# COMBUSTION TECHNOLOGY OVERVIEW

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The combustion of gas turbine fuels is the subject matter for the next two sessions. In the papers in this session combustor technology programs, as distinguished from combustion research of a more fundamental nature, are discussed, and the results of Government-funded contracts with engine manufacturers are described.

To evolve the combustor technology required for use of broadened-property fuels, several levels of combustor technology are being investigated. First, unmodified in-service combustors are being evaluated with broadened-property fuels. The intent of these investigations is to determine the extent to which fuel properties can be varied, to obtain a data base of combustion - fuel quality effects, and to determine the trade-offs associated with broadened-property fuels. Second, subcomponents of in-service combustors such as fuel injectors and liners, as well as air distributions and stoichiometry, are being altered to determine the extent to which fuel flexibility can be extended. Last, very advanced technology consisting of new combustor concepts is being evolved to optimize the fuel flexibility of gas turbine combustors.

The increasing concerns regarding the supply and quality of gas turbine fuels at present and for the future has served as the impetus for expanded research in many fuels and combustion areas. Department of Defense programs aimed at military aviation applications form a significant part of the material presented in this session. Specifically, two Air Force Wright Aeronautical Laboratory (AFWAL) programs are described by Thomas A. Jackson of AFWAL. These are the Fuel Character Effects on the J79 and F101 Engine Combustion Systems, a recently completed effort, and the Air Force Fuel Mainburner/Turbine Effects program, a major program currently in progress.

NASA Lewis programs aimed toward civil aviation applications include analyical evaluation of the effects of broadened-specification fuels on high-bypass turbofan engine combustors, which is described later in this overview; the Experimental Combustor Study program, a recently completed effort, which is described by John M. Kasper and Edward E. Ekstedt of the General Electric Co.; and the NASA Broadened-Specification Fuels Combustion Technology program, which is described in the papers by James S. Fear of NASA Lewis, Dr. Robert P. Lohmann of Pratt & Whitney, and Willard J. Dodds of General Electric Co.

A third area of fuels and combustion research, stationary-power gas turbines, is being pursued in the Department of Energy/NASA Low-$NO_x$ Heavy-Fuel Combustor Concept program. This program consists of contracts with five engine manufacturers and is aimed at evolving fuel-flexible, environmentally acceptable combustors capable of using heavy oil fuels and synfuels (non-petroleum-derived fuels) in utility and industrial applications. Although a presentation of this program is not included in this session, the program has been described in a recent ASME paper (ref. 1).

Before the NASA Lewis combustor technology programs were implemented, analytical studies were conducted under contracts with Pratt & Whitney Aircraft and the General Electric Co. These studies consisted of in-depth analyses of broadened-property fuel effects on the performance and emissions of current high-bypass-ratio, commercial aircraft engine combustors and future engine combustors of the Energy Efficient Engine ($E^3$) type. These studies have been completed and the results published as NASA Contractor Reports (refs. 2 and 3).

Study results indicated that in conventional combustors the use of broadened-property fuels could have the following undesirable effects:

1. Liner temperatures could be higher because of increased flame radiation to combustor walls. Local liner temperatures could increase by as much as 40 kelvins. The higher temperatures could reduce liner fatigue life by 25 to 40 percent.

2. Attempts to reduce liner temperatures by providing increased coolant airflows could adversely affect combustor exit-temperature-distribution uniformity and thereby reduce turbine life.

3. Broadened-property fuels have poorer atomization characteristics, which would produce poorer, less-uniform fuel sprays and result in poorer ignition and altitude relight performance, deteriorated temperature distributions, increased smoke at high-power conditions, and higher emission levels of carbon monoxide and unburned hydrocarbons at low-power conditions.

4. Maximum allowable fuel temperatures could be reduced by as much as 12 kelvins because of the poorer thermal stability of broadened-property fuels.

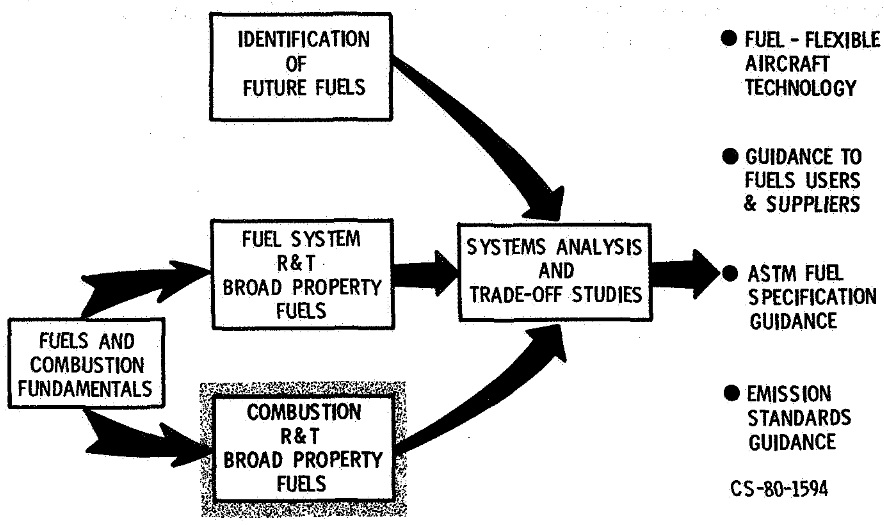
Study results also indicated that the effects of broadened-property fuels on combustors could be minimized by using multizone, lean-burning combustors. In these advanced combustor designs the combustion processes are more carefully controlled than in conventional combustors, and radiation levels to liners are minimized by burning at fuel-lean conditions during high-power operation. These indications have been substantiated in test rig and engine short-term evaluations where conventional combustors and multizone combustors were fueled with Jet A and broadened-property distillate fuels (refs. 4, 5, and 6).

## REFERENCES

1. Lister, E.; Niedzwiecki, R. W.; and Nichols, L.: Low $NO_x$ Heavy Fuel Combustor Program. ASME Paper 80-GT-69, March 1980.

2. Lohmann, R. P.; Szetela, E. J.; and Vranos, A.: Analytical Evaluation of the Impact of Broad Specification Fuels on High Bypass Turbofan Engine Combustors. NASA CR-159454, 1978.

## AIRCRAFT RESEARCH AND TECHNOLOGY FOR FUTURE FUELS




FUELS/COMBUSTION TECHNOLOGY PROGRAMS

| COMBUSTORS/ENGINES | OBJECTIVE | EMPHASIS |
|---|---|---|
| IN-SERVICE | ASSESS FUEL FLEXIBILITY<br>DATA BASE<br>TRADEOFFS | EXAMINE PERFORMANCE WITH BROAD PROPERTY FUELS |
| IN-SERVICE | EXTEND FUEL FLEXIBILITY | SUBCOMPONENT IMPROVEMENT |
| NEW CONCEPTS | OPTIMIZE FUEL FLEXIBILITY CAPABILITIES | EVOVLE ADVANCED COMBUSTION TECHNOLOGY |

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## GAS TURBINE FUELS/COMBUSTION RESEARCH

| ORGANIZATION | APPLICATION | PROGRAMS |
|---|---|---|
| DOD<br>AIR FORCE WRIGHT AERONAUTICAL LABORATORY | MILITARY AVIATION | • JT9, F101<br>• FUEL-MAIN BURNER /TURBINE EFFECTS |
| | JOINT EFFORT | |
| NASA-LeRC | CIVIL AVIATION | • ANALYTICAL STUDIES<br>• EXP COMB. STUDY<br>• COMB. TECHNOLOGY |
| | COMBINED EFFORT | |
| DOE<br>FOSSIL ENERGY DIVISION | STATIONARY POWER | • LOW $NO_x$ HEAVY FUEL COMBUSTOR<br>• SYNFUEL CHARACTERIZATION AND COMBUSTION STUDIES |

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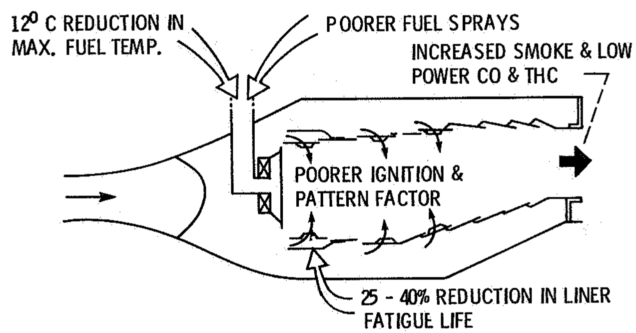
## ANALYTICAL STUDY RESULTS

IN CONVENTIONAL COMBUSTORS THE USE OF BROAD PROPERTY FUELS COULD RESULT IN:




FUEL EFFECTS COULD BE MINIMIZED BY MULTI-ZONE, LEAN BURNING COMBUSTORS

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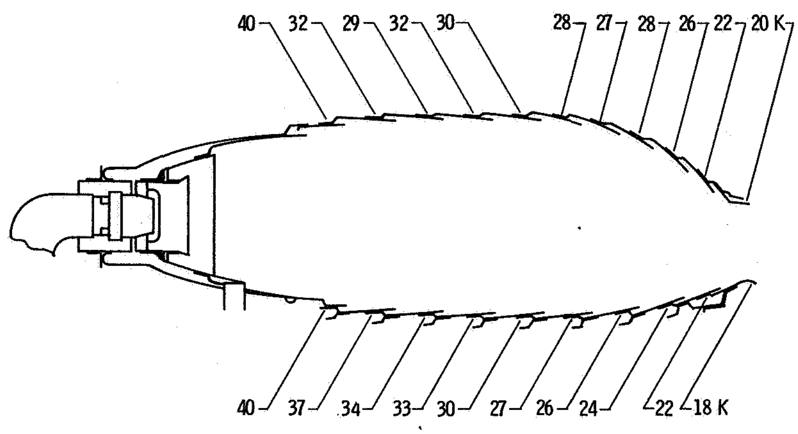
INCREASE IN LINER TEMPERATURES WITH ERBS FUEL

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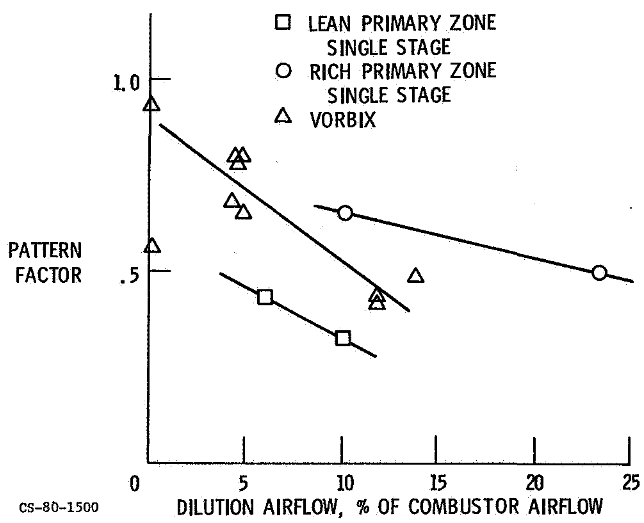
EFFECT OF DILUTION AIR QUANTITY ON COMBUSTOR PATTERN FACTOR

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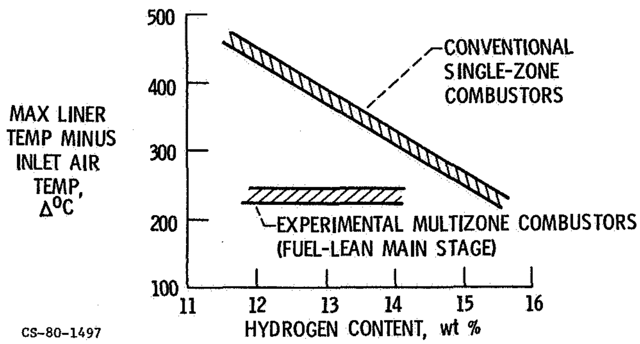
EFFECT OF HYDROGEN CONTENT OF FUEL
ON LINER TEMPERATURE

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