Improving Operational Safety in Oil Pipelines
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Abstract

PETROBRAS TRANSPORTE S.A – TRANSPETRO OSVAT 30 is a 30-inch pipeline that conducts crude oil from Guararema Terminal to Paulínia Refinery at a flowrate of 3100 m³/h. Its operation started in 1978 and it is 153 km long. Due to the local geography, this pipeline has sections that lay at different altitudes, starting at 665 m at Guararema Terminal and ending at 610 m at Paulínia Refinery. In this path, the highest point lays at an altitude of 1015 m.

At the time of its construction, this pipeline did not have an automated leak detection system. Therefore, the operating pressure was only enough for the oil to reach its destination, and there was no concern in maintaining a minimum pressure inside the pipeline after its operation had stopped. Thus, the pressure on the highest spots was lower than the product vapor pressure, and there were some areas, in which the product changed phases and slack line flow (column separation) happened. The problem was more serious when restarting operation, since there were large volumes filled only by vapor phase. It took around 30 minutes after pumping had begun for the product to start coming out in its destination (that is when the tight line flow happened). During this time, there was no information of pressure decrease, which means that a leak in the pipeline would not be detected until this time had passed.

Considering this situation, a project for installing measurement instruments and a controlling system was done. It also changed the way of operating the pipeline, which was at first locally operated, being only monitored by an operational control center. After this project, the operational control center controls both extremities of the pipeline. This paper aims to show how the pipeline and its operation were modified in order to enhance safety.

1. Introduction

Petrobras Transporte started transporting oil and oil products in the State of São Paulo back in the 1950’s. At that time, pipeline operation was different than today, and the focus was only on taking the product from the origin to its destination. The safety and environmental requirements, considering the available technology, demanded only the measurement of flow, temperature and pressure in each extremity of the pipeline.
Due to certain operational events and the evolution of the environmental scenery, as well as the improvement of the processes, which were reflected on the company’s guidelines, there was a restructuring of the pipelines operating philosophy. In the new procedures, there was a greater concern about the safety of the pipelines, and the technology evolution allowed the operational parameters to be measured with lower uncertainties. What is more, the concept of a centralized pipeline operation was introduced. This means that one person would have the control of the whole pipeline, in contrast with the previous model, in which the operators of each site controlled only one extremity of the line.

This paper aims to show a project done to adapt an existing pipeline to the new operating philosophy of the company, more specifically, its start up phase.

2. Pipeline Characteristics

Name: OSVAT 30"
Diameter: 30 inches
Length: 153 km
Operation start year: 1978
Normal flow rate: 2600 m³/h to 3100 m³/h
Product: Crude Oil
Origin: Guararema Terminal
Destination: Paulínia Refinery (REPLAN)
Volume transported in 2010: ~ 18 million m³
Altitude in Guararema Terminal: 665 m
Altitude in Paulínia Refinery: 610 m
Altitude in the highest point: 1015 m
Altitude in the lowest point: 547 m

3. Regular operation before the project

Before the implementation of the project, the control of OSVAT 30" was done by the operators at each extremity of the pipeline, and the National Operational Control Center (CNCO) only supervised the flow rate and the pressure in each extremity.

In these operations, there was no control of the minimum pressure inside the pipeline. Because of this, there was vapor accumulation in the higher points, since the pressure in these points was smaller than the vapor pressure of the product. When operation stopped, the liquid flowed from the highest points to the lowest points. In this situation, there was an estimated empty space of around 1600 m³ along the pipeline, which was filled by product vapor. Figure 1 represents the situation in which there is no flow and Figure 2 represents the situation in which there is slack line flow.
Because of this situation, every time operation began, part of the vapor started to get compressed and changed into liquid phase. Before steady flow was achieved, due to this compression, no product arrived to the destination for around 30 minutes, and there was no information if it was getting compressed or if there was a leak from the pipeline. This problem could only be perceived after the regular time of operation start had passed, and if this occurred, a lot of product would have already escaped.

Concerned about this possibility, Transpetro made a project to improve safety by eliminating the vapor accumulation, maintaining all the fluid inside the pipeline in the liquid phase. Besides the environmental issue, there is also a social matter, since this pipeline passes through populated areas, and a leak in these regions would cause a great disturbance to the community. Furthermore, the measurement and the billing of the transported quantities can be faster and more accurate, if there is no vapor phase in the line. The implanted project will be explained in the next section.
4. Pipeline Automation Project

The pipeline automation project consists of automating the pumps on one extremity of the pipeline and inserting control valves on its other extremity. It aims also to transfer the control of each extremity to a centralized control center (CNCO). This enables the installation of a leak detection system. This paper will focus on the start up process of the control valves.

4.1. Concept of the project

In order to solve the problem presented in the previous section, the pipeline should have a higher pressure in the destination, so that the pressure in the highest points also increased and the value was higher than the vapor pressure of the product. Figure 3 shows the hydraulic profile of the pipeline with slack line flow. The vertical left axis shows the head, the right vertical axis represents the flow rate and the horizontal axis represents the distance. The graph shows the head in each point of the pipeline, as well as the maximum admissible operating head (MAOH) and the flow. In this graph, it is possible to identify the points, in which vaporization occurs. These are the points, in which the line that represents the head touches the line that represents the elevation of the pipeline. The graph shows the results of the flow simulation in the transitory regime, about 10 minutes after the start of the operation. In the points where vaporization occurs, there is also a disturbance in the flow rate, which tends to decline after permanent regime is achieved.

![Figure 3 – Hydraulic profile of the pipeline with slack line flow](image-url)
Figure 4 shows how the hydraulic profile should be when the pressure in the
destination is increased. In the project, it was determined that the pressure in the
highest points should be 2 kgf/cm² higher than the vapor pressure, and control valves
were designed to be installed in the destination extremity of the pipeline, in order to
achieve this pressure. In comparison with the graph shown in Figure 3, it is possible
to observe that the flow is steady in the whole line, and that no slack line flow occurs.

![Figure 4- Hydraulic profile of the pipeline without slack line flow](image)

For the leak detection system to work, besides the need of having only liquid
inside the line, the control of the operation should be centralized, since in this kind of
operation one person has the control of both extremities, and it is possible to check if
the quantity of product that flows into the pipeline in the origin is the same as what
flows out of it in the destination. This system required a new measurement and
control system to be installed in Paulínia Refinery, and the pumps to be automated in
Guararema Terminal. The measurement system consists of a new ultrasonic flow
meter, substituting the existing orifice plate, a temperature meter, a density meter
and a pressure transmitter. The control system consists of two parallel control valves
that work alternately (one is a stand by of the other), two blocking valves for each
control valve and two pressure transmitters, one upstream and one downstream the
control valves. The only necessary change in the Guararema Terminal pumping
system was in the controlling program. Figure 5 schematically shows OSVAT 30°
pipeline with the pumping, measurement and control systems implanted.
Figure 5 – Schematic drawing of the pipeline with the instruments and valves in both extremities.

4.2. Project Phases

The first phase of the project was adapting the existing pipeline with new instruments and valves in both extremities. The project was divided in 3 parts: the measurement system, the control system and the pumps automation.

The measurement system, which consists of a flow meter, a density meter, a pressure transmitter and a temperature meter, was the first to be started up. The density and the temperature are used to calculate the flow rate at a standard temperature of 20 °C. In order to monitor leaks from the pipeline, pressure decreases are evaluated.

The control system consists of two control valves that operate alternately, two blocking valves for each control valve and two pressure transmitters, one upstream and the other downstream the control valves. These control valves are used for maintaining a minimum pressure inside the pipeline, so that there is no product vaporization.

The third part, pumps automation, consisted of the elaboration of a new logic for control and operation, and no physical adaptation of the system was needed. All this work aimed the system remote operation from the CNCO.

It is important to mention that the pipeline was not initially designed to operate with the pressure it does now, and hydraulic simulation and studies were needed to validate this condition. However, these studies showed that it was not necessary to
change any parts of the pipeline, since the mechanical structure was strong enough to tolerate the pressure.

The second phase consisted of the elaboration of the control logic in the Programmable Logic Controller (PLC), the data base and the operational screens of the supervisory system.

When a control valve is installed in a pipeline, it is necessary to find the reaction it causes in the flow rate and pressure. For each pipeline, these reactions are different, even if similar valves are used. Thus, it was necessary to simulate the insertion of this valve in the system, as well as to perform field tests to confirm the results of the simulation and to find out the control parameters of the valve, which are used for programming the PLC.

The tests have three main objectives: to check if the valves respond correctly to the commands given in the supervisory system, to check which valve opening percentage corresponds to which pressure value and to determine the process stabilization time. These data feed the controller, which uses a method based on the mathematical algorithm PID (Proportional, Integral and Derivative).

In order to prepare, execute and evaluate the results of these tests, a multidisciplinary workgroup was formed, so that the operation was made in the safest way possible. This group was responsible for the final field adjustments, the elaboration of the test procedures and reports and for contacting the logistics division to arrange the test.

The third phase of the project consisted in passing the control of the pipeline from the local to the remote operational console in CNCO. This change demanded the alteration of the operational procedures, since the process conditions would be different, and the pipeline would start and stop operation with full line and the control valve would be operating in automatic mode. Furthermore, a very important aspect was the training of the operators in both sites (local operation and CNCO), since the whole operating philosophy was altered.

The final phase is the implantation of the new leak detection system, which will be the next step of this work.

4.3. Results

After the implementation of this project, the pipeline is centrally controlled by CNCO. The line is full during the whole operation, as represented in Figure 6. It is now ready for implementing the leak detection system. The response in the other extremity of the line to any pressure or flow alteration is immediate and is monitored by the measurement system.
5. Conclusions

The implementation of the project presented was a challenge for the team that was responsible for it, since the whole operating philosophy needed to be changed. These changes consisted in the adaptation of the equipments, with the introduction of the pumps automation and the insertion of control valves in the destination. Furthermore, a training program of all the CNCO operation technicians was elaborated, in order to qualify them to the new operational needs and to the necessary behavior change.

The operational safety is enhanced by the full pipeline operation, since any disturbance in the process is promptly perceived by the supervisory system (SCADA). This will be improved by the implementation of the leak detection system.

Figure 6 - Pipeline operating with full line