AEROTHERMAL MODELING PROGRAM

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General Electric began work on this effort in August, 1982. Rather than describing progress, therefore, this presentation will indicate some significant features of the planned approach.

Figure 1 schematically shows the individual computerized models utilized in General Electric's combustor aero design approach. The preliminary design module provides the overall envelope definition of the burner. The diffuser module provides the detailed contours of the diffuser and combustor cowl region, as well as the pressure loss characteristics into each of the individual flow passages into the dome and around the combustor. The flow distribution module provides the air entry quantities through each of the aperatures and the overall pressure drop. The heat transfer module provides detailed metal temperature distribution throughout the metal structure as input to stress and life anlaysis that are not part of the aerothermo design effort.

The internal flow module, which entails 3-D elliptic flow field calculations, is not at present, used in General Electric's design method. It is planned, however, that it will be incorporated in the very near future to the extent that its usefulness is demonstrated. It is expected to be initially useful in providing improved hot gas side inputs to the heat transfer module and to help guide the development of combustor exit pattern factor. The capabilities include analysis of the mixing of the dilution region without chemical reaction, the treatment of fuel insertion, and the chemical reaction zone itself. While the phenomena in each of these regions is developed to a different extent of rigor, they all utilize the same basic 3-D elliptic framework.

General Electric's internal flow module, INTFLOW, has a basic core structure that can interchangeably use either the 3-D combustor performance model from the Combustor Design Criteria Validation Program prepared by Garrett Corporation

(HC Mongia, RS Reynolds, and TW Bruce, 1979) or the newer Northern Research and Engineering Corporation's version of this same type of 3-D elliptic code. These core packages are supplemented by special input routines and output plotting routines that have been prepared at General Electric. Figure 2 is the type of calculated output plots that are available from INTFLOW. The length of the arrows represent the relative velocity of the flows within this annular combustor, which includes swirl cups and a complex dilution pattern.

In the Aerothermal Modeling Program, comparisons are to be made with benchmark quality test data to permit evaluation of the accuracy of the modules and to identify the sources of error or inaccuracy within the modules. Data from the F101 series of General Electric combustors have been selected as a major basic source of this benchmark data. Extensive combustor liner metal temperature data and combustor exit gas temperature pattern data are available. These combustion aerothermodynamic data are particularly significant as these measured results are the important inputs in the stress and life analysis of the combustor structure and the turbine nozzles and vanes.

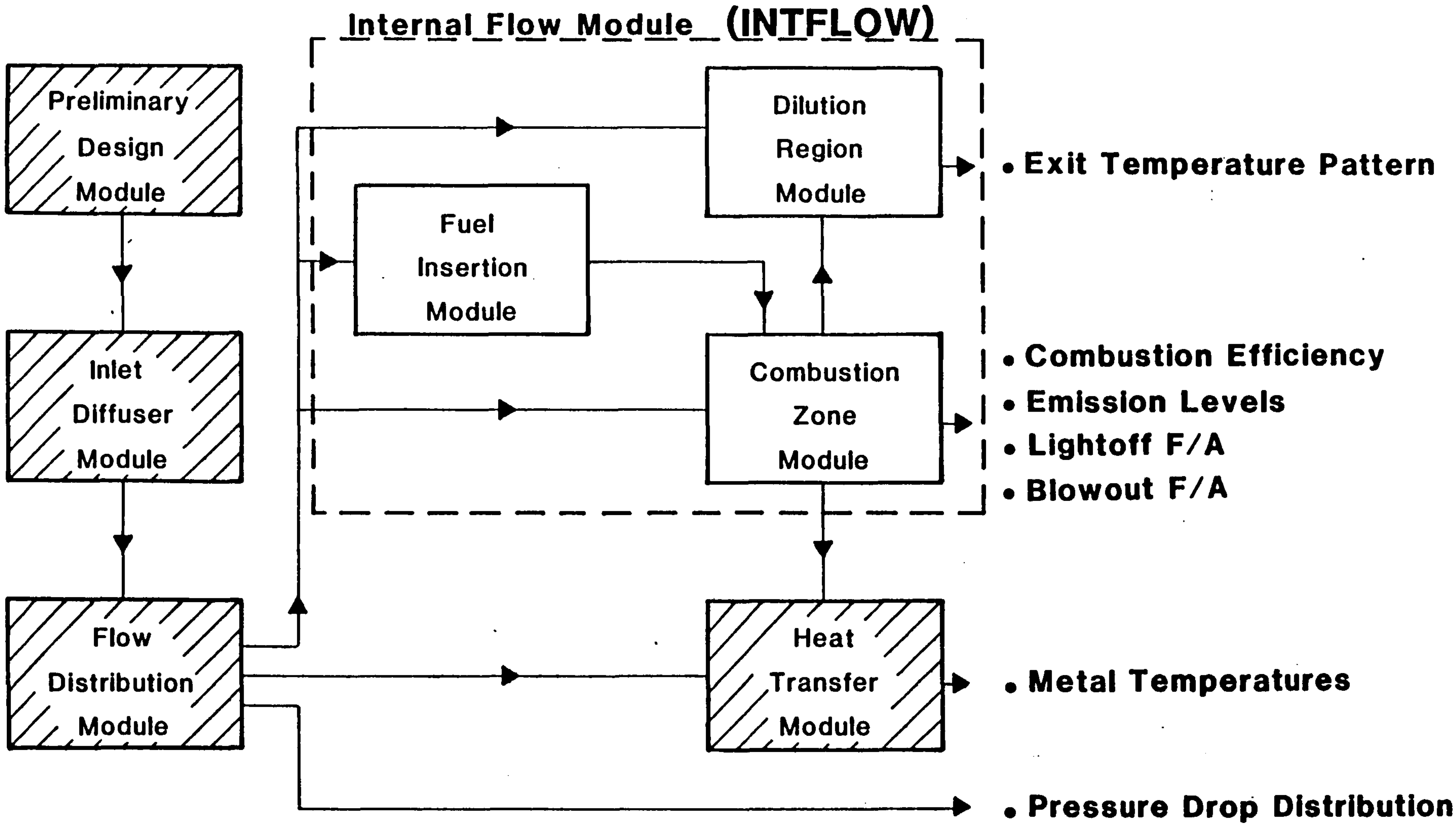
In addition, data from laboratory experiments, with more detailed flow data, will be utilized to help evaluate detailed features within the 3-D elliptic module. At General Electric, alternate computerized treatments are available as 2-D axisymmetric elliptic codes for: turbulence model modifications, numerics changes, kinetics treatment, and time fluctuation treatment. Hence, axisymmetric data will be selected for some of the computerized studies.

Also, a set of experiments will be conducted at General Electric with a test combustion sector having dilution hole characteristics like the General Electric F101 combustor, but with wall boundaries compatible with the current 3-D elliptic code model capabilities. At present, the 3-D elliptic codes available at

General Electric require that the combustor wall boundaries must be modeled along the cylindrical and axial grid lines; an axially curved wall such as the contraction at the aft end of most combustors cannot be accurately modeled. Thus, these experiments will be done with a combustor having a flat dome and cylindrical walls to correspond to the current model capabilities and permit the separation of the boundary shape effects. In addition, the experiments will be done with a series of tests of increasing complexity to help evaluate the error or inaccuracy due to each step in complexity.

Figure 3 indicates the steps in the exploration. A test will be done without burning and without swirl cups utilizing uniform dome flow. By utilizing a different temperature for the dilution flow, the dilution mixing can be documented with thermocouple measurements. Swirl cup flow is then introduced to examine the adequacy of modeling this complexity. The dilution holes complexity will also be varied. Burning tests will then be conducted first with gaseous fuel to avoid the question of spray drop size and vaporization and then with a liquid atomizing nozzle. A total of 15 different test setups are planned including either different configurations or different temperature traced regions.

Through comparison studies of model calculations with the type of data indicated, a program plan to improve the overall aerothermo model will be defined that will address the model deficiencies.



- **Shaded boxes are modules in current use in combustor design and development work.**
- **Open boxes are modules in General Electric's aerothermal model planned for use in the future in design and development work after adequate accuracy is demonstrated or developed.**

Figure 1. Internal flow module.

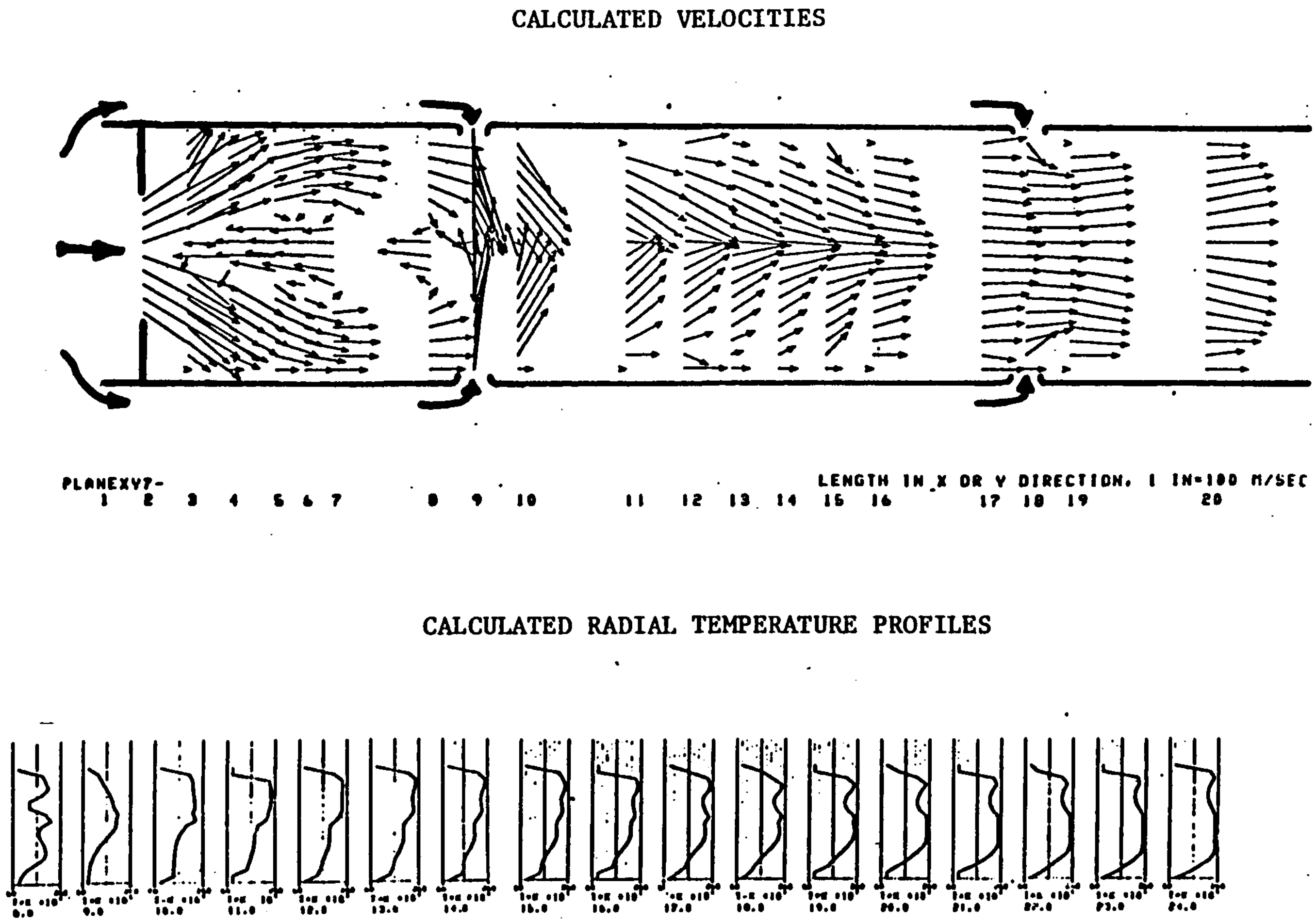


Figure 2. Illustration of computer plotted output for General Electric's INTFLOW module.

GENERAL ELECTRIC TEST PROGRAM WITH COMBUSTOR TEST CONFIGURATIONS COMPATIBLE WITH ELLIPTIC MODEL

NONBURNING TESTS: DOME FLOW TRACED WITH GAS AT DIFFERENT TEMPERATRUE THAN DILUTION AIR

- o PERFORATED PLATE DOME & F101 DILUTION HOLE PATTERN
- o F101 TYPE SWIRL CUP DOME
    - STANDARD F101 LINER DILUTION HOLE PATTERN
    - ONLY ONE ROW OF DILUTION HOLES
    - DILUTION HOLE PLACEMENT TO MODIFY HOT STREAKS
    - DILUTION HOLE TOLERANCE EFFECTS

BURNING TESTS

- o GASEOUS FUEL
- o LIQUID FUEL WITH PRESSURE ATOMIZING NOZZLE

A TOTAL OF 15 SET UPS PLANNED INCLUDING EITHER CONFIGURATION CHANGES OR TRACE REGION CHANGES

Figure 3. General Electric test program.