills at tank farms and pump stations are less disruptive than spills from line pipe

The OPS data provide a breakdown of the location in the system where an incident occurs: line pipe, pump station or tank farm. This breakdown is useful, because spills at tank farms and pump stations are less likely to cause disruption to the surrounding community or property damage to non-company property. The area around tanks is required to be surrounded by a dike or berm that can contain the entire volume of the tank; pump stations are often similarly bermed or designed to minimize off-site impact. The breakdown also confirms important differences in the cause of damage by location type. Third Party Damage – damage from excavating or farm equipment on the right-of-way – is a much more common cause of releases from line pipe, as will be discussed in more detail below.



Spills from line pipe have fallen much faster than other spills

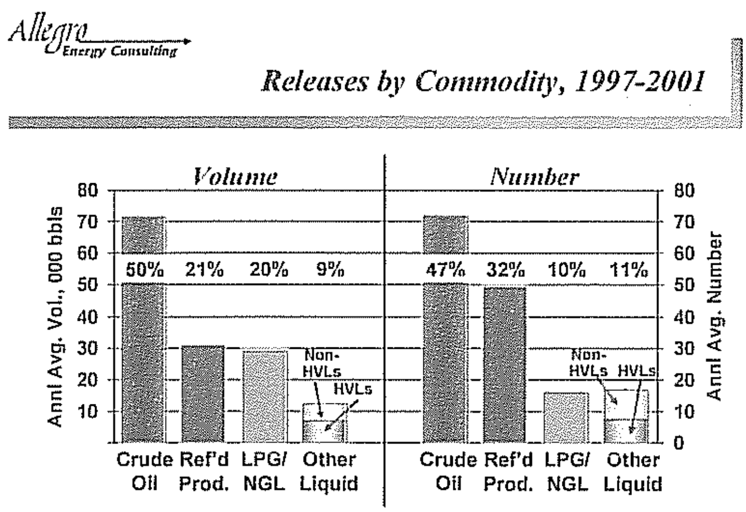
All parts of the pipeline system have contributed to the 60% decline in the annual volume of oil spilled over the last 34 years, as the graph shows. However, the spill volume coming from line pipe – that portion of the system where incidents are most likely to cause disruptions for the surrounding community – has fallen faster than the volume from the rest of the system. Spills from line pipe accounted for less than twice the volume spilled from the rest of the system over 1997-2001, compared to more than 2½ times in the late 1960's. (The very large spill in 1970, which occurred at a tank farm, inflates the average volume lost from non-pipe parts of the system in the early period.)

Recent Patterns, 1997-2001

By Commodity

Crude oil accounts for half the oil spilled by pipelines

The pipelines reporting to the Office of Pipeline Safety transport a wide variety of liquids, including crude oil, refined petroleum products, liquefied petroleum gases and natural gas liquids, as well as specialty products such as anhydrous ammonia. As shown in the chart, crude oil accounts for the largest share of the released volume by far (50% of the volume spilled between 1997 and 2001), followed by refined petroleum products (21%), the HVLs liquefied petroleum gases and natural gas liquids (20%) and miscellaneous commodities classified together here as "Other Liquid" (9%). However, no definitive conclusions can be drawn about why crude accounts for the majority of oil spilled because, as discussed above, there is a lack of DOT data on aspects of the pipeline network, such as miles of pipe by commodity transported.



Note: HVLs ("Highly Volatile Liquids") largely return to a gaseous state when released to atmospheric temperature and pressure. LPGs and NGLs are also HVLs.

Recovery and remediation needs are minimal for spills of Highly Volatile Liquids (HVLs)

It is helpful to differentiate between conventional liquids and so-called "highly volatile liquids" or HVLs, which include LPG and NGL, as well as a few commodities such as anhydrous ammonia classified as Other Liquid. HVLs, by definition, act differently when released to the environment. These compounds are gases at atmospheric temperature and pressure. They are only liquids when kept under pressure, as they are while being transported or stored, so HVLs largely return to a gaseous state when released.[7] Thus, HVLs – 25%

[7] Some HVLs contain a proportion of liquids, such as the condensate component of natural gas liquids, that pool on the ground in the event of a leak.

of the volume reported in the OPS database – leave little if any affected soils or water to be cleaned up or product to be recovered.

By Cause

Outside Force Damage, Corrosion and "Other" are the leading causes of oil spills, either by number or volume

Outside Force Damage accounts for the largest share – 32% – of the volume of oil and related products released from liquids pipelines between 1997-2001. Outside Force Damage includes third party damage such as that caused by excavation or farm equipment. It can also include such causes as weather-related damage and rock penetration resulting in a gouge in the pipe. (See Appendix for a breakout of the causes ASME found in the Outside Force Damage category. Approximately 82% were specifically third party damage and 7% were weather-related.) The second-ranked cause is the catchall category of Other, with 27% of the 1997-2001 volume released, followed by Corrosion, with 21%. (Again, see Appendix for a breakout of the causes that ASME found in the category Other.) Incorrect Operation by Operator Personnel accounts for only 5% of the volume.

Reportable Incidents For Liquids Pipelines, by Cause, 1997-2001

Cause	Avg. Ann'l Spill Vol. (Barrels)	Share of Vol. (%)	Avg. Ann'l Number	Share of Number (%)
Outside Force Damage	46,123	32	34.8	23
Other	39,282	27	49.2	32
Corrosion	30,642	21	39.4	26
Failed Weld	9,534	7	7.4	5
Incorrect Op. By Operator Personnel	7,528	5	10.2	7
Malfunction Of Control/Relief Equip.	4,144	3	6.4	4
Failed Pipe	6,397	4	6.2	4
Total	143,650	100	153.6	100

Note: Reflects data from DOT's Office of Pipeline Safety as of July 2002

The cause distribution for the *number* of incidents differs from that for volume lost, but the three leading causes remain Outside Force Damage (23%), Other (32%) and Corrosion (26%). Incorrect Operation by Operator Personnel remains a minor cause, accounting for just 7% of the incidents.

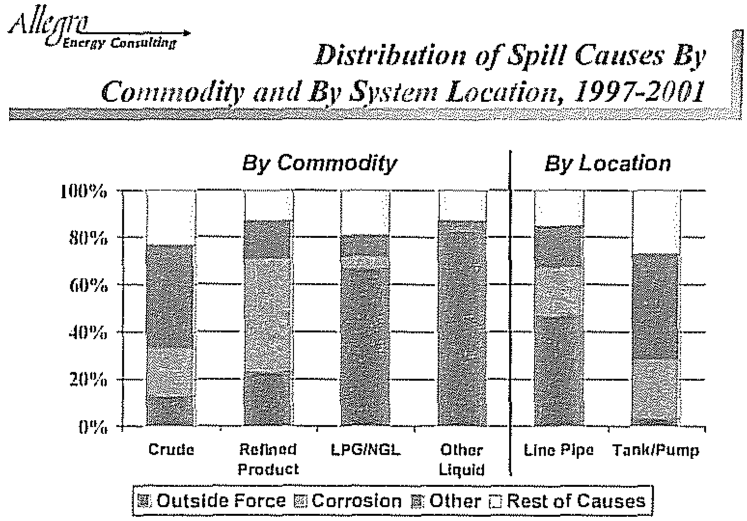
Spill sizes differ by cause, with Outside Force Damage incidents routinely larger than others

The cause distributions for incident numbers and released volume differ because spill sizes differ by cause. The average volume lost in a spill caused by Outside Force Damage (1,325 barrels) is two-thirds greater than the average volume lost in an incident caused by either Corrosion (778 barrels) or Other (798 barrels). Furthermore, Outside Force Damage incidents are routinely larger, not just driven by a few large incidents. The median spill size for Outside Force Damage incidents is 311 barrels (i.e., half the spills are smaller than 311 barrels), compared to 100 barrels for Corrosion incidents, 90 barrels for Other incidents and 126 barrels for all incidents.

Some of the minor causes of incidents also tend to be linked to large spills. For example, Malfunction Of Control/Relief Equipment incidents have the second highest median spill, at 225 barrels. Failed Weld incidents, in contrast, have the lowest median size, at 73 barrels, but some of the spills are large, pushing the average spill size of Failed Weld incidents to 1,288 barrels, just below Third Party Damage.

By Cause, Commodity and System Location

As noted above, the Office of Pipeline Safety data include the location in the system where an incident occurs: line pipe or pump station/tank farm, and the commodity involved. This breakdown shows significant differences in the patterns of incident causes, both for different commodities and for different system locations.



Note: "Pipe" is Line Pipe, "Tank/Pump" is Tank Farms, Pump Stations and "No Data"
*"Rest of Causes:" Failed Weld, Operator Error, Equipment Malfunction, Failed Pipe

Outside Force Damage is particularly important for LPG and Other Liquids spills...

Outside Force Damage, the leading cause of spill volumes, accounts for a greater share of products spills and a much greater share of LPG and other liquids spills than of crude oil spills. Many products and LPG pipelines serve distribution centers located in densely populated consuming regions. While they were typically constructed during the 1950s and 1960s through areas that were sparsely populated at the time, urban sprawl and a burgeoning suburbia have since brought commercial and residential development closer and closer to the once-rural rights-of-way.

... and for line pipe spills

Outside Force Damage is also far more important for line pipe than for the rest of the pipeline system (pump station and tank farm). As noted earlier, almost two-thirds of the spill volumes come from line pipe. Of these, close to half are attributable to Outside Force Damage.

The incident pattern for "Other" is the reverse

The second leading cause of spills volumes, "Other," has the opposite pattern. It is much more important for pump stations and tank farms than for line pipe, and for crude oil pipelines than for products, LPG or other liquids pipelines. As noted earlier, almost half of all spill volumes are crude oil. Of these, 44% are attributed to the OPS category Other. The ASME reclassified over 40% of these incidents as failures that can be characterized as equipment-related (see Appendix). Given these reclassifications, the relative importance of Other as a cause of pump station and tank farm spills probably reflects the greater amount (and miscellany) of equipment at those locations relative to along the line pipe itself.

Corrosion accounts for almost half of all products spills, due to three large incidents

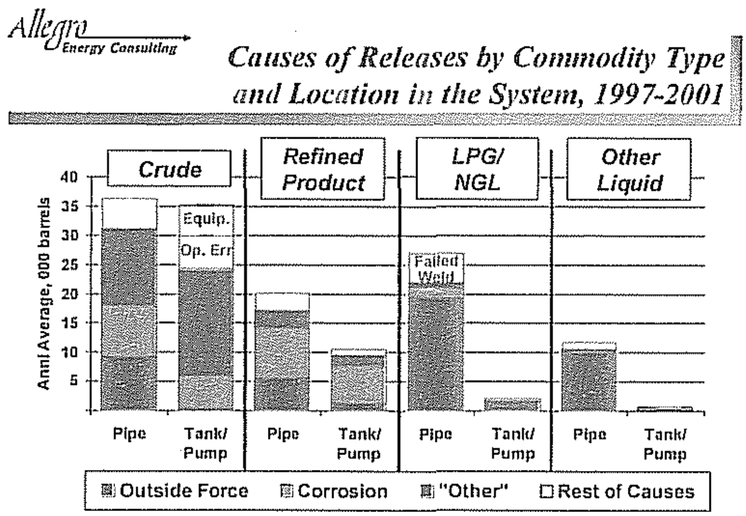
Unlike the two top causes, the third leading cause of spill volumes, Corrosion, accounts for approximately the same share of losses in both line pipe and the rest of the pipeline system. It initially appears, however, to have a strong commodity bias, accounting for almost half of all refined products spill volumes but only one-fifth of crude oil volumes and less than 5% of both LPG and Other Liquids volumes. Yet, when it comes to the number of incidents (as opposed to volume), Corrosion is only the third-ranked cause for refined product lines. This reversal is due to three large incidents that account for 75% of the total products spill volume over the period, and raise the average size of corrosion-related spills on refined product line pipe to double that on crude oil line pipe.

So the industry focus is on limiting both Outside Force Damage and Corrosion

Thus, it is clear that the industry's focus on preventing Outside Force Damage, and also on corrosion generally are both well-grounded in the OPS data. As is discussed in more detail later, there are many other parties working together with the pipeline industry to reduce the threat from Outside Force Damage. In addition, the industry continues to take the lead on cutting-edge solutions for reducing the threat from Corrosion, which not only causes many small incidents, but can cause large spills as well.

Relative importance of spill causes and location vary sharply between commodities

The data breakout can be taken a step further; the following chart separates releases on line pipe from releases on other parts of the system by commodity, and shows causes for each. For *crude oil*, a similar amount is released from both line pipe and from other parts of the pipeline system; the leading cause for both parts of the system is "Other," which is the designated cause of over 50% in the case of non-pipe. The patterns of line pipe versus other parts of the system get progressively more lop-sided for the other commodities: for *refined products*, line pipe accounts for almost two-thirds of the released volume, Corrosion is the leading cause of releases from both parts of the system, and its share is 60% in the case of non-pipe; for *LPG and natural gas liquids*, line pipe accounts for well over 90% of the total volume released, with Outside Force Damage responsible for over 70% of that; and for *Other Liquids*, line pipe accounts for 95% of the volume released, with Outside Force Damage responsible for nearly 90% of that.



Note: "Pipe" is Line Pipe, "Tank/Pump" is Tank Farms, Pump Stations and "No Data"
*"Rest of Causes:" Failed Weld, Operator Error, Equipment Malfunction, Failed Pipe

The 4 minor causes are particularly important for crude oil spills at tank farms or pump stations

This more detailed breakout also highlights that non-pipe crude oil losses include a relatively high share of losses due to the minor causes grouped together as "Rest of Causes": Failed Weld, Operator Error, Equipment Malfunction, Failed Pipe. The role of these minor causes shows a very different pattern by system location, accounting for 15% of line pipe volumes but almost double that, at 27%, of pump stations and tank farm volumes. One-third of the crude oil volumes released at tank farms and pump stations – as opposed to less than 20% of total crude oil volumes – come from these minor causes, and especially from Incorrect Operation by Operator Personnel and Malfunction of Relief or Control Equipment. Failed Weld and Failed Pipe are, understandably, both small factors in these non-pipe crude oil losses. However, Failed Weld accounted for 19% of LPG volumes released from line pipe.

By the American Society of Mechanical Engineers' Causes

As noted previously, a committee of the American Society of Mechanical Engineers (ASME) annually examines individual accident records to explore their implications for operational procedures and ASME pipeline standards. This B31.4 Committee[8] reclassifies the causes of incidents based on the incident narratives.

ASME reclassifies the 7 OPS incident causes into 20 categories, which we've regrouped into 11

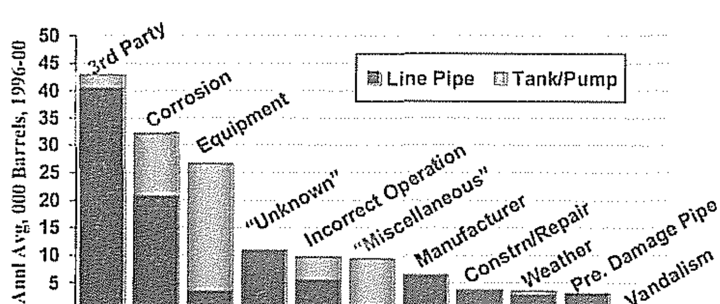
While the Office of Pipeline Safety uses seven incident causes in its published data, the ASME committee uses 20. For instance, the ASME uses three classifications related to weather: cold weather, heavy rains or flooding, and lightning, while the OPS does not use a separate weather category at all. The ASME committee also differentiates between failures due to a manufacturing defect, such as a defective pipe seam, those due to construction damage (such as a defective girth [circumference] weld), and those due to failed repairs. Each of the more narrowly defined causes, of course, carries different implications for preventive measures. For the purpose of this analysis, we have grouped the ASME's 20 classifications into 11 broader categories, as shown in the Appendix.

ASME data confirm greatest benefit is from preventing Third Party Damage to line pipe

The committee's findings for the 1996-2000 period (the latest year completed as of mid-2002) resoundingly confirm that the largest cause of pipeline losses is Third Party Damage (29% of the total volume).

Allegro Energy Consulting

ASME Causes: Volumes Spilled, 1996-2000



Line Pipe:	41%	21%	4%	11%	6%	1%	6%	4%	3%	3%	0%	100%
Tank/Pump:	5%	22%	45%	0%	8%	17%	0%	1%	1%	-	-	100%

Based on re-examination of OPS data by B31.4 Committee of the American Society of Mechanical Engineers. "Tank/Pump": tank farms, pumping stations, all other system parts

This is especially true for line pipe, where Third Party Damage (41% of the losses) accounts for more than the sum of shares attributable to Corrosion (21%), "Unknown" (11%) and Manufacturer (6%), the second-, third- and fourth-ranked line pipe causes respectively. It is probably also responsible for most of the 3% of losses attributed to Previously Damaged Pipe, as unreported dings and coating scratches from excavation and farm equipment are vulnerable to corrosion over time.

In switching from line pipe volume losses to numbers of line pipe incidents, Third Party Damage drops from being the top-ranked cause, accountable for the same share (41%) of losses as the next three causes combined, to being tied for first place with Corrosion, and accountable for just 32% of the incidents. This underscores the implication from the OPS data noted earlier, namely, that Third Party Damage tends to result in above-average spill volumes. It further suggests that preventing Third Party Damage would have a disproportionately beneficial effect on oil spill volumes that impact surrounding communities.

For non-line pipe, ASME data show the leading cause of spills is Equipment-related Failures . . .

Most incident cause categories show a marked disparity between their roles in line pipe and in tank farm/pump station incidents. Just as Third Party Damage disproportionately affects line pipe, so Equipment-related Failures (which includes the ASME categories ruptured or leaking gasket, O-ring, seal or pump packing and "threads stripped, broken nipple, or coupling failed" as well as malfunction of control or relief equipment) disproportionately affects tank farms and pump stations. It is responsible for just 4% of the line pipe volumes but for a highly significant 45% of the pump station/tank farm volumes, more than double the share for Corrosion, the second-ranked cause of non-line pipe spills (and also of line pipe spills). As a result, Equipment-related Failures is the third-ranked cause of spill volumes overall.

. . . due to significant reclassification of OPS "Other" by ASME

The ASME reclassified over 40% of the spill volumes that were shown as "Other" in the OPS reports to Equipment-related Failures, including the largest spill from 1996-2000. These incidents reclassified from "Other" finally contribute over 60% of the total spill volume for ASME's Equipment-related Failures, while the narrower OPS category Malfunction of Control/Relief Equipment contributes less than 20%, and another 15% comes from the OPS category Incorrect Operation by Operator Personnel.

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[8] "B31.4" refers to the section of the ASME standard that applies to liquids pipelines.

Non-line pipe Equipment-related Failures are typically associated with high spill recovery rates

When equipment at a pump station or tank farm does fail, the initial spill can be large, but incidents generally have high recovery rates, because of their location -- on company property, usually largely within a bermed area. For example, just two incidents account for more than 45% of the spill volume in this category, yet the overall recovery rate, including these two incidents, was 87%. (This calculation excludes releases of highly volatile liquids which turn to a gaseous state when released, leaving behind little, if any, spilled liquid to recover.)

Incorrect Operation by Carrier Personnel is a minor cause of incidents

Incorrect Operation By Carrier Personnel remains a minor cause of spills despite some significant reclassifications by the ASME committee (see Appendix). It reclassified the fourth largest spill of 1996-2000 from Incorrect Operation to Equipment-related Failures and the third largest spill from Corrosion to Incorrect Operation. The net result is that, of the volume that ASME finally classified as Incorrect Operation, only 41% was classified in that category in the OPS database, while 47% was re-classified by ASME from the OPS category Corrosion. After these re-classifications, Incorrect Operation By Carrier Personnel still accounted for only 6% of the volume lost from line pipe and 8% of the volume lost from the rest of the system over 1996-2000.

The ASME reclassification greatly reduces the proportion of spills in the catch-all categories

One significant benefit of the B31.4 committee's work is that it greatly reduces the proportion of incidents and spill volumes in catch-all categories. As noted earlier, among the OPS causes, "Other" is responsible for the largest share of incidents (32%) and the second-largest share of spill volumes (27%). The corresponding combined shares for ASME's Miscellaneous and Unknown are only 11% (number) and 13% (volume), as over 50% of "Other" spills in the OPS database have been reclassified as either Equipment-related or Third Party (see Appendix). This greater specificity makes it easier to develop spill prevention measures.

Prevention and Recovery

Third Party Damage and One-Call Programs

Pipelines focus on prevention of underground damage, and the spill data justify that.

The data above confirm the critical role of Third Party Damage in releases from oil pipelines, a role that has been apparent to the industry everyday. Third Party Damage is a large and largely preventable cause of liquids pipeline releases. Moreover, when Third Party damage is the cause, the release is often via a rupture of the line, making it likely that the release will involve larger volumes. For all these reasons, a strong focus by pipelines on underground damage prevention is justified as a way to achieve a significant impact on safety and environmental protection.

Pipeline companies operate diverse outreach and public awareness campaigns

Pipeline companies have undertaken diverse programs to limit outside force damage to their facilities, including outreach to excavators and public awareness "good neighbor" campaigns aimed at residents, businesses and communities along pipeline rights-of-way. OPS has worked with pipeline companies, states, excavators, operators of other underground facilities and interested members of the public to develop and pilot test a comprehensive public education program designed to make key individuals aware of the risks associated with damage to underground facilities.

State "one-call" notification programs are critical to all underground facility operators

Outside force damage is also a major cause of accidents at underground facilities other than oil pipelines, including those carrying natural gas, electricity, water, sewerage and telephone, cable, or Internet service. Operators of all these types of facilities share an interest with pipeline companies in minimizing such damage. Hence, the oil pipeline industry and the OPS frequently join with these other groups to work to strengthen state "one-call notification" programs.

Under a "one-call" program, an excavator (or homeowner) telephones the state one-call notification center to give notice of intent to dig in a specific area. The center then acts as a clearinghouse, informing any potentially-affected underground facility operator: liquids and natural gas pipelines, utility and telecommunications cables, and water and sewer lines. The facility operator then provides specific location information to the excavator and marks its underground facility in the area of the proposed digging. One-call programs are state-organized and run, and are generally governed by state law. One-call centers are typically funded by the state's underground facilities, usually on a per call basis.

The passage of TEA 21 (1998) has helped strengthen the effectiveness of state "one-call" programs

The industry has made it a priority to strengthen the effectiveness of state one-call notification programs. In 1998, a coalition of underground facility operators, states and one-call center organizations successfully supported enactment of the Transportation Equity Act for the 21st Century (TEA 21), federal legislation that encourages states to require/ foster one-call participation by all underground facilities and excavators and to focus on improving enforcement of one-call laws.

Industry coalition identifies and promotes damage prevention "best practices"

TEA 21 also directed the Secretary of Transportation to bring together representatives of underground facility operators, excavators, one-call centers, state and local governments, and other interested persons to conduct a study and publish a report on one-call notification and underground damage prevention "best practices." The resultant "*Common Ground Study Report*"[9], published in June 1999, examined a broad range of practices affecting underground damage prevention, including planning procedures for construction in areas where underground facilities operate, underground facility locating techniques, excavation practices, compliance and enforcement, one-call center practices, marking for rights-of-way and crossings, and public education and awareness, to arrive at its "best practices" list.

The main vehicle for this now is the Common Ground Alliance

Since the report was published, the cooperative effort to share information on best practices across affected and interested industries, regulators and other groups has continued, most notably through the Common Ground Alliance[10]. The purpose of this nonprofit organization, a follow-up to the Common Ground study, is to ensure public safety, environmental protection, and the integrity of services by promoting effective damage prevention practices. The Alliance's activities include the promotion of R&D efforts to develop new damage prevention technologies, the identification and dissemination of best practices, and acting as a clearinghouse for the collection, analysis and dissemination of damage prevention data.

One-call to be further improved through nationwide toll-free number

With the passage of the "Pipeline Safety Improvement Act of 2002," Congress recognized the continuing need to focus on preventing third-party damage to all types of underground facilities, including pipelines. Within one year of the enactment of the Act, that is, December 2003, the U.S. Department of Transportation and the Federal Communications Commission must provide for the establishment of a 3-digit nationwide toll-free telephone number (equivalent to 911 for emergencies or 411 for information) to be used by one-call notification systems. This toll-free number will simplify the notification process for those conducting excavations that may affect underground utilities.

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[9] Available at http://ops.dot.gov/document/OCSS062199A.pdf

[10] http://www.commongroundalliance.com/

Other Industry and OPS Initiatives to Prevent Spills

The PPTS is one of the pipeline industry's top initiatives for improving safety

The Environmental and Safety Initiative, the sponsor of this report, is another industry-wide program aimed directly at improving safety performance. It is a multi-faceted approach, encompassing regulatory issues, rights-of-way protection, data enhancement and interpretation, among other things. The Pipeline Performance Tracking System (PPTS) mentioned previously is a product of the Environmental and Safety Initiative, and one of its most important tools. The detailed examination of incident causes and circumstances provides companies with insights to use in their own prevention and assessment programs, and with new metrics for measuring their success.

Other industry-wide initiatives focus on improving risk assessment and response times

An example of another industry-wide initiative is the development and adoption of API Standard 1160, "Managing System Integrity in Hazardous Liquid Pipelines." This new standard prescribes a menu of options for assessing risk and developing mitigation strategies. A key feature is the requirement to integrate information from a variety of sources across the spectrum of technological complexity, including that developed from different kinds of inspections. Another new feature is the aggressive time frame for addressing identified anomalies. The Office of Pipeline Safety's rule requiring integrity management programs for pipelines in High Consequence Areas[11] has analogous provisions to the stringent new standard adopted by the industry.

To implement both the OPS rule on Integrity Management in High Consequence Areas and the industry's API Standard 1160, the National Association of Corrosion Engineers (NACE, at www.nace.org) is developing a number of new, more stringent standards. The standards will separately address "in-line inspection," "direct assessment" for external corrosion[12], "direct assessment" for internal corrosion, as well as standards addressing other forms of corrosion. Some of these new NACE standards were completed in 2002, and others are to be completed in 2003.

Individual safety initiatives abound too...

In addition to these industry-wide programs, individual pipeline companies have already undertaken a variety of initiatives to prevent oil spills and mitigate their impact if they do occur. While strategies differ, they range from detailed risk assessments of their systems, with corrective action where necessary, to aggressive investigation of even

[11] 49 CFR Part 195.452

[12] "Direct assessment" is used where in-line inspection is not possible because of the physical characteristics of the pipeline; this applies to a very low share of liquids lines.

near-misses, to investment in new technology for leak detection. The following paragraphs touch on a few examples of programs pipeline companies have undertaken.

... Some are directed at the prevention of risks to the line pipe

Some companies have institutionalized the corporate no-spill ethic by translating incident-free performance to employee (and sometimes, contractor) compensation. Some have bought land along an existing right-of-way to create an additional buffer. Some have even lowered sections of line pipe in order to provide deeper cover or, in the extreme, re-located a line to escape encroaching urban sprawl and its attendant risks of excavation damage.

As noted above, adverse weather and other natural hazards can lead to potentially disastrous spills. Pipeline companies have handled such risks in different ways. Alyeska's Trans-Alaska Pipeline System (TAPS) combats earthquake-generated movements with a zig-zag configuration and Teflon-coated shoe mounts that allow aboveground sections to move across their supporting trestles. This design, together with an advanced earthquake monitoring system (EMS), meant TAPS suffered no leaks in November 2002 when it was hit by one of the largest quakes (7.9 on the Richter scale) ever recorded on U.S. soil. Chevron Pipeline, as part of its participation in an OPS Risk Management Demonstration Project, conducted an assessment of geologic hazards on one of its lines, to identify potential risks from landslides and subsidence. Some companies step-up their aerial patrols of pipeline routes during the spring, checking for any exposure of normally-buried lines because the rains then can cause a problem with soil stability. One even called in geologists to identify the best corrective measures.

...Others use technology to minimize the risk of pipeline failure

The industry and its suppliers are also constantly advancing the application and testing of new technologies, construction methods and inspection tools to try to eliminate the risk of a pipeline failure. Each of the growing number of "in-line inspection" tools is designed to perform a different type of inspection, but all have the same aim: to identify potential problem areas before they weaken the pipe.

Increasingly sophisticated in-line inspection tools are smarter

The first of these inspection tools was the "smart pig" (see box), which has proven to be an important and effective weapon in the fight against failures caused by corrosion, the second largest named cause of pipeline system losses (after Outside Force Damage). The first smart pigs were "low-resolution," returning relatively few data points about an anomaly in the pipe wall. The newer "high-resolution" tools provide a sharper image by returning significantly more data points and thus, delineating external corrosion anomalies more finely. Yet another of the many special purpose in-line inspection tools that have been developed is the recently enhanced "crack tool," which detects

> ### *What is a Smart Pig?*
>
> Pigs started as a routine tool of liquid pipeline operation and maintenance. Cylindrical in shape and with the same internal diameter as the pipeline, pigs are used as a mechanical plug when the pipeline is filled, traveling at the front of the wall of liquid. Pigs are also used for routine cleaning.
>
> Smart pigs, first developed in the 1960's, record information about the condition of the pipe. Smart pigs are a series of instrumented modules with an articulated connection allowing them to move around bends in the line. All bends in newly constructed pipe must allow the passage of a pig.
>
> As the instrumented pig travels with the transported product through the pipeline, a magnetic field is induced in the pipeline wall. Corrosion pitting and other imperfections (internal or external) cause disturbances in the magnetic field that are then recorded by the pig.
>
> As computer and satellite technology has advanced, so has the amount of information available from an instrumented pig. GPS positioning, for instance, can now help pinpoint the location of a pipeline wall anomaly, indicating where increased cathodic protection or repair may be warranted.

anomalies in a pipe's longitudinal seam and microscopic flaws that may develop due to stress corrosion cracking.

Cathodic protection and advanced coatings enhance pipeline protection

Other tools have also been important in controlling corrosion. Cathodic protection[13] is required on all DOT pipelines, and has been for decades. New tools allow the pipeline's cathodic protection to be better-calibrated, and hence more effective. Improved coatings materials are also important contributors to managing the risk of a corrosion-related failure on the pipeline. As failures from corrosion can also result from earlier, unreported, outside force damage to the pipe, intensive efforts to reduce third party damage will also reduce the risk of these later, corrosion-related failures.

Other industry initiatives address Corrosion and Equipment-related Failures at tank farms and pumping stations

Tank farms and pump stations are an integral part of many pipeline systems. While third party damage such as that from excavators is only a limited threat to these facilities, there are other concerns. For instance, corrosion accounts for 25% of non-line pipe losses. The industry, therefore, developed aggressive inspection norms to reduce tank bottom corrosion, which the OPS then adopted as standards that all operators are now expected to follow.

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[13] It became apparent in the 1940s that corrosion was an electro-chemical process that could be counteracted by the use of "cathodic protection" – the application of an electrical current flowing in the opposite direction to offset the inherent corrosion in a pipe-to-soil interface. The applied current is "cathodic" because it makes the pipe the cathode in a galvanic cell.

In sharp contrast to its negligible role in line pipe or overall pipeline industry losses, Equipment-related Failures contribute 45% of the losses from tank farms and/or pump stations according to the ASME[14]. Companies are therefore focusing on tank refurbishment, rehabilitation and operation. For one of the OPS Risk Demonstration Projects, at crude oil breakout tanks in Patoka, Illinois, the operator systematically identified hazards and other risks at the facility, and then systematically eradicated them. These tank farm integrity initiatives will help OPS and operators identify the most effective methods of preventing spills from these facilities.

In spite of the fact that Operator Error is responsible for relatively small shares of the number of releases or of the release volume, the incidents are by their nature preventable. Thus, reducing incidents caused by Operator Error is also a central focus of industry efforts. As noted above, some operators incorporate metrics based on Operator Error into their performance measures, driving toward incident-free operation. The OPS rule on Operator Qualification, implemented in 2001, is a performance-based rule aimed at raising the bar for all operators, not just those that might enhance their training programs at their own initiative.

Pipeline operators have increased their security focus since September 11th

In general, pipeline systems are robust and redundant systems, with large portions of the pipeline infrastructure underground and, thus, less vulnerable to attack than aboveground facilities. However, as pipeline systems are crucial to the nation's energy supply, pipeline operators have not just updated their plans for handling emergency repairs and cleanup. They have also increased their focus on security since September 11. Working in cooperation with the federal government, pipeline operators have increased the security of the nation's most critical infrastructure components and developed specific protective measures for each Homeland Security Advisory System potential threat level, that are triggered automatically. Pipeline operators have conducted vulnerability assessments for their systems or participated in regional vulnerability assessments conducted by the Department of Energy or other federal or state agencies.

[14] See the Appendix for a list of the ASME causes included here in Equipment-related Failures

Recovery

Pipelines must have response plans and resources to respond to a worst case spill scenario

Pipeline companies are required to prepare comprehensive emergency response plans and to have access to the resources capable of responding to a worst case spill scenario. These response plans are reviewed and approved by the U.S. Department of Transportation's Research and Special Programs Administration (RSPA). Various federal, state, and local, emergency-planning officials are also involved in the review or testing of a pipeline company's emergency preparedness. The plans include detailed line maps, inventories of community facilities and health care resources, details of community water supply and other utility information, and the availability of response resources. The industry reviewed these plans in the light of the events of September 11th 2001, especially with regard to the definition of a worst case spill scenario, and updated them where necessary.

The response to any incident is controlled by a federal On-Scene Coordinator

In the unfortunate event of an oil spill, the pipeline operator, its contractors and other responders – federal, state, and local officials – are faced with a variety of immediate tasks. On-site control in the event of a major spill follows a Unified Incident Command System, a one-stop shop controlled by the federal On-Scene Coordinator and including other federal, state and local officials, the pipeline company and its contractors. Under the direction of the On-Scene Coordinator, the team of responders immediately moves to secure the safety of the surrounding community, contain the release, protect environmental receptors, such as nearby rivers or water supplies, and initiate clean up and repairs.

(The National Contingency Plan establishes the regulations for spill response, ensuring that all necessary federal resources will be available and creating a blueprint for priorities and command protocols. While the U.S. Coast Guard, in the event of a coastal spill, or the Environmental Protection Agency, in the event of an inland spill, has the regulatory power to assert control, as a practical matter, not every spill is "federalized." Even spill responses that are not federalized, however, are conducted under the oversight of the pertinent agency. Most spills are dealt with at the local level, using employees and contractors of the pipeline, under state and/local oversight.)

Recovery or clean-up of spilled oil is a key part of any spill response

The term "clean up" as used here may include a broad range of efforts at each stage of the process, covering everything from the direct recovery of liquid to long-term remediation and environmental monitoring of the affected area. Clean up operations begin immediately, continue intensively, and are closely monitored by local, state and federal officials. Thus, it is incorrect to assume that oil spilled from a pipeline is abandoned to damage the environment.

Recovery of Liquids Released from Pipeline Systems, 1997-2001

System Location	Avg Ann'l Loss (barrels)	Avg Ann'l Recovery (barrels)	Avg Ann'l Net Loss (barrels)	% Recovered
Line Pipe	61,205	25,701	35,503	42.0%
Tank Farms, Pump Stations	46,523	31,188	15,335	67.0%
Total	107,727	56,889	50,838	52.8%

Note: Data available from the OPS as of July 2002. Excludes Highly Volatile Liquids: commodities that return to a gaseous state when released.

Over half the oil spilled by pipelines over 1997-2001 was recovered directly

Direct recovery rates vary widely, depending on the specific circumstances for the incident. For the 1997-2001 period as a whole, over half of the spilled oil reported within the OPS data was recovered, reducing the annual average total net loss of oil in all pipeline incidents to 57,000 barrels.[15] For tank farms and pump stations, the OPS-reported oil recovery rate was much higher, averaging two-thirds of the initial oil spill, with over 40% of the incidents achieving recovery rates of over 90%.

Some real-world narratives of spill responses are available from the Environmental Protection Agency's (EPA) web site.[16] One concerns a 1993 pipeline spill near Sugarland Run in Fairfax, VA, for which an EPA official served as the On-Scene Coordinator. It states: "Recovery of the oil involved use of skimmers, vacuum trucks, sorbents, and a temporary pipeline to direct recovered oil into tanker trucks. Through these actions, response personnel recovered 372,498 of the 407,436 gallons released." Thus, according to the EPA, 91% of what it described as one of the largest inland oil spills in recent history was recovered directly.

Longer term remediation pushes the spill recovery rate significantly higher

The OPS data are limited to estimates of liquids recovered directly. However, today's environmental standards would normally require removal or treatment of most, if not all, of the remaining petroleum spilled and of the site too, to avoid environmental or public risks. This continued cleanup requires remediation and other recovery techniques – soil removal to proper treatment facilities, incineration of soils, on-site bioremediation, water treatment, etc. – that may take longer to complete, but are both real and effective. (While information on these remediation efforts is likely available for specific incidents from the

[15] The term "liquids" as used here and in the table excludes so-called "highly volatile liquids" (HVLs). See footnote 4.

[16] http://www.epa.gov/oilspill/colonial.htm. Operator data show slightly different totals, but still show recovery approaching 90%.

state environmental agency involved, it is not in a form or database that allows quantification for the purposes of this report.)

These longer-term remediation efforts are obviously dictated by specific site circumstances. What works for sandy soil may not be the best choice for clay-like soils, what is possible for crude oil or for diesel fuel may not be the best choice for gasoline, and so on. Thus, the commodity spilled, the characteristics of the soil, the proximity to groundwater and surface water, are each important determining factors for the type of remediation chosen. The menu of options includes both *ex-situ* methods (excavation and other removal methods) and *in-situ* methods (which may include, for example, bioremediation, natural attenuation, pump and treat, and/or extraction of the volatile organic compounds from the subsurface).

The appropriate assessment, treatment and long term monitoring plan for each unique site is developed and approved by the pertinent state or federal environmental agency. Furthermore, an affected state finally signs off on the data for spill recovery, remediation and restoration.

Comparison with Other Modes of Oil Transportation

Basis of the Comparisons

The oil spill and safety record of pipelines versus trucks, rail, tank ships and tank barges

This section compares the oil spill and safety record of four other modes of transport: trucks, rail, tank ships and tank barges, with that for pipelines, using data from a variety of sources within the U.S. Department of Transportation. The comparisons cover the 1997-2001 period, reflecting data availability during mid-2002. To make the comparisons valid, the incident data were adjusted both for the different reporting criteria and for the vast differences between modes of transport in the typical volume of oil they move and typical distance they move it through.

Data were normalized by using incident rates per barrel mile...

Trucks, for instance, commonly transport gasoline for the last leg of its trip to the gasoline station, but that leg is usually a very short distance in comparison to the distance from the refinery, where the gasoline was manufactured, to the truck's pick-up point, probably a distribution terminal. Using barrel-miles (where one barrel transported one mile equals one barrel-mile) rather than numbers of trips, total pipeline shipments account for over two-thirds of domestically transported crude oil and petroleum products, while total truck shipments account for just 3.6%, i.e. 1/19 of the pipeline shipments' share. Consequently, all comparisons in this chapter are based on rates of loss (or death or injury) per barrel-mile, rather than on simple gross losses (or deaths or injuries).

...and by including only Incidents involving commodities covered by the OPS data

In addition, the data were limited to only those incidents involving the same commodities carried in the liquids pipelines under OPS jurisdiction: crude oil, finished and intermediate petroleum products, and miscellaneous products such as anhydrous ammonia. It excludes any incident or accident or death where the truck or rail car or vessel cargo was neither oil nor any of these miscellaneous commodities.

Waterborne Shipments

Tankers and barges are, together, the second most important mode of transport for oil in the U.S.

Waterborne carriers, which include both tank ships and tank barges, accounted for about 28% of the total petroleum transported in the United States in 2000. This represents the stabilization of a long downward trend that in recent years reflected a sharp drop in the shipping required to transport Alaskan crude oil from Valdez in southern Alaska to the rest of the U.S. This was due to three interwoven developments: production in Alaska peaked and started to decline; the lower volumes became absorbable on the West Coast, thus drying up the former tank ship shipments via Panama; and the ban on exports of Alaskan crude was lifted, removing some shipments from the domestic totals.

The Coast Guard Data

The Coast Guard has a detailed, public database on spills and safety incidents

The U.S. Coast Guard maintains an extensive database of inter-related files that cover all marine casualties and spills. This is much more detailed than the information available for any other mode of oil transportation. The main files include reports of any spill of 100 gallons or more in water.[17] The database covers not just pollution but also death, injury, and all forms of vessel casualties, such as sinking, grounding, etc., together with details on the vessels or facilities involved and on the incident itself (location, first/second causal events, crew detail, commodities, quantities spilled in and out of water, weather conditions, etc.). It also provides a record of Coast Guard response and investigation activities.

But it is limited to closed cases, so most of the data were obtained directly from the Coast Guard

There are two important caveats regarding the Coast Guard's publicly available, incident-by-incident database. First, it includes only closed cases. The importance of this limitation can be enormous; a large case may remain open for years. For instance, only 14% of the total volume spilled from tank barges in 1996 was represented in the closed case file as of September 1998. Most of the volumes discussed here were provided directly by the U.S. Coast Guard, because volumes pertaining to open (and hence still confidential) cases would otherwise be unavailable. Second, the Coast Guard opens a case file each time it investigates an incident. A case file on a pollution threat may be quickly closed without further activity. On the other hand, the database includes some incidents, including some large oil spills, that occurred in foreign countries and so are outside the scope of this study. Thus, the user must exercise considerable care to include only pertinent data.

Trucks and Rail

Trucks and rail are both minor modes of transport for oil

In 2000, trucks accounted for 3.6% of the domestic petroleum shipments and rail for just over 2%. In discussing public safety, one must contrast a truck's route with a pipeline or railroad's route. The truck's operating corridor is a highway shared with the general population. For pipelines and railroads, in contrast, the operating

[17] Since 1994, the Coast Guard has maintained data on spills of less than 100 gallons in a separate database. The number of such incidents is high, but the total volume lost is small.

corridor is a separate right-of-way. Although railroads and pipelines do come in contact with populated areas and cross waterways and roads, they generally present less exposure for the general public than trucks transporting petroleum over public highways. Thus, trucks' pollution and safety incidents, which occur frequently, can quickly stress the local infrastructure and disrupt the normal flow.

The HazMat Data

Data on rail or road incidents are in the DOT's HazMat database on the Internet

The Department of Transportation's Research and Special Programs Administration, of which the Office of Pipeline Safety is a part, also compiles data on incidents occurring during the transport of hazardous materials by air, rail, water or highway. RSPA requires a transporter to file a report by telephone immediately if any of the following "occurs as a direct result of the hazardous material":

- A person is killed or hospitalized,
- Property damage exceeds $50,000,
- The general population is evacuated for an hour or more,
- At least one transportation artery is closed for an hour or more.

The transporter must then follow this up with a written report using Form 5800. In addition, a transporter must file a Form 5800 for "any unintentional release of a hazardous material during transportation."

The Form 5800 data are compiled into a database that is available on the Internet at http://hazmat.dot.gov/files/hazmat/hmisframe.htm. (Each year can be accessed separately.) Of the 14,000 to 17,500 incidents per year for the years 1997-2001, only around 5% pertained to tank trucks carrying petroleum as their cargo, and just 1% to rail cars.

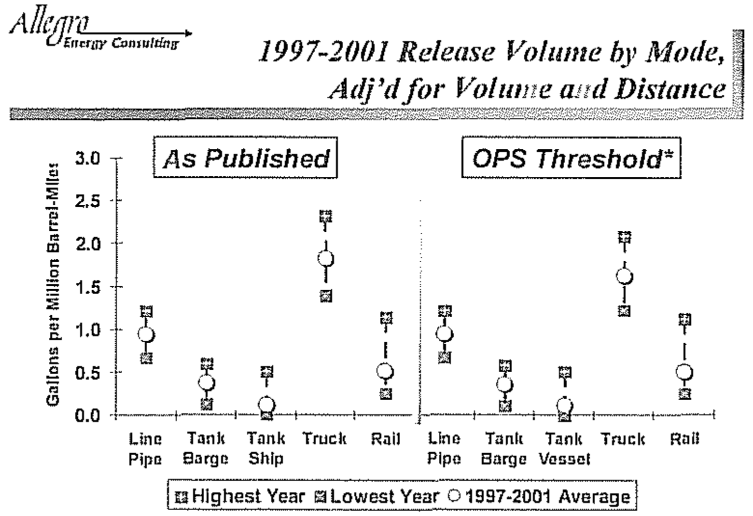
Oil Spill Performance By Mode

For each mode, spill volumes were divided by total barrel-miles of oil shipped, and then compared

As noted throughout, the data for spills and other safety incidents cannot be compared without adjusting for the differences in volume and distance for each of the modes. The graph that follows takes the spill volume for each mode and divides it by the number of barrel-miles of oil shipments for that mode.[18] The result is shown in gallons spilled per *million* barrel-miles of oil shipments.

All modes of oil transportation have extremely low spill rates

No spill is acceptable. The oil transportation industries have not reached this ultimate goal yet but, as this chart shows, the spill rate for each of the transportation modes is extremely low. Line pipe,[19] for instance, had initial losses of about one gallon per *million* barrel miles over the 1997-2001 period. In household terms, this is less than one *teaspoon* per *thousand* barrel miles.



*Incidents w/50 bbls (5 bbl HVL) or more, or fire, explosion, death, injury, or $50K or more damage

Trucks have by far the worst record on spill rates

On the left side of the chart, the "As Published" numbers include all of the oil spill data reported in the databases. Relative to line pipe over 1997-2001, the average annual spill rate was almost 100% higher for trucks (i.e. twice the line pipe rate), 45% lower for rail, 60% lower for

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[18] The estimates of barrel-miles for line pipe, truck and rail are taken from the Association of Oil Pipe Lines' *Shifts in Petroleum Transportation*. That report also shows total domestic shipments as reported by the Army Corps of Engineers' Waterborne Commerce Statistics Center, but does not include a breakdown of tank ship versus barge shipments. For barges, therefore, we based the barrel-miles for 1997-2000 on data provided directly by the Waterborne Commerce Statistics Center and made an estimate for 2001.

[19] Because data for terminals are not available for the other transportation modes, we are using only losses from line pipe for this inter-modal comparison.

barges and nearly 90% lower for tank ships. As indicated by the high and low marks, trucks have the widest range in year-to-year spill rates, with rail a close second. Even so, the best year for trucks in terms of spill rate was worse than the worst year for every one of the other modes.

Adjusting for the Reporting Threshold

Small spills with no other significant safety issues were excluded from Coast Guard and HazMat data

As discussed in detail above, the spill data used here were collected for different purposes on different forms by different agencies that have different reporting criteria. For volume, the Office of Pipeline Safety's threshold was the highest, at 50 barrels of non-HVL and 5 barrels of HVL, during the period under review. (Different criteria for reporting deaths and injuries will be discussed shortly). Obviously, we cannot add smaller spills to the Office of Pipeline Safety data, because we cannot create data that do not exist.[20] We therefore limited the Coast Guard and HazMat data by mimicking the OPS reporting criteria as closely as possible, specifying a volume threshold of 50 barrels (2100 gallons) of non-HVL per incident, and 5 barrels (210 gallons) of HVL, unless the incident also involved fire, explosion, death, injury or damages of $50,000.[21]

Aligning reporting criteria still left the truck spill rate more than 70% higher than the line pipe rate

Of particular interest, and intuitively correct, is that most of the values move only imperceptibly. (Line pipe, by definition, is unchanged.) The small spills that have been eliminated, while numerous, were not cumulatively responsible for significant volume. The new, higher volume threshold continues to capture at least 95% of the original barge, tank ship and rail volumes. Even with trucks, where the maximum spill size is necessarily constrained by the fact that trucks are unlikely to carry more than 9,000 gallons, the higher threshold captures 89% of the original volume. Thus, even after this adjustment, the truck spill rate is still more than 70% higher than the line pipe rate.

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[20] While reports of smaller pipeline spills are required by a number of states, they are not easily retrievable or comparable.

[21] It should be noted that some liquids operators report incidents to OPS that do not appear to reach any reportable threshold. We have not deleted these "apparently unreportable" records, which have little impact on volume.

Other Measures of Safety Performance

The four modes' safety records for deaths, injuries, fires and explosions were analyzed similarly

In comparing the safety performance of different modes of oil transport, petroleum spills are not the only measure to examine. We have also used the same data: OPS for line pipe, Coast Guard for barges and tank ships, HazMat for trucks and rail, to compare the different transport modes' records for deaths, injuries, and fires and/or explosions. We had to analyze the latter two hazards in combination, because the Coast Guard combines records for fires and explosions. In most cases, explosions coincide with fire.

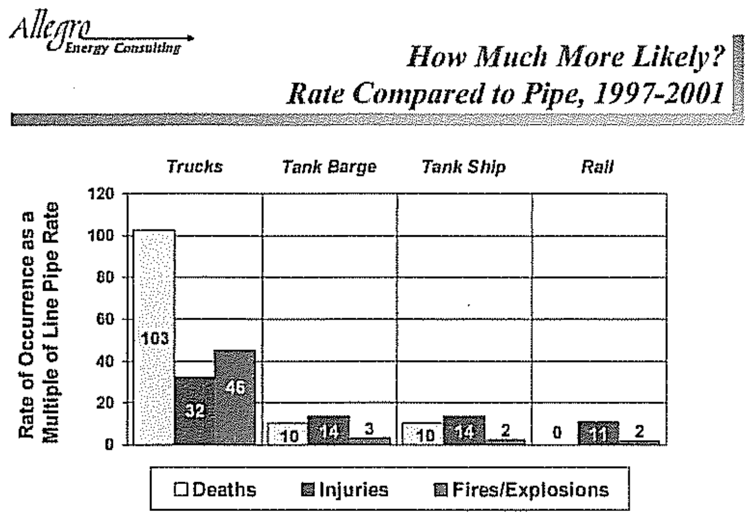
The data were again standardized where possible, but a HazMat undercount was unavoidable

There are significant differences in the reporting criteria for these safety measures, as there were for spills. For injuries and deaths, HazMat, the source of the truck and rail data, only wants reports on those that are specifically due to the hazardous material involved, not the incident *per se*. As HazMat's *Guide for Preparing Hazardous Materials Incident Reports* specifies: "A driver injured in a vehicle accident in which he was not physically affected by the hazardous material IS NOT recorded as an injury." [Emphasis in original.] Likewise, the deaths due to a collision between a tank truck and a car where all the occupants die will not be recorded unless the petroleum actually caused the deaths. In contrast, both the Coast Guard and OPS want reports on all incidents involving death or injury. However, the Coast Guard's definition of an injury is incapacitation for 72 hours, while the OPS definition was the broader one of bodily harm[22] to any person resulting in one or more of the following: loss of consciousness, necessity to carry the person from the scene, necessity for medical treatment, or disability which prevents the discharge of normal duties or the pursuit of normal activities beyond the day of the incident. Furthermore, HazMat reporting criteria exclude incidents involving fires or explosions alone, i.e., that do not meet one of its other criteria, although both the Coast Guard and OPS include them. Thus, HazMat, in particular, undercounts deaths, injuries, fires and explosions relative to OPS.

To simplify comparisons, the safety record for each mode was indexed to that for pipelines

We used a two-step process to compare the safety performances of the different transport modes. Step 1 replicated the calculation for spill rates by mode (shown in the previous chart) for deaths, injuries and fires and/or explosions, taking the reported number of deaths (for instance) associated with each mode's oil transport incidents from 1997-2001 and dividing by the mode's total ton-miles for that same period. Step 2 then converted the set of rates for each safety measure

[22] As noted earlier, the new Form 7000-1 that OPS adopted at the beginning of 2002 changes the definition of bodily harm to "personal injury requiring hospitalization."



A multiple of 1.0 means a rate of occurrence equal to the Line Pipe rate.

to an index based on line pipe's performance, by dividing each mode's rate by the corresponding pipeline rate. The result is a rate of deaths (or injuries or fires/explosions) that is a multiple of the line pipe rate: twice as many, ten times as many, or half as many.

Line pipe has the best overall safety record .....

As the chart shows, line pipe has the best overall safety record, outperforming the other modes over 1997-2001 on all except one count – rail had a lower death rate, as there were no deaths associated with any rail incident over the period.

. . . and trucks, line pipe's main competition, have by far the worst

At the other end of the scale, trucks, line pipe's main competition, have by far the worst safety record, with the highest rates of deaths, injuries, and fire and/or explosion among all the oil transport modes, despite the HazMat undercount. Relative to pipelines, the safety performance of trucks has been dramatically inferior: death rates 103 times higher, injury rates 32 times higher, and fire/explosion rates 46 times higher, based on normalized data.

Line pipe's safety advantage is much less relative to tank barge, tank ship and rail, but still significant.

Line pipe's out-performance on safety relative to the other three transport modes (tank barge, tank ship and rail) is less, but is still significant. Injuries per ton-mile, for instance, are 14 times higher for both tank barge and tank ship operations, and 11 times higher for rail operations than for pipeline operations, while deaths per ton-mile are 10 times higher for both tank barge and tank ship operations than for pipelines. The disparities between the rates of occurrence of fires and/or explosions are the least significant, but, even there, oil pipelines have the best record.

The data record, therefore, clearly indicates that, if the deciding factor is safety, as measured by death, injuries, or fires and/or explosions, pipelines are by far the best option for transporting oil.

Appendix

Highlights of ASME Re-Classifications

The table shows the proportion of incidents from 1996-2000 reclassified by the B31.4 Committee from each cause in the OPS data to the more complete list of ASME causes.

ASME Classification	OPS Classification (Share of numbers of incidents)							
	Corrosion	Failed Pipe	Failed Weld	Incorrect Opern. By Operator Personnel	Malfunction Of Control Or Relief Equipment	Other	Outside Force Damage	Total
Construction/Repair		5%	62%			4%		4%
Corrosion	94%	3%				1%	1%	25%
Equipment	1%	8%	5%	9%	79%	44%	1%	18%
Manufacturer		49%	24%			2%		4%
Miscellaneous	2%	10%			15%	16%	2%	7%
Operation	0%		2%	91%	3%	8%	1%	9%
Prev. Damaged Pipe	1%	13%				2%	6%	3%
Third Party	0%	3%				10%	82%	22%
Unknown	1%	10%	7%		3%	8%	1%	4%
Vandalism						2%		1%
Weather						4%	8%	3%
Total	100%	100%	100%	100%	100%	100%	100%	100%

- *For OPS category Outside Force Damage:*
  82% of the incidents were due to Third Party Damage;
  8% were weather-related -- cold weather, heavy rains or flooding, lightning, etc.;
- *For OPS category Other:*
  44% of the incidents were Equipment-related Failures, including gaskets, O-rings, valves etc;
  16% were due to "Miscellaneous" causes;
  10% were due to Third Party Damage
- *For OPS category Corrosion,*
  94% of the incidents were correctly classified.
- *For OPS category Failed Weld:*
  62% of the incidents were due to construction/repair
  24% were due to the manufacturer.
- *For OPS category Failed Pipe:*
  49% of the incidents were due to the manufacturer.
- *For OPS category Incorrect Operation:*
  91% of the incidents were correctly classified.
- *For OPS category Equipment Malfunction:*
  79% of the incidents were due to damaged or malfunctioning equipment.

This table shows the impact on volumes spilled of the B31.4 Committee's reclassification of incidents from 1996-2000 from each cause in the OPS data to the more complete list of ASME causes.

	OPS Classification (Share of Volume spilled)							
ASME Classification	Corrosion	Failed Pipe	Failed Weld	Incorrect Opern. By Operator Personnel	Malfunction Of Control Or Relief Equipment	Other	Outside Force Damage	Total
Construction/Repair		2%	52%			1%		3%
Corrosion	84%	6%				3%	1%	22%
Equipment	1%	3%	2%	50%	70%	42%	2%	18%
Manufacturer		65%	30%			4%		4%
Miscellaneous	1%	1%			28%	19%	0%	6%
Operation	13%		2%	50%	0%	2%	0%	7%
Prev. Damaged Pipe	0%	4%				2%	4%	2%
Third Party	0%	0%				8%	82%	29%
Unknown	2%	19%	15%		2%	18%	3%	7%
Vandalism						1%		0%
Weather						1%	7%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%

- *For OPS category Outside Force Damage:*
  82% of spill volumes were attributed to Third Party Damage;
- *For OPS category Other:*
  42% of spill volumes were reclassified to Equipment, which also includes the failure of gaskets, O-rings, valves etc;
  19% were reclassified to "Miscellaneous" causes;
  18% were reclassified to Unknown.
- *For OPS category Corrosion,*
  84% of the spill volumes remained attributed to Corrosion.
- *For OPS category Failed Weld:*
  52% of spill volumes were attributed to Construction/Repair
  30% were reclassified to Manufacturer.
- *For OPS category Failed Pipe:*
  65% of spill volumes were reclassified to Manufacturer.
- *For OPS category Incorrect Operation:*
  50% of spill volumes remained attributed to Incorrect Operation
  50% were reclassified to Equipment.
- *For OPS category Equipment Malfunction:*
  70% of spill volumes remained attributed to damaged or malfunctioning equipment
  28% were reclassified to Miscellaneous.

Category in this report	Includes these ASME cause categories
Construction/Repair	Defective Fabrication Weld Defective Girth Weld Defective Repair Weld
Corrosion	Corrosion-Related Failures - External Corrosion-Related Failures - Internal
Equipment	Malfunction of Control or Relief Equipment Ruptured or Leaking Gasket or O-ring Ruptured, Leaking Seal, Pump Packing Threads Stripped, Broken Nipple, or Coupling Fail
Manufacturer	Defective Pipe Defective Pipe Seam
Misc	Miscellaneous Other
Operation	Incorrect Operation by Carrier Personnel
Prev. Damaged Pipe	Rupture of Previously Damaged Pipe
Third Party	Third Party Inflicted Damage
Unknown	Unknown
Vandalism	Vandalism
Weather	Cold Weather Heavy Rains or Floods Lightning