Inspection of water injection pipelines and future needs

By: Mikael Georgson and Roger Hunsbedt

Statoil ASA

Abstract

Statoil ASA has recently inspected several water injection pipelines that have shown unexpected high corrosion rates. In one of the pipelines it was observed a rather high corrosion rate at the end of the pipeline. The corrosion was concentrated around the 6 o'clock position, resulting in extensive river bottom corrosion. The increase in corrosion rate occurs after a subsea manifold, where the water velocity is reduced. It is also concluded that there is scale in the water injection pipeline.

The river bottom corrosion, scale and the presence of a smooth bore flexible jumper in the middle of the pipeline system provided interesting challenges regarding pipeline cleaning prior to inline inspection.

This paper addresses the experience with pigging of water injection pipelines as well as pigging challenges that can be expected in the near future.

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Corroding water injection pipeline system with smooth bore flexible jumper

The 12” x 17,3 km long Vigdis water injection pipeline system starts at the Snorre A platform and ends at the Vigdis F template.

The Vigdis water injection pipeline system consists of

- Topside pig launcher and piping
- Flexible riser with carcass (J-lay)
- Rigid carbon steel pipeline Snorre A – Vigdis E
- Flexible static jumper without carcass (smooth bore)
- Subsea well template E
- Flexible static jumper with carcass
- Rigid carbon steel pipeline Vigdis E – Vigdis F
- Flexible static jumper with carcass
- Subsea well template F
- Pipeline End Manifold (PLEM)
- Temporary subsea pig receiver

An illustration of the pipeline lay out is shown in figure 1. below. Water from Snorre A is injected at Vigdis E, Vigdis F and is also routed through a 7” x 5 km flexible pipeline to Vigdis G.

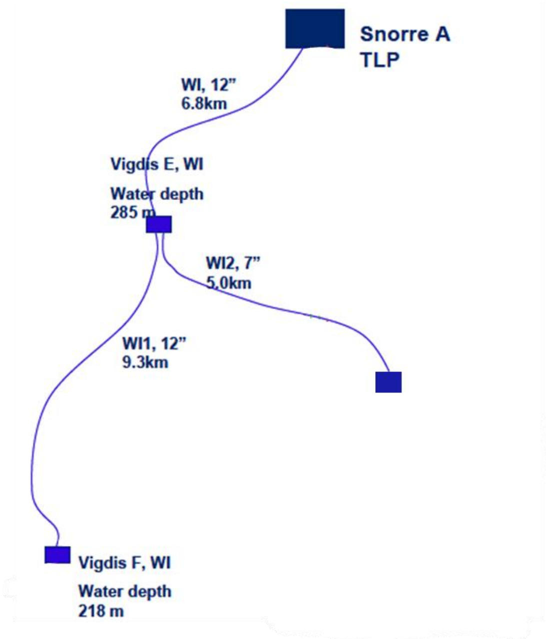

Figure 1. Illustration of the Vigdis water injection system.

Project challenges

The Snorre A – Vigdis E water injection pipeline has been in operation since 1997, and the Vigdis E – Vigdis F has been operational since 2004. The first pipeline from Snorre A to Vigdis E was inspected in 2001 using an ultrasonic inspection tool. A total of 8 cleaning pigs were sent through the pipeline system prior to inspection.

The next inspection was planned to be performed in October 2010. The in-line inspection and cleaning project started up in 2009. The smooth bore flexible jumper, located 7.8 km from Snorre A, was early in the project identified as a risk. This was due to a damage of the original installed flexible smooth bore riser caused by the pigging operation in 2001.

The figure below shows that the smooth bore flexible consists of several layers. The inner layer consists of a high density polyethylene (HD PE) plastic tube with thickness of 8.5 mm.

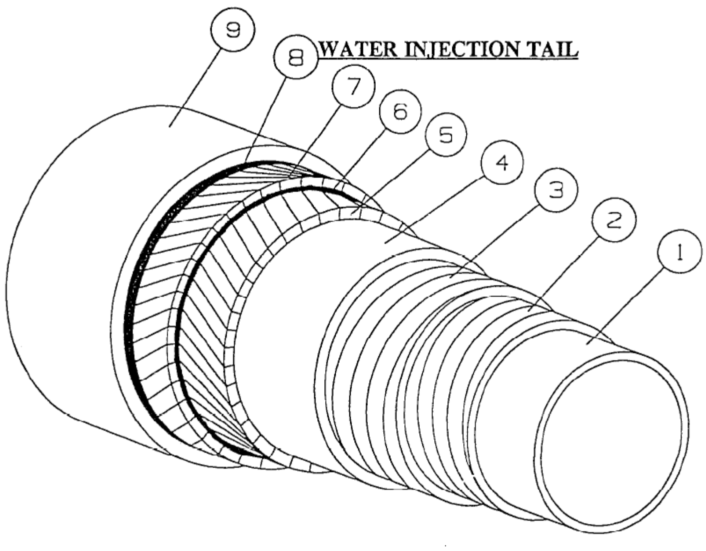

Figure 2. Smooth bore flexible layer by layer

Other identified risks could be large amounts of residual debris after cleaning operation, causing degraded inspection results. Statoil has similar experience with residual debris from other water injection pipeline systems. In standard rigid pipeline systems very aggressive brushes and studs have been utilised to remove debris from the pipe wall.

The main challenge was to clean the pipeline without causing damage to the smoothbore flexible jumper. Any significant damage to the smooth bore flexible HD PE would most likely cause a total burst of the flexible jumper. This would result in a longer shut down period of the Vigdis water injection system.

2010 pig testing

Based on these experiences the cleaning and inspection project decided to test all cleaning pigs prior to mobilisation.

Different types of pigs were pulled through an equivalent HD PE pipe 10 times. The roughness of the inner surface was measured with a surface roughness tester.

2010 operations

As a result of the risk evaluation made during planning of the pigging campaign, the pipeline was flushed with seawater at high flow prior to launching the first pig. The amount of debris removed during flushing was significant. The picture below shows some of the debris collected, which consists of typical scale found in water injection pipelines, mainly calcium carbonate ($CaCO3$) mixed with Iron/Sulphurs combinations.

Figure 3. Picture shows debris flushed out of the pipeline prior to launching pig no. 1 in October 2010

A total of 55 pigs with increasing aggressiveness were run prior to the ultrasound inspection tool. The amounts of debris in front of each pig were monitored by the camera installed on the ROV (Remote Operated Vehicle).

The pictures below shows the amount of debris coming out in front of the pig through the open end subsea pig receiver and pigs during receiving.

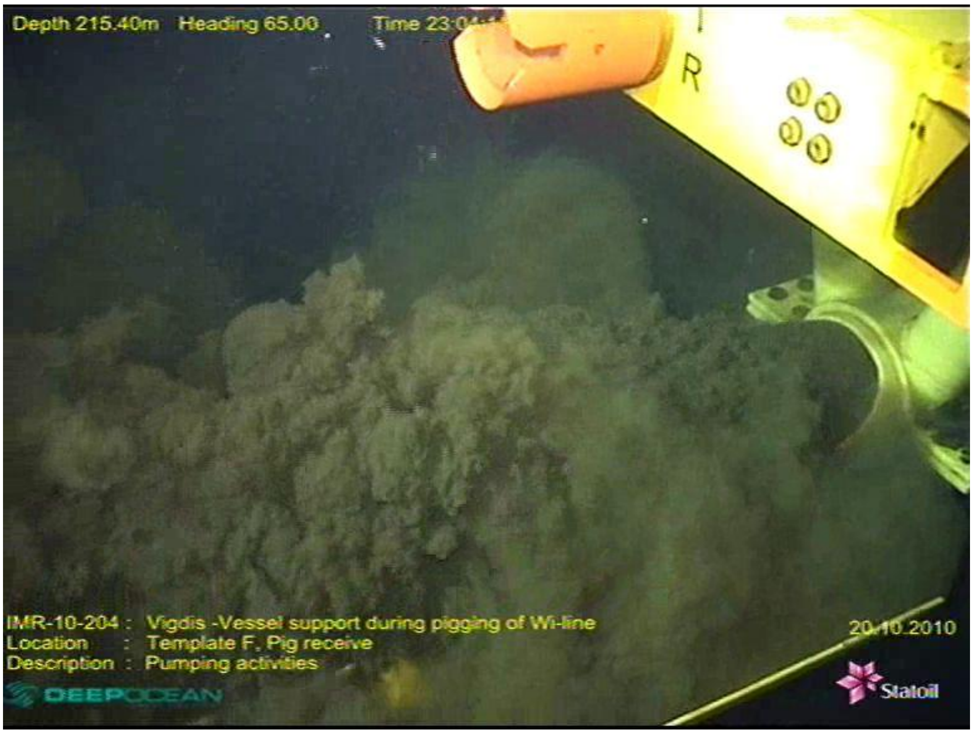

Figure 4. Large amount of debris flushed out during arrival of pig no. 02

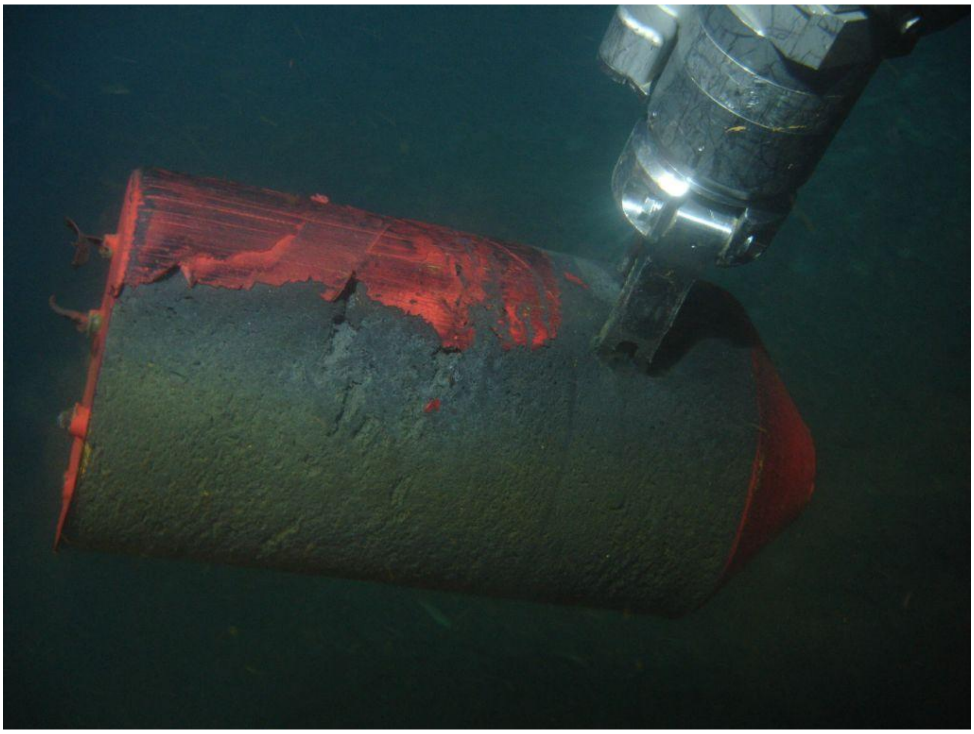

Figure 5. High wear on pig no. 02, foam pig with 4 x bypass holes

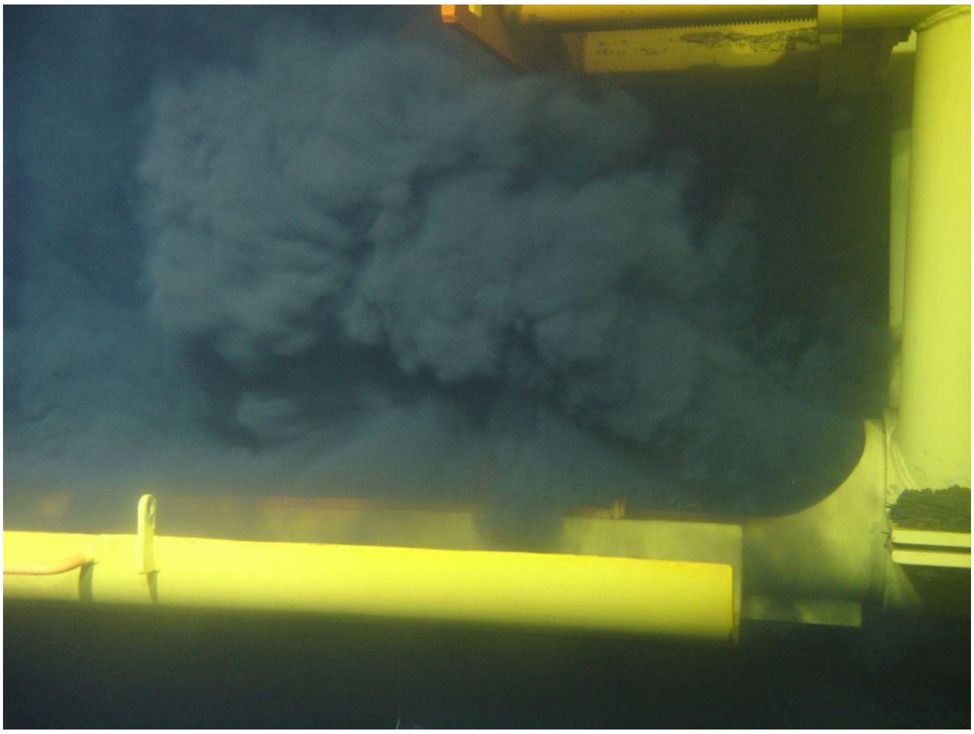

Figure 6. Still high amounts of debris flushed out during arrival of pig no. 31

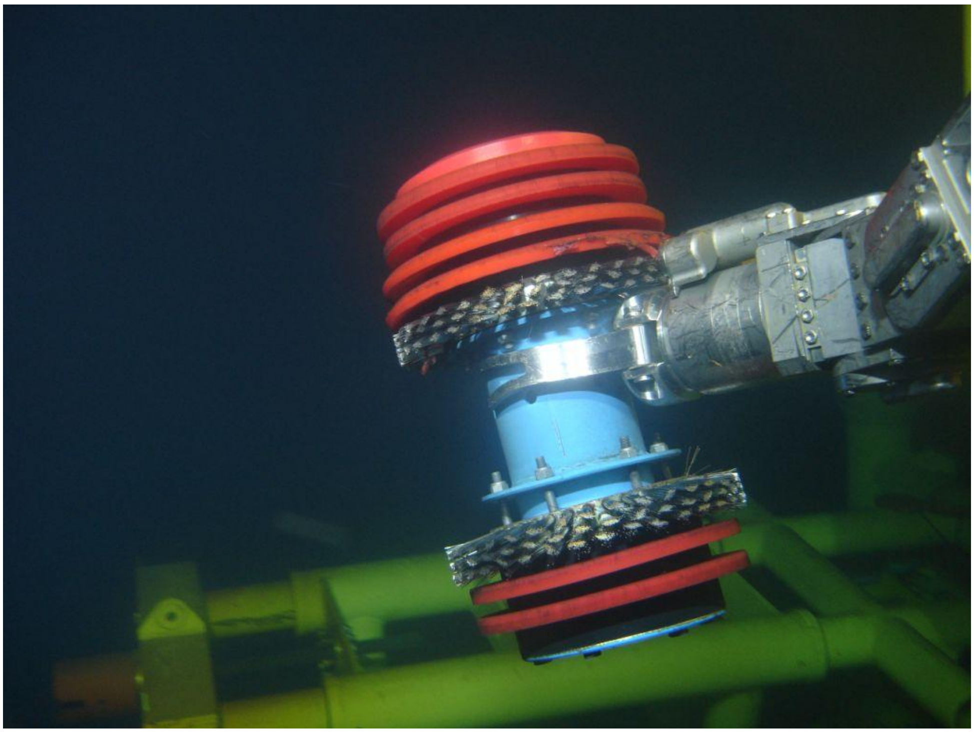

Figure 7. High wear on pig no. 31 (missing 2 rear seal discs)

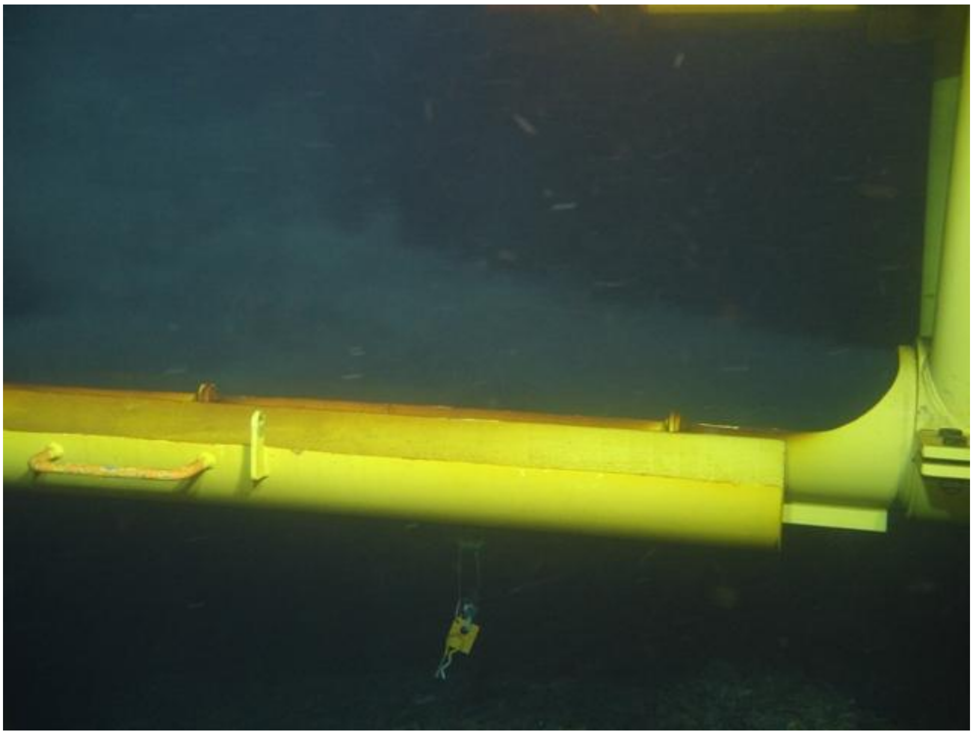

Figure 8. Finally less debris flushed out during arrival of pig no.54

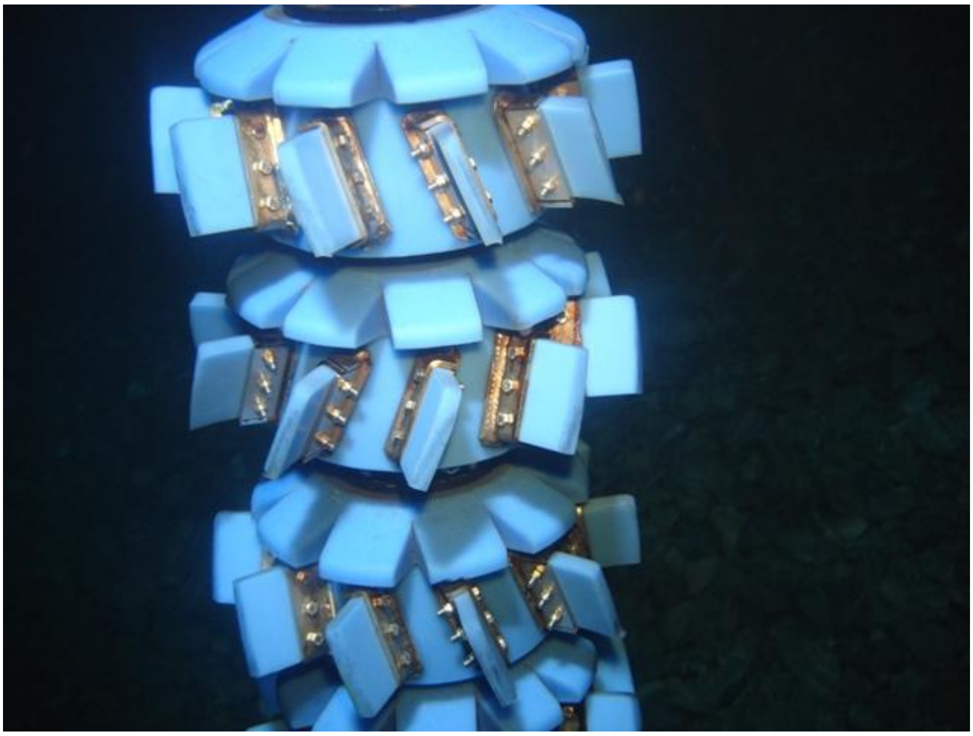

Figure 9. Wear on pig no 54

The pipeline system was cleaned and inspected in October 2010, and the results from the inspection showed both residual debris and corrosion.

Extract from the inspection report: "Residual Scale is widespread in the whole pipeline. Distribution of the residual scale deposit: First 9 km very thin thickness of the scale. From km 9 up to the flexible tail connecting pipeline 2 to the Vigdis F template very thin to thin thickness."

2011 pigging operations

Due to the inspection results showing corrosion, the inspection was decided to be repeated in June 2011. The scope of the inspection was to determine the corrosion growth rate.

With the new knowledge of the pipeline condition from the 2010 pigging operation, the project decided to improve the design and the performance of the cleaning pigs.

The cleaning pigs for removing scale were available with two different brush sizes diameters. The smaller diameter should clean the non-corroded pipe section whereas the slightly oversized brushes aimed at removing material at the six o´clock corrosion. This is illustrated in the picture below. The inner diameter is marked with D and this is also the rough diameter of the smaller brushes. In order to remove the debris at the corroded part at six o´clock in the pipeline, larger diameter brushes were used. This is indicated by the dashed line. In the non-corroded pipe the oversized brushes will bend and be less efficient, however in the corroded section it will be more aggressive to scale and debris.

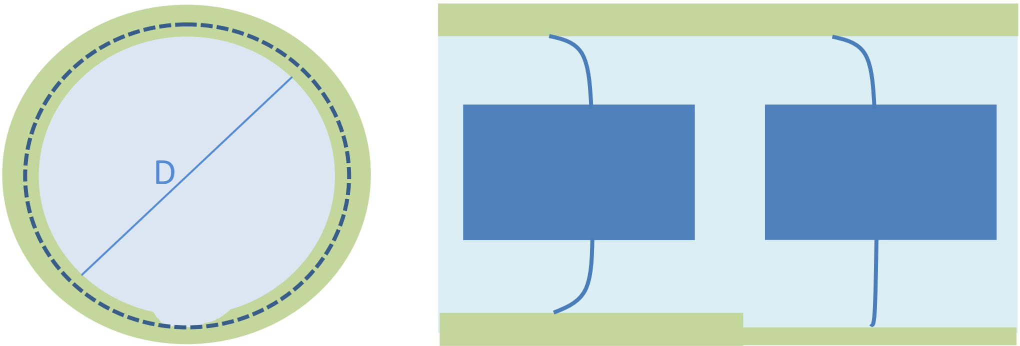

Figure 10. Illustration of brush sizes for cleaning of different diameters. The smaller brush diameter, indicated by D in the figure, is the same as the inner diameter of the pipe. The dashed line shows the diameter of the larger brushes, capable to clean in the corroded area.

The figures below show some of the pig designs used in order to remove the scale. The pigs were tested in similar smooth bore pipe which is found in the Vigdis water injection line.

Figure 11. Brush pigs for removing debris.

Figure 12. Scraper pig for removing scale.

Figure 13. Cleaning pigs for removing scale.

Figure 14. Pigs with magnets to remove magnetic debris.

The result from the 2011 inspection campaign indicated presence of scale and corrosion. The corrosion rate was established and even with a “fit for purpose” cleaning pig design residual scale were observed in the pipeline. The most affected part of the pipeline was located after the ‘E’ template, in the section with a lower flow rate.

The figures below show the C-scans from the same location in 2010 and 2011. The white dots in the top band indicate echo loss due to residual scale.

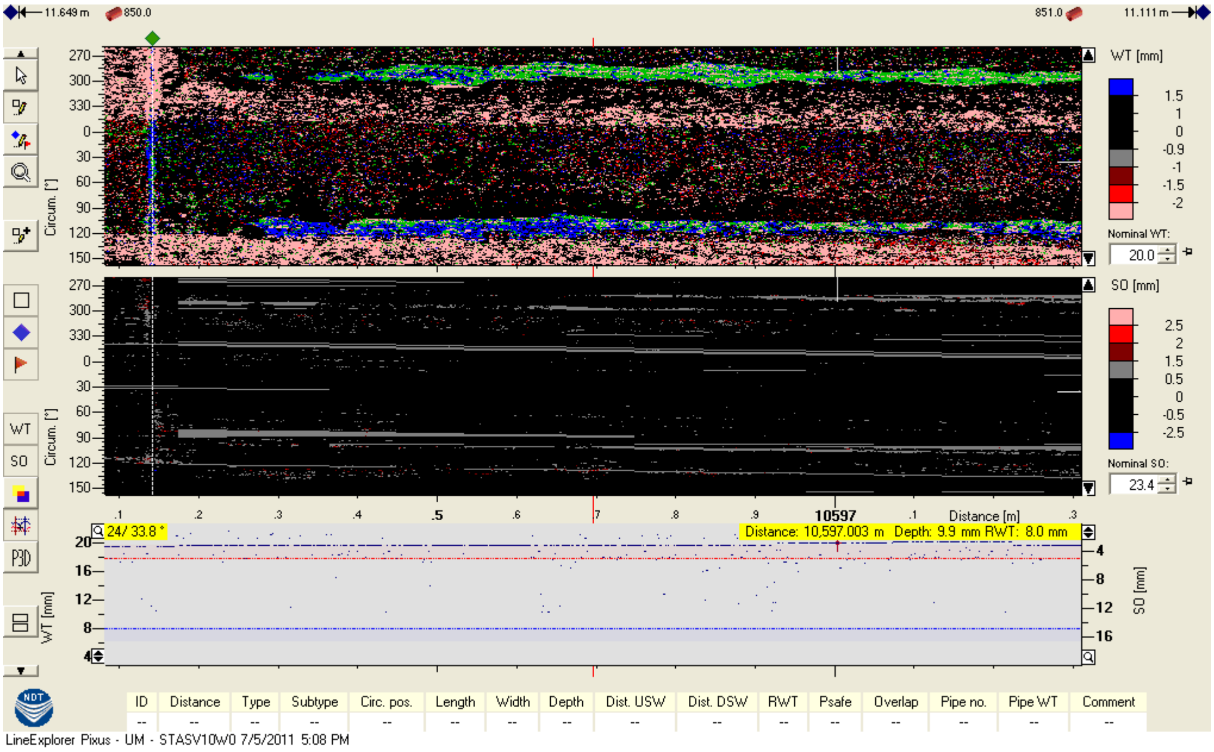

Figure15. Data from 2010 inspection showing some residual scale

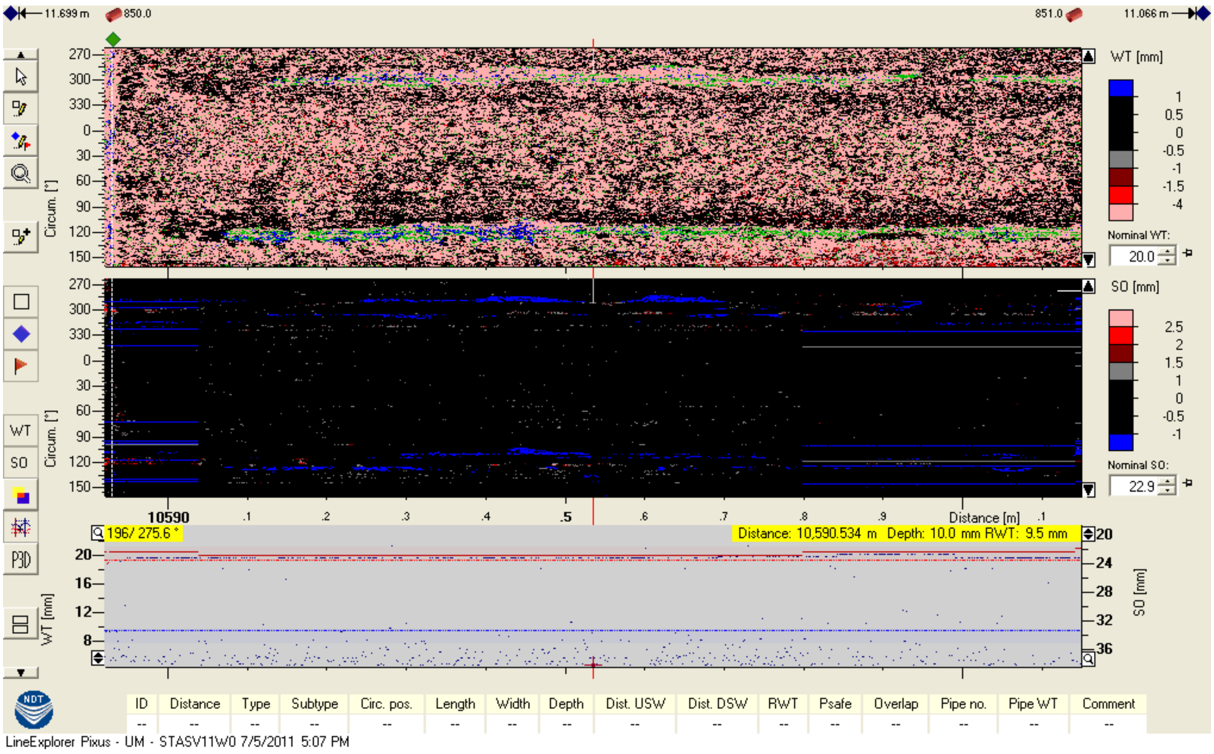

Figure16. Data from 2011 inspection showing more residual scale

The amount and distribution of the residual debris can be extracted from the ultrasound echo loss. Especially the wall thickness echo loss distribution can be relevant when analysing scale distribution.

The picture below shows the wall thickness echo loss rate vs. clockwise position as the vertical axis. The distance is showed in the horizontal axis. In the beginning from 100-700 meter we see high echo loss rates evenly distributed around the circumference. This comes from the flexible riser internal carcass pattern. At 7,8 km we see the same pattern and again at the end. All these are from subsea template or flexible pipelines. We can also see the river bottom corrosion path in the 6 o'clock position. Residual scale is spread around the circumference especially the last pipeline section from Template E to Template F.

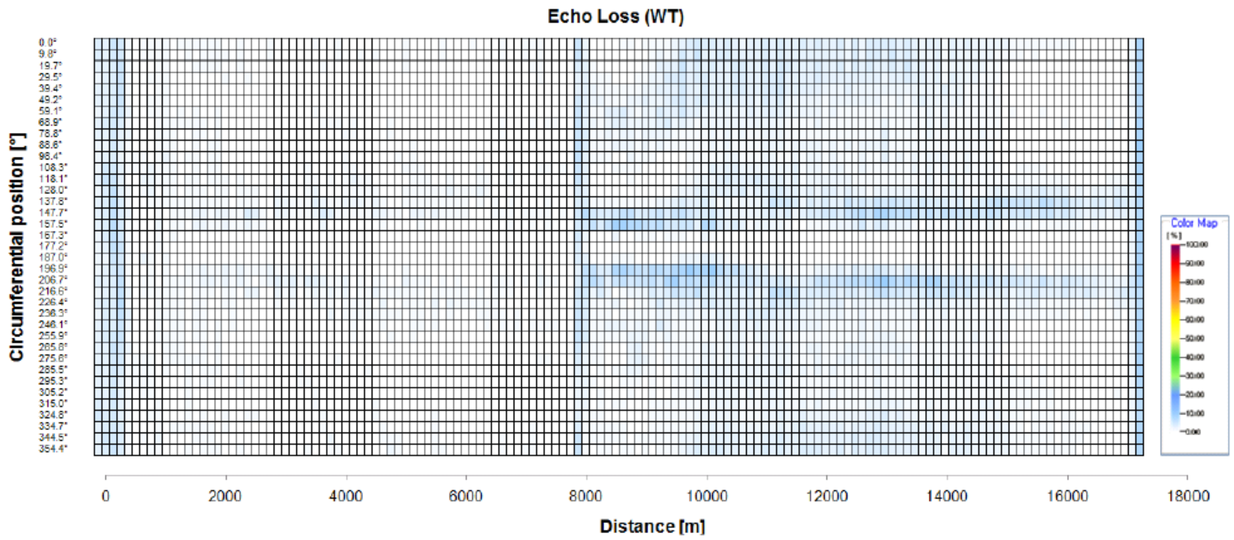

Figure 17. Diagram of echo loss along the pipeline.

Another example of residual scale

The Tordis 10" x12" pipelines were inspected in August 2010. The pipelines are laid in parallel from Gullfaks C to Tordis Central Manifold, with a pigging loop at the end manifold. Corrosion was found in both pipelines, mainly channelling corrosion in the bottom of the pipelines.

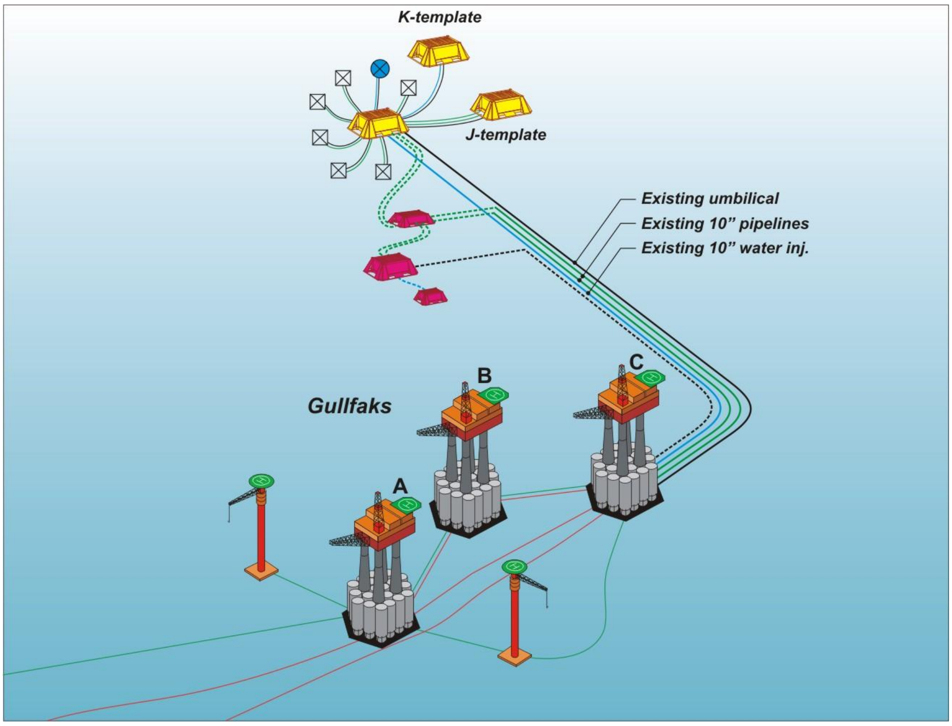

Figure 19. Illustration showing the Tordis subsea field tied in to Gullfaks C

When looking at the quality of the inspection data, residual scale was identified in the area of interest; 6 o'clock position. For one of the pipelines this lead to an increased uncertainty level of the ultrasound wall thickness measurements. This again led to decreased calculated capacity of the pipeline.

Again we identified a challenge; remove the scale in the corroded area. We choose the same methodology as for the Vigdis water injection and better brushes.

The results from the re-inspection in February 2011 showed no residual scale amongst the corrosion in the 6 o'clock position. Hence no further degrading of pressure capacity was necessary.

Conclusions

It is a real challenge to successfully clean and inspect water injection pipelines and it becomes even more of a challenge when the pipelines consist of soft bore sections. Inspection indicates that the scale build- up can accelerate which underlines the importance of efficient cleaning methods. However the efficiency is a trade-off between the aggressiveness of the tools and integrity of the pipeline.

Future needs

This paper showed two examples of challenging cleaning of pipelines with hard deposits on the pipe wall. It also point out the requirement for efficient ways of cleaning pipelines consisting of materials with different wear resistance.

Other requirements for the future are cleaning and inspection of multi diameter pipelines. Some field's shows decreasing production rate and new fields are interested in using the existing infrastructure. This means that new pipelines can be tied-in to existing structures.

In order to minimise the cost as much as possible, reduced pipeline diameter is preferred. This can lead to more multi diameter pipelines and more complex systems as the relative ID changes can be rather large.

Use of inline inspection tools with high resolution which can lead to enhanced defect detection. This is specially required in water injection pipelines with severe corrosion in the 6 o'clock position, resulting in extensive river bottom corrosion.

Decreasing production rate leads to low flow in the pipeline. This can be a challenge when it comes to availability of inspection tools with sufficient battery capacity in small diameter pipelines.

Wax rich pipeline has been mentioned before and is still a challenge, both when it comes to proper cleaning prior to inspection and to keep the sensors free of wax.

A helpful tool in cleaning operations would be a semi intelligent cleaning pig that can provide temperature profiles, indicate wax rich sections in pipelines and possibly indicate areas of scale build-up.

It can be useful for the pipeline operator to have access to unfiltered inspection data on standard format for an easier comparison of previous inspections.