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AN ANECHOIC WATER TANK FOR A BROAD FREQUENCY RANGE.

by
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Introduction.

During the past time the general problem of covering metallic or other "sound hard" surfaces with a lining material in order to decrease their acoustic reflectivity in underwater sound use has received widespread attention. This fact must be seen on the background of the limited dimensions of the water tanks available for laboratory investigations together with the wide radiation patterns for a number of more simple sound sources suitable for laboratory use. By lining the tank walls with an appropriate ling material an attempt is made to remove the "acoustical presence" of the walls, simulating an unlimited extended water space. The intended removal of the reflected signal should as far as possible be effective over a broad range of frequencies.

Among the possible subjects to be investigated in an anechoic water tank the following may be mentioned: a) Calibration of transducers and hydrophones by CW signals, b) exact measurements of directivity and beam patterns of underwater sound equipment, c) measurements of acoustical impedance and absorption properties by a number of materials and d) investigation of underwater sound scattering and reflection by wavy water surfaces.

By the development of a lining for an anechoic tank one has to face problems related to two different properties of the lining material. The first group of problems relates to the reflection of the signal caused by the difference in acoustical impedance between water and the lining material, and the other group of problems relates to the absorption properties of the lining material.In the present paper both properties are investigated by a number of possible lining materials and a detailed description of the results obtained are given. Furthermore, an acceptance level corresponding to an amplitude reflection coefficient being less than 10% has been established for the possible lining materials.

Classification of possible lining materials.

The damping mechanisms of the possible lining materials to be used in an anechoic water tank can roughly be shared in 3 groups:

1) Loss through flow viscosity in porous materials.
2) Loss through anelasticity of the materials.
3) Loss through absorption and scattering by air bubbles.

The first group of materials - extensively used for damping of sound waves in air - may be used for sound wave damping in water too, giving the greatest absorption in the regions of the sound wave where the particle velocity has its maximum. The streaming creates a number of small vortices leading to a dissipation of the energy in the wave. The so-called "Mason Lining" and the "Insulcrete" belong to this group.

The second group contains materials with an essential influence upon the pressure variation in the sound wave, giving the greatest absorption in the region of a sound wave where the sound pressure has its maximum. This is caused by the complex compressibility characterizing these materials and leading to a phase difference between stress and strain. The German "Alberich" and "Fafnir" belongs to this group. A tank lined with the last mentioned material has been reported to give an amplitude reflection coefficient less than 10% over the frequency range of 5 to 70 KHz.

Containing small air pockets some of the damping properties of the so-called "SOAB" material must be ascribed to action belonging to the 3'rd group, the absorption and scattering by air bubbles. Air bubble screens in water have during a long time been known as effective in reducing reflectivity caused by the diffuse scattering from the individual bubbles. Absorption in an air bubble screen has been found to be proportional to the concentration of bubbles being of resonant size at the frequency of the incident radiation. Rubberized horsehair mats used as an anechoic lining, containing spatially fixed small air bubbles in a thin latex coating on the individual horsehairs, belongs to this 3'rd group of damping materials.

Literature shows, that reasonable damping and reflection conditions may be obtained over limited ranges of frequencies by combining the properties of the materials and by including a gradual transition in acoustical impedance from the water to the lining.

Introductory measurements.

In order to find the best suitable material or combination of materials for an anechoic tank lining, measurements of the transmission and reflection properties by a number of materials were carried out in a water-filled unlined steel tank. The internal dimensions of the tank were 1 x 1 x 1.2 meter. The wall thickness of the tank was 3 mm.

The materials tested were:
a) Rubberized horsehair mats, thickness 30 mm.
b) Marine plywood plates, thickness 6 to 12 mm.
c) Fibre material filter mats, thickness 15 mm.
d) Auto rubber mats, thickness 12 mm.

e) Red corprene (Neebar) mats, thickness 3 to 13 mm.
f) Brown corprene (Neebar) mats, thickness 5 mm.
g) Closed cell polyurethane foam plates, thickness < 50mm.
h) Quartz sand boxes, thickness 50 mm.
i) Butyl rubber loaded with cork and aluminium powder, thickness 12.5 mm.

The following conclusions concerning the choise of the anechoic lining materials could be drawn from the measurements:

Over greater parts of the frequency range of interest the butyl rubber loaded with cork and aluminium powder showed the best loss and reflection properties. Furthermore, a backing of marine plywood on the butyl rubber plates showed a decrease in amplitude reflection coefficient from this combination over most of the frequency range.

Quartz sand seemed to be effective in removing some of the lower frequencies, but should be used in combination with the marine plywood forming the box for the sand and also forming a surface for the mounting of the loaded butyl rubber.

Caused by the great difference in acoustical impedance compared to water and caused by the buoyancy the polyurethane foam plates were rejected as a possible lining material.

Finally formed anechoic water tank and transducer positioning equipment.

Based upon the results arising from the preliminary measurements the final lining of the tank was carried out reducing the reflected sound level below the level of acceptance over a frequency range from about 10 KHz to more than 200 KHz.

Moving from the water into the lining a sound wave will first strike a gradual transition layer, changing the acoustical impedance from the one of water to the one of the lining over a distance of 150 mm. Wedges with the dimensions, base 75 x 75 mm and height 150 mm, formed by six layers of loaded butyl rubber plates glued together, are fixed to a backing plate consisting of a 25 mm thick layer of the loaded butyl rubber.The wedges and plate lining are again mounted on 12 mm thick marine plywood plates. Between the back of the marine plywood plates and the walls of the steel tank a 40 mm thick water space is situated.

On the edge of the tank a track for mowing the positioning equipment along was mounted. The positioning equipment consists of two columns mounted on tracks on a frame making an individual movement of each column possible over the whole horisontal plane. The x-y positioning in the horisontal plane can be carried out with an accuracy of ±0.1 mm in each direction. The same accuracy is obtained for movements in the vertical direction. Each column has a variable tilt angle of $\pm 70^{\circ}$ measured from the horisontal plane, and a variable azimuth angle of 360°, both angles determined with an accuracy better than $\pm 1^{\circ}$.

Capabilities of the anechoic water tank.

By the employment of an omnidirectional transducer and an omnidirectional hydrophone the reverberation decay time in the lined tank was measured, giving an average reverberation decay time of 0.52 msec over the whole frequency range considered.

Furthermore, the measurements revealed, that immediately after the reception of the end of the directly received signal, the signal level drops down 22 dB or more on frequencies higher than 20 KHz. During the reverberation time the signal level decreases to more than 40 dB below the directly received signal.

The employment of the standing wave ratio (SWR) in a vertical downward directed projection of sound gave the result, that the amplitude reflection coefficient for the whole frequency range over 20 KHz is over 20 dB below the reflection coefficient found for an unlined air-backed steel plate, with a further decrease in the reflection coefficient for frequencies above 200 KHz.

The recording of the sound pressure level as a function of the distance of separation between the transducer and the hydrophone for a continuous emission of sound on a number of frequencies was carried out in the lined tank, showing a satisfactory approximation to the theoretical 1/r spherical divergence curve.

In the finally lined tank the transmission and reflection properties of the lining materials considered were remeasured in order to remove the previous influence from the unlined steel walls.

Curves showing the anechoic capabilities of the tank together with the reflection and transmission properties of the materials considered are given over a frequency range from 10 KHz to 300 KHz.

It is concluded, that with the lining consisting of cork and aluminium powder loaded butyl rubber wedges on base plates of the same material and backed by a layer of marine plywood, it has been possible to fulfill the demands of low reflectivity by the water/lining interface and high absorption in the lining over a frequency range from at least 10 KHz to over 200 KHz, showing the possibility of further improved anechoic capabilities on even higher frequencies.