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Hazard Identification Procedure, Risk Analysis, and Determination of Controls for the Failure of a Line Valve in a Gas Pipeline

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Abstract. Petroleos Mexicanos (PEMEX) is a Mexican company that produces, transports, and refines petroleum products that cover the three segments of the oil value chain: downstream, midstream, and upstream. This company had around 8,400 kilometers of pipelines for the transportation of petroleum products and approximately 5,200 kilometers of oil pipelines for the transportation of crude oil. The operation of these transportation systems has an implicit risk that can affect the population and the environment when unwanted events occur such as leaks due to failures, mechanical integrity, or, where appropriate, leaks caused mostly by the illicit hydrocarbon market. In natural gas, on some occasions derived from a risk analysis performed during the design stage, a safe stop condition due to failure applied in the automated system of the gas ducts is necessary. For the example analyzed, humidity was found inside a safe box, it damaged the Limit Switch and caused a double-position failure, and it was not displayed in the SCADA system; some conclusions are that the failure report system activities are necessary, or anything related to the automated system. For all the parties involved, it is necessary to have a common agreement and criteria to take preventive and/or corrective actions in the gas duct transport management. Carrying out inspections regularly is needed because, for the analyzed case, the failure was a protection of the control system that sends a safe stop when detecting a disagreement in the feedback of the limit switch damaged by the presence of water.

Keywords: Risk analysis, pipelines, PLC, SCADA, control determination.

1 Introduction

One of the main activities in the entire value chain of the oil industry is the transportation of oil and its derivative products, which requires an infrastructure that can cover the entire national system and the demand for oil products. Gradually, the actors involved in fuel transportation and distribution logistics improve their options to cover increasingly larger market areas.

To bring products to consumer markets, the main means of transportation are pipelines, tankers, tank cars (railway), and tank cars (pipes). Strategic considerations for investments in fuel logistics infrastructure are based on a thorough analysis of the operating conditions of the means of transportation and distribution, and the growth of local markets. For local fuel distribution or short distances, self-tankers are used; these carry the fuel from the Storage and Distribution Terminals (SDT) to the service stations. Despite the different standards and inspections that are carried out continuously throughout the value chain, it is important to mention that since the oil industry is one of the riskiest due to the nature of hydrocarbons, the analyses and evaluations Risk assessments are carried out to find the causes and consequences of incidents and accidents.

1.1 PEMEX Logistica

Logistics involves managing order processing, inventory, transportation, and combining warehousing, material handling, and packaging, all of this integrated through the business network. The goal of logistics is to support the operational requirements of customer procurement, manufacturing, and supply. The challenge within a company is to coordinate functional capacity into an integrated operation that focuses on serving customers [1].

To supply the population in the national territory, the oil products produced or imported are transported from their point of origin, which may be a refinery, a maritime terminal (MT), or an entry point, to the storage terminals and distribution (SDT) supplied by service stations. This involves the passage between stations or plants for com-pression, pumping, processing, storage, and finally distribution. Pemex Logistics has six systems distributed in the eight statistical regions of the country [2].

The main pipeline builder throughout the country has been PEMEX. It has pipelines for the collection of crude oil and gas extraction from extraction wells, transportation to refineries, petrochemicals, and gas processing complexes, and the distribution of final products to SDT and final consumers (service stations) [3]. The oil distribution infrastructure can be analyzed from two areas: storage and transportation. Storage can be defined as the activity that includes the reception of petroleum products, property of third parties, at the reception points of their installation or system, keeping them in deposit, safeguarding them, and returning them to the depositor or whoever he or she designates. As well as, transportation is the activity of receiving, delivering, and, where appropriate, driving oil products from one place to another through pipelines

Table 1. PEMEX Logistica infrastructure [4].

Pipelines products	Kms	Facilities	Number	Transport Units	Number
Polyduct	8,390	Storage and dispatch terminal	74	Tanker	16
Oil duct	6,291				
LPG duct	1,395				
Gas duct	1,246	Liquefied gas distribution terminal	10	Pipe Tank	1,485
Chemical duct	828				
Gasoline	381				
Fuel oil	145	Navy terminal	6	Tank car	520
Basic petrochemicals	1,294				
Turbosin duct	81				

or other means [2]. Within the oil value chain, transportation is one of the most important activities.

The infrastructure is composed of pipelines, facilities, and transportation equipment as shown in Table 1 which are distributed in the various regions of the country.

1.2 Pipelines

These facilities, unlike others, are not located within an industrial complex with security features; on the contrary, they are located throughout lands owned by third parties, between cities and roads, or on agricultural lands, rivers, and natural landscapes. Which indicates a high probability of leaks or spills, contamination, and explosions [5]. We can classify the pipelines by oil pipelines, which are those that transport crude oil from the extraction areas to the refineries, petrochemical, and gas processing complexes, and the polyducts that transport all types of already processed fuels, mainly gasoline, and diesel [5].

The South-Gulf-Central-West Zone system is the largest, with a length of 4,962 kilometers, which allows the flow of oil products from the Gulf of Mexico to the center of the country and the Bajio, as well as to the Pacific through the Isthmus of Tehuantepec. The second is the Zona Norte system, with 3,152 kilometers, which has three cross border pipelines with the state of Texas in the United States, for the import of fuels. The remaining systems total 770 kilometers, between Guaymas, Rosarito, Topolo-bampo and Progreso.

The main hydrocarbons transported in Mexico are gasoline, diesel, jet fuel and fuel oil with 400.3, 273.8, 56.3 and 307.5 thousand barrels per day generated respectively, according to the Pemex Statistical Yearbook. In addition, other petroleum derivatives are generated in smaller quantities (68.4 thousand barrels per day in total) [6].

Gas pipelines are used to transport fuel gases on a large scale. Its function in current economic activity is very important. It consists of a conduction of steel pipes, through which the gas circulates at high pressure, from the place of origin. They are built buried in trenches at a usual depth of 1 meter. Exceptionally, they are built on the surface [7].

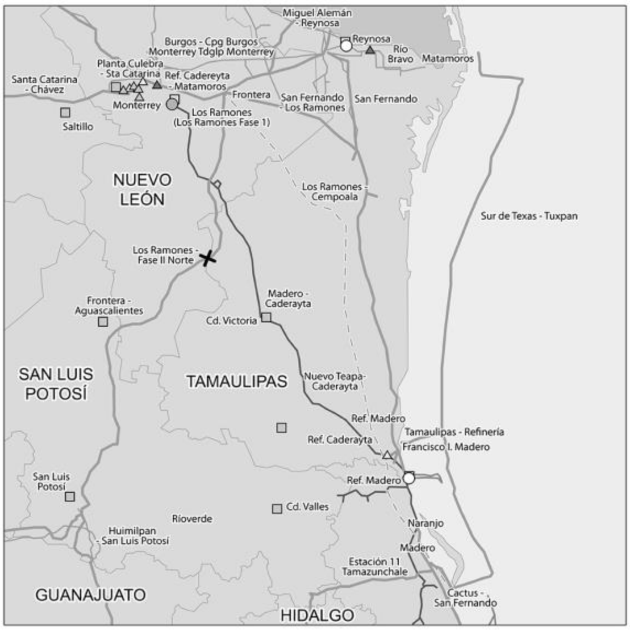

Fig. 1. Gas pipeline as a case study [5].

For the purposes established in the Hydrocarbon Sector Law, the following types of gas pipelines are considered:

1. High-pressure primary natural gas transportation pipelines: Those whose maximum design pressure is equal to or greater than 60 bars.
2. Secondary transport gas pipelines: Those whose maximum design pressure is between 60 and 16 bars.
3. Distribution gas pipelines: Those whose maximum design pressure is equal to or less than 16 bars and those others that, regardless of their maximum design pressure, are intended to convey gas to a single consumer starting from a gas pipeline of the Basic or secondary transport network.

For this study, a section of gas pipeline located on the border of Nuevo León and Tamaulipas was taken into consideration.

The Los Ramones project, which is the one that distributes gas from the coasts of the Gulf of Mexico and goes up to Hermosillo, Sonora, is one of the most important. from the northern zone and that are managed by foreign companies.

The gas pipeline runs from Camargo (Tamaulipas state) to Apaseo el Alto (Guanajuato state). Its route passes through key crossroads in Los Ramones (Nuevo León state), Villagran (Tamaulipas state), and Villa Hidalgo (San Luis Potosí state) before continuing south through San Luis de la Paz (San Luis state). Luis Potosí) and the Querétaro Industrial Park (Querétaro state) to Apaseo el Alto.

1.3 Chemical Accidents and Risk Analysis

Throughout history and the technological development that humanity has experienced, chemical substances have been present, whether in their liquid, solid, or gaseous state; At first, all these substances were used for a series of fortuitous discoveries and later to generate new technological developments that improved the quality of life of society. But the manipulation of all these chemical substances was accompanied by the first fires and explosions of which there is a record, situations that were repeated again and again, until the different physical and chemical properties of the substances used in the processes, the criteria that have been taken as a basis to make a classification of the most critical technological accidents worldwide are based on the number of people killed or affected by this type of events, the ecosystems that are damaged or the adverse impact that they cause. cause subsoil pollution in rivers, lakes, or seas and an increase in pollutants in the environment [8].

Due to the large number of accidents that have occurred in the world in the hydrocarbon sector, it is necessary to carry out a risk analysis. This can be done with different degrees of detail, depending on the risk, the purpose of the analysis and information, as well as the data and resources available. The analysis can be qualitative, semi-quantitative quantitative, or a combination of the three cases, depending on the circumstances. Consequences and their likelihood can be determined by modeling the outcomes of an event or set of events, or by extrapolating from experimental studies or available data. Consequences can be expressed in terms of tangible or intangible impacts, in some cases, more than one numerical value or descriptor is required to specify the consequences and their possibility for different times, places, groups, or situations [9]. Decisions should consider the broader context of the risk and include consideration of the tolerance of the risk by other parts of the organization that benefit from the risk. Decisions should be made in accordance with legal, regulatory, and other requirements. In some circumstances, risk assessment may lead to a decision to conduct further analysis. The risk assessment may also lead to a decision not to address the risk in any other way than by maintaining existing controls.

This decision will be influenced by the organization's attitude toward risk and the risk criteria that have been established [10].

The problem that will be analyzed in this paper is the failure in a section of a gas pipeline called Los Ramones. It is reported by the personnel that manages it that in the SCADA system, a partial closure signal is emitted in a mainline valve simultaneously. 95%, for this reason, and given that the closure cannot be carried out remotely, people from the different profiles assigned to the administration of the gas pipeline are summoned to carry out a risk analysis on the reported situation and avoid a major disaster.

2 Methodology Application to the Study Case

To carry out the proposed methodology, it is essential to collect all data regarding the reported failure. The Activity Manager must consult any matrix that has been

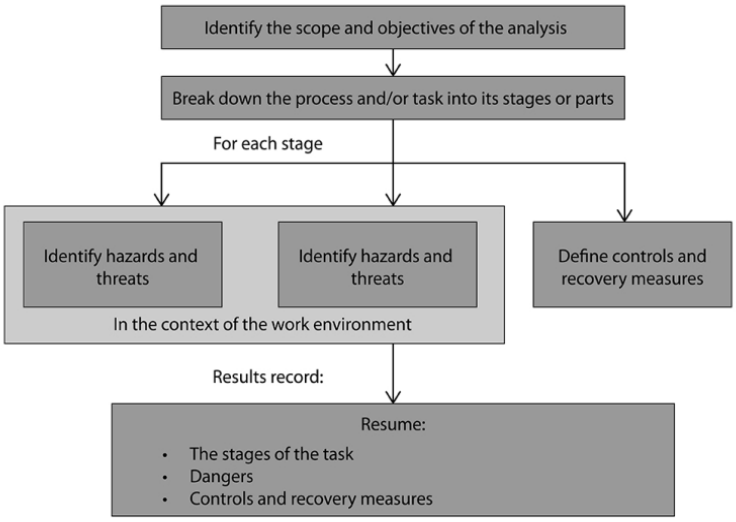

Fig. 2. Proposed Risk Analysis Flowchart.

prepared to show the library and/or inventory of the main safety and environmental risks and controls identified in the global process and must subsequently carry out the specific risk analysis (proposed format) for the task, whether routine or nonroutine, to detail the controls that will be implemented in the specific activities to be carried out.

The global risk analyses of the process (such as HAZOP studies, or any other risk matrix) and the task-specific risk analysis (prepared format) must be prepared based on the following criteria:

The analysis of all main stages of the process (gas transportation, operation, maintenance, dismantling, abandonment, etc.), and each step of the specific task, should be considered.

Activities that have the potential to cause significant incidents. Activities that have a history of incidents and accidents.

New activities or tasks that introduce new work methods.

The design of work areas, processes, use of machinery/equipment, type of operations, personnel requirements, requirements, and controls for contractors, subcontractors, service providers, and suppliers must be considered, and adaptation measures for personnel with special needs must be included. when it's requested.

Situations that are not controlled by the organization and that occur outside the workplace, but that may cause injury or damage to the health of people in the workplace and damage to the environment, for example: adverse weather, sabotage, crime, terrorism, outside personnel (visitors, contractors, suppliers, etc., who may cause damage), external factors such as damaged pipelines, nearby fires, road blockades, etc.

Physical capabilities and other human factors, for example: workloads, uncomfortable postures, fatigue, stress, anxiety, repetitiveness, skills, ergonomics, breaks, adaptation for personnel with special needs, etc.

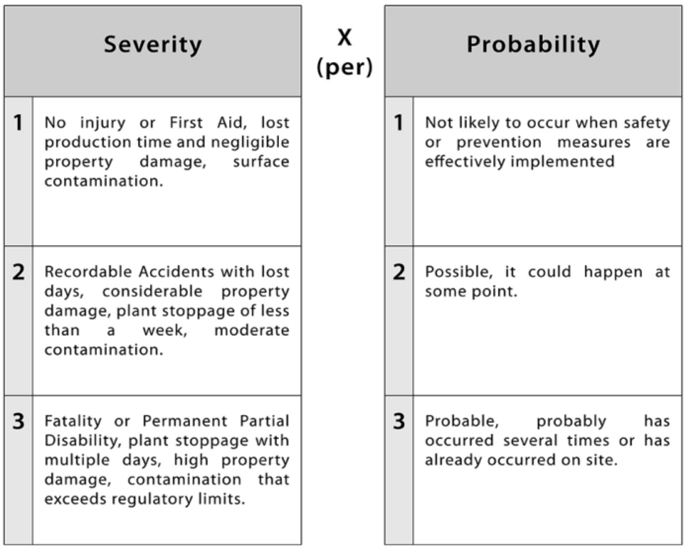

Fig. 3. Approximated Risk Value.

Activities carried out under unusual circumstances.

One-time tasks.

As verification of the hazard management elements of an established procedure or work instruction.

The diagram shows the steps to follow for the procedure described above. To begin the risk analysis, it is necessary to determine the process and/or activity to be analyzed and establish the scope of the work and the objectives of the analysis. This scope must include the stage of the process, activity, or task that will be analyzed, and we must consider the possible effects of the environment in which the activity will be carried out, considering infrastructure, equipment, materials, substances, physical conditions of the place, etc.

Later we will separate the process into basic stages or steps describing the activities to be carried out and their sequence. We must detail each of these and define each change that will be made to mitigate the effects of the risks they may generate.

The description of each stage must provide a declaration of the activities to be carried out, begin each action in the present, and end with the subject that is being analyzed, be it a pump, a tower, valve, and omit references to dangers.

To identify hazards, it is necessary to examine each stage and consider the spatial context that could increase the hazard and any incidents that could result from the location in which the activities are carried out. It is very important to consider any incident that has happened previously and is related to similar activities to avoid its recurrence.

For the risk evaluation part, it is important to mention that this is an approximate value that is obtained by multiplying the severity X the probability according to the data in the format shown below.

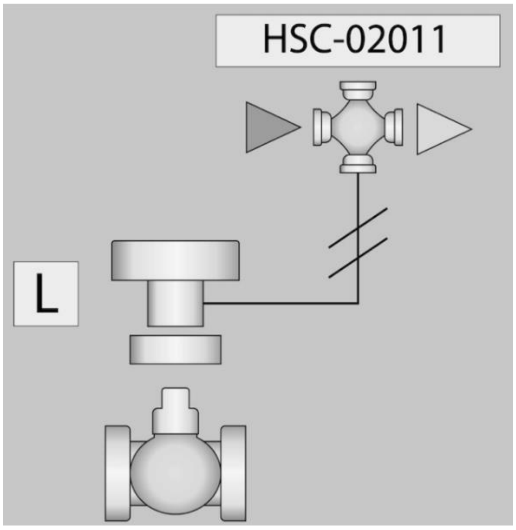

Fig. 4. MLV visualization in SCADA.

3 Discussion and Results

For 8 months there were no activities related to the Line Valve (MLV) itself, however, for this analysis, it is considered that the valve failed, and the SCADA technician visualized the valve in closed mode, and he informed the pipeline leader. about the status of the valve. The pipeline leader activates his on-call technical personnel to review the status conditions of the notified valve, so the SCADA leader receives a report that the valve is in closed status and informs the Operations Manager and the Pipeline Leader. The pipeline technician goes to the site to review the conditions of the Valve and performs valve opening maneuvers manually, leaving the 14" bypass open. Subsequently, they verify the current conditions of the valve with SCADA and report a failed status.

The SCADA Technician verifies the valve position via TVCC and notifies the pipeline technician of a second 50% closure on the valve.

The pipeline technician verifies and confirms to proceed to open the valve manually. He remains on site to monitor current conditions and after approximately 10 minutes he closes at 50% (for the third time). The pipeline technician opens the valve manually and tests the system by requesting the SCADA technician to close the valve and the closing command does not reach the valve, so the selector is positioned remotely to mode local.

The conditions that the open position remains are monitored again and in SCADA the visual mode sends the FAULT signal. The technician receives authorization to proceed to block the gas supply to the valve actuator from the pipeline leader, SCADA leader, and Operations Manager.

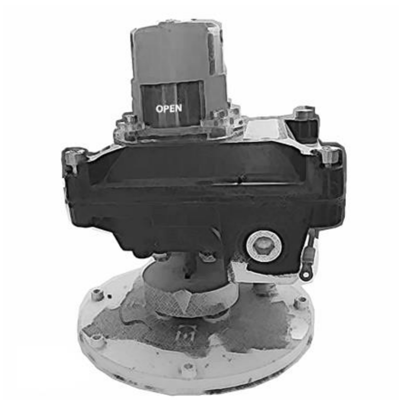

Fig. 5. Valve opening and visualization.

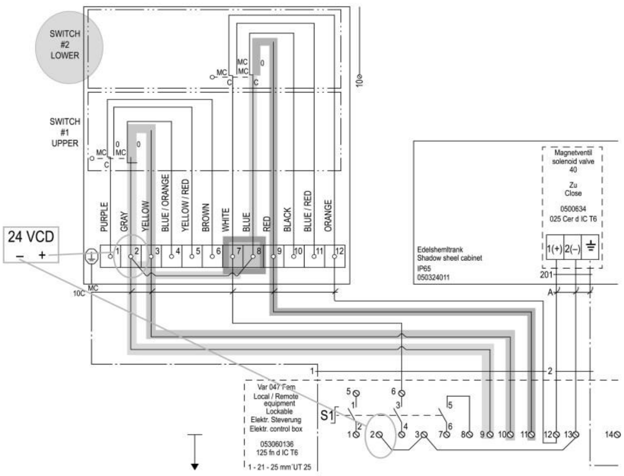

Fig. 6. Valve status before and after the error reported by the SCADA system.

3.1 Review and Inspection

Specialized personnel came to the site and verified that the tubing was not saturated/clogged by dust and that all the conduits were clean and free of blockages.

The Limit Switch Box was checked, and it was found that the closing screws on the top cover were loose, which were removed along with the cover, and it was observed that there was water inside the box.

The inside of the box was drained and cleaned, then the selector was changed from local to remote to verify any changes with the SCADA technician and the FAILURE mode continued.

Table 2. Research results and analysis. Part 1.

Cause	Recommendations	Reason	Actions to take
Due to humidity, it generates a bridge between lines 7 and 8 that sends a closing command.	Change the box of the Limit Switch Box.	By recommendation of the manufacturer and to guarantee the useful lifetime	Complete box replacement Field review of all valve locations with technical personnel
	Check that the hardware on all other boxes is adjusted correctly.	To validate that everything is in correct closure.	
	Arrange a visit with the maintenance personnel to carry out an internal inspection of the Limit Switch Box of all the valves of the gas pipeline systems.	To validate through reliability the findings generated in the internal inspection.	
Due to the tests carried out and having to repeatedly remove the lid.	Previously analyze the activities to be carried out and the implicit risks.	To minimize human factors of repetitions.	Performing task security analysis
	Present and continuous supervision whenever there are repetitive activities.	To guarantee the supplier's and operations recommendations comply with the procedure Performing the security analysis of the task	Always request the documents associated with the activity to be carried out (operational procedures, technical sheets, AST, Standards, etc.)
	To minimize human factors of repetitions.		

A local test of closing and opening the valve is carried out (after authorization by telephone with the SCADA technician) and the status is corroborated with the SCADA technician and his confirmation was that the FAILURE is maintained.

The valve is left blocked, gas is supplied to the valve actuator and specialized personnel are present to check the conditions of the valve.

The conditions of the valve and the position indicator are visually checked, subsequently, the conditions of the connections within the position indicator are verified.

Continuity tests were carried out based on the electrical diagram, which was provided by the manufacturer, and through these tests a damaged switch was detected, voltage measurement was also carried out and it was found that a CLOSED-OPEN signal was sent at the same time. It should be noted that the logic of a PLC sends a failure notification when the valve is like this.

Table 2. Research results and analysis. Part 2.

Due to bad practice of the contractor and client	Generate inspection procedures and formats for the delivery and reception of equipment, machinery, and facilities, among others.	To have transparently what is declared against what is received	At worktables with administration, supplies, and operations staff.
	Apply the controls established for DELIVERY-RECEPTION To have transparently what is declared against what is received	To have all parties involved in a common agreement	At a meeting with the people responsible for the DELIVERY-RECEPTION process
There are no visual or specific inspection recommendations from the manufacturer or supplier	Request the supplier/manufacturer for the technical sheet, valve inspection forms, operation manual	To objectively have all the points or aspects that must be reviewed preventively	Through the document/format that the manufacturer pro-vides
Analyze possible failures during the delivery period on the day of the event. Request SCADA to review its history if any failure occurs in this period.	Request SCADA to review its history if any failure occurs in this period	To evaluate the conditions or possible causes that caused it	In previous review with a worktable
Limit Switch Box Diagnosis	Ask the manufacturer to review and diagnose the box	To determine the causes that caused the damage to the box and its relation-ship with the valve closure	Disassembling, re-viewing electronic diagram, photo-graphic report, final failure report
Origin of 24 VDC	Perform inspection on OC and port card	Find the signal that could activate the Limit Switch Box solenoid.	Simulating the conditions (bypassing pins 7 and 8) of the Limit Switch Box diagram

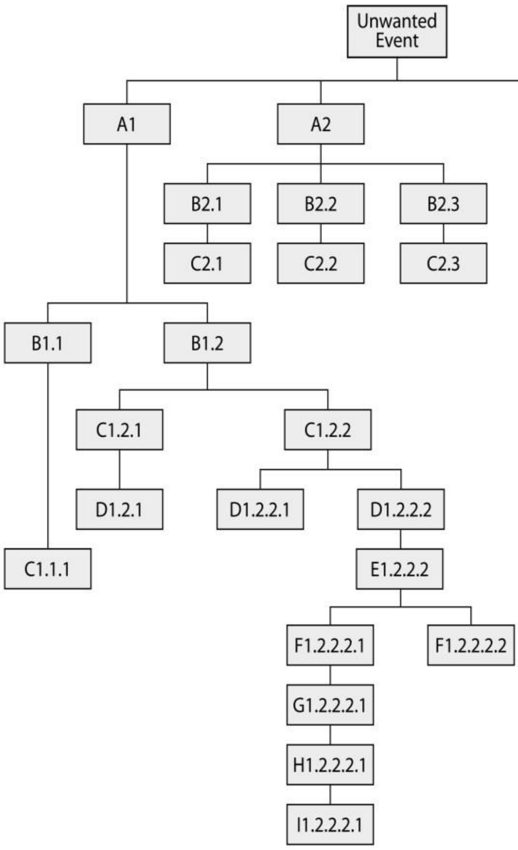

Fig. 7. Carried out analysis chart.

The SCADA technician is asked for the closing command to verify that the signal is arriving within the position indicator. This is confirmed on-site by the manufacturer's personnel.

For the coil to be energized, two conditions must be met:

- The remote local position switch must be set to remote.
- The position indicator should read OPEN.

Due to the data of the readings obtained in the SCADA system, it is possible to see that the valve is not closed due to the factors previously described, for this reason the manual opening was carried out to verify the way in which the SCADA system reflects it.

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3.2 Unwanted Event Valve Closure at 95%

- A1 Receives closing command.
- A2 LINEBRAKE was activated. A3 By closing locally.
- A4 Closes manually
- B1.1 SCADA system sends the closing command. B1.2 By voltage source that activates.
- B2.1 Natural gas leak.
- B2.2 Due to obstruction in the supply tubing B2.3 By pressure difference.
- B3.1 Collaborator performs closing maneuver.
- B4.1 At the time of closure there was no presence of personnel inside the MLV. C1.1 Not powered.
- C1.2.1 The fuse does not work.
- C1.2.2 Within the limit switch box there are 2 points with voltage present (1, and 8) C2.1 Condition not met.
- C2.2 Condition not met.
- C2.3 The pressure differential condition was not met to generate the activation of the Line Brake.
- C3.1 Personnel does not carry out closing operations, the conditions are not met. D1.2.1 Because it is an independent system of these electrical terminals of the Limit Switch.
- D1.2.2.1 By manual manipulation and creating a bridge between 7 and 8.
- D1.2.2.2 Due to humidity it generates a bridge between 7 and 8 that sends a closing command.
- E1.2.2.2 Poor closing of the limit switch cover (loose screws) F1.2.2.2.1 Failure to correctly close the LSB cover.
- F1.2.2.2.2 Due to the tests carried out and having to repeatedly remove the cover. G1.2.2.2.1 The MLV DELIVERY-RECEPTION procedure was not complied with. H1.2.2.2.1 There is no procedure.
- I1.2.2.2.1. Due to the bad practice of the contractor and client.

A fault tree analysis was applied to list the possible causes of the valve failure and determine those that occurred and led to the unwanted event reported by the SCADA system.

4 Conclusions

As a recommendation, you should continue with the reports and reports of failures in this type of pumping system in the midstream segment, as well as activities or things related to the gas pipeline and all the parties involved to have a common agreement and criteria to consider preventive and/or corrective actions.

The operations department of any pipeline monitoring area must carry out an inspection as a visual methodology for its field tours and continuous maintenance of the MLV's equipment.

The failure apparently is a protection of the control system that sends a safe stop when detecting a disagreement in the feedback of the limit switch damaged by the presence of water.

In the case of natural gas, on some occasions, the programmers, and operators, derived from the risk analysis carried out in this work and during the design, must have set a safe stop condition due to failure, therefore, when the operating personnel goes to open the valve, the PLC automatically orders it to close.

The solution to this type of problem is to have a maintenance mode in the control logic to allow people to operate in manual mode since the humidity found inside the box damaged the Limit Switch, which caused the double position failure. displayed in the SCADA system.

The supplier issued the recommendation that the starting system should have been completely changed in the box to put the Valve into operation and continue with the analysis of the origin of the failure.

The Supplier carried out the inspection of the box and all its internal components to determine if the failure caused by humidity was related to the closure of the valve, but the operational work group carried out some additional inspections as support to reinforce the diagnosis issued by the from the supplier and found no evidence of any other damage.

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