ADVANCED ELECTROMAGNETIC TUBULAR INSPECTION DURING WELL SERVICING

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ABSTRACT

"The Wellhead Scanalog is a new and effective approach to the evaluation of used oil field tubing. Designed to perform tubular inspection while the tubing is being pulled, it does not interfere with normal workover operations. The tool provides four non-destructive methods to detect and evaluate used tubing defects such as rodwear, corrosion pitting, erosion, holes, and splits. A new rotating magnetic field technique is used for rod wear, a modified flux leakage technique is used for pitting, and average wall measurements derive from a total flux concept. Eddy currents are used for holes and splits. Radiation techniques are not used for safety reasons. Sensing systems are non-contract, and not affected by scale, mud, paraffin and water, and there are no active or moving parts in the sensor package.

The tool bolts directly onto the well head, and in many fields several wells can be inspected each day. Sequential inspection of tubes in over 5000 wells inspected has revealed well tubing profiles which provide useful diagnostic information for well servicing programmes."

INTRODUCTION

There has always been a need for the integration of tubing inspection into a workover operation. The advantages of performing such real time inspection are as follows:

1. The operator can have tubing inspected while pulling a well for other reasons, often unconnected to the pipe.

2. Corrosion growth rates in wells can be assessed over long periods.

3. The effectiveness of corrosion mitigation programmes can be monitored over long periods.

4. There is often little need to transport large quantities of pipe to a wellsite when the inspected pipe can be dropped back into the well (often the same day).

An added advantage of performing 100% inspection of the tubing with regard to its position in the well, as opposed to the traditional method of removing the tubing from the wellsite, inspecting with flux leakage and gamma ray wall thickness techniques, and returning the pipe to this (or another) well, often in a different order, is that corrosion profiles of the well can be built up.

Until the introduction of the Wellhead Scanalog (WHS) only two choices existed for the quantitative nondestructive evaluation of used tubing, neither of which provides full coverage of the material. First, traditional EMI could be performed with the string laid down, or offsite, or an internal mechanical downhole caliper could be used. This paper outlines the development of the WHS and presents some practical results of its use.

DESIGN CRITERIA

Preliminary studies indicated that a successful NDE tool for the wellhead environment had to have the following qualities:

1. Be virtually invisible to the well servicing operation.

2. Be very rugged, mechanically simple, and extremely reliable.

3. All inspections should cover 100% of the pipe, ID and OD, at any pulling speed. In effect, the sensing system should exhibit no velocity dependence.

4. The inspections should be independent of the presence of scale, mud, and paraffin on the pipe.

5. The inspections should detect pitting of differing types on both pipe walls, rod wear, holes, splits, and be inherently more quantitative than the systems used in traditional EMI.

6. There should be no moving parts, no metal-to-metal contact with the pipe, and no sources of radiation. The sensors must be stationary and allow passage of the coupling.

DETECTION METHODS

Four non-interfering electromagnetic (and therefore noncontract) methods are designed into the inspection head, which bolts directly onto the well-head. Acoustic coupling difficulties precluded the use of ultrasonic methods, and radiation methods were excluded because of coverage limitations, safety, and the complexity of managing a radiation safety programme in the inspection environment.

The pipe is magnetized to saturation (Bs) longitudinally in passing through a coil in the inspection head. This DC field provides the flux for a magnetic cross-sectional area measurement (1), provides the magnetic flux leakage from pits (2), and controls the magnetic state of the pipe for the two eddy current inspections.

1. <u>Total Flux/Cross Sectional Area Measurement</u>. Since the cross-sectional area of the tube is proportional to the total saturation flux ($\Phi = \vec{B} \cdot \vec{A}$), an encircling pick-up coil has induced in it a voltage (fig.1) which when integrated is related to this flux through Faraday's law of induction:
$e = - N \Delta \Phi / \Delta t$

   The resulting integral, since Bs is constant, measures the cross-sectional area of the tube (A), and variations in it are related to erosion and corrosion wall loss mechanisms. Figure 2 which shows results of a tube inspected by this, and by hand scan ultrasonic methods, illustrates the effectiveness of the technique in assessing elongated areas of wall loss. From the CSA, and the known pipe diameter, a computer calculates and stores the average wall thickness (t_{AV}) from $A = \pi t_{AV}(D-t_{AV})$.

2. <u>Flux Leakage Pitting Measurement</u>. Magnetic Flux Leakage methods (3) are widely used in oilfield tubular and wire rope inspections. By using Hall element arrays as shown in fig. 3, speed dependence is eliminated and magnetic noise is greatly reduced while enhancing pit MFL signals at high lift off. Elimination of velocity dependence is essential because in a typical operation, the pipe starts at rest, accelerates to a speed determined by the workover crew and string weight, and decelerates to rest after 2 or 3 tubes have passed through the unit. Sensor design maximizes the correlation between flaw depth and signal amplitude.

   The MFL signals from the hall element array are compared with those in preprogrammed memory banks of "pit curves" developed by mechanical measurement, for the ambient wall thickness computed from the CSA measurement above.

3. <u>Eddy Current Hole/Split Detection</u>. Since it is often impossible to distinguish the MFL signals from holes and splits from those created by pitting, an eddy current method is used. The longitudinal DC field lowers the permeability of the tubing, permitting circumferential eddy current penetration. The frequency used is dependent upon the wall thickness and the ability to show high sensitivity to holes, but low sensitivity to OD flaws. Pick up coil arrays in a differential configuration are used as sensors to maximize S:N. and minimize off centering responses. Phase discrimination (fig. 4) determines holes from pits.

4. Rodwear Detection (4). In order to eliminate moving parts and provide 100% coverage, a rotating magnetic field technique is used. Here a two phase drive current passed through coil arrays and creates the illusion of motion. Circumferential eddy currents penetrate from the OD to rodwear because the tube is saturated. The phasor diagrams from two orthogonal detectors are then processed to determine the depth and circumferential location of the rodwear (fig. 5).

Typical results of the rodwear detection system are shown in comparison to UT readings in fig. 6. To generate these data, hand held UT took two hours, while the electromagnetic technique took less than five seconds (5).

THE SYSTEM

The four inspections occur in a small cylindrical annular space (fig. 7) around the tube which permits the passage of couplings but not downhole assemblies. Electronic information is fed to a computer van, processed, and displayed on a four channel recorder. The computer drives the recorder at a speed proportional to that of the pipe, irrespective of the pulling rate. Defects can then generally be found on the pipe within five cm of their indicated location. The four channel record traces are: (fig. 8).

a. Hole/split channel, with special blanking for couplings.

b. Corrosion pitting channel. Here a ROM look up table is used for various types of pitting e.g. CO_2. The baseline of this channel is tied to the CSA.

c. Average wall thickness from CSA measurement channel.

d. Rodwear channel.

All losses are in percent of the nominal for the tube under inspection. Note that the CSA wall loss in each tube is actually from rodwear.

PERFORMANCE

The WHS was first introduced in mid 1985. The 15 units in operation in mid 1990 have now inspected over 5000 wells in USA (Permian Basin, Gulf Coast, Rocky Mountains). In competitive tests and evaluations by spot UT readings, the tool generally called defects to within 5% of true depth.

Repeatability is excellent and has permitted studies to be made on corrosion rates in a group of wells to evaluate the effectiveness of a corrosion inhibitor programme. Here the strings were inspected at four month intervals and the wall losses measured and plotted. Fig. 9 shows the differential wall loss in an untreated and a treated string. The horizontal axes shows the differential wall loss in 3% increments.

Recently, corrosion pitting profiles and rodwear profiles for rod pumping wells are being required. Figures 10 and 11 show such profiles. This particular well had been treated with inhibitor from the top of the well. As shown the corrosion problem becomes progressively worse as the well gets deeper. The well also has a rodwear problem which starts at about joint 130 and continues to the bottom of the well. Thus the well operator can determine at the end of pulling a string the effectiveness of the corrosion prevention problem and to determine the need for, location of, and spacing of rod guides.

Obviously in cases of milder corrosion, where all the tubing is dropped back into the well in the same order, overlays of charts such as figures 9 and 10 will add new information on corrosion rates.

CONCLUSION

The WHS is not only a major innovative inspection technique which uses state-of-the-art NDE techniques for the assessment of tubing in wells during well servicing operations, but also can provide information on corrosion growth rates in various parts of wells. The technique is rapid, does not interfere with wellhead operations to any significant extent, and captures data that are often lost when the tubes are laid down and hauled away for traditional EMI. The lack of moving parts and radiation sources are two important safety features which complement the high coverage of the device.

REFERENCES

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5. J. Kahil, "New Technology for the Inspection of Used Tubing and Drill Pipe", Proc. Eighth International Conference on Offshore Mechanics and Arctic Engineering Vol. 1, Editors: J. C. Chung, C. P. Ellinas, J. Natvig, J. Wardenier, and R. Penny.

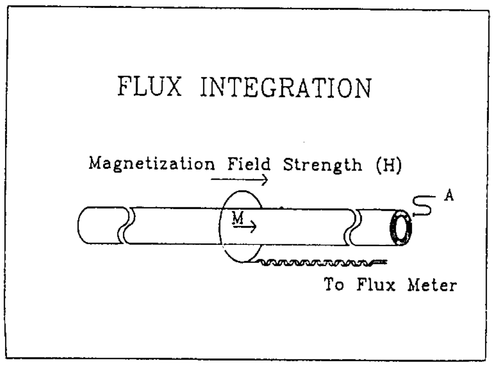


Figure 1

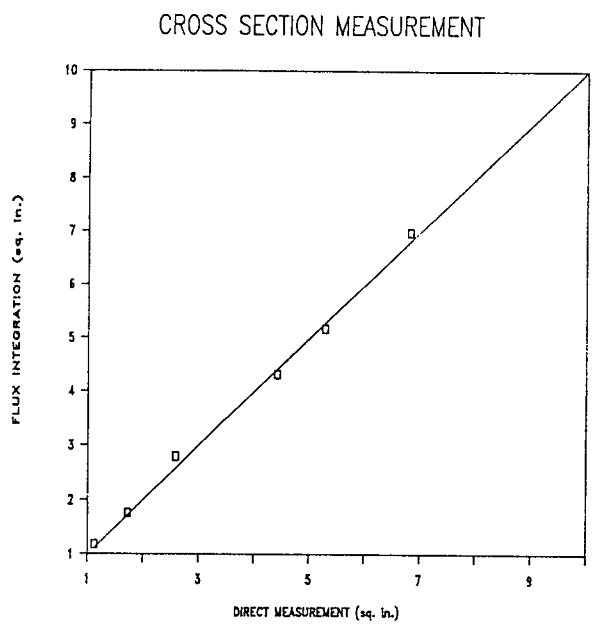


Figure 2

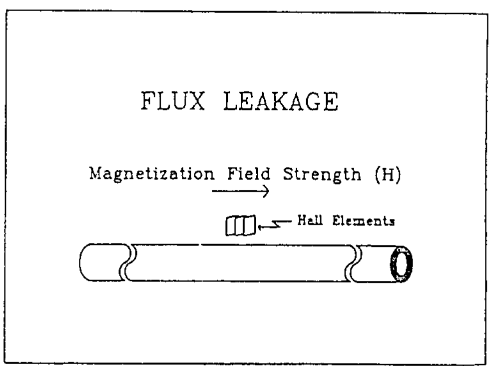
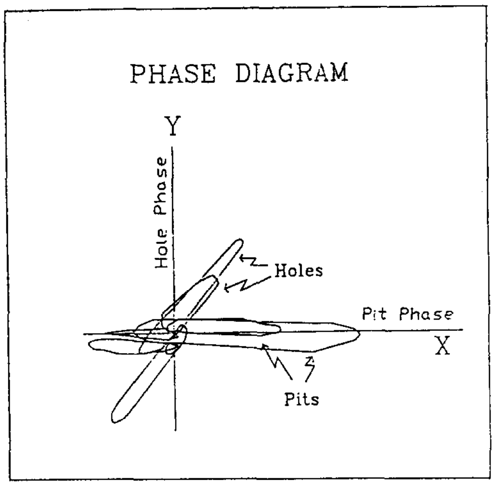


Figure 3



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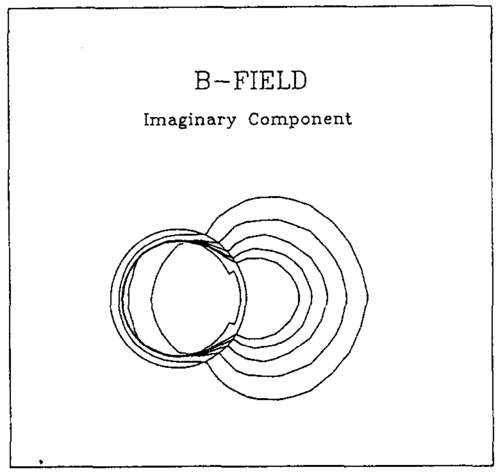

Figure 5

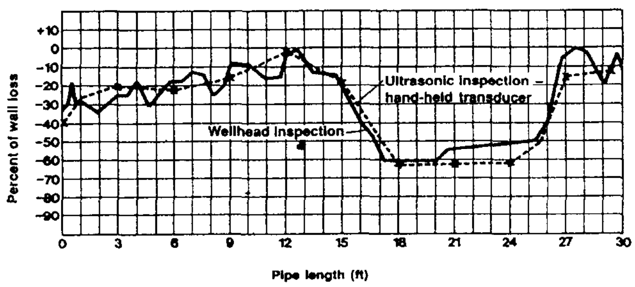

Figure 6 - Wellhead Scanalog rodwear inspection vs. ultrasonic mapping

Figure 7 - Inspection package

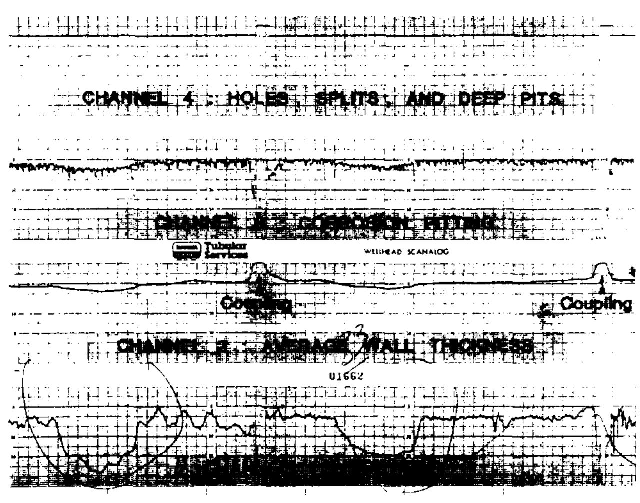

Figure 8 - Four-channel recorder output

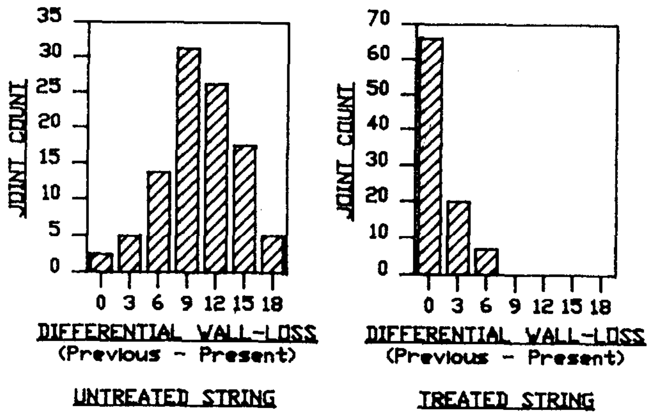

Figure 9 - Differential wall-loss histograms for two adjacent strings with different corrosion inhibitor treatments

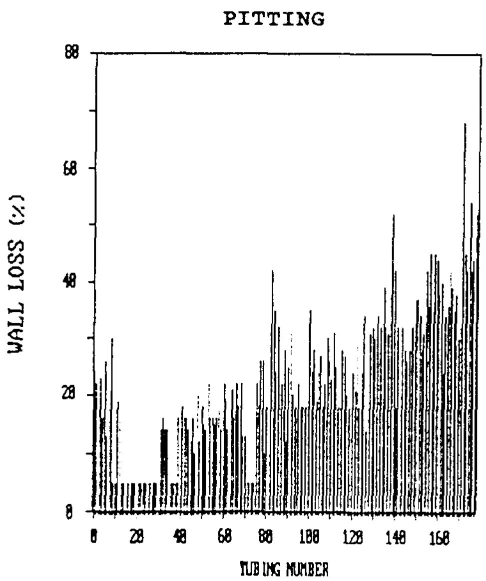

Figure 10

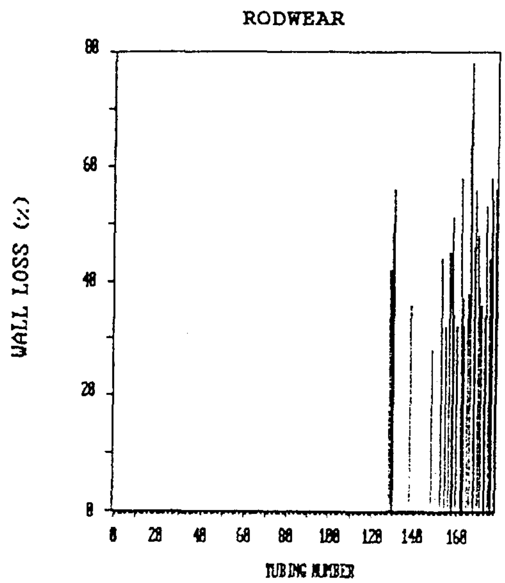

Figure 11