N92-32262

STME HYDROGEN MIXER STUDY

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ABSTRACT

The hydrogen mixer for the STME is used to mix cold hydrogen bypass flow with warm hydrogen coolant chamber gas, which is then fed to the injectors. It is very important to have a uniform fuel temperature at the injectors in order to minimize mixture ratio problems due to the fuel density variations. In addition, the fuel at the injector has certain total pressure requirements. In order to achieve these objectives, the hydrogen mixer must provide a thoroughly mixed fluid with a minimum pressure loss. The AEROVISC CFD code was used to analyze the STME hydrogen mixer, and proved to be an effective tool in optimizing the mixer design. AEROVISC, which solves the Reynolds Stress-Averaged Navier-Stokes equations in primitive variable form, was used to assess the effectiveness of different mixer designs. Through a parametric study of mixer design variables, an optimal design was selected which minimized mixed fuel temperature variation and fuel mixer pressure loss. The use of CFD in the design process of the STME hydrogen mixer was effective in achieving an optimal mixer design while reducing the amount of hardware testing.

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STME HYDROGEN MIXER STUDY

TENTH ANNUAL WORKSHOP FOR CFD APPLICATIONS IN ROCKET PROPULSION

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NASA MARSHALL SPACE FLIGHT CENTER

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April 30, 1992

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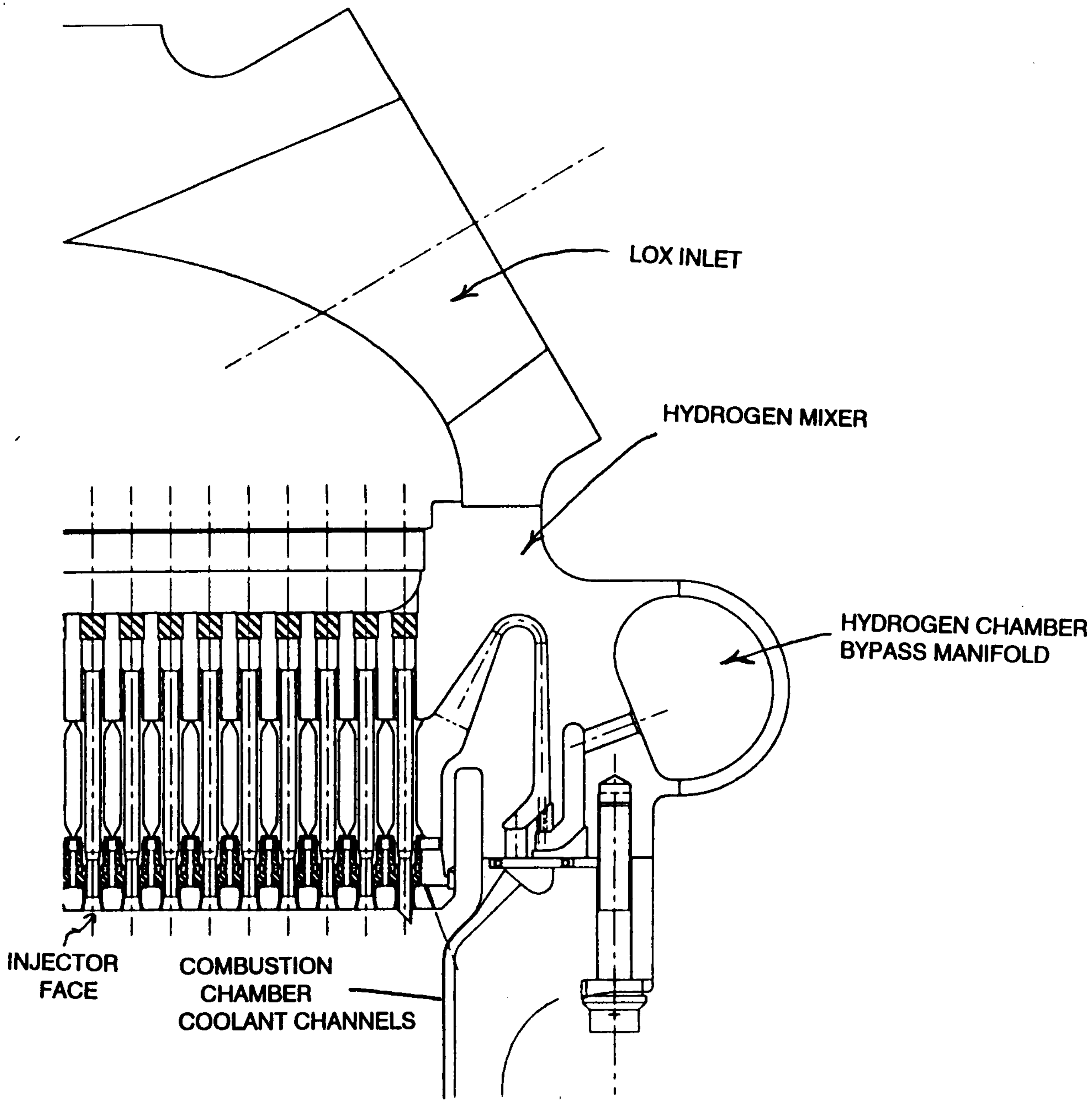
STME HYDROGEN MIXER PROVIDES UNIFORM TEMPERATURE HYDROGEN TO INJECTORS



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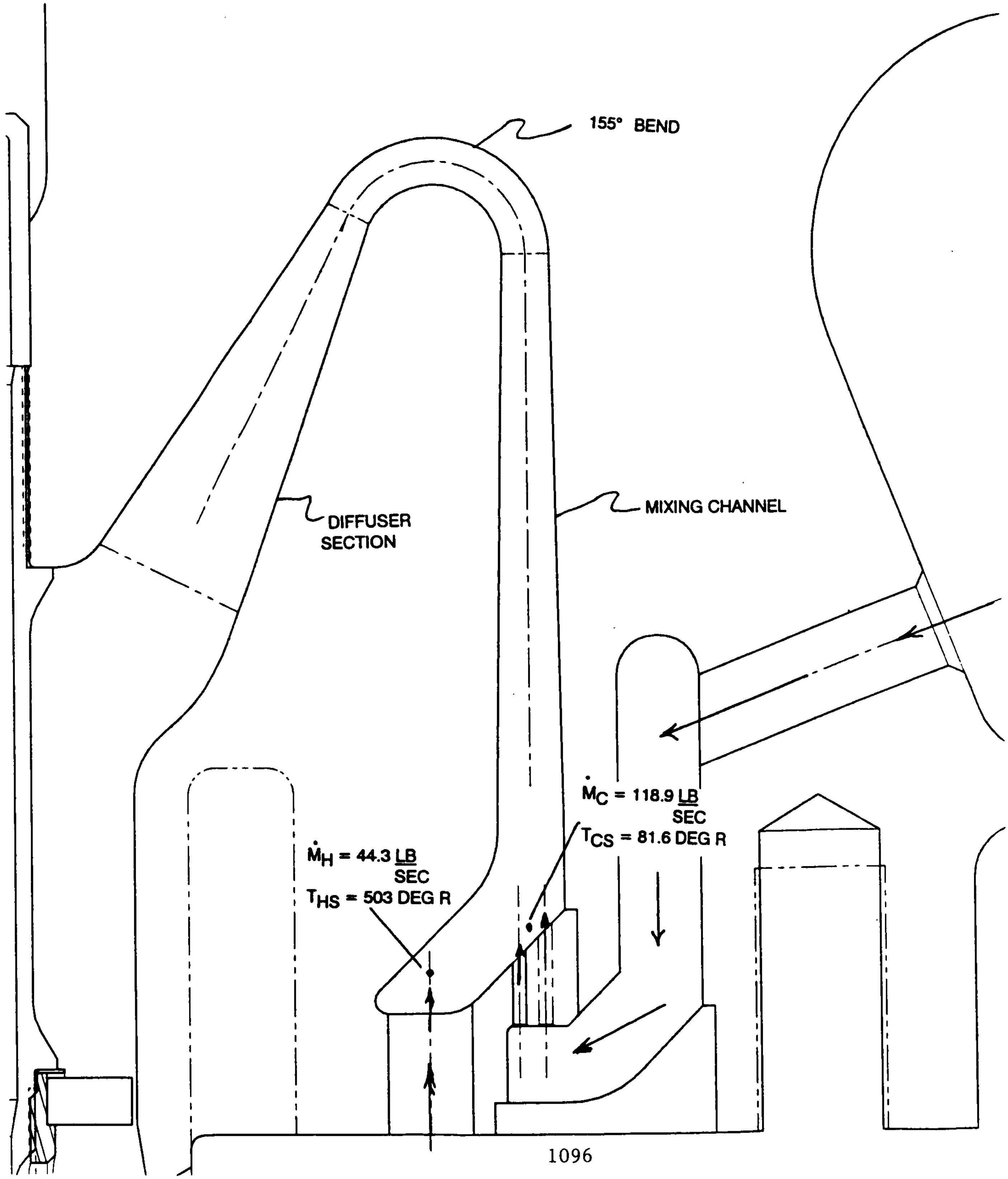
STME HYDROGEN MIXER



WHY IS MIXING IMPORTANT?

- Injector Elements All Designed With Identical Metering Orifice Areas and Equal ΔP Across Each Injector Element Which Therefore Require Uniform Hydrogen Density in Order to Have Equal H_2 Flow Rate to Each Element
- A Uniform Mixture Ratio Injector Core Delivers Highest ISP Performance
- Uniform H_2 Density (Mixture Ratio) Is Dependent on the Performance of the Hydrogen Mixer
- Uniform Temperature Implies Uniform Density

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MODELING ISSUES

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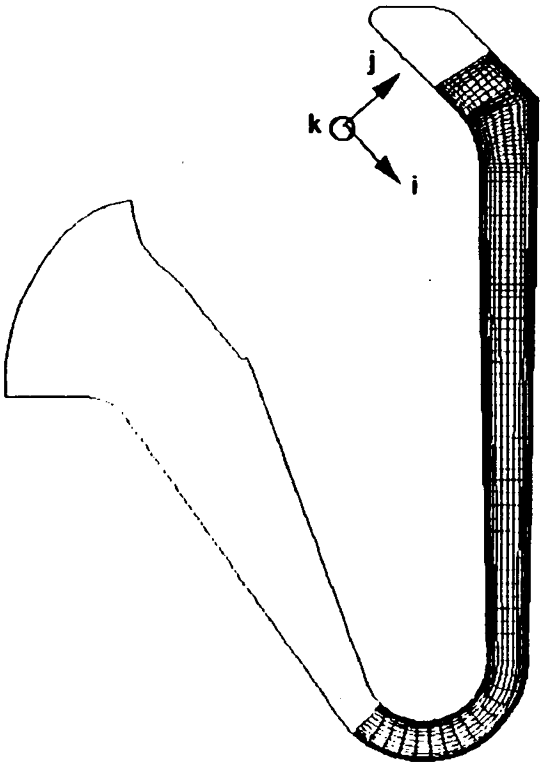
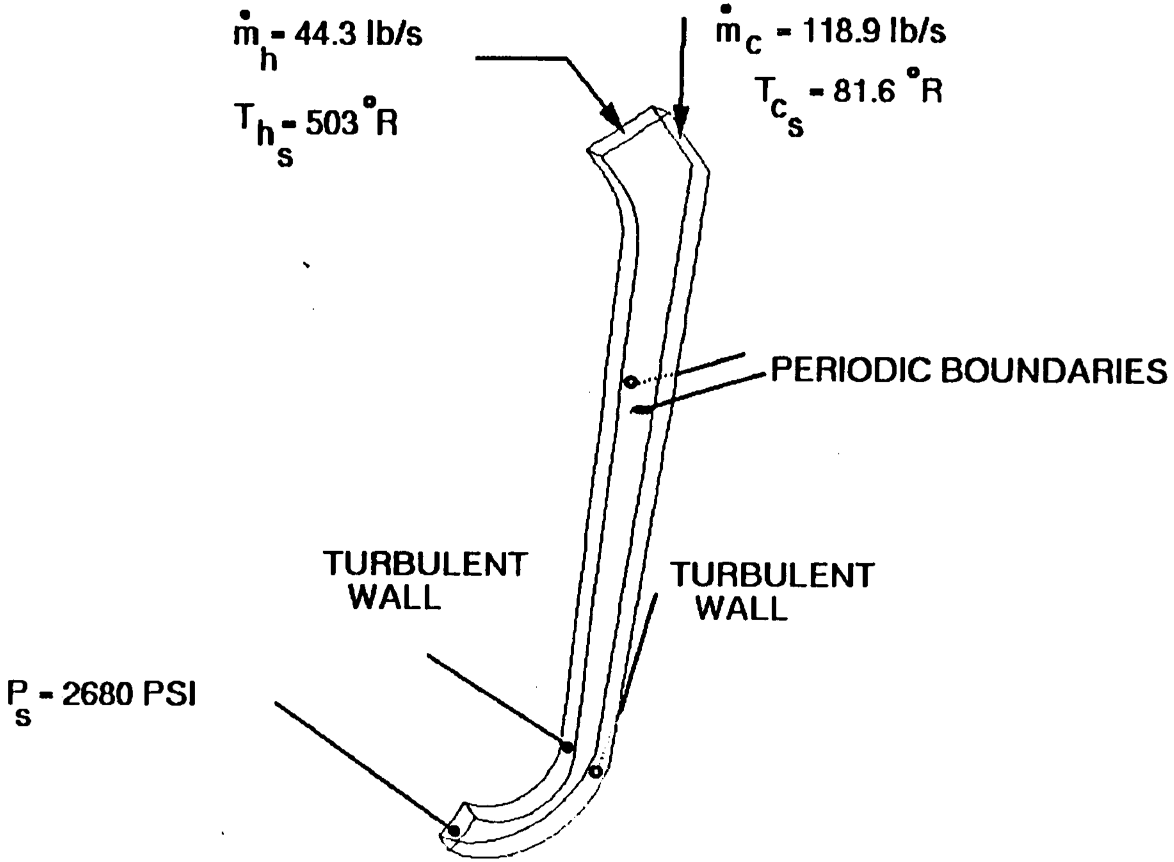


- DISCRETE COLD INLET HOLES
- HOT GAS INLET ASSUMES UNIFORM FLOW ACROSS PASSAGE
- 3-D WEDGE
- COMPRESSIBLE FLOW
- GAS PROPERTIES BASED ON MIXED TEMPERATURE
- STANDARD K-e TURBULENCE MODEL
- ADIABATIC WALLS
- EXIT PLANE AT BEGINNING OF DIFFUSER SECTION
- GRID SIZE 97 X 19 X 16


$\dot{m}_h$ = 44.3 lb/s
T_{h_s} = 503 °R
$\dot{m}_c$ = 118.9 lb/s
T_{c_s} = 81.6 °R
PERIODIC BOUNDARIES
TURBULENT WALL
TURBULENT WALL
P_s = 2680 PSI

STME HYDROGEN MIXER

- Cold Hydrogen Inlet Hole Size Varied to Determine Effect on Mixing

N_{CNOM}	N_C	D_C [in]	A_{CTOT} [in^2]	Wedge Angle [Deg]
500	495	0.091	3.22	1.45
750	749	0.074	3.22	0.96
1000	1033	0.063	3.22	0.70

- Cold Hydrogen Inlet Holes Are Staggered With Respect to the Mixing Channel Centerline

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STATIC TEMPERATURE CORRESPONDING TO DIFFERENT L/Dh LOCATIONS

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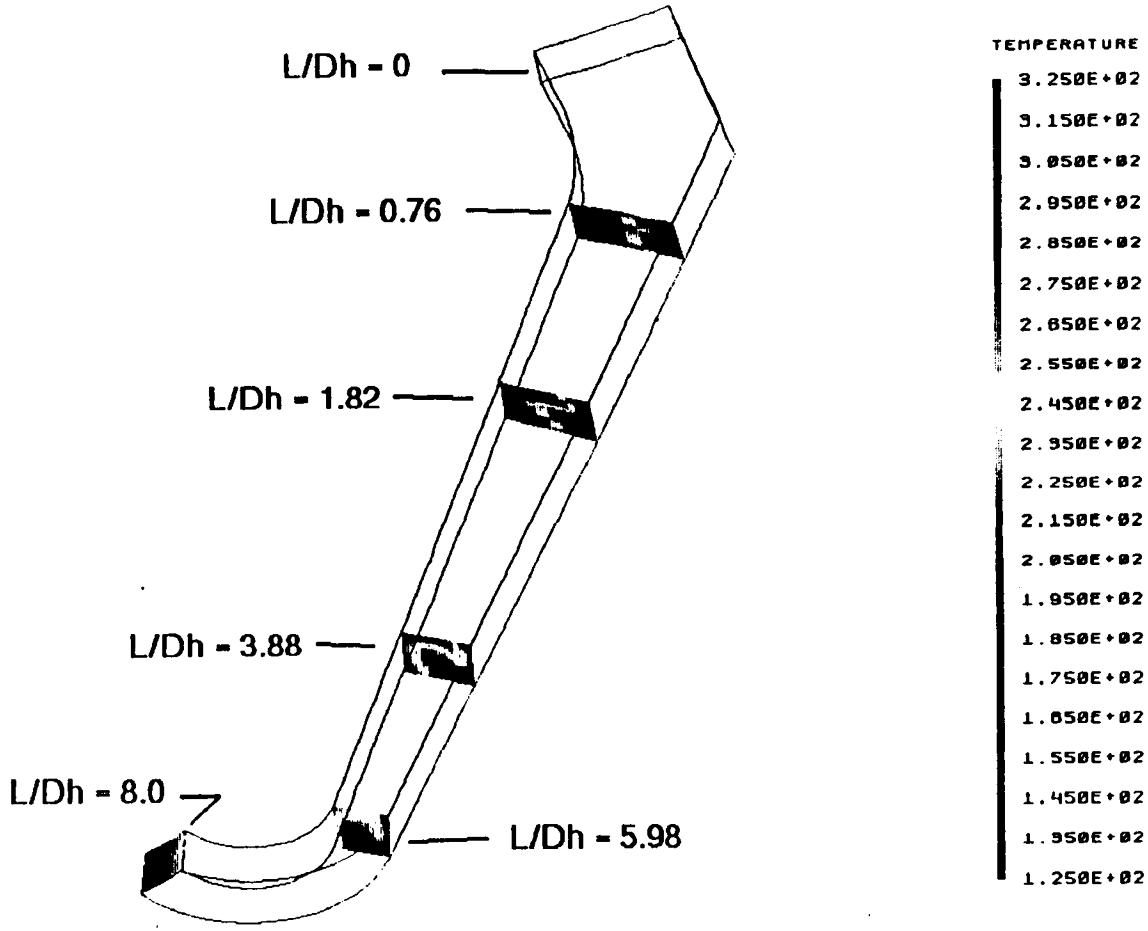

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TOTAL TEMPERATURE VARIATION INSIDE HYDROGEN MIXER

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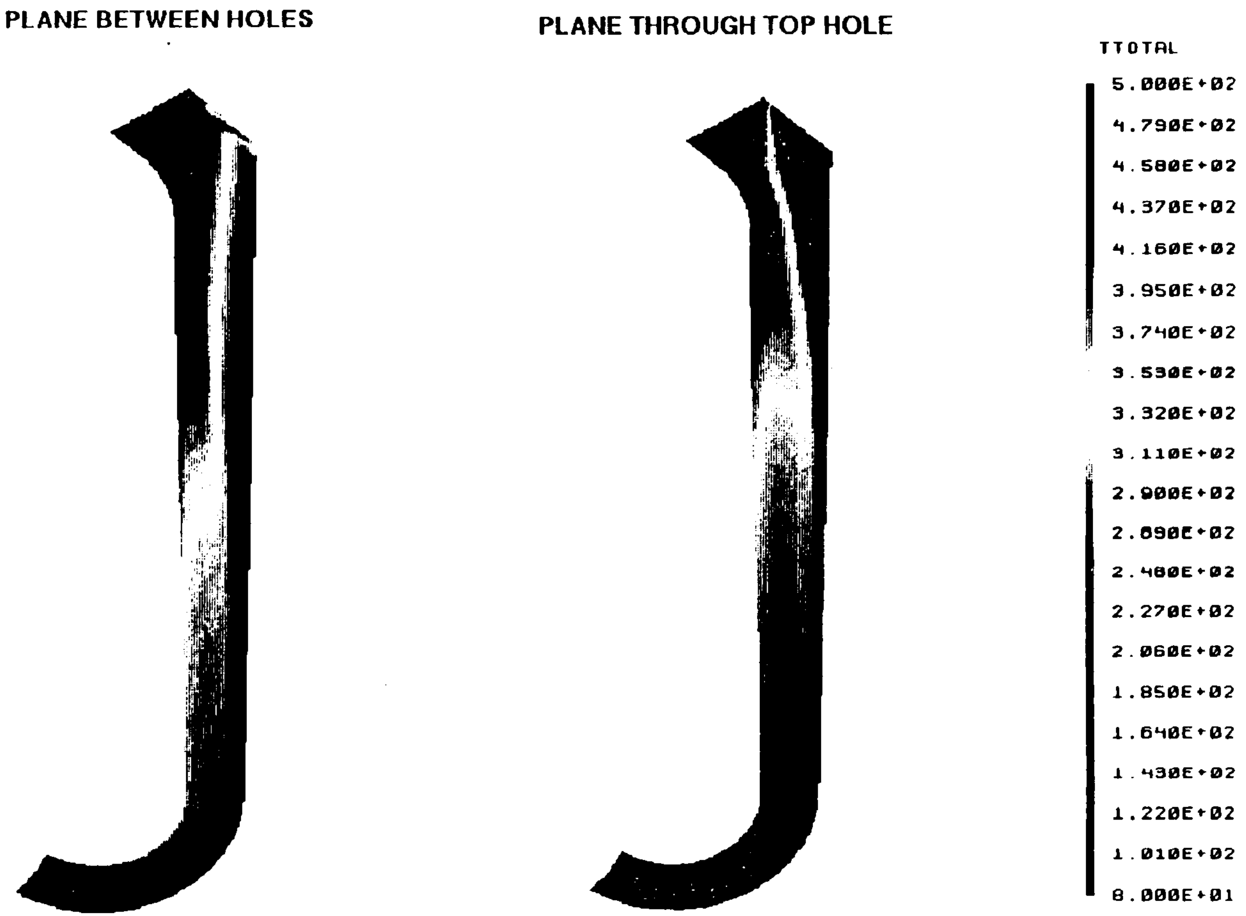

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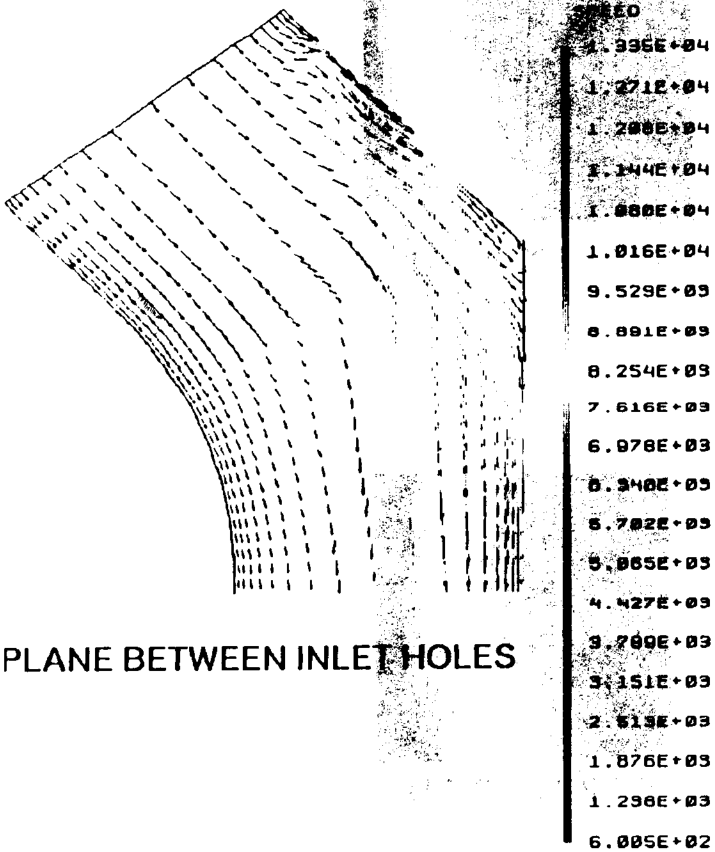
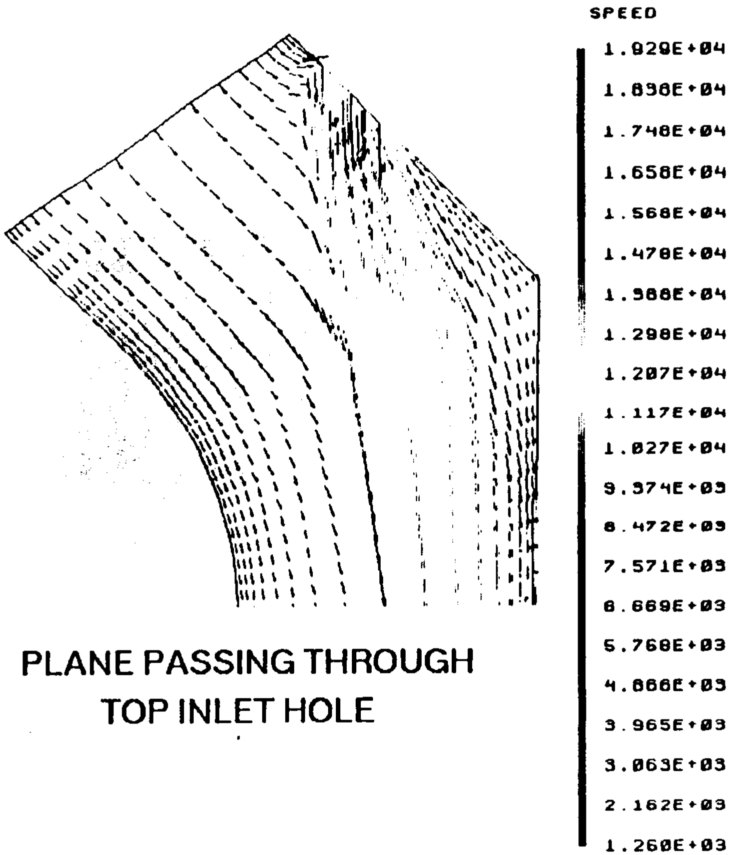
NC - 750 HOLES



PLANE BETWEEN INLET HOLES



PLANE PASSING THROUGH
TOP INLET HOLE

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EXIT PLANE TEMPERATURE DEPENDENT ON COLD HYDROGEN INLET HOLE SIZE

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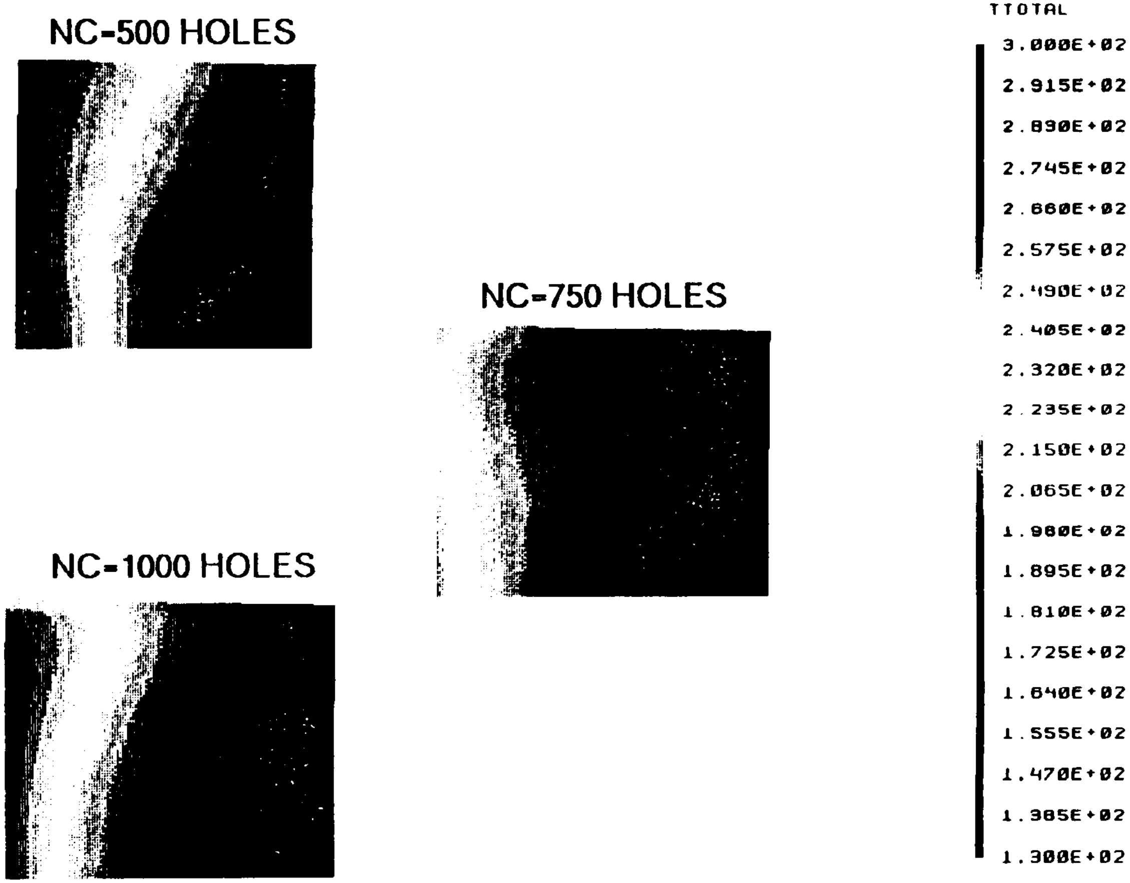

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LOCATION OF L/Dh WITH RESPECT TO CFD MODEL

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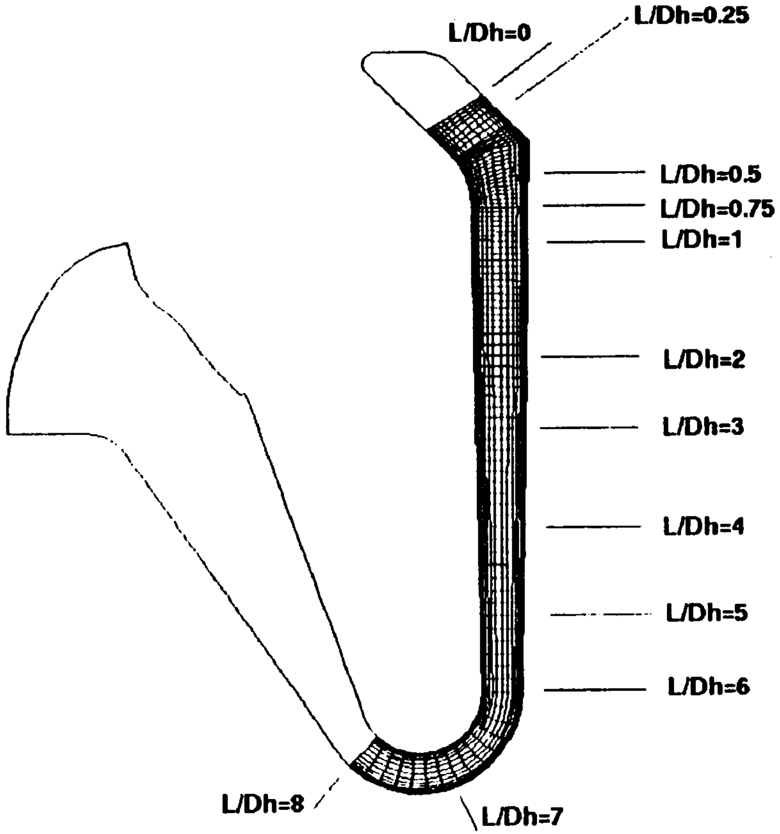

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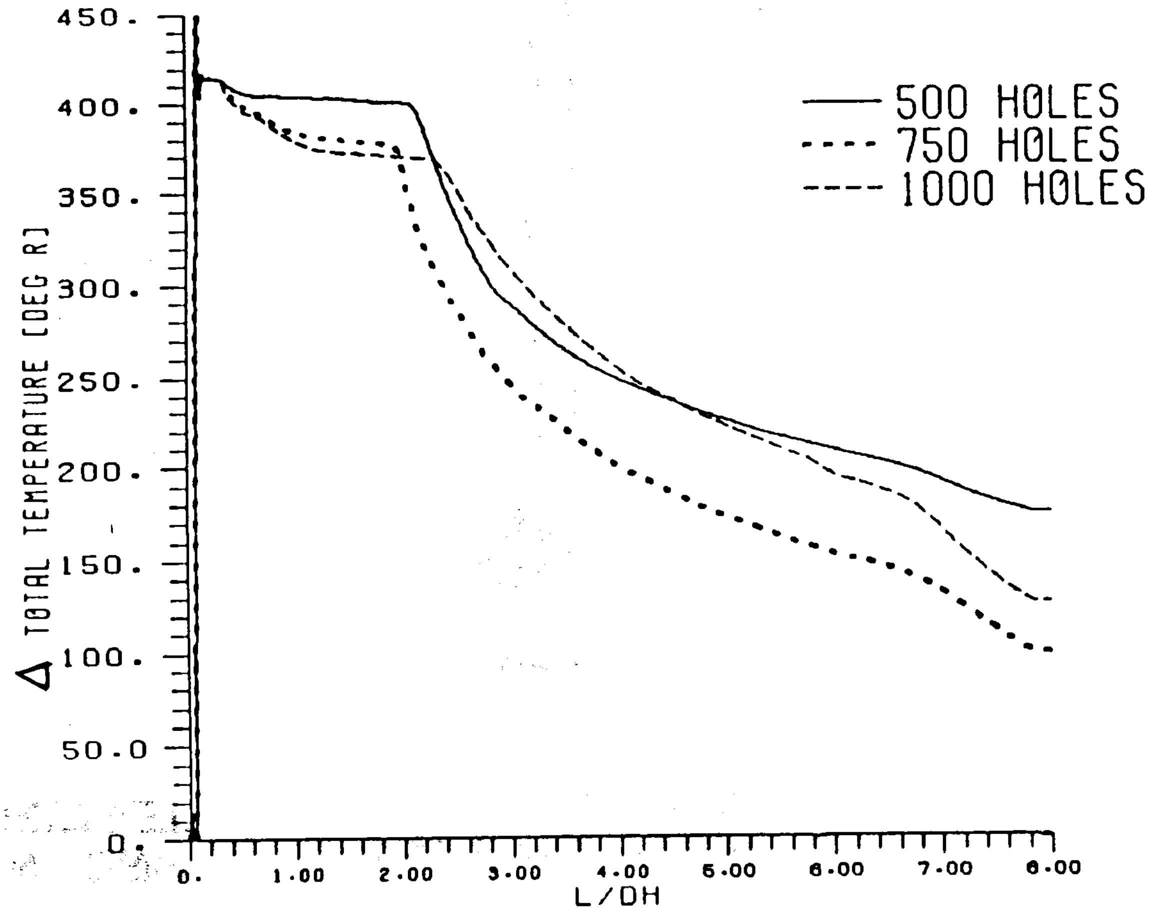
TOTAL TEMPERATURE VARIATION VS. L/DH

NC=500. 750. 1000 HOLES



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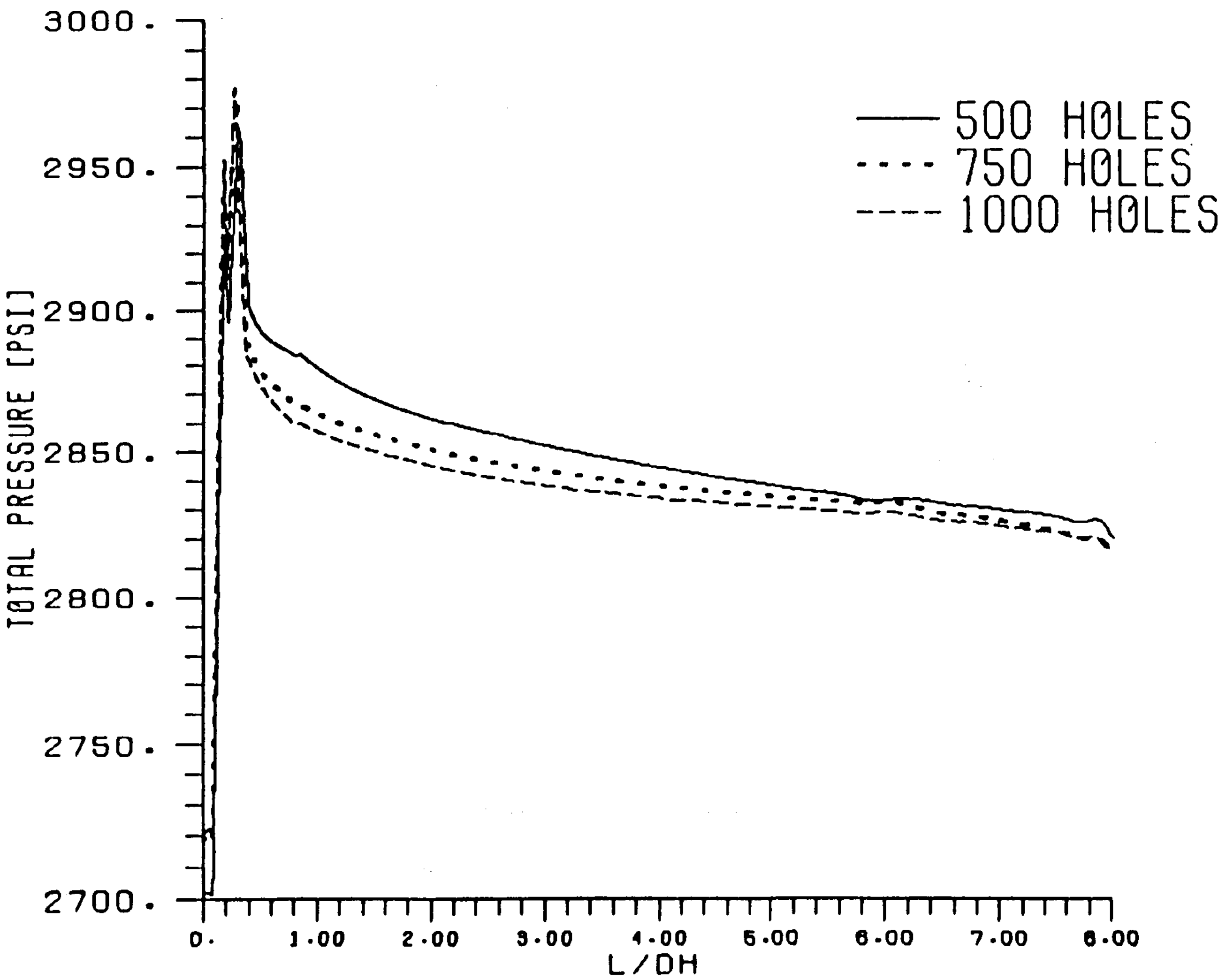
TOTAL PRESSURE VARIATION VS. L/DH

NC=500, 750, 1000 HOLES



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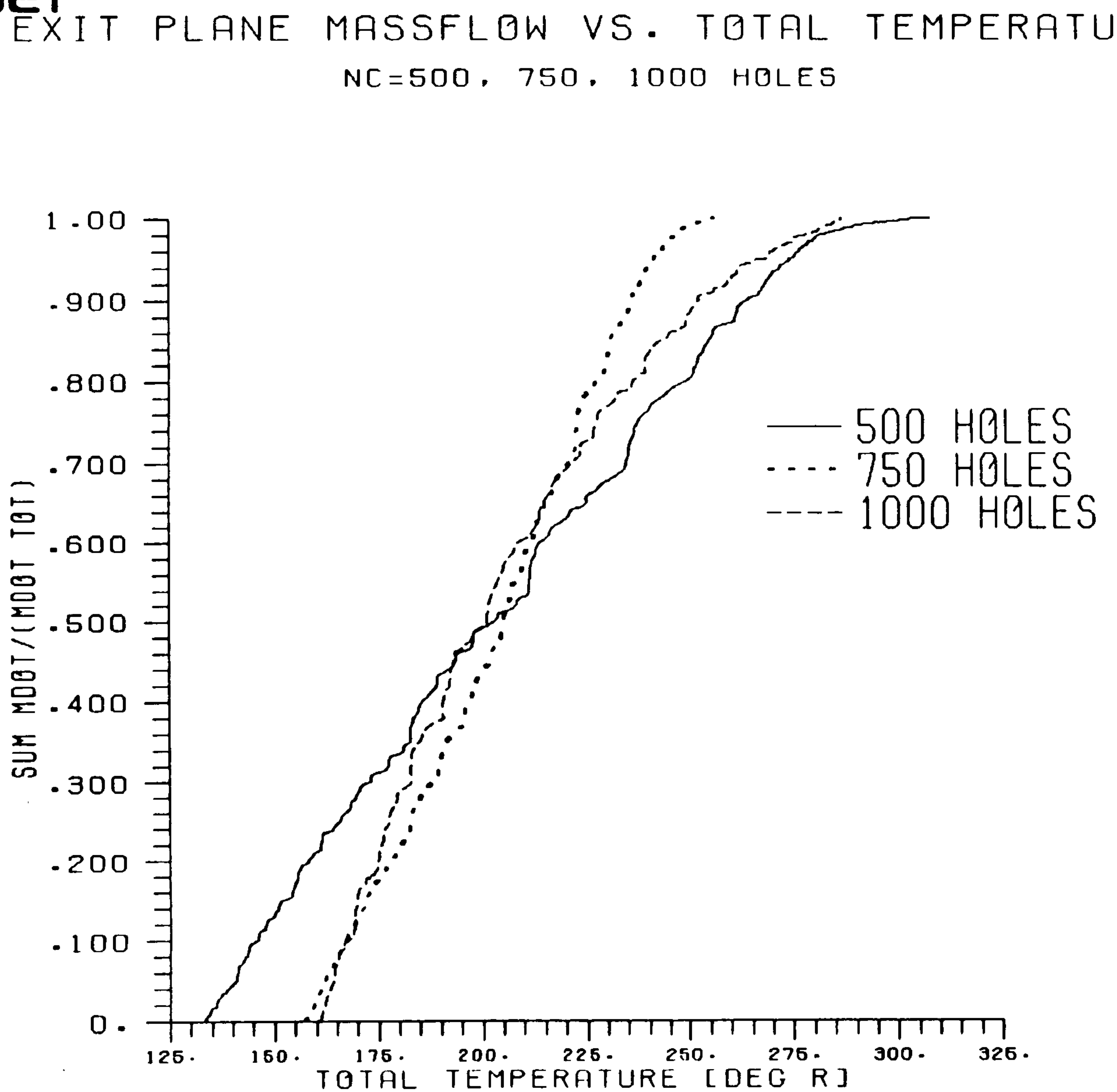
EXIT PLANE MASSFLOW VS. TOTAL TEMPERATURE
NC=500, 750, 1000 HOLES
SUM MDOT/(MDOT TOT)
1.00
.900
.800
.700
.600
.500
.400
.300
.200
.100
0.
125.
150.
175.
200.
225.
250.
275.
300.
325.
TOTAL TEMPERATURE [DEG R]
500 HOLES
750 HOLES
1000 HOLES

COLD HYDROGEN INLET HOLE SIZE RESULTS

N_C	T_{TAVE} [°R]	σ_T [°R]	ΔT_T [°R]	ΔP_T [Psi]
500	204.0	56.9	174.5	116.9
750	203.6	33.1	98.7	95.3
1000	205.5	44.2	126.2	93.3

T_{TAVE} = Mass-Averaged Value of Total Temperature at Exit Plane

ΔT_T = Total Temperature Range at Model Exit Plane

ΔP_T = Net Total Pressure Recovery (P_{TEXIT} - $P_{THINLET}$)

σ_T = Standard Deviation of Temperature at Exit Plane

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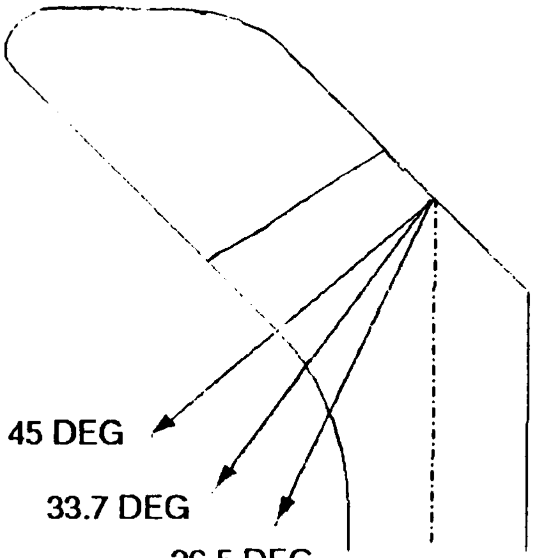
COLD HYDROGEN INLET FLOW ANGLE WAS VARIED TO
DETREMINE EFFECTS ON TOTAL TEMPERATURE AND PRESSURE



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EXIT PLANE TEMPERATURE DEPENDENT ON COLD HYDROGEN FLOW ANGLE

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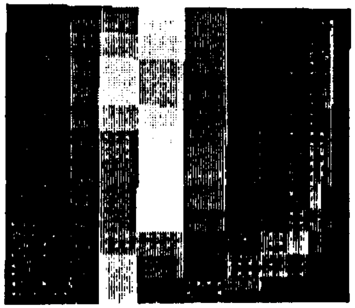
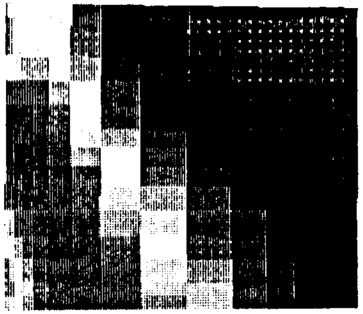
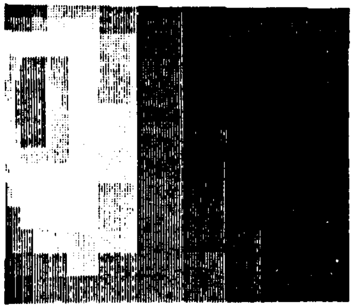
NC= 750 HOLES



THETA=0 DEG

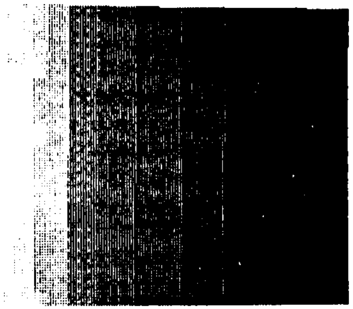
THETA=26.5 DEG





THETA=33.7 DEG

THETA=45 DEG



TTOTAL

2.500E+02
2.450E+02
2.400E+02
2.350E+02
2.300E+02
2.250E+02
2.200E+02
2.150E+02
2.100E+02
2.050E+02
2.000E+02
1.950E+02
1.900E+02
1.850E+02
1.800E+02
1.750E+02
1.700E+02
1.650E+02
1.600E+02
1.550E+02
1.500E+02

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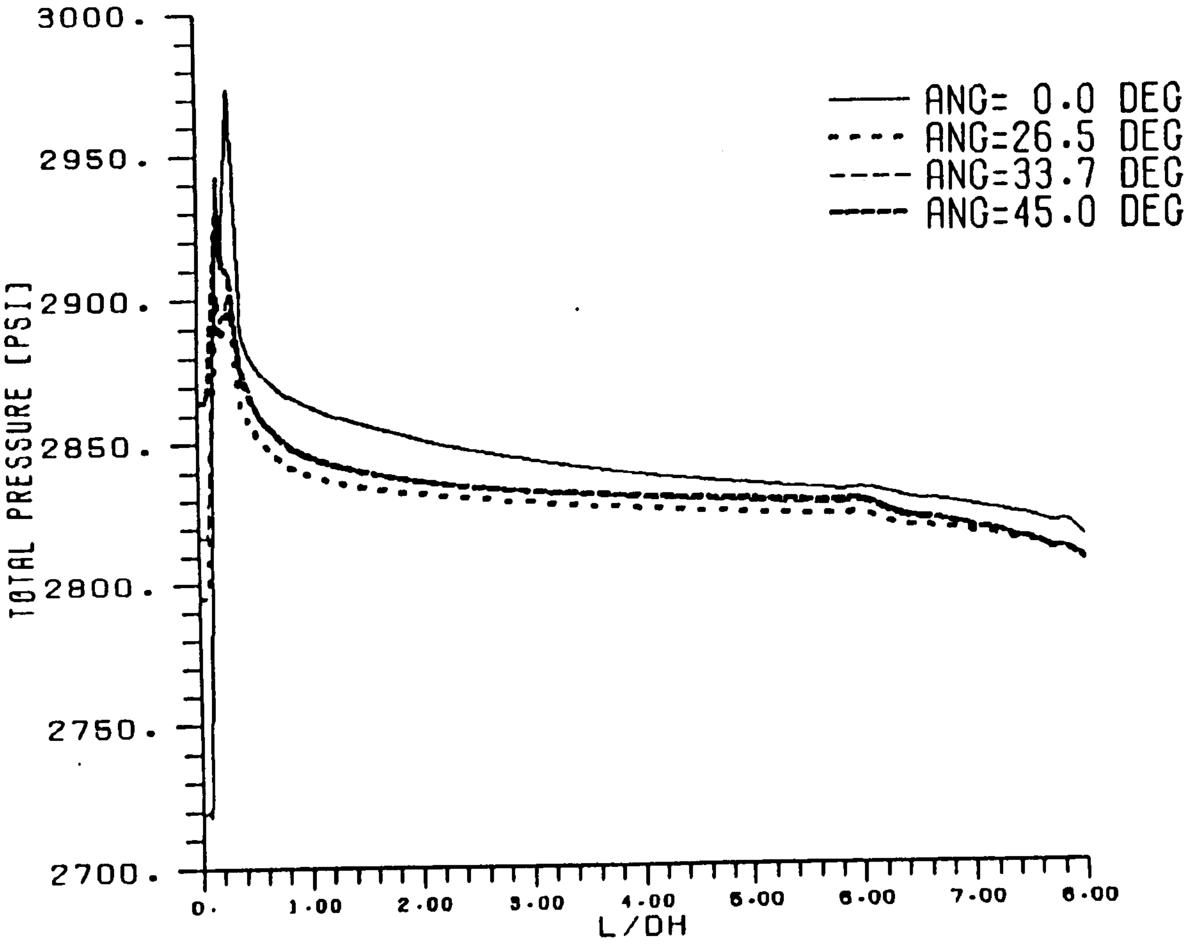
TOTAL PRESSURE VARIATION VS. L/DH

FLOW ANGLE=0, 26.5, 33.7, 45 DEG



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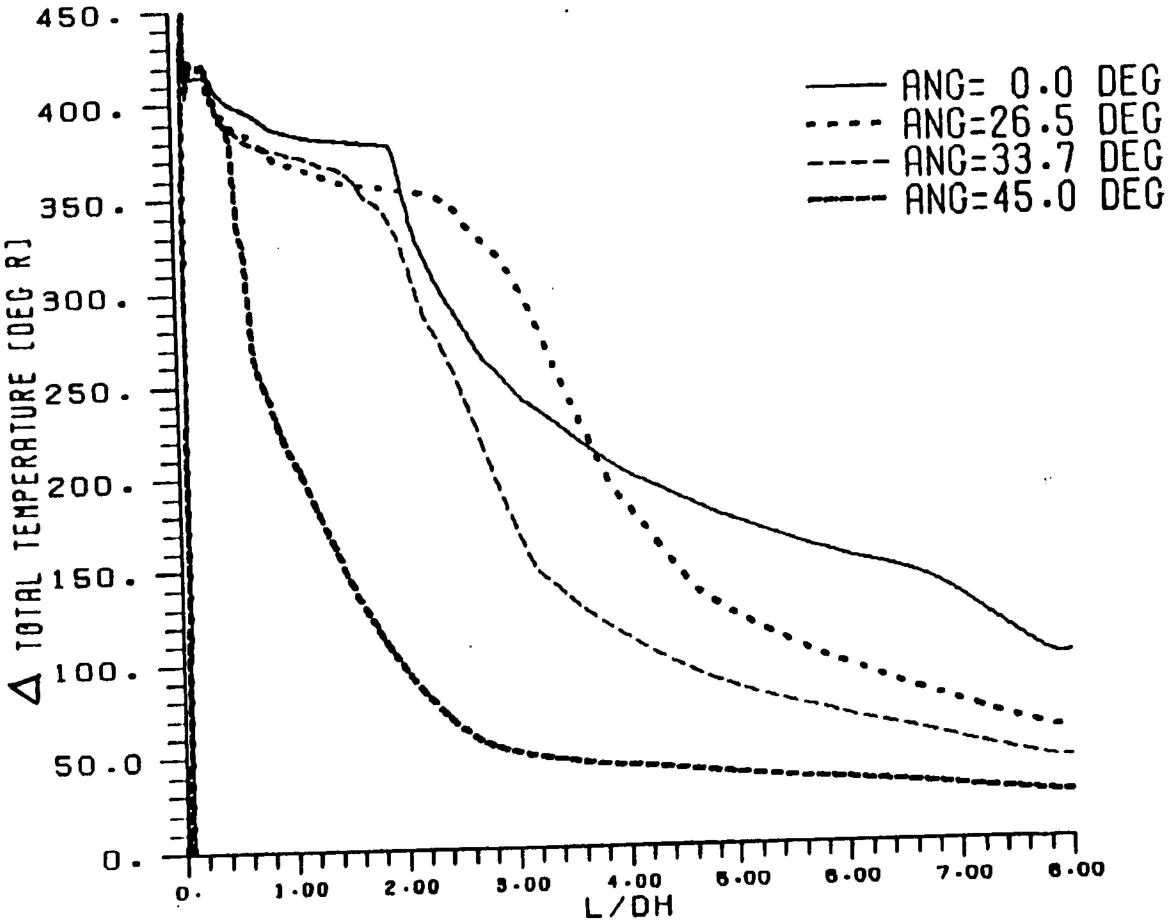
TOTAL TEMPERATURE VARIATION VS. L/DH

FLOW ANGLE=0, 26.5, 33.7, 45 DEG



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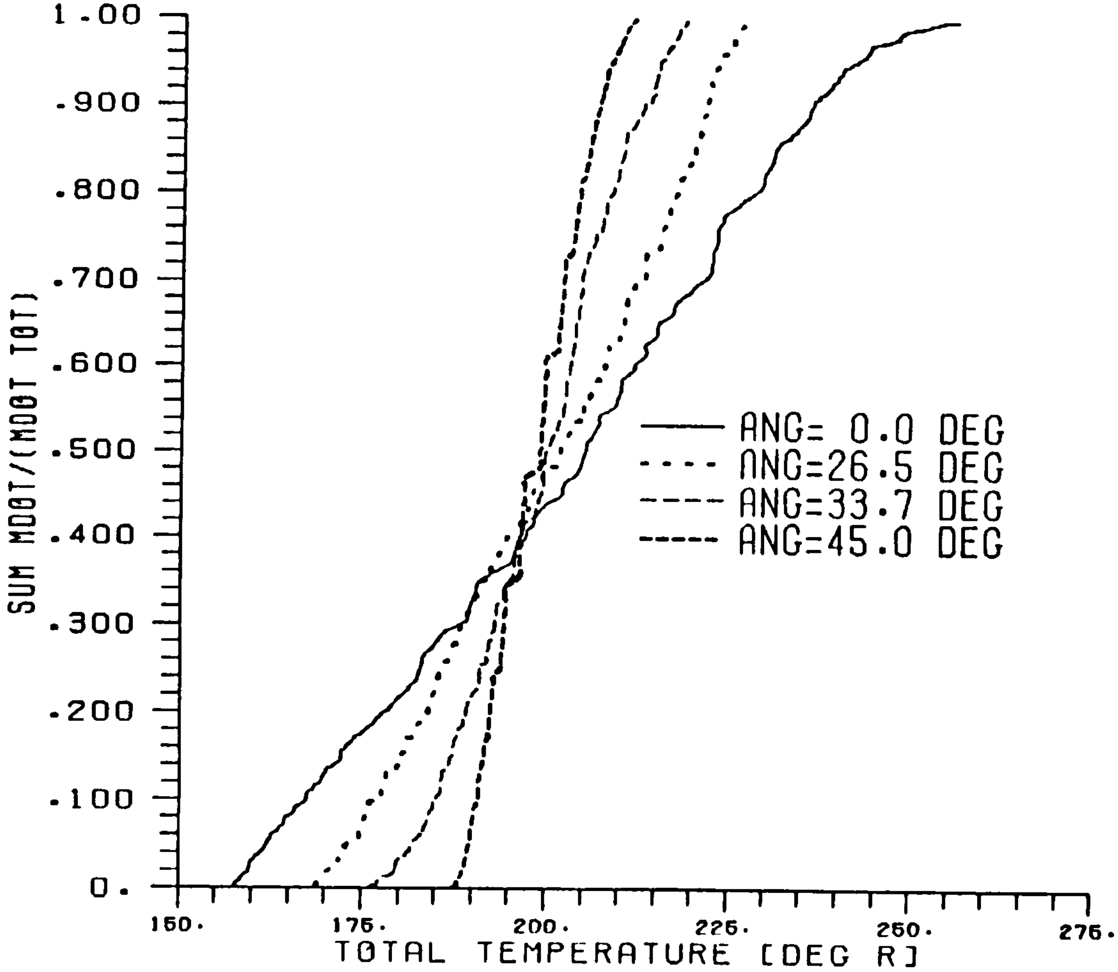
EXIT PLANE MASS FLOW VS. TOTAL TEMPERATURE

FLOW ANGLE=0, 26.5, 33.7, 45 DEG



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COLD HYDROGEN INLET FLOW ANGLE RESULTS

ANG [DEG]	T_{TAVE} [°R]	σ_T [°R]	ΔT_T [°R]	ΔP_T [Psi]
0	203.6	33.1	98.7	95.3
26.5	199.2	17.8	58.5	11.4
33.7	199.3	11.8	42.4	-9.5
45.0	198.8	8.1	24.3	-58.3

T_{TAVE} = Mass-Averaged Value of Total Temperature at Exit Plane

ΔT_T = Total Temperature Range at Model Exit Plane

ΔP_T = Net Total Pressure Recovery (P_{TEXIT} - $P_{THINLET}$)

Δ_T = Standard Deviation of Temperature at Exit Plane

FUTURE WORK

- Examine Other Configurations
  - Swirled Injection
  - Smaller Mixing Channel Area
  - Inline Cold Hydrogen Inlet Holes
  - Modifying Position of Cold Hydrogen Inlet Holes With Respect to the Mixing Channel Centerline
- Provide Design Requirements for Experimental Cold Flow Hardware
- Support Cold Flow Testing
- Analyze Cold Flow Data and Validate Aerovisc Predictive Capability
- Use Validated Model to Design Flight Mixer