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REMOVAL OF SCALE FROM THE TOTAL DUNBAR 16" MULTI-PHASE PIPELINE

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1. ABSTRACT

The 16" Dunbar Pipeline, operated by Total E&P UK PLC, transports raw multi-phase fluids 22km from the Dunbar platform to the North Alwyn Bravo platform in the North Sea. The pipeline was commissioned in 1994 and successfully intelligently pigged in 1997.

Video inspections of the pipeline conducted in recent years indicated a significant deposition of scale on the topside and riser pipework at the Dunbar platform. Scale throughout the length of the pipeline was also suspected.

In 2003, a program of work was initiated to clean the pipeline of scale and to enable an intelligent pig inspection. This consisted of a three-phased approach, performing a detailed study into options for safe removal of the scale, carrying out a comprehensive assessment of the scale quantities in the pipeline, executing modifications to the platform topsides, and culminating in the final pipeline de-scaling operations in 2004.

The detailed study was carried out over the second half of 2003, and looked at a number of possible techniques for removal of the scale. Prior to completion of this de-scaling study, a contract was awarded to assess the scale quantities, and shortly afterwards a second contract was awarded to clean and intelligently pig the pipeline.

The subject of the assessment of the scale quantities was covered in separate paper in 2005 [1]. This paper presents an outline of the options considered during the study phase of the work, and looks at the subsequent platform modifications and descaling work program undertaken, as well as summarising the results of the inspection runs which measured the effectiveness of the scale removal during autumn 2004.

This paper describes the technical challenges, which resulted in the successful removal of barium sulphate scale from a strategically important pipeline.

2. INTRODUCTION & BACKGROUND

The Alwyn and Dunbar Fields are located to the east of the Shetland Islands, and are operated by TOTAL E&P UK PLC. **Figure 1** shows the Dunbar export pipeline running from the Dunbar Platform to the North Alwyn Bravo Platform, a distance of some 22km in 110-140 metres of water.

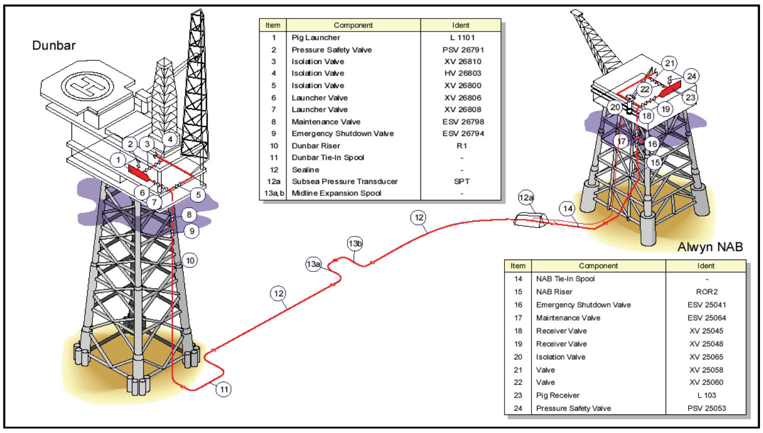

Figure 1 – Dunbar to Alwyn Export Pipeline

Installed in 1994, the pipeline was the first Pipe-in-Pipe (PiP) commissioned to a design by ITP. Prefabricated in 24m long double joints, the Dunbar PiP system consists on an inner 16" pipe (406.4mm by 17.5mm), an insulating layer of fibreglass and argon, and a 20" outer pipe (508mm by 11.91mm). At the end of each prefabricated joint, the outer and inner pipes are connected by a tulip type sealing arrangement, which is joined by the Interpipe weld. During installation, (from a conventional pipe lay vessel), each field joint was insulated using a prefabricated screwed sleeve arrangement. This gave an overall U value of 1.22 W/m2K.

The Dunbar Platform does not possess any processing facilities, and therefore exports raw unprocessed fluids, primarily gas with condensate and water. Velocities of the fluids vary from 1m/s in the liquid phase to >10m/s for the gas phase. This makes for a flow regime that is difficult to predict.

In 1997 the pipeline was intelligently pigged, using an Ultrasonic Inspection Pig.

After three years operation, the Ellon and Grant Fields were brought on stream and routed via the Dunbar platform through the export pipeline to Alwyn. Within a very short time, scale deposition became evident in the topsides pipe work. Subsequent investigation revealed that this was caused by the combination of the produced water from one of the Ellon wells and the produced water from some of the Dunbar wells. The scaling worsened over the following years despite a program of Scale inhibition and the separation and re-injection of Ellon produced water on the Dunbar topsides.

In 2002, with concern growing over the inability to verify the integrity of the pipeline, TOTAL initiated an investigation to try and detemine the extent of the scaling in the pipeline. A program was developed to run successive foam pigs of varying size and density, to then run in a gauge plate and finally a caliper pig. After the gauge plate became detached from it's pig, a retrieval operation determined that it had lodged in a mass of scale located at the top bend of the Dunbar riser. After retrieval of the gauge plate, a vide survey was carried out on the Dunbar riser to approximately 70 metres down the riser. This showed heavy scale deposition covering 100% of the riser inner surface to this depth.

In 2003, a study was undertaken to determine the best methods for removing the scale to enable an intelligent pig inspection.

3. DUNBAR PIPELINE SCALE REMOVAL STUDY

The study was subdivided into a number of discrete sections.

- Identification of the extent of the scaling problem in the riser/pipeline.
- Consultation with other Operators with scaling problems.
- Identification of how clean the riser and pipeline need to be.
- Scale Removal Methodologies.
  - Technical review.
  - Risk review.
  - Schedule review.
  - Commercial review.
- Review of alternatives to scaling removal.
- Final Selection of Scale Removal Methodology

Extent of the scaling problem

At the time of the start of the study, there was little detail about the extent of the scaling. The 315mm diameter 6mm thick aluminium gauge plate had not passed through the riser top bend out of the pig trap on Dunbar in 2002. After subsequent recovery of the gauge plate, the damage to the gauge plate indicated that the inside diameter of the riser was considerably less than expected. At the same time, video footage was taken down to the limits of the camera, (70m) which showed that the scale was evident to this depth (and beyond) over 100% of the riser internal surface.

Consultation with other Operators

A number of other Operators who were known to have experienced scaling problems, and who have tried to deal with them were contacted.

- In Norway, a 22" pipeline was suffering from apparently similar Barium Sulphate scaling problems to the Dunbar pipeline, successfully cleaned using hydro-mechanical methods.
- In the Northern North Sea UK Sector, a subsea manifold and pipework, frequently succumbed to scaling, which was regularly cleaned using HP water jetting techniques.
- In the Central North Sea UK Sector, heavy Barium Sulphate scaling downhole was a regular occurrence. Chemical methods were attempted, which only softened the surface of the scale, before it was finally cleaned using HP water jetting.
- In Southern England, at an onshore site, the local pipeline regularly had to be cleaned for UT pig inspection. After several methodologies had been tried, the Operator settled on hydromechnical cleaning.

How clean?

Several factors influence the required cleanliness of the system. For the Dunbar Pipeline System, the requirement was that an intelligent pig be run to verify the condition of the pipeline. As the pipeline is of pipe-in-pipe construction, only a UT Intelligent Pig will give meaningful results, and this requires bare steel to ensure the UT signal is not attenuated by other solids. Therefore the internal wall of the pipeline needed to be cleaned to bare metal.

Scale Removal Methodologies

A variety of cleaning methods were considered. Two main areas had to be considered when looking at the options available, firstly the effectiveness of removing the scale from the wall of the pipeline, and secondly, removal of the scale debris from the pipeline. During a brainstorming session, the following methodologies were identified.

- Conventional Scraper Pigging / Cleaning.
- Hydro-Mechanical cleaning.
- HP Water Jetting.
- Chemical Cleaning.
- Ultrasonic Cleaning.
- Explosive Techniques.
- Coiled Tubing.
- Electrostatic Potential.

Following consultations, a number of companies were invited to submit budgetary proposals based on a defined distribution of scale throughout the length of the pipeline. Proposals were invited for cleaning of just the riser or for the whole pipeline system. Restrictions on diameter were defined as 10" at the Dunbar Riser, opening out to full bore further down the pipeline, and the defined content equated to approximately 100 tonnes (25m^3) of scale. A number of responses were received and reviewed.

1. Conventional Scraper Pigging / Cleaning.

   This method involves utilisation of a combination of existing pigs (brush pigs, scraper pigs, pin wheel pigs, etc), which would be run in a predetermined sequence, dependant on the amounts of scale arriving at the NAB Pig Receiver. Most pigging contractors would be capable of carrying out this work scope.

   The two contractors who were invited both declined to submit a proposal, on the basis that their equipment would not be able to remove the levels and type of scale indicated. One these contractors had attempted a similar cleaning process on the 22" pipeline in Norway (referenced above) with very limited success.

2. Hydro-Mechanical cleaning.

   This method requires a considerable amount of pre-engineering be carried out. Generally, these are customised tools, designed specifically for the precise conditions found in the scale assessment phase. Only two contractors exist who have any track record with this technology, both of whom were approached.

   Both contractors submitted a proposal, one of which went into considerable technical detail. Both methods were similar, involving the flowing of high volume liquids to drive both the mechanical tools and the removed debris. One major difference between the two proposals was a requirement to separately clean the riser and the pipeline. Clarifications were carried out, in order to try and detail a workable methodology, including consultations with other Operators who had experience with both of these contractors. In the event of cleaning all in one go, the risk of debris blockage further down the pipeline was very high, given the unknown geometry and behaviour of the scale in being removed from the wall of the pipe, and the fact that any removed debris would have to travel 22km before coming out the end of the pipeline. In addition, should the water flow cease at any time during the running of the cleaning tools, then there was the additional risk that the suspended debris would settle out, and cause a blockage. The distance of travel could have been mitigated further by separately cleaning the two halves of the pipeline.

   Both of these proposals looked workable, although the difference in risks between the two was significant. Schedule for each of these two proposals was uncertain. Other operators experience of one of the contractors suggested the cleaning operation could take anything from weeks to months. The other contractor was better defined, stating that operations should take about two weeks, and this was reflected in conversations with other operators about their experiences.

3. HP Water Jetting.

   This method involves the use of an HP water jet head, to be inserted into the pipeline, and to blast the scale off, and flush it along the line. This will only work over relatively short distances, and is only likely to have applications for the riser cleaning or the partial cleaning scenario. Two submissions received proposed using jetting as a milling type tool, one of which had a proven track record. Another used this jetting to supplement their drilling solution, and is discussed under Drilling below.

   Of the two milling solutions, one recovered the debris back up the riser via a lift hose, the other require flushing it out the split subsea flange. Both were restricted in distance out from riser top, probably only as far as the pipeline flange.

   The estimate was that a couple of weeks would be required to clean the riser alone, and consideration was given to splitting the overall cleaning operation over two distinct phases.

4. Chemical Cleaning.

   This method is not possible by chemicals alone. Time exposure in batch pigging will not be enough to dissolve the scale, and a soak would involve a very high volume of chemicals, heating and agitation. As a minimum, scale removal would require some mechanical assistance by pigging and/or HP water jetting. One contractor submitted a proposal along these lines.

   The proposal received confirmed that cleaning by chemicals alone was not possible. It would be necessary to expose the entire scaled up pipe wall to the chemicals, involving a large volume (up to 2,500m^3), ideally this should be agitated, and heated to increase effectiveness of the chemicals. The proposal suggested that this methodology should be combined with a pigging program, using brush and scraper pigs.

5. Ultrasonic Cleaning.

   This is relatively unknown technology for pipelines, but works on the principle of ultrasonics, causing differential vibration of pipeline and scale, breaking the bond between the two. This has worked for equipment and plant, but has not been used on a larger scale (i.e. a pipeline). This may have applications for the riser-cleaning scenario, but the contractor declined to submit a proposal for cleaning the pipeline (or the riser).

6. Explosive Techniques.

   For down hole applications, lengths of primer cord have been used to 'shock' the scale off the pipe wall. Removal of the resulting debris has subsequently been by flowing the well. This application exposes the pipeline to risk of damage/fatigue resulting from the blast, and removal of the debris is not so easy. No submissions were received proposing this technique.

7. Coiled Tubing.

   This method involves the use of coiled tubing to create a closed loop system. The scale is removed by injecting a fresh water barrier, followed by a chemical mix to soak. Then in sequence a neutraliser is used to neutralise the chemical, followed by a hot fluid, displacement and flushing. Again, this would only work on the riser section of the system, and has the some of the limitations of chemical cleaning described above. Removal of the scale debris requires sufficient water flow in the pipeline, which coil tubing cannot provide, although the addition of water flushing from the NAB end may assist. To date, no operation on a pipeline of this diameter (15" ID) has been carried out.

   The proposal received for this had a number qualifications about the effectiveness of the cleaning process. In addition, the amount of equipment required on the Dunbar Platform was pushing the topsides capacity of the platform, in both weight and physical space.

8. Electrostatic Potential.

   This method involves the use of passive materials, which alter the electrostatic potential of the fluid, thereby suspending solid minerals and inhibiting formation of scale. Unfortunately, this is more geared towards scale prevention, rather than scale removal, and no proposal was submitted for consideration.

During the study, further inspection and survey work was carried out on the riser and pipeline as follows:

- During the dewatering of the pipeline, Tracerco injected a radioactive isotope at Dunbar and time of flight to Alwyn was measured. With the known flowrates, an estimate of the remaining pipeline volume was arrived at. When compared to theoretical volume, an estimate of scale volume could be determined.
- Inspectahire carried out a repeat video survey, this time to the bottom riser bend. This showed that the scale was continuous to the bottom bend [**Figure 2**], but that the worst area of deposition was at the top bend [**Figure 3**].
- In addition, Inspectahire deployed a sonar head to measure the minimum bore of the riser. This gave a worst case measurement of approximately 10". This was backed up by the physical size of the camera assembly, which was 9" across.

Figure 2 – Scale near bottom of Riser (2003)

Figure 3 – Scale at Riser Top (2003)

A detailed video survey of the NAB riser had been carried out in 2001, which showed little or no scaling evident. Therefore, it was considered a safe assumption that the scaling at the North Alwyn end of the pipeline would be less onerous.

Alternatives to scale removal?

In the event that cleaning was not carried out, what alternatives to scale removal were there? The purpose of the cleaning and inspection was to confirm the continued integrity of the pipeline system. Without this verification, the alternatives would require replacement of part or all of the system(s).

- Spare Riser – in the event that the upstream riser only was scaled up, a spare riser could be used. However, only smaller diameter risers are available on the Dunbar platform, and this was not considered feasible.
- Dunbar Riser/Spools only – in the event that the upstream riser only was scaled up, install and new riser and tie-in spools to the pipeline.
- Dunbar Riser/Spools and Pipeline to the Mid point expansion spools – in the event that the scaling extended into the pipeline, but less than halfway along the pipeline, advantage could be taken of the expansion spools located midway along the pipeline length.
- Dunbar Riser/Spools and Pipeline, and NAB spools – in the event that the scaling extended most of the way along the pipeline, then it would be necessary to replace the entire pipeline and riser at the Dunbar end. There was sufficient information about the NAB riser to know that it was not scaled up.

Final Selection of Scale Removal Methodology

It is fair to state that economically, scale removal was a far more attractive option than replacing any part of the pipeline.

From the above options, the Hydro-Mechanical cleaning seemed to be the favoured option, but a number of other factors had to be considered before selecting this final methodology and contractor.

- Schedule

  Scheduled for the summer of 2004 was a major 14 days shutdown of the Alwyn Area fields, including Alwyn, Dunbar, and the pipeline. The plan was to be ready to clean the pipeline during this shutdown. If time permitted, then an Intelligent Pig Inspection of the pipeline would also be carried out during this window.

- Disposal of Scale / Permits & Consents

  With two disposal areas, a variety of permits and consents had to be considered. For the disposal of the scale debris and number of factors were taken into account before considering the best route. As the scale contains low level LSA, the disposal options were further complicated. Four options were considered.

  - By routing the scale directly into the North Alwyn Process stream, there would be limited physical handling on the platform. However, the anticipated size and volume of debris could not be handled in the topsides process plant, and the back pressures would restrict any cleaning operations. Therefore, this was not considered further.

  - By re-injecting the scale downhole, there would also be limited physical handling on the platform. However, the debris needed to be reduced to a very small particle size, which would have meant separately dealing with the scale before re-injection. In addition, the available capacity for cuttings re-injection was extremely small, and the back pressures would also restrict any cleaning operation. Therefore, this was not considered feasible.

  - Collecting topsides Alwyn, by filtering the scale as it arrived. This gives rise to flowrate issues ($10m^3$ per minute) and scale, both of which could add in excess of thousand tonnes to topsides weight, in addition to the size and weight of the filtering equipment. While this method was not impossible, it would be extremely impractical, and could not be done in the time frames planned. The experience in Norway on the 22" pipeline suggested that this would not work.

  - Discharging directly to sea, represented the simplest solution, requiring minimal facilities topsides, and represented the safest route. However, environmental considerations had to be considered. The discharge may have a slightly oily content, although experience from previously de-oiling of the pipeline suggested that this would not be the case. Authorisation would be required to discharge scale with low level LSA. As part of the lead in to the cleaning operation, extensive sampling would be required to determine the LSA levels likely to be encountered.

- Water Flow

  With such a high water flow being required to flush the debris, Dunbar had the advantage of a water injection system, whereby water is pumped from North Alwyn down a separate 10" pipeline. This flow could (with modifications) be diverted into the Dunbar pipeline.

  Loss of water supply (and potential blockage of the pipeline) was considered a high risk, as a platform blackout on North Alwyn would shut down the water supply. As Dunbar is also powered from North Alwyn, any contingency water supply would have to some from an independent system on Dunbar, and so the Fire System was selected as a contingency water source for the cleaning.

- Extent of Cleaning

  Given that water supply was feasible, and that disposal of the scale debris should not pose a problem, it was considered preferable to clean the entire riser and pipeline in one campaign, rather than take two or more shutdowns, as the modifications required to provide the water flow would be extensive.

The conclusion of the study and the practical aspects of the Alwyn and Dunbar Platforms, that the preferred scale removal method for the pipeline was hydro-mechanical cleaning.

In early 2004, a contract was placed with **Kontroll Technik Norge As (KTN AS) / Reinhart** in Switzerland to hydro-mechanically clean the Dunbar pipeline from end to end, with the work scheduled to take place during the planned summer shutdown 2004. In addition, if time permitted, then an Intelligent Pig Inspection of the pipeline would also be carried out during this window.

4. CALIPER PIGGING

Prior to awarding the cleaning work, TOTAL E&P UK PLC contracted Weatherford Pipeline & Specialty Services to develop a Caliper Pig to survey the scale in the pipeline and assess the quantities and distribution, not just along the length of the pipeline, but around the circumference as well. This work is documented in reference.

The results, obtained in May 2004, are summarised in the following two figures. **Figure 4** presents a graph showing scale quantities against distance. This clearly shows the severe scale build up present at the start of the pipeline gradually reducing over the first 6 km. **Figure 5** shows the theoretical effects of any error in the measurement of the scale, illustrating the importance of the accuracy of any measurements of this type. The final calculated scale volume of 43.5m^3 equates to a weight of 170 tonnes of scale.

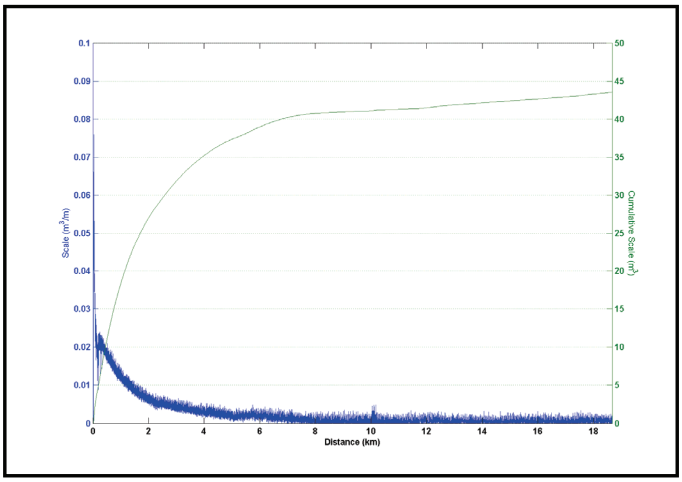

Figure 4 – Scale Assessment Results

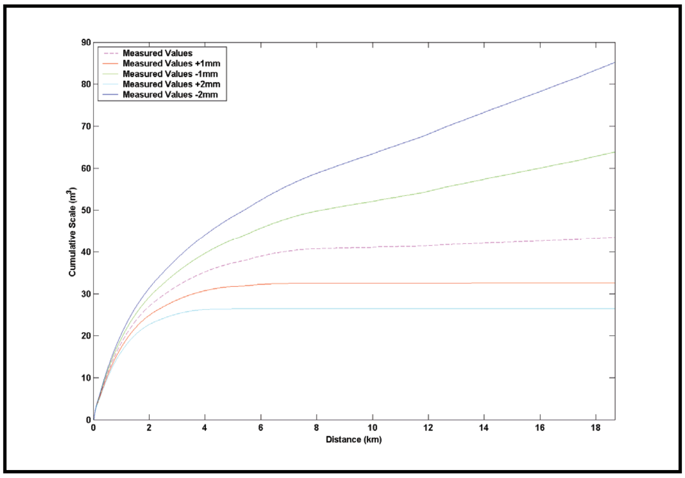

Figure 5 – Scale Assessment Sensitivity To Measurement Error

5. TOPSIDES MODIFICATIONS

Early in 2004, work began in earnest, to achieve the program of cleaning the pipeline during the summer shutdown. Topsides modifications were engineered and installed by the incumbent topsides contractor.

<u>Primary Water Supply System (Dunbar)</u>

Water Injection is provided to Dunbar platform from the North Alwyn platform via a 10" pipeline. With a difference in pressure rating between the two pipelines, 366 barg for the WI line, and 137 barg for the Dunbar pipeline, a pressure protection system had to be incorporated into the design. The water feed was taken from the Water Injection Header downstream of the existing isolation valve on Dunbar. Beyond this, the temporary pipework was teed in, with a second isolation valve, a flow control valve (hand operated with a small bypass), before the two high pressure PRV's. The pipework was then routed through an NRV before the contingency supply line tee, and then to the Pig Launcher. This is shown on the left hand half of **Figure 6**.

<u>Contingency Water Supply (Dunbar)</u>

The Contingency Water Supply is provided from one of the Fire Pumps. The Fire System has a very low pressure rating, and so a pressure protection system also had to be incorporated into this design. Temporary booster pumps and hose were hired in, and these were installed on the drill deck, the only place where there was sufficient lay down area. The water supply from the Fire Pumps was routed through a filter to the booster pumps, before passing the two low pressure PRV's before joining the supply line to the Pig Launcher. This is also shown on the left hand half of **Figure 6**.

<u>Scale/Water Reception Facilities (Alwyn)</u>

For the scale and water reception facilities on topsides Alwyn, a modified replacement Pig Receiver Door was fabricated, with a 6" outlet. Incorporated on the end of this nozzle was a 6" valve, and a sampling point. Downstream of this point, the pipework was routed via a flexible hose to sea level, to facilitate discharge. This is shown on the right hand half of **Figure 6**.

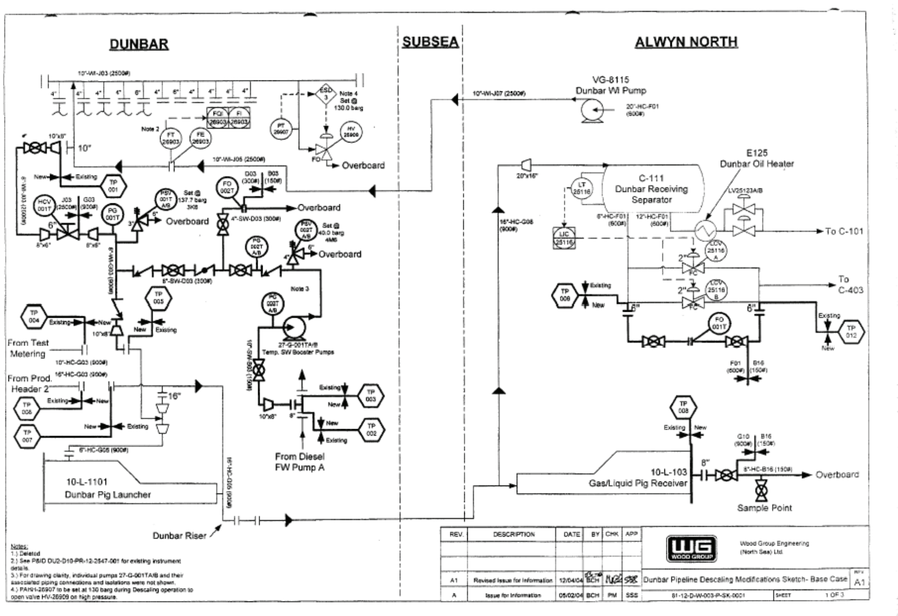

Figure 6 – Topsides Modifications

6. SUBSEA WORK

Early in 2004, a contract was put in place with Technip Offshore to provide a DSV and Diving support work at the base of the Dunbar Riser. In addition, they were contracted to provide the hardware necessary to safely catch the cleaning tools, without exposing the diving personnel to any hazards from scale or tools. A cassette type arrangement was fabricated, one for each riser cleaning tool, six in total. The arrangement is shown in **Figure 7**.

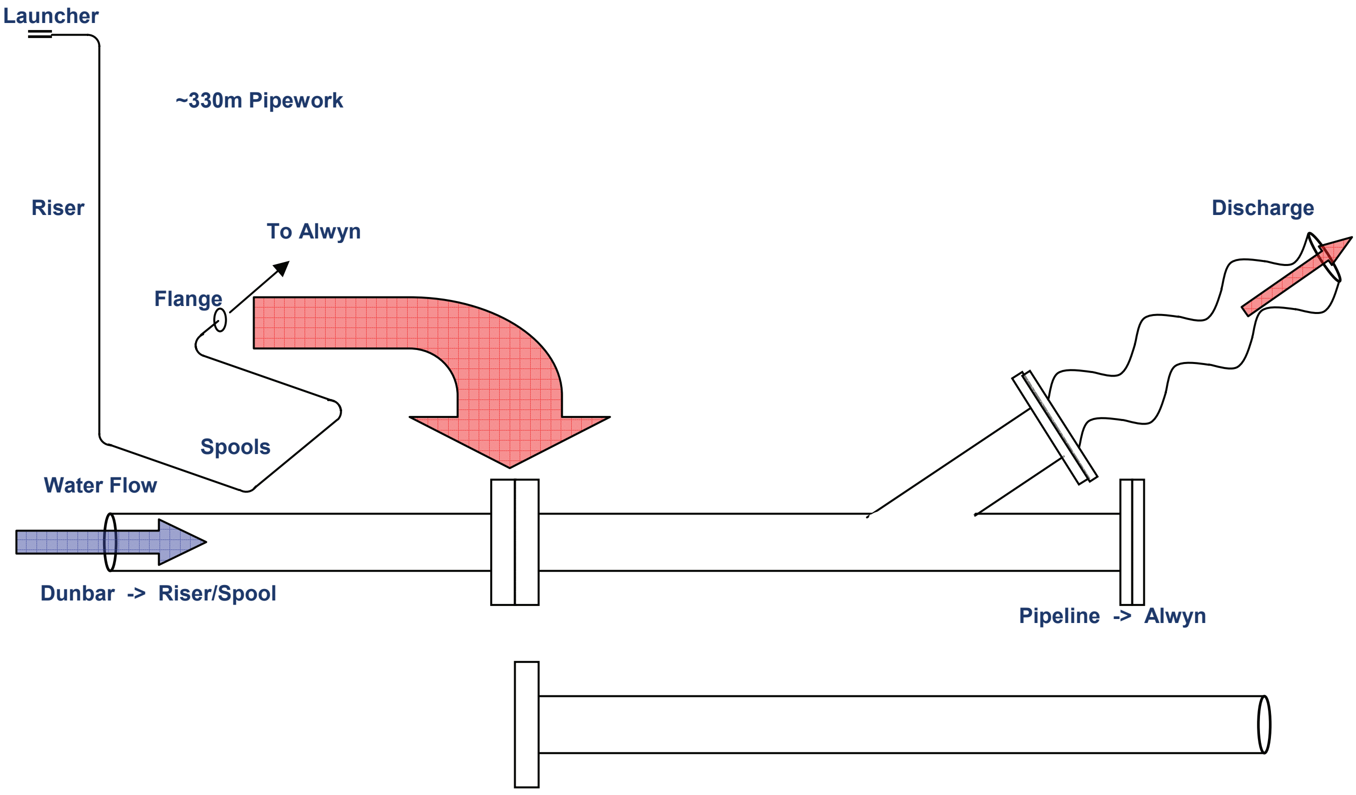

Figure 7 – Subsea Reception at Dunbar Riser

In addition to the reception facilities, some lengths of Dunbar linepipe, and two pipeline connectors were held in readiness, in the event that the line became blocked, and it became necessary to cut out a length of pipeline and replace it.

7. CLEANING TOOLS

The cleaning tools were all custom designed and manufactured at Reinhart's workshop in Switzerland. They were modular in design and manufactured to tight tolerances, using the knowledge of the pipeline internal dimensions. The sequence of tools was initially set as being 4 tools required for the riser, and then a further 6 tools for the Riser and pipeline combined.

Following receipt of the calliper survey results, two additional tools were added to the front end of the riser cleaning phase, because of the increased severity of the scale.

The final planned sequence of tools was as follows.

Run No	Tool Designation	Length	Weight (ex tube)	Weight (with tube)
Riser #1	PCT-US-10/2L	520mm	82kg	312kg
Riser #2	PCT-US-10/2L	520mm	82kg	312kg
Riser #3	RPCT-TOTAL	1,073mm	128kg	358kg
Riser #4	RPCT/5-AOS	1,078mm	170kg	400kg
Riser #5	PT-RRT-RST	1,982mm	278kg	508kg
Riser #6	PT-RRT-RST	1,982mm	278kg	508kg
Pipeline #1	RPCT-TOTAL–RRT-RST	2,099mm	288kg	518kg
Pipeline #2	RPCT/5-AOS–RRT-RST	2,104mm	330kg	560kg
Pipeline #3	PT-RRT-RST-RRT-RST	3,008mm	438kg	668kg
Pipeline #4	PT-ABC-ABC-ABC	2,495mm	199kg	429kg

Pipeline #5	PT-SS-SS-SS	2,495mm	199kg	429kg
Pipeline #6	PT-TIGER-TIGER-TIGER	2,186mm	199kg	429kg

For each cleaning tool run, the optimum tool speed was designed as 1.0m/s. Given the water bypass of the tool, a necessary function of flushing he scale debris ahead of the tool to avoid blockage, this requires a water velocity of 1.4m/s.

The tools were all partially assembled prior to shipment offshore, and a launching tube fabricated to suit the Dunbar Pig Launcher and ID of the pipeline.

8. CLEANING OPERATIONS – PHASE 1 - RISER

By the 2nd August, the primary Water Injection Modifications had been completed, but the contingency Fire Water System Modifications were not quite complete. All cleaning personnel and equipment had been mobilised to the Dunbar and North Alwyn platforms. The DSV had mobilised and was available in the field.

De-oiling of the pipeline commenced on 2nd August and took approximately 16 hours to run. The analysis for water cleanliness showed that cleaning operations could commence immediately.

As the contingency water supply was not yet ready, some concerns were expressed regarding the consequences of commencing the cleaning operations without a contingency water supply in place. However, as the first operation was cleaning of the riser, a relatively short length of pipeline (~300m), the risk of a blockage was considered very low, and the DSV commenced splitting the Dunbar pipeline/spool flange subsea. Divers noted approximately 15mm thick scale deposit on the internal pipe wall at the break point, verifying the caliper survey results.

A total of 6 cleaning tools were used for the Riser Cleaning. Because of the tight tolerance on diameter, and the high bypass that each tool would experience, a launching tube had to be used to load each tool in the pig launcher. Each Tool / Launching Tube assembly was loaded into the launcher and, to avoid risk of loss of water flow, the Dunbar topsides ESD's were locked open.

The sequence of activities for each Riser cleaning tool run was as follows :

- Cleaning Tool loaded into Launching Tube
- Cleaning Tool / Launching Tube loaded into Pig Launcher
- DSV ensure divers all clear of receiving cassette and discharge hose
- Topsides water supply de-isolated
- Cleaning Tool Launched
- Topsides water supply isolated
- DSV removes cassette from end of spool, and replaces with empty cassette

The run time for the each cleaning tool was about ten minutes. Subsea, the exhaust hose was monitored by ROV, and scale debris was clearly seen to be discharging throughout the pumping operations. Pumping was usually continued until the discharge became relatively clear.

On completion of the Riser cleaning, the flanged connection subsea was re-instated, the pipeline leak tested, and the six full cassettes were recovered to deck. It was noted by the divers during the reconnection of the flanges, that the platform side of the connection was cleaned back to bare metal.

Figure 8 shows the fifth Riser Cleaning tool in the cassette receiver onshore along with scale debris. **Figure 9** shows the mound of scale debris from the riser cleaning process, estimated at 6m by 3m by 1m high.

Figure 8 – Tool 5 (PT-RRT-RST) in Receiver Cassette

Figure 9 – Scale Mound from Riser Cleaning

9. CLEANING OPERATIONS – PHASE 2 - PIPELINE

By the end of the Riser cleaning operations, the contingency water supply was ready.

A total of 6 cleaning tools were used for the Pipeline Cleaning. For this phase of the work, each Tool / Launching Tube assembly was loaded into the launcher, the assemblies weighing from 429kg to 668kg. In addition, to avoid risk of loss of water flow, the topsides valves on both Dunbar and Alwyn were locked open.

The sequence of activities for each Pipeline cleaning tool run was as follows :

- Cleaning Tool loaded into Launching Tube
- Cleaning Tool / Launching Tube loaded into Pig Launcher
- Cleaning Tool Launched
- Alwyn removes tool from receiver on Platform

During insertion of the tools into the launching tube, a high pulling force was required (2-3 tonnes). During tools 4, 5, 6, the loads exceeded this, and each of these three tools had to be reduced in length by removing the last module, so the final three tools launched had the following designations :

- PT-ABC-ABC
- PT-SS-SS
- PT-TIGER-TIGER

In addition, the water flow rate for the last (TIGER) tool was reduced to 0.8m/s to allow the tool to work more efficiently.

The run time for the each tool was as follows :.

- Pipeline Tool 1 11:29 hrs (back pressure 14 barg)
- Pipeline Tool 2 7:27 hrs
- Pipeline Tool 3 5:47 hrs
- Pipeline Tool 4 6:02 hrs
- Pipeline Tool 5 6:28 hrs
- Pipeline Tool 6 8:05 hrs (back pressure 3 barg)

The reducing times for each run reflected the quantities of scale left in the pipeline.

10. INTELLIGENT PIG INSPECTION / SCALE CLEANING RESULTS

The final stage of the operation was to run the Intelligent Pig, The run time of this was 5:12 hrs, representing a pig speed of 1.2m/s. A qualitative analysis of the data shows that 3.5% of data was lost due to UT probe problems, and 2.4% due to residual scaling. The residual scale was located in two narrow bands located either side of the 12 o'clock position (see

Figure 10), and was initially 2mm thick (at KP 1.9), reducing the further away from Dunbar. By KP 8.5, the residual scale, while still evident, did not affect the Intelligent Pig data.

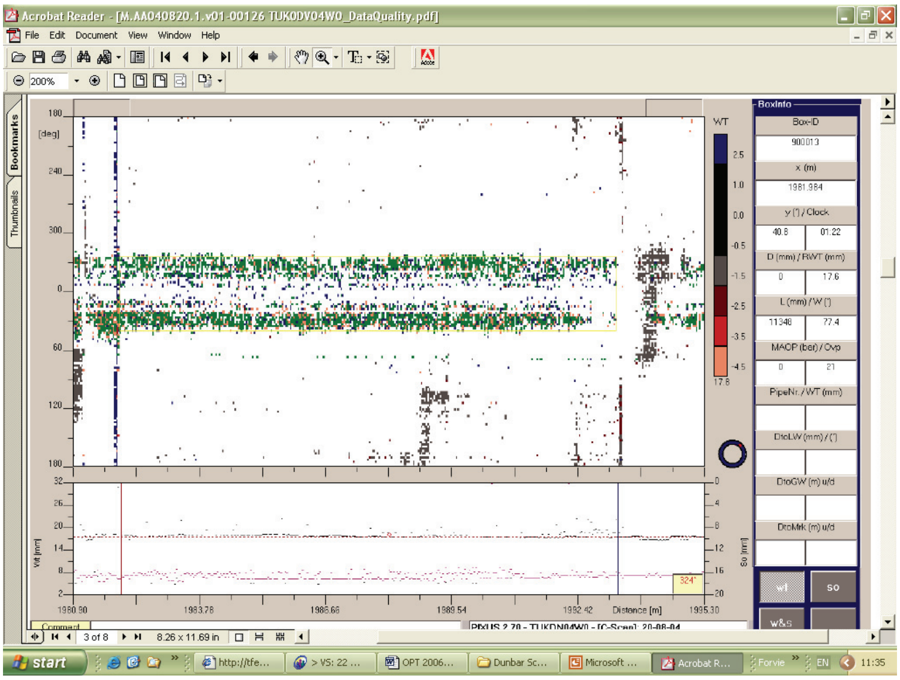

Figure 10 – Residual Scaling on Wall of Pipeline

11. CONCLUSIONS

With the pipeline cleaned of scale within the time frame permitted, without incident, and an Intelligent Pig Run giving 94% of the pipeline data, the overall Dunbar Scale Removal Operation was considered a success.

The whole operation has demonstrated just how important it is to gather as much information about the pipeline, its operation, and the scale, to minimise the risks to any cleaning operation.

Subsequent to the cleaning operation, TOTAL E&P UK PLC, in conjunction with Reinhart in Switzerland, now run cleaning tools in the pipeline on a regular basis, while still in production. This maintains the pipeline clean enough to carry out further Intelligent Pig Inspections if and when required.

12. REFERENCES

[1] – Allen, Gordon; Hawes, Jon. "Scale Assessment Pigging Of The Total Dunbar 16" Multi-Phase Pipeline", Offshore Pipeline Technology Conference, Amsterdam, Netherlands 2005.