Acoustic Design, Construction and Testing of Fisheries Research Vessels

One dark and stormy day…..
The End

Ray Fischer

Noise Control Engineering Inc.

nonoise@noise-control.com

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FRV Acoustic Design - Overview

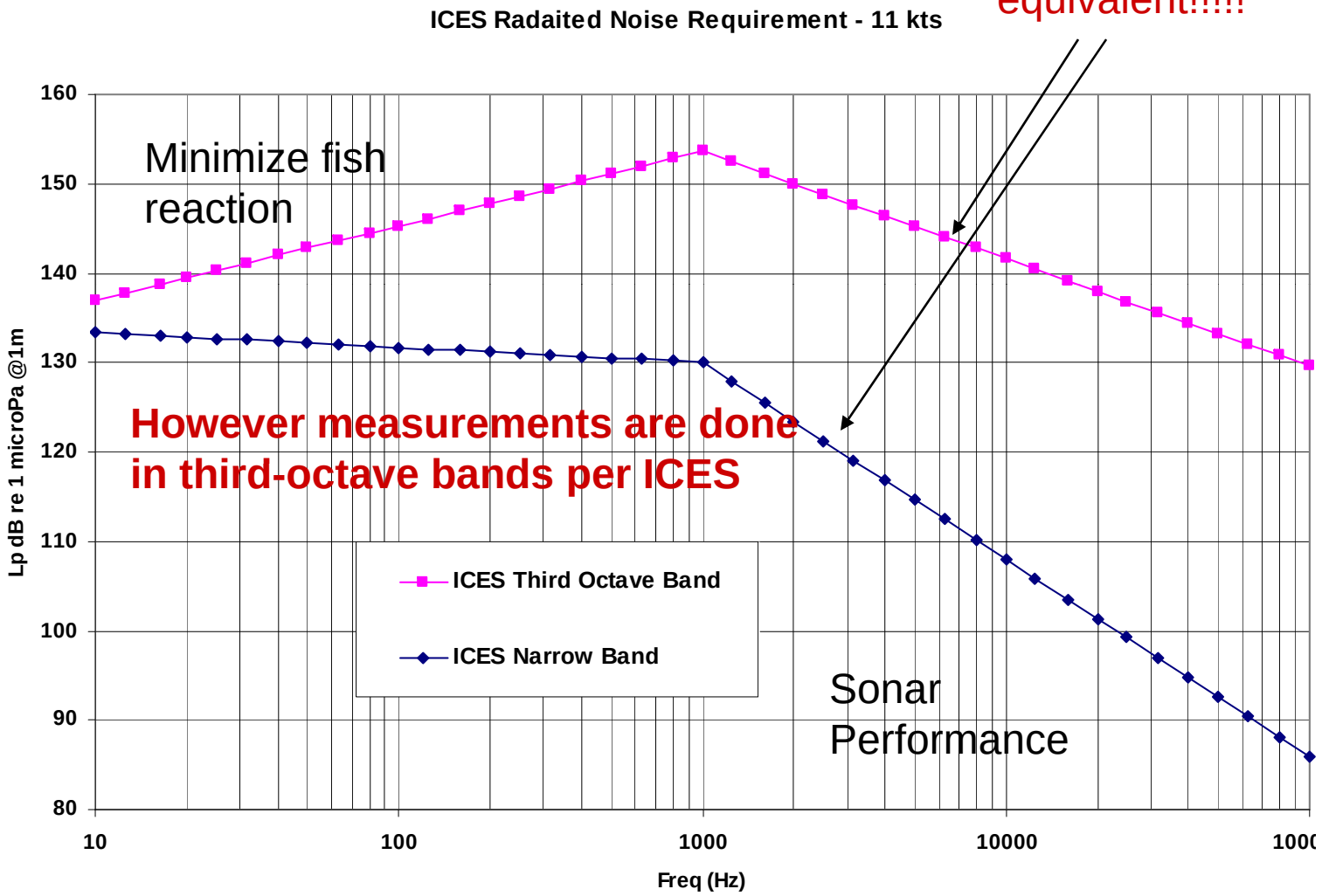
- ICES spec – narrow band v TOB (measurement procedure)
- Lessons learned
- NC approach –
  - N&V Control Plan – Schedule, approach, deliverables
  - Detail design – CAD, accuracy
  - Treatment optimization – trade-offs
  - Design changes - evaluation
- Shipyard Training
- QA
- Testing

NCE Experience - ICES

- NOAA FRV-40 (4 delivered)
- Univ. of Delaware – R/V HUGH R SHARP
- Machinery test and overside test– GO SARS
- Machinery test – JAMES COOK
- Reviewed Designer NOISE model of Spanish FRV
- ARRV – Preliminary Design & UAF agent
- RCRV – Preliminary Design
- Taiwan Research Vessel

ICES Limit

These 2 curves are equivalent!!!!!



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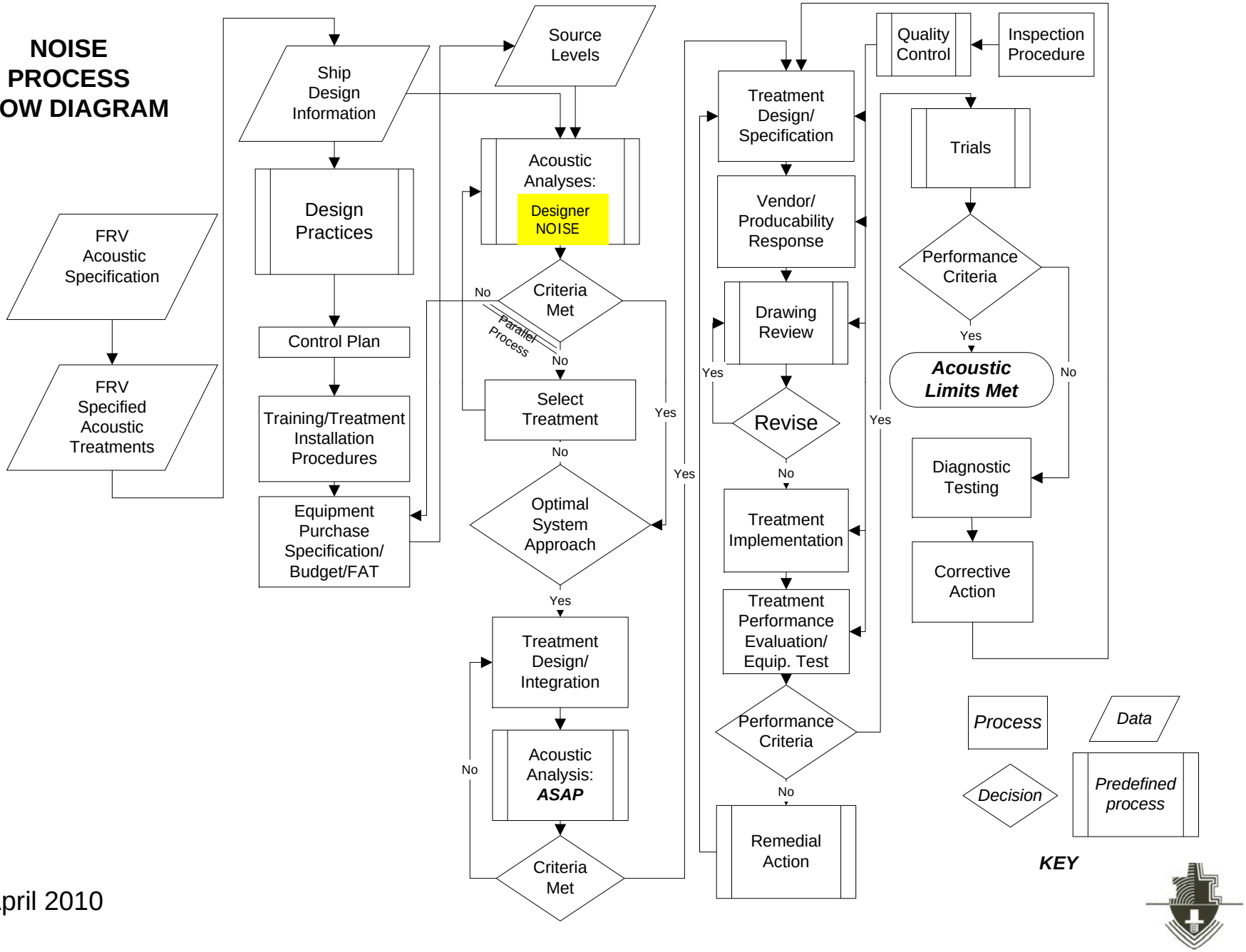
NOISE PROCESS FLOW DIAGRAM



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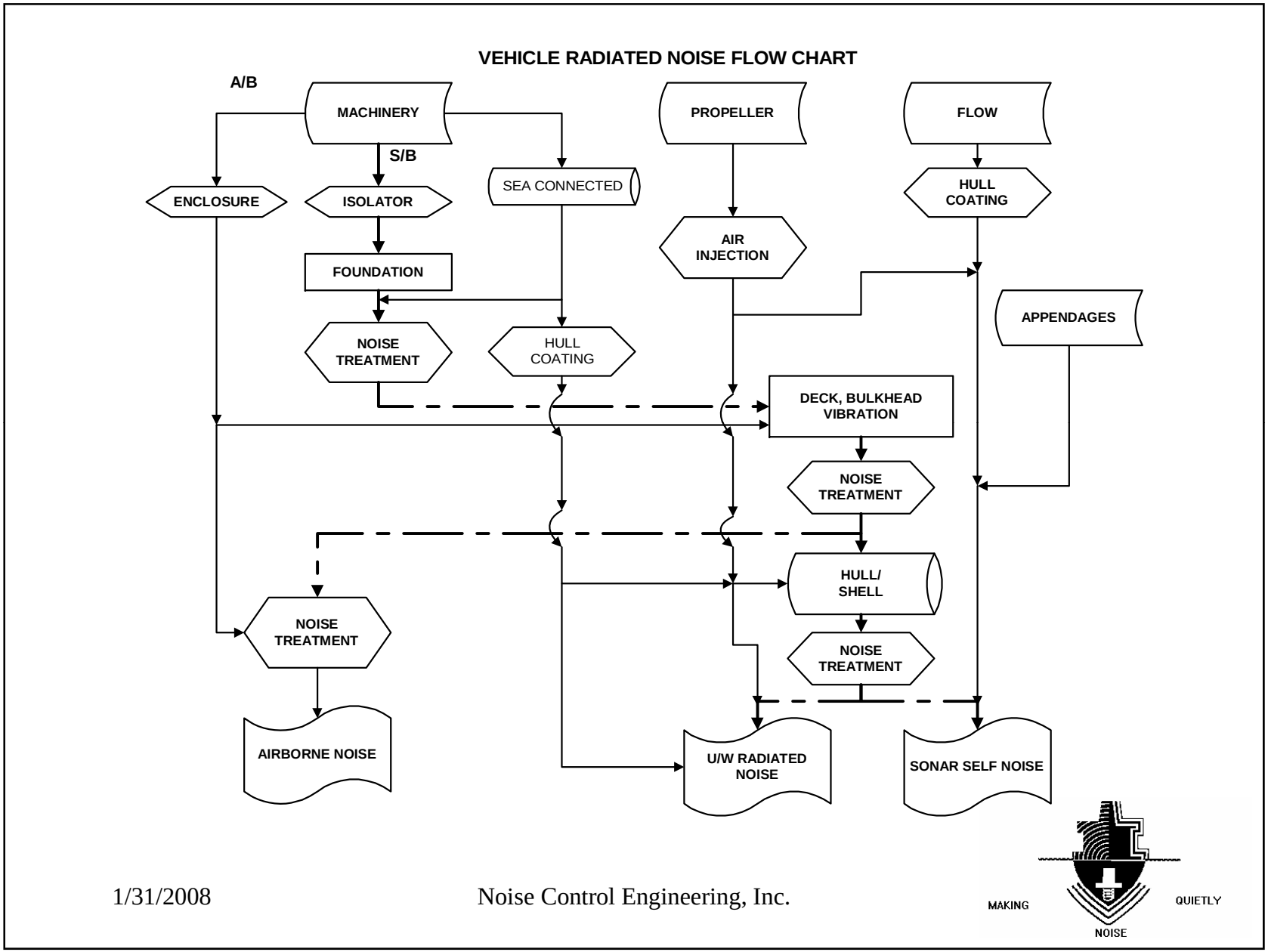
VEHICLE RADIATED NOISE FLOW CHART
A/B
MACHINERY
S/B
ENCLOSURE
ISOLATOR
FOUNDATION
NOISE TREATMENT
SEA CONNECTED
HULL COATING
PROPELLER
AIR INJECTION
FLOW
HULL COATING
APPENDAGES
DECK, BULKHEAD VIBRATION
NOISE TREATMENT
HULL/ SHELL
NOISE TREATMENT
NOISE TREATMENT
AIRBORNE NOISE
U/W RADIATED NOISE
SONAR SELF NOISE
1/31/2008
Noise Control Engineering, Inc.
MAKING
QUIETLY
NOISE

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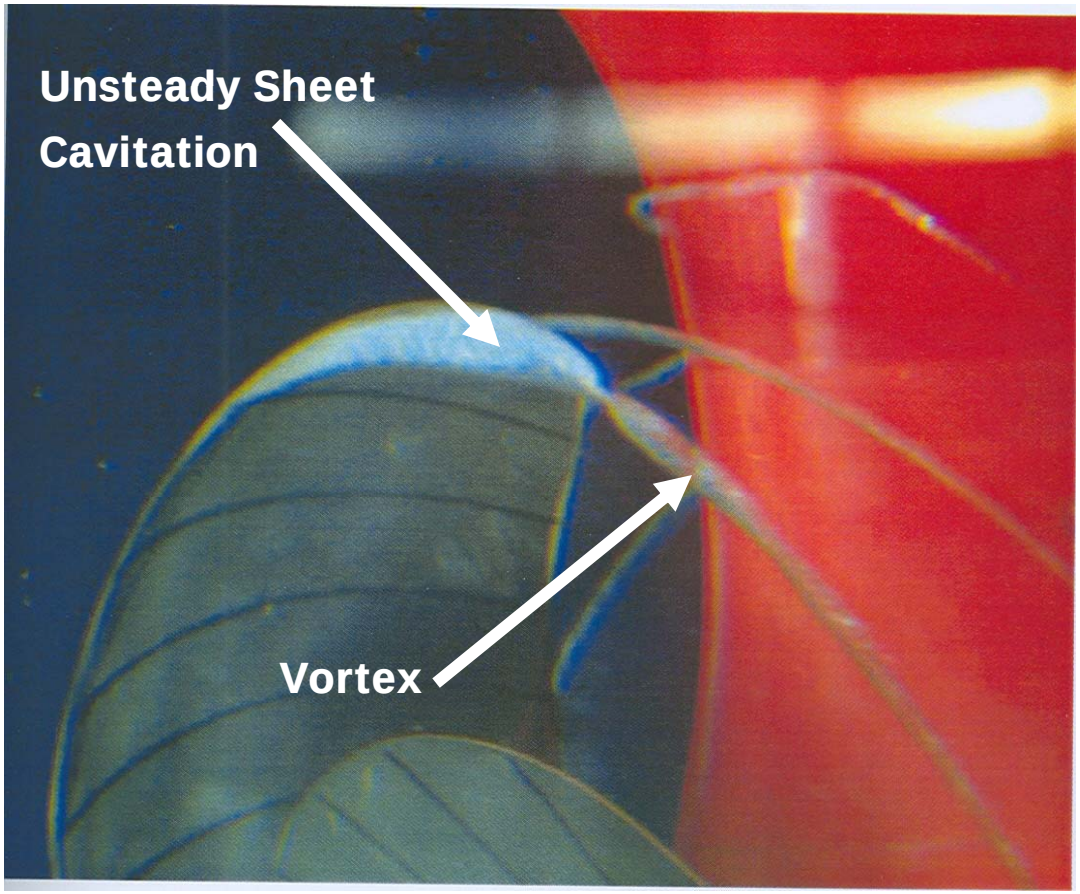
SHIP'S UW SIGNATURE

- Propeller – controls signature when cavitating
  - Cavitation – ICES – Cavitation free to 12 kts
  - AZIPOD – unacceptable for low noise vessel
  - Bow Thrusters – not operational for FRV quiet mode
- Machinery Noise
  - Propulsion Diesels or Motors
  - Diesel Generators
  - Large Reciprocating Machinery, Air Compressors
- Sea Connected Systems
  - Main Seawater Cooling
  - Auxiliary Seawater Cooling

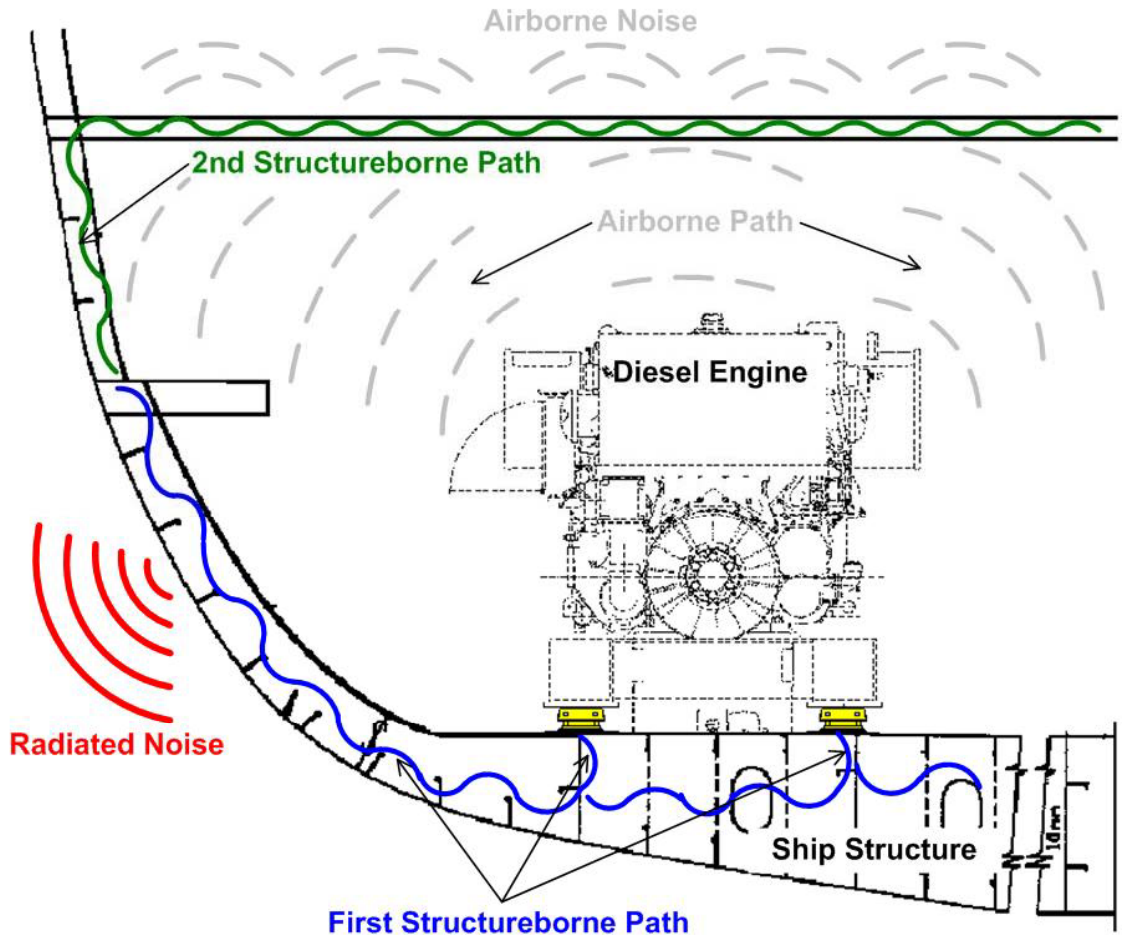
Propeller Noise – Cavitation…

… is the vaporization of water due to a decrease of the local pressure. This generates millions of very small vapor bubbles whose collapse generates significant underwater noise.

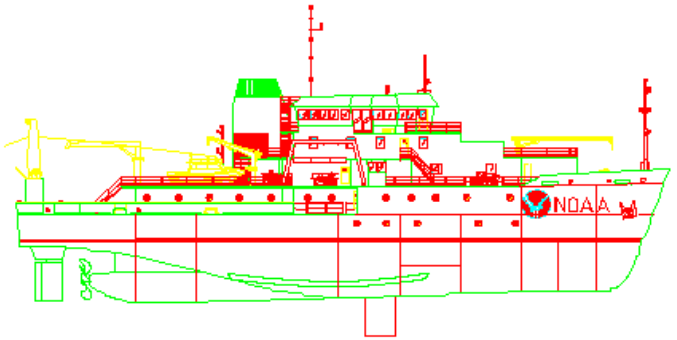


Paths for Machinery Noise

- Airborne
- First Structureborne
- Secondary Structureborne
- **U/W Radiated Noise**



OSCAR DYSON; Vessel Particulars.

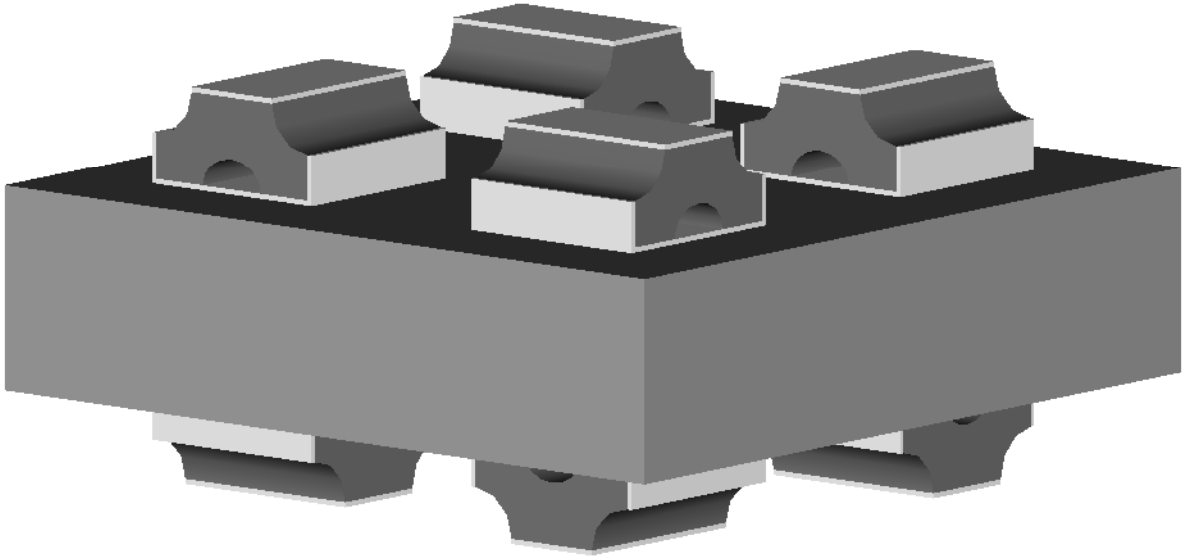


Length	64 meters
Beam	15 meters
Draft	6 meters (centerboard retracted), 9.2 meters (centerboard extended)
Displacement	2479 metric tons
Speed	14 knots (sustained), 11 knots (maximum quiet speed)
Diesel Generators	Two Caterpillar 3508 (910 kW, 1800 rpm) & Two Caterpillar 3516 (1360 kW, 1800 rpm)
Propulsion Motor	Two tandem 1950 kW @ 128 rpm
Propeller	Five blade, skewed

OSCAR DYSON; Summary of Noise Control Treatments.

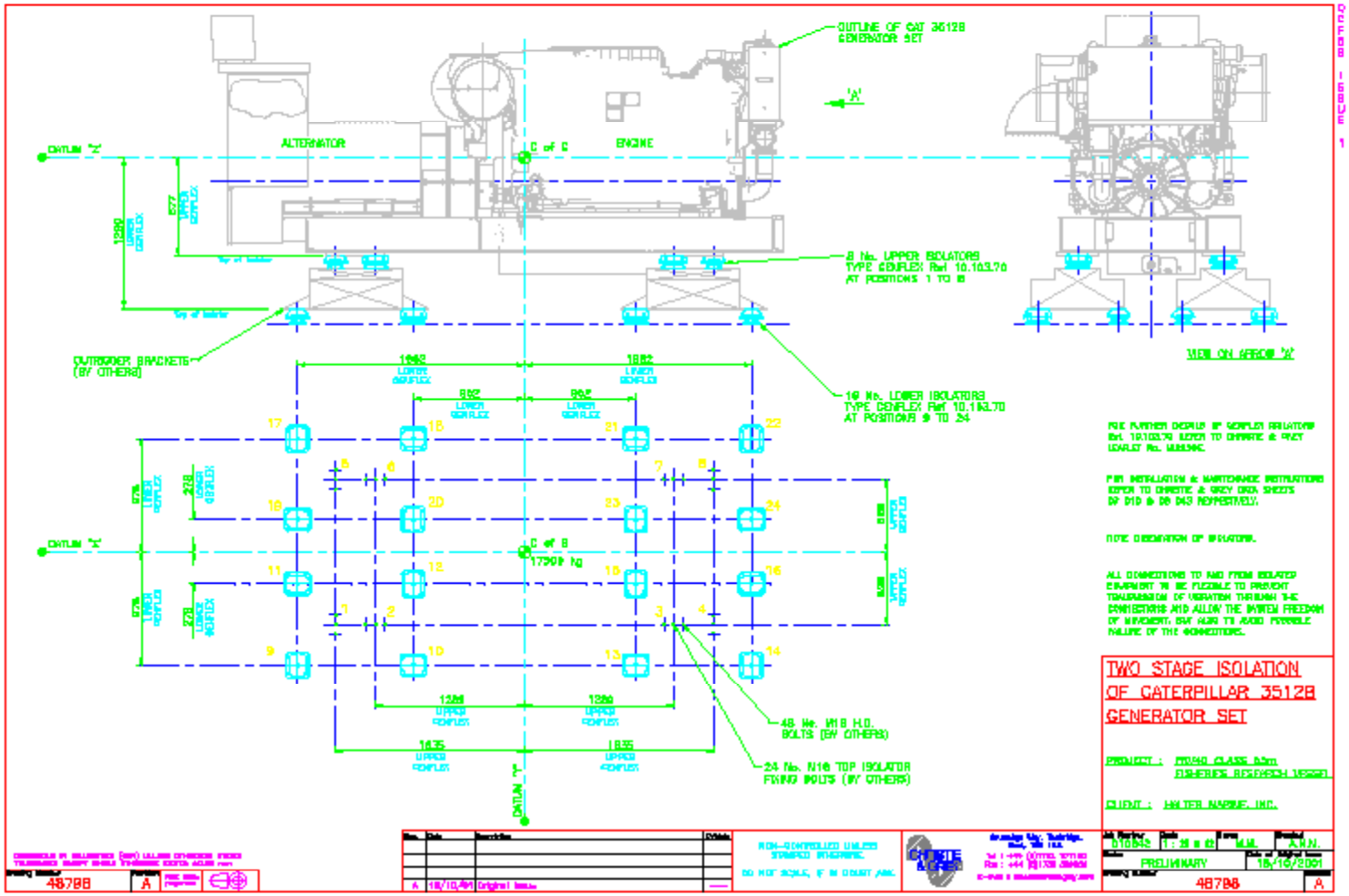
Low Noise Equipment	Propulsion Motor & Propeller Specially Designed
Double Stage Vibration Isolation	Diesel Generators & Reciprocating Equipment 3512 system – 18,113 kg; 3508 system – 14,770 kg
Single Stage Vibration Isolation	Auxiliary Equipment & HVAC
Acoustic Insulation	Perimeter of Engine Room and other noisy spaces
Damping Tiles	Applied to hull and bulkheads – constrained layer
Hull & Propeller	Specially designed by U.S. Navy (NSWC)

Specified Intermediate Mass Design



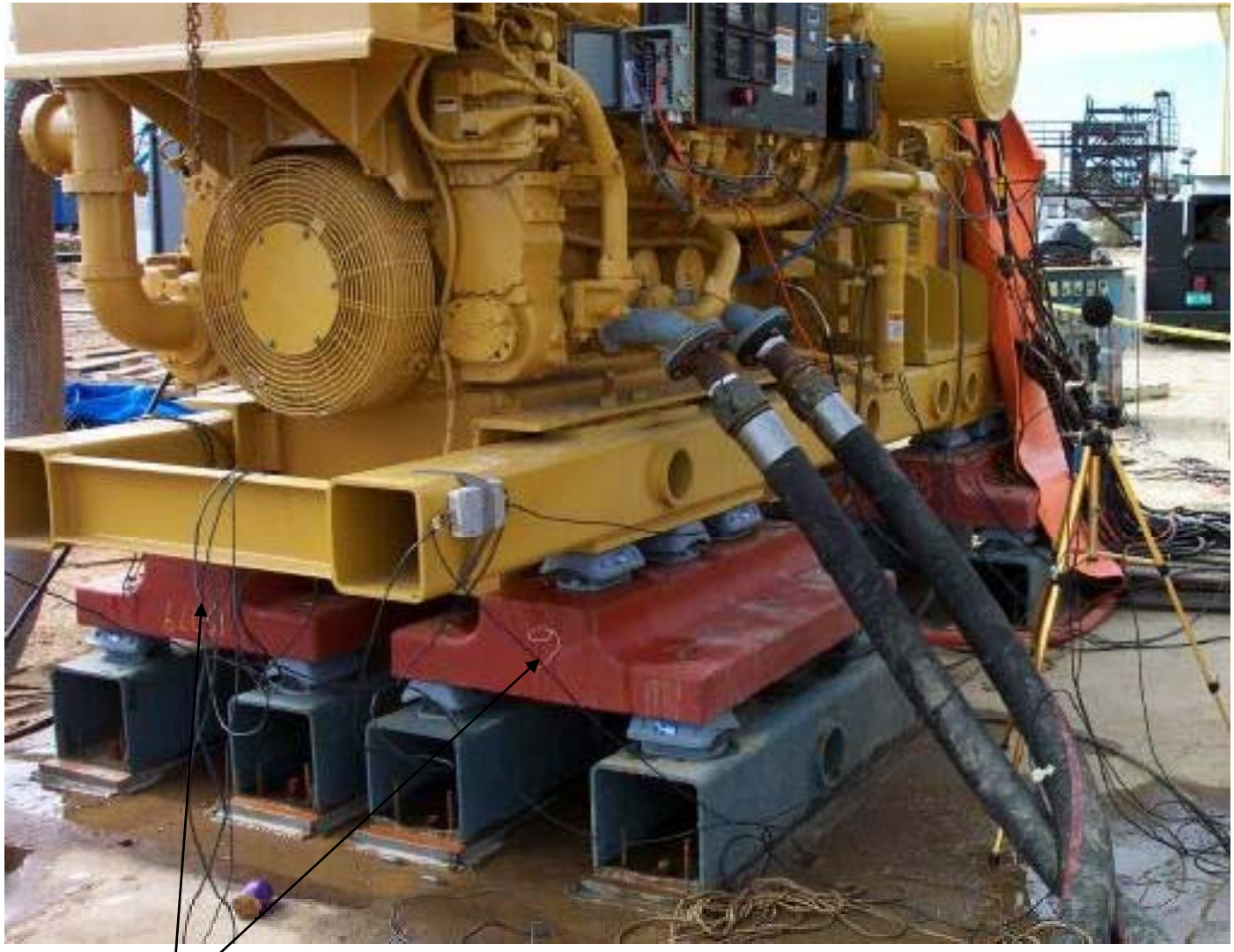
- Space problem –
  - Height and width

Bad to mix 'performance' and 'hardware' specification


OUTLINE OF CAT 3512B GENERATOR SET
ALTERNATOR
C of G
ENGINE
8 No. UPPER ISOLATORS TYPE CENFLEX Part 10.103.70 AT POSITIONS 1 TO 8
OUTRIGGER BRACKETS (BY OTHERS)
16 No. LOWER ISOLATORS TYPE CENFLEX Part 10.163.70 AT POSITIONS 9 TO 24
VIEW ON ARROW 'A'
C of G
17900 kg
48 No. M16 H.D. BOLTS (BY OTHERS)
24 No. M16 TOP ISOLATOR FIXING BOLTS (BY OTHERS)
TWO STAGE ISOLATION OF CATERPILLAR 3512B GENERATOR SET
PRELIMINARY
48788

Genset Factory Acceptance Test

GO SARS has 2 stage isolated diesel; single stage isolated generator. GO SARS has lower level diesel vibration.



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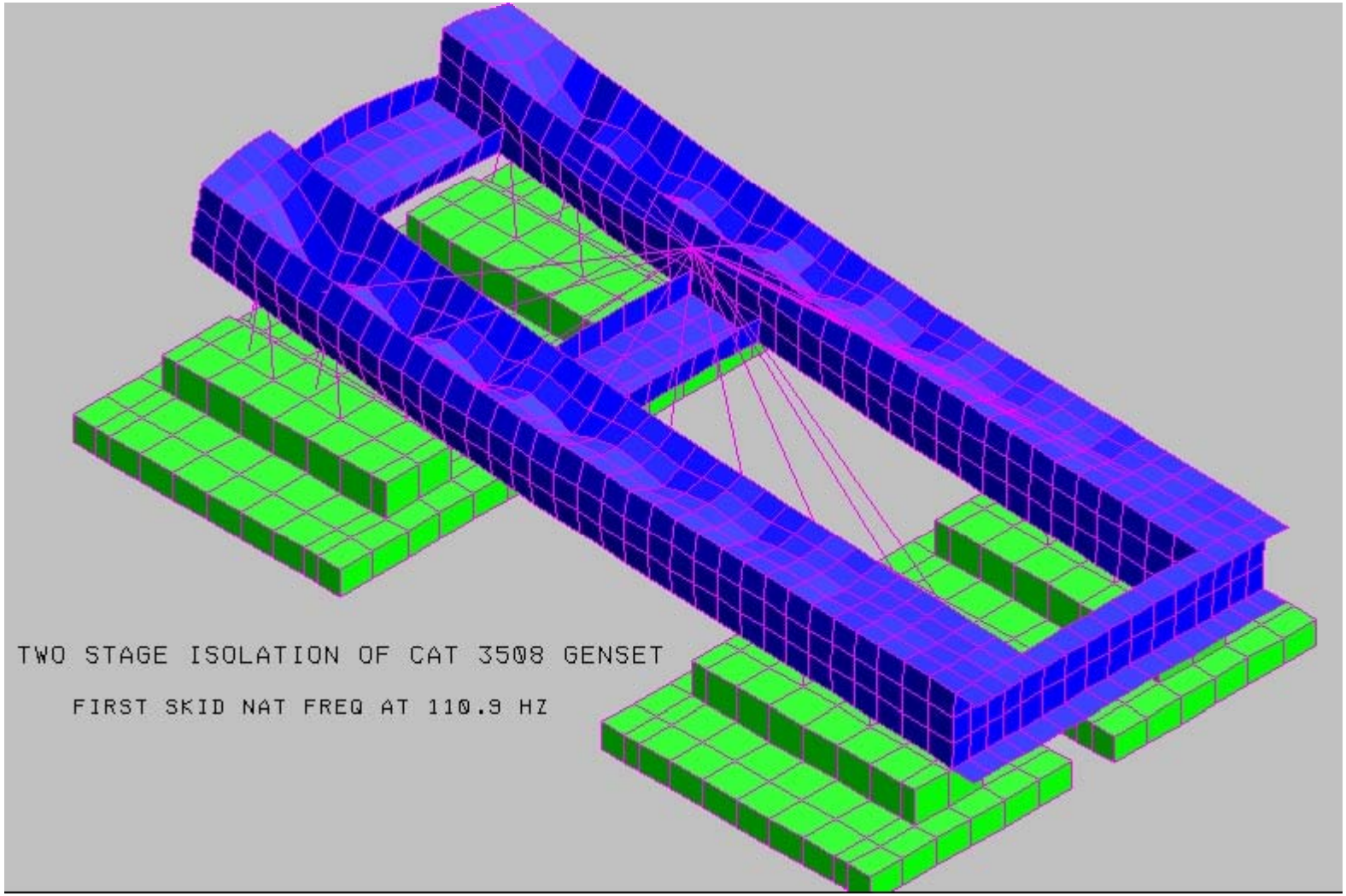
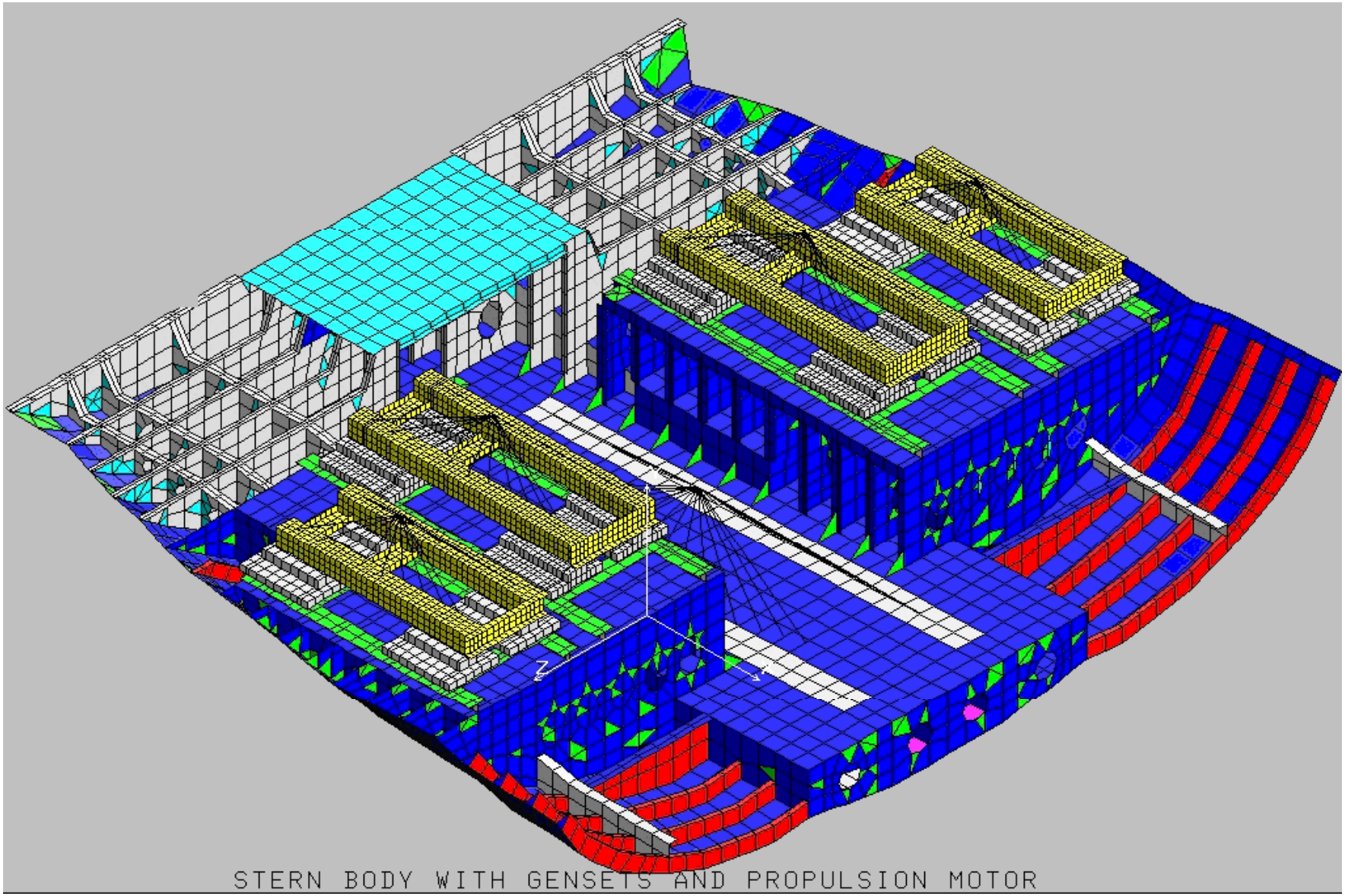
10% of genset mass in each block

Cat 3508 1st Skid Mode at 110.9 Hz



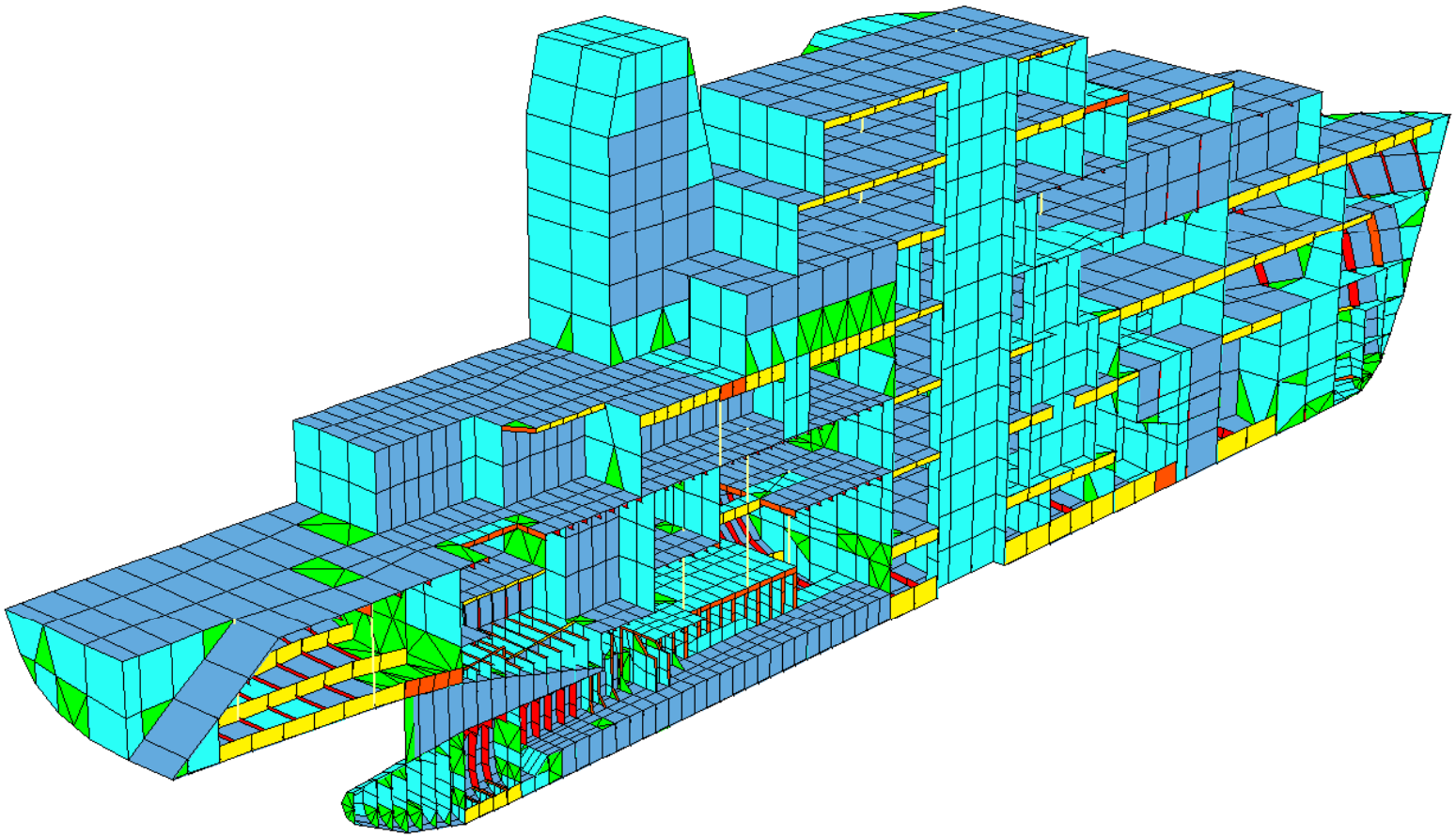

STERN BODY WITH GENSETS AND PROPULSION MOTOR

Vendor Weight SNAFU

Cat 3512 Genset	lbs	kg
Scaled wt of Dyson/Bigelow 3512	34610	15732
Design weight	28178	12808
Delta	6432	2924
		123%

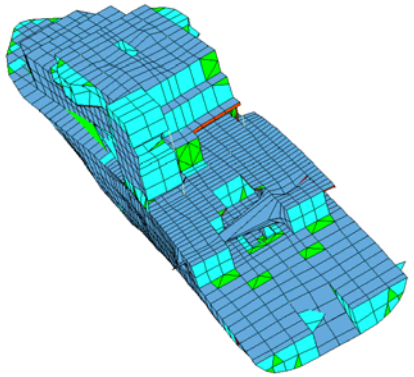
N.B.: Wrong Center of Gravity also provided

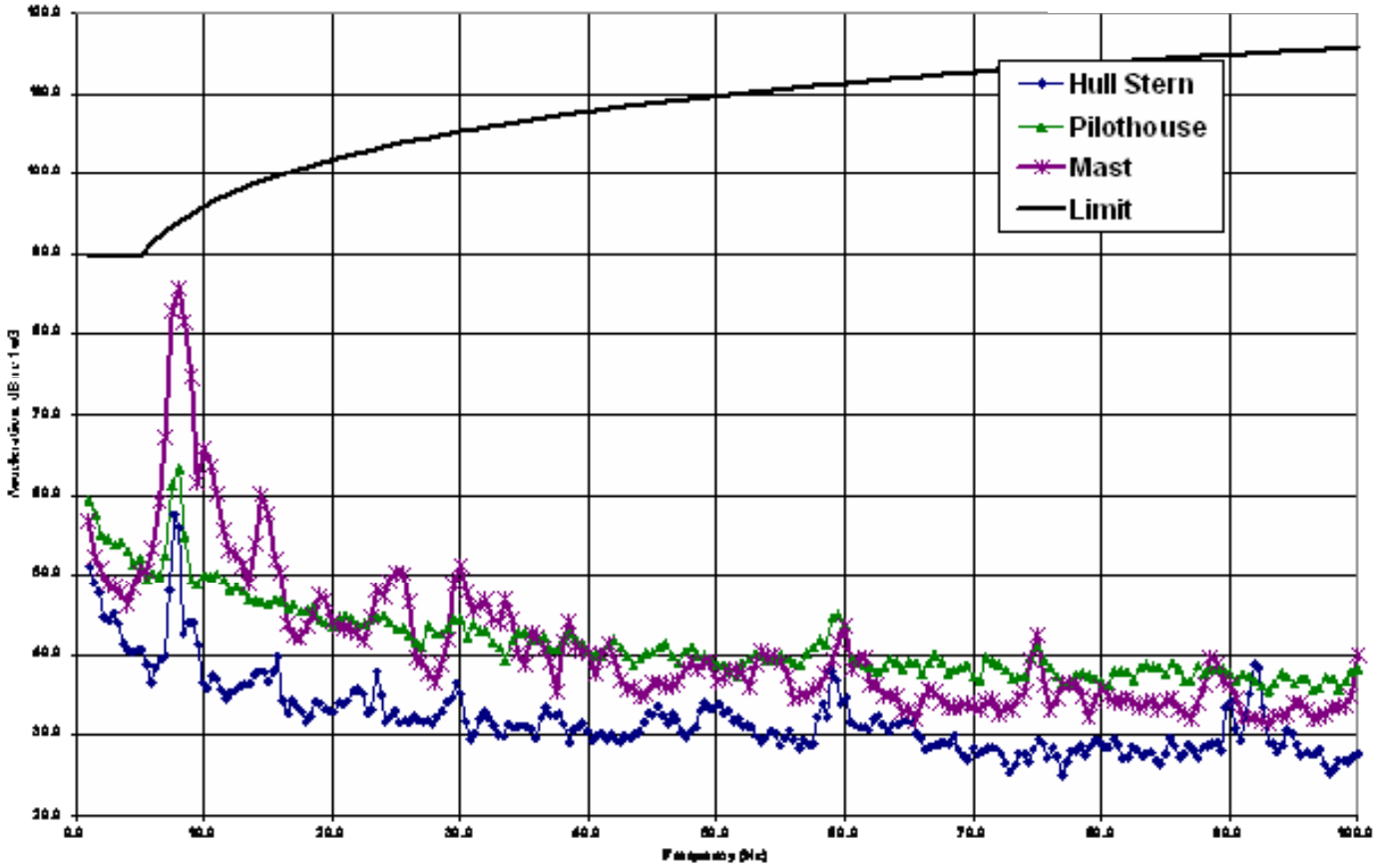
FEA Model – Resonance avoidance & forced response (habitability vibration)

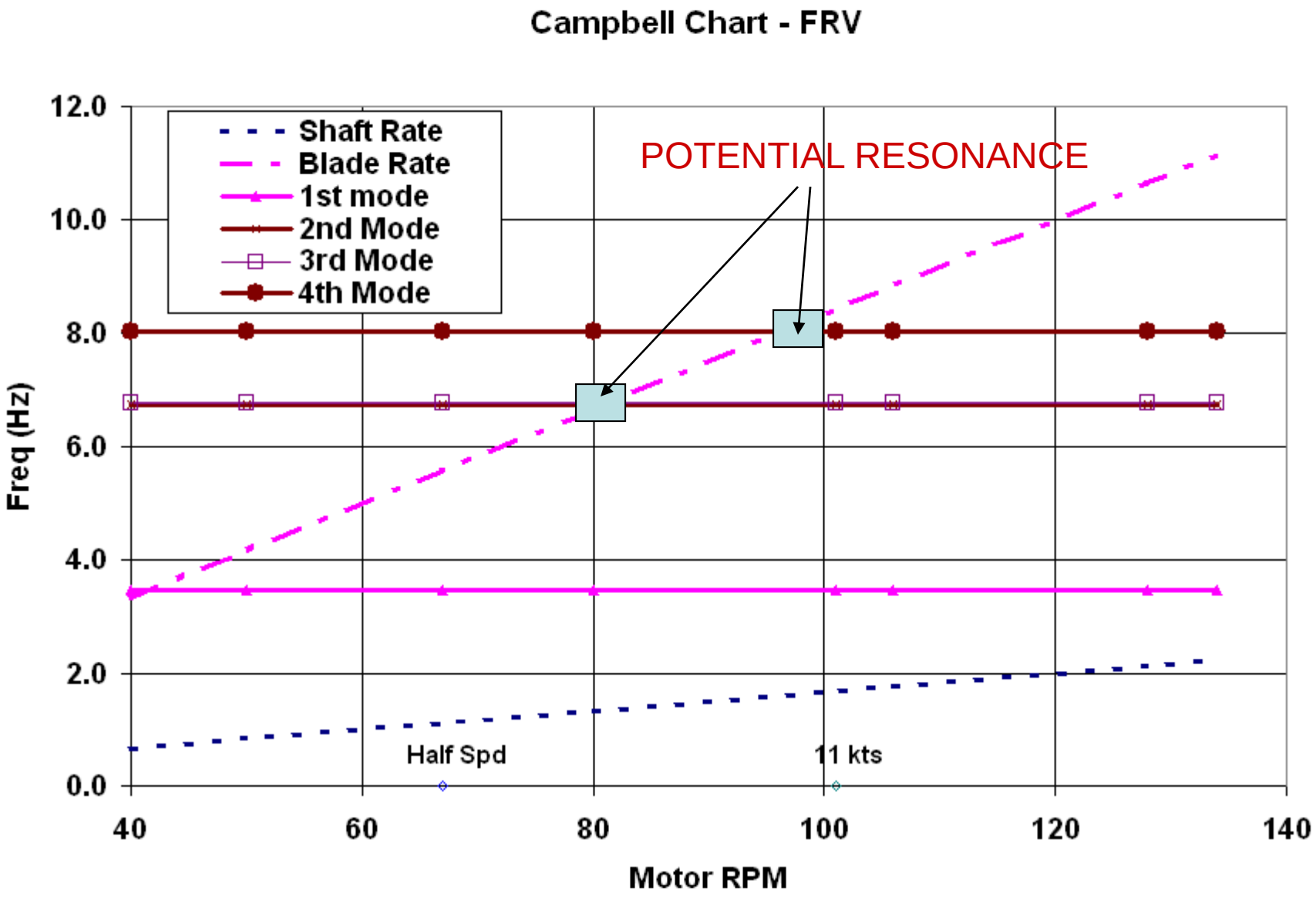


3rd Hull Mode = 8 Hz

Transverse Bending






Campbell Chart - FRV
Shaft Rate
Blade Rate
1st mode
2nd Mode
3rd Mode
4th Mode
POTENTIAL RESONANCE
Half Spd
11 kts
Freq (Hz)
Motor RPM
12.0
10.0
8.0
6.0
4.0
2.0
0.0
40
60
80
100
120
140

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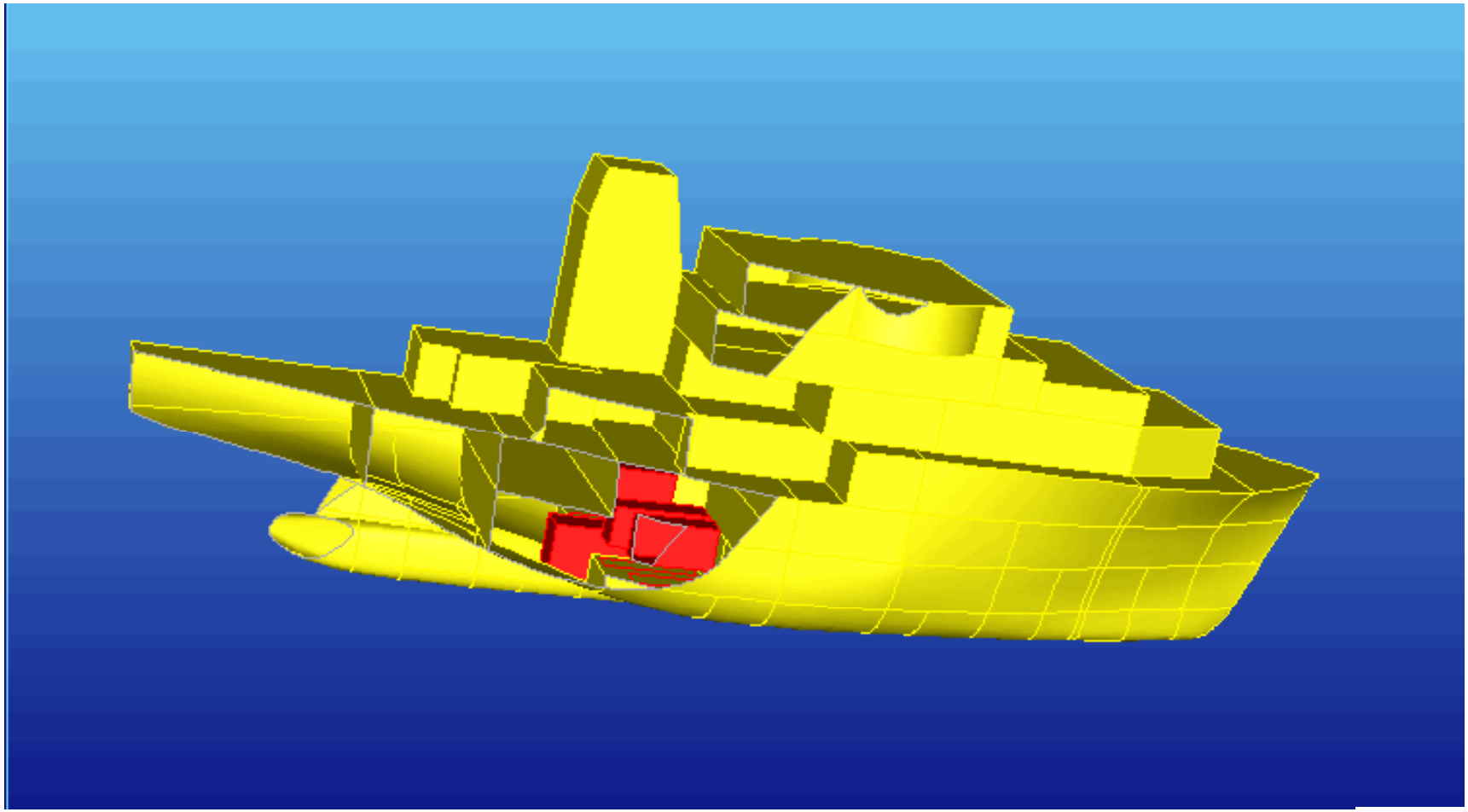
NSWCCD design -
GFI

Even a little marine growth will cause cavitation below 11 knots.

Noise Prediction Methods

- Use CAD tool to predict hull vibration from all machinery over airborne & structureborne paths (including ‘secondary structureborne’ path.
- Predict Underwater Noise by applying Hull Vibration-to-UW noise “Transfer Function” (unclassified).

Designer NOISE™ 3-D MODEL



SOURCE/PATH WEIGHTING

Receiver	Source	Transmission Path			
		Airborne	Structure-borne	Secondary Structure-borne	Total
Dry Lab	3508 Port D/G	53	42	41	53
	3508 Stbd D/G	52	38	41	52
	3512 Port D/G	55	39	44	56
	3512 Stbd D/G	54	35	43	54
	DC Motor	26	14	23	28
	All Sources	59	45	49	60

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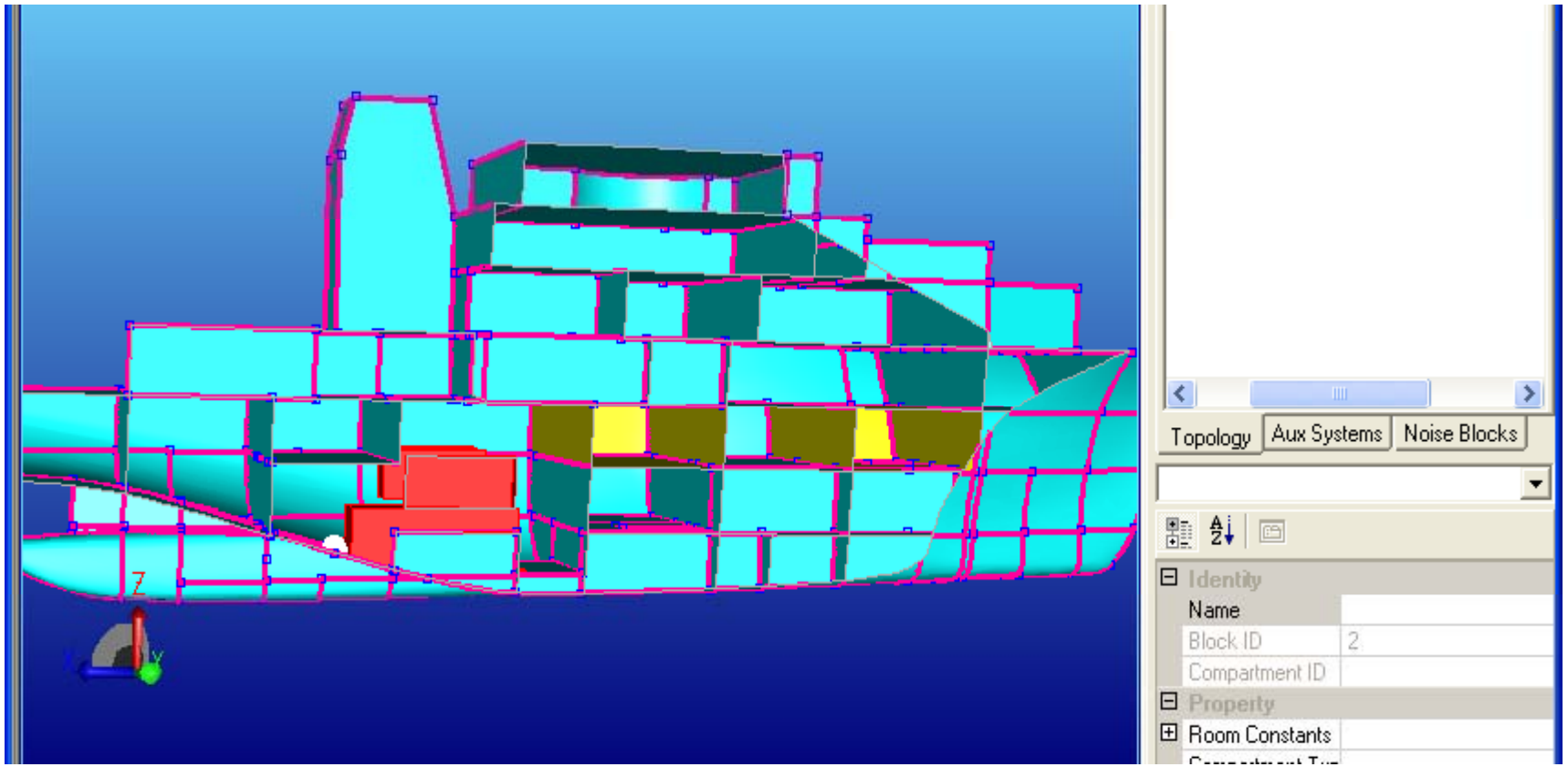
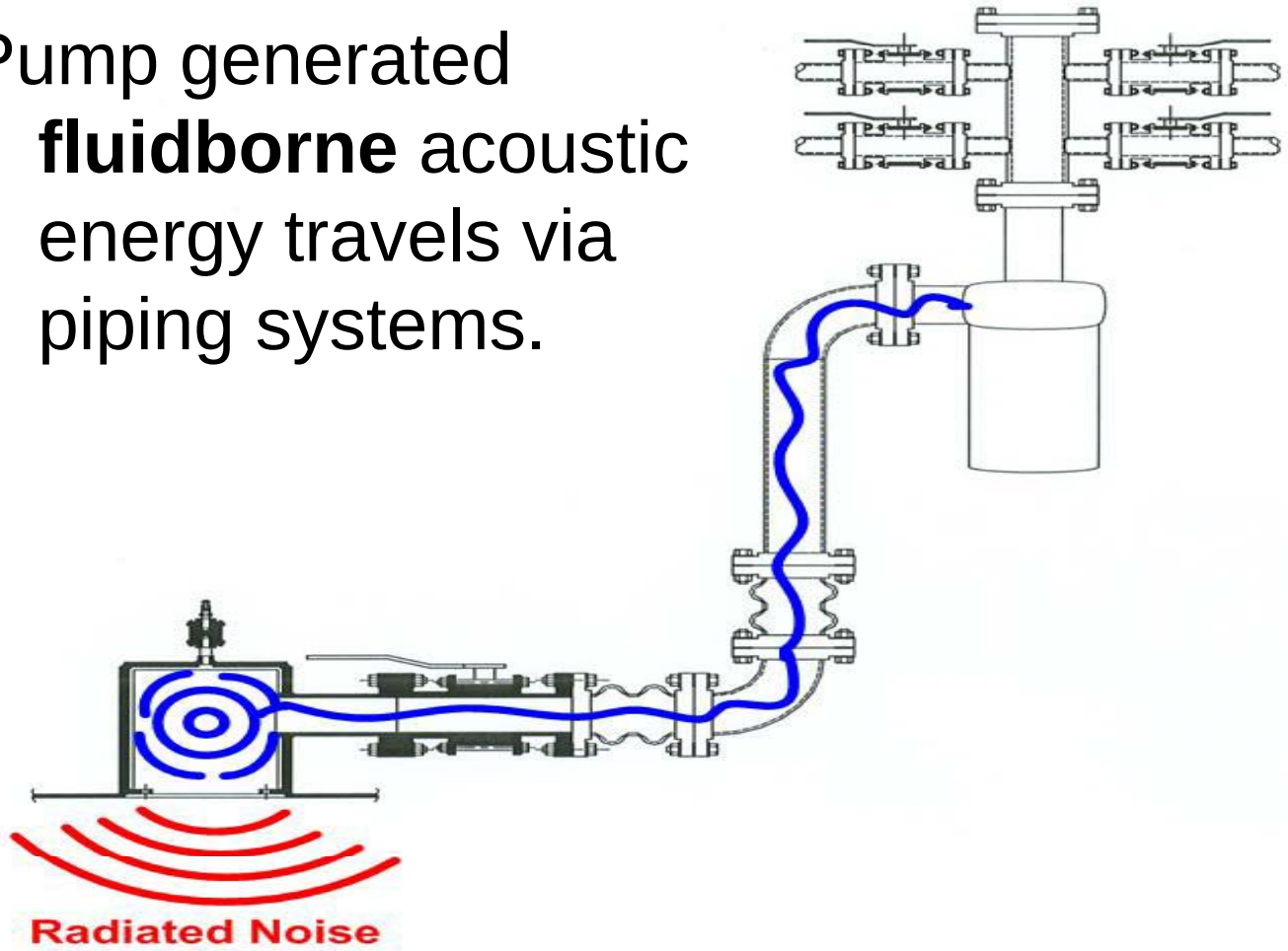
Noise Levels on FRV-40



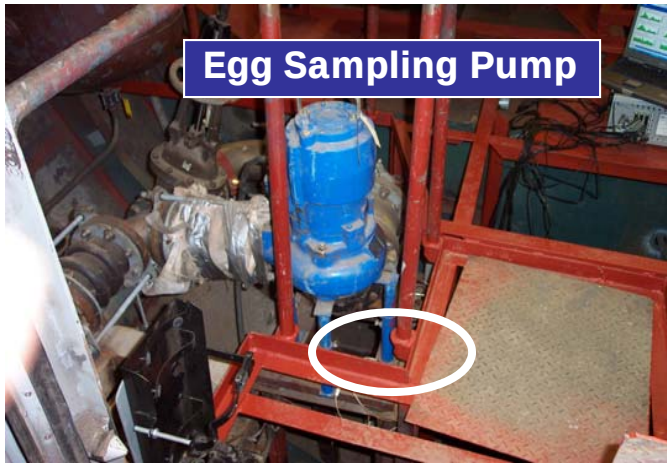
Compartment	Measured Level, dB(A)	Predicted Level, dB(A)
Aft Staterooms	58	56
Forward Staterooms	51	49

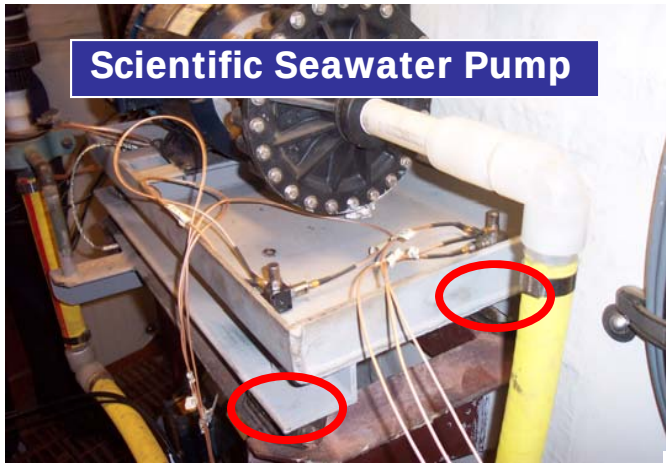
Sea Connected Systems – FluidBorne Noise

Pump generated **fluidborne** acoustic energy travels via piping systems.

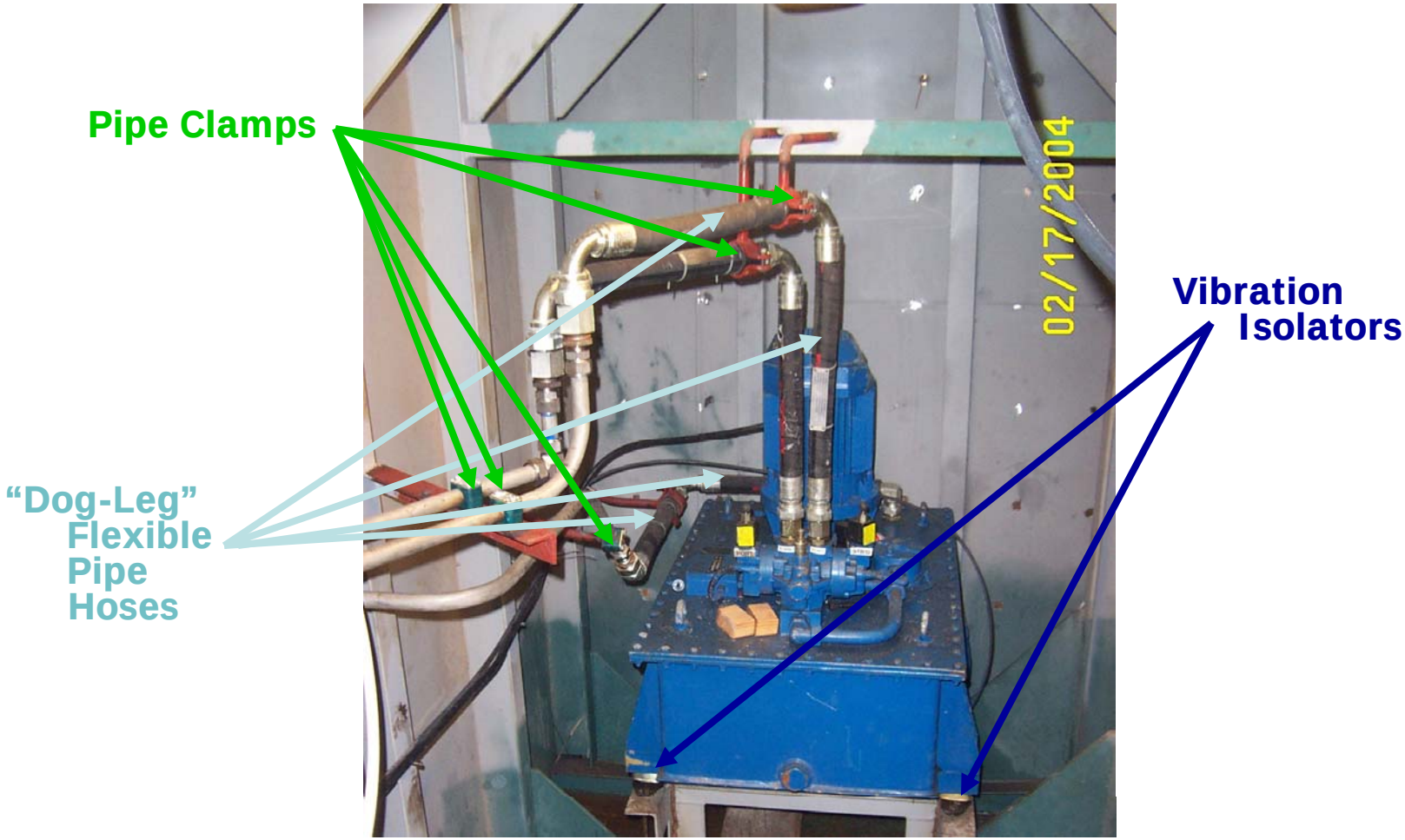


FRV-40 – Isolated Auxiliaries





FRV-40 – Typical Isolation System



FRV-40 – Pipe Clamps

HOW DID THIS HAPPEN?!?

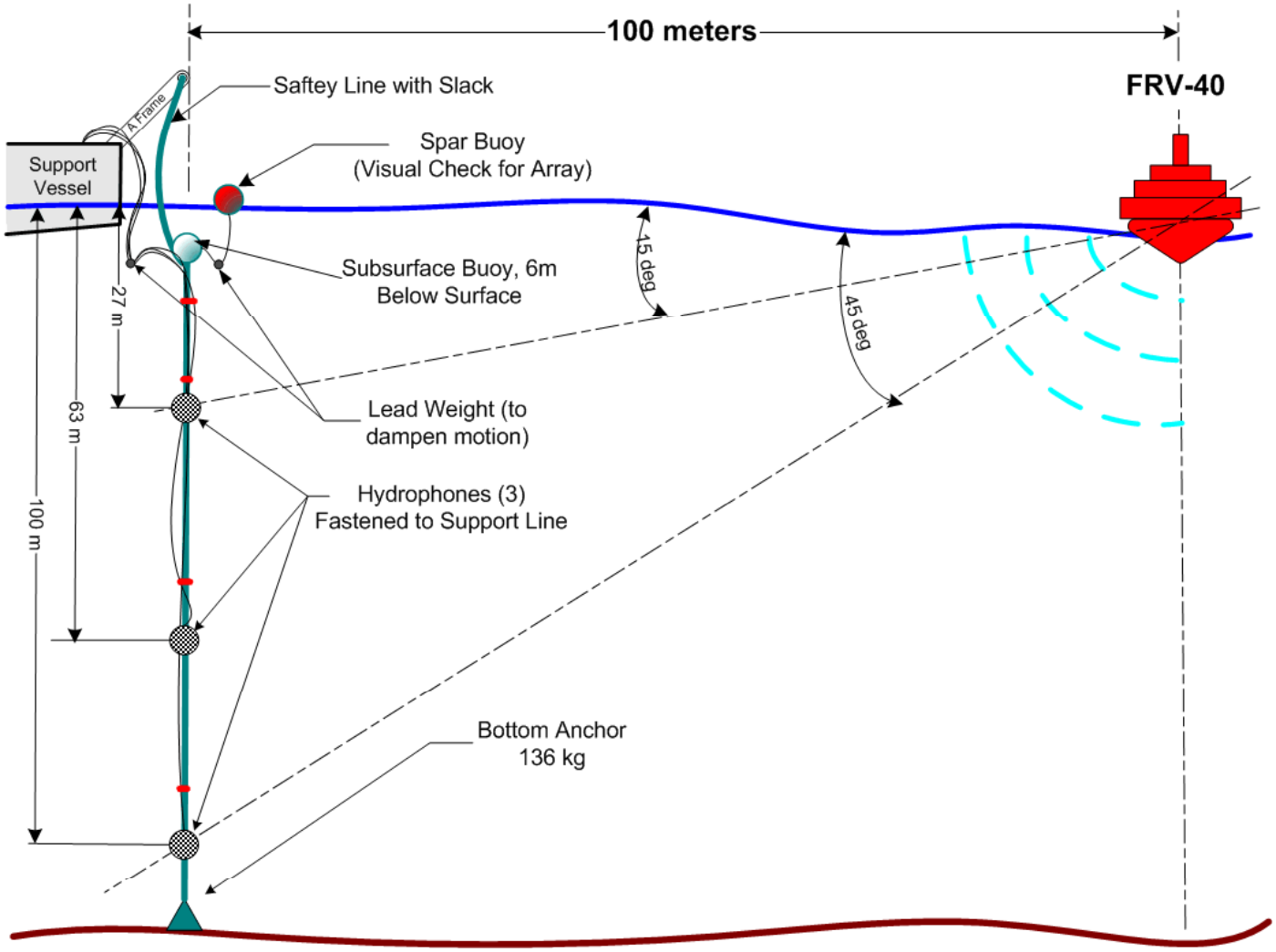

02/17/2004


02/16/2004

FRV-40 – Required Testing

- Machinery Vibration in Factory
- Machinery Noise in Factory
- Machinery Vibration in Ship
- Airborne Noise in all Ship Spaces
- Structural Vibration in Ship (wide)
- Sonar Self Noise
- Underwater Radiated Noise
- NB: New ASA S12.64-2009 meas't std.

RADIATED NOISE TEST



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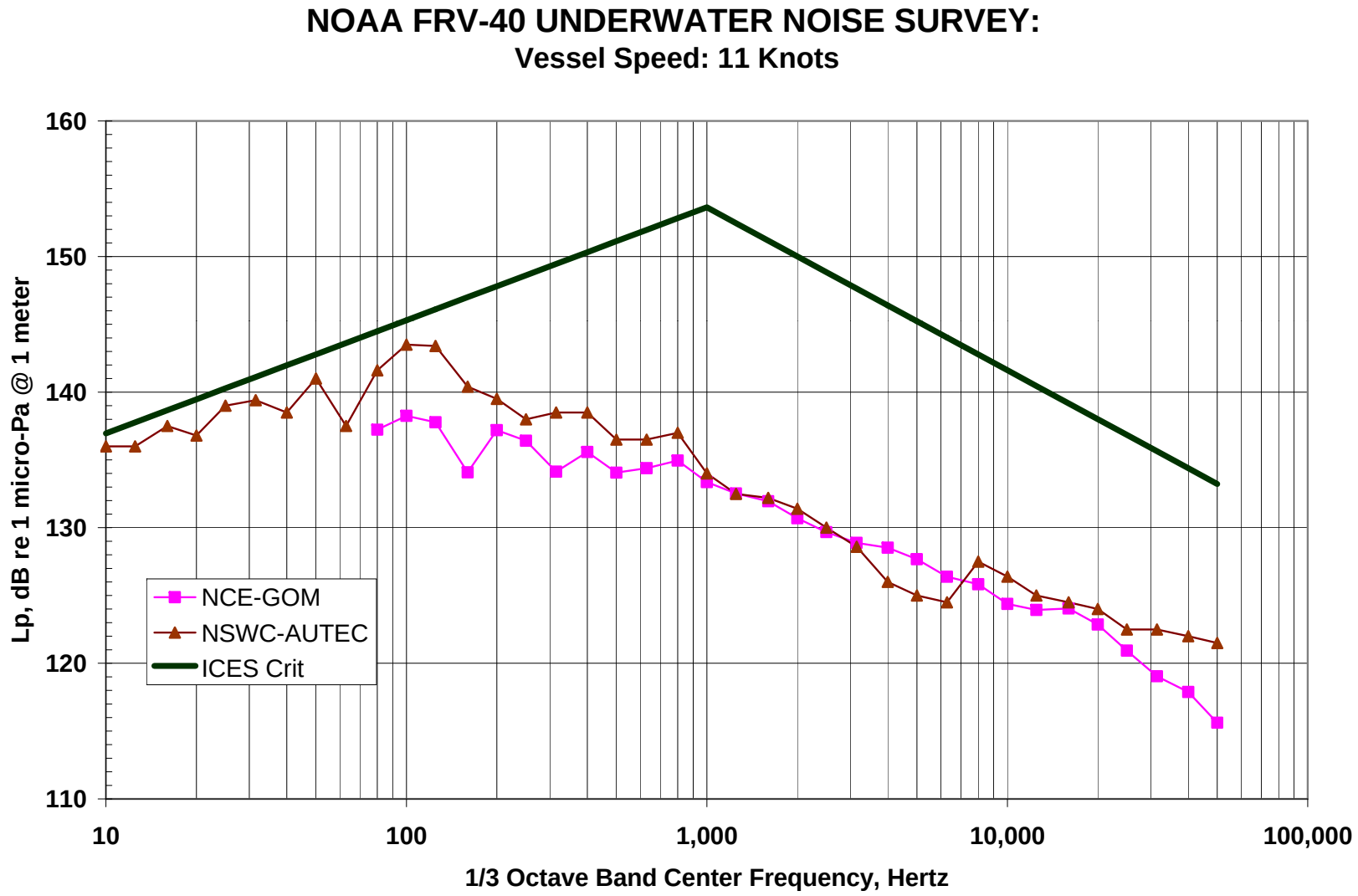
RADIATED NOISE SIGNATURE



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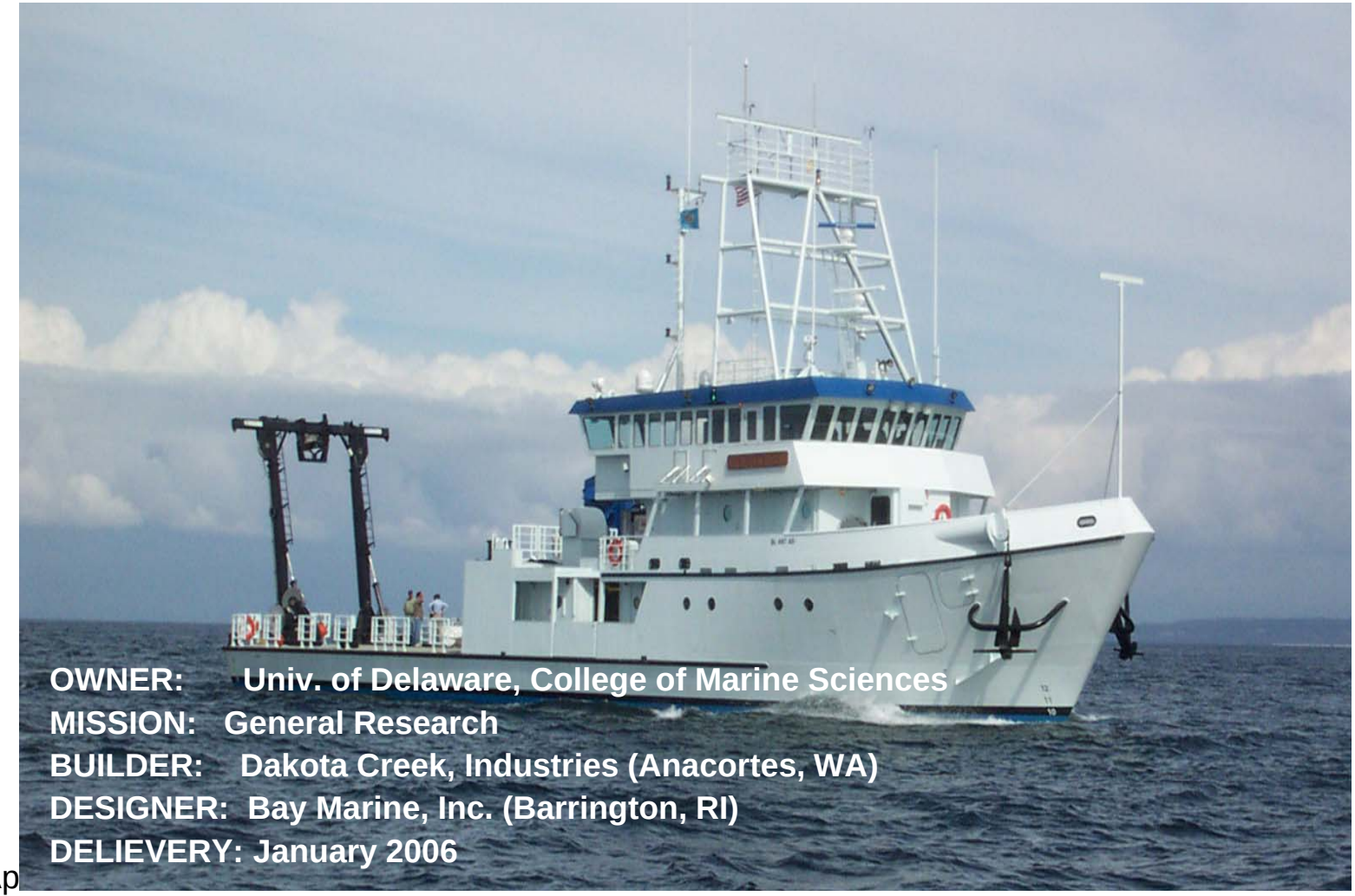
R/V HUGH R. SHARP

University of Delaware

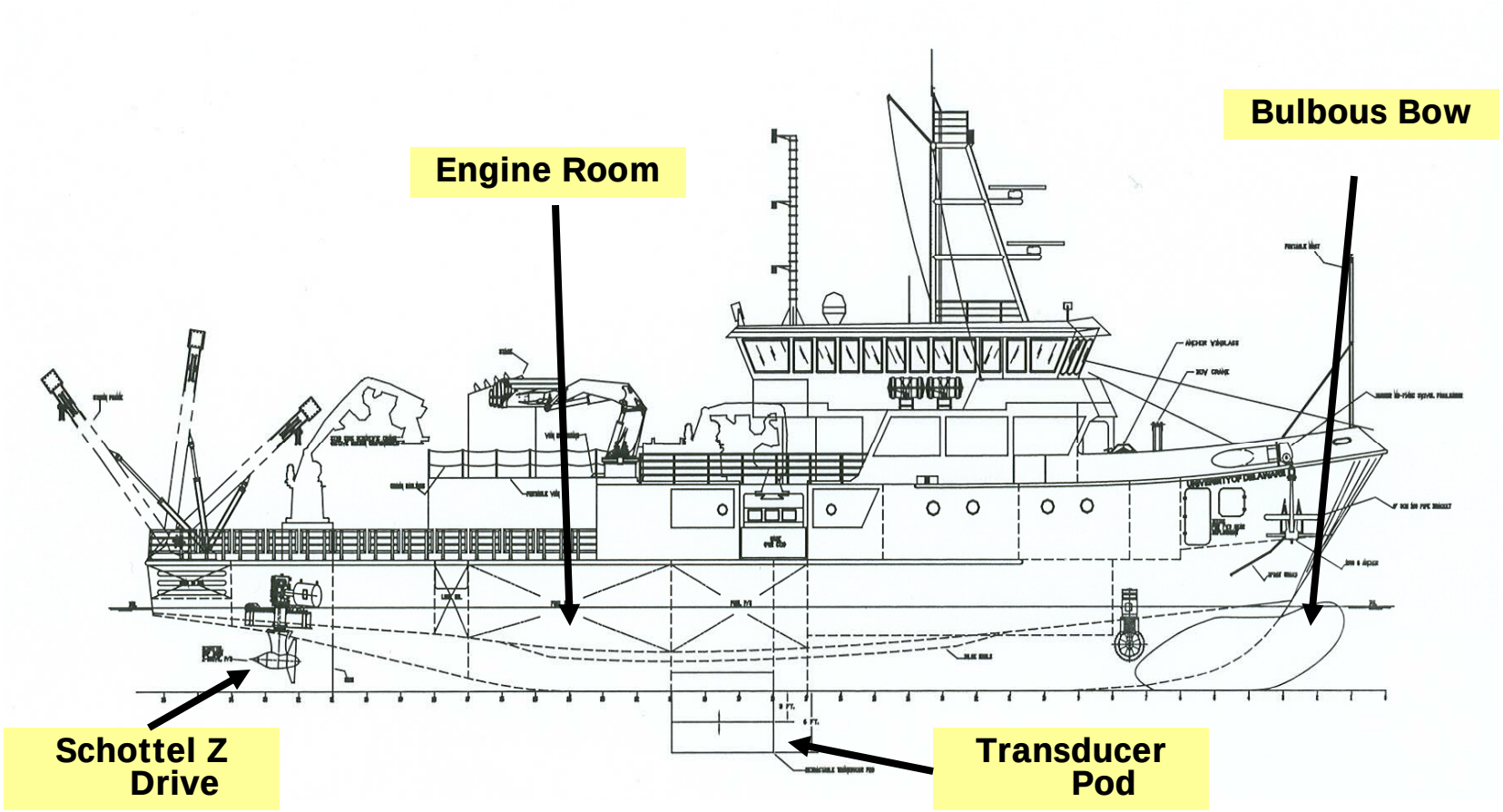


Ap

R/V SHARP – Design Features

- Meet ICES Limit at 8 knots
- Diesel Electric Plant
- Double Isolated Diesel Generators
- Isolated ASIR DC Motors
- Isolated Schottel Z-Drives
- Isolated Auxiliary Machinery
- Retractable Transducer Pod

R/V SHARP - Profile



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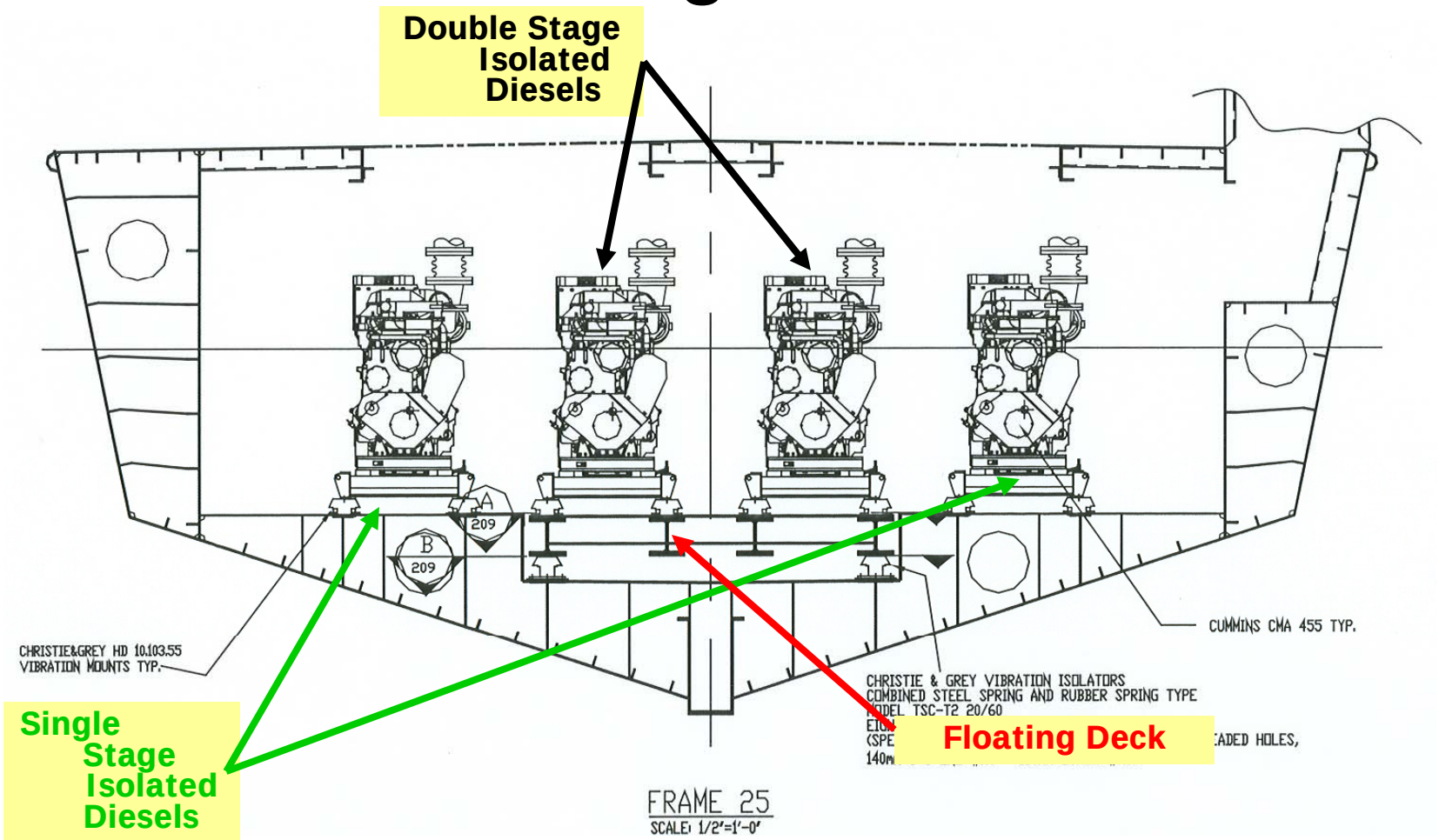
R/V SHARP – Floating Deck Diagram



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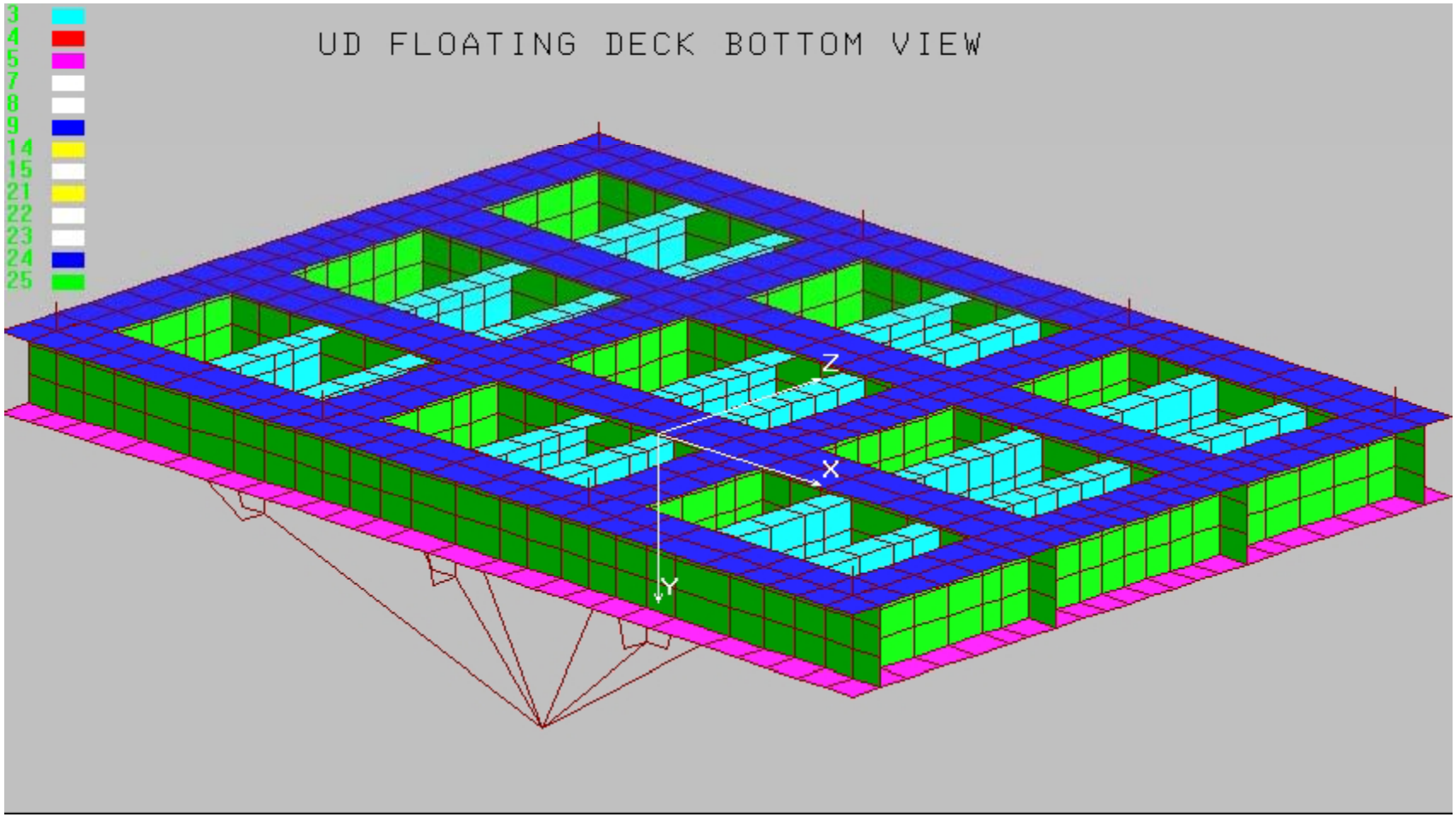

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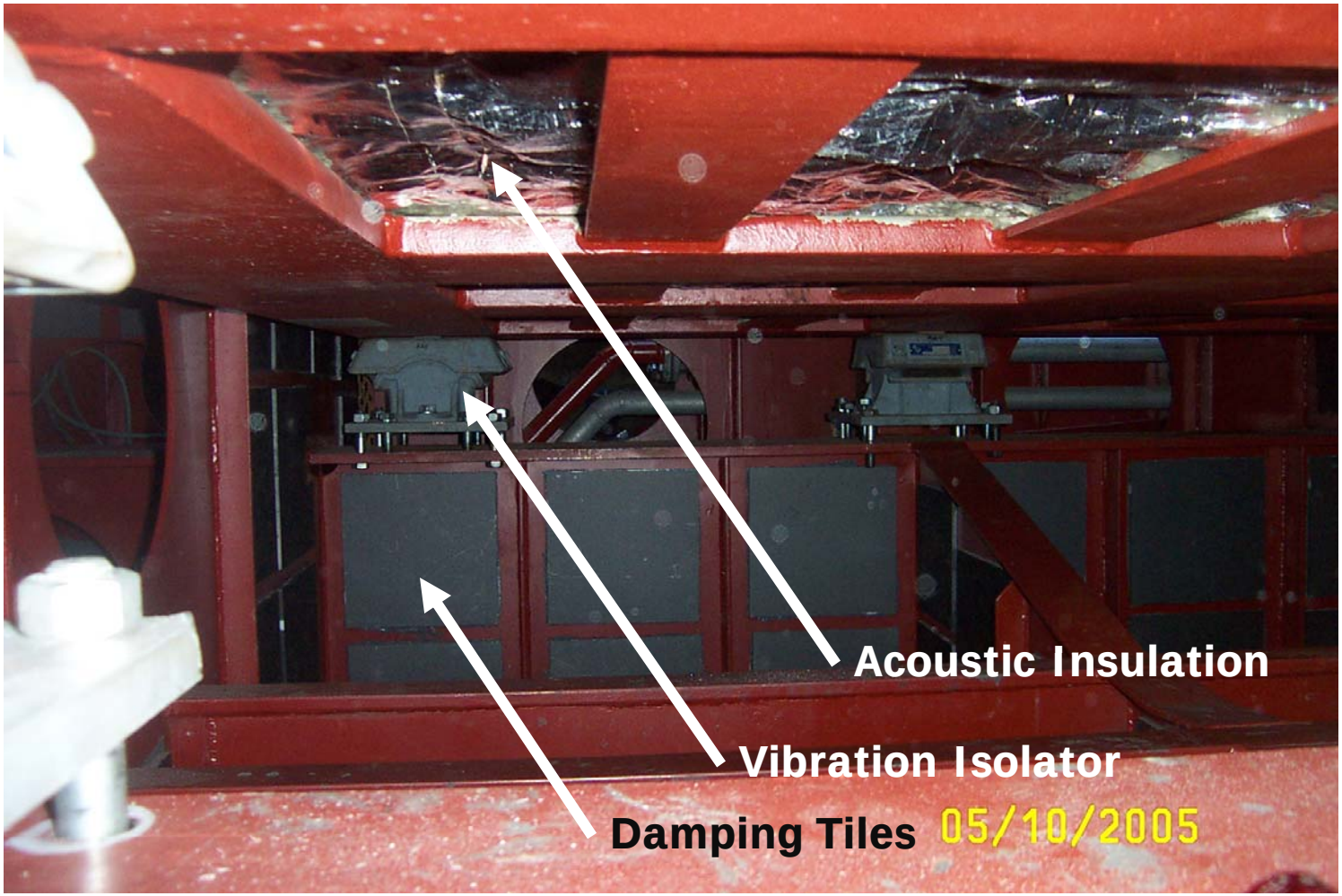
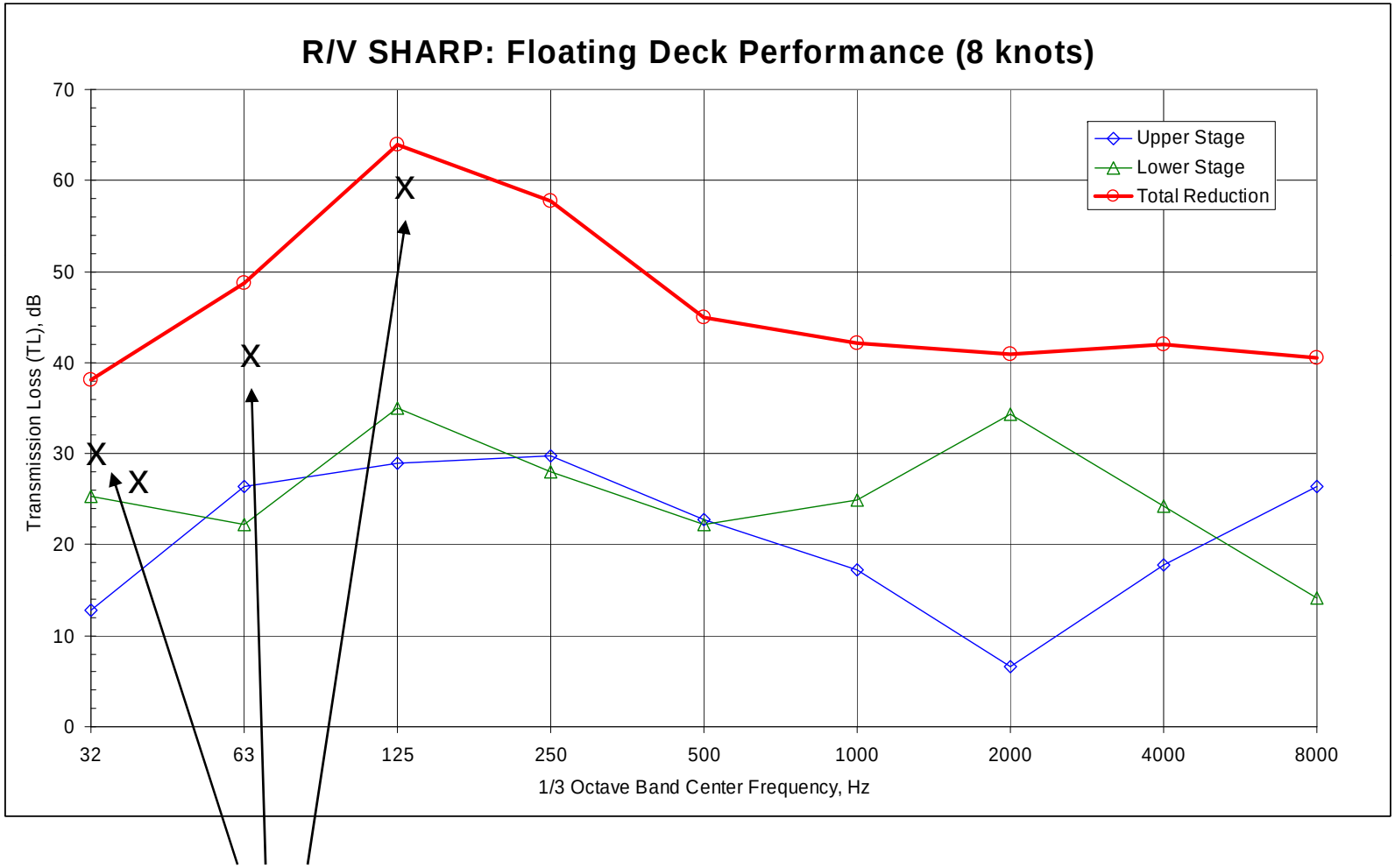
R/V SHARP – Floating Deck



R/V SHARP – Floating Deck Transmission Loss (TL)



PRV Mount Performance

R/V SHARP – Damping Tiles

Summary

- Comprehensive acoustic control plan needed
  - Design
  - Construction
  - Testing
- Use of an accurate 3-D noise modeling, empirical and FEA tools allowed:
  - treatment types and areas of coverage to be optimized
  - thereby reducing weight, cost and space required and Total Cost of Ownership.
- Result - vessels with low acoustic signature and low noise/vibration onboard environment

Things to consider

- Require the use of expert with direct experience with acoustic design of FRVs
- Require the use of CAD acoustic modeling such as Designer NOISE or equal
- Require Noise & Vibration Control Plans and detailed analysis, addressing ice strengthening
- Define criterion (NB v TOB), deliverables, test verification methods, penalties/incentives
- Check weights of critical items
- QA – construction inspections