Flame Instability (Combustion-driven Oscillation) Mitigation

The performance of modern combustion systems including fuel efficiency, emissions, pattern factor, and lean flammability limit depend on mixing process between the combustion air and the fuel. For proper mixing, modern combustors rely on a combination of large and small scale turbulent eddies and vortices to control mixing, fuel droplet dispersion (for liquid fuel), flame stabilization/holding mechanism, and ultimately the heat release.

Under favorable conditions turbulent eddies and vortices can couple with fluctuating heat release and one (or multiple) acoustic resonant mode(s)/standing-wave(s) of the combustion chamber. This feedback coupling mechanism results in pulsations (at the resonant frequency of the acoustic mode) with large amplitudes which can become self-sustaining, and often damaging, if the rate at which the heat release perturbation produces acoustic energy exceeds the rate at which acoustic energy is removed/dissipated from the combustion chamber. This pressure oscillation better known as ***thermoacoustic instability*** (also known as '***combustion-driven oscillation***', '***combustion instability***', or '***flame instability***') generates an extremely loud tonal sound superimposed on the 'combustion roar' sound.

Combustion processes with turbulent flame generate a band-limited pseudo-random sound that is often referred to as "combustion roar." Although combustion roar sound is moderately intense but it is rather straight forward to quiet to a non-objectionable level by properly applying sound absorbing material around the burner area.

In addition to the 'roar' sound which always exists in any turbulent-flame combustion, on occasion an intense, often damaging, narrow-band pressure pulsation, resulting in a loud tonal noise, is also generated in a combustion chamber.

Combustion instability (thermoacoustic instability) manifests itself in many of today's combusting systems including propulsion systems, land and marine gas turbines, industrial boilers/heaters, etc. In addition to causing extreme annoyance, combustion instability can result in hardware damage of the combustion system. Thermoacoustic instability can be suppressed by either making the heat release mechanism (flame) put less acoustic energy into the sympathetic acoustic mode of the combustion chamber or by removing more acoustic energy from it. The former treatment is done by modifying the heat release aspect of the flame and the latter is done by adding acoustic damping to the combustion enclosure. Either one of these strategies for instability mitigation can be done passively or actively.

DEICON promotes passive acoustic damping approach for mitigating combustion instability, when the frequency of the unstable mode is not time-varying. This strategy is typically implemented by utilizing a perforated liner for abating instabilities occurring at higher frequencies. For larger combustion chambers, combustion instability occurs at lower frequencies making a Helmholtz resonator or a quarter wave tube a more suitable damping device than an acoustic liner. In many applications, the unstable frequency varies with time, depending on the operating conditions of the combustion system. This is either because heat release dynamics couples with different acoustic modes (with different frequencies) depending on the operating conditions or despite the fact that the sympathetic mode does not change but its frequency changes due to variation in the combustor temperature (and thus the speed of sound in the chamber) caused by load variation. Under these circumstances, DEICON promotes semi-active/active acoustic damping solutions.

The red trace in the figure depicts the power spectrum of pressure measured in a gas-fired combustor with thermoacoustic instability occurring at 100 Hz; note the sharp peak in 100 Hz. The blue trace shows the same power spectrum when the combustor was treated by one of DEICON's tuned acoustic damping devices. Comparison of the two power spectrum traces together clearly indicates the effectiveness of DEICON's acoustic damping treatment in mitigating acoustic instability.

DEICON provides passive, semi-active, and active acoustic damping solutions for abating combustion instability.