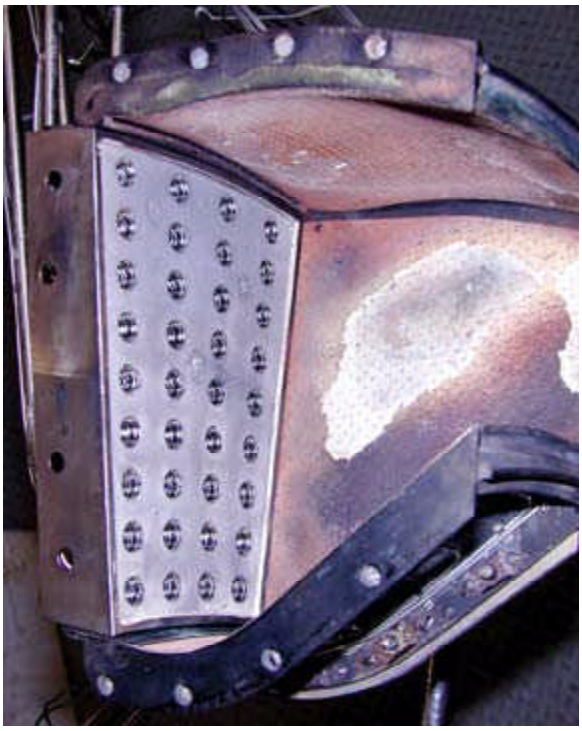
Sector Tests of a Low-NO_x, Lean, Direct-Injection, Multipoint Integrated Module Combustor Concept Conducted

The low-emissions combustor development described is directed toward advanced high-pressure aircraft gas-turbine applications. The emphasis of this research is to reduce nitrogen oxides (NO_x) at high-power conditions and to maintain carbon monoxide and unburned hydrocarbons at their current low levels at low power conditions. Low-NO_x combustors can be classified into rich-burn and lean-burn concepts. Lean-burn combustors can be further classified into lean-premixed-prevaporized (LPP) and lean direct injection (LDI) concepts. In both concepts, all the combustor air, except for liner cooling flow, enters through the combustor dome so that the combustion occurs at the lowest possible flame temperature. The LPP concept has been shown to have the lowest NO_x emissions, but for advanced high-pressure-ratio engines, the possibility of autoignition or flashback precludes its use. LDI differs from LPP in that the fuel is injected directly into the flame zone, and thus, it does not have the potential for autoignition or flashback and should have greater stability. However, since it is not premixed and prevaporized, good atomization is necessary and the fuel must be mixed quickly and uniformly so that flame temperatures are low and NO_x formation levels are comparable to those of LPP.

The LDI concept described is a multipoint fuel injection/multiburning zone concept. Each of the multiple fuel injectors has an air swirler associated with it to provide quick mixing and a small recirculation zone for burning. The multipoint fuel injection provides quick, uniform mixing and the small multiburning zones provide for reduced burning residence time, resulting in low NO_x formation. An integrated-module approach was used for the construction where chemically etched laminates, diffusion bonded together, combine the fuel injectors, air swirlers, and fuel manifold into a single element.



This revolutionary combustor concept employs multipoint arrays of lean-burning combustion zones to reduce NO_x emissions to extremely low levels. The multipoint array of lean direct injectors is shown integrated into a sector combustor rig.

The multipoint concept combustor was demonstrated in a 15° sector test. The configuration tested had 36 fuel injectors and fuel-air mixers that replaced two fuel injectors in a conventional dual-annular combustor. During tests, inlet temperatures were up to 870 K and inlet pressures were up to 5400 kPa. A correlation was developed that related the NO_x emissions with the inlet temperature, inlet pressure, fuel-air ratio, and pressure drop. At low-power conditions, fuel staging was used so that high combustion efficiency was obtained with only one-fourth of the fuel injectors flowing. The test facility had optical access, and visual images showed the flame to be very short, approximately 25 mm long.

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