# TURBOCHARGER UNSTABLE OPERATION DIAGNOSIS USING VIBROACOUSTIC MEASUREMENTS

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# TURBOCHARGER UNSTABLE OPERATION DIAGNOSIS USING VIBROACOUSTIC MEASUREMENTS

- §Unstable operation detection
- §Experimental study
- §Performance characteristics and operating regimes
- §Unsteady signal features for different operating conditions
- §Criteria for unstable operation Detection
- §Conclusions

# Existing methods for unstable operation detection

- Aerodynamic Methods
  - Fast response pressure sensors
  - Hot wires and hot films
- Mechanical Methods
  - Displacement Probes
- Other methods combining performance measurements and calculation algorithms

**A method based on vibroacoustic behavior is presented in this paper**

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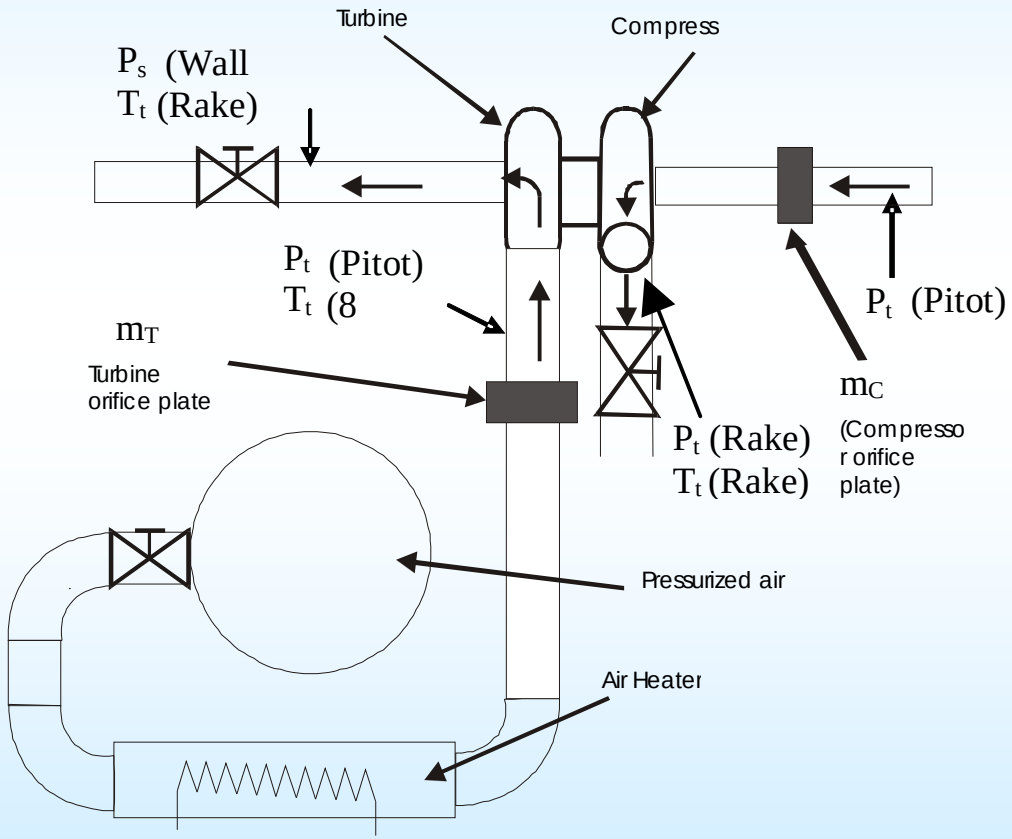
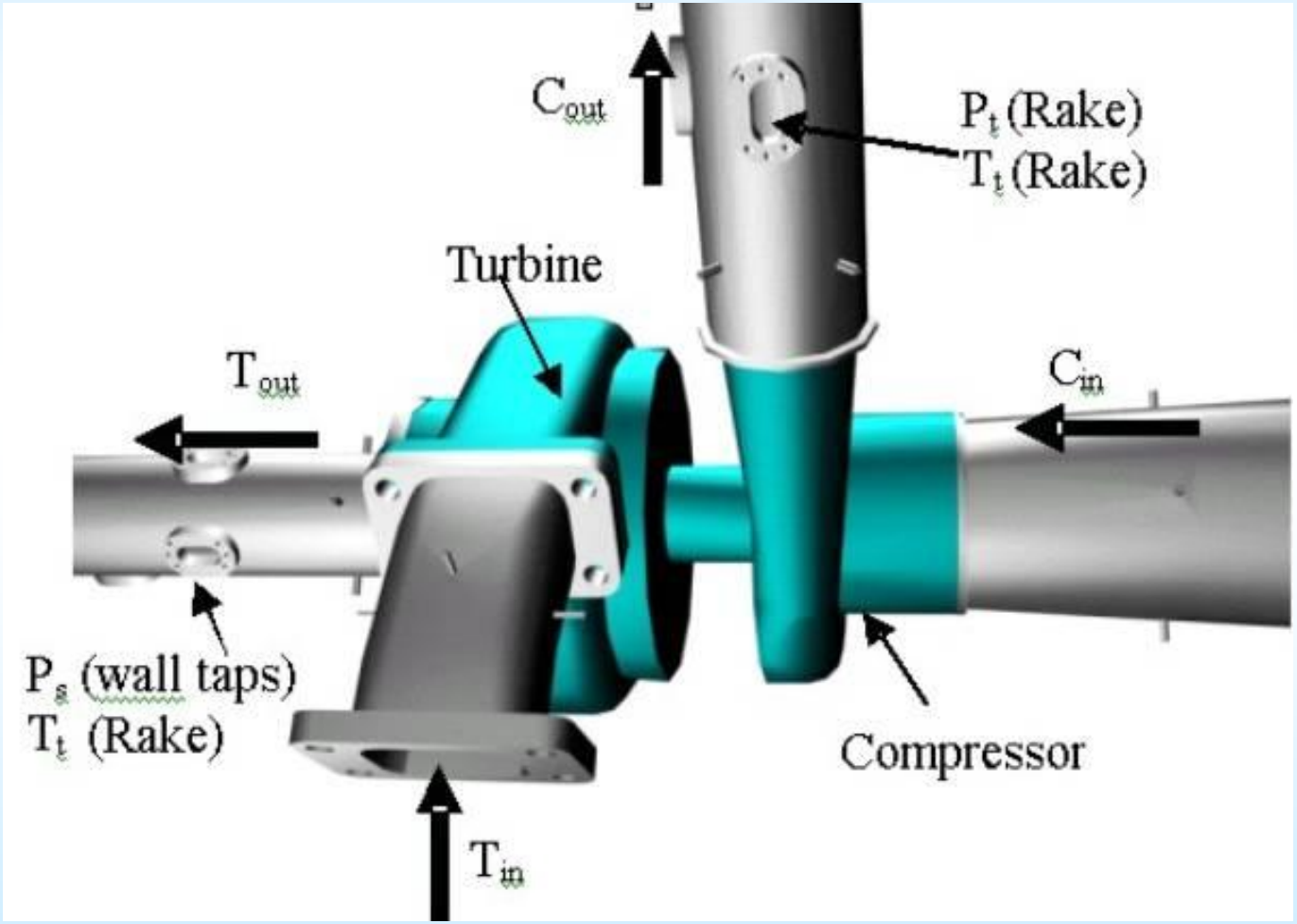
# Test Facility

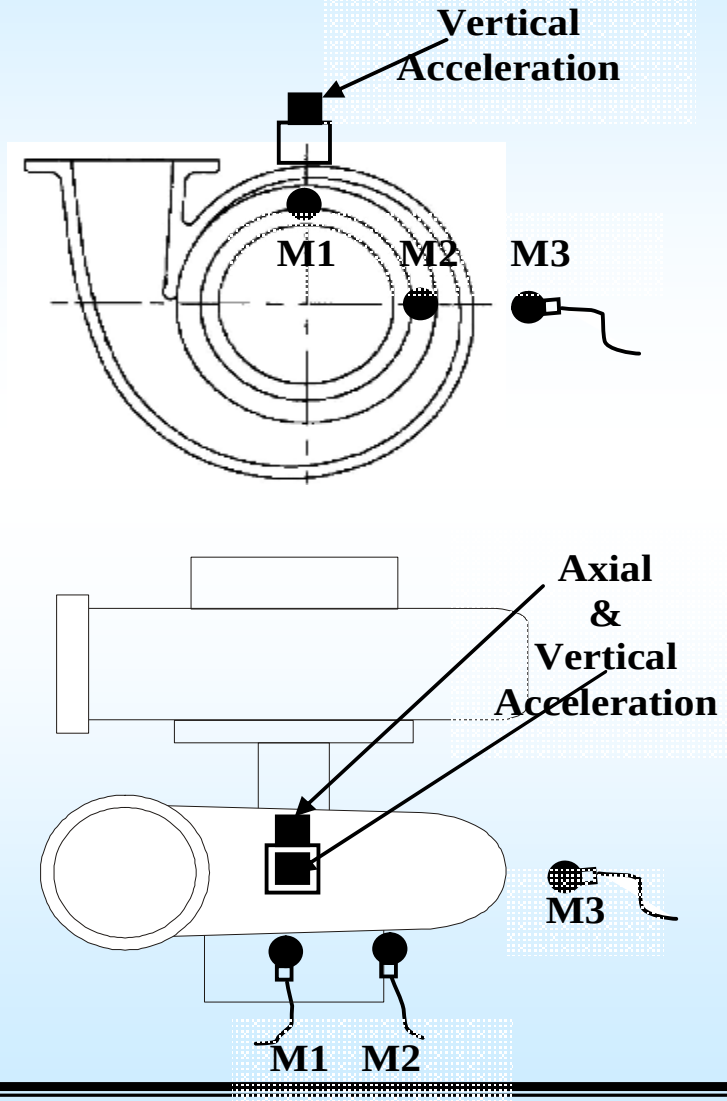


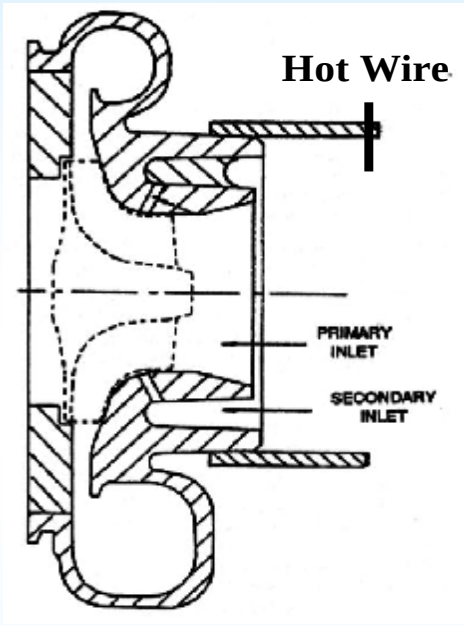
# Test Facility

# Measurments for Component Performance

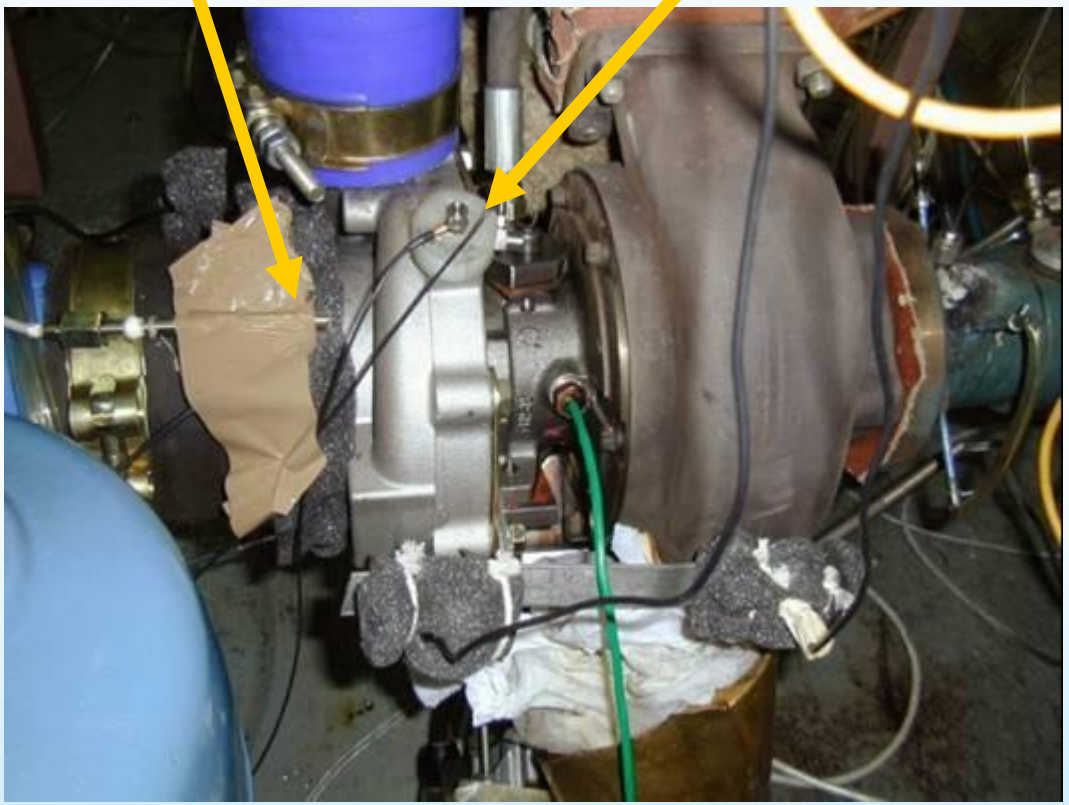


# Fast Response Instrumentation



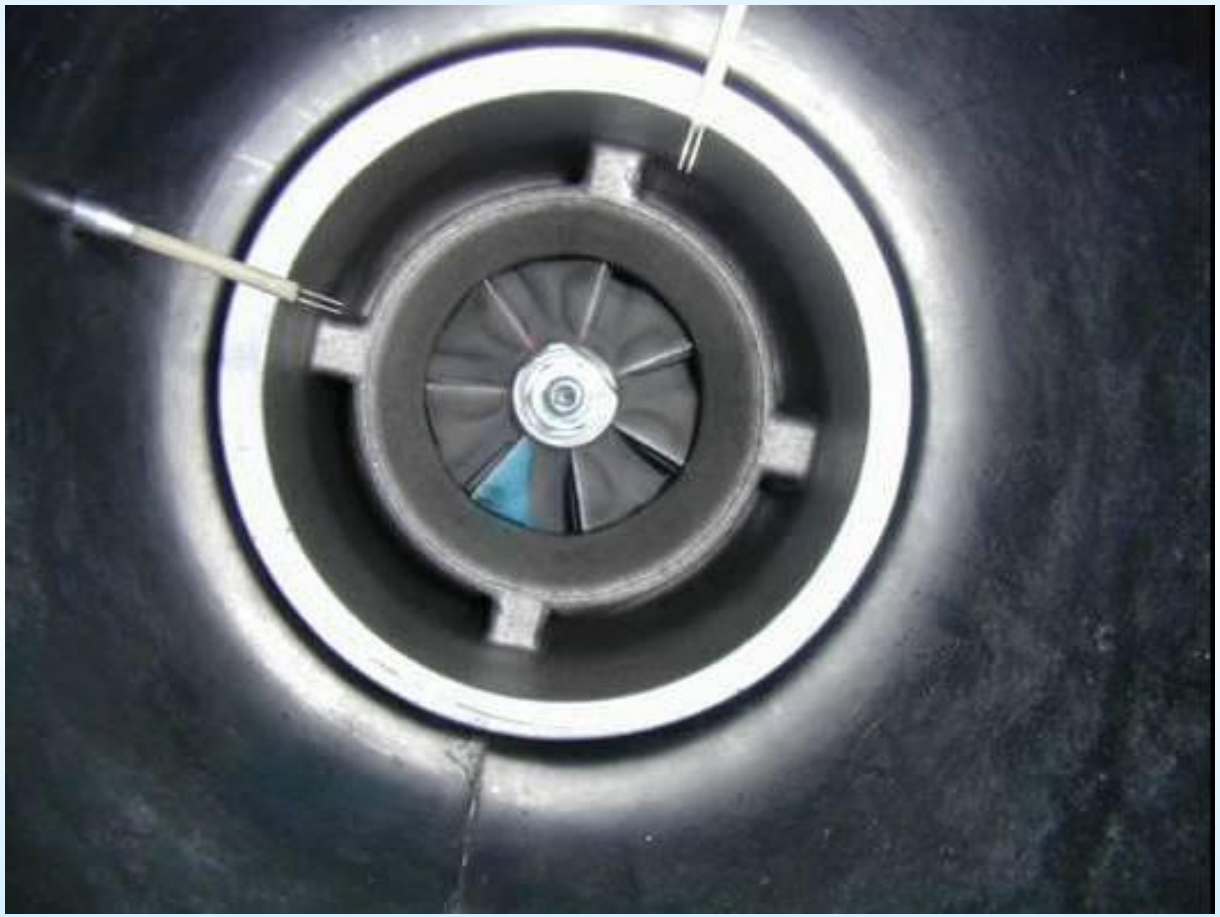
# Side view of Instrumented Turbocharger: Microphones, Accelerometers,



# Accelerometers On Casing

# Inlet View of Instrumented Compressor: Hot wires

# Close up of Hot Wires in Compressor Inlet Duct



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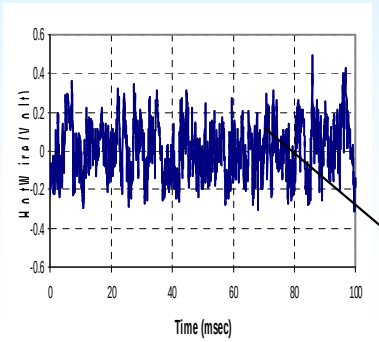
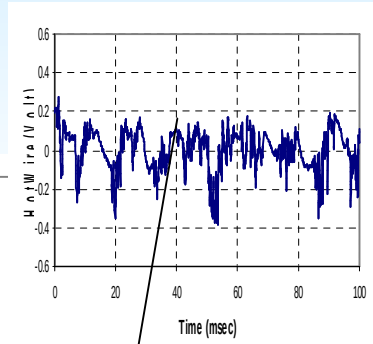
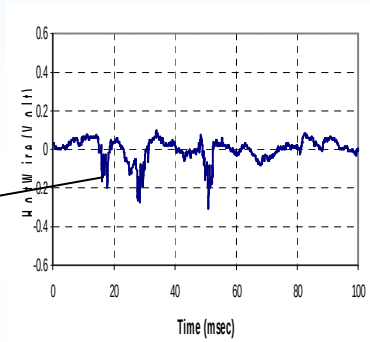
# Hot Wires Signals Along Compressor Characteristic Curve

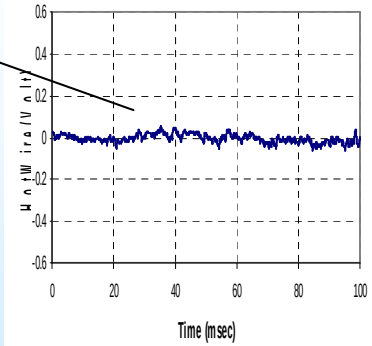


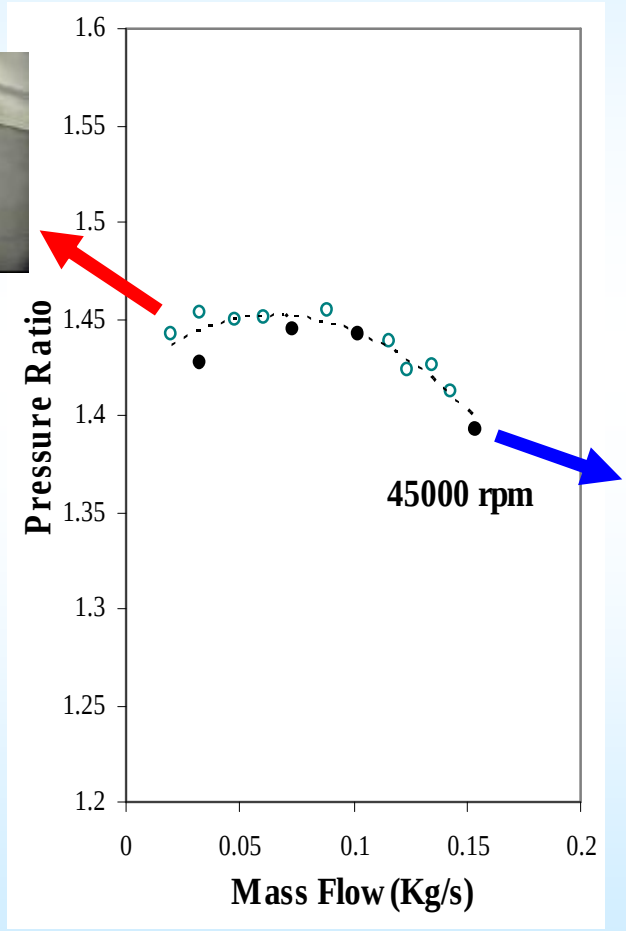






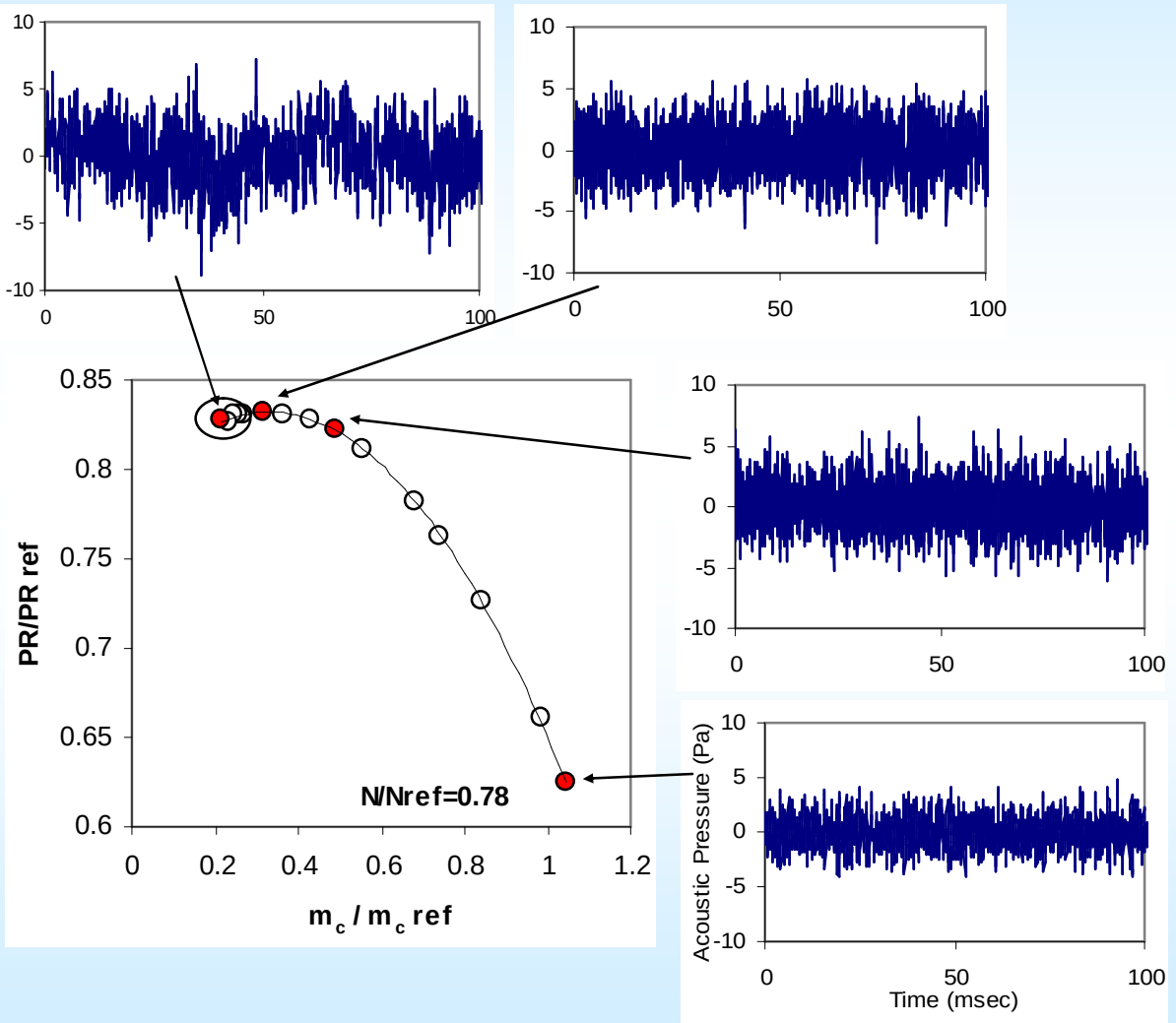

Occurrence of Instabilities clearly observed

# Hot Wires Signals Along Compressor Characteristic Curve



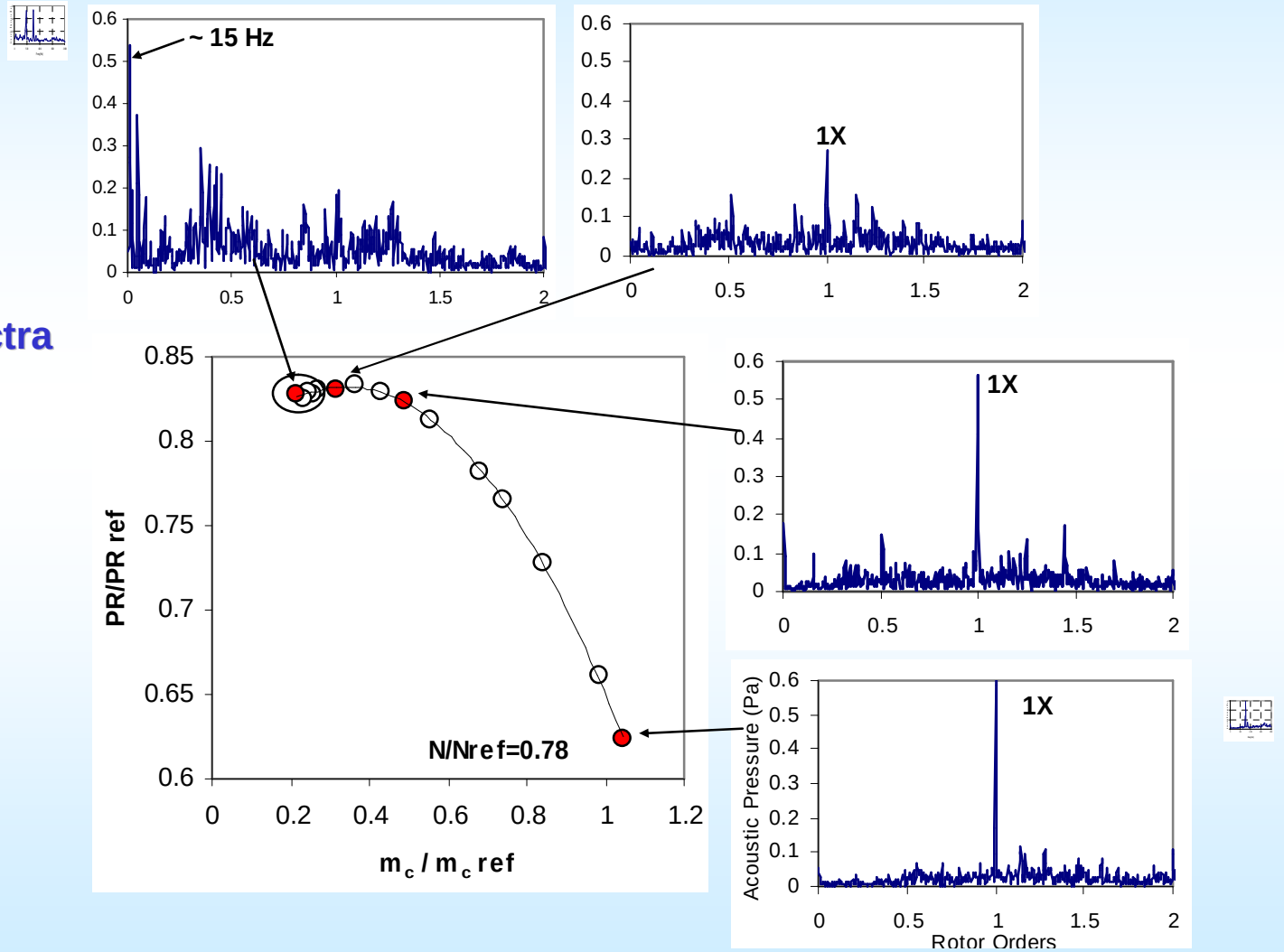

# Microphone Signals Along Compressor Characteristic Curve

Signal observation not clear indicator



# Performance characteristics and operating regimes

**F Acoustic Pressure spectra**



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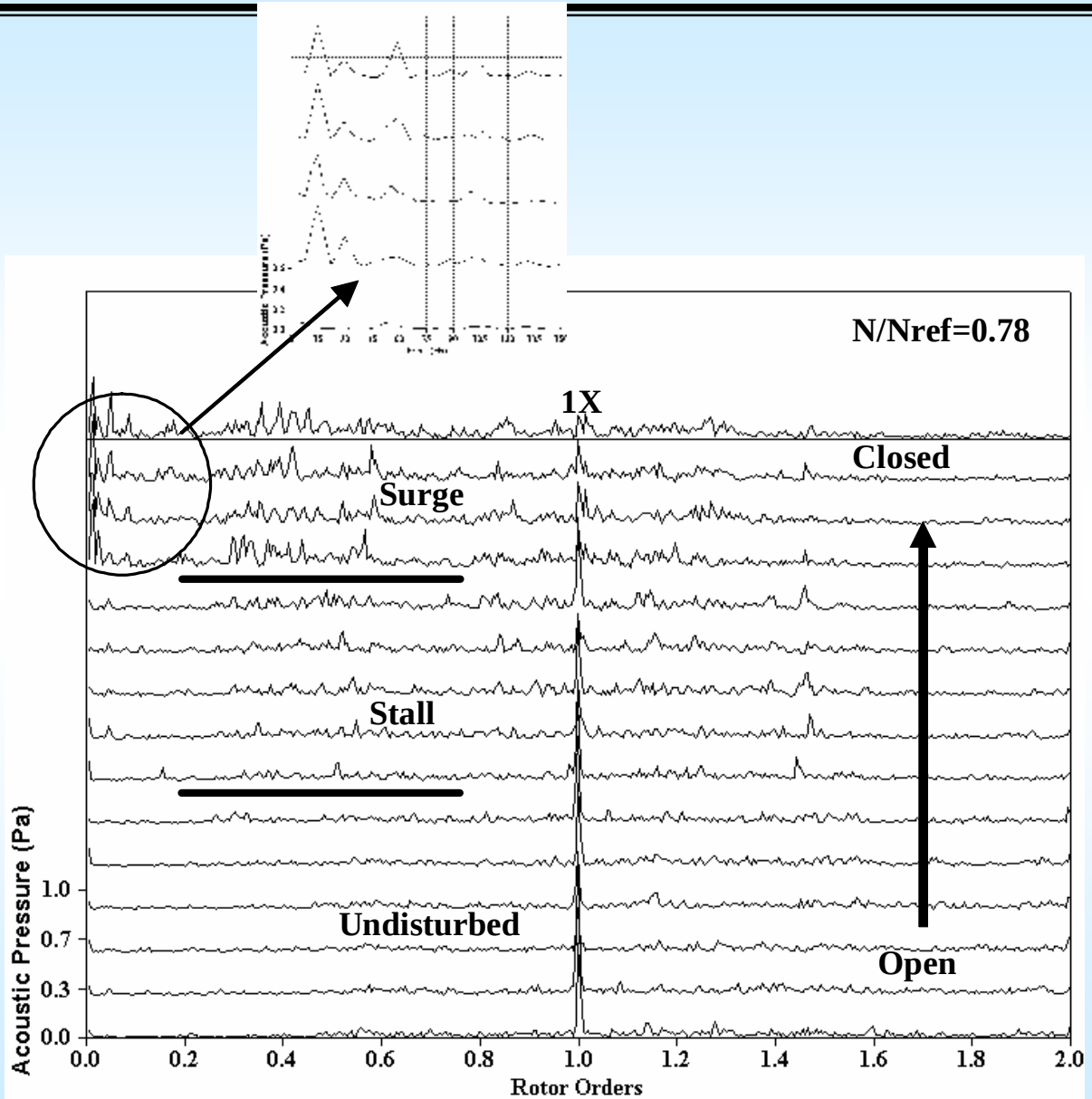
## Unsteady signal features for different operating conditions



# Unsteady signal features for different operating conditions

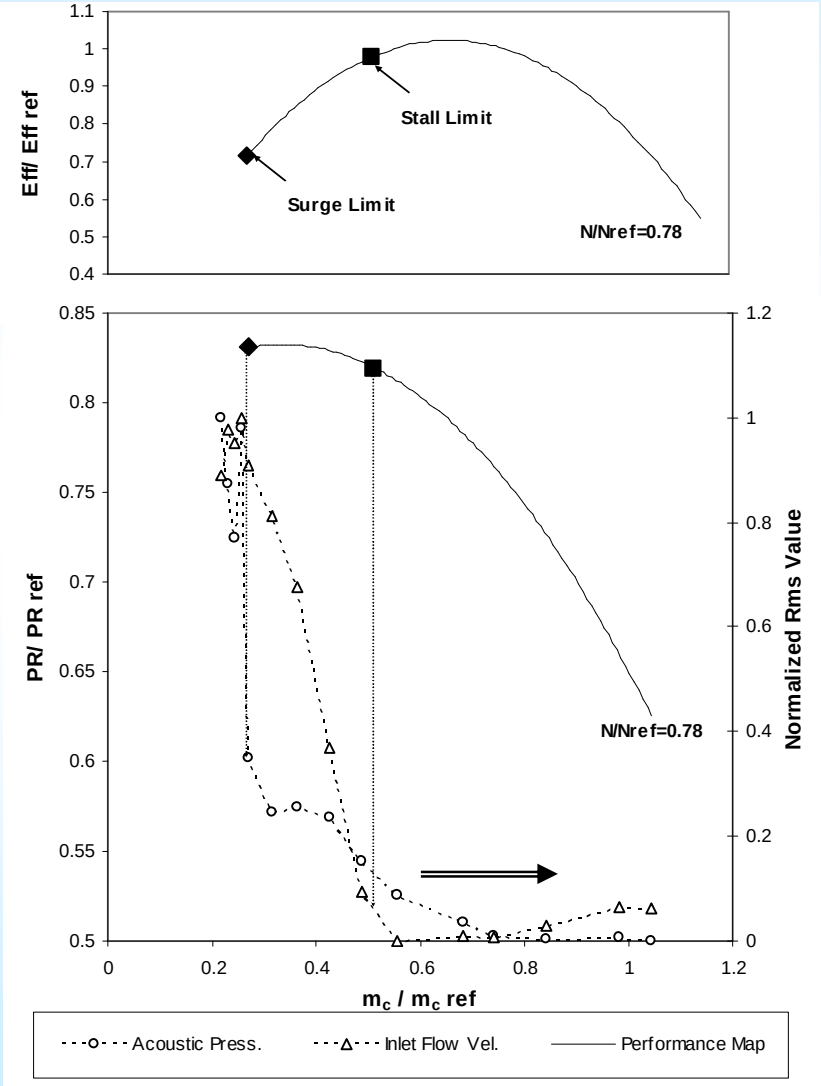
- Instabilities affect the low-frequency part of the spectrum

- RMS-value indicating operating conditions:

$$s_F = \sqrt{\frac{1}{F}\int_0^F S_{pp}(f)\cdot df}\,, F = 0.9X$$

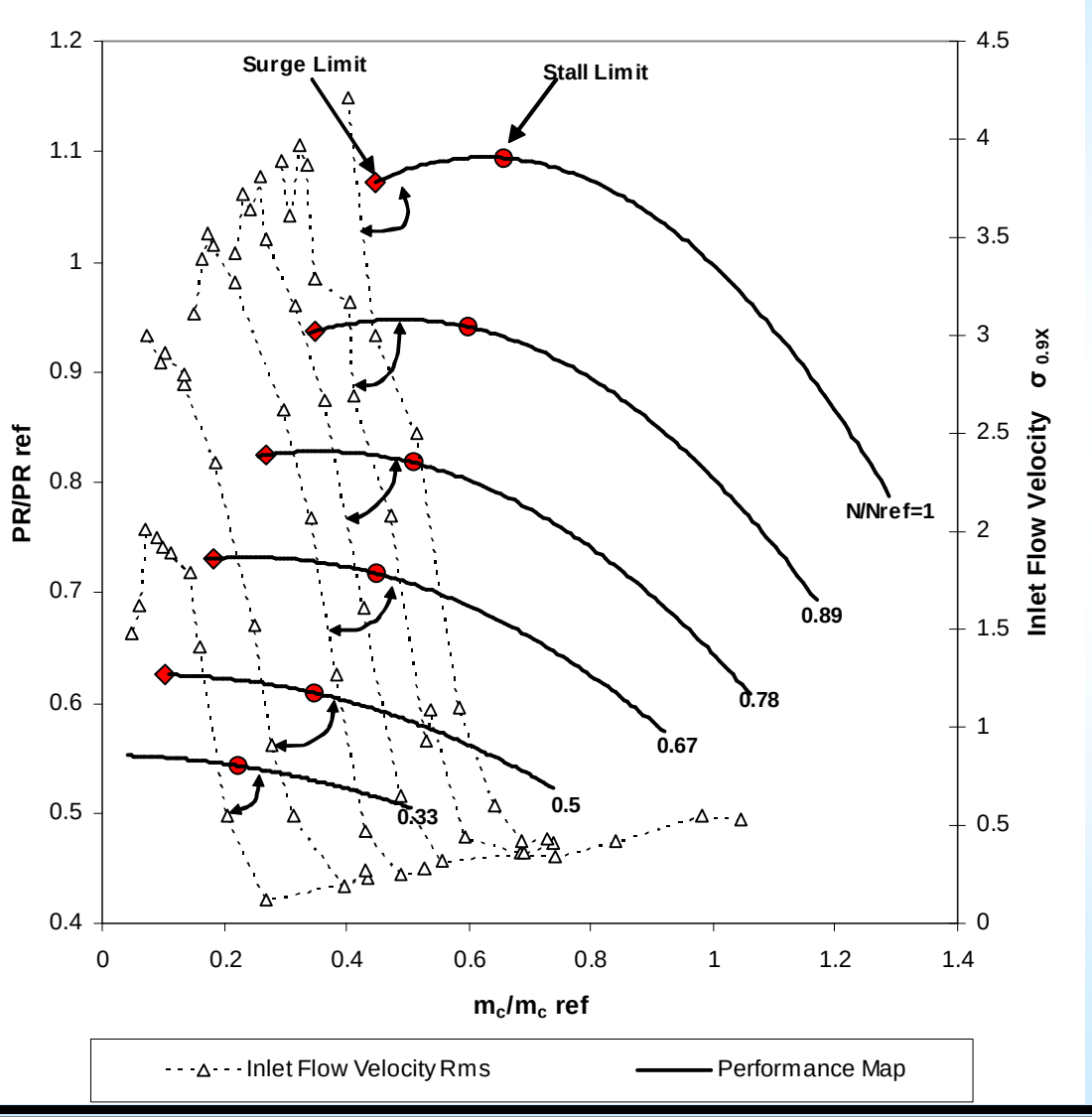
# Unsteady signal RMS along performance characteristic

**F Acoustic pressure and flow velocity RMS level**



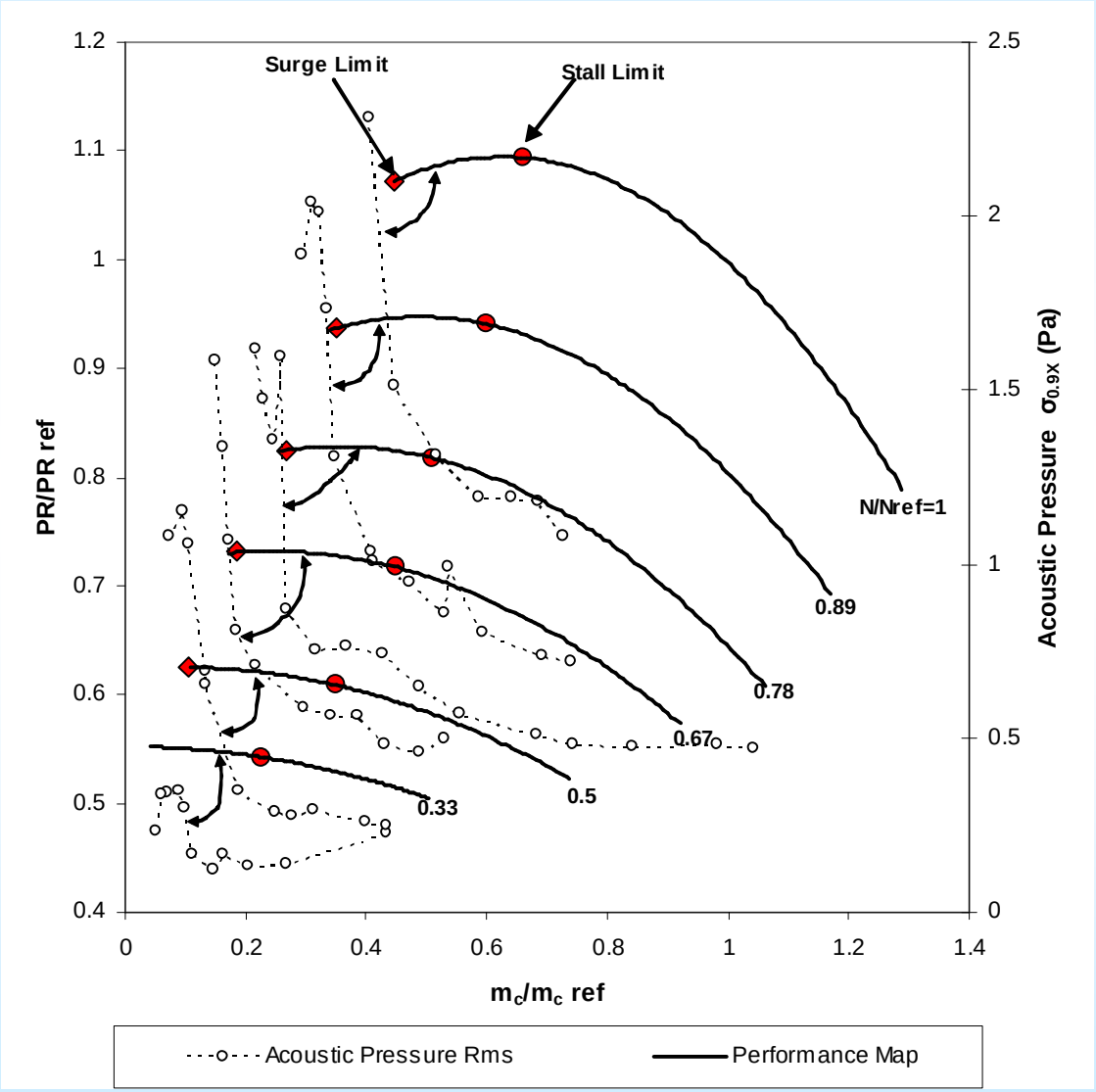
# Unsteady signal RMS over performance map

- Inlet flow velocity RMS
- Stall/surge occurs at different RMS level for each rotational speed



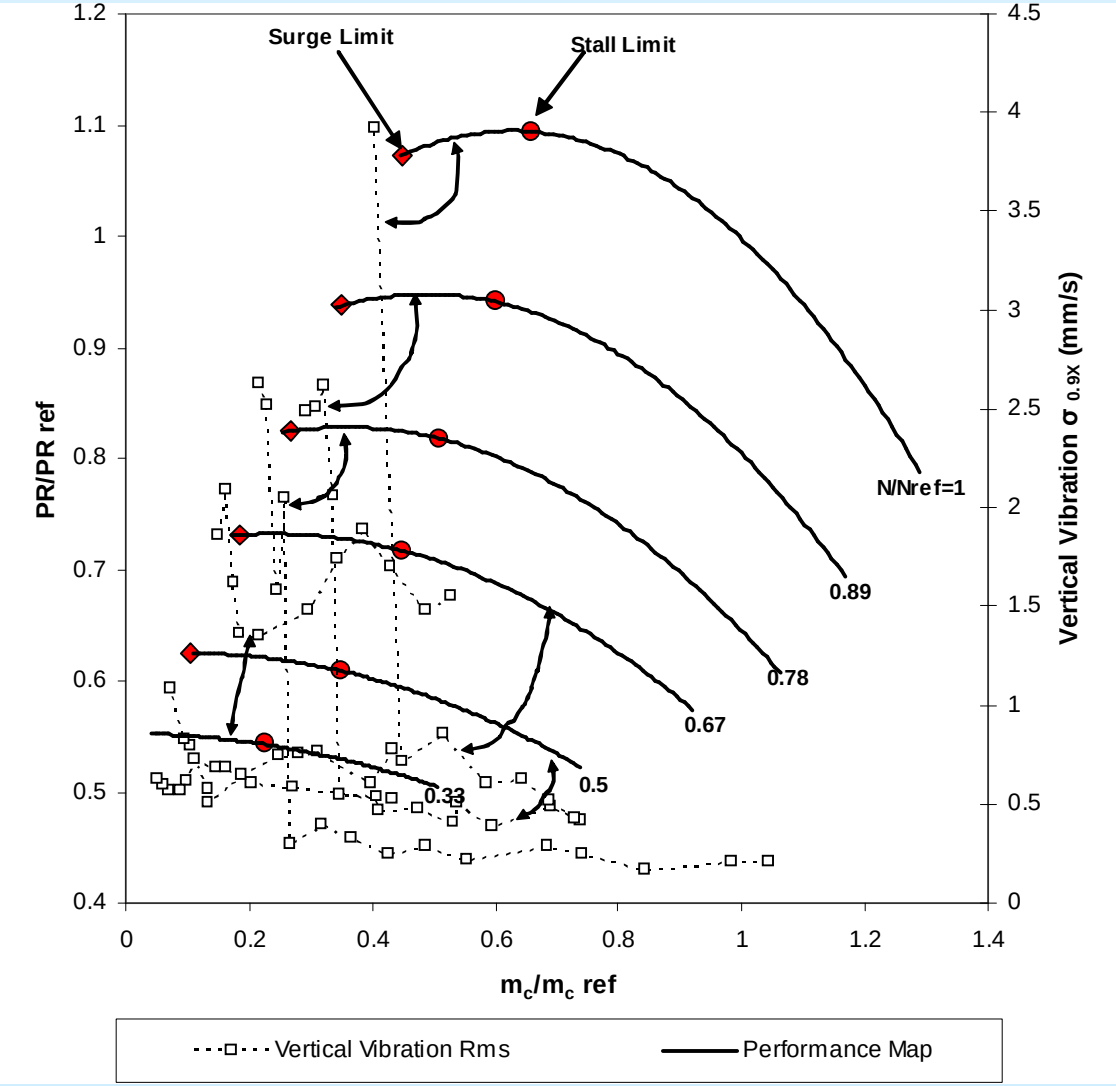
# Unsteady signal RMS over performance map

**F Acoustic pressure RMS**



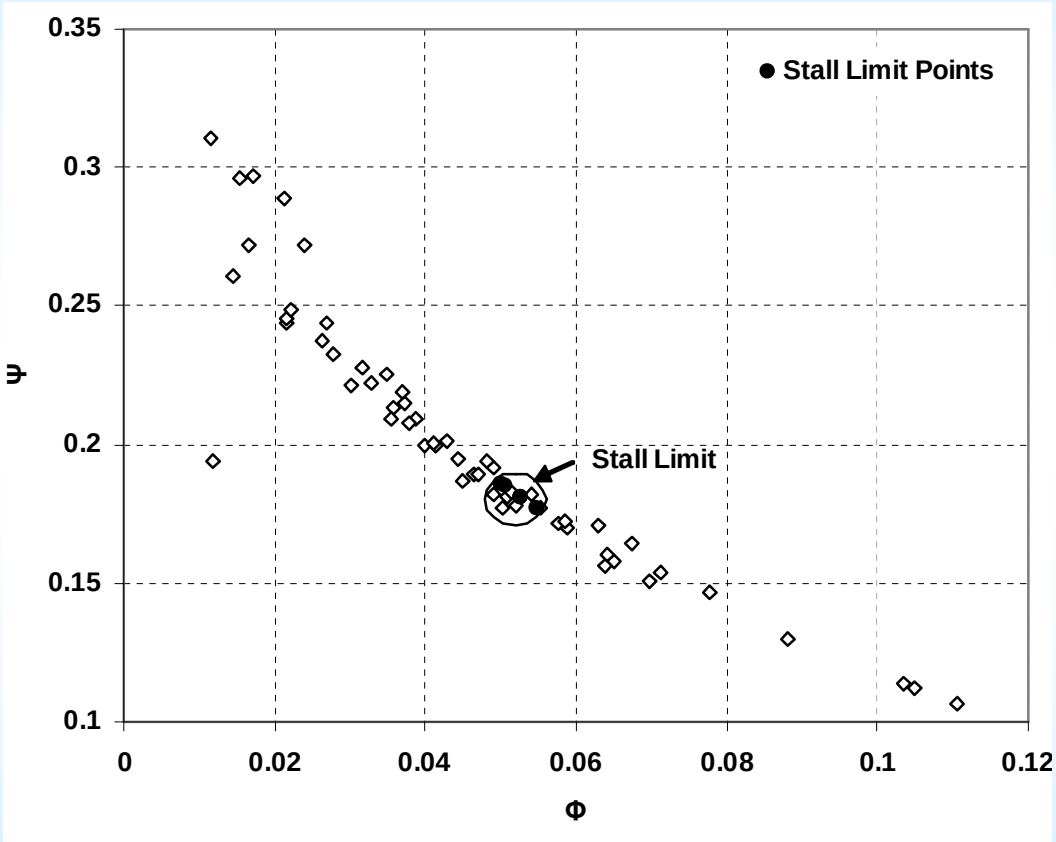
# Unsteady signal RMS over performance map

- Vertical casing vibration RMS
- Rises only the onset of surge: not suitable for detection



# The Φ-Ψ performance characteristic and points of stall occurrecnce

- Stall points all very closely spaced
- Stall occurs at a specific value of Φ




$$\Phi = \frac{m_c}{r \cdot \mathrm{A} \cdot U}, \quad \Psi = \frac{\Delta \mathrm{H}_c}{U^2}$$

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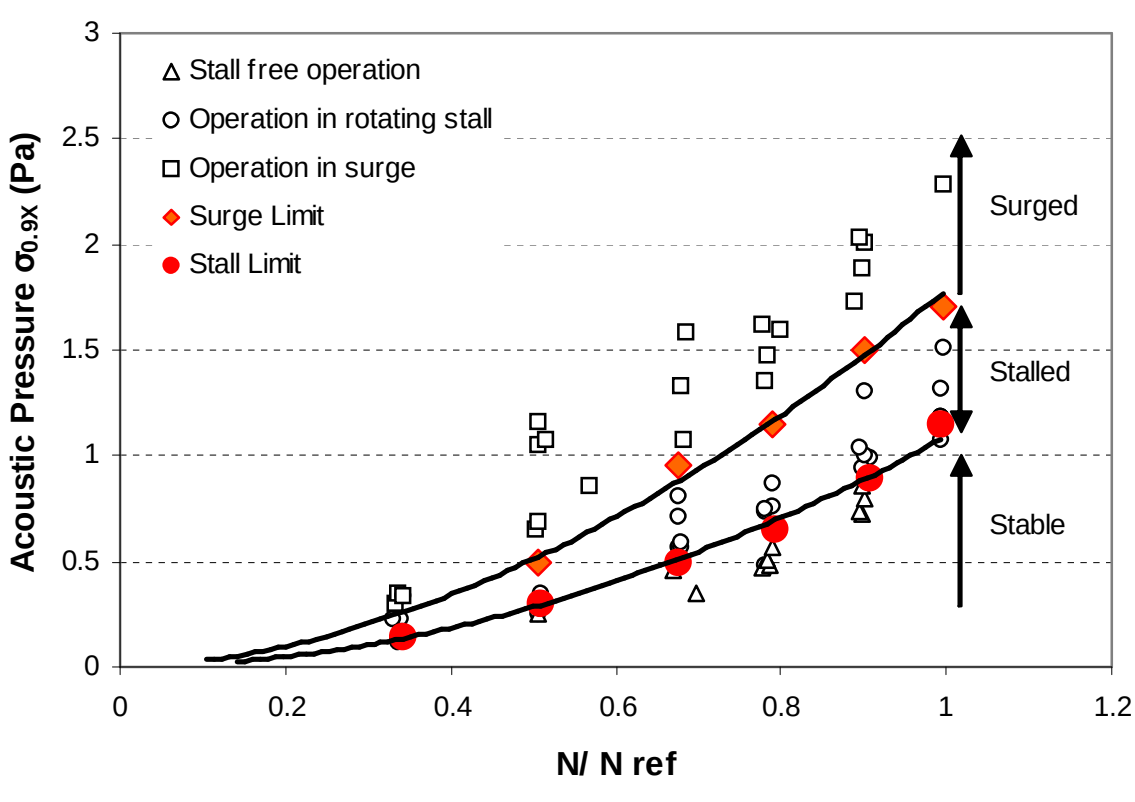
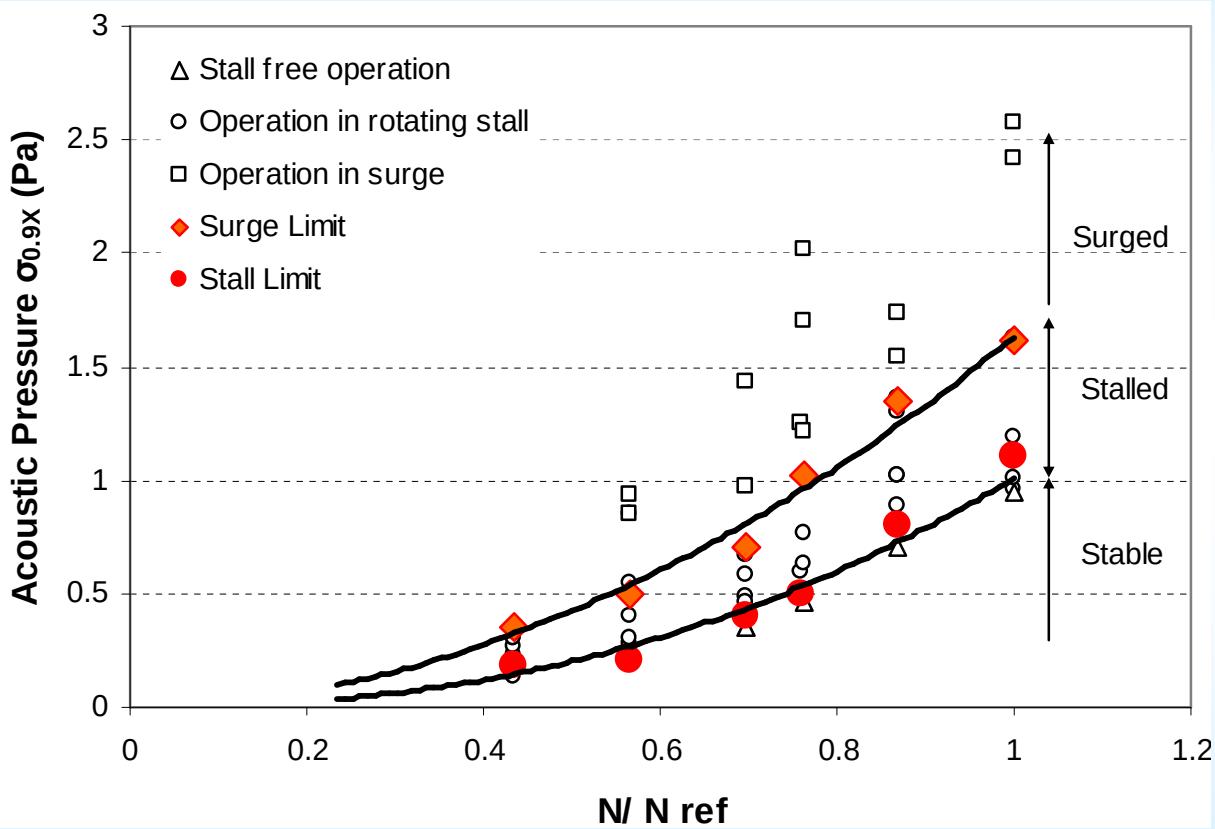
# Establishment of acoustic criteria for surge detection

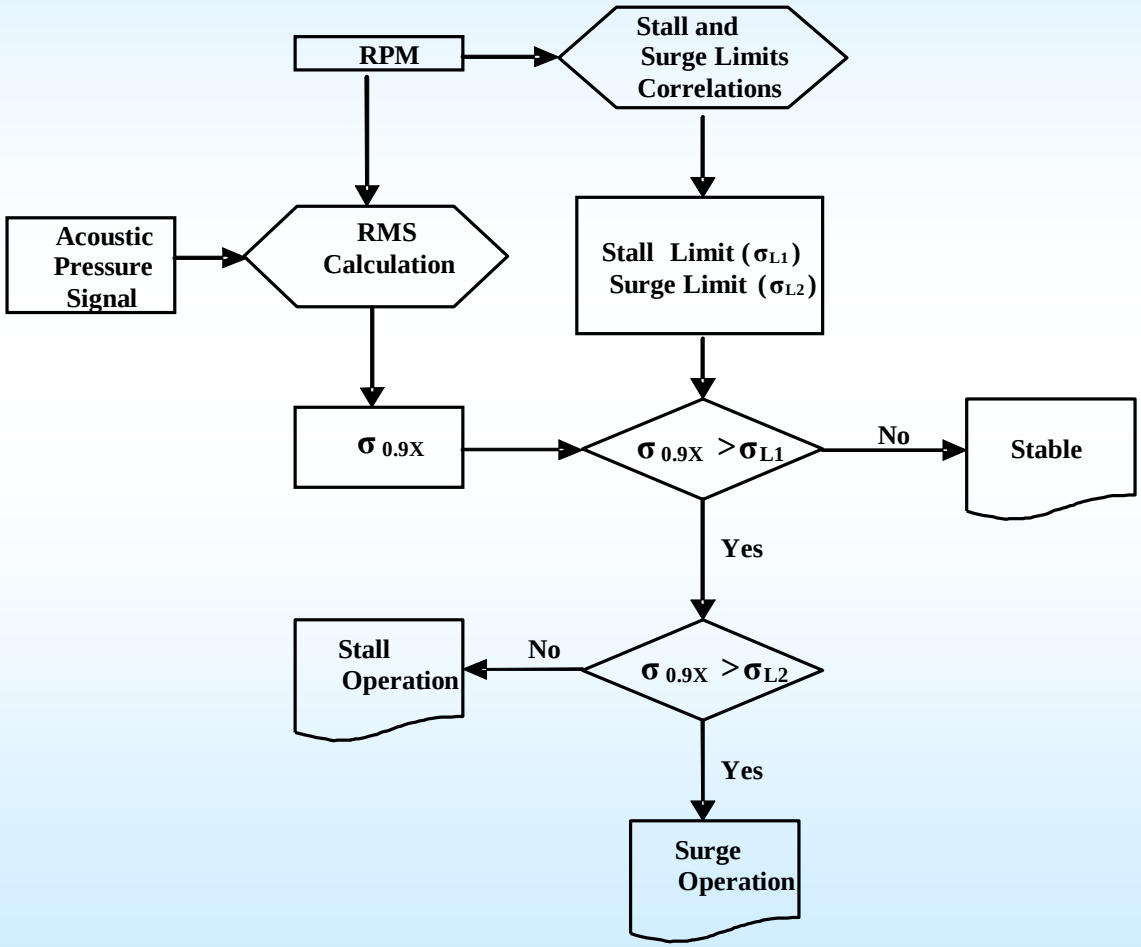



**F Correlation between acoustic pressure RMS level and compressor speed**

# Generalization(?): Results from a different turbocharger



# Procedure for stall and surge diagnosis in a radial compressor



# Conclusions

§Acoustic signal features correlate well with operating condition

§The RMS value in the sub-synchronous part of the spectrum suits best for unstable operation detection

§Well defined limits of the RMS parameter for different operating regimes have been established

§Applicability to a different turbocharger, indicates generalization possibility