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Comprehensive Well Integrity Solutions in Challenging Environments Using Latest Technology Innovations

Omar Alaref, Marvin Rourke, Murat Khabibullin, Alfir Yakupov, GOWell International LLC

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Abstract

The impact of corrosion on the oil, gas and geothermal industry is big and affects both capital and operational expenditures (CAPEX and OPEX). There is a growing public awareness and rising concerns with well integrity and health, safety and the environment (HSE).

One of the first steps for corrosion mitigation is to evaluate downhole tubular. The reduction of metal thickness leads to a loss of mechanical strength and structural failure. When metal pitting accelerates in localized zones, very considerable structural weakening may result from a relatively small amount of metal loss. Additionally, the alteration or loss of surface properties including erosion, increased fluid flow friction at the pipe surface, surface reflectivity or heat transfer across a surface, cause such weakness.

Corrosion evaluation using electric-line logging is of growing importance in the industry. Technologies that can evaluate multiple barriers are vital for cost-effective evaluations as rig time is saved by not having to retrieve the completion to evaluate production casings. This is the case especially in the offshore environment where the casing design is generally more complicated and consists of extra number of casing strings. Current technologies available include magnetic flux leakage or eddy current, or to some extent ultrasonic which has some limited capability of multi-barrier evaluation.

A multi-sensor electromagnetic corrosion tool (EM) has been developed especially for multi-barrier evaluations; the technology is based on pulsed eddy current physics. When combined with conventional multi-finger calipers and other tools such as radial cement bond logs or noise detection technologies, it offers a better understanding of well integrity.

Introduction

Well integrity monitoring is of growing importance in maturing fields as oil industry continues to be exploited in hostile and corrosive environments with strict regulatory requirements. It is only in the last decade that the industry has embraced the necessity for an efficient approach to well integrity management.

The industry's growing needs are giving motivation to technology developments to provide better equipment for evaluating well integrity both at the surface and downhole. At certain points in the lifetime of a well, it is important to evaluate the tubular and annuli integrity by running logs such as cement bond evaluation, production flow meters, and tubular corrosion inspection logs. At the well construction phase, the cement placement is evaluated by cement bond logs and sometimes early after well completion, a baseline set of tubing and casing inspection logs are run. These baseline logs form part of a corrosion monitoring strategy which allows field wide predictions to be made which is especially important in areas of corrosive fluid production. Alternatively, old wells that don't have those basline logs can still be run peroidicly to reduce the risk of un-anticipated damages or leaks.

The real challenge of an operator would be to find the best way to inspect the full integrity of the well by using the right technology, as well as identifying the well to be safe for production or injection by making sure no important information is missed out. Here comes the importance of working with service providers on ensuring the right combination is chosen while optimizing the operation time and cost. The main technology innovations in well integrity are mainly 1) multi-finger caliper 2) electro-magnetic corrosion detection 3) cement bond evaluation through the use of radial cement bond technology and 4) Noise and temperature used for leak detection purposes.

Technology Overview

Electromagnetic technology (EM)

The technique used is called Pulsed Eddy Current (PEC) where a short high-energy EM pulse from a transmitter coil "charges" the surrounding concentric pipes. Immediately after the excitation pulse, a co-located receiver coil measures the collapsing eddy currents. Embedded within this received "decay" curve is a complex signature, which is a function of the surrounding pipe's geometry and EM properties. Forward modeling and simulation reveals that early part of the decay is sensitive to only the inner pipe whereas in later time outer pipe signals appear. By employing an inversion processing technique, the composite decay signal can be unraveled allowing for determination of multiple tubular thicknesses. In particular, the identification of corrosion or defects in a second or third outside tubular is possible. The co-located transmitter and receiver coil configuration helps to improve the vertical resolution compared to RFEC tools. The advantage to this technique is that the source of the problems can be located without the need to "pull the completion" as the slim PEC tool can be run through tubing. Another application is the evaluation of surface casing behind the cemented production string.

Multi finger caliper (MFC)

Multi finger caliper is used to accurately measure variations in the inner wall diameter of the tubing. The spherical edges of the caliper exert on average 2 kg of contact force, thus avoiding any damage to the pipe coatings. Interchangeable caliper fingers allows corrosion monitoring over a wide range of tubing sizes, by having different number of fingers in different tools. Each set of feelers can be opened and closed downhole, particularly in repeat passes across zones of interest. Each of the sensors generates an independent signal recorded versus depth. Used in both drilling and production environments, applications include the evaluation of corrosion, erosion, wear, bending, buckling, pits, holes and other defects.
Measuring fingers move radially along the inner casing or tubing wall, detecting any diameter change. This produces a high resolution record of the tubular geometry which can be viewed and presented as a conventional log, a cross section, or a 3-D color enhanced image.

The Multi-Finger Caliper may also be used to measure the buildup of scale, paraffin or other mineral deposits in the wellbore. Auxiliary measurements include an integral wellbore temperature probe, along with deviation and relative bearing information.

Cement Evaluation Using Radial Bond Log (RBL)

The Radial Bond Log (RBL) simultaneously evaluates the quality of cement bonding as well as the condition and integrity of both the pipe and formation by calculating the measurements of the cement bond amplitude through near receivers, variable density log, and far receivers.
The primary use of this technology is to guarantee the integrity of the well by ensuring that the cement is effectively placed between the casing strings and the formation. Poor cement placement can typically result in unwanted situations such as water or gas production and fluid migration. With RBL, it is possible to get an accurate insight into the quality of the cement, which is extremely important, as a correct diagnosis and assessment of the problem is essential to understanding the remedial work required for oil, gas and even water wells.

Noise & Temperature logging for leak detection

Tubing or casing leaks generate noises at different frequencies and disturb the temperature profile. Combining these two sensors would indicate possible leaks and ensure any fluid movement behind pipes would be detected. The conventional noise technology consists of a sensitive hydrophone acquiring data at low and high frequencies in a passive measurement. That enables the sensor to listen to leaks (even with small rates) behind several pipes. Moreover, temperature is useful to confirm what noise would indicate as it plays a big role when entering fluid would have significantly dissimilar temperature than that in the wellbore.

Combining Technologies

In many cases when an operator would like to evaluate the integrity of the well to check if it is fit for production or injection, multiple sensors are required in order to give a complete assessment. However, the financial aspect is an important factor when doing so; whether it is the rig time considered or the number of tools tools that can be run in the well. Consequently, in order to offer a good and cost efficient service, it need to preferably be combinable in one run or at least with the same rig up. This will reduce time spent acquiring data which is at the same time could be very expensive in challenging offshore environments. The other important aspect is optimizing the sensors used in one run, which will depend on the objective of the well integrity assessment required. For example if the expected problems are in the casing, then it is recommended to combine the EM tool with cement evaluation log or noise log. This is done to ensure both pipe integrity and isolation. Another scenario, in which the tubing is the suspected source of problems, an EM tool can be run in combination with MFC so the inner (assessed by MFC) and outer (assessed through EM) can both be evaluated.

To sum up, optimizing the sensor combination is crucial for having an informed understanding of the well, which ensures that no crucial phenomenon is overlooked, saves costs and keeps data acquisition as effective as possible and in turn financially optimized.

Case Studies

Case Study 1: Running EM/MFC Combination

An old offshore well in the Middle East was in need of a special service in order to evaluate the inner and outer condition of a complex well consisting of 3 tubing strings together inside larger casing, figure (1) demonstrates the well schematic. The well was a water injector and has been injecting for a long time. The operator identified losses of water injected into different formations. The challenge here was finding the source of leak or leaks and evaluating the full condition of the pipes by identifying the metal loss in the tubing whether it was in inner pipe of the tubing or outside. In addition - to evaluate the casing condition surrounding the three tubing strings.

The combination chosen for this well was running the multi finger caliper in order to evaluate the inner condition of the tubing, along with EM corrosion tool in order to identify the total thickness of the tubing. Then, the inner wall loss would be subtracted from the total to give the outer. Moreover, the outer casing would be evaluated qualitatively.

The results of this survey enabled the operator of that well to identify the sources of the damages in the tubings. Examples of damages found in the well are illustracted in figure (2), (3) and (4). Consequently the log helped plan an adequate workover using the rig to retrieve the damaged pipes and put the well back on injection safely without having any losses.

Case Study 2: Running EM with Noise and Temperature for Leak Detection

Generally this combination is best suited for well abandonment. It is powerful in giving the operator a complete assessment of the pipes and can detect any movement of fluids behind the pipes. The noise temperature are usually run in two modes, shut-in and bleeding off the pressurized annulus. Additionally, corrosion log can be done with either passes as it won’t be affected by the type of fluid in the wellbore.

Accordingly, an operator in Southeast Asia noticed high pressure build up in the annulus. The main objective was to find the source of the leak and check if there are any other weaknesses in the well where a leak might arise in the future. Figure (5) illustrates the situation. Consequently, a survey consisting of corrosion assessment in addition to noise and temperature was acquired in order to find out the source of the leak and patch it or retrieve the whole completion. The well consisted of tubing and two casings inside the conductor pipe. The leak was observed between casing and tubing, which is considered to be annulus A. Therefore, the leak was suspected to be in the casing because a pressure test was performed and no pressure change was observed in the tubing due to leak, yet there was a slight pressure build up in annulus B (annulus between two casings). The pressure in annulus A was building up to 300 psi and quick measure was needed to fix the leak.

The main findings of the survey showed the location of the leak that was near water bearing formation and identified the casing near the leak was in a bad shape and there was a need to do remedial job for the casing. Multiple corrosion points were identified by EM corrosion logs but the noise indicated that there is no leak yet, but the possibility of it is big taking into account the significantly high corrosion. The survey enabled the operator to have a clear picture of the source of the leak and the corrosion level of the completion without having to retrieve the tubing at first or change the fluid inside. This played role in making the job convenient financially in addition to saving operation on rig. Part of the log results is clarified in figure (6).

Case Study 3: Running EM with RBL & MFC

A well in the US land was requiring an assessment of the integrity for its completion in addition to checking the quality of cement. Consequently, MFC & corrosion evaluation tools were run in tandem with a radial bond tool. This unique combination serves as a powerful tool to check for any defect or weakness in both casing and tubing, as well as evaluating the isolation between the pipes and ensure the annulus, that is between the pipes, is well cemented and isolating fluids in a proper manner to stop any cross flow behind the casing or through the formation.

The three technologies combo can be a very useful tool to run at any stage of the lifetime of the well. The main one is when operator would like to decide whether to continue with producing the well or sending it to workover. Another one is when having production or injection losses. That is to check whether there is clear isolation between casing and formation between two formations or two perforation intervals. The cement evaluation is very useful then and can also check the perforation through MFC.

The main findings of the log was identifying the corrosion points in tubing whether it was internal or external. Moreover, radial cement map indicated the weak zones where cement was not of good quality. All log findings plotted simultaneously is explained in figure (7).

Conclusion

It is of utmost importance for the oil industry to keep improving the well integrity evaluation and assess multi barriers without the need to remove the tubing, especially for offshore where it would be very costly to do so. This would help a well engineer to better plan for life cycle of the well and possibly increase it. Moreover, evaluation objectives should be clear and the right technology must be used in order to ensure a financially feasible and time efficient operation.

Acknowledgments

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Nomenclature

CAPEX	Capital Expenditure
OPEX	Operating Expenses
HSE	Heath Safety & Enviorment
EM	Electro-Magnetic
PEC	Pulsed Eddy Current
MFC	Multi Finger Caliper
RBL	Radial Bond Log
GR	Gamma Ray
TEMP	Temperature
LSPD	Line (Wireline) Speed
LTEN	Line (Wireline) tension
IDAV	Average ID
IDMIN	Minimum ID
IDMAX	Maximum ID
AMPMX	Maximum Amplitude

AMPMN Minimum Ampiltude

References

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2) Javier Garcia, Karam Yateem, Neeraj Sethi, Nacer Guergueb and Peter Zhang, March 2013, "Successful Application of a New Electromagnetic Corrosion Tool for Well Integrity Evaluation in Old Wells Completed with Reduced Diameter Tubular", IPTC conference held in Beijing, China.

Attachments

Case Study 1 Figures

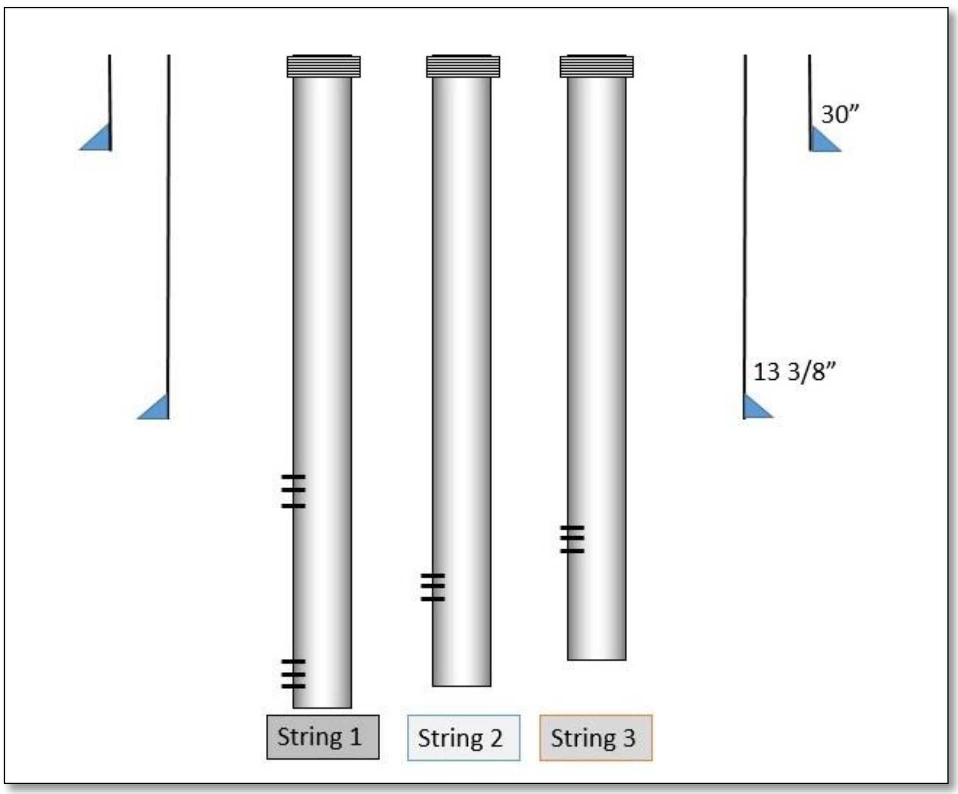

Figure (1): Well schematic illustrating the completion design for case study 1 in the Middle East. The well consists of three tubings isolated by cement and perforated at different depths.

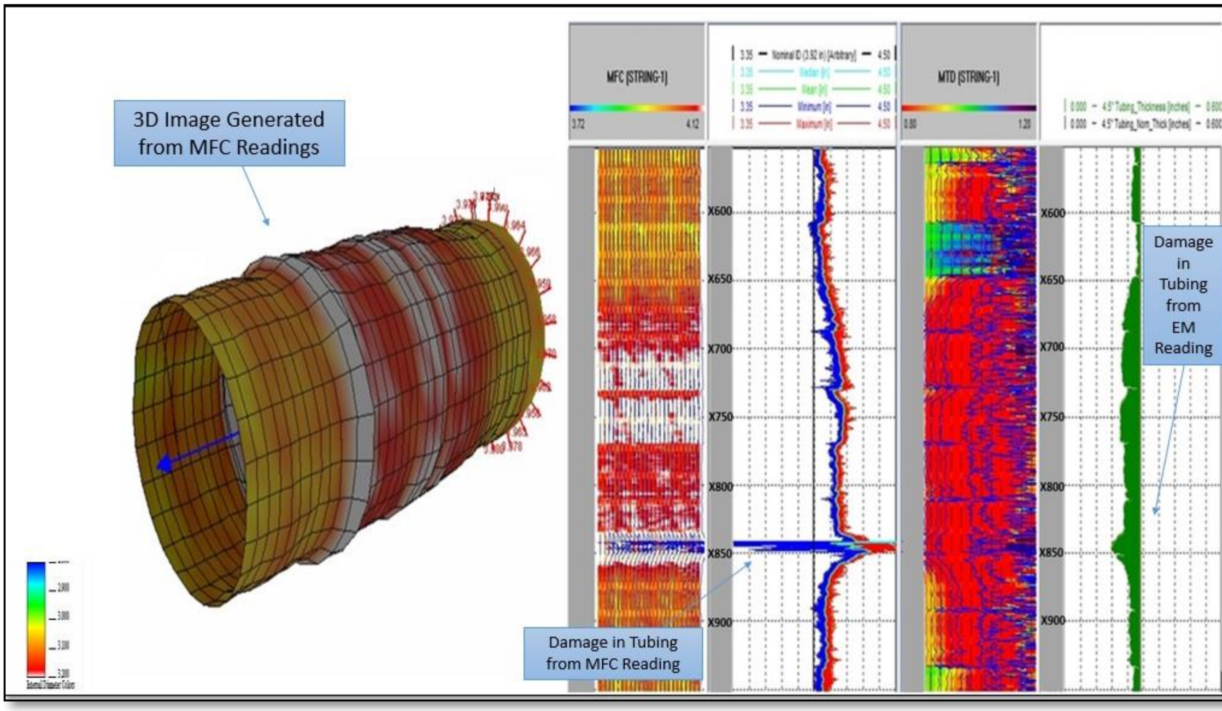

Figure (2): The log shows from left to right the 3D diagram of the tubing string condition, MFC log and EM log. The defect is identified through both MFC and EM logs. The corrosion is uniform around the circumference. Moreover, the evaluation shows a very bad condition for this section of the first string.

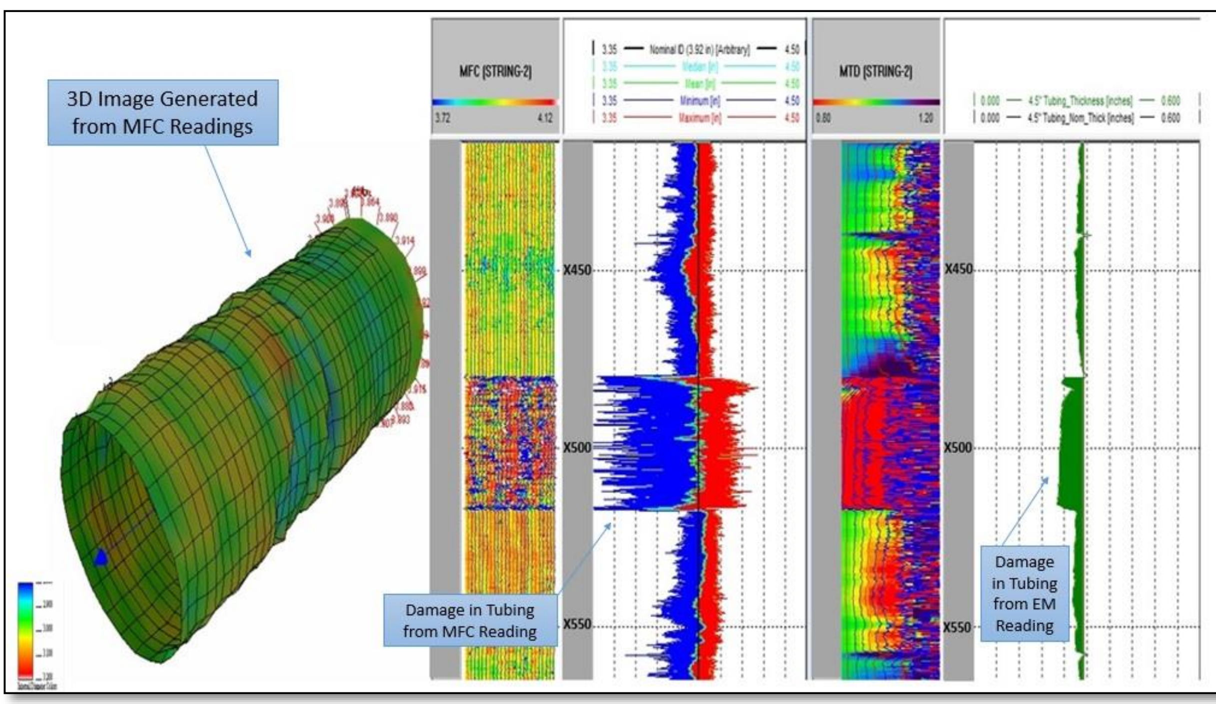

Figure (3): The log shows from left to right the 3D diagram of the tubing condition, MFC log and EM log. The condition of the tubing is clearly very bad. The corrosion is highly localized pitting with multiple holes. It’s worth noting that this section is in a relatively high temperature at the end of the well for the second string.

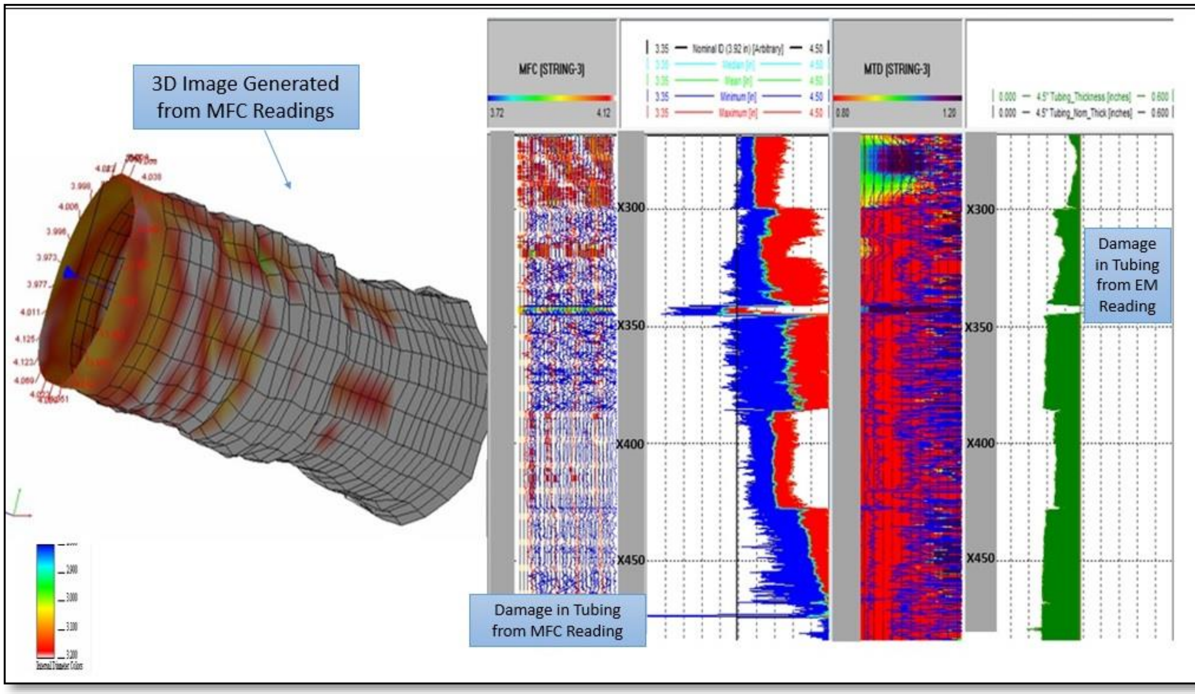

Figure (4): The log shows from left to right the 3D diagram of the tubing condition, MFC log and EM log. A Complete joint is affected shown by both MFC and EM logs. The results are shown for a section of the third string.

Case Study 2 Figures

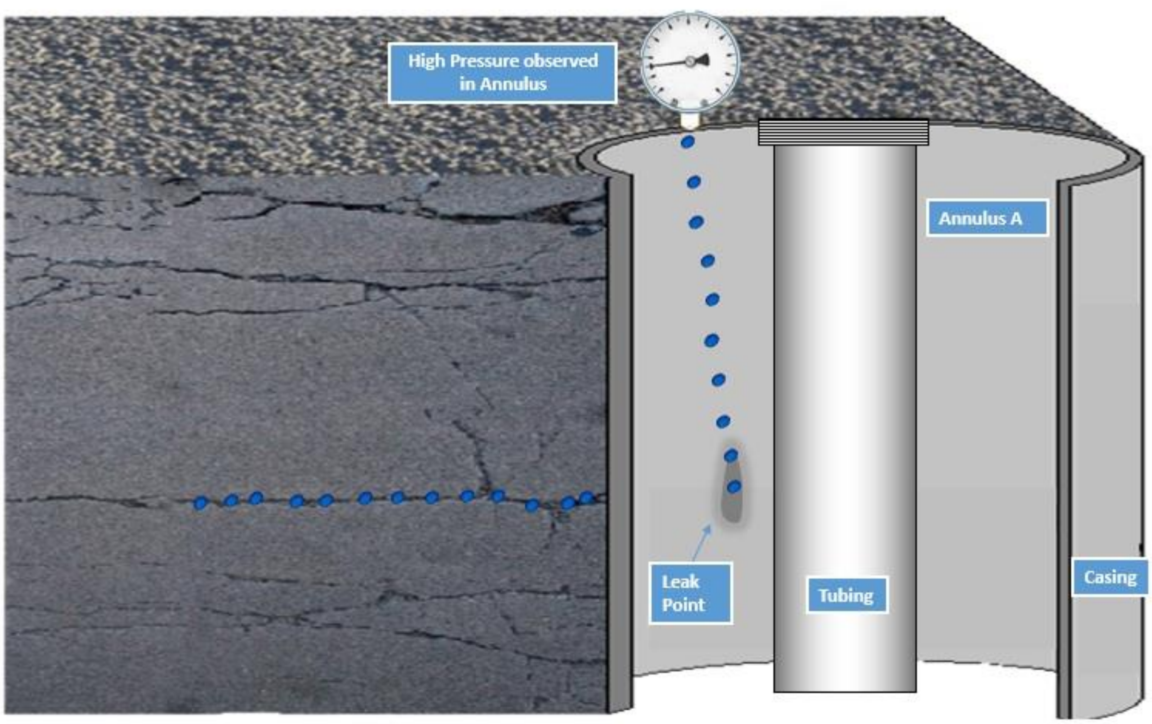

Figure (5): Well schematic illustracting the leak point in the casing. Annulus A pressure was observed to be around 300 psi.

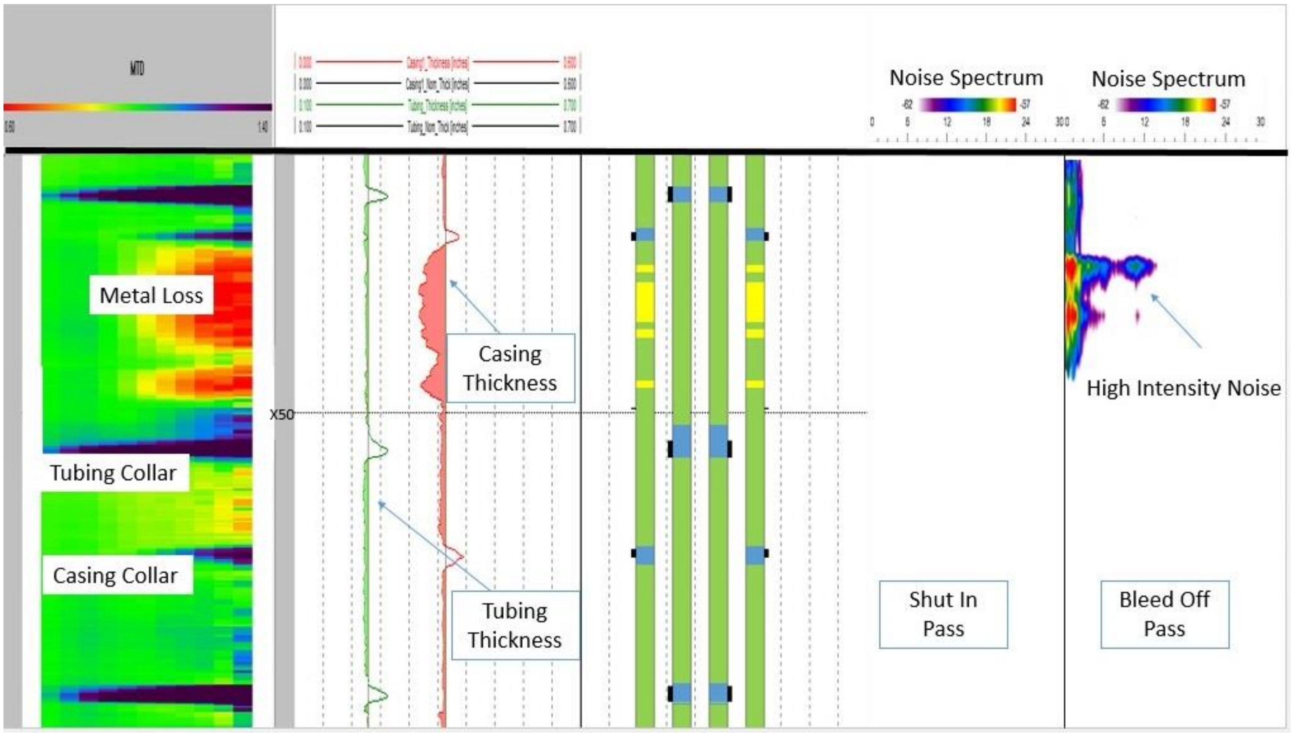

Figure (6): Picture showing the results of the survey using noise and EM logs. The EM logs show a clear defect in the casing and corresponding noise at same depth. This led to conclusion of the joint that is leaking.

Case Study 3 Figures

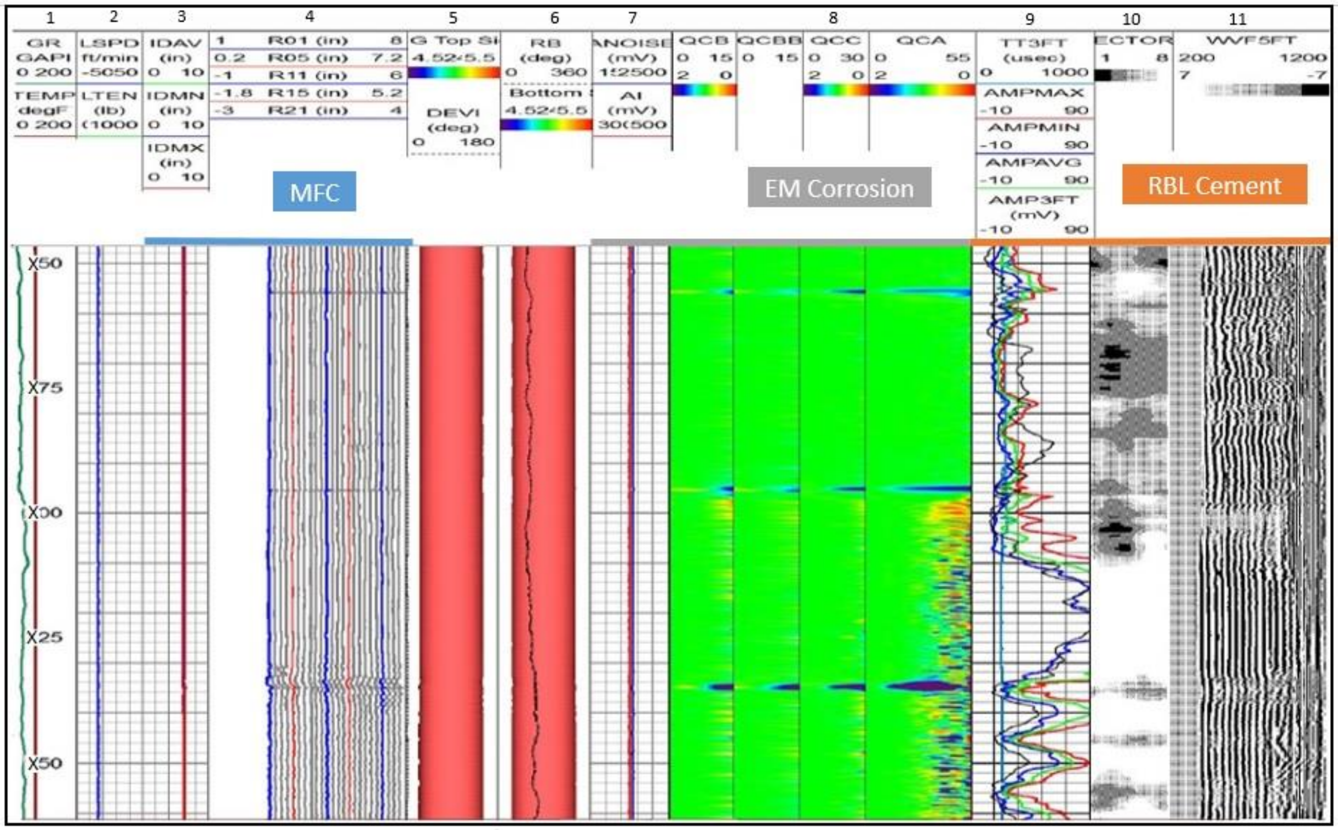

Figure (7): The figure shows the plot acquired from running the combination of MFC/EM/RBL. The curves from left to right are 1) Gamma Ray (GR) and Temperature (TEMP) which are essential sensors run with all tools. 2) Line speed (LSPD) and e-line tension (LTEN) and they are important for smooth logging operation. 3) Average min & max ID (IDAV), (IDMIN) & (IDMAX) and these curves are MFC tool readings used to indicate defects. 4) Radius (R) which is radius reading from 24 sensors for the arms of the multi finger caliper. 5) Deviation (DEV). 6) Realtive Bearing (RB). 7) QC curves for EM (ANOISE) and (AI). 8) Raw Curves for EM. 9) Max, min and avergae Amplitude (AMPMAX), (AMPMIN) & (AMPAVG) and these are radial cement reading. 10) Cement Map (SECTOR). 11) VDL cuvre (WWF5FT).