

Nine-Month Effort

In Search Of The Lost Pig

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A mandril pig was lost and then found in an operating oil pipeline in Brazil's Amazon forest in a project that involved six field operations involving 48 days of work over a nine-month period.

The adventure began when a 14-inch mandril pig was launched from the Urucu Unit to run through the ORSOL I oil pipeline in the Amazon and did not arrive at the Coari Terminal, located 280 km from the launch site. The crew at Coari was surprised, to say the least, when the pig did not turn up on time. In cleaning operations, low-density foam pigs normally were used in ORSOL I. This mandril pig was used for the first time in ORSOL I to improve the cleaning process. In the past, other types of mandril pigs were used without problems.

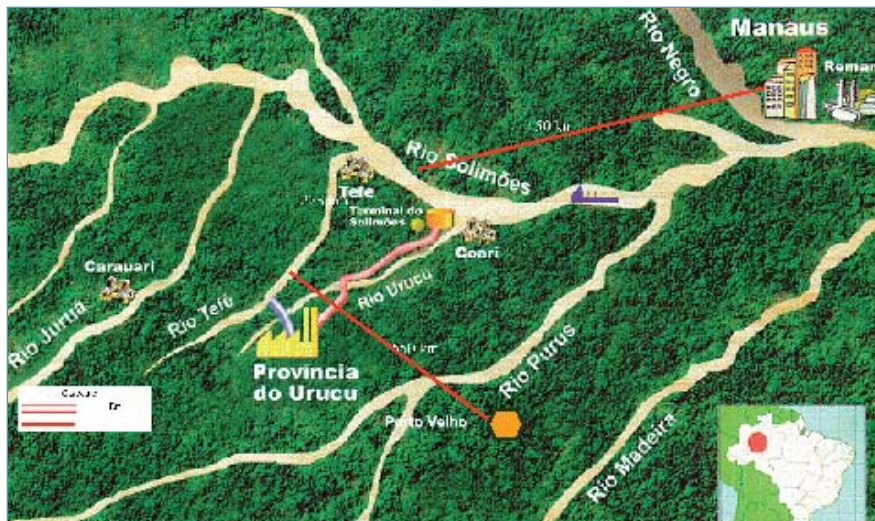
Once the pig was determined to be lost, considering the possibility of a lack of sealing, the crew decided to launch a low-density foam pig with an abrasive coating. When the original mandril pig and the foam pig didn't arrive, the crew sent two more foam pigs without success. Pieces of the foam pigs were recovered in the receiver but most pieces remained lost somewhere inside the pipeline, along with the mandril pig.

R&D Center Called

CENPES, the Petrobras Research & Development Center in Rio de Janeiro, was contacted by the Coari Storage and Loading Terminal and a team of specialists went to the Urucu Unit to collaborate in recovery of the pig. The first step of the recovery process was to compile and analyze the technical data available (pipeline design, pig characteristics, flow rate and pressure records). The main characteristics of the pipeline are as follows:

- Length — 280 km.
- Internal diameter — 13.5 inches.
- Minimum bend radius - 30 D.
- Flow rate — 220 to 525 m³/h.
- Operating pressure — 15 to 93 kgf/cm².
- Types of valves — swing check valves and ball valves.
- Launcher and receiver — designed according to Petrobras standards and specifications for pigging operation.
- Access areas — there are 18 buried valve stations, 14 with check valves and five of those with satellite communication with the Coari Terminal to enable remote valve operation from that terminal. They may be accessed only by helicopter.
- Cleaning routine — one low-density foam pig with abrasive coating once a week.

Not all check valves in ORSOL I are completely piggable. Consequently, they continue



to lack the system sometimes installed to open the flap (and maintain it open) during the pig's passage. They also lacked the optional device that normally indicates the position of the flap aperture. The lost pig was new, equipped with three piston-type cups.

The product transported in this pipeline is a light crude oil with a low amount of wax. Prior to the pig's disappearance, the flow conditions were normal; a flow rate of 300 m³/h and a pressure of 60 kgf/cm² at the launcher and 5 kgf/cm² at the receiver. Surprisingly, after the pig's disappearance, those rates remained unchanged. At the same time, as mentioned earlier, due to the characteristics of the light crude oil in the pipeline, heavy wax deposits were not considered as a cause for the pig to become stuck. However, light deposits were, at one stage, considered as a remote possibility.

Timing

Time is of fundamental concern in any recovery operation. A prolonged recovery time, as occurred in the case of ORSOL I, could have caused serious problems such as:

- Wax accumulation — in regular pigging routines, wax accumulation is controllable. However, disruption to a cleaning routine could create a significant wax accumulation.
- Water accumulation — in addition to wax removal, pigging removes water. A disruption to the cleaning routine could create a significant accumulation of water which could, in turn, create a pipeline blockage.
- Pipeline erosion — an increase in flow

velocity in the specific location of the lost pig could amplify the erosion factor and cause further damage to the pipeline.

Preliminary Observations

Control system data of the lost pig's journey revealed only one abnormality in the flow records — a pressure peak was registered in the control system at the Urucu Unit that corresponded approximately to the location of Valve Station 5.

The check valves in ORSOL I were not fully piggable. Our previous negative experiences with this type of valve led us to consider the strong possibility that the pig was trapped in one of the 14 valve stations. As mentioned, three low-density foam pigs with abrasive coatings, were launched by the Urucu Unit and Coari Field Crews in periodic succession to remove the lost pig. This procedure, while unsuccessful, provided important strategic information; the low-density foam pigs were able to pass through the gap between the pipe wall and the lost pig without the risk of causing a pipeline blockage.

With this data, it was possible to prepare a list of the most likely causes of the problem, such as:

- Pig dismantling — the pig launched was a mandril pig assembled with only one central bolt. This design has a reputation for structural vulnerability;
- Pig trapped — the pig may have been trapped in one of the 14 check valves.

Strategies

Based on the pressure peak registered at the Urucu Control System, which corresponded with Valve Station 5, strategies that focused on



that specific location were formulated.

Maximum priority was always given to the avoidance of accidents to personnel and/or the environment, and any interruption whatsoever to production. With this in mind, the first strategy was to adopt non-intrusive techniques.

Searching Stages

As the first stage of search produced no substantial solutions in the search for the lost pig, the following operations expanded the focus to the entire pipeline, including low-risk intrusive techniques such as the use of foam pigs with instrumentation. Contrary to the initial expectations, after nine months, the lost pig was located 20 km farther away from the launcher.

Six field operations were conducted over a period of nine months to retrieve the pig. The final operation retrieved the pig and was comprised of the following steps:

- The CENPES Group first recommended the excavation of Valve Station 1 to allow for access to its check valve as well as a second closure of ORSOL I and the drainage of the pipeline backwards from Valve Station 2 to the Urucu Unit.
- The check valve was opened and the lost mandril pig finally appeared.
- The final stage of the search was completed by the Coari and Urucu Field Groups in eight hours, 38 minutes. Some parts of the lost pig, the coatings of two foam pigs and two electromagnetic transmitters were removed.
- ORSOL I returned to its normal operation. A sequence of low-density foam pigs then pushed the parts of the lost pig and packages of magnets that had remained in the pipeline to the receiver.

Summary

"In Search Of The Lost Pig" was an epic challenge when we consider some random figures:

- Six field operations involving 48 days in the Amazon forest;
- Approximately 30 persons were directly or indirectly involved in the field operations;
- The entire operation from the pig's disappearance to its location and removal lasted nine months.
- In addition to Petrobras, eight national and international companies provided technical support. Namely, from Brazil — Hidropig, Tracerco, IVC, and Transcontrol; from Canada — Apache, from the United Kingdom — Pigtek, and from the USA — CDI.

The Lost Pig

After removal from the pipeline the lost pig was sent to CENPES for a detailed analysis to identify the possible causes of its dismantling. It was observed that the weld connection between the longitudinal bolt and the frontal metal disc was inadequate to support the loads

applied on the pig. Based on the examination and analysis of all pig components, it was concluded that the pig could be dismantled:

- 1) Due to a valve misalignment,
- 2) Caused by a dent in the sector of pipeline between the launcher and Valve Station 1,
- 3) As a result of inadequate construction whereby, the pig was unable to support the operational loads, or
- 4) From an operational failure during the launching.

Clear evidence of extensive wear was also identified on the Nylstop locknut at the rear of the pig. This abrasive action was undoubtedly caused by the friction between the nut and pipe wall as the foam pigs pushed the mandril pig from the moment that it dismantled until it became trapped in Valve Station 1. An inspection of the pipeline was subsequently scheduled to verify all those physical causes.

Observations And Recommendations

Mandril pigs fixed with only one bolt have shown to be vulnerable. In the case of a bolt failure there is no back-up. This type of assemblage has not been a Petrobras preference, particularly for application in long pipelines with or without check valves. Specifically, they lack the strength required to support normal operational loads and their impact against the flap of a check valve.

Pipelines which work with pigs must be designed and equipped with all necessary facilities to allow the passages of all types of pigs applicable.

As a general practice, check valves are not ideally suited where pigging occurs. However, there are definite instances where check valves are necessary. In such instances, they must be equipped with a system which allows for the opening of the flap to ensure that it stays in the open position during the pig's passage.

In pipelines such as ORSOL I where valve access is difficult, installation of a Remote Operation System, or at least a check valve with a counterbalanced flap, is strongly recommended.

Check valves have, to date, been buried with no access for routine inspection. One substantial contribution from this entire operation is that the Petrobras engineering groups are changing this standard specification. The need for routine check valve access, as demonstrated in the previous account, is becoming the standard.

Whenever possible, during the design stages of a long pipeline, strategically located pig signalers should be considered to allow for pig tracking and, in the case of a lost or stuck pig, to narrow down the search area.

Identification of a foam pig's passage with the use of geophones is difficult, particularly in buried pipelines. Sometimes common noises, either internal or external to the pipeline, could be considered as a pig noise. A second limitation of geophones is their inability to record the pig passage. Excessive and exhausting amounts of time may be expended as the geophone operator waits for the pig passage noise.

Stuck pigs, even a mandril, can cause dis-

proportionably small pressure drops, given the mass and density of a pig and the relevant amount of physical blockage in the pipeline. In this recovery operation, the initial pressure drop expectation was around 14.22 psi but the reality was 0.6 psi. **P&GJ**

Acknowledgements

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Lost pig found in check valve at valve station 1.