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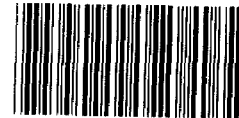
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PIPELINE SAFETY

Use of Instrumented
Technology
to Inspect Pipelines

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Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to be part of the Subcommittee's review of the March 28, 1993, pipeline incident in Reston, Virginia, as it seeks to improve pipeline safety. Today we will discuss our report on the role that instrumented internal inspection devices--called smart pigs--can play in improving pipeline safety.¹ Also, we will comment on the recent Reston incident.

Pipelines provide a vital transportation service. Approximately one-half of the nation's supplies of crude oil and petroleum products, and virtually all natural gas supplies, are transported through a network of over 1.7 million miles of pipelines. The overall safety record of pipelines is relatively good in comparison with that of other modes that carry hazardous materials. However, the Reston incident serves as a reminder that increasingly effective inspection technologies should be continually sought.

Our September 1992 report addressed the capabilities, limitations, costs, and regulations associated with the use of smart pigs in natural gas pipelines. While our report focused on natural gas pipelines, our findings on smart pig inspection capabilities have bearing on liquid pipelines as well. Our testimony also discusses various actions relating to pipeline safety that were taken after our report was issued. In addition, at your request, we will comment on ways pipeline safety can be enhanced to minimize the risk of incidents such as the Reston spill.

In summary, our work shows the following:

- A smart pig is the only pipeline inspection technique that can detect internal and external corrosion without excavating the pipe.² Pipeline corrosion is the second leading cause of natural gas pipeline incidents after

¹Natural Gas Pipelines: Greater Use of Instrumented Inspection Technology Can Improve Safety (GAO/RCED-92-237, Sept. 28, 1992)

²Two types of smart pig technologies--magnetic-flux leakage measuring and ultrasonic--are used to detect corrosion. Magnetic-flux pigs are used for inspecting hazardous liquid and natural gas pipelines. Ultrasonic pigs are used for inspecting liquid pipelines, because they require a liquid medium such as methanol, glycol, or water to operate. Ultrasonic pigs can be used, however, for inspecting a natural gas pipeline, provided it is emptied first and refilled with a liquid medium. A magnetic-flux smart pig is illustrated in app. I.

damage caused by accidental excavation. While smart pigs can detect other pipe flaws such as gouges and dents, they cannot detect defects such as longitudinal cracks and metal loss in pipe welds. Furthermore, while many pipelines can accommodate smart pigs, others cannot because of operational limitations such as sharp bends in the pipeline. Companies responding to our survey reported the cost of using smart pigs per mile of on-stream pipeline ranged from \$650 to \$2,400 in 1991.

- Currently, there are no federal regulations governing the use of smart pigs or the frequency of smart pig inspections. Our September 1992 report recommended that the Department of Transportation's (DOT) Research and Special Programs Administration (RSPA) complete the feasibility study on smart pigs mandated by the Pipeline Safety Reauthorization Act of 1988 (P.L. 100-561). Also, we recommended that RSPA issue the regulations mandated by the act, which required new or replacement pipelines--gas and liquid--to accommodate smart pigs.
- In response to our recommendations, RSPA issued the feasibility study in November 1992 and took actions to issue the regulations mandated by the 1988 act that could enhance the use of smart pigs. RSPA is now evaluating the comments received as a result of its proposed rulemaking.
- Over the years, the National Transportation Safety Board (NTSB) has investigated numerous pipeline incidents and has made several recommendations for enhancing pipeline safety. For example, NTSB recommended that new or replacement pipelines be capable of accommodating smart pigs.
- Aging pipelines are of concern because there is a higher risk that they will result in pipeline incidents. The Reston pipeline incident points out that even relatively newer pipelines are subject to failure. While the true cause of the failure is unknown at this time, that incident points out the need for pipeline companies to periodically inspect their pipelines to identify defects and flaws and take needed corrective action. We believe that smart pigs, in conjunction with other inspection techniques, and the NTSB recommended improvements can strengthen the federal strategy to ensure pipeline integrity and safety and minimize incident damage.

BACKGROUND

RSPA's Office of Pipeline Safety is responsible for developing, issuing, and enforcing safety regulations for more than 1.7 million miles of natural gas and hazardous liquid pipelines in the United States. RSPA has five Regional Pipeline Safety Offices

with a total of 22 inspectors. RSPA's Eastern Region, which covers Virginia and 13 other states, has three inspectors. The Colonial Pipeline Company has a pipeline that transports refined petroleum products from Pasadena, Texas, to Linden, New Jersey. This pipeline runs through three RSPA regions having a total of 12 inspectors.

Most of the nation's natural gas pipelines were constructed in the 1950s and 1960s; 10 percent of the lines were constructed before 1950 and 9 percent before 1940. Comparable data on the age of hazardous liquid pipelines are not readily available. However, the majority of liquid lines were built after 1950. Although the pipeline industry has a reasonably good safety record, each year several hundred pipeline incidents occur. The safety of aging pipelines is of increasing concern. Older pipelines may exhibit a greater potential for leakage or rupture than newer lines because of pipe corrosion. Pipeline leakage can cause severe damage to human health, property, and the environment.

From 1985 through 1992, 1,906 natural gas pipeline incidents involving 146 fatalities and 721 injuries were reported to RSPA. By far, the leading cause of natural gas pipeline failure is accidental damage caused by excavation by third parties; the second leading cause is corrosion. Appendix II shows natural gas pipeline incidents for 1985 through 1992, and appendix III shows the causes of these incidents for 1992. For the same period, 1985 to 1992, 1,591 hazardous liquid pipeline incidents involving 24 fatalities and 180 injuries were reported to RSPA. The leading causes of hazardous liquid pipeline failure are corrosion and damage caused by outside forces, such as third parties. Appendix IV shows hazardous liquid pipeline incidents for 1985 through 1992, and appendix V shows the causes of these incidents in 1992.

Pipelines must be protected while being transported and installed. During operations, pipelines must be protected from damage and degradation from other causes such as corrosion, mechanical damage, fatigue, and stress-corrosion cracking.³ Determining and maintaining the structural integrity and safety of natural gas pipelines and improving the baseline knowledge of their condition requires a combination of external corrosion controls and inspection techniques.

We reported that pipeline inspection techniques include (1) visual inspection techniques, such as line walking and the use of light aircraft or helicopters to check for evidence of leaking; (2)

³Such cracking is characterized by multiple longitudinally oriented tight cracks--usually accompanied by poor or distorted coating in a coated pipeline.

x-raying pipe welds; (3) hydrostatic pressure testing;⁴ and (4) placing a smart pig inside the pipe to record flaws as it is propelled by the product being transported.

FACTORS ASSOCIATED WITH USING SMART PIGS

Our work showed that smart pigs can improve pipeline integrity and safety. However, they have certain capabilities and limitations associated with their use. Furthermore, companies we surveyed reported varying costs.

Capabilities and Limitations of Smart Pigs

Smart pig technology is the only pipeline inspection technique available to detect internal and external corrosion without excavating the pipeline. Corroded areas and other pipeline flaws identified by smart pigs can be repaired or replaced before they rupture. Smart pig use also produces data on the metal integrity⁵ and condition of the pipeline. Without such data, it is not possible to evaluate the total integrity and safety of the pipeline. On the other hand, hydrostatic testing provides information on the pressure integrity of the pipeline. Hydrostatic testing identifies significant defects by causing the pipe segment to fail during testing. However, hydrostatic testing provides confidence in the pipeline's integrity and safety only at the time of the test. No information can be obtained about the extent or severity of any remaining corrosion damage or other existing pipeline flaws. Therefore, neither technique can be substituted for the other because each produces information unique within its own scope. An advantage of the smart pig technology is that it does not require emptying the pipeline of the product being transported, as hydrostatic testing does. Such emptying results in revenue loss to pipeline operators because operations are interrupted. Also, the water used in hydrostatic testing must be properly treated and disposed of.

During the course of our work on smart pig technology, we received survey responses from 15 U.S. and 3 Canadian natural gas pipeline companies. Nine of the U.S. and all three Canadian companies reported success in using smart pig technology. Companies that had used smart pigs told us that the pigs identified corrosion pitting, mechanical damage, gouges, dents, and manufacturing defects, as well as the location of girth welds, valves, and bends in pipelines. Some companies also noted that

⁴Hydrostatic testing--forcing water through a pipeline at high pressure--provides data on the pipeline's operating pressure integrity and identifies significant pipeline defects by exposing the pipeline to pressure above its maximum operating pressure.

⁵Soundness of the pipe's metal.

smart pigs enabled them to rank repair work on the basis of the location and severity of problems identified, minimize pipeline downtime, and plan effective maintenance. Other benefits cited were that smart pig usage minimizes costly loss of natural gas, ensures that the pipeline is being operated and maintained in a safe manner, and enables prospective sellers and buyers to evaluate the value of pipelines before sale or purchase of pipeline systems.

Companies also told us of limitations. They said that smart pigs could not identify metal loss in circumferential welds (where two ends of pipes are welded together) and longitudinal cracks (cracks that run the length of pipes). They also stated that smart pigs could not establish the integrity of external coatings, including the location of coatings that have separated from the pipe. We also found that neither the magnetic-flux nor the ultrasonic pig technologies had been sufficiently developed to locate potential pipe seam failure of electric-resistance-welded pipes.⁶ We also found that smart pigs cannot be used to inspect all pipelines for several reasons: Some pipelines are not able to accommodate pigs due to sharp bends; valves that cannot be fully opened obstruct pig passage; and pipe walls are too thin.

We found specific instances in which smart pig inspections of natural gas pipelines could improve pipeline integrity and safety. For example, in one case a smart pig inspection detected the presence of corrosion in a gas pipeline company's transmission line. However, no follow-up action was taken. This line subsequently ruptured, causing five deaths and property damage. According to the state gas pipeline safety office that conducted the investigation, the incident could have been prevented had the company interpreted the data from the smart pig inspection as an impetus for corrective action. Another company found the use of smart pigs so successful that its current 20-year plan includes pig inspection of all of its lines. A third pipeline company voluntarily invested \$100 million to make 9,000 miles of its pipelines "piggable" and has reported many advantages to the use of smart pigs.

In terms of improvements they would like to see, companies responding to our survey specified data analysis and interpretation of inspection logs, particularly for magnetic-flux pig technology. These companies told us that smart pigs should be improved to enhance their ability to more accurately measure the depth and length of corrosion. The companies also desired improvements in data interpretation, such as more readable inspection logs, computerized analysis of the data on personal computers at the field level, and correlation of pig inspection logs with actual

⁶A low frequency electric resistance welding method prevalent in the United States before the 1970s.

measurement of pipe anomalies obtained after excavation of the line. Several smart pig manufacturers told us that, over time, market demand would bring about such technology improvements.

Cost of Using Smart Pigs

Companies responding to our survey told us that the cost of using smart pigs depends on a number of variables, such as the type of smart pig used--first-generation or second-generation. In general, second-generation smart pigs have state-of-the-art technology and more advanced capabilities for detecting pipeline flaws. Some companies said they used first-generation smart pigs because of their availability and lower cost. Other companies used second-generation smart pigs because they are capable of providing more detailed data on pipe flaws. Other variables affecting cost cited by these companies include the diameter of the pipeline, cleanliness of the pipeline, length of pipeline for which the smart pig is used, level of competition among smart pig vendors, and the amount of data analysis and interpretation needed for the corrosion reported. Pipeline operators may incur other costs to excavate, inspect, and repair any pipe segments where a smart pig has indicated significant anomalies.

These variables help to explain the broad range of costs reported by nine of the companies responding to our survey. The companies reported that the costs of using smart pigs per mile of on-stream pipeline ranged from \$650 to \$2,400 in 1991. The only company that provided detailed cost information on the use of smart pigs had used a second-generation pig. This company reported that the inspection cost of a first-generation smart pig is typically one-third to one-half of the inspection cost for a high-resolution, or second-generation, smart pig.

REGULATIONS RELATED TO THE USE OF SMART PIGS

To improve the safety of natural gas and hazardous liquid transmission pipelines, the Congress passed the Pipeline Safety Reauthorization Act of 1988 (P.L. 100-561, Oct. 31, 1988), directing DOT to (1) prepare a feasibility study on requiring the use of a smart pig to inspect transmission pipelines and (2) establish regulations requiring that new or replacement pipeline facilities, to the extent practicable, be capable of accommodating smart pigs. As we will discuss later, the Congress more recently passed the Pipeline Safety Act of 1992 (P.L. 102-508), which mandates regulations on the use of instrumented inspection technology for inspecting pipelines.

Despite congressional mandates and the benefits identified by several pipeline operators, there are no federal regulations on smart pig use or on the frequency of smart pig inspections. When we issued our report in September 1992, RSPA had not completed the feasibility study on smart pigs that the 1988 act mandated be issued

by May 1990. Also, RSPA had not issued the mandated regulations requiring new or replacement pipelines, to the extent practicable, to accommodate smart pigs. We found that the delays resulted from RSPA's resource shortages and the agency's decision to devote resources to other work.

In our report we recommended that the Secretary of Transportation act to expeditiously (1) provide the Congress with the final report from the smart pig feasibility study mandated by the 1988 act or notify the Congress when the study would be available and (2) issue the regulations mandated by the 1988 act. In carrying out these actions, we pointed out that DOT should (1) determine how smart pig technology can effectively be used in natural gas transmission pipelines, especially those in densely populated areas, and (2) consider the capabilities, limitations, and costs of smart pigs in determining the role that these inspections should play in an overall strategy for ensuring pipeline integrity and safety.

RSPA, however, had recognized the capabilities of smart pig inspection. Over the previous 6 years, RSPA had served hazardous facility and consent orders to natural gas and hazardous liquid pipeline companies following incidents in their lines. In those cases, RSPA required the companies to use smart pig inspections to verify pipeline integrity.

RECENT ACTIONS TO ENHANCE SMART PIGS' USE

In November 1992, RSPA issued the feasibility study mandated by the 1988 act.⁷ The report assessed the feasibility of requiring the inspection of transmission facilities with smart pigs at periodic intervals. It concluded that, under certain circumstances, it may be feasible to require periodic inspections of natural gas transmission and hazardous liquid pipelines with a smart pig if the pipelines are constructed to accommodate the pigs.

RSPA also took actions to issue the regulations mandated by the 1988 act. In November 1992, DOT published in the Federal Register a Notice of Proposed Rulemaking requiring that new or replacement natural gas transmission pipelines, new and replacement hazardous liquid pipelines, and certain carbon dioxide pipelines be designed to accommodate smart pigs. The proposed rules do not apply to specific installations for which such design and construction would be impracticable. DOT invited interested parties to submit comments. RSPA is currently evaluating the comments received and plans to issue final regulations by the end of this year.

⁷Instrumented Internal Inspection Devices (A Study Mandated By P. L. 100-561), Research and Special Programs Administration, U.S. Department of Transportation, Nov. 1992.

Subsequent to our report, the Pipeline Safety Act of 1992 was enacted on October 24, 1992. It contains provisions that could increase the use of smart pig inspections in pipelines. The act directs the Secretary of Transportation to issue regulations, within 3 years of enactment, requiring pipeline operators to periodically inspect natural gas pipelines in high-density population areas and hazardous liquid pipelines in environmentally sensitive and high-density population areas. The regulations are to prescribe the circumstances, if any, under which such inspections should be conducted with an instrumented internal inspection device. The act provides that, when an instrumented internal inspection device is not required, the Secretary shall require the use of an inspection method that is at least as effective as the use of a such a device in providing for the safety of the pipeline.

NTSB PIPELINE SAFETY RECOMMENDATIONS

NTSB has made several recommendations to RSPA regarding pipeline safety that are relevant to the Reston incident. For example, in 1987, NTSB recommended that RSPA require operators of natural gas and liquid transmission pipelines to construct new pipelines to facilitate the use of smart pigs and to require operators to incorporate smart pig facilities when repairing or modifying existing systems. These recommendations were subsequently incorporated into the Pipeline Safety Reauthorization Act of 1988, which, as we pointed out earlier, required RSPA to issue regulations addressing these requirements. RSPA, however, did not issue a Proposed Notice of Rulemaking on this requirement until November 1992.

In 1987, NTSB also recommended that RSPA develop operational criteria for determining safe intervals between hydrostatic tests of pipelines. RSPA has not adopted this recommendation. We noted that federal regulations require hydrostatic testing of new pipelines but do not require retesting unless the pipeline is relocated, replaced, or otherwise changed. However, in the course of pipeline operations, the pipeline may be displaced, deformed, and damaged because of movement of the earth, and/or third-party construction damage. This damage--dents and gouges--may weaken the pipe and remain unknown to the operator. In addition, hazardous liquid lines are subject to fluctuating pressure changes that, in a weakened pipe, can result in fatigue cracking of the pipe's metal. Fatigue cracking propagates over time. These cracks can result in leaks or ruptures. Hydrostatic testing could detect such flaws by causing the pipeline to fail during the test.

NTSB also recommended in 1987 that RSPA require the installation of remote-operated valves on pipelines that transport hazardous liquids and determine the spacing of the valves on the basis of the population at risk. In response to the 1988 act, a 1991 RSPA study found the following:

- Remotely controlled valves and check valves are the only effective emergency flow-restricting devices.
- From a cost standpoint, it is reasonable to retrofit all manually operated valves to be remotely controlled on hazardous liquid pipelines located in urban areas.
- There are other locations where remotely controlled valves should be installed to protect environmentally sensitive areas.

The Pipeline Safety Act of 1992 requires that RSPA assess the effectiveness of emergency flow-restricting devices--including remotely controlled valves--and issue regulations prescribing the circumstances under which operators of hazardous liquid pipelines must use such emergency flow restricting devices. To date, RSPA has not begun to develop these regulations.

Despite the 1987 NTSB recommendations, it is worth noting that there are still no federal regulations (1) requiring inspections with an instrumented inspection device, (2) setting forth frequency criteria for hydrostatically retesting pipelines, and (3) requiring installation of remotely controlled operating valves. Furthermore, there are no federal criteria that specify the size of dents, gouges, and groves on pipelines that would require a section of pipe to be repaired or replaced once they are detected.

RESTON, VIRGINIA, PIPELINE INCIDENT

We have not conducted a detailed review of the March 28, 1993, spill in Reston, Virginia. However, as requested by the Subcommittee, we are providing comments on these matters as they relate to the issue of pipeline safety.

The Colonial Pipeline Company hazardous liquid pipeline which ruptured in Reston, Virginia, spilled an estimated 336,000 gallons of fuel oil. About 236,000 gallons of the spill entered the Sugarland Run Creek, a tributary of the Potomac River. The pipeline segment that ruptured is part of Colonial's 36-inch pipeline between pump stations at Chantilly, Virginia, and Dorsey Junction, Maryland. This pipeline was commissioned in 1980 and is part of Colonial's overall system, which runs from Pasadena, Texas, to Linden, New Jersey. RSPA and NTSB are currently investigating the causes of the Reston incident.

Following the incident, RSPA, on March 30, 1993, issued a Hazardous Facility Order to the Colonial Pipeline Company. The order required Colonial to reduce the operating pressure at the Chantilly pump station to 20 percent below the pressure prior to the pipeline failure. It also mandated certain analysis of the failed pipeline segment and of the failure site. Following further investigation into the cause of the incident, RSPA amended its order

to restrict the operating pressure for the pipeline segment to 50 percent of the maximum operating pressure. The order also required Colonial to submit a plan by April 12, 1993, for the internal instrumented inspection of the pipeline between Chantilly, Virginia, and Dorsey Junction, Maryland, and to prescribe the actions to be taken to correct the problems found.

In its April 12, 1993, plan, Colonial stated that it would inspect the pipeline segment with a caliper pig and subsequently with a magnetic-flux pig. The caliper pig will identify the location of anomalies such as dents, wrinkles, buckles, ovalities, and flat spots by measuring the reduction of a pipe's diameter resulting from these anomalies. The use of the caliper pig also ensures that a smart pig will then be able to traverse the line.

RSPA told us that the Colonial Pipeline Company has made considerable use of smart pigs. However, while it used a caliper pig in 1989 on this segment of pipeline, it has never inspected this segment with a magnetic-flux pig. RSPA also told us that Colonial had not hydrostatically tested this segment since its 1980 construction. In addition, this 35-mile pipeline segment does not have remotely controlled operating valves in the transmission line between the Chantilly and Dorsey Junction pumping stations. Remotely controlled operating valves located closer together could have reduced the amount of fuel oil spilled. However, as discussed earlier, there are no federal regulations requiring the use of smart pigs, periodic hydrostatic testing, or the installation of remotely controlled valves.

RSPA officials also told us that the Colonial pipeline segment that ruptured is not designed to easily accommodate magnetic-flux or ultrasonic smart pigs. This is because the pipeline changes in diameter from 36 inches to 32 inches around pumping stations. Colonial plans to modify the pipeline to accommodate smart pigs.

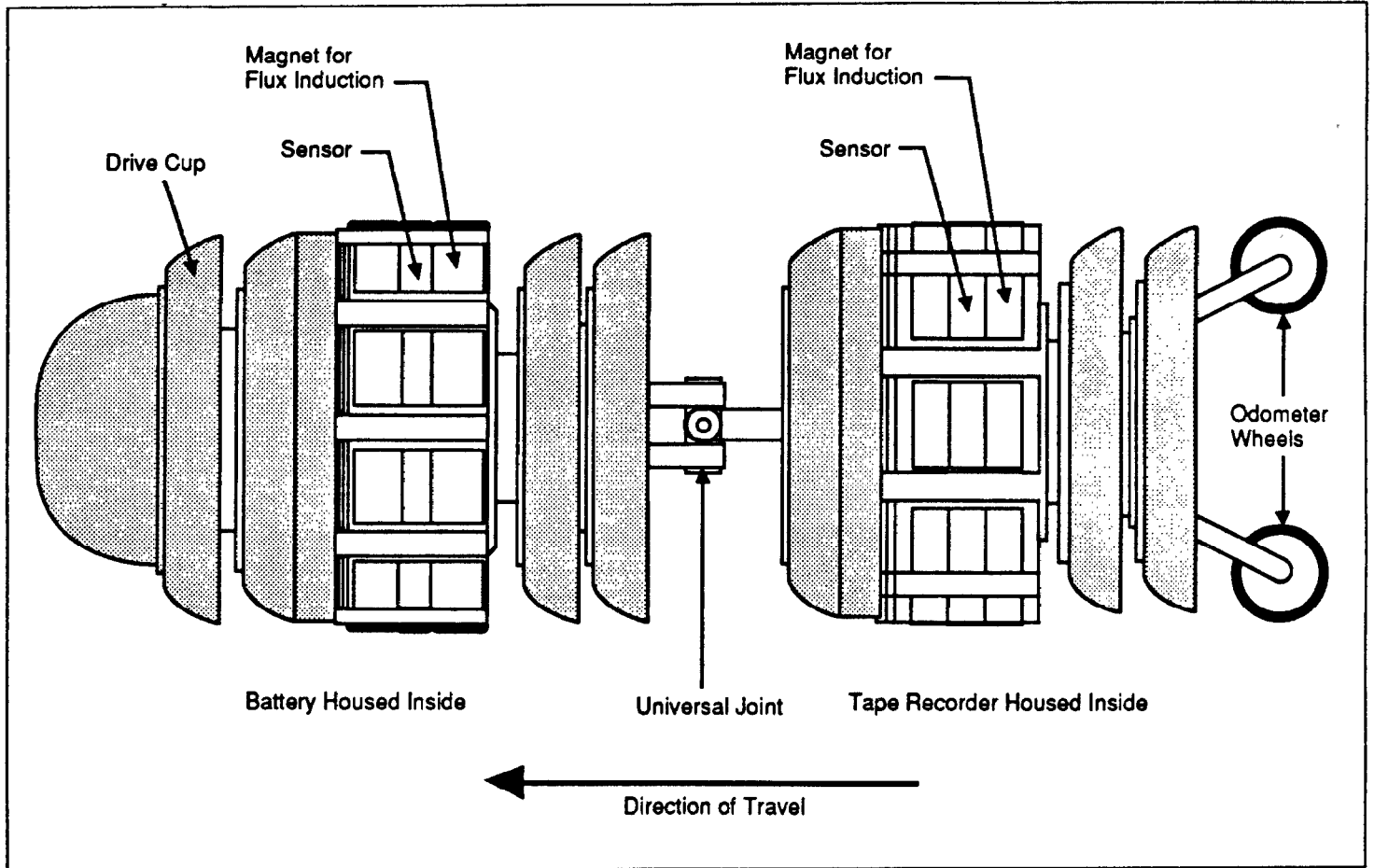
CONCLUSIONS

Smart pigs, in conjunction with other inspection techniques, and the improvements recommended by NTSB, can strengthen the federal strategy to ensure pipeline integrity and safety and minimize incidents and damage. Although aging pipelines are of concern because they have a higher risk of resulting in pipeline incidents, the Reston spill points out that even relatively newer pipelines are subject to failure. Accordingly, there is good reason for pipeline companies to use all available technologies to better ensure the integrity and safety of their pipelines.

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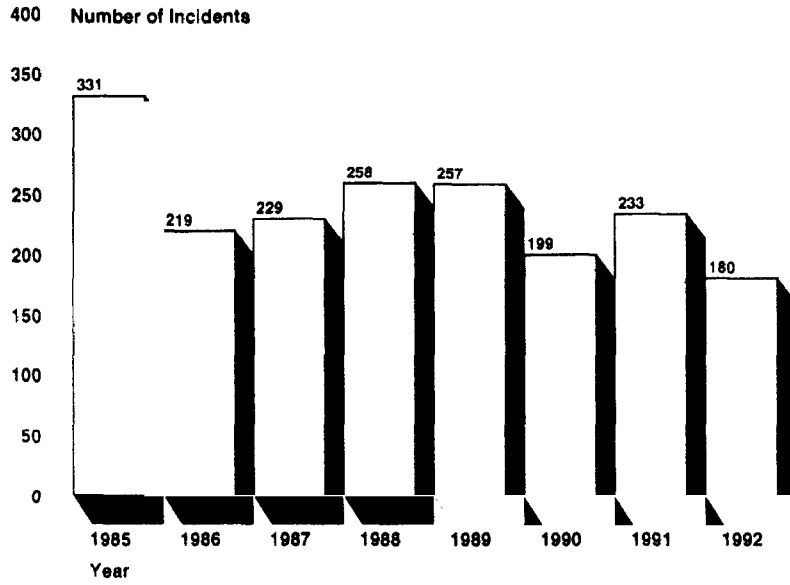
Mr. Chairman, this concludes our testimony. We would be very happy to respond to any questions you or other Subcommittee members might have.

MAGNETIC-FLUX SMART PIG



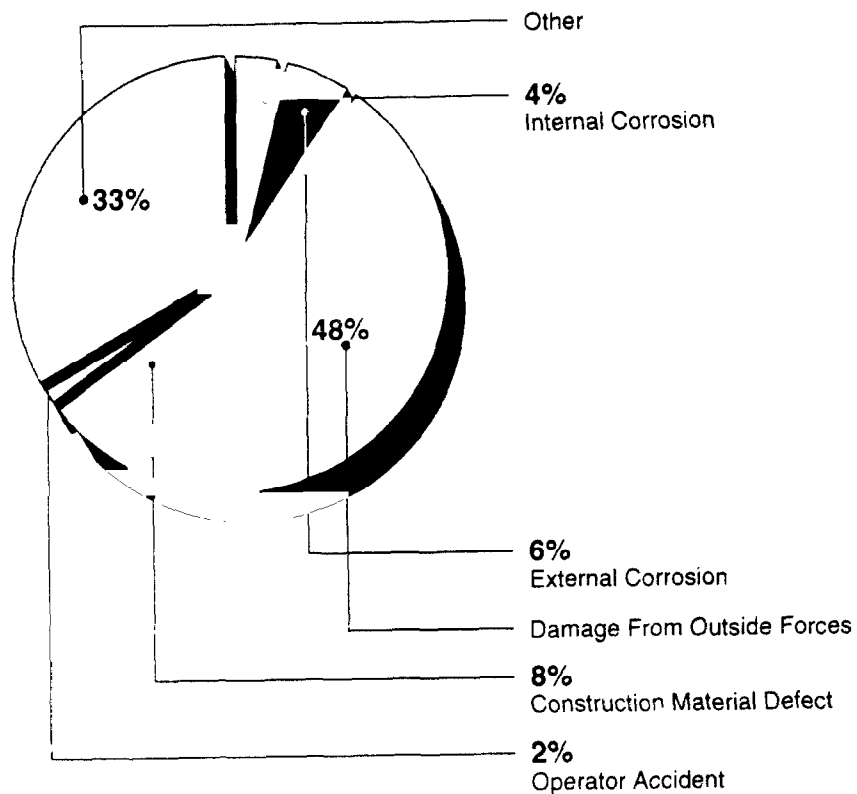
Source: Vetco Pipeline Services.

NATURAL GAS PIPELINE INCIDENTS (1985-92)



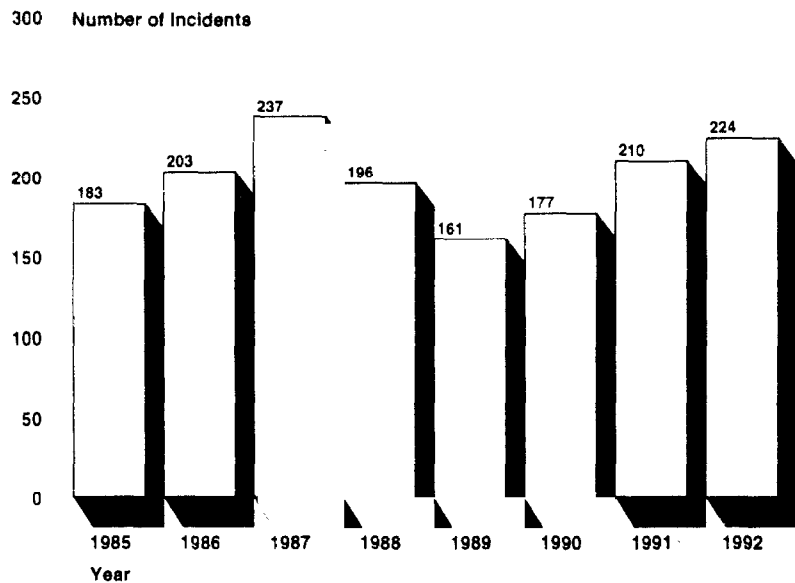
Source: RSPA

NATURAL GAS PIPELINE INCIDENTS BY CAUSE (1992)



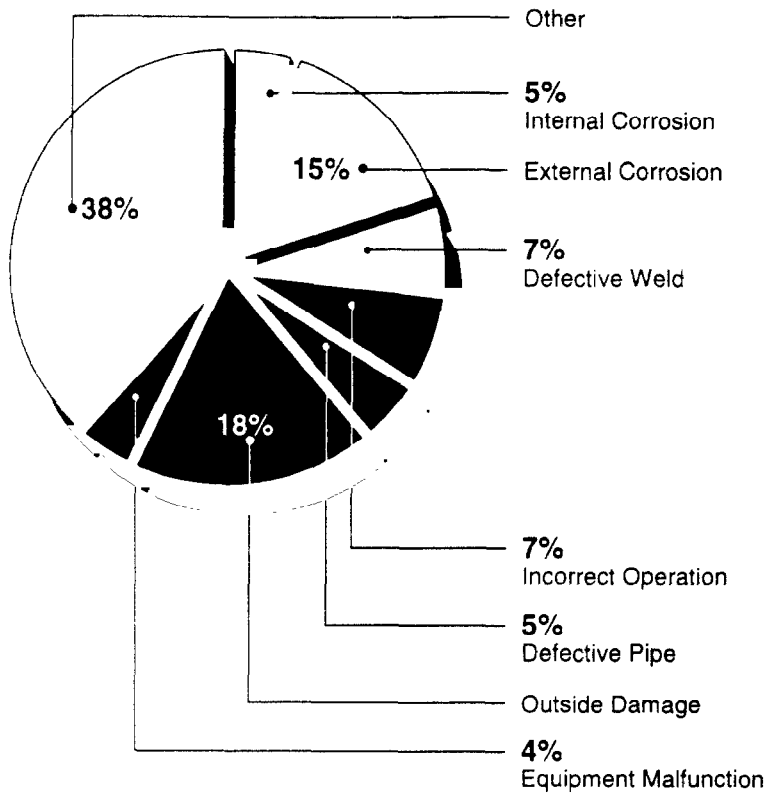
Source: RSPA

HAZARDOUS LIQUID PIPELINE INCIDENTS (1985-92)



Source: RSPA

HAZARDOUS LIQUID PIPELINE INCIDENTS BY CAUSE (1992)



Source: RSPA

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