

## A brief note on Gas Turbine Combustors

Over a period of five decades, the basic factors influencing the design of combustion systems for gas turbines have not changed, although recently some new requirements have evolved. The key issues may be summarized as follows.

- The temperature of the gases after combustion must be comparatively controlled to suit the highly stressed turbine materials. Development of improved materials and methods of blade cooling, however, has enabled permissible combustor outlet temperatures to rise from about 1100K to as much as 1850 K for aircraft applications.
- At the end of the combustion space the temperature distribution must be of known form if the turbine blades are not to suffer from local overheating. In practice, the temperature can increase with radius over the turbine annulus, because of the strong influence of temperature on allowable stress and the decrease of blade centrifugal stress from root to tip.
- Combustion must be maintained in a stream of air moving with a high velocity in the region of 30-60 m/s, and stable operation is required over a wide range of air/fuel ratio from full load to idling conditions. The air/fuel ratio might vary from about 60:1 to 120:1 for simple cycle gas turbines and from 100:1 to 200:1 if a heat-exchanger is used. Considering that the stoichiometric ratio is approximately 15:1, it is clear that a high dilution is required to maintain the temperature level dictated by turbine stresses
- The formation of carbon deposits ('coking') must be avoided, particularly the hard brittle variety. Small particles carried into the turbine in the high-velocity gas stream can erode the blades and block cooling air passages; furthermore, aerodynamically excited vibration in the combustion chamber might cause sizeable pieces of carbon to break free resulting in even worse damage to the turbine.
- In aircraft gas turbines, combustion must be stable over a wide range of chamber pressure because of the substantial change in this parameter with altitude and forward speed. Another important requirement is the capability of relighting at high altitude in the event of an engine flame-out.
- Avoidance of smoke in the exhaust is of major importance for all types of gas turbine; early jet engines had very smoky exhausts, and this became a serious problem around airports when jet transport aircraft started to operate in large numbers. Smoke trails in flight were a problem for military aircraft, permitting them to be seen from a great distance. Stationary gas turbines are now found in urban locations, sometimes close to residential areas.
- Although gas turbine combustion systems operate at extremely high efficiencies, they produce pollutants such as oxides of nitrogen ( $NO_x$ ), carbon monoxide (CO) and unburned hydrocarbons (UHC) and these must be controlled to very low levels. Over the years, the performance of the gas turbine has been improved mainly by increasing the compressor pressure ratio and turbine inlet temperature (TIT). Unfortunately this results in increased production of  $NO_x$ . Ever more stringent emissions legislation has led to significant changes in combustor design to cope with the problem.

Probably the only feature of the gas turbine that eases the combustion designer's problem is the peculiar interdependence of compressor delivery air density and mass flow which leads to the velocity of the air at entry to the combustion system being reasonably constant over the operating range.

For aircraft applications there are the additional limitations of small space and low weight, which are, however, slightly offset by somewhat shorter endurance requirements. Aircraft engine combustion chambers are normally constructed of light-gauge, heat-resisting alloy sheet (approx. 0.8 mm thick), but are only expected to have a life of some 10000 hours. Combustion chambers for industrial gas turbine plant may be constructed on much sturdier lines but, on the other hand, a life of about 100000 hours is required. Refractory linings are sometimes used in heavy chambers, although the remarks made above regarding the effects of hard carbon deposits breaking free apply with even greater force to refractory material.