DILUTION ZONE MIXING

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Motivated by considerations of dilution zone mixing in gas turbine combustion chambers, NASA sponsored, in 1972 - 1975 contract and grant studies of the mixing characteristics of a row of jets injected normally into a duct flow of a different temperature (references 1, 2, & 3). Based on the favorable response to these studies, and the areas for further work which they identified, NASA Lewis is currently conducting a balanced program of contract, grant, and in-house research on various aspects of the 'jet in a confined crossflow' problem. Included in these are: 1) development of interactive computer codes for analysis of dilution jet mixing, and 2) extension of the experiments on jets in a confined crossflow.

From the data of References 1 & 2, an empirical model was developed (refs. 4 & 5) to describe the observed temperature distributions. The current interactive code provides a 3-D pictorial representation of the temperature, as given by these correlations, for any user-specified downstream location, flow, and orifice parameters. Although calculations can be performed for (almost) any flow and geometric conditions of interest, they are, of course, most reliable for conditions within the range of the experiments. These codes will be improved and extended, and options added, as new data become available.

The experiments in References 1 to 3 dealt primarily with a single row of jets mixing into an isothermal flow in a constant cross-section duct. Variations in the mixing were observed as a function of jet-to-mainstream momentum ratio, orifice size, and spacing. The current experiments examine perturbations of this problem characteristic to gas turbine combustion chambers, namely: flow area convergence, non-isothermal mainstream flow, and opposed in-line and staggered injection.

Specifics of grant studies on free-stream turbulence effects and reverse flow geometries, and analytical calculations of jets in crossflow are presented in companion papers at this conference.

REFERENCES

1. Walker, R.E. and Kors, D.L.: Multiple Jet Study Final Report. NASA CR-121217, 1973.

2. Holdeman, J.D., Walker, R.E., and Kors, D.L.: Mixing of Multiple Dilution Jets with a Hot Primary Airstream for Gas Turbine Combustors. AIAA Paper 73-1249, 1973.

3. Kamotani, Y. and Greber, Isaac: Experiments on Confined Turbulent Jets in Cross Flow. NASA CR-2392, 1974.

4. Walker, R.E. and Eberhard, R.G.: Multiple Jet Study Data Correlations. NASA CR-134796, 1975.

5. Holdeman, J.D. and Walker, R.E.: Mixing of a Row of Jets with a Confined Crossflow. AIAA Journal, vol.15, no.2, Feb.1977, pp243-249.

DILUTION ZONE MIXING STUDIES

OBJECTIVE - TO CHARACTERIZE DILUTION ZONE MIXING IN SUFFICIENT DETAIL TO:

* IDENTIFY AND UNDERSTAND THE DOMINANT PHYSICAL MECHANISMS GOVERNING THE MIXING PROCESS
* REFINE AND EXTEND EMPIRICAL MODELS TO PROVIDE A NEAR-TERM COMBUSTOR DESIGN TOOL
* PROVIDE A DATA BASE FOR VERIFICATION OF ANALYTICAL MODELS

DILUTION ZONE MIXING STUDIES

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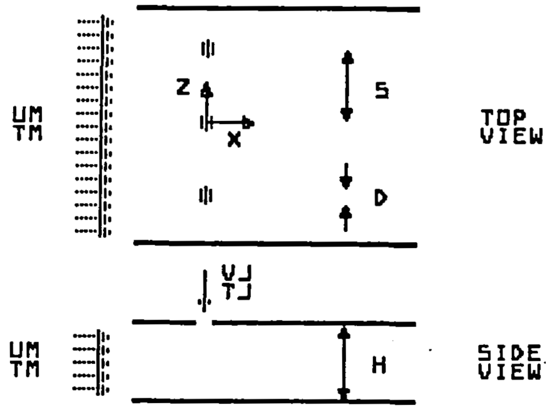
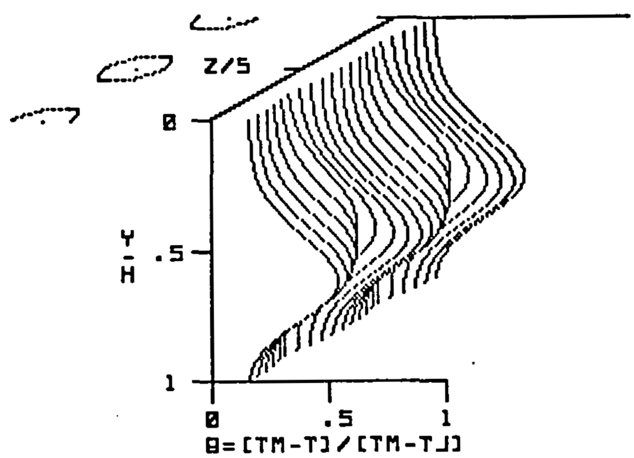
* EXPERIMENTS ON EFFECTS OF FREE-STREAM TURBULENCE ON A JET IN CROSSFLOW (MSU GRANT)
* EXPERIMENTS ON DILUTION JETS IN REVERSE FLOW COMBUSTOR GEOMETRIES (CWRU GRANT)
* DEVELOPMENT OF INTERACTIVE CODES FOR EVALUATION OF DESIGN ALTERNATIVES (IN-HOUSE)
* EXPERIMENTS ON JETS IN A CONFINED CROSSFLOW (GARRETT CONTRACT)
* ANALYTICAL CALCULATIONS OF JETS IN CROSSFLOW (IN-HOUSE)

DILUTION ZONE DESIGN COMPUTER PROGRAMS

OBJECTIVE:	DEVELOPMENT OF INTERACTIVE COMPUTER CODE FOR ANALYSIS OF MIXING OF JETS WITH A CONFINED CROSSFLOW
FEATURES:	PROVIDES A 3-D PICTORIAL REPRESENTATION OF THE TEMPERATURE FIELD
PURPOSE:	EVALUATE EFFECTS OF VARYING FLOW AND GEOMETRY
	GUIDE DESIGN TO REDUCE DEVELOPMENT TIME AND COST
STATUS:	CODES WILL BE IMPROVED AND OPTIONS ADDED AS NEW DATA BECOME AVAILABLE

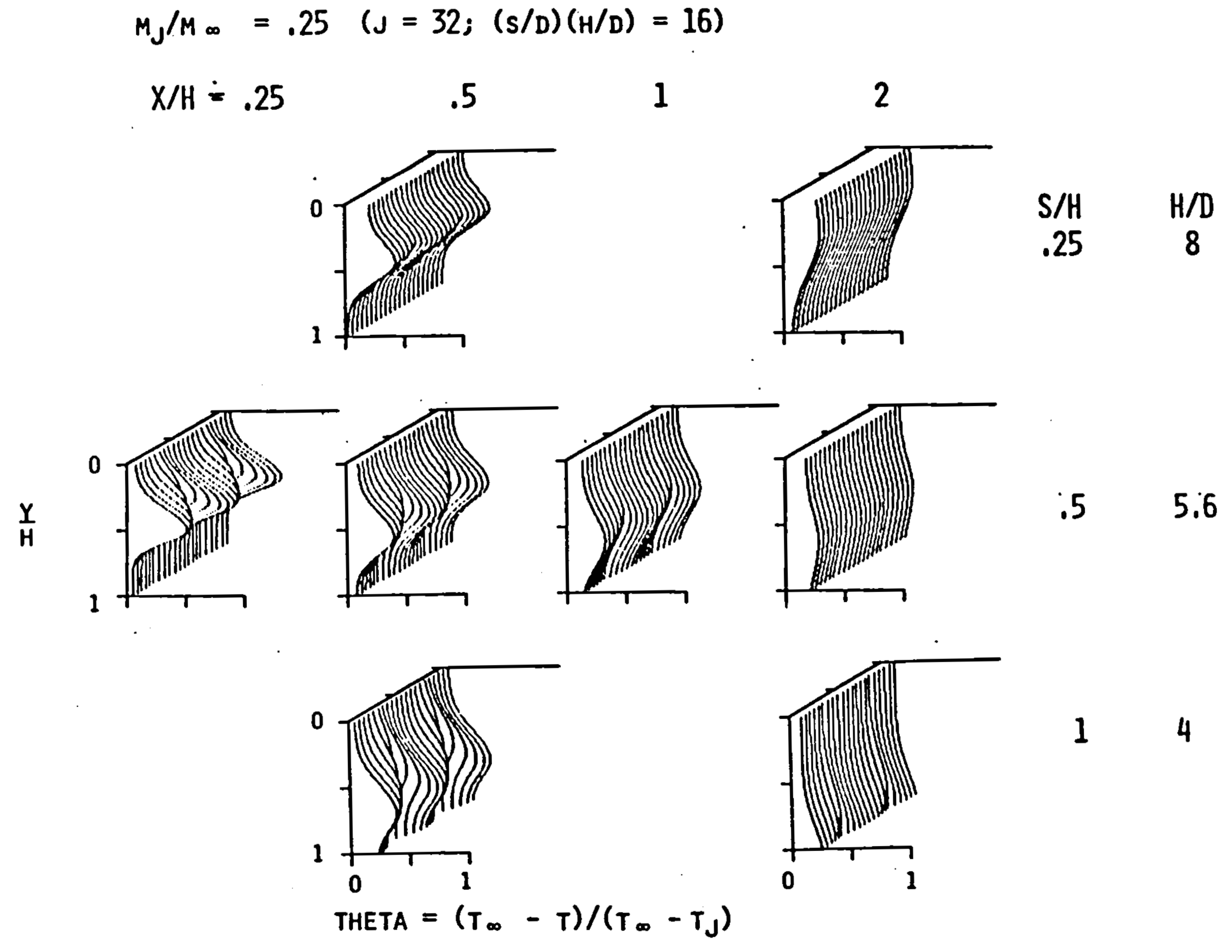


Jet in a Confined Crossflow



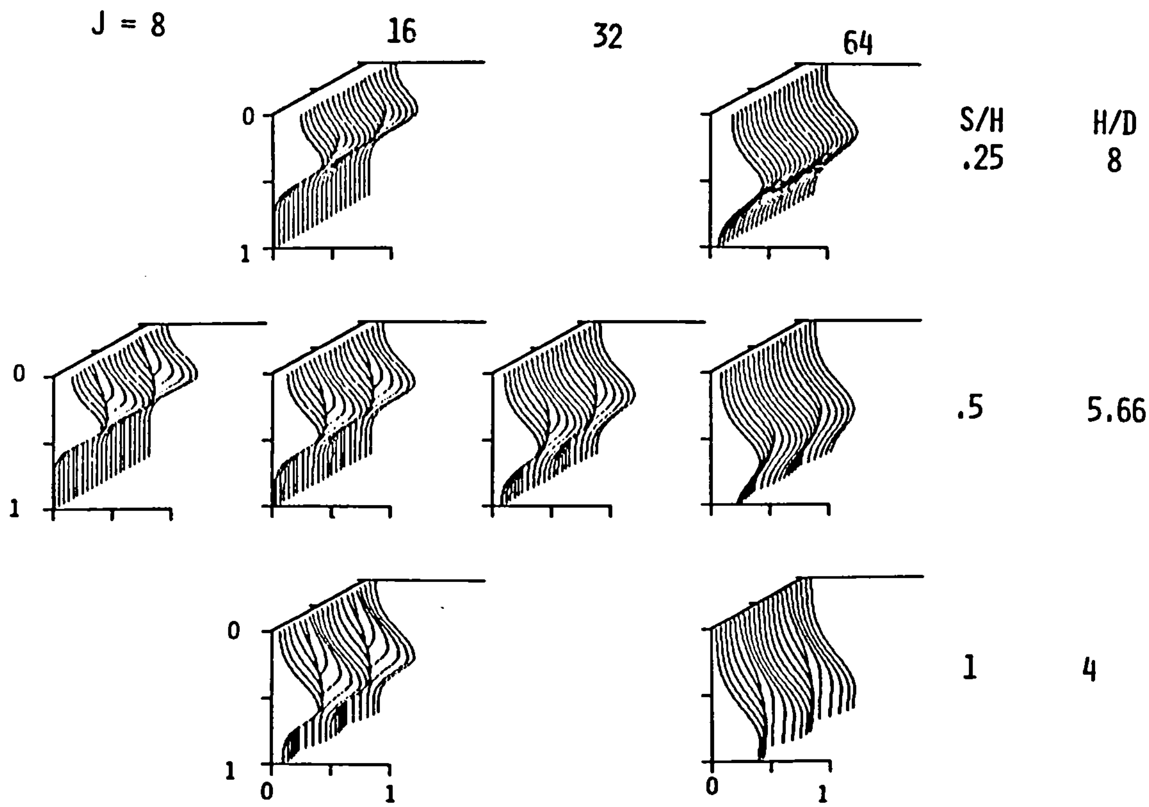
S/D=2 H/D=4 J=32 DR=2 CD=.64
X/H=.5 MR=.5 TB=.33 PF=.34

Typical Temperature Profile Distribution in Y - Z Plane



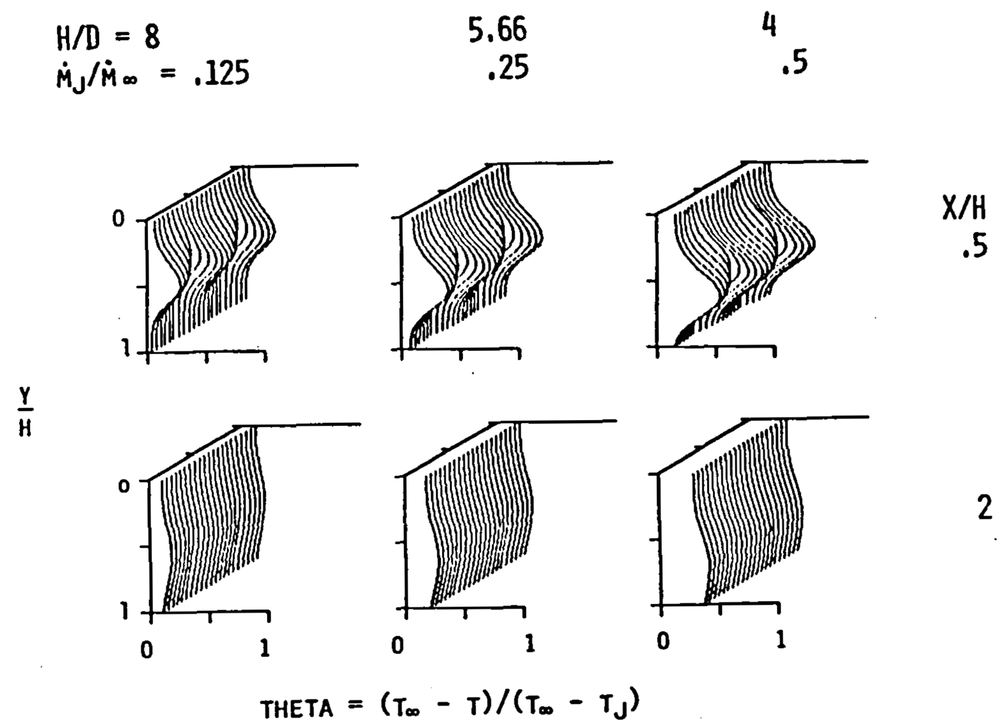
Variation in Temperature Distributions with Downstream Distance

X/H = .5; (S/D)(H/D) = 16



THETA = $(T_\infty - T)/(T_\infty - T_J)$

Varations in Temperature Distributions with Momentum Ratio



Variation in Temperature Distributions with Orifice Size at Constant Spacing to Height Ratio (S/H = .5; J = 32)

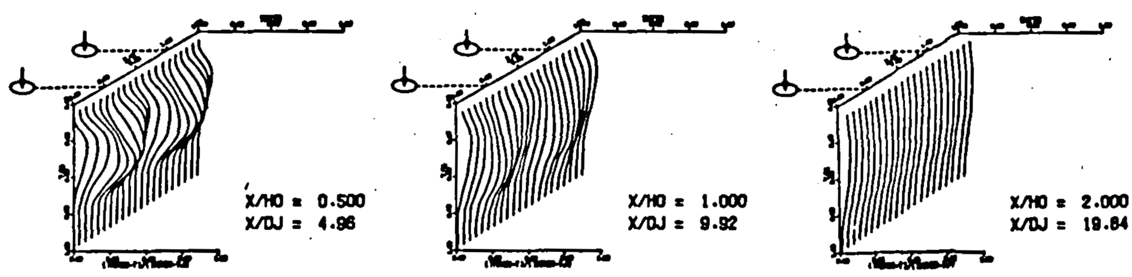
DILUTION JET MIXING PROGRAM

OBJECTIVE – EXTEND KNOWLEDGE OF PENETRATION AND MIXING

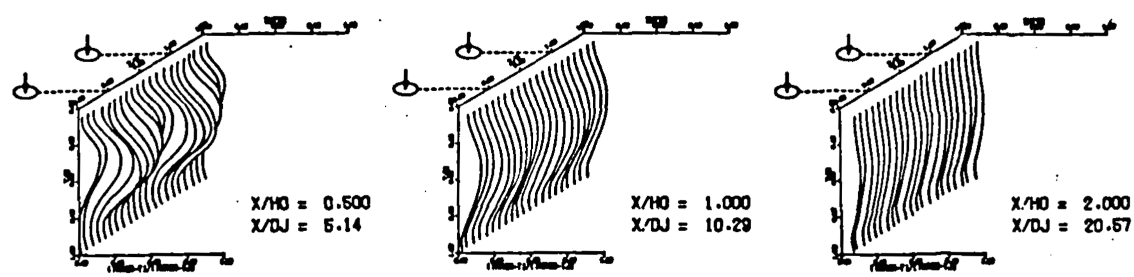
– PROVIDE A DATA BASE TO VALIDATE COMBUSTOR ANALYTICAL MODELS

APPROACH – PERFORM EXPERIMENTS AND EXTEND EMPIRICAL CORRELATIONS TO MODEL:

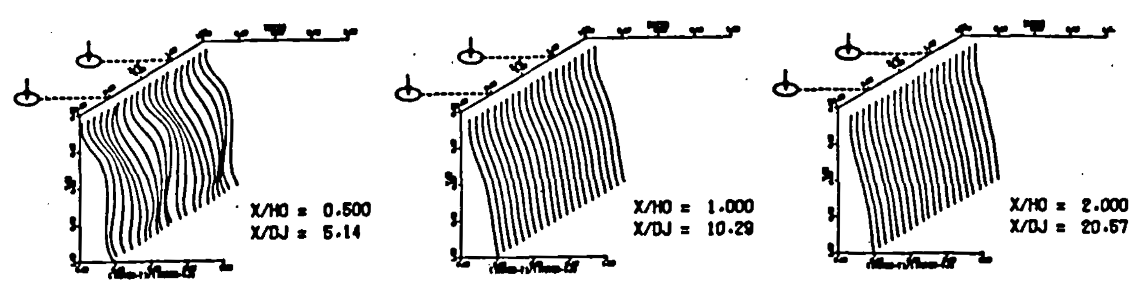
* NON-ISOTHERMAL MAINSTREAM
* FLOW CONVERGENCE
* OPPOSED & STAGGERED JETS



a) Hot Jets – Ambient Mainstream; DR=.75, J=31, R=6.4

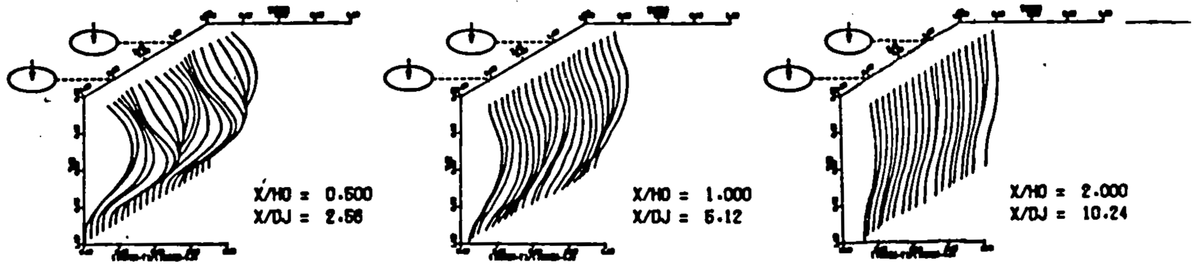


b) Ambient Jets – Hot Mainstream; DR=2.2, J=26, R=3.5

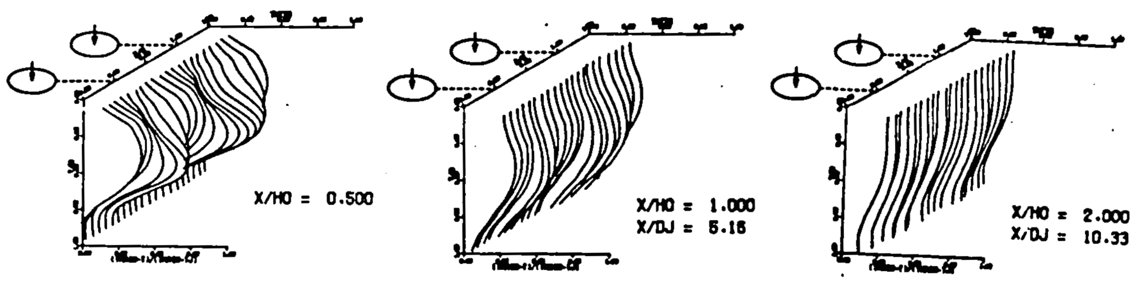


c) Ambient Jets – Hot Mainstream; DR=2.3, J=109, R=6.9

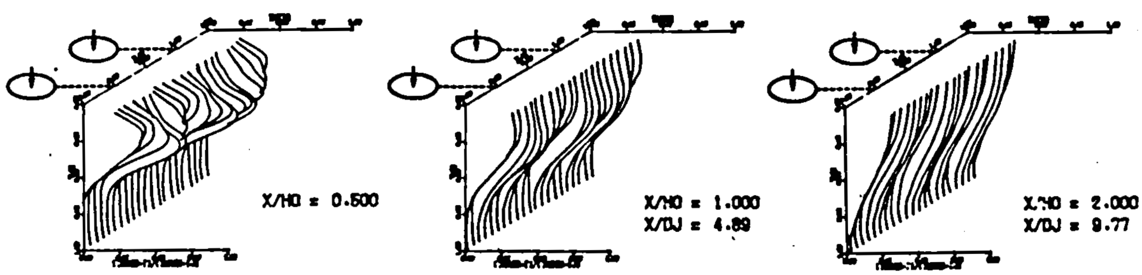
Effect of Density Ratio on Temperature Profiles (S/D=4, H/D=8)



a) Hot Jets - Ambient Mainstream; DR=.62, J=31, M=3.8

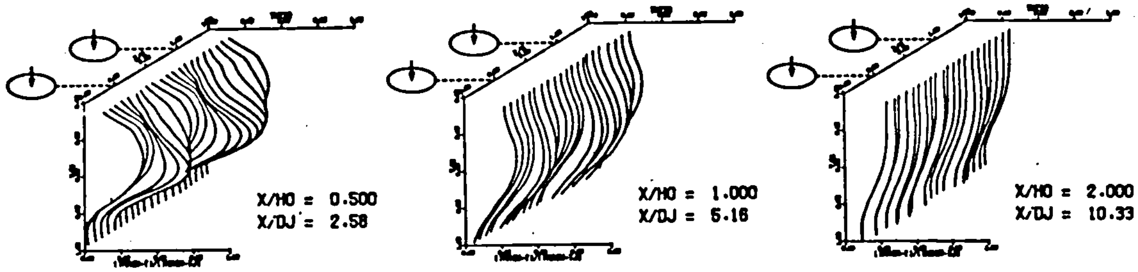


b) Ambient Jets - Hot Mainstream; DR=2.1, J=21.6, M=6.3

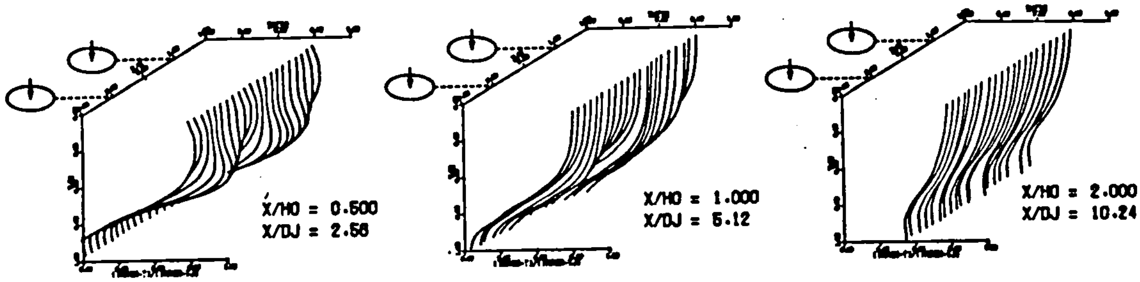


c) Ambient Jets - Hot Mainstream; DR=2.1, J=5.7, M=3.2

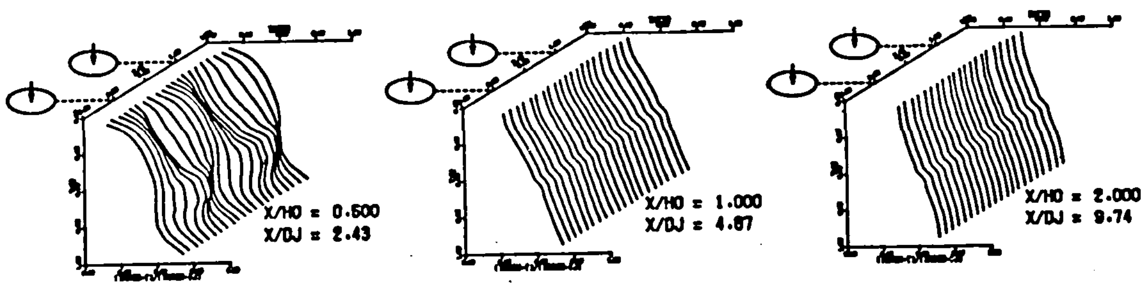
Effect of Density Ratio on Temperature Profiles (S/D=2, H/D=4)



a) Isothermal

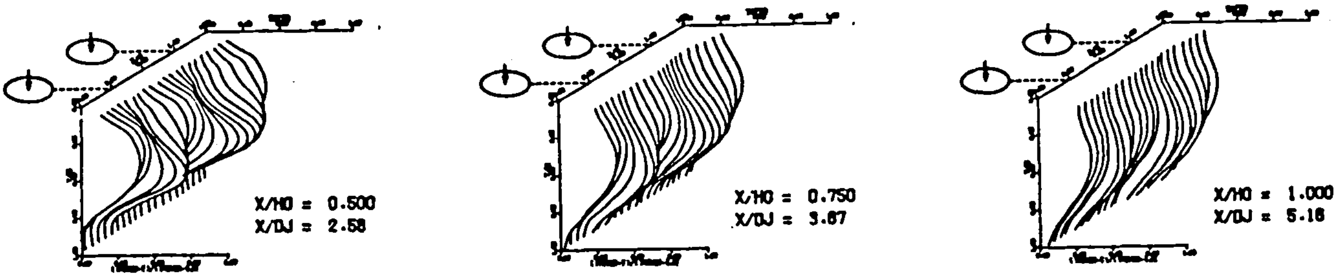


b) Top Cold

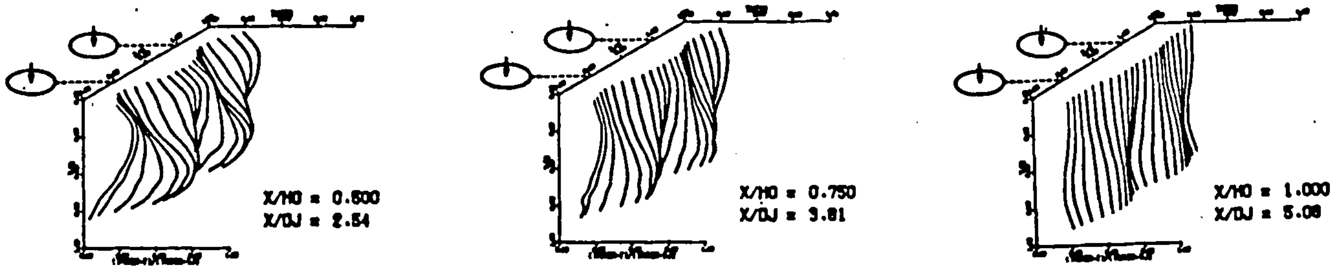


c) Top Hot

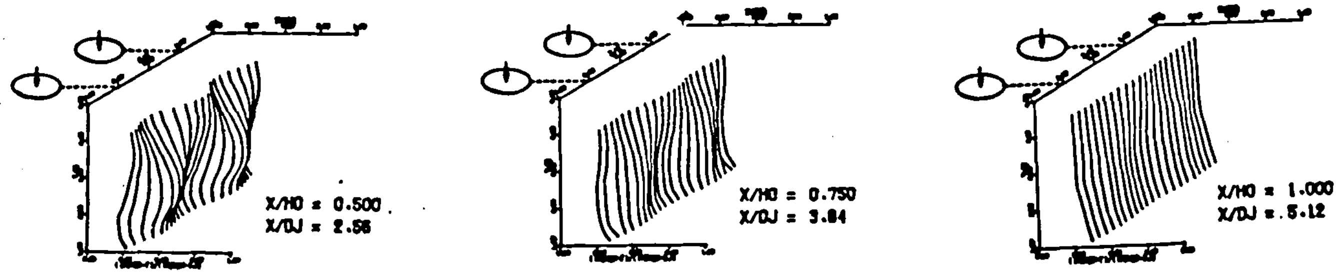
Influence of non-uniform Mainstream on Temperature Profiles



a) Straight Duct

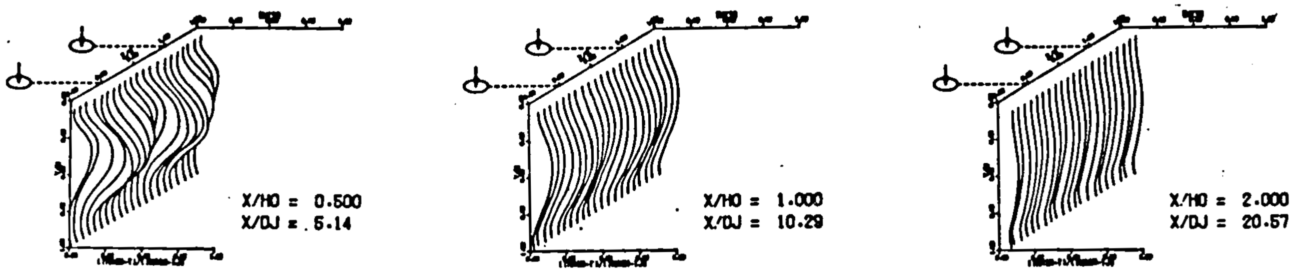


b) Symmetric Convergence (.5/1)

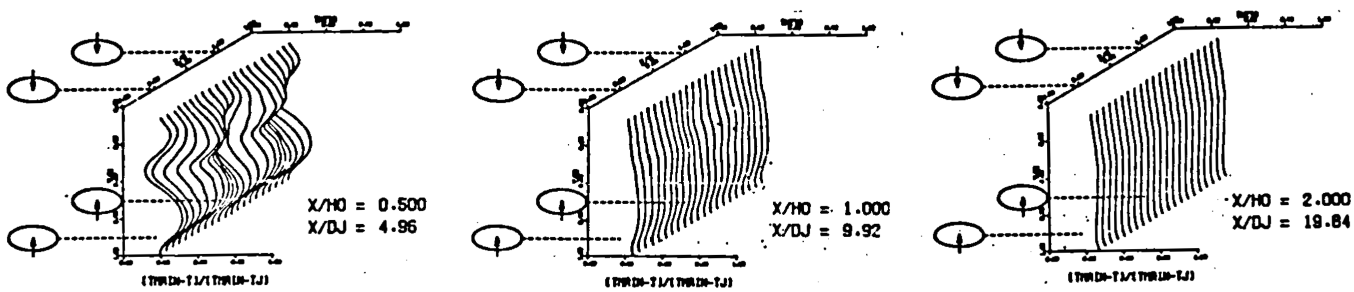


c) Injection Wall Converging (.5/1)

Influence of Flow Area Convergence on Temperature Profiles



a) Single-side (top) Injection (S/H=.5, J=26.3)



b) Two-side (opposed) Injection (S/H=.25, J=25)

Comparison Between Single-side and Opposed Jet Injection