GAS TURBINE COMBUSTORS:

The heat is added to the air flowing through the gas turbine in the combustors.1 The air leaving the compressor enters the combustors. Its temperature increases while the pressure drops slightly across the combustors. Thus, combustors are direct-fired air heaters. The fuel is burned almost stoichiometrically with 25 to 35 percent of the air entering the combustors. The combustion products mix with the remaining air to arrive at a suitable temperature for the turbine. The three major types of combustors are tubular, tuboannular, and annular. All combustors, despite their design differences, have the following three zones:

1. Recirculation zone

2. Burning zone

3. Dilution zone

The fuel is evaporated and partially burned in the *recirculation zone*. The remainder of the fuel is burned completely in the *burning zone*. The dilution air is mixed with the hot gas in the *dilution zone*. If the combustion is not complete at the end of the burning zone, the addition of dilution air can chill the hot gas. This prevents complete combustion of the fuel. However, there is evidence that some combustion occurs in the dilution zone if the burning zone is run over rich. The fuel-to-air ratio varies during transient conditions. It is high during the acceleration phase and low during the deceleration phase. Thus, the combustor should be able to operate over a wide range of mixtures. The combustor performance is measured by efficiency, pressure drop across the combustor, and evenness of the outlet temperature profile. The combustor efficiency is a measure of combustion completeness. It affects the fuel consumption directly because the unburned fuel is wasted. The combustor efficiency is the ratio of the increase in gas enthalpy and the theoretical heat input of the fuel. It is given by

$$\eta_c = \frac{\Delta h_{\text{actual}}}{\Delta h_{\text{theoretical}}} = \frac{(\dot{m}_a + \dot{m}_f)\, h_3 - \dot{m}_a h_2}{\dot{m}_f(\text{LHV})}$$

where η_c = combustor efficiency
$\dot{m}_a$ = mass flow of gas
$\dot{m}_f$ = mass flow of fuel
h_3 = enthalpy of gas leaving the combustor
h_2 = enthalpy of gas entering the combustor
LHV = fuel heating value

The pressure drop across the combustor affects the fuel consumption and power output. It is normally around 2 to 8 percent of the static pressure. This pressure drop is equivalent to a decrease in compressor efficiency. It results in an increase in the fuel consumption and a lower power output from the machine. The combustor outlet temperature profile must be uniform. Any non-uniformity in this temperature profile causes thermal stress on the turbine blades, which could lead to fracture.

It also results in a decrease of the efficiency and power output of the machine. Satisfactory operation of the combustor is achieved by having a self-sustaining flame and stable combustion over a wide range of fuel-to-air ratio to prevent loss of ignition during transient operation. The temperature gradients, carbon deposits, and smoke should be minimized due to the following reasons:

- Temperature gradients cause warps and cracks in the liner.
- Carbon deposits increase the pressure loss and distort the flow patterns.
- Smoke is environmentally objectionable.

During the last half-century, the operating conditions of gas turbine combustors have changed significantly. Following is a summary of these changes:

- Combustion pressures have increased from 5 to 50 atmosphere (atm) (73.5 to 735 psi).
- Inlet air temperatures have increased from (300 to 800°C).
- Combustor outlet temperatures have increased from (900 to 1700°C).

Despite these major changes in operating conditions, today's combustors operate at almost 100 percent combustion efficiency over their normal operating range and during idling conditions.