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DILUTION JET MIXING PROGRAM - PHASE III*

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INTRODUCTION

Improvements in manufacturing technology of surface coatings and other high-temperature materials have directed emphasis toward increasing combustor exit temperatures. Such increases are achieved by reducing the available dilution air, which necessitates effective use of the available dilution air to meet the combustor discharge temperature distribution requirements.

The combustor discharge temperature quality is influenced by almost all aspects of the combustor design and particularly by the dilution zone. To tailor the combustor discharge temperature pattern, the discharge temperature distribution must be characterized in terms of the dilution zone geometric and flow parameters. Such characterization requires an improved understanding of the dilution jet mixing processes.

OBJECTIVES

The objectives of the Phase III program are to:

- Extend the data base on mixing of a single-sided row of jets with a confined crossflow
- Collect data base on mixing of multiple rows of jets with confined crossflow
- Develop empirical jet mixing correlations
- Perform limited three-dimensional (3-D)calculations for some of these test configurations

RESULTS

The tests were performed with uniform mainstream conditions for several orifice plate configurations. Schematics of the test section and the orifice configurations are shown in Figure 1. Temperature and pressure measurements were made in the test section at 4 axial and 11 transverse stations, using a 60-element rake probe. The measured temperature distributions for these tests are reported in Reference 1.

In addition to the experimental efforts, several 3-D numerical calculations were performed. Figure 2 shows a comparison of measured and predicted temperature distributions for the case with a double row of jets in an in-line configuration. The momentum flux ratio for this case is 26.6. The 3-D model underestimates mixing, especially in the transverse direction, with predicted peak temperature difference values higher than the data. Figure 3 shows a similar comparison of predicted and

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measured velocity distributions. The 3-D model correctly predicts the jet penetration but underestimates the jet spreading rate.

Although the 3-D model can be applied to any orifice configuration, it is not cost-effective for redesigning dilution zone configurations. For such modifications, it is desirable to develop empirical models to characterize the combustor exit temperature profile quality as a function of dilution zone geometric and flow parameters. In this program, such correlations have been developed that are applicable to single-row, double-row, and opposed-jet configurations. In addition, this model is applicable to circular as well as noncircular orifices. For opposed and double-row jets, the temperature distributions are obtained by superimposing those due to each individual row of jets. A description of the empirical model is provided in References 1 through 3.

CONCLUSIONS

The following conclusions are drawn by comparing the empirical model results with the test data:

- The NASA/GTEC empirical model includes the effects of aspect ratio of discrete slots for predicting jet mixing characteristics. This model predicts the temperature field due to streamlined slots within first-order accuracy. For bluff slots, this empirical model gives an inferior agreement with the data. Additional work is needed to improve the empirical model predictions.

- The empirical model predictions for double-row jets are obtained by superimposing the temperature field due to each individual row of jets. This superposition scheme gives good correlation with the data, especially in the regions beyond $X/H_0 = 0.5$. In the regions closer to the jet injection plane, the data shows non-Gaussian profiles that are not predicted by the empirical model, but even in those regions, the model is accurate for engineering calculations.

- The empirical model accurately predicts the lateral shift of centerplanes for 45-degree slots, but does not account for the rotation of the temperature contours.

- The modified empirical model provides a valuable first-order tool for designing gas turbine combustor dilution zones. This model can be applied to single-sided or two-sided jets, single or double rows of jets, as well as to circular and noncircular orifice configurations. The model is applicable over a wide range of geometric and flow conditions observed in gas turbine combustion systems.

LIST OF SYMBOLS

D	Geometric orifice diameter
D_j	Effective orifice diameter
H_0	Duct height at the jet injection plane
H	Local duct height at the survey plane
J	Momentum flux ratio, $\rho_j V_j^2/\rho_m V_m^2$
P_t	Stagnation pressure
P_s	Static pressure
S	Orifice spacing
T	Temperature

V	Velocity
X	x direction, parallel to duct axis
Y	y direction, parallel to orifice centerline (radial direction)
Z	z direction, normal to duct axis (transverse direction)
Θ	Temperature difference ratio, $(T_m - T)/(T_m - T_j)$
ρ	Density

Subscripts

j	Jet property
m	Cross-flow property, average value

REFERENCES

1. Srinivasan, R.; Myers, G.; Coleman, E.; and White, C.; Dilution Jet Mixing Program - Phase III Report, NASA CR-174884, 1985.

2. Srinivasan, R.; Berenfeld, A.; and Mongia, H.C.; Dilution Jet Mixing Program - Phase I Report, NASA CR-168031, 1982.

3. Srinivasan, R.; Coleman, E.; and Johnson, K.; Dilution Jet Mixing Program -Phase II Report, NASA CR-174624, 1984.

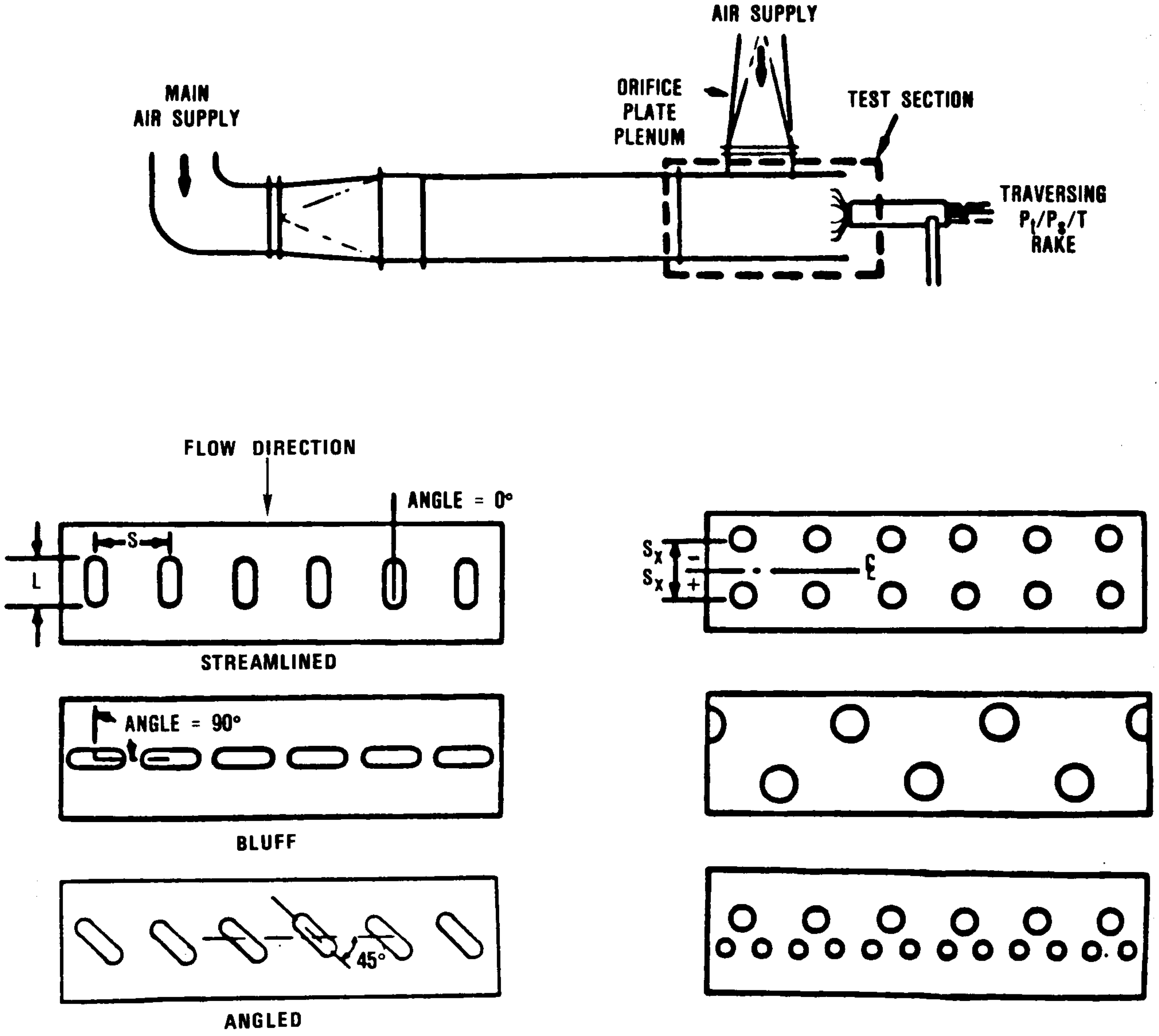

Figure 1. Dilution Jet Mixing Rig Schematic and Orifice Plates.

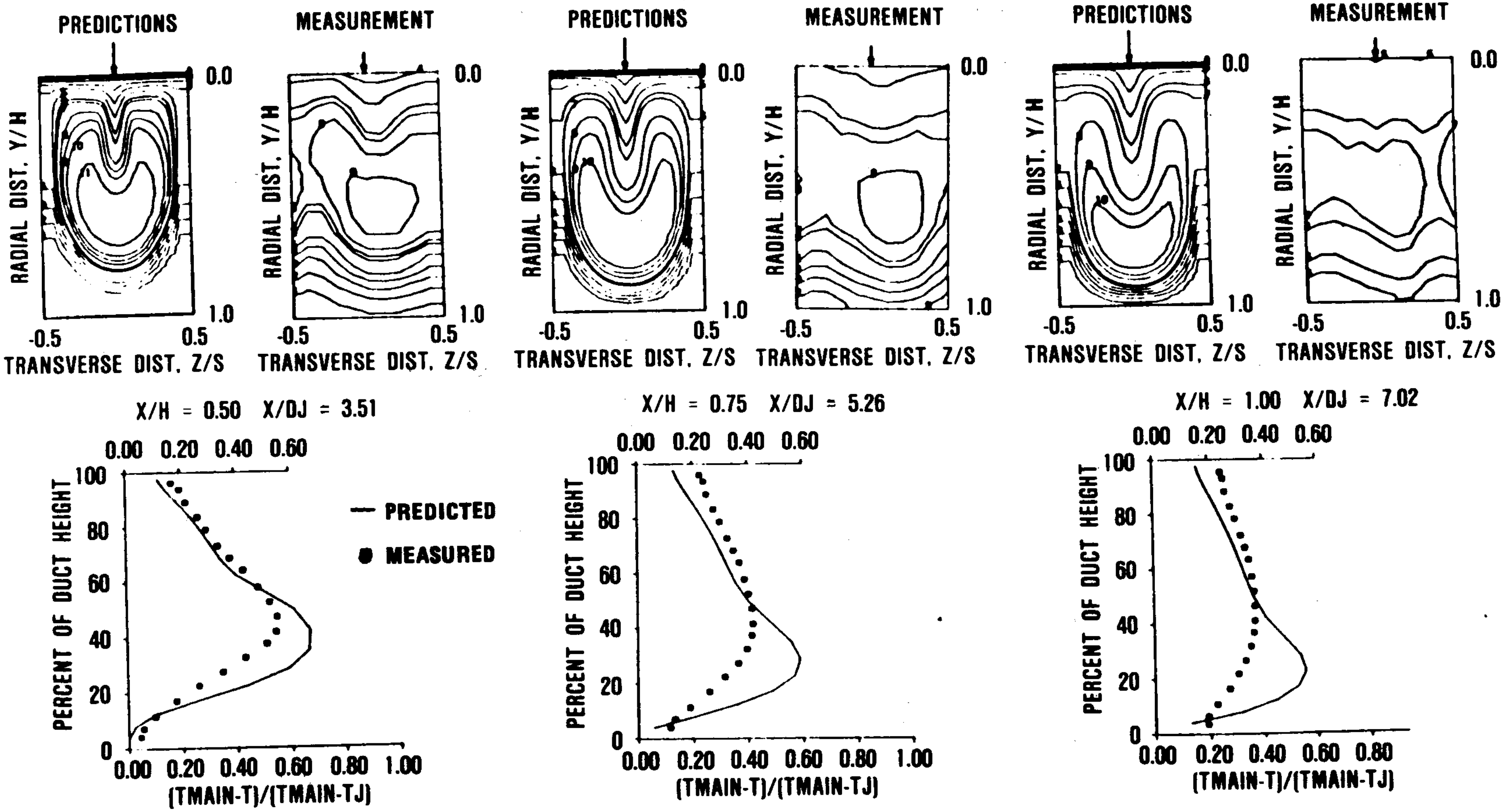

Figure 2. Comparison of Temperature Distributions Between 3-D Model Results and Data for Double Row of Jets, J = 26.6, S/H = 0.5, Using 41 x 23 x 21 Nodes.

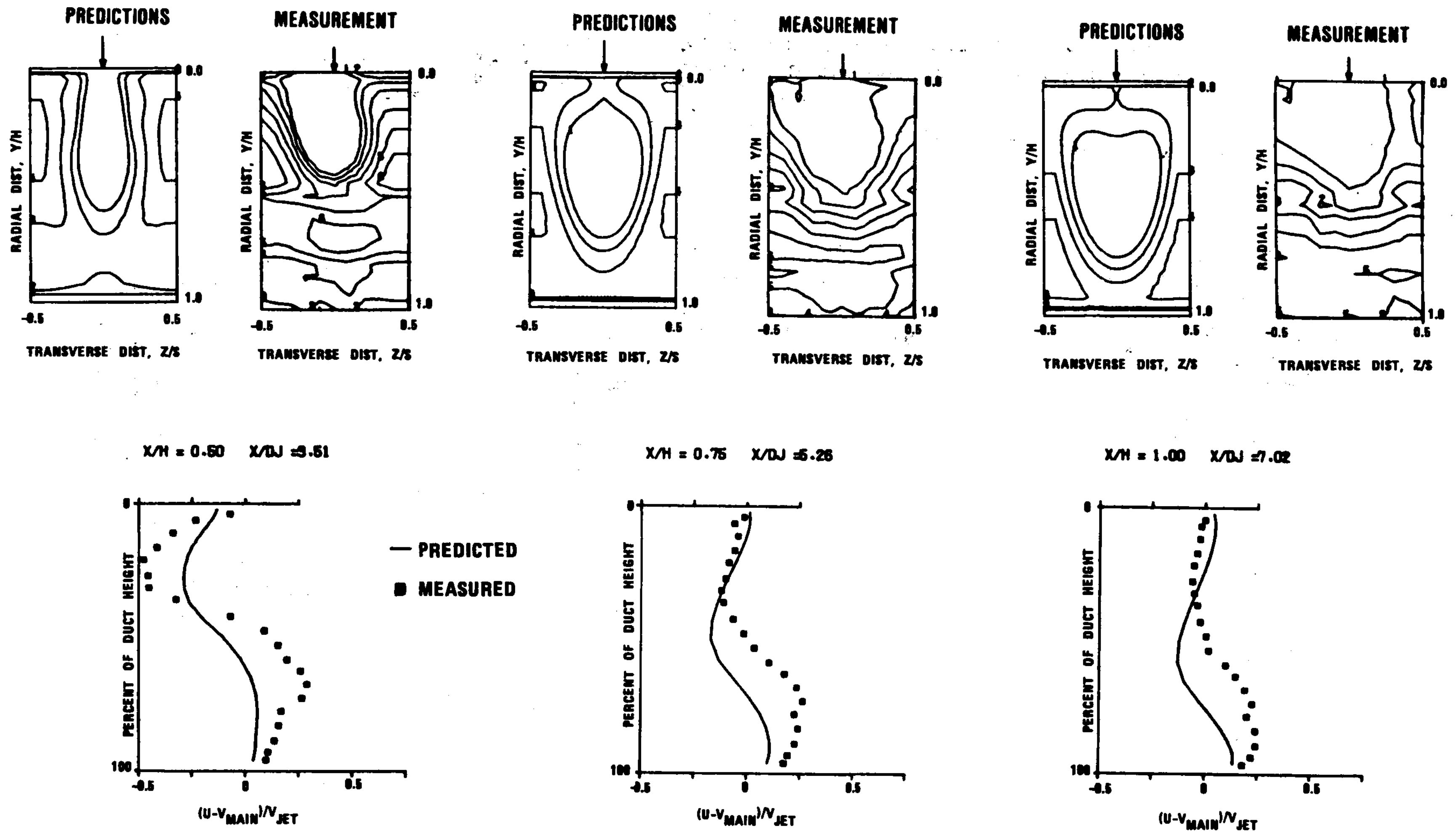

Figure 3. Comparison of Velocity Distributions Between 3-D Model Results and Data for Double Row of Jets, J = 26.6, S/H = 0.5, Using 41 x 23 x 21 Nodes.