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A tale of three pigs

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This paper considers three incidents, which involve the pigging of pipelines. In one case there was a departure from normal operations and the other two were one-off activities. In each case the recognition and assessment of risk was inadequate.

Pigging incident 1

Incident description

In the time leading up to the incident a combination of low flows and water ingress into a 300 mm diameter gas gathering line had resulted in suspected hydrate blockages and large slugs of water/glycol/condensate causing operational problems.

Following complete blockage of the line, believed to be due to hydrates, it was completely depressured and the decision was taken to pig the line at lower than normal pressure. Two pigs were launched into the 7.5 km line and were due at the receiving plant the following day.

The pig receiver was provided with two pig signals (see Figures 1 and 2). The first was upstream of the receiver isolation valve and the tee to the plant and the second was downstream of it, just before the transition point where the receiver diameter increased from 300 to 400 mm.

FIGURE 1: SHOWING MAIN ISOLATION VALVE ON LEFT AND THE SECOND PIG SIGNAL DEVICE (BLACK BOX ON TOP OF RECEIVER BEFORE TRANSITION SECTION)

FIGURE 2: SHOWING, FROM LEFT TO RIGHT, SECOND PIG SIGNAL RECEIVER, TRANSITION SECTION, PSV, VENT AND VENT VALVE, AND RECEIVER DOOR

Operators at the plant observed that the first pig signal activated indicating that the pig had arrived. However the second signal did not operate, indicating that the pig had failed to move completely into the receiver. The operator vented the pressure off the receiver and in a few seconds there was a noise and the second pig signal activated, showing that the pig was in the receiver. The receiver isolation valve was closed and standard procedures followed to vent the receiver and remove the pig.

The pressure gauge indicated that there was 6 barg in the system, and after venting the gauge showed 0. As an additional check the bleed screw on the receiver door was removed to ensure that the vessel was completely depressured, and the door was opened.

The pig was not immediately visible and as the operators prepared a pig retrieval stick the pig blew out of the receiver and landed approximately 50 metres away, demolishing part of a fence in the process (sees Figure 3). Approximately one minute had elapsed since the door had been opened. Nobody was injured.

FIGURE 3: SHOWING DAMAGE TO THE PERIMETER FENCE

Investigation findings

The pig was retrieved and examined but did not appear to be damaged in any way or lead the investigation team to believe it had stuck because of faulty design or pig damage.

The team concluded that the root cause of the incident was that if the pig remained in the transition section of the receiver the design of the system did not allow pressure upstream of the pig to be bled off.

Other contributory causes were:

- The lower pressure in the gathering line increased the potential for the pig to become stuck.
- Lack of pressure indication immediately downstream of the receiver isolation valve prevented the operators from identifying that pressure had been trapped, and lack of depressuring facilities at this point prevented it being vented.
- The work instructions for pigging operations did not adequately identify the potential for pigs to become stuck in the receiver.

The following recommendations were made:

- ReHAZOP the pig launcher and receiver.
- Install pressure gauges with bleed valves to atmosphere immediately downstream of the isolation valve before carrying out any further pigging operations.
- Modify the vent system to allow simultaneous venting of both ends of the receiver.
- Rewrite pigging procedure to reflect hazards of stuck pigs in the receiver and use the new pressure gauges to check that the receiver has been correctly vented. Include a sign-off checklist approach.
- Update P&IDs.
- Carry out JSEA on the new pigging operation work instruction and attach as part of procedure.
- Revise JSEA procedure to include guidewords of 'trapped energy' and 'trapped pressure'.
- Conduct pigging safety awareness training to advise all shift personnel of the incident and the modifications to equipment and procedures.
- Review mechanical isolations procedure with respect to single valve isolation when opening pig receiver/launcher doors.

Pigging incident 2

Incident description

A contractor was dewatering a 10 mile section of pipeline after a hydrostatic test. The water was being displaced by a foam pig which was being propelled by compressed air. The displaced water was being removed from the line through a 12-inch by-pass. For reasons unknown at the time the pig stopped moving. Deciding that some obstruction was preventing the pig from moving freely, the end of a temporary pig trap, which was nothing more than a blind flange, was removed (see Figure 4) and the decision was taken to increase the air pressure to 400 psig to remove the pig from the line.

Recognizing that the pig could come out with some velocity, a large front end loader was placed in front of the open pig trap to 'catch' the pig.

A quick calculation would have shown that the differential force on the pig was approximately 45,000 pounds force, but it seems the figure was never calculated.

When the pig shot out of the trap it completely flipped the loader over (see Figure 5) and continued for an additional 150 yards, destroying a wooden platform on the way. The contractor did have the foresight to remove all personnel from the 'line of fire' as otherwise there would surely have been fatalities. The final picture (Figure 6) shows the remains of the pig. The overhead line in the distance is beside the pig trap and shows the distance covered.

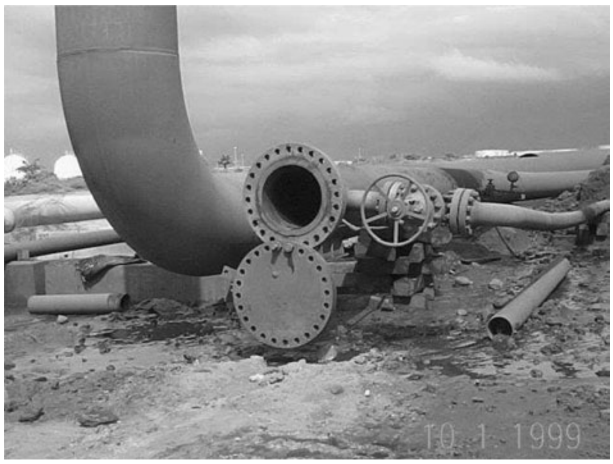

FIGURE 4: SHOWING TEMPORARY PIG TRAP WITH OPEN END FLANGE

Figure 5: The Loader after Failing to Catch the Pig

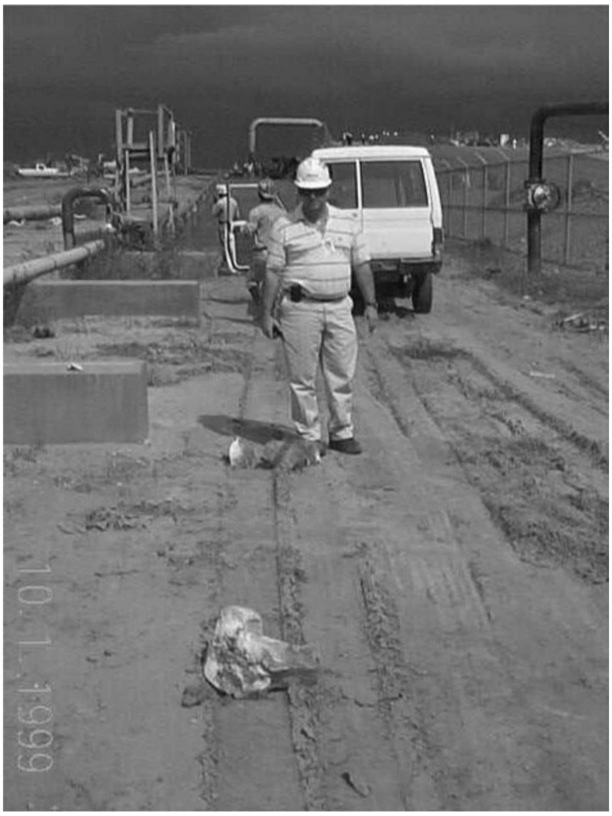

Figure 6: Remains of the Foam Pig

Investigation findings

No details of the subsequent investigation or its report are available but the incident serves to show the care that must be taken when dealing with pig traps and differential pressure. A simple calculation would have shown that the pig would have a force of over 20 tons on it, and that rather more appropriate control measures were needed.

Pigging incident 3

Incident description

A new riser had been installed at the platform end of a pipeline from an offshore platform to an onshore gas processing plant. The pipeline had been filled with water to isolate the line and allow the riser to be replaced safely.

It was decided that a number of spheres (or spherical pigs) would be used in a ‘train’ to clear the line of water in preparation for resuming gas flow. The first two spheres were separated by a nitrogen charge and the subsequent spheres were propelled by produced gas from the platform.

At the plant end of the pipeline there was a main inlet isolation valve, a slug catcher to receive liquids displaced by the spheres and a sphere receiver to allow removal of the spheres from the line.

The pipeline which was 30 inches in diameter and tens of miles in length had a steep rise as it approached the shore and the spheres appeared to stop at this point. Consequently the pressure of the produced gas in the line was increased to get the spheres moving again. In addition the drain valves on the slug catcher on the end of the pipeline were opened to drain water more rapidly from the system and reduce the back pressure.

The increased pressure differential caused the spheres suddenly to start moving again. As the displaced water surged towards the sphere receiver a tee piece, installed at the point where the slug catcher line and the sphere receiver diverted from each other, burst releasing water and gas to atmosphere.

A remote control was operated to close the main pipeline inlet valve to the plant, but it was found that the line to the actuator was isolated close to the valve and nothing happened. It was several minutes before the isolation could be removed and the valve closed, shutting off the release. No personnel were injured but a major release of hydrocarbon had occurred.

Investigation findings

The subsequent incident investigation determined that:

- The tee piece failed due to water hammer. Instead of the pipeline being filled completely with water in front of the spheres, gas had passed them and migrated along the pipeline towards the plant, possibly assisted by the rise in the pipeline as it neared the shore. This meant that when the pressure was increased offshore and the spheres started moving again a volume of gas, followed by a slug of water, was propelled in front of the spheres. When the gas entered the plant section of the line the following water slug accelerated and when it came to the first restriction in the line, which was the tee piece, a pressure surge occurred which caused the tee to rupture.

- The tee piece was fabricated from several pieces of steel rather than being a single forging. Although it was pressure tested satisfactorily before the dewatering operation commenced it was not able to contain the pressure surge generated by the water hammer.
- After the new pipeline riser had been installed offshore the whole system from the top of the riser to the onshore slug catcher had been pressure tested. This included the tee and the main pipeline inlet valve. To prevent the valve closing accidentally during the test the control line to the closing actuator had been isolated. This was to prevent high pressure water being trapped upstream of the valve, which might subsequently have to be opened with a high pressure differential across it, possibly damaging the seals. The dewatering procedure called for the isolation on the actuator to be removed once the pressure testing was completed, but it had not been.

Further investigation

Further discussion over why the spheres had allowed such a considerable volume of gas to pass them resulted in a study being made of the pipeline. A gauging pig was run through the line and revealed a buckle some distance from the platform. The only explanation for the buckle was that it had been formed during the construction of the line many years before and never detected. The buckle was several inches high and probably stopped a sphere passing until another was run, displacing the first sphere which travelled on to the plant. Over the years there had been a history of 'lost' spheres in the line. When the dewatering operation commenced the first sphere might have been stopped by the buckle, allowing nitrogen to pass until the next sphere arrived. This would have formed the bubble in the line necessary for the water hammer to occur.

The line was again flooded and the buckle removed. The subsequent dewatering operation, with a new tee piece and correctly followed procedure, was completed without incident.

Lessons learned

The fabricated tee piece had withstood static pressure testing but failed when subjected to water hammer. There was no way to determine the pressure reached and the only precautions which could be taken were procedural ones to prevent the recurrence of water hammer. Although a forged tee was substituted there was no guarantee that it would be able to withstand a similar water hammer incident if one occurred.

Although the line had been in operation for many years no serious attempt had been made to explain the apparent 'missing' pig problem. It was accepted as one of the peculiarities of the system. In itself it presented no real operational problem but when the circumstances changed it became a hazard.

Increasing the differential pressure across a pig needs to be performed with extreme care and adequate time. The length of pipeline involved meant that it took quite some time for pressure changes to reach the pig. Downtime is expensive and no doubt there was a desire to complete the task, but, as in the other example, changing pressures significantly can have dramatic results.

Procedures for de-isolation of systems need to be followed just as carefully as those for isolation. Many organizations have procedures requiring a second physical check and signature on each step.

Conclusion

Pigging operations are a routine and necessary part of many pipeline operations and are handled in the majority of cases in a safe and appropriate manner. However when even a small departure from the routine is introduced a number of hazards can arise and need to be addressed. If these are not recognized and the operation is regarded as routine, the risk assessment is not representative of the actual conditions, and the consequences can be disastrous.

Nobody was injured in any of the incidents described above but the potential existed for several fatalities. This tale of three (not so little) pigs could have had a very different ending.