PPTS OPERATOR ADVISORY: THE INS AND OUTS OF CORROSION RELEASES

Executive Summary

This Advisory reviews corrosion releases in hazardous liquids pipeline facilities and along the pipeline right-of-way (ROW). The numbers reported here are drawn from the Pipeline Performance Tracking System (PPTS) data set from 1999-2012.

Overall Corrosion Trends

A significant reduction (79% reduction from about 130 incidents per year) in the number of corrosion releases has been experienced over the last 14 years, but corrosion remains the second largest cause of all releases and is the leading cause of releases along the ROW.

While external corrosion is still the cause of the most corrosion incidents along the ROW, the reduction in external corrosion releases has been more rapid than the reduction in internal corrosion releases.

There are now more corrosion releases in facilities piping than there are along the ROW because the number of corrosion releases reported on the ROW has dropped and the number in facilities has increased.

Corrosion on the Right of Way

Despite the steady decline in corrosion related releases along the ROW, corrosion is still the leading cause of ROW release incidents in 2012.

There are few large corrosion related releases along the ROW. The majority of corrosion releases, 61%, are less than 5 barrels, only 2% are over 1,000 barrels.

Corrosion in Facilities

Although corrosion is not the leading cause of facility releases (Equipment Failure 53%, Operator Error 17%, Corrosion 16%) it contributes the highest volume. Internal corrosion is responsible for 81% of facility corrosion releases.

Internal corrosion in facilities is confined almost exclusively to facility piping in crude oil service with intermittent or no flow; e.g. relief lines, drain lines, dead legs, etc.

Considerations for Operators

External Corrosion:

- External corrosion is more prevalent under coal tar and tape coat coating, but it needs to be considered and evaluated no matter the coating type, both along the ROW and within facilities, even when the assets have cathodic protection.
- Each type of metal loss in-line inspection tool (smart pig) has strengths and weaknesses. Varying tool type (e.g. alternating a conventional MFL tool with a circumferential MFL tool on successive runs) is an effective strategy for monitoring corrosion of various sizes and shapes along the ROW.

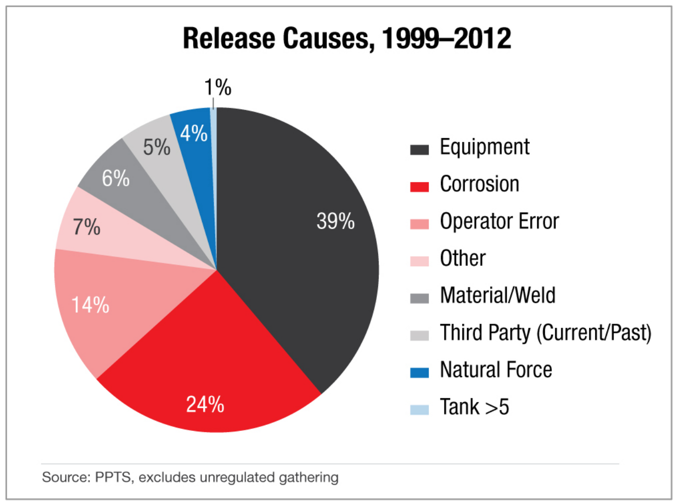
Internal Corrosion:

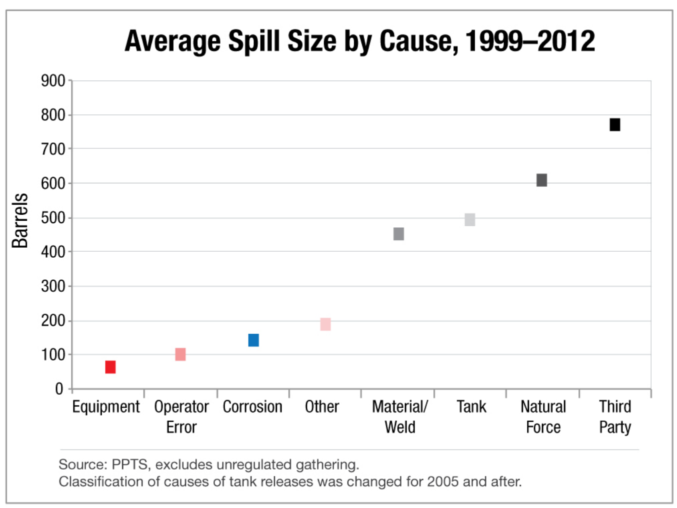
- Some operators have successfully used internal liners for prevention and /or mitigation of internal corrosion, but this would preclude the use of ILI tools.
- Changes in production volumes or throughput in crude oil systems should be carefully monitored to ensure turbulent flow when possible and provide incremental internal corrosion mitigation steps if necessary when turbulent flow is no longer possible.
- Changes in the transported commodity should be monitored so that changes can be made to the internal corrosion mitigation program as necessary.
- Dead Legs in facilities should be removed or isolated from active piping.
- Prevention, mitigation and inspection activities for low flow/intermittent flow lines should be developed.
- Prevention and mitigation can include flushing the line, treating the product, or installing internal liners.

A Note about the Data

Pipeline Performance Tracking System (PPTS) is a voluntary reporting database for hazardous liquids pipeline operators. Participants report all hazardous liquid releases greater than 5 gallons and all releases to water or that result in injury, death, fire or explosion. Participants in PPTS operate about 75% of the hazardous liquid pipeline mileage under the jurisdiction of the Pipeline and Hazardous Materials Safety Administration (PHMSA). In addition, PPTS participants report releases from terminal and other assets that are not reportable to PHMSA.

Until 2007, incidents that were less than 5 barrels and did not result in a death, injury, fire or explosion were reported on the "short form" which did not collect information on internal versus external corrosion or other details. For this reason, when looking at the data in detail, a smaller data set (releases from 2007-2012) is used in some instances rather than the overall data set (1999-2012). Each graph in this advisory contains a note that indicates which data set was used.



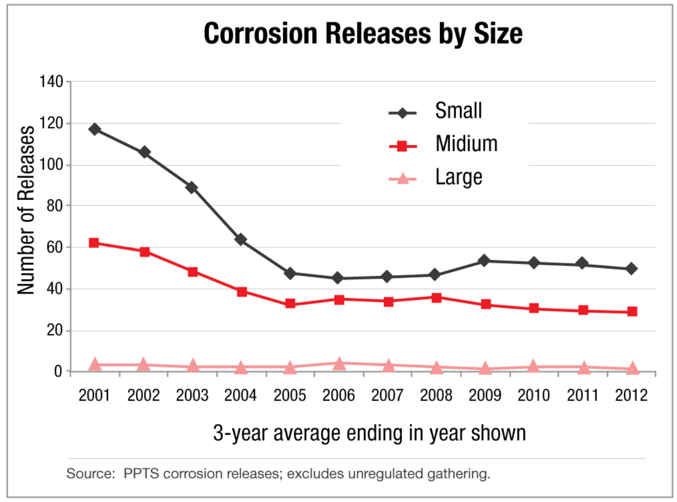


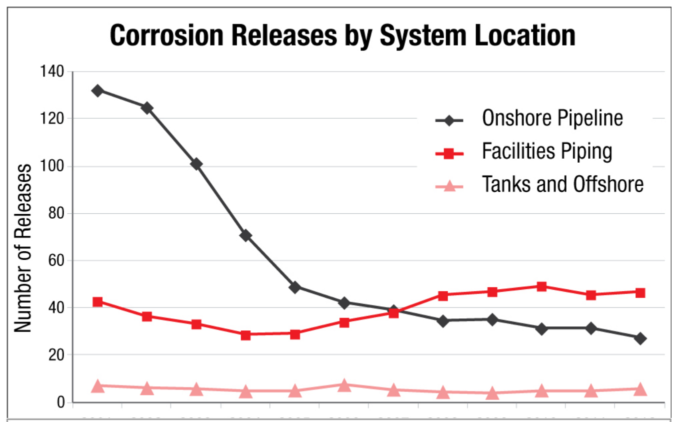
Overall Corrosion Trends

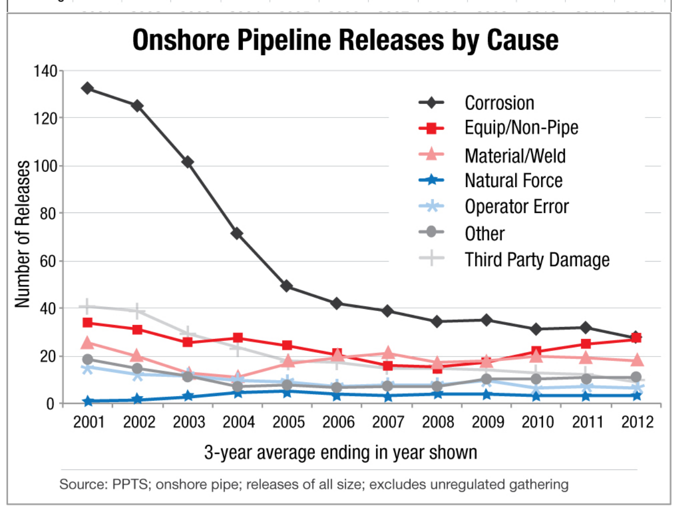
Numbers: Corrosion is a major cause of releases from liquid pipelines. Over the past 14 years, corrosion has caused 24% of all incidents reported to PPTS. Only equipment failure, with 39%, has a higher percentage share of overall incidents. When looking exclusively at releases along the ROW, corrosion is the leading cause of incidents over this time period, causing 42% of ROW releases. It is important to note, however, that the corrosion releases occurring on PPTS operators' onshore pipelines did NOT cause any fatalities, explosions, or fires. While one injury is too many, only two incidents out of 881 resulted in an injury.[1]

Volumes: Although there have been a few large corrosion releases, most corrosion releases are small in volume compared to other cause types. Half of corrosion releases are less than 2 barrels. In fact, only equipment failure and operator error have smaller average spill sizes. There has been a downward trend in corrosion releases of all sizes with the biggest decline in small releases of less than 5 barrels. Medium size releases (greater than 5 and less than 1,000) have also been on a decline over the years. Large corrosion releases (over 1,000 barrels) have been rare since the start of PPTS and have declined throughout the past decade. While there is still room for improvement, progress has been made in preventing corrosion releases of all sizes.

Similar to other release cause categories, the total number of corrosion incidents is declining. The significant drop in corrosion releases along the ROW is attributed to the suite of strategies that operators utilize to prevent corrosion and maintain the integrity of the pipelines. Such strategies include in-line inspection technology (smart pigging), pipeline repairs, and other aspects of integrity management programs (e.g., regular use of cleaning tools, corrosion inhibitors, cathodic protection, etc.) On the other hand, facilities appear to have an increasing number of corrosion releases in recent years. Beginning in 2007 corrosion releases in facilities began to outnumber those along the ROW and that has been the trend through 2012.



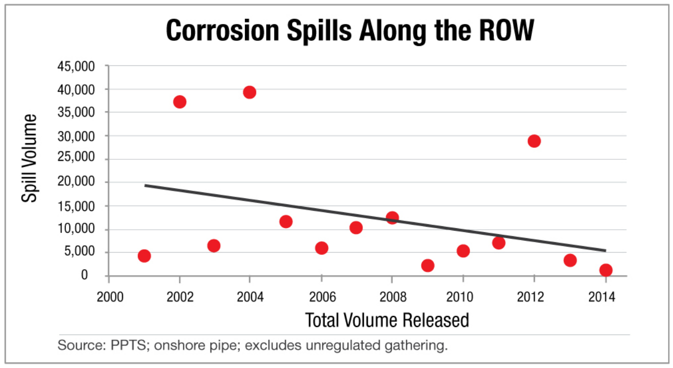




[1] There was one additional external corrosion release in 2004 on a non-PPTS operator HVL line that resulted in 12 injuries to the general public.

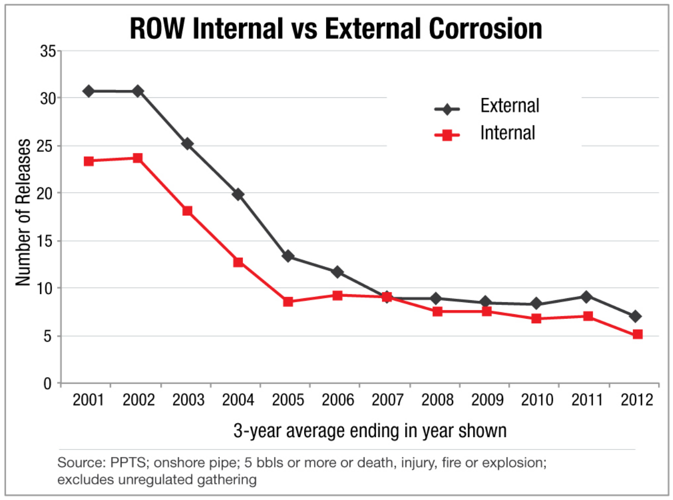
Corrosion: Two Distinct Types, Two Distinct Places

As with all releases, location matters. Incidents occurring along the ROW and incidents in facilities should be looked at separately for a variety of reasons including differing effects of the release and unique mitigation strategies. Any serious look at corrosion releases will indicate a need to break the category into the two distinct types: external and internal corrosion. Although in-line inspection tools (smart pigs) can identify both types in mainline pipelines, each corrosion type has unique contributing factors and prevention and mitigation strategies. The main example of this, as discussed later in this document, is the effect of the transported commodity characteristics on internal corrosion.

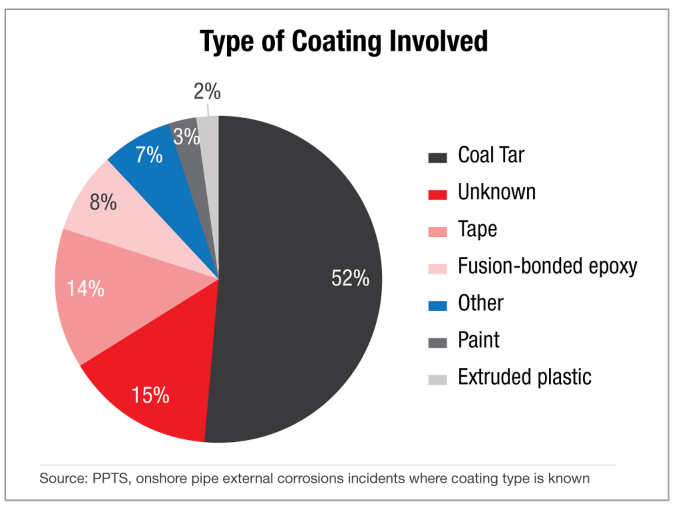


Corrosion Along the Right of Way

As previously mentioned, corrosion as a release cause along the ROW (facility type: Onshore Pipeline) has seen a significant drop of 79% over the past 14 years. When reviewed over a three year average, corrosion releases and equipment releases are now roughly equal in number.



In addition to the dramatic decrease in number, corrosion releases are generally smaller in volume than those in the past. Overall volume is trending downwards, with 2012 having the lowest volume due to corrosion on the ROW since PPTS started collecting data. A single large external corrosion release in 2010 drove the upward spike in the volume, but the past two years have seen a return to the previous trend. In 2012 there were no corrosion releases along the ROW greater than 1,000 barrels.



In or Out?

External: Along the ROW, is internal or external corrosion the bigger issue? PPTS did not collect the location data for incidents under 5 barrels until 2007 so the overall data set available to answer this question is smaller than the total dataset (as reflected in the smaller numbers in the graph ("ROW Internal vs. External Corrosion"). The number of external corrosion incidents formerly outnumbered the number of internal corrosion incidents, but the decline in the external corrosion incidents has caused the numbers per year to converge. The numbers of external and internal corrosion releases greater than 5 barrels along the ROW are now approximately equal. When looking at incidents of all size from 2007-2012, the trend remains the same - external corrosion releases of all sizes along the ROW have fallen from 67% of all corrosion releases in 2007 to 46% in 2012.

External corrosion affects pipelines of all commodity types. The two most important tools in the fight against external corrosion are coating and cathodic protection. Coating type and condition are the most important factors that influence external corrosion. Pipelines without coating were involved in 20% of the external incidents along the ROW. For incidents where the pipe was coated and coating type was known, the coating type most often involved in external corrosion incidents was coal tar, followed by tape. This pattern mirrors industry construction patterns and industry coating practices over time. Of all coating types, more miles of coal tar coating were installed and are currently in service. Both coal tar and tape are known to be less effective than fusion-bonded epoxy (FBE). FBE has been in use since the early 1990's and is the most common coating type used on new pipelines today. FBE has proven effective at preventing external corrosion.

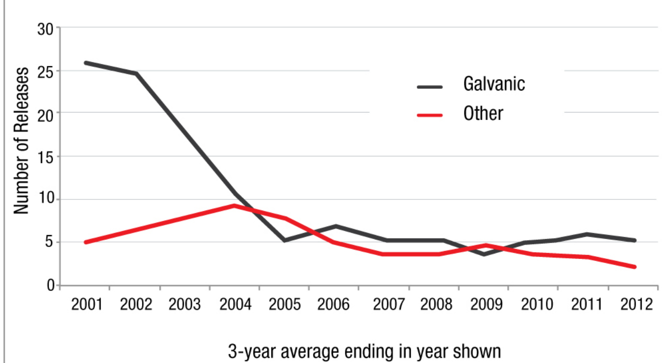
In at least 25% of the releases, shielding, tenting or disbonded coating was noted as a factor in the release. In 31% of releases "I don't know" was the answer given to the question of whether coating condition was a factor in the release. This indicates that coating condition may be a factor in more than the 25% of releases reported. 90% of the releases occurred on piping that had cathodic protection, reinforcing the point that coating and cathodic protection do not always adequately protect against external corrosion and that ongoing inspection programs and follow up activities are crucial for overall integrity management.

Only 10% of the external corrosion releases along the ROW occurred at or near a cased crossing, however 6 of these 28 incidents occurred in the past two years. It is unclear why there is a spike in recent years in occurrences at cased crossings, but these crossings should be monitored carefully. Shorted casings which prevent cathodic protection from reaching the pipe and casings that have filled with water tend to set up an ideal corrosion environment and are two conditions to look for when performing inspections and maintenance at cased crossings.

An Operator:

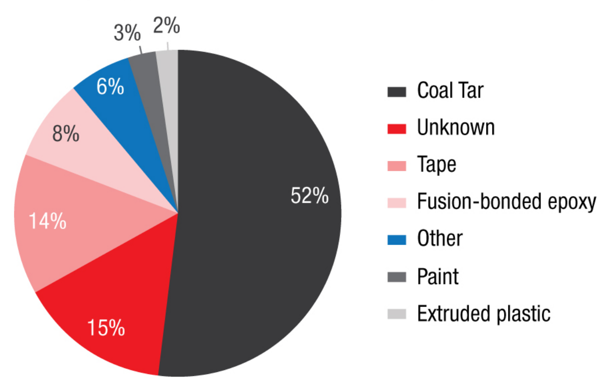
"Different types of smart pigs have different strengths and limitations. We found that conventional MFL missed areas of longitudinally oriented metal loss after a release from one of these corrosion areas on a pipeline that had seen multiple conventional smart pigs. Running circumferential metal loss tools allowed us to find corrosion that had been missed in previous smart pigs runs and repair the areas before they had a chance to grow to failure."

Type of External Corrosion



Source: PPTS; onshore pipe; 5 bbls or more or death, injury, fire or explosion; excludes unregulated gathering

Coating Type Involved in Onshore Pipe Releases



Source: PPTS, onshore pipe external corrosions incidents where coating type is known

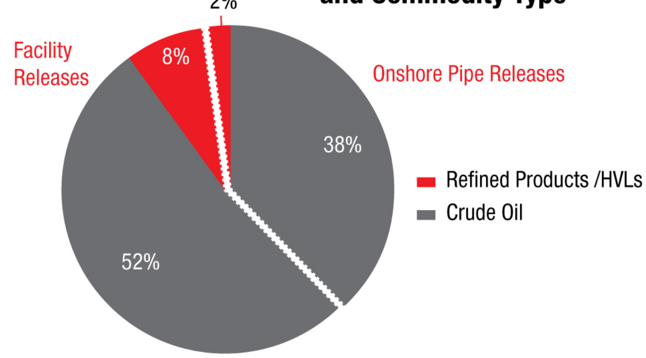
Galvanic corrosion, which occurs when two dissimilar metals touch in the presence of an electrolyte making one metal corrode faster than it would otherwise, continues to be the corrosion type involved in most releases. There has been a 90% reduction in the number of releases on the ROW attributed to this type of corrosion since the days before implementation of the Integrity Management Rule. This reduction has moved galvanic corrosion closer to the combined numbers of other types of external corrosion including stress corrosion cracking, selective seam corrosion and atmospheric corrosion.

Internal: Corrosion inside the pipe is different than outside the pipe. Because of the characteristics of internal corrosion and the diverse properties of different hydrocarbons, the commodity transported is an important factor in the potential for internal corrosion. In fact, in both facilities and along the right of way, internal corrosion is almost exclusively a crude oil issue. This is not due to the crude oil itself, but because crude oil is more likely to carry water and other potential contaminates (e.g., sediment, paraffins) than refined products or HVLs. Of the 204 total internal corrosion incidents along the ROW during the 1999-2012 period, 105 of the pipelines had some sort of corrosion prevention or mitigation in place. This indicates that internal corrosion is also a complex issue.

In 2009, a new question was added to the PPTS release survey to try to determine if flow rate is a factor in internal corrosion releases. As suspected, of the 52 internal corrosion releases in 2009-2012, 31 had intermittent flow and 7 had no flow. In intermittent flow and no flow conditions, water and other contaminates (e.g., sediment, paraffins) can drop out of the hydrocarbon and collect against the pipe wall where corrosion begins unless preventative steps are taken.

Low spots are another area where water can drop out of the transported commodity and internal corrosion is more likely. There are different methods to attack the problem including: routine maintenance pigging, internal liners, corrosion inhibitor, flushing of lines that see infrequent flow, monitoring coupons or other devices, sampling and condition monitoring through repeat inspections.

Internal Corrosion Releases by Location and Commodity Type



Source: PPTS, Excludes unregulated gathering, includes all incidents where internal vs external was specified.

Operator Experience: Polymer Liners for mitigation on lines with Internal Corrosion issues.

While not appropriate in all circumstances, some operators have found that internal polyethylene liners are an effective means to mitigate internal corrosion. There are tradeoffs involved such as loss of some throughput and a requirement to hydrostatic pressure test for integrity assessment instead of in-line inspection (ILI). This method is suitable for both pipelines and facility piping.

An Operator:

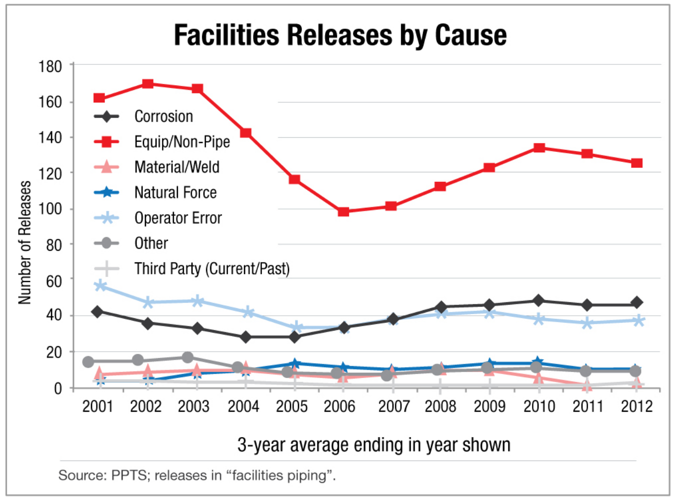
"In my experience, if you have one internal corrosion release on a mainline, it may be just your first one. So we figure it out: check for low spots again, check the flow, check the commodity characteristics, and increase the schedule for cleaning pigs and other mitigation."

Corrosion in Facilities

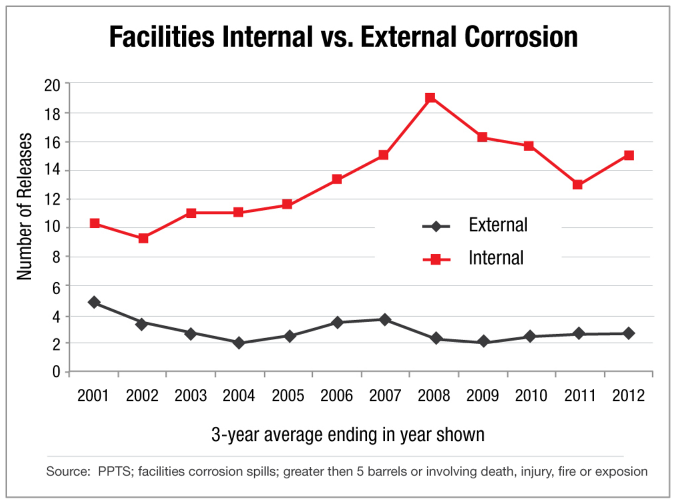
Unlike spills along the ROW, corrosion is not the leading cause of facility releases. That distinction belongs to equipment failure (53%), followed by operator error (17%) and then corrosion (16%). However, unlike spills along the ROW, corrosion related spills in facilities account for the largest average spill volume of all release types in facilities. In addition, both the number and size of corrosion related spills in facilities are on an upward trend. In facilities, external corrosion causes a smaller percentage of corrosion releases than internal corrosion.

External: The chart "Facilities Internal vs. External Corrosion" includes only spills larger than 5 barrels due to the reporting requirements that existed prior to 2007, but the same pattern holds when looking at all facility corrosion releases from 2007-2012. External corrosion is not as big of an issue as internal corrosion in facilities. Commodity type does not affect the number of external corrosion releases. Most of the external corrosion releases happened on pipe or pipe seams although there were a few that involved pumps, meter/provers and threaded or other fittings. There is no clear pattern or trend that can be seen for external corrosion releases from the facility data as far as a particular coating type involved or any other parameter collected. As with most facilities issues, there are a wide variety of contributing factors to external corrosion releases and multiple methods to address the issues.

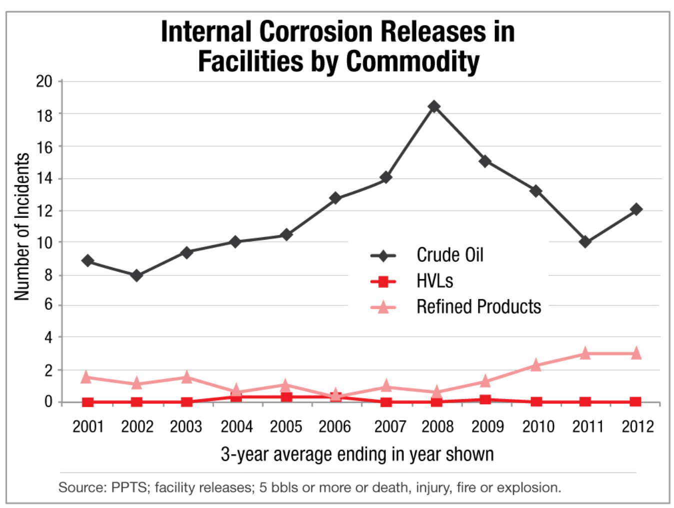
Internal: Internal corrosion continues to be the bigger issue in facilities. As is the case along the ROW, the vast majority of instances are found in crude oil facilities. For the 312 facility releases identified as being caused by internal corrosion, 89% (268 incidents) occurred in a crude oil facility. Since crude oil is more likely to contain water and other contaminants that can cause or contribute to internal corrosion, more attention to internal corrosion is needed when dealing with crude oil facilities. In 2009, a question on flow characteristics for internal corrosion releases was added to PPTS. For the 30 internal corrosion releases that occurred from 2009-2012 in refined product service, all were in areas of intermittent or no flow. Only 6 of 111 internal corrosion incidents in crude oil service during the same time period occurred on pipe that had continuous flow. Combined, over 96% of internal corrosion incidents occurred in areas of intermittent or no flow.



Source: PPTS; releases in "facilities piping".



Source: PPTS; facilities corrosion spills; greater then 5 barrels or involving death, injury, fire or exposion



Source: PPTS; facility releases; 5 bbls or more or death, injury, fire or explosion.

This further illustrates the point detailed in the ROW section above that water and other contaminants are likely to drop out in areas of low or no flow, resulting in areas where internal corrosion can occur. Consequently, operators should consider removing or draining and isolating dead legs that serve no present purpose and implementing preventative and mitigative measures for lines that are active but see intermittent or low flow. Preventative and mitigative measures for these lines can include flushing the lines on regular intervals and/or the use of corrosion inhibitors. Most importantly operators should have some type of ongoing inspection or monitoring program for these facility lines. In 24% (74 of 312 incidents) of the internal corrosion facility releases in PPTS, the operator had some sort of internal corrosion mitigation in place so a combination of mitigation and inspection is prudent. Since facility piping is usually not piggable by conventional smart pigs, a creative approach is needed for a facilities inspection program. Tools such as spot ultrasonic testing, tethered tools, specialty in-line inspection devices, bi-directional tools, External Corrosion Direct Assessment, and guided wave ultrasonic testing are all techniques that can be used in various ways on facility piping to provide a picture of the integrity of the facility piping. There are improvement opportunities in the area of facility corrosion, but it is a complex issue that requires a varied approach to tackle.

Considerations for Operators

External Corrosion

- External corrosion is more prevalent with certain types of coatings but needs to be considered and evaluated no matter what commodity is transported or the coating type, both along the ROW and within facilities.
- In-line inspection using metal loss tools continues to be the preferred assessment method for detecting external corrosion for mainline piping.
- Different metal loss tools have different strengths and weaknesses. Consider alternating metal loss tool types (e.g., MFL vs. CMFL) to get a full picture of metal loss in the system.
- For facility piping and other lines that cannot be easily pigged by traditional methods, there are a variety of technologies for assessment of external corrosion including: tethered tools, bi-directional tools, robotic inspection, External Corrosion Direct Assessment, and guided wave ultrasonic testing.
- Facility piping supports or other metal to metal contact may increase the potential for external corrosion. Use of non-metallic separation barriers (such as high density polyethylene I-rod) can mitigate the potential for external corrosion at pipe supports and other metal-to-metal contact points. Inspection of these contact points during atmospheric inspection is key. Use of adjustable supports will facilitate effective inspection of the bottom of pipe at the support location.

Internal Corrosion

- Some operators have successfully used internal liners for prevention and/or mitigation of internal corrosion, but this technique precludes the future use of ILI tools.
- Changes in production volumes or throughput in crude oil systems should be carefully monitored to ensure turbulent flow when possible and provide incremental internal corrosion mitigation steps if necessary when turbulent flow is no longer possible.
- Changes in the transported commodity should be monitored so that changes can be made to the internal corrosion mitigation program as necessary. This applies for crude and products facilities. The following should all trigger an evaluation of internal corrosion mitigation plans:

    - A change to a crude with a higher BS&W count;
    - Starting to take product from a barge offloading facility;

  - Commodity from a different source, and
  - Changes in product quality.

- For intermittent, low or no flow lines, particularly in crude systems, the first step is to identify them. If possible, reconfigure the pipeline or facility piping to either increase flow or remove the no flow segment altogether. If that is not possible, then it may be necessary to take a series of steps such as flushing the line or treating the product in it with corrosion inhibitors in a carefully designed program that considers different corrosion mechanisms and appropriate intervals for treatment, and of course, inspecting the identified segment at defined intervals.
- Since facility piping typically is not piggable, a non-destructive and non-intrusive testing method such as external Ultrasonic Testing (UT) can be used. Also, tethered tools, bi-directional tools, robotic inspection, Internal Corrosion Direct Assessment, and guided wave ultrasonic testing can be used to various degrees in facility piping.
- API 570, Piping Inspection Code, and API RP 2611, Terminal Piping Inspection are additional references for integrity inspections of facility piping.

The following NACE International documents can be consulted for more information on corrosion related topics.

External Corrosion

- SP0169-2013 Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- SP0207-2007 Performing Close-Interval Potential Surveys and DC Surface Potential Gradient Surveys on Buried or Submerged Metallic Pipelines
- TM0109-2009 Aboveground Survey Techniques for the Evaluation of Underground Pipeline Coating Condition
- SP0200-2008 Steel-Cased Pipeline Practices
- 35103 External Stress Corrosion Cracking of Underground Pipelines (would there be interest in converting to a standard practice?)
- 35110 AC Corrosion State-of-the-Art: Corrosion Rate, Mechanism, and Mitigation Requirements (TG 430 is developing a draft standard on AC corrosion)

Internal Corrosion

- SP0106-2006, Control of Internal Corrosion in Steel Pipelines and Piping Systems

Integrity Assessment for Corrosion

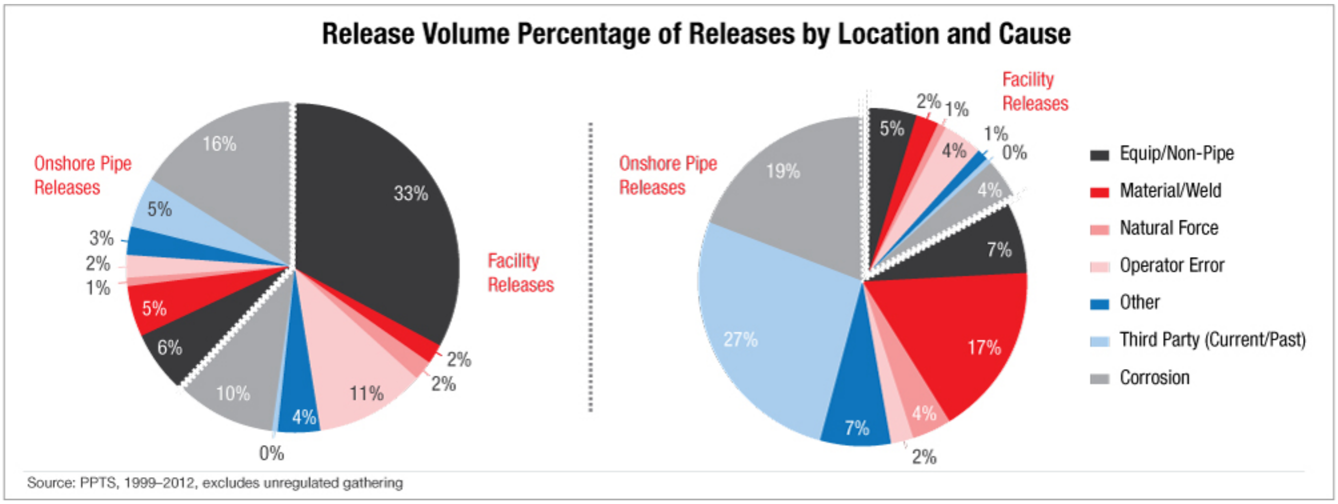
- SP0102-2010 (formerly RP0102), In-Line Inspection of Pipelines
- ANSI/NACE SP0502-2010 Pipeline External Corrosion Direct Assessment Methodology
- SP0208-2008 Internal Corrosion Direct Assessment Methodology for Liquid Petroleum Pipelines
- SP0204-2008 Stress Corrosion Cracking (SCC) Direct Assessment Methodology

Corrosion Management

- Guide to Improving Pipeline Safety by Corrosion Management

Appendix – Graphs of Release Numbers and Size by Location and Cause

The following graphs present an overall picture of the differences between Facility releases and Onshore Pipe releases both in numbers and volumes. Cause is broken up by location to illustrate the different threats in facilities versus the ROW and the different impact (release volume) that the different threats pose in each location.



PPTS Operator Advisory	Date	Number
Corrosion: Just the Facts	April 2003	2003–1
Internal Corrosion and Crude Oil	April 2003	2003–3
Overview of Incidents Occurring on Facilities Piping and Equipment	June 2005	2005–3
Facilities Piping and Equipment: Focus on Items Involved and Causes of Incidents	June 2005	2005–4
Crude Oil Releases, 1999-2004	Sept 2006	2006–4
New Findings on Releases from Facilities Piping	October 2009	2009–5

Find this and other Advisories drawn from the hazardous liquid industry's Pipeline Performance Tracking System at www.api.org/ppts

The hazardous liquids pipeline industry undertook a voluntary environmental performance tracking initiative in 1999, recording detailed information about spills and releases, their causes and consequences.

The pipeline members of the American Petroleum Institute and the Association of Oil Pipe Lines believe that tracking and learning from spills improves performance, and demonstrates the industry's firm commitment to safety and environmental protection by its results. This is one in a series of Advisories based on the Pipeline Performance Tracking System, "PPTS."

The standards and documents referenced herein are intended solely for reference purposes. This reference does not make any claims of association, responsibility or ownership of those documents.

NOTE: The "Considerations for Operators" in this document represent the experience of a limited number of subject matter experts from a variety of liquids pipelines operators. They were not developed under the consensus process prescribed by the American National Standards Institute and do not represent a Standard or a Recommended Practice of the API or its member companies.