Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 510365
UNCLASSIFIED	

TITLE

EVALUATION OF NOISE REDUCTION COATINGS

System Number:

Patron Number:

Requester:

Notes: Paper #22 contained in Parent Sysnum #510343

DSIS Use only:

Deliver to: DK

#510365 (22)

Evaluation of Noise Reduction Coatings

by

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ABSTRACT

The use of exterior hull tiles can have a significant impact on the noise signature of surface ships and submarines as demonstrated by trial on HMCS ANNAPOLIS. At this point, DND cannot compare the effectiveness of various commercial noise reduction tiles, except through large scale tests. This paper describes current work on developing small scale evaluation tests for noise reduction coatings. To partially simulate the radiation of acoustic energy from hulls, mechanically driven 2' x 2' x 3/8" steel plates were fluid-loaded on one side. Two water tanks of significantly different volume ($5.8m^3$ and $80m^3$) were used to see what role reverberation plays in the data interpretation. Radiation from non-tiled plates was measured and compared to the radiation from plates with damping tiles. Tiles of several thicknesses were used. Noise reduction spectra were also compared for plates of different shape to separate the effects of flexural damping and velocity reduction (decoupling).

Objective

- Develop a small scale evaluation test for underwater noise reduction materials.
  - damping and decoupling materials
  - free field versus reverberent field
  - analysis framework (size, shape)

Motivation

- Noise reduction materials are currently used on CF ships (interior and exterior). Can often be used to solve noise problems.
- Direct experimental data needed for cases where modelling is not possible:
  - no material data available
  - complex structure (voids)
- Small scale tests are more rapid, less expensive than full scale tests.

Definition

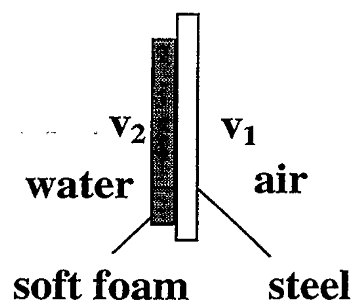
- A noise reduction coating reduces the radiated noise signature of a naval vessel when applied to the exterior or interior of the ship hull.
- The coating may affect the radiated noise by
    - decoupling (exterior only)
    - mass damping
    - free layer damping
    - constrained layer damping
    - changes in radiation efficiency

Decoupling

Surface velocity reduction due to soft coating. Ignoring wave effects:

$$VR = 20\log\left|\frac{v_1}{v_2}\right|$$

$$\frac{v_1}{v_2} \approx 1 + \frac{i\omega\rho_o c_o d_2}{L_2}$$



where L_2 is dialational modulus of coating.

Damping

- Consider single DOF system:

$$v = \frac{F_{in}}{i\omega m + \frac{\bar{k}}{i\omega}(1 + i\eta)}$$

Coating will alter substrate velocity through changes in

- mass m
- system loss factor η

Free Layer Damping

- System loss factor η :

$$\eta = \frac{3\eta_2 \overline{E}_2 d_2}{\overline{E}_1 d_1}\left(1 + \frac{d_2}{d_1}\right)^2$$

Substrate = 1 Coating = 2

η_2 = coating loss factor

E_1, E_2 = substrate, coating Young's moduli

d_1,d_2 = substrate, coating thicknesses

Radiation Efficiency

Acoustic power radiated, W_{ac}, depends on radiation effieciency, σ,

$$\mathbf{W_{ac}} = \rho_o c_o A \langle v^2 \rangle \sigma$$

$\langle v^2 \rangle$ is mean squared velocity over plate

- Coating may alter σ

Materials

- Substrate: Steel, 3/8" x 2' x 2'
- Coatings:
  - Decoupling: Foamed Neoprene

    Lossy material, energy conversion to heat
  - Damping: Isodamp EAR C-1002

    Impedance mismatch, energy reflection

Experimental Design

- **Acoustical Considerations**

  - free-field conditions hard to achieve at low frequencies

  - reverberant tank tests necessary (2 tank sizes)

  - far-field measurements difficult in tanks of limited size

  - homogeneous / isotropic sound field

- **Mechanical Considerations**

  - emulate hull via steel plates fluid loaded on one side

  - different plate shape/mass change modal characteristics

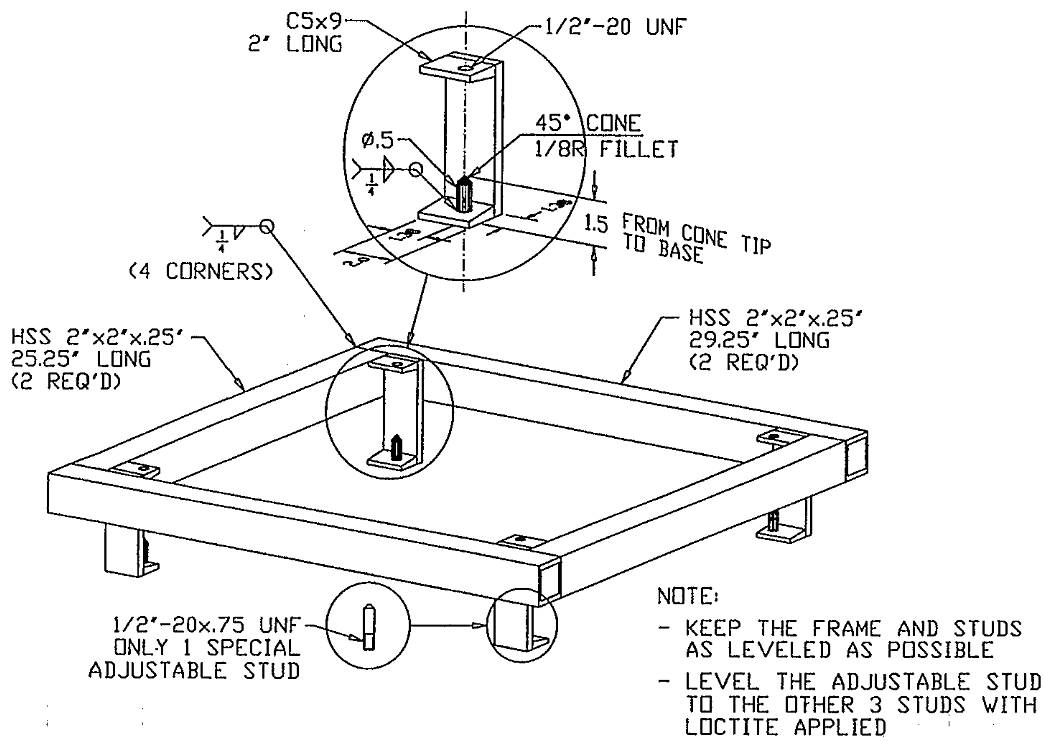
  - reduce energy loss to supporting structure

  - reduce energy radiated from supporting structure

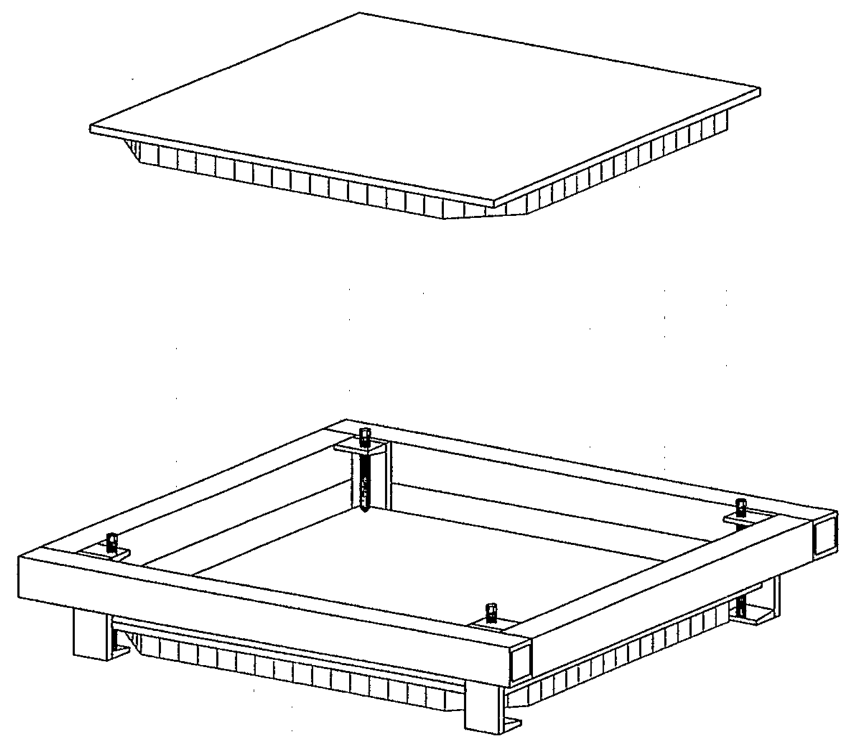
  - monitoring sensors and locations

Experimental Requirement

- Should in some way emulate hull damping (fluid loaded plates).
- Monitor the radiated sound power.
- Evaluate the coating material for damping purposes.
  (Do not want to evaluate the substrate).

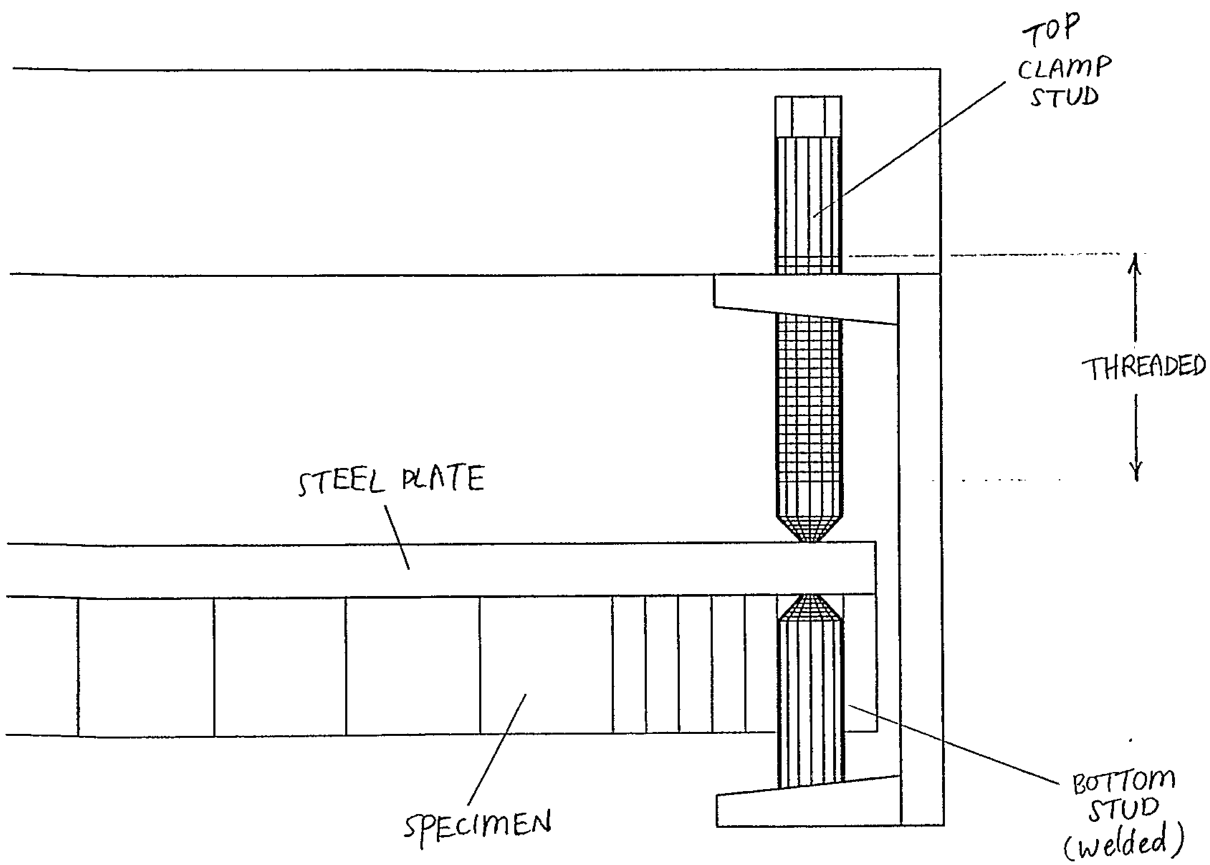


Apparatus for plate support



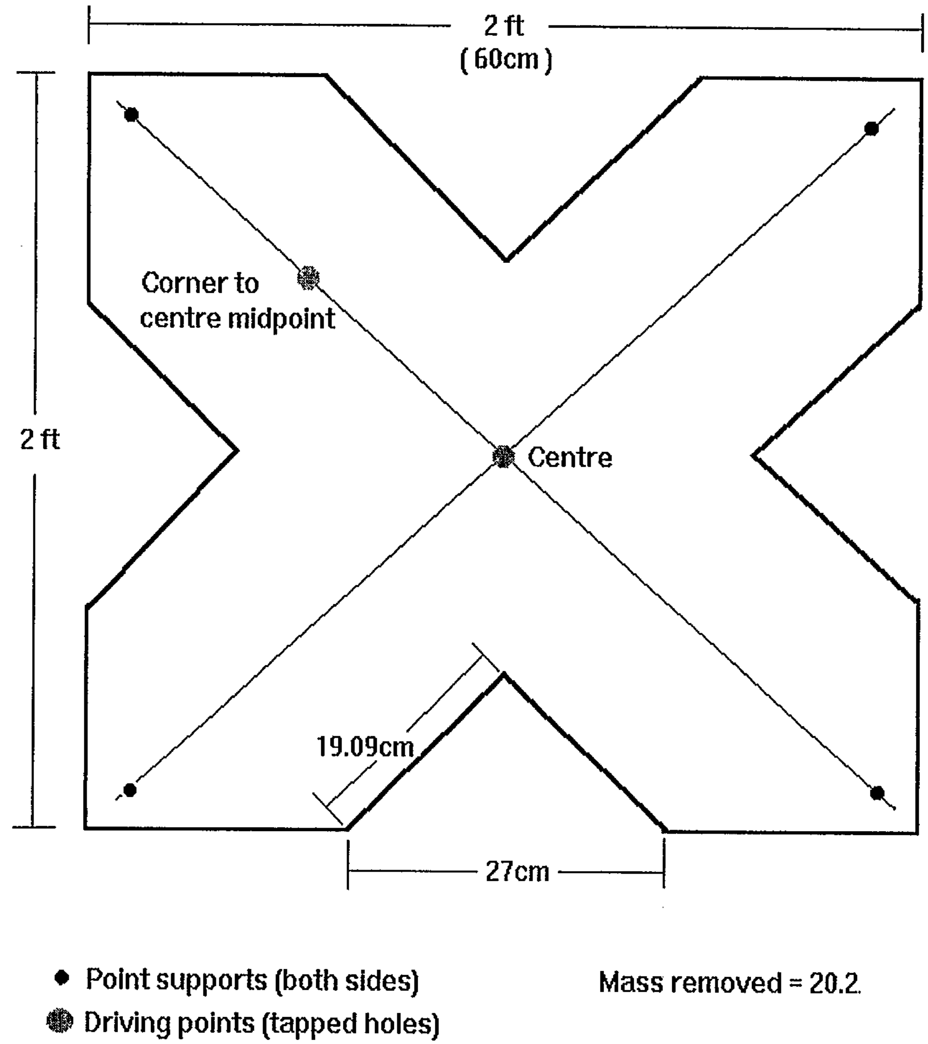
Apparatus shown with plate and damping material

Detail of plate support with plate and damping material shown

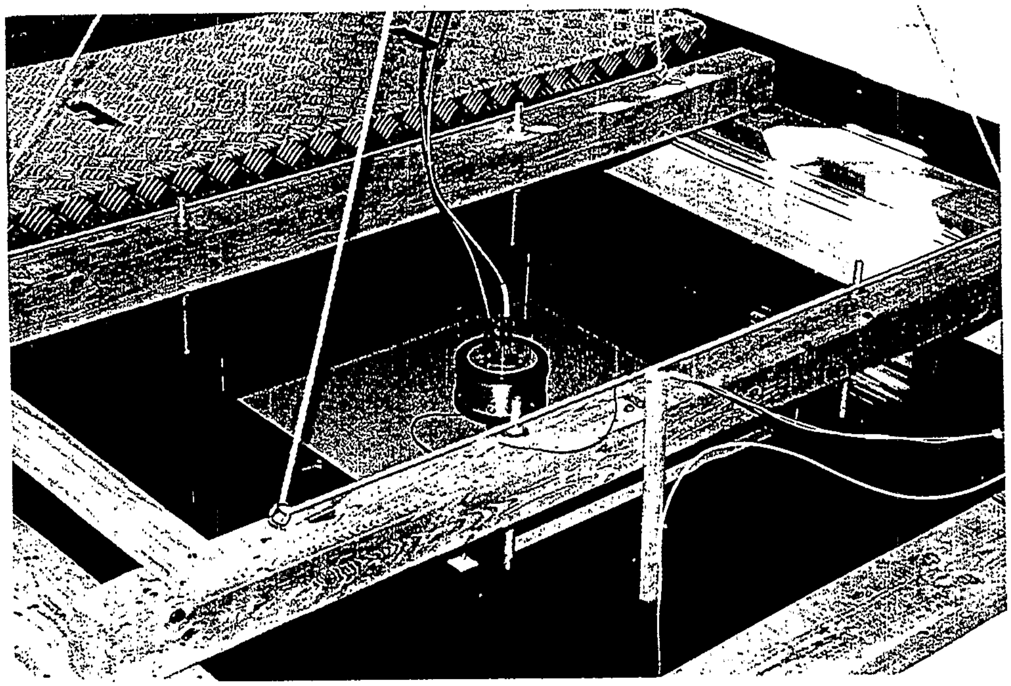


NOTE:

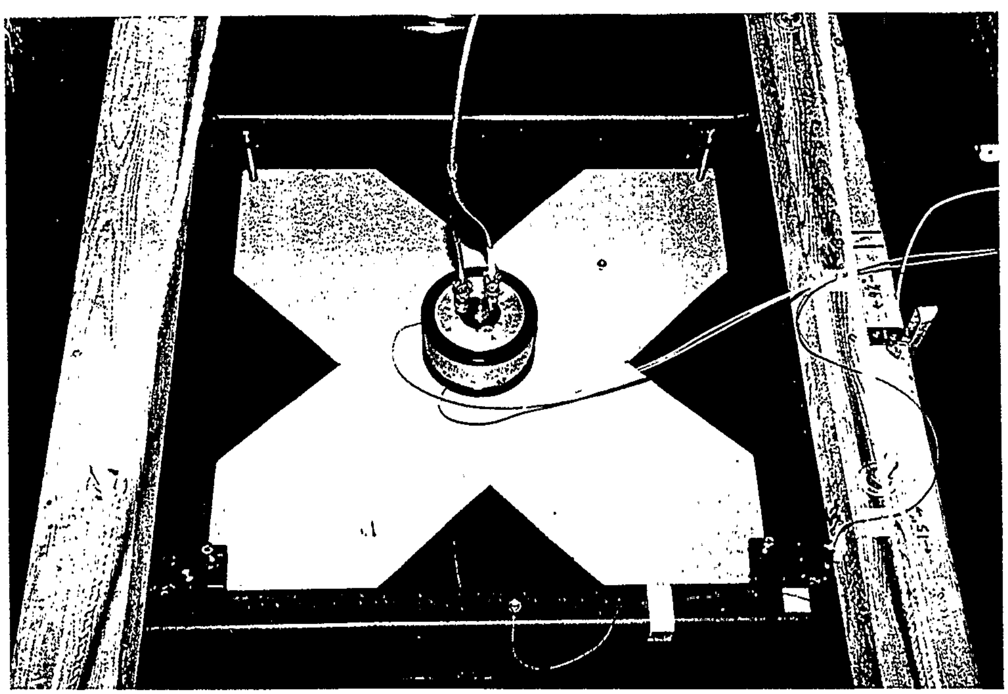
- STUD POINTS ARE 90°
- DIMPLES ON THE STEEL PLATE ARE 118° (STD. DRILL BIT)

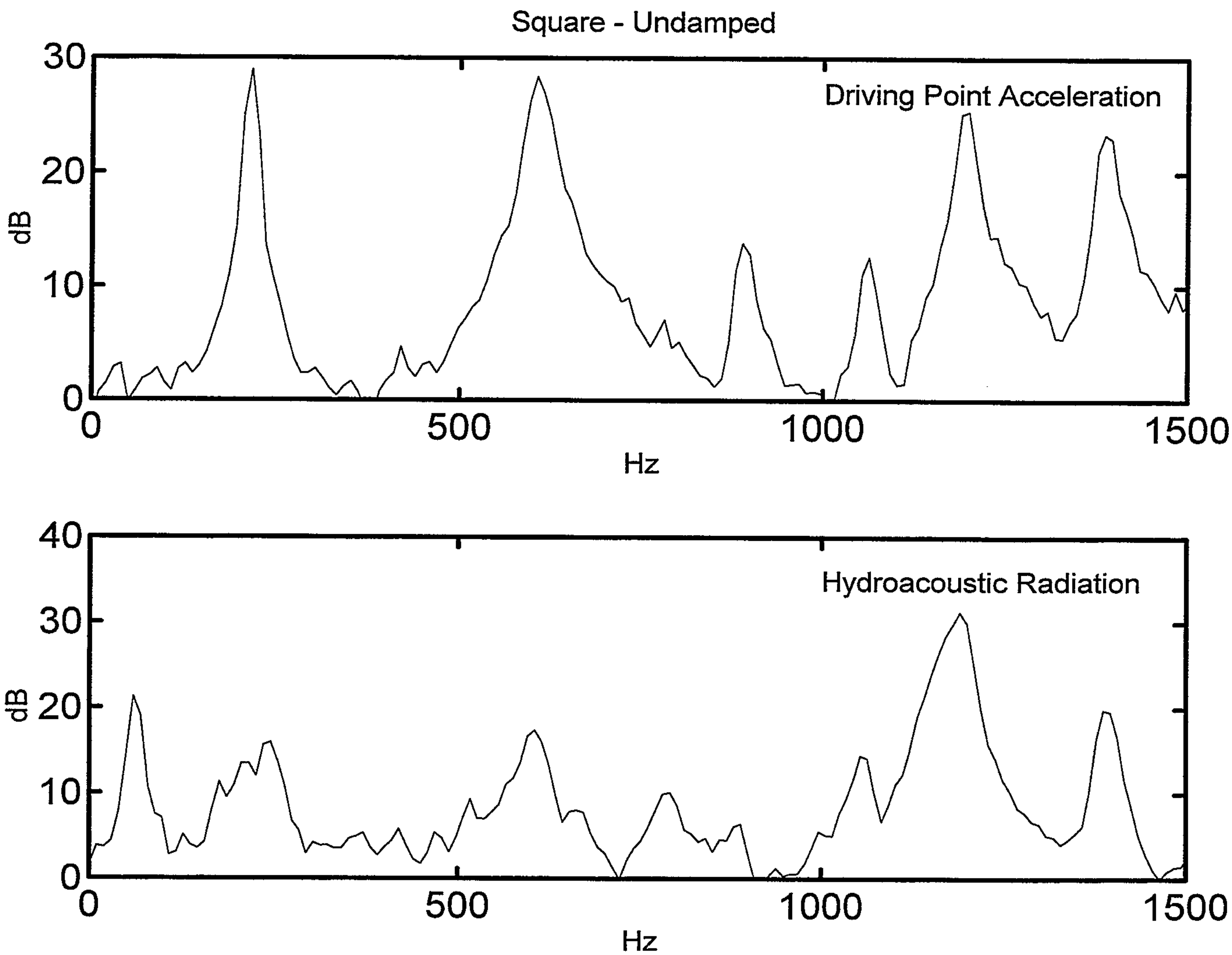


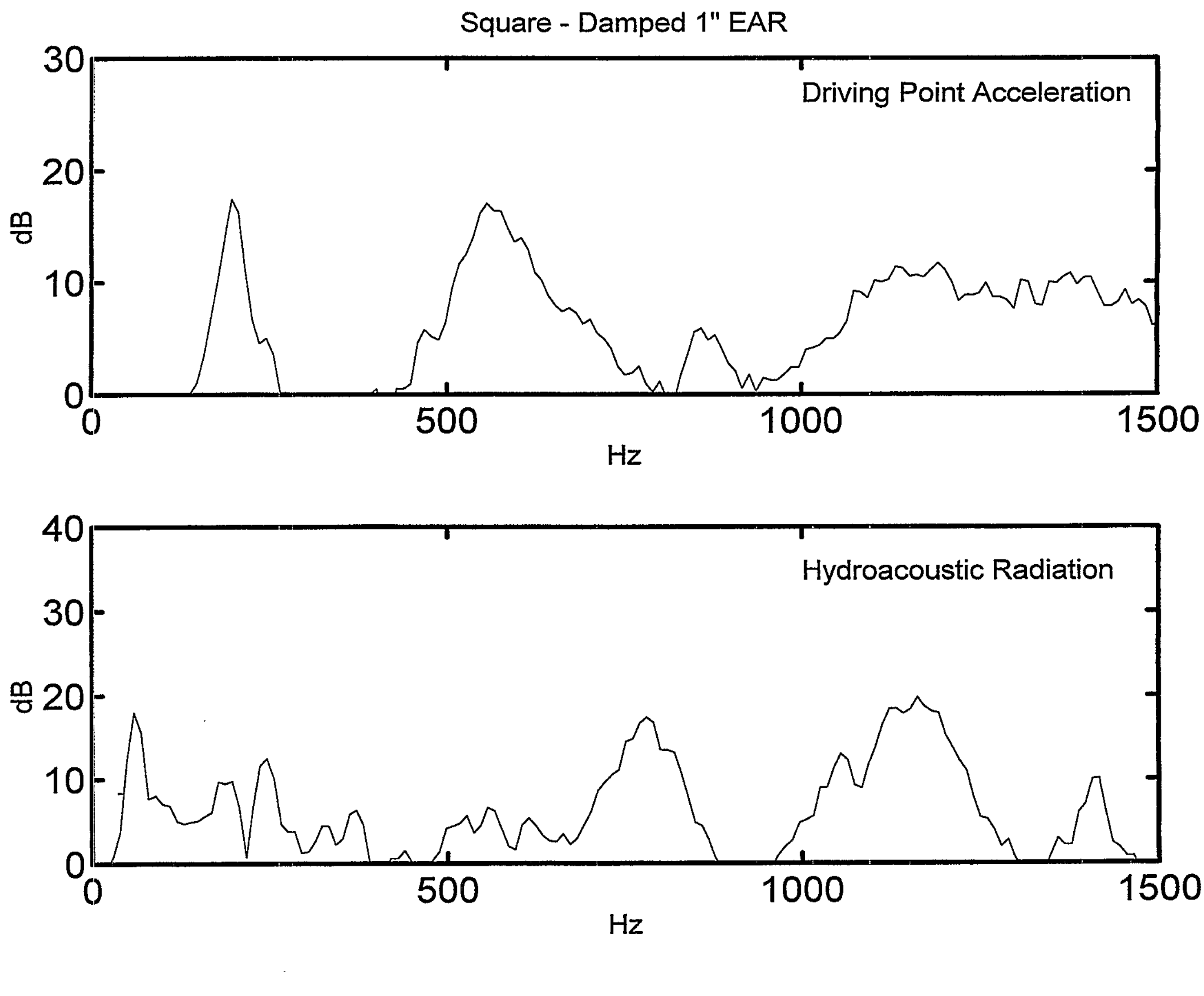
Detail of X-Plate showing driving and support points



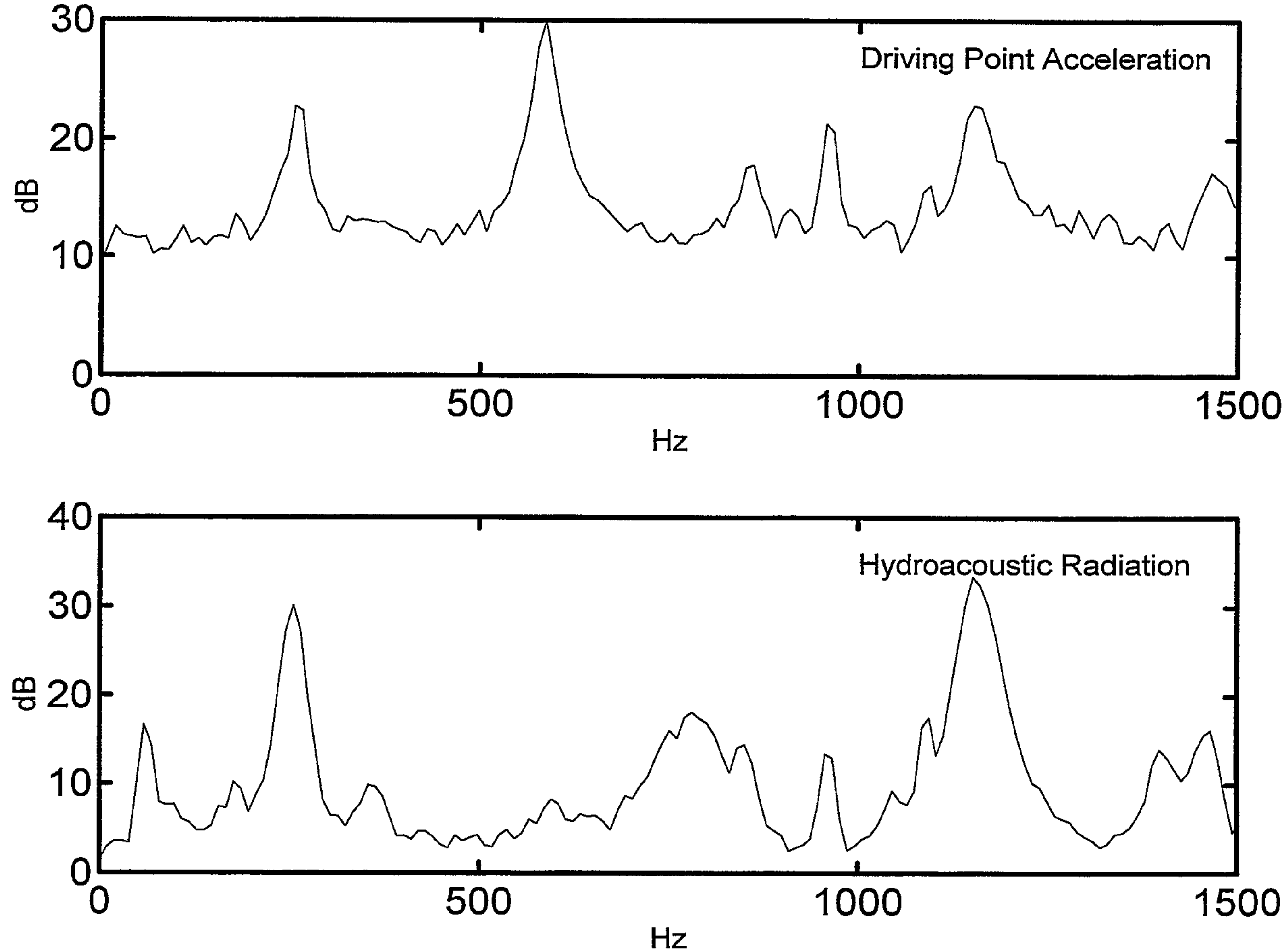
Top: Fluid-loaded square plate shown in small tank with shaker
Bottom: Fluid-loaded X-plate shown in small tank with shaker

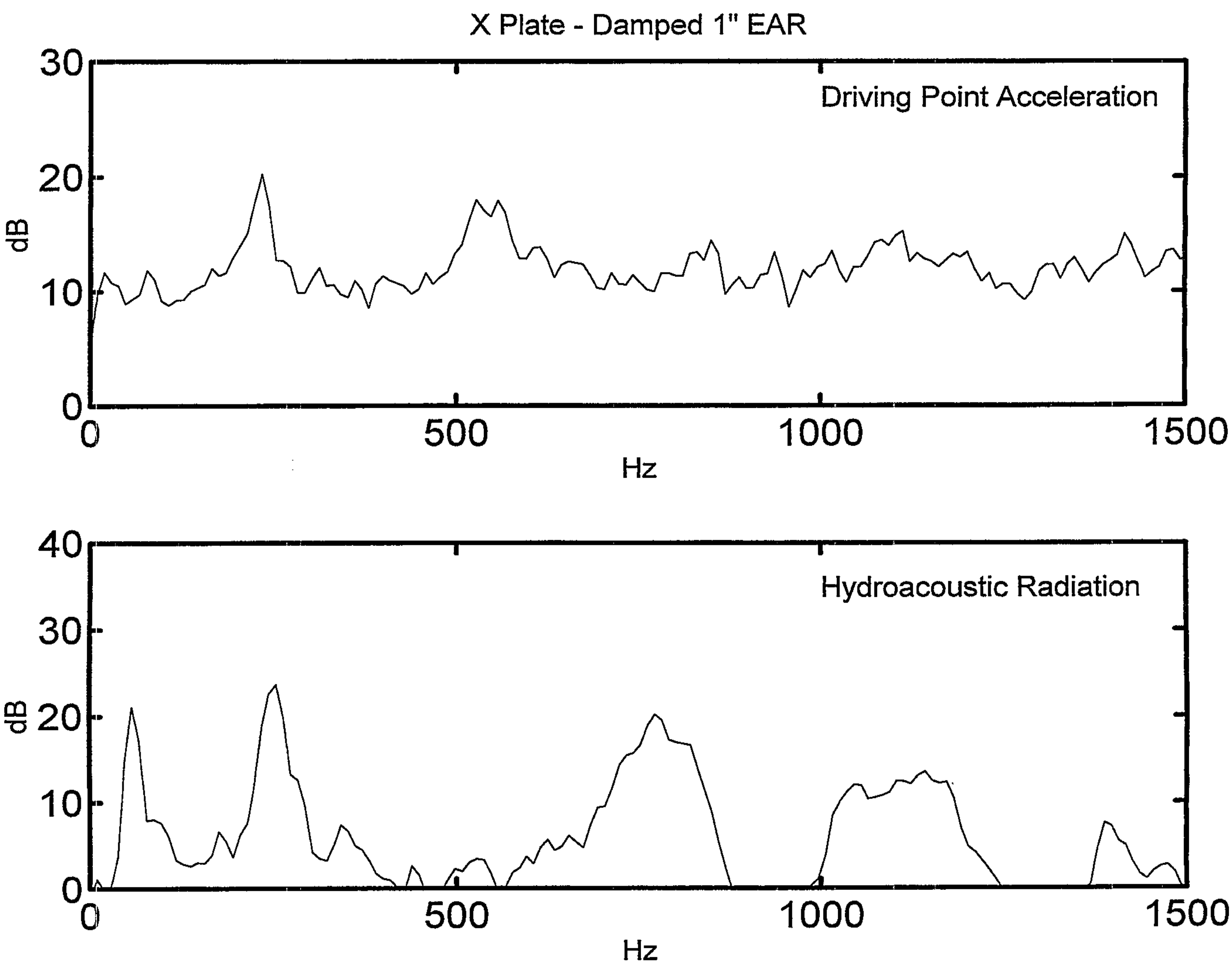



Square - Undamped
Driving Point Acceleration
dB
30
20
10
0
0
500
1000
1500
Hz
Hydroacoustic Radiation
dB
40
30
20
10
0
0
500
1000
1500
Hz


Square - Damped 1" EAR
Driving Point Acceleration
dB
30
20
10
0
0
500
1000
1500
Hz
Hydroacoustic Radiation
dB
40
30
20
10
0
0
500
1000
1500
Hz

X Plate - Undamped




X Plate - Damped 1" EAR
Driving Point Acceleration
dB
30
20
10
0
0
500
1000
1500
Hz
Hydroacoustic Radiation
dB
40
30
20
10
0
0
500
1000
1500
Hz

Summary

- Early data shows expected trend
- Trying different figures-of-merit to evaluate effectiveness of coatings
- Approximately 10-20 dB reduction in radiated sound power observed