API American Petroleum Institute

2010-2024

OPERATOR ADVISORY

LIQUID FACILITIES PIPING & EQUIPMENT

OPERATOR ADVISORY 2025-1

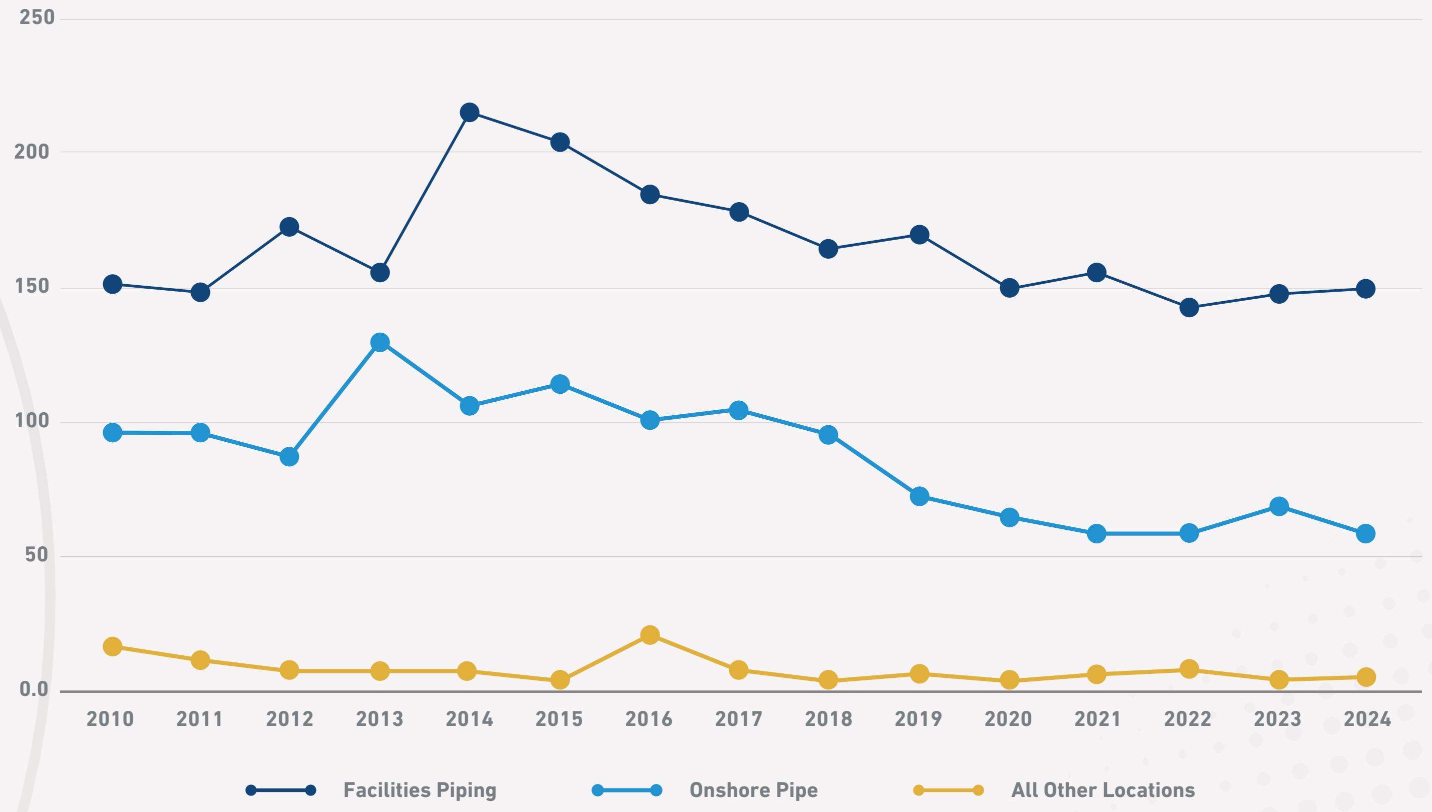
OVERVIEW

For the past several decades, the petroleum pipeline industry has undertaken a voluntary performance tracking initiative, recording detailed information about spills and releases and analyzing data on these incidents to better understand their causes and consequences. Industry members of the American Petroleum Institute (API) and the Liquid Energy Pipeline Association (LEPA) believe that tracking and learning from incidents that lead to releases from pipeline facilities is a core foundation of Pipeline Safety Management Systems (PSMS) and continuous improvement across the industry, thus demonstrating the industry's firm commitment to public safety and environmental protection. This advisory bulletin utilizes information captured in PHMSA's accident liquids data to analyze the leading causes of facility piping releases and provide recommendations for operational and integrity management improvements to industry operators.

Understanding Facility Releases

Industry accident data collected since 2010 indicates that the greatest number of releases continue to occur at facilities (versus onshore pipeline right of way incidents). While recent data shows a continuing declining trend to a lower number of facility incidents, this advisory addresses continuous improvements in pipeline facility integrity programs and approaches operators should consider as the industry continues to better understand the causes of facility releases and drive for zero incidents.

FIGURE 1. PIPING INCIDENTS BY PIPELINE SYSTEM AND YEAR



Facility releases are mostly occurring from pipe and operating equipment that is collectively referred to as "facility piping." Facility piping accounts for 80% of all facility releases. While the released volume is usually very small (<=5 barrels, or BBLs) and do not impact people or the environment, these incidents continue to represent a majority of the liquids pipeline industry total.

FIGURE 2. PHMSA HAZARDOUS LIQUID FACILITY RELEASES BY TYPE

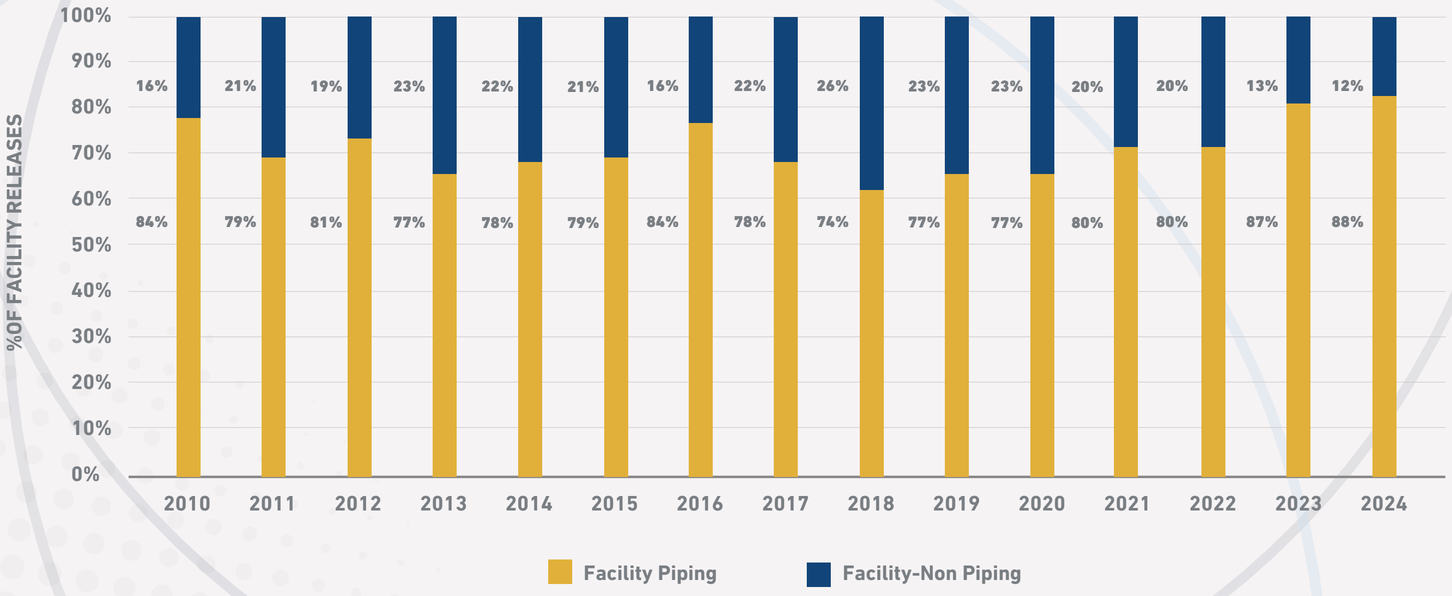


FIGURE 3. 2010-2016 PIPING INCIDENTS BY PIPELINE SYSTEM

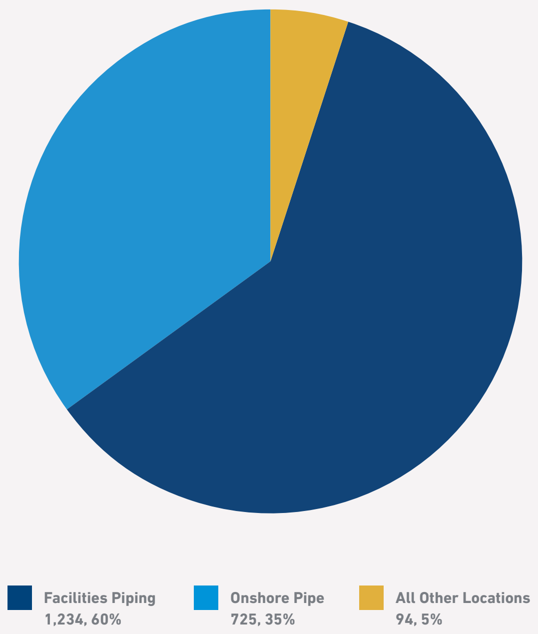
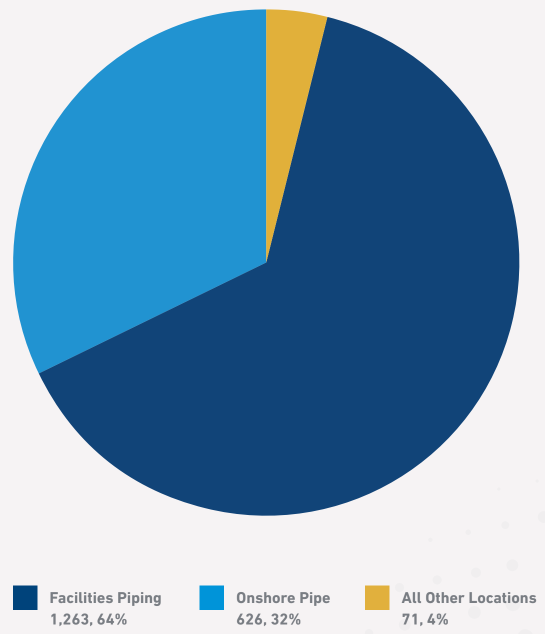


FIGURE 4. 2017-2024 PIPING INCIDENTS BY PIPELINE SYSTEM



[1] Facility piping includes pipe, valves, pumps, and other equipment at liquids pipeline operating facilities (i.e., booster/pump stations, breakout tank farms, etc.) such as meters/provers, sumps, tubing, launchers and receivers for in-line inspection systems, and filters, strainers, and separators (see Figure 6 below). The term "facility piping" was addressed in PPTS Advisory Bulletin 2009-5 and was established as a means to assess facility releases in a comprehensive manner and allow for comparative analysis of incident frequency and causes.

FIGURE 5. 2010-2024 RELEASES REPORTED ON FACILITIES PIPING

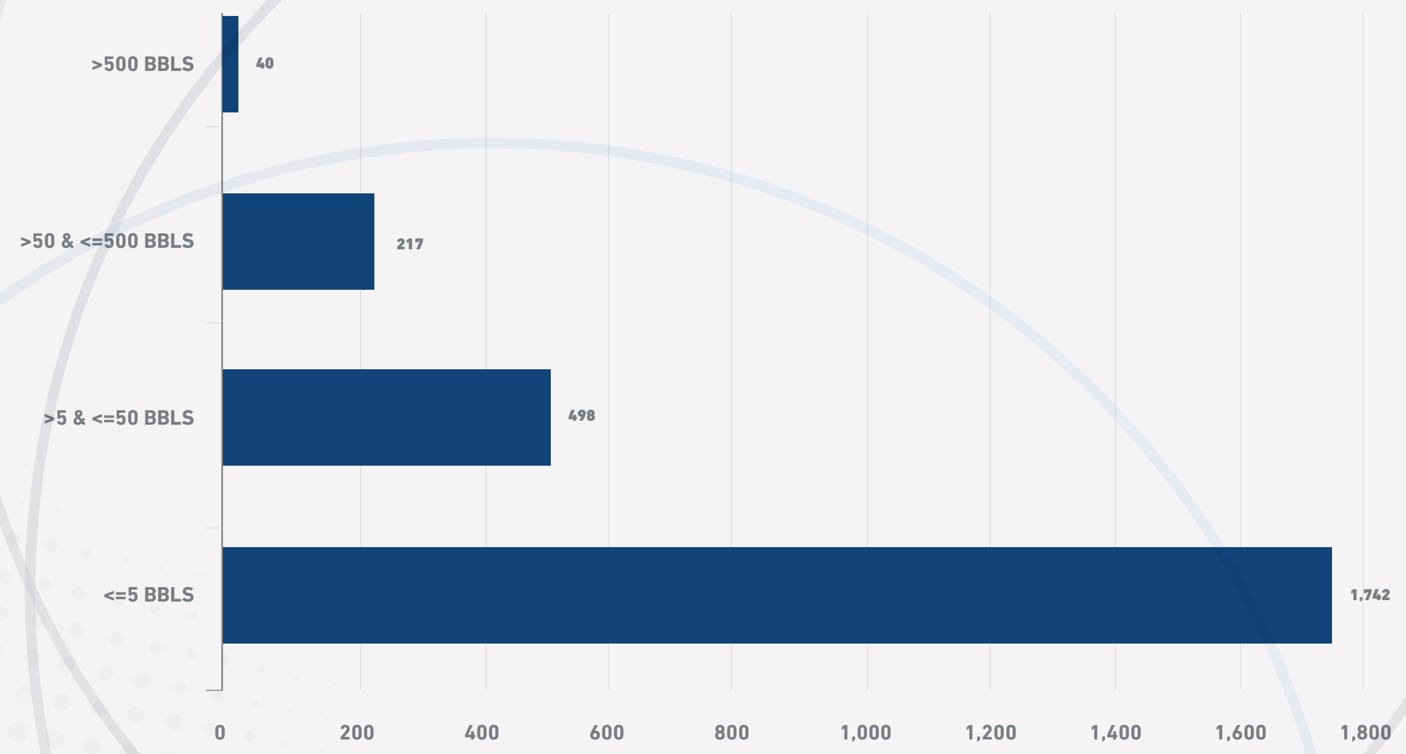
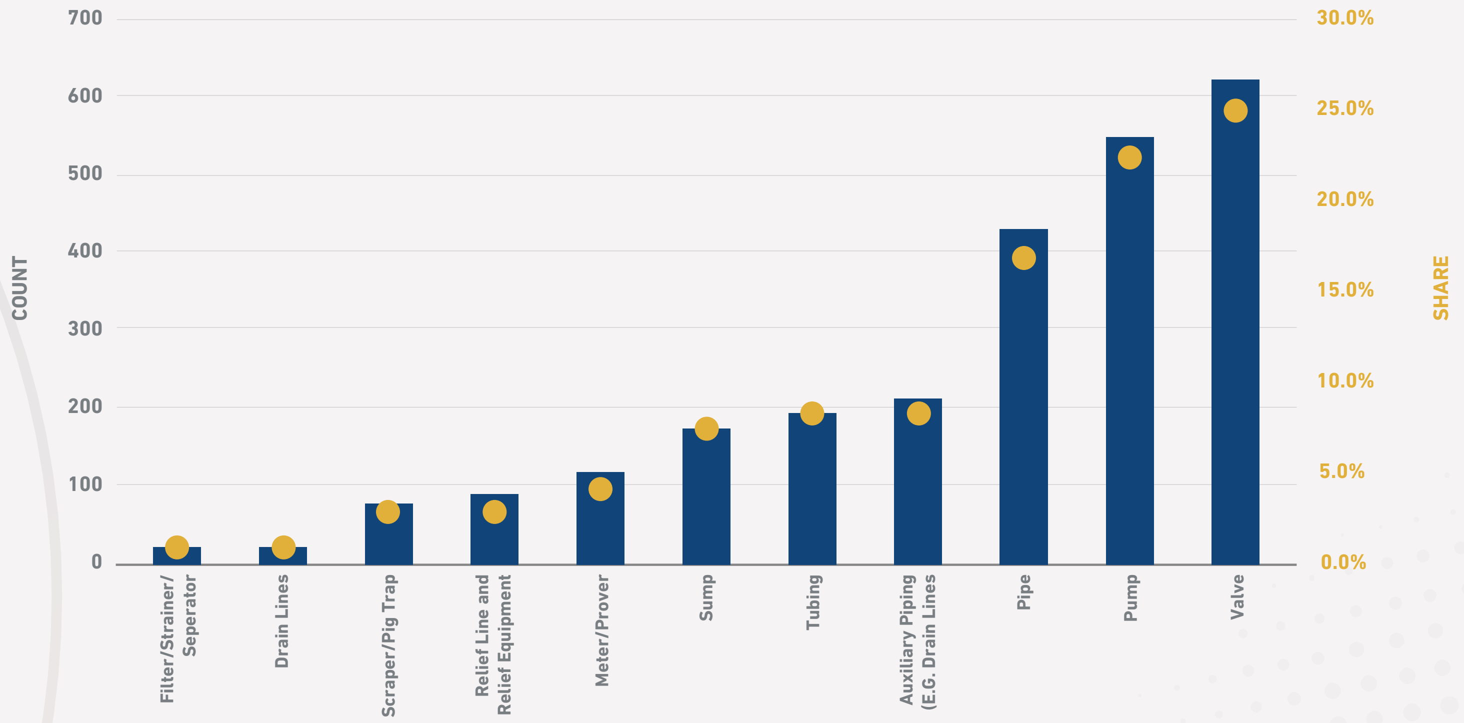
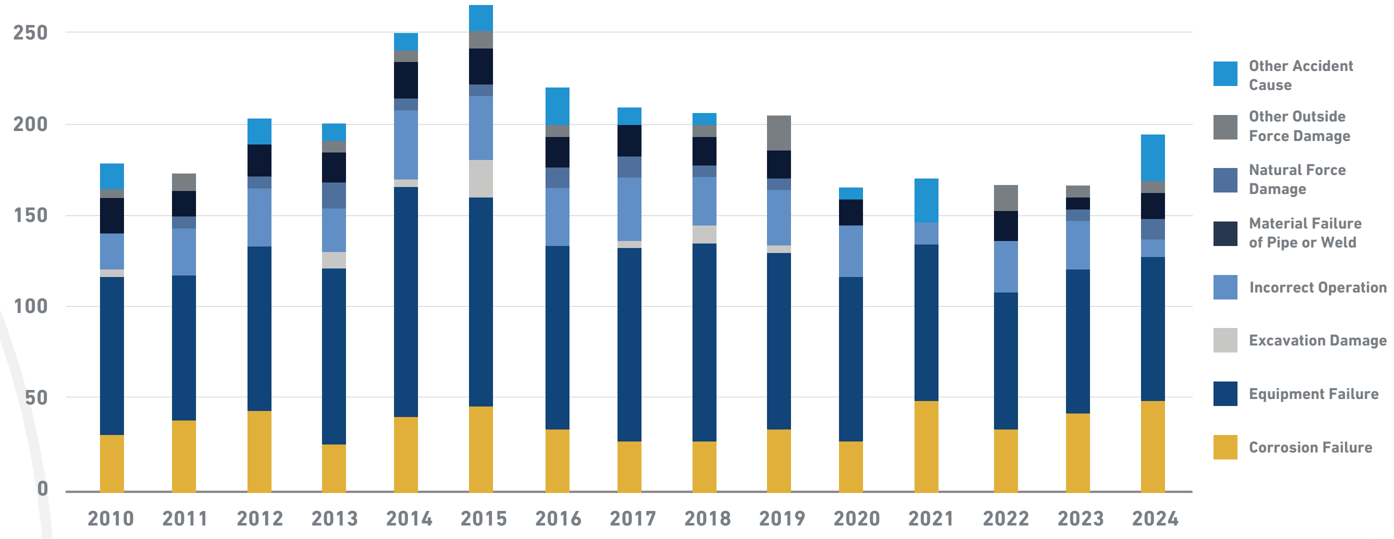


FIGURE 6. 2010-2024 RELEASES REPORTED ON FACILITIES PIPING



The number of releases due to equipment failures, incorrect operation, and corrosion has remained relatively constant since 2010. The top four (4) facilities piping items failing were valve, pump, pipe, and auxiliary piping including drain lines. These four items accounted for 73% of all facilities piping incidents during the period 2010-2024. The leading causes of facility piping releases are equipment failure, corrosion, and incorrect operation (see Figure 7).

FIGURE 7. 2010-2024 FACILITY PIPING RELEASES BY CAUSE AND YEAR



The details presented in the sections above provide a broad view of facility piping incidents based on industry data. The sections that follow below are a more detailed analysis of the various failure modes and mechanisms that have occurred within pipeline facilities and facility piping.

Valve Results:

Valves accounted for the largest number of facility piping incidents, at 617 of the 2,497 (or 25%) the incidents reported. The leading cause of incidents involving valves was equipment failure related to the valve operation. As shown in Figure 9, the highest proportion of failures regarding the type of valve is attributed to relief valves at 38%. Across all valve types, Non-threaded connection failure and Malfunction of Control/ Relief Equipment accounted for 33% and 29% of the equipment failures that led to an incident. Seal (not pump seal) or Packing and O-Ring accounted for 62% and 29% of Non-threaded connection failures respectively. Additional factors contributing to these failures include manufacturing defects and improper installation.

FIGURE 8. 2010-2024 VALVE RELEASES DUE TO EQUIPMENT FAILURES BY CAUSE

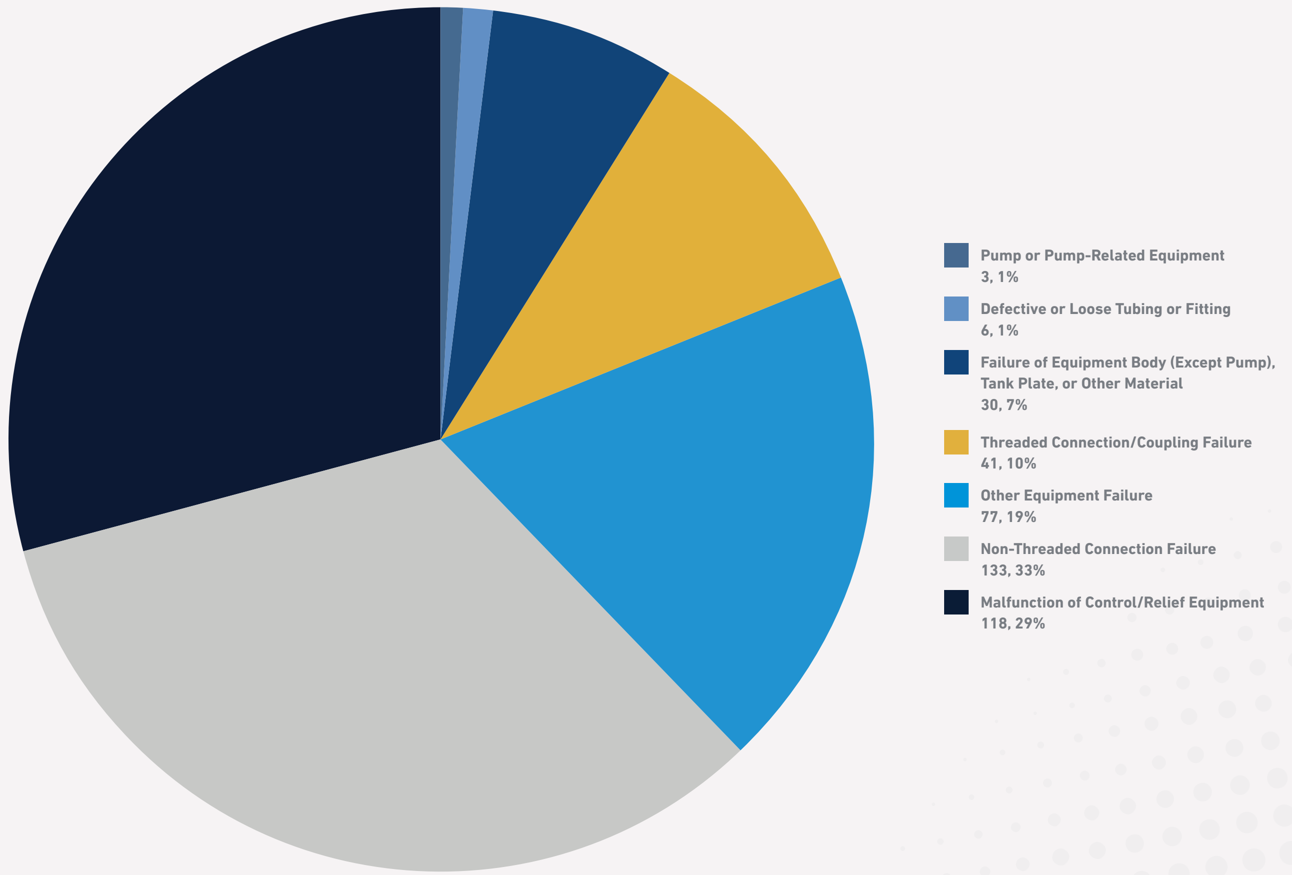
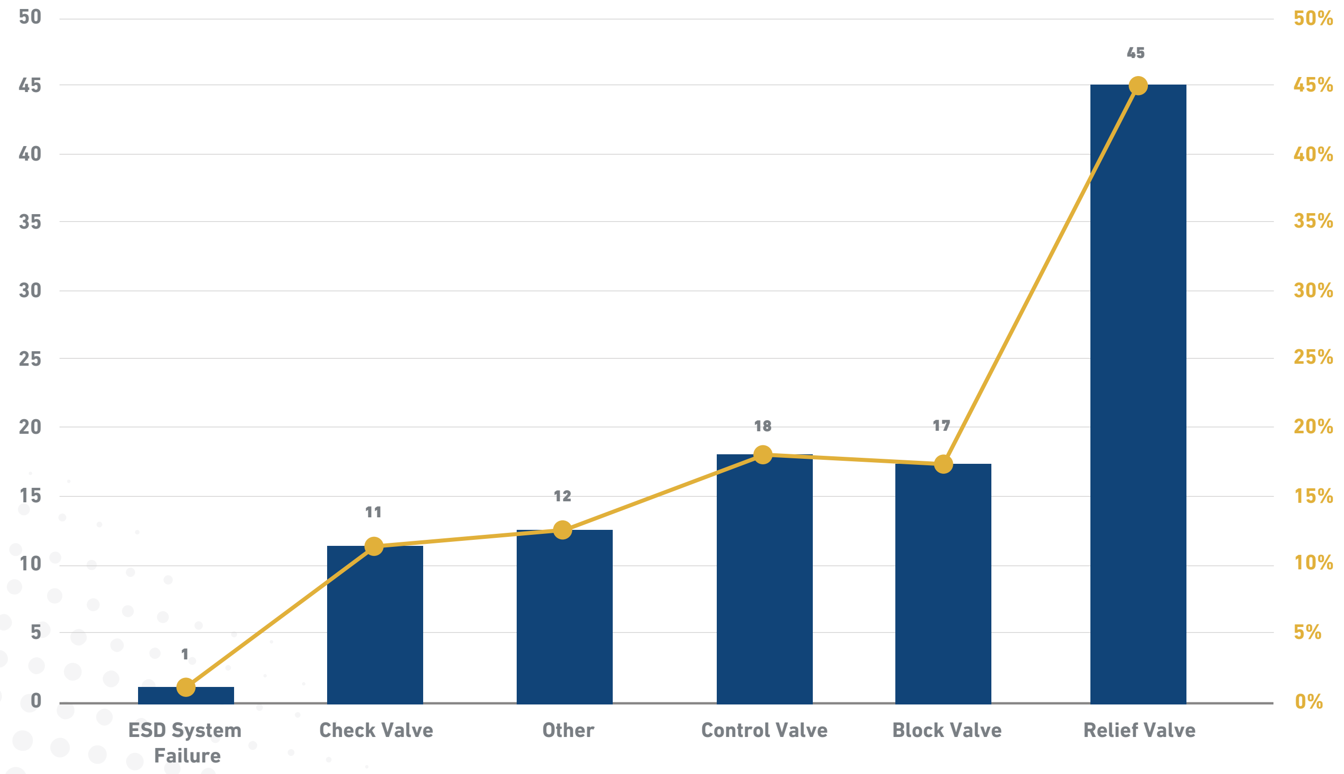


FIGURE 9. 2010-2024 VALVE RELEASES DUE TO EQUIPMENT FAILURES (MALFUNCTION OF CONTROL/RELIEF EQUIPMENT)



The second leading cause of valve incidents, though well below equipment failure (see Figure 10) was Incorrect Operation, accounting for 22% of all facility piping incorrect operation failures. The primary type of incorrect operation failure by far was Valve left or placed in wrong position accounting for 46% of incorrect operations (see Figure 11). The next leading cause was Tank, Vessel or Sump/Separator allowed or caused to overfill or overflow at 13%. 11 of the 18 incidents from this secondary type were because of valve misalignment.

65 of the 137 incorrect operations incidents involving a valve were related to Failure to follow procedure, and most of these incidents occurred during normal operating conditions and routine maintenance (see Figures 12 and 13). 59% of the tasks being performed that led to the accident were identified as covered tasks in the operator's qualification program. 64 of the 66 covered tasks were performed by qualified individuals (see Figures 14 and 15).

FIGURE 10. 2010-2024 FACILITY PIPING RELEASES BY CAUSE

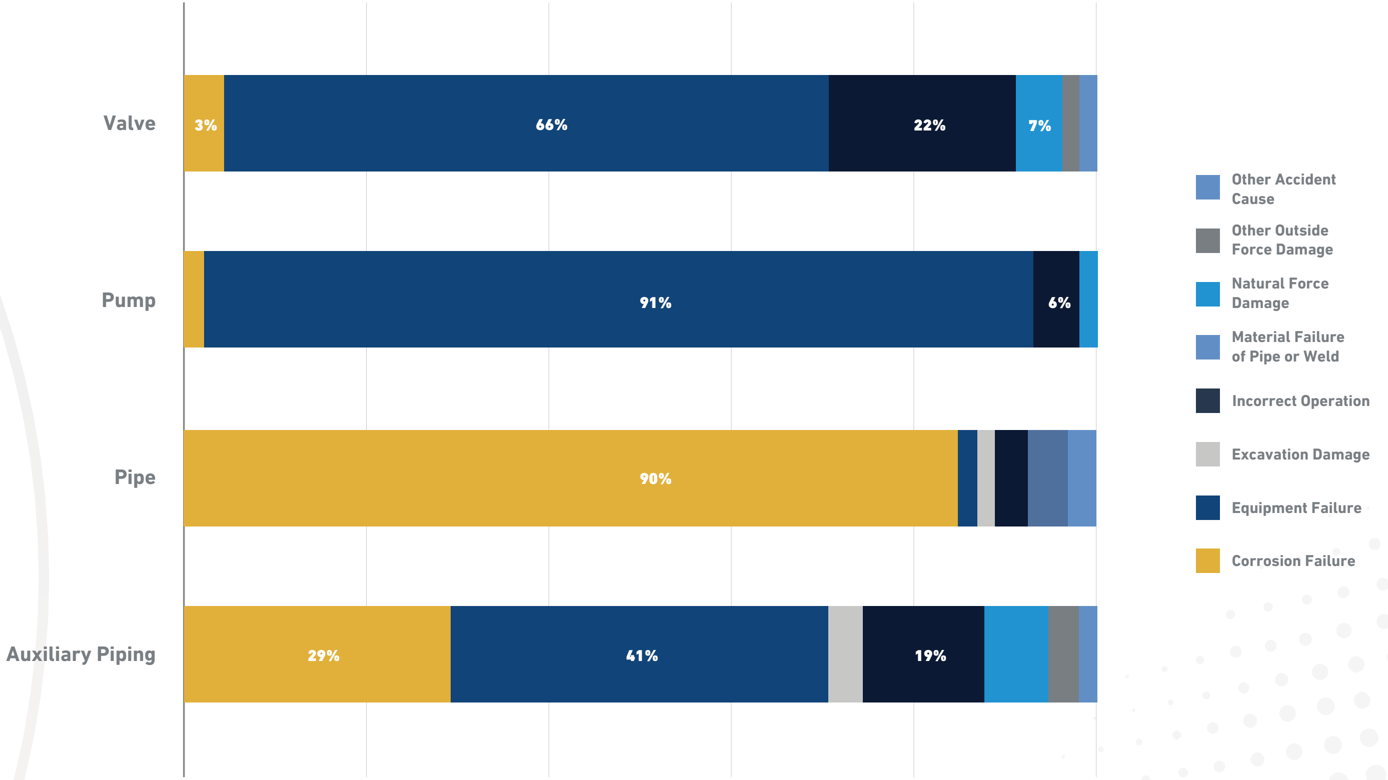


FIGURE 11. 2010-2024 VALVE FAILURES DUE TO INCORRECT OPERATION

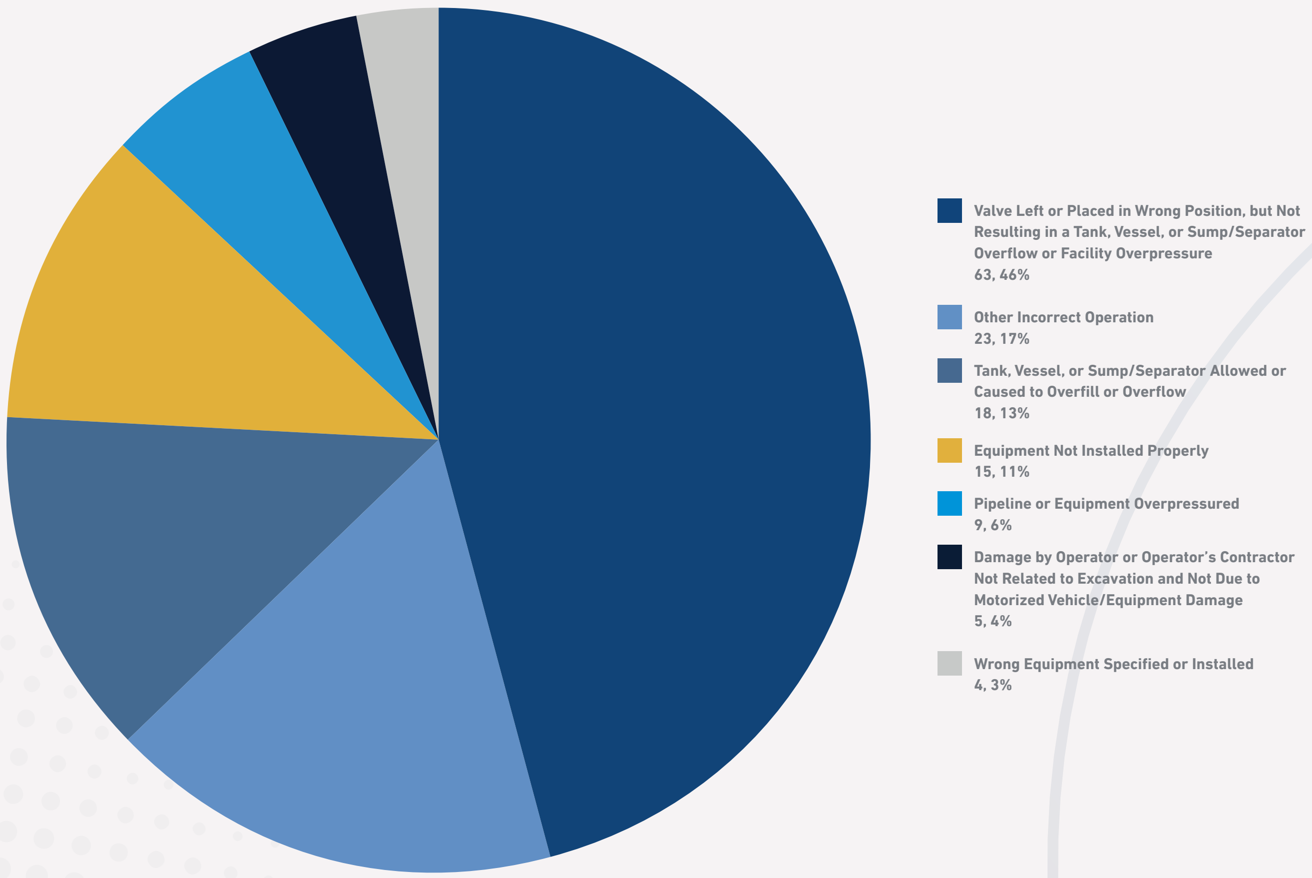


FIGURE 12. 2010-2024 VALVE FAILURES DUE TO INCORRECT OPERATION (OPERATION FAILURE REASON)

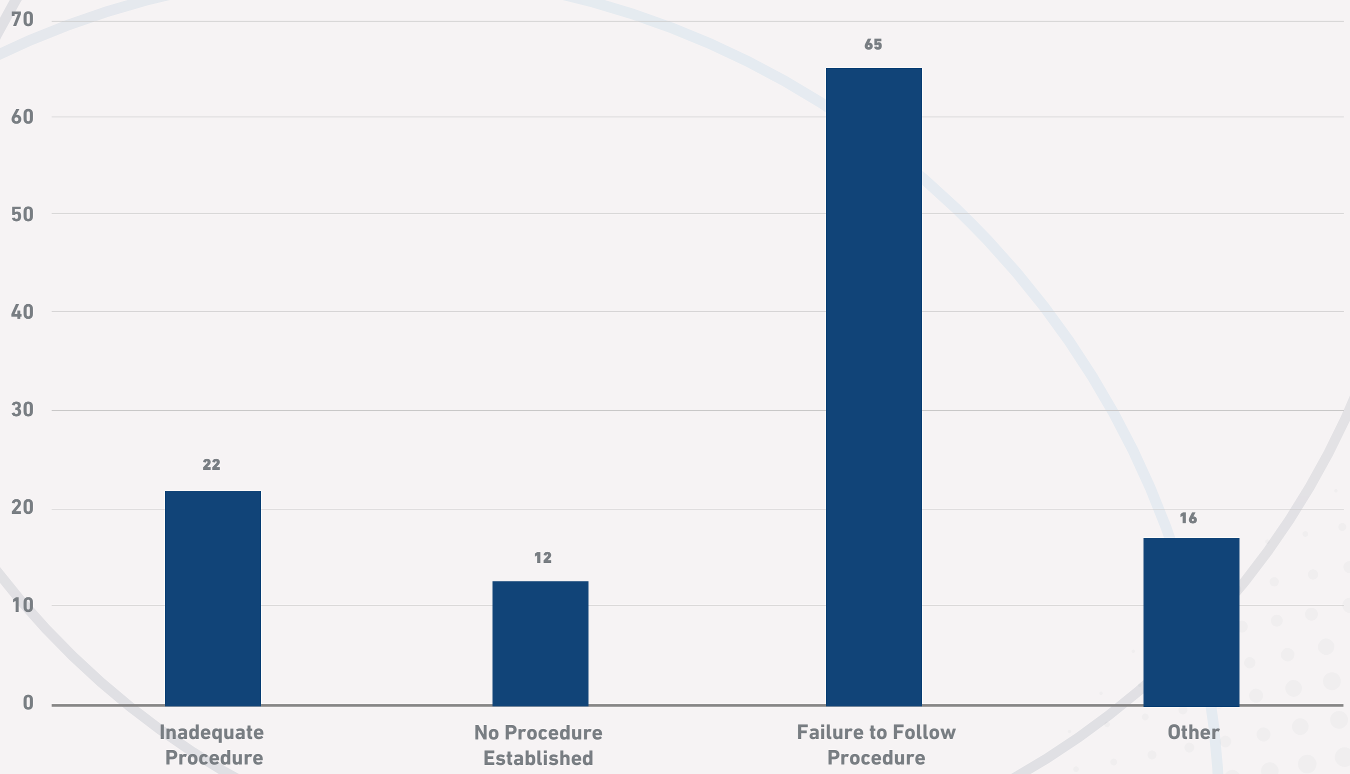


FIGURE 13. 2010-2024 VALVE FAILURES DUE TO INCORRECT OPERATION (CATEGORY TYPE)

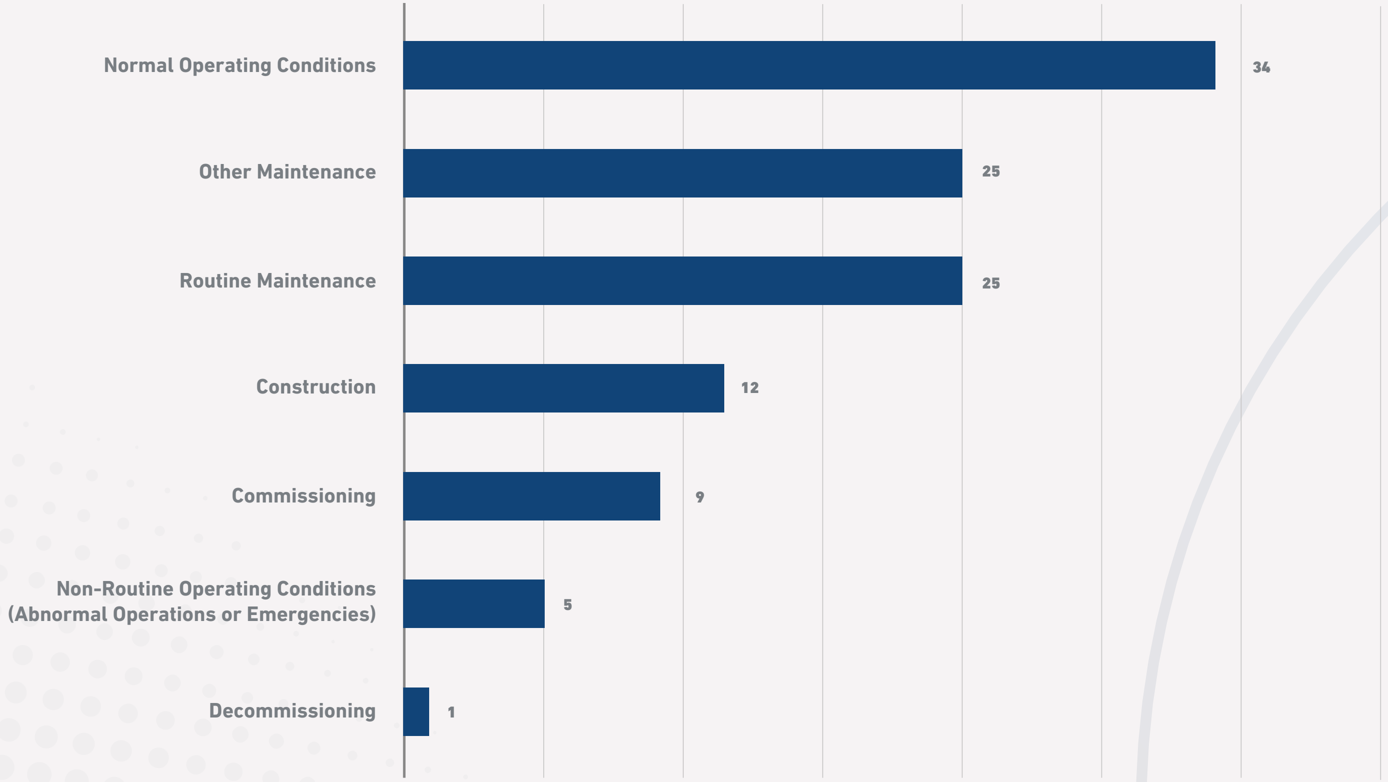


FIGURE 14. COVERED TASK IN OQ PROGRAM?

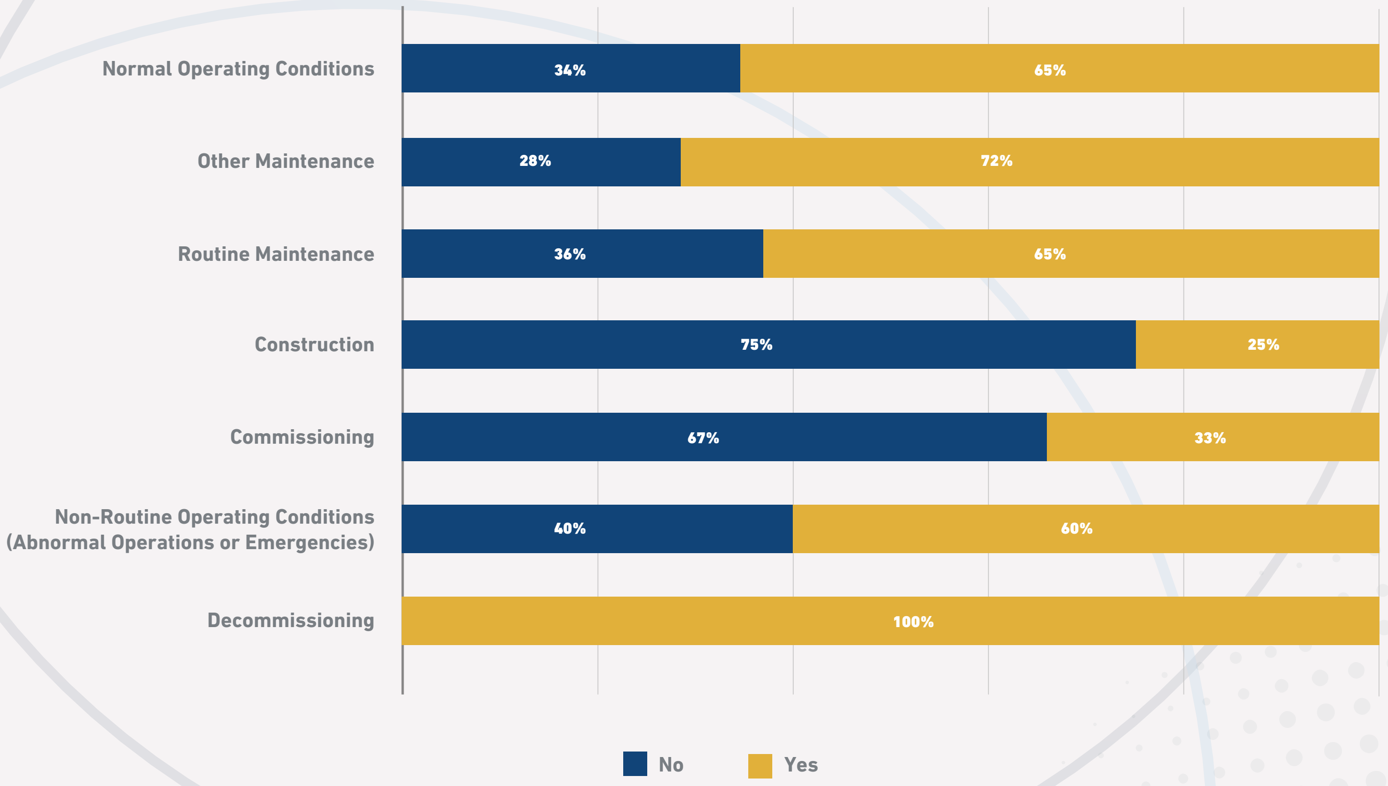
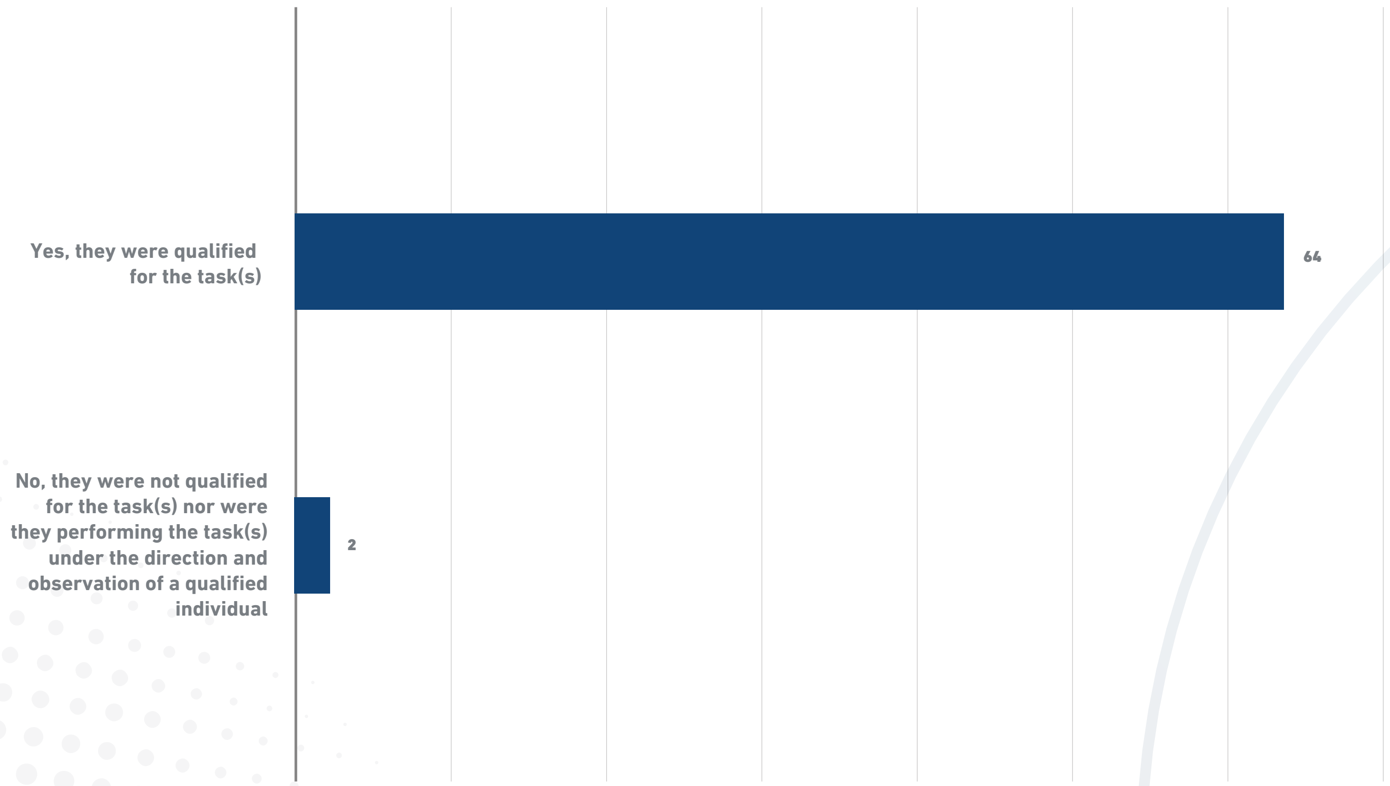


FIGURE 15. 2010-2024 VALVE FAILURES BY OPERATOR QUALIFICATION



Pump Results

Pumps were the second highest number of facilities piping incidents at 543 of the 2,497, or 22% of the facility piping incidents reported since 2010 (see figure 6). However, they are the largest number of items failing from equipment failure at 493 of the 1,398 equipment failures of facilities piping, or 35%. The Pump itself or pump-related equipment was by far the predominant failure type accounting for 94% (465 of 493) of pump equipment failures.

Seal/packing failure was the leading items/parts failing at 81% of pump failures. Additional factors contributing to seal/packing failures include excessive vibration, manufacturing defect, improper installation, misalignment, thermal stress, and breakdown of soft goods due to compatibility issues with transported commodity.

FIGURE 16. 2010-2024 EQUIPMENT FAILURES BY FACILITY PIPING

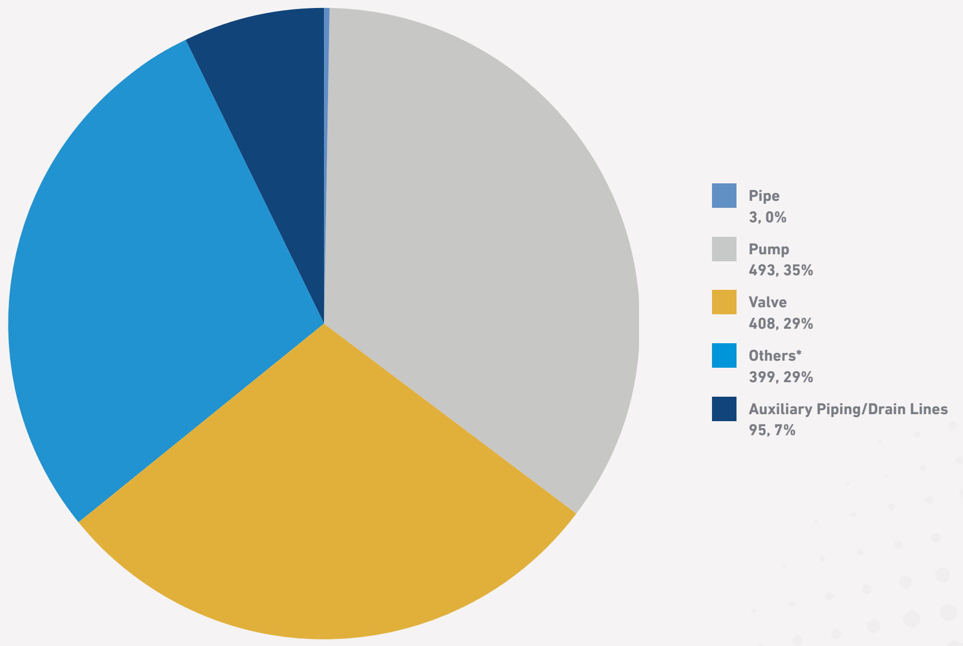


FIGURE 17. 2010-2024 PUMP EQUIPMENT FAILURE RELEASES BY CAUSE

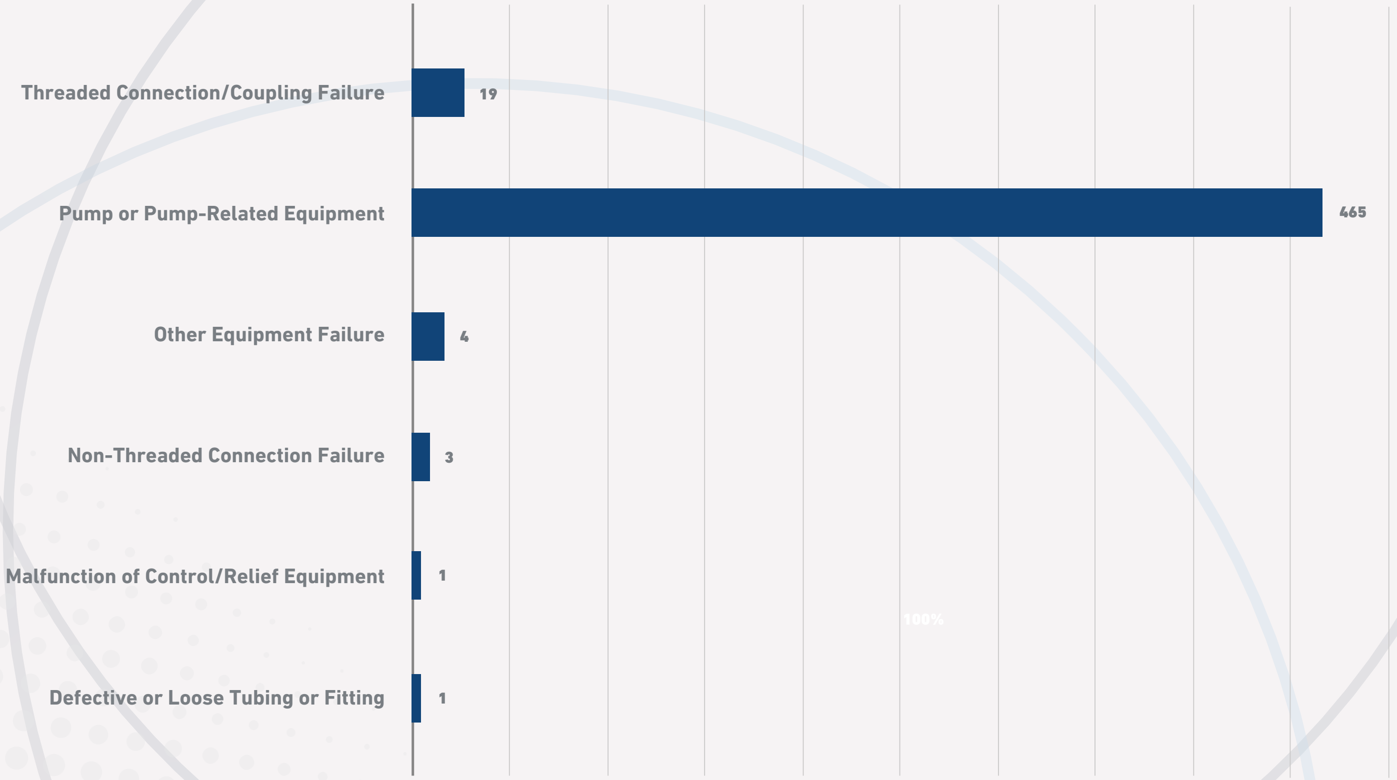
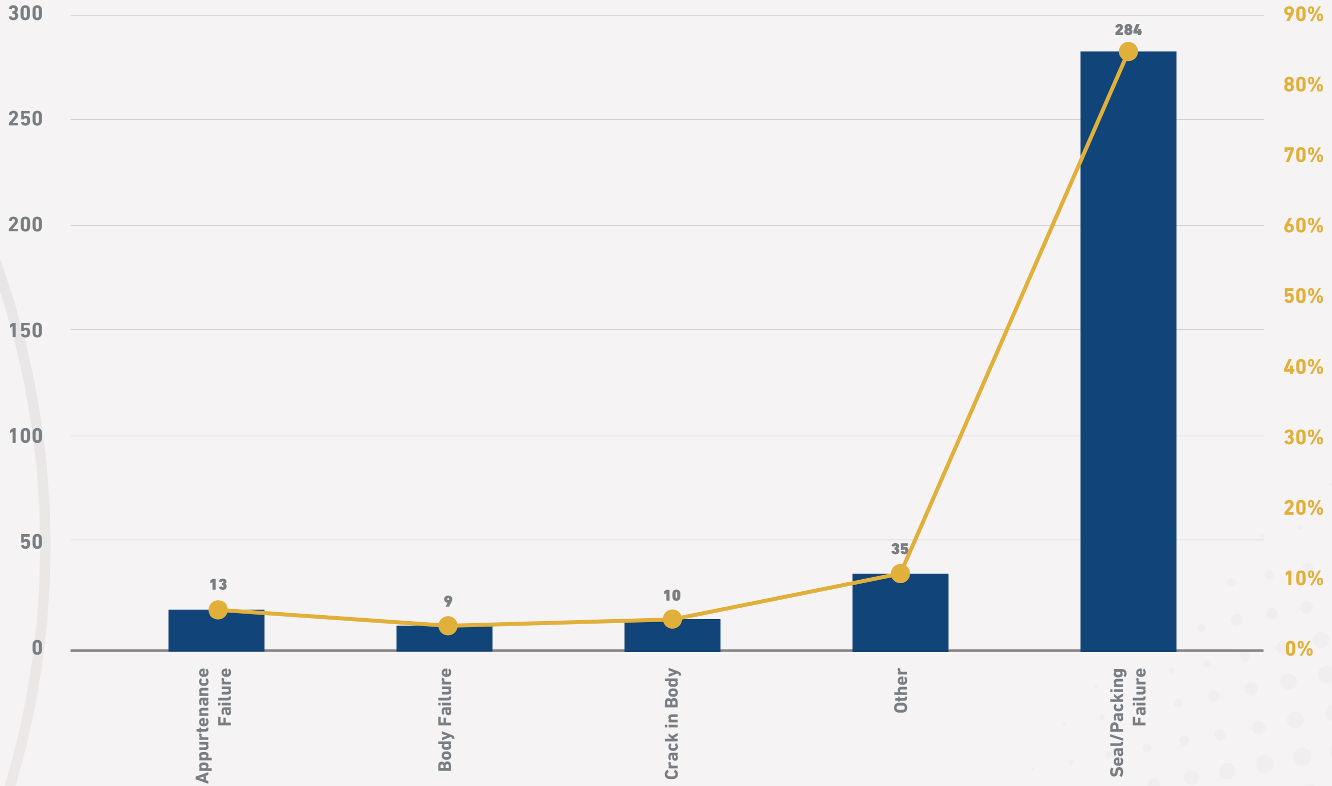


FIGURE 18. 2010-2024 PUMP EQUIPMENT FAILURE RELEASES (PUMP OR PUMP-RELATED EQUIPMENT)



Pipe Results

Pipe incidents were the third highest number of facilities piping incidents at 436 of the 2,497, or 17% of the facility piping incidents reported since 2010 (see figure 6). However, the most common cause of facility pipe incidents was corrosion (394 of 436) or 90% of all facility piping corrosion incidents (see figure 10). The most common corrosion type affecting pipe was internal corrosion at 86% and the predominant commodity contributing to internal corrosion was crude oil at 92%. 81% of internal corrosion pipe incidents were small releases or releases of 5 barrels or less (see figures 19, 20, and 21).

When visually examined, the most common form of corrosion was localized pitting at 70%. 56% of these pipe incidents were not treated with inhibitors or biocides, 98% did not have protective coating, did not have cleaning or dewatering pigs used, and did not have internal inspection at the point of accident. This is not surprising as 88% of the pipe incidents involved were not mainline pipe and is likely due to the design and configuration of most liquids facilities not being capable of inspection using inline inspection technologies (i.e., unpiggable). (See figures 22-26) The main causes of internal corrosion were microbiological and water drop-out/acid, and they frequently occurred in the low point in pipe (see figures 27 and 28).

FIGURE 19. 2010-2024 CORROSION FAILURE PIPE INCIDENTS BY TYPE

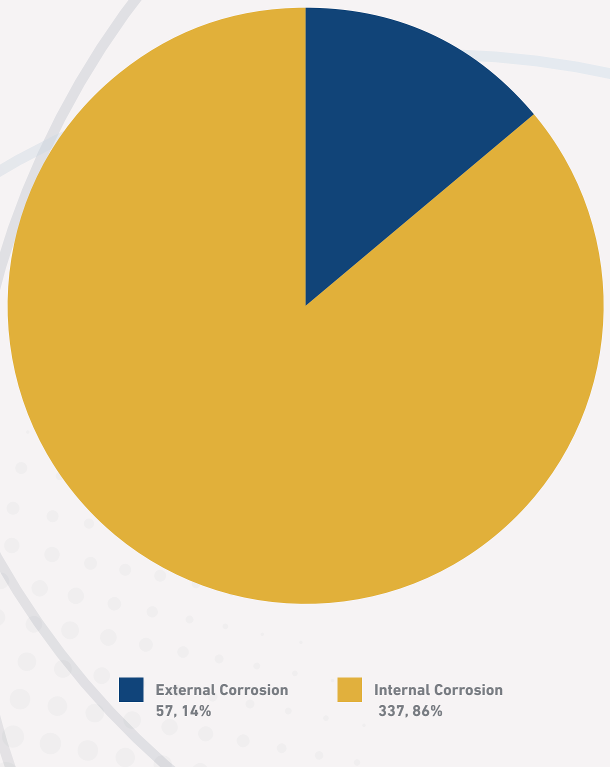


FIGURE 20. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS BY COMMODITY TRANSPORTED

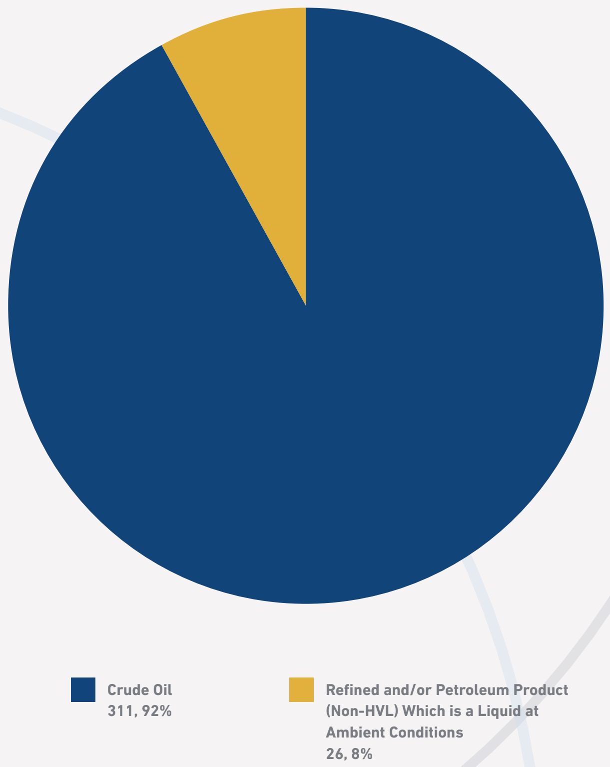


FIGURE 21. 2010-2024 CORROSION FAILURE PIPE INCIDENTS BY RELEASE SIZE

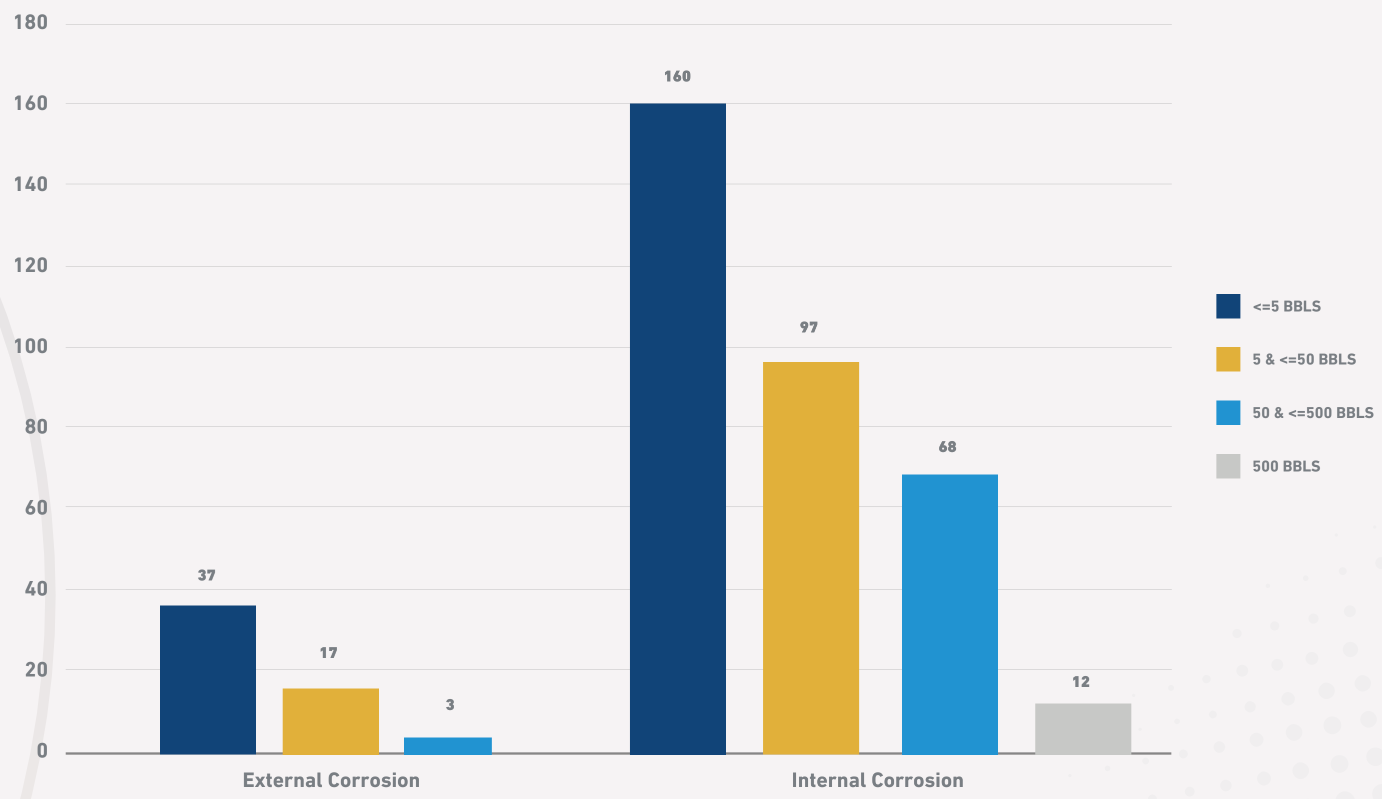


FIGURE 22. 2010-2024 FACILITY PIPE INTERNAL CORROSION INCIDENTS BY RESULT OF VISUAL EXAM

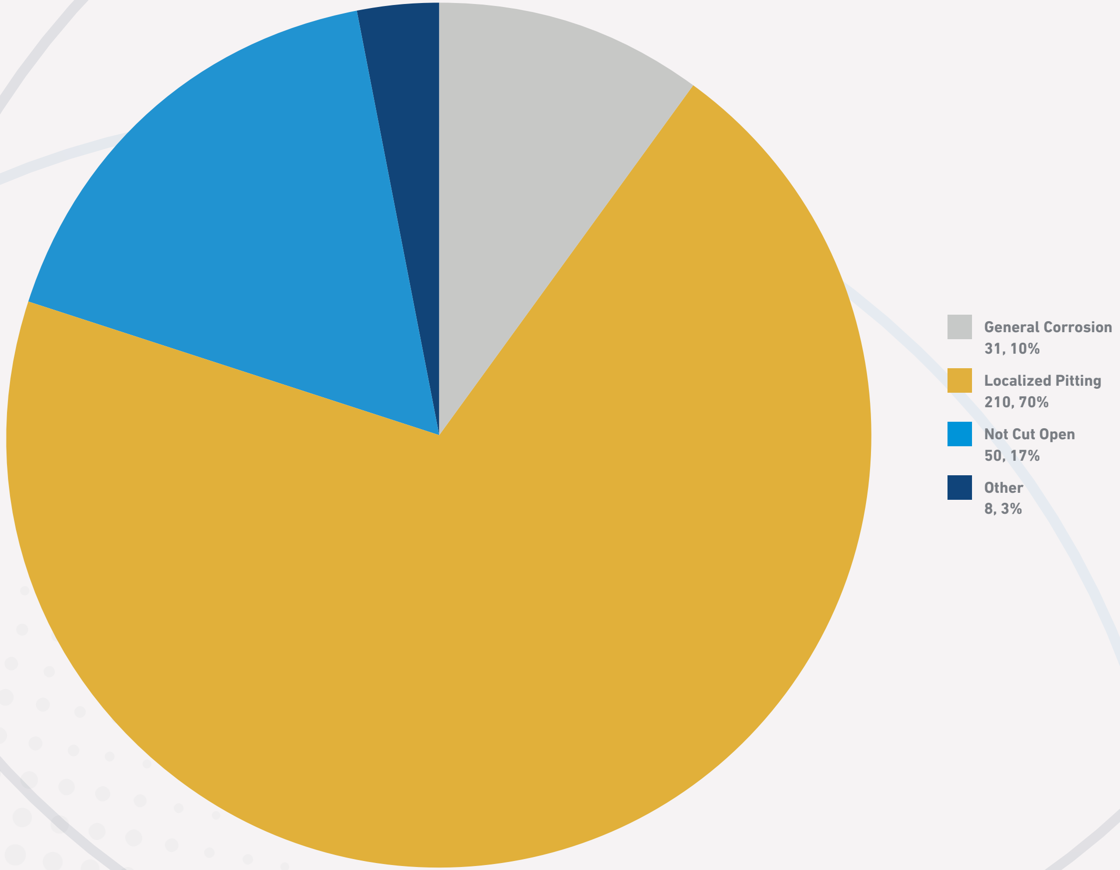


FIGURE 23. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS - TREATED WITH INHIBITORS OR BIOCIDES?

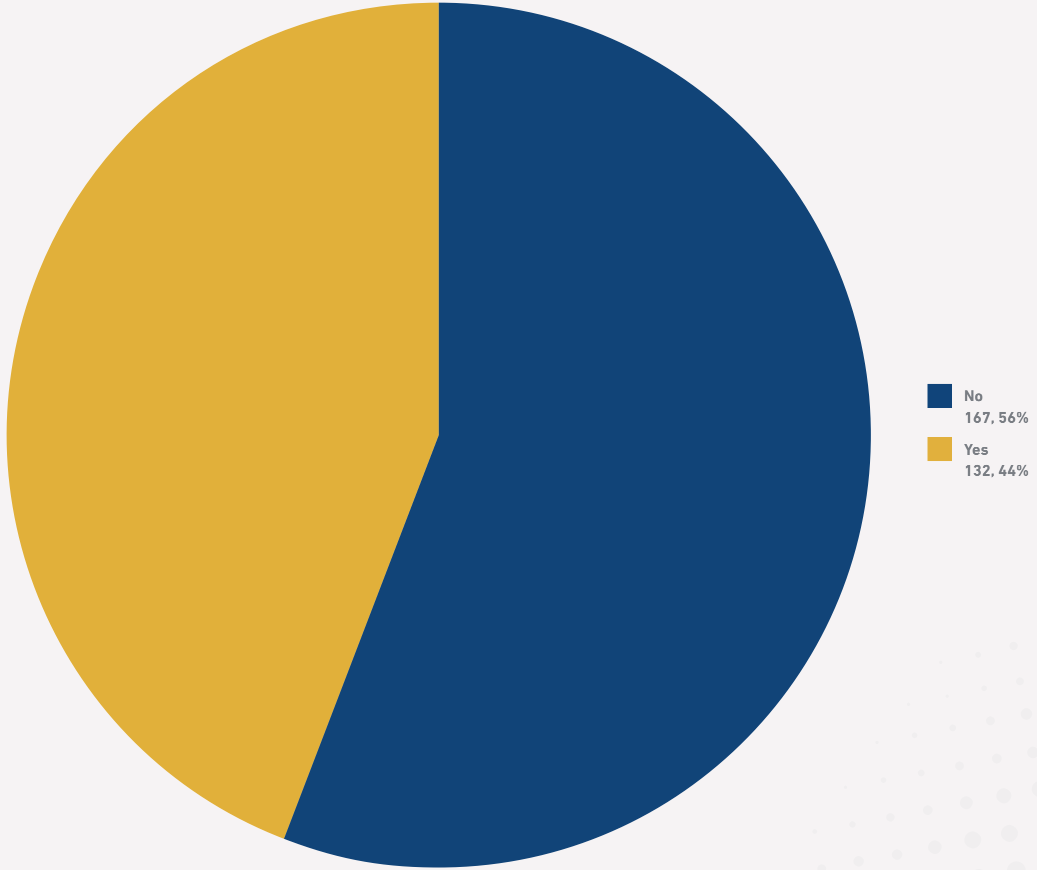


FIGURE 24. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS - PROTECTIVE COATING?

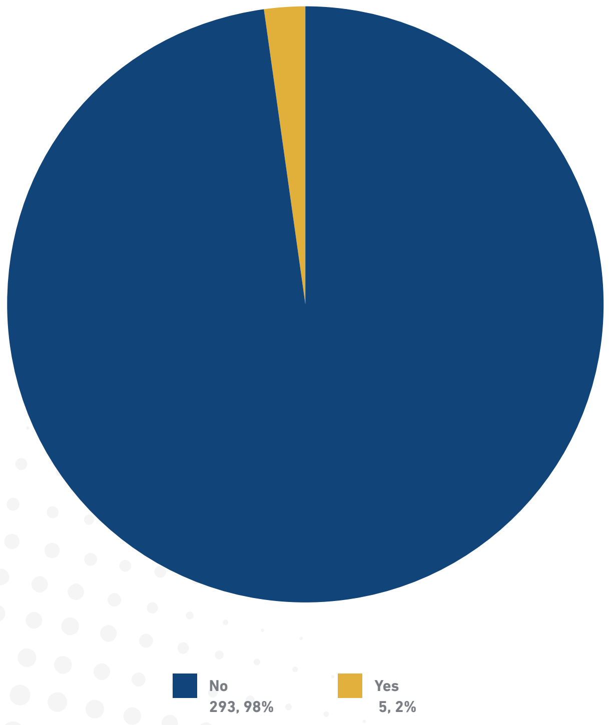


FIGURE 25. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS - CLEANING/DEWATERING PIGS USED?

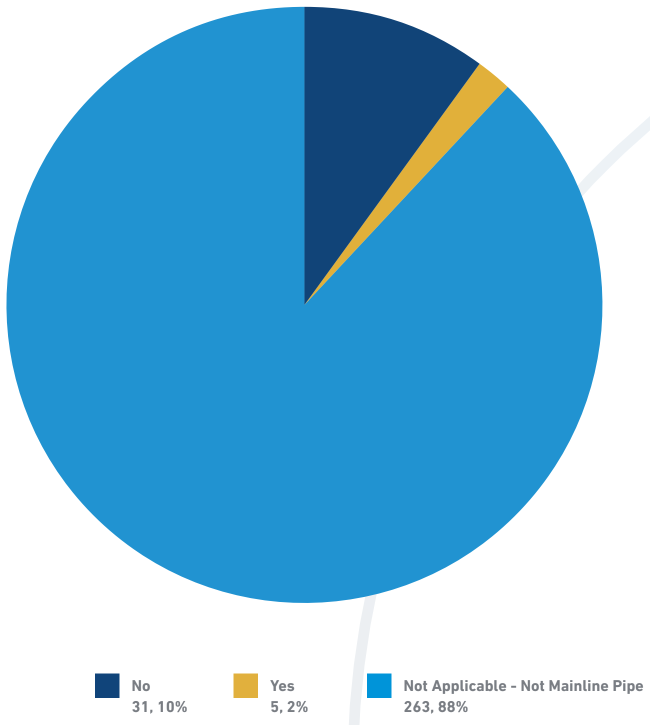


FIGURE 26. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS - INTERNAL INSPECTION CONDUCTED AT POINT OF ACCIDENT?

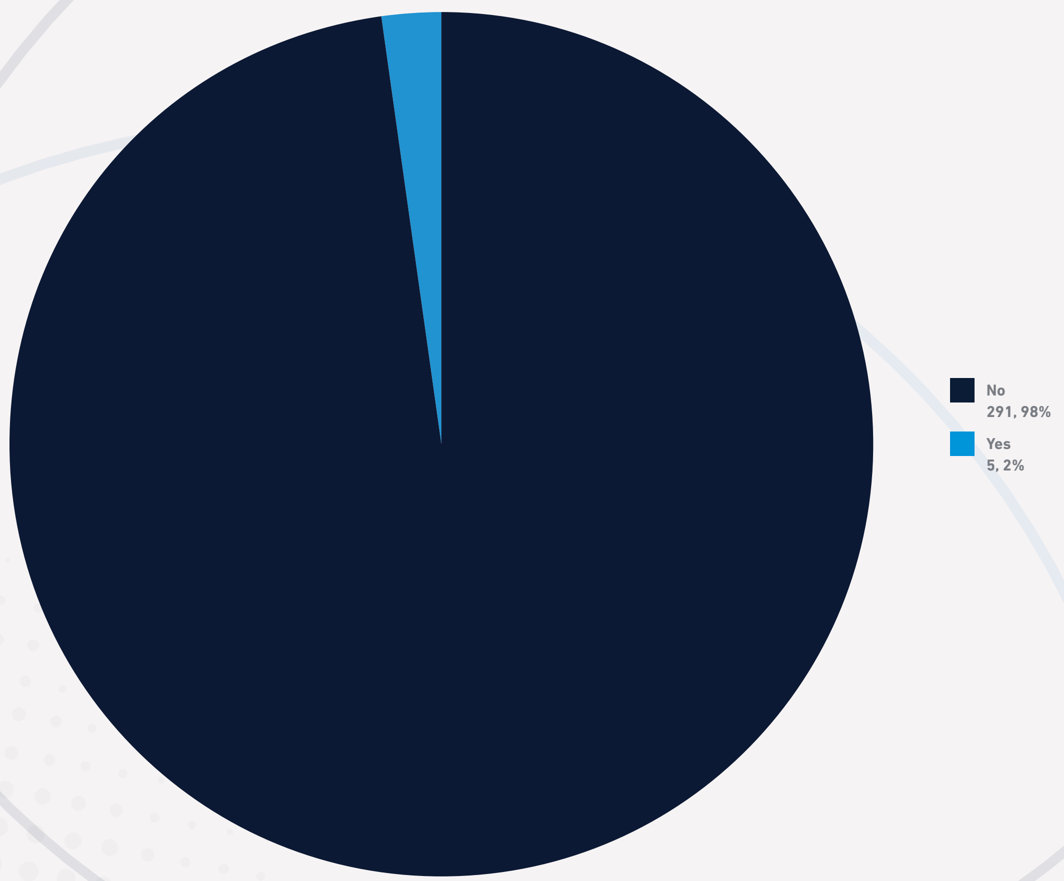


FIGURE 27. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS BY CAUSE OF CORROSION

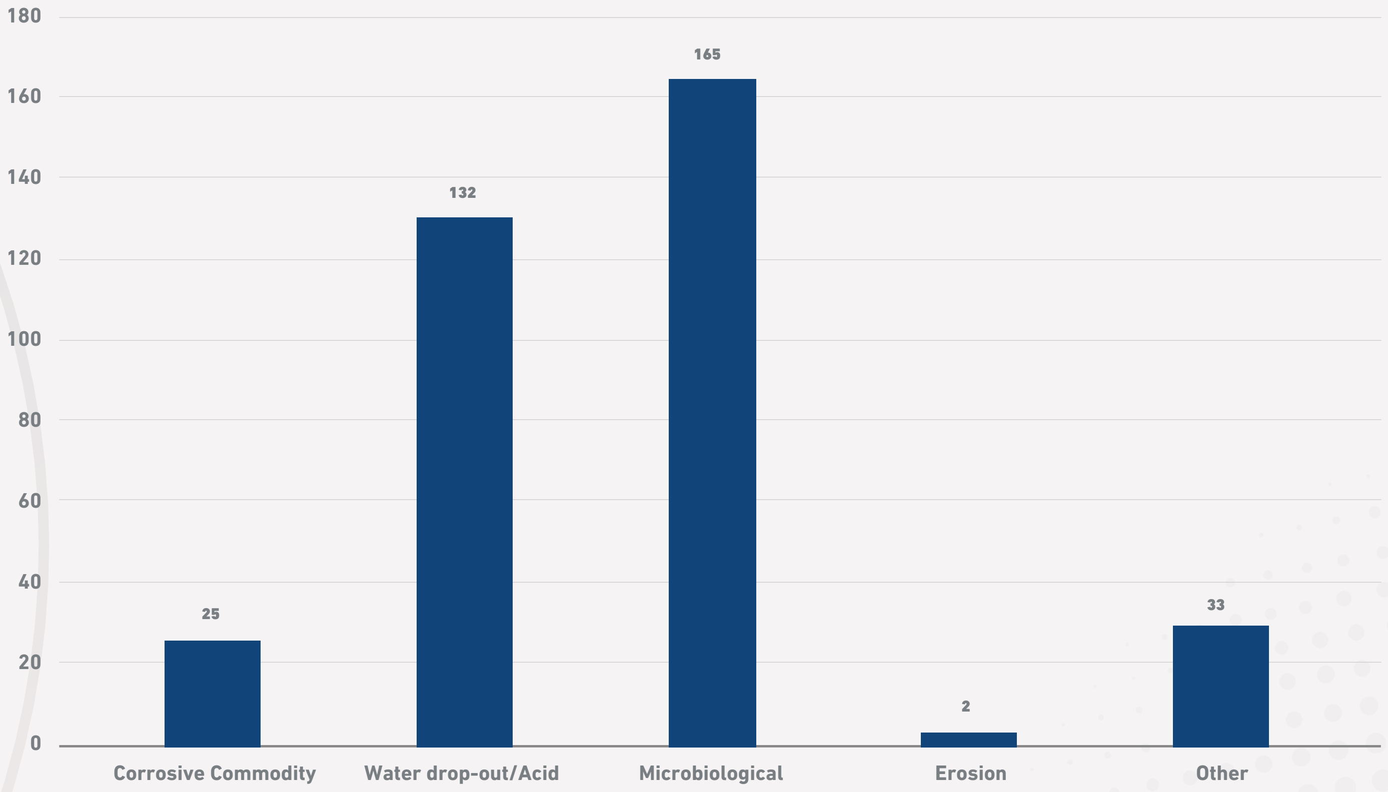


FIGURE 28. 2010-2024 INTERNAL CORROSION FAILURE PIPE INCIDENTS BY LOCATION OF CORROSION

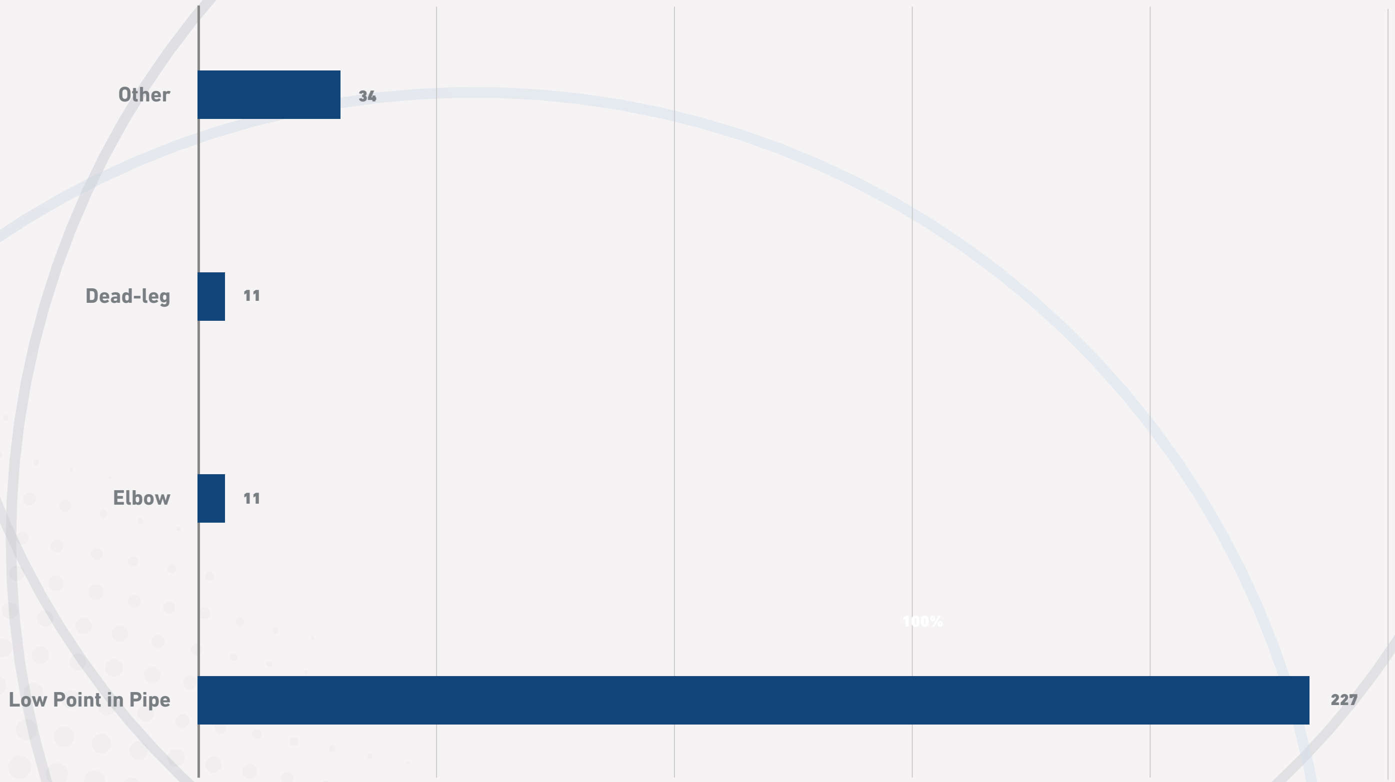
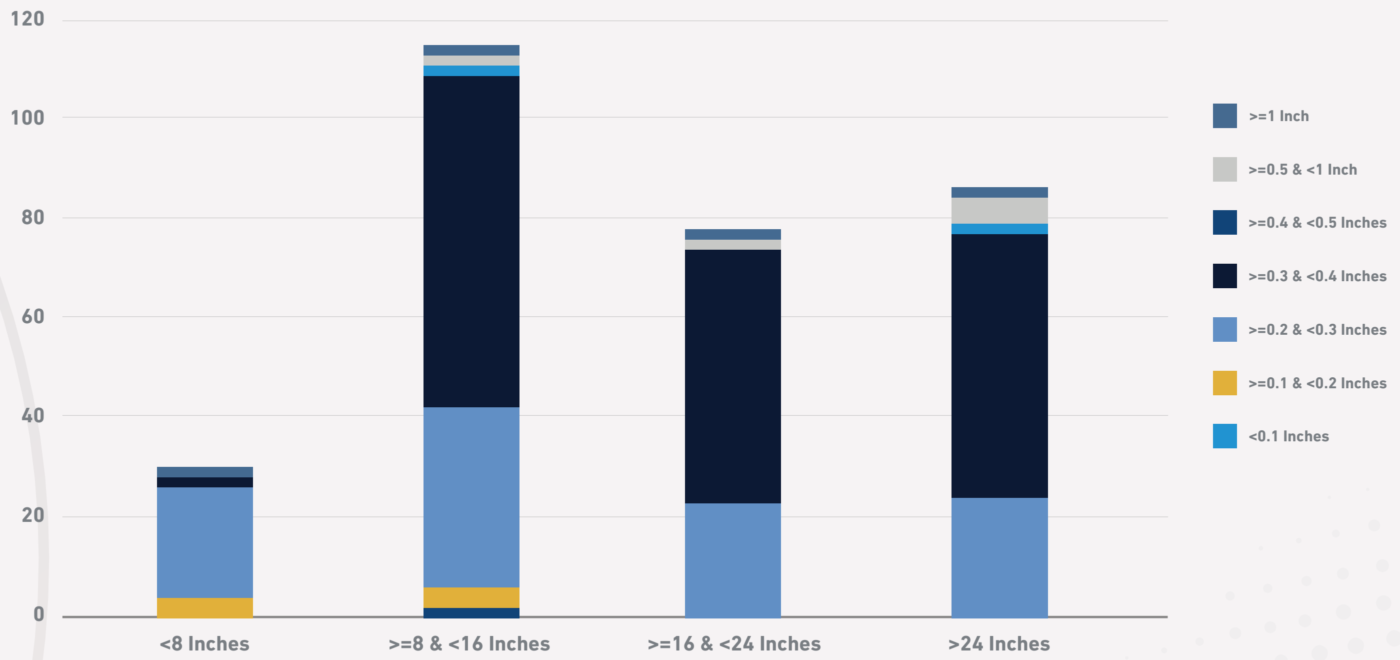


FIGURE 29. 2010-2024 INTERNAL CORROSION FACILITY PIPE INCIDENTS BY PIPE WALL THICKNESS AND PIPE DIAMETER



For Auxiliary Piping/Drain Lines it is worth noting that "Standard" wall thickness for pipe and fittings >=8" diameter ranges from 0.322" to 0.375", making it the predominant wall thickness utilized in facility construction.

Auxiliary Piping/Drain Line Results

Auxiliary Piping/Drain Lines (AP&D) incidents were the fourth highest number of facilities piping incidents at 231 of the 2,497, or 9% of the facility piping incidents reported since 2010 (see figure 6). 41% of AP&D incidents were caused by equipment failures, 29% were caused by corrosion failures, and 19% were caused by incorrect operation (see figure 10). Over half (54% or 51 of 95) of AP&D equipment failures were because of threaded connection/coupling failures with the pipe nipple and threaded fitting accounting for 89% of the failures. Excessive vibration also contributed to these threaded connection/coupling failures (see figures 30, 31 and 32).

FIGURE 30. 2010-2024 AUXILIARY PIPING/DRAIN LINES EQUIPMENT FAILURE RELEASES

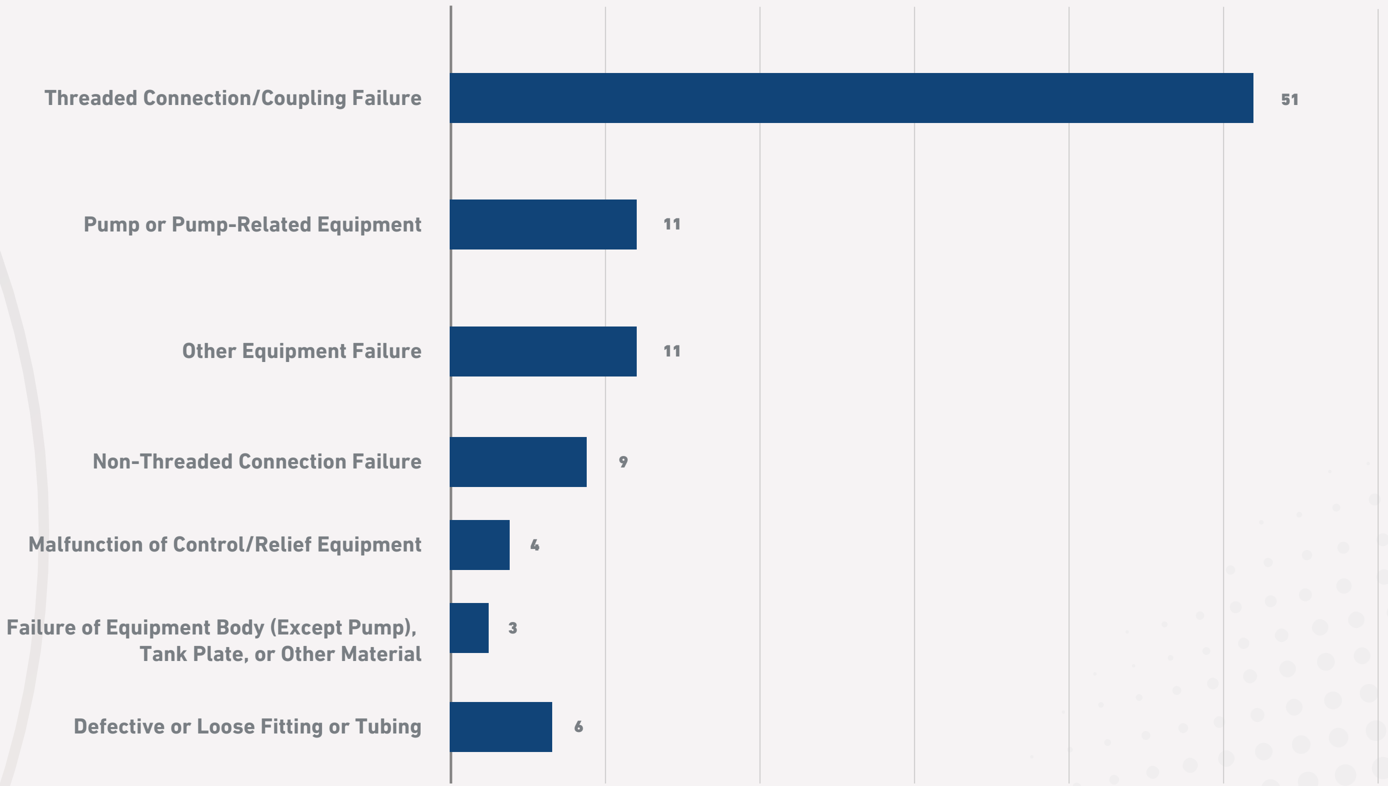


FIGURE 31. 2010-2024 AUXILIARY PIPING/DRAIN LINES EQUIPMENT FAILURE RELEASES (THREADED CONNECTION/COUPLING FAILURE)

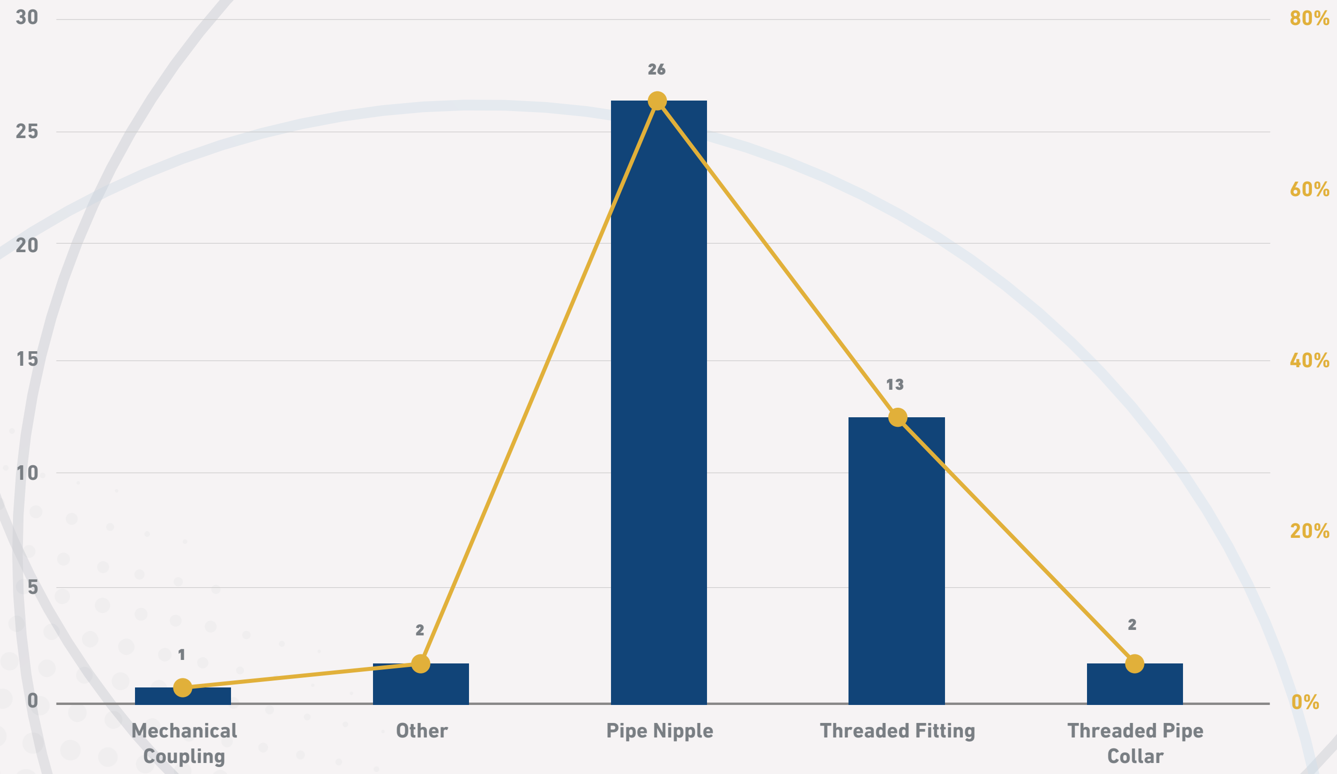
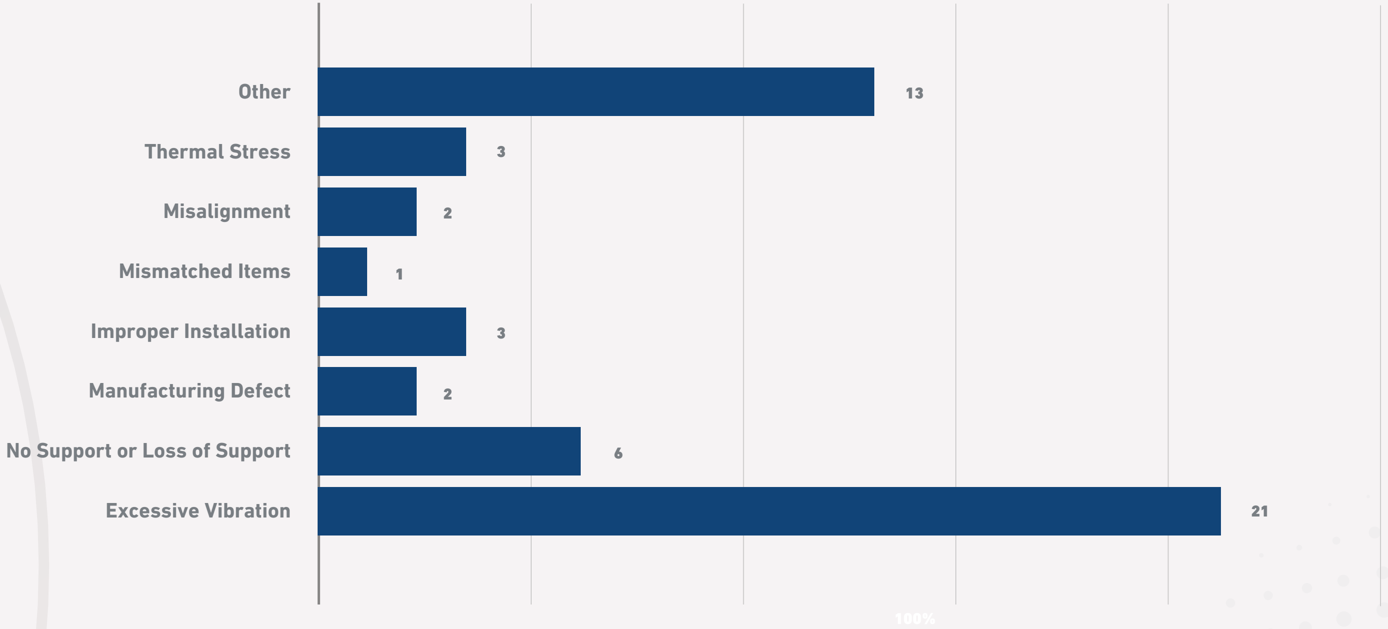


FIGURE 32. 2010-2024 2010-2024 AUXILIARY PIPING/DRAIN LINES (ADDITIONAL FACTORS) THREADED CONNECTION/COUPLING FAILURE



52 of 66 (79%) AP&D corrosion incidents were due to internal corrosion and when visual exam of the internal pipe wall was able to be conducted it revealed that 67% of these internal corrosion incidents were localized pitting. They were also mostly due to microbiological or water drop-out/acid and occurred in the low point in pipe. Like facility pipe, most of the AP&D were not treated with inhibitors or biocides, did not have protective coating, or other corrosion treatment (see figures 33 – 38).

FIGURE 33. 2010-2024 AUXILIARY PIPING/DRAIN LINES CORROSION FAILURE INCIDENTS BY TYPE

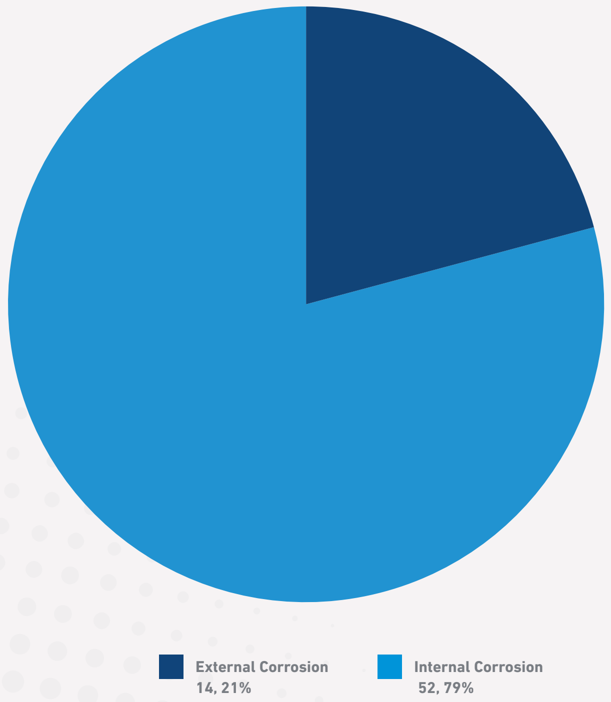


FIGURE 34. 2010-2024 INTERNAL CORROSION FAILURE - AUXILIARY PIPING/DRAIN LINES - BY RESULTS OF VISUAL EXAM

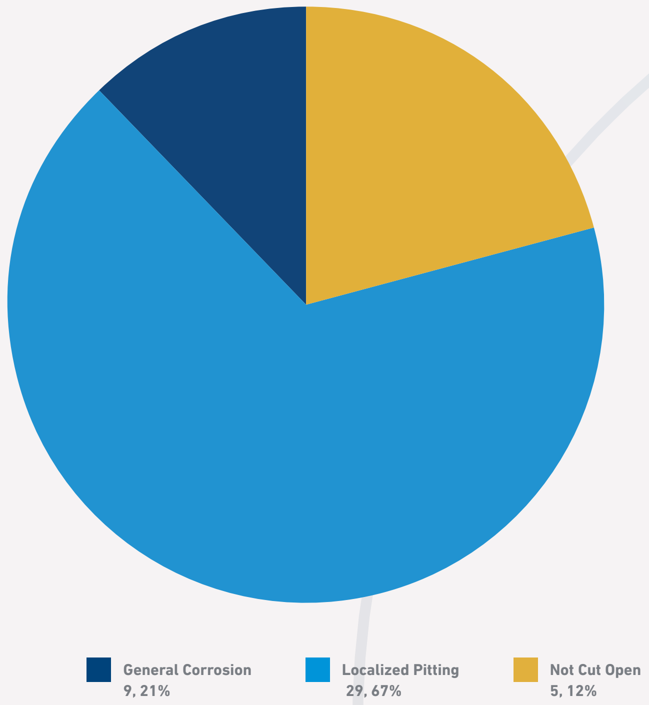


FIGURE 35. 2010-2024 INTERNAL CORROSION FAILURE - AUX.PIPING/DRAIN LINES BY CAUSE OF CORROSION

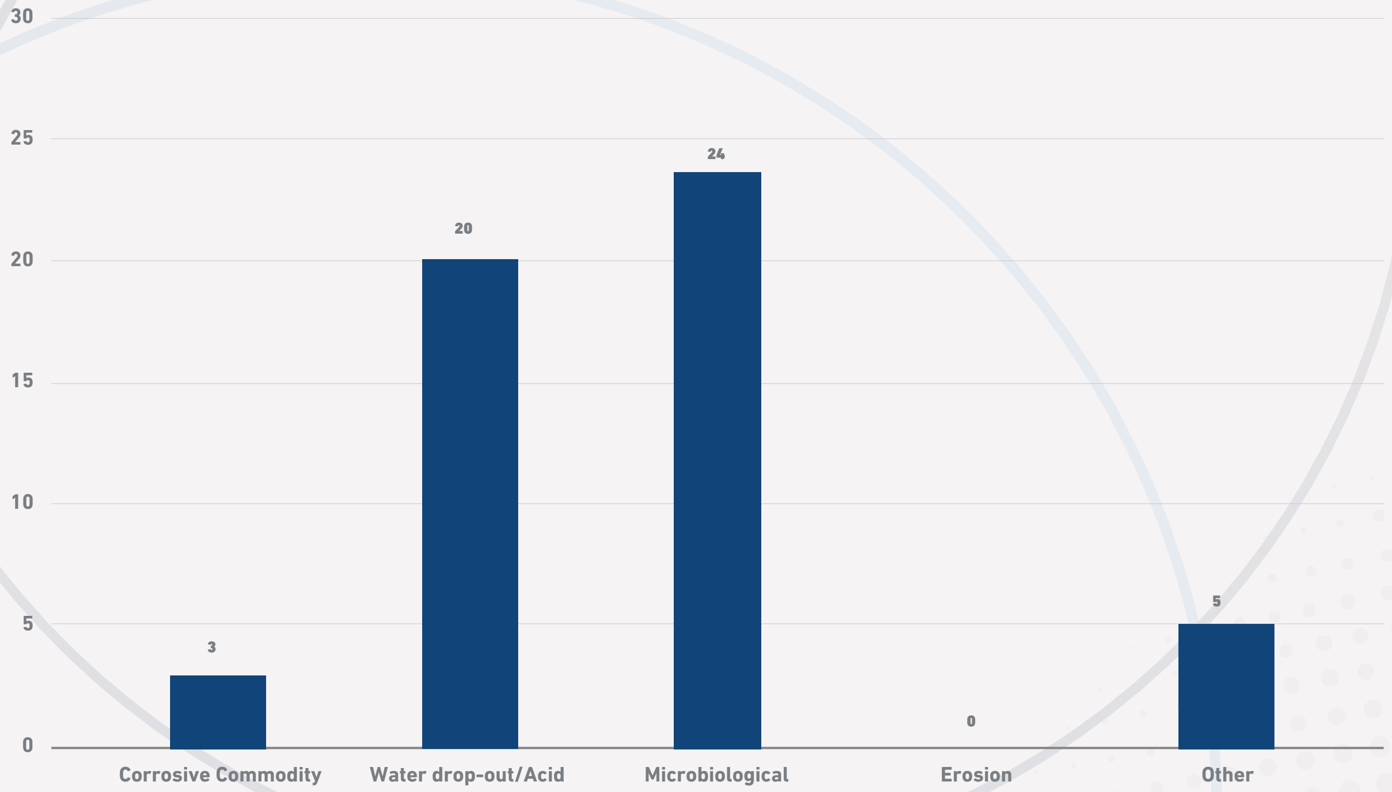


FIGURE 36. 2010-2024 INTERNAL CORROSION FAILURE - AUX.PIPING/DRAIN LINES BY LOCATION OF CORROSION

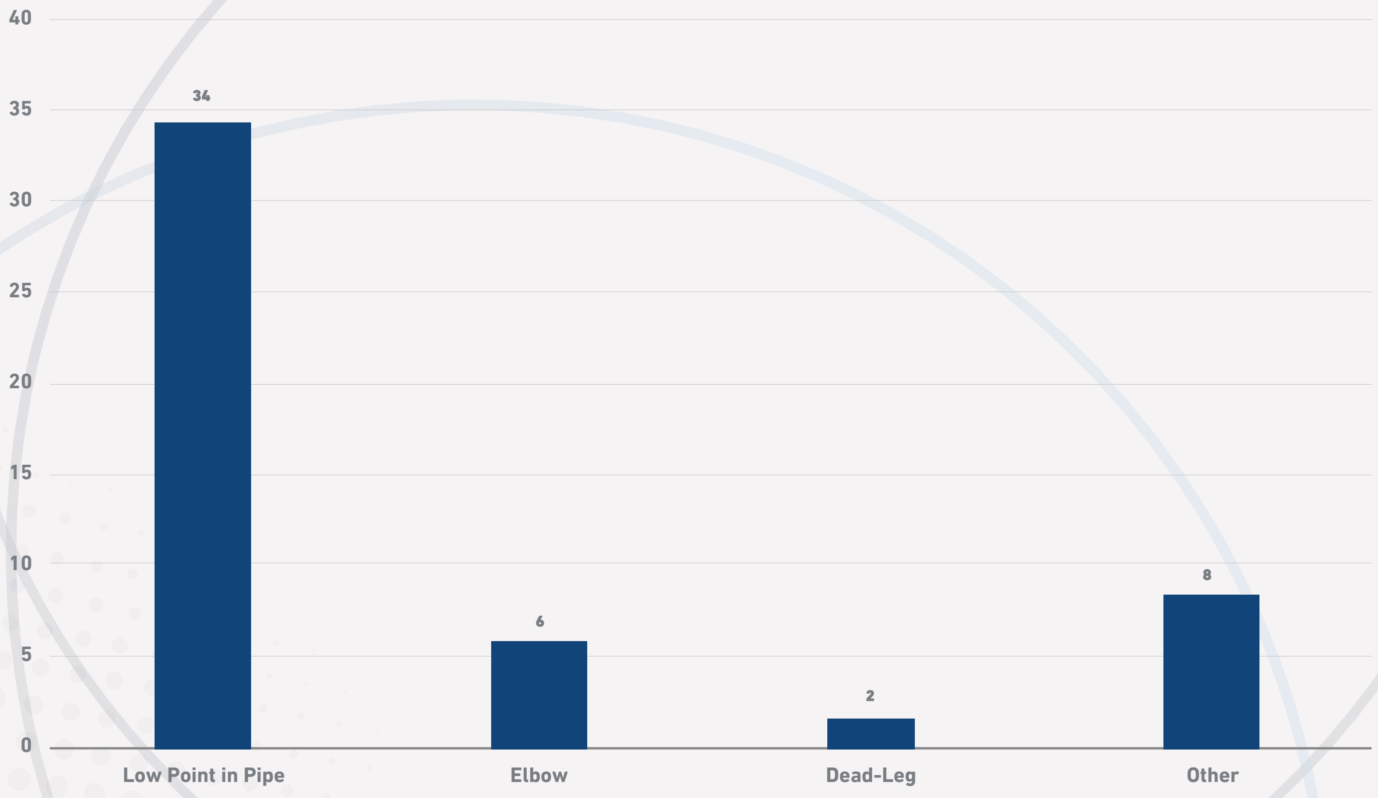


FIGURE 37. 2010-2024 INTERNAL CORROSION FAILURE - AUX.PIPING/DRAIN LINES - TREATED WITH INHIBITORS OR BIOCIDES?

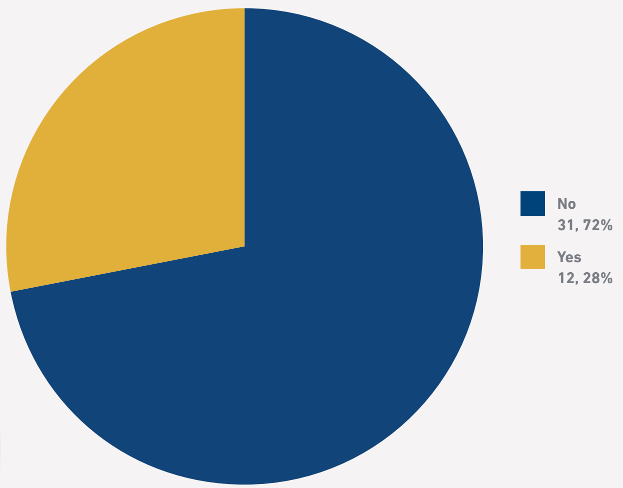
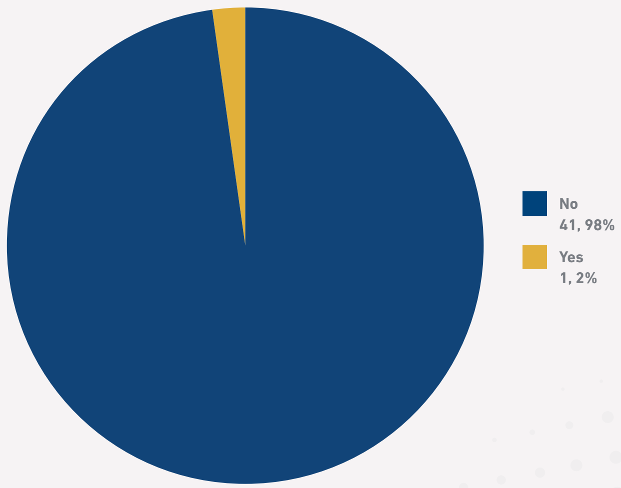


FIGURE 38. 2010-2024 INTERNAL CORROSION FAILURE - AUX.PIPING/DRAIN LINES - PROTECTIVE COATING?



78% (35 of 45) AP&D incorrect operation incidents were due to valve left or placed in wrong position, other incorrect operation, and equipment not installed properly. Like valves, 51% of the AP&D tasks that led to the accident were identified as covered tasks under the Operator Qualification program. Most covered tasks activity involved normal operating conditions, routine maintenance, other maintenance, and construction (see figures 39 and 40).

FIGURE 39. 2010-2024 AUXILIARY PIPING/DRAIN LINES - INCORRECT OPERATION FAILURES?

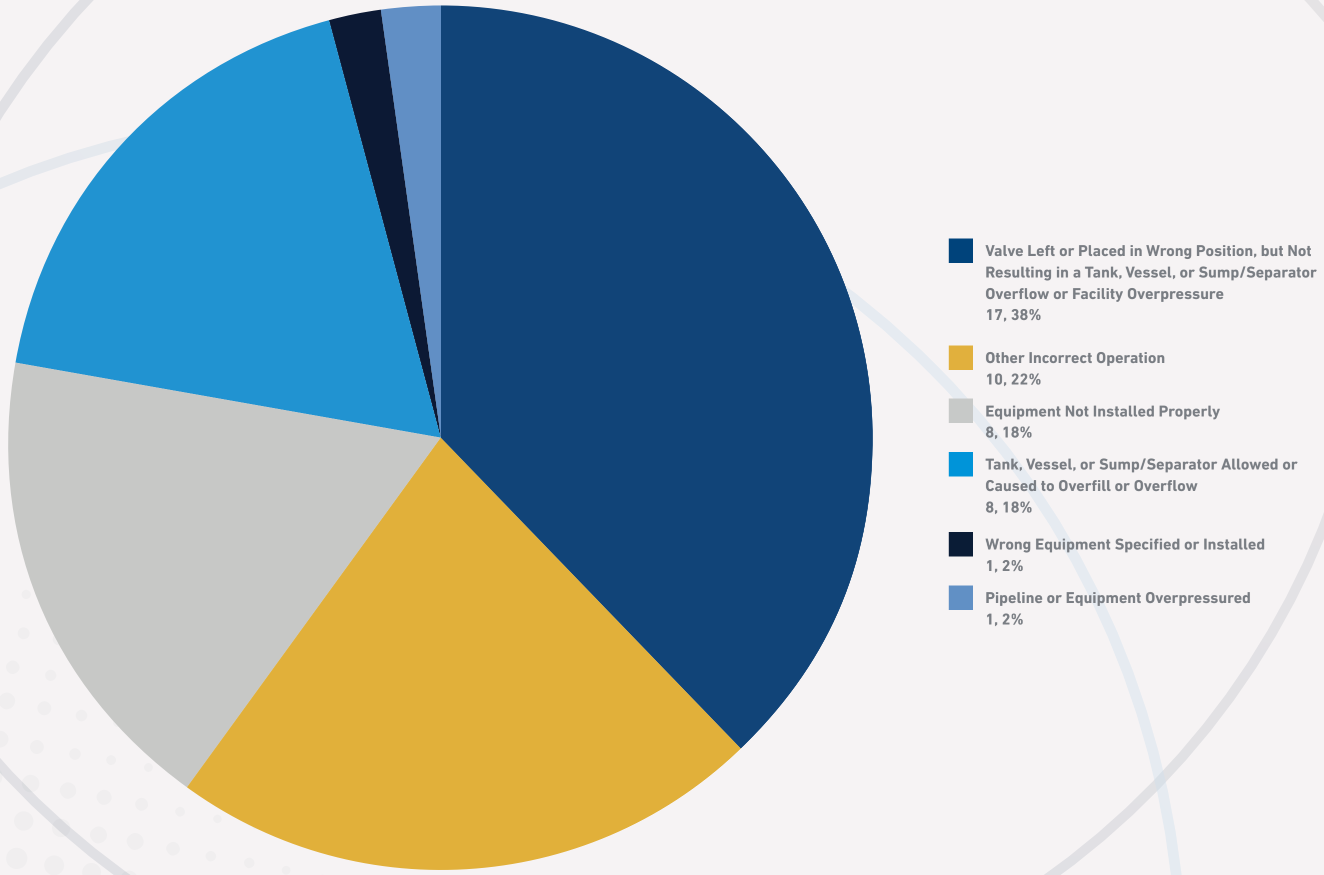


FIGURE 40. COVERED TASK IN OQ PROGRAM?

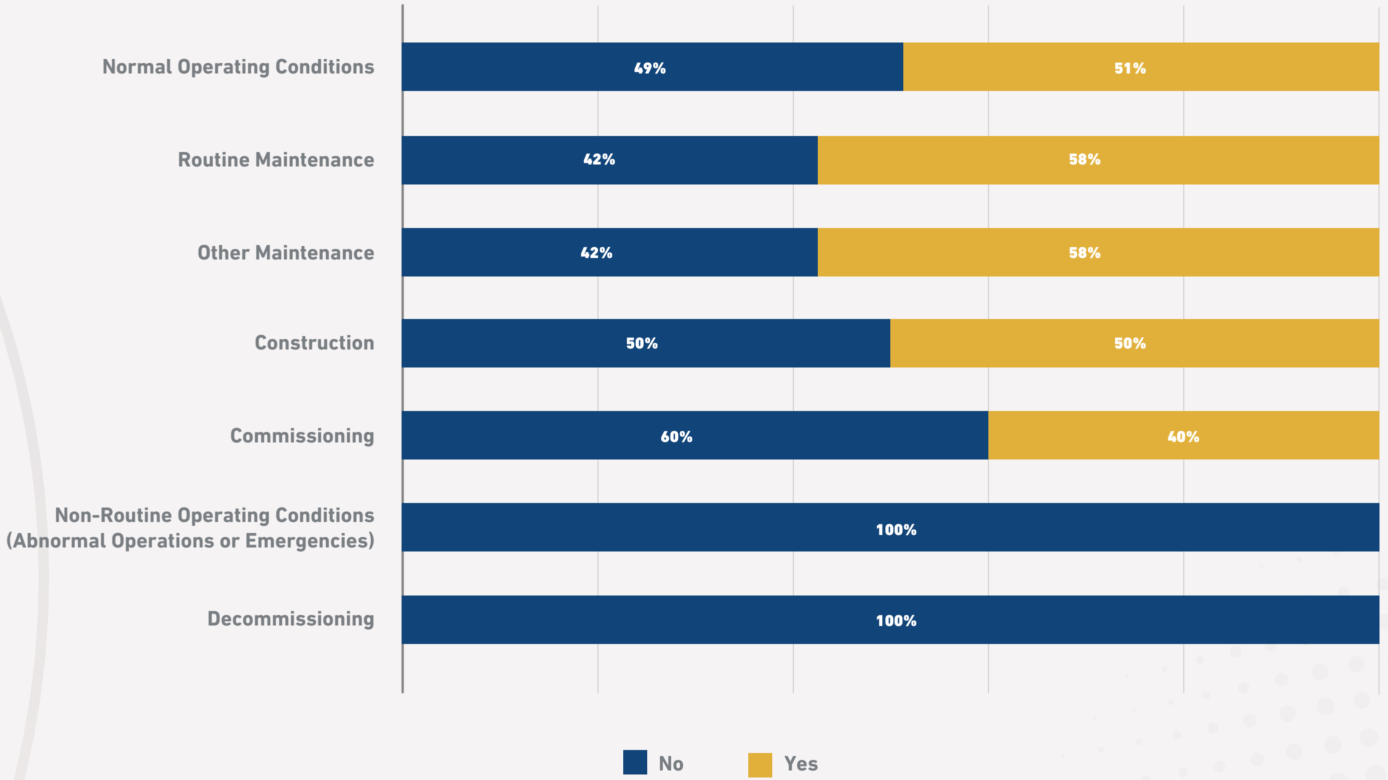


FIGURE 41. TOP 4 EQUIPMENT FAILURE FACILITY PIPING INCIDENTS BY DECADE OF ITEM INSTALLED

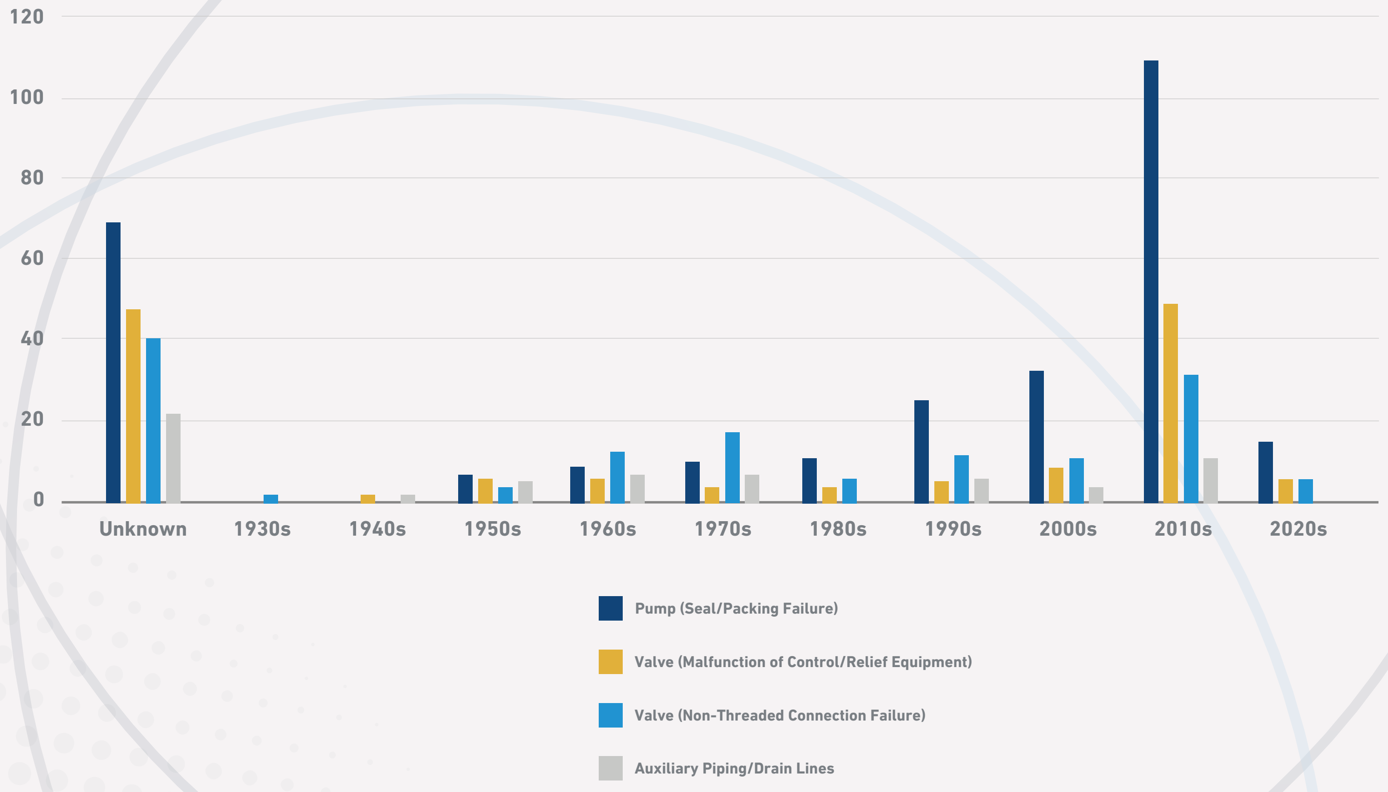
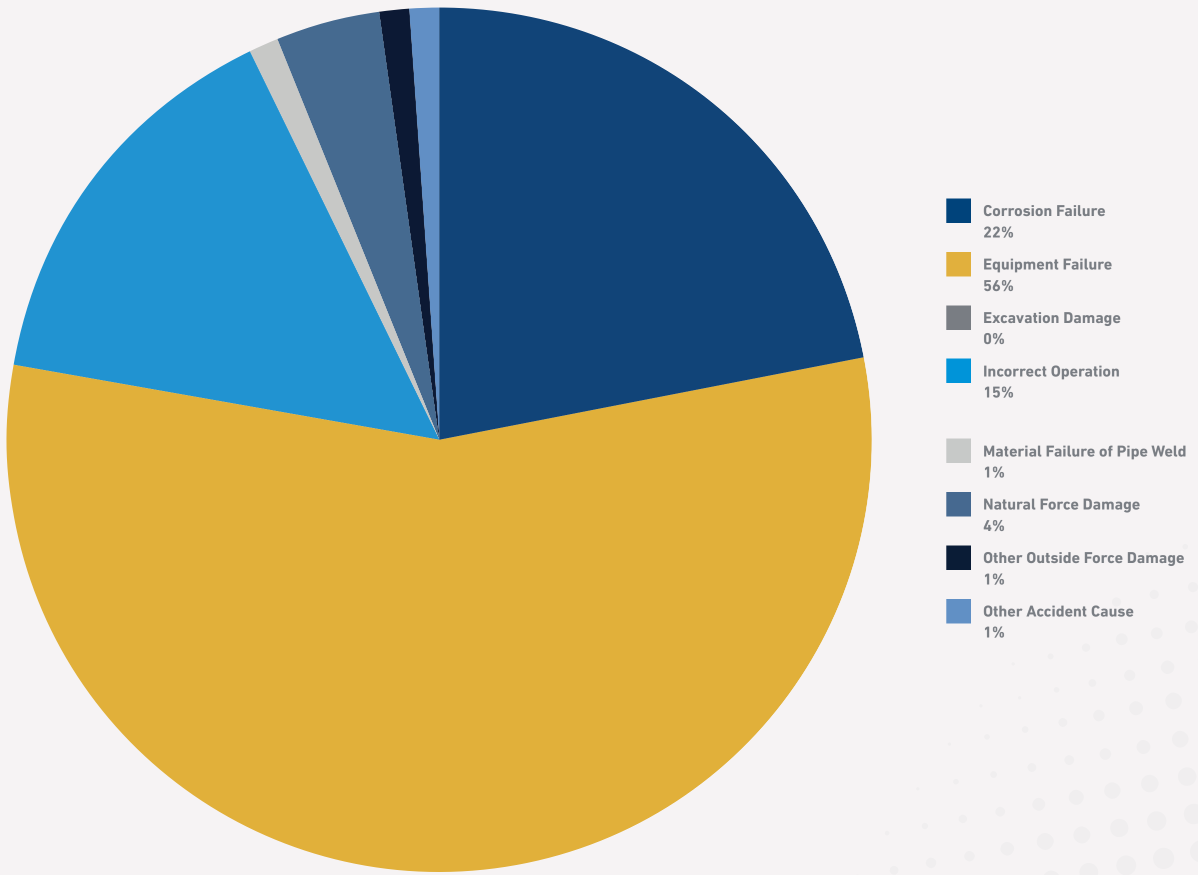


FIGURE 42. 2010-2024 FACILITY PIPING RELEASES BY CAUSE



KEY FINDINGS

- Within the equipment failure category, pumps are the leading cause. This is due primarily to seal /packing failures, followed by gasket or O-ring failures. Additional factors that contribute to pump failures are excessive vibration, improper installation, manufacturing defects, breakdown of soft goods and thermal stress.
- The contributing factor for facility releases under incorrect operations includes: incorrect valve positions, tank overfills and improperly installed equipment, fittings, and materials (seals, gaskets, flanges, etc.).
- The information above is based on large amounts of raw data; therefore, determining the root causes and corrective actions to address them needs further individual operator investigation.

OTHER OPERATOR CONSIDERATIONS

Process Safety Information (PSI) is an element within OSHA's Process Safety Management (PSM) framework and most facilities are regulated by PHMSA and are PSM exempt. Operators should consider whether PSI principles could be applied at PSM exempt facilities to supplement their facility integrity management programs. PSI principles to include in the evaluation could include the following:

- Mechanical integrity and reliability engineering processes.
- Asset management software tools.
- Preventative and predictive maintenance and use of asset management software tools to support it.

SEAL FAILURE RECOMMENDATIONS INCLUDE:

- Failure of the pump shaft seal is the most common cause of facility releases. Even though pump seal failures depend highly on the seal type and material pairing, common causes for failure include excessive heat, high vibration, excessive friction (inadequate lubrication and/or running dry) and improper material construction for commodity transported.
- Best practices to extend seal life and minimize failures include performing failure analyses when seal failures occur and adopting recommendations found in API Standard 682 (Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps), Fourth Edition into the operators' preventative maintenance program(s).
    - API Standard 682, Fourth Edition includes seal technology advancements; improved seal cooling processes, improved seal leakage detection methods, and recommendations for updated design features. The standard also includes methods to periodically test pump seals that enhance failure detection to prevent unwanted releases

INTERNAL CORROSION RECOMMENDATIONS INCLUDE:

- Of the facility releases caused by internal corrosion, at least 50% occurred at the low point in the pipe where corrosion is most likely to occur.
- Dead legs (lines that physically cannot flow), intermittently used facility lines (or "operational dead legs"), drain lines and relief lines all have a common denominator: limited flow, sporadic flow, or no flow and the integrity management issues these conditions entail. Dead Legs have historically shown that they are susceptible to internal corrosion, particularly in crude oil service, and should be considered at higher risk for this specific threat. As a result, many operators have eliminated or are in the process of eliminating dead legs in their systems, either by complete removal and abandonment of lines that physically cannot flow or by

making engineering design and operational changes to address operational dead legs. Integrity management of dead legs is discussed in API Recommended Practice 1188, Hazardous Liquid Pipeline Facilities Integrity Management, and API Technical Report 1189, Internal Corrosion in Pipeline Facilities, which is a supplement to RP 1188.

- Operators should have procedures in place that address "operational dead legs" which are piping circuits within facilities that by design and operation have infrequent flow such as pressure relief lines and unused portions of tank headers that cannot be removed from service.

Operators should consider the following:

- Draining and isolating or removing dead legs in crude oil service that serve no further process purpose.
- Developing a phase-out plan for systematically removing these dead legs.
- Create a schedule for flushing dead legs and intermittently used lines with fluids that contain biocide(s) to inhibit microbial growth and reduce the threat of internal corrosion. If inhibitors are used, an operator is required to monitor 2x per year per 195.579(b).
- Incorporate a dead leg program into an operator's facility integrity management program.
- Incorporate a piping inspection program within the facility, which includes elevation as a variable.

INCORRECT OPERATIONS RECOMMENDATIONS INCLUDE:

- Although much of pipeline operations can now be automated, humans continue to serve a primary role in many activities touching nearly all aspects of pipeline operations. The data indicates that volumes released during incorrect operation incidents tend to be smaller in volume and the number of incidents has generally remained consistent since 2010.

Operators should consider the following:

- Reevaluate Operator Qualification program for improvement opportunities.
- Implementation of RP-1173 Pipeline Safety Management System (PSMS).
- Plan carefully for unusual operations and one-time events. Develop and review detailed work plans with subject matter experts through a Process Hazard Analysis, HAZOP, and pre-start up safety reviews, or management of change process to help reduce risk due to unfamiliar situations.
- Plan for the changing work force: as experienced personnel retire or move on and are replaced by less experienced personnel, the opportunity for operator error could increase without appropriate training and retraining.
- Analyze abnormal events and unintentional releases using root cause analysis methods to expose possible operator errors and implement procedure changes and corrective action where needed.
- Refer to PPTS Advisory 2008-2 A Look at Operator Error or Other Incorrect Operation
- Refer to PPTS Advisory 2003-7 An Expanded View of Operator Error

ADDITIONAL INFORMATION FOR OPERATORS:

- For more details, please refer to PPTS Advisory 2016-1 Facilities Piping and Equipment, PPTS Advisory 2009-5 New Findings on Releases from Facilities Pipeline, and PPTS Advisory 2003-5 Facility Piping and Equipment Facts for more details.

Find this and other advisories drawn from the hazardous liquid industry's Pipeline Performance Tracking System at 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 Liquid Energy Pipeline Association believe that tracking and learning from spills improves performance and demonstrates the industry's firm commitment to safety and environmental protection by its results.

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