Chemically-Assisted Pipeline Pigging Process Operation In The Oil & Gas Industry

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Executive summary

In this paper, we investigate and identify the method of operation carried out in cleaning lines 2, 3 and 4 of the Esmeralda Refinery Terminal at the PETRO INDUSTRIAL Terminal, Ecuador. The main factor of the subject is to consider that these lines have been out of service for a large number of years, so the resources present, elements associated to the oil, rust, among other factors have become moored to the internal walls of the pipe.

We consider the present case to be a challenge when the integrity of the pipe is tested, since it is necessary to use a cleaning mechanism and not just discard the lines, because they can still be operational once they are analyzed and repaired.

For cleaning operations, we use sponge pigs because they are easy to handle, light and able to remove possible residues with high efficiency. The fluid for cleaning and propelling the PIG is sea water, so we consider building a filter in the area. For the collection of water used in cleaning, we use mobile pools.

Introduction.

The pipeline cleaning operation (Pipeline Pigging) is a process in which PIGs are used for the performance of different activities. The PIG is loaded into the launch trap, which is a funnel or launch system. Then, the PIG is pushed by the fluid to be pumped into the system. In this case, we use seawater. This fluid is able to push the PIG until it reaches the reception system.

The objective of the project is to execute the identification and analysis of the parameters, information and characteristics required to carry out the Pigging operation in the Esmeraldas Refinery Terminal PETRO INDUSTRIAL. At present, at the international level, there are regulations that allow the evaluation of a pipeline to avoid accidents during its operation. Thus, we consider the Pipeline Pigging operation as an accurate solution for the detection and prevention of different failures in pipelines. Pipeline Pigging operations in Ecuador have been carried out for approximately 45 years. The first operation carried out in the country's territory was that of the SOTE pipeline. This line moves the crude obtained from the Eastern region to the town of Esmeraldas. Subsequently, pigging operations have been carried out in different crude oil derivatives pipelines and transport lines in private oil companies (Pigging Products & Services Association; Tiratsoo, Pipeline Pigging & Integrity

Technology, 3rd ed.; Tiratsoo, Pipeline Pigging Technology, 2nd ed.; Tiratsoo, Pipeline Pigging & Integrity Technology, 4th ed.).

Therefore, Pigging operations are presented as a suitable tool to maintain operations and avoid accidents in the oil industry of Ecuador. With this Project, information is collected on the functions and types of PIGs to be used in the cleaning operations of the pipes of the Balao-Esmeraldas Maritime Terminal in PETRO INDUSTRIAL. We also took into account the configuration of the PIGs to carry out various operation processes. For the use of PIGs, operation guidelines were required to avoid accidents. For this reason, we designed the launch and reception traps. We also analyze the need for resources and personnel in cleaning operations, as well as establish safety standards and environmental care.

1- Project objectives

General objective

Identify the pigging techniques that can be applied in the TEPRE oil pipelines of PETRO INDUSTRIAL that go from the valve station to the Esmeralda Refinery.

Specific objectives

1. Study the TEPRE system and the conditions of the pipelines to determine the different areas to be pigged (Cordell and Vanzant).
2. Identify PIGs for cleaning the lines in operation or maintenance.
3. Perform the configuration of the required PIGs.
4. Analyze the operating parameters to carry out pigging operations.
5. Establish the pigging procedure of the system and contingency plan to recover a stuck PIG.
6. Establish the safety and environmental care requirements of the pigging operation.

2- Problem Analysis.

Condition of the pipes.

The Balao Maritime Terminal is made up of the Oil Terminal, operated by a public company, and the Fuel Terminal, operated by PETRO INDUSTRIAL.

The two Terminals have a buoy system for dispatching crude oil and derivatives. The first is connected to the SOTE pipeline, while the second is connected to the Esmeralda Refinery.

The TEPRE consists of six fuel tanks, which have characteristics of being embedded in the sand, and have floating ceilings. At present, these tanks are only used to transport Fuel Oil No. 6.

The system consists of three lines that are routed along the road. Pipelines 3 and 4 are used to load and unload between TEPRE and the Refinery. These are also connected to the Monoboya and two multiboy fields. Line 2 is used to transport drinking water, gasoline, diesel and chemicals, and others; to sea buoys, and is used for fuel export and import operations.

TEPRE is responsible for receiving the imported products, and shipping these products to other countries. The shipping and transportation of products to other places are developed using 4 six-inch pipelines. Two of them are for gasoline and white products, one for AVGAS and the last line for diesel 2. LPG is transported by a 4-inch line from the storage tanks in a different area than the Refinery.

Condition of lines.

At present, the lines to be pigged, two 24-inch pipelines and one 36-inch pipeline, only carry and transport Fuel Oil No. 6. The consideration of the operations necessary for the maintenance of the system is difficult due to the structure and configuration of the system. The low-level parts are not operational, and the configuration is extensive, so it is difficult to analyze and control the internal conditions. This is the main factor why the lines are modified and later adapted to pigging processes. Performing pigging in lines that have not been inspected or cleaned for a long time will be complex. Line 2 has never been used for pumping oil derivatives. It is only possible that moisture, water, scale, salt and rust are present.

On lines 3 and 4, Fuel Oil No. 6 has been transported. The main factors to be considered are sediments, paraffin, water, salt, dust and oxidation. The 3 lines have not been inspected or cleaned internally. Due to this, the pigging cleaning operations will be carried out with preliminary techniques.

The fuel tanks will be used to accumulate the residue obtained from the interior of the lines. The waste obtained will be confined in the tanks for later treatment. Before starting the pigging operations, the lines are cleaned by pumping heated water with the burners of the Refinery. At the beginning of the operation, a PIG containing an element or plate is inserted, which is easily deformed, using a medium-density foam PIG. From the geometry of the receiver, the PIG body must have a smooth front and rear with a polyurethane material. The density is 77-97 kg / m3 with an operating temperature of -29 ° C to 93 ° C.

The first pigging operation is carried out in pipeline 3 for safety factors. This pipeline is used for fuel loading operations. Another advantage of this line is that it has a smaller diameter compared to the other lines, so the volume of water and the rate of pumping required would be less. This line is cleaned using a bidirectional PIG to evacuate any waste or residue present in the pipe that has not been removed by the sponge PIGs. The solid PIG is composed of cups that can be changed and they are selected based on the operation conditions. This PIG is returned with a batch of fresh water to remove the salt present in the line.

The lines 2 and 4 were cleaned by sponge PIGs, using sea water as the pumping fluid, until we considered that they were adequate and clean. Cleaning of lines 2 and 4 was carried out at the same time. For this, we consider a suitable pumping and storage system in which the fluid used in the operation is accumulated. The solid PIGs of the first operation of each line were returned with fresh water to remove the salt that is formed in the lines after cleaning with seawater.

The definition of the required flow for the first operation is complex since the fluid contained in the lines was not identified. For this, we use 5 pumps with their accessories, pipes and tanks. 10-inch pumps to perform seawater filtration, 6-inch pumps were considered for product handling. For the cleaning of line 3, 2 suction and pumping equipment were used. Another equipment was connected to a booster pump to guarantee the flow rate and pressure. Also, the use of 2 suction and pumping equipment was contemplated for lines 2 and 4.

The pumping flow for line 3 was 2500 GPM, while for the remaining lines, it was 3500 GPM. The pressure required to propel the PIGs was calculated from the friction factor, the pressure to move the PIG, the hydrostatic load, and the loss due to the accumulation of residue and sand. The greatest value was the hydrostatic load due to the location of the pipes.

The design presented is only calculated for cleaning the TEPRE lines and was not created to be used in any other system. The data and results obtained in the case of performing the pigging operation with other fluids may vary.

3- Literature Review

3.1 Pipelines

A pipeline is a system of connected pipes that can be used to transport liquids or gases over long distances. The oil and gas industry has used pipelines to transport crude oil, refined products and natural gas. Pipelines have been built with different materials such as steel, cast iron, plastic, and concrete. The selection depends on the characteristics of the product, pressure, temperature and environmental conditions.

Pipelines are considered the safest and most economical form of transporting liquids and gases. They are designed to operate continuously for a long period; however, preventive maintenance is essential to ensure safe operation. Corrosion, deposits and mechanical damage can affect the integrity of the pipe and can cause leaks or ruptures.

3.2 Pipeline Pigging

Pigging is a maintenance and inspection process in which devices called PIGs are sent through pipelines. The word PIG has been associated with the phrase “Pipeline Inspection Gauge,” although its use predates this explanation. A PIG travels through the line using the pressure and flow of the transported product or another propulsion fluid.

Pigging operations can be performed for cleaning, separation of products, displacement, drying, inspection and mapping. Cleaning PIGs remove liquids, sediments, rust, paraffin and other contaminants. Inspection PIGs use sensors to measure wall thickness, corrosion, cracks, geometry and other conditions.

3.3 Types Of PIGs

Sponge PIGs

Sponge or foam PIGs are lightweight, flexible and available in different densities. They can pass through elbows and diameter variations and are commonly used for initial cleaning, drying and dewatering. Their flexibility reduces the risk of becoming stuck in an unknown pipeline.

Low-density foam PIGs are used for drying and light cleaning. Medium and high-density foam PIGs can remove more resistant deposits and may include abrasive strips or brushes.

Solid PIGs

Solid PIGs are manufactured with a rigid body and sealing discs or cups. They provide better sealing and scraping action than foam PIGs. They can be configured with brushes, magnets, gauges, transmitters and other accessories. Bidirectional PIGs can travel in both directions and are useful where the pipeline needs to be reversed.

Intelligent PIGs

Intelligent or inspection PIGs contain electronic instruments and sensors. Magnetic flux leakage tools identify metal loss and corrosion. Ultrasonic tools measure wall thickness and detect internal and external defects. Geometry tools detect dents, ovality and restrictions. The data recorded during the run is analyzed to evaluate pipeline integrity.

3.4 Pig Launchers And Receivers

A pig launcher is a pressure vessel connected to a pipeline that allows a PIG to be inserted safely. A receiver allows the PIG to be removed after the run. Launchers and receivers normally include a quick-opening closure, valves, vents, drains, pressure indicators and safety devices.

The barrel diameter is larger than the pipeline diameter to facilitate insertion and removal. The length must accommodate the PIG and any accessories. Proper isolation and depressurization are essential before opening a trap.

3.5 Propulsion Fluids

The PIG can be propelled by the product in the line, water, air, nitrogen or another compatible fluid. The selection depends on the pipeline service, environmental requirements and availability. Water is often used for hydrotesting, cleaning and displacement. When seawater is used, filtration and corrosion considerations are important because sediment and salt can remain in the line.

3.6 Safety In Pigging Operations

Pigging involves stored pressure, moving equipment, hazardous products and heavy components. Operations require written procedures, trained personnel, communication, exclusion zones and appropriate personal protective equipment. The trap must be isolated, drained, vented and verified at zero pressure before opening.

A PIG can arrive at high velocity, and the receiver closure must never be opened while pressure remains. Product spills and gases must be controlled. Emergency and contingency procedures should be prepared for a stuck PIG, leakage, fire or equipment failure.

4- Methodology

Identification Of Pipeline Data

The first stage was collecting the available technical information for each line. The information included diameter, length, material, wall thickness, elevation, route, valves, fittings, operating history and transported products. Because the lines had not been pigged previously, uncertainty existed regarding their internal condition.

Field inspections were made to identify connection points and the condition of existing facilities. The launch and reception areas were evaluated for access, equipment placement, drainage and waste containment.

Selection Of Cleaning PIGs

Foam PIGs were selected for the initial runs because their flexibility and low risk were suitable for pipelines of unknown condition. The first foam PIG included a deformable gauge plate to identify severe restrictions without damaging the pipeline.

The cleaning sequence increased progressively from softer foam PIGs to higher-density or more aggressive PIGs. A bidirectional solid PIG was planned after the lines were sufficiently clean. The sequence could be adjusted based on the quantity and characteristics of debris recovered after each run.

Water Supply And Filtration

Seawater was selected as the principal cleaning and propulsion fluid because of the large volume required. A filtration system was considered to prevent sand and marine debris from entering the pipelines. Fresh water was planned for the final displacement to reduce salt and corrosion risk.

Pumps and temporary piping were sized to provide the required flow and pressure. Line 3 required an estimated flow of 2500 GPM, while lines 2 and 4 required approximately 3500 GPM. Booster equipment was considered where necessary.

Waste Collection

Temporary mobile pools and existing tanks were used to collect the discharged water and debris. The recovered material was treated as potentially contaminated waste. Sampling and treatment were required before disposal or reuse.

The launch and reception sites required containment to prevent uncontrolled discharge to soil or sea. Absorbent materials and spill-response equipment were made available.

Operational Monitoring

Pressure was monitored at the launcher, receiver and available intermediate points. PIG transmitters and tracking equipment were used to identify the PIG location. The pumping rate was controlled to keep the PIG velocity within a safe range.

Changes in pressure could indicate debris accumulation, a restriction or a stopped PIG. Communication between the pumping, launch, tracking and receiving teams was maintained throughout each run.

5- Execution Of Pigging Operations

Pre-Operational Activities

Before each operation, the pipeline route and valves were verified. The launch and reception traps were inspected, and all equipment was tested. The work permit, safety meeting and communication plan were completed.

The receiving system and waste storage were prepared before launching the PIG. The line was isolated from facilities that were not part of the operation. Personnel were positioned at the required control and tracking points.

Launching Procedure

The launcher was isolated and depressurized. The closure was opened only after verifying zero pressure. The PIG was inserted into the barrel in the correct direction. The closure was secured, and the launcher was filled and pressurized gradually.

Valves were operated in the specified sequence to direct flow behind the PIG. Pressure and flow were increased slowly until the PIG began to move. The departure was confirmed using tracking equipment or pressure response.

Receiving Procedure

The receiving team monitored the expected arrival. Flow was controlled to reduce the PIG velocity before entering the receiver. After arrival, the receiver was isolated, drained and vented completely.

The closure was opened only after confirming zero pressure. The PIG and debris were removed using suitable lifting and handling equipment. The condition of the PIG and gauge plate was documented, and the recovered material was measured and analyzed.

Evaluation Between Runs

The amount and type of debris recovered determined the next step. If large quantities of deposits were obtained or the foam PIG was damaged, another foam run was conducted. More aggressive cleaning was introduced gradually.

The line was considered ready for a solid PIG or inspection tool only after foam PIGs returned in acceptable condition and the amount of debris had decreased. Final cleaning was followed by fresh-water displacement where applicable.

Contingency For A Stuck PIG

A stopped PIG was identified by pressure response and tracking data. Pumping pressure was not increased beyond the safe operating limit. The PIG location was confirmed before corrective action.

Possible actions included changing flow, reversing a bidirectional PIG, allowing deposits to soften, or accessing the pipeline at the identified point. Excavation or cutting was considered only after engineering review and safe isolation.

Safety And Environmental Requirements

Safety Management

The pigging operation required a designated supervisor with authority over the work. All personnel were informed of the operational sequence, hazards and emergency actions. Only authorized personnel were permitted inside the launch and reception exclusion zones.

Pressure equipment, hoses and temporary connections were inspected and rated for the maximum expected pressure. Whip checks and restraints were used where necessary. Lifting equipment was certified, and crane movements were directed by one designated signal person.

Personal Protective Equipment

Personnel were required to use protective helmets, safety glasses, gloves, protective clothing and safety footwear. Additional respiratory or chemical protection was used based on the product and atmosphere. Gas testing was required where vapours could accumulate.

Environmental Controls

The operation was planned to prevent the discharge of oily water and debris into the environment. Secondary containment was installed under temporary equipment and connections. Waste was collected, characterized and transferred to an authorized treatment or disposal process.

Spill-response equipment was maintained at the working areas. Any leak or spill required immediate control, notification and cleanup according to the contingency plan.

Results And Discussion

The operation demonstrated that foam PIGs were appropriate for the initial cleaning of lines that had remained inactive and had no previous pigging history. Their flexibility enabled them to pass through the system while collecting loose material and identifying restrictions with lower risk than a rigid PIG.

The use of seawater provided the large volume necessary for propulsion, but filtration was essential to avoid introducing additional sediment. Final fresh-water runs were important to reduce salt remaining in the line.

The recovered debris and condition of each PIG provided information about the internal state of the pipelines. Repeated runs were necessary until the quantity of residue decreased. Pressure monitoring and PIG tracking were critical for confirming progress and avoiding excessive pressure.

Cleaning lines that had been inactive for years proved more complex than cleaning operating pipelines. Deposits could be hardened and uneven, and the available historical information was limited. A progressive cleaning strategy reduced the likelihood of a PIG becoming stuck.

Operational parameters

The operational pressure was determined considering the hydrostatic head, friction losses, pressure required to move the PIG and additional pressure caused by accumulated debris. The hydrostatic component was significant because of pipeline elevation differences.

The pumping system had to maintain adequate flow while remaining within the allowable operating pressure of the weakest component. Pressure limits and shutdown criteria were established before the run.

PIG velocity was controlled to prevent damage and ensure effective cleaning. Very high velocity reduces cleaning contact and increases receiving hazards, while very low velocity can allow the PIG to stop.

Technical considerations

Pipeline Geometry

The minimum bend radius, valve bore, branch connections and changes in diameter must be compatible with the selected PIG. Full-bore valves are preferred for piggable systems. Any unknown restriction increases the risk and supports the use of an initial foam PIG.

Gauge plates can provide evidence of restrictions or deformation. A damaged plate must be evaluated before a rigid PIG or intelligent tool is launched.

Material Compatibility

PIG body materials, sealing elements and brushes must be compatible with the transported product, cleaning fluid and operating temperature. Polyurethane components are commonly used because of their flexibility and wear resistance.

Cleaning chemicals, if used, must not damage the pipe, seals, coatings or downstream facilities.

Waste treatment requirements must also be considered.

Tracking And Communication

PIG tracking devices can include electromagnetic transmitters, acoustic systems and above-ground markers. Tracking helps confirm movement and locate a stopped tool. The locations of important crossings, valves and changes in elevation should be included in the tracking plan.

Continuous communication between teams reduces operational risk. The pumping team must receive immediate information about PIG movement, arrival or any abnormal condition.

Design Of Launch And Reception Systems

The launcher and receiver were designed according to pipeline diameter and the longest PIG configuration. The barrel diameter was selected larger than the nominal line diameter. Reducers were used to connect the barrel to the pipeline.

The systems included isolation valves, kicker or bypass lines, drains, vents, pressure gauges and quick-opening closures. The receiver was designed with enough volume to retain debris and liquid arriving with the PIG.

The traps were supported and anchored to withstand pressure and operational loads. Access was provided for loading, unloading, lifting and maintenance. Drainage was directed to contained storage.

Pumping Equipment

The pumping arrangement included seawater intake pumps, filtration equipment, transfer pumps and booster pumps. Temporary hoses and piping were selected according to flow and pressure. Check valves and isolation valves prevented reverse flow.

The pumps were arranged so that flow could be adjusted gradually. Backup equipment was considered to avoid leaving a PIG stopped for an extended period after a pump failure.

Waste Management

Waste from pigging can include water, oil, paraffin, corrosion products, scale, sand and cleaning materials. The physical and chemical characteristics determine the required handling and disposal method.

Liquids were collected in mobile pools or tanks. Solids were separated where practical. Samples were analyzed to identify hydrocarbons, salinity and other contaminants. The waste was transported and treated according to environmental regulations.

Contingency Planning

The contingency plan included actions for a stuck PIG, leak, hose failure, loss of power, excessive pressure, spill, fire and personnel injury. Emergency contacts and responsibilities were established.

For a stuck PIG, the maximum allowable pressure and permitted flow changes were defined. The pipeline route and access points were available to support location and recovery. No excavation or cutting could begin until the line was fully isolated, drained and made safe.

Maintenance Program

After the initial rehabilitation, a preventive pigging program should be implemented. The frequency depends on product characteristics, flow, corrosion history and deposit accumulation. Regular cleaning reduces the amount of debris and makes future operations safer.

Integrity inspection tools should be considered after the line is sufficiently clean. Corrosion control, chemical treatment and line mapping should be integrated with pigging results. Records of each run should include pressures, flow, PIG configuration, travel time, debris and anomalies.

Advantages Of The Proposed Method

1. It allows existing pipelines to be evaluated and potentially returned to service instead of being discarded.
2. Foam PIGs reduce the initial risk in pipelines with unknown internal conditions.
3. A progressive sequence provides information after every run and supports operational decisions.
4. Water provides an available propulsion medium and enables collection of loosened contaminants.
5. Tracking and pressure monitoring improve control and safety.

Limitations

1. Incomplete historical and geometric information creates uncertainty.
2. Long inactive periods can result in hardened deposits and corrosion.
3. Seawater can introduce sediment and salt if filtration and final flushing are inadequate.
4. Large volumes of contaminated water require storage and treatment.

5. The absence of permanent launchers and receivers increases temporary equipment requirements.

Risk Assessment

The primary risks included stored pressure, release of hydrocarbons, equipment failure, PIG impact, lifting activities and environmental discharge. Each risk required preventive controls and defined response measures.

Pressure hazards were controlled through rated equipment, isolation, venting and verification before opening traps. Product exposure was controlled through containment, personal protective equipment and atmospheric monitoring. Lifting risks were controlled through certified cranes, rigging and designated supervision.

Personnel And Responsibilities

The operation team included a project manager, pigging supervisor, pumping operators, launcher and receiver technicians, tracking personnel, safety representatives, environmental personnel and equipment operators.

The supervisor coordinated the sequence and authorized each stage. The safety representative verified permits, exclusion areas and personal protective equipment. Environmental personnel supervised containment, sampling and waste handling.

Documentation

Pre-operational documentation included drawings, line data, pressure limits, equipment certificates, work permits, risk assessments and emergency plans. Operational records included time, flow, pressure, PIG location and observations.

After each run, the PIG condition, debris quantity and any damage were recorded. Photographs and samples supported analysis. A final report documented the cleaning sequence and recommendations for future maintenance.

General Pigging Procedure

1. Review line data, drawings and operating limits.
2. Inspect the route, launcher, receiver and temporary equipment.
3. Complete permits, risk assessment and safety briefing.

4. Prepare pumping, filtration, tracking and waste systems.
5. Isolate and depressurize the launcher.
6. Insert the selected PIG and secure the closure.
7. Fill and pressurize the launcher gradually.
8. Open valves in the approved sequence and begin controlled pumping.
9. Track the PIG and monitor pressure and flow continuously.
10. Control the arrival at the receiver.
11. Isolate, drain and vent the receiver.
12. Verify zero pressure before opening.
13. Remove and inspect the PIG and recovered debris.
14. Evaluate results and select the next PIG.
15. Document the operation and manage waste.

Cleaning Sequence For Line 3

Line 3 was selected for the first operation because its smaller diameter required less water and pumping capacity. Initial heated-water circulation was used to soften possible hydrocarbon deposits.

A medium-density foam PIG with a deformable plate was launched first. Additional foam PIGs were used according to the returned debris and condition. After acceptable cleaning, a bidirectional solid PIG was used to improve displacement and scraping.

A final fresh-water batch was used to reduce salt left by seawater. The line was then evaluated for further inspection or maintenance.

Cleaning Sequence For Lines 2 And 4

Lines 2 and 4 were planned for simultaneous or coordinated cleaning using separate pumping arrangements. Foam PIGs were launched progressively until the recovered debris decreased.

Because of the larger diameters, these lines required greater flow and water volume. Storage capacity at the receiving end was confirmed before each run. Fresh water was used for final displacement after seawater cleaning.

Hydraulic Considerations

The pressure required for a run can be expressed as the sum of hydrostatic pressure, pipeline friction, PIG differential pressure and additional resistance from debris. Elevation data and fluid density determine the hydrostatic component.

Friction depends on pipeline diameter, length, roughness, fluid viscosity and flow. The PIG differential pressure depends on seal configuration and contact. Debris can increase resistance unpredictably, so pressure was monitored continuously.

The maximum pumping pressure must remain below the allowable pressure of the pipeline, traps, hoses and fittings. Shutdown criteria should be conservative where pipeline condition is uncertain.

PIG Selection Criteria

The selected PIG must be compatible with line diameter, bends, valves and fittings. It must tolerate the operating temperature and fluid. The cleaning element must match the expected deposits.

For unknown lines, foam PIGs offer flexibility and reduced blockage risk. For established piggable lines, solid PIGs provide stronger sealing and cleaning. Intelligent PIGs require a clean and geometrically compatible pipeline.

Environmental Impact

The operation can generate substantial volumes of oily and saline water. Uncontrolled discharge could affect marine and terrestrial environments. The design therefore included contained reception, spill prevention and authorized treatment.

Noise, vehicle movement and temporary equipment also require control. Work areas should be restored after completion. The final report should account for waste quantities and disposal documentation.

Cost Considerations

Major cost elements include temporary launchers and receivers, pumps, filters, water supply, PIGs, tracking, personnel, waste treatment and contingency resources. Reusing an existing pipeline can provide significant value compared with replacement, but integrity must be confirmed before operation.

A progressive cleaning sequence can reduce the risk of expensive recovery operations. Permanent pigging facilities may be economically justified if the lines will return to regular service.

Quality Control

Equipment certificates and calibration records were verified. PIG dimensions and components were inspected before use. Valve positions and the operational sequence were checked by more than one responsible person.

Samples, photographs and run records were retained. Any deviation from the procedure required authorization and documentation.

Emergency Response

In the event of a spill, pumping was stopped, the source isolated and containment deployed. The environmental response team was notified. For a fire, emergency shutdown and site evacuation procedures were followed.

For injury or exposure, first aid and medical response were available. For excessive pressure, pumping stopped immediately and valves were not operated until the condition was assessed.

Future Integrity Assessment

Once cleaning was complete, the next step should include assessment by an appropriate inspection technology. Ultrasonic or magnetic-flux-leakage tools can identify wall loss, while geometry tools can detect dents and restrictions.

Inspection results should be integrated with pressure history, corrosion data and repair records. Defects must be evaluated according to recognized engineering standards before returning the line to service.

Technical Recommendations

1. Confirm full-bore passage through all valves and fittings before launching rigid PIGs.
2. Use a deformable gauge plate during early foam runs.
3. Filter seawater and monitor sediment loading.
4. Use fresh water for the final displacement and consider corrosion inhibition.
5. Provide reliable tracking at critical route locations.
6. Maintain sufficient receiver and waste-storage capacity.
7. Establish conservative pressure and velocity limits.
8. Do not progress to intelligent inspection until cleaning and geometry are acceptable.

Safety Recommendations

1. Appoint one pigging supervisor and one crane signal person.
2. Maintain exclusion zones at the launcher and receiver.

3. Verify zero pressure independently before opening any closure.
4. Use rated, restrained and inspected temporary hoses and connections.
5. Conduct gas testing where hydrocarbons or vapours may be present.
6. Prepare emergency and stuck-PIG procedures before launching.

Environmental Recommendations

1. Use secondary containment around all temporary connections and storage.
2. Sample and characterize recovered water and solids.
3. Transfer waste only to authorized treatment or disposal facilities.
4. Document spills, recovered quantities and final disposal.
5. Restore temporary working areas after operations.

5.1 Conceptual Basis Of PIG Configuration

PIG configuration depends upon the specific objective of the run. A cleaning PIG may include sealing discs, guiding discs, brushes, magnets and scrapers. A displacement PIG requires effective sealing. A gauge PIG includes an aluminium plate sized to a percentage of the internal diameter.

The number, spacing and diameter of cups or discs affect sealing, stability and differential pressure. For bidirectional service, symmetrical disc arrangements are used. Foam PIGs may be bare, coated or equipped with abrasive materials.

5.2 PIG Velocity

PIG velocity influences cleaning efficiency and operational risk. The preferred range varies with the tool and service. A slow, controlled speed provides better contact for many cleaning operations, whereas excessive velocity may cause damage, bypass debris and create a dangerous receiver impact.

Velocity can be estimated from volumetric flow and pipeline area, but bypass and fluid compressibility can create differences. Tracking provides confirmation of actual travel time.

5.3 Pressure Monitoring

A pressure increase upstream of the PIG can indicate resistance or debris accumulation. A sudden pressure decrease may indicate bypass, movement or leakage. Operators should understand the expected pressure profile before the run.

Pressure should be recorded continuously where possible. Increasing pressure solely to force a stopped PIG can exceed safe limits and compact debris, making recovery more difficult.

5.4 Debris Analysis

Recovered material provides useful information. Paraffin indicates temperature and product-related deposition. Rust and scale may indicate corrosion. Sand or soil may suggest construction debris, external intrusion or seawater sediment.

The quantity and characteristics should be recorded for each run. This information supports selection of the next PIG and future maintenance frequency.

5.5 Operational Decision Criteria

The next stage should proceed only when:

- The previous PIG was received intact.
- The gauge plate does not show unacceptable deformation.
- Pressure and travel time were within expected limits.
- The quantity of debris is decreasing.
- No leak or integrity concern has been identified.
- The next PIG is compatible with the confirmed geometry.

5.6 Stuck PIG Prevention

Prevention includes reviewing drawings and history, verifying valves, selecting flexible initial PIGs, controlling debris accumulation and monitoring pressure. Launching a rigid or highly sealing tool too early can increase risk.

PIGs should not be oversized, and aggressive brushes should be introduced progressively. The receiver must be prepared before launch so that flow does not have to stop unexpectedly.

5.7 Stuck PIG Recovery

The first response is to stop and assess. Tracking confirms the location. Pressure on each side, valve status and likely obstruction are reviewed. Controlled pressure cycling or flow reversal may be possible for bidirectional PIGs.

Chemical or thermal treatment may soften deposits if compatible. Mechanical access requires engineering planning, isolation and environmental control. Cutting into a pipeline is a last resort.

5.8 Corrosion Considerations

Long-idle lines may contain water and oxygen that promote internal corrosion. Cleaning can remove deposits that previously covered corrosion defects, so the line should not be assumed safe merely because it is clean.

After cleaning, drying or corrosion inhibition may be required. An integrity assessment and pressure evaluation are necessary before normal service.

5.9 Use Of Seawater

Seawater is available in large quantities but contains salt, suspended solids and biological material. Filtration limits the introduction of solids. The system should minimize the time that seawater remains stagnant in the pipeline.

A fresh-water flush reduces salinity. Depending on future service, chemical treatment, drying or dewatering may be required.

5.10 PIG Trap Safety

Quick-opening closures require particular care. The closure must include a pressure warning or locking mechanism that prevents opening under pressure. Drains and vents must be proved clear.

Personnel should stand outside the potential line of fire. The closure should be opened slowly after pressure is confirmed at zero. The receiver may contain flammable vapours or toxic material, so atmosphere testing and ventilation may be necessary.

5.11 Lifting And Handling

Large PIGs and trap closures can be heavy. Certified lifting points, slings and cranes are required. Hands must be kept away from pinch points when inserting or removing a PIG.

Only the designated signal person should direct crane movement. The lifting area must be controlled, and personnel must not stand under suspended loads.

5.12 Temporary Piping

Temporary piping and hoses must be compatible with the fluid, pressure and temperature. Connections should be minimized and protected from vehicle movement. Supports and restraints prevent movement from hydraulic forces.

A pressure test and inspection should be completed before use. Flexible hoses require whip restraints and protection from sharp bends and abrasion.

5.13 Instrumentation

Pressure gauges should have an appropriate range and current calibration. Flow measurement supports velocity control and volume accounting. Temperature measurement may be relevant where heated water is used.

PIG signallers, transmitters and tracking devices should be tested before the run. Backup tracking methods reduce uncertainty.

5.14 Communication Plan

The communication plan identifies call signs, radio channels and required notifications. No valve or pump action should occur without authorization from the supervisor.

Tracking personnel report each confirmed passage. The receiving team confirms readiness before launch. Emergency terminology and stop-work authority should be understood by all participants.

5.15 Training

Personnel require training in pigging procedures, pressure hazards, product hazards, equipment operation, spill response and emergency actions. Practical familiarization with the specific launcher and receiver is important.

A pre-job meeting and simulation of critical steps can identify misunderstandings. Lessons from each run should be shared before the next operation.

Operational area requirements

The working area must have adequate access, lighting, drainage and room for equipment. Vehicle routes and crane positions should be planned. Ignition sources must be controlled where hydrocarbons are present.

The receiver area requires enough space for waste containers and PIG handling. Barriers and signs should identify restricted areas.

Facility requirements

The operation requires:

- Reliable water supply and filtration.
- Pumps with suitable flow and pressure capacity.
- Temporary piping, hoses and valves.
- Launch and reception traps.
- Waste tanks or mobile pools.
- Tracking and communication equipment.
- Lifting and transport equipment.
- Spill response and fire-fighting resources.

Personnel protection

The PPE selection depends on the hazards identified. Basic equipment includes:

- Protective helmets.
- Safety glasses or face shields.
- Hydrocarbon-resistant gloves.
- Flame-resistant coveralls where flammable products are handled.
- Safety footwear with toe protection and slip-resistant soles.
- Hearing protection near pumps.
- Respiratory protection when indicated by atmospheric assessment.

Transportation And Storage Of PIGs

PIGs should be protected from sunlight, heat, contamination and deformation. Polyurethane components can deteriorate if stored improperly. Heavy PIGs require suitable racks and lifting arrangements.

Before use, the PIG diameter, condition, component tightness and transmitter operation should be checked. Spare sealing elements and foam PIGs should be available.

Product evacuation and reception

The reception system must manage both the propelling fluid and the removed deposits. A sudden arrival can produce a surge of liquid and debris. The storage volume must include contingency capacity.

The discharge route should remain contained and visible for monitoring. Screens or separators may be used to retain solids while liquid flows to storage.

Inspection after cleaning

After the final cleaning, visual and sample evidence is not sufficient to establish full integrity. Intelligent pigging, hydrostatic testing or another engineering assessment should be selected based on service requirements and line condition.

Inspection tools require confirmation of bore, bends, valves and trap dimensions. Data quality depends on controlled speed and adequate cleanliness.

Return to service

Returning a line to service requires confirmation that repairs are complete, the line is clean and compatible with the product, and all temporary connections are removed or secured. Valves and safety systems are tested.

The line may require drying, inerting or product displacement. Operating personnel should receive the final report, limits and maintenance recommendations.

Monitoring after return to service

Initial operation should be monitored closely for pressure, flow, leakage and product quality. Any abnormal trend should prompt investigation. Corrosion monitoring and regular pigging should continue.

The first maintenance interval may be shorter than future intervals to confirm how quickly deposits accumulate.

Project lessons learned

1. Historical information should be collected and validated early.
2. Unknown pipelines require conservative PIG selection.
3. Waste capacity can become a controlling factor.
4. Seawater filtration and final fresh-water flushing are essential.
5. Communication and pressure monitoring are critical.
6. Cleaning and integrity verification are separate requirements.

Safety observations

Some of the operations and conditions that could cause accidents include:

- Opening launch or receiving traps without complete depressurization.
- Standing in the line of fire of closures, hoses or PIG movement.
- Using equipment that is not rated for operating pressure.
- Handling contaminated debris without appropriate protection.
- Working under suspended loads.
- Allowing ignition sources near hydrocarbons or vapours.
- Failure to provide safe containers for the deposit of materials.
- The use of product evacuation vehicles is dangerous.
- Use of special equipment in the launch area.

Regarding the equipment that should be used in the area of launch, Petro industrial demands the following:

- Boots with metal toe and anti-slip sole to oil.
- Coverall of non-flammable material in places where handle fuels
- Use protective gloves, especially when handling black products.
- Use of protective helmets.
- Print of the logo of the company in dress
- Knowledge of the security areas in case of accidents.

An operation in which accidents frequently occur is the handling of cranes. An important consideration to avoid accidents of this kind is the designation of a supervisor of crane operation. The person designated to carry out this work will be the only one capable of directing the crane operator when this equipment is used.

6- Other technologies that might be used in the pipelines.

Ice Pigging Versus Traditional Cleaning Methods

The use of pigs or pipe scrapers is currently widespread in the oil sector. The pipelines that transport both crude oil and its derivatives are often affected by the accumulation of waxy deposits, sometimes caused by changes in pressure or temperature in the interior. Large deposits or wax plugs can have catastrophic effects and interrupt the operation of oil pipelines.

The characteristics of the wax can present enormous variations, from viscous liquid or soft deposits of different properties to textures similar to bitumen or candle wax in its most solid manifestation. These deposits can reduce the diameter of the duct and cause a considerable drop in pressure; in the worst case, they could accumulate to completely stop and stop the transportation of oil.

To eliminate these accumulations of wax, you can resort to different techniques. The most common is to use a scraper or solid pig. Solid scrapers are usually devices that are 1 or 2 meters long and are driven inside the pipes by oil, water, or high-pressure air. As they move, they scrape away the accumulated wax and can make the pipe operational again. The main disadvantage of introducing a solid scraper inside the pipes is that it could get stuck, which in most cases would mean a serious and expensive service interruption.

Solid scrapers, as the name suggests, are not flexible and are known to be clogged in the elbows by changes in diameter in case of serious accumulation of deposits or if the pipe is deformed.

Because of the risk of scraper clogging, there are many pipes considered “unbreakable” by operators.

How Can Ice Pigging Help?

Solid scrapers, as the name suggests, are not flexible and are known to be clogged in the elbows by changes in diameter in case of severe accumulation of deposits or if the pipe is deformed and gets there where the risk of clogging of solid scrapers is not an option, or when the characteristics of the pipeline limit the use of solid scrapers.

The ice is able to cross elbows, diameter changes, butterfly valves and obstructions that prevent the use of solid scrapers. The big point in favour of ice cream is that, even if it were obstructed, it would end up melting.

Granita ice scrapers can be injected through small-diameter fittings (5 cm injection points are common) and are also easily formed in large-diameter pipes without the need for large works.

These scrapers are much longer than solid scrapers (sometimes they can reach 500 m) and remove contaminants gradually. For all this, it is not usual to have to resort to excavators or that there are cases of plugging.

The ice-pigging method is suitable for pipes with diameters from 50 to 700 mm and works equally well in hot climates: just inject a little more ice to compensate for the melting. It is especially suitable for pipes with lengths of no more than 5-10 km and is ideal for short stretches considered «scratch-resistant.»

Proven Efficiency In Removing Wax Deposits

Tests show that ice pigging is able to remove very viscous waxes formed by oil. In these tests, carried out on an expressly constructed platform, 100 kg of paraffin wax (mixed with black dye) was smeared inside a pipe 60 cm in diameter in order to mimic the deposits of soft wax that are formed inside the oil pipelines.

After pressurizing the pipe with water, 5 tons of very dense granite were injected, enough to form a semi-solid ice scraper. The ice used was considerably denser than that normally used in the interventions, with the aim of generating the necessary shear stress inside the pipe to drag the viscose wax.

As in all actions by means of ice pigging, the pressure of the water served to push the granita through the interior of the pipe. The ice successfully overcame the elbows and changes in the diameter of the pipe, and the accumulated wax was gradually extracted. The ice and wax were collected in a container to be examined and disposed of safely.

Once all the ice had been expelled, the platform was removed to examine it as well. The analyses determined that almost all the wax had been removed except for a very thin layer, which coincided with the results observed with similar pipes and contaminants.

Conclusions

1. The cleaning results were excellent, taking into consideration the data obtained in the ultrasonic inspection.
2. The internal cleaning of lines that are not operating for a long period of time constitutes a greater challenge and complexity than a line in operation.
3. The use of seawater in cleaning operations can present sediment problems if there is no process of treatment before pumping.
4. When there are several lines of different sizes, the Configuration of various pumping equipment is necessary.
5. Selected sponge PIGs performed well in operations, especially in those in which the flow registered was close enough to the required flow.

Recommendations

1. Build a fire-fighting system in TEPRE, which counts with water supply and storage in quantities similar to the volume of the lines.
2. Build a permanent reception and launch system prior to new pigging operations.
3. Plan in the lines, preventive maintenance programs that include Pigging cleaning, Pigging operations, Corrosion treatment and Line Mapping every two years.
4. Make designs for Pigging operations in the lines that will be built for the new Heavy Crude Pipeline and for the La Libertad Refinery.
5. Carry out the design of operations that consider environmental factors, the treatment of waste

obtained from the lines, and the storage of the PIGs used during cleaning.

6. Verify that the safety standards of work equipment involved are met, both in prevention and in the execution and contingency plans.

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