



SEA Applied to Machinery Design at Trane



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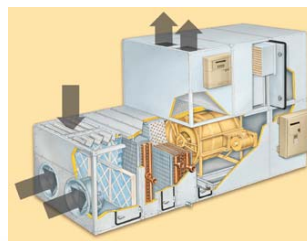
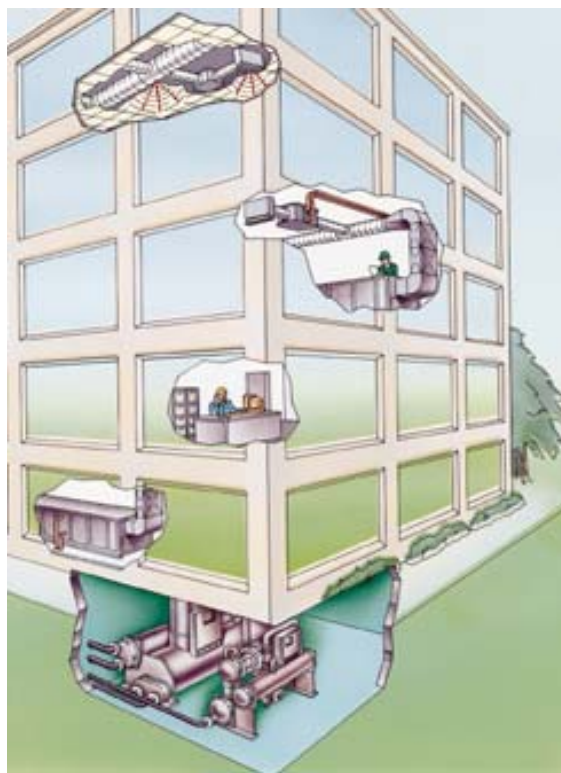


Overview

- **Introduction**
 - Trane and our design environment
- **SEA as a Concept Design Tool**
 - Scroll Compressor application
 - Water Chiller application
- **Closing Comments**

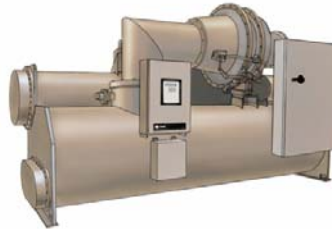


Trane Makes HVAC Equipment



Air Handlers

- fans
- motors
- controls



Water Chillers

- water cooled
- air (fan) cooled



Compressors

- centrifugal
- screw
- scroll
- reciprocating

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Wide range of products, sizes, materials and noise sources



Our Design Environment

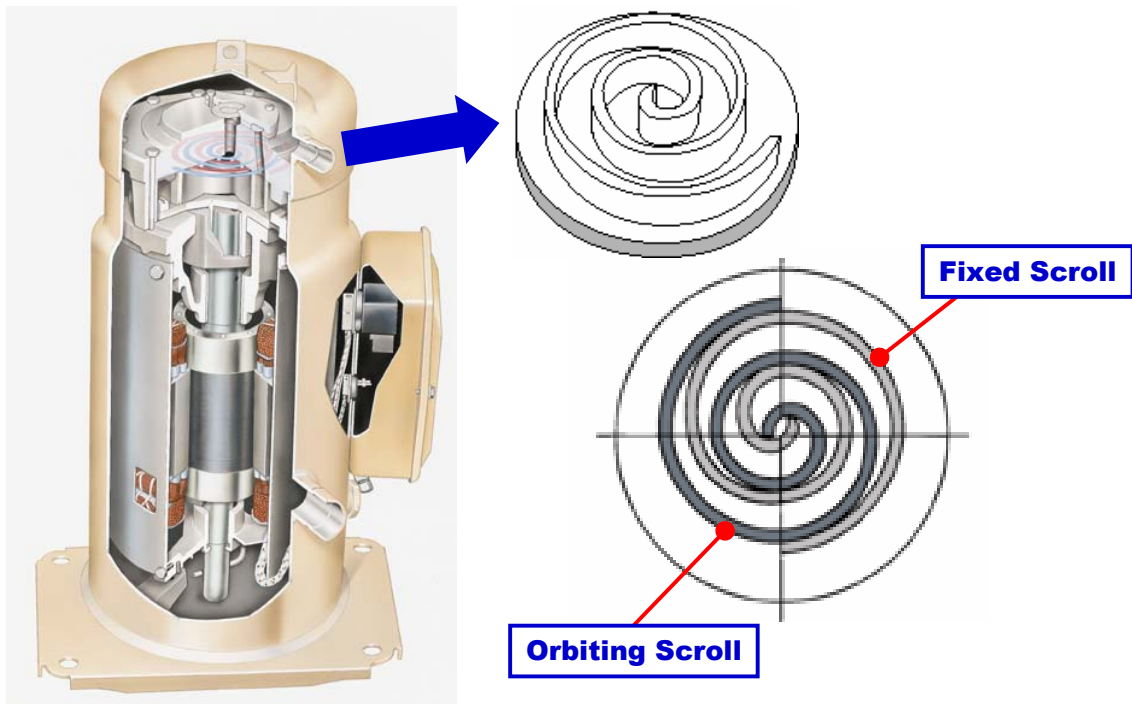
- **Noise increasingly important to sales**
 - ... and current products are not always quiet enough
- **Short design time requirements**
 - We need to think out of the box, but we must do it quickly
- **Competitive pressures in a global market**
 - Cost control
 - designs must use parts and materials efficiently
 - standardization of suppliers
 - High reliability assumed to be a given
 - ... but it's not!

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Technology -- noise prediction tools -- key to success



SEA as a Concept Design Tool: Scroll Compressor Application

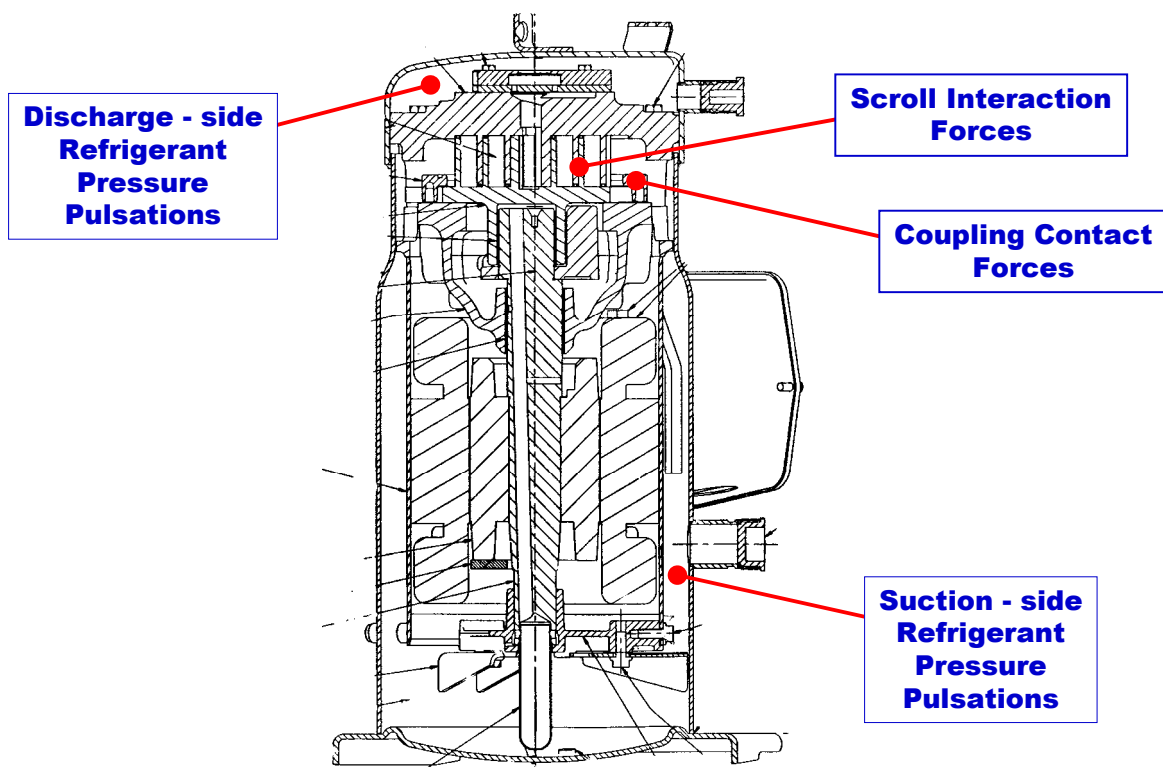


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Key noise source in small chillers and air handlers



Scroll Compressor Excitation



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Multiple independent but correlated excitation sources



Understanding Vibration & Noise Transmission Mechanisms

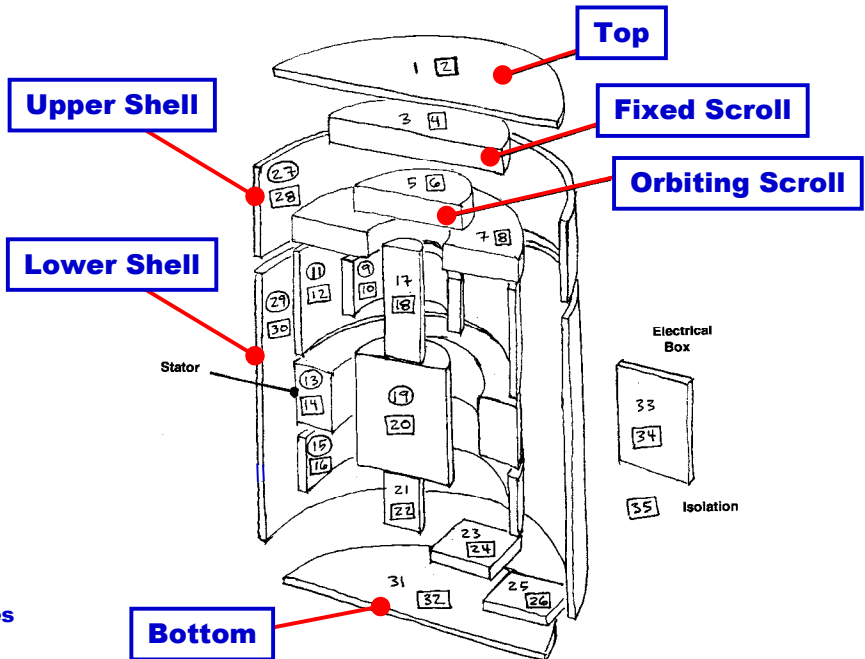
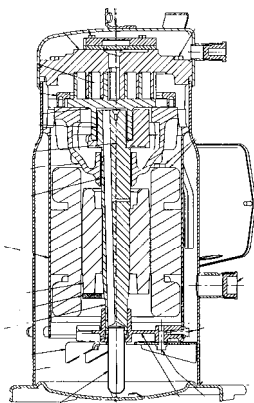
- **Need to separate noise due to each noise source**
 - Noise control approach -- and cost -- different for each
- **Separating mechanical and fluid effects by test is difficult**
 - Various forces and pressures are correlated
- **System vibration & noise model needed for:**
 - Predicting the effects of design changes
 - Interpreting the behavior of an operating unit

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System model useful for both design and diagnostics



SEA Model of Scroll Compressor



SEA Mode Groups:

xx Plate Bending modes

xx Inplane modes

xx Cylindrical bending modes

xx Acoustic modes

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Reference: '98 Purdue Compressor Conference Paper



Specifying Excitation Strengths

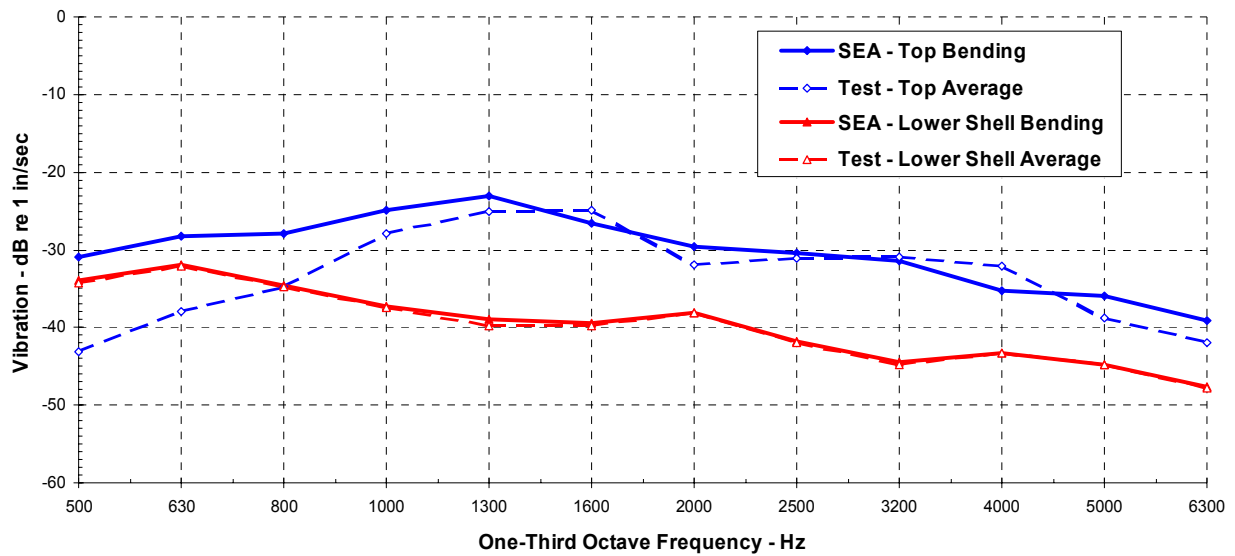
- **The SEA model and operational tests together show that:**
 - The Top is controlled by discharge pulsation
 - Measured internal level applied as excitation
 - Vibration of the Lower Shell is controlled by scroll force excitation
 - Forces not directly measurable
 - Back-calculate forces from measured lower shell vibration
 - Suction pulsation excitation is the least important noise source
 - Measured levels about 20 dB below discharge

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Model used to infer scroll forces



Top and Lower Shell Vibration Test vs. SEA



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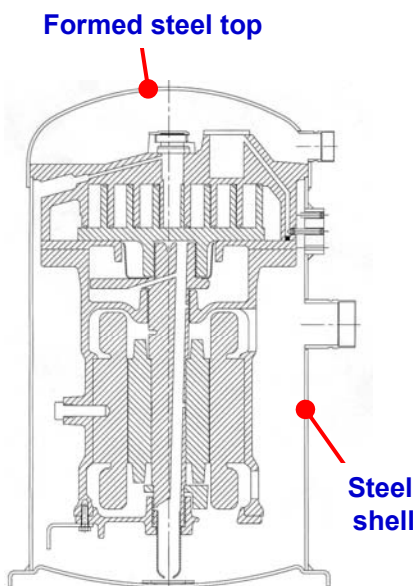
Current production design used to benchmark model



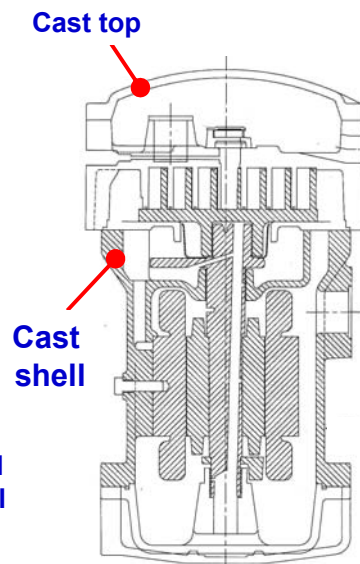
Scroll Compressor Concept Evaluation

Alternate Configurations

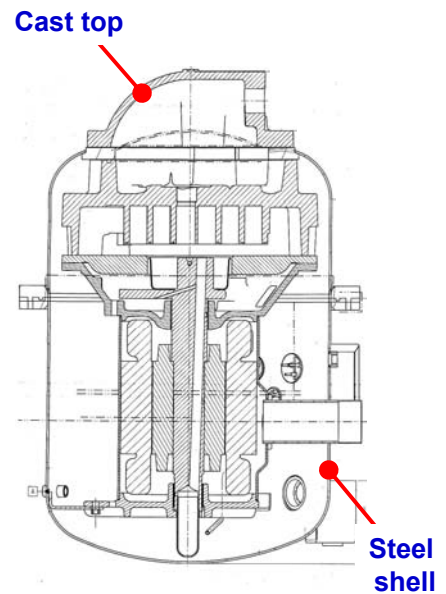
AMERICAN
STANDARD
COMPANIES



Welded Shell
(1/8" – 5/8" wall)



Cast Shell
(1/2" ave wall)



Mixed Shell

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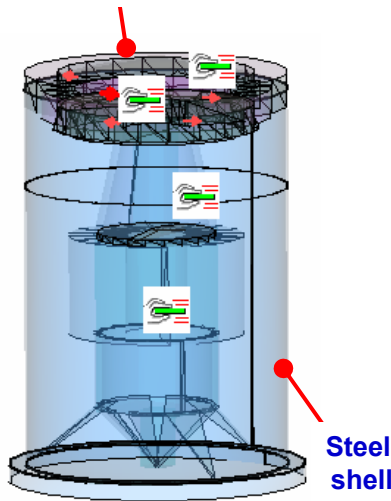
Key Question: how do these designs compare w.r.t. noise?



Next Generation Scroll Compressor Alternate Configurations – SEA Models

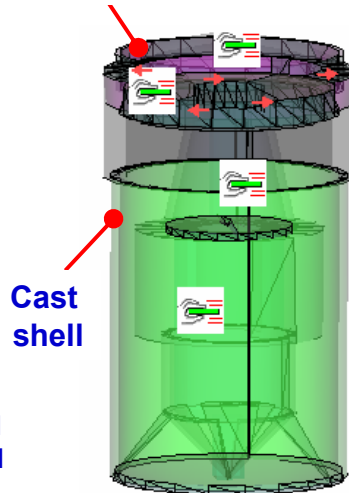


Formed steel top



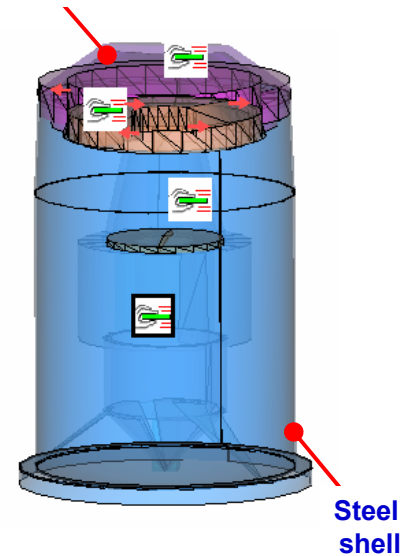
Welded Shell
(1/8" – 5/8" wall)

Cast top



Cast Shell
(1/2" ave wall)

Cast top



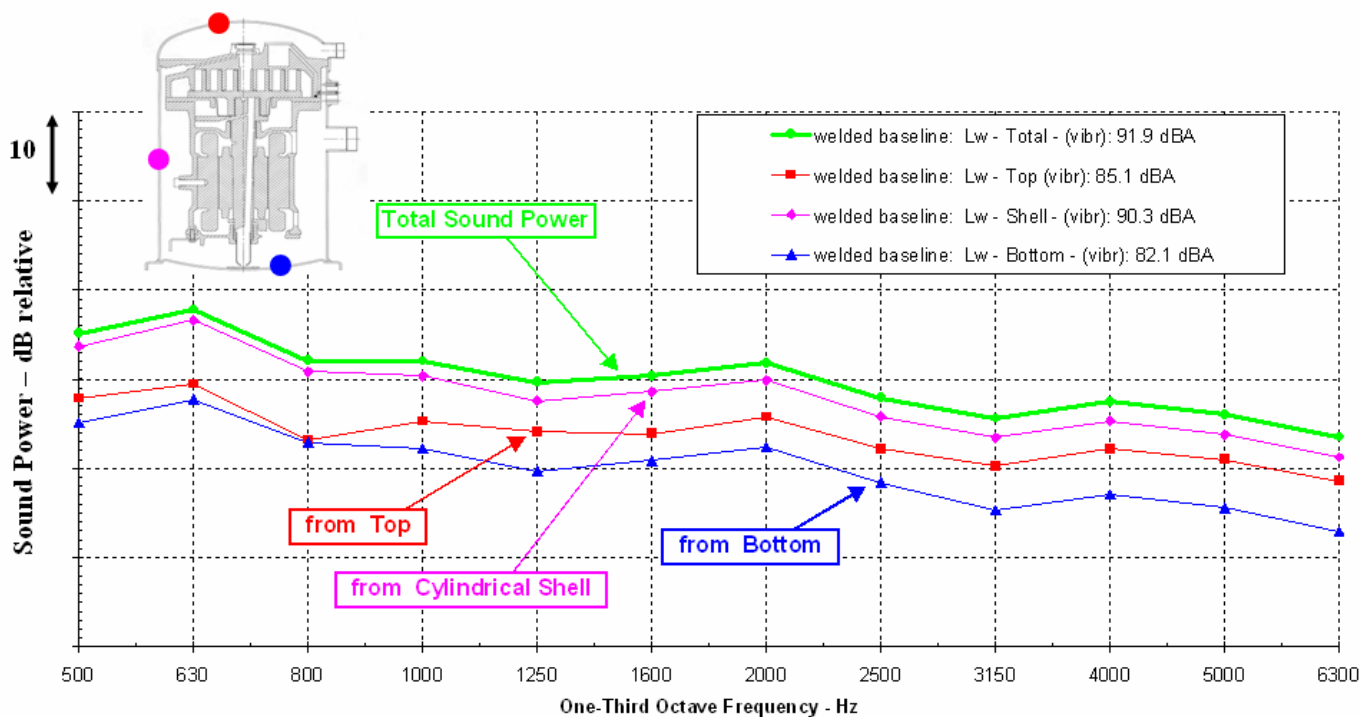
Mixed Shell

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SEA models developed from rough design sketches



SEA Results: "Welded Shell" Design Sound Power Radiation

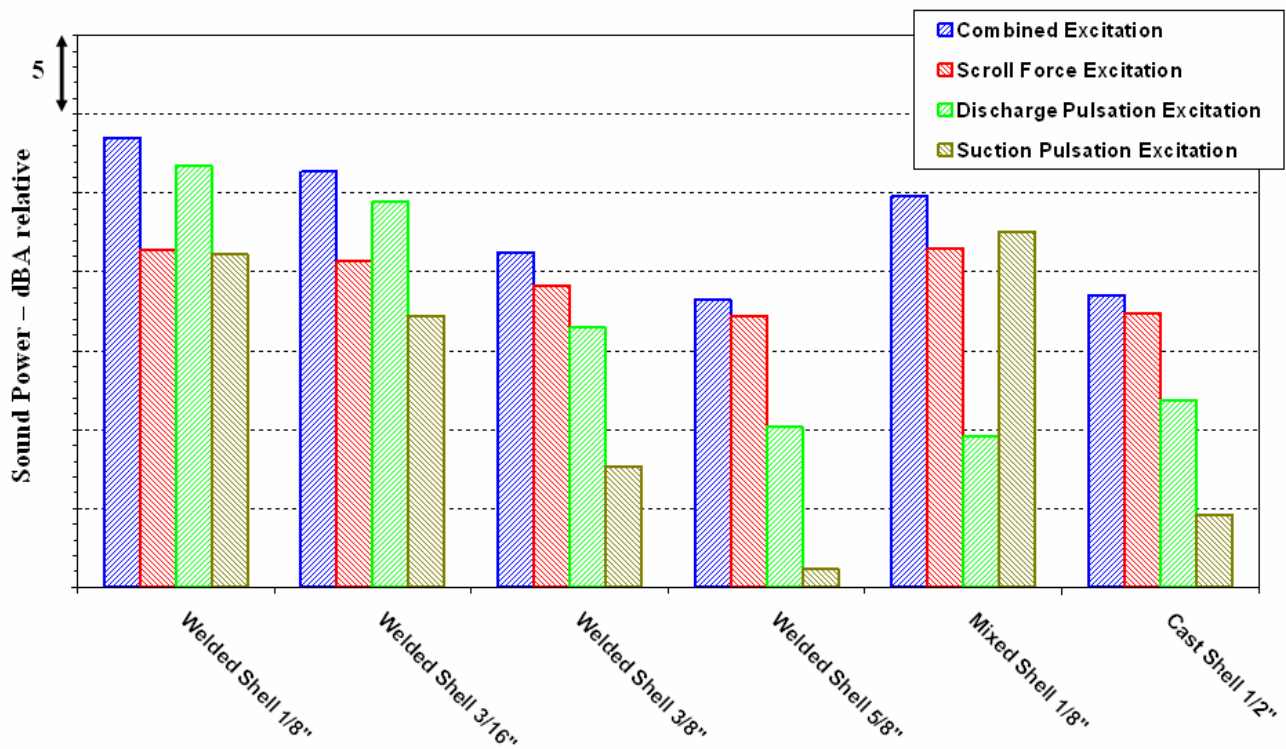


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Noise radiation quantified across compressor



Overall Sound Power by SEA Various Configurations Compared

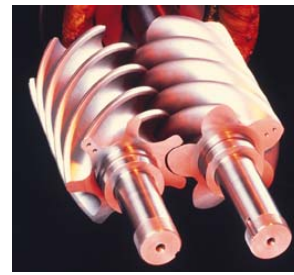


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SEA provides guidance needed for Concept Design



SEA as a Concept Design Tool: Water Chiller Application



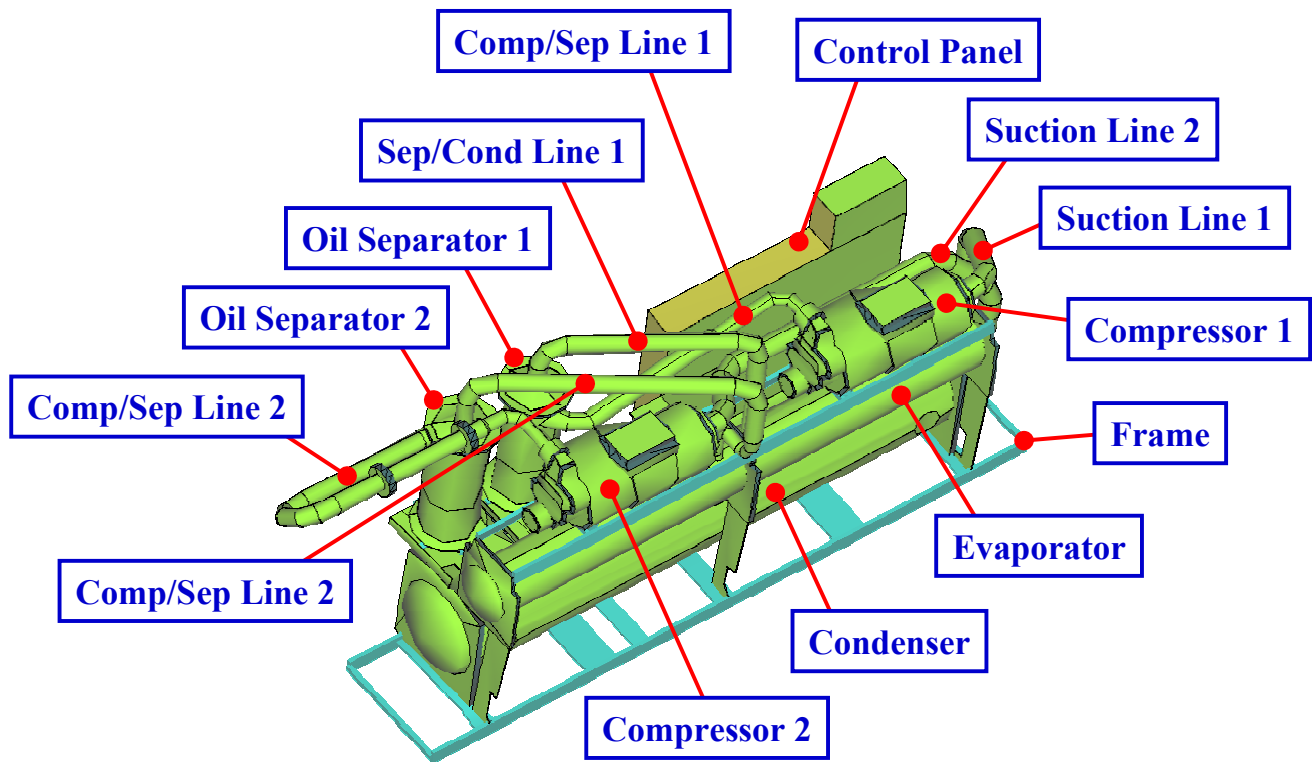
- screw compressors
- refrigerant lines
- oil separators
- control panel
- evaporator
- condenser

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Key question: how to configure the system for low noise?



Screw Chiller SEA Model

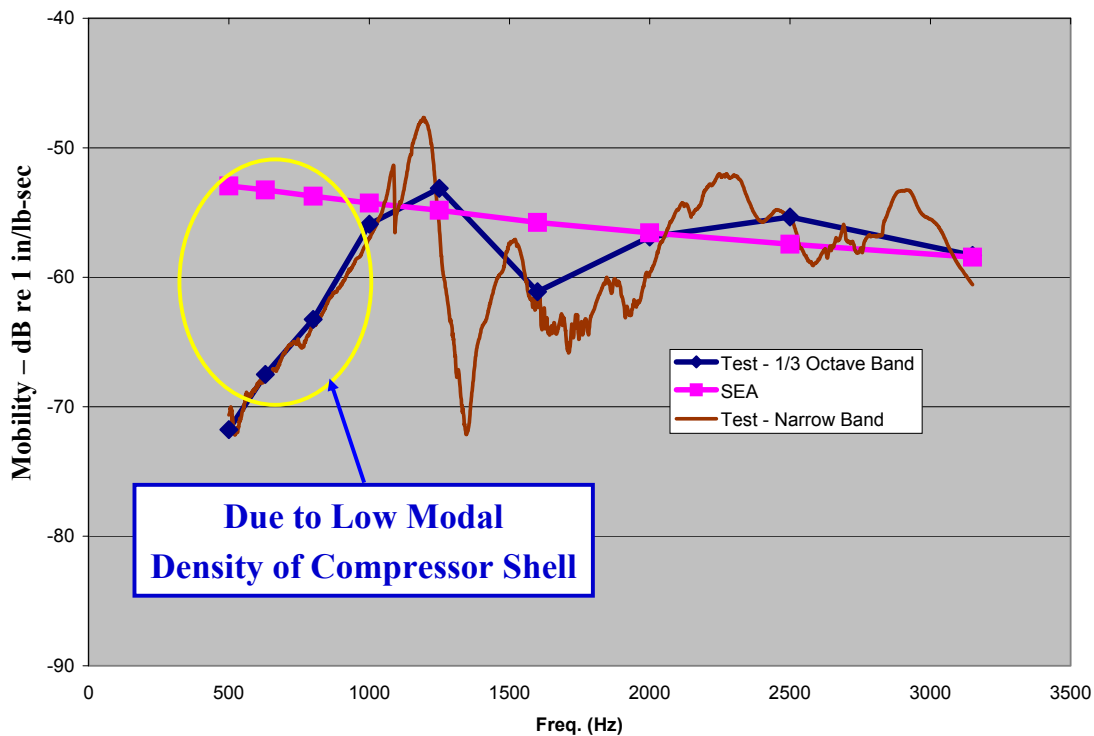


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SEA used to tailor noise radiation from components



Drive Point Mobility: Test vs. SEA Compressor Housing

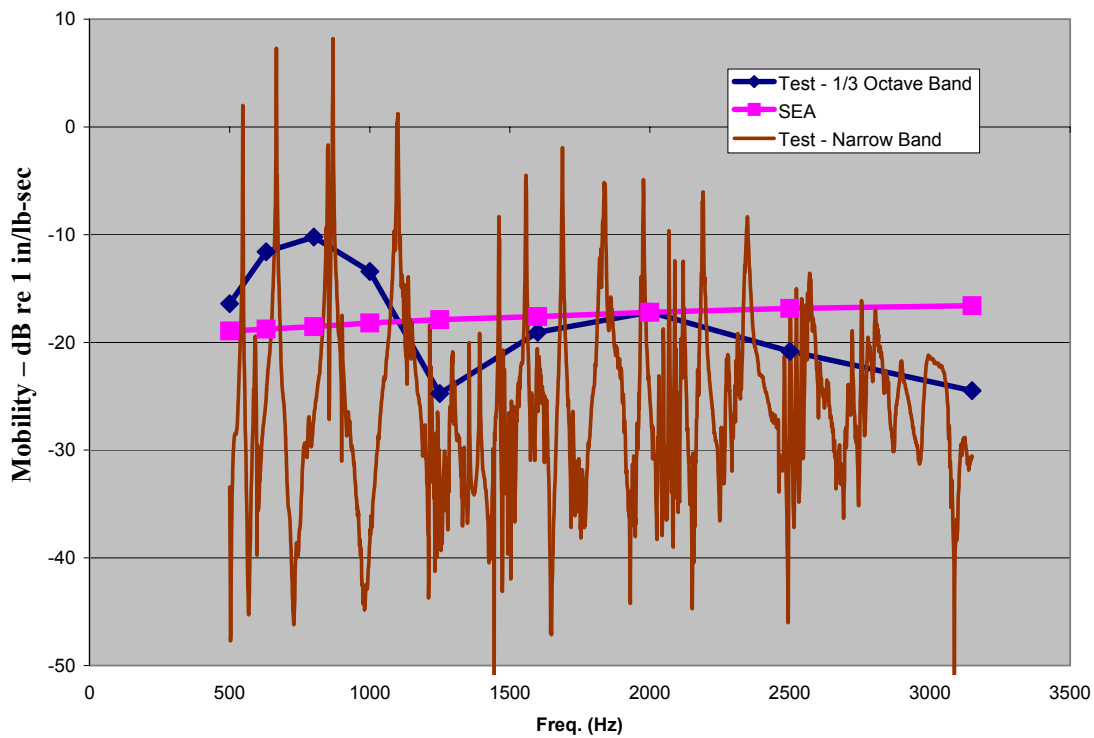


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Compressor SEA and test mobilities comparable > 1 KHz



Drive Point Mobility: Test vs. SEA Oil Separator – to - Condenser Line

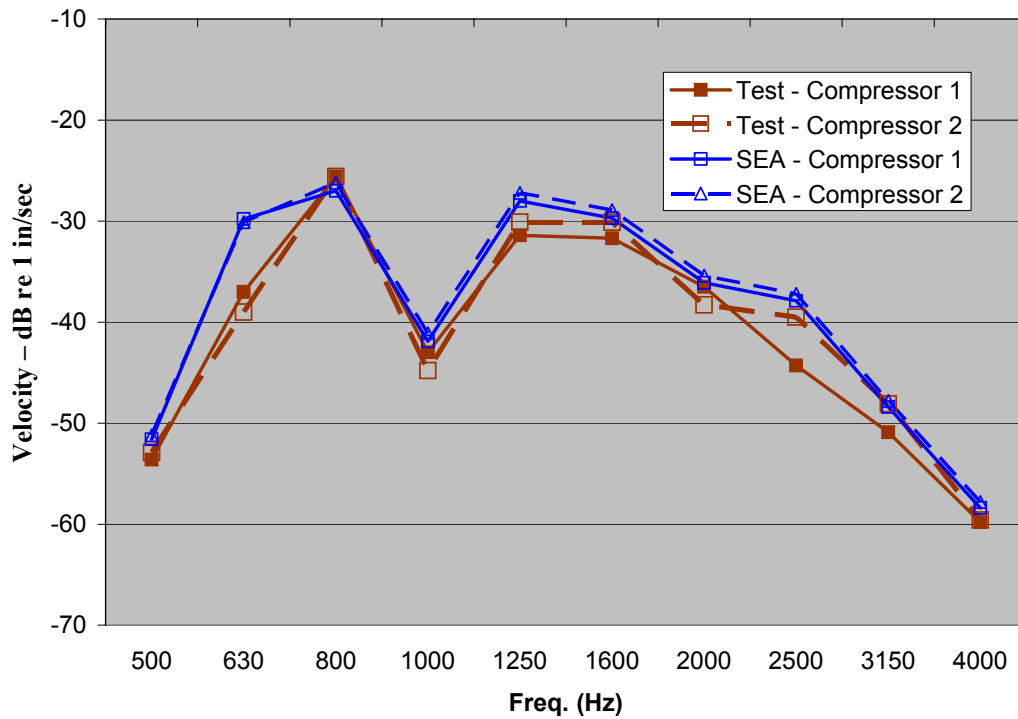


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Discharge Line SEA mobility comparable to test



Operational Vibration: Test vs. SEA Compressors

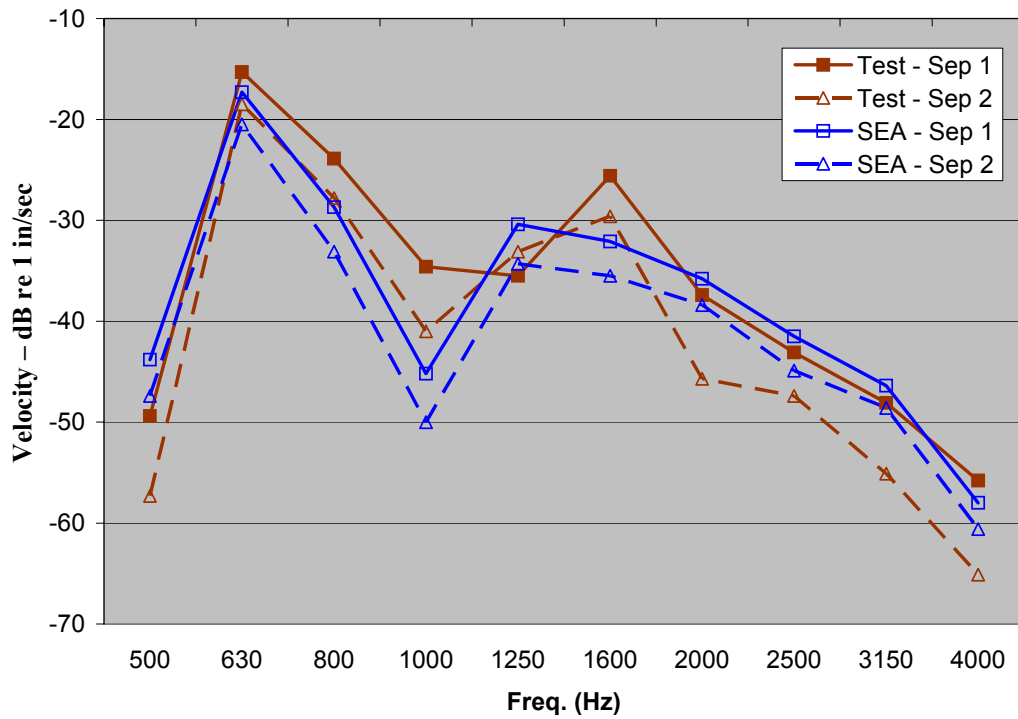


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SEA forces back-calculated from compressor vibration test



Operational Vibration: Test vs. SEA Oil Separators

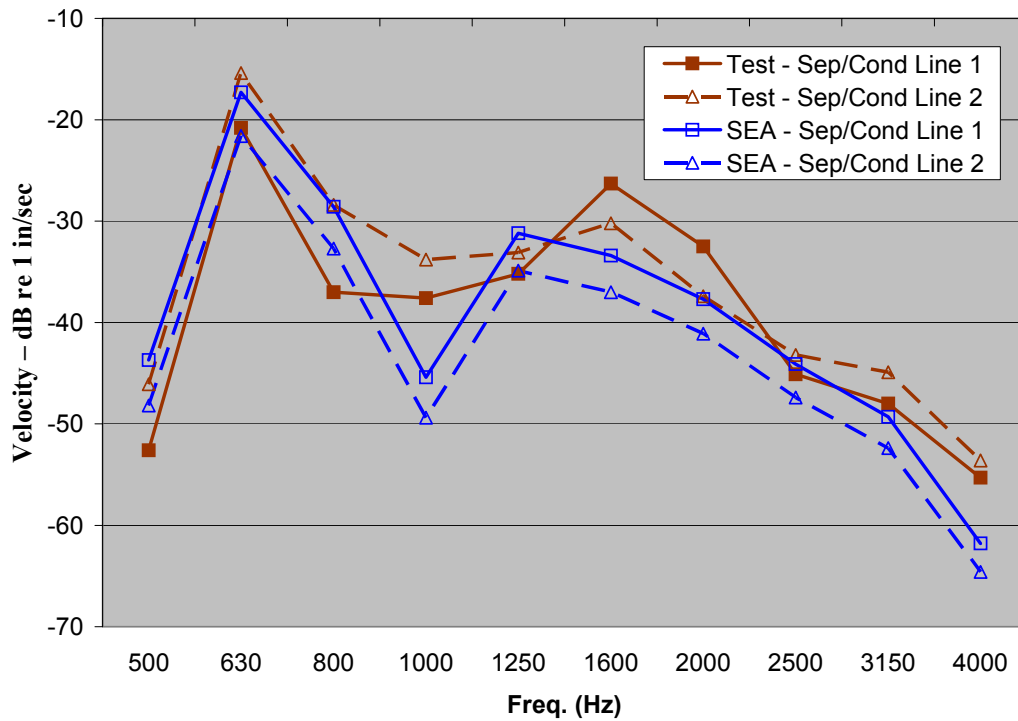


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SEA and test show similar vibration of oil separators



Operational Vibration: Test vs. SEA Oil Separator – to - Condenser Lines

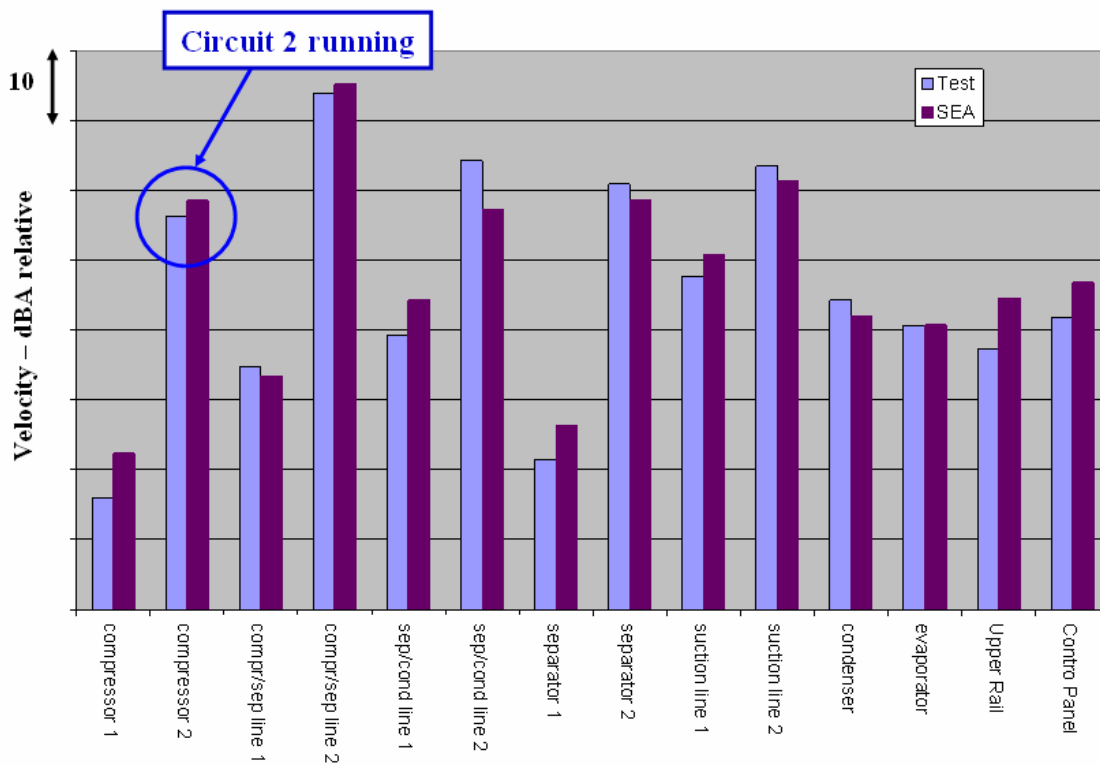


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SEA and test show similar vibration of lines



Operational Vibration: Test vs. SEA Overall Velocity for All Components



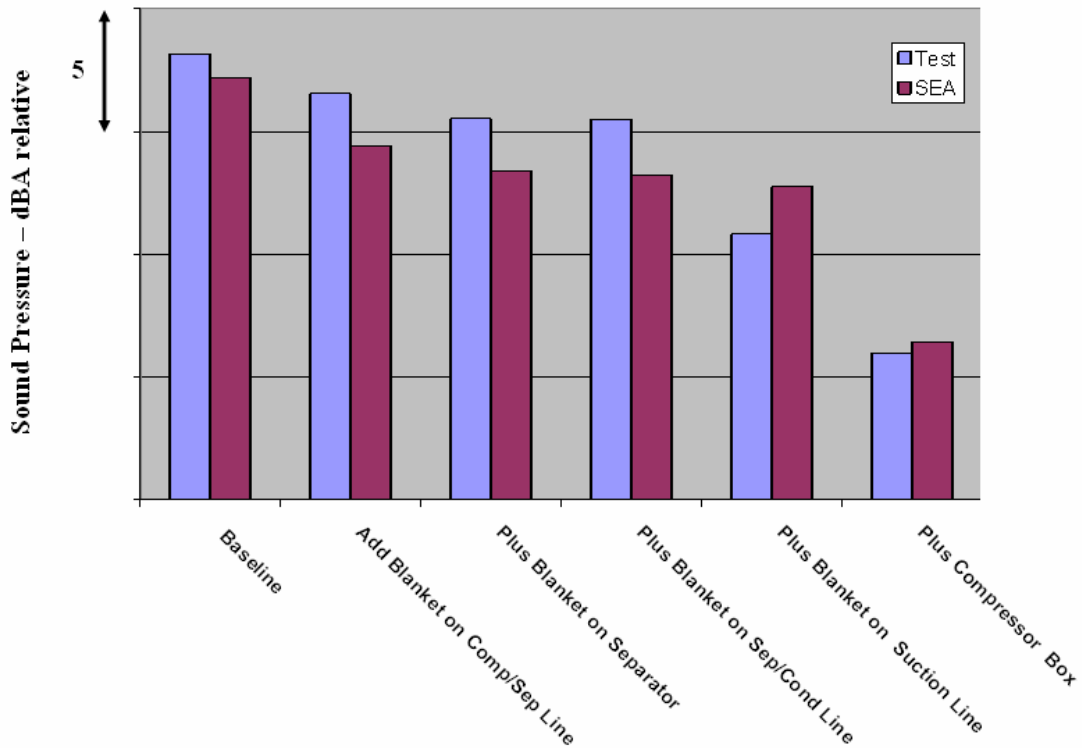
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SEA and test vibration comparable -- across 50 dBA range



Acoustic Treatment Effects: Test vs. SEA

Overall Sound Pressure – Treatment Effects



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SEA noise predictions and treatment effects reasonable



SEA in Machine Design at Trane

How Big of a Deal is This, Anyway?



- **Okay, SEA isn't perfect**
 - Estimates break down at low frequencies
 - Sometimes systems don't behave like 'classical' mode groups
 - **Need to benchmark model for each type of machinery**
- **But the design insight SEA provides can be crucial**
 - Especially early in the design process, when rough guidance is needed
 - **Maximum design leverage**
 - Wide range of design alternatives can be compared quickly
 - **Allows out-of-the-box thinking with minimal resources**
 - Quantifying noise trade-offs key to 'selling' low noise concepts
 - **Particularly when the goals are aggressive**

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SEA can make the difference in successful concept design