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HOT FLOW TESTING OF MULTIPLE
NOZZLE EXHAUST EDUCTOR SYSTEMS

by

James Allan Hill

September 1979

Thesis Advisor: P.F. Pucci

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Hot Flow Testing of Multiple Nozzle Exhaust Eductor Systems

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

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TABLE OF CONTENTS

I. INTRODUCTION -------------------------------------- 15

II. THEORY AND ANALYSIS ----------------------------- 18

A. MODELING TECHNIQUE ---------------------------- 18

B. ONE-DIMENSIONAL ANALYSIS OF A SIMPLE EDUCTOR - 19

C. NONDIMENSIONAL SOLUTION OF SIMPLE EDUCTOR ANALYSIS ----------------------------- 26

D. CORRELATION OF EXPERIMENTAL DATA ------------- 29

III. EXPERIMENTAL APPARATUS --------------------------- 30

A. COMBUSTION GAS GENERATOR -------------------- 30

B. EDUCTOR AIR METERING BOX -------------------- 31

C. EDUCTOR SYSTEM ------------------------------- 32

1. Mixing Stack ---------------------------- 32

2. Eductor Nozzles ------------------------- 33

3. Standoff Ratio -------------------------- 33

D. INSTRUMENTATION ----------------------------- 33

IV. EXPERIMENTAL METHOD ----------------------------- 36

V. DISCUSSION OF EXPERIMENTAL RESULTS -------------- 38

A. SOLID WALL MIXING STACK ---------------------- 38

B. SLOTTED AND SHROUDED MIXING STACK WITH ONE DIFFUSER RING ---------------------- 39

C. SLOTTED AND SHROUDED MIXING STACK WITH TWO DIFFUSER RINGS --------------------- 41

VI. CONCLUSIONS ------------------------------------- 45

VII. RECOMMENDATIONS --------------------------------- 47

VIII. FIGURES --- 48

IX. TABLES -- 122

APPENDIX A: COMBUSTION GAS GENERATOR OPERATION --------- 160

APPENDIX B: DETERMINATION OF THE EXPONENT IN THE NONDIMENSIONAL PUMPING COEFFICIENT --------- 166

APPENDIX C: UNCERTAINTY ANALYSIS ---------------------- 167

DATA REDUCTION PROGRAM ---------------------------------- 170

LIST OF REFERENCES -- 174

INITIAL DISTRIBUTION LIST ------------------------------- 175

LIST OF FIGURES

Figure	Description	Page
1	Schematic Diagram of Simple Exhaust Gas Eductor	48
2	Simple Single Nozzle Eductor System	49
3	Schematic Diagram of Combustion Gas Generator	50
4	Combustion Gas Generator	51
5	Schematic Diagram of Gas Generator Fuel System	52
6	Gas Generator Fuel Supply System	53
7	Eductor Air Metering Box	54
8	Eductor Air Metering Box Arrangement	55
9	Interior of Air Metering Box Showing Mixing Stack and Primary Nozzles	56
10	Interior of Air Metering Box Showing Mixing Stack and Primary Nozzles	57
11	Dimensional Diagram of Expanded Slotted Mixing Stack	58
12	Schematic Diagram of Slotted Mixing Stack	59
13	Slotted Mixing Stack	60
14	Dimensional Diagram of Mixing Stack with One Diffuser Ring	61
15	Mixing Stack with One Diffuser Ring	62
16	Dimensional Diagram of Mixing Stack with Two Diffuser Rings	63
17	Mixing Stack with Two Diffuser Rings	64
18	Dimensional Diagram of Primary Flow Nozzles	65

Figure	Description	Page
19	Dimensional Diagram of Primary Flow Nozzle Plate	66
20	Primary Flow Nozzle Plate (Back View)	67
21	Primary Flow Nozzle Plate (Front View)	68
22	Schematic Diagram of Pressure Measurement System	69
23	Schematic Diagram of Temperature Measurement System	70
24	Fuel Flow Calibration Curve	71
25	Entrance Nozzle Calibration Curve	72
26	Developed View of Mixing Stack Thermocouple Locations	73
27	Illustrative Plot of the Experimental Data Correlation in Equation (13)	74
28	Performance Plots of Solid Wall Mixing Stack	75
29	Performance Plots of Slotted and Shrouded Mixing Stack with One Diffuser Ring	78
30	Performance Plots of Slotted and Shrouded Mixing Stack with Two Diffuser Rings	81
31	Temperature Plots for Slotted and Shrouded Mixing Stack with One Diffuser Ring	84
32	Temperature Plots for Slotted and Shrouded Mixing Stack with Two Diffuser Rings	92
33	Exit Plane Temperature Plots for Solid Wall Mixing Stack	100
34	Exit Plane Temperature Plots for Slotted and Shrouded Mixing Stack with One Diffuser Ring	101

Figure	Description	Page
35	Exit Plane Temperature Plots for Slotted and Shrouded Mixing Stack with Two Diffuser Rings	109
36	Schematic Diagram of Compressor Layout	117
37	Cooling Tower Switches and Cooling Water Valve	118
38	Carrier Air Compressor, Butterfly Suction Damper, and Cooling Water Valve	119
39	Auxiliary Oil Pump and Switch	120
40	Main Air Supply Globe Valve	121

LIST OF TABLES

Table	Description	Page
I.	Summary of Results	126
II.	Performance Data, Solid Wall Mixing Stack	127
III.	Performance Data, Slotted and Shrouded Mixing Stack with One Diffuser Ring	130
IV.	Performance Data, Slotted and Shrouded Mixing Stack with Two Diffuser Rings	138
V.	Exit Plane Temperature Profiles, Solid Wall Mixing Stack	146
VI.	Exit Plane Temperature Profiles, Slotted and Shrouded Mixing Stack with One Diffuser Ring	147
VII.	Exit Plane Temperature Profiles, Slotted and Shrouded Mixing Stack with Two Diffuser Rings	155
VIII.	Uncertainties in Measured Values from Table III	163

NOMENCLATURE

ENGLISH LETTER SYMBOLS

A	-	Area, in^2
C	-	Sonic velocity, ft/sec
D	-	Diameter, in
f	-	Friction factor
F	-	Functional denotation
F_{fr}	-	Wall skin-friction force, lbf
g_c	-	Proportionality factor in Newton's Second Law, g_c = 32.174 lbm-ft/lbf-sec^2
h	-	Enthalpy, Btu/lbm
k	-	Ratio of specific heats
L	-	Length, in
P	-	Pressure, in H_2O
P_a, B	-	Atmospheric pressure, in Hg
R	-	Gas constant for air, 53.34 ft-lbf/lbm-°R
S	-	Standoff distance, in
T	-	Temperature, °F, °R
U	-	Velocity, ft/sec
W, $\dot{m}$	-	Mass flow rate, lbm/sec
x	-	Axial distance from mixing stack entrance, in

Dimensionless Groupings

A*	-	Secondary flow area to primary flow area ratio
K_e	-	Kinetic energy correction factor

K_m	-	Momentum correction factor at the mixing stack exit
K_p	-	Momentum correction factor at the primary nozzle exit
M	-	Mach number
ΔP^*	-	Pressure coefficient
Re	-	Reynolds number
T^*	-	Secondary flow absolute temperature to primary flow absolute temperature ratio
W^*	-	Secondary mass flow rate to primary mass flow rate ratio
ρ^*	-	Secondary flow density to primary flow density ratio

Greek Letter Symbols

μ	-	Absolute viscosity, $lbf\text{-}sec/ft^2$
ρ	-	Density, lbm/ft^3
β	-	$K_m + \frac{f}{2} A_w/A_m$

Subscripts

0	-	Section within secondary air plenum
1	-	Section at primary nozzle exit
2	-	Section at mixing stack exit
B	-	Burner
m	-	Mixed flow or mixing stack
P	-	Primary
s	-	Secondary
u	-	Uptake
w	-	Mixing stack inside wall

Tabulated Values

DELPN, PN	-	Pressure drop across entrance transition nozzle, in H_2O
FHZ	-	Fuel flow meter reading, Hz
P*	-	Pressure coefficient
PA, B	-	Ambient pressure, in Hg
PA-PS, ΔPS	-	Pressure differential across secondary flow nozzles, in H_2O
PMIX, PMS	-	Mixing stack static pressure, in H_2O
PNH	-	Static pressure upstream of entrance transition nozzle, in Hg
PU-PA	-	Uptake static pressure, in H_2O
P*/T*	-	Dimensionless pressure coefficient
T*	-	Absolute temperature ratio, secondary flow to primary flow
TAMB	-	Ambient temperature, °F
TMIX	-	Mixing stack wall temperature, °F
TUPT	-	Uptake temperature, °F
UM	-	Average velocity in mixing stack, ft/sec
UP	-	Primary flow velocity at nozzle exit, ft/sec
UU	-	Primary flow velocity in uptake, ft/sec
WP	-	Primary mass flow rate, lbm/sec
WS	-	Secondary mass flow rate, lbm/sec
WPA	-	Mass flow rate of primary air, lbm/sec
WPF	-	Mass flow rate of fuel, lbm/sec
W*	-	Secondary mass flow rate to primary flow rate ratio

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I. INTRODUCTION

The gas turbine engine has become the prime mover of choice for recent naval applications. One of the unique features of gas turbine engines is their hot and voluminous exhaust. This presents problems such as overheating of antennae and other equipment by exhaust plume impingement and the creation of an undesirable infra-red signature of the hot exhaust plume. An effective means of reducing the exhaust gas temperature is to mix it with ambient air prior to its discharge from the stack. Exhaust gas eductor systems presently in service have demonstrated their effectiveness in cooling by such a mixing process.

The subject of this investigation is the application of multiple nozzle eductor systems for cooling the exhaust gas from gas turbine powered ships. This research is an extension of work reported by Lt. C. R. Ellin [1], Lt. C. P. Staehli and Lt. R. J. Lemke [2], Lt. D. R. Welch [3], and Lt. C. M. Moss [4]. The scope of the work reported here includes verification of some of the results reported by Welch [3], and hot flow testing of two systems initially investigated by Staehli and Lemke [2].

The exhaust gas eductor system, illustrated schematically in Figure 1, is defined as the portion of the uptake which discharges the exhaust gas through nozzles into a mixing stack. The purpose of the eductor system is to induce a flow of cool ambient air which is mixed with the hot exhaust gas in order to lower the temperature of the exhaust stack and exhaust plume. These gas eductors must meet three major requirements. They must pump large amounts of secondary (cooling) air into the mixing stack, they must adequately mix the hot high velocity exhaust gas and the cool low velocity secondary air, and they must not adversely affect the gas turbine's performance.

A one-dimensional flow analysis of a simple single nozzle eductor system, as a unit, facilitates determination of the nondimensional parameters which govern the flow phenomenon. An experimental correlation of these nondimensional parameters has been developed and is used to evaluate eductor performance.

The geometric parameters which influence the gas eductor's performance include the number and size of primary nozzles, the length of the mixing stack, the ratio of the primary nozzle flow area to the mixing stack area, the ratio of the length of the mixing stack to its diameter, and the distance from the primary nozzles to the mixing stack. Numerous combinations of and variations in these parameters have been investigated and reported in References [1] through [4].

The intent of this investigation was to obtain data using hot flow testing of gas eductor systems to establish the effect of uptake gas temperature on the eductor's performance. Temperature data is unavailable from cold flow testing; correlation of hot flow data with previous cold flow data allows a validation of the hot gas generator and a validation of the use of cold flow models for hot flow prototypes.

Two exhaust eductor models were tested. Both geometries were tested previously using cold flow facilities, by Staehli and Lemke [2]. Tests were made over a range of temperatures, but retained the same flow parametric values.

II. THEORY AND ANALYSIS

Evaluation of the effects of eductor geometry on prototype eductor performance through experimentation with models requires the following: assurance of similtude between model and prototype; the identification of the dimensionless groupings pertinent to the flow phenomenon; and a suitable means of data analysis and presentation. Dynamic similarity was maintained by using Mach number similarity to establish the model's primary flow rate. Determination of the dimensionless groupings that govern the flow was accomplished through the analysis of a simple air eductor system. Based on this analysis, an experimental correlation of the nondimensional parameters was developed and used in presenting and evaluating experimental results.

A. MODELING TECHNIQUE

For the flow velocities considered, the primary flow through the model eductor is turbulent (Reynolds number based on diameter of approximately 10^5). Consequently, turbulent momentum exchange outweighs shear interaction, and the kinetic and internal energy terms influence the flow more than viscous forces. Since Mach number can be shown to represent the square root of the ratio of kinetic energy of a flow to its internal energy, it is a more significant parameter than Reynolds number in describing the primary flow through the uptake.

Mach number similarity was therefore used to model the primary flow. Mach number is defined as the ratio of flow velocity to sonic velocity in the medium considered. For a perfect gas, sonic velocity, c, is calculated

$$c = (g_c kRT)^{0.5}$$

The prototype Mach number is .064.

The geometric scale factor was influenced by test facility flow capabilities, primary flow velocities and availability of modeling materials.

B. ONE-DIMENSIONAL ANALYSIS OF A SIMPLE EDUCTOR

The theoretical analysis of an eductor may proceed in two ways. One method attempts to analyze the details of the mixing process of the primary and secondary flows inside the mixing stack and thereby determines the parameters that describe the flow. This requires an interpretation of the mixing phenomenon, which when applied to multiple nozzle systems becomes extremely complex. The second method, employed in this study, analyzes the overall performance of the eductor system as a unit. Since details of the mixing process are not considered in this method, an analysis of the simple single nozzle eductor system shown in Figure 2 leads to a determination of the dimensionless groupings governing the flow. The following one dimensional analysis is from Ellin [1].

The primary fluid, flowing at a rate W_p and velocity U_p, enters the constant area section of the mixing stack, inducing a secondary flow rate of W_s at velocity U_s. The primary and secondary flows are mixed and leave the mixing stack at a flow rate of W_m and a bulk average velocity of U_m.

The one-dimensional flow analysis of the simple eductor system described depends on the simultaneous solution of the equations of continuity, momentum, and energy with an appropriate equation of state and specified boundary conditions.

The following simplifying assumptions are made:

1. Both flows are perfect gases with constant specific heats.
2. Steady, incompressible flow throughout the eductor and plenum exists.
3. The flow throughout the eductor is adiabatic. The flow of secondary air from the plenum (at section 0) to the entrance of the mixing stack (at section 1) is isentropic. Irreversible adiabatic mixing occurs between the primary and secondary flows in the mixing stack (between sections 1 and 2).
4. The static pressure distributions across the entrance and exit planes of the mixing stack (at sections 1 and 2) are uniform.
5. At the mixing stack entrance (section 1), the primary flow velocity U_p and temperature T_p are uniform

across the primary stream, and the secondary flow velocity U_s and temperature T_s are uniform across the secondary stream; but U_p does not equal U_s, and T_p does not equal T_s.

6. Incomplete mixing of the primary and secondary flows in the mixing stack is accounted for by the use of a non-dimensional momentum correction factor, K_m, which relates the actual momentum rate to the rate based on the bulk-average velocity and density and by the use of a non-dimensional kinetic energy correction factor, K_e, which relates the actual kinetic energy rate to the rate based on the bulk-average velocity and density.
7. Potential energy differences due to elevation are negligible.
8. Pressure changes P_o to P_1 and P_1 to P_a are small relative to the static pressure so that the gas density is principally dependent upon temperature and atmospheric pressure.
9. Wall friction in the mixing stack is accounted for with the conventional pipe friction factor term based on the bulk-average flow velocity U_m and the mixing stack wall area A_w.

The conservation of mass principle for steady state flow yields

$$W_m = W_p + W_s \tag{1}$$

where

$$W_p = \rho_p U_p A_p$$

$$W_s = \rho_s U_s A_s \qquad (1a)$$

$$W_m = \rho_m U_m A_m$$

Substituting for W_m, the bulk-average velocity becomes

$$U_m = \frac{W_s + W_p}{\rho_m A_m} \qquad (1b)$$

Now, from assumption 1

$$\rho_m = \frac{P_a}{R\, T_m} \qquad (2)$$

where T_m is calculated as the bulk-average temperature for the mixed flow. Applying assumptions 4 and 6, the momentum equation for the flow in the mixing stack may be written

$$K_p\left[\frac{W_p\, U_p}{g_c}\right]_1 + \left[\frac{W_s\, U_s}{g_c}\right]_1 + P_1 A_1 = K_m\left[\frac{W_m\, U_m}{g_c}\right]_2 + P_2 A_2 + F_{fr} \qquad (3)$$

with $A_1 = A_2$. The momentum correction factor K_p is introduced to account for a possible non-uniform velocity profile across the primary nozzle exit. It is defined in a manner similar to that of K_m and by assumption 5 is equal to unity but is included here for completeness. The momentum correction factor for the mixing stack exit is defined by the relation

$$K_m = \frac{1}{K_m U_m} \int_0^{A_m} U_2^2 \rho_2 \, dA \tag{4}$$

The actual variable velocity and a weighted average density at section 2 are used in the integrand. The wall skin-friction force F_{fr} can be related to the mean velocity by

$$F_{fr} = f A_w \left[\frac{U_m^2 \rho_m}{2 g_c} \right] \tag{5}$$

For turbulent flow, the friction factor may be calculated from the Reynolds number as

$$f = 0.046 (Re_m)^{-0.2} \tag{6}$$

where

$$Re_m = \frac{\rho_m U_m D_m}{\mu_m}$$

Applying the conservation of energy principle to the steady flow in the mixing stack with assumption 7

$$W_p \left[h_p + \frac{U_p^2}{2g_c} \right]_1 + W_s \left[h_s + \frac{U_s^2}{2g_c} \right]_1 = W_m \left[h_m + K_e \frac{U_m^2}{2g_c} \right]_2 \tag{7}$$

where K_e is the kinetic energy correction factor defined by the relation

$$K_e = \frac{1}{W_m U_m^2} \int_0^{A_m} U_2^3 \rho_2 \, dA \qquad (8)$$

It may be demonstrated that for the purpose of evaluating the mixed mean flow temperature T_m, the kinetic energy terms may be neglected to yield

$$h_m = \frac{W_p}{W_m} h_p + \frac{W_s}{W_m} h_s \qquad (9)$$

where $T_m = F(h_m)$ only, from assumption 1.

The energy equation applied to the flow of secondary air between the plenum entrance and the mixing stack entrance may be reduced to

$$\frac{P_0 - P_1}{\rho_s} = \frac{U_s^2}{2g_c} \qquad (10)$$

This comes from the steady, adiabatic flow, energy equation

$$dh = -d\left[\frac{U_s^2}{2}\right]$$

recognizing that

$$T\,ds = dh - \frac{1}{\rho} dP = 0$$

for the postulated isentropic conditions. Thus

$$\frac{dP}{\rho} = -d\left[\frac{U_s^2}{2}\right] \tag{10a}$$

Pressure changes from the plenum to the mixing stack are small (assumption 8) and the temperature and density are relatively constant, and thus equation (10) is readily obtained.

The foregoing equations may be combined to yield the partial vacuum produced by the eductor in the plenum chamber

$$P_a - P_o = \frac{1}{2g_c A_m}\left\{K_p \frac{W_p^2}{A_p \rho_p} + \frac{W_s^2}{A_s \rho_s}\left[1 - \frac{A_m}{2A_s}\right] - \frac{W_m^2}{A_m \rho_m}\left[K_m + \frac{f}{2}\frac{A_w}{A_m}\right]\right\} \tag{11}$$

where A_p and ρ_p apply to the primary flow at the entrance to the mixing stack (section 1), A_s and ρ_s apply to the secondary flow at this same section, and A_m and ρ_m apply to the mixed flow at the exit of the mixing stack (section 2). P_a is atmospheric pressure and is equal to the pressure at the exit of the mixing stack P_2. This equation also incorporates the assumption that $(\rho_s)_1 = (\rho_s)_0$ so that ρ_s may be taken as the density of the secondary flow in the plenum.

C. NONDIMENSIONAL SOLUTION OF SIMPLE EDUCTOR ANALYSIS

Normalizing equation (11) leads to the following non-dimensional terms:

$$\Delta P^* = \frac{\dfrac{P_a - P_0}{\rho_s}}{\dfrac{U_p^2}{2\, g_c}}$$

a pressure coefficient which compares the "pumped head" $\frac{P_a - P_0}{\rho_s}$ for the secondary flow to the "driving head" $\frac{U_p^2}{2\, g_c}$ of the primary flow.

$$W^* = \frac{W_s}{W_p}$$

a flow rate ratio, secondary-to-primary mass flow rate.

$$T^* = \frac{T_s}{T_p}$$

an absolute temperature ratio, secondary-to-primary.

$$\rho^* = \frac{\rho_s}{\rho_p}$$

a flow density ratio. Note that since $P_s = P_p$ and the fluids are perfect gases, $\rho^* = \frac{T_p}{T_s} = \frac{1}{T^*}$.

$$A^* = \frac{A_s}{A_p}$$

area ratio of secondary flow area to primary flow area

$\frac{A_p}{A_m}$ area ratio of primary flow area to mixing stack cross sectional area

$\frac{A_w}{A_m}$ area ratio of wall friction area to mixing stack cross sectional area

K_p momentum correction factor for primary flow

K_m momentum correction factor for mixed flow

f wall friction factor

With these non-dimensional groupings, equation (11) may be written as

$$\frac{\Delta P^*}{T^*} = 2\frac{A_p}{A_m}\{[K_p - \frac{A_p}{A_m}\beta] - W^*(1 + T^*)\frac{A_p}{A_m}\beta$$

$$+ W^{*2}\, T^*[\frac{1}{A^*}(1 - \frac{A_m}{2A^*\, A_p})\beta - \frac{A_p}{A_m}\beta]\} \qquad \text{(11a)}$$

where

$$\beta = K_m + \frac{f}{2}\frac{A_w}{A_m}.$$

For a given eductor geometry, equation (11a) may be expressed in the form

$$\frac{\Delta P^*}{T^*} = C_1 + C_2\, W^*(T^* + 1) + C_3\, W^{*2}\, T^* \qquad (11b)$$

where

$$C_1 = 2\,\frac{A_p}{A_m}(K_p - \frac{A_p}{A_m}\,\beta)$$

$$C_2 = -2(\frac{A_p}{A_m})^2\,\beta \qquad (11c)$$

$$C_3 = 2\,\frac{A_p}{A_m}\{\frac{1}{A^*}(1 - \frac{A_m}{2\,A^*\,A_p})\,\beta - \frac{A_p}{A_m}\,\beta\}$$

Equation (11b) may be expressed as a simple functional relationship

$$\Delta P^* = F(W^*, T^*) \qquad (12)$$

This same relationship results from a dimensional analysis of the mixing process within the mixing stack (Ellin [1]).

Two geometric dimensionless quantities were added to this investigation. The distance, S, from the primary flow nozzle exit to the mixing stack entrance and the distance, x, from the entrance to the mixing stack, normalized with respect to the mixing stack diameter, D, were also defined as nondimensional quantities. The two additional quantities are listed below:

$\frac{x}{D}$ ratio of the axial distance from the mixing stack entrance to the diameter of the mixing stack.

$\frac{S}{D}$ standoff; the ratio of the axial distance between the primary nozzle exit plane and the mixing stack entrance to the diameter of the mixing stack.

D. CORRELATION OF EXPERIMENTAL DATA

In the experimental apparatus, a given Mach number can be achieved over a wide variation in pressures, temperatures, and flow rates. Accordingly a means of presenting the experimental data was developed which is pseudo-independent of the dimensionless groupings ΔP^*, T^*, and W^*. From equation (11b), a satisfactory correlation of P^*, T^*, and W^* takes the form

$$\frac{\Delta P^*}{T^*} = F(W^* T^{*n}) \tag{13}$$

where the exponent n has been experimentally determined to be 0.44 (Appendix B). $\Delta P^*/T^*$ is plotted as a function of $W^*T^{*(0.44)}$ to yield an eductor's pumping characteristic curve. For ease of discussion, $W^*T^{*(0.44)}$ will be referred to as the pumping coefficient.

III. EXPERIMENTAL APPARATUS

Hot primary gas is supplied to the nozzle and mixing stack system by the combustion gas generator and associated ducting illustrated in Figures 3 and 4. The eductor system under test is mounted in a secondary air plenum. ASME long radius flow nozzles mounted in the plenum walls allow measurement of the secondary air flow.

A. COMBUSTION GAS GENERATOR

The input air to the combustion gas generator is supplied by a Carrier model 18P350 centrifugal air compressor. The compressor is located in an adjacent building and the input air is piped underground to an eight inch inside diameter (ID) horizontal pipe with a butterfly shutoff valve and a globe bypass valve. All air demands for this testing can be met with the bypass valve.

An entrance transition nozzle mates the eight inch ID compressor discharge piping with the four inch ID system piping. The pressure drop across this nozzle is used to measure the primary air flow.

Under control of the operator, a portion of the input air, the bypass air, travels straight through to the exhaust stack while the remainder passes through the U-bend piping to the combustion section. The combustion section includes the burner can and igniter assembly from a Boeing model 502-6A gas turbine engine. Certain fuel system components from this engine were also utilized. The fuel system is shown schematically in Figure 5 and pictured in Figure 6.

After the air is heated in the combustion section, it is mixed with the cooler air after both pass through the turbine nozzle box containing the bypass air mixer. The exhaust stack temperature is controlled by the ratio of bypass air to combustion air, and by fuel supply to the burner. The procedure for system light-off and operation is included in Appendix A.

The hot gas passes through a flow straightening section and then up the exhaust stack to the primary nozzles and the eductor system.

B. EDUCTOR AIR METERING BOX

Secondary air flow is measured with a large metering box which encloses the entire eductor assembly and acts as an air plenum. A set of standard ASME long radius flow nozzles of varying cross-sectional areas are mounted in the metering box away from the eductor. The metering box design allows a full range of alignment motions as well as a variety of mixing stack sizes, configurations, and placements. The metering box general arrangement is pictured in Figure 7 and a dimensional layout for a typical mixing stack installation is given in Figure 8. The interior of the air metering box is pictured in Figures 9 and 10.

For flexibility, the secondary air flow measuring system utilizes three different flow nozzle sizes: four of four inch throat diameter, three of two inch diameter and three of one and one-half inch throat diameter; various combinations produce a wide variety of secondary cross-sectional flow areas.

No attempt was made to measure air flow rates through the stack film cooling slots or through the diffuser ring. Staehli and Lemke [2] made such measurements in a cold flow test.

C. THE EDUCTOR SYSTEM

The eductor system includes the eductor nozzles and the mixing stack. Figure 1 shows the general eductor system arrangement.

1. The Mixing Stack

Two mixing stacks were tested, both constructed from 7.5 inch OD, 7.122 inch ID steel pipe. Referenced to the ID, the first was 2.5 diameters long (17.805 inches) and was tested to verify earlier experimental data and to gain operational familiarity with the equipment. The second stack was 1.75 diameters long (12.464 inches) with the wall pierced by six rings of angled cooling slots. This stack was shrouded, with a one- or two-ring diffuser added. The diffuser half-angle and ID were held constant, and the total mixing length was maintained at 2.5 diameters. The dimensional layout of this stack is shown in Figures 11 and 12 and is pictured in Figure 13. The stack with shroud and one diffuser ring is shown in Figures 14 and 15; the stack with shroud and two diffuser rings is shown in Figures 16 and 17. The mixing stack inlet edge was rounded, and the stack was supported inside the secondary air plenum by an adjustable saddle.

2. Eductor Nozzles

Welch [3] had found a satisfactory nozzle geometry to consist of four nozzles, with a ratio of total nozzle cross-sectional area to mixing stack cross sectional area of 2.5. This nozzle system was used here. It is shown schematically in Figures 18 and 19 and pictured in Figures 20 and 21. The nozzle entrances were rounded.

3. Standoff Ratio (S/D)

All tests were made at an S/D ratio of 0.5. Previous testing [4] has shown this to be approximately the optimum standoff ratio.

D. INSTRUMENTATION

The performance of an eductor is calculated from pressure and temperature data. Necessary measurements include the primary mass flow rate (fuel and air), the secondary mass flow rate, the uptake stack Mach number, and the mixing stack temperature and pressure profiles.

Several manometers are used to obtain the pressure and pressure drop measurements--a six inch inclined water manometer, two 20 inch upright water manometers, and a 20 inch upright mercury manometer. Atmospheric pressure is measured with a mercury barometer. The pressure measurement system is schematically shown in Figure 22.

Temperature measurements are made with either copper-constantan or chromel-alumel thermocouples wired to Newport model 267A digital pyrometers. The pyrometers are capable of monitoring 18 inputs each through barrel selector switches. Ambient air temperature was measured with a mercury-in-glass thermometer. A schematic of the temperature measurement system is shown in Figure 23.

Fuel flow measurement is made with a Cox Instrument model V40-A vortex flowmeter coupled to an Andadex Instruments model CPM 603 frequency counter. Ross [5] performed the calibration of fuel flow rate versus frequency, and this curve is shown in Figure 24.

The calculation of the primary air mass flow rate requires the measurement of the inlet absolute pressure to the entrance nozzle (PNH), the pressure drop across this nozzle (DELPN), and the inlet air temperature. Calibration data of mass flow rate versus these parameters was obtained by Ross [5] and the curve is shown in Figure 25.

The calculation of the secondary air mass flow rate requires the measurement of the ambient pressure and temperature, the pressure drop across the secondary air nozzles (PA - PS), and the total nozzle cross-sectional area. Different combinations of nozzles are blocked or opened to control the mass flow rate.

The uptake stack Mach number depends on the uptake temperature and pressure, and the primary mass flow rate (air and fuel). The uptake temperature (TUPT) is measured with a chromel-alumel thermocouple inserted through the primary nozzle plate at the centerline and protruding approximately two inches into the stack. Uptake pressure (PUP) is measured through a four-point averaging pressure tap located one diameter upstream of the primary nozzles.

Previously gathered experimental pressure data for solid wall mixing stacks were instrumental in designing the slotted wall mixing stack under test in this study. The wall, shroud, and ring temperatures were the focus of primary interest, and so pressure taps were not included although numerous thermocouples were fitted. Each ring of slots had two thermocouples--one in line with a primary nozzle (position A) and one between two nozzles (position B). They were placed such that no slot with a thermocouple had any downstream interference, and such that the exit wires were evenly spaced around the circumference (Figure 26). The shrouds and rings were also instrumented with thermocouples, evenly spaced in sets of two (position A and position B) along the length. Other thermocouples were placed to allow proper operation of the gas generator and to allow calculations of the various mass flows. Temperature profiles at the exit plane of the mixing stack were from a chromel-alumel thermocouple on an adjustable traversing mechanism.

IV. EXPERIMENTAL METHOD

As indicated in Chapter II the experimental system has been modeled with Mach number similarity. The Mach number in the model is achieved through a non-unique set of mass flow rates, temperatures, and pressures, which are then correlated in dimensionless form through the pumping coefficient, $W^*T^{*(0.44)}$. The restrictive ASME flow nozzles used to measure secondary air flow depart from the protytype condition of essentially unimpeded air flow. To determine the pumping coefficient at the unimpeded operating point, the secondary air flow rate was incrementally varied from zero to its maximum measurable value. The pumping coefficient was computed at each point and plotted. (Especially when most of the secondary flow nozzles were blocked, hot exhaust gas was forced back into the plenum through the annular space between the diffuser rings. This unmeasured flow resulted in an understated pumping coefficient. After this effect was noted, the annular space was blocked during subsequent tests.) Extrapolation of the characteristic curve yielded the pumping coefficient for unimpeded secondary flow. Figure 27 is a typical characteristic curve. When extrapolating the curve, less weight was given to the more uncertain low pressure differences. The pumping coefficient at the operating point is used to compare different eductors.

After the data had been taken to determine the characteristic curve of the eductor, the plenum end plates and diffuser ring plugs were removed to simulate the 'open to the environment' condition. Temperature measurements on the mixing stack wall and on the shrouds and rings were then recorded. Two temperature profile traverses were made at the exit plane of the mixing stack. The horizontal traverse crossed two nozzles, the diagonal traverse went between the nozzles. Of interest is the maximum temperature and the overall flatness of the profile, which indicates the degree of mixing of the flows.

The eductor system performance was evaluated over the range of prototype uptake temperatures from 550 F to 850 F, in 100 degree intervals. For each model, the experimental series was run twice, once on each of two days. This was done to determine the reliability and repeatability of the data.

V. DISCUSSION OF EXPERIMENTAL RESULTS

The experimental apparatus was checked carefully prior to any model testing. Possible air leaks were plugged, and the range of alignment motions was increased. The FORTRAN data reduction program was rewritten and tailored for the addition of numerous temperature measurements.

A. SOLID WALL MIXING STACK

The first model testing was done with a solid wall mixing stack tested by Welch [3], for the purpose of verifying his data, verifying the data reduction program, and gaining operational familiarity with the equipment. Tests were made only at the endpoints of the temperature range--cold flow and 850 F. Results are plotted in Figure 28 and tabulated in Table II. At each temperature, the values of the pumping coefficient agreed within 2%. The value at the uptake temperature of 850 F was .53. Normalized mixing stack temperatures were not so close, but were within 10%. The maximum absolute value recorded was 370 F. Of significance is that a pressure depression below atmospheric in the mixing stack was confirmed with close agreement (less than 5% difference). This pressure distribution was the foundation for the slotted mixing stack design, which uses this pressure depression to draw film cooling air through the slots. Exit plane temperature profiles at 850 F showed a maximum temperature of 604 F at the centerline (Figure 33, Table V).

B. SLOTTED AND SHROUDED MIXING STACK WITH ONE DIFFUSER RING

Temperatures were the primary data of interest in this study; temperature readings were taken on the mixing stack, the shroud, and the diffuser rings. All temperatures are plotted in Figure 31, and tabulated in Table III. Along the mixing stack, the temperatures in position A were greater than those in position B. This was expected since position A is the line of nozzle impingement. The temperatures also showed an increase along the length of the stack. The air drawn through the film cooling slots at the downstream end has had more preheating than the air drawn through the first slots, and there is less air induced because of the pressure recovery within the mixing stack. The maximum mixing stack temperature was 267 F, at an uptake temperature of 850 F. The shroud temperatures also exhibited an increase along the length which may be explained as above, but were the same for positions A and B. The temperatures were close to ambient at the shroud inlet, and the maximum recorded temperature was 138 F at the downstream end when the uptake temperature was 850 F. The diffuser ring temperatures showed a difference between position A and position B, but the latter was greater than the former. This result is minor, and unexplained. The downstream temperatures were higher than the upstream temperatures, which are shielded by the shroud and have the benefit of fresh cooling air. The maximum diffuser ring temperature was 144 F, at an uptake temperature of 850 F. The downstream ring temperatures were about the same as the downstream shroud temperatures.

The pumping coefficient showed a general decrease with increasing temperature. This confirms a trend noted by Welch [3]. The pumping coefficient was .72 at an uptake temperature of 850 F. Pumping coefficients are plotted in Figure 29(a) and 29(b), and tabulated in Table III. Repeatability of the results was within 1.5% as shown in Figure 29(c). Staehli and Lemke [2] tested a model with a ported mixing stack and a shroud merged into a diffuser ring. The results were similar to those of the slotted and shrouded mixing stack with one diffuser ring under discussion here. Their value for the pumping coefficient was .72 at cold flow. A direct comparison cannot be made because of differences in geometry; still the figures are in reasonable agreement.

The back pressure shows an increase with uptake temperature, ranging from 8.3 to 9.6 inches of water. This compares favorably with the range of 8.3 to 9.5 inches of water reported for the solid wall mixing stack tested by Welch [3]. This good agreement is to be expected, since for compressible flow the pressure ratio across a nozzle is fixed by the Mach number and area ratio. The geometry was identical and uptake conditions were similar, so the downstream pressure must agree between the two experiments.

The exit plane temperatures are plotted in Figure 34 and tabulated in Table VI. The curves are symmetric with no peaks, which indicates good mixing. The maximum temperatures were recorded at the centerline, and were 400 F for an uptake temperature of 550 F and 570 F for an uptake temperature of 850 F.

C. SLOTTED AND SHROUDED MIXING STACK WITH TWO DIFFUSER RINGS

Temperatures for this case are plotted in Figure 32 and tabulated in Table IV. As with one diffuser ring, mixing stack temperatures were higher along position A than position B, and increased with length. Even the highest mixing stack temperature was far below the corresponding temperature for a solid wall mixing stack. Temperature data recorded by Welch [3] for a solid wall mixing stack at an uptake temperature of 850 F are plotted with the temperatures obtained in this study in Figure 32(h); the slotted wall stack is everywhere at least 150 degrees F cooler than the solid wall mixing stack. The maximum mixing stack temperature recorded was 269 F for an uptake temperature of 850 F, essentially the same as for the one diffuser ring model. This indicates that the smaller annular space, .1875 inch versus .3125 inch for the stack with one ring, does not degrade the cooling capability of the film air flow. The shroud temperatures showed the same trends--an increase with length but about 15 to 25 degrees F higher than for the one diffuser ring case. The maximum shroud temperature was 158 F at an uptake temperature of 850 F. The first ring yielded temperatures higher at the downstream end than at the upstream end, but no differences due to position A or B. The ring was significantly cooler than for the one diffuser ring model; this may be explained because cooling air flows on both sides of the ring when a second ring is added. Maximum ring temperature recorded was 132 F at an uptake temperature of 850 F. The second ring temperatures were likewise not influenced by being at position A or B, and were much cooler than the downstream shroud temperatures. The second ring in the two ring diffuser, then, does not have the same temperatures as the ring in the one-ring diffuser; evidently the extra air flow past the first ring effectively shields the second ring from the hot gas flow. The maximum temperature recorded on the second diffuser ring was 134 F at an uptake temperature of 850 F.

The pumping coefficients decreased with increasing temperature. They are plotted in Figure 30(a) and 30(b), and tabulated in Table IV. The anomalous characteristic curve at uptake temperature 550 F (Figure 30(b)) is explained by noting the unusual operating pressures and pressure drops recorded for that run, which also resulted in a shift from one end of the allowed Mach number range to the other. The value of the pumping coefficient at an uptake temperature of 850 F was .74--this value is less than a 3% difference from the value reported for the stack with one diffuser ring; the difference is not considered significant. The repeatability of pumping coefficient measurements is within 1.5%, as shown in Figure 30(c). There is no corresponding cold flow model.

Although Staehli and Lemke [2] had a model with two rings, the first ring was analogous to the shroud used in this investigation and their model was compared to the stack with one diffuser ring. Nevertheless, they found very little difference in pumping coefficients between one- and two-ring diffuser models--the same conclusion reached here.

Uptake back pressure varies with plenum pressure as well as temperature. During tests with the two diffuser ring model, the annular spaces between the diffuser rings were not plugged and exhaust gas was drawn back into the plenum, thus raising the plenum pressure. This not only resulted in a less certain figure for the pumping coefficient, but also in a less certain figure for back pressure. With this warning in mind, the back pressure ranged from 8.4 to 10.0 inches of water. (Higher back pressure figures were recorded for run number one, 850 F (Table IV), but are considered uncertain. During this run the flow from the gas generator was surging, and uptake temperature was oscillating about the nominal 850 F. Temperature and pressure measurements were not recorded simultaneously, so the listed values do not necessarily reflect the same flow conditions.)

The exit plane temperatures are plotted in Figure 35, and tabulated in Table VII. As before, the curves are symmetric with no peaks, indicating well-mixed flow. The maximum temperatures recorded were 400 F at an uptake temperature of 550 F, and 580 F at an uptake temperature of 850 F. These are the same maxima as recorded for the stack with one diffuser ring, and shows that the effects of adding a second ring are not felt at the flow centerline.

VI. CONCLUSIONS

This investigation studied the effects on the eductor temperature performance of adding film cooling slots, a mixing stack shroud, and a one- or two-ring diffuser. Detailed descriptions of these eductor systems are given in Section III above. Trends and comparisons between models tested and cold flow analogs were discussed in Section V. Only a review of the main conclusions resulting from this investigation are presented here. A summary of the temperatures, pumping coefficients, back pressures and exit plane temperatures is presented in Table I.

A. Adding film cooling slots to a solid wall mixing stack significantly reduces mixing stack wall temperatures, from a maximum of 370 F to a maximum of 270 F in this study.

B. Adding a shroud further reduces the external temperature of the mixing stack assembly, to a maximum of about 155 F. Further, this temperature is recorded only in the last one-quarter of the stack length; the preceding section is much cooler. The maximum shroud temperature is also reduced by increasing the annular gap between the shroud and the mixing stack.

C. Adding one diffuser ring to the slotted and shrouded mixing stack covers the hot portion of the shroud, thus reducing the visible surface temperature by about 10 degrees F, and cuts in half the area at this temperature. Adding one diffuser ring improves the pumping coefficient by about 35%, a significant gain, but increases the back pressure from about 9.0 inches of water to about 9.4 inches of water. The maximum centerline exhaust gas temperature at the exit plane of the mixing stack is reduced from 605 F for the solid wall mixing stack to 570 F. This reduction is probably due to the effects of film cooling air and air brought in through the shroud, rather than due to the diffuser ring.

D. Adding two diffuser rings to the slotted and shrouded mixing stack drops the maximum visible skin temperature of the mixing stack assembly to about 135 F. The pumping coefficient, back pressure, and maximum centerline exhaust gas discharge temperature are all unchanged from the values obtained from the stack with one diffuser ring.

schematically shown in Figure 22.

VII. RECOMMENDATIONS

In addition to providing insight into the effects on temperatures that can be achieved, this study has generated an awareness of the investigation's shortcomings and sparked suggestions for further research.

A. Investigate the optimum size and placement of film cooling slots. It appears that fewer slots could be used in the upstream portion of the stack without causing unacceptable temperature rise. This would slow the pressure recovery in the stack and allow more air to be induced through the downstream slots.

B. Investigate the optimum diffuser angle, including the possibility of different spacing between the shroud and mixing stack than between the rings and shroud.

C. Install a globe or needle valve in the fuel pump recirculation line for more precise and positive control of fuel flow.

VIII. FIGURES

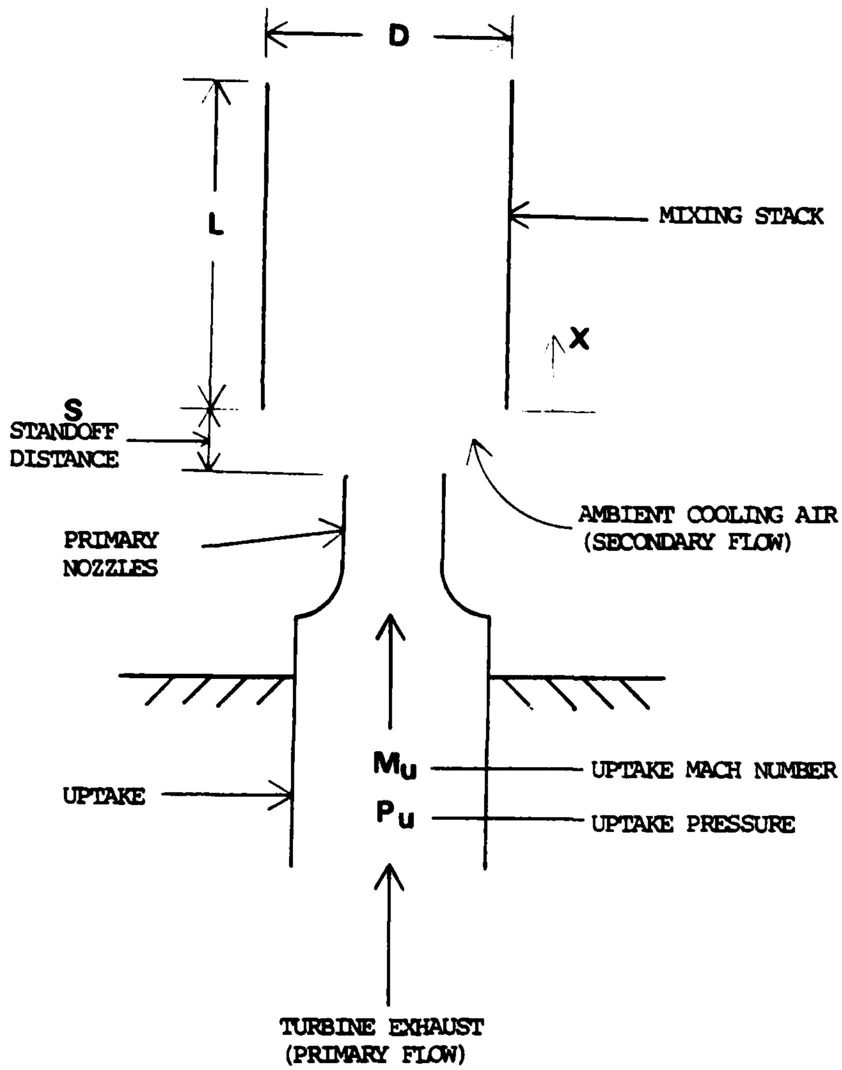


FIGURE 1. Schematic Diagram of Simple Exhaust Gas Eductor

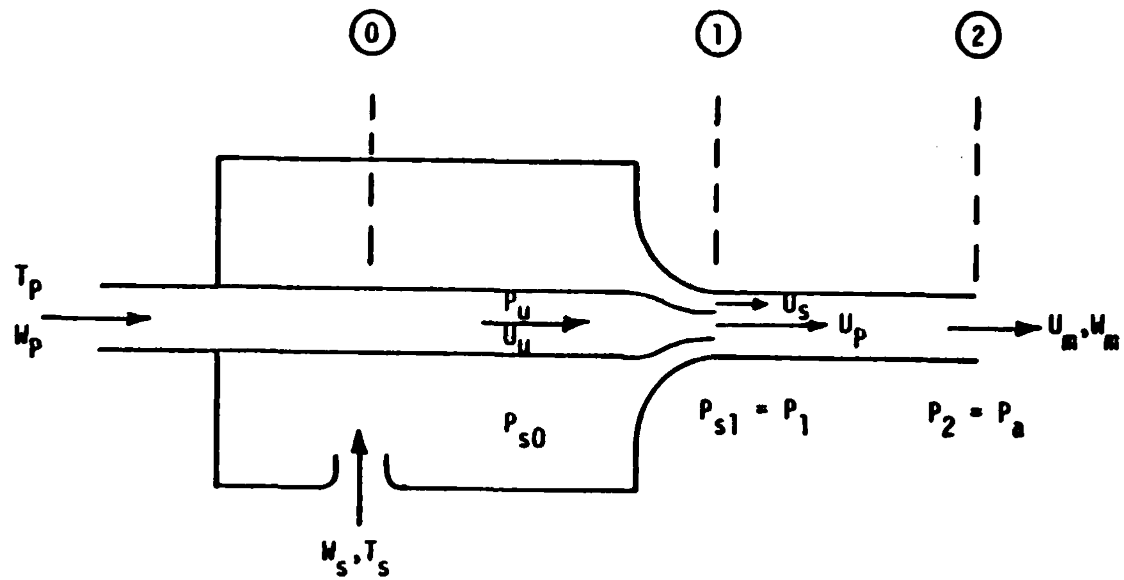


FIGURE 2. Simple Single Nozzle Eductor System

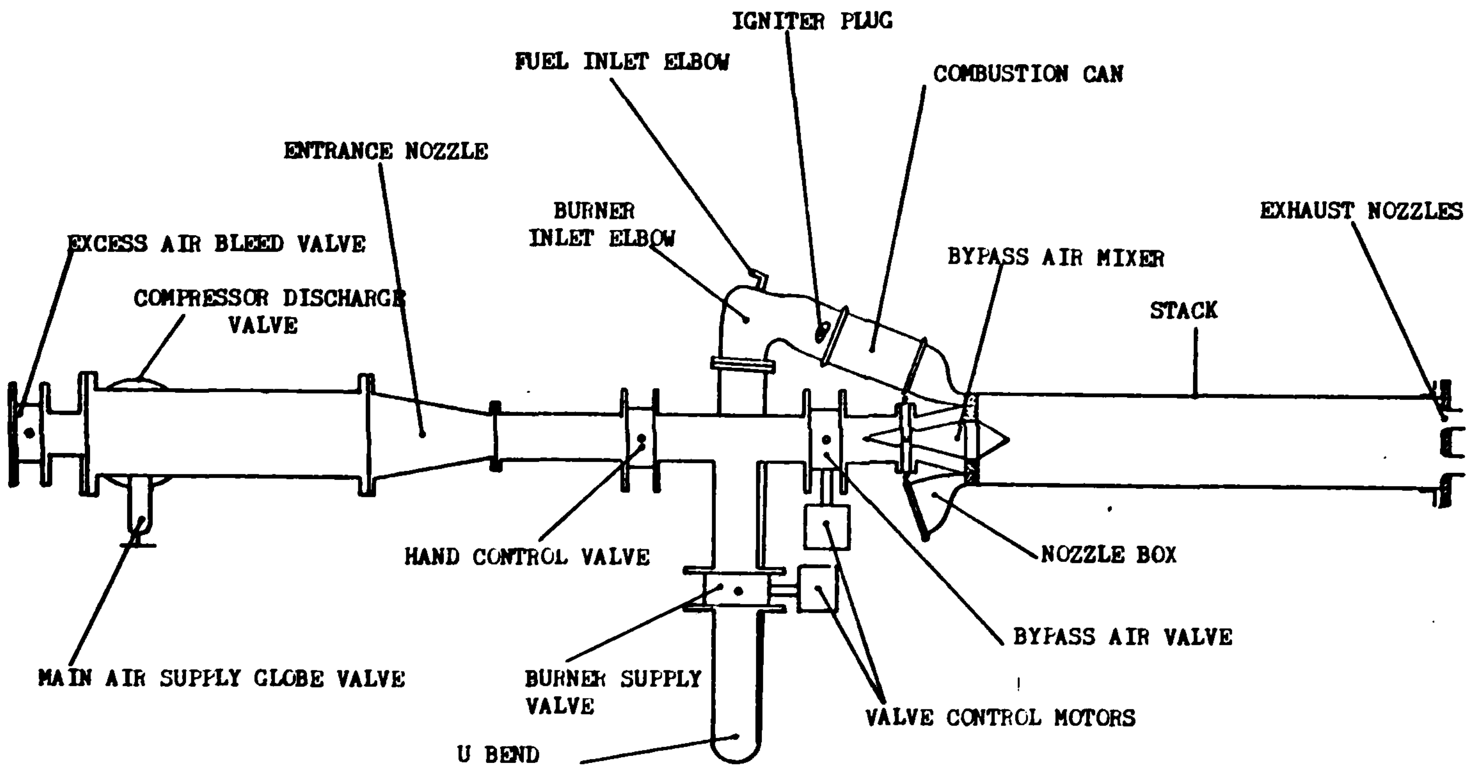


FIGURE 3. Schematic Diagram of Combustion Gas Generator

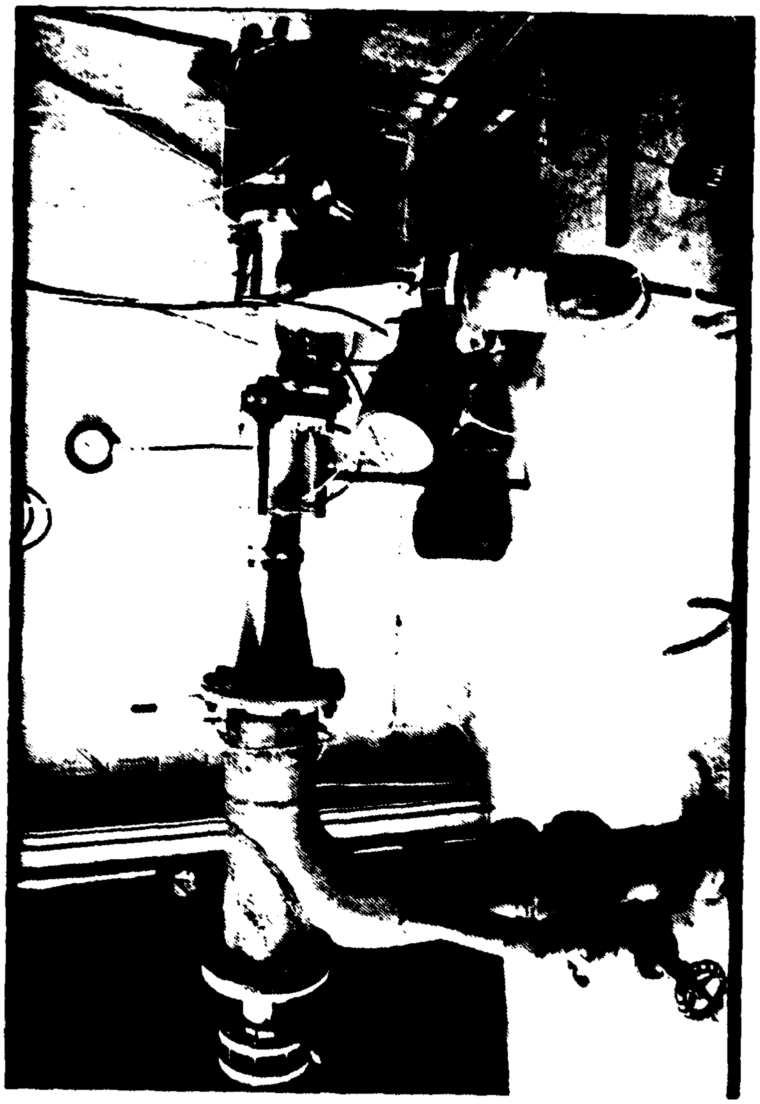


FIGURE 4. Combustion Gas Generator

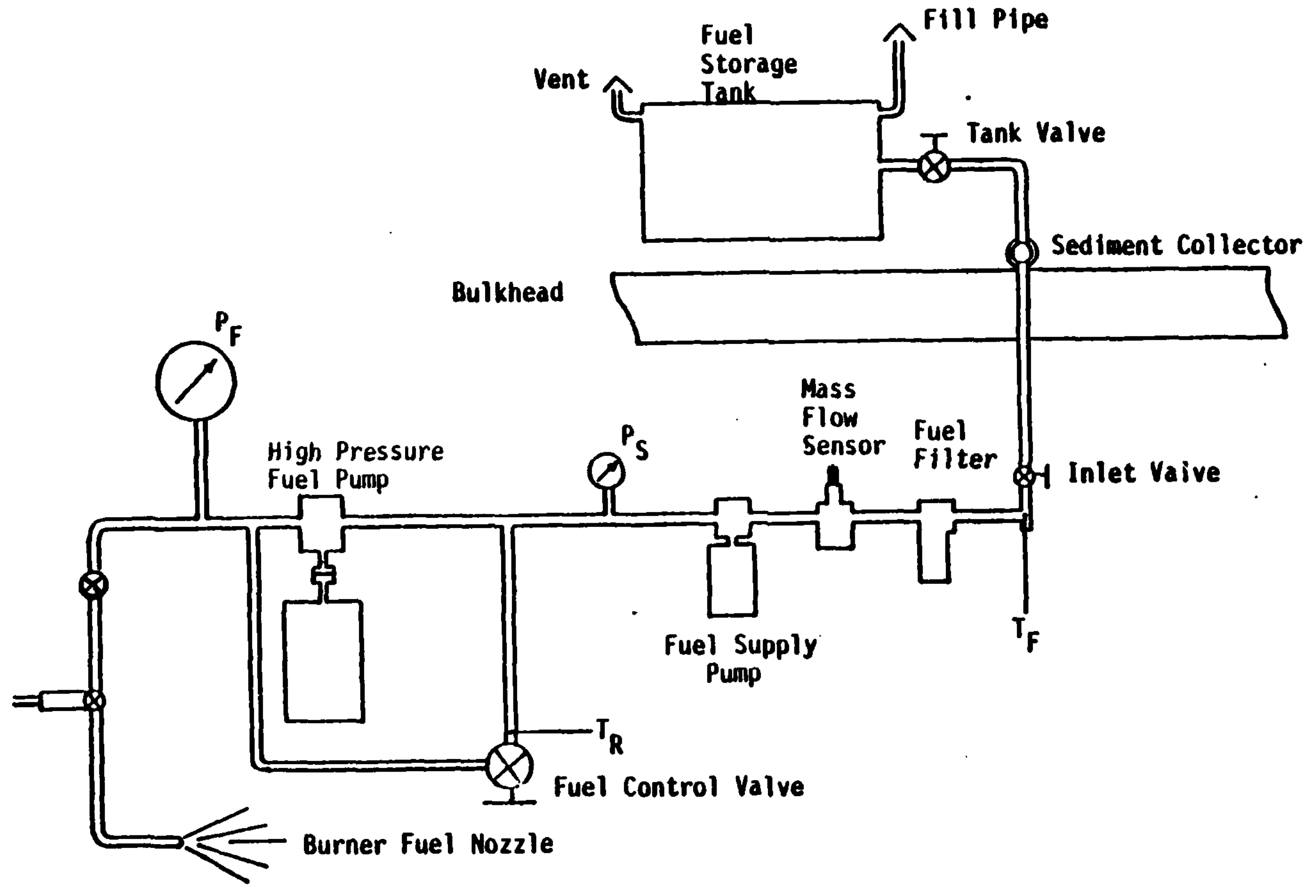


FIGURE 5. Gas Generator Fuel System

shroud temperatures.

FIGURE 6. Gas Generator Fuel Supply System

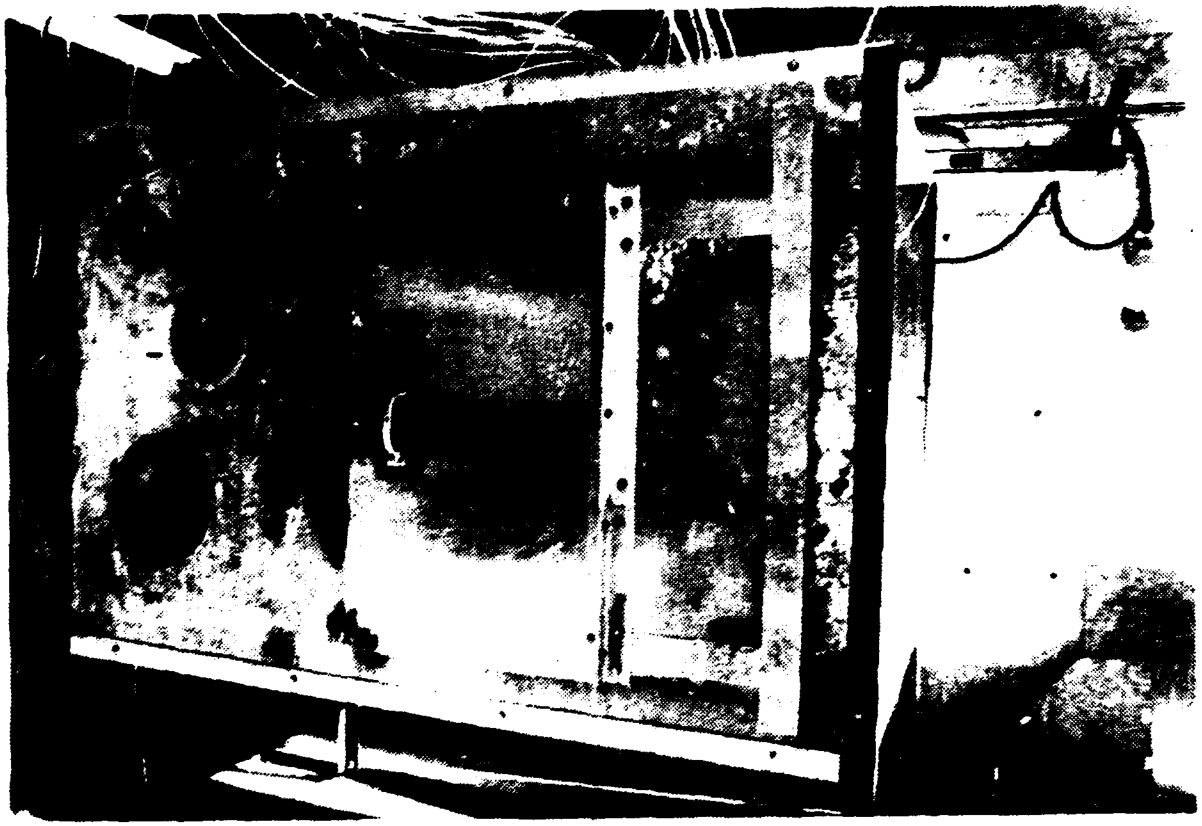
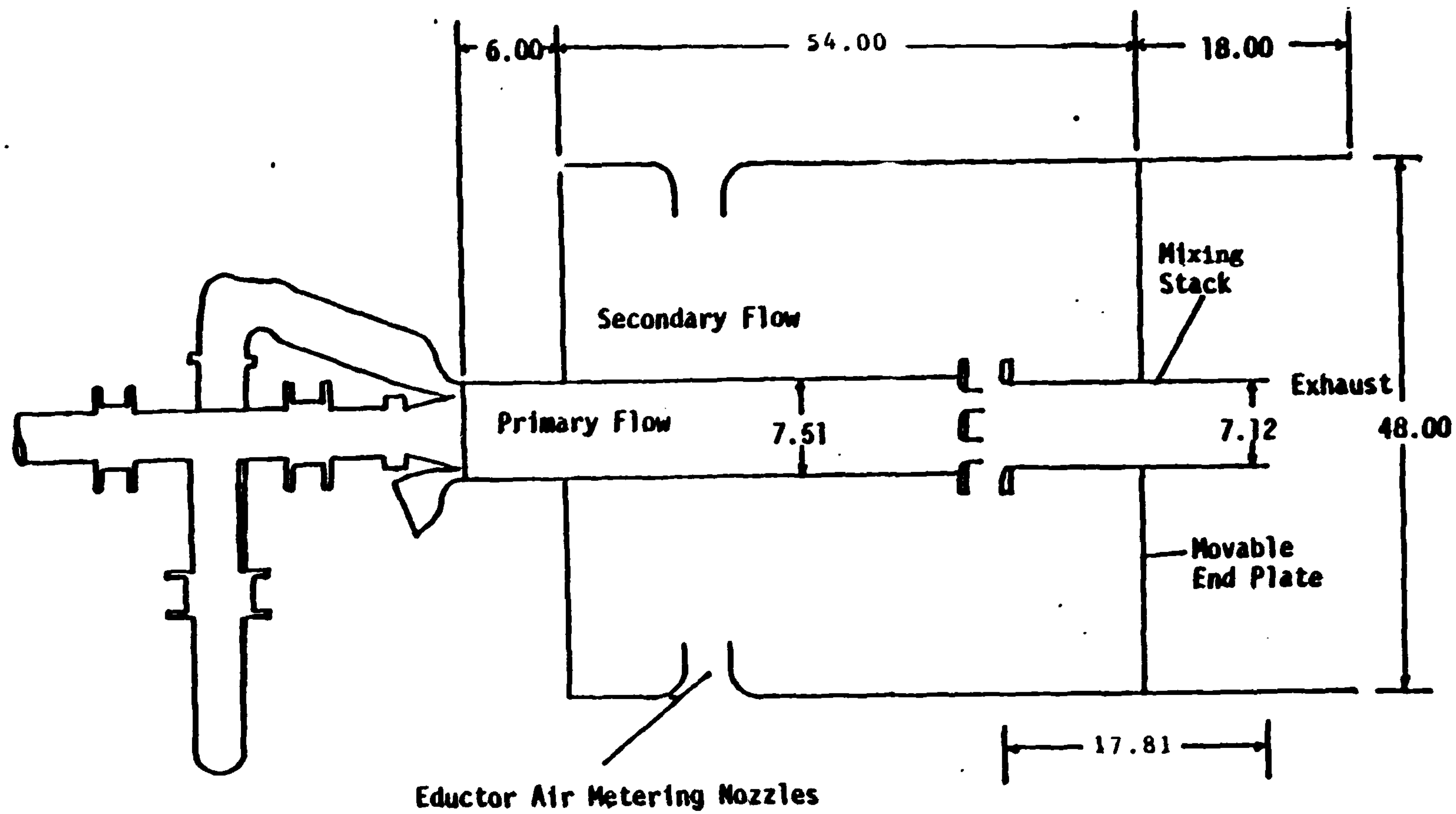


FIGURE 7. Eductor Air Metering Box



Overall box dimensions: 48x48x72

All dimensions in inches.

FIGURE 8. Eductor Air Metering Box Arrangement

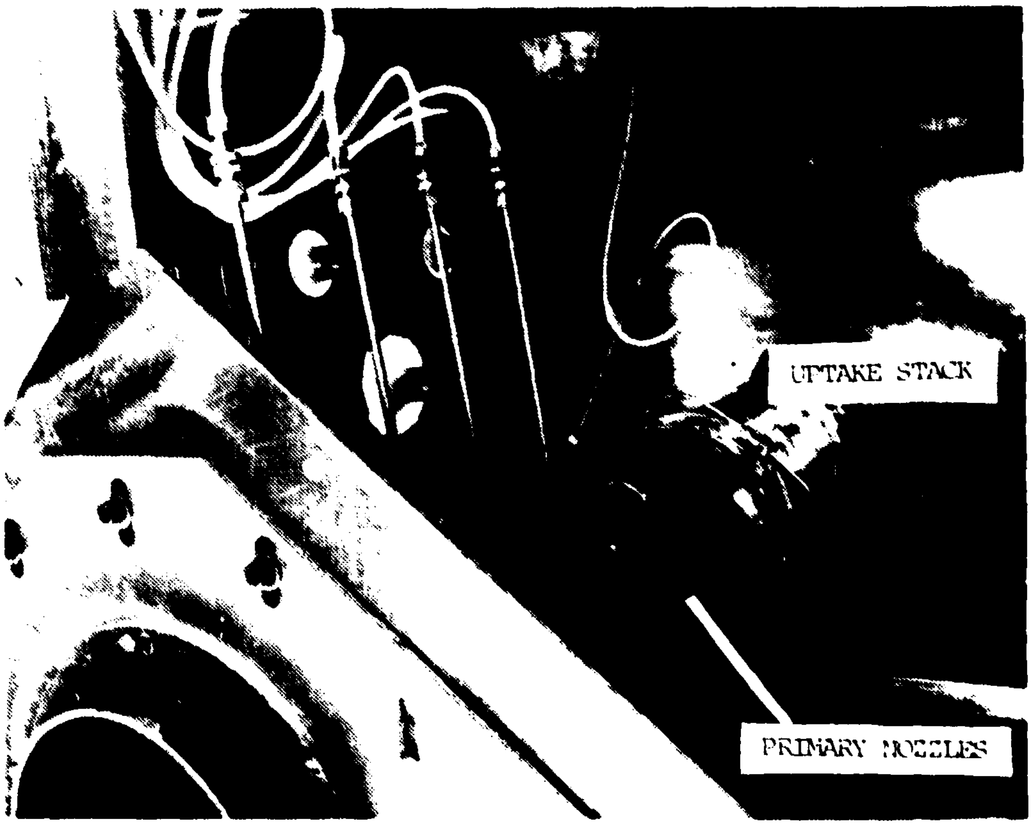


FIGURE 9. Interior of Air Metering Box Showing Uptake Stack and Primary Nozzles

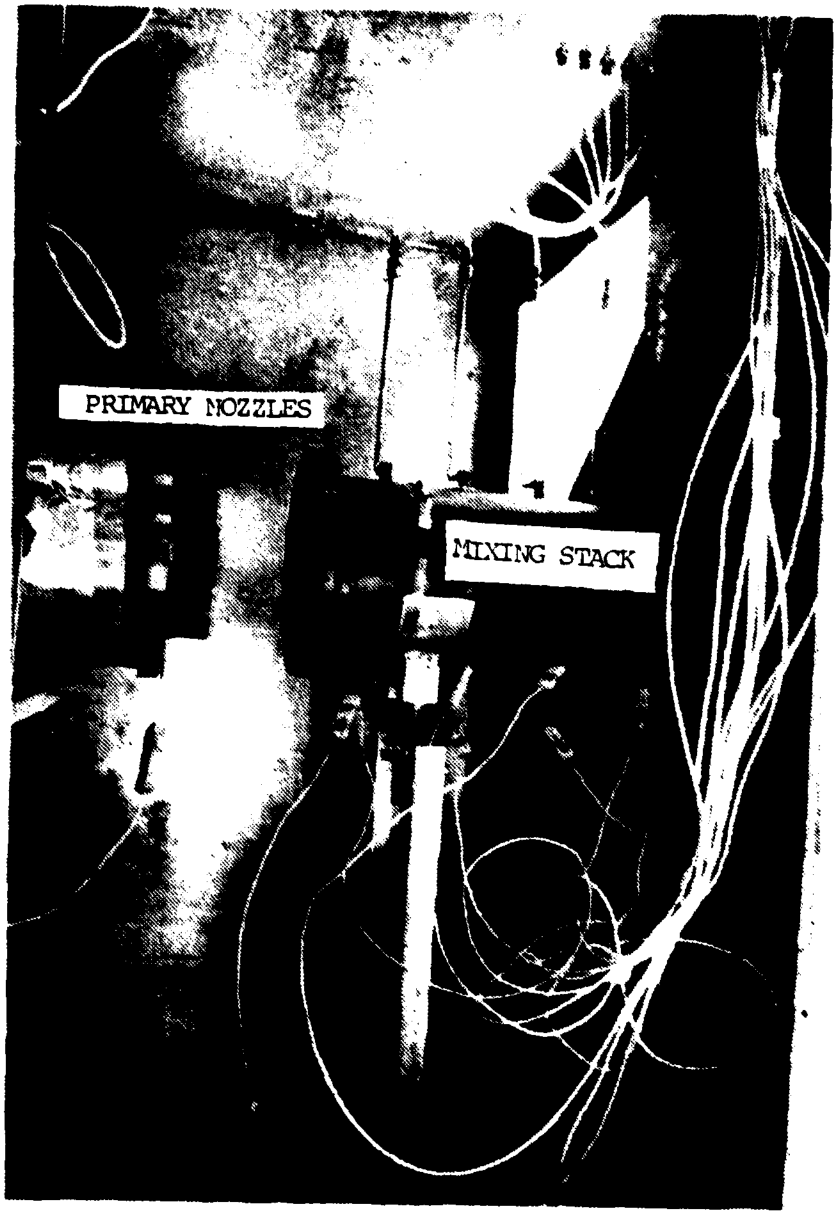


FIGURE 10. Interior of Air Metering Box Showing Mixing Stack and Primary Nozzles

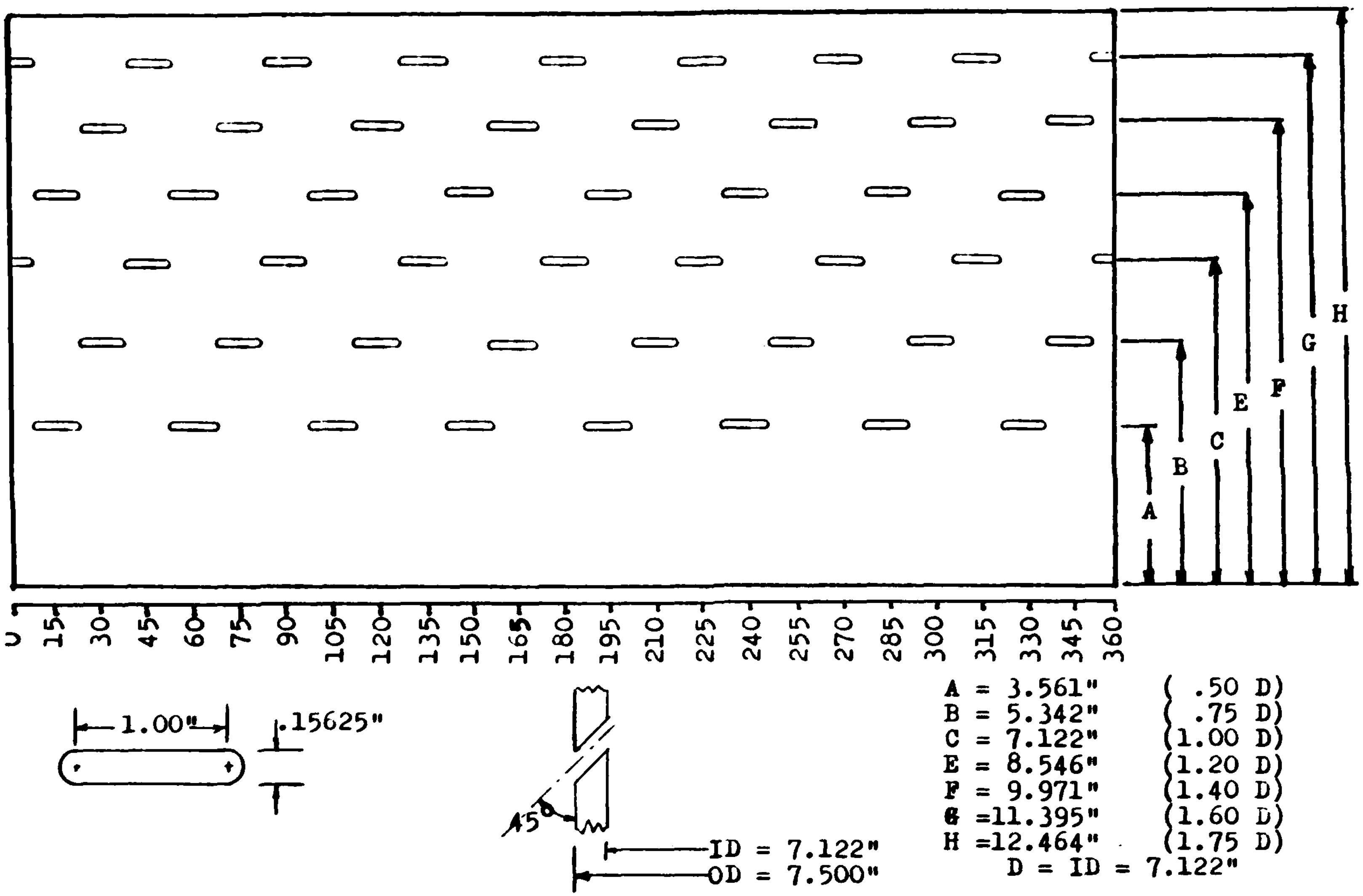


Figure 11. Dimensional Diagram of Expanded Slotted Mixing Stack

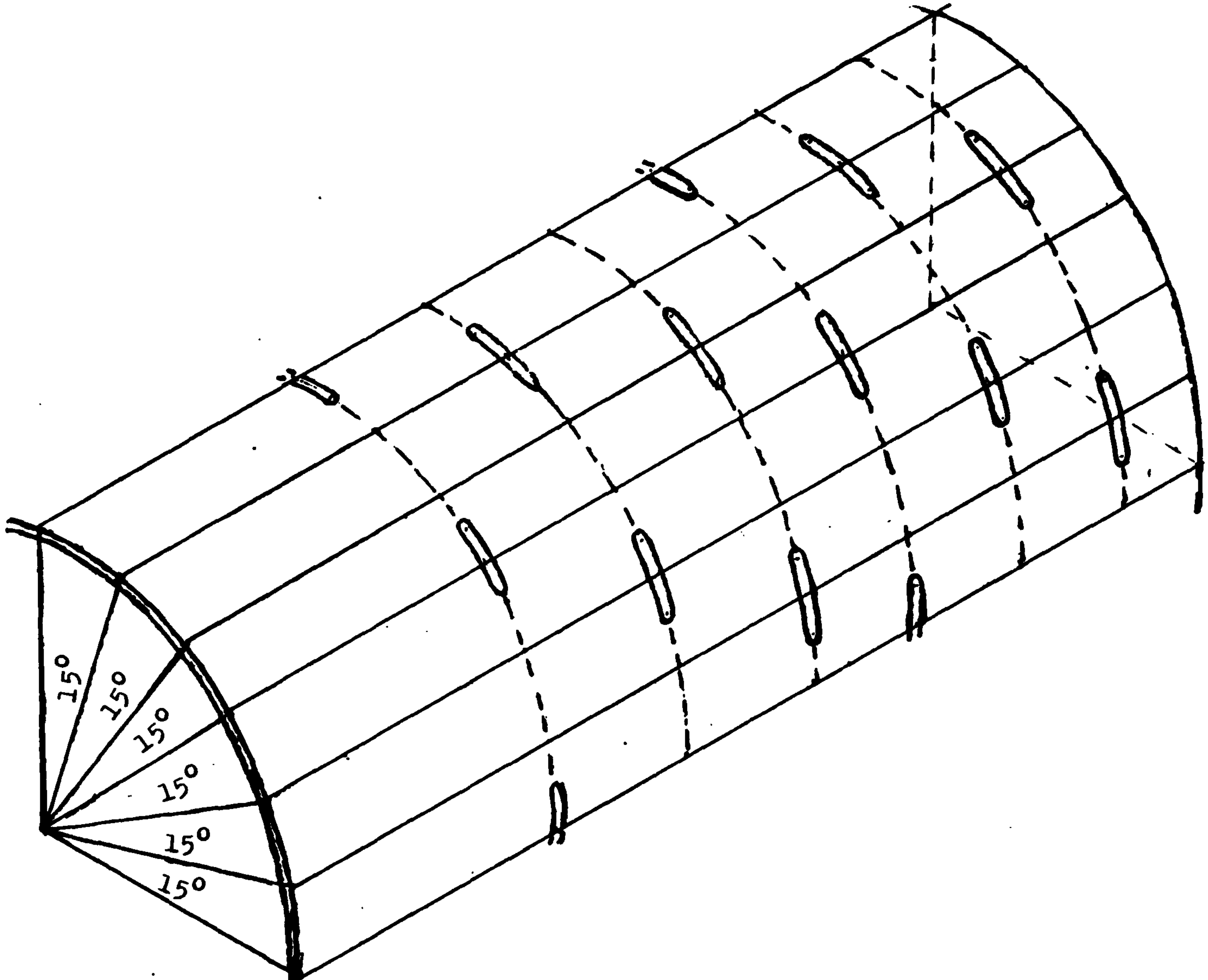


Figure 12. Schematic Diagram of Slotted Mixing Stack

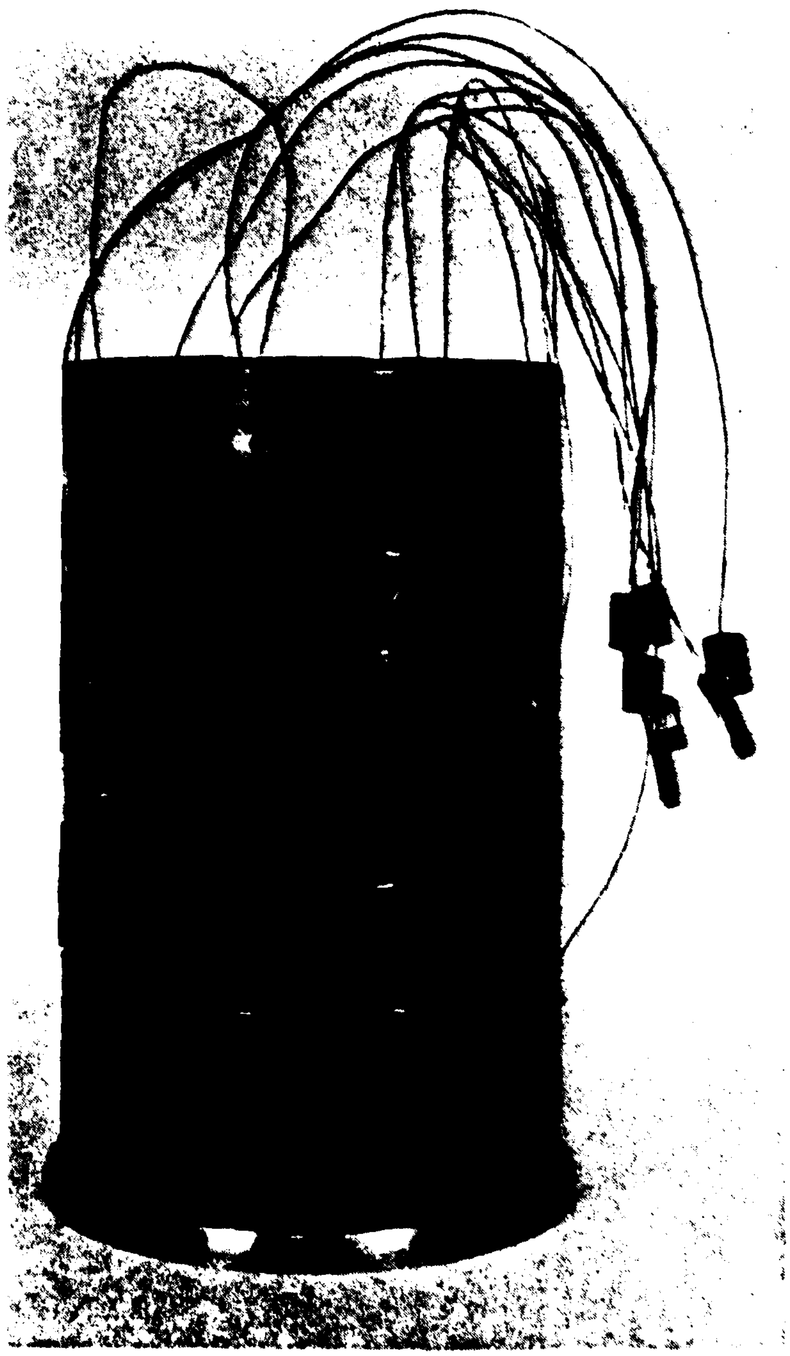


Figure 13. SLOTTED MIXING STACK

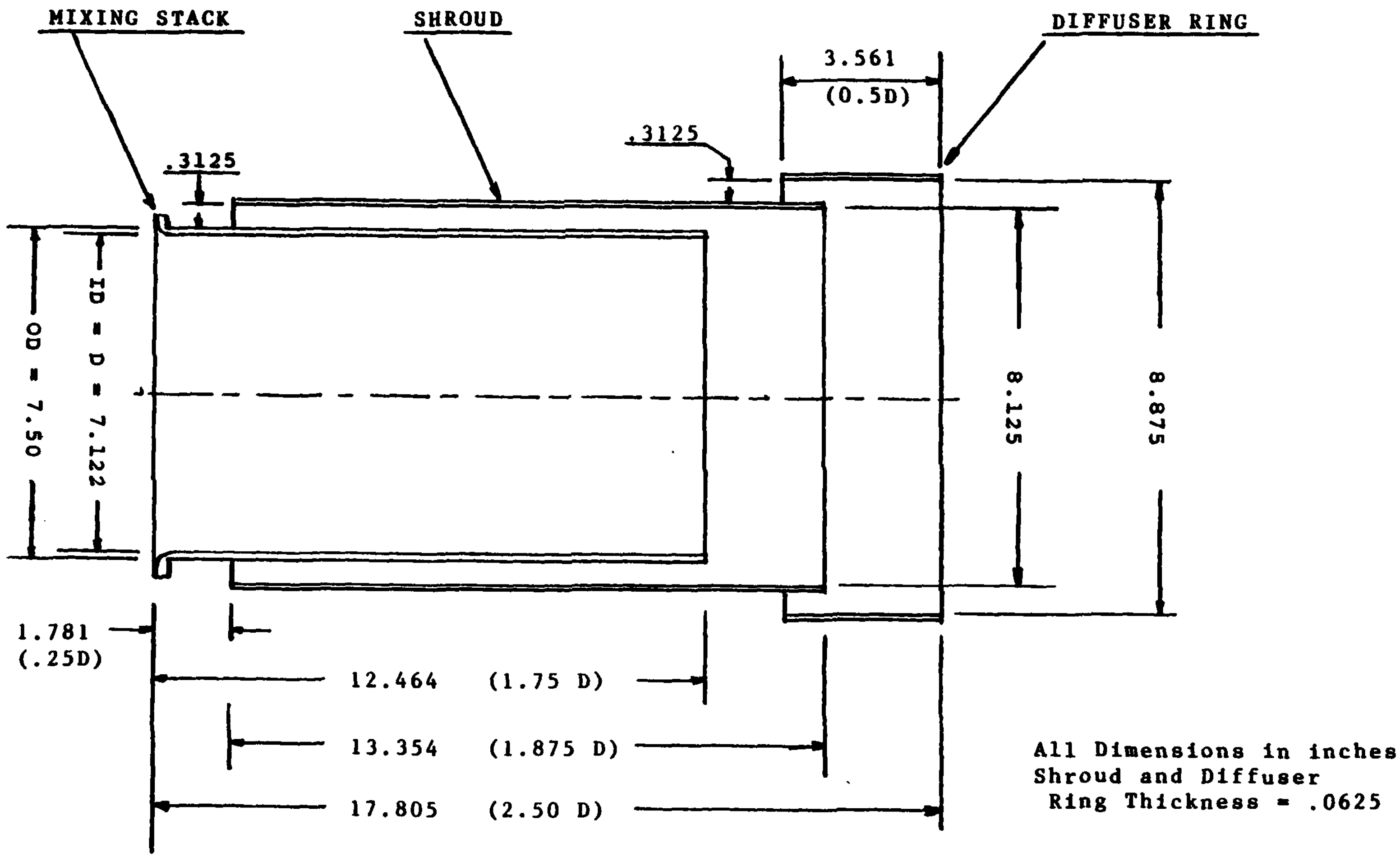


Figure 14. Dimensional Diagram of Mixing Stack with One Diffuser Ring

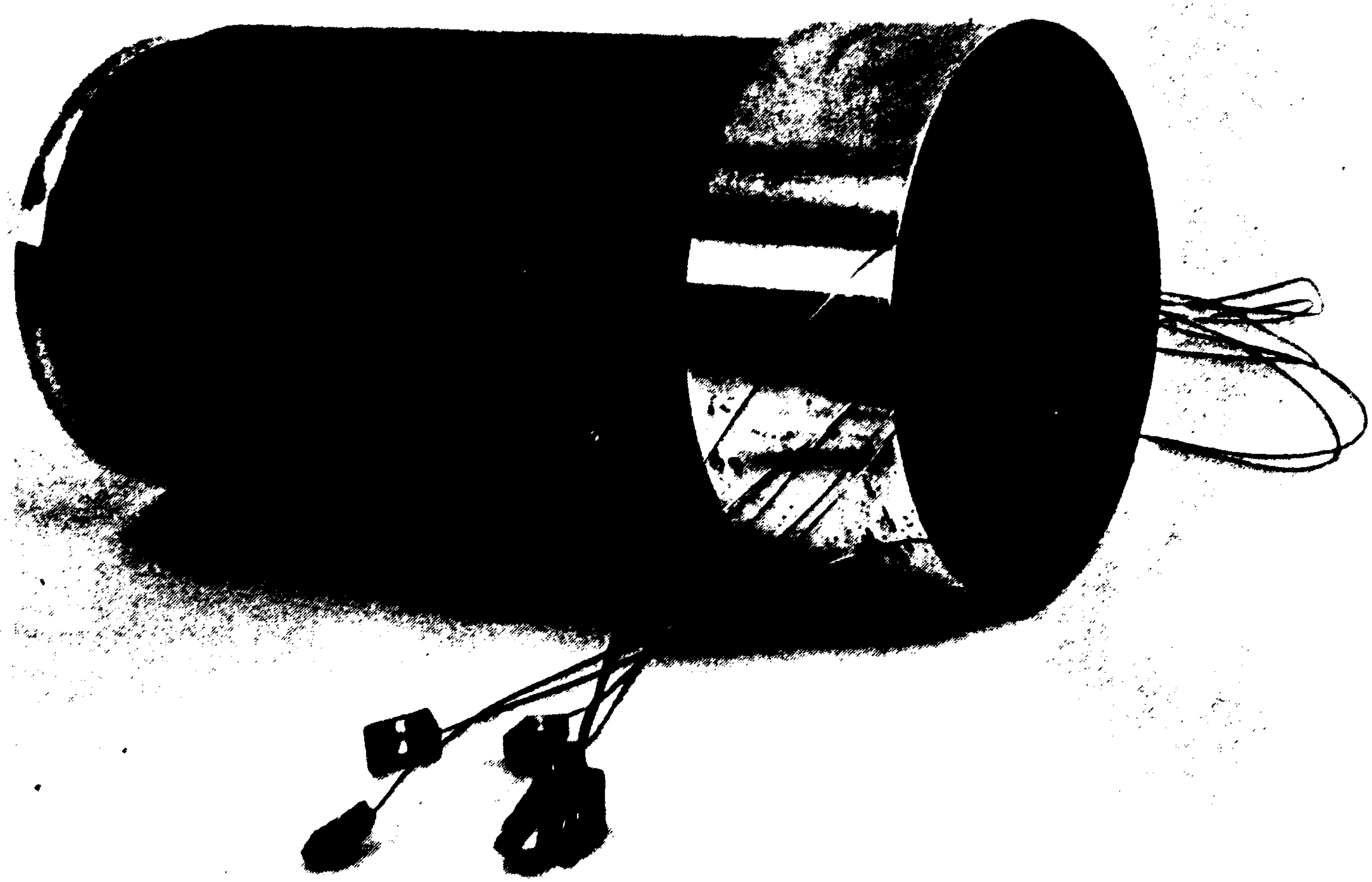


Figure 15. MIXING STACK WITH ONE DIFFUSER RING

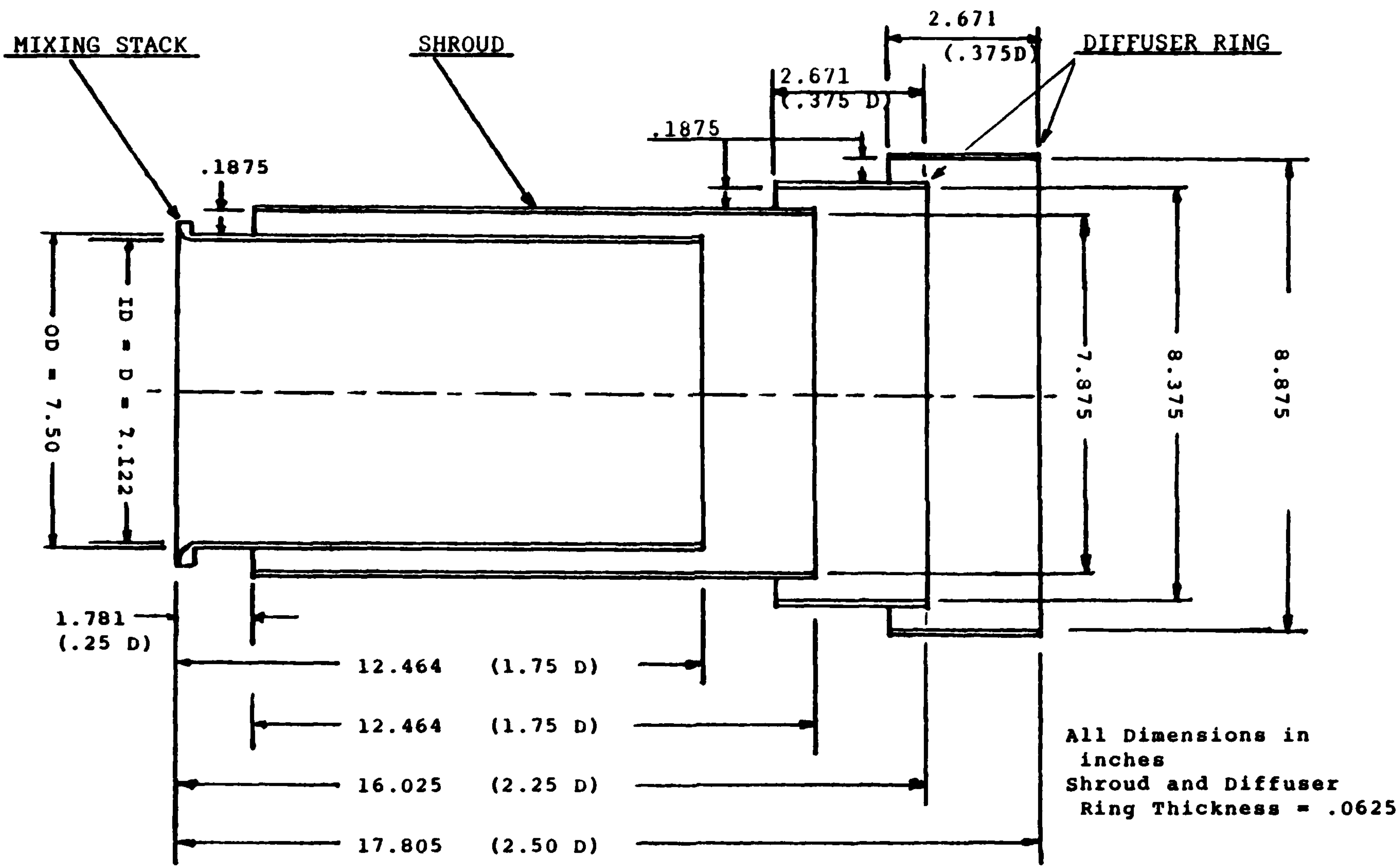


Figure 16. Dimensional Diagram of Mixing Stack with Two Diffuser Rings

Figure 17. MIXING STACK WITH TWO DIFFUSER RINGS

	$A_m/A_p = 2.5$
A	1.251
B	1.126
C	1.770
D	2.520
E	.250
F	.125
G	.500

All dimensions in inches

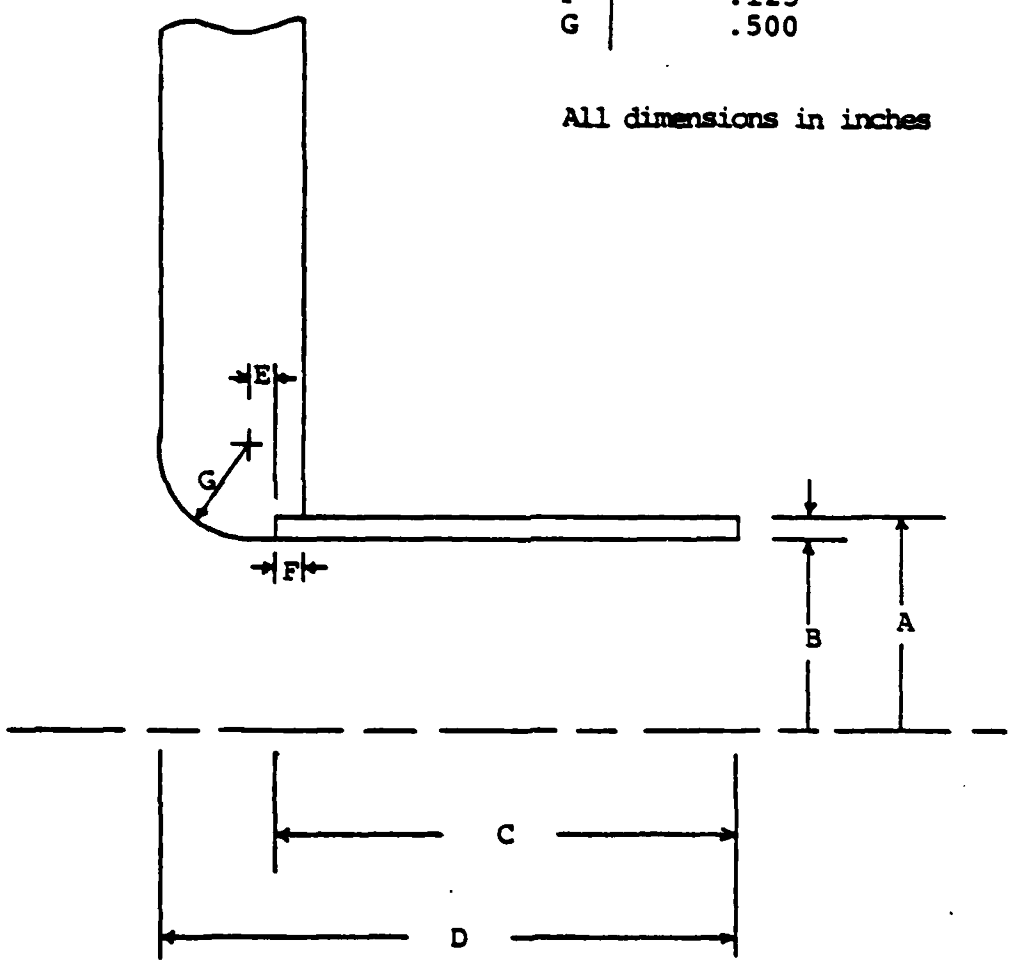


FIGURE 18. Dimensional Diagram of Primary Flow Nozzles

	$A_m/A_p = 2.5$
A	10.000
B	45°
R_1	1.126
R_2	1.251
R_3	2.070
R_4	4.509
R_5	3.729
R_6	4.108

All dimensions in inches

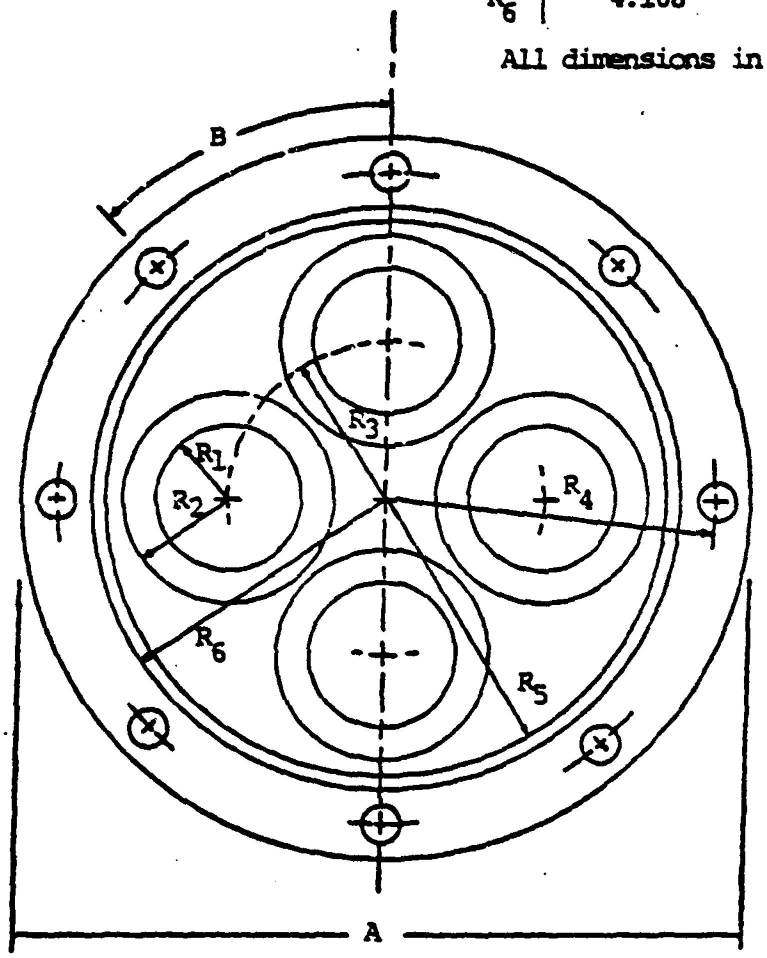


FIGURE 19. Dimension Diagram of Primary Flow Nozzle Plate

FIGURE 20. Primary Flow Nozzle Plate (Back View)

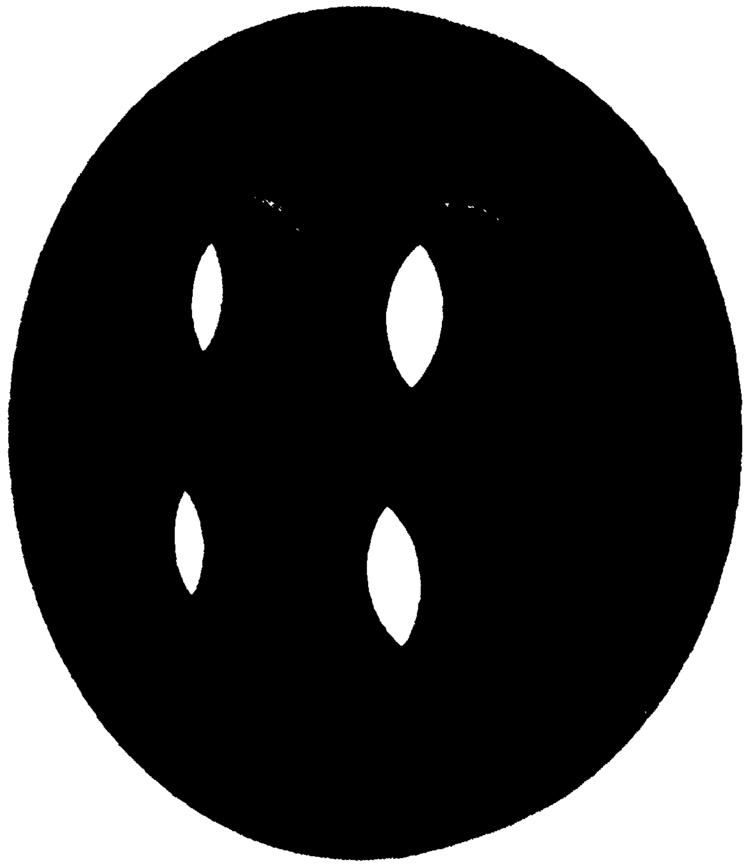


FIGURE 21 Primary Flow Nozzle Plate (Front View)

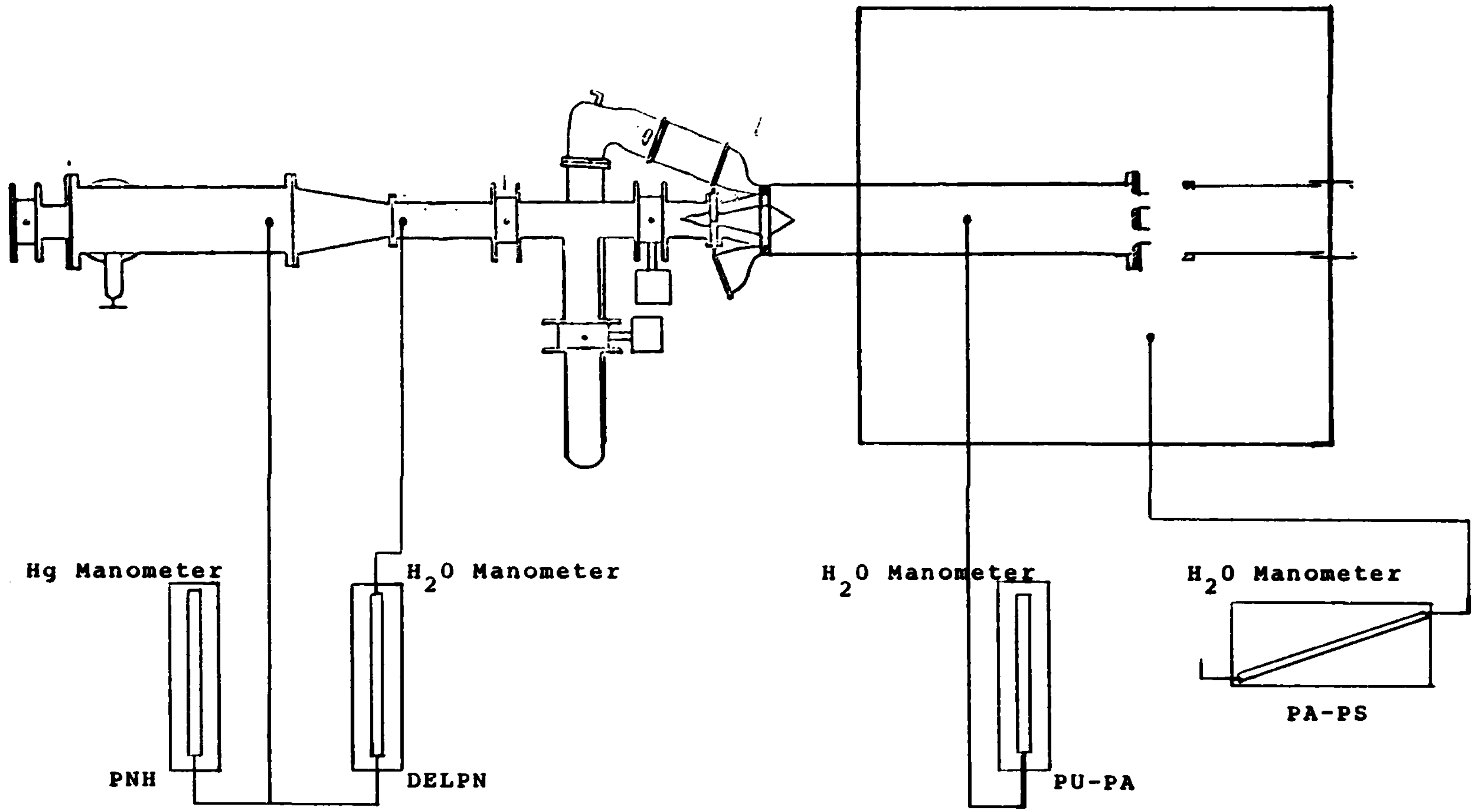


Figure 22. Schematic Diagram of Pressure Measurement System

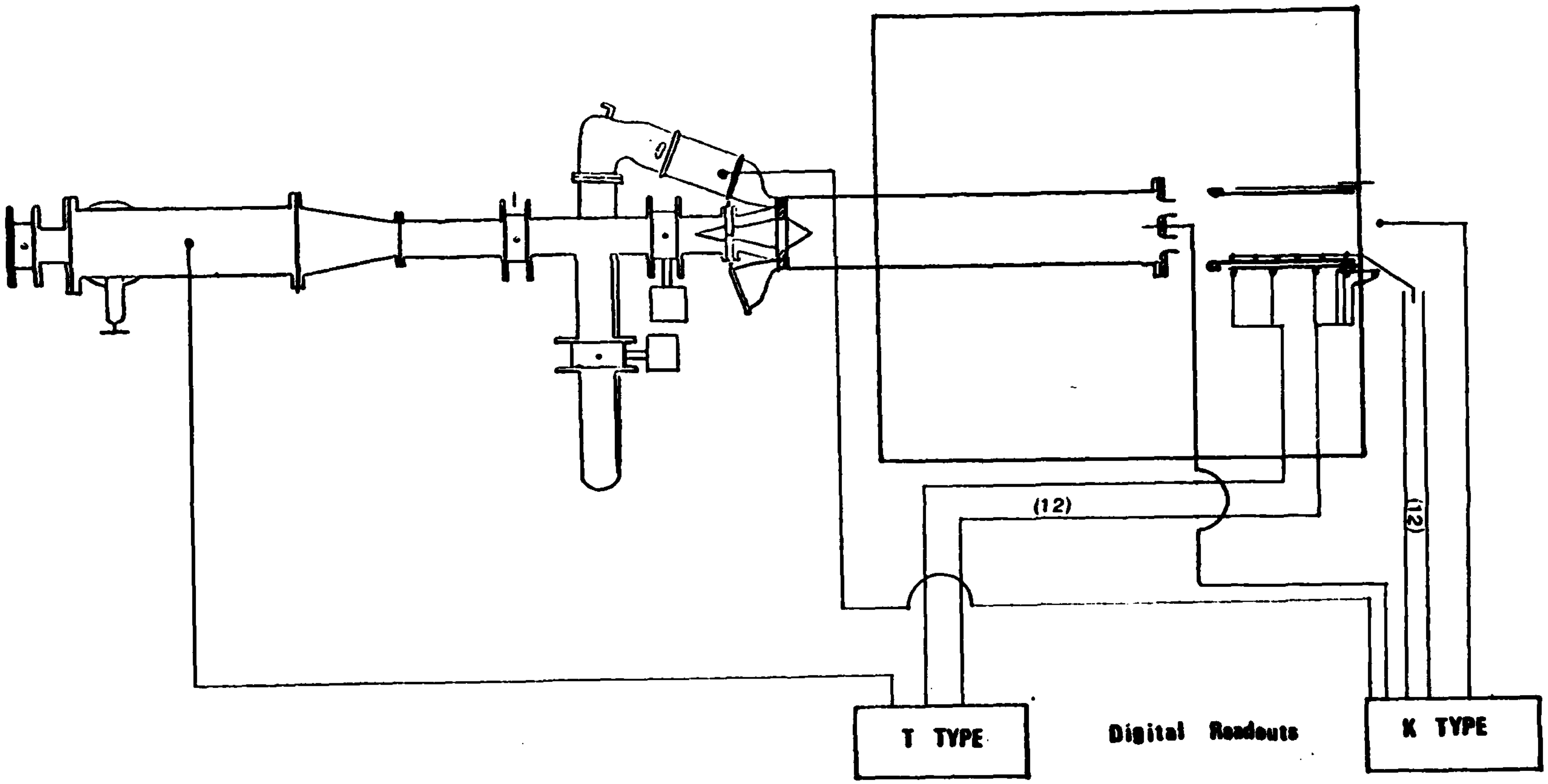


Figure 23. Schematic Diagram of Temperature Measurement System

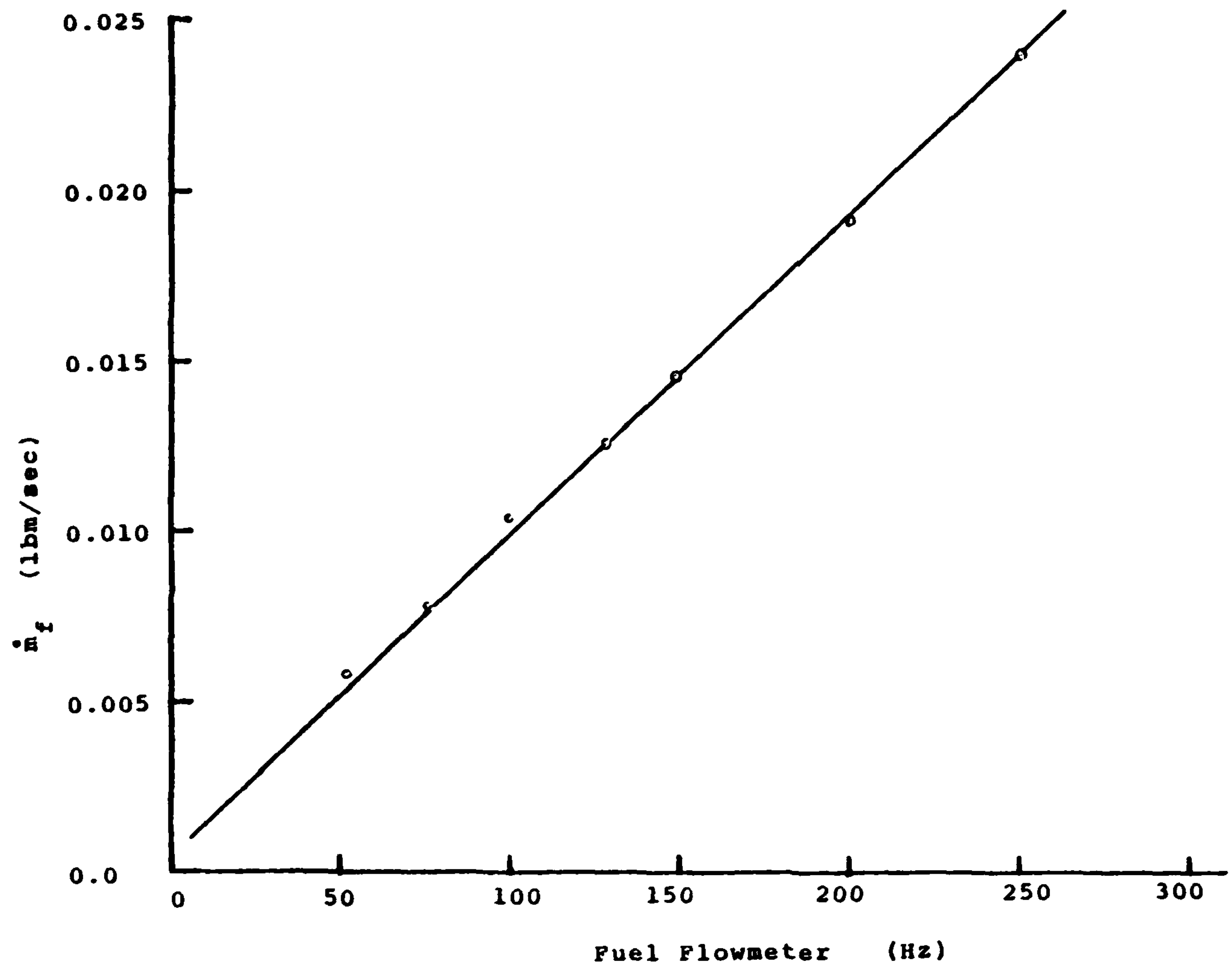


Figure 24. Fuel Flow Calibration Curve

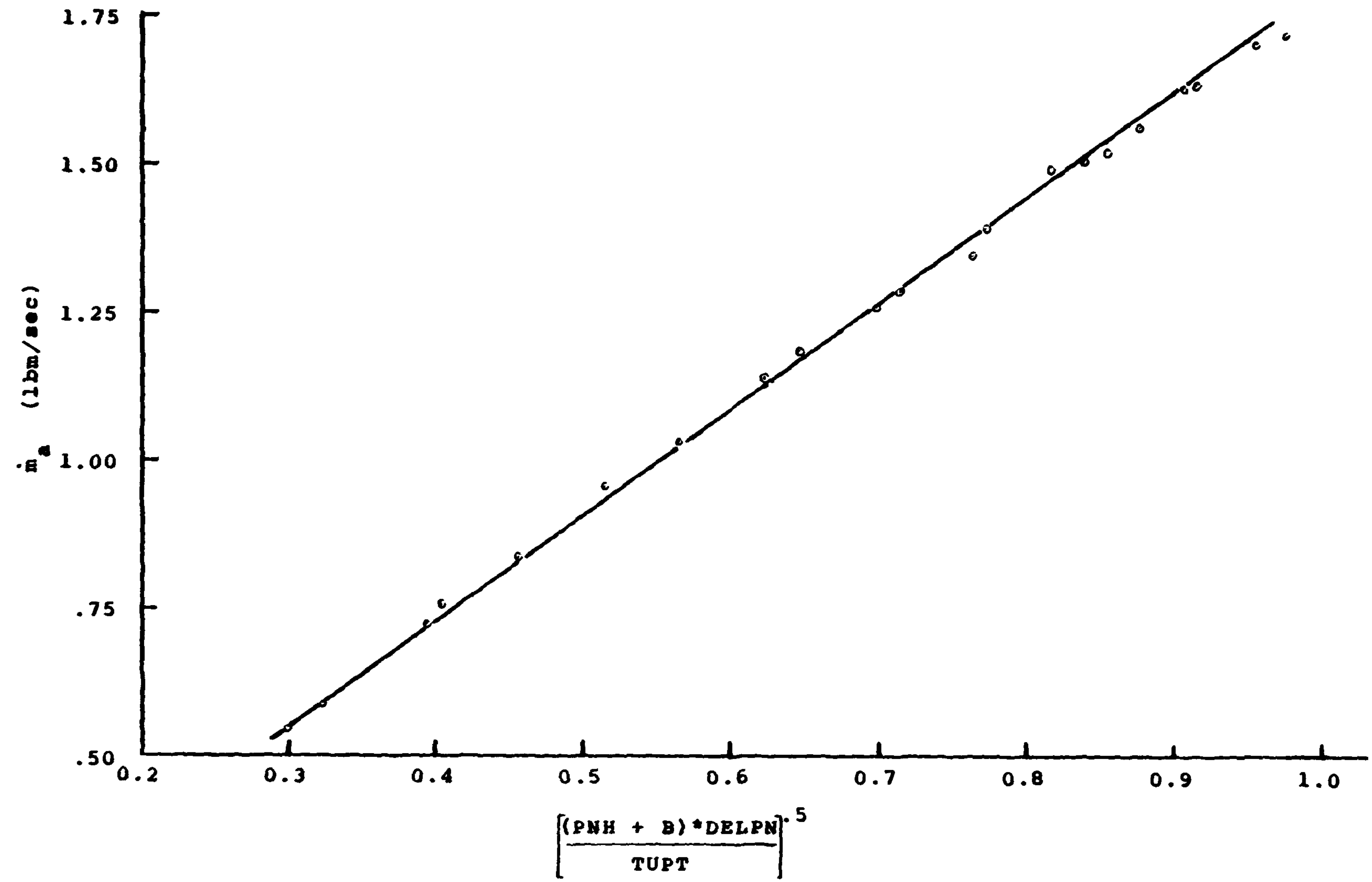


Figure 25. Entrance Nozzle Calibration Curve

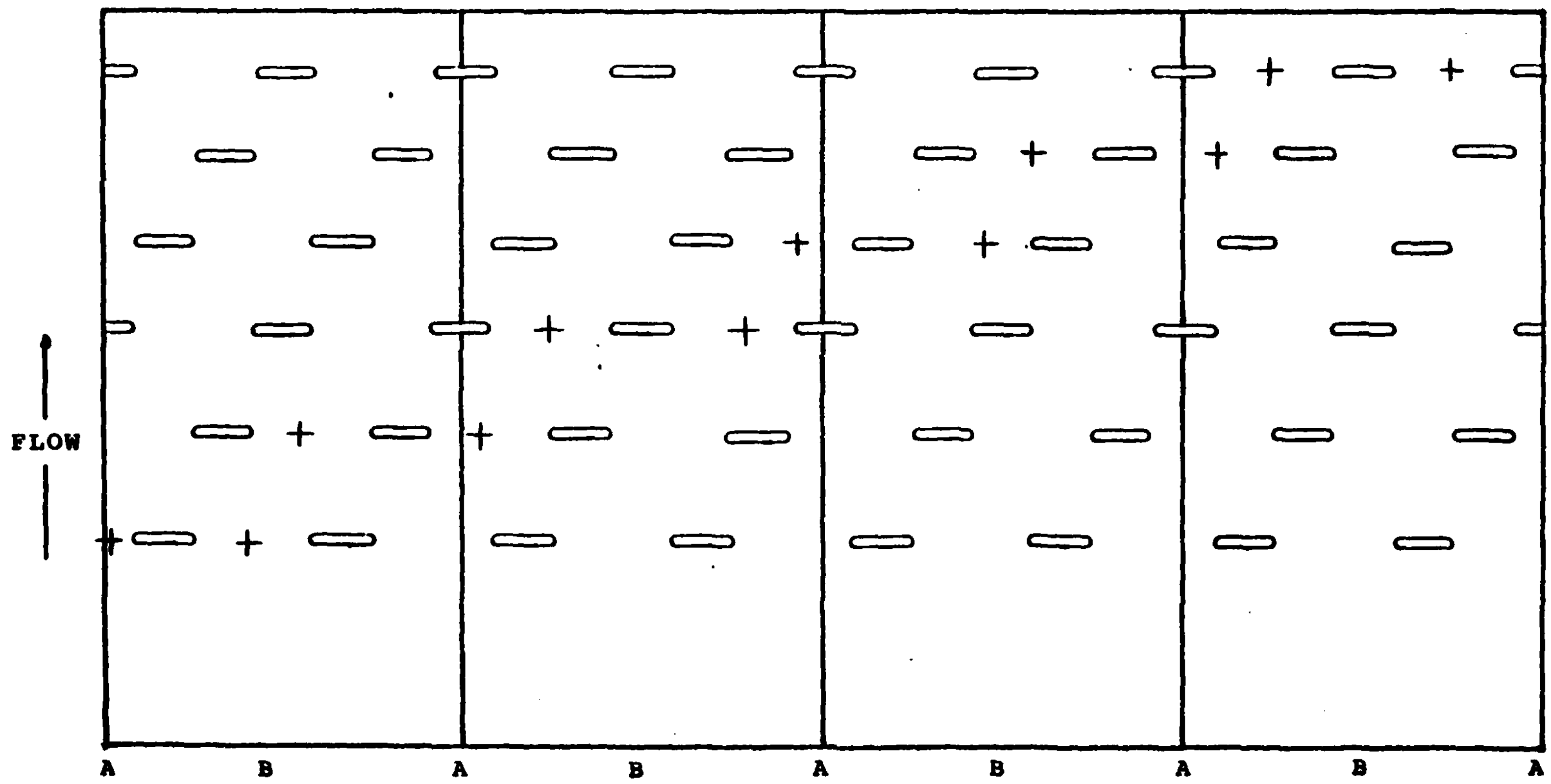


Figure 26. Developed View of Mixing Stack Thermocouple Locations

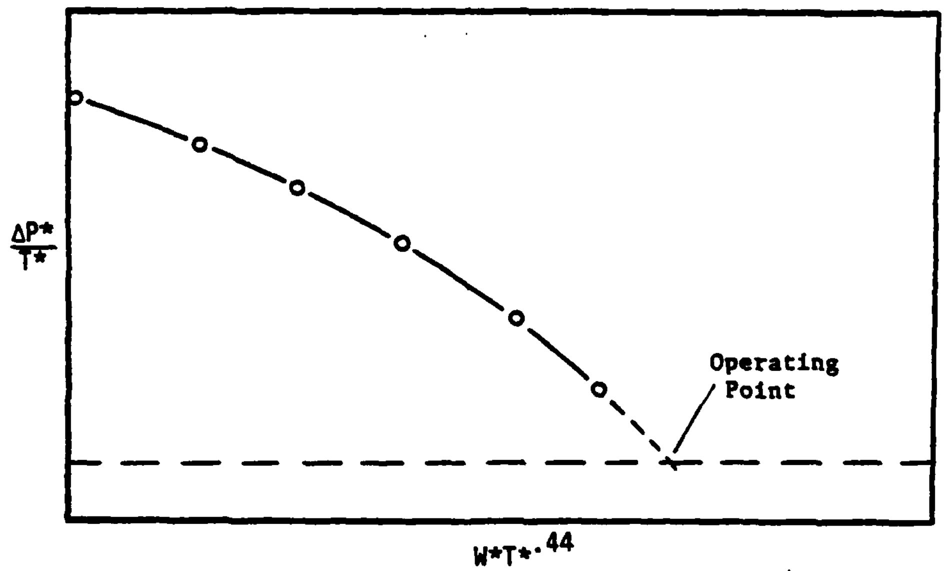


FIGURE 27. Illustrative Plot of the Experimental Data Correlation in Equation (14).

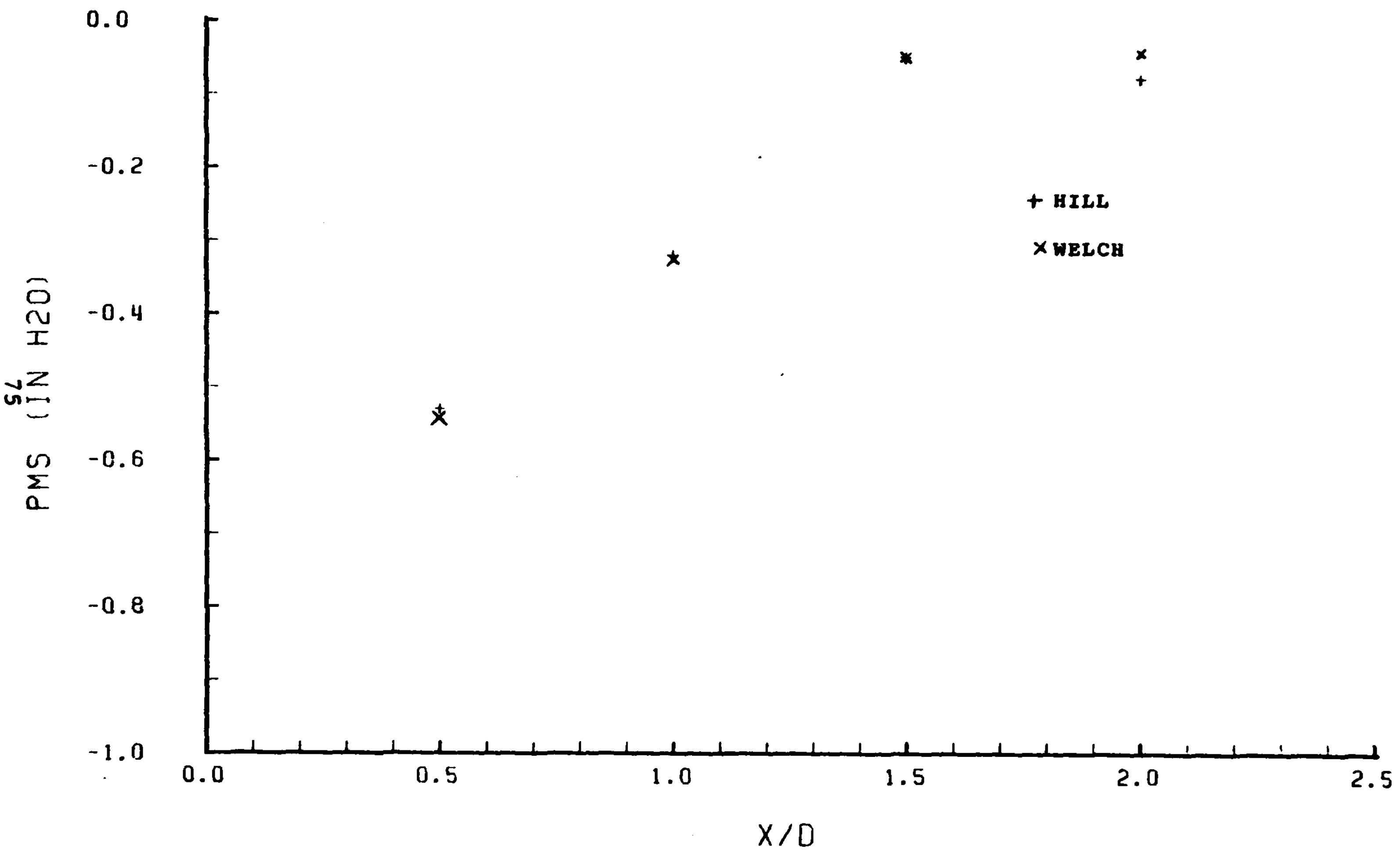


Figure 28. Performance Plots of Solid Wall Mixing Stack
TUPT = 850 F

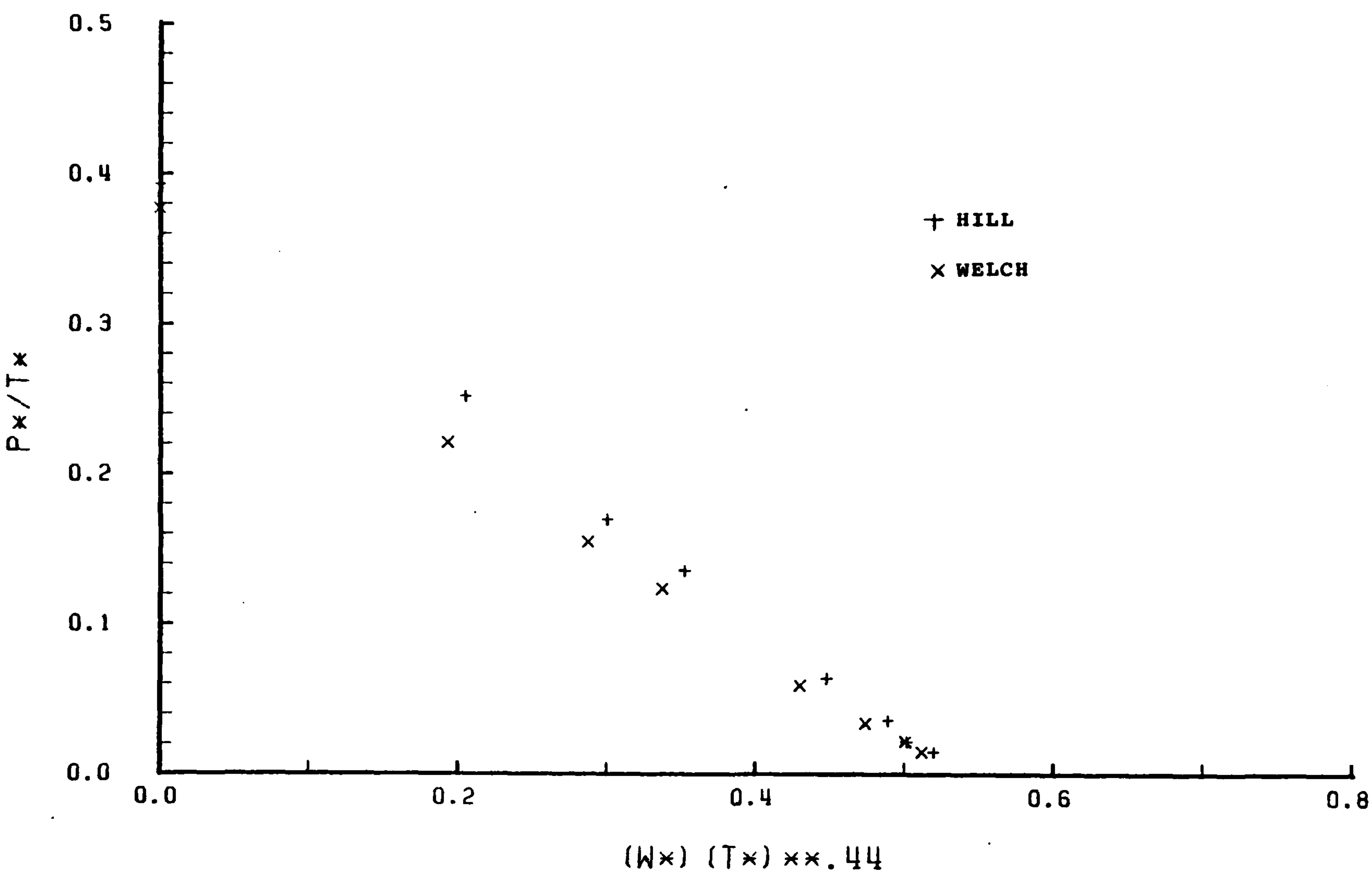


Figure 28. (Continued)

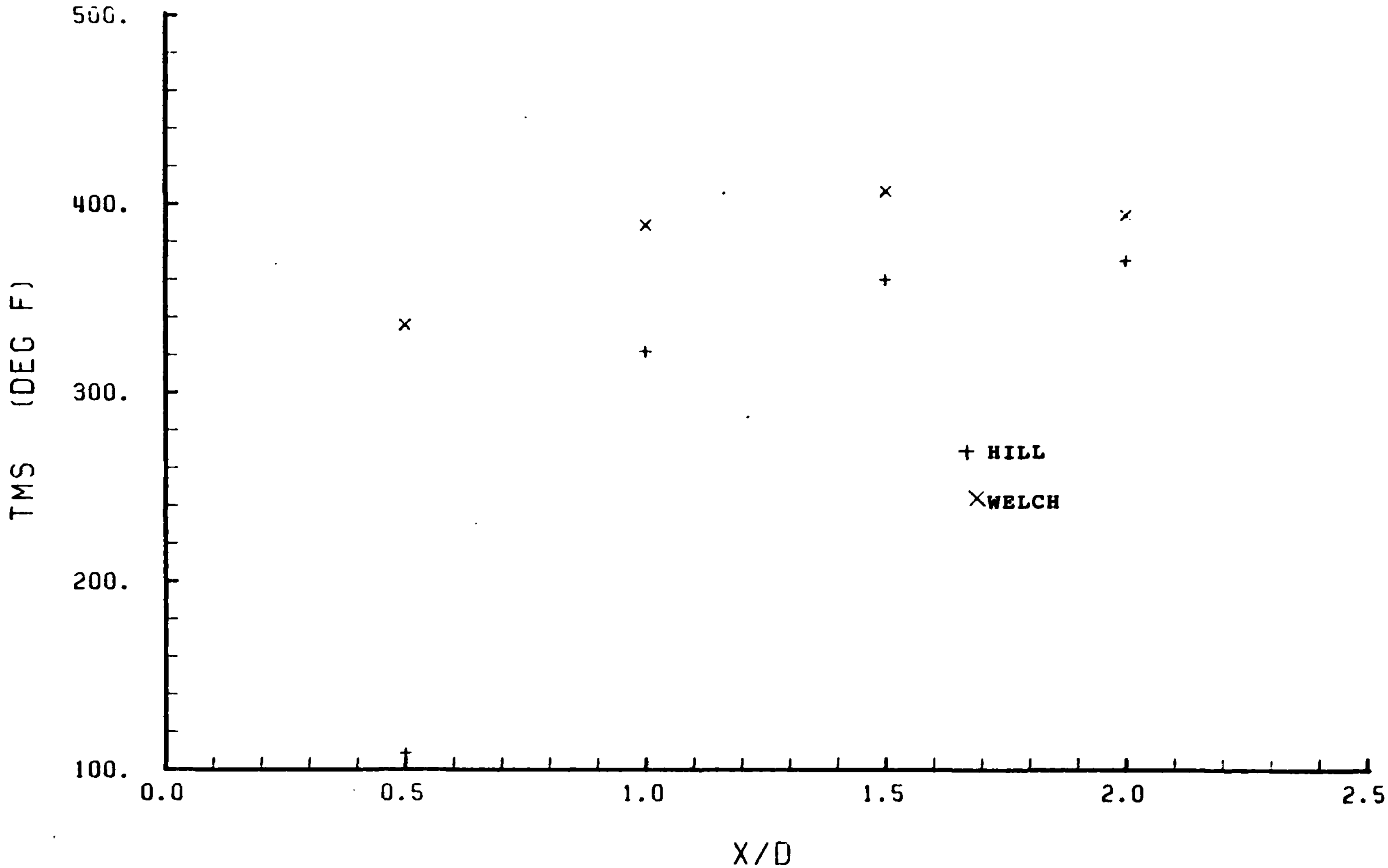
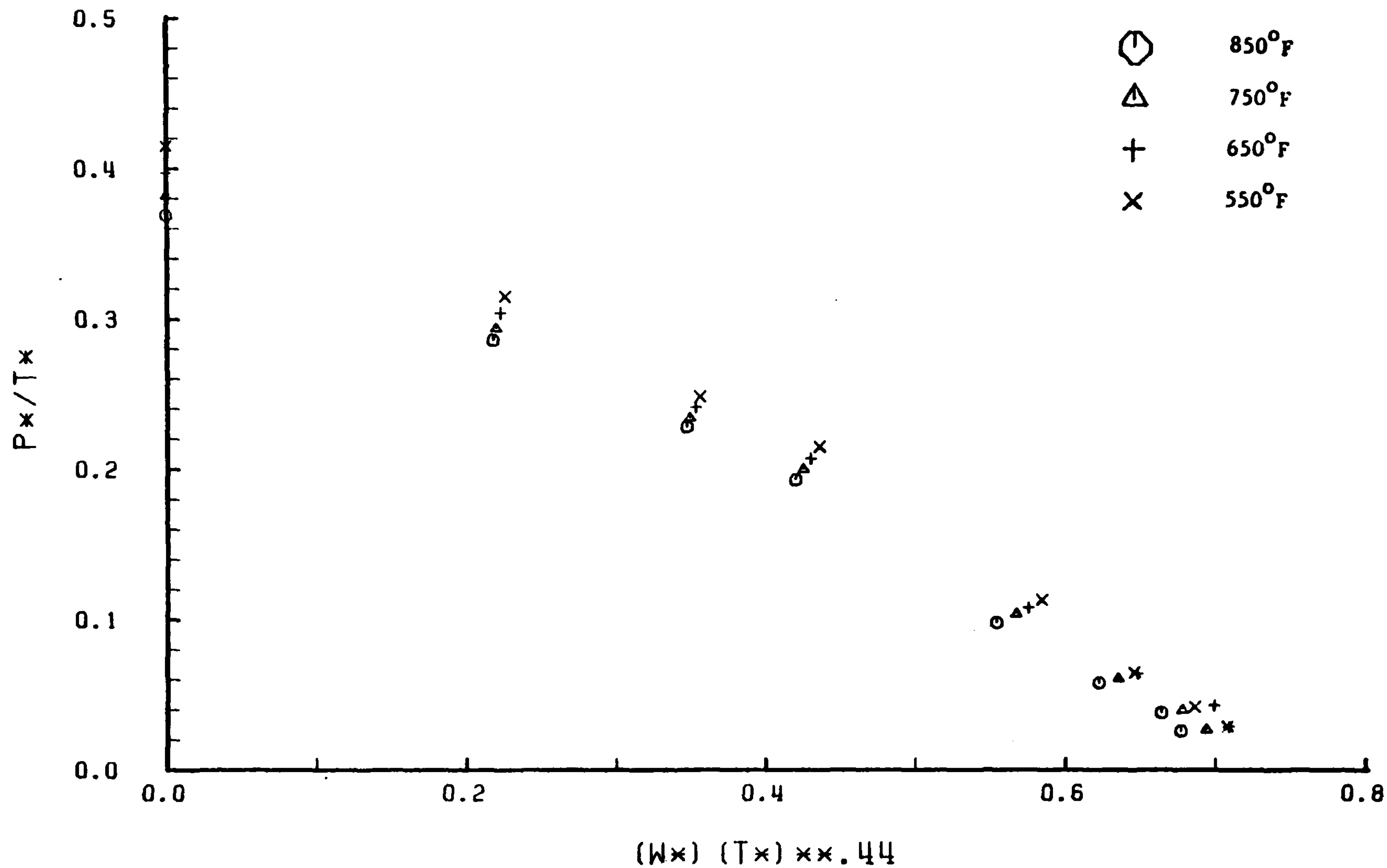
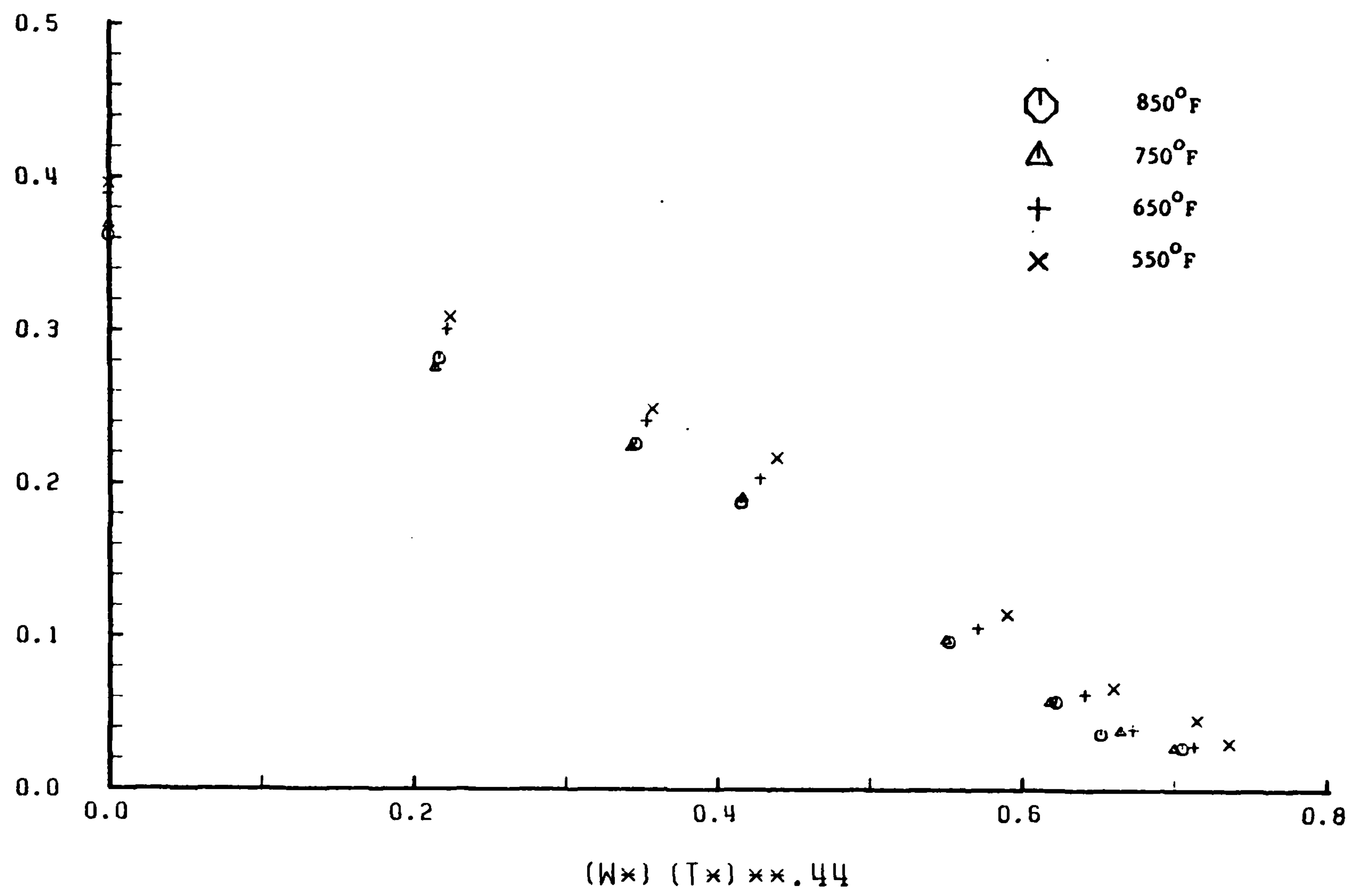


Figure 28. (Continued)



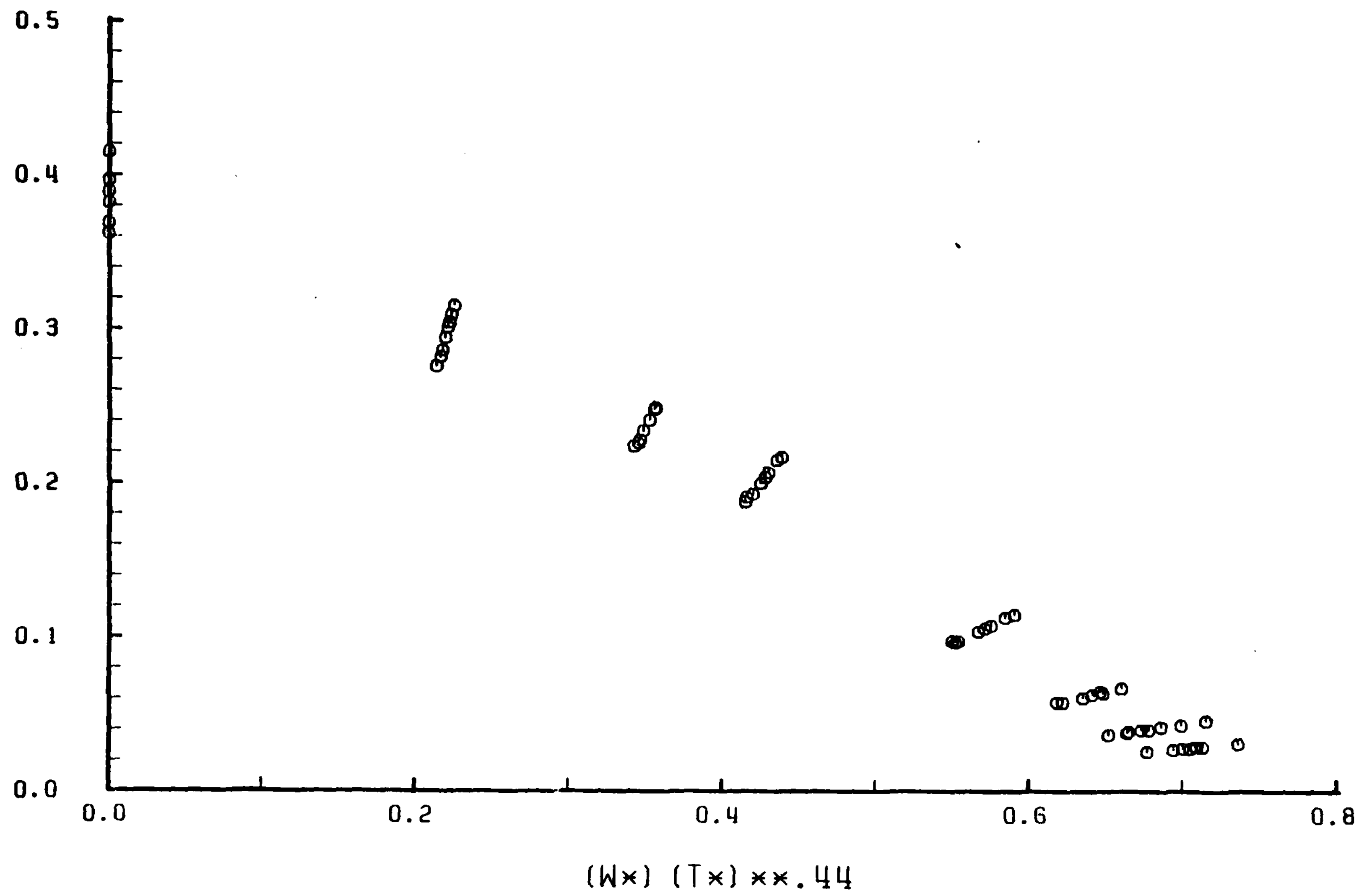
a) One Diffuser Ring, Run Number One

Figure 29. Performance Plots of Slotted and Shrouded Mixing Stack with One Diffuser Ring



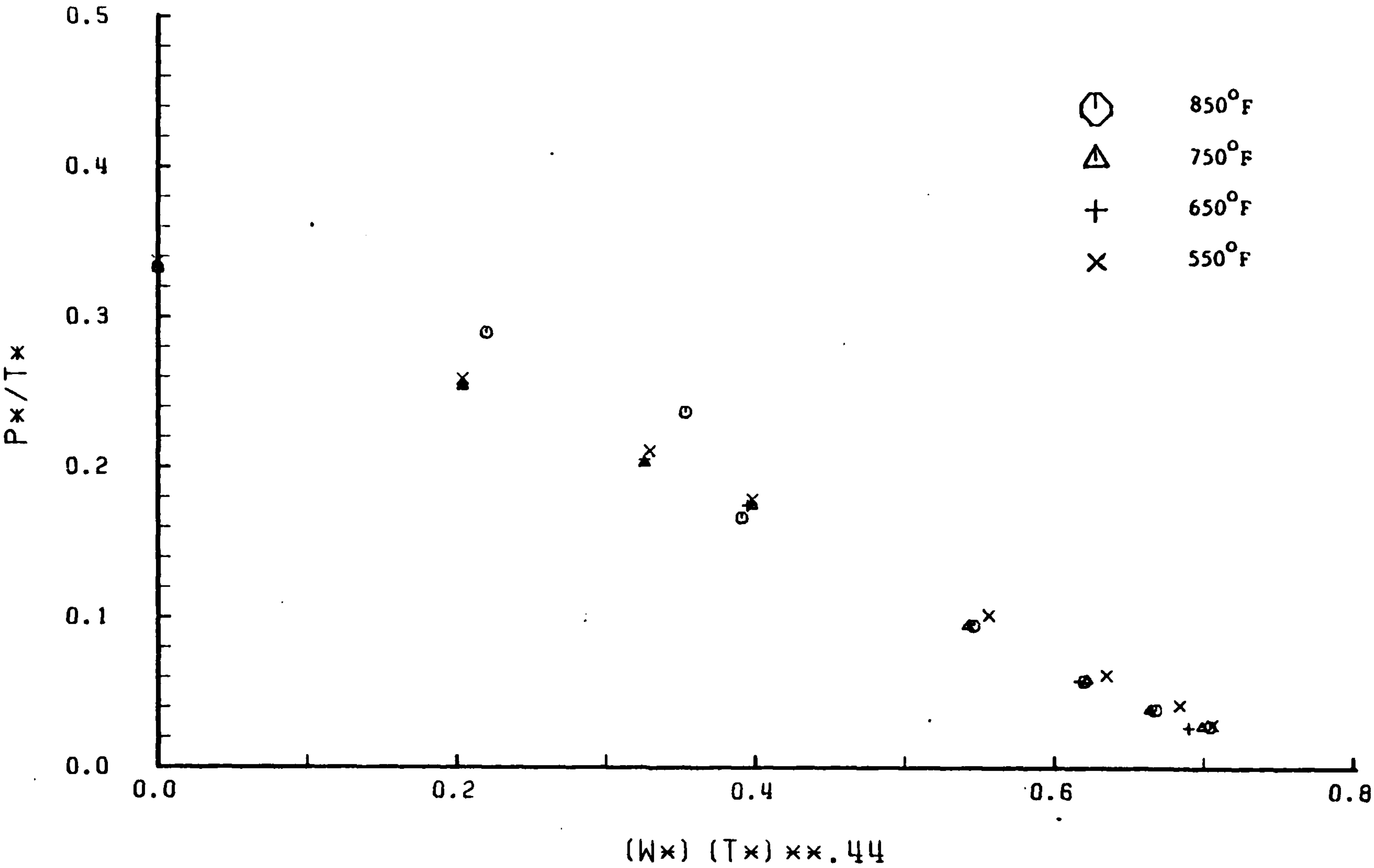
b) One Diffuser Ring, Run Number Two

Figure 29. (Continued)



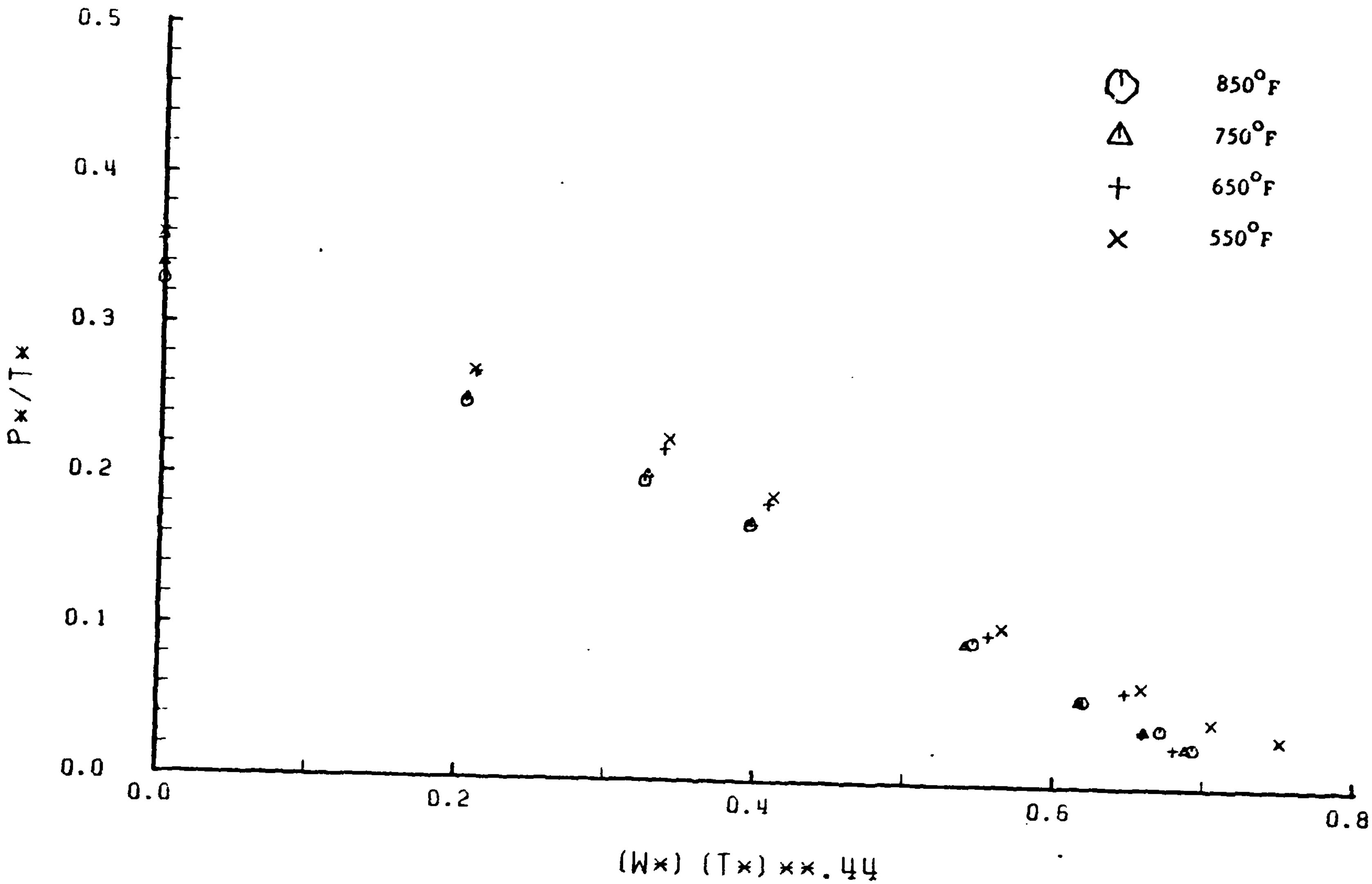
c) One Diffuser Ring, Composite Comparison Plots

Figure 29. (Continued)



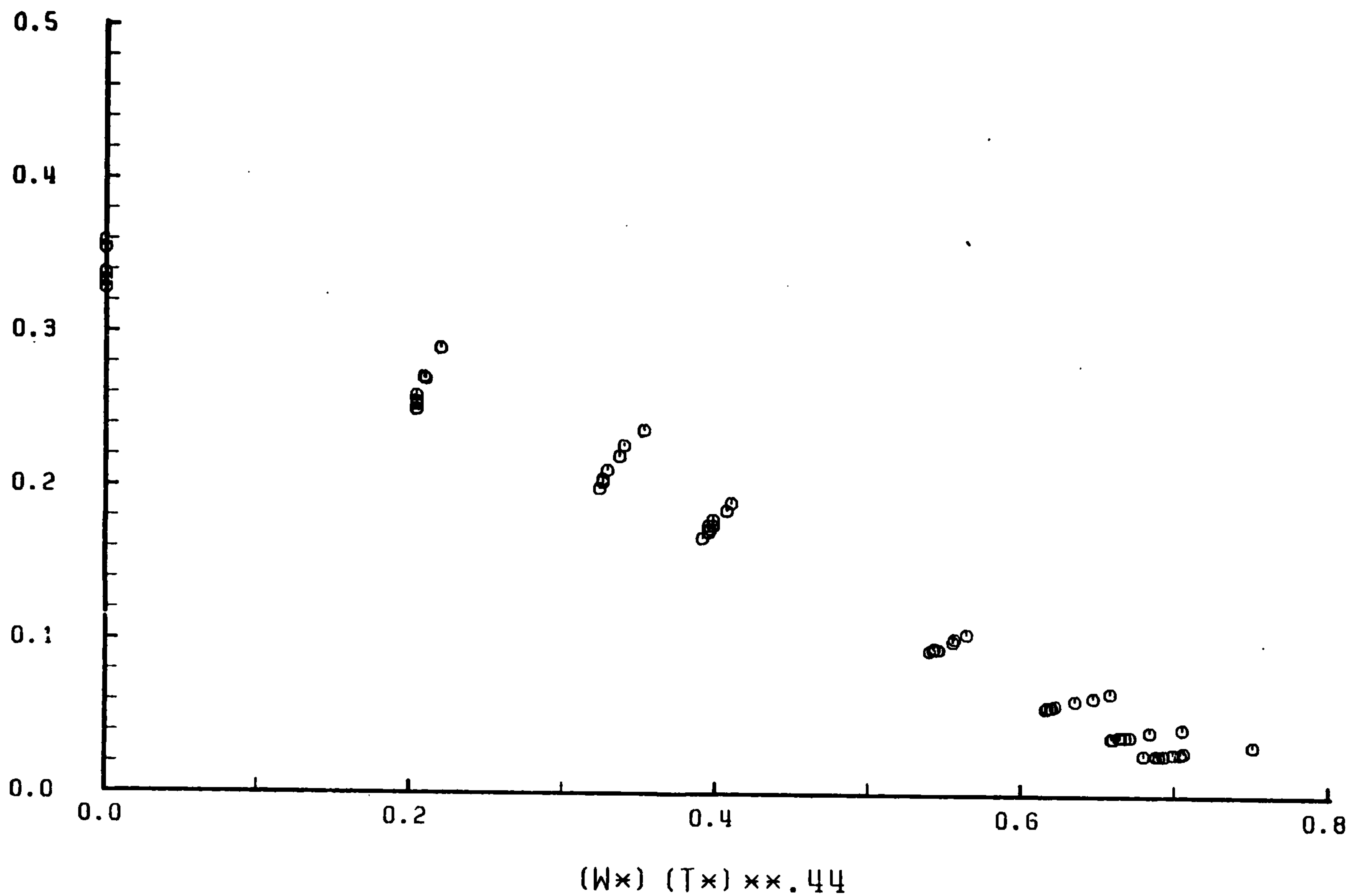
a) Two Diffuser Rings, Run Number One

Figure 30. Performance Plots of Slotted and Shrouded Mixing Stack with Two Diffuser Rings



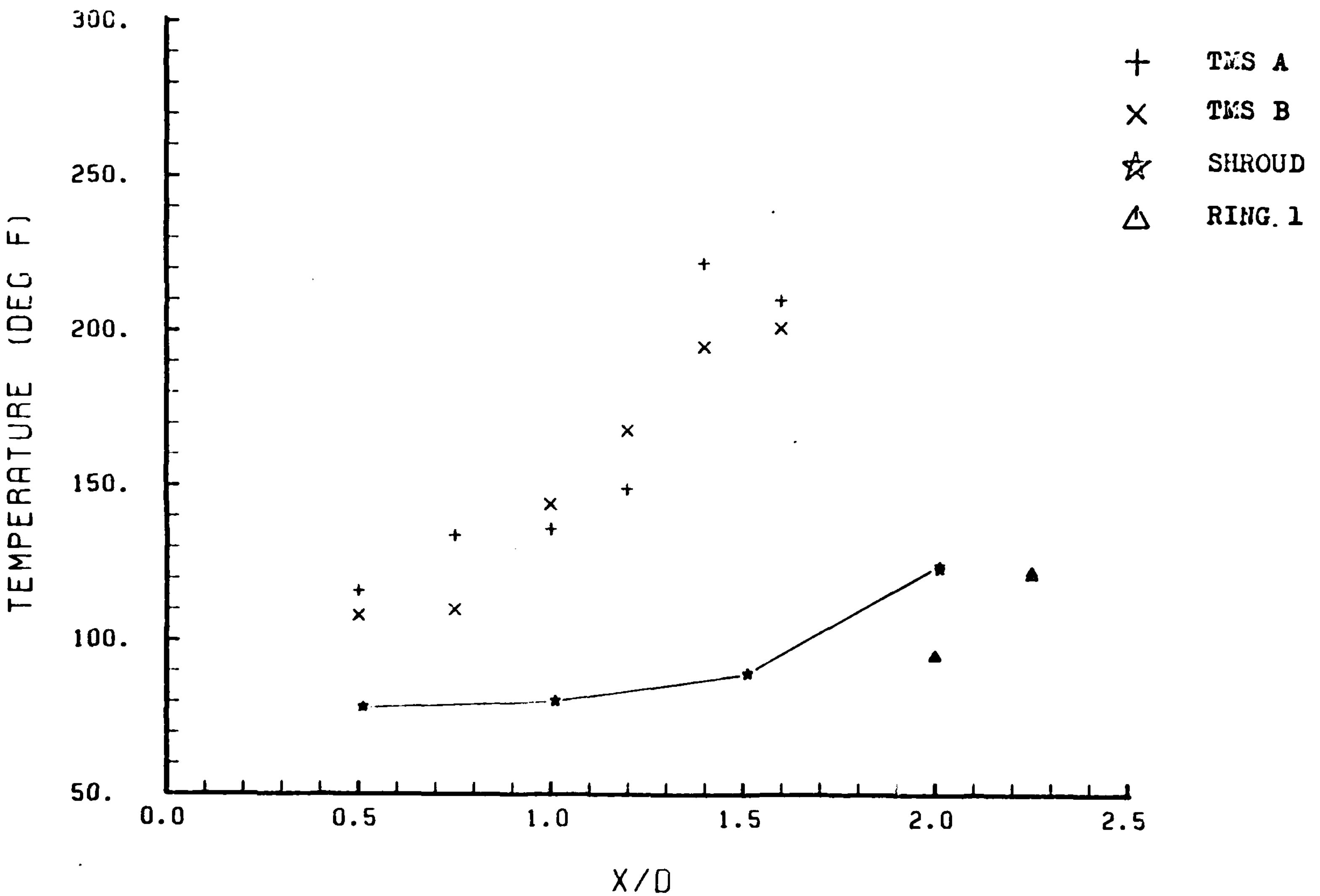
b) Two Diffuser Rings, Run Number Two

Figure 30. (Continued)



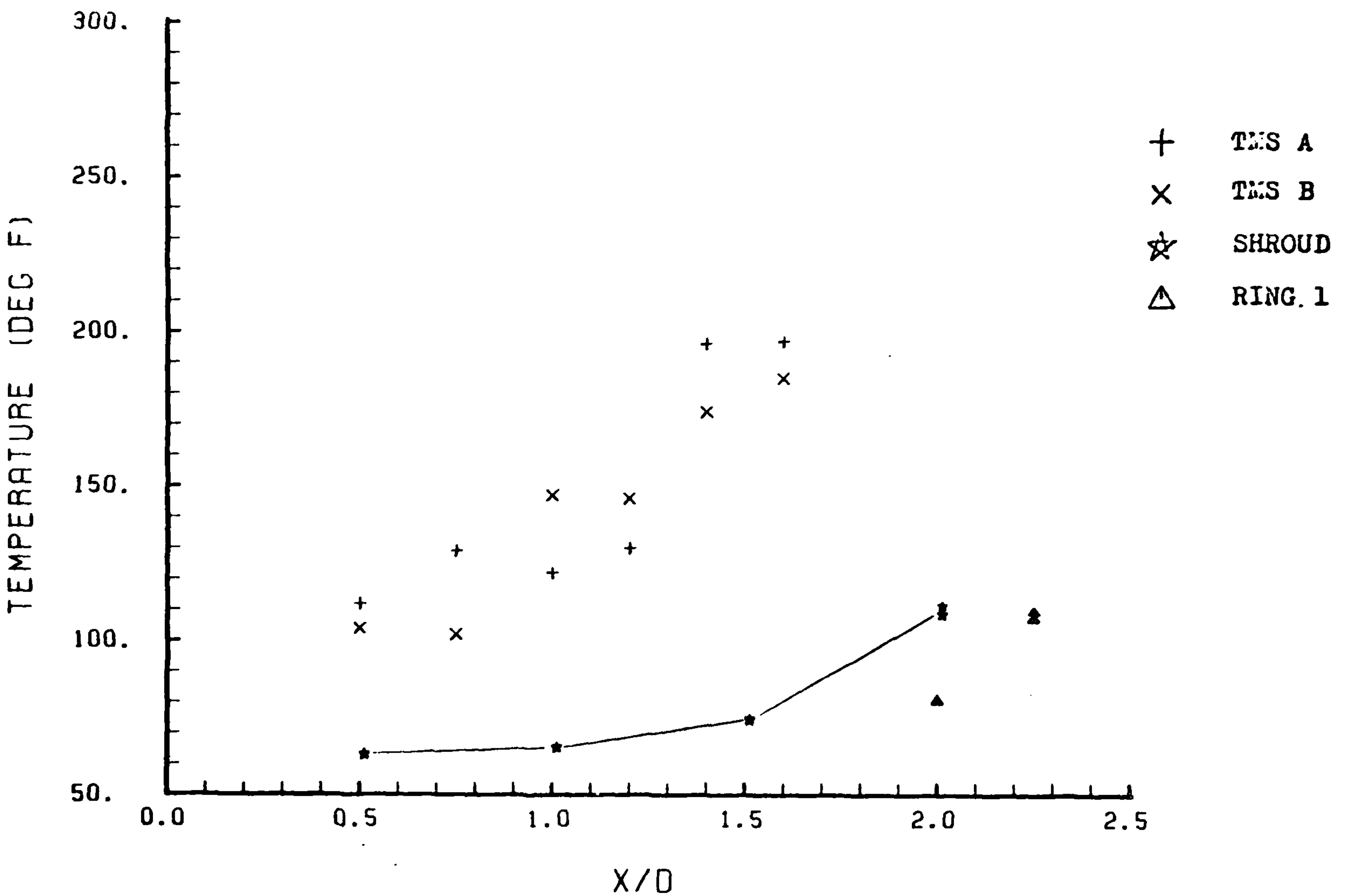
c) Two Diffuser Rings, Composite Comparison Plots

Figure 30. (Continued)



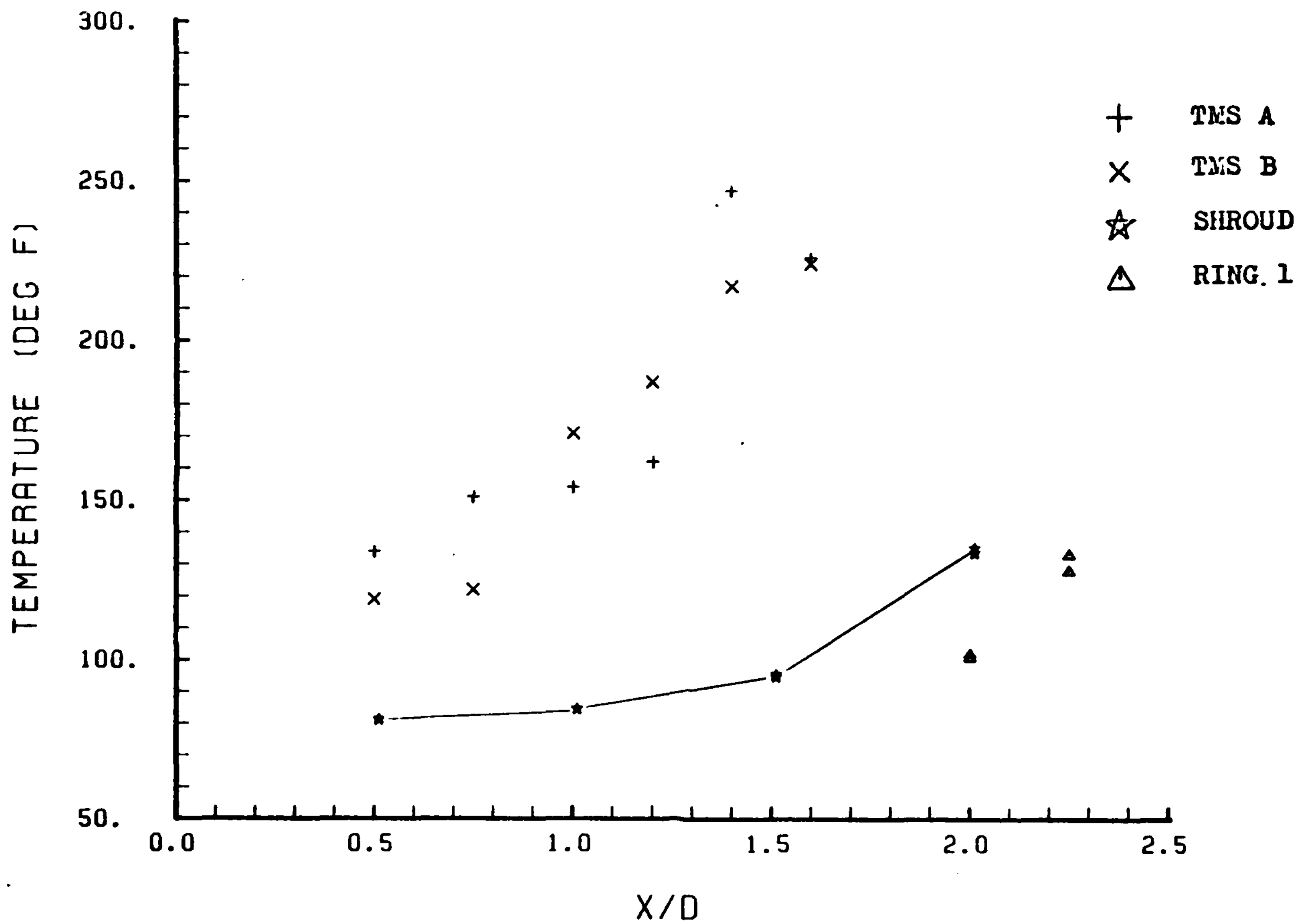
a)One Diffuser Ring, TUPT = 550 F, Run No. One

Figure 31. Temperature Plots for Slotted and Shrouded Mixing Stack with One Diffuser Ring



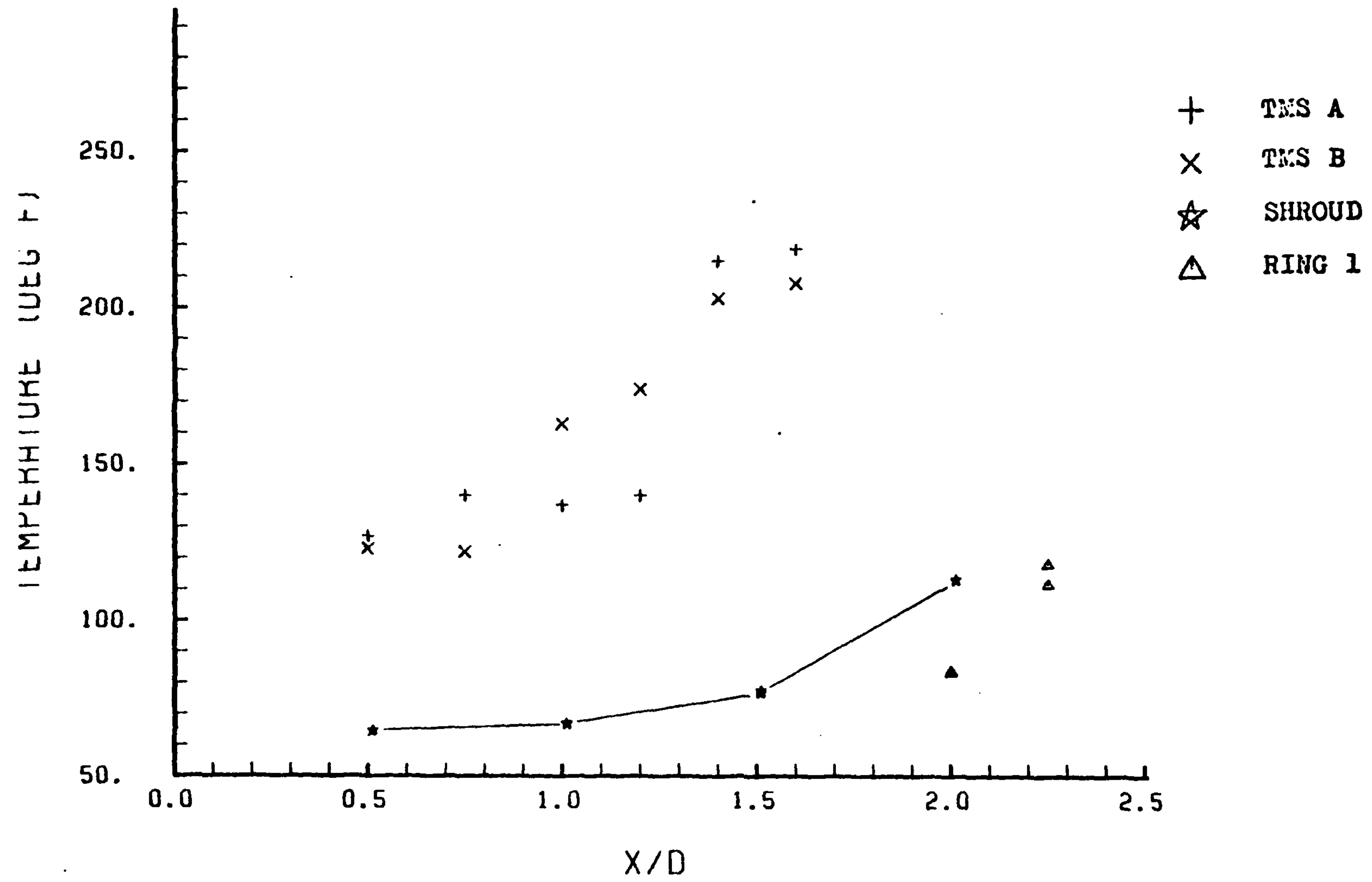
b)One Diffuser Ring, TUPT = 550 F, Run No. Two

Figure 31. (Continued)



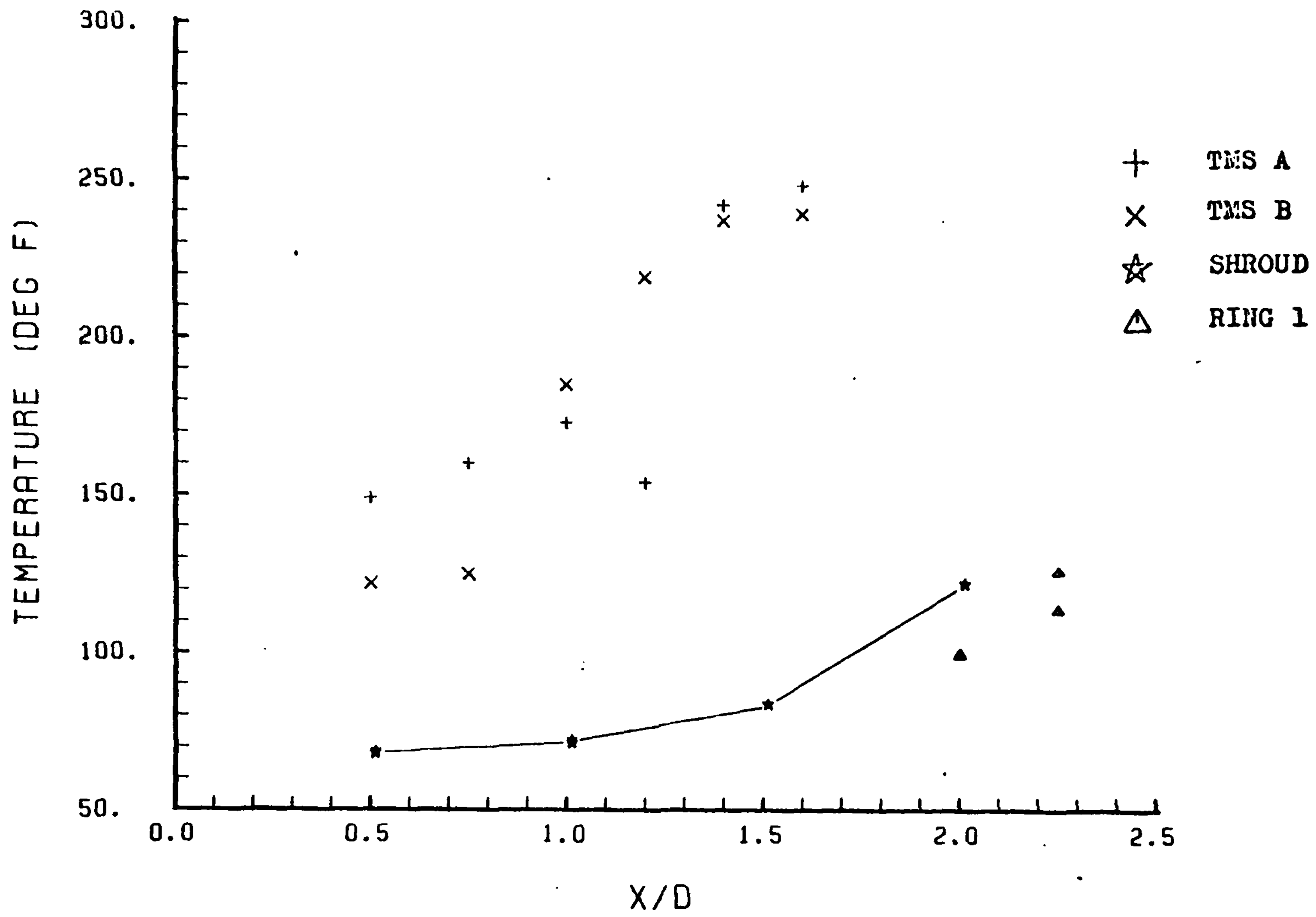
c) One Diffuser Ring, TUPT = 650 F, Run No. One

Figure 31. (Continued)



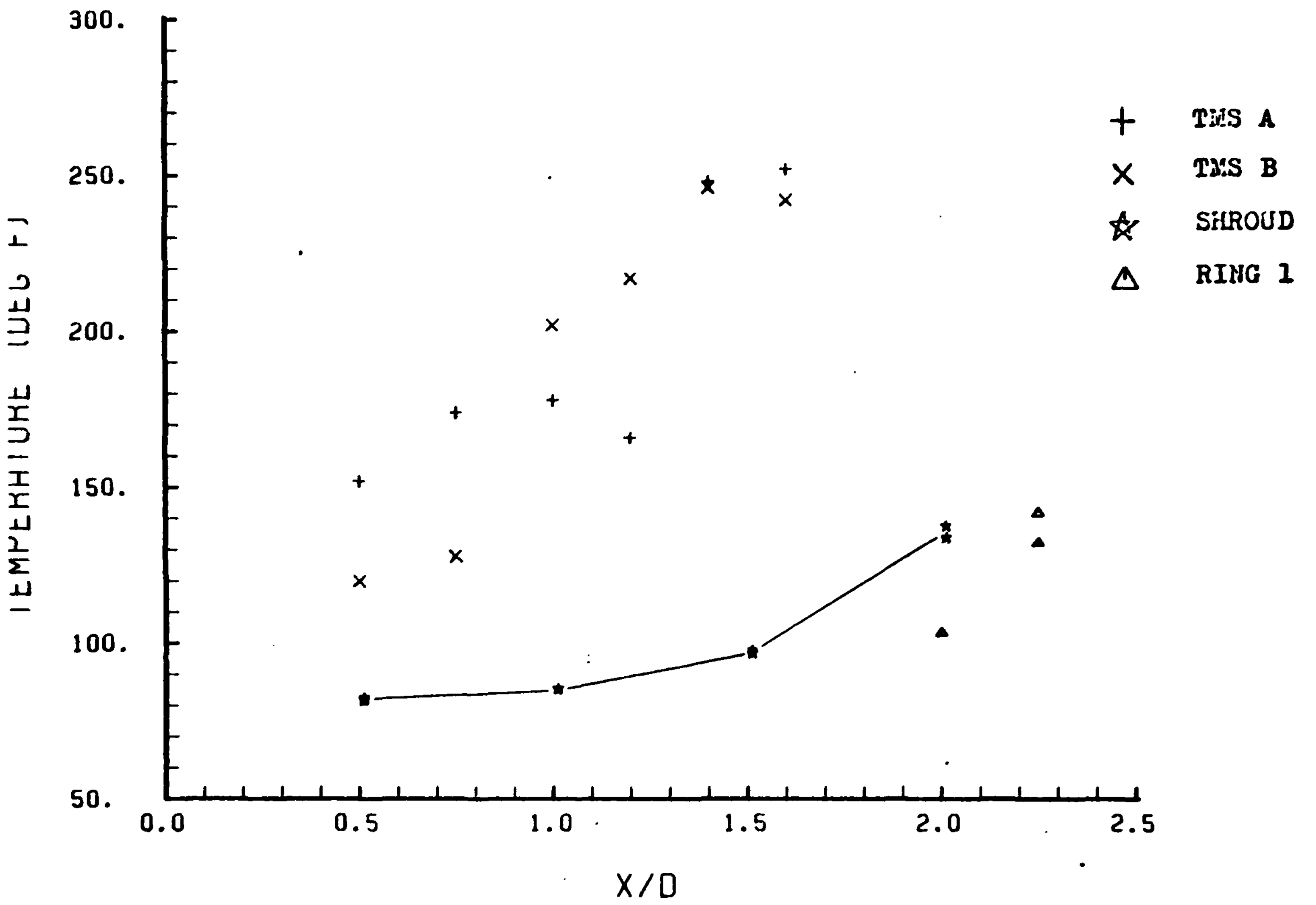
d) One Diffuser Ring, TUPT = 650 F, Run No. Two

Figure 31. (Continued)



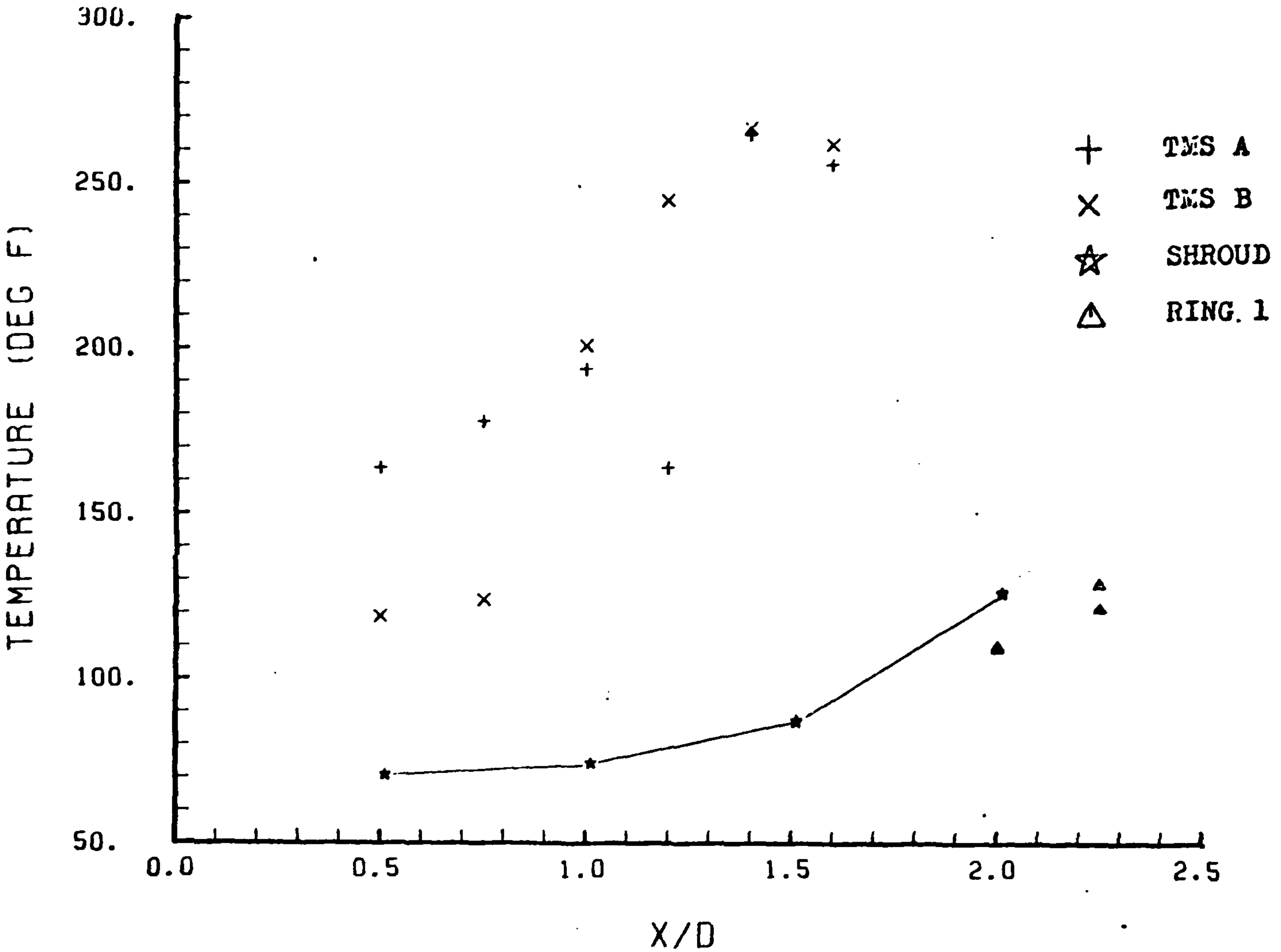
e) One Diffuser Ring, TUPT = 750 F, Run No. One

Figure 31. (Continued)



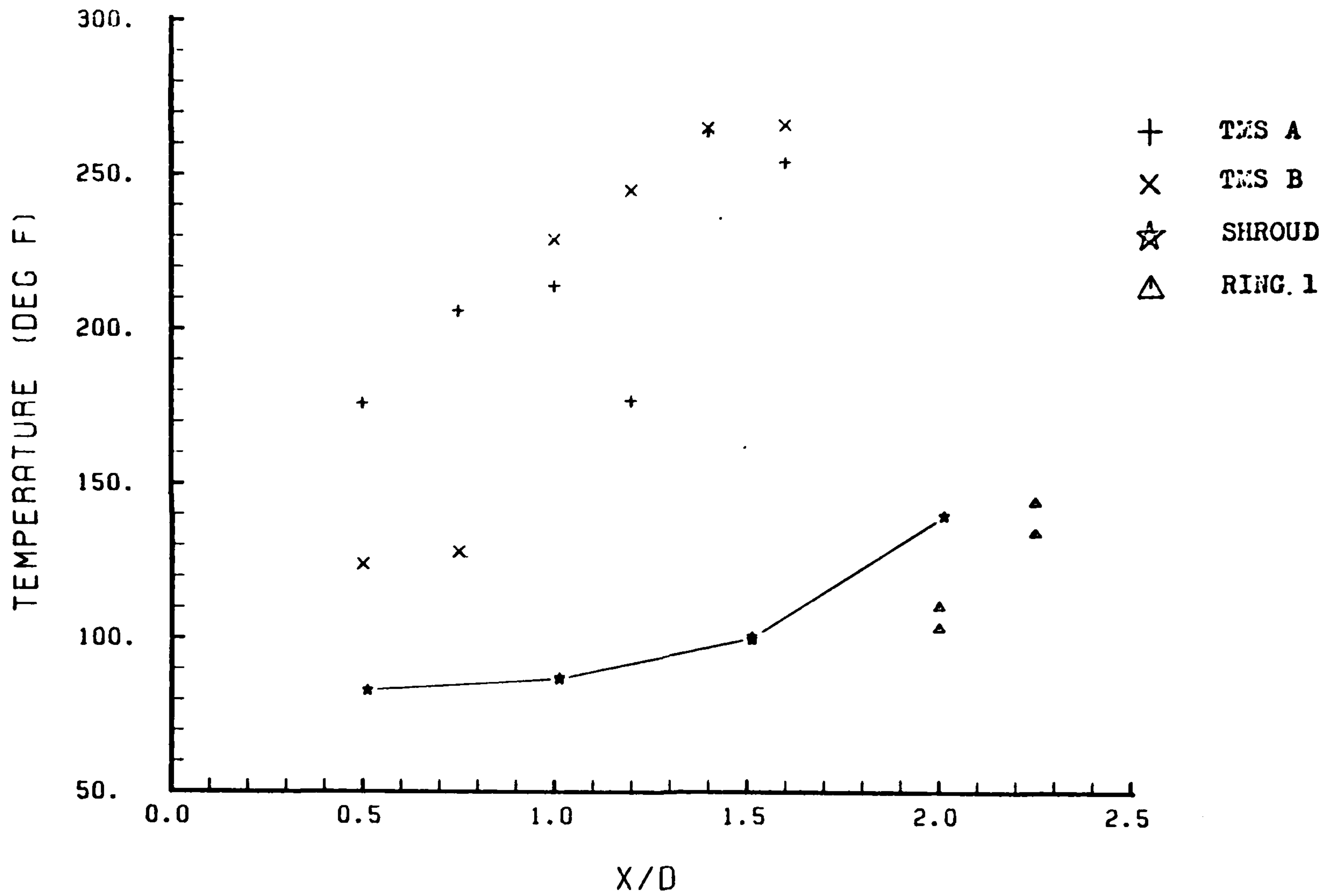
f) One Diffuser Ring, TUPT = 750 F, Run No. Two

Figure 31. (Continued)



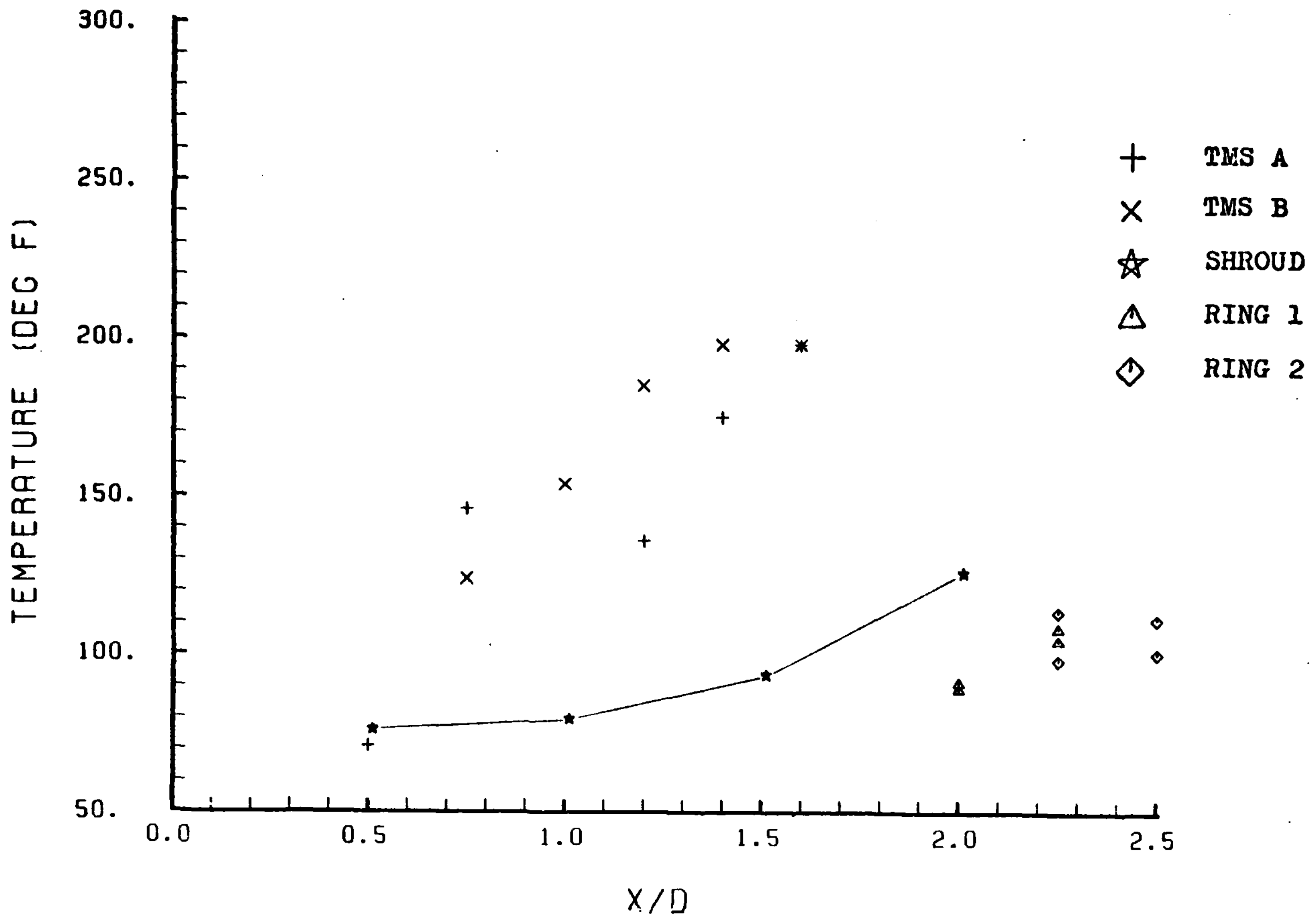
g) One Diffuser Ring, TUPT = 850 F, Run No. One

Figure 31. (Continued)



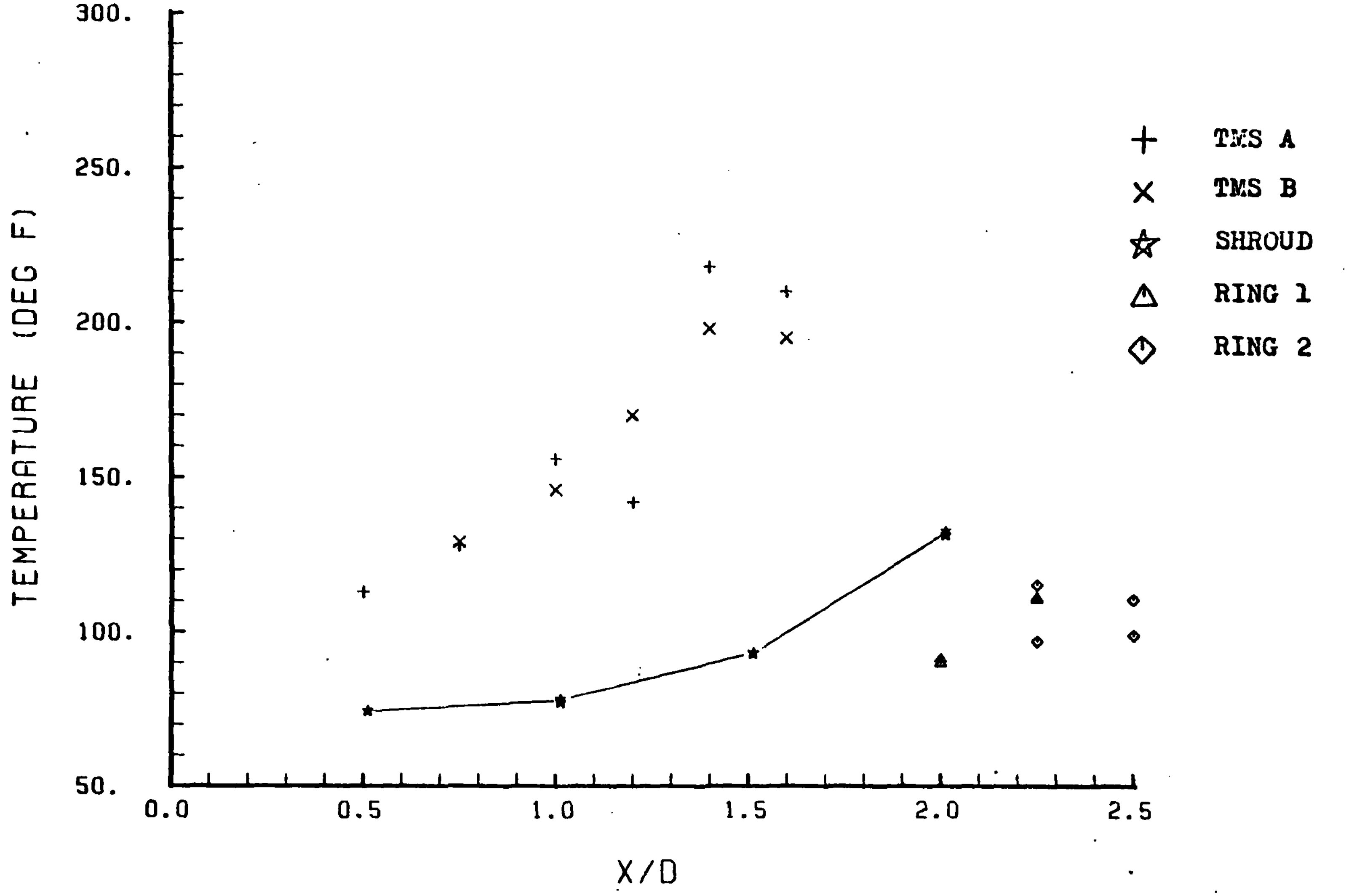
h) One Diffuser Ring, TUPT = 850 F, Run No. Two

Figure 31. (Continued)



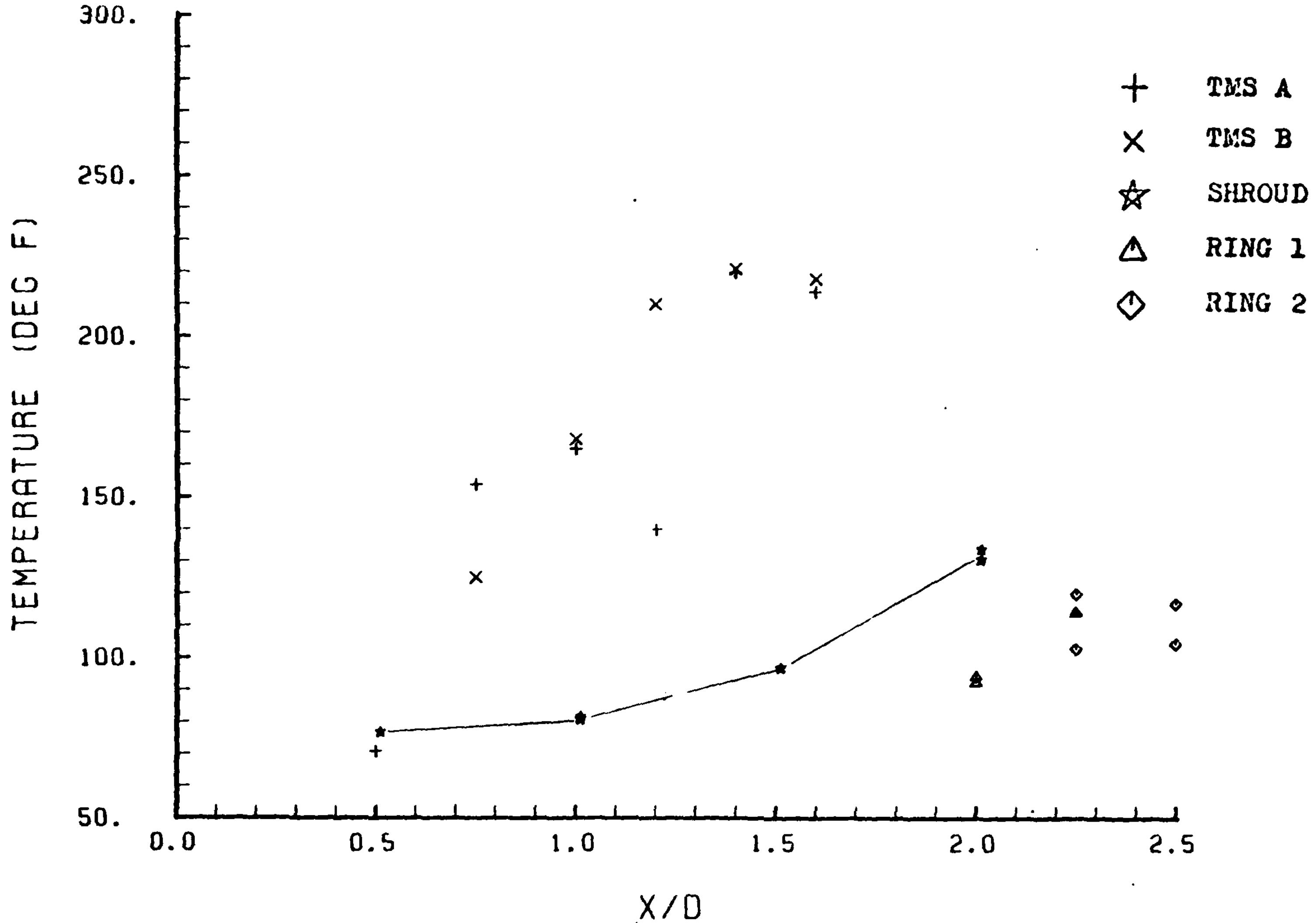
a) Two Diffuser Rings, TUPT = 550 F, Run No. One

Figure 32. Temperature Plots for Slotted and Shrouded Mixing Stack with Two Diffuser Rings



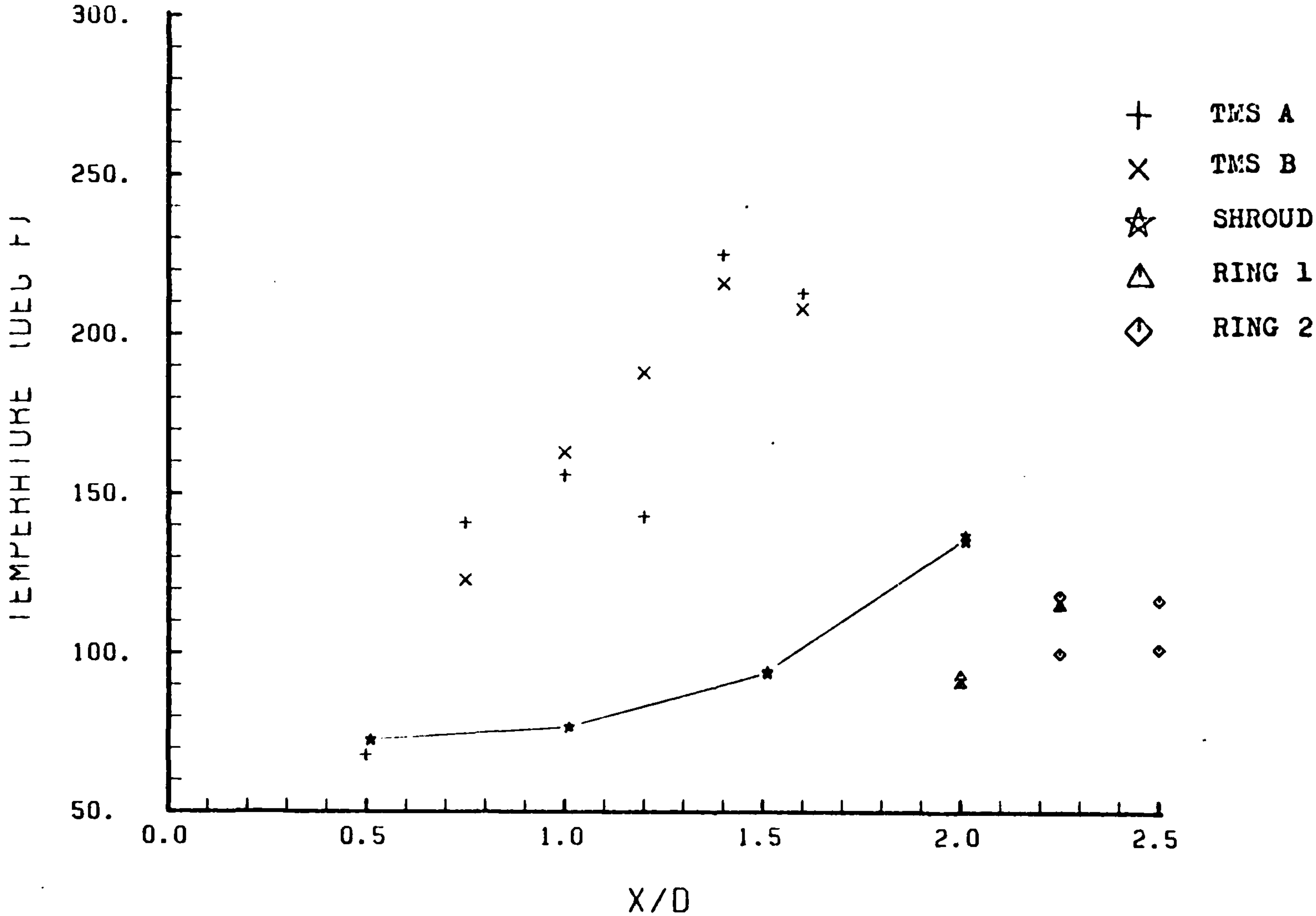
b) Two Diffuser Rings, TUPT = 550 F, Run No. Two

Figure 32. (Continued)



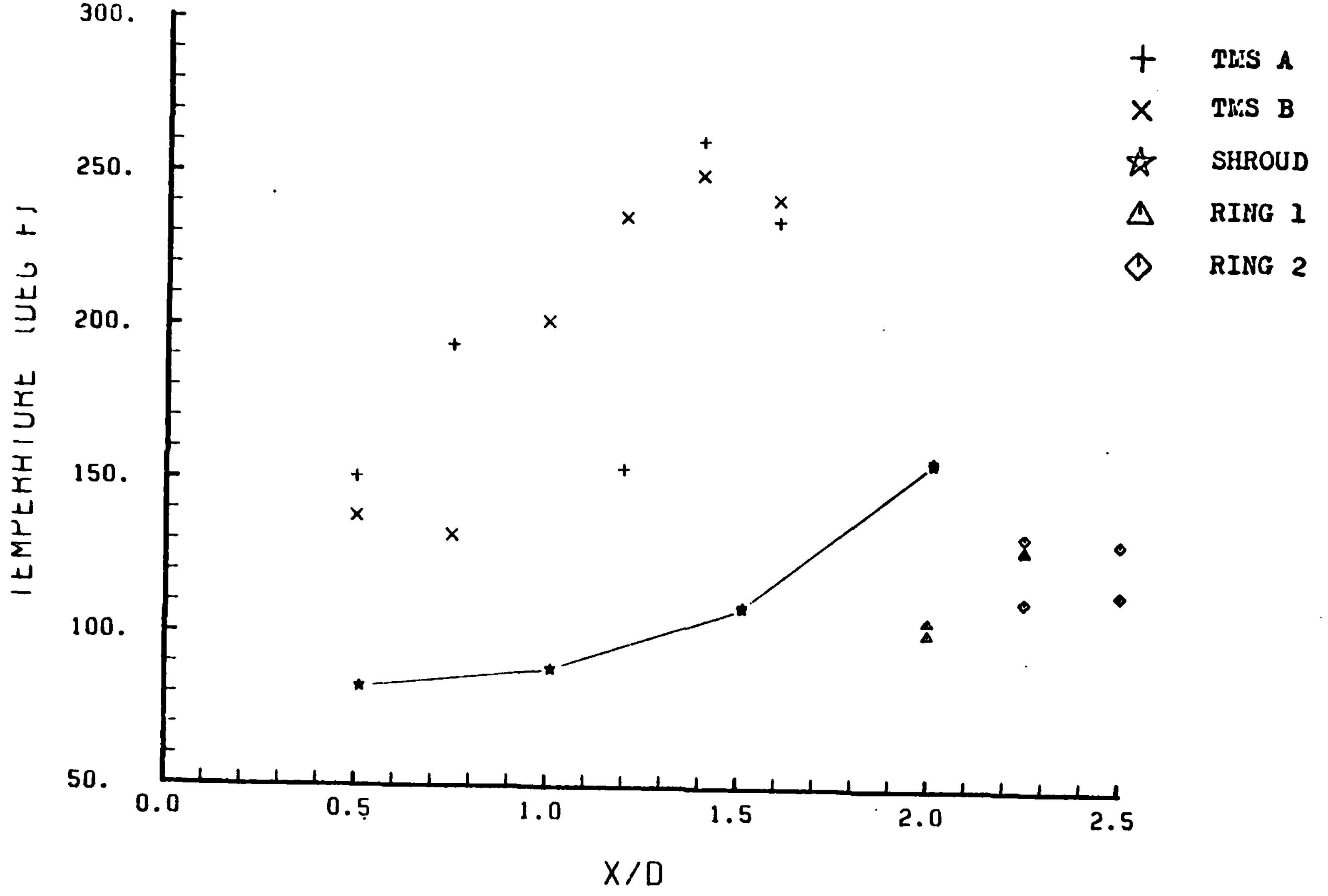
c) Two Diffuser Rings, TUPT = 650 F, Run No. One

Figure 32. (Continued)



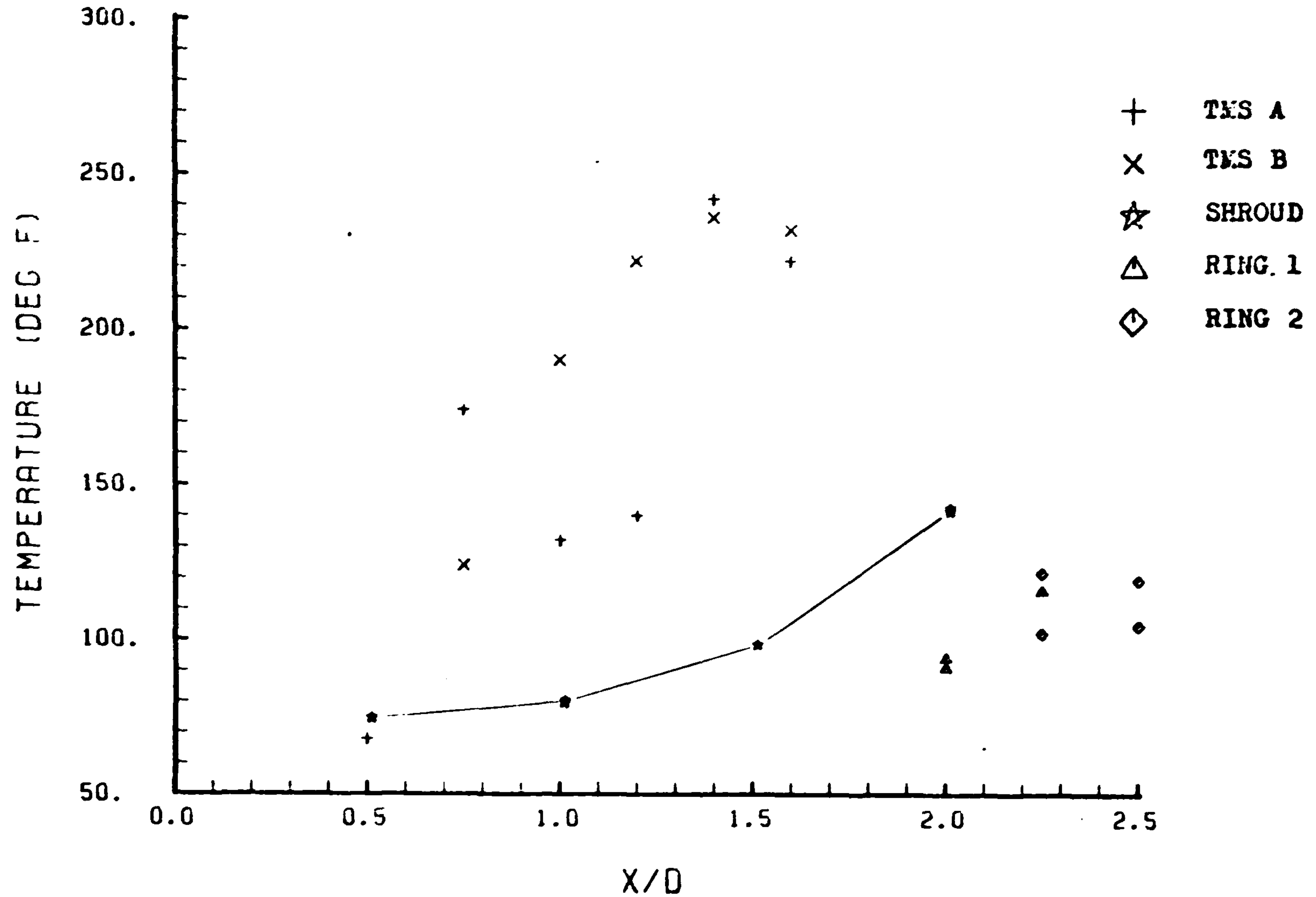
d) Two Diffuser Rings, TUPT = 650 F, Run No. Two

Figure 32. (Continued)



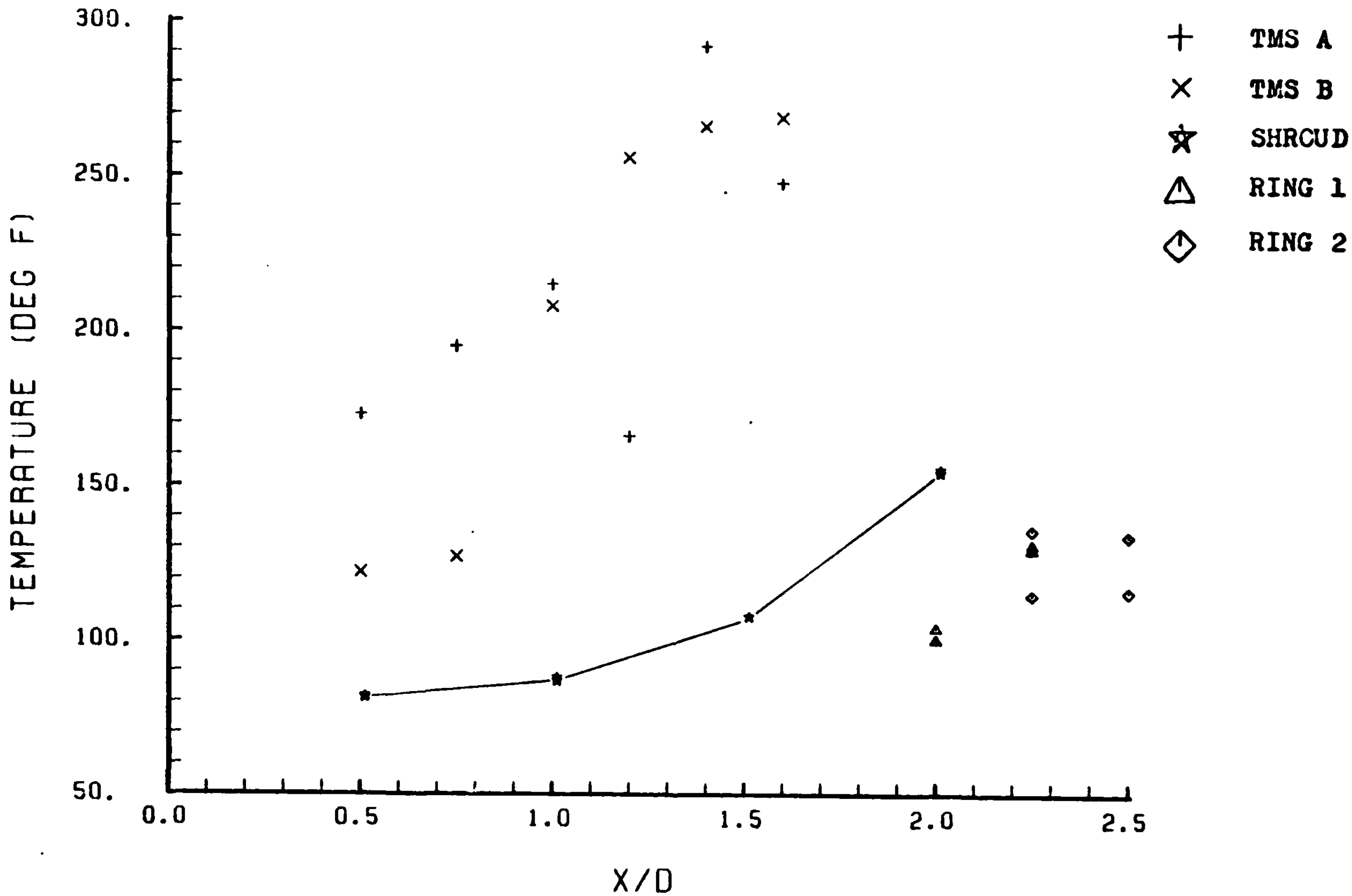
e) Two Diffuser Rings, TUPT = 750 F, Run No. One

Figure 32. (Continued)



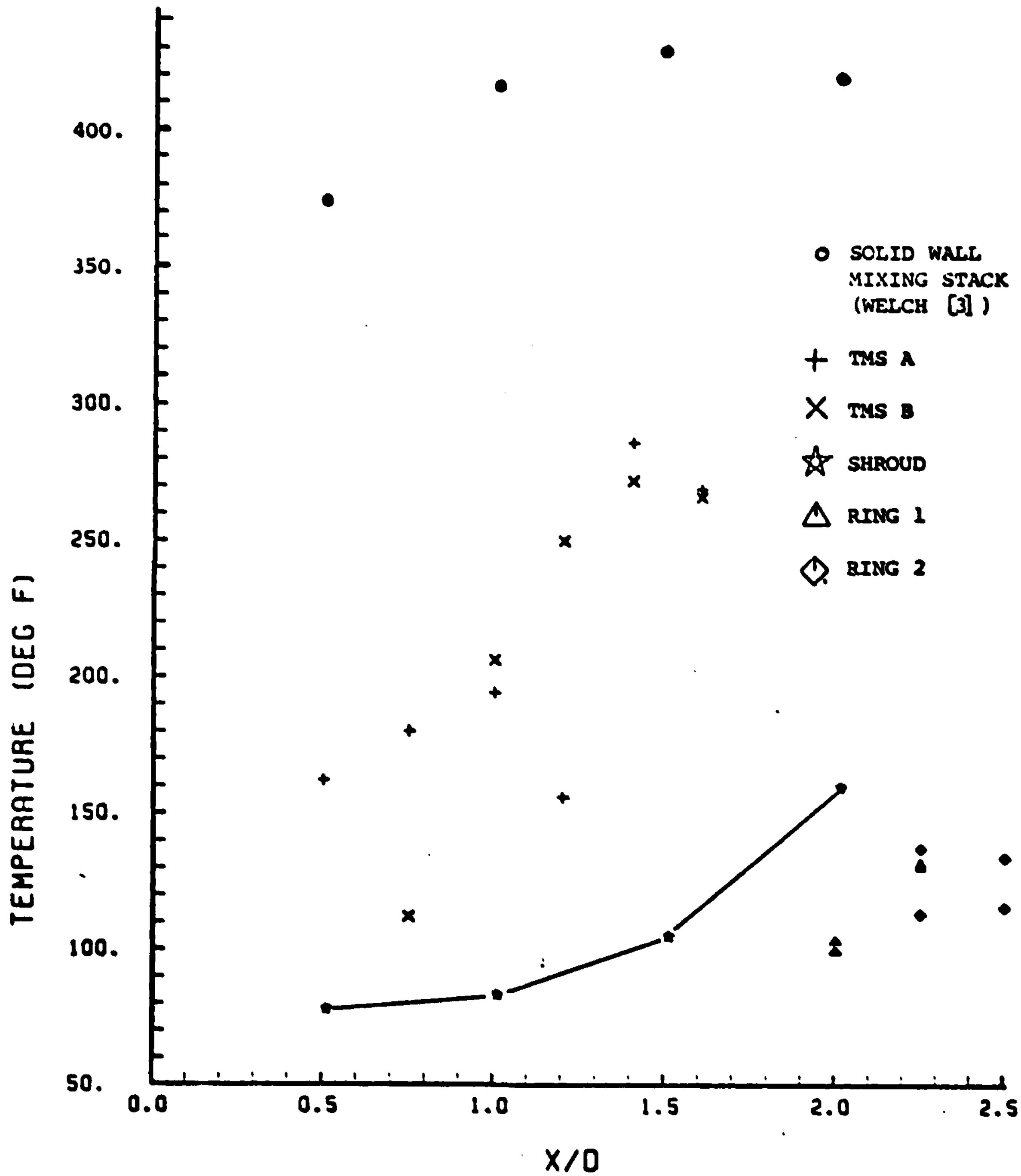
f) Two Diffuser Rings, TUPT = 750 F, Run No. Two

Figure 32. (Continued)



g) Two Diffuser Rings, TUPT = 850 F, Run No. One

Figure 32. (Continued)



h) Two Diffuser Rings, TUPT = 850 F, Run No. Two

Figure 32. (Continued)

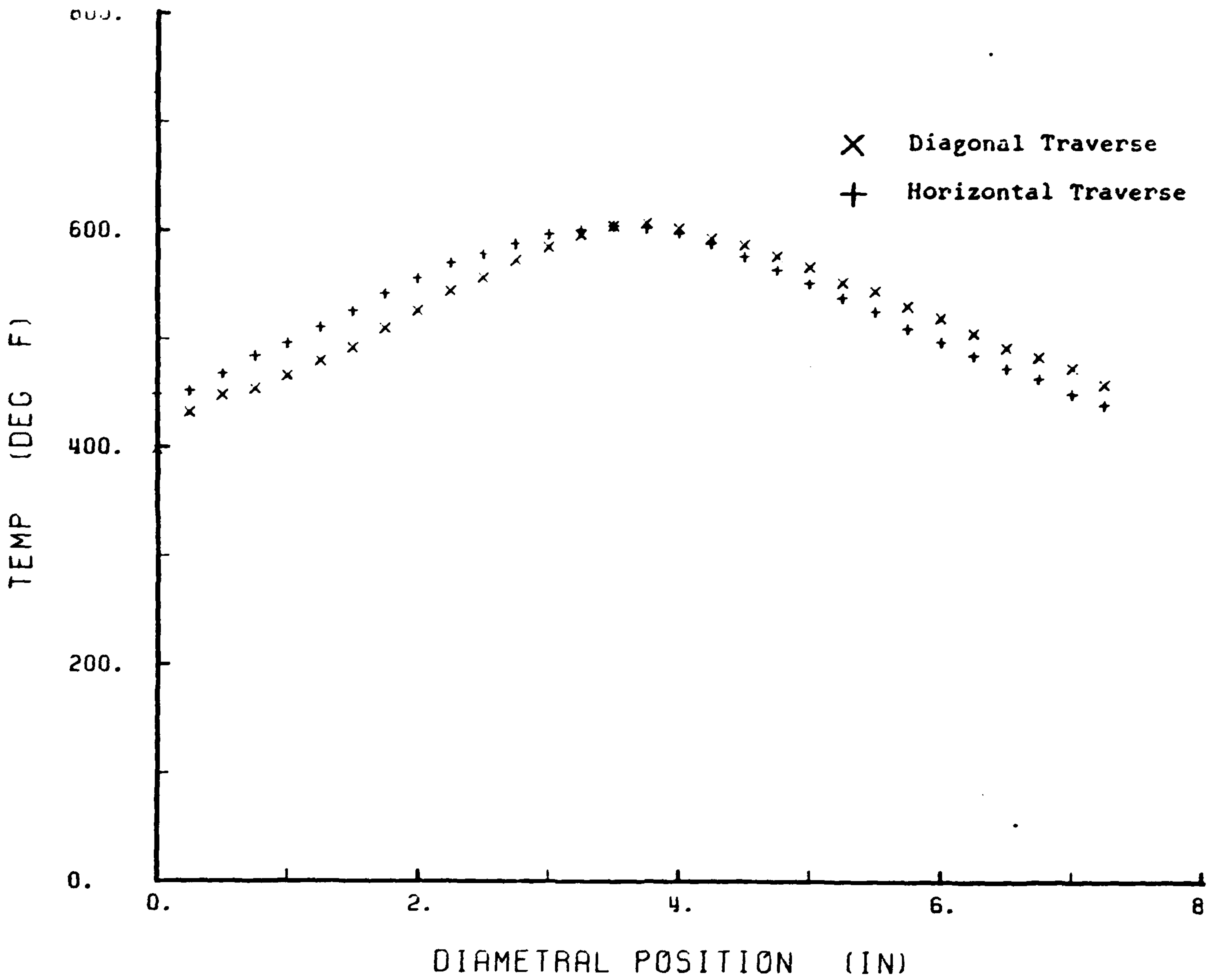
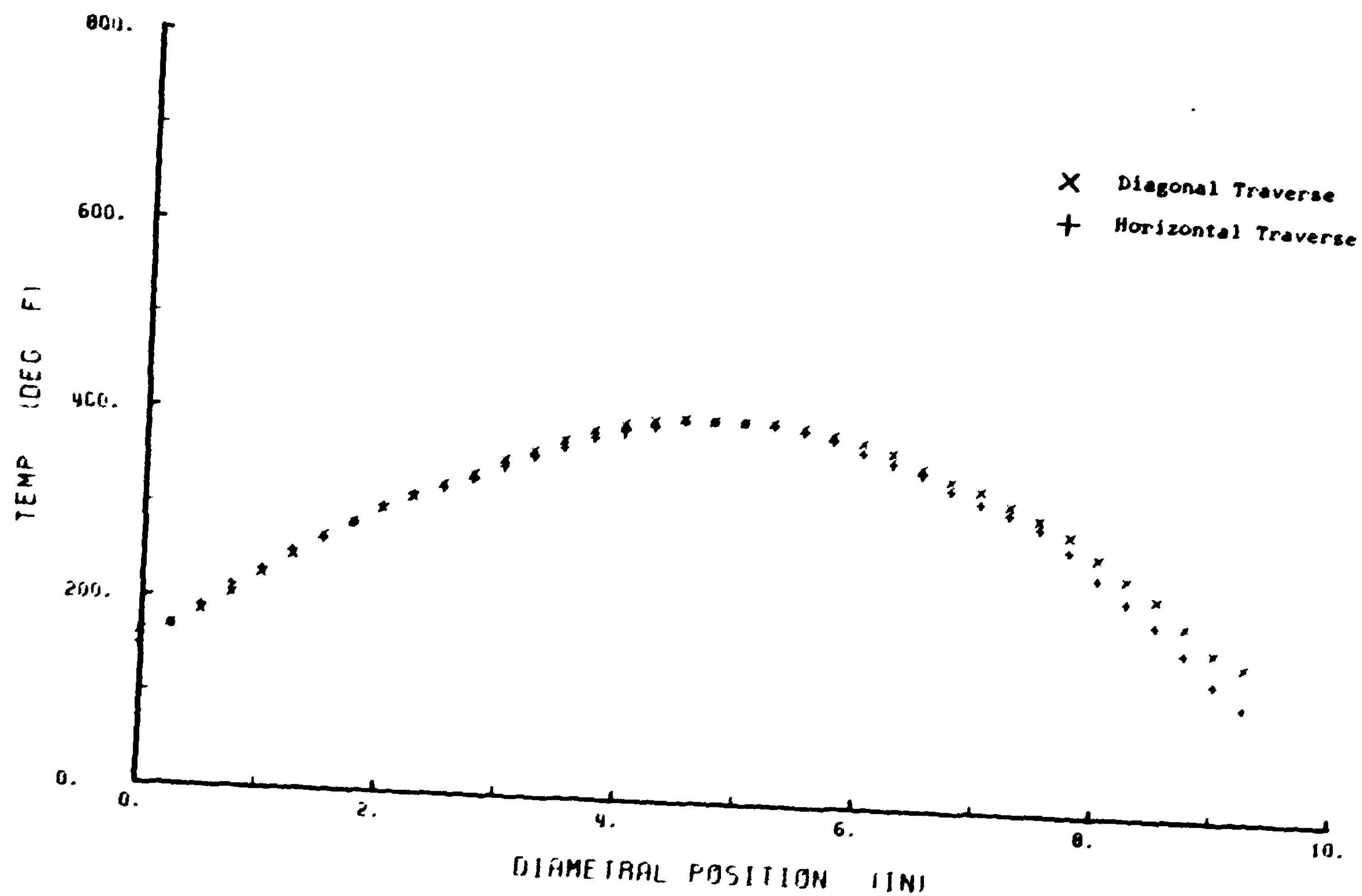
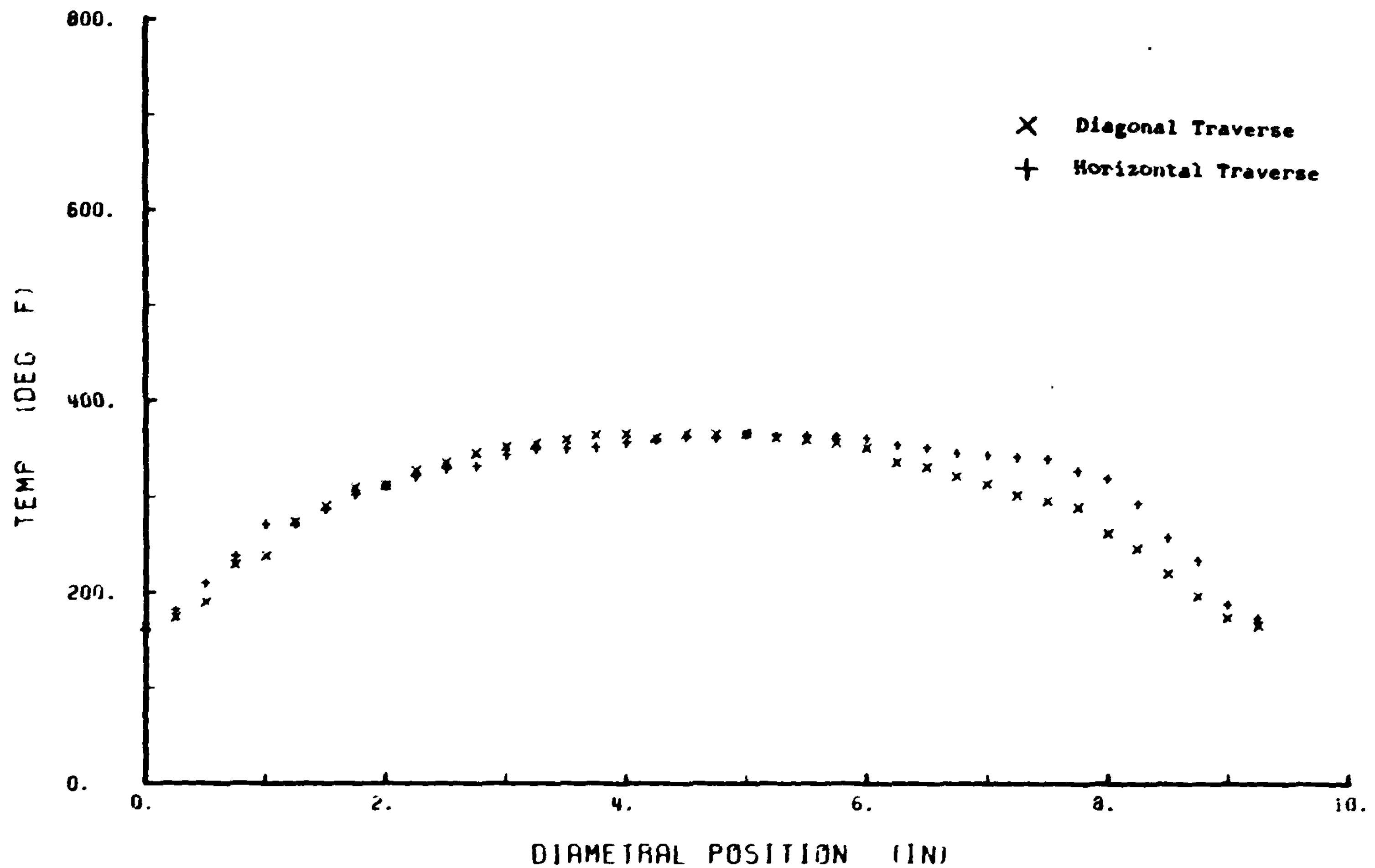


Figure 33. Exit Plane Temperature Plots for Solid Wall Mixing Stack, TUPT = 850 F



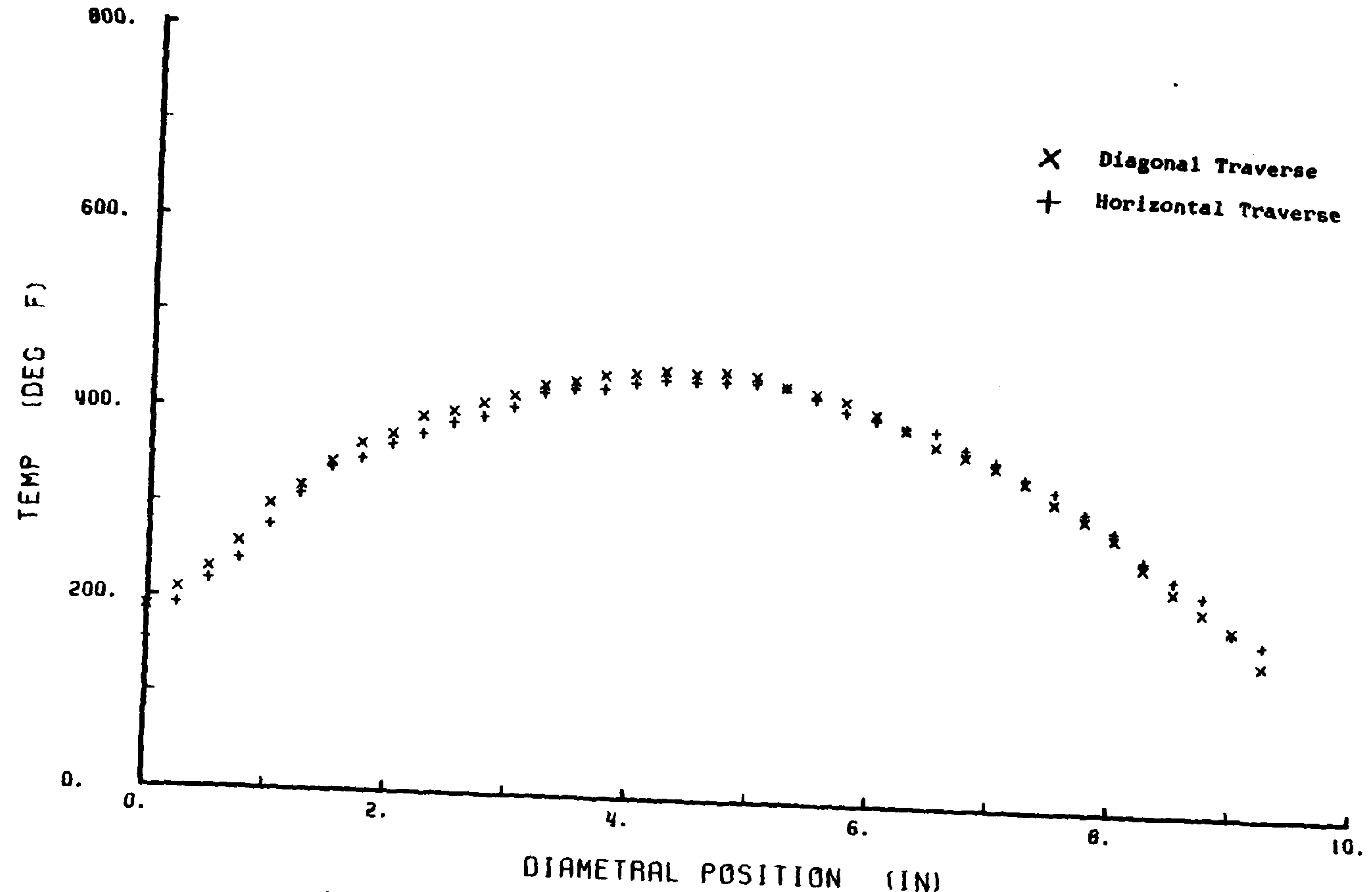
a) One Diffuser Ring, TUPT = 550 F, Run No. One

Figure 34. Exit Plane Temperature Plots for Slotted and Shrouded Mixing Stack, with One Diffuser Ring



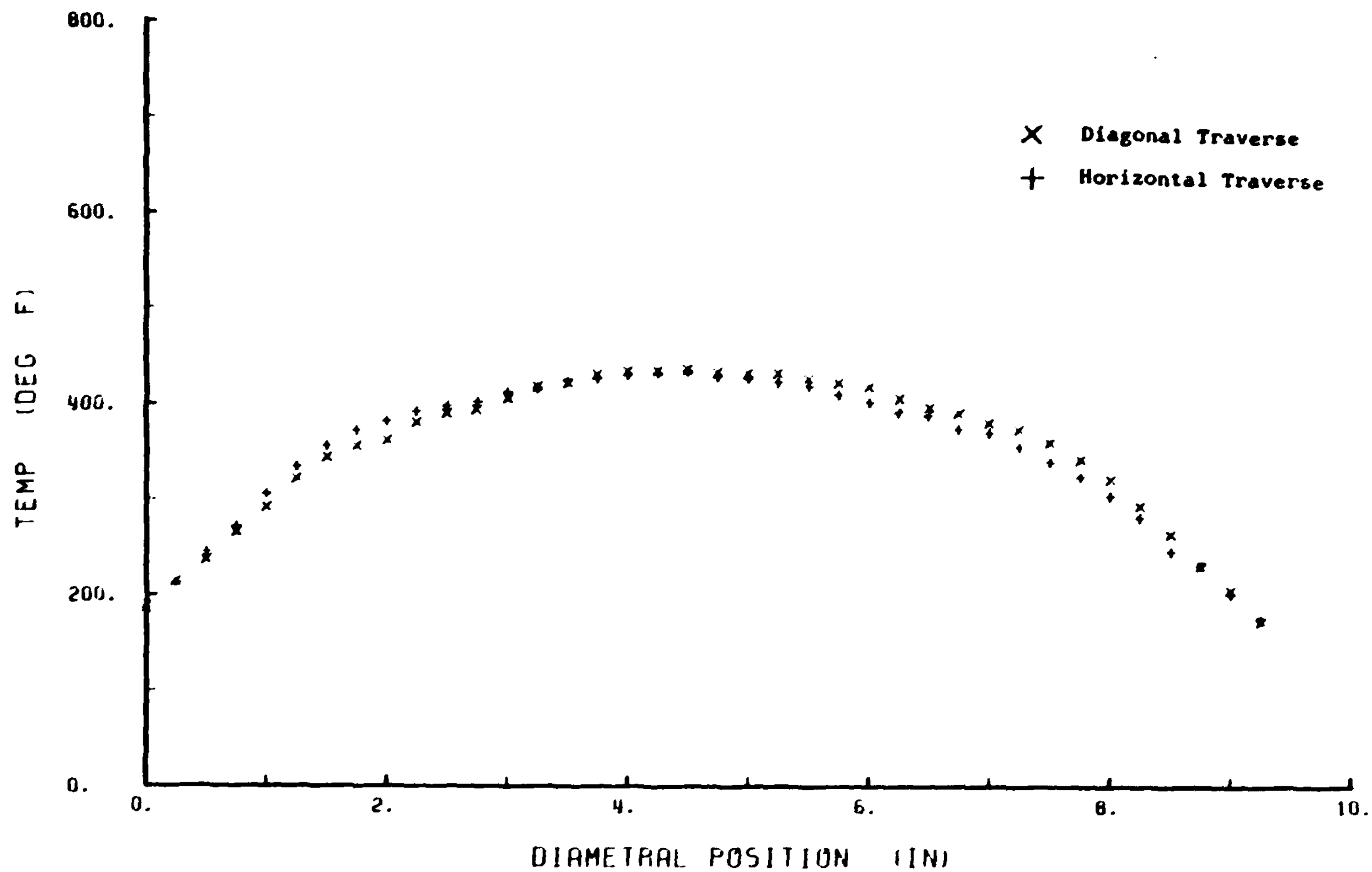
b) One Diffuser Ring, TUPT = 550 F, Run No. Two

Figure 34. (Continued)



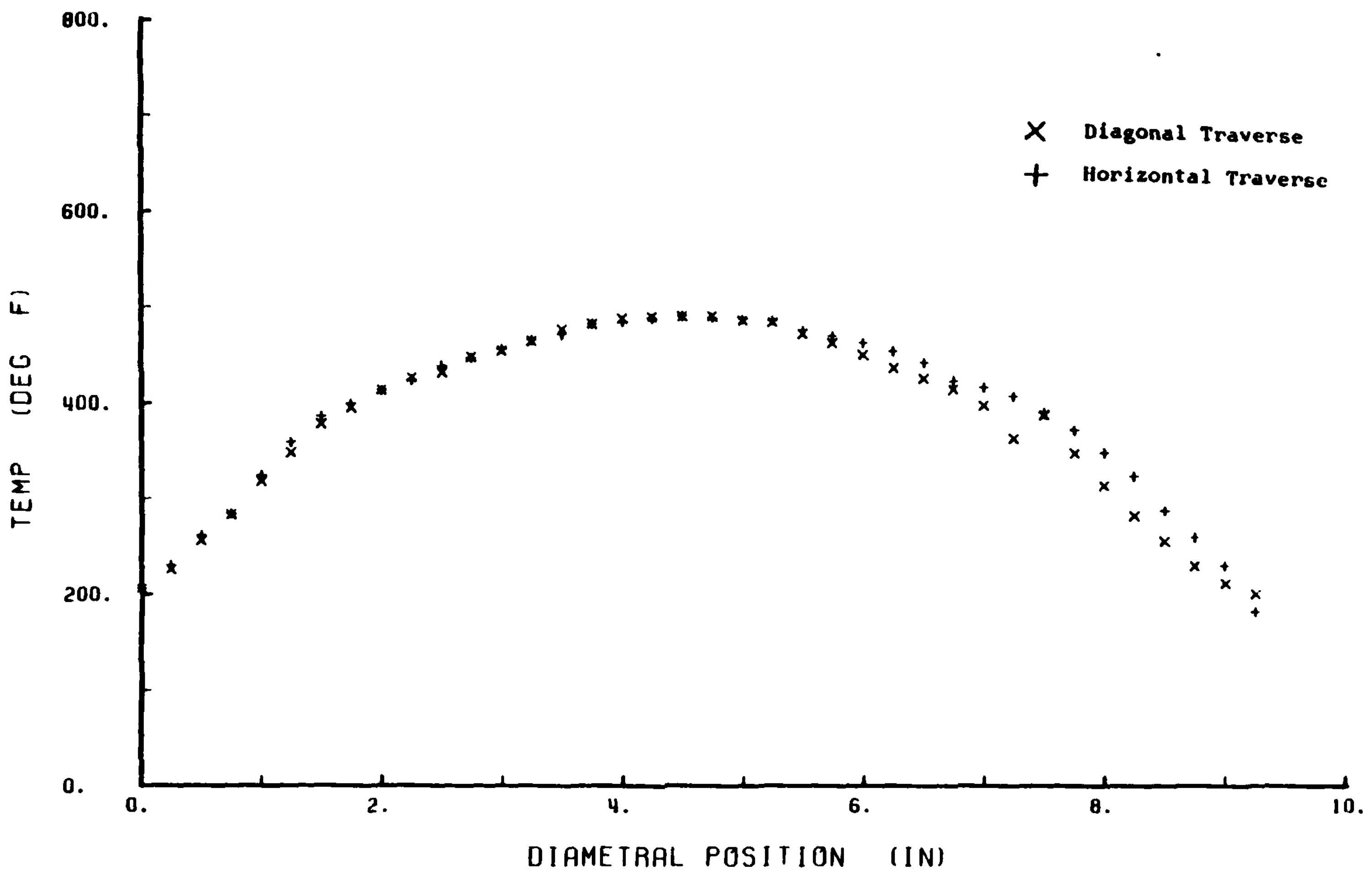
c) One Diffuser Ring, TUPT = 650 F, Run No. One

Figure 34. (Continued)



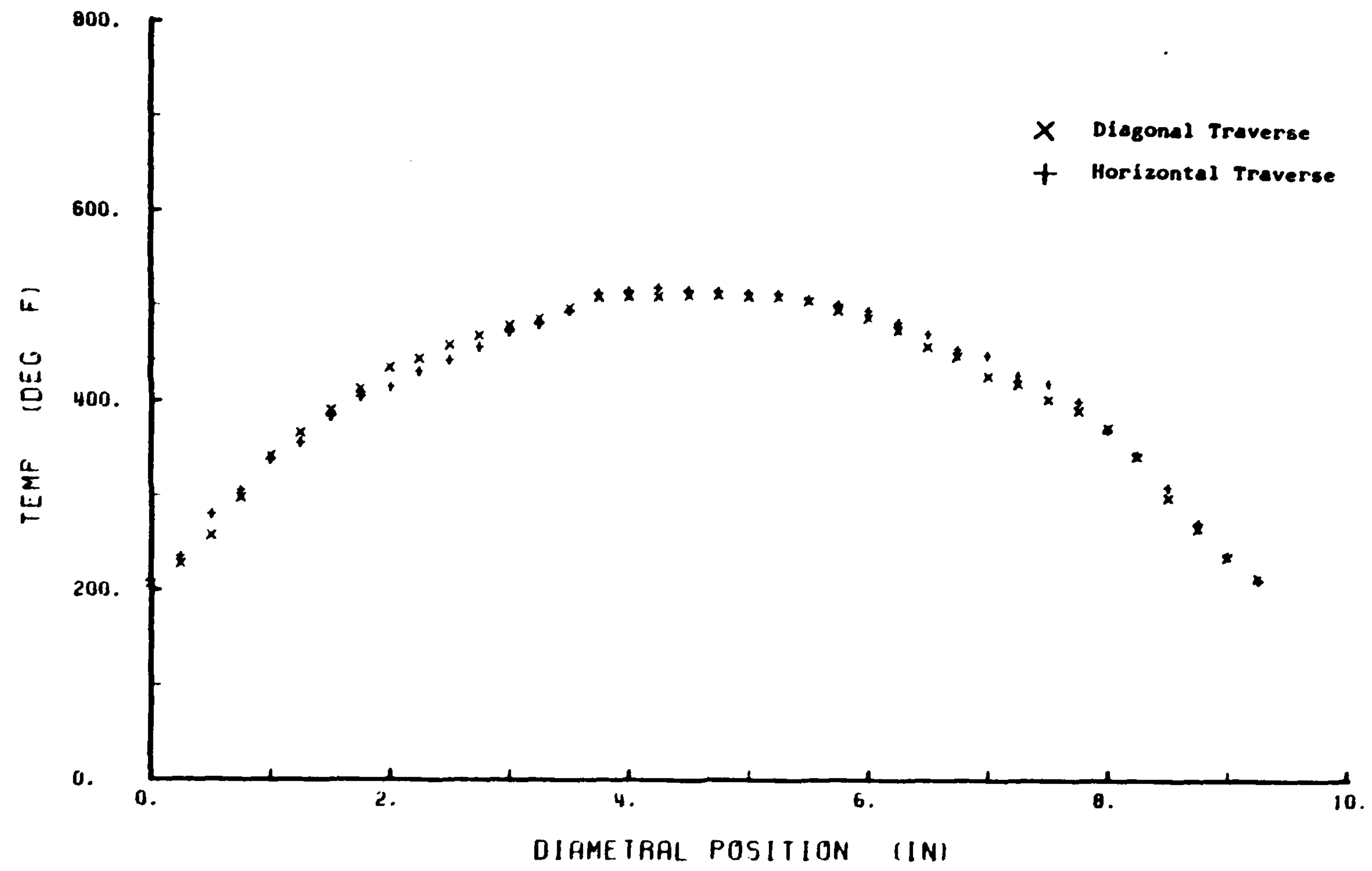
d) One Diffuser Ring, TUPT = 650 F, Run No. Two

Figure 34. (Continued)



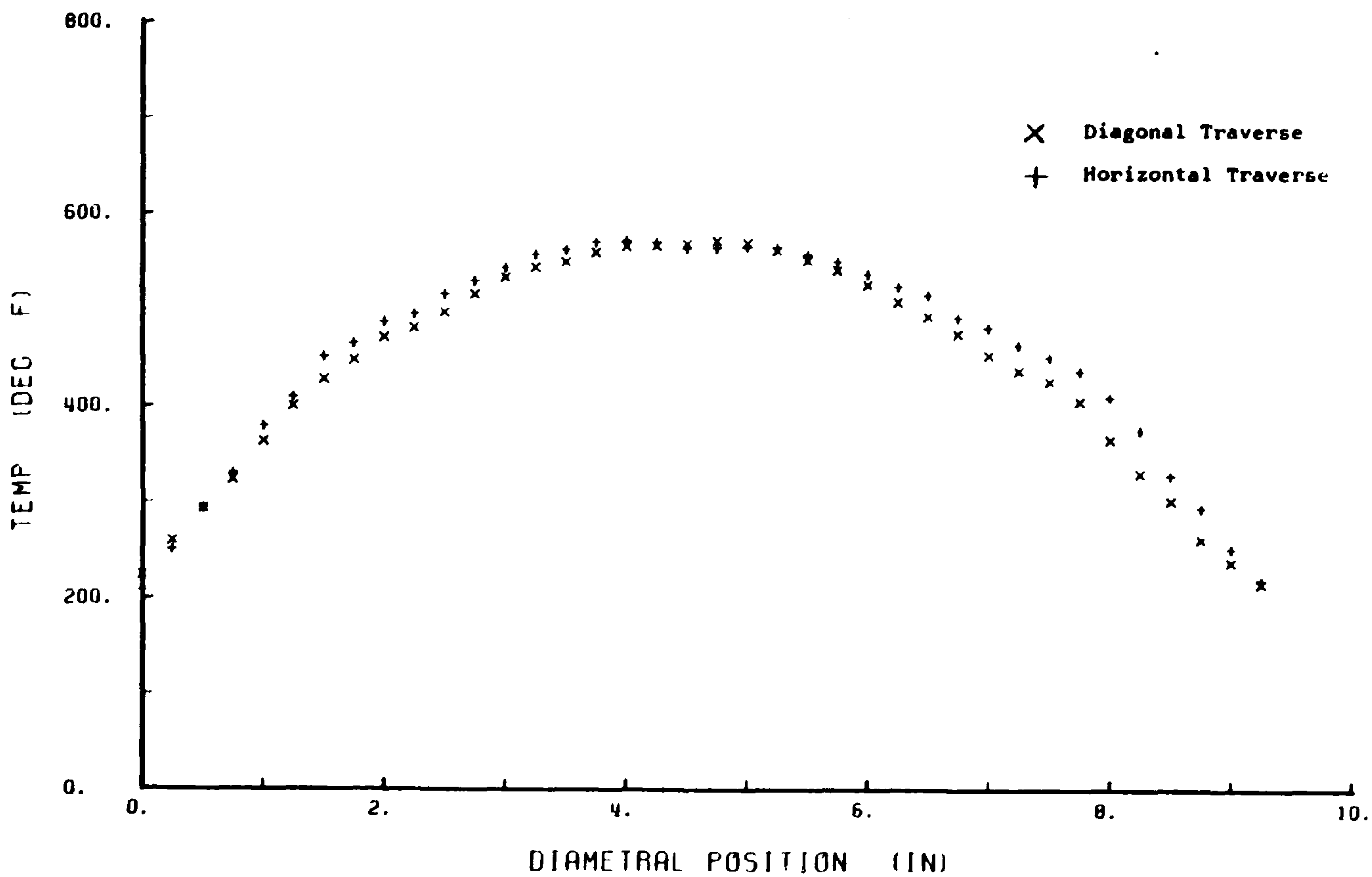
e) One Fiffuser Ring, TUPT = 750 F, Run No. One

Figure 34. (Continued)



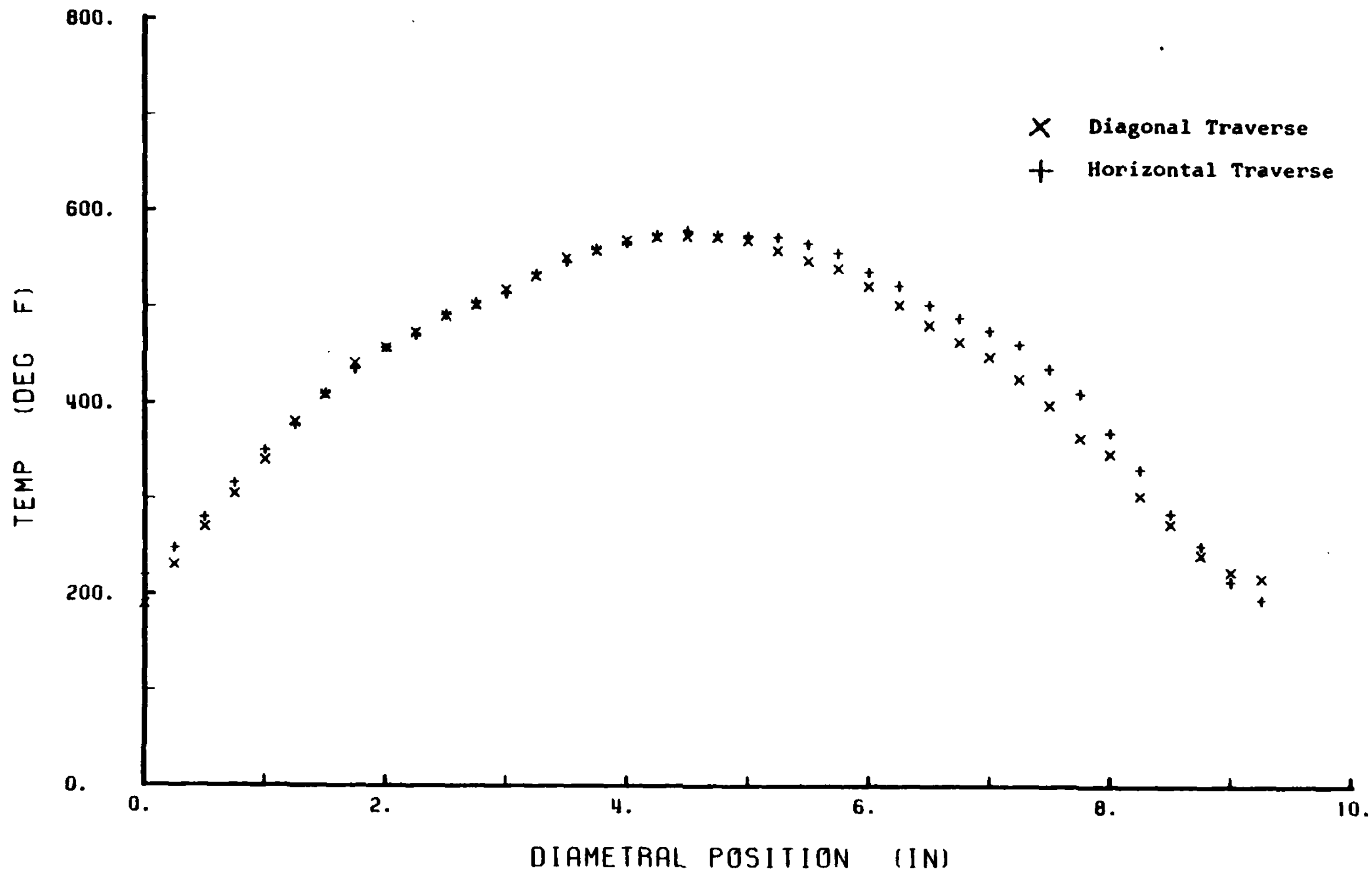
f) One Diffuser Ring, TUPT = 750 F, Run No. Two

Figure 34. (Continued)



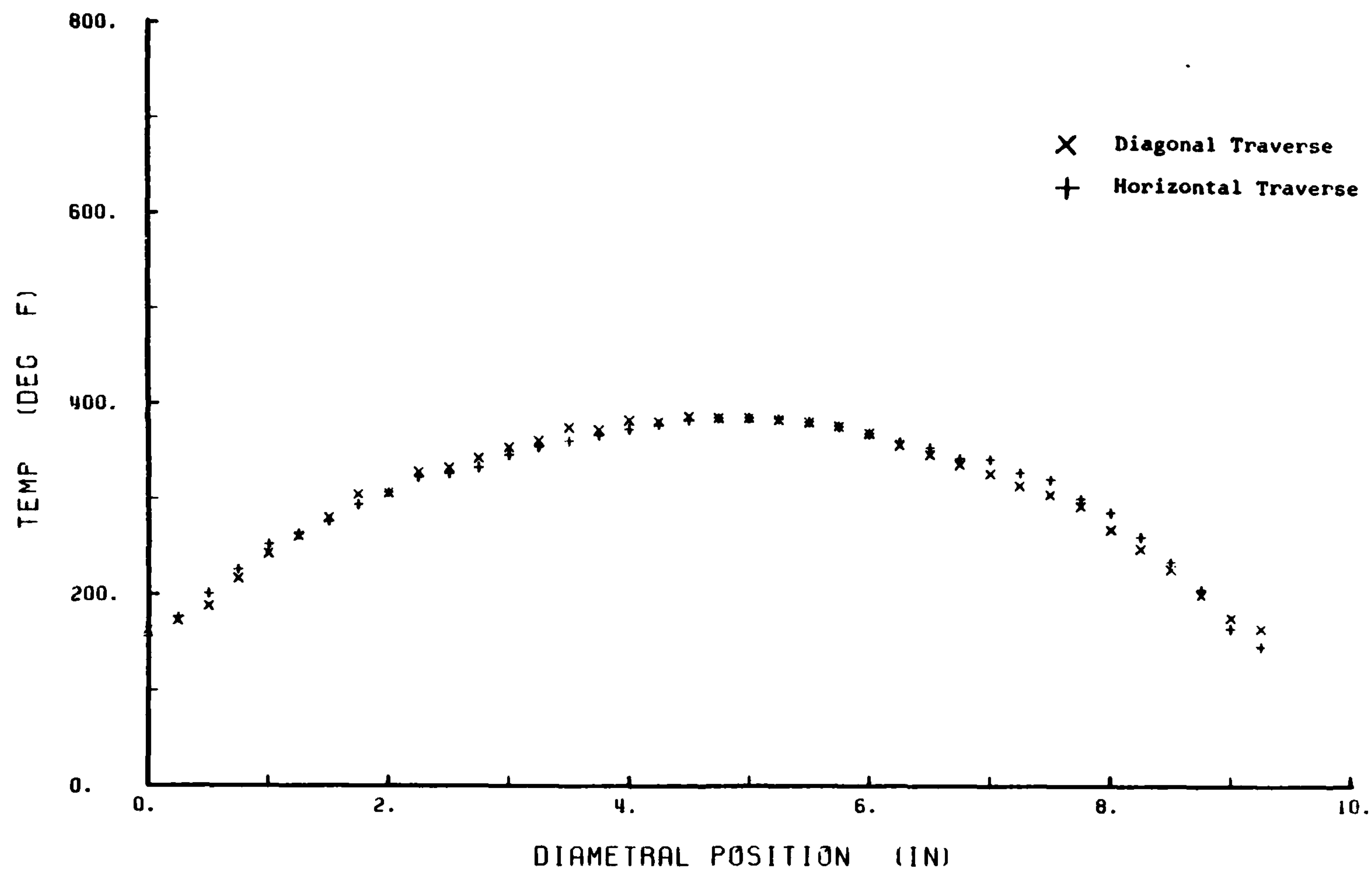
g) One Diffuser Ring, TUPT = 850 F, Run No. One

Figure 34. (Continued)



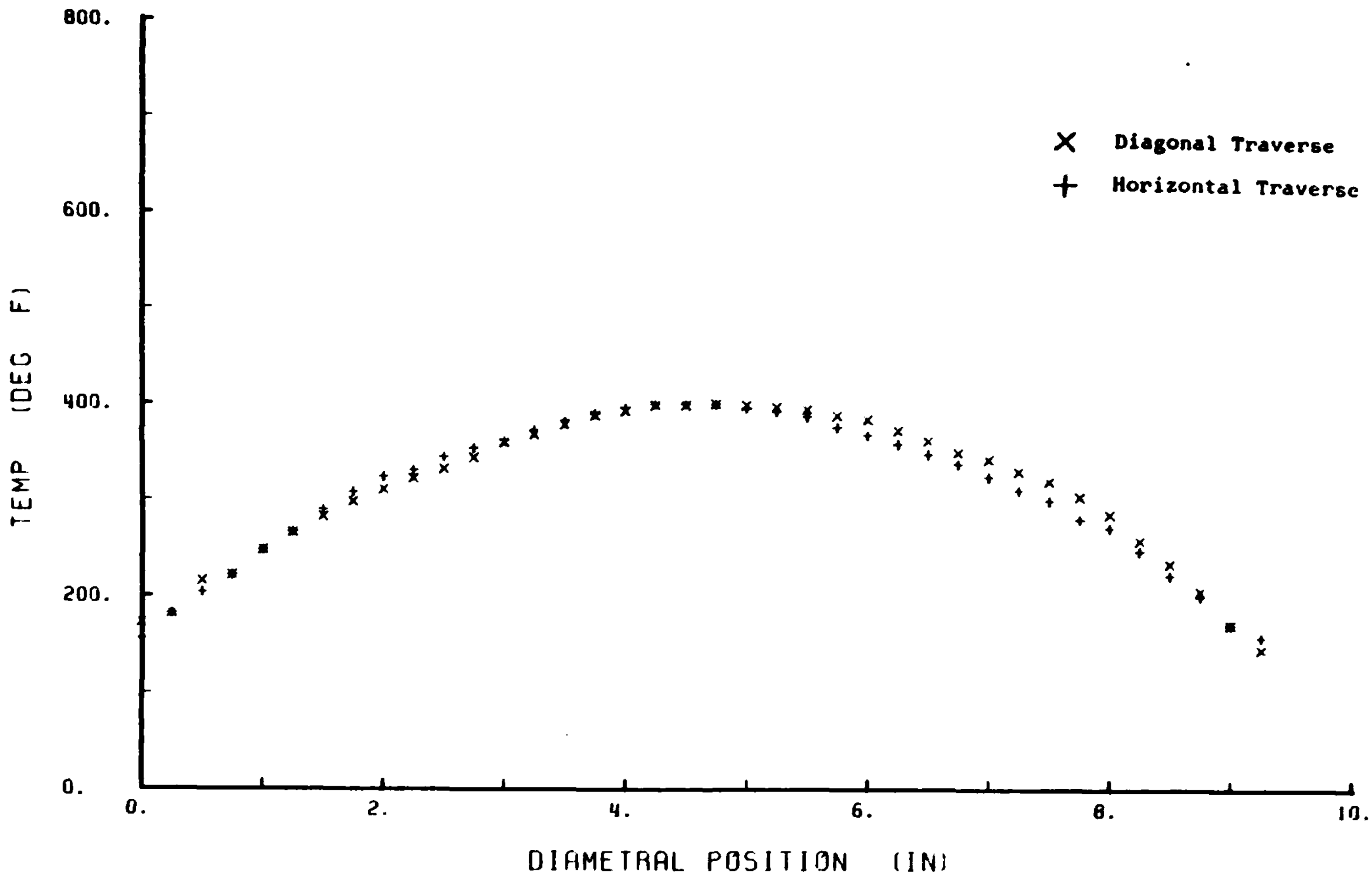
h) One Diffuser Ring, TUPT = 850 F, Run No. Two

Figure 34. (Continued)



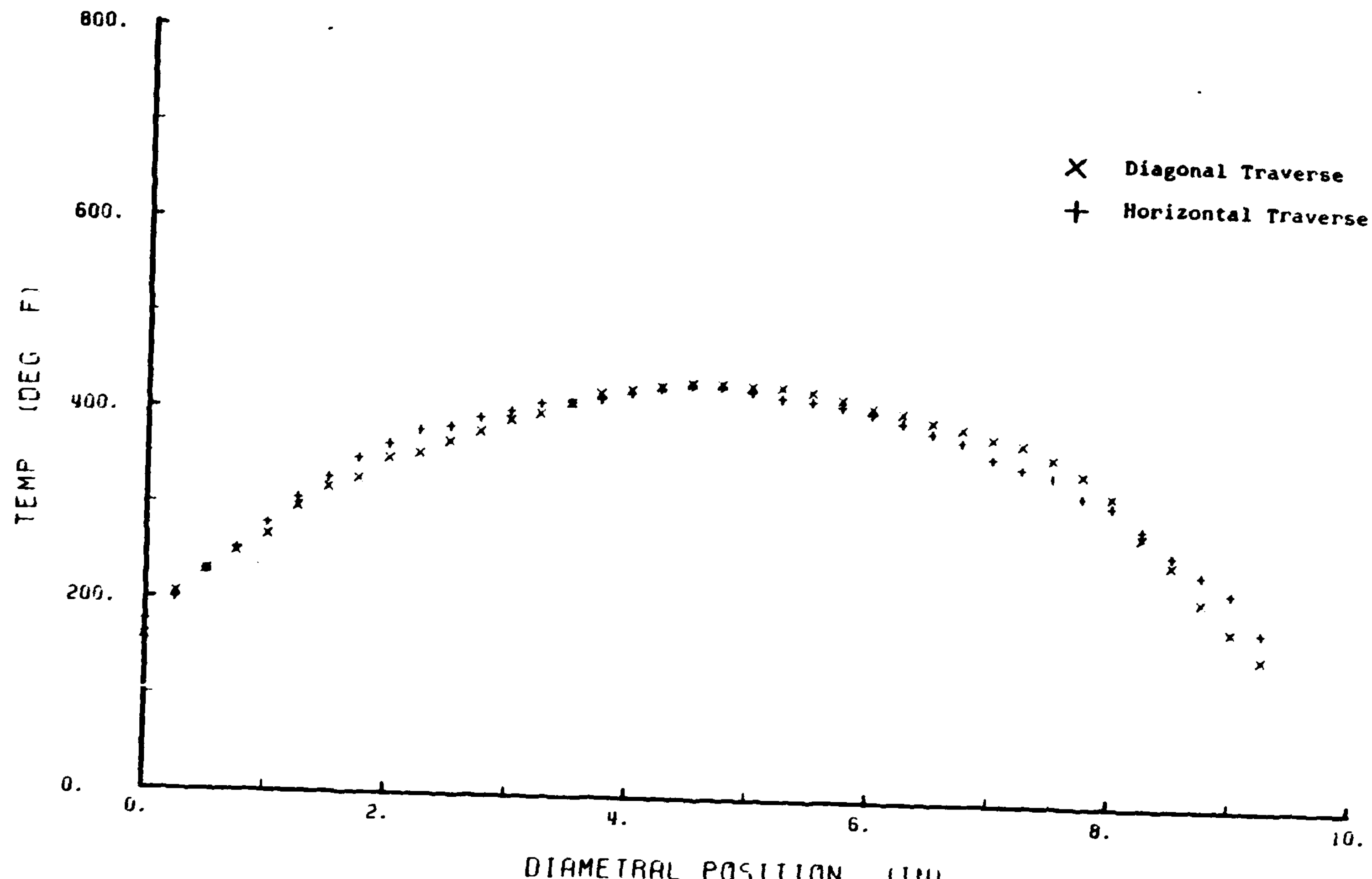
a) Two Diffuser Rings, TUPT = 550 F, Run No. One

Figure 35. Exit Plane Temperature Plots Slotted and Shrouded Mixing Stack with Two Diffuser Rings



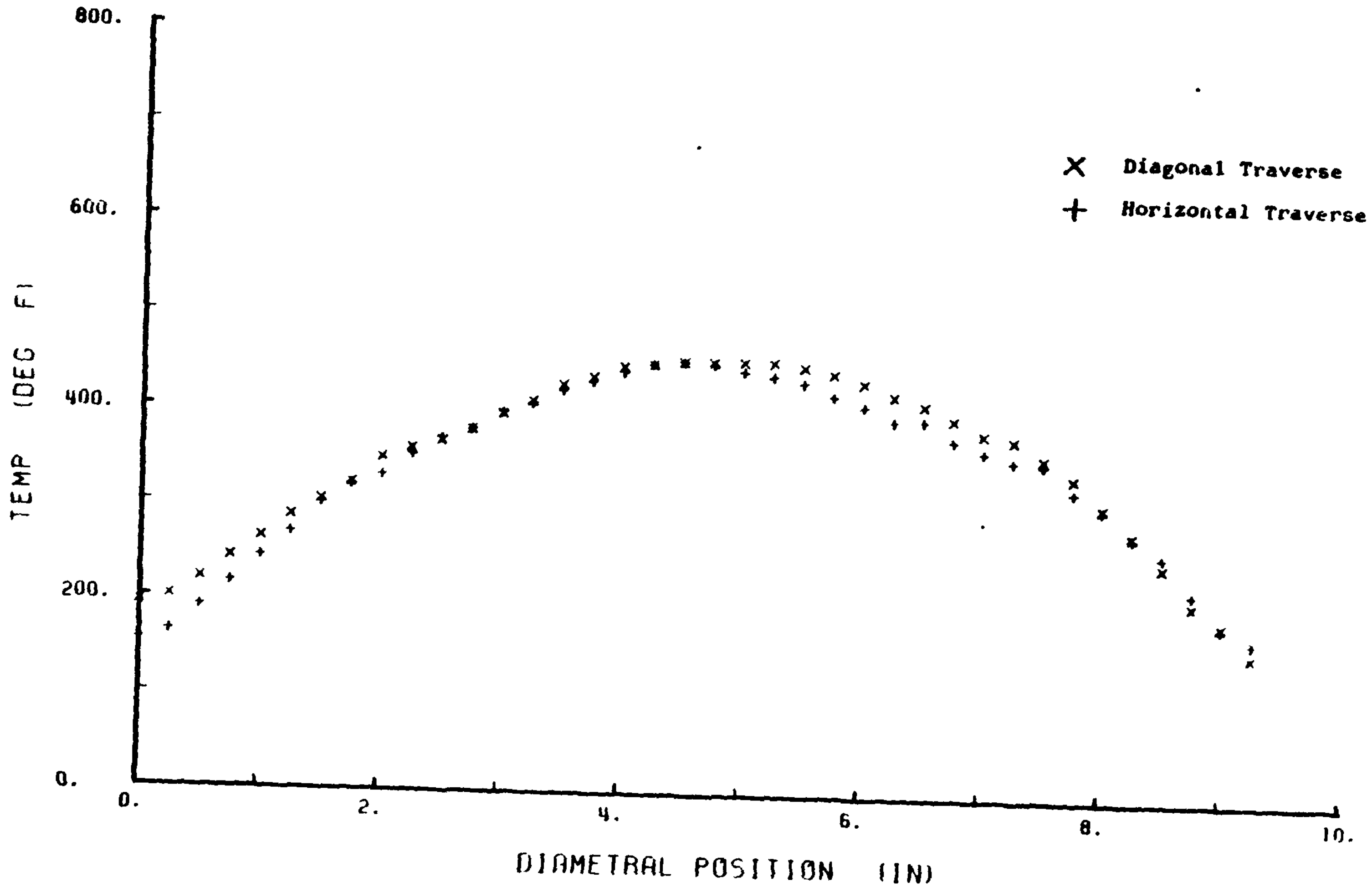
b) Two Diffuser Rings, TUPT = 550 F, Run No. Two

Figure 35. (Continued)



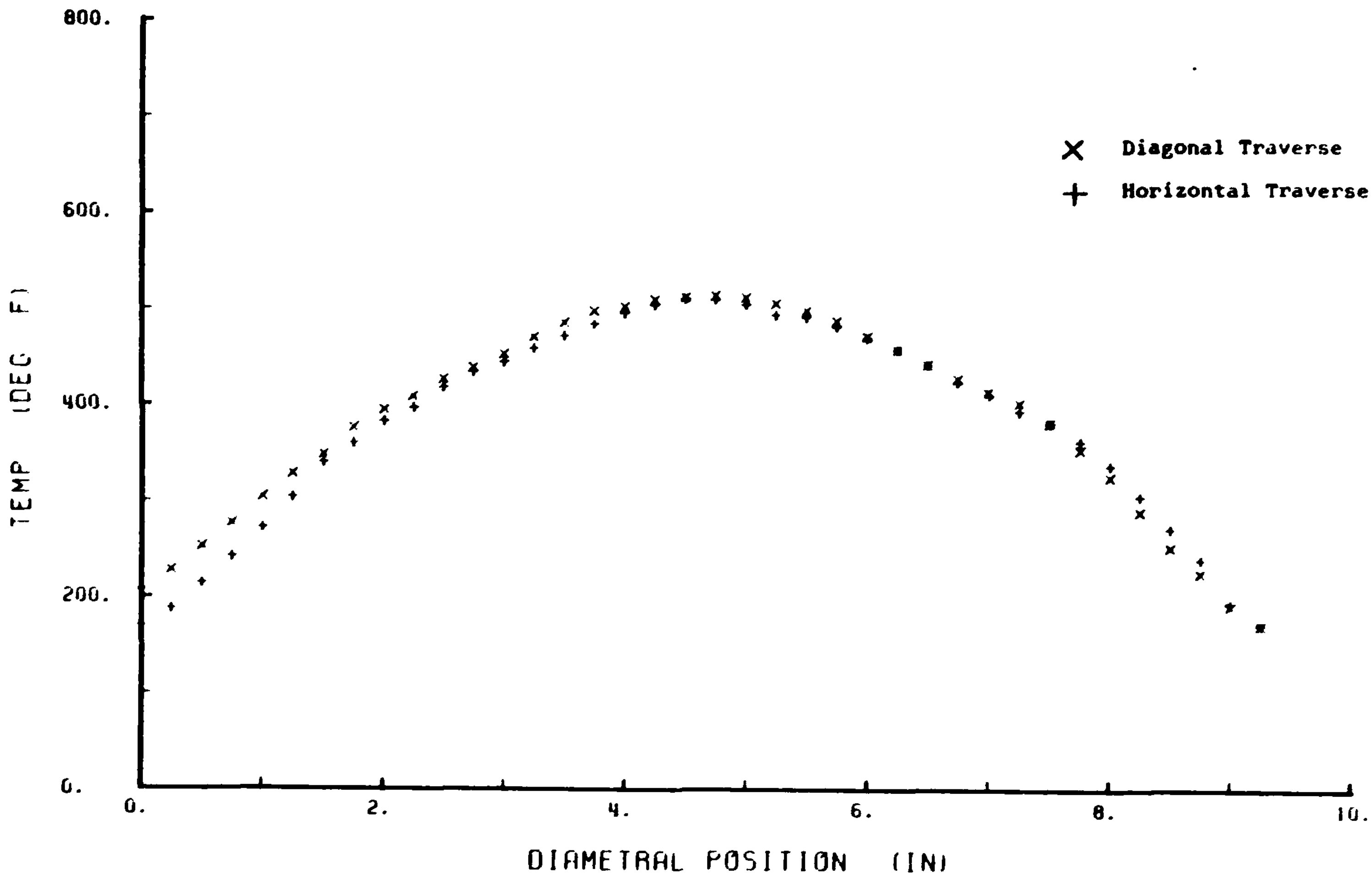
c) Two Diffuser Rings, TUPT = 650 F, Run No. One

Figure 35. (Continued)



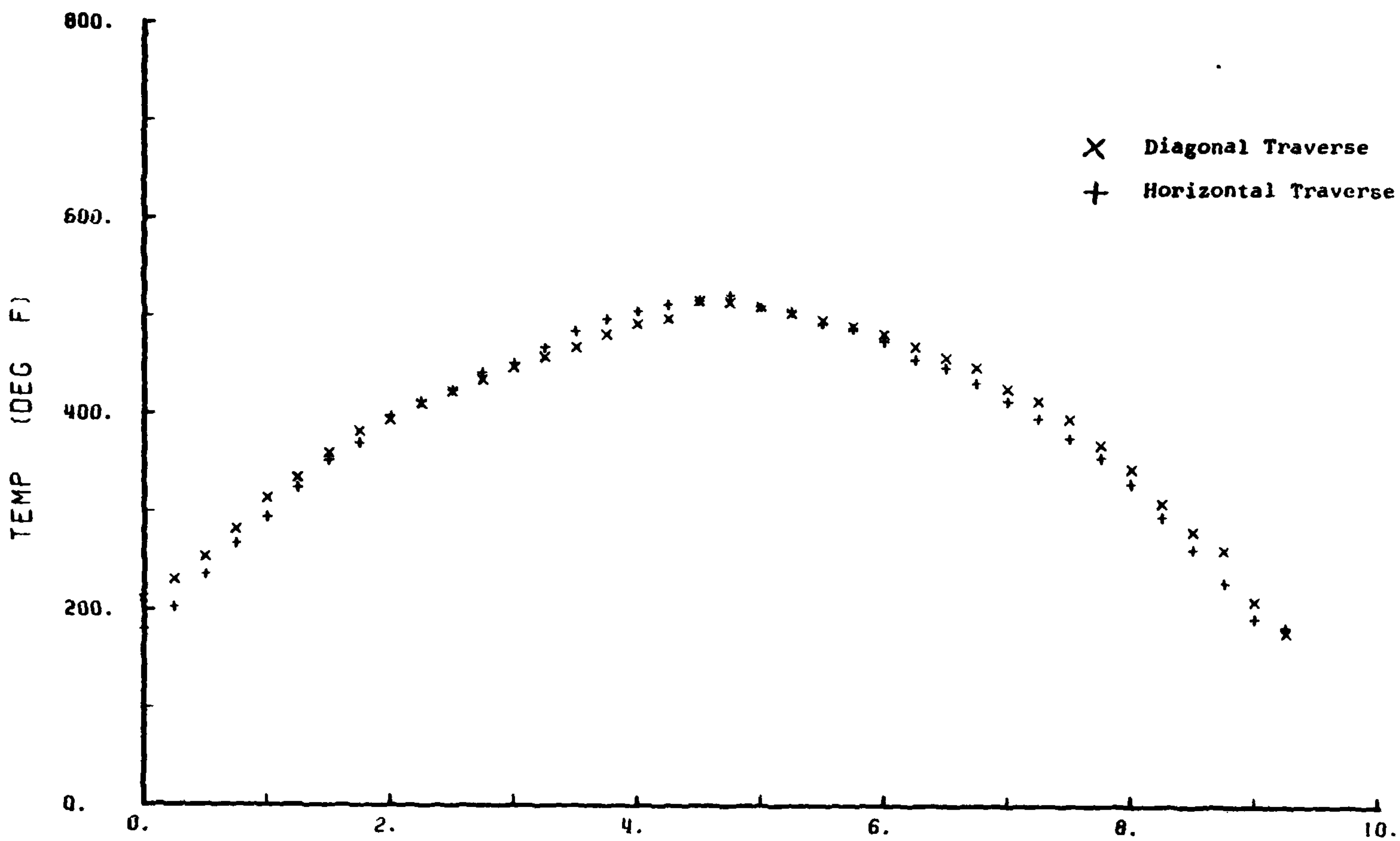
d) Two Diffuser Rings, TUPT = 650 F, Run No. Two

Figure 35. (Continued)



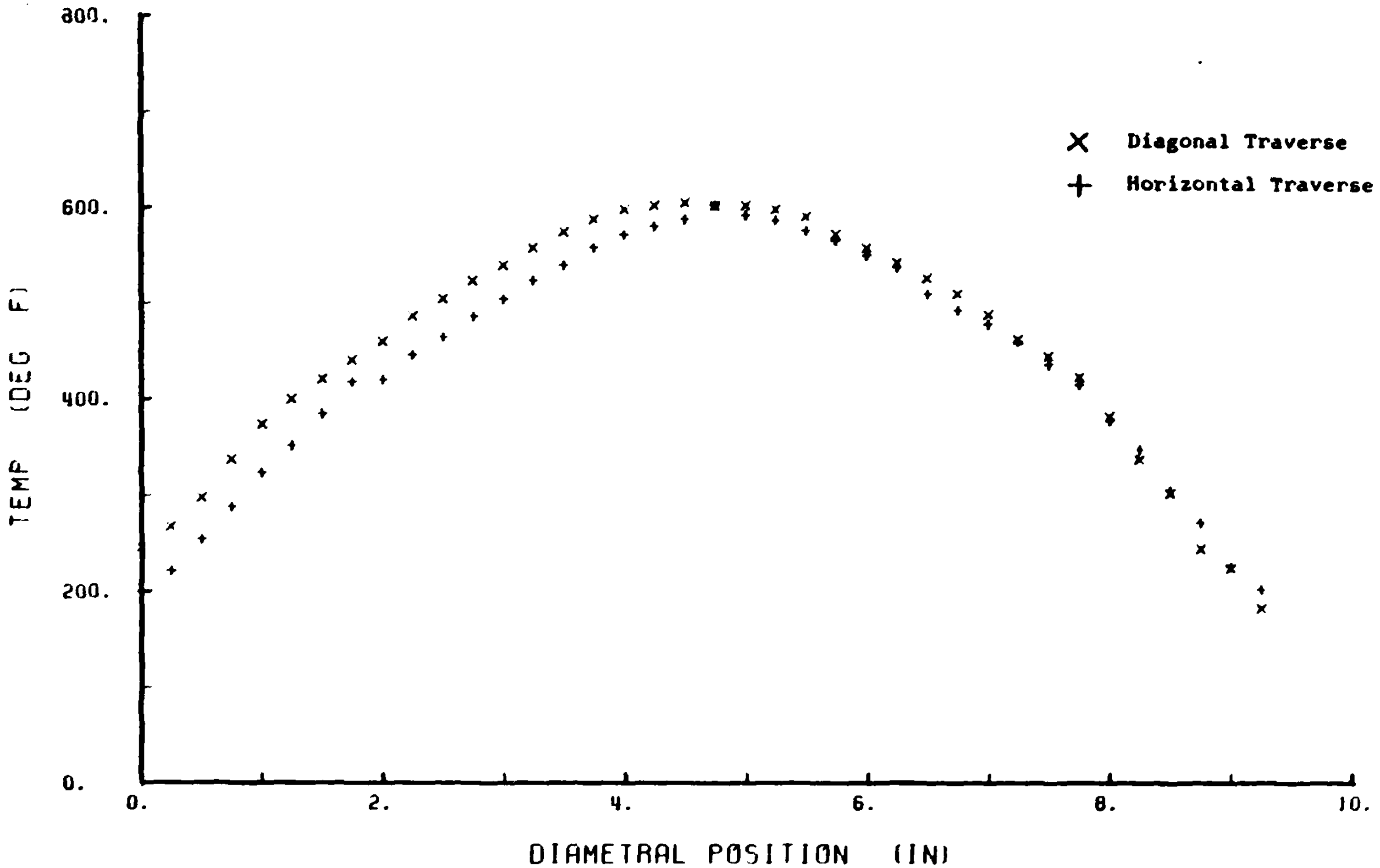
e) Two Diffuser Rings, TUPT = 750 F, Run No. One

Figure 35. (Continued)



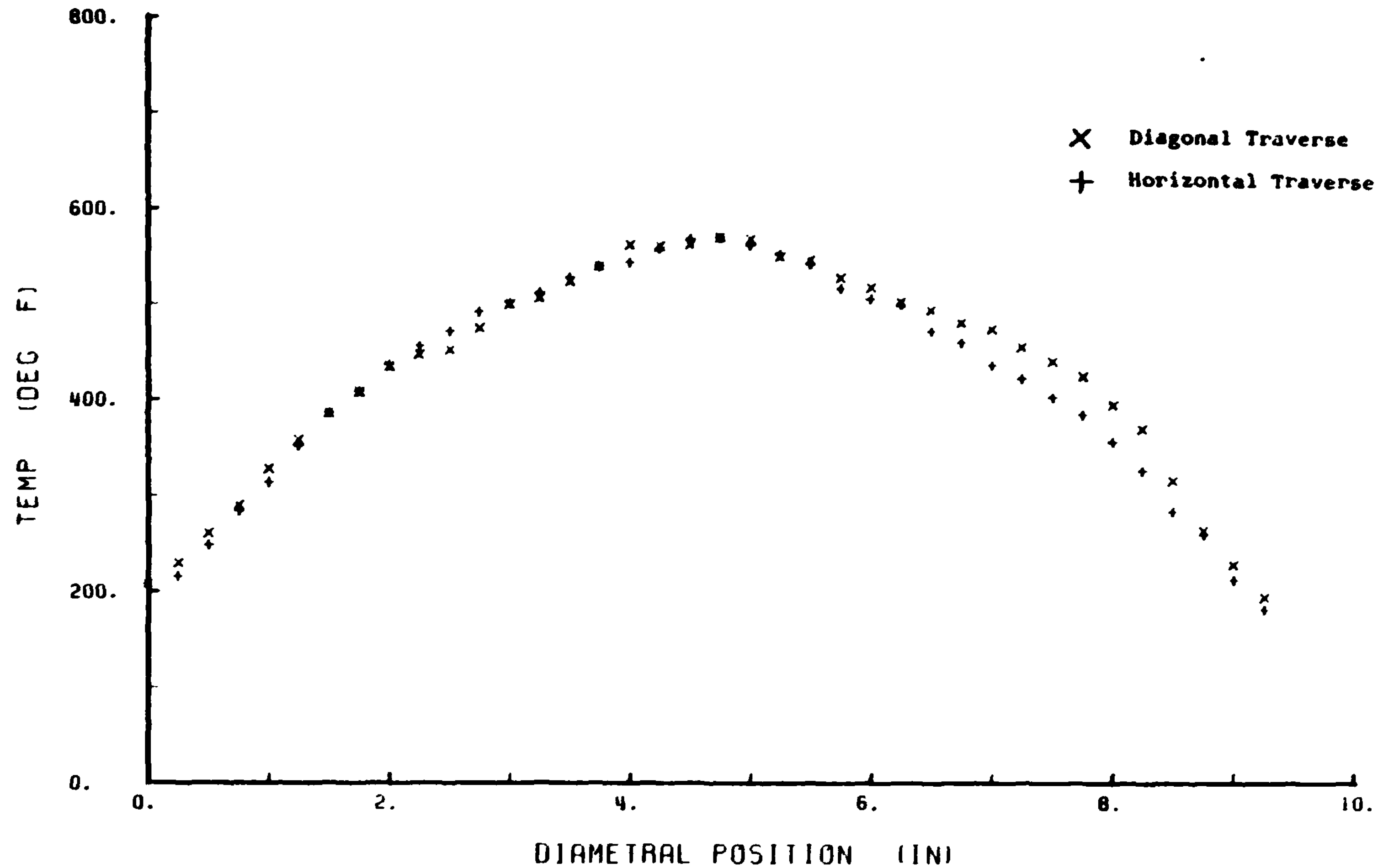
f) Two Diffuser Rings, TUPT = 750 F, Run No. Two

Figure 35. (Continued)



g) Two Diffuser Rings, TUPT = 850 F, Run No. One

Figure 35. (Continued)



h) Two Diffuser Rings, TUPT = 850 F, Run No. Two

Figure 35. (Continued)

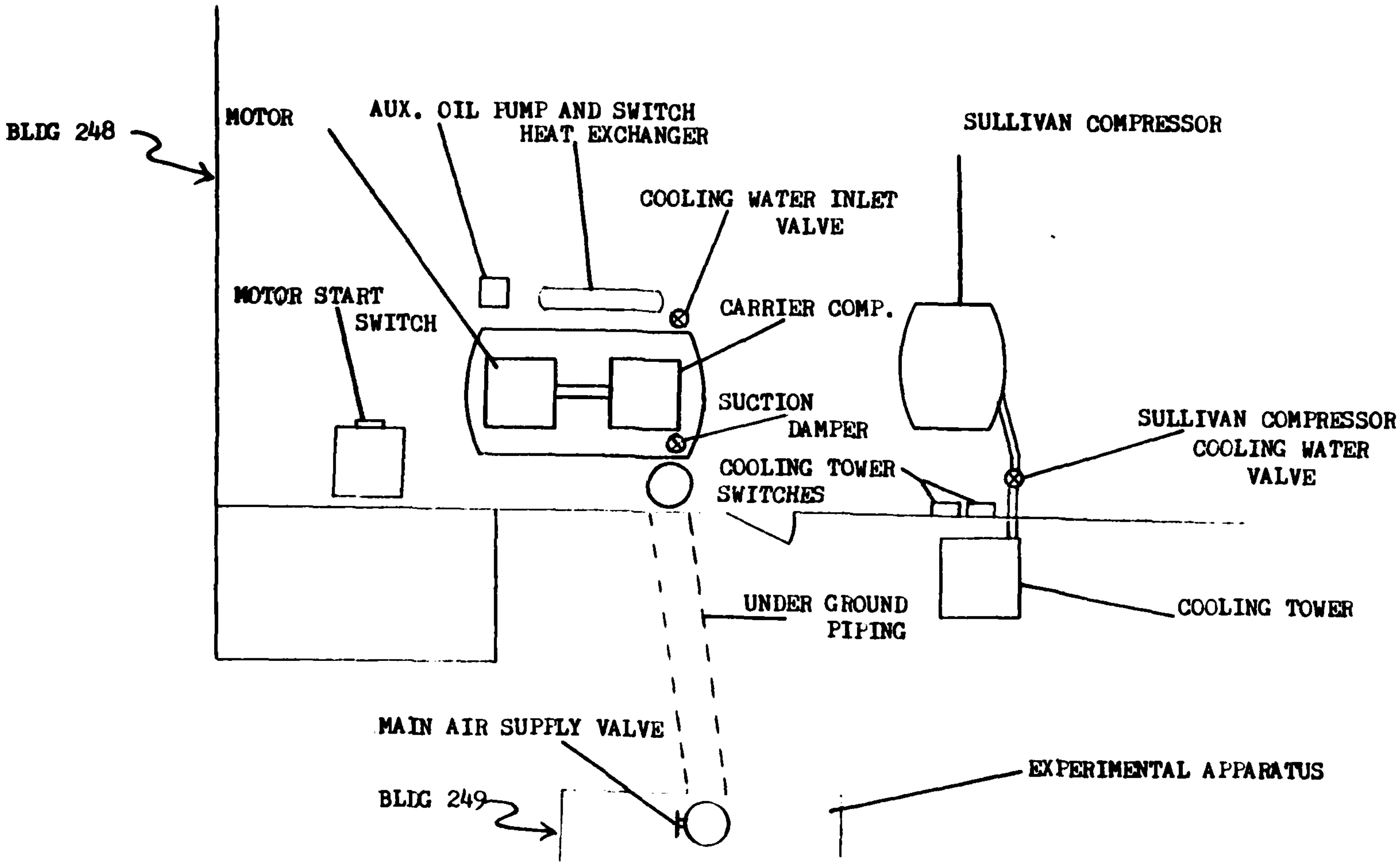


FIGURE 36. Schematic Diagram of Compressor Layout

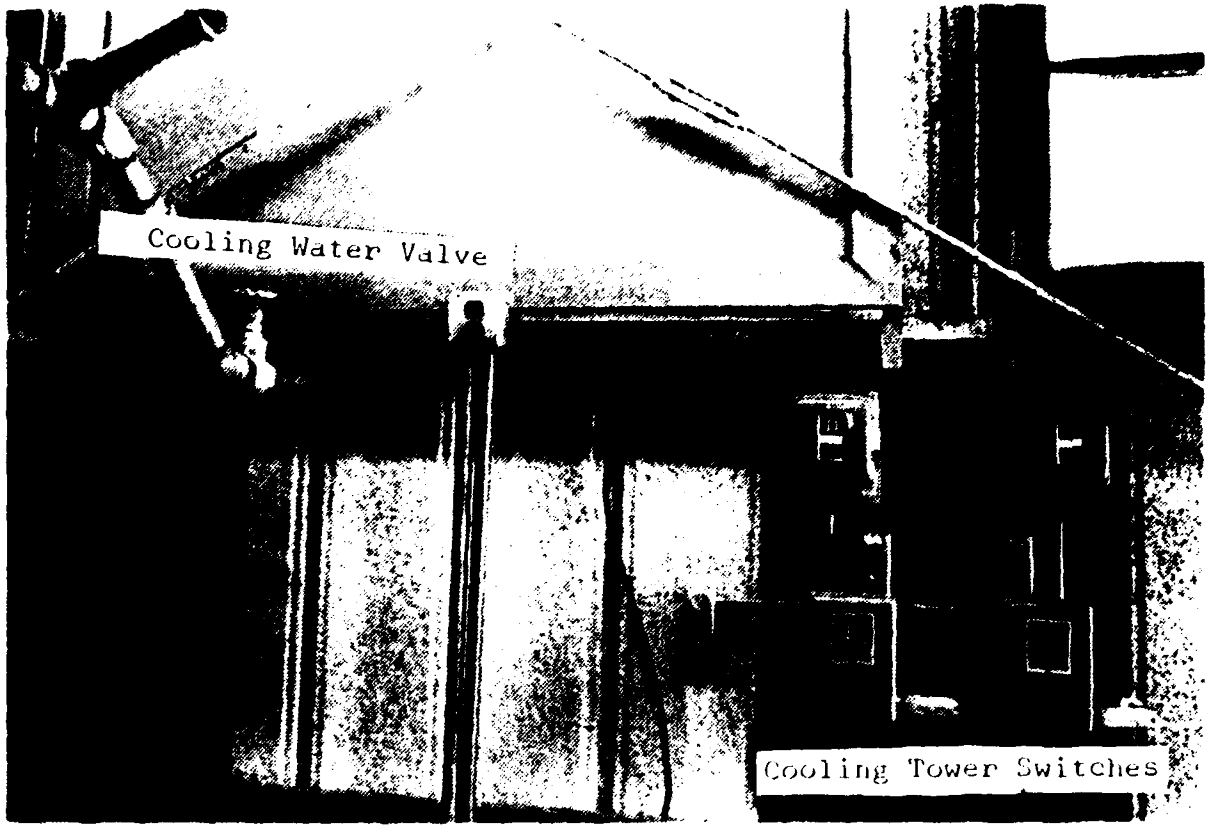


FIGURE 37. Cooling Tower Switches and Cooling Water Valve

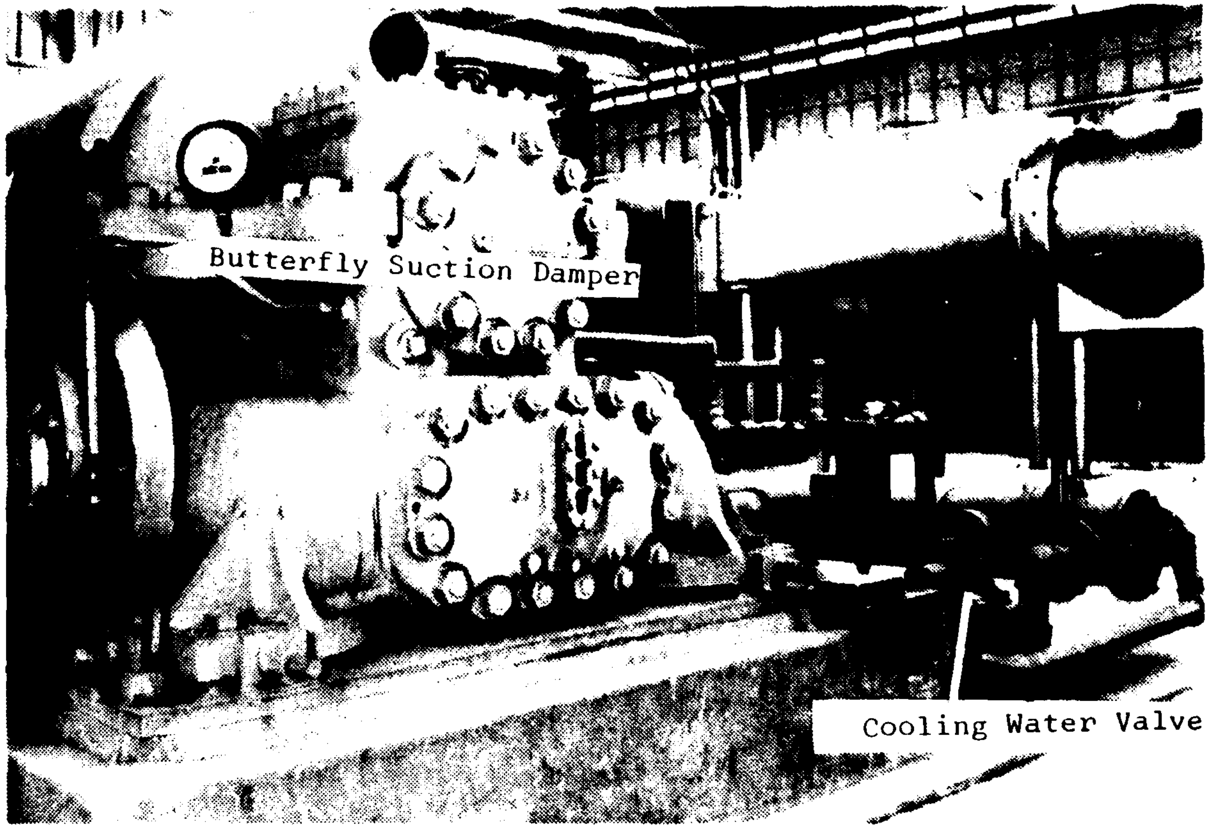


FIGURE 38. Carrier Air Compressor, Butterfly Suction Damper, and Cooling Water Valve

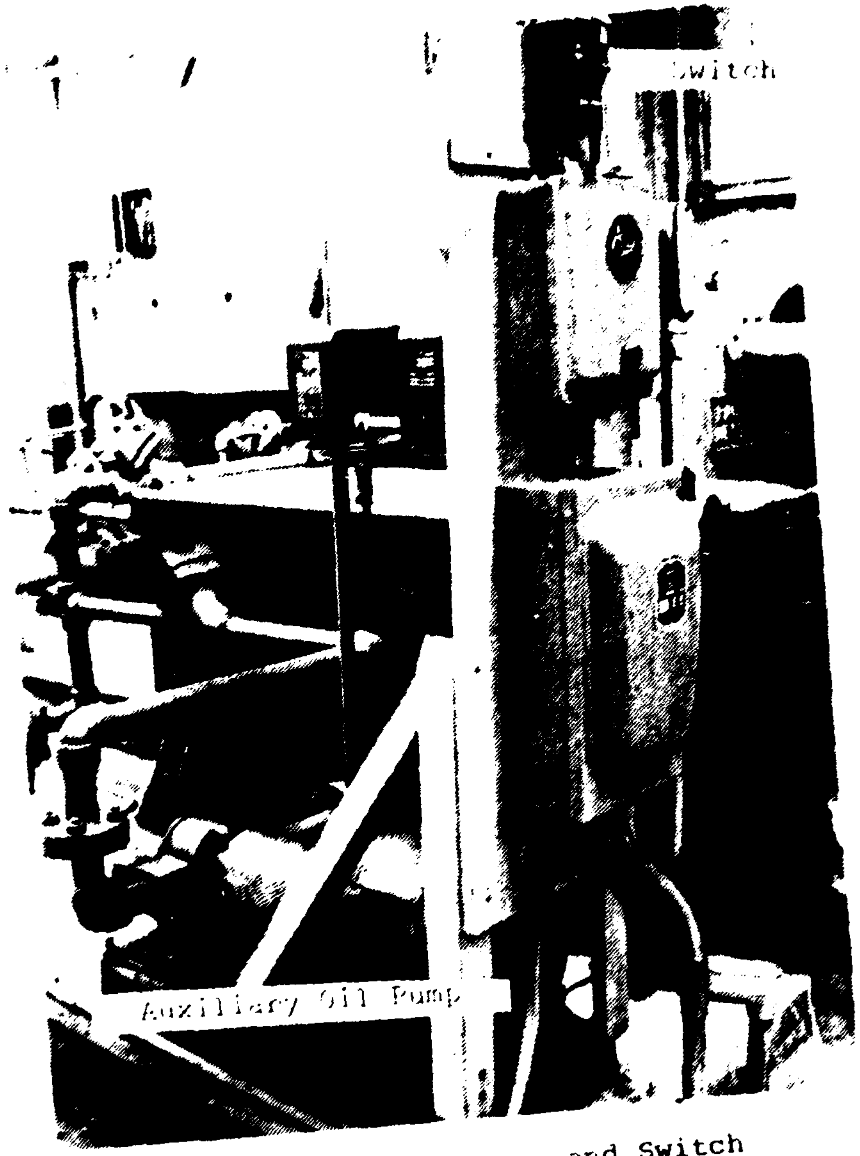


FIGURE 39. Auxiliary Oil Pump and Switch

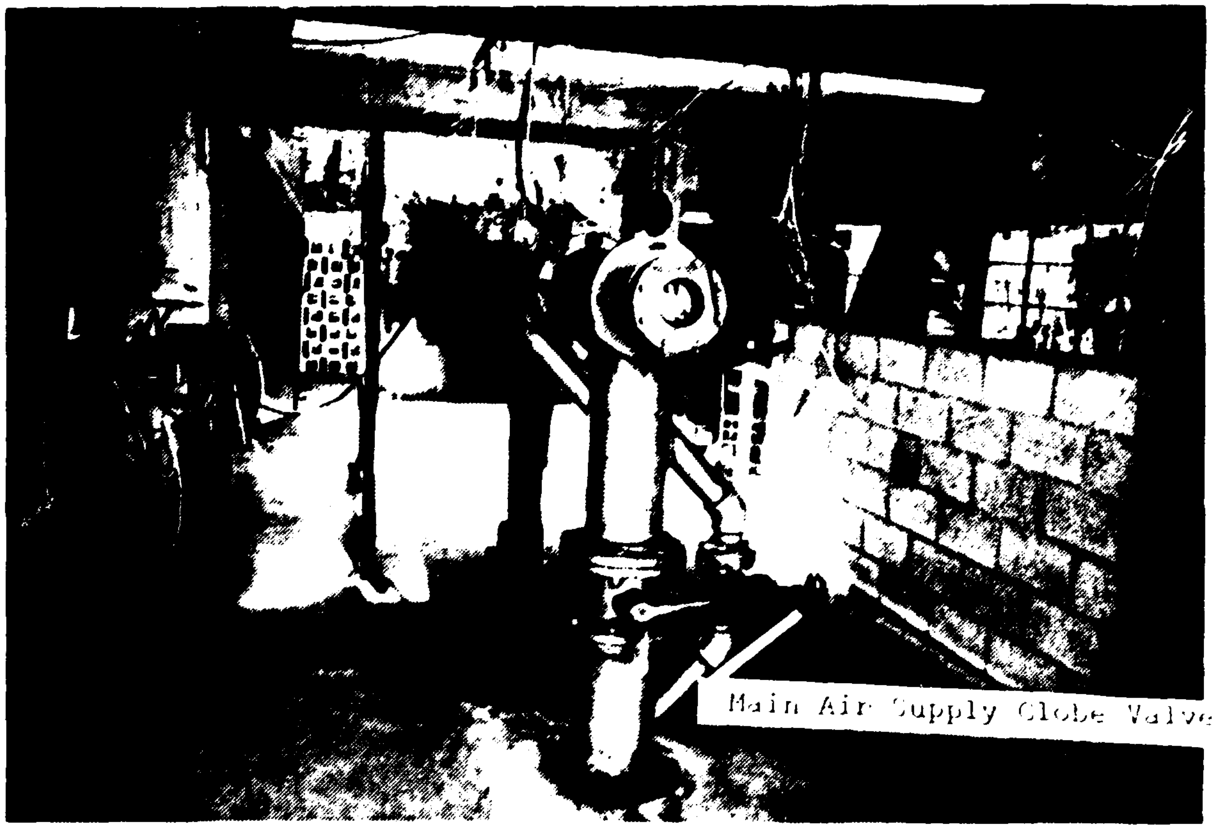


FIGURE 40. Main Air Supply Globe Valve

IX. TABLES

Parameter (TUPT = 850 °F)	Solid Wall Mixing Stack	Slotted and Shrouded Mixing Stack: One Diffuser Ring	Slotted and Shrouded Mixing Stack: Two Diffuser Rings
Maximum Mixing Stack Temperature (°F)	370	267	269
Maximum Shroud Temperature (°F)	N.A.	138	158
Maximum Diffuser Temperature (°F)	N.A.	144	132
Pumping Coefficient	.53	.72	.74
Back Pressure (in H_2O)	9.0	9.6	10.0
Maximum Exhaust Gas Temperature (°F)	604	570	580

TABLE I. Summary of Results

*** [illegible] PERFORMANCE ***

DATE: 31 MAY 73

NUMBER OF PRIMARY NOZZLES: 6
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
[illegible] DIAMETER: 7.510 INCHES
AREA RATIO, AP/AS: [illegible]
[illegible]: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 29.93 INCHES HG

NO	P-M IN HG	DEL-P IN H2O	TMP DEG F	FREQ HZ	TAPMS DEG F	EXIT DEG F	TAMB DEG F	PU-PS IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.50	6.3[illegible]	168.3	125.0	1323.0	852.0	72.0	6.50	1.73	0.0
2	4.36	6.1[illegible]	170.5	12[illegible]	1310.[illegible]	8[illegible]7.0	74.0	7.7[illegible]	2.30	6.283
3	4.3[illegible]	6.[illegible]	171.4	125.0	1297.[illegible]	865.0	74.[illegible]	8.4[illegible]	1.55	11.152
4	4.3[illegible]	6.10	171.8	125.0	1271.0	871.[illegible]	74.[illegible]	3.40	1.29	14.726
5	4.4[illegible]	6.2[illegible]	174.3	125.0	1268.0	866.0	75.0	9.30	0.59	27.293
6	4.4[illegible]	6.2[illegible]	175.2	126.0	1252.0	868.0	75.0	9.70	0.33	35.855
7	4.45	6.20	176.0	124.0	1234.0	864.0	75.0	9.80	0.20	52.425
8	4.46	6.20	176.1	125.0	1237.[illegible]	864.[illegible]	75.[illegible]	9.80	0.14	64.992
9	4.4[illegible]	6.20	178.2	125.0	1242.0	866.0	77.[illegible]	9.90	0.06	******

NO	WPA LBM/S	WF LBM/S	WP LBM/S	W LBM/S	ws	PA	PU	DPSTB	WSTMN.SS	CP FT/S	UM FT/S	UMS FT/S	[illegible]
1	1.055	0.012	1.068	0.0	0.0	0.073	0.432	0.182	0.0	323.7	129.2	114.0	.0[illegible]
2	1.045	0.012	1.052	0.321	0.306	0.131	0.432	0.252	0.205	323.6	143.7	112.3	.0[illegible]
3	1.039	0.012	1.051	0.471	0.444	0.168	0.430	0.170	0.303	320.[illegible]	150.7	112.2	.0[illegible]
4	1.035	0.012	1.05[illegible]	0.55[illegible]	0.526	0.[illegible]	0.401	0.136	0.352	320.5	155.[illegible]	112.3	.0[illegible]7
5	1.04[illegible]	0.012	1.056	0.737	0.668	0.[illegible]	0.403	0.[illegible]	0.448	321.0	162.7	112.5	.0[illegible]
6	1.046	0.012	1.058	0.772	0.729	0.[illegible]	0.403	0.036	0.439	321.2	165.9	112.6	.0[illegible]
7	1.045	0.012	1.057	0.79[illegible]	0.747	0.[illegible]	0.404	0.022	0.502	319.9	164.3	112.1	.0[illegible]
8	1.045	0.012	1.057	0.823	0.775	0.0[illegible]	0.404	0.015	0.520	319.9	167.7	112.1	.0[illegible]
9	1.04[illegible]	0.012	1.056	*****	*****	0.0[illegible]	0.405	0.00[illegible]	*****	319.7	*****	112.1	.0[illegible]7

MIXING STACK DATA, OPEN TO ATMOSPHERE

	X/D	0.5	1.0	1.5	2.0
[illegible] IN H2O		-0.330	-0.320	-0.[illegible]	-0.090
	EP TB	-0.[illegible]23	-0.014	-0.002	-0.[illegible]
[illegible]	DEG F	109.0	324.0	360.0	37[illegible].0
	THETA	0.429	0.590	0.613	0.626

Table II. Performance Data, Solid Wall Mixing Stack

DATA TAKEN ON 31 AUGUST BY E. D. WELCH *** HOT RIG PERFORMANCE ***
4 NOZZLES AM/AP=2.5 L/D=2.5 S/D=.5 TUPT=850 DEG F

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.12 INCHES
MIXING STACK L/D: 2.50

UPTAKE DIAMETER: 7.51 INCHES
AREA RATIO, AM/AP: 2.50

AMBIENT PRESSURE: 29.57 INCHES HG

N	PNP	DELPN	PP2	TUPT	TAMB	PU-PA	PA-PS	SECONDARY AREA	WPA	WPF
RUN	IN.HG	IN.H2O	H2	DEGREES	F.	INCHES OF WATER		SQUARE INCHES	LBM/SEC	
1	3.70	6.05	104.0	854.0	65.0	5.60	3.30	0.0	1.0342	0.0104
2	3.80	6.05	104.0	856.0	65.0	7.10	1.50	6.283	1.0357	0.0104
3	3.83	6.05	104.0	856.0	65.0	7.70	1.28	11.152	1.0361	0.0104
4	3.85	6.05	104.0	857.0	65.0	8.00	1.10	14.726	1.0364	0.0104
5	3.50	6.05	103.0	856.0	65.0	8.50	0.52	23.253	1.0371	0.0103
6	3.90	6.00	102.0	857.0	65.0	8.70	0.30	35.859	1.0330	0.0102
7	3.90	6.00	103.0	857.0	65.0	8.80	0.19	52.425	1.0330	0.0103
8	3.90	6.00	103.0	857.0	65.0	8.50	0.13	64.552	1.0330	0.0103
9	3.56	6.00	103.0	859.0	65.0	8.57	0.00	**********	1.0330	0.0103

N	W*	P*	T*	P*/T*	W*T**.44	WF	WS	UP	UM	UU	UPT MACH
RUN						LBM/SEC	LBM/SEC	FT/SEC	FT/SEC	FT/SEC	
1	0.0	0.1506	0.3994	0.3771	0.0	1.045	0.0	314.60	125.85	113.19	0.064
2	0.2893	0.0882	0.3988	0.2212	0.1530	1.046	0.303	314.52	140.23	113.13	0.064
3	0.4305	0.0618	0.3988	0.1549	0.2873	1.046	0.451	314.20	147.16	113.01	0.064
4	0.5056	0.0492	0.3985	0.1235	0.3373	1.047	0.529	314.31	150.96	113.05	0.064
5	0.6439	0.0233	0.3988	0.0585	0.4297	1.047	0.674	313.82	157.49	112.87	0.063
6	0.7111	0.0133	0.3985	0.0335	0.4744	1.043	0.742	312.60	160.42	112.44	0.063
7	0.7506	0.0086	0.3985	0.0216	0.5007	1.043	0.783	312.55	162.37	112.42	0.063
8	0.7667	0.0058	0.3985	0.0146	0.5115	1.043	0.800	312.50	163.15	112.40	0.063
9	********	0.0002	0.3979	0.0006	********	1.043	*******	312.88	******	112.54	0.063

MIXING STACK PRESSURE DISTRIBUTION FOR RUN: 9 POSITION A

X/D:	0.5	1.0	1.5	2.0
PMS(IN. H2O):	-0.540	-0.325	-0.050	-0.050
PMS*:	-0.024	-0.015	-0.002	-0.002
TMIX (DEG.F):	336.0	389.0	467.0	394.0
TMS*:	0.606	0.645	0.659	0.648

Table II. (Continued)

[illegible]

[illegible] TEST TAKEN BY [illegible] HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.511 INCHES
AREA RATIO [illegible]: 2.[illegible]0
GAMMA: 1.40

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.12[illegible] INCHES
MIXING STACK L/D: [illegible].50
STANDOFF RATIO: .5[illegible]
AMBIENT PRESSURE: 30.0[illegible] INCHES HG

#	[illegible] IN HG	[illegible] IN H2O	[illegible]	FRZ HZ	TUPT DEG F	TOUT DEG F	TAMB DEG F	[illegible] IN H2O	[illegible] IN H2O	SEC AREA SQ IN
1	[illegible]	[illegible]	[illegible]	[illegible]	157.0	164.0	61.0	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	0.0	157.0	170.0	[illegible]	6.30	2.65	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	15[illegible].0	[illegible]	67.0	[illegible]	1.[illegible]	11.197
4	[illegible]	[illegible]	[illegible]	[illegible]	15[illegible].0	[illegible]	[illegible]	[illegible]	1.[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	16[illegible].0	175.0	[illegible]	8.10	0.6[illegible]	27.2[illegible]3
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]6.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	0.0	[illegible]	[illegible]	70.0	8.65	[illegible]	52.[illegible]25
8	[illegible]	[illegible]	[illegible]	[illegible]	163.0	180.0	70.0	8.70	[illegible].13	64.952
9	[illegible]	[illegible]	[illegible]	0.0	172.0	18[illegible]	7[illegible].0	[illegible]	[illegible]	[illegible]

#	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TM	[illegible]	[illegible]	[illegible] FT/S	[illegible] FT/S	[illegible] FT/S	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.[illegible]	0.[illegible]46	[illegible]	[illegible]	[illegible]1.7	[illegible]	[illegible]	.[illegible]37
2	[illegible]	[illegible]	[illegible]	[illegible]	0.222	0.231	0.0[illegible]	0.276	0.215	22[illegible].1	1[illegible]7.1	7[illegible].4	[illegible]
3	1.[illegible]	[illegible]	[illegible]	[illegible]	0.332	0.168	[illegible]	[illegible]	[illegible]	[illegible]	114.9	7[illegible].4	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	0.3[illegible]	0.123	0.0[illegible]2	0.[illegible]2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]773	0.4[illegible]	0.0[illegible]1	[illegible]	[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.027	[illegible]	0.51[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]247	0.[illegible]	0.02[illegible]	[illegible]	[illegible]550	225.0	13[illegible].5	[illegible]	[illegible]
8	1.[illegible]7	[illegible]	1.[illegible]	[illegible]535	0.604	0.016	0.020	[illegible]	0.5[illegible]	[illegible]	1[illegible].1	7[illegible].4	[illegible]
9	1.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]	0.02[illegible]	[illegible].000	[illegible]	[illegible]7.[illegible]	[illegible]	7[illegible]	.[illegible]2

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	-[illegible]	-[illegible]13	-[illegible]10	-0.1[illegible]
	[illegible]	-[illegible]	-[illegible]	-0.[illegible]	-0.[illegible]4
TM[illegible]	[illegible]	[illegible]	1[illegible]	11[illegible]	116.0
	[illegible]	[illegible]	[illegible]77	[illegible]	0.[illegible]54

Table II (Continued)

[illegible]

DATE: [illegible]

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.511 INCHES
AREA RATIO, [illegible]: 2.50
GAMMA: 1.40

TESTS TAKEN BY [illegible] HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.12 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.09 INCHES HG

#	[illegible] IN HG	[illegible] IN HG	[illegible] DEG F	FNZ HZ	[illegible] DEG F	TSEC DEG F	TAMB DEG F	PO-PA IN H2O	PA-P IN H2O	SEC AREA SQ IN
1	[illegible]	[illegible]	[illegible]	[illegible]	152.0	164.0	63.0	4.23	5.96	0.0
2	[illegible]	[illegible]	[illegible]	0.0	157.0	170.0	65.0	6.30	2.65	6.253
3	[illegible]	[illegible]	[illegible]	0.0	151.0	162.0	67.0	7.55	1.77	11.197
4	[illegible]	[illegible]	[illegible]	[illegible]	150.0	160.0	[illegible]	7.63	1.42	15.726
5	[illegible]	[illegible]	[illegible]	[illegible]	165.0	175.0	68.0	8.10	0.65	27.253
6	[illegible]	[illegible]	[illegible]	0.0	166.0	170.0	69.0	8.50	0.61	39.859
7	[illegible]	[illegible]	[illegible]	0.0	166.0	179.0	70.0	8.65	0.26	52.429
8	[illegible]	[illegible]	[illegible]	0.0	163.0	180.0	70.0	8.70	0.15	64.992
9	[illegible]	[illegible]	[illegible]	0.0	172.0	184.0	73.0	9.00	0.03	******

#	[illegible] LB/S	[illegible] LB/S	[illegible] LB/S	WS LB/S	[illegible]	[illegible]	TX	[illegible]	[illegible]	[illegible] FT/S	[illegible] FT/S	[illegible] FT/S	[illegible]
1	[illegible]	[illegible]	[illegible]	[illegible]	0.0	[illegible]	[illegible]	[illegible]	0.0	221.7	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	0.222	0.231	[illegible]	0.276	0.215	220.1	107.1	75.4	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	0.332	0.168	0.847	0.196	[illegible]	224.5	114.9	75.4	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	0.384	0.123	0.842	0.152	[illegible]	226.4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	0.493	[illegible]	[illegible]	[illegible]	[illegible]	224.6	126.5	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.827	[illegible]	0.513	[illegible]	130.9	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.825	0.025	0.540	225.0	131.5	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	0.535	0.604	0.016	0.828	0.019	0.556	[illegible]	135.1	75.3	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	*****	0.003	0.823	0.000	*****	227.3	[illegible]	75.6	.0042

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.163
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.214
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	116.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.254

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Table II (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 550
1 DIFFUSER RING

DATE: 22 AUG 79 | DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.38

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.10 INCHES HG

NO	PAM IN HG	DELPN IN H2O	TPRM DEG F	FRZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.50	8.50	192.9	78.0	1438.0	548.0	73.0	4.50	3.90	0.0
2	4.90	8.50	192.2	60.0	1428.0	552.0	73.0	5.70	2.97	6.283
3	4.90	8.50	192.3	78.0	1405.0	552.0	73.0	6.50	2.33	11.192
4	4.90	8.50	192.4	75.0	1428.0	553.0	75.0	6.60	2.02	14.726
5	4.90	8.50	192.5	78.0	1445.0	548.0	75.0	7.50	1.05	27.293
6	4.90	8.50	192.5	78.0	1440.0	545.0	74.0	7.70	0.60	39.855
7	4.90	8.40	192.3	76.0	1433.0	552.0	74.0	7.70	0.39	52.425
8	4.90	8.40	191.9	77.0	1440.0	552.0	74.0	8.00	0.27	64.992
9	4.90	8.40	190.0	76.0	1412.0	552.0	76.0	8.40	0.00	******

NO	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.215	0.008	1.223	0.0	0.0	0.220	0.529	0.415	0.0	283.3	113.1	99.5	.0644
2	1.216	0.008	1.224	0.366	0.299	0.166	0.527	0.315	0.226	283.9	131.2	99.8	.0645
3	1.216	0.008	1.224	0.578	0.472	0.131	0.527	0.248	0.356	283.4	141.3	99.6	.0643
4	1.216	0.008	1.224	0.707	0.578	0.113	0.528	0.215	0.436	283.5	147.7	99.7	.0644
5	1.216	0.008	1.224	0.944	0.772	0.060	0.531	0.113	0.584	281.4	158.3	98.9	.0641
6	1.216	0.008	1.224	1.044	0.853	0.034	0.531	0.065	0.646	280.2	162.6	98.6	.0639
7	1.209	0.008	1.217	1.107	0.909	0.022	0.528	0.042	0.686	280.4	165.7	98.7	.0638
8	1.209	0.008	1.217	1.142	0.938	0.015	0.528	0.029	0.708	280.4	167.3	98.7	.0638
9	1.211	0.008	1.219	*****	*****	0.000	0.529	0.000	*****	280.7	*****	98.7	.0638

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	116.0	134.0	136.0	149.0	222.0		210.0		
TMS (POSITION B)	168.0	110.0	144.0	168.0	195.0		201.0		
SHROUD (POSIT A)	77.0		78.9			68.2		122.1	
SHROUD (POSIT B)	76.5		79.2			68.1		123.0	
RING 1 (POSIT A)								95.4	121.1
RING 1 (POSIT B)								94.9	122.5

Table III. Performance Data, Slotted and Shrouded Mixing Stack with One Diffuser Ring

*** HOT RIG PERFORMANCE *** TUPT: 550
1 DIFFUSER RING

DATE: 23 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.38

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.08 INCHES HG

NR	PRM IN HG	DELPN IN H2O	TPNM DEG F	FMZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SFC AREA SQ IN
1	4.90	7.90	150.0	76.0	1260.0	555.0	63.0	5.00	3.72	0.0
2	4.90	7.90	154.5	78.0	1289.0	553.0	63.0	5.10	2.87	6.283
3	4.90	7.90	155.6	78.0	1400.0	550.0	61.0	6.10	2.30	11.152
4	4.80	8.00	157.1	76.0	1364.0	550.0	61.0	6.50	2.01	14.726
5	4.70	8.00	158.5	75.0	1368.0	552.0	61.0	7.30	1.06	27.293
6	4.70	8.00	159.3	76.0	1345.0	550.0	61.0	7.70	0.62	39.859
7	4.70	8.00	160.4	76.0	1360.0	552.0	61.0	7.90	0.42	52.425
8	4.70	8.00	161.0	76.0	1330.0	555.0	61.0	8.10	0.29	64.992
9	4.80	8.00	163.8	76.0	1350.0	558.0	61.0	8.30	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.212	0.008	1.220	0.0	0.0	0.204	0.515	0.396	0.0	284.5	113.6	100.0	.0645
2	1.206	0.008	1.215	0.363	0.299	0.159	0.516	0.309	0.224	282.3	130.1	95.4	.0642
3	1.206	0.008	1.214	0.581	0.478	0.128	0.516	0.249	0.357	280.8	139.8	98.8	.0639
4	1.207	0.008	1.215	0.714	0.588	0.112	0.516	0.217	0.439	280.8	146.1	98.8	.0639
5	1.208	0.008	1.215	0.961	0.791	0.059	0.515	0.115	0.590	280.8	157.7	98.8	.0638
6	1.207	0.008	1.215	1.074	0.884	0.035	0.516	0.067	0.660	279.8	162.6	98.4	.0637
7	1.206	0.008	1.214	1.162	0.958	0.023	0.515	0.046	0.715	279.9	166.8	98.5	.0636
8	1.205	0.008	1.213	1.197	0.987	0.016	0.513	0.031	0.736	280.5	168.7	98.7	.0637
9	1.204	0.008	1.212	*****	*****	0.000	0.512	0.000	*****	280.9	*****	98.9	.0637

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	112.0	129.0	122.0	130.0	196.0		197.0		
TMS (POSITION B)	104.0	102.0	147.0	146.0	174.0		185.0		
SHROUD (POSIT A)	62.0		64.1			73.5		107.3	
SHROUD (POSIT B)	61.6		64.3			73.1		110.0	
RING 1 (POSIT A)								80.6	107.3
RING 1 (POSIT B)								81.1	109.6

Table III (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 650
1 DIFFUSER RING

DATE: 22 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.10 INCHES HG

NO	PRIM IN HG	DELPN IN H2O	TPRIM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	3.60	7.70	184.4	55.0	1410.0	662.0	75.0	5.00	3.68	0.0
2	3.70	7.70	184.9	56.0	1430.0	658.0	75.0	5.70	2.81	6.283
3	3.70	7.70	185.1	54.0	1450.0	656.0	75.0	6.20	2.22	11.192
4	3.70	7.70	185.5	55.0	1449.0	652.0	75.0	6.50	1.90	14.726
5	3.80	7.70	185.3	55.0	1450.0	652.0	75.0	7.40	0.99	27.253
6	3.80	7.70	185.8	55.0	1452.0	653.0	75.0	7.80	0.59	39.859
7	3.90	7.60	186.0	54.0	1450.0	645.0	75.0	8.10	0.40	52.425
8	3.90	7.60	186.2	55.0	1480.0	656.0	75.0	8.70	0.27	64.952
9	3.50	6.60	187.4	65.0	1476.0	646.0	77.0	8.50	0.00	******

NO	WPL LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.144	0.009	1.153	0.0	0.0	0.169	0.477	0.397	0.0	297.1	116.6	104.4	.0641
2	1.145	0.010	1.154	0.356	0.308	0.145	0.478	0.304	0.223	295.7	135.5	104.0	.0639
3	1.145	0.009	1.154	0.563	0.488	0.115	0.479	0.241	0.353	294.7	145.2	103.7	.0638
4	1.144	0.009	1.154	0.685	0.594	0.100	0.481	0.207	0.430	293.3	150.6	103.2	.0636
5	1.146	0.009	1.156	0.917	0.794	0.052	0.481	0.106	0.575	293.1	161.7	103.1	.0636
6	1.146	0.009	1.155	1.034	0.895	0.031	0.481	0.064	0.648	293.0	167.3	103.1	.0635
7	1.155	0.009	1.164	1.120	0.962	0.021	0.484	0.043	0.699	293.0	171.4	103.0	.0637
8	1.154	0.009	1.164	1.140	0.980	0.014	0.479	0.029	0.709	295.8	173.5	103.9	.0639
9	1.161	0.009	1.170	*****	*****	0.000	0.485	0.000	*****	294.4	*****	103.6	.0640

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	134.0	151.0	154.0	162.0	247.0		226.0		
TMS (POSITION B)	115.0	122.0	171.0	187.0	217.0		224.0		
SHROUD (POSIT A)	80.0		82.9			94.2		132.2	
SHROUD (POSIT B)	79.7		83.2			93.5		133.7	
RING 1 (POSIT A)								101.0	127.9
RING 1 (POSIT B)								102.1	133.0

Table III (Continued)

*** HOT RIG PERFORMANCE ***
1 DIFFUSER RING

TUPT: 650

DATE: 23 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AP/AP: 2.50
GAMMA: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.08 INCHES HG

NR	PIN IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.30	7.50	174.4	83.0	1338.0	650.0	63.0	5.10	3.60	0.0
2	4.30	7.50	174.2	83.0	1322.0	650.0	63.0	5.60	2.78	6.283
3	4.30	7.50	173.8	83.0	1319.0	650.0	63.0	6.20	2.22	11.192
4	4.40	7.50	173.6	83.0	1310.0	650.0	63.0	6.50	1.69	14.726
5	4.40	7.50	173.4	83.0	1340.0	650.0	63.0	7.40	0.98	27.253
6	4.40	7.50	172.7	83.0	1326.0	650.0	63.0	7.80	0.58	39.855
7	4.40	7.50	172.2	83.0	1321.0	651.0	63.0	8.00	0.37	52.425
8	4.40	7.50	171.7	83.0	1335.0	649.0	63.0	8.20	0.27	64.952
9	4.40	7.40	167.2	84.0	1330.0	652.0	62.0	8.30	0.00	******

NR	WPL LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.149	0.008	1.157	0.0	0.0	0.183	0.471	0.389	0.0	295.1	117.8	103.7	.0640
2	1.149	0.008	1.157	0.358	0.309	0.142	0.471	0.301	0.222	294.5	134.7	103.6	.0639
3	1.150	0.008	1.158	0.565	0.492	0.113	0.471	0.241	0.353	294.2	144.7	103.5	.0638
4	1.151	0.008	1.160	0.651	0.596	0.096	0.471	0.204	0.428	294.4	150.6	103.6	.0639
5	1.152	0.008	1.160	0.923	0.795	0.050	0.471	0.106	0.571	293.8	161.3	103.4	.0638
6	1.152	0.008	1.160	1.036	0.893	0.030	0.471	0.063	0.641	293.7	166.6	103.3	.0637
7	1.153	0.008	1.161	1.089	0.938	0.019	0.471	0.040	0.673	293.9	169.1	103.4	.0638
8	1.153	0.008	1.161	1.153	0.993	0.014	0.471	0.029	0.713	293.4	172.0	103.2	.0637
9	1.149	0.008	1.158	*****	*****	0.000	0.469	0.000	*****	293.2	*****	103.2	.0636

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	127.0	146.0	137.0	140.0	215.0		219.0		
TMS (POSITION B)	123.0	122.0	163.0	174.0	233.0		208.0		
SHROUD (POSIT A)	63.3		65.6			76.2		111.7	
SHROUD (POSIT B)	63.2		65.8			75.6		112.1	
RING 1 (POSIT A)								83.3	111.7
RING 1 (POSIT B)								84.0	118.2

Table III (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 750
1 DIFFUSER RING

DATE: 22 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, A/AP: 2.50
[illegible]: 1.37

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.10 INCHES HG

N	PSM IN HG	DELPM IN H2O	TPRM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	3.70	7.00	182.2	100.0	1465.0	753.0	74.0	5.30	3.52	0.0
2	3.70	7.00	182.0	100.0	1470.0	758.0	74.0	5.90	2.71	6.283
3	3.70	7.00	181.2	100.0	1462.0	755.0	74.0	6.40	2.15	11.192
4	3.70	7.00	181.0	100.0	1465.0	756.0	74.0	6.70	1.84	14.726
5	3.70	7.00	180.8	100.0	1460.0	753.0	74.0	7.50	0.95	27.293
6	3.70	7.00	180.5	100.0	1458.0	752.0	74.0	7.90	0.56	39.859
7	3.70	7.00	180.2	100.0	1460.0	758.0	74.0	8.10	0.37	52.425
8	3.60	7.00	180.3	100.0	1448.0	750.0	74.0	8.20	0.25	64.992
9	3.60	7.00	176.5	100.0	1435.0	750.0	72.0	8.50	0.00	******

N	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.095	0.010	1.105	0.0	0.0	0.168	0.440	0.382	0.0	307.6	122.8	108.1	.0640
2	1.095	0.010	1.105	0.350	0.316	0.129	0.438	0.294	0.220	308.3	140.1	108.4	.0641
3	1.096	0.010	1.106	0.555	0.502	0.103	0.439	0.234	0.349	307.3	149.7	108.0	.0639
4	1.096	0.010	1.106	0.675	0.611	0.088	0.439	0.200	0.425	307.3	155.6	108.1	.0639
5	1.096	0.010	1.106	0.899	0.813	0.046	0.440	0.104	0.567	305.9	165.5	107.6	.0637
6	1.096	0.010	1.106	1.008	0.912	0.027	0.440	0.061	0.635	305.5	170.9	107.4	.0637
7	1.096	0.010	1.106	1.076	0.974	0.018	0.438	0.040	0.678	306.9	174.8	108.0	.0638
8	1.095	0.010	1.105	1.098	0.994	0.012	0.441	0.027	0.694	304.3	174.8	107.1	.0635
9	1.101	0.010	1.111	*****	*****	0.000	0.440	0.000	*****	305.9	*****	107.6	.0638

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	152.0	174.0	178.0	166.0	248.0		252.0		
TMS (POSITION B)	120.0	128.0	202.0	217.0	246.0		242.0		
SHROUD (POSIT A)	81.2		83.9			96.4		136.2	
SHROUD (POSIT B)	80.4		84.2			95.5		132.4	
RING 1 (POSIT A)								103.5	132.3
RING 1 (POSIT B)								103.6	142.0

Table III (Continued)

*** HOT RIG PERFORMANCE ***
1 DIFFUSER RING

TUPT: 750

DATE: 23 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.37

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.08 INCHES HG

NR	PNM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.50	6.90	178.8	100.0	1354.0	746.0	61.0	6.30	3.42	0.0
2	4.40	7.00	179.0	100.0	1360.0	748.0	61.0	6.90	2.59	6.283
3	4.40	7.00	175.1	55.0	1352.0	749.0	61.0	7.20	2.10	11.152
4	4.30	7.00	179.0	99.0	1355.0	751.0	61.0	7.50	1.79	14.726
5	4.30	7.00	175.1	96.0	1348.0	751.0	61.0	8.40	0.91	27.293
6	4.40	7.00	175.3	98.0	1349.0	752.0	61.0	8.70	0.54	39.859
7	4.40	7.00	175.8	98.0	1352.0	750.0	61.0	8.80	0.36	52.425
8	4.40	7.00	180.1	96.0	1348.0	752.0	61.0	9.00	0.26	64.992
9	4.40	7.00	180.1	98.0	1346.0	749.0	61.0	9.20	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.102	0.010	1.112	0.0	0.0	0.159	0.432	0.369	0.0	308.0	123.0	108.0	.0641
2	1.108	0.010	1.118	0.346	0.309	0.119	0.431	0.276	0.214	309.5	140.1	108.6	.0644
3	1.108	0.010	1.118	0.555	0.496	0.097	0.431	0.224	0.343	309.4	149.9	108.6	.0644
4	1.107	0.010	1.117	0.674	0.604	0.082	0.430	0.191	0.416	309.2	155.5	108.5	.0643
5	1.107	0.010	1.116	0.851	0.798	0.042	0.430	0.098	0.550	308.5	165.4	108.3	.0642
6	1.108	0.010	1.118	1.002	0.896	0.025	0.430	0.058	0.618	308.9	170.8	108.4	.0642
7	1.106	0.010	1.117	1.076	0.963	0.017	0.430	0.039	0.665	308.1	174.0	108.2	.0642
8	1.107	0.010	1.117	1.134	1.015	0.012	0.430	0.028	0.700	308.5	176.9	108.3	.0642
9	1.107	0.010	1.117	*****	*****	0.000	0.431	0.000	*****	307.5	*****	108.0	.0641

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	149.0	166.0	173.0	154.0	242.0		248.0		
TMS (POSITION B)	122.0	125.0	165.0	219.0	237.0		239.0		
SHROUD (POSIT A)	67.3		70.0			82.4		120.7	
SHROUD (POSIT B)	66.6		71.0			82.2		121.0	
RING 1 (POSIT A)								99.3	114.0
RING 1 (POSIT B)								100.1	126.1

Table III (Continued)

*** HOT RIG PERFORMANCE ***
1 DIFFUSER RING

TUPT: 850

DATE: 22 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.10 INCHES HG

NR	PNM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.20	6.20	160.2	109.0	1266.0	848.0	70.0	6.10	3.42	0.0
2	4.20	6.20	160.6	108.0	1284.0	850.0	70.0	6.90	2.65	6.283
3	4.20	6.20	162.6	107.0	1285.0	852.0	70.0	7.40	2.10	11.192
4	4.20	6.20	163.2	107.0	1293.0	853.0	70.0	7.70	1.78	14.726
5	4.30	6.20	163.9	107.0	1265.0	849.0	70.0	8.50	0.90	27.293
6	4.30	6.20	164.6	105.0	1249.0	846.0	70.0	8.80	0.53	39.859
7	4.30	6.20	165.0	104.0	1244.0	848.0	70.0	8.90	0.35	52.425
8	4.30	6.30	165.9	104.0	1252.0	847.0	70.0	9.00	0.24	64.992
9	4.40	6.30	168.4	106.0	1282.0	852.0	71.0	9.00	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.057	0.011	1.068	0.0	0.0	0.149	0.405	0.369	0.0	320.4	127.9	112.4	.0643
2	1.056	0.011	1.067	0.347	0.325	0.116	0.404	0.286	0.218	320.1	144.6	112.3	.0642
3	1.055	0.011	1.065	0.550	0.517	0.092	0.404	0.228	0.347	319.7	154.3	112.2	.0641
4	1.054	0.011	1.065	0.667	0.626	0.078	0.404	0.193	0.420	319.6	159.8	112.1	.0641
5	1.055	0.011	1.066	0.879	0.824	0.040	0.405	0.098	0.554	318.2	169.4	111.7	.0639
6	1.055	0.010	1.065	0.985	0.924	0.024	0.406	0.058	0.622	316.9	174.0	111.2	.0637
7	1.054	0.010	1.065	1.052	0.988	0.015	0.405	0.038	0.664	317.1	177.3	111.3	.0637
8	1.062	0.010	1.072	1.080	1.008	0.010	0.405	0.026	0.677	319.1	179.4	112.0	.0641
9	1.061	0.010	1.072	*****	*****	0.000	0.405	0.000	*****	320.0	*****	112.4	.0642

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	176.0	206.0	214.0	177.0	264.0		254.0		
TMS (POSITION B)	124.0	128.0	229.0	245.0	265.0		266.0		
SHROUD (POSIT A)	81.8		85.6			99.3		138.4	
SHROUD (POSIT B)	81.7		86.0			98.2		138.2	
RING 1 (POSIT A)								103.5	134.1
RING 1 (POSIT B)								110.4	144.2

Table III (Continued)

*** HOT RIG PERFORMANCE ***
1 DIFFUSER RING

TUPT: 850

DATE: 23 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.08 INCHES HG

NR	PNM IN HG	DELPN IN H2O	TPNM DEG F	FMZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.30	6.30	181.8	105.0	1292.0	656.0	61.0	6.30	3.32	0.0
2	4.30	6.30	182.0	102.0	1286.0	860.0	61.0	6.90	2.59	6.283
3	4.30	6.40	182.0	102.0	1280.0	852.0	61.0	7.40	2.09	11.152
4	4.30	6.40	181.7	102.0	1281.0	860.0	61.0	7.70	1.75	14.726
5	4.40	6.30	181.6	101.0	1280.0	860.0	61.0	8.50	0.89	27.293
6	4.40	6.30	182.0	101.0	1293.0	858.0	61.0	8.80	0.53	39.859
7	4.40	6.40	182.6	99.0	1296.0	652.0	61.0	8.90	0.34	52.425
8	4.40	6.40	183.0	101.0	1294.0	860.0	62.0	9.10	0.26	64.992
9	4.60	6.30	180.1	100.0	1280.0	856.0	61.0	9.60	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.049	0.010	1.059	0.0	0.0	0.143	0.396	0.362	0.0	319.9	127.7	112.2	.0640
2	1.048	0.010	1.059	0.346	0.327	0.111	0.395	0.282	0.217	320.2	144.3	112.3	.0640
3	1.057	0.010	1.067	0.554	0.519	0.090	0.397	0.226	0.346	320.3	154.2	112.4	.0642
4	1.057	0.010	1.067	0.666	0.625	0.074	0.395	0.188	0.415	322.1	160.3	113.0	.0644
5	1.050	0.010	1.063	0.881	0.831	0.038	0.395	0.097	0.552	319.4	169.3	112.1	.0639
6	1.050	0.010	1.060	0.993	0.937	0.023	0.395	0.058	0.622	318.5	174.2	111.8	.0638
7	1.058	0.010	1.067	1.046	0.980	0.015	0.397	0.037	0.652	319.1	177.0	112.0	.0640
8	1.057	0.010	1.067	1.133	1.061	0.011	0.395	0.028	0.705	321.0	181.9	112.7	.0642
9	1.054	0.010	1.064	*****	*****	0.000	0.396	0.000	*****	318.9	*****	111.9	.0638

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.50
TMS (POSITION A)	164.0	176.0	194.0	164.0	265.0		256.0		
TMS (POSITION B)	119.0	124.0	201.0	245.0	267.0		262.0		
SHROUD (POSIT A)	65.6		73.0			86.2		125.2	
SHROUD (POSIT B)	65.6		72.9			85.8		124.8	
RING 1 (POSIT A)								109.4	121.6
RING 1 (POSIT B)								110.2	128.9

Table III (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 550
2 DIFFUSER RING

DATE: 17 AUG 79 — DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.33

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.06 INCHES HG

NR	PAM IN HG	DELPA IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	10.60	7.20	190.0	73.0	1012.0	556.0	72.0	6.30	3.15	0.0
2	10.60	7.20	190.0	73.0	1022.0	558.0	72.0	7.00	2.42	6.283
3	10.60	7.20	190.0	73.0	1015.0	558.0	72.0	7.40	1.97	11.192
4	10.60	7.20	190.1	73.0	1018.0	556.0	72.0	7.70	1.67	14.726
5	10.70	7.20	190.0	73.0	1022.0	559.0	72.0	8.30	0.95	27.293
6	10.70	7.20	190.4	73.0	1015.0	556.0	72.0	8.70	0.58	39.859
7	10.70	7.20	190.8	73.0	1006.0	558.0	72.0	8.90	0.39	52.425
8	10.70	7.20	190.8	73.0	1020.0	558.0	72.0	9.00	0.27	64.992
9	10.70	7.20	191.4	73.0	1014.0	559.0	72.0	9.20	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UL FT/S	UMACH
1	1.209	0.007	1.216	0.0	0.0	0.176	0.523	0.337	0.0	283.6	113.2	95.5	.0642
2	1.209	0.007	1.216	0.331	0.272	0.135	0.522	0.259	0.204	283.7	129.4	99.5	.0641
3	1.209	0.007	1.216	0.532	0.437	0.110	0.522	0.211	0.329	283.4	139.0	99.4	.0641
4	1.209	0.007	1.216	0.644	0.530	0.094	0.523	0.179	0.398	282.6	144.1	99.2	.0639
5	1.210	0.007	1.217	0.900	0.740	0.053	0.522	0.102	0.556	283.3	156.7	99.5	.0640
6	1.210	0.007	1.217	1.027	0.844	0.033	0.523	0.062	0.635	282.1	162.4	99.0	.0639
7	1.209	0.007	1.217	1.108	0.911	0.022	0.522	0.042	0.684	282.4	166.4	99.2	.0639
8	1.209	0.007	1.217	1.143	0.939	0.015	0.522	0.029	0.706	282.4	168.1	99.1	.0639
9	1.209	0.007	1.216	*****	*****	0.000	0.522	0.000	*****	282.3	*****	99.1	.0638

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	71.0	146.0	******	136.0	175.0		198.0			
TMS (POSITION B)	******	124.0	154.0	185.0	198.0		198.0			
SHROUD (POSIT A)	75.0		78.3			92.4		124.5		
SHROUD (POSIT B)	74.8		78.6			92.3		125.0		
RING 1 (POSIT A)								91.2	108.4	
RING 1 (POSIT B)								89.1	104.6	
RING 2 (POSIT A)									113.7	100.4
RING 2 (POSIT B)									98.4	111.3

Table IV. Performance Data, Slotted and Shrouded Mixing Stack with Two Diffuser Rings

*** HOT RIG PERFORMANCE *** TUPT: 550
2 DIFFUSER RING

DATE: 18 AUG 79

DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.38

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.03 INCHES HG

NR	PNH IN HG	DELPN IN H2O	TPNH DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	3.40	8.70	195.4	78.0	1292.0	557.0	70.0	5.30	3.32	0.0
2	3.40	8.70	195.4	78.0	1296.0	557.0	70.0	6.00	2.50	6.283
3	3.40	8.60	195.4	78.0	1262.0	552.0	70.0	6.30	2.10	11.192
4	3.50	8.70	195.3	78.0	1263.0	555.0	70.0	6.60	1.75	14.726
5	3.50	8.80	195.3	76.0	1264.0	549.0	70.0	7.40	0.97	27.293
6	3.60	8.80	195.3	76.0	1264.0	550.0	70.0	7.80	0.62	39.859
7	3.60	9.00	195.3	75.0	1222.0	548.0	70.0	8.10	0.42	52.425
8	3.70	9.00	195.2	75.0	1236.0	542.0	70.0	8.30	0.31	64.992
9	3.70	9.00	194.0	75.0	1228.0	541.0	69.0	8.30	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UL FT/S	UMACH
1	1.200	0.008	1.208	0.0	0.0	0.187	0.521	0.359	0.0	282.4	112.7	99.3	.0640
2	1.200	0.008	1.208	0.337	0.279	0.141	0.521	0.271	0.209	281.8	128.8	99.1	.0639
3	1.207	0.008	1.214	0.550	0.453	0.119	0.524	0.227	0.340	281.7	139.1	99.1	.0640
4	1.202	0.008	1.209	0.660	0.546	0.099	0.522	0.190	0.410	281.2	144.2	98.9	.0638
5	1.208	0.008	1.216	0.911	0.749	0.055	0.525	0.105	0.564	280.5	156.0	98.7	.0639
6	1.210	0.008	1.218	1.064	0.873	0.035	0.525	0.067	0.658	280.9	163.5	98.8	.0639
7	1.224	0.008	1.231	1.151	0.935	0.023	0.526	0.044	0.705	283.3	168.7	99.6	.0645
8	1.226	0.008	1.233	1.226	0.995	0.017	0.529	0.033	0.751	282.0	171.8	99.1	.0644
9	1.227	0.008	1.234	*****	*****	0.000	0.528	0.000	*****	281.7	*****	99.1	.0644

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/C	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	113.0	128.0	156.0	142.0	218.0		210.0			
TMS (POSITION B)	******	129.0	146.0	170.0	198.0		195.0			
SHROUD (POSIT A)	73.0		76.0			91.7		130.1		
SHROUD (POSIT B)	72.9		77.0			92.1		131.2		
RING 1 (POSIT A)								91.3	111.1	
RING 1 (POSIT B)								89.9	110.6	
RING 2 (POSIT A)									115.2	99.1
RING 2 (POSIT B)									97.0	110.4

Table IV. (continued)

*** HOT RIG PERFORMANCE *** TUPT: 650
2 DIFFUSER RING

DATE: 17 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.38

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.06 INCHES HG

NR	PNM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	5.00	7.80	192.7	80.0	1166.0	642.0	72.0	7.60	3.15	0.0
2	5.00	7.80	192.8	80.0	1168.0	644.0	72.0	7.70	2.41	6.283
3	5.00	7.80	193.2	81.0	1175.0	646.0	72.0	8.10	1.94	11.192
4	5.00	7.80	193.0	80.0	1172.0	645.0	72.0	8.40	1.65	14.726
5	5.10	7.80	193.0	80.0	1170.0	644.0	72.0	9.10	0.91	27.293
6	5.10	7.80	192.9	80.0	1170.0	645.0	72.0	9.40	0.55	39.859
7	5.10	7.80	192.9	81.0	1172.0	645.0	72.0	9.60	0.37	52.425
8	5.10	7.80	192.5	81.0	1178.0	649.0	72.0	9.70	0.26	64.992
9	5.10	7.80	193.1	81.0	1190.0	651.0	72.0	9.90	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.166	0.008	1.174	0.0	0.0	0.161	0.483	0.333	0.0	297.1	118.6	103.9	.0643
2	1.166	0.008	1.174	0.330	0.281	0.123	0.482	0.255	0.204	297.1	134.7	104.1	.0644
3	1.166	0.008	1.174	0.528	0.449	0.099	0.481	0.205	0.326	297.2	144.3	104.1	.0644
4	1.166	0.008	1.174	0.640	0.545	0.084	0.481	0.175	0.395	296.8	149.6	104.0	.0643
5	1.168	0.008	1.176	0.881	0.749	0.046	0.482	0.096	0.543	296.4	161.0	103.9	.0642
6	1.168	0.008	1.176	1.000	0.851	0.028	0.481	0.058	0.617	296.4	166.8	103.9	.0642
7	1.168	0.008	1.176	1.079	0.918	0.019	0.481	0.039	0.665	296.3	170.5	103.8	.0642
8	1.168	0.008	1.176	1.122	0.954	0.013	0.480	0.027	0.690	297.4	173.0	104.2	.0643
9	1.168	0.008	1.176	*****	*****	0.000	0.479	0.000	*****	297.6	*****	104.3	.0643

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	71.0	154.0	165.0	140.0	220.0		214.0			
TMS (POSITION B)	******	125.0	168.0	210.0	221.0		218.0			
SHROUD (POSIT A)	75.5		79.5			95.5		132.5		
SHROUD (POSIT B)	75.5		80.2			95.8		129.3		
RING 1 (POSIT A)								94.5	114.2	
RING 1 (POSIT B)								92.5	114.6	
RING 2 (POSIT A)									119.9	104.5
RING 2 (POSIT B)									103.0	116.9

Table IV. (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 650
2 DIFFUSER RING

DATE: 18 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
STRIKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.33

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.06 INCHES HG

NO	PPM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TAURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	5.10	7.50	184.6	83.0	1271.0	647.0	67.0	5.60	3.29	0.0
2	5.10	7.50	134.2	83.0	1271.0	647.0	67.0	6.30	2.50	6.283
3	5.10	7.50	184.4	83.0	1272.0	649.0	67.0	6.70	2.04	11.192
4	5.20	7.60	194.2	83.0	1272.0	648.0	68.0	6.90	1.74	14.726
5	5.20	7.60	134.2	83.0	1272.0	645.0	66.0	7.60	0.94	27.293
6	5.20	7.60	163.6	83.0	1274.0	646.0	68.0	8.00	0.60	39.859
7	5.20	7.60	133.6	83.0	1272.0	647.0	66.0	8.20	0.36	52.425
8	5.20	7.60	183.3	83.0	1281.0	647.0	66.0	8.30	0.25	64.992
9	5.20	7.50	182.1	83.0	1278.0	650.0	67.0	8.40	0.00	******

NO	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.153	0.008	1.161	0.0	0.0	0.169	0.476	0.354	0.0	295.2	117.9	103.7	.0641
2	1.153	0.008	1.161	0.338	0.291	0.128	0.476	0.270	0.210	294.7	133.9	103.6	.0640
3	1.153	0.008	1.161	0.544	0.468	0.104	0.475	0.220	0.337	294.9	143.9	103.6	.0640
4	1.162	0.008	1.170	0.660	0.564	0.088	0.476	0.185	0.407	296.7	150.3	104.3	.0644
5	1.162	0.008	1.170	0.899	0.768	0.048	0.478	0.100	0.555	295.4	161.2	103.9	.0642
6	1.163	0.008	1.171	1.049	0.896	0.031	0.477	0.064	0.647	295.5	168.4	103.9	.0642
7	1.163	0.008	1.171	1.069	0.913	0.018	0.477	0.038	0.659	295.6	169.4	104.0	.0642
8	1.163	0.008	1.171	1.104	0.943	0.013	0.477	0.027	0.680	295.6	171.0	104.0	.0642
9	1.156	0.008	1.165	*****	*****	0.000	0.475	0.000	*****	294.6	*****	103.6	.0639

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	66.0	141.0	156.0	143.0	225.0		213.0			
TMS (POSITION B)	******	123.0	163.0	188.0	216.0		208.0			
SHROUD (POSIT A)	71.4		75.4			93.0		135.7		
SHROUD (POSIT B)	71.3		75.6			92.4		134.1		
RING 1 (POSIT A)								93.2	114.8	
RING 1 (POSIT B)								90.6	115.2	
RING 2 (POSIT A)									118.2	101.7
RING 2 (POSIT B)									100.3	117.0

Table IV. (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 750
2 DIFFUSER RING

DATE: 17 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.37

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.08 INCHES HG

NR	PAM IN HG	DELPN IN H2O	TPMH DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.70	7.10	186.6	102.0	1281.0	750.0	73.0	7.00	3.16	0.0
2	4.80	7.03	186.1	103.0	1288.0	749.0	73.0	7.10	2.38	6.283
3	4.90	7.00	186.0	103.0	1286.0	747.0	73.0	8.10	1.91	11.192
4	4.50	7.00	186.3	103.0	1277.0	746.0	73.0	8.80	1.64	14.726
5	4.90	7.00	186.0	103.0	1286.0	750.0	73.0	9.00	0.89	27.293
6	4.50	7.00	186.0	103.0	1275.0	748.0	73.0	9.40	0.55	39.859
7	4.50	7.00	186.0	102.0	1274.0	741.0	73.0	9.50	0.36	52.425
8	4.90	7.00	186.0	102.0	1266.0	745.0	73.0	9.60	0.26	64.992
9	4.70	7.00	179.6	99.0	1215.0	745.0	72.0	9.70	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.114	0.010	1.124	0.0	0.0	0.146	0.440	0.332	0.0	312.2	124.6	105.4	.0648
2	1.109	0.010	1.119	0.328	0.293	0.112	0.441	0.254	0.204	309.8	139.6	108.7	.0645
3	1.110	0.010	1.120	0.523	0.467	0.090	0.441	0.203	0.326	309.4	149.0	108.4	.0644
4	1.110	0.010	1.120	0.638	0.569	0.077	0.442	0.175	0.398	308.8	154.3	108.1	.0642
5	1.110	0.010	1.120	0.871	0.777	0.042	0.440	0.095	0.542	309.4	165.8	108.4	.0643
6	1.110	0.010	1.120	1.000	0.892	0.026	0.441	0.059	0.622	308.6	171.7	108.2	.0642
7	1.110	0.010	1.120	1.064	0.950	0.017	0.444	0.039	0.664	306.6	174.0	107.5	.0640
8	1.110	0.010	1.120	1.121	1.001	0.012	0.442	0.028	0.699	307.6	177.1	107.8	.0641
9	1.112	0.010	1.122	*****	*****	0.000	0.441	0.000	*****	307.9	*****	108.0	.0642

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	151.0	194.0	******	154.0	261.0		235.0			
TMS (POSITION B)	138.0	132.0	202.0	236.0	250.0		242.0			
SHROUD (POSIT A)	81.2		87.3			108.3		154.9		
SHROUD (POSIT B)	80.9		87.5			107.4		156.1		
RING 1 (POSIT A)								105.1	128.8	
RING 1 (POSIT B)								100.9	128.4	
RING 2 (POSIT A)									133.0	114.4
RING 2 (POSIT B)									112.0	130.9

Table IV. (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 750
2 DIFFUSER RING

DATE: 18 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.37

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.03 INCHES HG

NR	PNM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.00	6.80	162.2	95.0	1288.0	744.0	66.0	5.90	3.12	0.0
2	4.00	6.80	163.2	96.0	1284.0	743.0	66.0	6.60	2.32	6.283
3	4.00	6.80	164.0	96.0	1296.0	744.0	66.0	7.00	1.87	11.192
4	4.10	6.80	165.2	95.0	1298.0	744.0	66.0	7.20	1.59	14.726
5	4.10	6.80	165.8	95.0	1299.0	745.0	66.0	7.90	0.86	27.293
6	4.60	6.70	166.7	96.0	1265.0	757.0	66.0	9.00	0.53	39.859
7	4.60	6.70	167.5	96.0	1260.0	756.0	66.0	9.60	0.35	52.425
8	4.80	6.80	169.3	95.0	1253.0	746.0	66.0	9.60	0.25	64.992
9	4.60	6.80	171.1	96.0	1271.0	748.0	66.0	9.80	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.100	0.009	1.109	0.0	0.0	0.148	0.437	0.338	0.0	307.0	122.6	107.8	.0641
2	1.099	0.010	1.109	0.326	0.294	0.110	0.437	0.253	0.204	305.9	137.8	107.5	.0639
3	1.096	0.010	1.108	0.521	0.470	0.089	0.437	0.204	0.326	305.6	147.1	107.4	.0638
4	1.099	0.009	1.108	0.632	0.570	0.076	0.437	0.173	0.396	305.5	152.3	107.4	.0638
5	1.098	0.009	1.108	0.861	0.777	0.041	0.436	0.094	0.540	305.1	163.1	107.2	.0637
6	1.097	0.010	1.107	0.987	0.892	0.025	0.432	0.057	0.616	307.7	170.2	107.9	.0638
7	1.097	0.010	1.106	1.055	0.954	0.016	0.432	0.038	0.660	307.1	173.2	107.6	.0637
8	1.106	0.009	1.116	1.105	0.991	0.012	0.436	0.027	0.688	307.1	175.6	107.7	.0639
9	1.105	0.010	1.114	*****	*****	0.000	0.435	0.000	*****	307.0	*****	107.6	.0639

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	68.0	174.0	132.0	140.0	242.0		222.0			
TMS (POSITION B)	******	124.0	190.0	222.0	236.0		232.0			
SHROUD (POSIT A)	73.2		78.3			97.0		140.2		
SHROUD (POSIT B)	73.4		78.9			97.0		141.3		
RING 1 (POSIT A)								94.2	116.0	
RING 1 (POSIT B)								90.9	115.8	
RING 2 (POSIT A)									121.8	104.8
RING 2 (POSIT B)									102.2	119.5

Table IV. (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 850
2 DIFFUSER RING

DATE: 17 AUG 79

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.30
GAMMA: 1.36

DATA TAKEN BY J A HILL

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.13 INCHES HG

NO	PUM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TBURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.30	6.20	156.9	117.0	1205.0	842.0	68.0	6.40	3.10	0.0
2	4.20	6.30	163.9	114.0	1246.0	844.0	67.0	6.70	2.70	6.283
3	4.20	6.30	163.5	113.0	1225.0	843.0	67.0	7.10	2.20	11.192
4	4.30	6.20	166.0	114.0	1245.0	860.0	68.0	7.80	1.55	14.726
5	4.30	6.20	167.0	115.0	1240.0	862.0	68.0	8.30	0.88	27.293
6	5.50	5.90	171.9	124.0	1180.0	887.0	71.0	10.50	0.53	39.859
7	5.60	6.10	173.1	122.0	1156.0	857.0	71.0	10.80	0.36	52.425
8	5.70	6.60	173.2	122.0	1172.0	675.0	71.0	11.20	0.26	64.992
9	5.70	6.20	175.0	122.0	1222.0	850.0	71.0	11.40	0.00	******

NO	WCA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.062	0.012	1.073	0.0	0.0	0.135	0.405	0.333	0.0	320.0	127.8	112.3	.0644
2	1.062	0.011	1.074	0.351	0.327	0.117	0.404	0.290	0.220	320.4	144.8	112.4	.0645
3	1.062	0.011	1.074	0.565	0.526	0.096	0.404	0.237	0.353	319.7	154.8	112.2	.0644
4	1.054	0.011	1.065	0.624	0.585	0.067	0.400	0.167	0.391	320.9	158.1	112.6	.0642
5	1.053	0.011	1.064	0.871	0.818	0.038	0.399	0.095	0.546	320.6	169.8	112.6	.0641
6	1.041	0.012	1.053	0.984	0.934	0.023	0.394	0.058	0.620	323.0	176.4	112.9	.0637
7	1.059	0.012	1.071	1.067	0.996	0.01	0.403	0.039	0.668	320.9	179.5	112.2	.0640
8	1.052	0.012	1.064	1.124	1.057	0.011	0.398	0.028	0.704	323.0	183.1	112.8	.0639
9	1.067	0.012	1.079	*****	*****	0.000	0.405	0.000	*****	321.4	*****	112.3	.0642

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	173.0	195.0	215.0	166.0	292.0		248.0			
TMS (POSITION B)	122.0	127.0	208.0	256.0	266.0		269.0			
SHROUD (POSIT A)	60.5		85.5			106.4		153.0		
SHROUD (POSIT B)	80.1		86.5			106.5		153.9		
RING 1 (POSIT A)								103.9	129.3	
RING 1 (POSIT B)								100.2	130.9	
RING 2 (POSIT A)									135.7	116.0
RING 2 (POSIT B)									114.9	134.0

Table IV. (Continued)

*** HOT RIG PERFORMANCE *** TUPT: 850
2 DIFFUSER RING

DATE: 18 AUG 79 DATA TAKEN BY J A HILL

NUMBER OF PRIMARY NOZZLES: 4
PRIMARY NOZZLE DIAMETER: 2.25 INCHES
UPTAKE DIAMETER: 7.510 INCHES
AREA RATIO, AM/AP: 2.50
GAMMA: 1.36

MIXING STACK LENGTH: 17.81 INCHES
MIXING STACK DIAMETER: 7.122 INCHES
MIXING STACK L/D: 2.50
STANDOFF RATIO: .50
AMBIENT PRESSURE: 30.03 INCHES HG

NR	PPM IN HG	DELPN IN H2O	TPNM DEG F	FHZ HZ	TAURN DEG F	TUPT DEG F	TAMB DEG F	PU-PA IN H2O	PA-PS IN H2O	SEC AREA SQ IN
1	4.10	6.50	190.2	103.0	1226.0	851.0	70.0	6.30	3.03	0.0
2	4.10	6.50	190.2	103.0	1225.0	846.0	70.0	6.50	2.30	6.283
3	4.10	6.50	185.8	103.0	1221.0	851.0	70.0	7.30	1.84	11.192
4	4.10	6.40	190.8	103.0	1227.0	851.0	70.0	7.50	1.55	14.726
5	4.20	6.40	190.5	103.0	1221.0	848.0	70.0	8.20	0.86	27.293
6	4.30	6.50	190.6	103.0	1227.0	847.0	70.0	8.60	0.53	35.859
7	4.30	6.50	190.2	103.0	1240.0	850.0	70.0	8.80	0.36	52.425
8	4.30	6.50	191.4	103.0	1234.0	852.0	70.0	8.80	0.25	64.992
9	4.30	6.50	191.4	104.0	1226.0	858.0	70.0	9.20	0.00	******

NR	WPA LBM/S	WF LBM/S	WP LBM/S	WS LBM/S	W*	P*	T*	P*/T*	W*T**.44	UP FT/S	UM FT/S	UU FT/S	UMACH
1	1.054	0.010	1.064	0.0	0.0	0.132	0.404	0.328	0.0	320.7	128.0	112.5	.0643
2	1.054	0.010	1.064	0.323	0.303	0.101	0.406	0.250	0.204	318.9	143.0	111.9	.0641
3	1.055	0.010	1.065	0.514	0.483	0.081	0.404	0.199	0.324	319.8	152.6	112.3	.0642
4	1.046	0.010	1.056	0.621	0.588	0.069	0.404	0.171	0.395	317.0	156.6	111.3	.0636
5	1.047	0.010	1.058	0.858	0.811	0.038	0.405	0.095	0.545	316.2	167.7	111.1	.0636
6	1.057	0.010	1.067	0.983	0.922	0.023	0.405	0.058	0.619	318.5	174.7	111.9	.0641
7	1.057	0.010	1.067	1.066	0.999	[illegible]	0.404	0.035	0.671	319.2	178.5	112.1	.0641
8	1.056	0.010	1.067	1.101	1.033	0.011	0.404	0.027	0.693	319.3	180.7	112.2	.0641
9	1.056	0.010	1.067	*****	*****	0.000	0.402	0.000	*****	320.6	*****	112.6	.0642

MIXING STACK TEMPERATURES (DEG F), OPEN TO ATMOSPHERE

X/D	0.50	0.75	1.00	1.20	1.40	1.50	1.60	2.00	2.25	2.50
TMS (POSITION A)	142.0	180.0	194.0	156.0	286.0		269.0			
TMS (POSITION B)	******	112.0	206.0	250.0	272.0		266.0			
SHROUD (POSIT A)	76.8		81.8			104.0		156.7		
SHROUD (POSIT B)	76.3		82.1			103.5		157.9		
RING 1 (POSIT A)								103.3	130.4	
RING 1 (POSIT B)								99.6	131.7	
RING 2 (POSIT A)									127.2	115.8
RING 2 (POSIT B)									113.2	134.0

Table IV. (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 866.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	449.0	398.0	0.685	0.647
0.25	452.0	432.0	0.688	0.673
0.50	468.0	446.0	0.700	0.685
0.75	485.0	454.0	0.713	0.689
1.00	496.0	466.0	0.721	0.698
1.25	511.0	480.0	0.732	0.709
1.50	526.0	492.0	0.744	0.718
1.75	542.0	510.0	0.756	0.731
2.00	556.0	526.0	0.766	0.744
2.25	570.0	544.0	0.777	0.757
2.50	579.0	557.0	0.784	0.767
2.75	588.0	573.0	0.790	0.779
3.00	597.0	585.0	0.797	0.788
3.25	601.0	596.0	0.800	0.796
3.50	604.0	604.0	0.802	0.802
3.75	603.0	607.0	0.802	0.805
4.00	596.0	602.0	0.798	0.801
4.25	590.0	593.0	0.790	0.794
4.50	576.0	587.0	0.781	0.790
4.75	564.0	577.0	0.772	0.782
5.00	552.0	567.0	0.763	0.774
5.25	539.0	553.0	0.753	0.764
5.50	526.0	545.0	0.744	0.753
5.75	510.0	531.0	0.731	0.747
6.00	498.0	520.0	0.722	0.739
6.25	480.0	506.0	0.713	0.728
6.50	474.0	493.0	0.704	0.719
6.75	464.0	484.0	0.697	0.712
7.00	450.0	474.0	0.686	0.704
7.25	440.0	455.0	0.679	0.693

Table V. Exit Plane Temperature Profiles, Solid Wall Mixing Stack

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 549.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	162.0	164.0	0.616	0.618
0.25	182.0	174.0	0.636	0.628
0.50	210.0	190.0	0.664	0.644
0.75	238.0	229.0	0.692	0.683
1.00	272.0	239.0	0.725	0.693
1.25	272.0	274.0	0.725	0.727
1.50	288.0	291.0	0.741	0.744
1.75	303.0	310.0	0.756	0.763
2.00	312.0	312.0	0.765	0.765
2.25	322.0	329.0	0.775	0.781
2.50	330.0	337.0	0.783	0.790
2.75	333.0	346.0	0.786	0.799
3.00	344.0	353.0	0.797	0.806
3.25	350.0	356.0	0.803	0.809
3.50	351.0	360.0	0.804	0.813
3.75	352.0	365.0	0.805	0.818
4.00	357.0	366.0	0.810	0.819
4.25	360.0	362.0	0.813	0.815
4.50	362.0	366.0	0.815	0.819
4.75	362.0	366.0	0.815	0.819
5.00	366.0	366.0	0.819	0.819
5.25	365.0	362.0	0.818	0.815
5.50	365.0	360.0	0.818	0.813
5.75	364.0	357.0	0.817	0.810
6.00	362.0	352.0	0.815	0.805
6.25	355.0	337.0	0.808	0.790
6.50	352.0	332.0	0.805	0.785
6.75	346.0	322.0	0.799	0.775
7.00	344.0	314.0	0.797	0.767
7.25	342.0	302.0	0.795	0.755
7.50	341.0	297.0	0.794	0.750
7.75	328.0	290.0	0.781	0.743
8.00	320.0	263.0	0.773	0.716
8.25	294.0	247.0	0.747	0.701
8.50	259.0	221.0	0.714	0.675
8.75	234.0	197.0	0.688	0.651
9.00	188.0	174.0	0.642	0.628
9.25	174.0	166.0	0.629	0.620

Table VI. Exit Plane Temperatures, Slotted and Shrouded Mixing Stack with One Diffuser Ring

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 550.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	149.0	162.0	0.603	0.616
0.25	170.0	171.0	0.624	0.625
0.50	192.0	187.0	0.645	0.640
0.75	214.0	205.0	0.667	0.658
1.00	232.0	228.0	0.685	0.681
1.25	253.0	248.0	0.706	0.701
1.50	266.0	270.0	0.719	0.723
1.75	284.0	285.0	0.737	0.738
2.00	303.0	300.0	0.755	0.752
2.25	316.0	314.0	0.768	0.766
2.50	324.0	328.0	0.776	0.780
2.75	334.0	340.0	0.786	0.792
3.00	348.0	356.0	0.800	0.808
3.25	360.0	367.0	0.812	0.819
3.50	371.0	379.0	0.823	0.831
3.75	382.0	390.0	0.834	0.842
4.00	291.0	398.0	0.743	0.849
4.25	396.0	403.0	0.847	0.854
4.50	404.0	406.0	0.855	0.857
4.75	404.0	404.0	0.855	0.855
5.00	404.0	404.0	0.855	0.855
5.25	402.0	404.0	0.853	0.855
5.50	397.0	400.0	0.848	0.851
5.75	388.0	394.0	0.840	0.845
6.00	376.0	387.0	0.828	0.839
6.25	366.0	377.0	0.818	0.829
6.50	356.0	362.0	0.808	0.814
6.75	340.0	350.0	0.792	0.802
7.00	327.0	340.0	0.779	0.792
7.25	317.0	326.0	0.769	0.778
7.50	303.0	312.0	0.755	0.764
7.75	281.0	297.0	0.734	0.749
8.00	252.0	274.0	0.705	0.727
8.25	228.0	252.0	0.681	0.705
8.50	205.0	232.0	0.658	0.685
8.75	175.0	205.0	0.630	0.658
9.00	145.0	178.0	0.599	0.632
9.25	121.0	164.0	0.575	0.618

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 642.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	182.0	189.0	0.582	0.589
0.25	213.0	214.0	0.611	0.611
0.50	245.0	237.0	0.640	0.632
0.75	272.0	266.0	0.664	0.659
1.00	306.0	292.0	0.695	0.682
1.25	335.0	322.0	0.721	0.710
1.50	357.0	345.0	0.741	0.730
1.75	372.0	356.0	0.755	0.740
2.00	382.0	362.0	0.764	0.746
2.25	392.0	381.0	0.773	0.763
2.50	398.0	390.0	0.779	0.771
2.75	402.0	394.0	0.782	0.775
3.00	413.0	406.0	0.792	0.786
3.25	417.0	418.0	0.796	0.797
3.50	424.0	422.0	0.802	0.800
3.75	427.0	431.0	0.805	0.808
4.00	430.0	434.0	0.808	0.811
4.25	433.0	435.0	0.810	0.812
4.50	434.0	436.0	0.811	0.813
4.75	428.0	433.0	0.806	0.810
5.00	427.0	432.0	0.805	0.809
5.25	423.0	432.0	0.801	0.809
5.50	419.0	427.0	0.798	0.805
5.75	410.0	422.0	0.789	0.800
6.00	402.0	418.0	0.782	0.797
6.25	392.0	406.0	0.773	0.786
6.50	388.0	397.0	0.769	0.778
6.75	374.0	391.0	0.757	0.772
7.00	370.0	381.0	0.753	0.763
7.25	356.0	374.0	0.740	0.757
7.50	340.0	360.0	0.726	0.744
7.75	325.0	343.0	0.712	0.729
8.00	305.0	322.0	0.694	0.710
8.25	282.0	294.0	0.673	0.684
8.50	247.0	265.0	0.641	0.658
8.75	233.0	232.0	0.629	0.629
9.00	203.0	206.0	0.602	0.604
9.25	176.0	174.0	0.577	0.575

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 656.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	155.0	189.0	0.551	0.581
0.25	192.0	208.0	0.584	0.598
0.50	218.0	231.0	0.607	0.619
0.75	240.0	258.0	0.627	0.643
1.00	277.0	299.0	0.660	0.680
1.25	310.0	319.0	0.690	0.698
1.50	339.0	344.0	0.716	0.720
1.75	348.0	364.0	0.724	0.738
2.00	364.0	375.0	0.738	0.748
2.25	376.0	394.0	0.749	0.765
2.50	388.0	400.0	0.760	0.771
2.75	396.0	410.0	0.767	0.780
3.00	406.0	419.0	0.776	0.788
3.25	422.0	430.0	0.790	0.797
3.50	427.0	435.0	0.795	0.802
3.75	428.0	442.0	0.796	0.808
4.00	435.0	445.0	0.802	0.811
4.25	439.0	448.0	0.805	0.814
4.50	438.0	447.0	0.805	0.813
4.75	439.0	449.0	0.805	0.814
5.00	439.0	446.0	0.8[illegible]	0.812
5.25	436.0	436.0	0.803	0.803
5.50	425.0	430.0	0.793	0.797
5.75	412.0	423.0	0.781	0.791
6.00	404.0	410.0	0.774	0.780
6.25	396.0	395.0	0.767	0.766
6.50	394.0	379.0	0.765	0.752
6.75	377.0	369.0	0.750	0.743
7.00	364.0	358.0	0.738	0.733
7.25	349.0	344.0	0.725	0.720
7.50	336.0	324.0	0.713	0.702
7.75	315.0	307.0	0.694	0.687
8.00	296.0	288.0	0.677	0.670
8.25	266.0	259.0	0.650	0.644
8.50	247.0	234.0	0.633	0.622
8.75	231.0	214.0	0.619	0.604
9.00	194.0	196.0	0.586	0.588
9.25	182.0	160.0	0.575	0.555

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 760.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	209.0	207.0	0.548	0.547
0.25	236.0	228.0	0.570	0.564
0.50	281.0	258.0	0.607	0.588
0.75	306.0	298.0	0.628	0.621
1.00	339.0	343.0	0.655	0.658
1.25	356.0	367.0	0.669	0.678
1.50	384.0	391.0	0.692	0.697
1.75	405.0	413.0	0.709	0.715
2.00	415.0	435.0	0.717	0.734
2.25	431.0	444.0	0.730	0.741
2.50	442.0	458.0	0.739	0.752
2.75	456.0	468.0	0.751	0.761
3.00	472.0	479.0	0.764	0.770
3.25	480.0	486.0	0.770	0.775
3.50	494.0	497.0	0.782	0.784
3.75	512.0	508.0	0.797	0.793
4.00	515.0	509.0	0.799	0.794
4.25	518.0	509.0	0.802	0.794
4.50	516.0	510.0	0.800	0.795
4.75	514.0	510.0	0.798	0.795
5.00	512.0	509.0	0.797	0.794
5.25	512.0	508.0	0.797	0.793
5.50	506.0	504.0	0.792	0.790
5.75	501.0	494.0	0.788	0.782
6.00	494.0	486.0	0.782	0.775
6.25	482.0	474.0	0.772	0.766
6.50	470.0	457.0	0.762	0.752
6.75	454.0	446.0	0.749	0.743
7.00	448.0	426.0	0.744	0.726
7.25	427.0	418.0	0.727	0.720
7.50	419.0	402.0	0.720	0.706
7.75	400.0	390.0	0.705	0.697
8.00	371.0	372.0	0.681	0.682
8.25	344.0	342.0	0.659	0.657
8.50	310.0	299.0	0.631	0.622
8.75	272.0	266.0	0.600	0.595
9.00	238.0	236.0	0.572	0.570
9.25	212.0	214.0	0.551	0.552

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 767.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	206.0	206.0	0.543	0.543
0.25	231.0	227.0	0.563	0.560
0.50	262.0	257.0	0.588	0.584
0.75	285.0	284.0	0.607	0.606
1.00	325.0	319.0	0.640	0.635
1.25	360.0	349.0	0.668	0.659
1.50	387.0	379.0	0.690	0.684
1.75	400.0	396.0	0.701	0.698
2.00	414.0	414.0	0.712	0.712
2.25	424.0	427.0	0.720	0.723
2.50	439.0	432.0	0.733	0.727
2.75	447.0	448.0	0.739	0.740
3.00	457.0	455.0	0.747	0.746
3.25	466.0	465.0	0.755	0.754
3.50	472.0	477.0	0.760	0.764
3.75	482.0	482.0	0.768	0.768
4.00	485.0	488.0	0.770	0.773
4.25	489.0	490.0	0.773	0.774
4.50	491.0	490.0	0.775	0.774
4.75	489.0	491.0	0.773	0.775
5.00	488.0	486.0	0.773	0.771
5.25	486.0	484.0	0.771	0.769
5.50	476.0	472.0	0.763	0.760
5.75	470.0	463.0	0.758	0.752
6.00	463.0	450.0	0.752	0.742
6.25	454.0	437.0	0.745	0.731
6.50	443.0	426.0	0.736	0.722
6.75	423.0	414.0	0.720	0.712
7.00	417.0	398.0	0.715	0.699
7.25	408.0	364.0	0.707	0.671
7.50	391.0	388.0	0.693	0.691
7.75	373.0	348.0	0.679	0.658
8.00	349.0	314.0	0.659	0.631
8.25	324.0	283.0	0.639	0.605
8.50	288.0	256.0	0.610	0.583
8.75	260.0	230.0	0.587	0.562
9.00	231.0	212.0	0.563	0.548
9.25	182.0	201.0	0.523	0.539

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 846.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	208.0	224.0	0.511	0.524
0.25	251.0	260.0	0.544	0.551
0.50	295.0	294.0	0.578	0.577
0.75	331.0	324.0	0.606	0.600
1.00	380.0	364.0	0.643	0.631
1.25	410.0	401.0	0.666	0.659
1.50	452.0	429.0	0.698	0.681
1.75	466.0	449.0	0.709	0.696
2.00	488.0	472.0	0.726	0.714
2.25	497.0	482.0	0.733	0.721
2.50	517.0	498.0	0.748	0.733
2.75	531.0	517.0	0.759	0.748
3.00	544.0	534.0	0.769	0.761
3.25	558.0	545.0	0.779	0.769
3.50	563.0	550.0	0.783	0.773
3.75	571.0	560.0	0.789	0.781
4.00	572.0	566.0	0.790	0.786
4.25	570.0	567.0	0.789	0.786
4.50	564.0	569.0	0.784	0.788
4.75	565.0	572.0	0.785	0.790
5.00	566.0	570.0	0.786	0.789
5.25	565.0	562.0	0.785	0.782
5.50	558.0	552.0	0.779	0.775
5.75	551.0	542.0	0.774	0.767
6.00	538.0	527.0	0.764	0.756
6.25	525.0	509.0	0.754	0.742
6.50	516.0	494.0	0.747	0.730
6.75	493.0	476.0	0.733	0.717
7.00	483.0	454.0	0.722	0.700
7.25	465.0	438.0	0.708	0.688
7.50	452.0	427.0	0.698	0.679
7.75	438.0	406.0	0.688	0.663
8.00	410.0	366.0	0.666	0.632
8.25	376.0	331.0	0.640	0.606
8.50	329.0	302.0	0.604	0.583
8.75	295.0	262.0	0.578	0.553
9.00	252.0	238.0	0.545	0.534
9.25	219.0	216.0	0.520	0.517

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 847.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	220.0	190.0	0.520	0.497
0.25	248.0	231.0	0.542	0.529
0.50	260.0	270.0	0.566	0.558
0.75	316.0	305.0	0.594	0.585
1.00	351.0	341.0	0.620	0.613
1.25	378.0	381.0	0.641	0.643
1.50	410.0	409.0	0.666	0.665
1.75	436.0	442.0	0.685	0.690
2.00	458.0	458.0	0.702	0.702
2.25	472.0	474.0	0.713	0.715
2.50	492.0	491.0	0.728	0.728
2.75	504.0	502.0	0.738	0.736
3.00	515.0	518.0	0.746	0.748
3.25	535.0	532.0	0.761	0.759
3.50	547.0	551.0	0.770	0.773
3.75	560.0	558.0	0.780	0.779
4.00	567.0	569.0	0.786	0.787
4.25	575.0	572.0	0.792	0.790
4.50	575.0	573.0	0.795	0.790
4.75	575.0	572.0	0.792	0.790
5.00	574.0	569.0	0.791	0.787
5.25	573.0	559.0	0.790	0.780
5.50	566.0	548.0	0.785	0.771
5.75	556.0	540.0	0.777	0.765
6.00	537.0	522.0	0.763	0.751
6.25	523.0	503.0	0.752	0.737
6.50	503.0	482.0	0.737	0.721
6.75	489.0	464.0	0.726	0.707
7.00	476.0	449.0	0.716	0.695
7.25	462.0	426.0	0.705	0.678
7.50	437.0	399.0	0.686	0.657
7.75	411.0	365.0	0.666	0.631
8.00	370.0	348.0	0.635	0.618
8.25	332.0	304.0	0.606	0.584
8.50	296.0	275.0	0.571	0.562
8.75	252.0	242.0	0.545	0.537
9.00	215.0	225.0	0.516	0.524
9.25	196.0	218.0	0.502	0.519

Table VI (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 559.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	156.0	173.0	0.604	0.621
0.25	182.0	182.0	0.630	0.630
0.50	204.0	216.0	0.652	0.663
0.75	222.0	222.0	0.669	0.669
1.00	248.0	248.0	0.695	0.695
1.25	267.0	266.0	0.713	0.712
1.50	290.0	283.0	0.736	0.729
1.75	308.0	298.0	0.754	0.744
2.00	324.0	311.0	0.769	0.757
2.25	331.0	322.0	0.776	0.767
2.50	345.0	332.0	0.790	0.777
2.75	354.0	344.0	0.799	0.789
3.00	362.0	360.0	0.807	0.805
3.25	373.0	368.0	0.817	0.813
3.50	383.0	378.0	0.827	0.822
3.75	390.0	388.0	0.834	0.832
4.00	396.0	393.0	0.840	0.837
4.25	400.0	399.0	0.844	0.843
4.50	400.0	399.0	0.844	0.843
4.75	400.0	400.0	0.844	0.844
5.00	396.0	399.0	0.840	0.843
5.25	392.0	397.0	0.836	0.841
5.50	387.0	394.0	0.831	0.838
5.75	376.0	388.0	0.820	0.832
6.00	368.0	384.0	0.813	0.828
6.25	359.0	373.0	0.804	0.817
6.50	348.0	362.0	0.793	0.807
6.75	338.0	350.0	0.783	0.795
7.00	325.0	343.0	0.770	0.788
7.25	311.0	330.0	0.757	0.775
7.50	300.0	320.0	0.746	0.765
7.75	281.0	304.0	0.727	0.750
8.00	272.0	286.0	0.718	0.732
8.25	248.0	259.0	0.695	0.705
8.50	223.0	235.0	0.670	0.682
8.75	201.0	206.0	0.649	0.653
9.00	172.0	172.0	0.620	0.620
9.25	159.0	146.0	0.607	0.595

Table VII. Exit Plane Temperature Plots, Slotted and Shrouded Mixing Stack with Two Diffuser Rings

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 541.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	156.0	163.0	0.615	0.622
0.25	176.0	173.0	0.635	0.632
0.50	201.0	188.0	0.660	0.647
0.75	226.0	217.0	0.685	0.676
1.00	252.0	243.0	0.711	0.702
1.25	263.0	261.0	0.722	0.720
1.50	277.0	280.0	0.736	0.739
1.75	294.0	305.0	0.753	0.764
2.00	307.0	306.0	0.766	0.765
2.25	323.0	328.0	0.782	0.787
2.50	327.0	333.0	0.786	0.792
2.75	333.0	343.0	0.792	0.802
3.00	346.0	354.0	0.805	0.813
3.25	355.0	361.0	0.814	0.820
3.50	361.0	375.0	0.820	0.834
3.75	367.0	372.0	0.826	0.831
4.00	373.0	382.0	0.832	0.841
4.25	378.0	381.0	0.837	0.840
4.50	383.0	386.0	0.842	0.845
4.75	385.0	385.0	0.844	0.844
5.00	385.0	385.0	0.844	0.844
5.25	384.0	383.0	0.843	0.842
5.50	381.0	380.0	0.840	0.839
5.75	376.0	376.0	0.835	0.835
6.00	369.0	369.0	0.828	0.828
6.25	360.0	357.0	0.819	0.816
6.50	354.0	347.0	0.813	0.806
6.75	343.0	336.0	0.802	0.795
7.00	342.0	327.0	0.801	0.786
7.25	328.0	314.0	0.787	0.773
7.50	321.0	305.0	0.780	0.764
7.75	301.0	293.0	0.760	0.752
8.00	286.0	268.0	0.745	0.727
8.25	261.0	248.0	0.720	0.707
8.50	235.0	227.0	0.694	0.686
8.75	206.0	200.0	0.665	0.659
9.00	165.0	176.0	0.624	0.635
9.25	146.0	165.0	0.605	0.624

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 651.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	155.0	194.0	0.553	0.589
0.25	164.0	201.0	0.562	0.595
0.50	191.0	220.0	0.586	0.612
0.75	216.0	242.0	0.608	0.632
1.00	244.0	264.0	0.634	0.652
1.25	269.0	286.0	0.656	0.671
1.50	301.0	304.0	0.685	0.688
1.75	320.0	322.0	0.702	0.704
2.00	331.0	349.0	0.712	0.728
2.25	352.0	359.0	0.731	0.737
2.50	370.0	367.0	0.747	0.744
2.75	380.0	380.0	0.756	0.756
3.00	398.0	396.0	0.772	0.770
3.25	408.0	410.0	0.781	0.783
3.50	422.0	428.0	0.794	0.799
3.75	432.0	437.0	0.803	0.807
4.00	443.0	448.0	0.813	0.817
4.25	450.0	450.0	0.819	0.819
4.50	454.0	454.0	0.823	0.823
4.75	452.0	454.0	0.821	0.823
5.00	445.0	455.0	0.815	0.824
5.25	440.0	455.0	0.810	0.824
5.50	434.0	451.0	0.805	0.820
5.75	421.0	444.0	0.793	0.814
6.00	410.0	435.0	0.783	0.806
6.25	396.0	422.0	0.770	0.794
6.50	396.0	412.0	0.770	0.785
6.75	376.0	398.0	0.752	0.772
7.00	364.0	383.0	0.742	0.759
7.25	356.0	378.0	0.734	0.754
7.50	352.0	358.0	0.731	0.736
7.75	325.0	339.0	0.706	0.719
8.00	306.0	309.0	0.689	0.692
8.25	278.0	280.0	0.664	0.666
8.50	259.0	248.0	0.647	0.637
8.75	220.0	208.0	0.612	0.601
9.00	186.0	189.0	0.581	0.584
9.25	171.0	156.0	0.568	0.554

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 650.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	176.0	160.0	0.573	0.558
0.25	200.0	206.0	0.594	0.600
0.50	230.0	230.0	0.622	0.622
0.75	253.0	250.0	0.642	0.640
1.00	280.0	268.0	0.667	0.656
1.25	307.0	298.0	0.691	0.683
1.50	328.0	318.0	0.710	0.701
1.75	350.0	329.0	0.730	0.711
2.00	365.0	350.0	0.743	0.730
2.25	380.0	356.0	0.757	0.735
2.50	385.0	365.0	0.761	0.747
2.75	395.0	380.0	0.770	0.757
3.00	402.0	393.0	0.777	0.768
3.25	411.0	400.0	0.785	0.775
3.50	413.0	412.0	0.786	0.786
3.75	416.0	422.0	0.789	0.795
4.00	423.0	426.0	0.795	0.798
4.25	428.0	430.0	0.800	0.802
4.50	433.0	434.0	0.804	0.805
4.75	432.0	434.0	0.804	0.805
5.00	427.0	433.0	0.799	0.804
5.25	421.0	432.0	0.794	0.804
5.50	418.0	428.0	0.791	0.800
5.75	413.0	420.0	0.786	0.793
6.00	406.0	412.0	0.780	0.786
6.25	397.0	407.0	0.772	0.781
6.50	387.0	398.0	0.763	0.773
6.75	379.0	392.0	0.756	0.767
7.00	362.0	382.0	0.740	0.758
7.25	352.0	377.0	0.731	0.754
7.50	344.0	363.0	0.724	0.741
7.75	324.0	347.0	0.706	0.727
8.00	314.0	324.0	0.697	0.706
8.25	291.0	283.0	0.676	0.669
8.50	264.0	254.0	0.652	0.643
8.75	245.0	216.0	0.635	0.609
9.00	226.0	186.0	0.618	0.582
9.25	186.0	158.0	0.582	0.557

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 759.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	180.0	211.0	0.525	0.550
0.25	203.0	231.0	0.544	0.567
0.50	236.0	254.0	0.571	0.586
0.75	268.0	283.0	0.597	0.609
1.00	295.0	314.0	0.619	0.635
1.25	324.0	334.0	0.643	0.651
1.50	353.0	360.0	0.667	0.673
1.75	370.0	382.0	0.681	0.691
2.00	398.0	394.0	0.704	0.700
2.25	413.0	410.0	0.716	0.714
2.50	424.0	423.0	0.725	0.724
2.75	442.0	435.0	0.740	0.734
3.00	452.0	448.0	0.748	0.745
3.25	469.0	459.0	0.762	0.754
3.50	484.4	468.0	0.775	0.761
3.75	498.0	482.0	0.786	0.773
4.00	506.0	493.0	0.792	0.782
4.25	513.0	498.0	0.798	0.786
4.50	517.0	516.0	0.801	0.801
4.75	522.0	515.0	0.806	0.800
5.00	511.0	511.0	0.796	0.796
5.25	506.0	504.0	0.792	0.791
5.50	494.0	497.0	0.783	0.785
5.75	488.0	490.0	0.778	0.779
6.00	475.0	482.0	0.767	0.773
6.25	457.0	470.0	0.752	0.763
6.50	448.0	458.0	0.745	0.753
6.75	432.0	448.0	0.732	0.745
7.00	414.0	427.0	0.717	0.728
7.25	396.0	414.0	0.702	0.717
7.50	377.0	396.0	0.687	0.702
7.75	357.0	370.0	0.670	0.681
8.00	330.0	345.0	0.648	0.660
8.25	296.0	310.0	0.620	0.632
8.50	264.0	282.0	0.594	0.609
8.75	229.0	262.0	0.565	0.592
9.00	193.0	210.0	0.536	0.550
9.25	184.0	178.0	0.528	0.523

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 748.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	170.0	204.0	0.521	0.550
0.25	188.0	228.0	0.536	0.569
0.50	215.0	253.0	0.559	0.590
0.75	242.0	277.0	0.581	0.610
1.00	272.0	304.0	0.606	0.632
1.25	304.0	328.0	0.632	0.652
1.50	340.0	348.0	0.662	0.669
1.75	360.0	376.0	0.679	0.692
2.00	383.0	395.0	0.698	0.708
2.25	397.0	409.0	0.709	0.719
2.50	418.0	427.0	0.727	0.734
2.75	435.0	439.0	0.741	0.744
3.00	445.0	453.0	0.749	0.756
3.25	459.0	471.0	0.761	0.771
3.50	472.0	485.0	0.771	0.783
3.75	485.0	498.0	0.782	0.793
4.00	496.0	503.0	0.791	0.797
4.25	505.0	510.0	0.799	0.803
4.50	511.0	512.0	0.804	0.805
4.75	510.0	514.0	0.803	0.806
5.00	505.0	512.0	0.799	0.805
5.25	494.0	506.0	0.790	0.800
5.50	492.0	499.0	0.788	0.794
5.75	482.0	488.0	0.780	0.785
6.00	471.0	472.0	0.771	0.771
6.25	458.0	458.0	0.760	0.760
6.50	443.0	443.0	0.747	0.747
6.75	425.0	428.0	0.733	0.735
7.00	412.0	414.0	0.722	0.723
7.25	394.0	403.0	0.707	0.714
7.50	382.0	382.0	0.697	0.697
7.75	363.0	354.0	0.681	0.674
8.00	338.0	326.0	0.661	0.651
8.25	306.0	290.0	0.634	0.621
8.50	272.0	253.0	0.606	0.590
8.75	240.0	226.0	0.579	0.568
9.00	195.0	192.0	0.542	0.540
9.25	173.0	172.0	0.524	0.523

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 870.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	200.0	246.0	0.496	0.531
0.25	222.0	268.0	0.513	0.547
0.50	255.0	298.0	0.537	0.570
0.75	289.0	338.0	0.563	0.600
1.00	324.0	374.0	0.589	0.627
1.25	352.0	400.0	0.610	0.647
1.50	385.0	421.0	0.635	0.662
1.75	418.0	441.0	0.660	0.677
2.00	420.0	460.0	0.662	0.692
2.25	446.0	487.0	0.681	0.712
2.50	465.0	505.0	0.695	0.725
2.75	487.0	524.0	0.712	0.740
3.00	505.0	540.0	0.725	0.752
3.25	524.0	558.0	0.740	0.765
3.50	540.0	575.0	0.752	0.778
3.75	559.0	588.0	0.766	0.788
4.00	572.0	598.0	0.776	0.795
4.25	581.0	602.0	0.783	0.798
4.50	588.0	605.0	0.788	0.801
4.75	603.0	602.0	0.799	0.798
5.00	592.0	602.0	0.791	0.798
5.25	587.0	598.0	0.787	0.795
5.50	576.0	591.0	0.779	0.790
5.75	566.0	573.0	0.771	0.777
6.00	550.0	558.0	0.759	0.765
6.25	538.0	542.0	0.750	0.753
6.50	510.0	527.0	0.729	0.742
6.75	493.0	510.0	0.716	0.729
7.00	478.0	488.0	0.705	0.713
7.25	460.0	462.0	0.692	0.693
7.50	436.0	445.0	0.674	0.680
7.75	415.0	423.0	0.658	0.664
8.00	378.0	382.0	0.630	0.633
8.25	348.0	338.0	0.607	0.600
8.50	306.0	303.0	0.576	0.574
8.75	272.0	245.0	0.550	0.530
9.00	227.0	225.0	0.516	0.515
9.25	202.0	182.0	0.498	0.483

Table VII (Continued)

EXIT PLANE TEMPERATURE DATA
UPTAKE TEMPERATURE: 858.0 DEG F

DIAMETRAL POSITION	HORIZONTAL TRAVERSE	DIAGONAL TRAVERSE	T(H)/TUPT	T(D)/TUPT
0.0	208.0	208.0	0.507	0.507
0.25	216.0	230.0	0.513	0.523
0.50	249.0	261.0	0.538	0.547
0.75	284.0	290.0	0.564	0.569
1.00	314.0	328.0	0.587	0.598
1.25	352.0	358.0	0.616	0.621
1.50	386.0	386.0	0.642	0.642
1.75	409.0	408.0	0.659	0.658
2.00	437.0	435.0	0.680	0.679
2.25	456.0	447.0	0.695	0.688
2.50	472.0	452.0	0.707	0.692
2.75	492.0	475.0	0.722	0.709
3.00	502.0	500.0	0.730	0.728
3.25	512.0	506.0	0.737	0.733
3.50	528.0	524.0	0.750	0.747
3.75	540.0	540.0	0.759	0.759
4.00	544.0	562.0	0.762	0.775
4.25	559.0	561.0	0.773	0.775
4.50	568.0	562.0	0.780	0.775
4.75	570.0	570.0	0.781	0.781
5.00	562.0	568.0	0.775	0.780
5.25	553.0	550.0	0.769	0.766
5.50	542.0	547.0	0.760	0.764
5.75	517.0	528.0	0.741	0.750
6.00	506.0	518.0	0.733	0.742
6.25	500.0	502.0	0.728	0.730
6.50	472.0	494.0	0.707	0.724
6.75	460.0	481.0	0.698	0.714
7.00	436.0	474.0	0.680	0.709
7.25	422.0	455.0	0.669	0.694
7.50	403.0	440.0	0.655	0.683
7.75	385.0	425.0	0.641	0.671
8.00	357.0	395.0	0.620	0.649
8.25	327.0	370.0	0.597	0.630
8.50	284.0	316.0	0.564	0.589
8.75	260.0	264.0	0.546	0.549
9.00	213.0	229.0	0.510	0.523
9.25	182.0	195.0	0.487	0.497

Table VII (Continued)

Variable	Value	Uncertainty
T_s, TAMB	521 °R	± 1 °R
T_p, TUPT	1316 °R	± 2 °R
B,P_a	30.08 in Hg	± .005 in Hg
DELPN	6.40 in H_2O	± .05 in H_2O
PU-PA	9.10 in H_2O	± .05 in H_2O
PA-PS, P	.26 in H_2O	± .005 in H_2O
FHZ	101 Hz	± 1 Hz
PNH	4.40 in Hg	± .05 in Hg

Values are for the mixing stack with one diffuser ring, TUPT = 850 °F, Run Number Two

TABLE VIII. Uncertainties in Measured Values from Table III

APPENDIX A

OPERATION OF THE COMBUSTION GAS GENERATOR

A. COMPRESSOR LIGHT OFF

The primary air flow is supplied by the Carrier model 18P350 centrifugal air compressor located in Building 248. This compressor's cooling system is piped into the cooling tower system located behind the building. Figure 36 gives a schematic of the compressor layout.

In preparation for compressor light off ensure that the cooling water valve to the Sullivan compressor is closed, and that air supply valves to other experiments are closed. Start the cooling tower pump and fan by pushing both start buttons located on the south wall of Building 248 (Figure 37). If necessary, vent the pump inlet to achieve flow through the pump. The compressor can then be started by completing the following steps.

1) Check the sight glass on the external oil sump.
2) Ensure that the compressor butterfly suction damper in the airstream between the filter (on the roof) and the compressor is closed (Figure 38).
3) Start the auxiliary oil pump by positioning the on-off automatic switch (Figure 39) in the "hand" position.
4) Open fully the inlet water valve to the oil cooler (Figure 38).
5) When the oil pressure rises to at least 16 PSIG, start the compressor.

6) When the compressor is up to speed, switch the auxiliary oil pump to "automatic."

7) Open the butterfly suction damper.

Notes:

1) Normal oil pressure supplied by the auxiliary oil pump is 30 PSIG. Normal oil pressure supplied by the attached oil pump is 24 PSIG. When in "automatic" the auxiliary oil pump will start if oil pressure falls to 6 PSIG.

2) Normal outlet temperature from the oil cooler is 100 F to 105 F. Normal bearing temperatures are 140 F to 145 F. Check the bearings periodically during operation to ensure temperatures do not exceed 185 F.

B. GAS GENERATOR LIGHT OFF

After the supply air compressor is in operation, the following is a recommended starting sequence.

1) Energize the main power panel and the thermocouple and mass flowmeter readouts, and open the fuel inlet valves.

2) Calculate the required mass flow rate to achieve the desired uptake Mach number, M_u. The formula for this calculation (derived in Reference [5]) follows:

$$M_u = \frac{C_1(\dot{m}_a + \dot{m}_f)\,TUPT^{0.5}}{\frac{PUP}{13.572} + B}$$

where

C1 = constant due to unit conversions and ratio of specific heats, depends on TUPT; approximately .05

TUPT = uptake temperature (degrees R)

PUP = uptake pressure (inch H_2O)

B = atmospheric pressure (inch Hg)

$\dot{m}_a$ = mass flow rate of air (lbm/sec)

$\dot{m}_f$ = mass flow rate of fuel (lbm/sec)

3) Figure 25 gives the primary air mass flow rate versus the pressure product. The pressure product comes from the transition nozzle calibration and is defined

$$\left[\frac{(PNH + B) * DELPN}{TUPT}\right]^{0.5}$$

where where

PNH = nozzle high pressure (inch Hg)

B = atmospheric pressure (inch Hg)

DELPN = pressure drop across entrance nozzle (inch H_2O)

TUPT = uptake temperature (degrees R)

From Figure 25 find the pressure product corresponding to the required mass flow rate found in step 2 above.

4) With the burner air valve 100% open and the bypass air valve (Figure 3) 50% open, open the main air supply globe valve (Figure 40) until the desired pressure product is reached. Good light off values are 3.7 inches Hg for PNH and 6.1 inches water for

Do not allow burner temperature to exceed 1500 F.

c) Simultaneously with (b), open the fuel recirculation valve to achieve a fuel flow meter reading of about 110 Hz.

C. TEMPERATURE ADJUSTMENT

Temperature adjustment is an iterative process consisting of the following steps.

1) Adjust the fuel control valve to achieve approximately the desired uptake temperature, while monitoring the burner temperature.
2) Check the pressure product. Re-adjust the main air supply globe valve to obtain the correct value.
3) Adjust the fuel control valve and the bypass air valve (Figure 3) to achieve the desired temperature. Rough temperature control is achieved with the bypass air valve and fine control with the fuel control valve. The fuel pump outlet valve must be mostly closed to achieve the low flow rates required for the low uptake temperatures.

Normally the burner air valve is kept 100% open, but at low uptake temperatures closing this valve to about 60% open can reduce smoking.

Although desired Mach number can be achieved over a wide range of temperatures and pressures, the gas generator runs smoothly over a much narrower band. Surging, pressure

DELPN. The globe valve is open about $2\frac{1}{4}$ turns to achieve these values.

5) Open the bypass air valve to 80% open. PNH will drop to about 1.8 inches Hg and DELPN may climb to around 6.8 inches H_2O. If measured, pressure drop across the U bend would be about 1 inch H_2O.

6) Turn on the fuel supply pump and the high pressure fuel pump.

7) Adjust the fuel control valve to obtain 150 PSIG on the high pressure fuel gage (Figure 5).

8) Energize the igniter plug and glow coil by depressing the spring-loaded igniter switch. Hold this switch down for a few seconds before opening the fuel shutoff.

9) Open the fuel shutoff valve by putting the emergency shutoff switch in the "on" position. Ignition should be noted within three to four seconds. If ignition does not occur quickly, turn off the emergency shutoff switch.

10) If ignition does not occur, check the settings of all valves and controls, and let system purge before attempting light off again.

11) When ignition does occur

    a) Let go the igniter switch,

    b) Begin closing the bypass air valve immediately while monitoring burner temperature. Continue closing the bypass air valve to about 50% open.

pulses, and unstable burner temperatures are the indications that the machinery is not in the comfortable operating zone.

D. SYSTEM SHUT DOWN

1) Close the emergency fuel shutoff valve.

2) Turn off the fuel supply pump and the high pressure fuel pump.

3) Allow the system to cool for five to ten minutes.

4) Close the compressor butterfly suction damper.

5) Turn off the compressor. Immediately turn the auxiliary oil pump switch to the "hand" position.

6) Allow the bearing temperatures to reach 80 F before turning off the oil pump and the cooling tower pump and fan.

7) Close the fuel inlet valves and the main air supply globe valve.

APPENDIX B

DETERMINATION OF THE EXPONENT IN THE NONDIMENSIONAL PUMPING COEFFICIENT

The method used to determine the value of the exponent n in equation (13) is outlined below.

(1) Select a given geometry, assume reasonable values for K_p, K_m and f, and calculate C_1, C_2 and C_3 for use in equation (11b).

(2) Set $T^* = 1.0$, $\Delta P^* = 0$, and solve for W^*max. Equation (11b) plots as indicated in Figure 27; for $\Delta P^* = 0$ and $T^* = 1.0$, the intersection of the curve with the W^*T^{*n} axis yields the value of W^*max. Note that for each value of $T^* < 1.0$ ($T^* = T_s/T_p$ and $T_s < T_p$ therefore $T^* < 1.0$) a different curve will result.

(3) For the same geometric configuration and other values assumed and calculated in step (1), calculate $\Delta P^*/T^*$ using equation (11b) with W^*T^{*n} for different values of T^* in each case varying W^* from 0 to W^*max in equal increments of W^*max. For each new value of T^* tried, vary n until the resulting plots of $\Delta P^*/T^*$ vs W^*T^{*n} for $T^* < 1.0$ come close enough to the initial plot obtained in step (2) where $T^* = 1.0$ that, for all practical purposes, all such plots can be represented by a single curve.

(4) The value of n which most effectively collapses all performance curves onto the $T^* = 1.0$ case is $n = 0.44$.

APPENDIX C

UNCERTAINTY ANALYSIS

The experimentally determined pressure coefficient and pumping coefficient are used in determining eductor operating points which in turn provide the basis for comparison and evaluation of eductor system performance. Data for the eductor with one diffuser ring and an uptake temperature of 850 F (Table III) is considered a representative case and is used to calculate representative uncertainties in the pumping and pressure coefficients.

For a single sample measurement the value of a specific variable should be given in the format:

$$x = \bar{x} \pm \delta x$$

where

$\bar{x}$ = mean value of the variable x

δx = estimated uncertainty in x.

Variations for the variables in the defining equations for the two coefficients are listed in Table VIII. Having described the uncertainties in the basic variables of a relationship, it is now necessary to determine how these uncertainties propagate into the result. Consider the relation where the result R is the product of a sequence of terms.

$$R = x_1^{a}\, x_2^{b}\, x_3^{c} \qquad \text{(a)}$$

A reasonable prediction of the uncertainty in the result R is obtained by using the second order equation suggested by Kline and McClintock [6].

$$\delta R = [(\frac{\partial R}{\partial x_1}\, \delta x_1)^2 + (\frac{\partial R}{\partial x_2}\, \delta x_2)^2 + (\frac{\partial R}{\partial x_2}\, \delta x_3)^2]^{1/2} \qquad \text{(b)}$$

Evaluating the partial derivatives appearing in equation (b), and normalizing by dividing through by result R yields the simplified form of equation (b) which will be used in this analysis.

$$\frac{\delta R}{R} = [(\frac{a\ \delta x_1}{x_1})^2 + (\frac{b\ \delta x_2}{x_2})^2 + (\frac{c\ \delta x_3}{x_3})^2]^{1/2} \qquad \text{(c)}$$

Determination of the uncertainty in the pressure coefficient is facilitated by writing it as the product of a series of terms,

$$\frac{\Delta P^*}{T^*} = (\rho_s)^{-1}\ (\Delta P)\ (U_p)^{-2}\ (T^*)^{-1} \qquad \text{(d)}$$

where ΔP represents the pressure difference $(P_a - P_0)$. Constants such as 2 g_c in the equation for the pressure coefficient will be cancelled out when used in equation (c) and are therefore not included in this analysis. Applying equation (c) to the pumping coefficient in equation (d) yields the following expression for its uncertainty:

$$\frac{\delta \frac{\Delta P^*}{T^*}}{\frac{\Delta P^*}{T^*}} = [(\frac{(-1)\ \delta\rho_s}{\rho_s})^2 + (\frac{(1)\ \delta(\Delta P)}{\Delta P})^2$$

$$+ (\frac{(-2)\ \delta U_p}{U_p})^2 + (\frac{(-1)\ \delta T^*}{T^*})^2]^{1/2} \qquad \text{(e)}$$

Taking into account the respective equations defining the individual variables, the terms of equation (e) are expanded as follows:

$$\rho_s = \frac{P_a}{R\ T_s}, \qquad [\frac{\delta\rho_s}{\rho_s}]^2 = [\frac{\delta P_a}{P_a}]^2 + [\frac{\delta T_s}{T_s}]^2$$

$$U_p = \frac{W_p}{\rho_p A_p}, \qquad [\frac{\delta U_p}{U_p}]^2 = [(\frac{\delta W_p}{W_p})^2 + (\frac{\delta\rho_p}{\rho_p})^2 + (\frac{\delta A_p}{A_p})^2]$$

$$T^* = \frac{T_s}{T_p}, \qquad [\frac{\delta T^*}{T^*}]^2 = [\frac{\delta T_s}{T_s}]^2 + [\frac{\delta T_p}{T_p}]^2$$

Using the values of the variable and their respective uncertainties listed in Table VIII, the uncertainty in the pressure coefficient is estimated to be

$$\frac{\delta(\frac{\Delta P^*}{T^*})}{\frac{\Delta P^*}{T^*}} = .0194 = \pm\ 1.9\%$$

By a similar process, the uncertainty in the pumping coefficient is estimated to be

$$\frac{\delta(W^*T^{*\cdot 44})}{W^*T^{*\cdot 44}} = .0217 = \pm\ 2.2\%.$$

```
C     J A HILL                       23 MAY 79,  REVISED 6 AUG 79
C     THIS PROGRAM READS RAW DATA FROM THE HOTRIG EXPERIMENT, PERFORMS THE
C     DATA REDUCTION AND YIELDS TABULAR AND GRAPHICAL OUTPUT.
C
C
C
C     ************************
C     VARIABLE NAMES
C
C     AM      AREA OF MIXING STACK, SQ FT
C     AMAP    AM/AP
C     AP      AREA OF PRIMARY NOZZLES, SQ FT
C     AUP     AREA OF UPTAKE, SQ FT
C     B       BAROMETER READING, IN HG
C     C1      CONVERSION OF P/RT TO DENSITY
C     C2      CONVERSION OF INCH WATER TO INCH HG
C     C3      CONVERSION OF DEG F TO DEG R
C     C4      CONVERSION OF IN H2O TO LBF/SQ FT
C     DATE    DATE OF RUN
C     DELPN   PRESSURE DROP ACROSS ENTRANCE NOZZLE, IN H2O
C     DM      DIAMETER OF MIXING STACK, IN
C     DP      DIAMETER OF PRIMARY NOZZLES, IN
C     DU      DIAMETER OF UPTAKE, IN
C     FHZ     FREQUENCY FROM FUEL FLOW METER, HZ
C     GAMMA   RATIO OF AIR SPECIFIC HEATS
C     LD      LENGTH TO DIAMETER RATIO OF MIXING STACK
C     LMS     LENGTH OF MIXING STACK, IN
C     NNOZ    NUMBER OF PRIMARY NOZZLES
C     NR      NUMBER OF RUNS
C     PAPS    PRESSURE DROP ACROSS SECONDARY NOZZLES, IN H2O
C     PNH     PRESSURE UPSTREAM OF ENTRANCE NOZZLE, IN HG
C     PRTR    P*/T*
C     PSTR    NON DIMENSIONAL PRESSURE, P*
C     PUPA    UPTAKE PRESSURE, IN H2O
C     RHOA    DENSITY OF AMBIENT AIR, LBM/CU FT
C     RHOM    DENSITY IN MIXING STACK, LBM/CU FT
C     RHOP    DENSITY AT PRIMARY NOZZLE, LBM/CU FT
C     RHOS    DENSITY OF SECONDARY AIR, LBM/CU FT
C     RHOUP   DENSITY IN UPTAKE, LBM/CU FT
C     SD      STANDOFF RATIO
C     TAMB    AMBIENT TEMPERATURE, DEG F
C     TAMBR   AMBIENT TEMPERATURE, DEG R
C     TBURN   BURNER TEMPERATURE, DEG F
C     TMR     DIFFUSER RING TEMPERATURE, DEG F
C     TMS     MIXING STACK TEMPERATURE, DEG F
C     TMSH    SHROUD TEMPERATURE,DEG F
C     TMSTR   NON DIMENSIONAL MIXING STACK TEMPERATURE
C     TPNH    ENTRANCE NOZZLE TEMPERATURE, DEG F
C     TPNHR   ENTRANCE NOZZLE TEMPERATURE, DEG R
C     TSTR    NON DIMENSIONAL TEMPERATURE, T*
C     TUPT    UPTAKE TEMPERATURE, DEG F
C     TUPTR   UPTAKE TEMPERATURE, DEG R
C     UM      VELOCITY IN MIXING STACK, FT/SEC
C     UMACH   UPTAKE MACH NUMBER
C     UP      VELOCITY IN PRIMARY NOZZLES, FT/SEC
C     UU      VELOCITY IN UPTAKE, FT/SEC
C     WF      MASS FLOW OF FUEL, LBM/SEC
C     WPA     MASS FLOW OF PRIMARY AIR, LBM/SEC
C     WP      MASS FLOW THROUGH PRIMARY NOZZLES, LBM/SEC
C     WS      MASS FLOW OF SECONDARY AIR, LBM/SEC
C     WSTR    NON DIMENSIONAL MASS FLOW RATE, W*
C     WSTR44  EMPIRICAL PUMPING COEFFICIENT
C     XDMS    X/D, POSITION ALONG MIXING STACK
C     XDR1    X/D, POSITION ALONG MIXING STACK, ON RING 1
C     XDR2    X/D, POSITION ALONG MIXING STACK, ON RING 2
C     XDSH    X/D, POSITION ALONG MIXING STACK, ON SHROUD
C     $       SINGLE PRECISION ARRAYS
C
C
C
C     ************************************
C       INPUT AND INITIAL DATA
C
```

```
      IMPLICIT REAL*8(A-H,O-W)
      REAL*8 LD,LMS
      REAL*4 TMSA,TMSB,TMSHA,TMSHB,TMR1A,TMR1B,TMR2A,TMR2B
C
      DIMENSION DATE(2)
      DIMENSION PNH(10),DELPN(10),TPNH(10),FHZ(10), TBURN(10),TUPT(10),
     *PUPA(10),PAPS(10),TAMB(10),SECAIR(10)
      DIMENSION WPA(10),WF(10),WP(10),WS(10),WSTR(10),PSTR(10),TSTR(10),
     *PRTR(10),WSTR44(10),UP(10),UM(10),UJ(10),UMACH(10)
      DIMENSION XD(10),XDMS(6),XDSH(4),XDR1(2),XDR2(2)
      DIMENSION TMSA(6),TMSB(6),TMSHA(4),TMSHB(4),TMR1A(2),TMR1B(2),
     *TMR2A(2),TMR2B(2)
      DIMENSION S44(10),SPR(10)
C
      DATA NNOZ/4/,DP/2.25D0/,DL/7.51D0/,AMAP/2.50D0/,AP/.110446D0/
     *,LMS/17.81D0/,DM/7.122D0/,LD/2.50D0/,SD/.5D0/,AM/.276650400/,
     *AUP/.30761480D/
      DATA C1/1.32156D0/,C2/13.5717D0/,C3/459.67D0/,C4/5.19408D0/
      DATA SECAIR/0.0D0,5.283D0,11.192D0,14.726D0,27.293D0,35.859D0,
     *52.425D0,64.992D0,2*1004.0D10/
      DATA XDMS/.5,.75,1.0,1.2,1.4,1.6/
      DATA XDSH/.5,1.0,1.5,2.0/
      DATA XDR1/2.0,2.25/
      DATA XDR2/2.25,2.5/
      DATA XD/.5,.75,1.0,1.2,1.4,1.5,1.6,2.0,2.25,2.5/
      DO 555 JJK=1,8
      READ (5,100) DATE,B,GAMMA,NR,MR,MTUPT
100   FORMAT(2A8,F5.2,F4.2,I2,I1,I3)
C
C
      DO 90 I=1,NR
      READ (5,110) PNH(I), DELPN(I),TPNH(I),FHZ(I),TBURN(I),TUPT(I),
     *PUPA(I),PAPS(I),TAMB(I)
110   FORMAT (10 F8.3)
C
C
C
C   *************************
C     DATA REDUCTION
C
      TUPTR=TUPT(I)+C3
      TAMBR=TAMB(I)+C3
      TPNHR=TPNH(I)+C3
      WPA(I)=1.77340D0*DSQRT((PNH(I)+B)*DELPN(I)/TPNHR) + .018088D0
      WF(I)=9.59155D-5*FHZ(I) + 3.23D-4
      WP(I)=WPA(I)+WF(I)
      RHOP=C1*(B+(PUPA(I)/C2))/TUPTR
      RHOS=C1*(B-(PAPS(I)/C2))/TAMBR
      RHOP=RHOS*TAMBR/TUPTR
      RHOA=C1*B/TAMBR
      WS(I)=.123808D0*SECAIR(I)*DSQRT(RHOA*PAPS(I))
      WSTR(I)=WS(I)/WF(I)
      UP(I)=WP(I)/RHOP/AP
      PSTR(I)=(PAPS(I)*C4/RHOS)/(UP(I)*UP(I)/64.348D0)
      UJ(I)=WP(I)/RHOUP/AUP
      RHOM=(WP(I)+WS(I))/((WS(I)/RHOS)+(WP(I)/RHOP))
      UM(I)=(WP(I)+WS(I))/RHOM/AM
      TSTR(I)=TAMBR/TUPTR
      WSTR(I)=WS(I)/WP(I)
      PRTR(I)=PSTR(I)/TSTR(I)
      WSTR44(I)=WSTR(I)*TSTR(I)**.44D0
      UMACH(I)=UJ(I)/41.42658D0/DSQRT(GAMMA*TUPTR)
90    CONTINUE
C
C
C   MIXING STACK SECTION
C
      READ (5,120) TMSA,TMSB,TMSHA,TMSHB,TMR1A,TMR1B,TMR2A,TMR2B
120   FORMAT (6F8.1/6F8.1/4F8.1/4F8.1/2F8.1/2F8.1/2F8.1/2F8.1)
C
C
C
C   *************************
```

```
C     TABULAR OUTPUT
C
      WRITE (6,500) MTUPT,MR
500   FORMAT('1',/T49,'***   HOT RIG PERFORMANCE   ***',
     *20X,'TUPT:  ',I3/T57,I1,' DIFFUSER RING'//)
      WRITE (6,510) DATE
510   FORMAT (/T4,'DATE:  ',2A8,T65,'DATA TAKEN BY J A HILL')
      WRITE (6,520) NNOZ,LMS
520   FORMAT(/T4,'NUMBER OF PRIMARY NOZZLES: ',I2,T65,'MIXING STACK',
     *' LENGTH:  ',F5.2,'  INCHES')
      WRITE (6,530) DP,DM
530   FORMAT (T4,'PRIMARY NOZZLE DIAMETER:  ',F5.2,'  INCHES',T65,
     *'MIXING STACK DIAMETER:  ',F6.3,'  INCHES')
      WRITE (6,540) DL,LD
540   FORMAT(T4,'UPTAKE DIAMETER:  ',F5.3,'  INCHES',T65,
     *'MIXING STACK L/D:  ',F4.2)
      WRITE (6,550) AMAP,SD
550   FORMAT (T4,'AREA RATIO, AM/AP:  ', F4.2,T65,
     *'STANDOFF RATIO:  ',F3.2)
      WRITE (6,560) GAMMA,B
560   FORMAT(T4,'GAMMA:  ',F4.2,T65,'AMBIENT PRESSURE:  ',F5.2,
     *'  INCHES HG')
      WRITE (6,570)
570   FORMAT (///1X,'NR',T7,'PNH',T16,'DELPN',T25,'TPNH',T34,'FHZ',
     *T41,'TBURN',T50,'TUPT',T59,'TAMB',T68,'PU-PA',T77,'PA-PS',
     *T86,'SEC AREA')
      WRITE (6,580)
580   FORMAT(1X,T6,'IN HG',T16,'IN H2O',T25,'DEG F',T35,'HZ',T41,'DEG F'
     *,T50,'DEG F',T59,'DEG F',T68,'IN H2O',T77,'IN H2O',T86,'SQ IN')
      WRITE (6,590) (I,PNH(I),DELPN(I),TPNH(I),FHZ(I),TBURN(I),
     *TUPT(I),TAMB(I),PUPA(I),PAPS(I),SECAIR(I),I=1,NR)
590   FORMAT(/1X,I2,T7,F5.2,T16,F5.2,T25,F5.1,T33,F5.1,T41,F6.1,T50,
     *F5.1,T59,F4.1,T()),F5.2,T79,F4.2,T87,F6.3)
      WRITE (6,600)
600   FORMAT (///1X,'NR',T7,'WPA',T16,'WF',T25,'WP',T34,'WS',T43,'W*',
     *T52,'P*',T61,'T*',T69,'P*/T*',T77,'W*T**.44',T88,'UP',T97,
     *'UM',T106,'UU',T113,'UMACH')
      WRITE (6,610)
610   FORMAT(1X,T6,4('LBM/S',4X),T97,3('FT/S',5X))
      WRITE (6,620) (I,WPA(I),WF(I),WP(I),WS(I),WSTR(I),PSTR(I),TSTR(I),
     *PRTR(I),WSTR44(I),UP(I),UM(I),UU(I),UMACH(I),I=1,NR)
620   FORMAT(/1X,I2,T6,F5.3,T15,F5.3,T24,F5.3,T33,F5.3,T42,F5.3,T51,
     *F5.3,T60,F5.3,T69,F5.3,T78,F5.3,T87,F5.1,T96,F5.1,T105,F5.1,
     *T113,F5.4)
      WRITE (6,630)
630   FORMAT(///' MIXING STACK TEMPERATURES (DEG F), ',
     *'OPEN TO ATMOSPHERE')
      WRITE (6,640) XD,TMSA,TMSB,TMSHA,TMSHB,TMR1A,TMR1B,TMR2A,TMR2B
640   FORMAT (/1X,T15,'X/D',5X,2(F5.2,4X),8(F5.2,4X)//
     *1X,'TMS (POSITION A)',4X,5(F6.1,3X),5X,F6.1//
     *1X,'TMS (POSITION B)',4X,5(F6.1,3X),9X,F6.1//
     *1X,'SHROUD (POSIT A)',4X,F6.1,12X,F6.1,21X,F6.1,13X,F6.1//
     *1X,'SHROUD (POSIT B)',4X,F6.1,12X,F6.1,21X,F6.1,13X,F6.1//
     *1X,'RING 1 (POSIT A)',4X,64X,2(F6.1,3X)//
     *1X,'RING 1 (POSIT B)',4X,64X,2(F6.1,3X)//
     *1X,'RING 2 (POSIT A)',4X,73X,2(F6.1,3X)//
     *1X,'RING 2 (POSIT B)',4X,73X,2(F6.1,3X))
C
C
C
C   **************************
C     GRAPHICAL OUTPUT
C
C   PLOTG REQUIRES REAL*4 INPUT ARRAYS
      DO 96 J=1,NR
      S44(J)=SNGL(WSTR44(J))
96    SPR(J)=SNGL(PRTR(J))
C
C
      CALL PLOTG(S44,SPR,8,1,0,14,'(W*)(T*)**.44',13,'P*/T*',5,
     *0.0,.80,0.0,.50,8.0,5.0)
      CALL PLOTG(XDMS,TMSA,6,1,0,3,'X/D',3,'TEMPERATURE (DEG F)',19,
     *0.0,2.5,50.0,300.,6.25,5.0)
```

```
      CALL PLOTG(XDMS,TMSB,6,2,0,4,' ',1,' ',1,0.,0.,0.0,0.0,6.25,5.0)
      CALL PLOTG(XDSH,TMSHA,4,3,0,14,' ',1,' ',1,.0,.0,.0,.0,6.25,5.0)
      CALL PLOTG(XDSH,TMSHB,4,4,0,14,' ',1,' ',1,0.,0.,0.,0.,6.25,5.0)
      CALL PLOTG(XDR1,TMR1A,2,5,0,2,' ',1,' ',1,0.,0.,0.,0.,6.25,5.0)
      CALL PLOTG(XDR1,TMR1B,2,6,0,2,' ',1,' ',1,0.,0.,0.,0.,6.25,5.0)
      CALL PLOTG(XDR2,TMR2A,2,7,0,5,' ',1,' ',1,0.,0.,0.,0.,6.25,5.0)
      CALL PLOTG(XDR2,TMR2B,2,8,0,5,' ',1,' ',1,0.,0.,0.,0.,6.25,5.0)
      CALL PLOT (0.0,0.0,999)
C
  555 CONTINUE
      STOP
      END
```

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