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Stability Analysis of HEG Shots 1302 and 1324

Ross Wagnild

Engineering Sciences Center

Sandia National Laboratories

Albuquerque, NM 87123

Stability Analysis Parameters

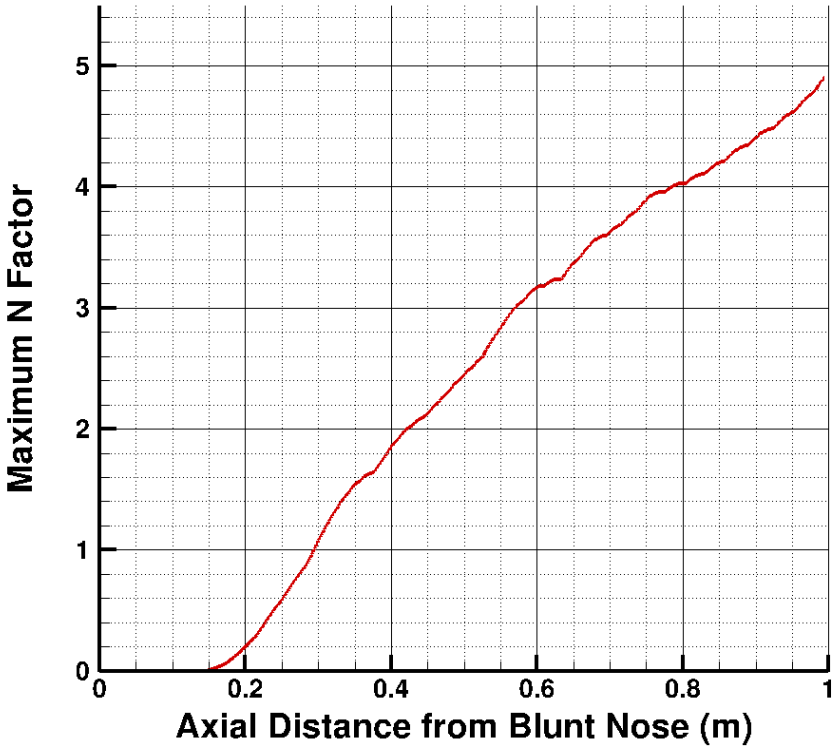
- 7º Half-angle circular cone
  - 2.5mm-diameter nose radius, 1.0 m long
    - Grid uses 1215 x 350 cells, axi-symmetric
- Run Conditions - 1302
  - Velocity = 2399 m/s; Density = 10.7 g/m^3;
  - Temperature = 264 K; Vibrational Temperature = 264 K
  - Wall Temperature = 293 K; Mach 7.35
  - Mass Fractions
    - N2 = 0.7527; O2 = 0.2163; NO = 0.0307; O = 0.0003

Stability Analysis Parameters

- Run Conditions - 1324
  - Velocity = 4354 m/s; Density = 17.1 g/m^3;
  - Temperature = 1286 K; Vibrational Temperature = 1286 K
  - Wall Temperature = 293 K; Mach 6.09
  - Mass Fractions
    - N2 = 0.7381; O2 = 0.1601; NO = 0.0619; O = 0.0399
- 5 species air assumed
  - Blended viscosity model based on Sutherland and Blottner data
  - Eucken relation for heat transfer
  - Reacting; Two-temperature non-equilibrium

Maximum N Factor : 1302

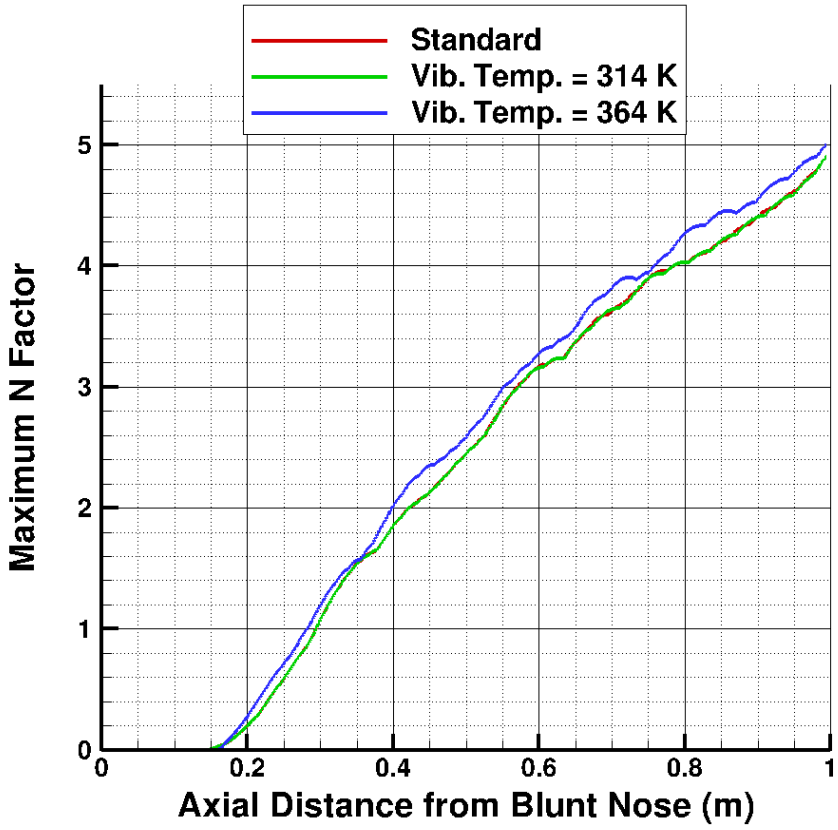
- Max N factor comparison
  - STABL predicts smaller N factor at $s = 1.0\ m$ (4.9 vs. 5.1)



N factor versus axial distance

Maximum N Factor : 1302

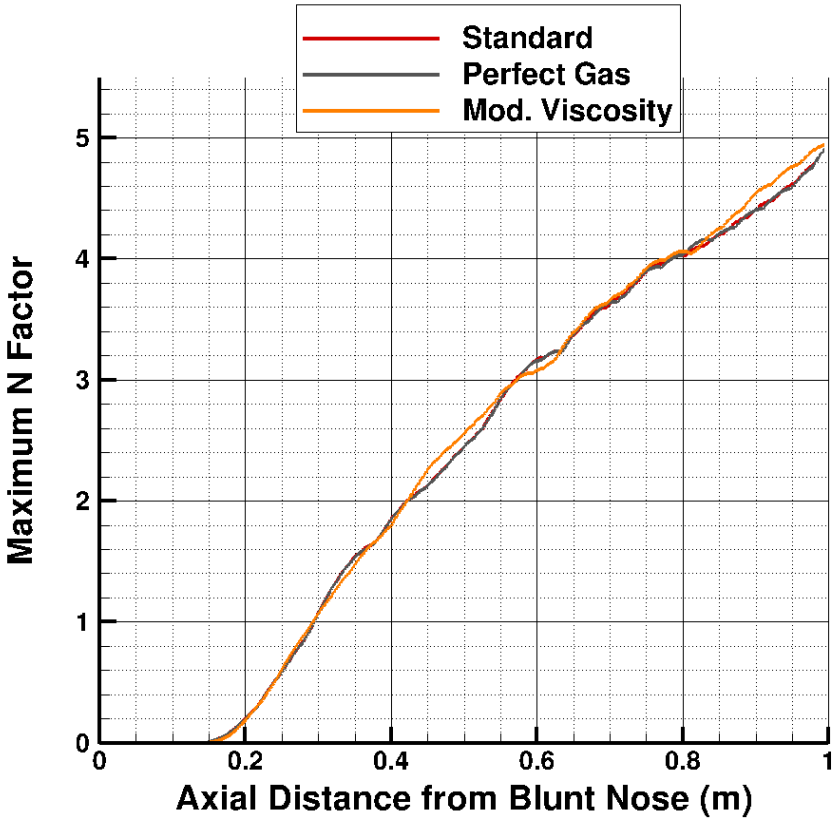
- Vibrational Temperature
  - Based on experience in the GALCIT T5 tunnel, thermal non-equilibrium exists for enthalpies < 6MJ/kg
  - Estimated thermal non-equilibrium values (+50 K and +100 K) have negligible effect



N factor versus axial distance

Maximum N Factor : 1302

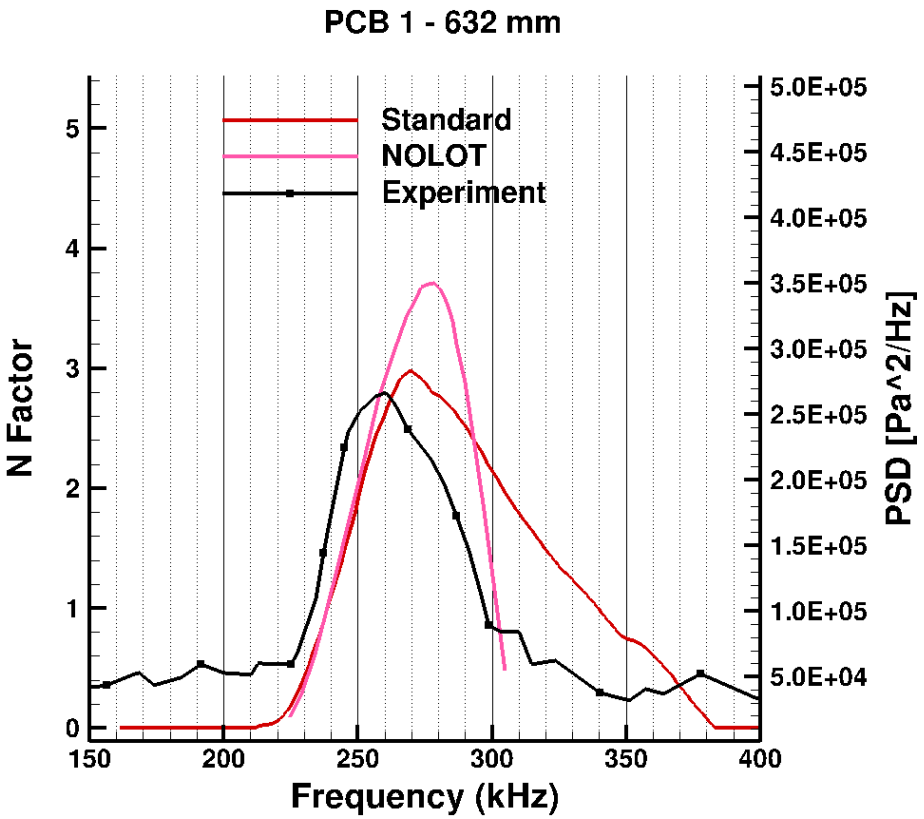
- Gas Modifications
  - Tested 5 species air compared with perfect gas air
    - Results in negligible difference at this enthalpy
  - Tested a 10% increase in viscosity to increase boundary layer thickness
    - Results in negligible difference



N factor versus axial distance

PSD Comparison: PCB 1

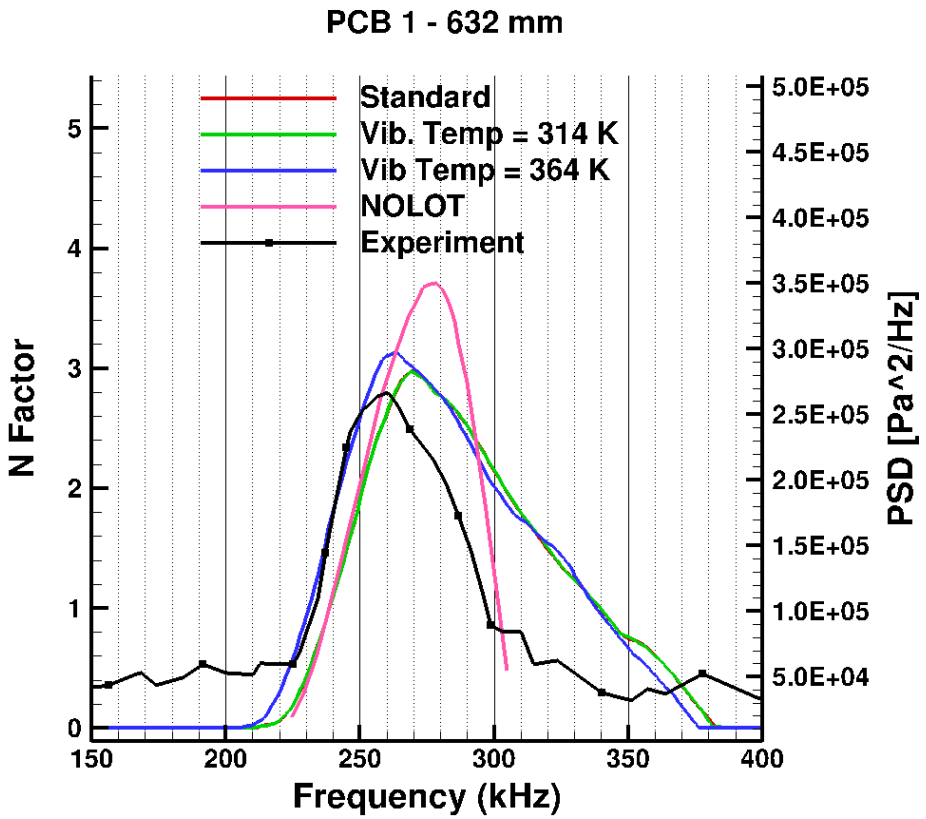
- Good Agreement
  - STABL predicts a similar most-amplified frequency; a few kHz less than NOLOT
  - STABL predicts a smaller N factor – this requires some further investigation



N factor and PSD versus frequency

PSD Comparison: PCB 1

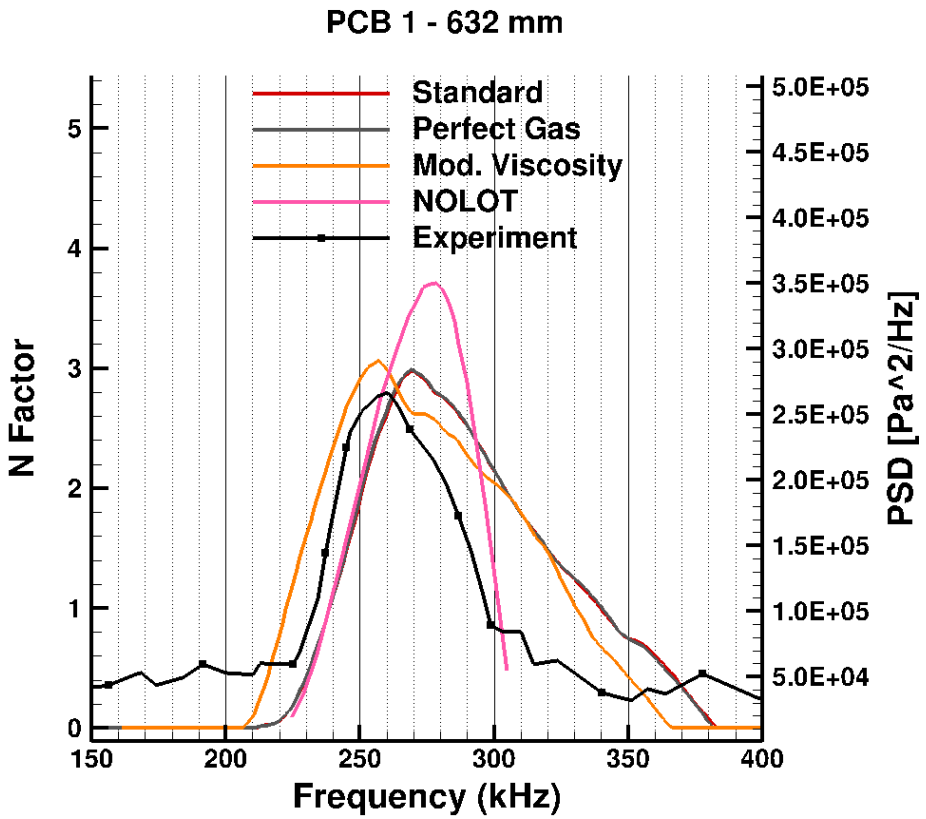
- Modifying Vibrational Temperature
  - Small increase has no change (+ 50K , labeled as Vib. Temp = 314 K)
  - Larger increase affects disturbance frequencies (+100 K, labeled as Vib. Temp = 364 K)
  - Based on T5 data – +50 K is feasible, +100 K seems unlikely
  - Nozzle flow simulations with thermal non-equilibrium necessary



N factor and PSD versus frequency

PSD Comparison: PCB 1

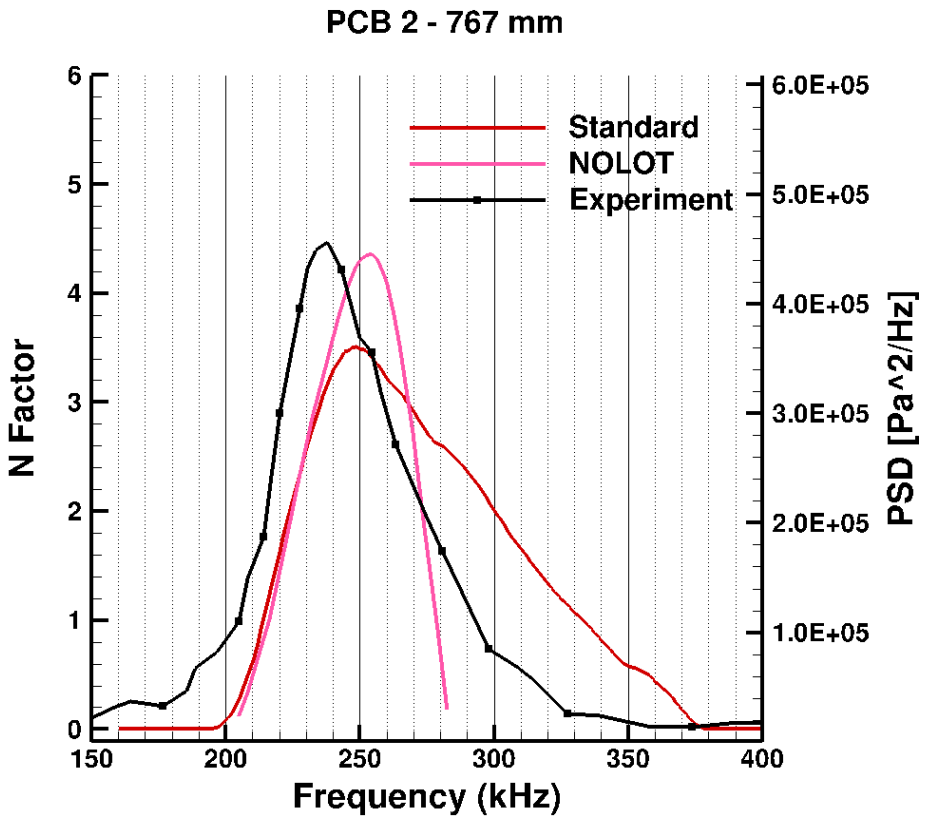
- Perfect Gas in STABL
  - Has a negligible change on most-amplified disturbance frequency
- Modifying Viscosity
  - 10% increase in all species viscosities
  - Nearly matches experimental most-amplified disturbance frequency
  - Labeled Mod. Viscosity



N factor and PSD versus frequency

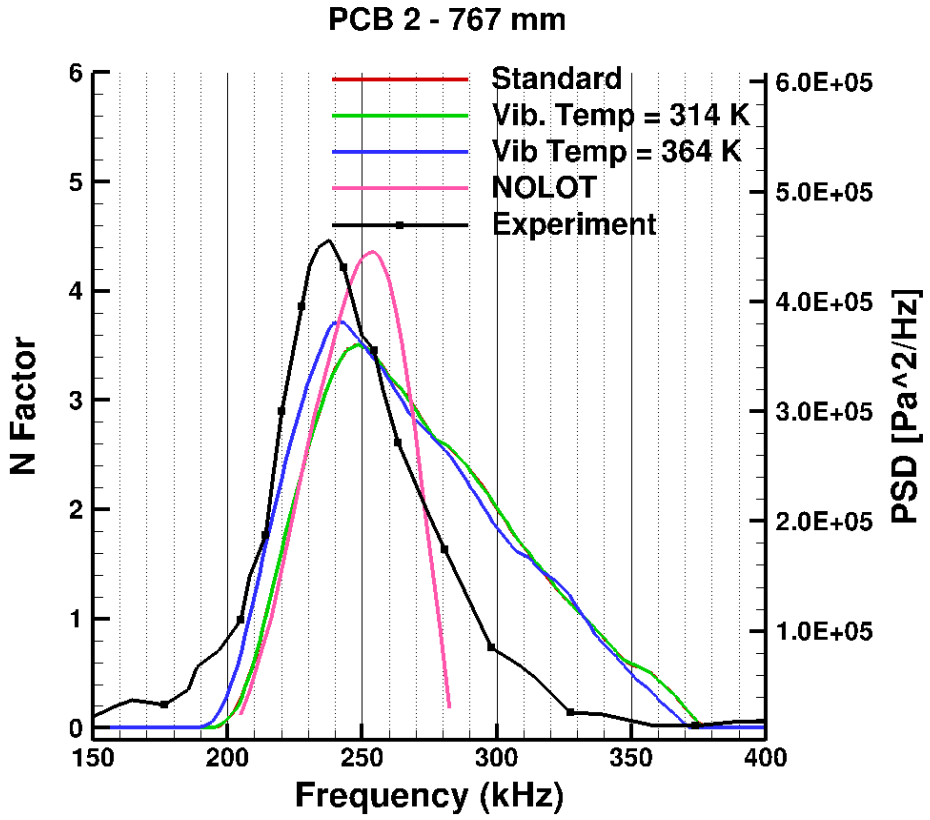
PSD Comparison: PCB 2

- Similar Results
  - Comparisons and effects similar for PCB 2

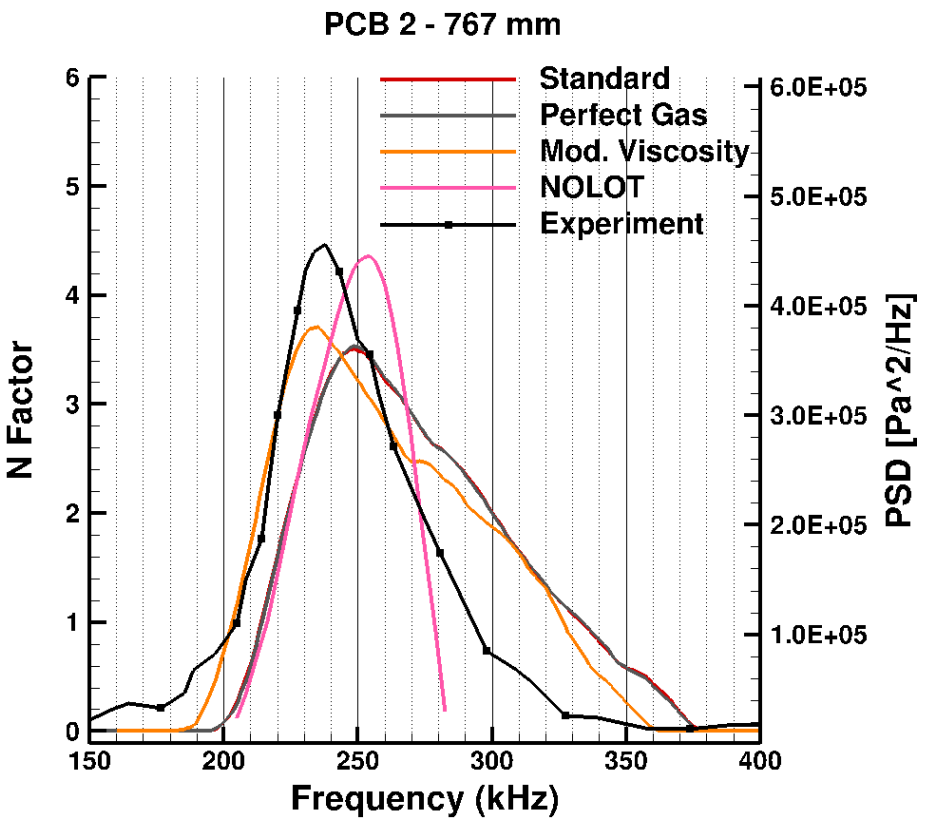


N factor and PSD versus frequency

PSD Comparison: PCB 2



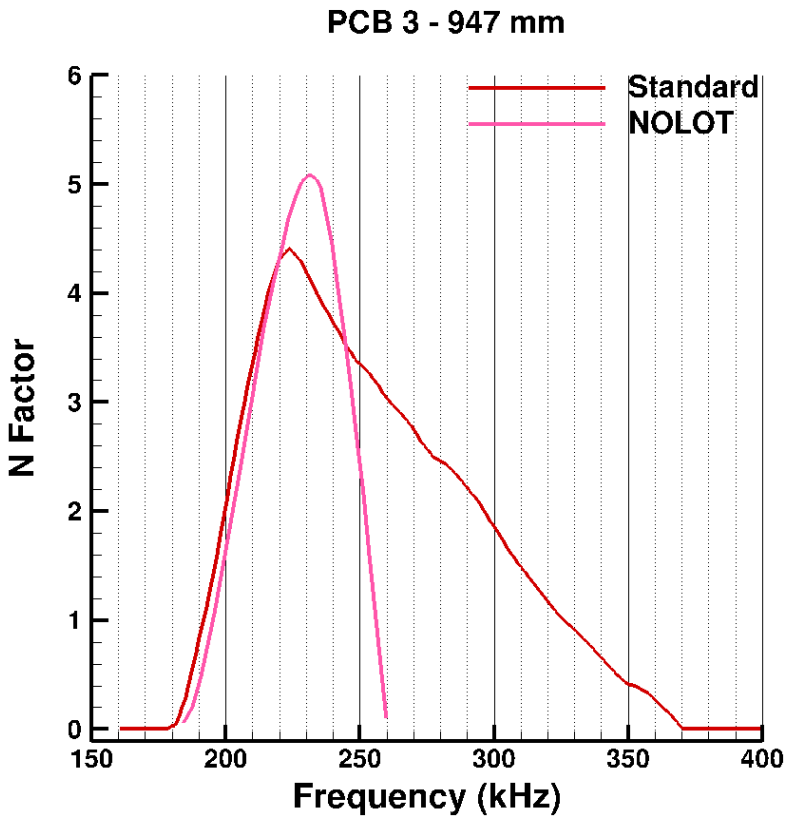
N factor and PSD versus frequency



N factor and PSD versus frequency

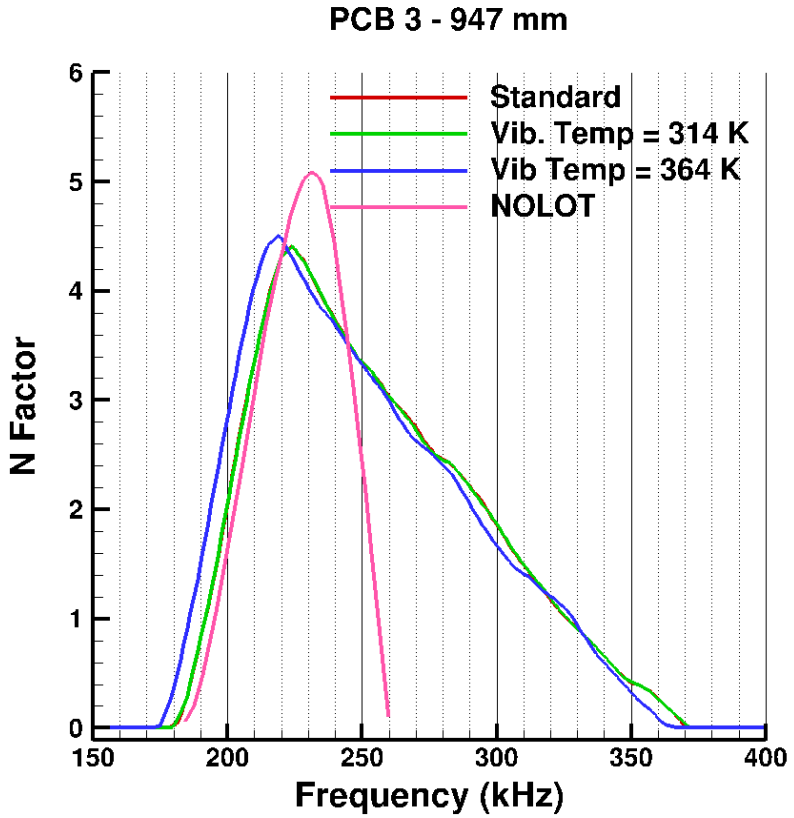
PSD Comparison: PCB 3

- Similar Results
  - Comparisons and effects similar for PCB 3

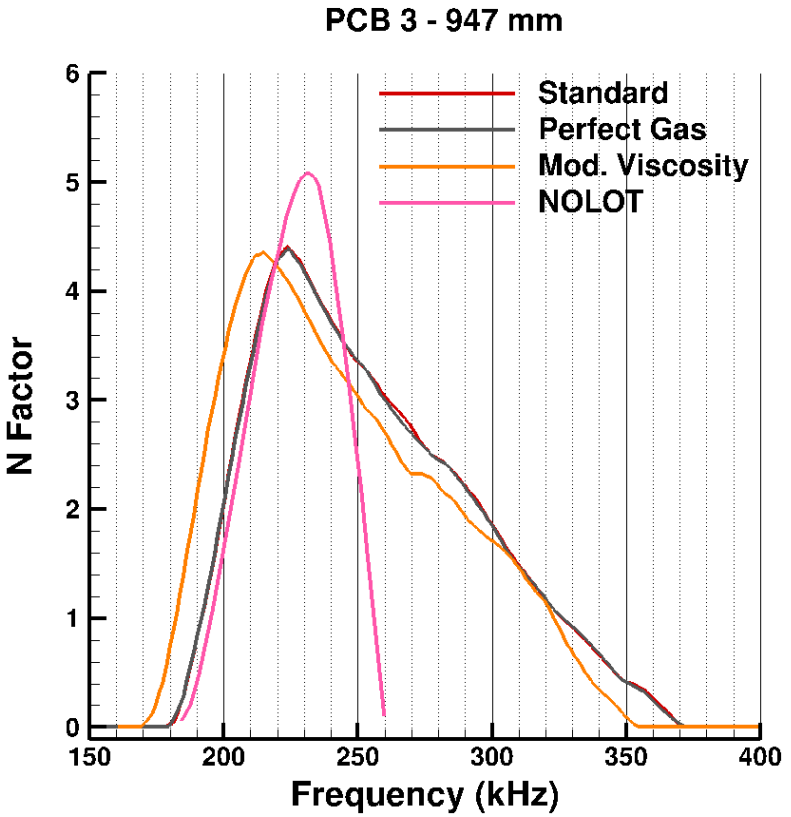


N factor and PSD versus frequency

PSD Comparison: PCB 3



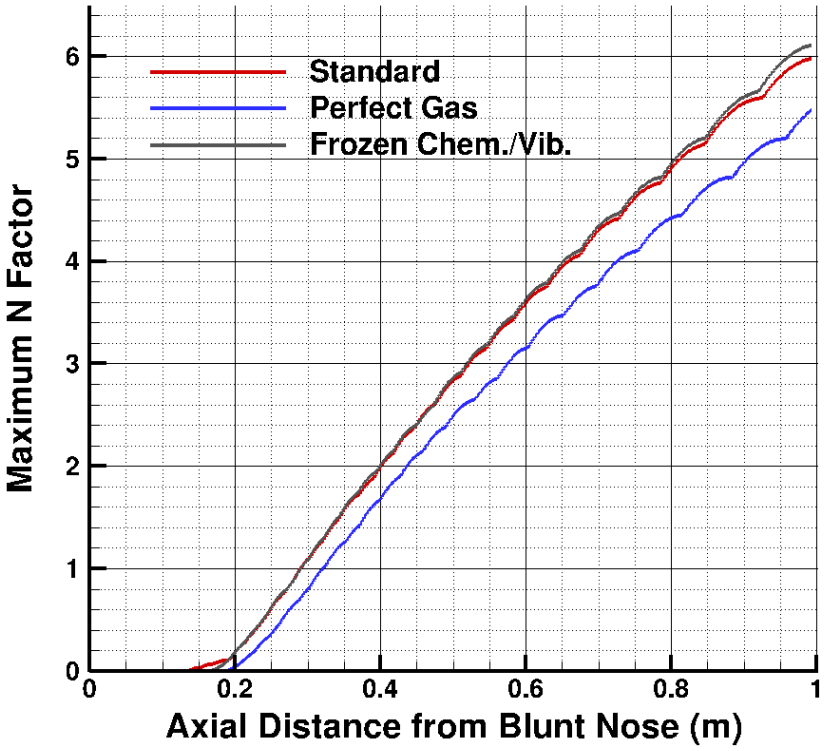
N factor and PSD versus frequency



N factor and PSD versus frequency

Maximum N Factor : 1324

- Real Gas Effects
  - ‘Standard’ has 5 species thermochemical non-equilibrium throughout the mean flow and stability analysis
  - ‘Perfect Gas’ has 1 species throughout the analysis
  - ‘Frozen Chem./Vib.’ has 5 species thermochemical non-equilibrium for the mean flow calculation, but not for the stability analysis



N factor versus axial distance

Conclusions

- Conclusions for Shot 1302
  - Reasonable agreement between NOLOT and STABL
  - Differences in most-amplified disturbance frequency could be due to (among other factors):
    - Thermal non-equilibrium in the mean flow
    - Inaccurate viscosity data
- Conclusions for Shot 1324
  - Current analysis in agreement with previous works:
    - Chemistry and vibration in the mean flow reduce boundary layer stability and increase N Factor
    - Chemistry and vibration have a negligible impact on the disturbance propagation and amplification
  - Comparisons needed for most-amplified disturbances