Learning from Pigging Operation Failures – What We Can Learn from These Incidents: a Case Study

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Pipeline Pigging and Integrity Management Conference

February 12-16, 2024

Organized by
Clarion Technical Conferences

https://doi.org/10.52202/072781-0070

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Abstract

As in-line inspection (ILI) yields the highest-per-mile discovery of anomalies, running cleaning pigs and ILI tools are an important part of most integrity management programs. However, not without their risks. On June 28, 2021, a natural gas explosion occurred after workers inserted a gauge plate in a launcher trap as part of a routine pigging activity. The explosion went through the open launcher enclosure, ejecting the pig from the barrel, injuring two workers and killing two more. On November 15, 2021, PHMSA published the Final Rule: Safety of Gas Gathering Pipelines (86 FR 63266). With this rule, more than 425,000 additional miles of gas gathering pipelines are now covered by Federal reporting requirements. Proactive operators are beginning to ascertain the ILI feasibility of thousands of miles of gathering pipelines for future ILI. Many of these pipeline operators are beginning to audit and review their pigging procedures to prevent catastrophic incidents. This paper describes the entire process from the perspective of a pipeline operator; including the most common pitfalls discovered during tens of pigging operations audits.

Introduction

On June 28, 2021, a natural gas explosion occurred during routine maintenance activities at a gas facility near Farmersville, Texas. A pipeline was about to be pigged. It has an outside diameter (OD) of 24 inches and a maximum allowable operating pressure (MAOP) of 800 psig. At the time of the accident the pipeline was operating at 638 psig [2]. Natural gas ignited and exploded after workers inserted a gauge plate (pig) into a launcher. Seven workers were on-site at the time of the accident, the explosion occurred while the workers were removing the pig insertion tool, a 16-foot-long metal pole with a cup welded on the end that was used to push the pig, into the launcher during the sixth of a series of in-line inspections. The explosion was directed through the open launcher door, ejecting the pig from the launcher, injuring two of the workers and killing two more. Shortly before the explosion, workers used a portable flaring system to vent natural gas from the launcher. See Figure 1.

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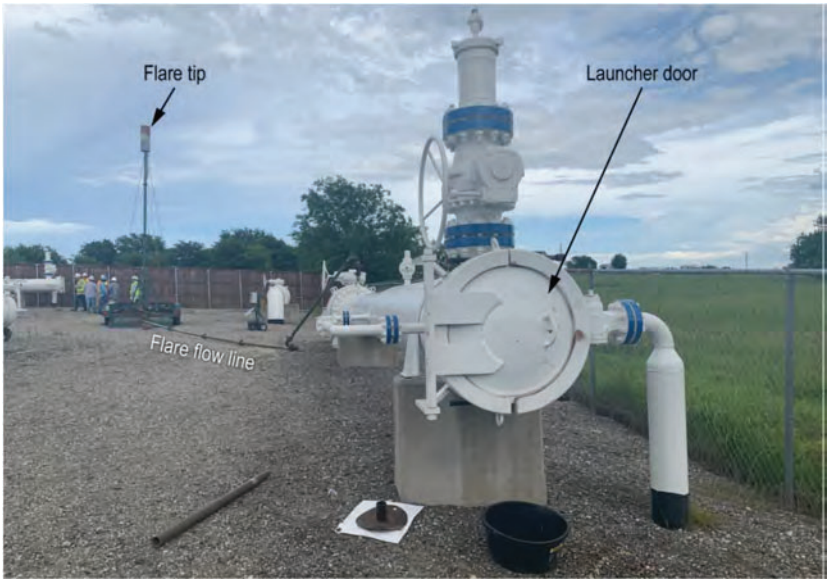

Figure 1. Pig launcher and flare tip at accident location near Farmersville, Texas

A worker opened the 1-inch valve that connected the flare flow line to the launcher and allowed natural gas to vent from the launcher to the flare tip, where it was successfully ignited. As natural gas pressure in the launcher decreased and less natural gas flowed to the flare tip, the work crew observed the flame die down and extinguish. The workers, who were overseeing the contractor personnel, did not expect gas to be leaking from the mainline valve, but they did note in interviews that they thought the flare system would provide a safe path for gas leaking past the mainline valve to vent to atmosphere if any leakage happened to occur. The workers were not using any form of gas monitoring other than observing the flare tip [1], (see Figure 2).

Figure 2. Examples of typical gas monitoring devices

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Figure 3. Farmersville accident site after explosion

Study Observations / Findings

After the Farmersville incident in 2021, many proactive operators have performed independent third-party audits of their pigging operations. These audits included an analysis of current pigging procedures, safety, and observed practices during pigging operations. After the audit, modifications to the procedure were suggested. After performing tens of safety audits, the following common issues were encountered:

1. Incomplete Job Safety Analysis

Job Safety Analysis (JSA) or job hazard analysis is a technique that focuses on job tasks as a way to identify hazards before they occur. A hazard often is associated with a condition or activity that, if left uncontrolled, can result in an injury or illness. The JSA focuses on the relationship between the worker, the task, the tools, and the work environment. Ideally, after you identify all uncontrolled hazards, you will take steps to eliminate or reduce them to an acceptable risk.

It was found during audits to various pipeline operators that the JSAs were incomplete and did not list all potentials for harm. Figure 3 show an example of a typical JSA performed before an ILI execution.

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For a job hazard analysis to be effective, all potential hazards need to be identified. Several job safety analysis forms did not include some potential hazards, such as sources of ignition, chemical hazards, and magnetic hazards. The most overlooked potential hazard in the performed audits was "sources of ignition".

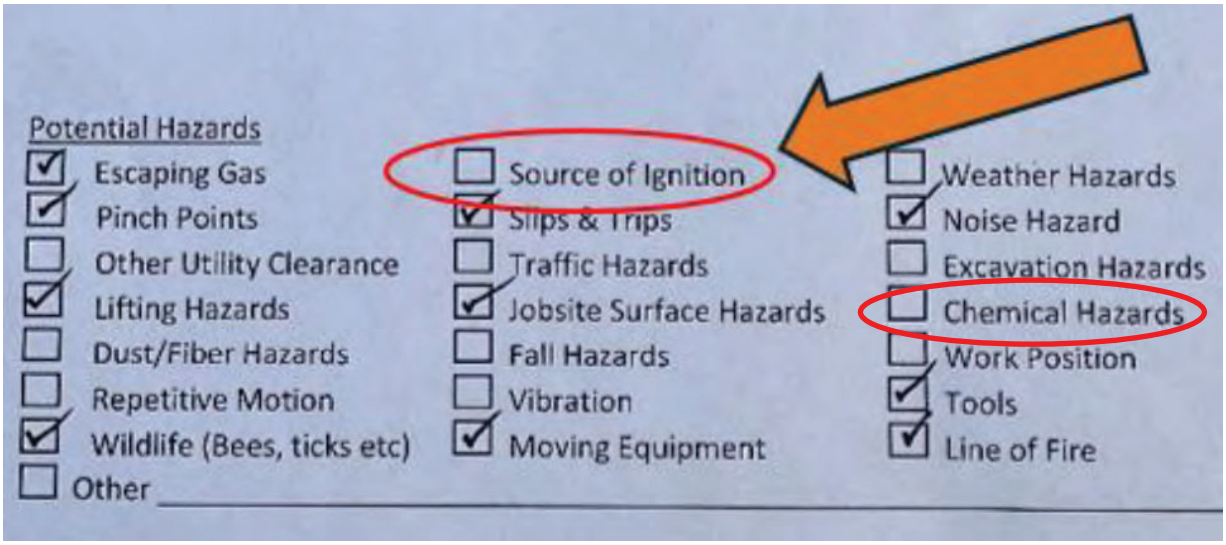

Figure 4. Potential hazards identification in a JSA

It is recommended that pigging procedures highlight and define some of these hazards.

Sources of ignition

Here are some examples of sources: cell phones, metallic cables, and chains (used to retrieve the ILI tool, they may strike pipe surfaces), jump cables for establishing an electrical connection between the pig tray and receiver barrel, electrical and mechanical tools, etc.

Consider the inclusion of instructions to establish an electrical connection (e.g., jump leads) between the tray and the launcher, to avoid sparks because of potential differences. Never establish or remove an electrical connection while the trap door is open! Some steps should be performed before the trap door is open. The holder points of the electrical connection between the tray and receiver must be cleared from any insulating layer! See Figure 5.

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Figure 5. Never establish electrical connection while the trap door is open

Here is a suggested order in which the electrical connections may be performed during the launching of the ILI tool:

(1) Drain the receiver.
(2) Establish an electrical connection (e.g., jump leads) between the pig tray and receiver while the trap door remains closed! The holder points of the electrical connection between the tray and receiver must be cleared from any insulating layer. Never establish or remove an electrical connection while the trap door is open!
(2) Open the trap door.
(3) Place the tray right in front of the launcher.
(4) Fasten the tray to the launcher.

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(5) Push the inspection tool by the chosen insertion system into the launcher until the first cup sleeve has reached at least the nominal diameter, otherwise, the inspection tool will not move because of bypass.
(6) Remove the insertion tools.
(7) Withdraw the tray.
(8) Close the trap door.
(9) Remove the electrical connection between the launcher and the tray.
(10) Remove the tray from the hazardous area

Here is a suggested order in which the electrical disconnections may be performed during the retrieval of the ILI tool:

(1) Drain the receiver.
(2) Establish an electrical connection (e.g., jump leads) between the pig tray and receiver while the trap door remains closed! The holder points of the electrical connection between the tray and receiver must be cleared from any insulating layer. Never establish or remove an electrical connection while the trap door is open!
(3) Open the trap door.
(4) Place and fix the tray in front of the receiver trap.
(5) Pull the inspection tool on the tray with the help of a rope driven by a winch or crane.
(6) Fasten the inspection tool to the tray to prevent shifting.
(7) Withdraw the tray and close the trap door.
(8) Remove the electrical connection between the tray and the receiver trap.
(9) Transport tray and inspection tool out of the hazardous area.

Chemical hazards

Debris from pigging can contain waxes, solids, liquids, and gases, see Figure 5. All debris should initially be treated as potentially harmful material. Potential contaminants include but are not limited to benzene, H2S, and NORM (naturally occurring radioactive materials). It is recommended to minimize the exposure to NORM by minimizing the time that workers spend in areas where NORM may be present and by measuring the potential radiation present in the debris. As all surface contamination monitors are 'active' detectors, they should be intrinsically safe or procedures should be put in place to ensure that a flammable atmosphere is not present during the use of the instrument. An explosion-proof or intrinsically safe dose rate meter (μSv/h)[1] should be applied for monitoring the external radiation dose rate around (potentially) contaminated areas with debris and compared to background values.

Many of the examined procedures failed to mention that eating, drinking, smoking, and chewing should not be allowed in work areas where there is potential NORM. Only essential personnel should

[1] μSv/h, micro Sievers per hour. As an example, a single chest x-ray exposes the patient to about 0.1 mSv. A natural background dose is ~2.4 mSv/year [3]

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be allowed in the work areas where NORM is potentially present. The use of engineered controls and personal protection equipment (PPE), especially respirators in areas where NORM could become aerosolized should be recommended.

Magnetism

Increase awareness of the consequences for pacemakers, hearing aids, and other medical devices.

Reduced oxygen environment

Increase the awareness of the consequences of a reduced oxygen environment (i.e., nitrogen used to purge the natural gas)

Figure 6. Debris in ILI tool after survey, a potential source of NORMs

2. Incomplete Qualifications

Minimum federal safety standards for the transportation of natural gas by pipeline are codified by the Pipeline and Hazardous Materials Safety Administration (PHMSA) in 49 CFR Part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards. 49 CFR Part 192 Subpart N, Qualification of Pipeline Personnel, identifies requirements for qualification of pipeline personnel. These requirements are applicable to individuals performing covered tasks on a pipeline facility.

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A qualification program, requires, in part, that operators have and follow a written qualification program that identifies covered tasks, ensures through evaluation that individuals performing covered tasks are qualified, and communicates changes that affect covered tasks to individuals performing those covered tasks (49 CFR 192.805). Qualified means that an individual has been evaluated and can perform assigned covered tasks and recognize and react to abnormal operating conditions (49 CFR 192.803). Abnormal operating condition means a condition identified by the operator that may indicate a malfunction of a component or deviation from normal operations that may (a) indicate a condition exceeding design limits or (b) result in a hazard(s) to persons, property, or the environment (49 CFR 192.803).

On April 7, 2022, NTSB investigators met with PHMSA subject matter experts (SMEs) to discuss Operator Qualification (OQ) requirements pertaining to launching and receiving pigs. During this meeting, PHMSA's OQ SMEs indicated that launching and receiving pigs meets the definition of a covered task. While an industry standard, such as American Society of Mechanical Engineers (ASME) B31Q, Pipeline Personnel Qualification, or American Petroleum Institute (API) RP 1161, Pipeline Operator Qualification may provide a useful starting point for identifying industry-accepted covered tasks, the absence of a task within an industry standard does not mean that the task is not a covered task. Operators must evaluate each task they perform and determine whether it is a covered task using the four-part test. A covered task is an activity, identified by the operator, that:

- Is performed on a pipeline facility
- Is an operations or maintenance task
- Is performed as a requirement of this part, and
- Affects the operation or integrity of the pipeline.

In the Farmersville accident, two of the workers had a combined 50 years of experience working in the natural gas industry, and a combined 20 years of experience conducting safe pigging operations; they had received consistent on-the-job training in accepted and well-understood practices for safe pigging operations memorialized in the Transmission Integrity Management Plan. However, minimum federal safety standards in 49 CFR Part 192 require operators to ensure through evaluation that employees be qualified to perform covered tasks, such as pig loading. Qualifications include the ability to safely handle abnormal operating conditions, according to the NTSB investigation report [1]. Operators are required to ensure its workers and contractors can recognize and react to the abnormal operating conditions they experienced, such as the leaking mainline valve. At the time of the incident, the operator didn't require employees or contractors to be qualified to load pigs. Instead, the company expected employees to rely on their experience and on-the-job training. However, as the NTSB report notes, "Despite their many years of collective experience, the workers were not qualified as required by federal regulations and were not using gas monitors to monitor for hazardous atmosphere." As the NTSB report states: "experience does not compensate for lack of training".

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Operator qualification programs must identify all applicable covered tasks. Some examples include integrity management tasks such as launching and receiving pigs.

3. Lack of awareness to address leaking valves and valve malfunctioning

As in the Farmersville incident, where gas entered the barrel after the main line valve had been closed due to a valve leak, procedures may need to address the eventual use of bleeding valves to alleviate the pressure of a leak in the main launcher valve. The hazards need to be discussed and annotated to prevent incidents.

Figure 7. Bleeding valve used to alleviate pressure due to a valve leakage

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4. Incomplete safety equipment

During some of the performed audits the safety equipment was incomplete, or it was not properly used. The recommendation is to have fire extinguishers of the adequate class, correct use of PPE, and the use of gas monitoring devices by all personnel in the launcher/receiver during pigging operations.

Gas Monitoring Devices

It is recommended that operators extend the requirement to carry gas monitoring devices for hazardous atmospheres to all contractors working in the launcher/receiver area during pigging operations.

Fire Extinguishers

It is also recommended that fire extinguishers be available in the field. They need to be of the following classes:

- Class ABC fire extinguishers for flammable solids, liquids, and gases as well as those involving electrical equipment. Some dry chemical agents may aggravate a class D fire.
- Class D fire extinguishers to manage pyrophoric material (reactive metals such as iron sulphide at the receiver). Class D extinguishers have specific dry power agents that are very effective on such fires, but not effective on other types of fires.

Gloves

Many Occupational Safety and Health Administration (OSHA) standards require employers to conduct workplace hazard assessments so that proper precautions can be taken to protect personnel. Employers shall select and require employees to use appropriate hand protection when employees' hands are exposed to hazards such as those from skin absorption of harmful substances. In addition, PPE standards should require a hazard assessment to determine what type of PPE is required. Gloves (neoprene, nitrile, or nitrile rubber) should be worn when there is a potential presence of chemical contaminants (e.g., NORMs). See Figure 8. In general, Gloves should be used unless they can be caught and pulled into machinery, trapping the worker.

Figure 8. Gloves should be used when there is a potential for contaminants such as NORMs

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Conclusions

- New rulemakings promulgated by PHMSA have caused a significant impact on operators who were not previously regulated. More than 425,000 miles of gas gathering pipelines will be regulated or subjected to annual incident reporting requirements as stated in 49 CFR Part 191. As more and more pipelines are going to be pigged and inspected, operators' qualification programs and procedures will need to be updated.

- JSAs should include a thorough discussion of all possible sources of ignition such as cell phones; metallic cables, chains, and metallic poles used to retrieve the ILI tool (avoid the use of metallic poles and chains as they may strike pipe surfaces); jump cables for establishing an electrical connection between pig tray and receiver barrel; electrical and mechanical tools, etc. In addition, it is recommended that the discussions during the Job Safety Analysis ensure the risk control measured selected are sufficient to reduce the risk so far as reasonably practicable.

- Procedures may need to address eventual leaks in the main launcher and receiver valves (increase the awareness of the possibility that gas enters the barrel after the main line valve has been closed due to a valve leak).

- Pig loading Qualifications should include the ability to safely handle abnormal operating conditions as required by current regulations. In addition to provide personnel with the ability to safely handle abnormal operating conditions, the AOCs course needs to provide guidance on hazard zones near launcher and receiver barrels, and criteria for stopping work.

- Monitoring devices or equipment for oxygen, hydrocarbons, H2S, and NORM should be used by all personnel during the pigging operations when applicable. Gloves should be used unless they can be caught and pulled into machinery trapping the worker.

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