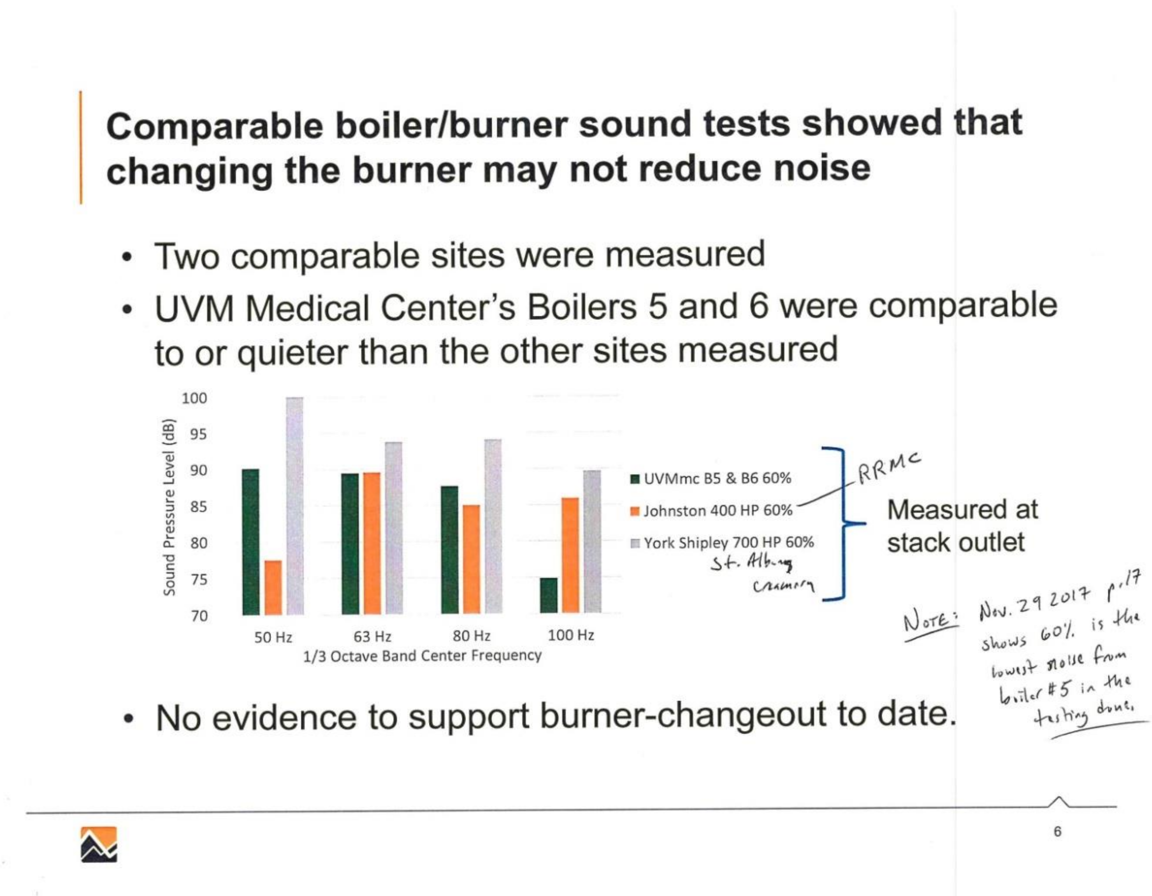
- Boilers 5 & 6 are 600 hp and have Flue Gas Recirculation (FGR), which brings partially burned gases back into the burn chamber and can cause a chaotic/unstable mixing environment in the boiler leading to substantial low frequency noise. FGR has been flagged as a likely contributor to noise and vibration by experts at several burner/boiler companies and faculty in UVM's Mechanical Engineering Dept with expertise in vibration and boilers.
- The study included only two boilers.
- Comparisons were made at the quietest level (60%) for UVMMC's boiler (cf. page 17 of RSG's Nov. 29, 2017 presentation).
- One boiler was louder than UVMMC's and one was quieter than UVMMC's.
- The noisier boiler was larger than UVMMC's and much older.
- The quieter boiler was smaller than UVMMC's boiler.
- UVMMC has two other 600 hp boilers (boilers #1 & 2) which do not have FGR, and are much quieter.
- The conclusion was 'no evidence to support burner change-out.'
  - The most generous interpretation would be that the results of this study are equivocal at best, if you ignore all of the uncontrolled factors in the comparison.
  - This is a flawed analysis of a poorly designed study.

The small sample size, number of uncontrolled variables, variables controlled at levels to favor a specific outcome, and over-interpretation of the data are not appropriate. It provides a good example of bias for an undergraduate statistics class, but it is not a scientific study.



Thermoacoustic Vibrations in Industrial Furnaces and Boilers **(continued on the next page …)**

Flynn T, Timothy A, Fuller T, Rufener S Finney C, and Daw C. 2017. AFRC Industrial Combustion Symposium.

Thermoacoustic Vibrations in Industrial Furnaces and Boilers

Industrial boilers and furnaces occasionally suffer *low-frequency vibrations* generated by a dynamic feedback process between the burner (or burners) and acoustic modes in adjacent gas-filled cavities in the main combustion chamber or connecting ductwork. This occurs when pressure pulses associated with acoustic resonances propagate to the burner so that they are in phase with combustion rate fluctuations caused by turbulence and reaction dynamics. When these pressure pulses become sufficiently phase-synchronized with fluctuations in heat release from the flame, the forces that normally dissipate the pressure waves are overwhelmed and an amplifying feedback loop is created. In the literature, such oscillations are referred to as thermoacoustic oscillations or ‘rumble,’ and their basic physics have been the subject of numerous investigations for well over a century. Unfortunately, rumble amplitudes can be large enough to negatively impact thermal efficiency and emissions, and the associated mechanical vibrations they cause can even lead to structural damage.