Proceedings of IPC2008
7th International Pipeline Conference
September 29-October, 2008, Calgary, Alberta, Canada

IPC2008-64626

Feeler Pig: a Simple Way to Detect and Size Internal Corrosion

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ABSTRACT

Submarine pipeline inspection traditionally employs the same technologies used for onshore pipelines. One of such technologies is the instrumented pig, which usually runs under the same parameters and procedures as those used for onshore inspections. However, it is very common to find submarine pipelines with many kinds of obstacles that may prevent the use of conventional instrumented pigs, like magnetic flux leakage pigs - MFL - and ultrasonic ones. The relevant factors that make the inspection difficult are the different diameters along the pipeline, small radius bends, equipments installed in the pipeline (such as manifolds and valves), increased wall thickness,multi-phase fluids, etc.

A currently available alternative technique to inspect these pipelines is the use of ultrasonic and magnetic pigs, which nevertheless, have their own limitations. For ultrasonic pigs, the need of a homogeneous fluid, with good acoustic properties, to serve as sonic wave coupling is a relevant factor. On crude oil pipelines, this homogeneous fluid is not always available, as these lines carry multi-phase products. For magnetic ones, their magnetic power is significantly limited by high wall thickness, due to structural reasons of offshore pipelines.

Focusing on this context, a new tool was developed to detect and size up loss of wall thickness associated to internal corrosion. This tool, called Feeler Pig, was designed to be able to overcome diverse limitations that conventional pigs have. The Feeler Pig performs the direct dimensional measure of pipeline internal corrosion by contact, with no practical limit of wall thickness to inspect and no need of homogeneous fluid during the inspection job. The system was tested in field and had its performance compared to a standard ultrasonic instrumented pig. Excellent defect correlation was observed between the Ultrasonic and Feeler Pig data, not only but in geometry but also in deepness of internal corrosion. With this high confidence, other prototypes of Feeler Pigs were developed. One of them, named Feeler Snake Pig, was built with the installation of feeler nails into a flexible polyurethane support yielding tool with ultra high tolerance to geometric restrictions and is able to navigate through sharp bends and geometric accessories. The excellent results of the prototype and its robustness against line geometric restrictions immediately open a wide range of opportunities for the Feeler Snake Pig technology in field applications.

INTRODUCTION

There are some particularities on inspection procedures that must be considered. Onshore pipelines are usually easy to access, and that enables excavating for field verifications and correlations, thus allowing inspection quality measurement. The same is not true for submarine pipelines, in which a correlation of data acquired by two or more instrumented pig implies very high costs or, in some cases, is not technologically available. In Brazil, during the 1980's and 1990's, onshore pipelines received strong investments to be adapted for instrumented pig inspections, such as: the remove of small radius bends; installation of launchers and receivers; unification of diameters; and removal of obstacles. Some submarine pipelines received the same treatment, but these adaptations were not extended to the whole network. It is very common, for instance, to find submarine pipelines with multi-diameters and small radius bends, among other obstacles that prevent the use of conventional instrumented pigs.

As oil production heads for deeper and deeper waters, pipelines become thicker for structural reasons, and that implies loss of magnetic flux leakage pigs – MFL – measurement capacity. These pigs present reduced sensitivity as from 15 mm-thick wall, with practical limit of 20 mm. The problem gets even worse in pipelines with diameters smaller than 14-inch, which present large thickness and small internal volume, making magnetization very difficult, once the space available to

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place magnetizers is restricted. With current technology, there are not enough compact and high-power magnetizers to be used for large thickness in such small spaces. Another particularity of submarine pipelines is that their external visual inspection is almost always possible since those pipelines are accessible from outside using ROVs – Remotely Operated Vehicles. Those vehicles are already periodically used to inspect PETROBRAS' submarine pipelines in order to identify external damages, measure cathodic protection and electrochemical potential, identify spans, etc. The external visual access is, compared to onshore pipelines, the greatest distinguishing feature regarding submarine pipelines inspection.

Other aspect that favors submarine pipelines is that the main cause of deterioration is internal corrosion, generally in lower generatrix, which occurs in presence of produced water. External corrosion is easily prevented with cathodic protection, while damages caused by collisions or anchor action are, mostly, identified through ROV visual inspection. Therefore, the main objective of oil and gas production submarine pipeline inspection is to detect and quantify internal corrosion.

Besides inspecting onshore and offshore pipelines, the feeler pig have been achieving good results in refinery pipeline inspections, especially in furnace pipes. These pipes have some characteristics that restrict the measurement of internal corrosion as well, turning the operational and inspection itself difficult. Figure xxx shows a 6 inches furnace pipe inspected by a feeler pig.

As mentioned before, another currently available technique to detect internal corrosion in pipelines is the use of pigs with ultrasonic technology, but depending on its mechanical design, the ultrasonic pig may not tolerate high variations in diameter. A severe limitation to that method is the need of a homogeneous fluid, with good acoustic properties, to serve as sonic wave coupling. That limitation makes it difficult to inspect gas pipelines, requiring introduction of a diesel batch, resulting in a strong operational impact. This fluid is not homogeneous in production pipelines with "live oil" (oil + gas + water), making ultrasonic inspection practically impossible [1], [2].

The feeler pig is programmed according to pipeline specifications, such as multi-diameters and wall thickness along the pipeline, to intent different ranges of wall thickness measurement. This range is generally set between + 5mm and -20mm, so that the circumferential welds root and pits can be measured. Submarine pipelines with high thickness can always be inspected, since the only thing necessary is the adjustment of feeler-type sensors the sensibility. One of the feeler pig limitations, in case of deeper and small defect dimensions, is that the stick can not geometrically reach the bottom of the defect. As such cases are rare, that is not a strong limitation of the tool.

The pipeline cleaning condition for a inspection using the feeler pig is similar to that needed by conventional instrumented pigs.

FEELER PIG METHOD

Given the known difficulties of submarine pipelines inspection, a R&D project was started to devise a new method to detect and size up loss of wall thickness associated to internal corrosion. The Feeler Pig was developed to perform the direct dimensional measure of pipeline internal corrosion by contact, with no practical limit of wall thickness to inspect and no need of homogeneous fluid during the inspection job. It consists of several feeler-type sensors accurately distributed along the pig's body that measure internal corrosion, as illustrated in figures 1 and 2 [3], [4]. Thus, any movement generated by internal corrosion are measured according to angle variation of sticks, then a proportional analog sign is stored in the embedded electronic.

The first special pig prototypes were developed to inspect small diameter production pipelines, using just a few sensors to inspect furnace refinery pipes. Later, thanks to the excellent results obtained in field tests, the concept was extended to large diameter pipelines, such as 12-16", 22" and 24" (inches).

That tool carried out an inspection of a submarine pipeline, confirming its potential in real inspections. Figure 3 shows the pig assembled and ready to use. Results delivered by the pig's 250 feeler-type sensors were compared to the data collected by a previous inspection performed with a commercial ultrasonic pig on the same pipeline. The new tool delivered results that were almost identical to those of the ultrasonic pig in terms of defect deepness and extension, confirming the technical viability of the new internal corrosion detection and quantification method.

Those results, of feeler pig and ultrasonic one, were compared and the most relevant points were plotted. A good correlation between both techniques was observed, as figure xxx show.

Some inspections in oil pipelines were did in 2007, and the technical effectiveness was proved by the system.

Based on the aforementioned results, several inspections using that system are being scheduled for 2008, including oil and gas pipelines with or without diameter variation, in addition to short and long pipelines with a wide range of flow speed.

CALIBRATION

In order to achieve accuracy in deepness measurements it is fundamental to employ a calibration procedure before launching the pig to the inspection. Every sensor is individually programmed to meet the operational range of the project, considering the pipeline characteristics such as internal diameter and wall thickness. The sensor must be able to measure within its range, for example, a 100% thickness loss without saturating. Since there still may be some variability between sensors due to mechanical differences, magnets positioning and strength, the tool is then calibrated with all sensors mounted over the main structure.

The calibration consists of passing the tool through a 6-meters long plastic tube, with the same diameter as the nominal inspection target. The tube has an access window where a calibration staircase is inserted. Every step of the staircase is precisely known, providing calibration values to the entire range of thickness which the tool is meant to measure. The figure 6 shows the staircase and the tube used for calibration of the feeler snake pig.

As the pig is pulled within the tube, the signal representing the staircase is acquired for every sensor, as seen by that particular sensor in figure xx. Since the staircase does not cover the entire 360º span, the procedure is repeated until a valid signal is obtained for all sensors. The figure x shows the characteristic staircase signal of the feeler type sensor. The known values of step heights provide a precise calibration

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reference to be later used in data analysis. The process is fully automated with individual polynomial fitting for every sensor. Once calibrated, the measurements taken by the pig are presented in millimeters to the operator.

In the case of feeler pigs with more than 10 inches it is necessary to bring the tool to the CTDUT, a pipeline test place, for calibration. The same calibration procedure is executed with a identical pipe of the line to be inspected, therefore the pipe has an access window were a calibration staircase is inserted. The figure x show the "fingerprints" of feeler-type sensors in CTDUT`s pipe.

SOME FIELD RESULTS

In January, 2005, the 16" feeler pig performed an inspection in a submarine pipeline. After the data analysis, no corrosion was found. In Figure 7 it is possible to see the high sensitivity of the feeler pig. All welds – circumferential or longitudinal – were detected. Also, as longitudinal welds reached the circumferential, it was possible to detect and size the internal grinding of longitudinal welds. Figure 8 shows the results obtained by the snake feeler 8" pig.

Until now, the feeler pig ran between 0.5m/s to 2m/s in field inspections. However, in laboratory some testes showed a good quality of measurement in velocities around 4m/s. Thus, It is not expected to occur any problems if the pig velocity remains below 4m/s.

In July, 2006, an inspection was performed using a feeler snake pig, which is a fully innovative design using the method mentioned above. Figure 5 shows the new concept of instrumented pig, in which feeler type sensors are mounted over a flexible polyurethane body. That tool enabled a multi-size inspection, with small radius bends, a kind of inspection that tools commercially available cannot provide. As a result, 7.6 kilometers of a submarine pipeline were recovered. Figure 8 shows the results obtained by Snake Feeler 8" Pig. Also in this 15 year-old pipeline, no internal corrosion was found. According to figure 8, all circumferential welds were detected.

Another field inspection was made in November, 2007, with the 24" feeler pig in an onshore pipeline. After the data analysis, the pig founded internal corrosion localized in the lower generatrix of the pipeline. This result was caused by the high levels of produced water with oil (90 % BSW), so that the morphology of this pipeline does not permit good measuring by ultrasonic and magnetic pigs. The figure x,y z shows some data results about this inspection.

CONCLUSION

As the feeler pig technology and the feeler snake pig concept are consolidated, PETROBRAS is changing its submarine pipeline inspection system, prioritizing this technology for internal corrosion control. The use of other pigs, such as MFL and ultrasound, will still occur whenever external corrosion is suspected. With the new system, PETROBRAS intends to inspect the great majority of its submarine pipelines, practically eliminating the expression "non-piggable line" from its offshore production fields.

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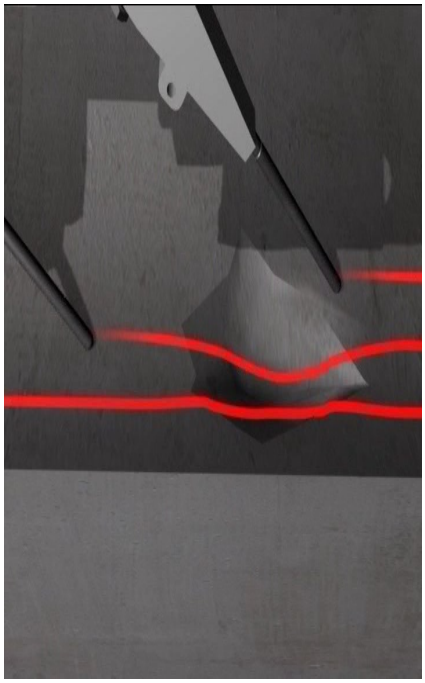


Figure 1 – Feeler pig measuring method. Corrosion effects (pits) are measured according to angle variation of sticks.

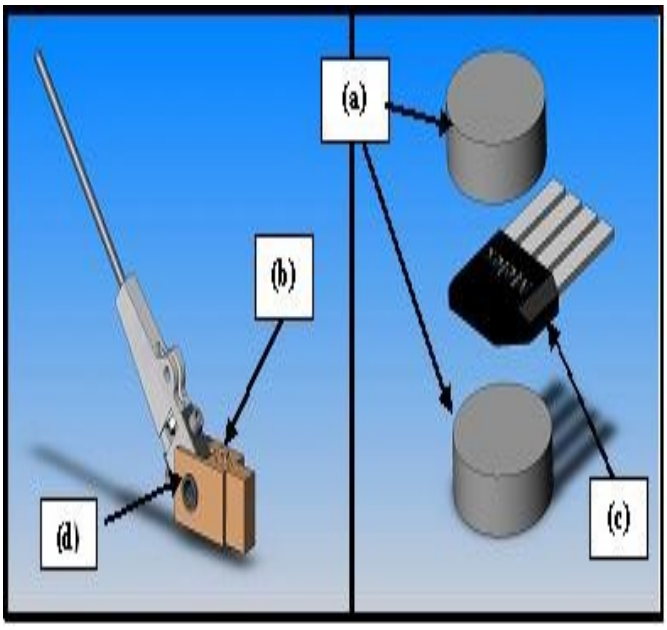
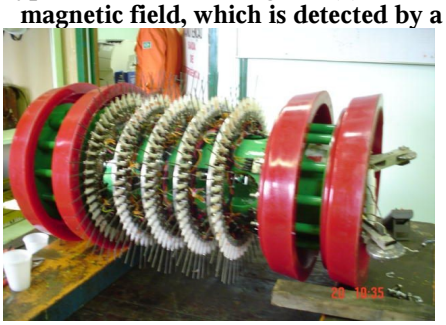
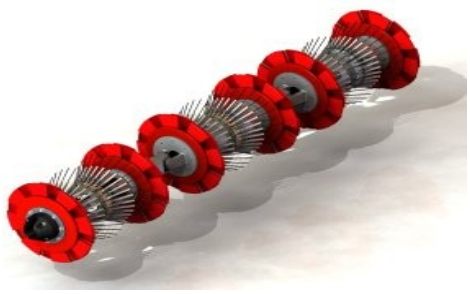


Figure 2 – Feeler pig typical sensor. Two magnets (a) are fixed on the stick base (b); any movement produces a change in the magnetic field, which is detected by a Hall sensor (c) located inside the axis (d).





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Figure 3 – (a) Feeler pig for 22", with 250 sensors (sticks); (b) Feeler pig for 12” to 16", with 180 feeler-type sensors

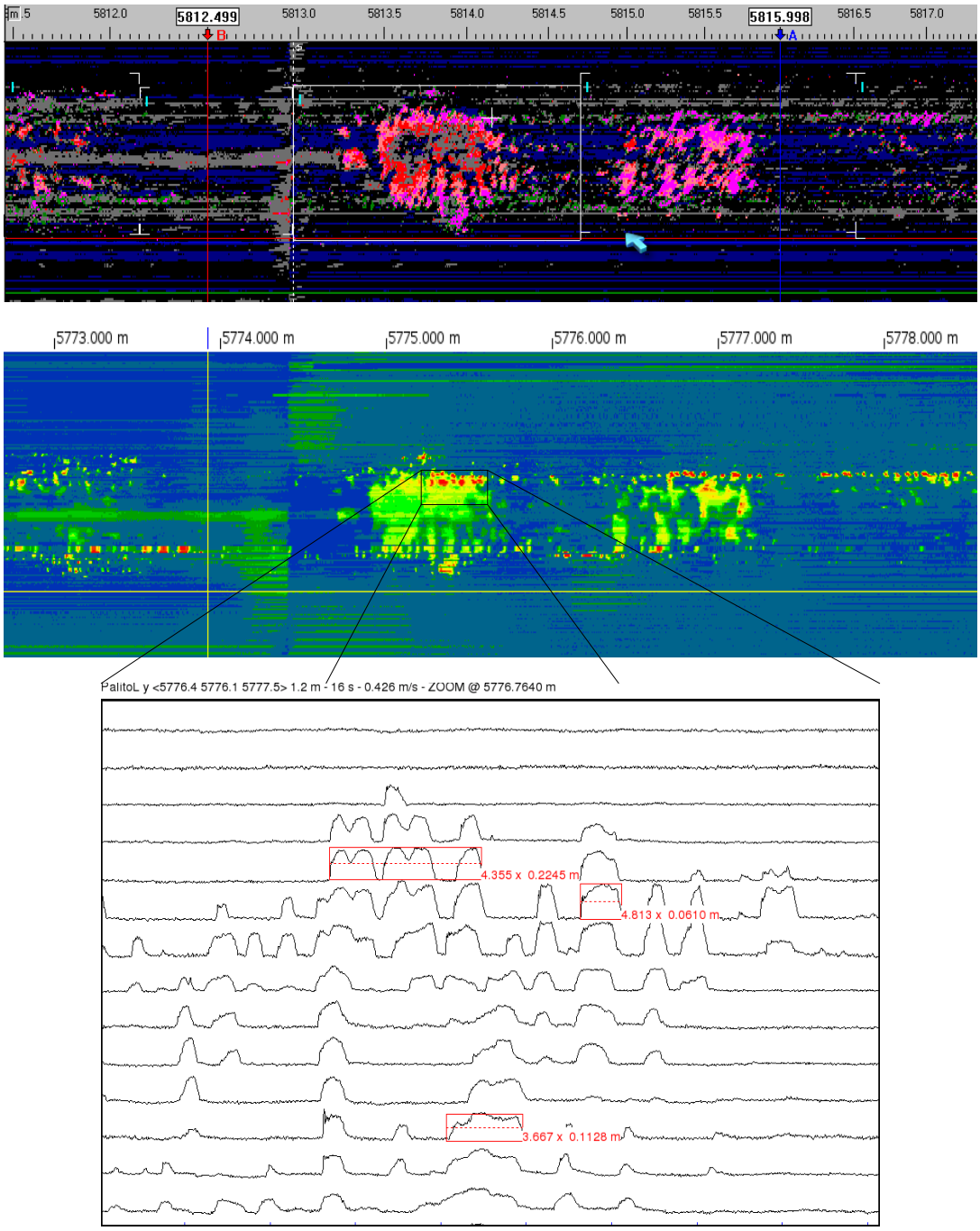


Figure 4 – Three pictures extracted from data analysis software. (a) a corroded area detected by a commercial ultrasonic system; (b) the same corroded area detected by 22” feeler pig; and also the quantified line graph piece of segment (c)

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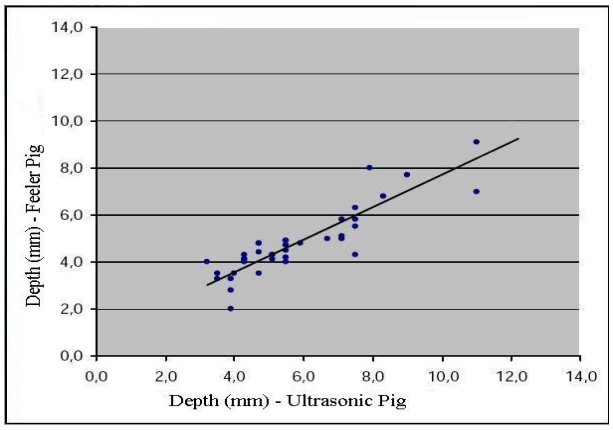


Figure 5 – General depth performance comparing between feeler pig and ultrasonic pig for internal corrosion detection.



Figure 6 – Feeler Snake Pig – (a) a new concept of instrumented pig; (b) equipment being received from offshore pipeline.



Figure 7 – (a) Calibration staircase. (b) Tube with the staircase in place (c) Pipe with feeler-type sensors "fingerprints".

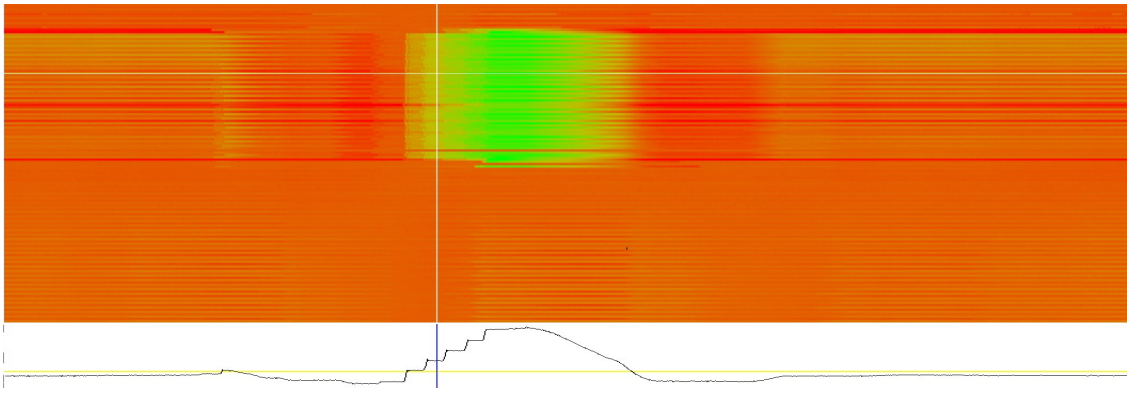


Figure 8 – Data analysis collected from the staircase to calibrate the feeler type sensors

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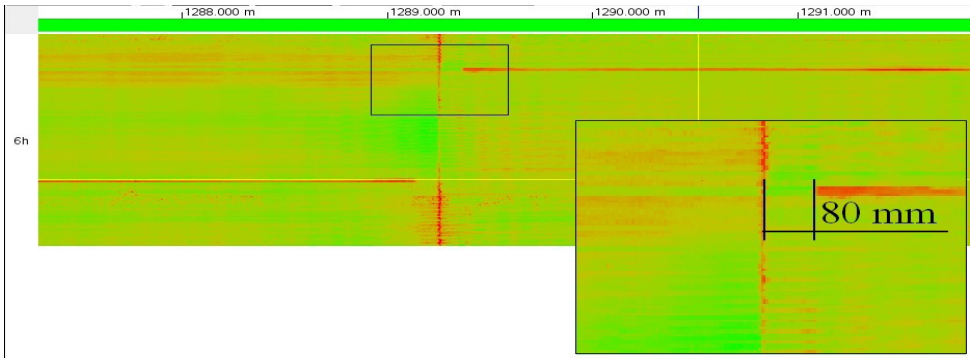


Figure 9 – A c-scan picture shows an internal surface free from corrosion. Longitudinal (a) and circumferential (b) welds were detected by 16" feeler pig. The grinding areas, as longitudinal welds reach the circumferential, were also detected(c).

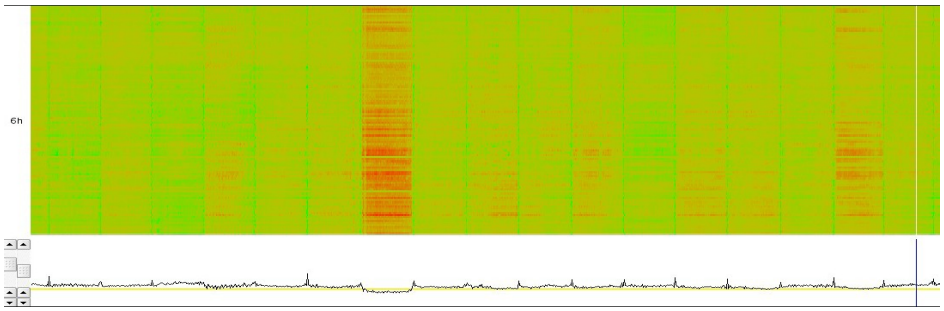


Figure 10 – Results from Snake Feeler Pig. (a) circumferential welds. (b) 4 mm larger tube diameter was detected.

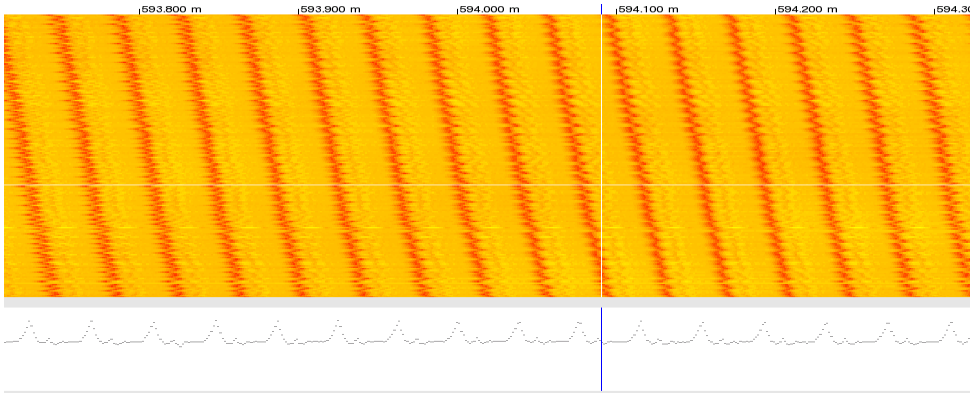
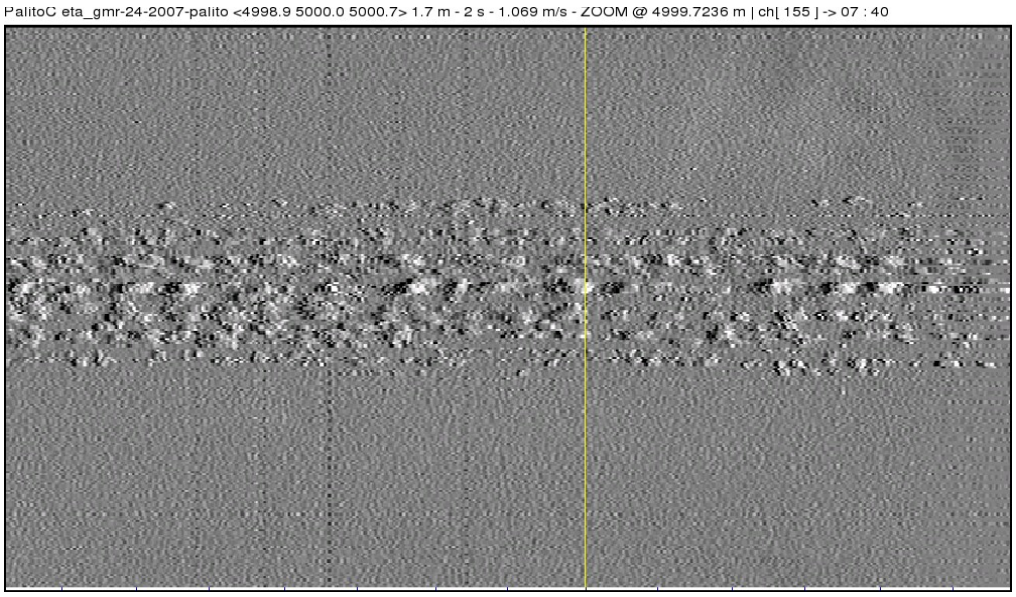
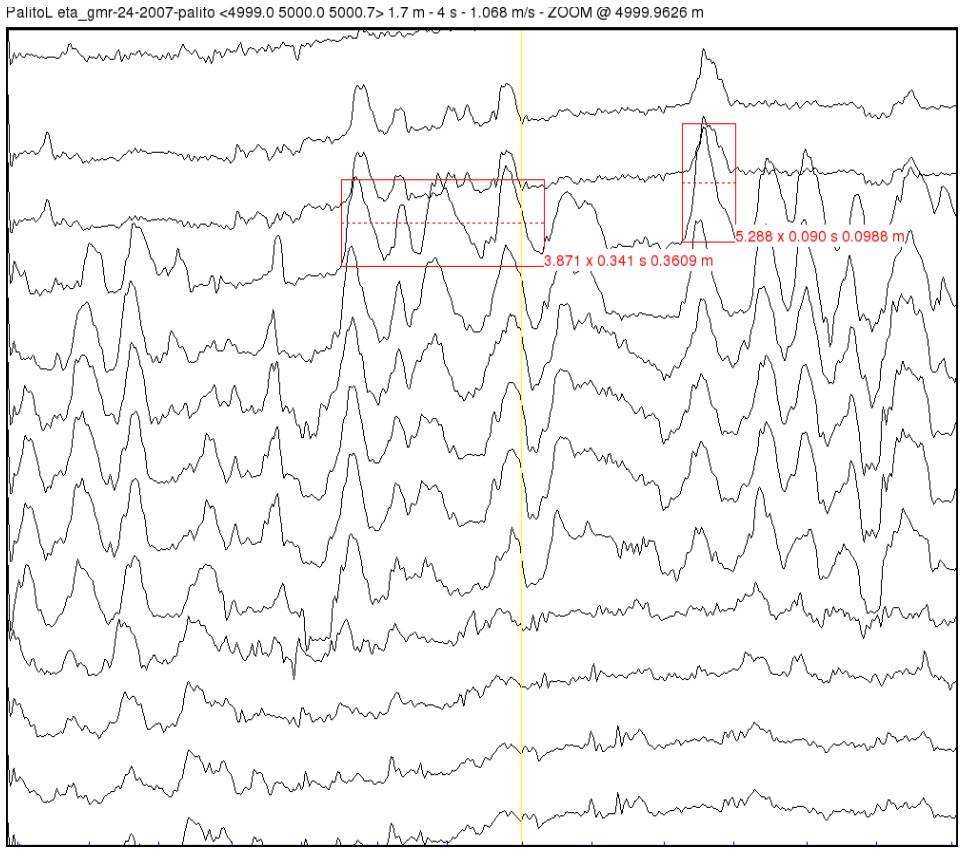


Figure 5 – View of two flanges (a), small valve with grade (b) and also the longitudinal segment profile of the pipeline internal wall.

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