NEAR DRUM CRACKING IN RECOVERY BOILER GENERATING BANK TUBES

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ABSTRACT

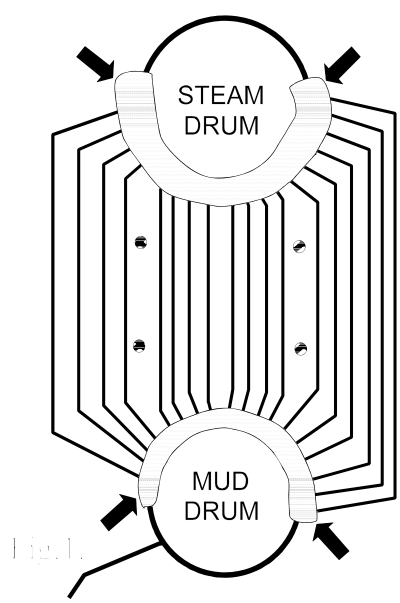
This paper describes a new automated ultrasonic inspection system that has been engineered to search for cracks in the short swaged tube sections immediately adjacent to the upper or lower drum in the generating bank tube section of black liquor chemical recovery boilers.

Near drum cracking can be detected using this automated immersion method utilizing controlled scanning and logical analysis of both straight beam and angle beam (shear wave) data.

Real time computer display of B and C scans using color graphics simplify the large volume of data into an easily understandable output for non-technical personnel.

Crack indications with depths as low as 10% of the wall thickness can be detected for external cracks and 20% of the wall thickness for internal cracks.

Fig.1.   Boiler Generating Bank Arrangement



INTRODUCTION

Recovery boiler generating bank tubes can be prone to cracking at either drum interface.

External cracking is generally attributed to unusually high cyclic vibration stresses induced by gas flow patterns in boilers where the generating tubes are relatively long and have not been fitted with vibration restraints. In some cases, cracking may have initiated when vibration dampers have been removed to reduce plugging problems.

Internal cracking has also been reported in this area due to corrosion fatigue and thermal causes.

The presence of cracks is usually discovered as a result of a tube failure. Subsequent failure analysis of a cracked tube is difficult since the cracks are usually very close to the drum and the sample is difficult to remove without damaging the area of interest. See Fig.2 for details of tube geometry.

Fig.2.   Generating Bank Tube Detail

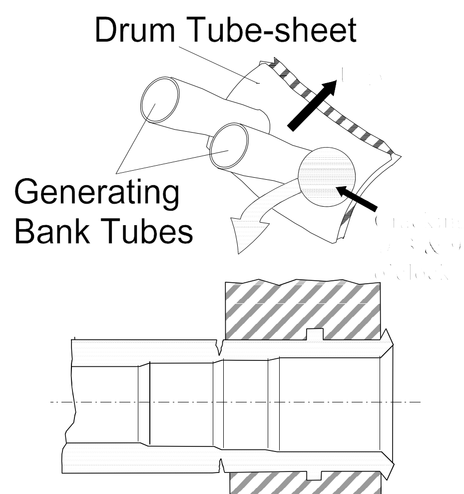


Fig.2.

DISCUSSION
Circumferential fatigue cracks initiate from the outer surface due to bending stresses. Corrosion fatigue cracking usually initiates from the inner surface.

Cracking is typically in the circumferential direction, but axial (longitudinal) cracking has also been reported. This may be related to isolated fusion problems in older ERW tubing seams but to-date there has been insufficient data to confirm this .Near drum cracking usually occurs within 50mm (2") of the drum O.D. . External fatigue- related cracking typically occurs at the 3 o'clock and 9 o'clock positions of the tube. Internal cracking can occur in any orientation and can be near the drum or some distance from the drum. The inspection is further complicated by the presence of internal rolling ridges (formed by the tube expanding process during construction) which can result in non-relevant crack-like indications. Scale deposits which are typically present also impede both ultrasonic and surface inspection methods.

Inspection Methods
Inspection for detection of cracking is best carried out from the inner bore during outage periods since there is no other access to the area of interest, except for a few tubes that may be accessible from sootblower lane cavities. In addition, the exterior surface of the tubes in this area is usually very poor with significant scale, salt cake deposits and other debris covering the area of interest. The close tube spacing makes cleaning to the degree required for most NDT methods generally impracticable.

External crack inspections. Inspecting for external cracking requires a volumetric inspection method such as ultrasonics. Surface inspection methods from the tube interior are of limited value. Magnetic particle inspection could be carried out using miniature coils to induce magnetic fields. It is likely that the overall sensitivity of this inspection would be limited to detection of external cracks that are at least 50% through the tube wall.

Internal crack inspections. Internal cracks can be inspected from the tube interior using a surface method but requires extensive surface preparation to remove all traces of deposits and scale etc.. The liquid penetrant method will reveal all internal cracks open to the inner surface. Sensitivity will depend on how clean the surface is and whether the cracks are filled with foreign material. The magnetic particle method will also reveal all internal cracks open to the surface or near the surface. The sensitivity of this method is less dependant on surface cleanliness and whether the cracks are filled with foreign material or not. Both of these methods are also fairly time consuming given the physical constraints typical of this area of the boiler.

The near drum internal rolling ridges make all ultrasonic Contact techniques generally undesirable due to probe lift-off. Probe lift-off results in uncontrolled sound path variations or couplant loss, and/or uncontrolled changes in the desired refraction angle. Immersion systems are better suited for this type of entry surface.

Other electromagnetic methods of inspection such as Remote Field Eddy Current or Magnetic Flux Leakage techniques are also less effective due to internal rolling ridges and also to the close proximity of these cracks to the large drum mass.

The Acoustic Emission method may be useful in detecting and subsequent monitoring of crack-like acoustic events, but it cannot readily pin-point which tube may have a crack nor can the severity of a crack be evaluated to a known standard.

Automated Immersion Ultrasonic System
The ultrasonic system devised uses some existing technology which was originally developed and patented by Stasuk Testing in 1989 for near drum thinning inspections, and was re-engineered to allow for high speed shear wave scanning in 1995 & 1996. The system uses an automated, immersion technique, with both straight-beam and angle beam (shear wave) scans, with precision motor control in both the axial and circumferential direction to accurately scan 100% of the tube volume in the swaged-down area. All probe movements are fully computer controlled and can be programmed to provide various scan resolutions. Both straight beam data and shear wave data are analysed to produce real time, full colour B-scans and C-scans for corrosion (thinning) and crack detection simultaneously.

The system is typically operated using an assistant to place the probe into a tube, while a technician controls the probe operation via a laptop computer and data acquisition equipment nearby. The probe is equipped with water seals which allows the tube to be filled with about 150mm (6") of water. The computer instructs the probe to scan in and out of the tube according to the preset depth (based on drum thickness) and resolution desired.

The thickness scan is carried out initially, followed by a shear wave scan. The reason for the initial thickness scan is twofold:

(1) The thickness scan reveals any abrupt thinning, ridges, pits, grooves etc. and therefore aids with the evaluation of subsequent shear wave indications.

(2) A successful thickness scan proves that the ultrasonic signal can fully penetrate into the tube wall. Areas of thick scale or unbonded scale are immediately detected. This is very important as an angle beam scan alone does not reveal any areas of scale unbond or signal loss which would result in no coverage in those areas.

Real time B- scans and colored coded C-scans are displayed, as applicable, for each scan. All probe movements and color-coding of data are fully programable. All data to reproduce the actual real-time computer images are saved on magnetic media and can be reviewed at any time. Calibration of the system is carried out using an A178 boiler tube sample with known wall thickness and internal and external notches of varying depths and lengths, used to simulate cracks. A typical 50mm (2") scan takes about a minute to complete.

Scanning Considerations

Scanning direction is an important consideration. Scanning in the forward direction (ie. away from the drum) is usually better suited to avoid non-relevant indications from internal rolling ridges. Scanning in the reverse direction (towards the drum) usually results in non-relevant indications from internal ridges which would be very difficult to differentiate from cracks if they were to occur in the same location. See Fig.3 for illustration.

Fig.3. Forward vs. Reverse Scanning Methods

Scanning for internal cracks is generally the same as for

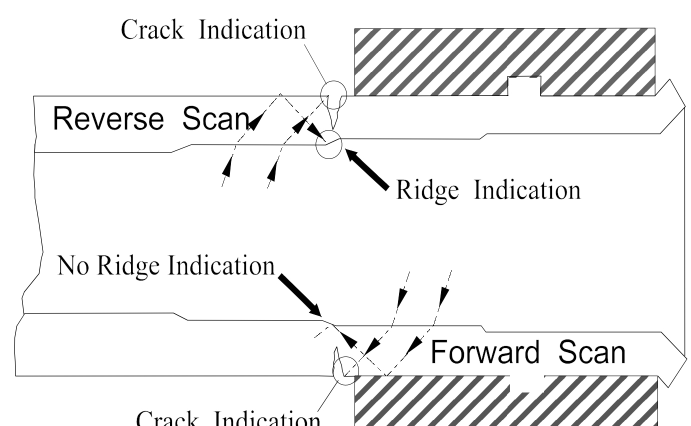


Fig.3.

external cracks except that for internal crack inspection the UT signal path must first reflect off the OD surface resulting in a longer sound path. This also results in a poorer quality signal due to higher attenuation from distance and reflection losses. In addition, the total signal amplitude due to reflection from ID crack indications is always less than the signal amplitude from an equivalent OD crack indication because the ID surface is convex, thereby allowing much of the signal to reflect away from the desired return sound path. See Fig.4 for details.

Fig.4. Signal Amplitude- External vs. Internal Crack

Tube Preparation

An important consideration prior to the actual inspection is to

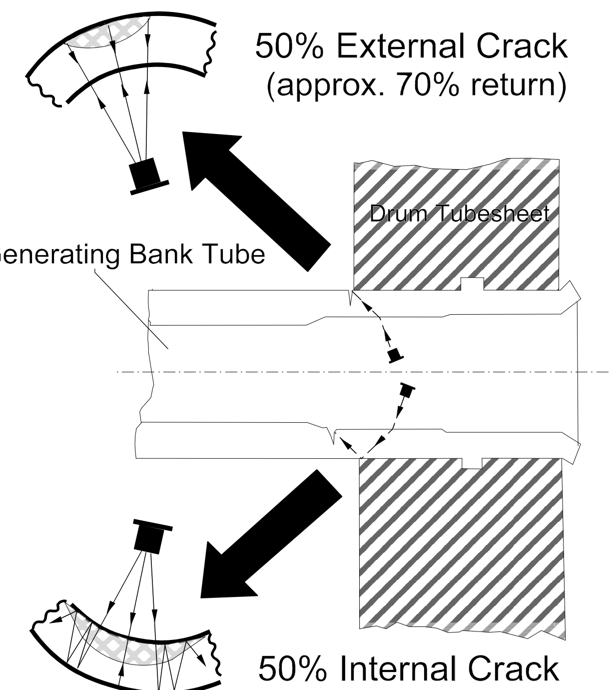


Fig.4.

ensure that the tube inner surface is clean and free from scale deposits that would interfere with the UT signal. Tightly bonded thin scale, approx. 0.25mm (0.010"), can usually be tolerated but heavy or unbonded scale cannot be penetrated by typical UT signals. The cleanliness of the tube interior is directly related to the quality of the inspection results.

Crack Indication Evaluation

In normal shear wave crack inspections the evaluation of crack indications for length and depth is based on signal amplitude from the indication. The length is determined by plotting the end points where the maximum signal amplitude has been reduced by 50%. This method also works well for tube crack length evaluation.

The depth of a crack is normally determined by comparison of the maximum signal amplitude to a known standard notch or, calculation of the sound path and using geometry to estimate its depth.

These methods may require corrections for differences in material attenuation and generally are only valid for indications that are large compared to the transducer crystal size, and really are a measurement of the actual reflective area of an indication (ie. a long shallow indication may look the same as a shorter deeper indication with the same reflective area.).

External cracking formed by cyclic bending stresses may tend to propagate into the tube in proportion to their circumferential growth. It may therefore be possible to estimate the crack depth of external circumferential crack indications based on their circumferential length only. Some tests conducted with simulated cracks shaped like real fatigue cracks (clam shell-like with rounded corners) tend to support this.

SUMMARY

1. Recovery Boiler Generating Bank Tubes (near drum) can be inspected for external and internal cracking using this system.

2. Crack lengths can be accurately evaluated.

3. External fatigue crack depths can be estimated based on crack length or signal amplitude techniques.

4. Internal crack depths can only be estimated using signal amplitude techniques.

5. Permanent image data and records can be maintained on computer and used for future comparisons.

RECOMMENDATIONS

1. Additional research needs to be carried out to increase the accuracy of the determination of actual crack depths from ultrasonic data for both external and internal cracks in boiler tubes.

2. Boiler owners should be encouraged to take make every effort to carefully remove generating bank tubes that have failed due to cracking. Insufficient samples are available for follow up failure analysis to allow a good understanding of the actual crack shapes and fracture mechanisms involved.

REFERENCES

1. Stasuk, D.G., *Tappi Engineering Conference*, “Recovery Boiler Generating Bank Tube Thinning”, Sept.1991