Large above ground storage tanks filled with hydrocarbon and hazardous liquids such as oil, oil-derived products, chemicals and process plant liquids are in widespread use in the UK, Europe and throughout the world. Tank farms are normally located in coastal areas close to large centres of population. Leakage from corroded storage tanks, especially their floors, is a major environmental, economic and safety hazard for the UK and Europe. The tank farms above are normally coastal and close to large population centres. The current and growing risk of tank failure together with the potential risk for fire and explosion at nearby petrochemical plants is unacceptable.

This paper illustrates the use of Long Range Ultrasonic Guided Wave for the inspection and monitoring of large above ground bulk liquid, storage tank floors without the need for access to the inside of the tank or to empty its contents. The propagation of the guided wave signals has been simulated and experimentally validated on actual tank floor. This paper covers the study of the sensitivity of guided wave to degradation and the limits of performance over the target tank range of 30metres radius i.e. range of penetration.

Keywords: guided wave, ultrasonic, long range ultrasonic, tank floor, corrosion, tomography, storage tanks.

1 Introduction
Various non-destructive testing (NDT) methods such as penetrant testing, magnetic particle, radiographic testing, eddy current, thermography, acoustic emission are used to inspect storage tanks floors [1,2]. Current inspection methods require the tank to be drained and made safe for human entry for inspection which is time consuming and expensive. As such, there is a need to develop a faster, lower cost and safer method to assess the structural integrity of the tank floors. The objective of this study was to develop a structural health monitoring method for the tank floors using low frequency ultrasonic guided waves (UGW). The low frequency ultrasonic guided waves has the ability to propagate long distances in planar and tubular structures and is already been used for inspection of pipes [3].

2 Experimental Set-Up
2.1 Tank Monitoring System
A 4m diameter tank floor was used to carry out the structural health monitoring experiments for damage location and detection. The wall thickness of the tank floor is 7mm and has a seam weld running along the diameter of the tank floor. The tank is shown in Figure 1.
A multitude of transducers was permanently attached around the perimeter of the tank floor. The commercially available 24 channel Teletest system and an additional 80 channel multiplexer were used to collect a broadband frequency range of data. The botany of the tank floor structural health monitoring system is illustrated in Figure 2.

2.2 Ultrasonic Guided Waves
The ultrasonic guided waves propagate in the plate structure contain various wave modes. Depending on the frequency of excitation, the fundamental wave modes generated are the symmetric S0 and asymmetric A0 wave modes. In this study, the characteristics of the S0 wave mode are used. The presence of the S0 and A0 in the acquired time domain signals is illustrated in Figure 3.
3 Result

3.1 Reliability

The structural health monitoring system was used to collect data continuously over 3 months. One important factor for a robust structural health monitoring system is the reliability of the transducers and electronics. The stability of the transducers was studied over the 3 months period of time is illustrated in Figure 4 with the intermittent generation of the tomograms. It can be seen that the distribution of the energy over the circular structure is fairly constant over the long period of time suggesting no failure or degradation in the performance of the transducers and electronics.

3.2 Defect Detection and Location

The capability of defect detection in terms of size and location was studied. A large set of baseline data were acquired which covers a wide environmental condition changes.
A single defect of diameter 70mm and through thickness was introduced initially. A second and third defect of 70mm and 20mm was then added to the tank floor. A set of data was then collected after each defect addition. The position of the defects are shown in Figure 5.

![Figure 5 Defect Size and Location: 70mm defect (left) and 70mm, 70mm, 20mm defect (right)](image)

The tomograms are generated using characteristics of the S0 wave mode acquired at the opposite receiving transducers. The detection and location of the added defects have been possible by the tomography technique used. The tomograms are shown in Figure 6.

![Figure 6 Tomograms for 70mm defect (left) and for 70mm, 70mm, 20mm defects (right)](image)

4 Conclusion

The use of ultrasonic guided waves for the structural health monitoring of storage tanks has been investigated on a 4m diameter tank floor. For the purpose of structural health monitoring, it is of paramount importance to have a reliable system in terms of transducer performance and a stable pulser-receiver system. The experiments carried out and based on the data acquired, demonstrated the stable performance of the permanently attached transducer and of the pulser-receiver used. The S0 wave mode from the receiving transducers has been used to generate the tomograms. The tomography technique has been successfully implemented with the developed structural
health monitoring system for the detection and location of defects of 20mm to 70mm sizes.

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6 References

