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Introduction: Combustion Dynamics in Lean-Premixed Prevaporized (LPP) Gas Turbines

GAS turbines have made substantial gains in performance since their initial demonstration in jet powered aircraft and power turbines. Modern power turbines have higher operating efficiencies and emit fewer pollutants than other major combustion energy converting devices. In addition, the low capital costs, ease of permitting, and quick installation have made them attractive to investors. As a result, gas turbines have become a dominant technology for new power generating capacity in the U.S. and worldwide.

With the passage of the Clean Air Act Amendments of 1990, the Environmental Protection Agency (EPA) imposed strict guidelines on the control of nitrogen oxides (NO_x) from stationary sources. Such sources include power plants fueled by coal, oil, and natural gas. These and other pollutant emissions requirements have provided one of the key drivers in the designs of modern power generating gas turbines.

This special section focuses upon a particularly serious difficulty in low emissions gas turbines: combustion-driven oscillations. These instabilities routinely constrain the operating envelope and power output of fielded machines and, in some cases, lead to serious damage of hot section components. Gas turbine users have found that components such as combustor liners, transition pieces, and fuel nozzles need routine examination for part cracking or excessive wearing because of vibration induced fretting. At a minimum, this requires downtime for inspections and part repair, reducing machine availability. At worst, a cracked piece may be liberated into the hot gas path, potentially requiring replacement of very expensive turbine components. In addition, users in certain geographic areas have found that machines must be re-tuned to eliminate combustion oscillations several times each year due to seasonal temperature changes. The cost for the repair and replacement of hot section components, much of which is directly attributable to the combustion dynamics problem, exceeds \$1 billion annually and constitutes up to 70% of the non-fuel costs of F-class gas turbines.

The propensity of low emissions turbines to generate high levels of combustion dynamics stems from the fact that their design goals are also ideal for promoting combustion instabilities. Consider the following points:

–These systems operate lean, premixed, and very near the blowout point. As such, the system is already on the stability line where small perturbations may produce very large responses.

–As opposed to aero-type systems, minimal dilution jets or film cooling air is supplied along the combustor. Removal of these holes substantially reduces acoustic damping in the combustor.

–Because of the physical layout of the combustor and the need for a high velocity fuel-air premixer to avoid flashback, the flame is typically situated at an acoustic pressure maximum. A heat release perturbation at this point (as opposed to an acoustic pressure node) is most suitably located to add energy to the acoustic field.

–In order to facilitate CO burnout, combustor and transition piece hardware are long relative to the flame. As such, the flame is very short relative to an acoustic wavelength, resulting in a concentrated heat release.

Over the last decade, substantial efforts have been expended in the industrial, government, and academic communities to understand the unique issues associated with combustion dynamics in low-emissions gas turbines. The objective of this special section is to compile these results into a series of articles that address various facets of the problem. In planning this issue, it was decided to include a few comprehensive articles, rather than a large number of more narrowly focused contributions. As such, it was not possible to solicit articles from every contributor to the field, although it is certainly our hope that their work is appropriately represented in these articles.

A total of eight articles are included in this special issue and are grouped into three areas. The *Instability Mechanisms and Characterization* section addresses the basic phenomenology of combustion instabilities, the mechanisms through which unsteady heat release processes may become self-excited, and measurement techniques for characterizing them. Next, the *Combustor Modeling* section describes analytical and computational approaches to model the complex acoustic characteristics of combustor geometries and the response of flames to acoustic waves. Finally, the *Control Approaches* section addresses active and passive control of combustion instabilities, including an industry perspective into approaches for incorporating dynamics considerations into the design process.

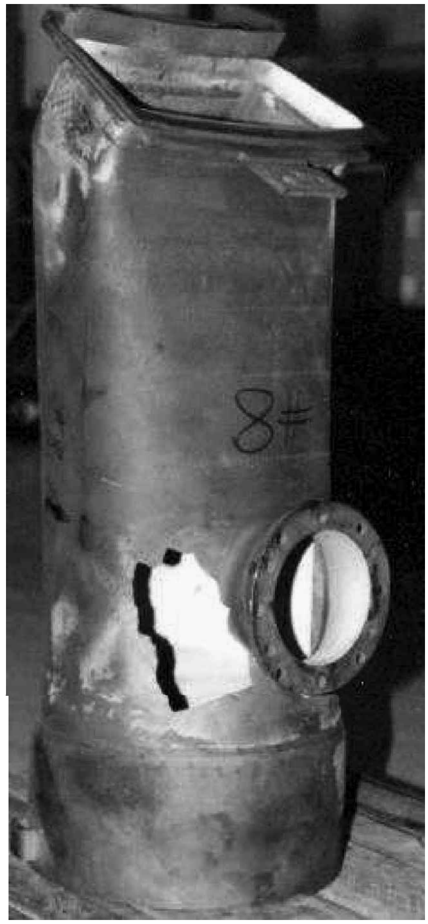

Fig. 1 High thermal stresses and combustion driven oscillations contributed to the failure of this transition piece. Image courtesy of ©Calpine Corporation.

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