BLOCKAGE LOCATION – THE PULSE METHOD

Presented by John Pitchford
Pitchford In-Line

Author James Pitchford

ABSTRACT

Pipeline blockages can result from a number of different mechanisms: wax or solid hydrates can build up over time, pigs can become lodged in the lines, and pigging can also draw solids down the line to accumulate into a plug. Once a pipeline is blocked, production is lost and it becomes a matter of urgency to locate and remove the blockage. In the spring of 2002 an accumulation of hydrate was thought to be blocking a North Sea line and Pitchford In-Line were commissioned to identify the position of the blockage. Using the established theory of reflecting a pressure pulse off the blockage and detecting its return, a Blockage Location tool was developed and used with great success on the line in question. This paper illustrates the technique, making comparisons with work done by the Petrobras Research Center ("Blockage Remediation in Deep Water Pipelines") and Saipem ("Pig Location Techniques").

The North Sea Blockage, Spring 2002

A blockage was thought to be caused by hydrate that could only be removed by dropping the pressure or heating the line. The line was standing at 157.6 bar and it was not possible to reduce the pressure. The option of heating the line could only be effective if the location of the blockage could be determined.

It was proposed that a pressure pulse be generated by opening and shutting a vent at the platform and therefore momentarily dropping the pressure. This pulse would then travel down the line and reflect off the blockage. When it returned to the platform, it would be detected, and its reflection time measured.

Creation of a Pressure Pulse

A pressure pulse was generated by venting gas from the pipeline and a pressure drop of 0.6 bar was expected. When passing down a pipe, a pulse will always suffer attenuation, so the reflection was not expected to be greater than a few hundred millibars. Originally it was hoped that the valve could be cycled from on to off in about 1 second but it was found that the minimum cycle time of the valve was about 6 seconds.

Examination of the operation of the vent valve revealed that there was a delay of about 15 seconds between the signal from the control room and the vent valve opening. It was important for the valve to be open for the shortest possible time. To achieve this an operator was asked to observe the movement of the vent valve and advise the control room over the intercom as soon as it opened. The control room then closed the valve.

Equipment

A pulse of 300mbar at a line pressure of 160bar gives a variation of approximately 0.2%. The sensitivity limit of most transducers is around ±0.2%, so it was obvious that a special transducer and processing pack would be required. A transducer was procured with high sensitivity and response characteristics. A processing pack was put together incorporating an oscilloscope, amplifier, and power supplies for the equipment. The processing pack was connected directly to a laptop through a parallel port.

When the measurement system was connected to the pipeline and tested at pressure, it was found that the signal was corrupted by electronic noise. Minor changes were made and the noise was reduced to an acceptable level. There were also very strong spikes observable which were believed to be caused by the FPSO intercom.

Analysis of the Pressure Trace

The recording equipment was switched on, and the vent valve opened and closed to generate the pulse. The resulting pressure trace is shown in Figure 2.

The vertical axis of the trace gives the amplified signal from the transducer in millivolts. The horizontal axis gives the time in milliseconds.

The first feature on the trace is a spike at 11.0 seconds. This was thought to be the result of the operator instructing the control room over the intercom to open the vent valve.

The next feature at 28.6 seconds is a further spike. Again this was thought to be the operator advising the control room that the vent valve was opening.

At 30.7 seconds the millivolt signal starts to rise to a positive peak that occurs at 32.4 seconds. This was a result of the negative[1] pressure pulse generated as the vent valve opened.

At 41.4 seconds a negative peak occurs, which is the result of a positive pressure pulse caused by the vent valve closing.

The trace continues with a small ripple until a positive peak occurs at 154.1 seconds. This is followed by a negative peak at 163.3 seconds. This feature is the pressure pulse returning after being reflected from the blockage.

The trace continues with a small ripple until a third pair of peaks occur, the first (positive) being at 276.1 seconds and the second (negative) at 284.8 seconds. This feature is the second reflection of the pressure pulse from the blockage.

Each bi-polar pair of peaks is clearly the pressure pulse as they each have a pitch of between 8.7 and 9.2 seconds, and are separated by 121.6 and 122.0 seconds respectively.

Further confirmation that the bi polar peaks are reflections from the same pressure pulse is given in Figure 1 where the plot of the first return pulse (red) is superimposed on the primary outgoing pulse. This figure also facilitates the determination of the duration between the pulses to be estimated more accurately at 121.5 ±0.1s.

Calculation of the Distance to the Blockage

Information from the pipeline operator stated that the velocity of sound in the gas was 442 m/s. Thus for a duration between the pulse signals of 121.5 seconds, the distance travelled by the pulse is 53724.6 m. The distance to the blockage is therefore 26.8 km. In this case, it turned out that the length of the pipeline up to the next closed isolation valve was approximately 26 km. This proved that the line was actually clear up to the isolation valve, and that the blockage was in a different branch altogether. The branch line was isolated and depressurised, removing the blockage successfully.

[1] An increase in the millivolt signal indicates a reduction in pressure.

Accuracy

In this case the accuracy was not critical, but obviously where it becomes necessary to heat the line locally to remove the blockage, then the location must be determined to within a few metres. The technique used in this example relies on a value for the speed of sound that is supplied by the pipeline operator. If the value for the speed of sound is not available, it can be calculated for a liquid using the product density and bulk modulus. If the value for the speed of sound is inaccurate by say 2 %, because of an inaccurate bulk modulus or varying temperature/pressure etc, then the resulting distance will also be inaccurate by 2%. For a 12 km line this would be equivalent to 240 m. In order to find the location of the blockage more accurately, the speed of sound must be measured, by calibrating the system with a simulated blockage (eg a closed isolation valve) at a known distance. Although this method does increase the accuracy, it still relies on the calibration distance being known accurately. If the calibration distance is known precisely, then it should be possible to calibrate the tool so that the blockage can be located to within a few metres.

There are other factors that affect the accuracy, such as varying density and varying line diameter or wall thickness. It is possible to account for the change in pipe attributes through calculation, but a change in density through the line may give rise to additional small errors.

Range

The attenuation of the pressure pulse in the pipeline is the limiting factor when considering the operable range for this technique.

A PETROBRAS paper[2] states that the pressure pulse technique has been used to locate blockages up to 9km away.

By considering the pulse as a length of fluid that is travelling at a different velocity to the rest of the fluid, then the speed of that length will eventually be slowed by friction at the pipe-wall. The extent of this reduction can be calculated from the Darcy Weisbach equation. This method shows that the reduction is virtually negligible, even over a few hundred kilometres. In reality, we see that the amplitude of the pulse from the North Sea blockage was reduced by about one third each time it returned to the transducer (see Figure 2). The attenuation probably arose from volatile compounds precipitating on the wall of the pipeline as the pressure pulse passed.

Even with this amount of attenuation it is clear that the pulse can travel up and down the pipeline a number of times and still retain sufficient amplitude to be detected. Under similar conditions with the same equipment it should be possible to detect a blockage up to 75 km away.

A paper by John Hough[3] of Saipem Australia shows that the attenuation of an acoustic signal in an air-filled line is very dependent on the frequency of the signal. As the frequency approaches 100 Hz, the signal will all but disappear over 100 km.

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[2] Blockage Remediation in Deep Water Pipelines (Produced for the 4th International Pipeline Conference, Sept 29th – Oct 3rd 2002)

[3] Pig Location Techniques (For the Pipeline Pigging Conference, June 29th – July 2nd 1998)

It is stated in this paper that the longest distance over which echoes were received using this technique was 277 km. This was done in an air filled line without the use of signal processors. Using a processing pack with signal filters to eliminate the noise should increase the operable range of the technique further still.

Further Development

Pitchford In-Line have further refined the technique and now have a system that incorporates noise reduction filters and improved sensitivity. It is housed in a small rugged unit that can be quickly connected to the pipeline in order to locate complete or partial blockages and stuck pigs.

Figure 2: Pressure Pulse Reflections