NEW ACOUSTIC PRESSURE VESSEL CAPABILITY FOR THE UK

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1. INTRODUCTION

Currently, UK measurement standards for sound in water between 2 kHz and 500 kHz are based on three-transducer spherical-wave reciprocity and established in an open tank. One of the major limitations of this implementation is that calibrations can only be performed at ambient hydrostatic pressure and temperature. One way to overcome this limitation is to undertake the calibrations in a closed pressure vessel whose temperature and hydrostatic pressure can be controlled. Furthermore, such a vessel must not only provide a working environment which is sufficiently large to enable free-field conditions to be realised but it must also be possible to provide adequate positional control for the transducers and hydrophones being calibrated. A specially designed pressure vessel is needed to meet these requirements which would inevitably be large and expensive. Until recently, no such acoustic pressure vessel facility existed in the UK.

Through a collaborative project between the Underwater Sound Reference Detachment (USRD, Naval Underwater Weapons Center, Orlando and Newport, USA) the UK Defence Evaluation and Research Agency (DERA, Winfrith), the UK Department of Trade and Industry, and the National Physical Laboratory, a large acoustically lined pressure vessel is being transferred from the USA to the UK. This vessel will provide the environment to enable calibrations and tests to be established over a range of hydrostatic pressure and temperature. Once established and commissioned, the vessel will form an essential part of the UK's National Measurement System for underwater acoustics. The facility will enable the development and dissemination of measurement standards, thereby providing industry with traceable calibrations and tests for underwater acoustical devices under simulated ocean conditions.

This paper provides details of the technical specification of the pressure vessel facility and describes the types of tests and calibrations which will be available once the vessel is commissioned and operational.

2. PRESSURE VESSEL SPECIFICATION

The pressure vessel [1] shown schematically in Figure 1 consists of a steel tank 2.5 m diameter and 7.6 m long fitted with temperature and pressure control equipment to simulate depths to 687 m (6,895 kPa or 1000 psi). The vessel weighs 75,000 kg excluding water and it holds 35,000 kg of water.

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The inside walls of the vessel are lined with insulkrete [2] wedges, a material made from a mixture of cement and pine sawdust having a high acoustic absorption which is independent of hydrostatic pressure. The wedges at the two dome-ends of the tank vary in length between 1.4 m and 1.8 m. The cylindrical walls of the vessel are also lined with wedges 0.3 m long over most of the central region. With the wedges in place, the free volume of the vessel is 1.93 m diameter and 4.0 m long. Access to the vessel is through two ports which are 2.4 m apart. One port has an access of diameter 0.84 m and is used for large heavy items under test and the other is of diameter 0.50 m, and is used for mounting monitor devices such as hydrophones. The large port has a rotator shaft allowing rotation of devices weighing up to 350 kg. The small port provides access to a movable carriage allowing devices to be moved over a distance between 0.8 m to 2.5 m from the large port axis. Azimuth control on the movable carriage provides 30° movement.

The vessel, which weighs approximately 110 tonne when filled with water, will be supported on four air-filled antivibration mounts to provide two basic functions. The first is to isolate the vessel from ground-borne vibrations in order to achieve a low ambient noise level in the tank (sea-state zero). The second is to provide isolation of the tank so that noise and vibration is not transferred to the supporting floor and building during the operation of high power acoustic sources in the vessel. Using high pressure pumps, pressurisation will be from 20 kPa to 6895 kPa with a rate of change variable from 35 kPa per minute to 1500 kPa per minute. Using gas-filled accumulators, it will also be possible to provide a rapid rate of change of up to 7000 kPa/min. To avoid air bubbles on either the acoustic wedges or other surfaces, the water in the vessel is maintained air-free by being evacuated prior to and during filling. Once filled, the temperature of the water will be controlled over the range 2 °C to 35 °C using a water circulation system. Water circulation will only be undertaken with the vessel at atmospheric pressure.

During the design of the overall facility, care has been taken to address environmental issues and also to provide rapid operational capability, both during routine operation and also when it may be necessary to drain the vessel. Some key features include:

- Provision of a 'Holding tank', of capacity similar to that of the pressure vessel, which will provide the ability to transfer the water from the pressure vessel, hold it for whatever time is necessary and then transfer the water back to the pressure vessel. Overall transfer time will be less than 4 hours. This transfer process can take place over the range of water temperatures used, thereby minimising loss of energy.
- Provision of a 'Dump tank' which will allow water to be drained and held whilst awaiting clearance for disposal, either to a drain or to be removed by road tanker. This facility could be very valuable in the event of needing to deal with contaminated water.
- Provision of a pre-soak tank to enable a group of devices to be immersed in water over pre-determined periods and at a pre-set temperature prior to introduction in the main vessel.

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Once the pressure vessel is established to the planned specification, it will enable simulations to be undertaken under the following conditions:

- Static hydrostatic pressure in the range 20 kPa to 6.9 MPa;
- Static water temperature in the range 2 °C to 35 °C;
- Gradual and rapid controlled change in hydrostatic pressure to simulate change in ocean depth (to maximum depth 687 m);
- Pressure cycling between fixed pressure points and at defined rates;
- Gradual controlled change in temperature;
- Low noise environment - ambient noise level of sea-state zero or lower.

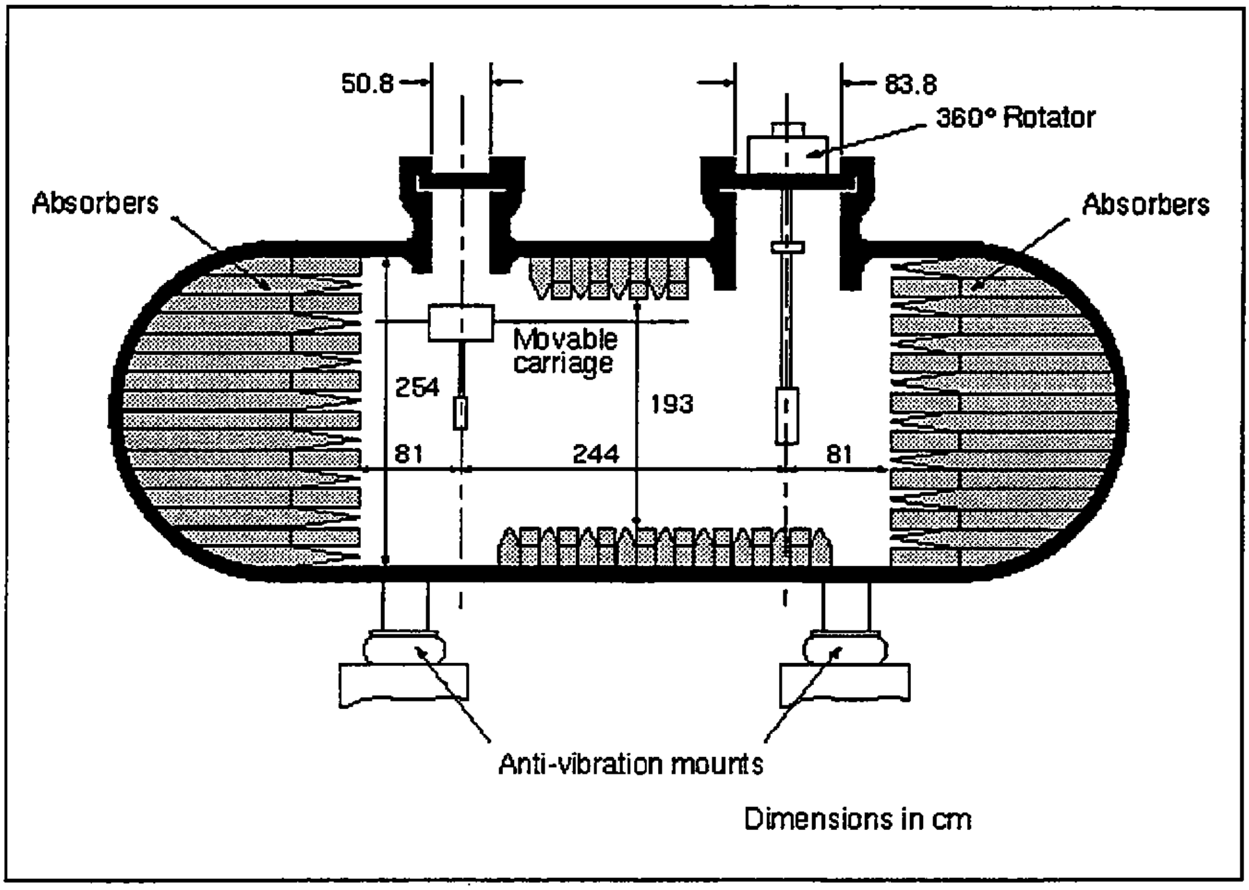

Figure 1: Schematic diagram of the acoustic pressure vessel facility

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3. ACOUSTICAL PERFORMANCE

Damer [2] gives information on the acoustical performance of the bulk insulkrete material used to make the acoustical wedges. The material has a density of 1.4 kg/m^3 and a speed of sound of 1900 m/s. Absorption is quoted as 0.9 at 10 kHz and 0.99 at 100 kHz although it is not clear what thickness this refers to. The overall acoustical performance of the pressure vessel lined with the insulkrete wedges will be very dependent on frequency. Damer [2] showed that, compared with an unlined tank, insulkrete lining provided a reduction in reverberation level by 27 dB at 50 kHz and 20 dB at 10 kHz for a source operating at a pulse repetition rate of 60 Hz. Much of the benefit comes from the deep insulkrete wedges at the ends of the tank which ensure that the ends are almost totally absorbing at all frequencies. This leads to the significant reduction in reverberation time compared to that if the tank were not lined. Pulse repetition rates up to approximately 30 Hz can therefore be utilised depending on the background noise level from the residual reverberation which can be tolerated. In practice, the actual reverberation level depends not only on the frequency and pulse repetition rate but also on the directional response of the source and receiver.

For pulsed transducer operation, the free-time available in the vessel together with the Q of the source transducer define the lowest frequency under which free-field conditions can be established. For a separation of 1.5 m between source and receiver, simple geometrical considerations give the number of 'free' acoustic cycles as approximately 10, 5, 2 and 1 at 10, 5, 2 and 1 kHz respectively. Under these conditions, and given low Q devices, it should be possible to operate down to low kilohertz frequencies. It may also be possible to extend tests below the free-time limit of the vessel (approximately 1 ms) through either modelling of the reverberations in the tank or modelling of the response of the source. It is planned to undertake studies of suitable methods of extending calibration and tests using method such as those described by Harris and Robinson [this volume]. This work indicates that for certain types of source it should be possible to predict the free-field continuous excitation level from sampling limited to one acoustic cycle. Such techniques would enable the vessel to be used below its strict free-time limit, down to frequencies of approximately 1 kHz.

4. ACOUSTICAL CALIBRATION AND TEST

It is planned to establish absolute calibration methods based on free-field reciprocity to establish calibrated reference measuring hydrophones and reference sources over the range of hydrostatic pressure and temperature. This will also involve the determination of the sensitivity of hydrophones and transducers to changes in hydrostatic pressure and temperature. Once established, it is then planned to develop the capability to determine:

- Transmit current and voltage sensitivities;
- Source level;
- Transmit power response;
- Receive sensitivities;

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- Near-field measurements;
- Electrical impedance and admittance;
- Directional response;
- Harmonic distortion;
- Linearity;
- Insertion loss;
- Echo reduction;
- Noise level.

As noted in Section 3, the frequency range over which measurements will be able to be made will be dependent on the type of source, its directional characteristics and its Q. In general, it should be possible to undertake measurements down to between 1 kHz and 2 kHz.

Although the main application area will be the calibration and test of underwater acoustical transducers, it is also planned to examine the use of the facility for the suppression and control of acoustic cavitation in applications such as high power ultrasound used in industrial process control.

5. CONCLUSION

The new pressure vessel being established at NPL will provide the UK with a new capability to set up measurement standards and to undertake test and calibration of underwater acoustical devices over a range of controlled hydrostatic pressure in the range 20 kPa to 6.9 MPa and temperature in the range 2 °C to 35 °C, thereby simulating ocean conditions.

6. ACKNOWLEDGEMENTS

The authors would like to thank Dr Lee van Buren, Bill Carlson and numerous other colleagues of the USRD, NUWC, who have enabled this project to take place. The authors would also like to thank Dr David Randles of DERA, Winfrith, of the UK Defence Evaluation and Research Agency, which will own the pressure vessel, for his considerable assistance during this project. The authors acknowledge the support and funding of the National Measurement System Policy Unit of the UK Department of Trade and Industry.

7. REFERENCES

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