Norman Schlemmer EP46

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SPACE SHUTTLE MAIN ENGINE POWERHEAD STRUCTURAL MODELING, STRESS AND FATIGUE LIFE ANALYSIS

VOLUME I - GASDYNAMIC ENVIRONMENT OF THE SSME HPFTP AND HPOTP TURBINES

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FOREWORD

This report summarizes the results of work performed on Contract NAS8-34978. The work was performed by personnel of the Product Engineering & Development Section of Lockheed's Huntsville Research & Engineering Center, for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama. The Contracting Officer's technical representative for this study is Mr. Norman C. Schlemmer, Structures and Propulsion Laboratory, Engineering Analysis Division, Stress Analysis Branch (EP46).

This report is divided into four volumes with a section covering one aspect of analysis for all components and loads, and a fourth section for investigation of unscheduled events and special tasks undertaken during the effort. The volumes are:

Volume I - Gasdynamic Environment of the SSME HPFTP and HPOTP Turbines, LMSC-HREC TR D867333-I.

Volume II - Dynamics of Blades and Nozzles - SSME HPFTP and HPOTP, LMSC-HREC TR D867333-II.

Volume III - Stress Summary of Blades and Nozzles at FPL and 115 percent RPL Loads SSME HPFTP and HPOTP Blades and Nozzles, LMSC-HREC TR D867333-III.

Volume IV - Summary of Investigation of Unscheduled Events and Special Tasks, LMSC-HREC TR D867333-IV.

It should be noted that this report summarized our findings. A great body of data exists in the form of computer printout and magnetic tapes and is available to any interested reader for either amplification of the summarized data or as a basis for further work.

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1. INTRODUCTION

The objectives of these analyses are to define the gasdynamic and thermal environments acting on the HPFTP and HPOTP nozzles and turbine blades during steady state engine operation. Flow analyses were performed for operation at full power level (FPL) and 115 percent of rated power level (RPL).

2. GASDYNAMIC ANALYSIS FOR THE TURBINE BLADES AND NOZZLE VANES

2.1 ONE-DIMENSIONAL FLOW ANALYSIS

One-dimensional models of the HPFTP and HPOTP turbines (REf. 1) were used to generate average velocity and pressure data at the inlet and discharge of the turbine blades. Required program inputs consist of the following parameters:

1. Turbine inlet pressure and temperature
2. Turbine flow rate
3. Turbine discharge pressure
4. Pump speed.

Program output is described in Table 2-1.

The thermal environment in the first and second stage blade platform and shank regions was calculated based on hot gas leakage and turbine coolant flow rates obtained from the HPFTP and HPOTP turbine coolant models (Ref. 1). Heat transfer coefficients were computed using correlations for flow across a flat plate and a correlation for convection heat transfer in rotating systems (Ref. 2).

<u>Laminar Flow</u>

$$hcx = 0.332 \cdot K \cdot Re^{0.5} \cdot Pr^{0.333}/x$$

<u>Turbulent Flow</u> (Transition at $Re = 5 \times 10^5$)

$$hcx = 0.0288 \cdot K \cdot Re^{0.8} \cdot Pr^{0.333}/x$$

Table 2-1

NOMENCLATURE FOR ONE-DIMENSIONAL TURBINE ANALYSES

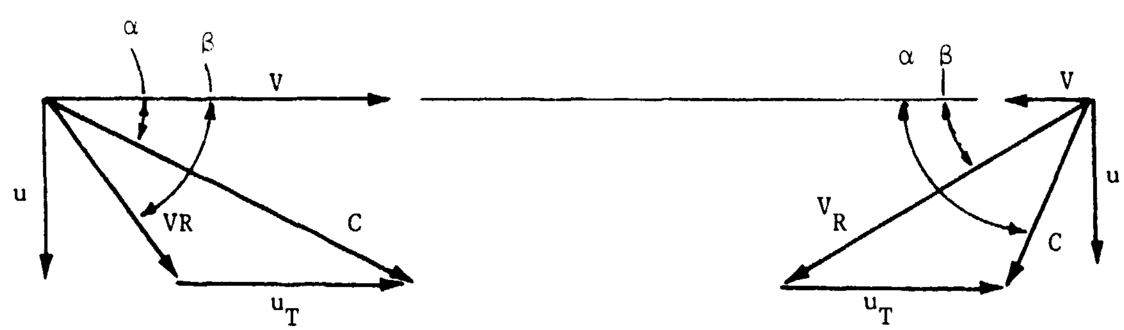
Nomenclature:

P_o	fluid total pressure, psia
P	fluid static pressure, psia
T_o	fluid total temperature, R
T	fluid static temperature, R
α	fluid absolute flow angle, deg
β	fluid relative flow angle, deg
C	fluid absolute velocity, ft/sec
V	fluid tangential velocity, ft/sec
u	fluid axial velocity, ft/sec
VR	fluid relative velocity, ft/sec
u_T	blade velocity, ft/sec
$\dot{w}$	turbine flow rate, lbm/sec
RPM	pump speed

Velocity Diagrams

Blade Inlet

Blade Exit



Rotating Systems

$$hc = 0.035 \cdot K \cdot (Re_{ro})^{0.7} \cdot (Re_s)^{0.1} \cdot (r_i/r_o)^{0.3} \cdot (2a/r_o)^{1.06}/2a$$

where:

- K is thermal conductivity
- Re is the Reynolds no., $\rho \cdot V \cdot x/\mu$
- Pr is the Prandtl no., $\mu \cdot cp/K$
- X is the flow distance along the plate
- Re_{ro} is the rotational Reynolds no., $\rho \cdot \omega \cdot r_o^2/\mu$
- Re_s is the source flow Reynolds no., $\dot{w}/(4\pi \cdot a \mu)$
- r_i is the inner radius of the rotating disk
- r_o is the outer radius of the rotating disk
- a is the gap between the rotating and stationary disks.
- ω is the rotational velocity, rad/sec
- $\dot{w}$ is the flow rate, lbm/sec

2.2 FLOWFIELD CALCULATIONS BASED ON NASA-LEWIS CODES ANALYSIS

The gasdynamic environment of the HPFTP and HPOTP nozzle vanes and turbine blades was calculated with a set of three codes obtained from NASA-Lewis Research Center. The first step in the analysis uses an inviscid flow code designated MERIDL (Refs. 3 and 4) and determines the flow characteristics at the plane located at the midpoint between the two mean-camber lines of adjacent blades. The second step in the inviscid calculation procedure is the blade-to-blade calculation for each of eleven stream sheets using the code TSONIC (Ref. 5). By use of the MERIDL and TSONIC codes, a quasi three-dimensional calculation is effected.

The thermal environment experienced by the blade was determined by use of the boundary layer code BLAYER (Ref. 6). This code sovles the two-dimensional, compressible, laminar and turbulent boundary layer equations in an arbitrary pressure gradient.

3. HPFTP TURBINE ANALYSIS

3.1 ONE-DIMENSIONAL ANALYSIS RESULTS

Average velocity and pressure data at the inlet and discharge of the turbine blades were computed as described in Section 2.1. Data were computed at the FPL and 115 percent power levels using revision F engine balance data. Results of these analyses are presented in Table 3-1.

The thermal environment in the platform and shank region of the turbine blades was also computed at both power levels. Coolant and hot gas leakage flow data used in the analysis are shown in Table 3-2. Results are presented in Tables 3-3 through 3-12. The heat transfer correlations and method of analysis are described in Section 2.1.

3.2 NASA-LEWIS CODES ANALYSIS RESULTS

The computer codes described in Section 2.2 were used to generate thermal and pressure loads for the HPFTP turbine nozzles and blades at the FPL and 115 percent power levels. Input data were obtained from Revision F engine balance data and from the one-dimensional analysis results shown in Table 3-1. Analysis results for vane pressure, heat transfer coefficient and adiabatic wall temperature profiles at five radial locations are contained in Appendixes A through D.

Pressure data obtained from the BLAYER program were integrated over the vane surface to obtain the net torque force on the first and second stage blades. These forces are compared to approximate values based on the torque obtained from engine balance data in Table 3-13. The forces obtained from engine balance data are approximately 10 percent higher than those obtained from the NASA-Lewis codes analysis. Part of this discrepancy is due to smoothing of the pressure profile data which is required to obtain execution of the BLAYER program.

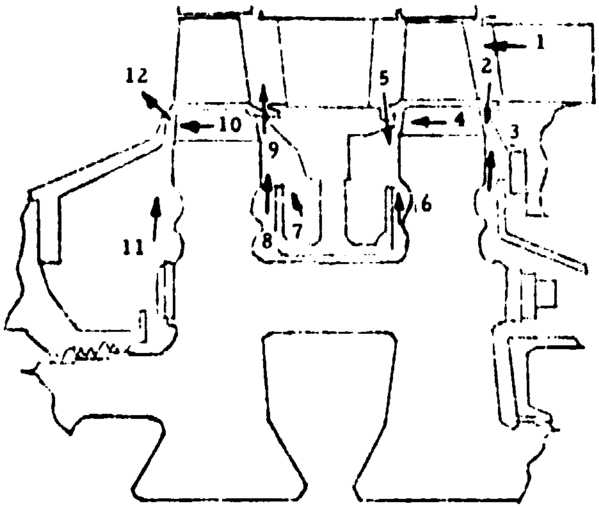
Table 3-1

AVERAGE FLUID PROPERTIES AT INLET AND DISCHRAGE
OF HPFTP TURBINE BLADES AT THE MEAN DIAMETER

	FPL		115 Percent	
	First Stage Blade	Second Stage Blade	First Stage Blade	Second Stage Blade
		Blade Inlet		
P_o	5564.7	4481.5	6009.1	4831.8
P	4784.0	3838.3	5151.1	4119.5
T_o	1993.6	1906.8	1941.5	1854.3
T	1917.4	1831.7	1865.6	1778.7
α	24.5	26.75	24.5	26.75
β	54.7	59.0	56.3	60.4
C	2678.0	2650.6	2685.6	2669.4
V	2436.9	2366.9	2443.8	2383.7
u	110.6	1193.0	1113.7	1201.5
VR	1361.6	1392.3	1338.6	1381.9
u_T	1649.14	1649.14	1700.98	1700.98
w	160.78	162.18	176.34	177.74
RPM	37091.0	37091.0	38257.0	38257.0
		Blade Exit		
P_o	4555.3	3665.1	4900.4	3932.8
p	4427.1	3557.5	4761.1	3815.7
T_o	1903.7	1809.4	1850.9	1757.5
T	1889.7	1795.4	1837.1	1743.7
α	77.4	79.2	79.5	81.3
β	30.5	31.1	30.5	31.1
C	1146.4	1145.0	1143.7	1143.5
V	250.2	215.1	208.2	172.9
u	1118.8	1124.6	1124.6	1130.4
VR	2204.4	2177.2	2215.7	2188.4
ul	1649.14	1649.14	1700.98	1700.98
w	160.78	162.18	176.34	177.74
RPM	37091.0	37091.0	38257.0	38257.0

Table 3-2

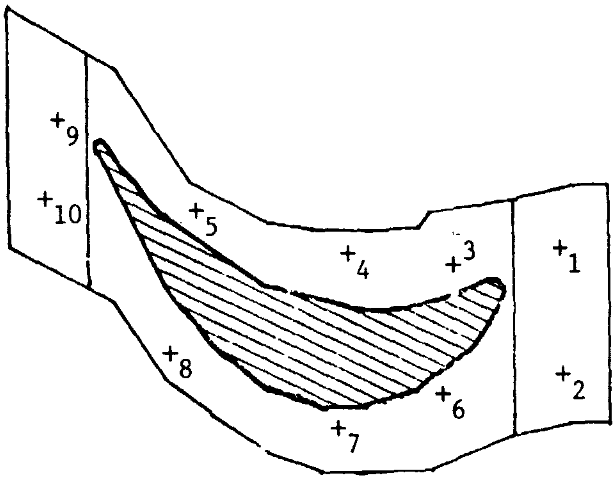
HPFTP TURBINE COOLANT AND LEAKAGE FLOW ANALYSIS



	FPL			115 Percent		
Flow Path	Flow Rate (lbm/sec)	Temperature (R)	Pressure (psia)	Flow Rate (lbm/sec)	Temperature (R)	Pressure (psia)
1	164.18	1917	4784	179.74	1865	5151
2	3.90	1993	4230	4.27	1941	4540
3	0.52	147	↑	0.51	152	↑
4	4.42	1610	|	4.78	1604	|
5	2.15	1903	↓	2.36	1850	↓
6	0.52	155	4230	0.52	161	4540
7	7.09	1513	4215	7.66	1513	4525
8	0.24	155	4215	0.26	161	4525
9	3.68	1438	3838	3.97	1439	4120
10	3.65	1435	4205	3.95	1437	4515
11	0.36	145	4205	0.36	151	4515
12	4.02	1221	3558	4.31	1279	3816

Table 3-3

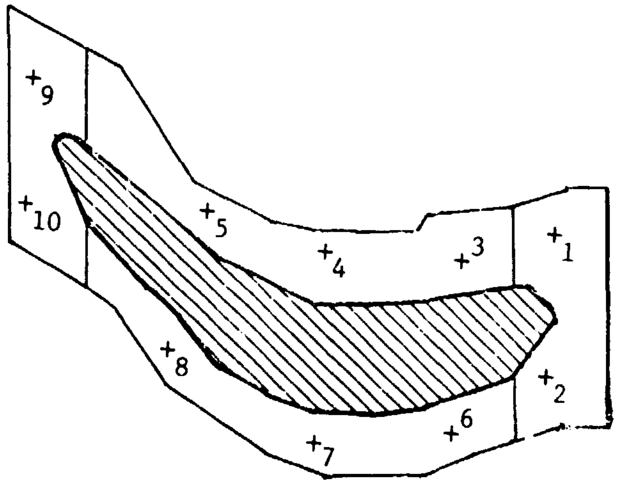
**HPFTP FIRST STAGE ROTOR BLADE (TOP OF PLATFORM)
GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES**



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.012	.013	1535	1485
2	.012	.013	1535	1485
3	.028	.030	1475	1425
4	.025	.027	1475	1425
5	.030	.032	1475	1425
6	.027	.029	1475	1425
7	.026	.028	1475	1425
8	.030	.033	1475	1425
9	.031	.033	1475	1425
10	.031	.033	1475	1425

Table 3-4

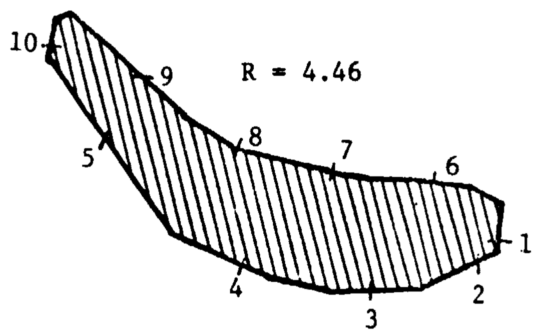
HPFTP FIRST STAGE ROTOR BLADE (BOTTOM OF PLATFORM)
GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.012	.013	1535	1485
2	.012	.013	1535	1485
3	.0030	.0031	1493	1446
4	.0016	.0017	1363	1331
5	.0013	.0013	1255	1237
6	.0018	.0018	1458	1415
7	.0013	.0013	1322	1296
8	.0049	.0052	1178	1169
9	.011	.012	1445	1392
10	.011	.012	1445	1392

Table 3-5

HPFTP FIRST STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.012	.013	1153	1112
2	.0026	.0027	1149	1111
3	.0015	.0016	1150	1123
4	.0053	.0056	1151	1135
5	.0049	.0052	1152	1144
6	.0036	.0037	1148	1110
7	.0018	.0019	1150	1120
8	.0014	.0014	1151	1130
9	.0051	.0055	1152	1141
10	.012	.013	1309	1282

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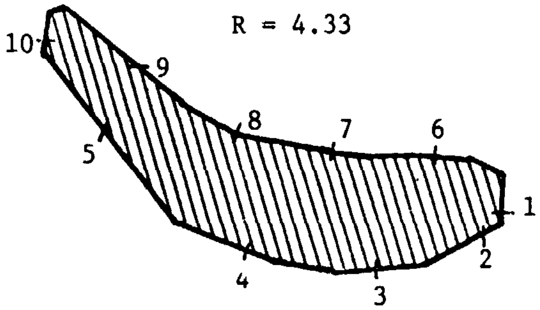
Table 3-6

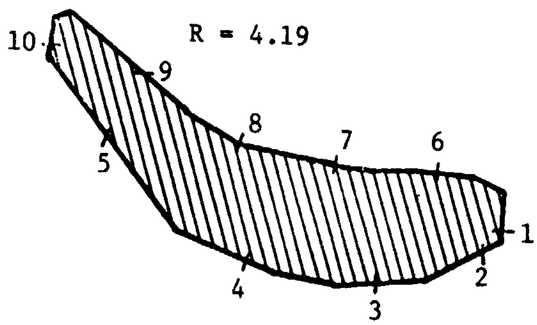
HPFTP FIRST STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in²-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.014	.015	443	437
2	.0030	.0031	541	522
3	.0016	.0017	750	736
4	.0058	.0061	941	932
5	.0051	.0054	1096	1089
6	.0032	.0033	545	525
7	.0017	.0018	732	717
8	.0061	.0065	885	873
9	.0053	.0056	1050	1042
10	.013	.014	1264	1243

Table 3-7

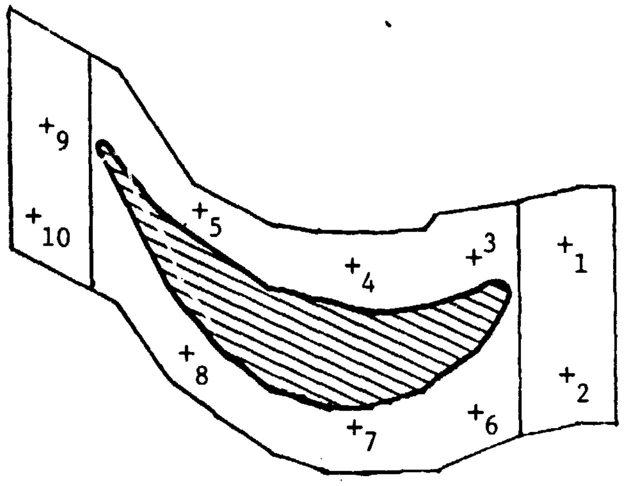
HPFTP FIRST STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.039	.041	-312	-307
2	.030	.031	-163	-159
3	.0089	.0091	204	205
4	.0069	.0073	542	541
5	.0058	.0061	852	848
6	.030	.031	-163	-159
7	.0089	.0091	204	205
8	.0069	.0073	542	541
9	.0058	.0061	852	848
10	.014	.015	1242	1223

Table 3-8

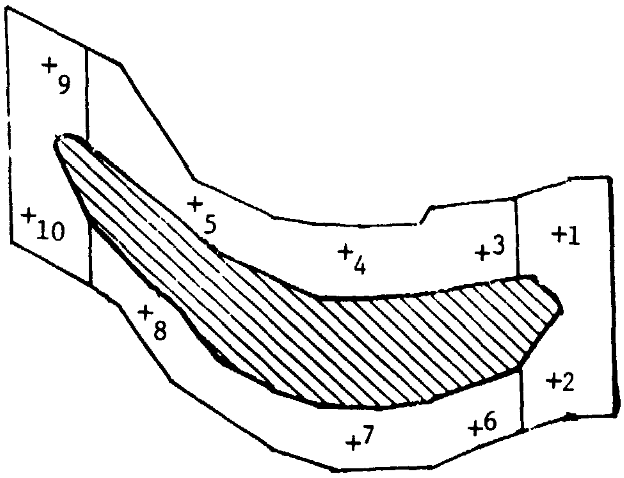
HPFTP SECOND STAGE ROTOR BLADE (TOP OF PLATFORM) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.015	.016	976	976
2	.015	.016	976	976
3	.024	.026	1392	1340
4	.021	.023	1392	1340
5	.025	.027	1392	1340
6	.023	.025	1392	1340
7	.022	.024	1392	1340
8	.026	.028	1392	1340
9	.026	.028	1392	1340
10	.026	.028	1392	1340

Table 3-9

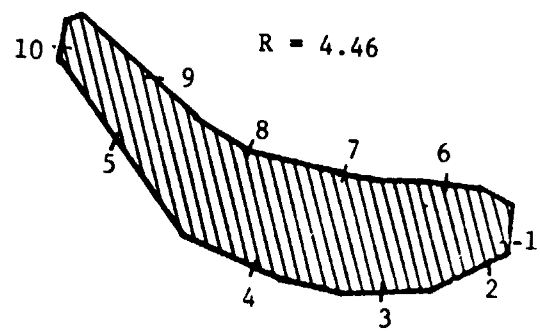
HPFTP SECOND STAGE ROTOR BLADE (BOTTOM OF PLATFORM) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.015	.017	977	977
2	.015	.017	977	977
3	.0028	.0029	977	977
4	.0015	.0015	977	977
5	.0012	.0012	977	977
6	.0017	.0017	977	977
7	.0012	.0012	977	977
8	.0043	.0046	977	977
9	.015	.017	787	801
10	.015	.017	787	801

Table 3-10

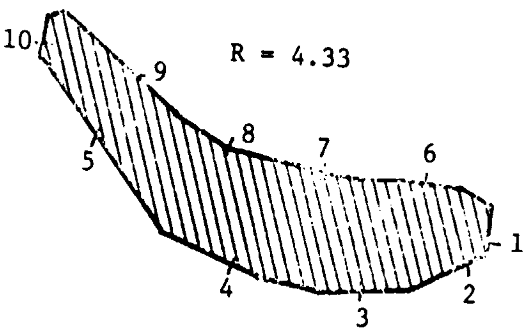
HPFTP SECOND STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.015	.016	977	977
2	.0024	.0024	977	977
3	.0014	.0014	977	977
4	.0011	.0049	977	977
5	.0043	.0046	977	977
6	.0032	.0034	977	977
7	.0016	.0017	977	977
8	.0012	.0013	977	977
9	.0045	.0048	977	977
10	.015	.017	773	788

Table 3-11

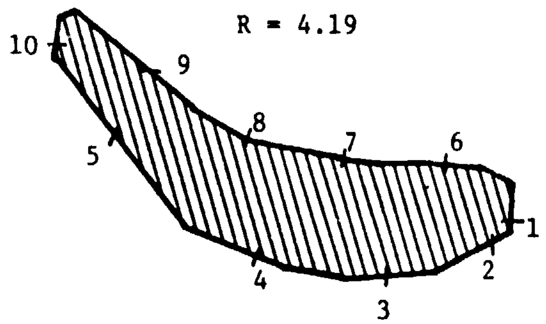
HPFTP SECOND STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in^2-sec-F) FPL	Heat Transfer Coefficients (Btu/in^2-sec-F) 115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	Adiabatic Wall Temperatures (F) 115 Percent Power Level
1	.015	.016	977	977
2	.0024	.0025	977	977
3	.0014	.0014	977	977
4	.0011	.0049	977	977
5	.0044	.0046	977	977
6	.0026	.0027	977	977
7	.0015	.0015	977	977
8	.0012	.0012	977	977
9	.0045	.0047	977	977
10	.015	.016	640	661

Table 3-12

HPFTP SECOND STAGE ROTOR BLADE (SHANK) GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES



Sta. No.	Heat Transfer Coefficients (Btu/in²-sec-F) FPL	115 Percent Power Level	Adiabatic Wall Temperatures (F) FPL	115 Percent Power Level
1	.015	.016	977	977
2	.0024	.0025	977	977
3	.0014	.0015	977	977
4	.0011	.0011	977	977
5	.0045	.0047	977	977
6	.0024	.0025	977	977
7	.0014	.0015	977	977
8	.0011	.0011	977	977
9	.0045	.0047	977	977
10	.038	.040	-304	-298

Table 3-13

HPFTP TURBINE BLADE TORQUE FORCES (lbf)

	FPL		115 Percent	
	BLAYER Program	Approximate (based on engine balance data)	BLAYER Program	Approximate (based on engine balance data)
First Stage	188	209	204	226
Second Stage	191	213	209	231

4. HPOTP TURBINE ANALYSIS

4.1 ONE-DIMENSIONAL ANALYSIS RESULTS

The one-dimensional turbine program (described in Section 2.1) was used to generate average velocity and pressure data at the inlet and discharge of the turbine blades. Data were computed at the FPL and 115 percent power levels using revision F engine balance data. Results of these analyses are presented in Table 4-1.

Coolant and hot gas leakage flow data for the HPOTP nozzles and blades are shown in Fig. 4-1 and Table 4-2. These data were used to generate the thermal environment in the platform and shank region of the turbine blades (Tables 4-3 and 4-4). The heat transfer correlations and method of analysis are described in Section 2.1.

4.2 NASA-LEWIS CODES ANALYSIS RESULTS

The computer codes described in Section 2-2 were used to generate thermal and pressure loads for the HPOTP turbine nozzles and blades at the FPL and 115 percent levels. Input data were obtained from Revision F engine balance data and from the one-dimensional analysis results shown in Table 3-1. Analysis results for vane pressure, heat transfer coefficient and adiabatic wall temperature profiles at three radial locations are contained in Appendixes E through H.

Pressure data obtained from the BLAYER program were integrated over the vane surface to obtain the net torque force on the first and second stage blades. These forces are compared to approximate values based on the torque obtained from engine balance data in Table 4-5. The forces obtained from engine balance data are 8 to 15 percent higher than those obtained from the NASA-Lewis codes analysis. Part of this discrepancy is due to smoothing of the pressure profile data which is required to obtain execution of the BLAYER Program.

Table 4-1

AVERAGE FLUID PROPERTIES AT INLET AND DISCHARGE
OF HPOTP TURBINE BLADES AT THE MEAN DIAMETER

	FPL		115 Percent	
	First Stage Blade	Second Stage Blade	First Stage Blade	Second Stage Blade
Blade Inlet				
P_o	5459.5	4219.3	5980.5	4580.7
P	4182.1	3664.7	4537.9	3948.5
T_o	1499.8	1407.0	1686.0	1585.1
T	1395.4	1354.2	1566.5	1523.4
α	16.0	22.5	16.0	22.5
β	26.2	46.8	26.1	46.0
C	3327.6	2368.7	3648.2	2494.5
V	3198.7	2188.4	3333.9	2304.6
u	917.2	906.5	956.0	954.6
VR	2075.4	1243.6	2172.7	1327.0
u_T	1336.94	1336.94	1382.81	1382.81
$\dot{w}$	66.73	67.85	72.00	73.18
RPM	30367.0	30367.0	31409.0	31409.0
Blade Exit				
P_o	4271.8	3597.0	4640.7	3874.5
P	4152.5	3534.2	4504.6	3802.5
T_o	1404.6	1342.8	1582.5	1511.7
T	1393.9	1336.4	1570.0	1504.1
α	69.9	85.6	69.1	83.6
β	30.5	30.5	30.5	30.5
C	1069.4	827.5	1125.0	877.4
V	367.8	63.8	401.3	97.4
u	1004.2	825.1	1050.9	871.9
VR	1978.5	1625.7	2070.6	1717.9
u_T	1336.94	1336.94	1382.81	1382.81
$\dot{w}$	66.73	67.85	72.00	73.18
RPM	30367.0	30367.0	31409.0	31409.0

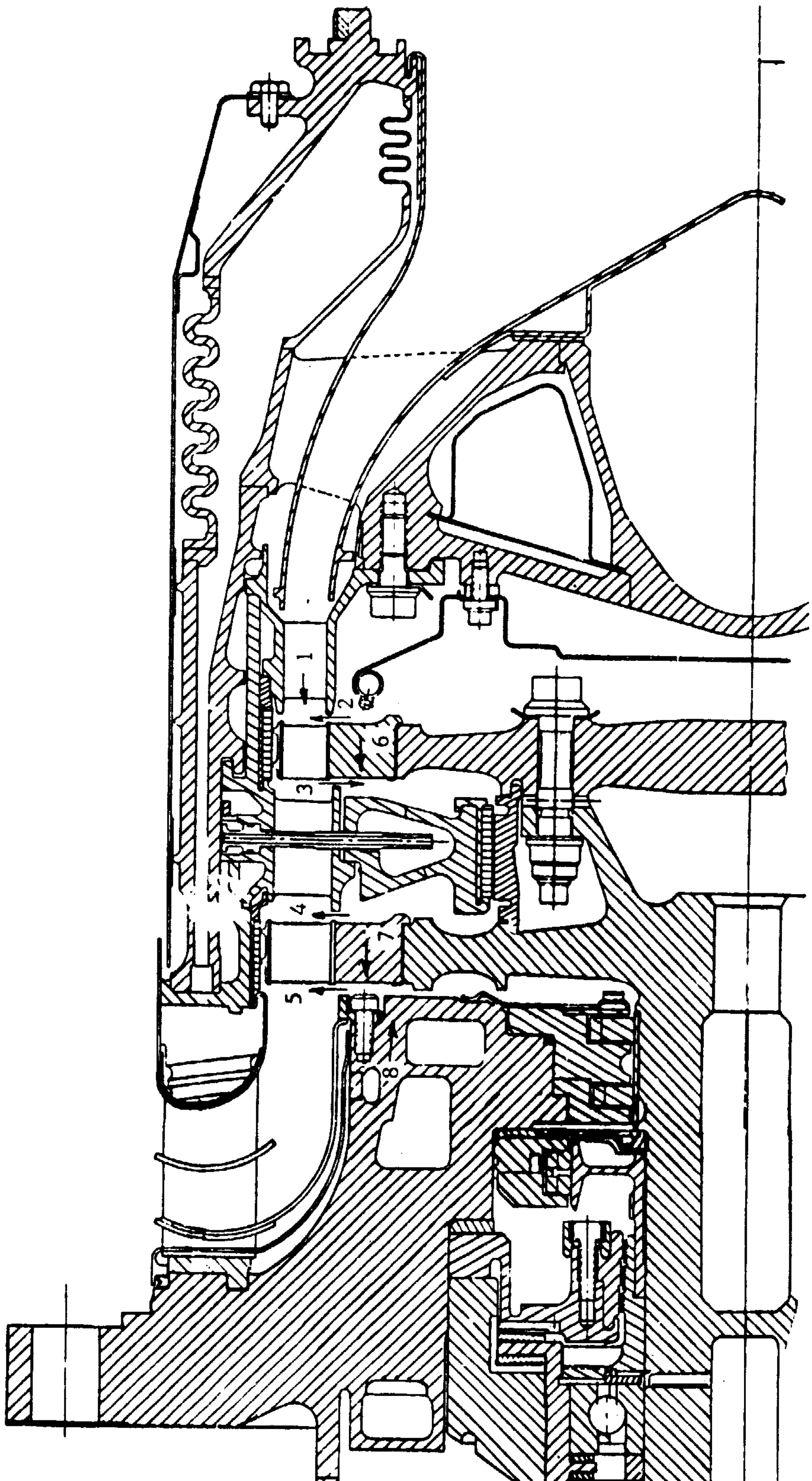


Fig. 4-1 HPOTP Turbine Coolant and Leakage Flow Analysis

Table 4-2

HPOTP TURBINE COOLANT AND LEAKAGE FLOW ANALYSIS

	FPL			115 Percent		
Flow Path	Flow Rate (lbm/sec)	Temperature (R)	Pressure (psia)	Flow rate (lbm/sec)	Temperature (R)	Pressure (psia)
1	65.88	1395	4180	71.11	1565	4540
2	0.84	715	4180	0.88	790	4540
3	1.47	1395	4150	1.57	1570	4505
4	2.60	1025	3665	2.78	1145	3950
5	0.09	810	3535	0.10	895	3800
6	0.09	715	4180	0.11	790	4540
7	0.17	1025	3665	0.18	1145	3950
8	0.39	715	3535	0.42	795	3800

Table 4-3

HPOTP FIRST STAGE ROTOR BLADE SHANK, PLATFORM AND SHROUD
GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES

		Heat Transfer Coeff. (Btu/in^2 -sec-F)		Adiabatic Wall Temp. (F)	
Zone	Description	FPL	115 Percent	FPL	115 Percent
1	Front Face of Shank	.018	.017	255	330
2	Back Face of Shank	.013	.013	950	1130
3	Sides of Shank	.00014	.00016	255	330
4	Under Side of Platform	Same as zones 1 and 2 at front and back, same as zone 3 on sides.			
5	Top of Platform	Interpolation of pressure and suction side airfoil data at the hub (see Section 4.2).			
6	Bottom of Shroud	Interpolation of pressure and suction side airfoil data at the tip (see Section 4.2).			

Table 4-4

HPOTP SECOND STAGE ROTOR BLADE SHANK, PLATFORM AND SHROUD GAS FILM COEFFICIENTS AND ADIABATIC WALL TEMPERATURES

		Heat Transfer Coeff. (Btu/in^2-sec-F)		Adiabatic Wall Temp. (F)	
Zone	Description	FPL	115 Percent	FPL	115 Percent
1	Front Face of Shank	.015	.016	580	700
2	Back Face of Shank	.012	.012	350	435
3	Both Sides of Shank	.0002	.0002	580	700
4	Under Side of Platform	Same as zones 1 and 2 at front and back, same as zone 3 on sides.			
5	Top of Platform	Interpolation of pressure and suction side airfoil data at the hub (see Section 4.2)			
6	Bottom of Shroud	Interpolation of pressure and suction side airfoil data at the tip (see Section 4.2)			

Table 4-5

HPOTP TURBINE BLADE TORQUE FORCES (LBF)

	FPL		115 percent	
	BLAYER Program	Approximate (based on engine balance data)	BLAYER Program	Approximate (based on engine balance data)
First Stage	80	92	90	97
Second STage	57	66	65	70

REFERENCES

1. Teal, G.A., "SSME Turbopump Flow Models - User's Manual," LMSC-HREC TR D867623, Lockheed Missiles & Space Company, Huntsville, Ala., October 1982.

2. Keith, F., Advances in Heat Transfer Vol. 5, Academic Press, New York, 1968, p. 192.

3. Katsanis, Theodore, and W.D. McNally, "Revised FORTRAN Program for Calculating Velocities and Streamlines on the Hub-Shroud Mid-Channel Stream Surface of an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct - Vol. II - Programmer's Manual," NASA TN D-8431, July 1977.

4. Katsanis, Theodore, and W.D. McNally, "Revised FORTRAN Program for Calculating Velocities and Streamlines on the Hub-Shroud Mid-Channel Stream Surface of an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct - Vol. I - User's Manual," NASA TN D-8430, March 1977.

5. Katsanis, Theodore, "FORTRAN Program for Calculating Transonic Velocities on a Blade-to-Blade Stream Surface of a Turbomachine," NASA TND-5427, September 1969.

6. McNally, William D., "FORTRAN Program for Calculating Compressible Laminar and Turbulent Boundary Layers in Arbitrary Pressure Gradients," NASA TN D-5681, May 1970.

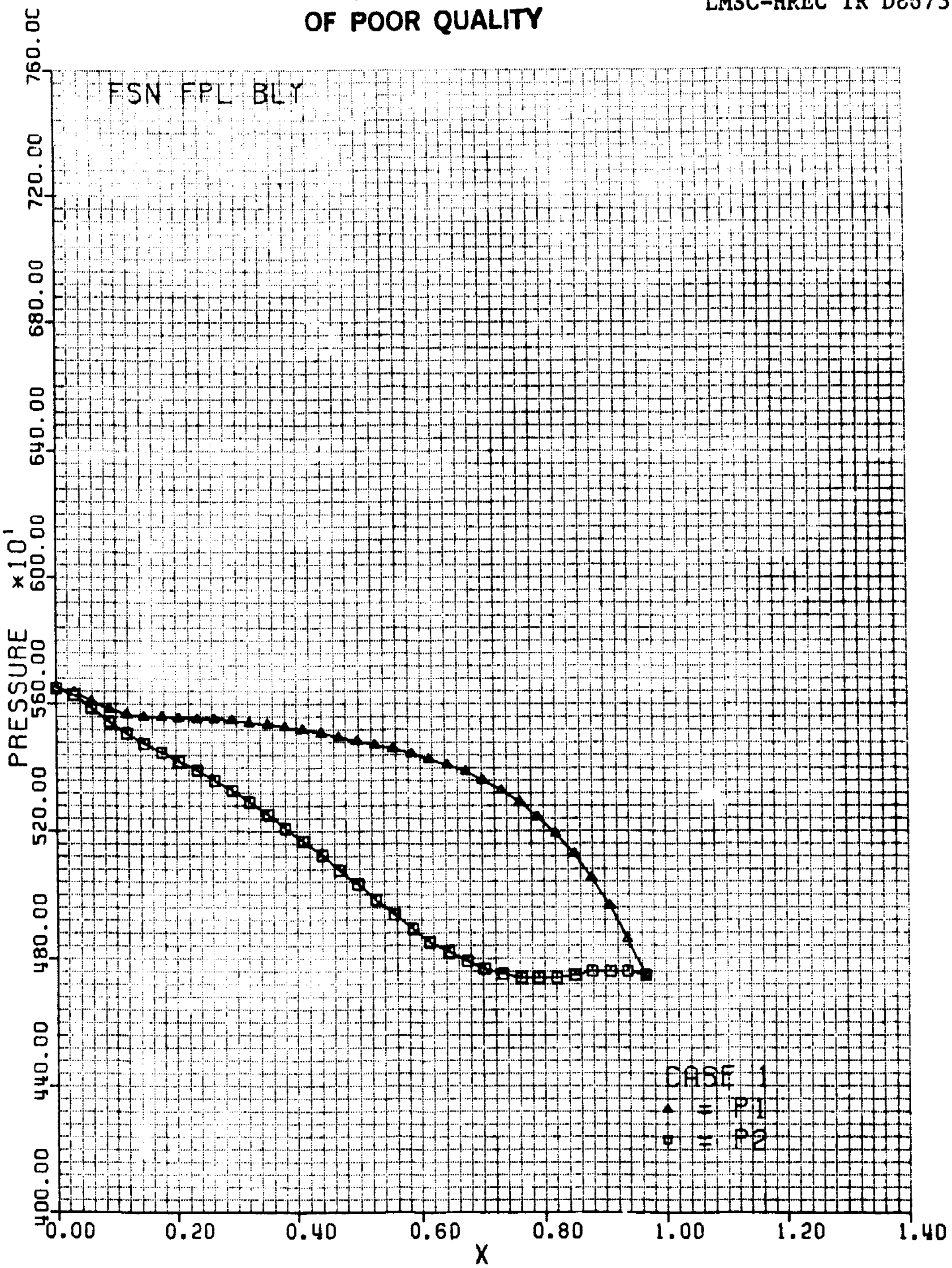
Appendix A

HPFTP FIRST STAGE NOZZLE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

A.1 FPL Pressure Distributions
A.2 115 Percent Power Level Pressure Distributions
A.3 FPL Heat Transfer Coefficients
A.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Pressure Surface △
Surface 2 - Suction Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Case 1 - R = 4.5965 Hub	1530	1476
Case 2 - R = 4.79 Intermediate	↓	↓
Case 3 - R = 5.033 Mean	↓	↓
Case 4 - R = 5.23 Intermediate	↓	↓
Case 5 - R = 5.4695 Tip	↓	↓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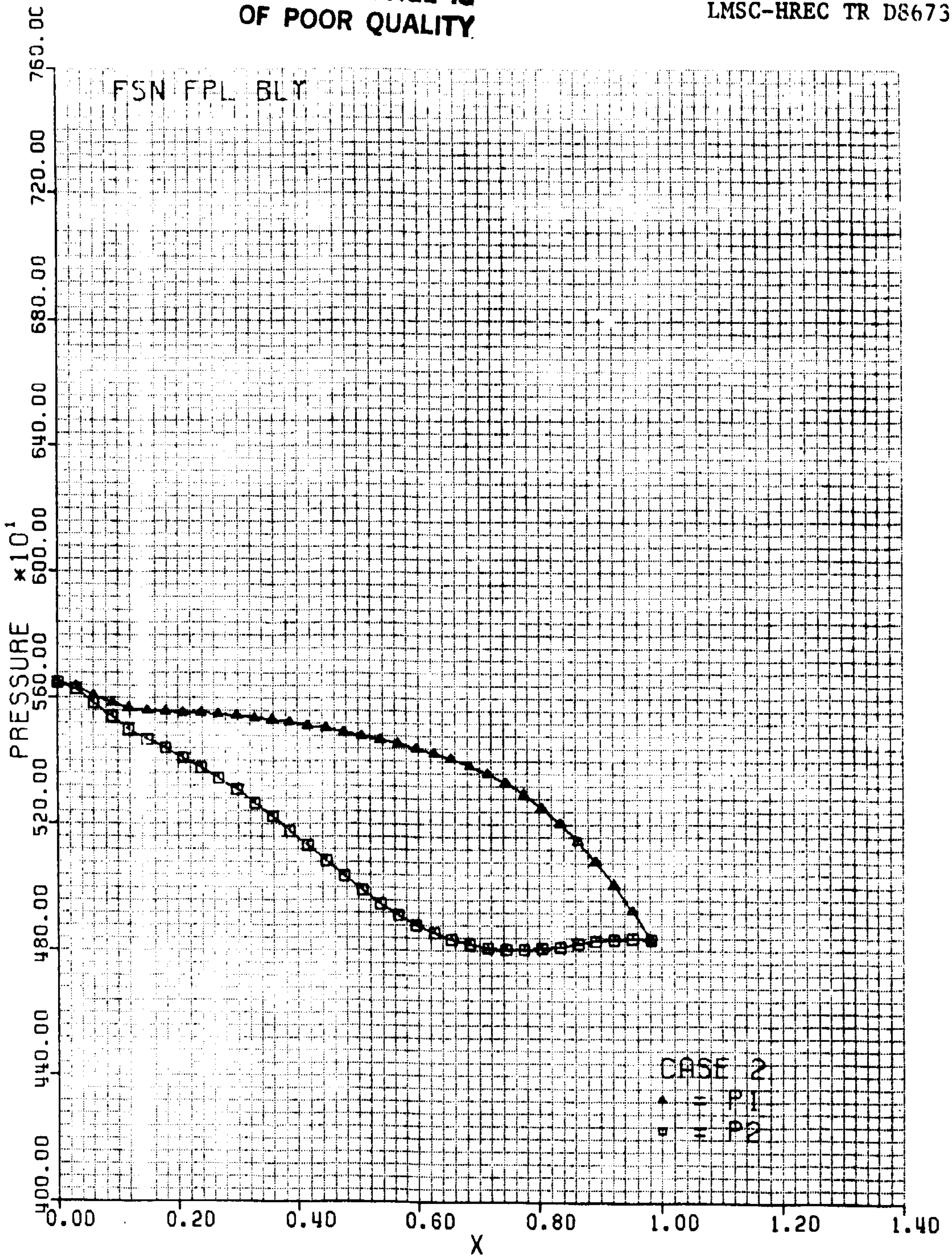
PRESSURE *10[1]
760.00
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = P1
▫ = P2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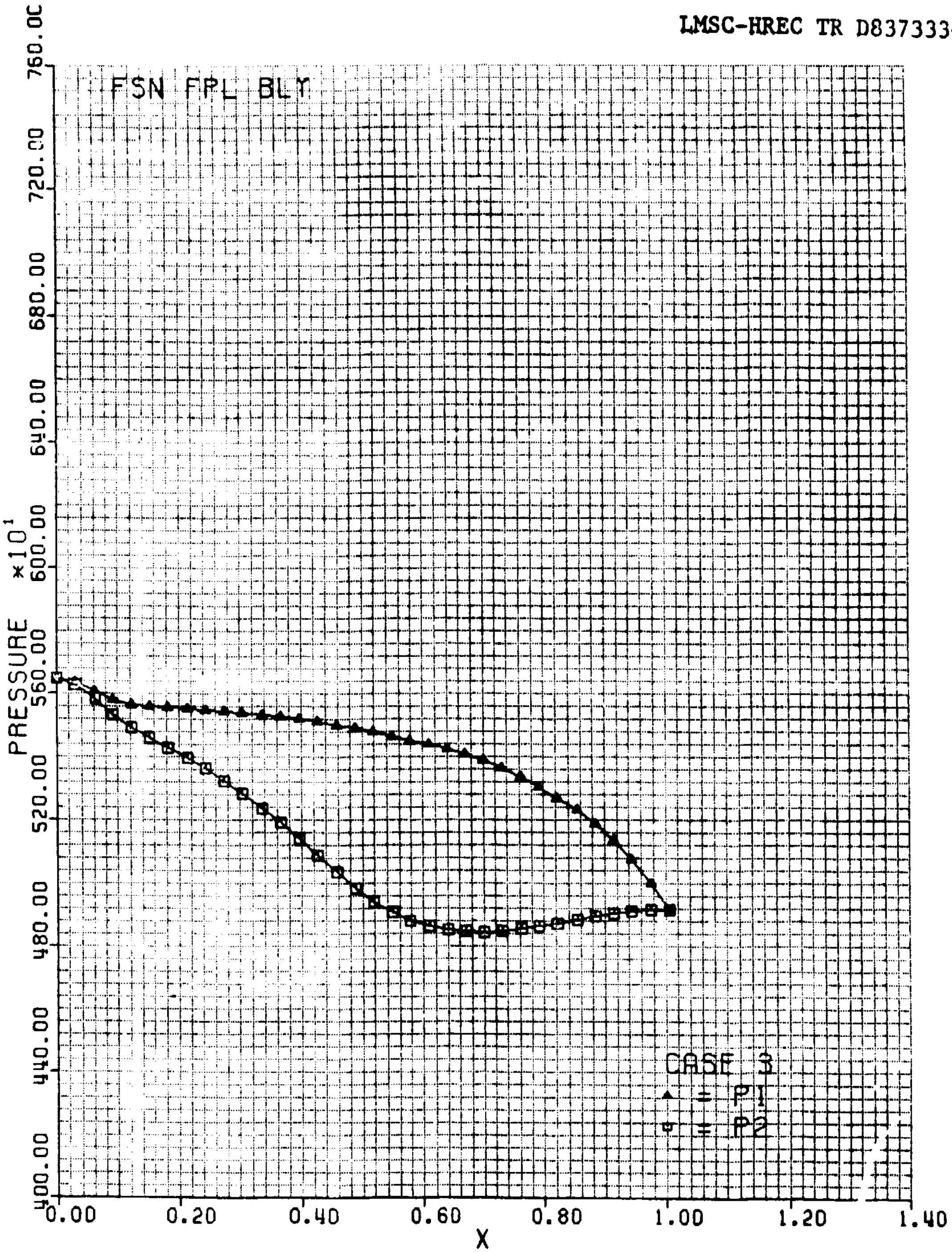
PRESSURE ×10¹
760.00
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
= P1
= P2



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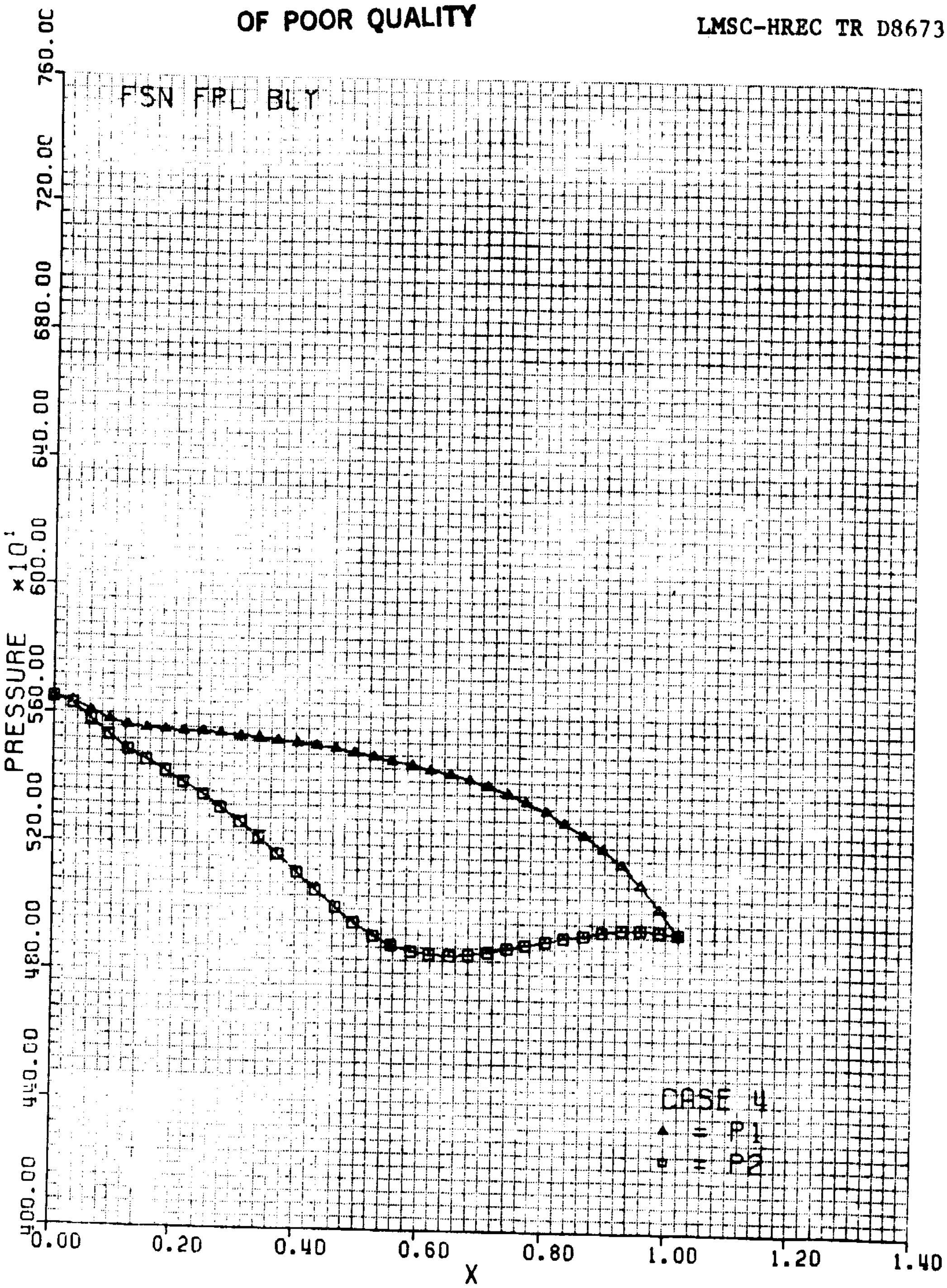

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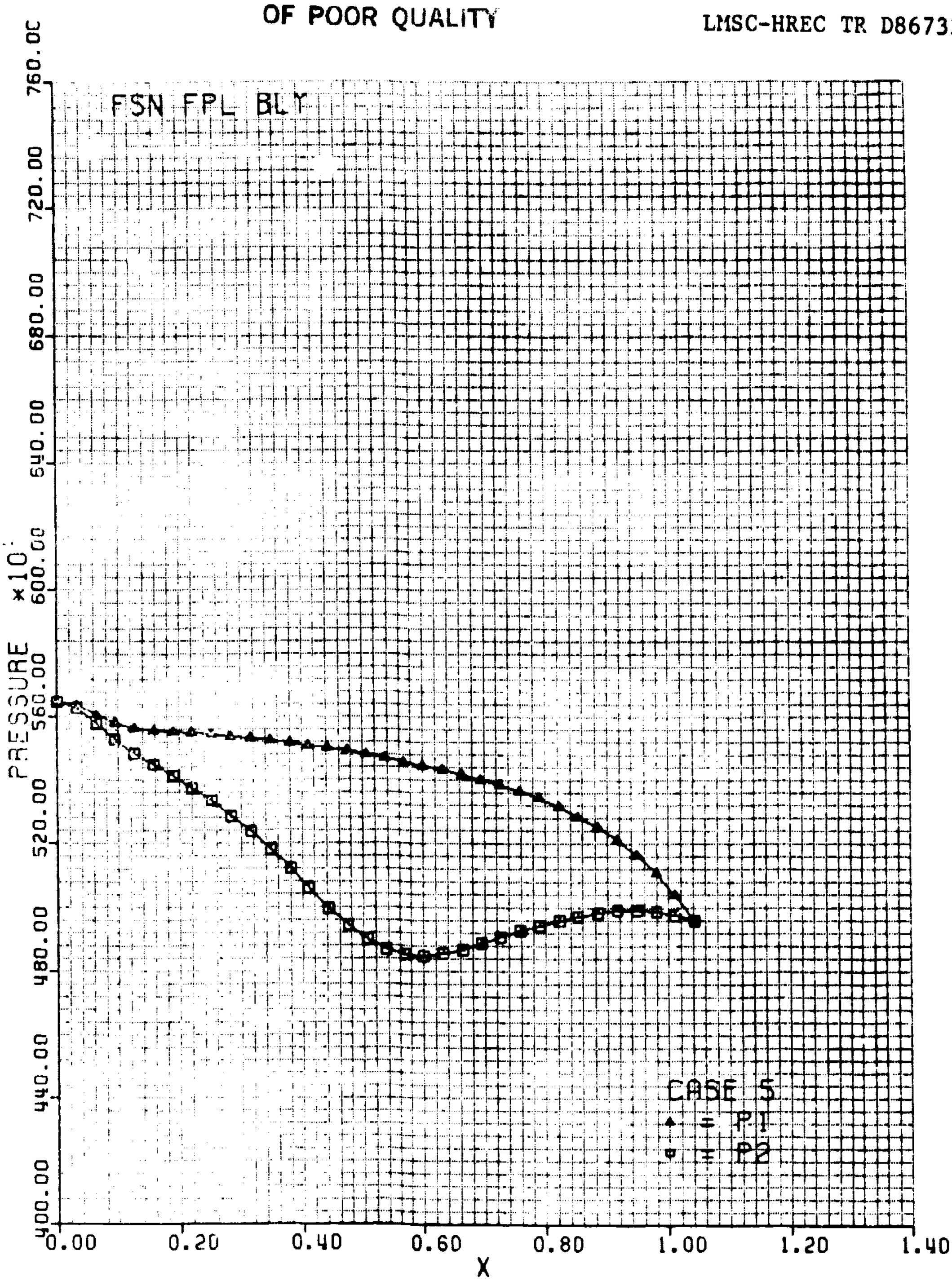

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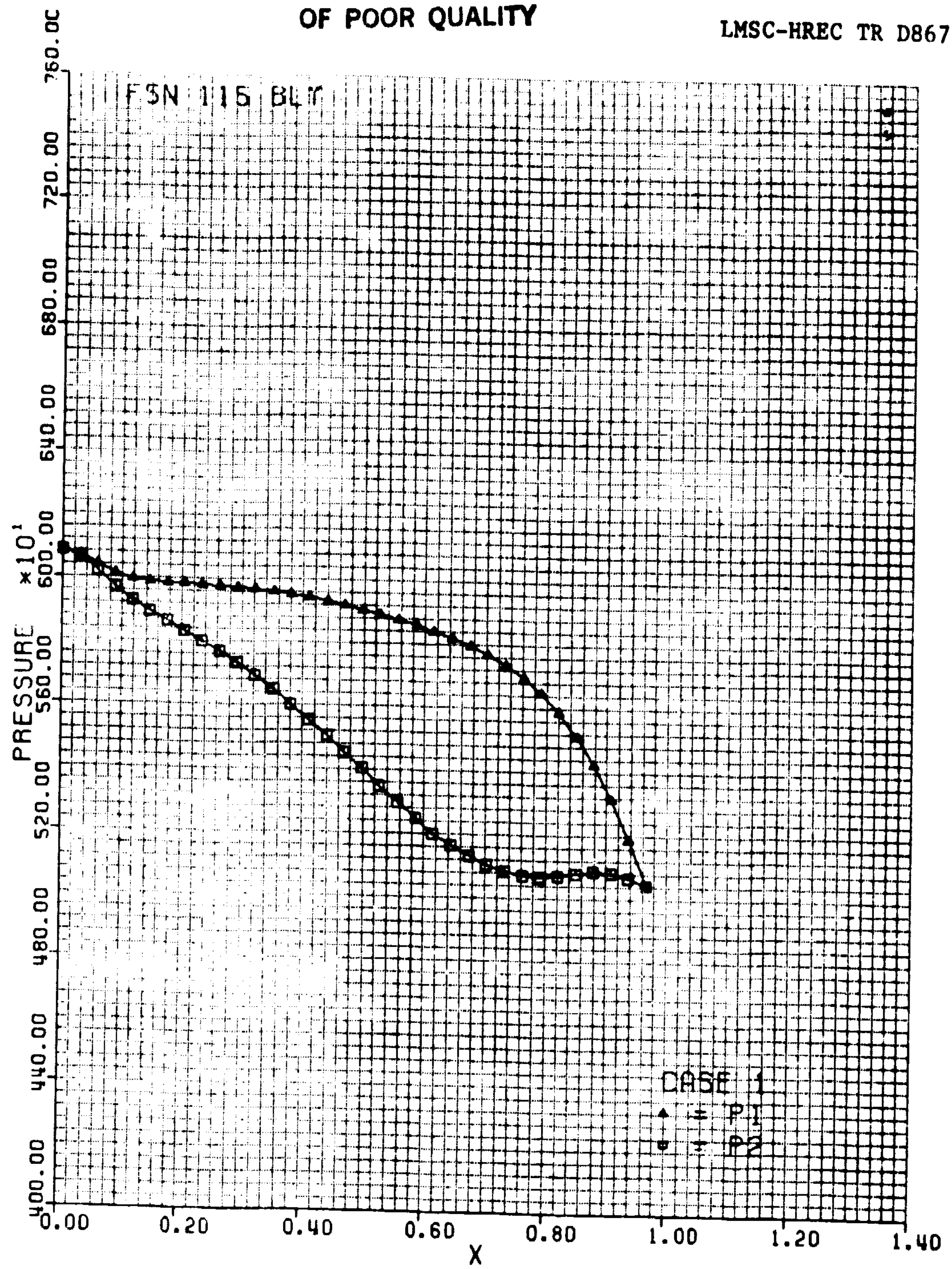
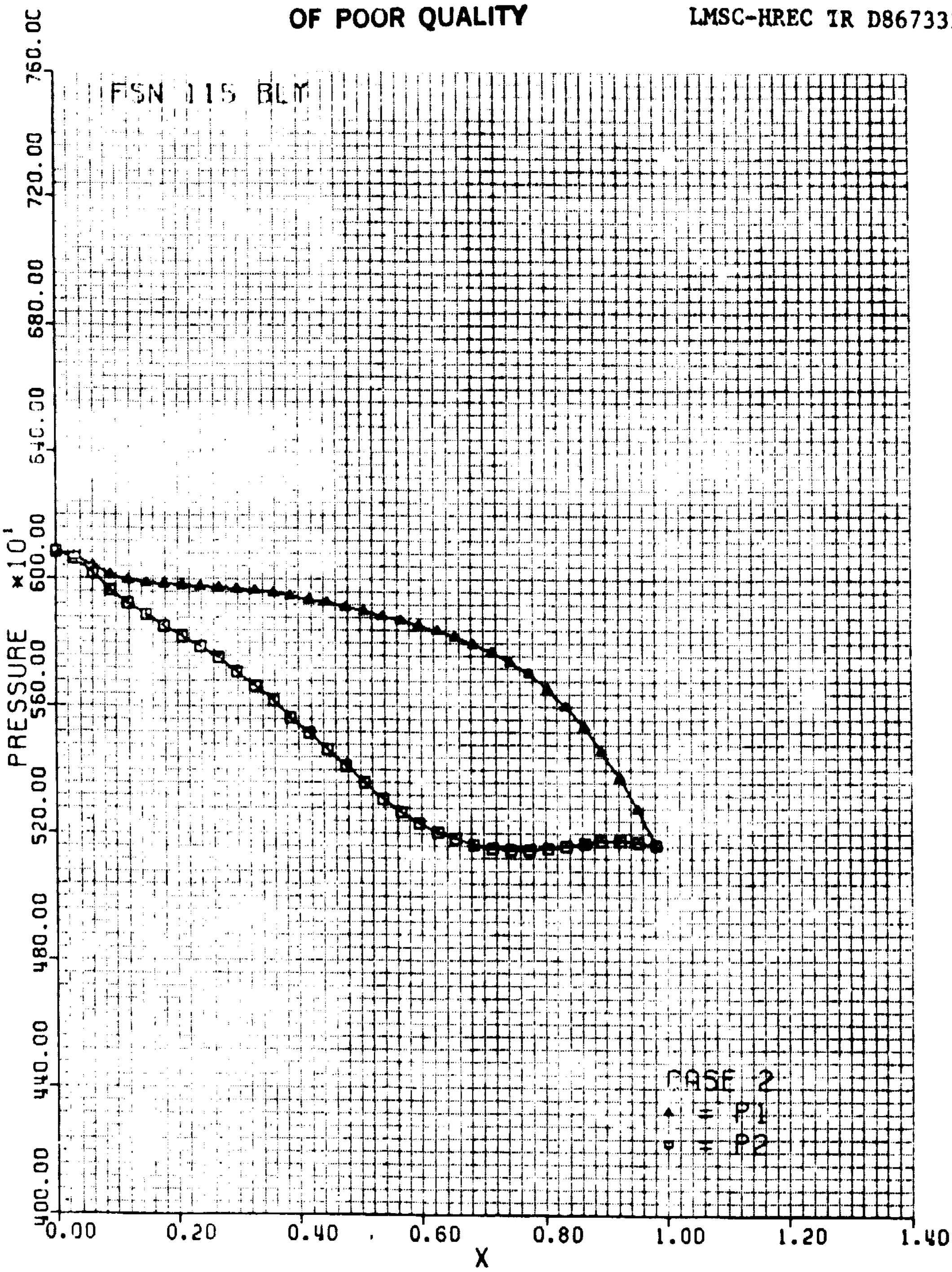
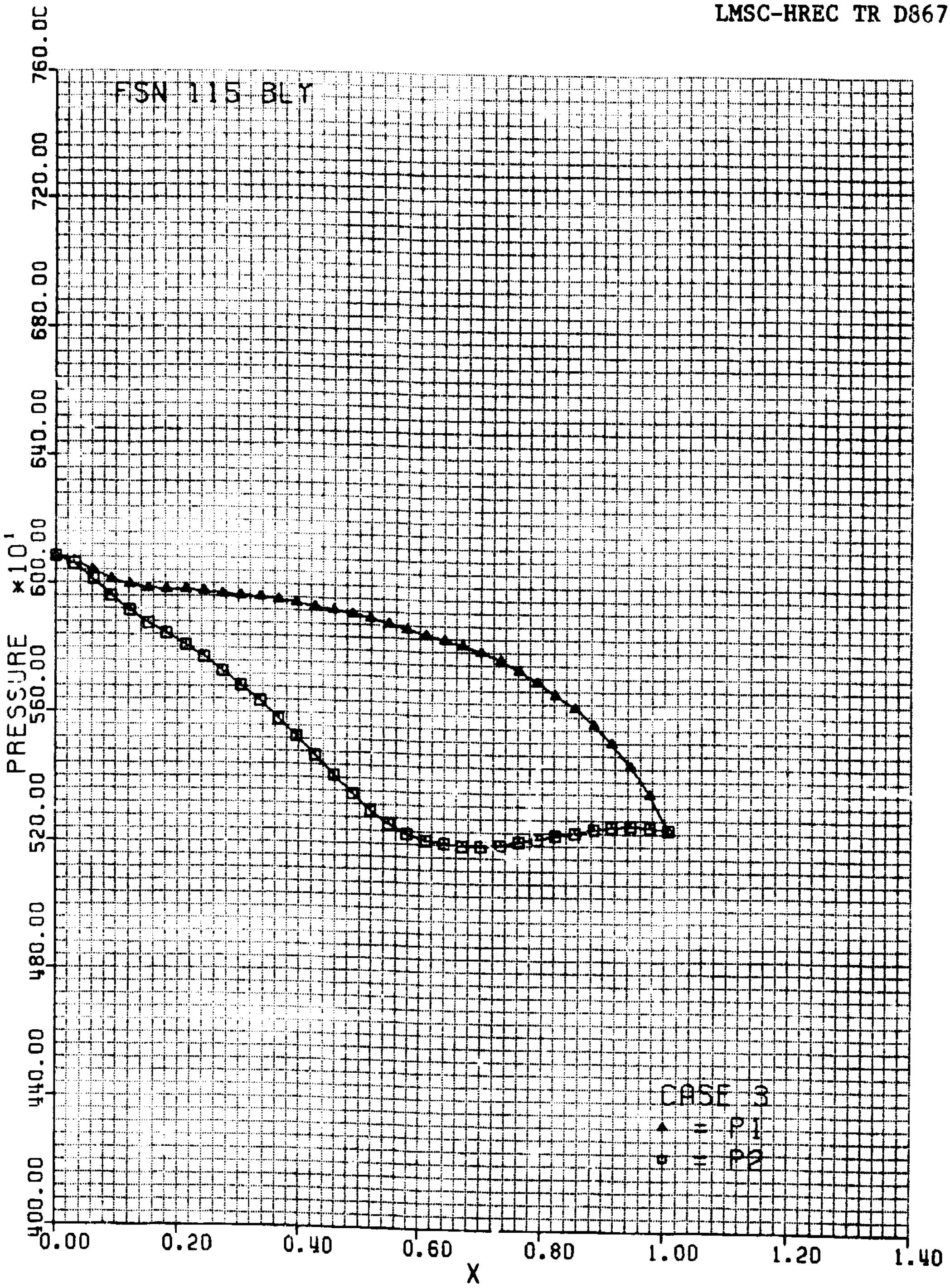



FSN 115 BLM
PRESSURE ×10¹
760.00
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
▲ = P1
▽ = P2



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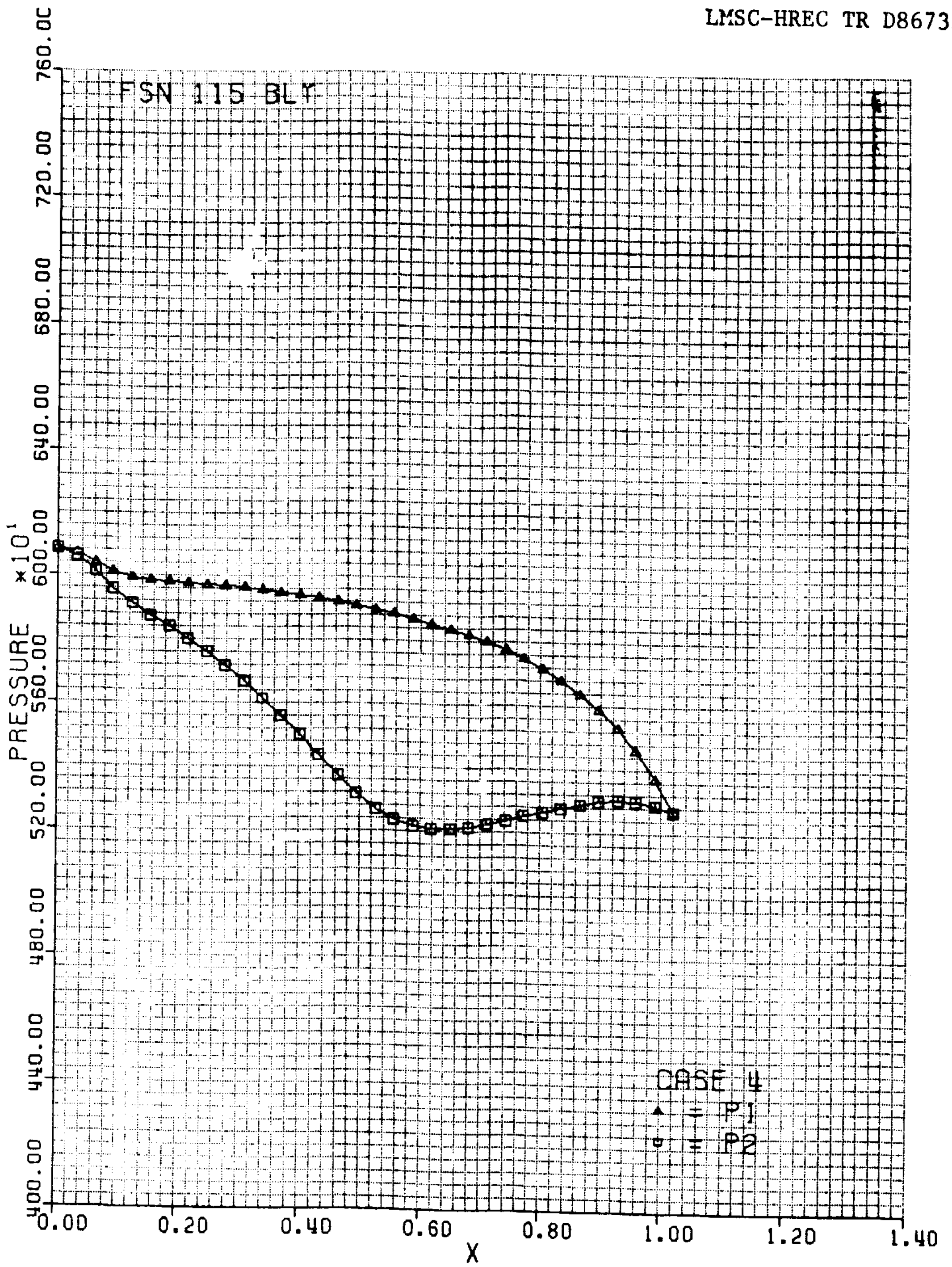
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PRESSURE *10^1
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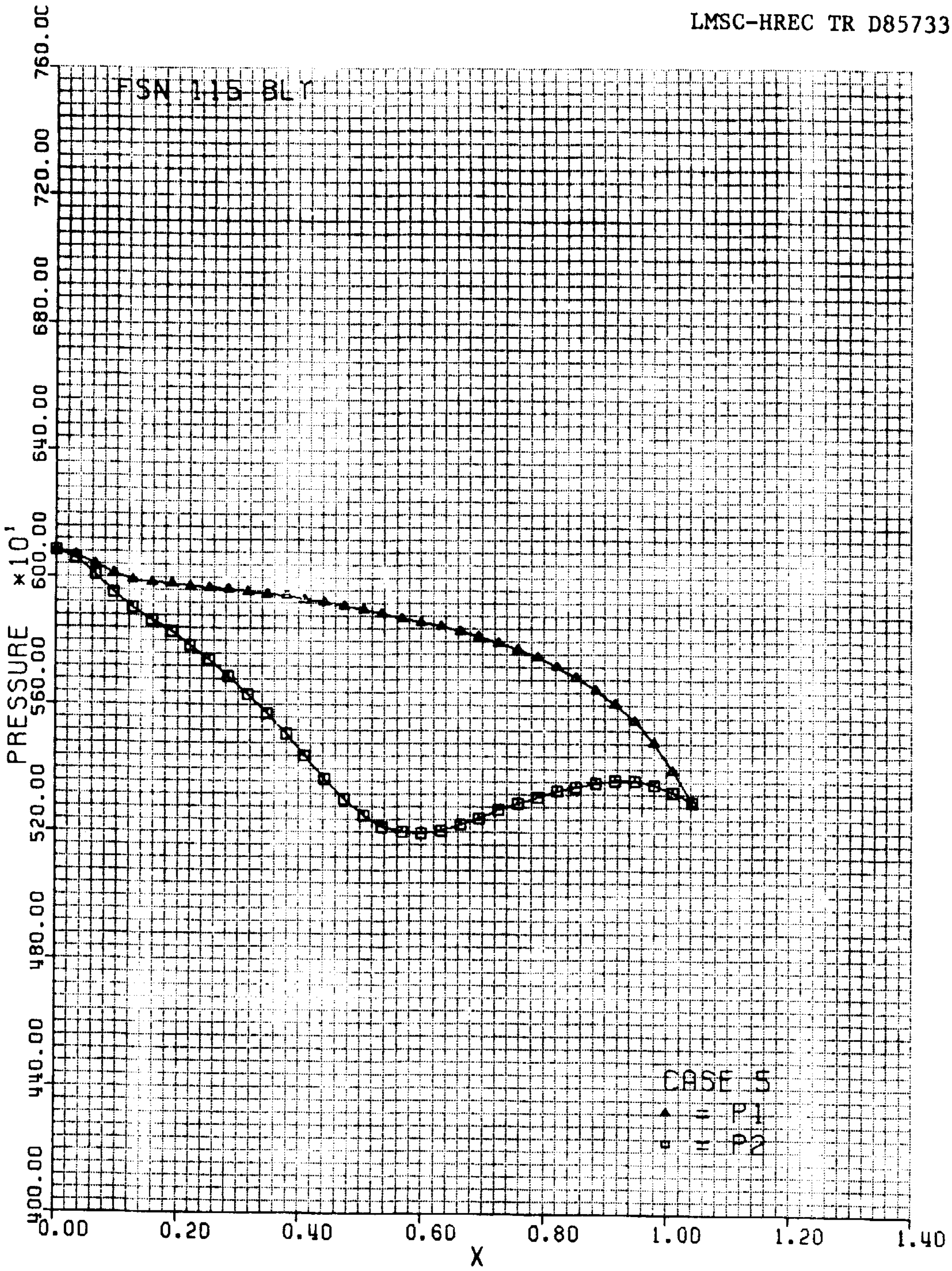
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
▲ = P1
□ = P2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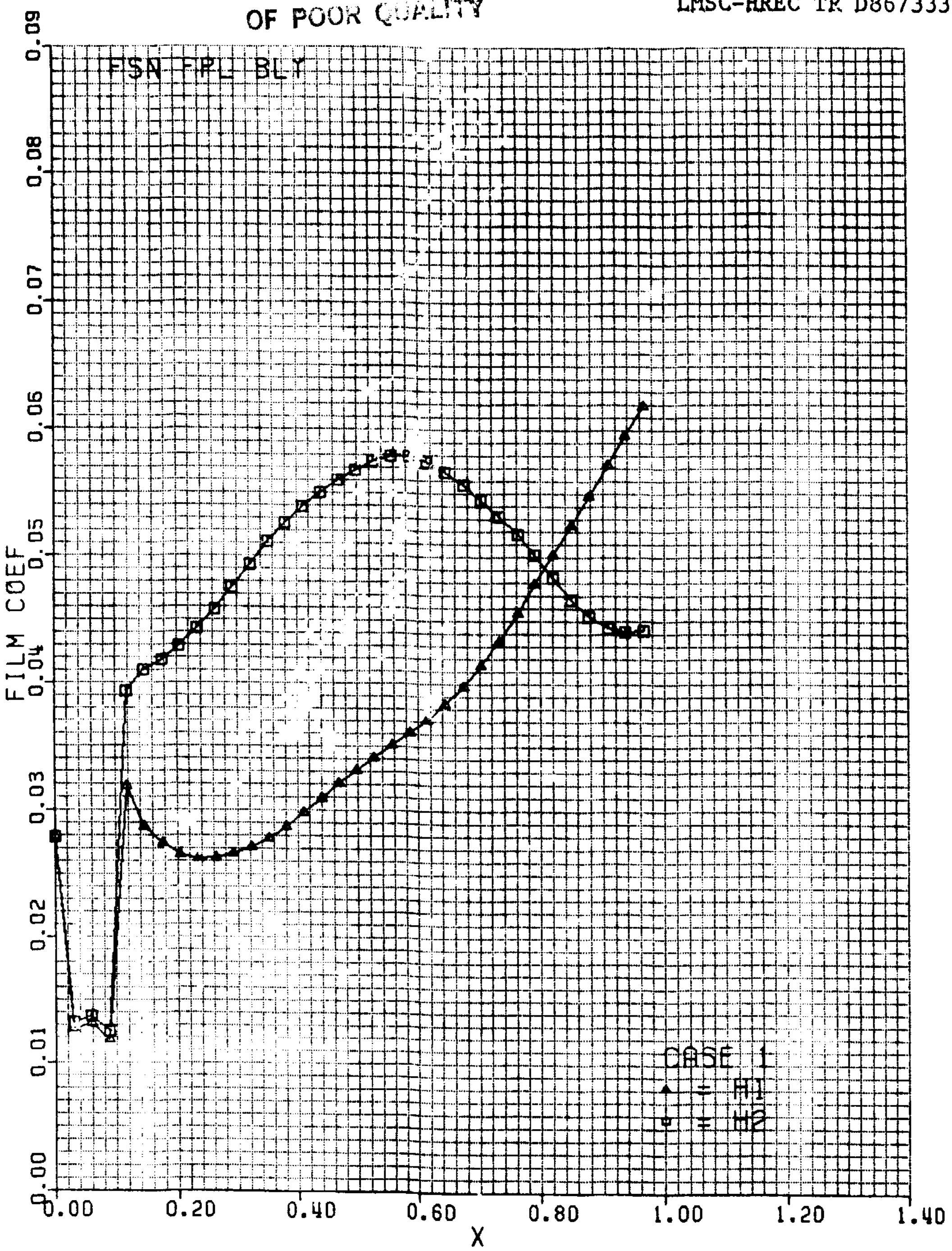
720.00
680.00
640.00
600.00
560.00
520.00
480.00
440.00
400.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
▲ = P1
▫ = P2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FILM COEF
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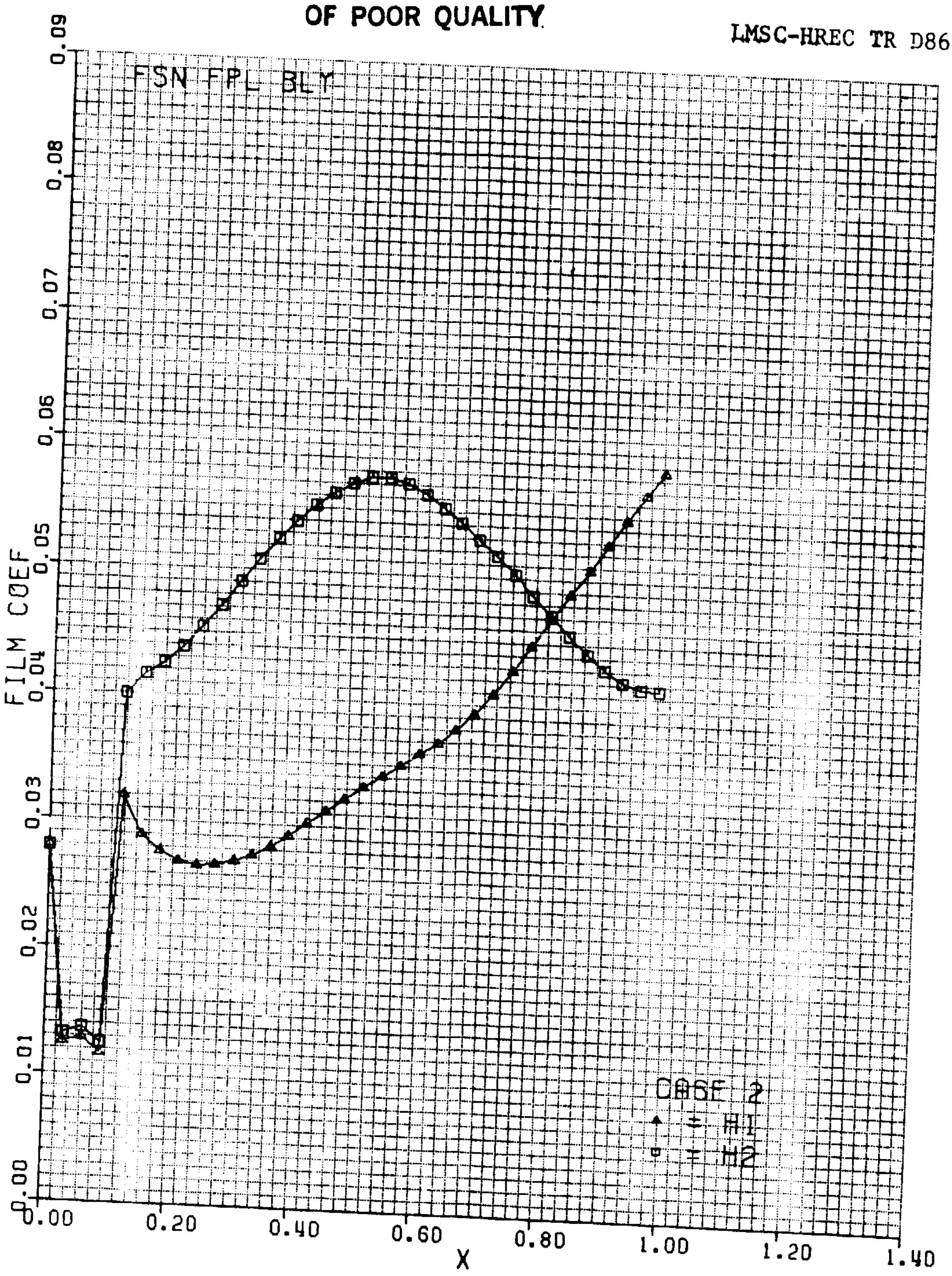
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = H1
□ = H2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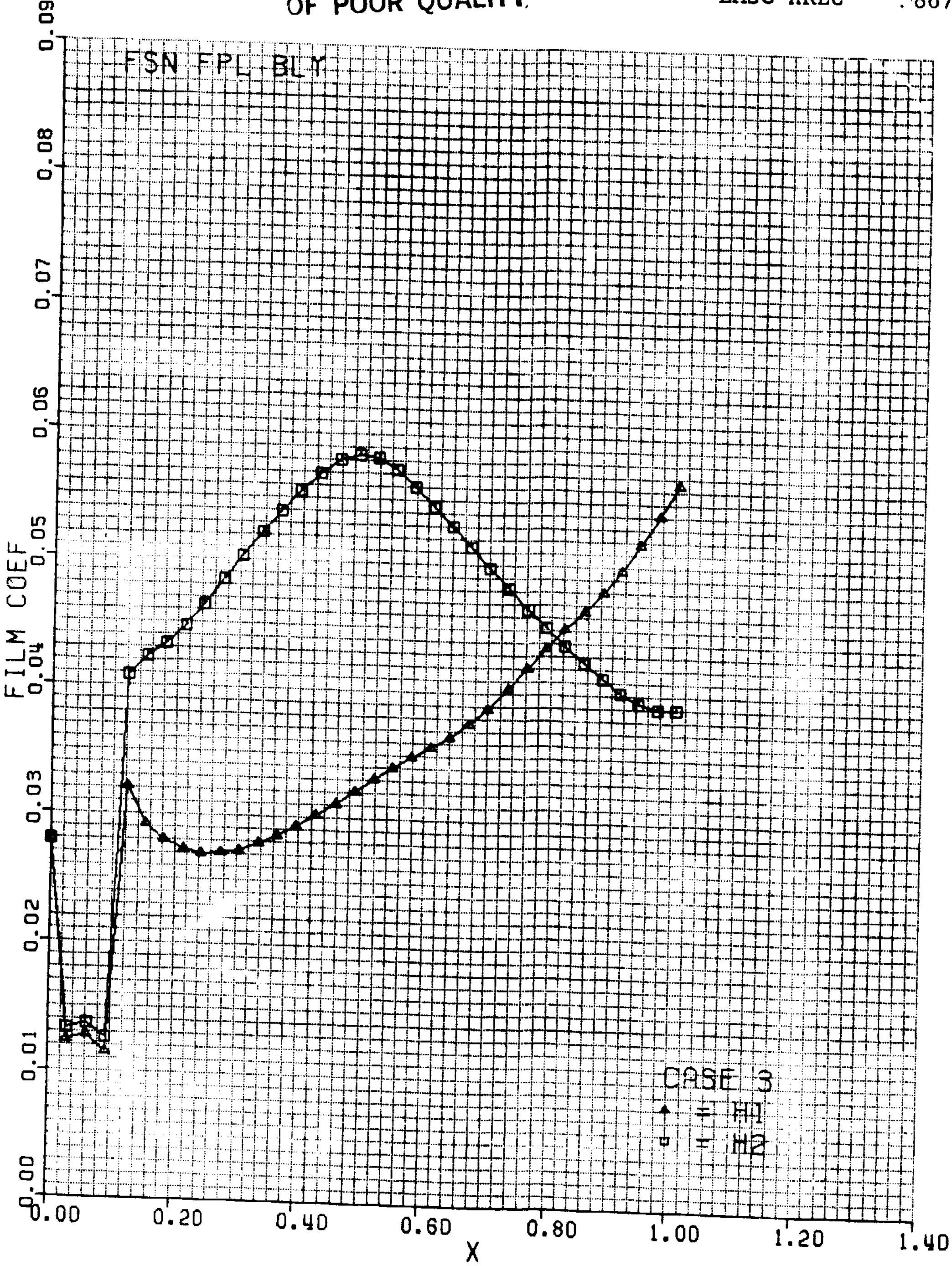
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
= H1
= H2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FILM COEF
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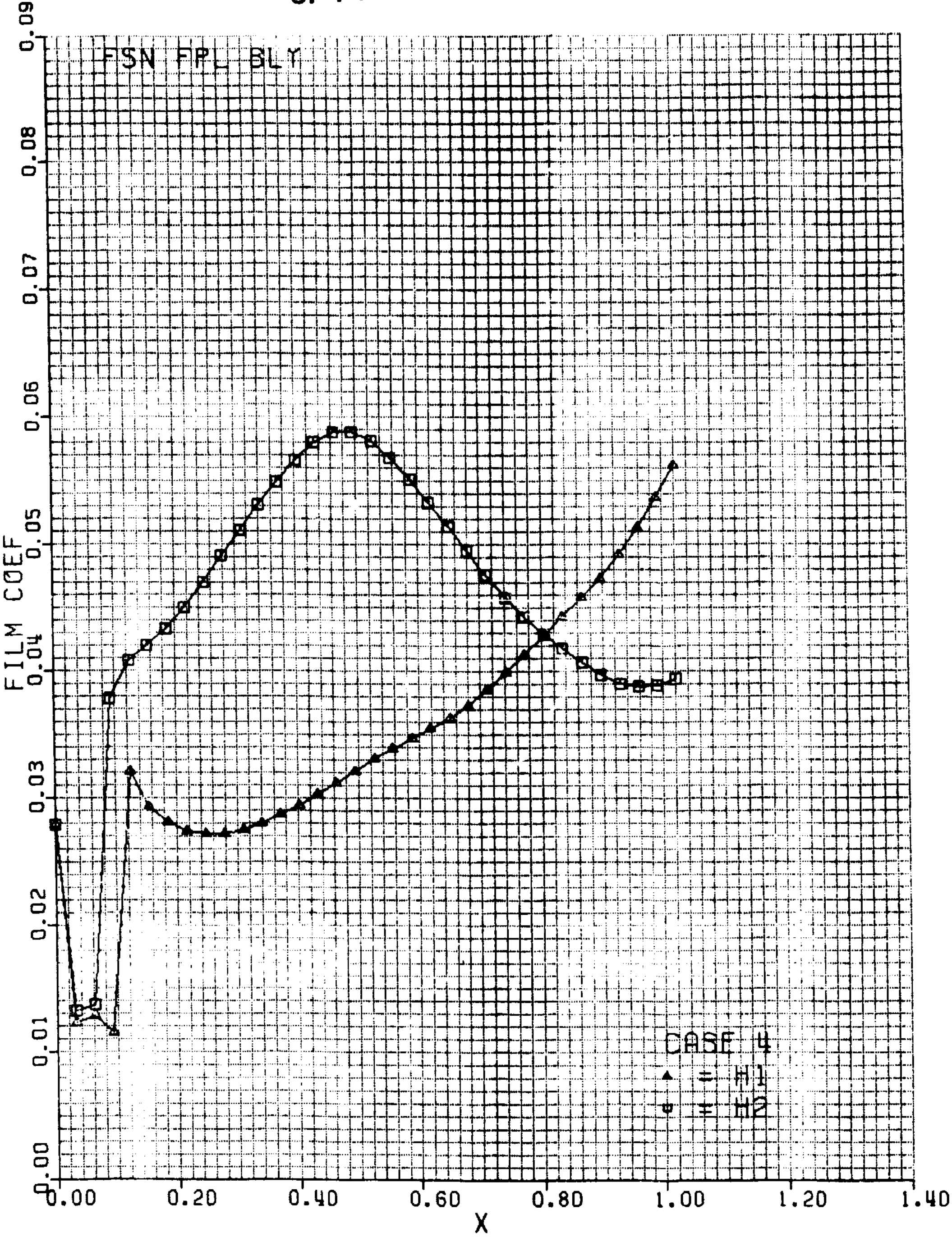
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 3
= H1
= H2


FSN FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 4
▲ = H1
⊡ = H2

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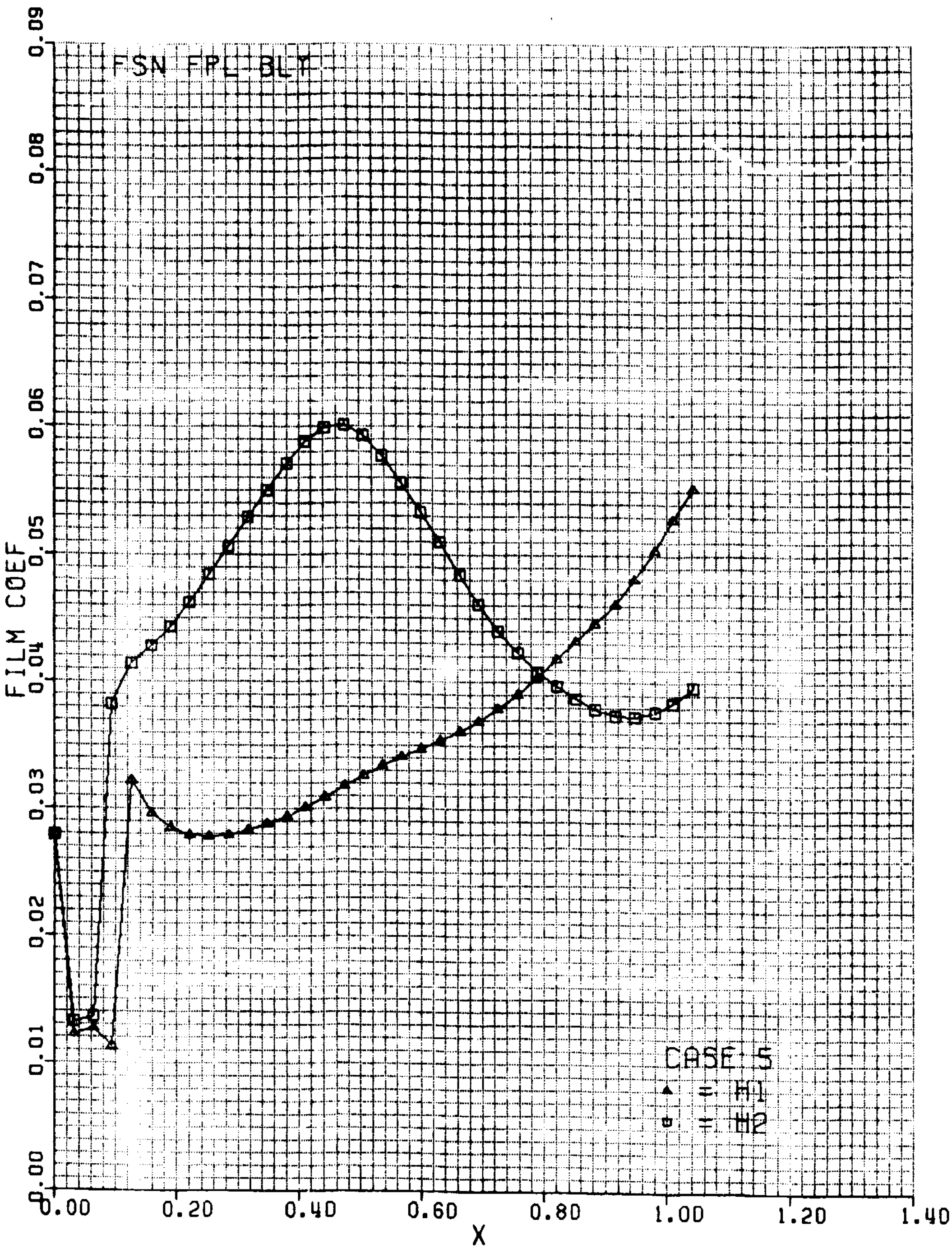

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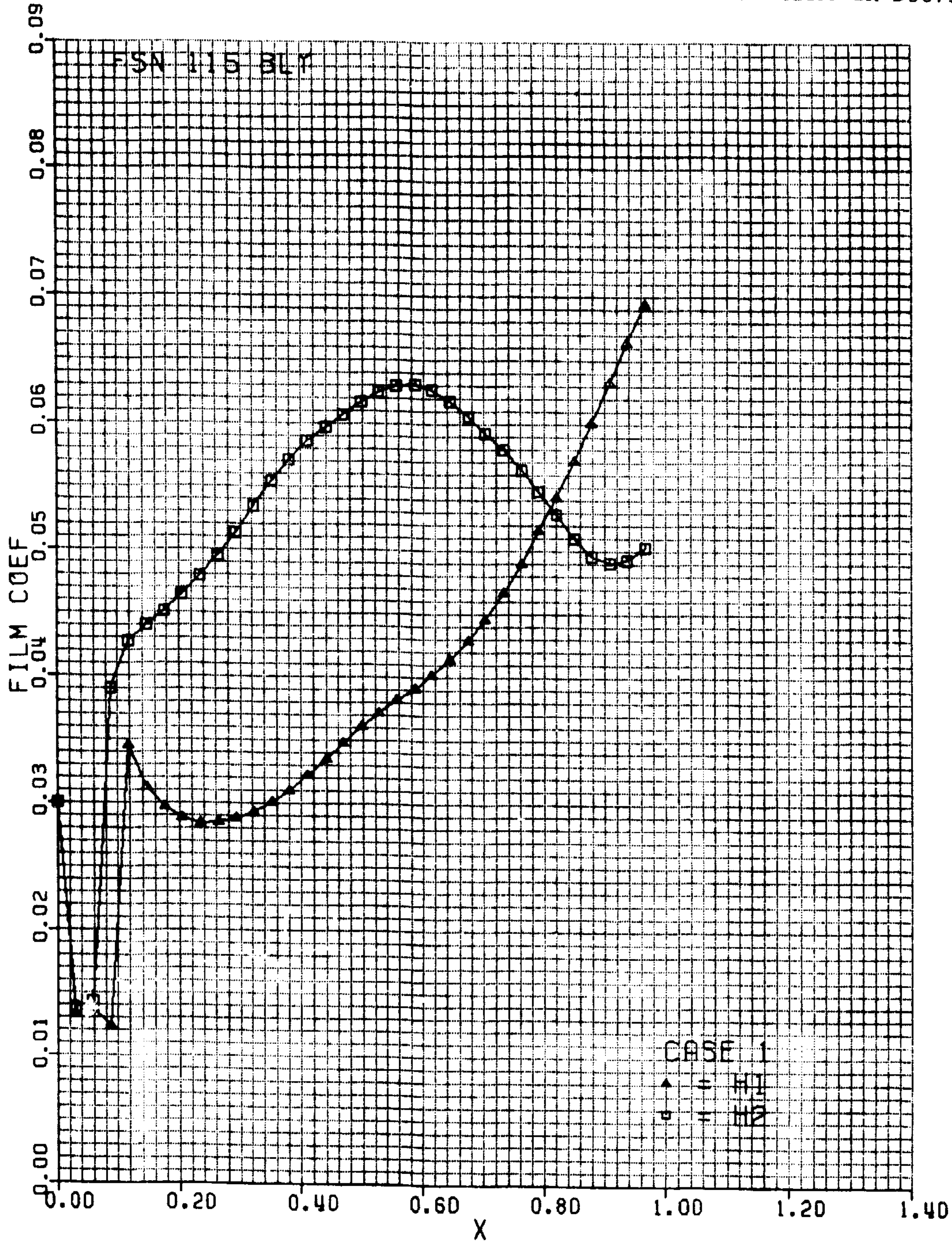

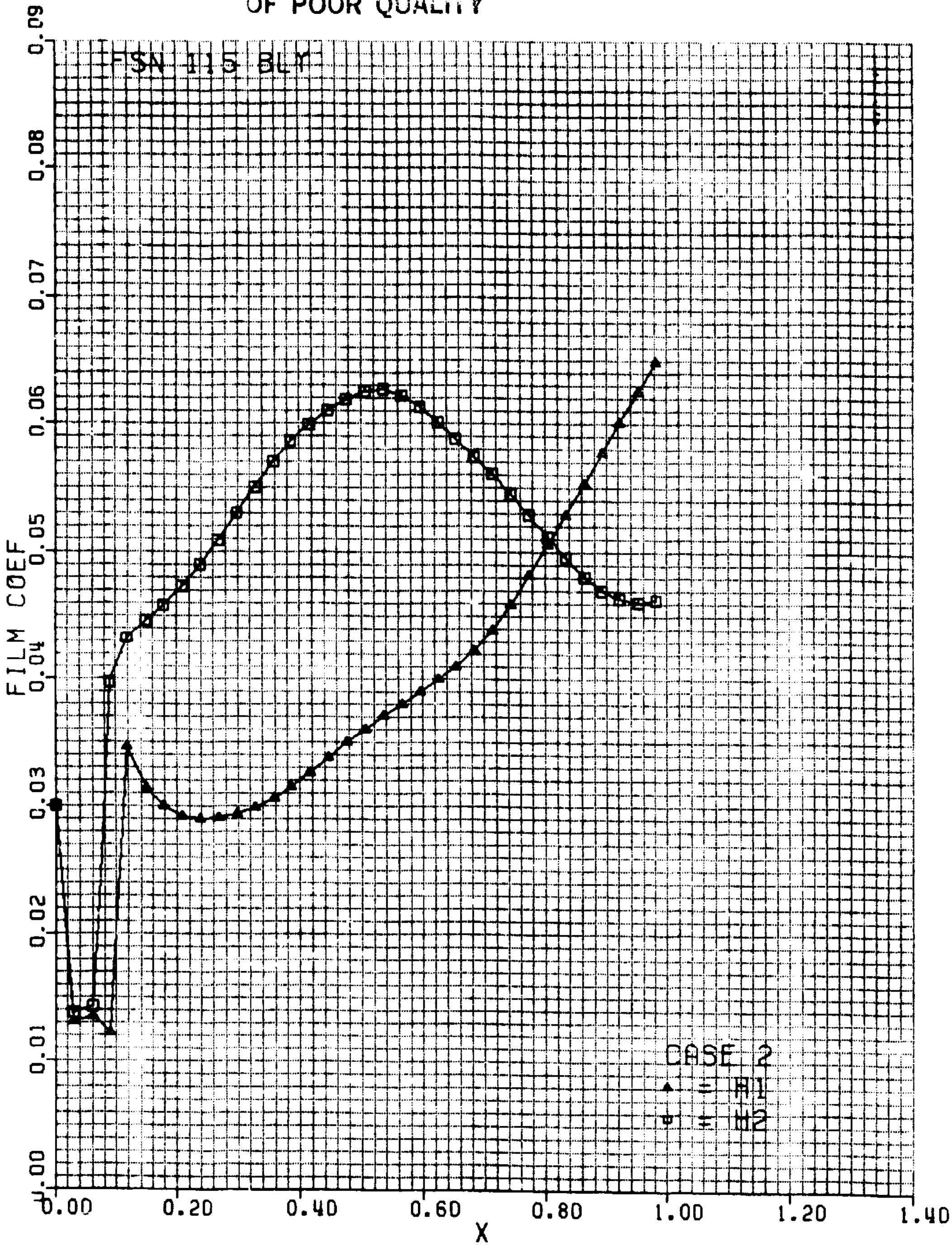
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FILM COEF
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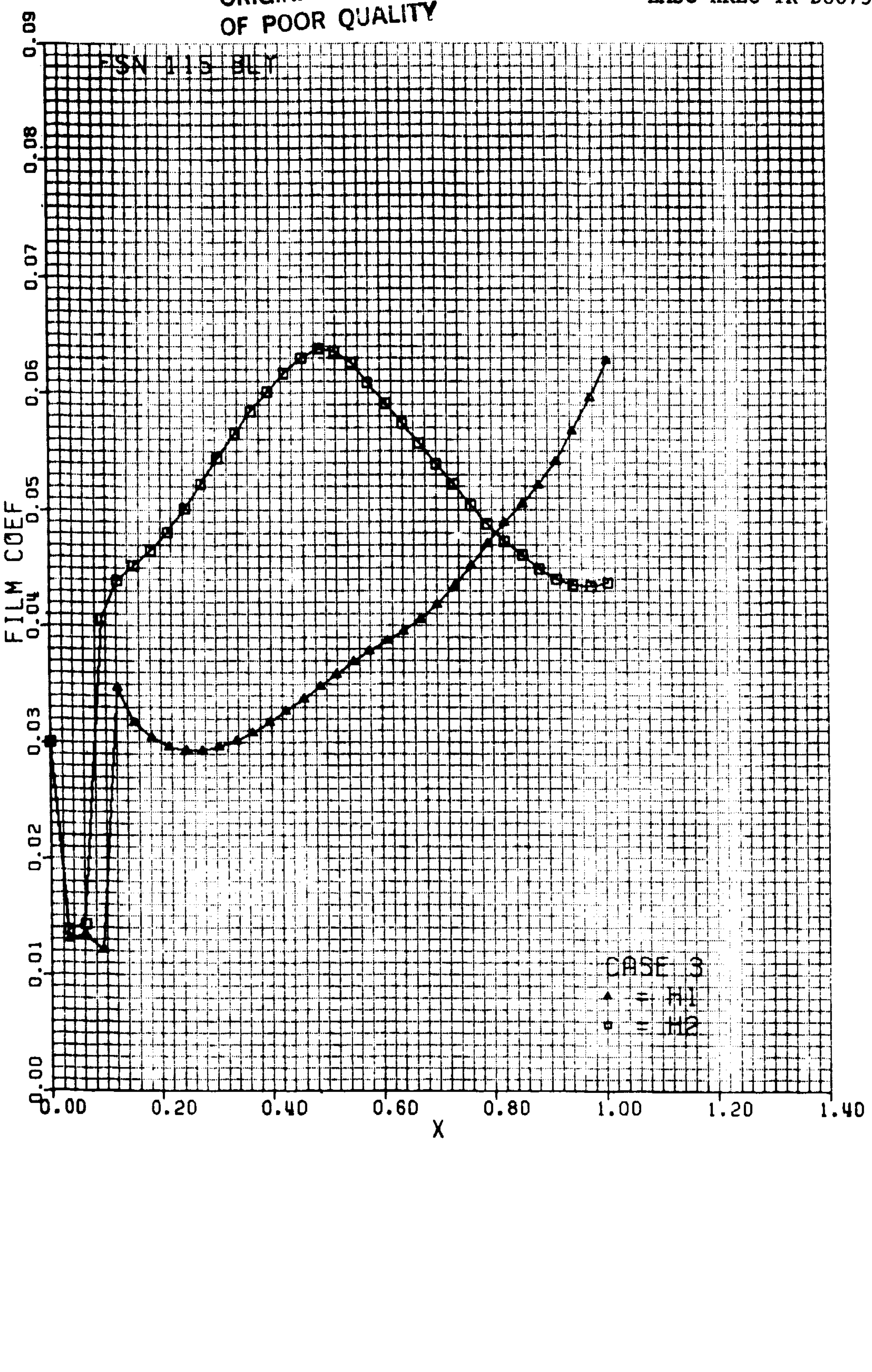
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
▲ = H1
□ = H2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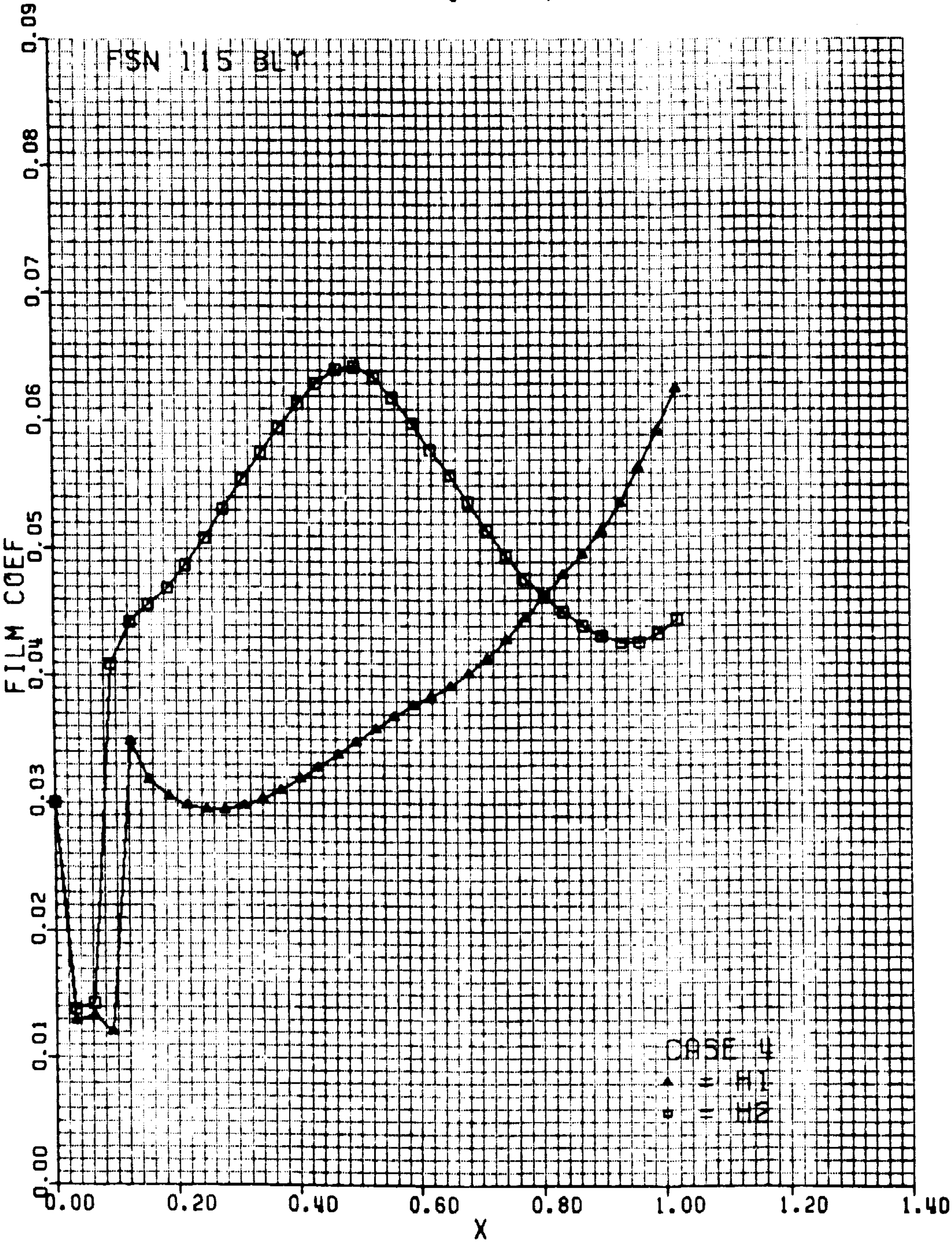
FILM COEF
X
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 3
▲ = H1
◻ = H2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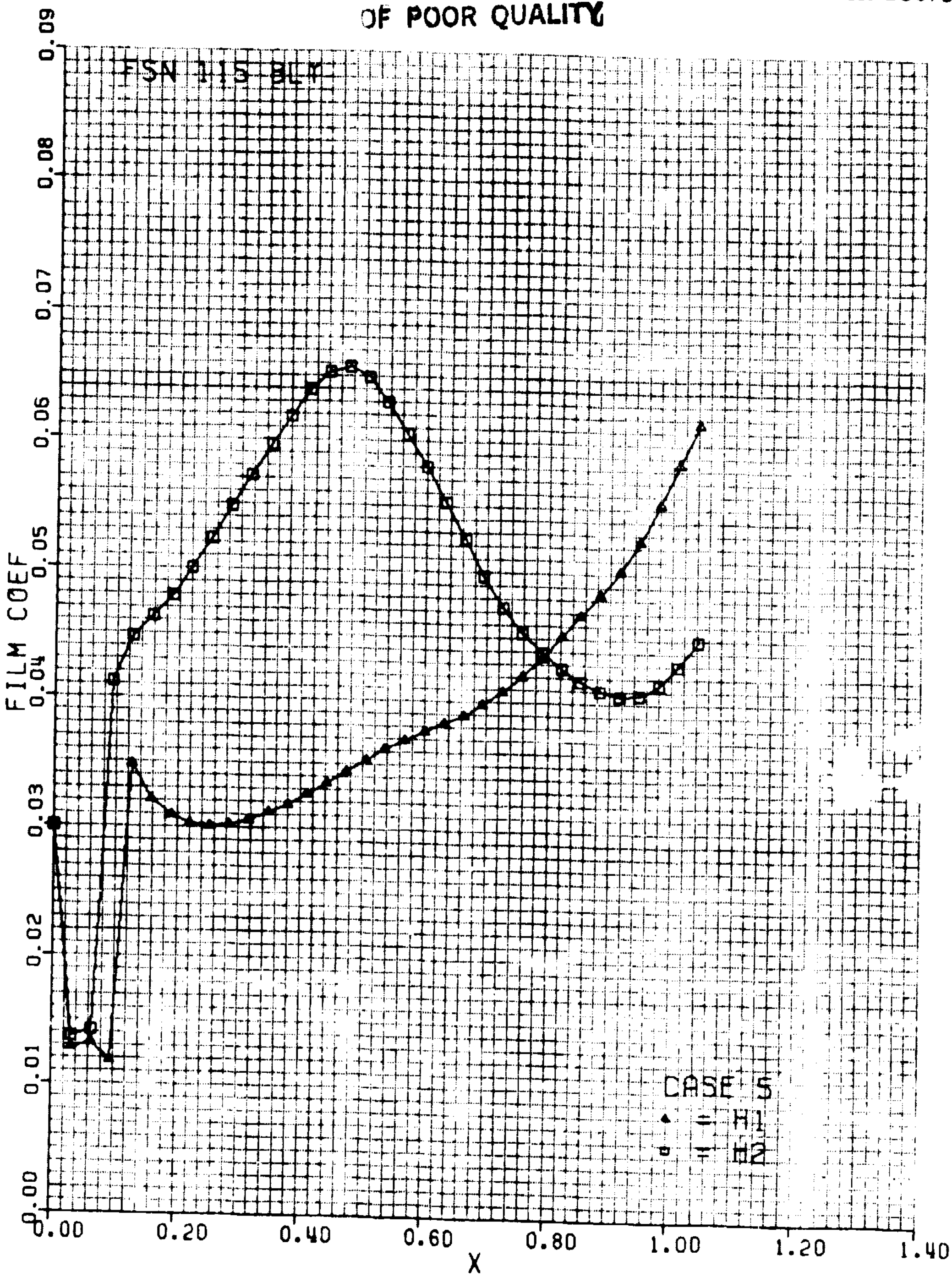
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
= H1
= H2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FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
= H1
= H2

A.4.5

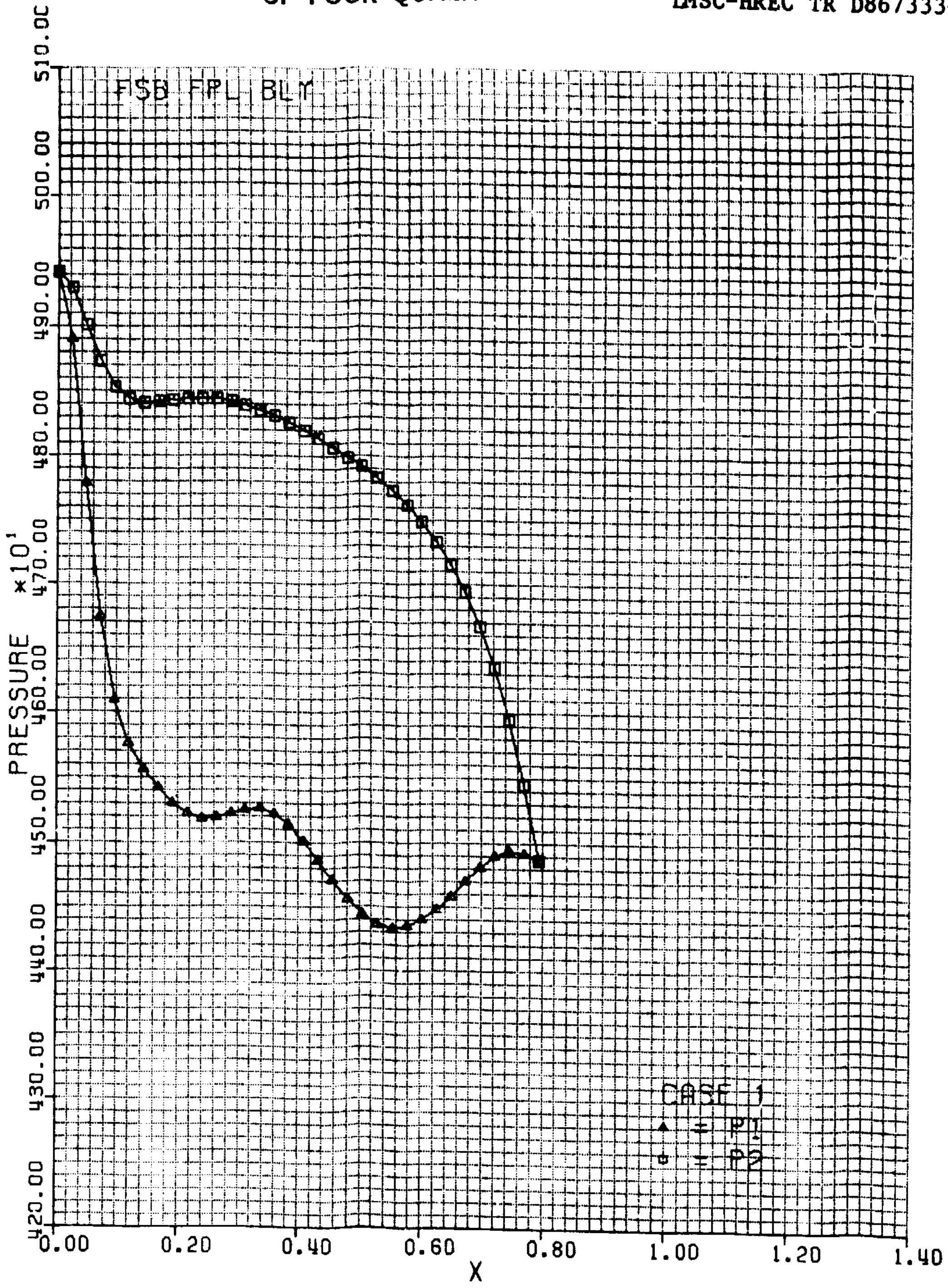
Appendix B

HPFTP FIRST STAGE BLADE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

B.1 FPL Pressure Distributions
B.2 115 Percent Power Level Pressure Distributions
B.3 FPL Heat Transfer Coefficients
B.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 – Suction Surface △
Surface 2 – Pressure Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Case 1 – R = 4.6438 Hub	1475	1420
Case 2 – R = 4.83 Intermediate	↓	↓
Case 3 – R = 5.0797 Mean	↓	↓
Case 4 – R = 5.27 Intermediate	↓	↓
Case 5 – R = 5.5156 Tip	↓	↓


FSB FPL BLY
PRESSURE *10[1]
510.00
500.00
490.00
480.00
470.00
460.00
450.00
440.00
430.00
420.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = P1
□ = P2

B.1.1

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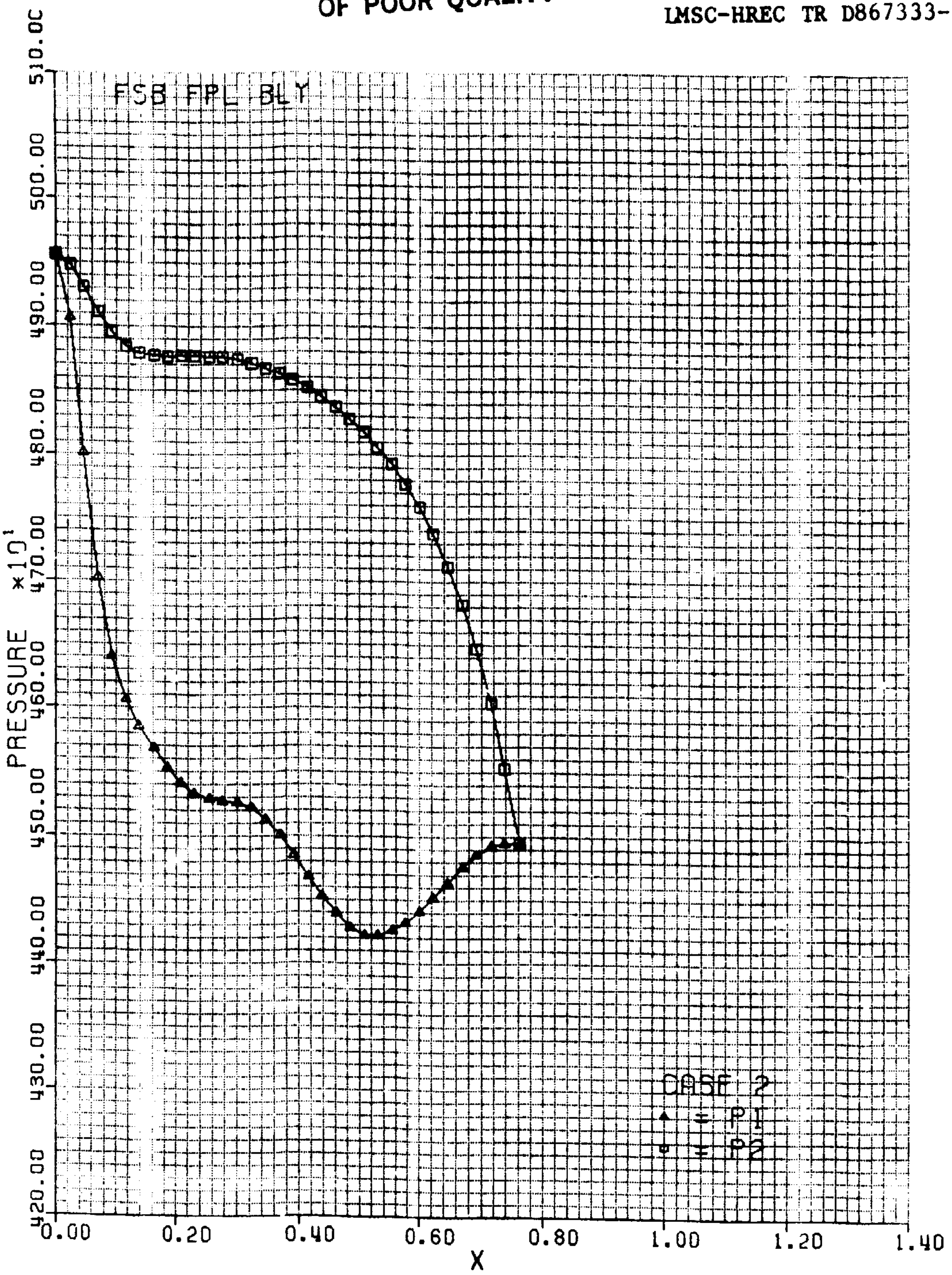
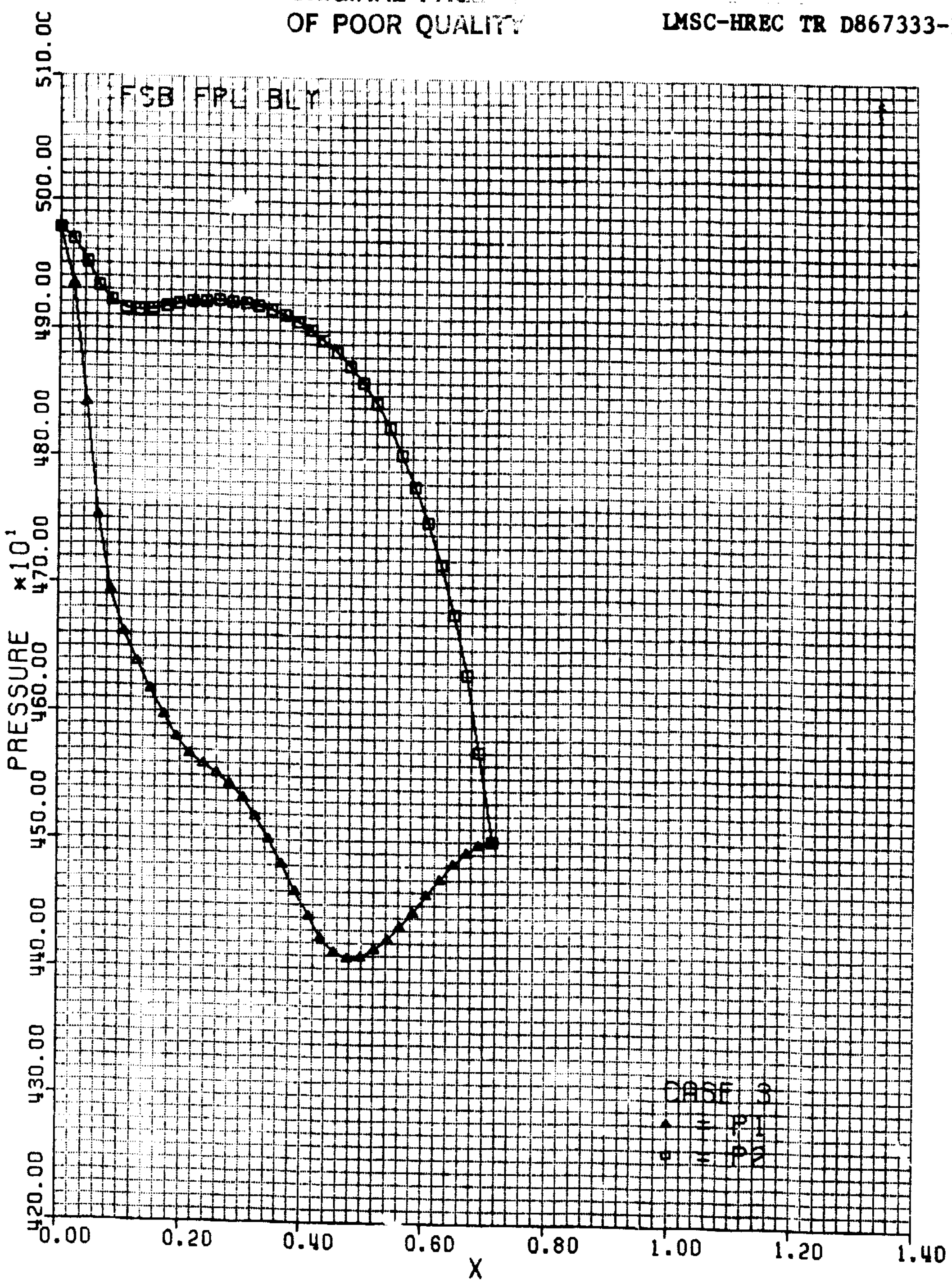
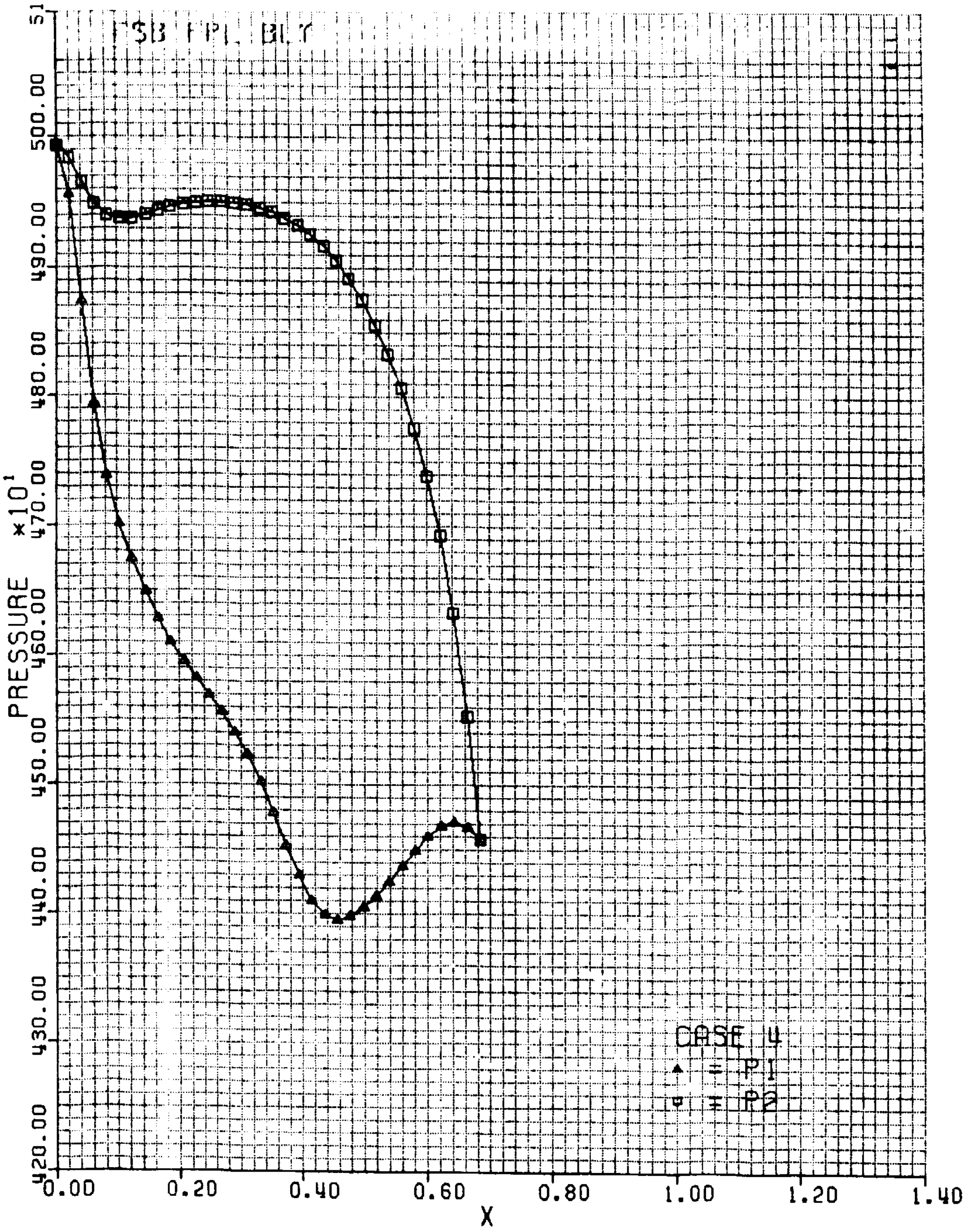



FSB FPL BLY
PRESSURE ×10¹
510.00
500.00
490.00
480.00
470.00
460.00
450.00
440.00
430.00
420.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 3
= P1
= P2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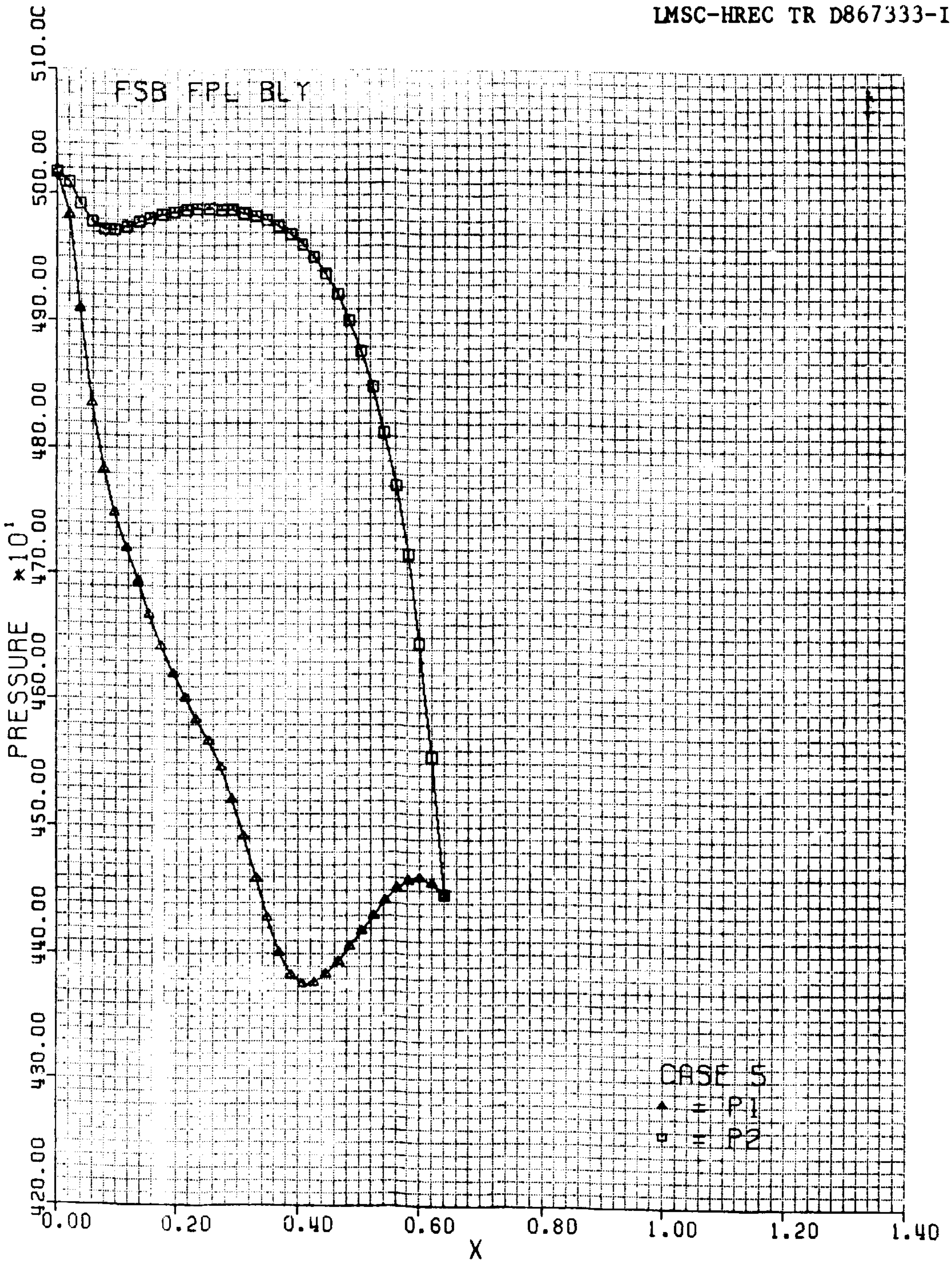
500.00
490.00
480.00
470.00
460.00
450.00
440.00
430.00
420.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
= P1
= P2



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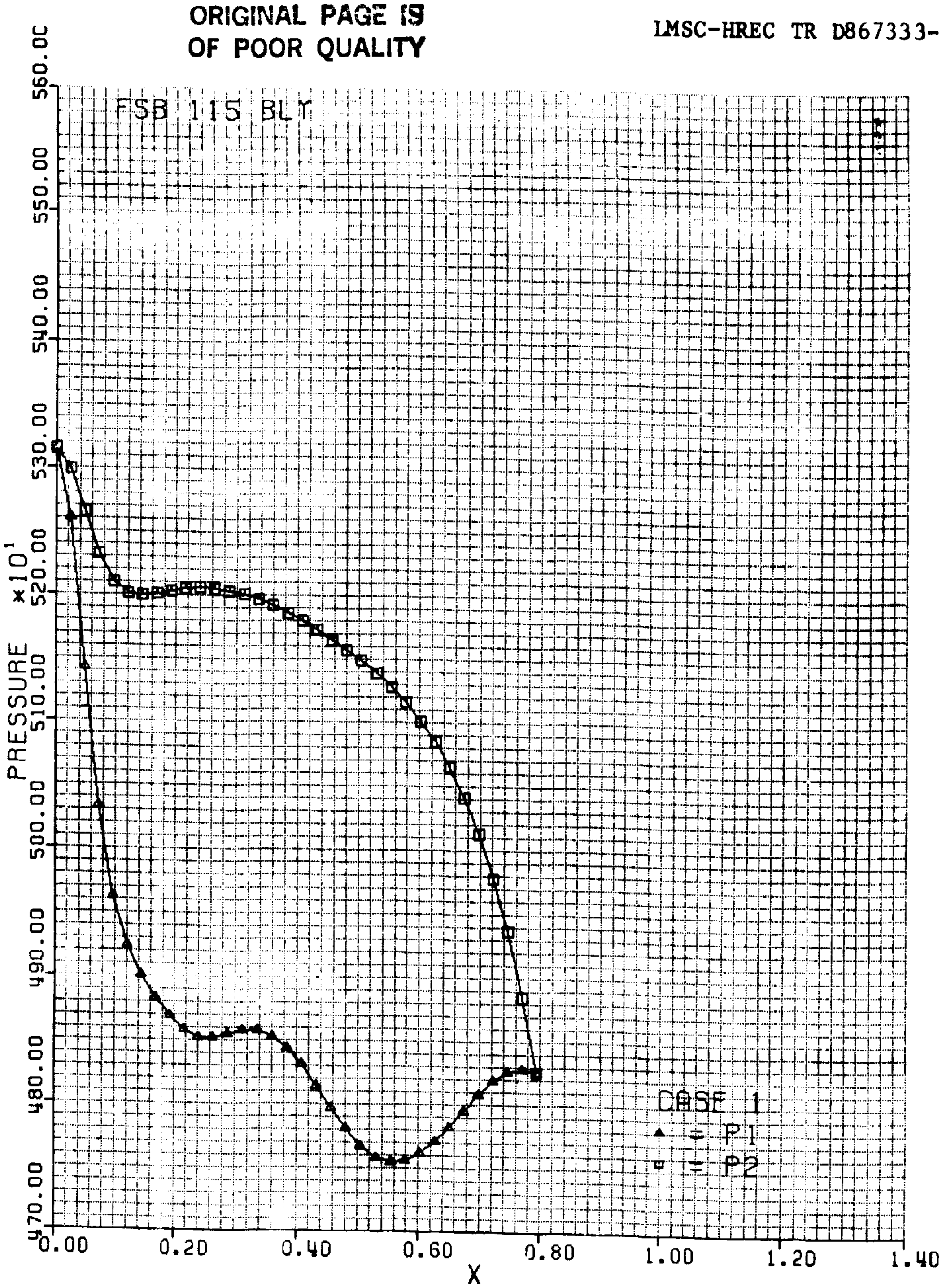
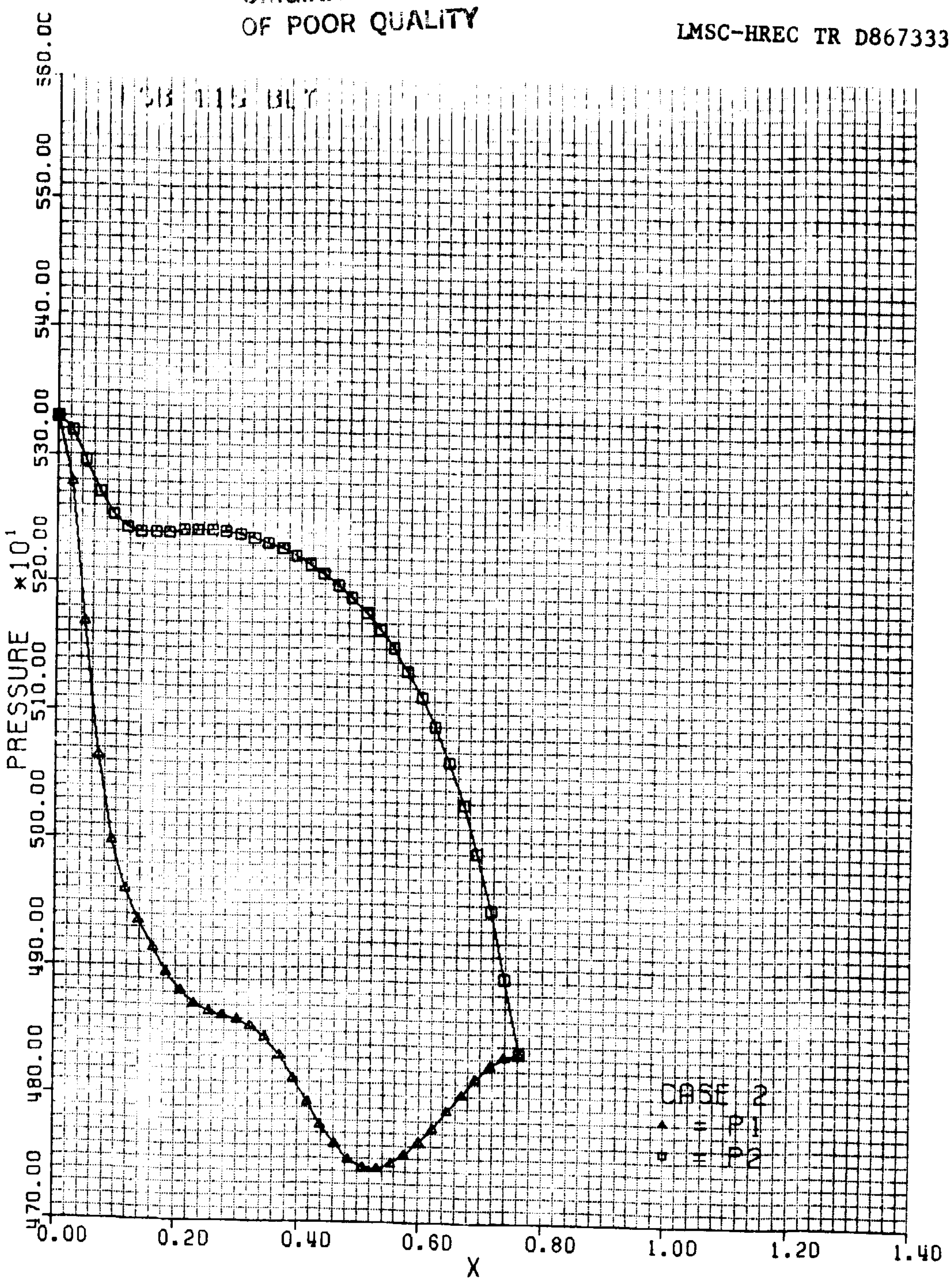
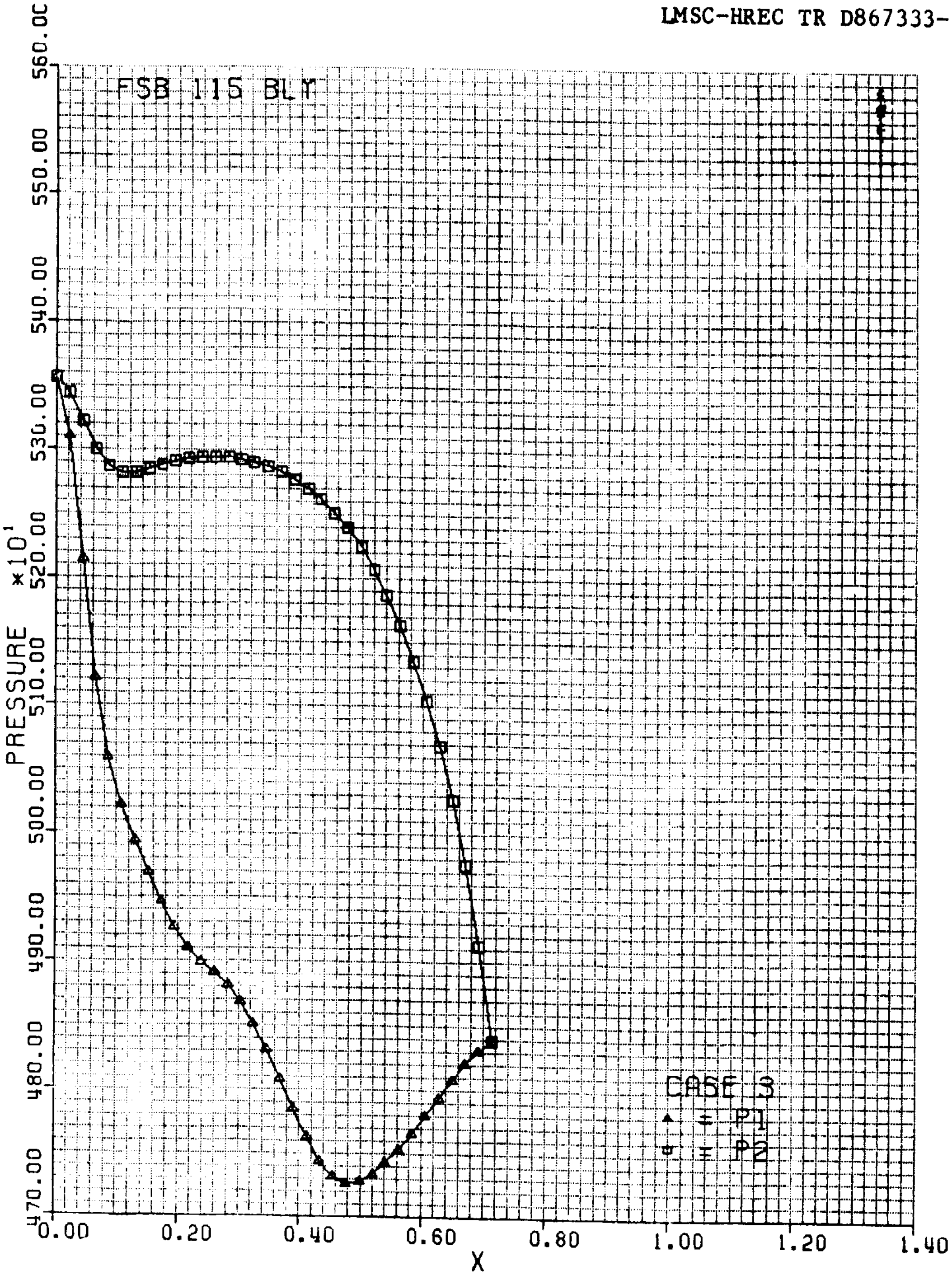

FSB 115 BLY
PRESSURE *10[1]
560.00
550.00
540.00
530.00
520.00
510.00
500.00
490.00
480.00
470.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = P1
□ = P2


PRESSURE *10[1]
X
CASE 2
= P1
= P2
470.00
480.00
490.00
500.00
510.00
520.00
530.00
540.00
550.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40


FSB 115 BLY
PRESSURE ×10¹
560.00
550.00
540.00
530.00
520.00
510.00
500.00
490.00
480.00
470.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 3
= P1
= P2

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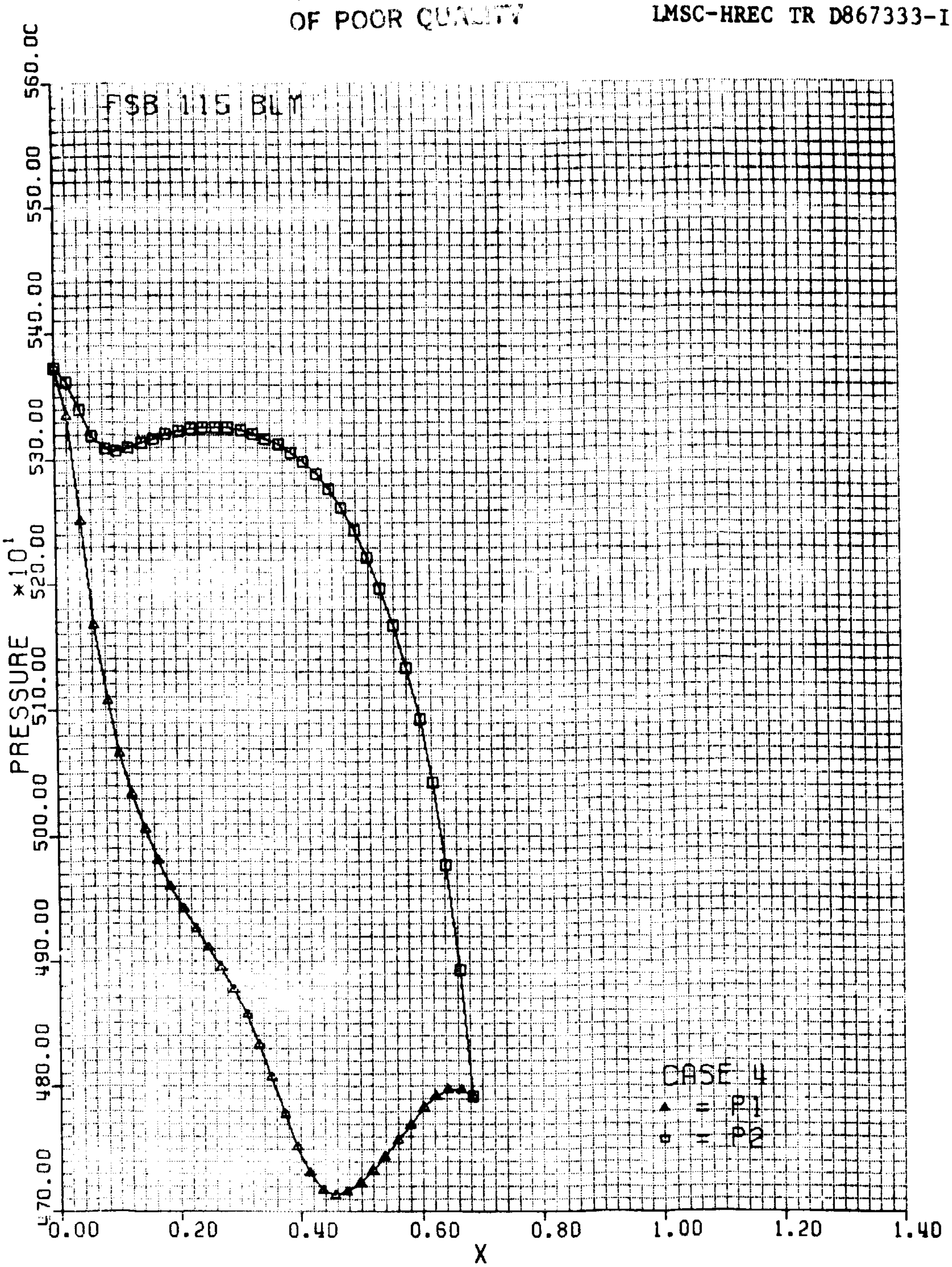
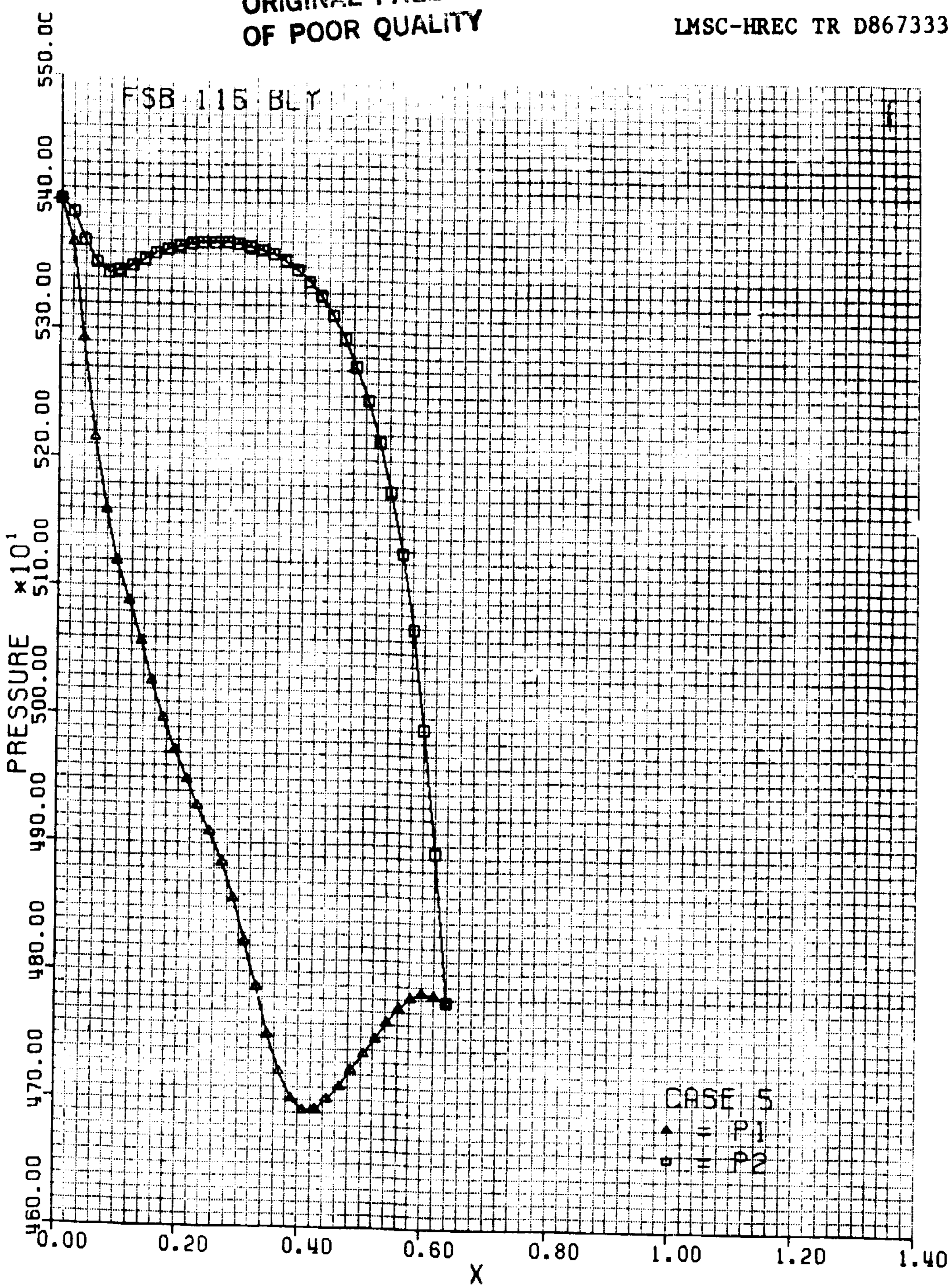
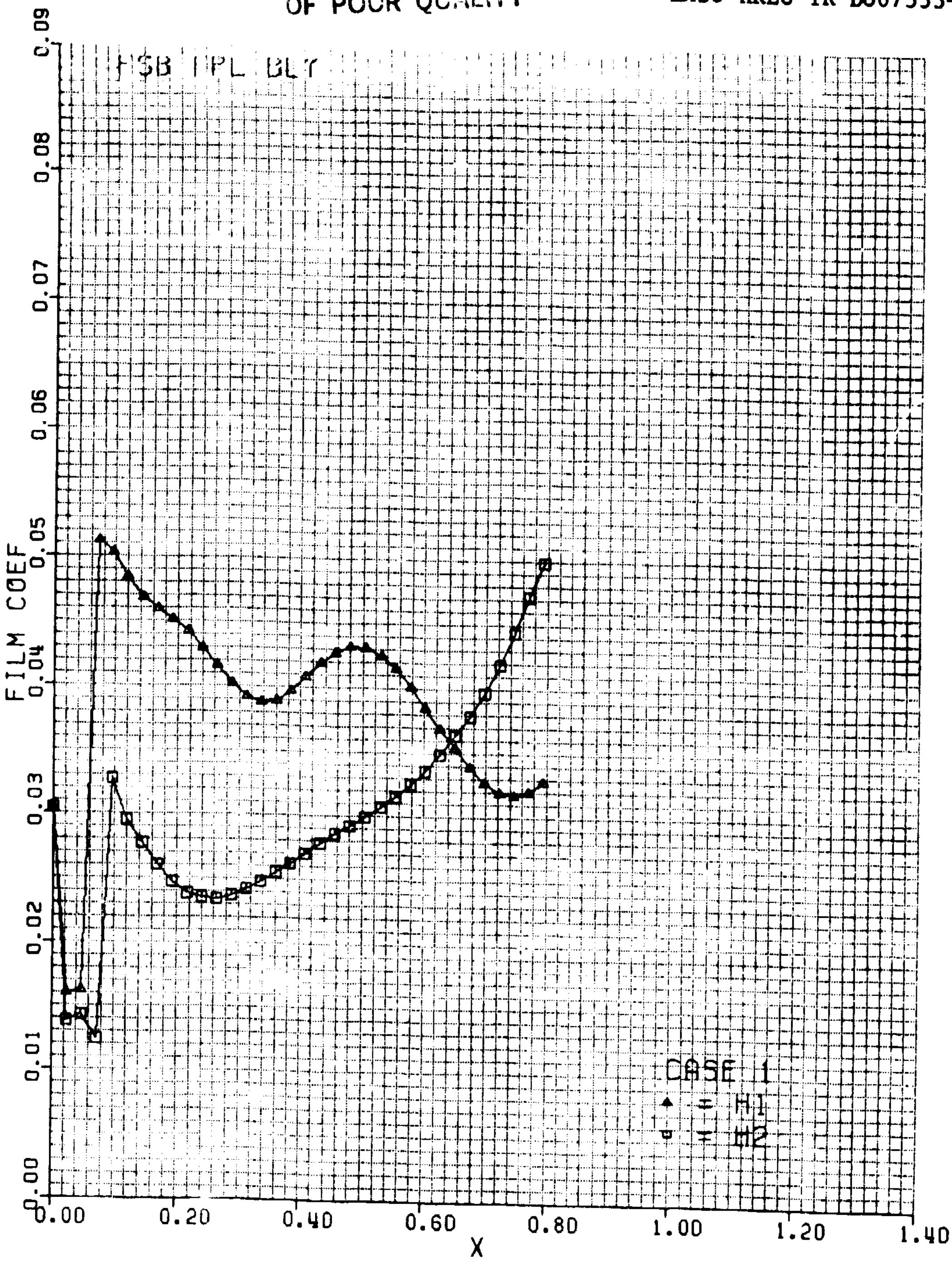
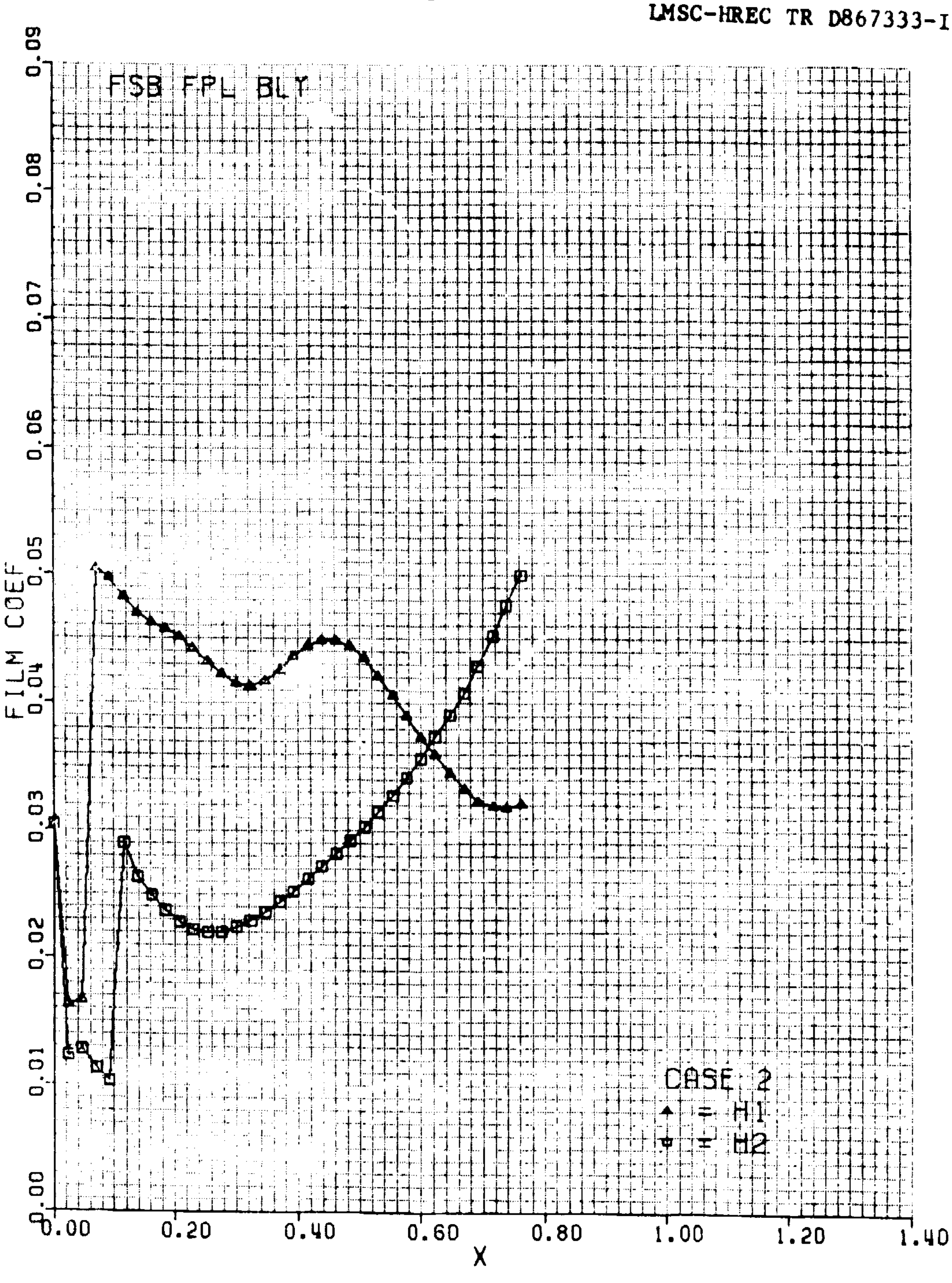
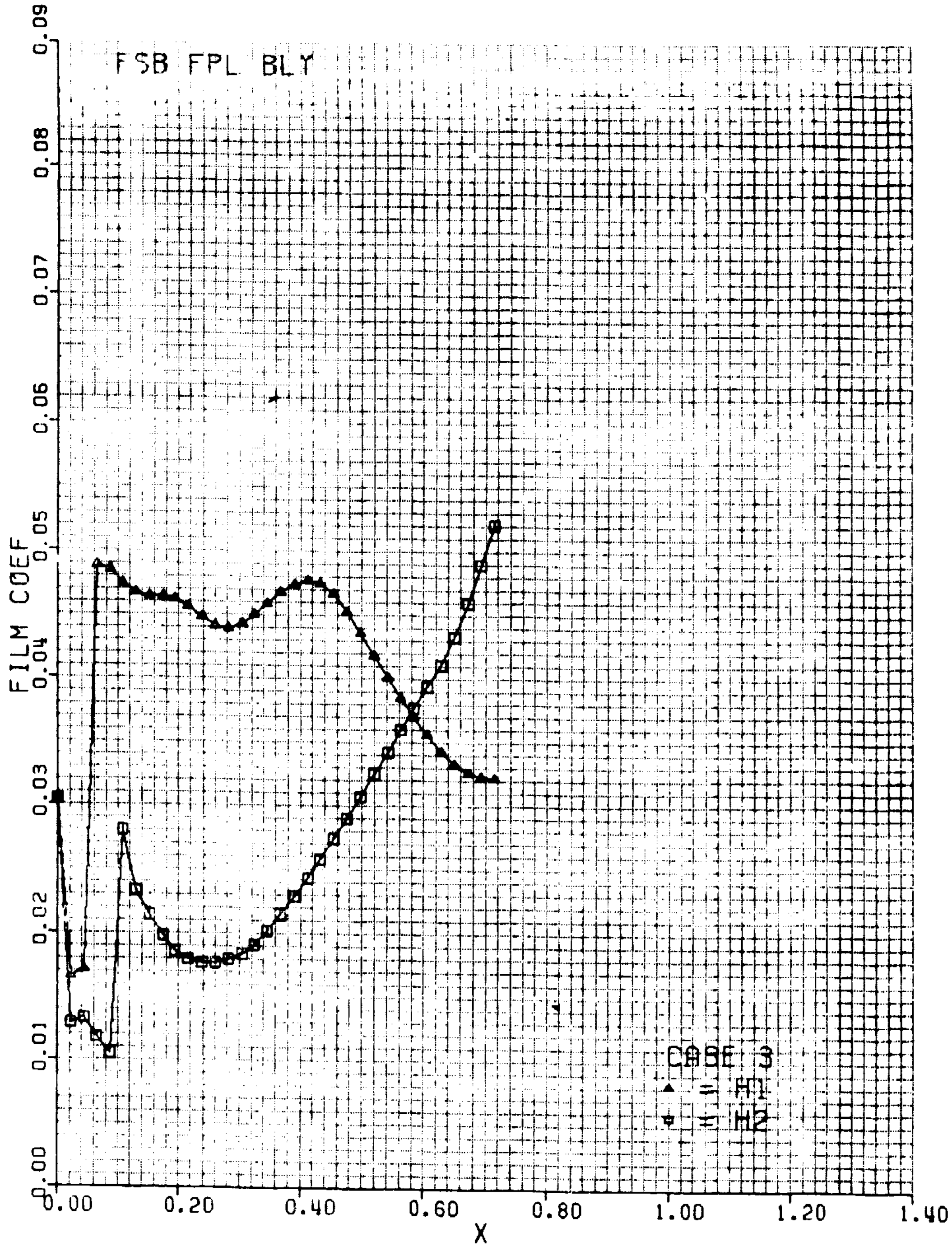
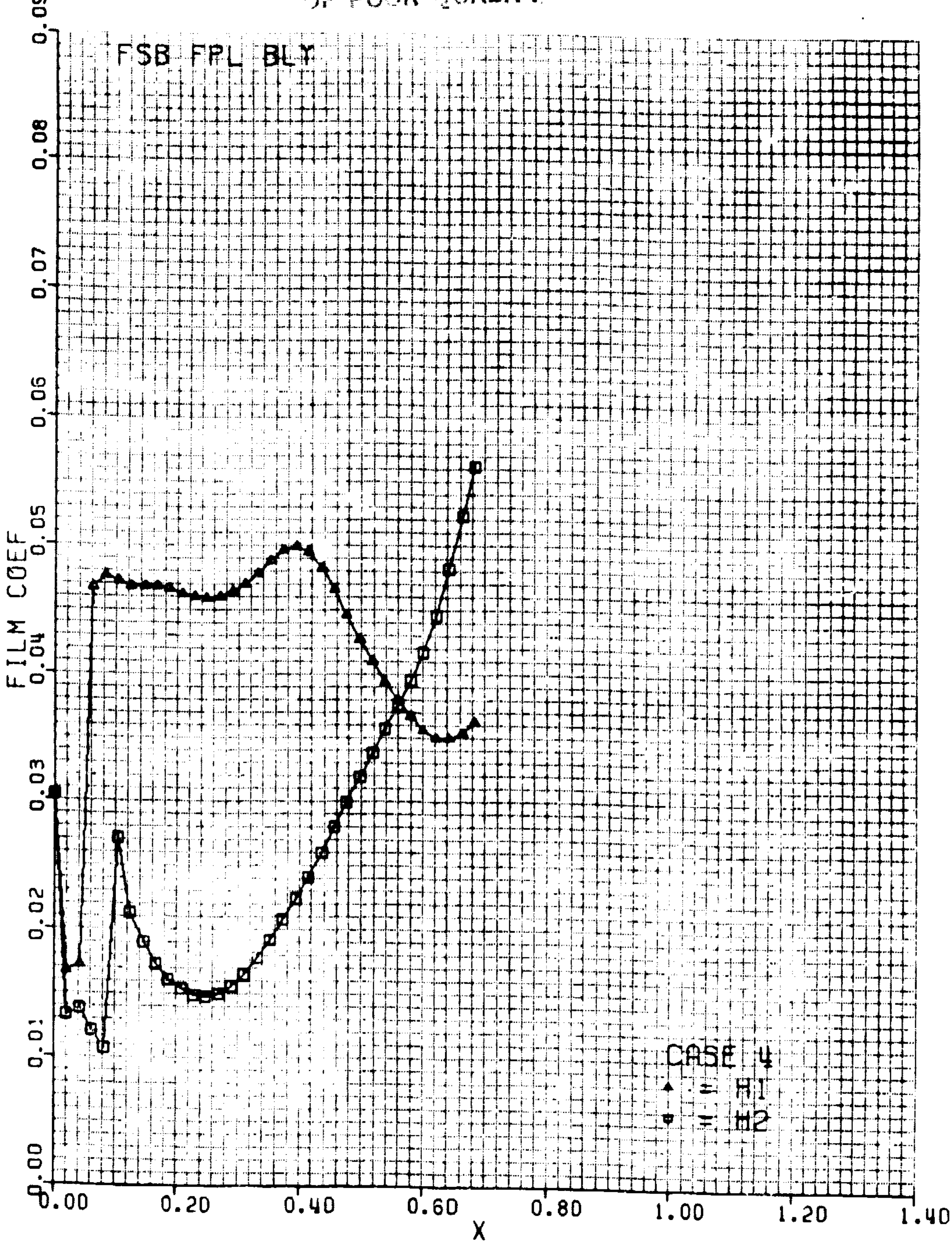


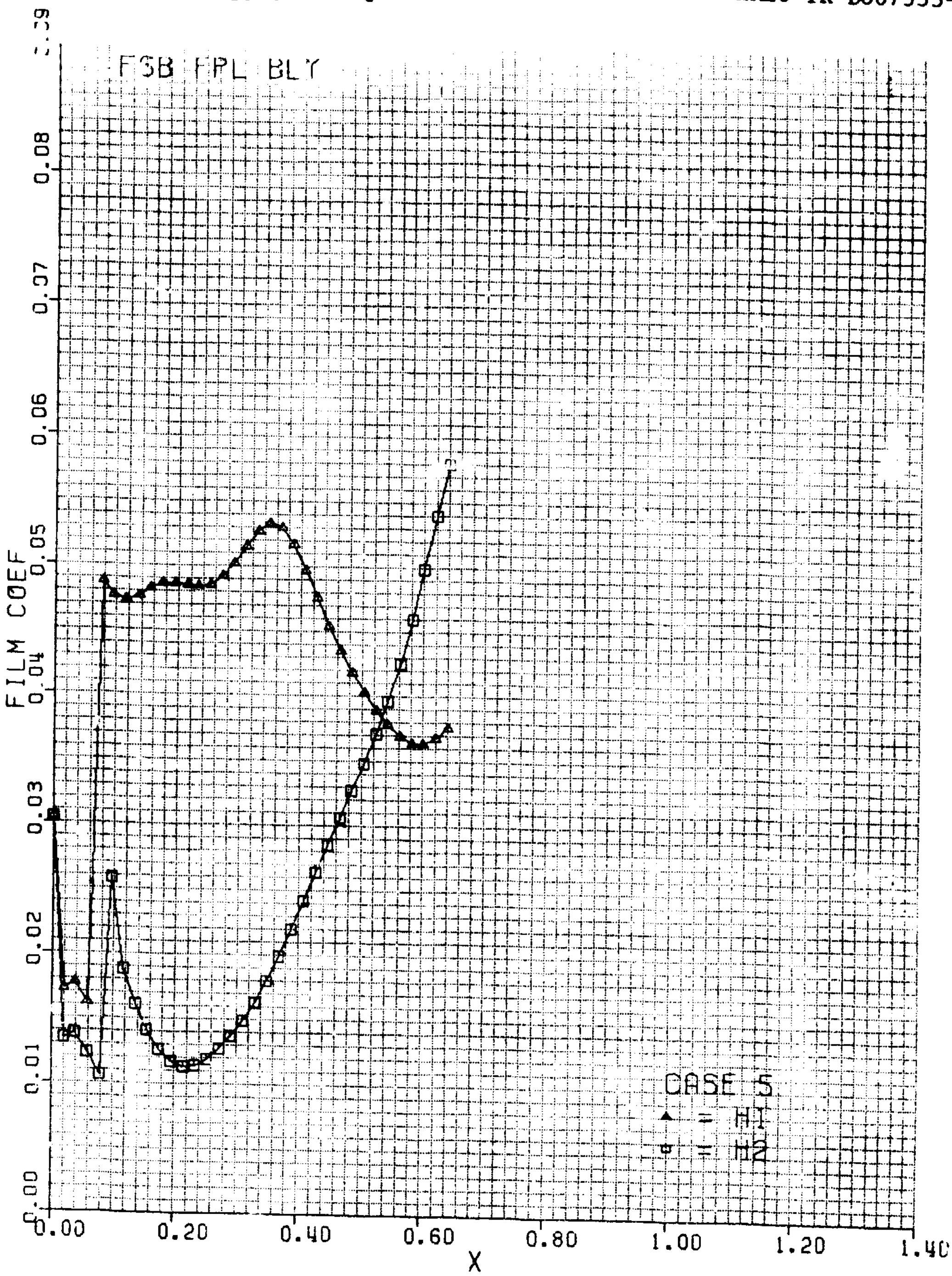

FSB 115 BLY
PRESSURE ×10[1]
550.00
540.00
530.00
520.00
510.00
500.00
490.00
480.00
470.00
460.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
▲ = P1
□ = P2

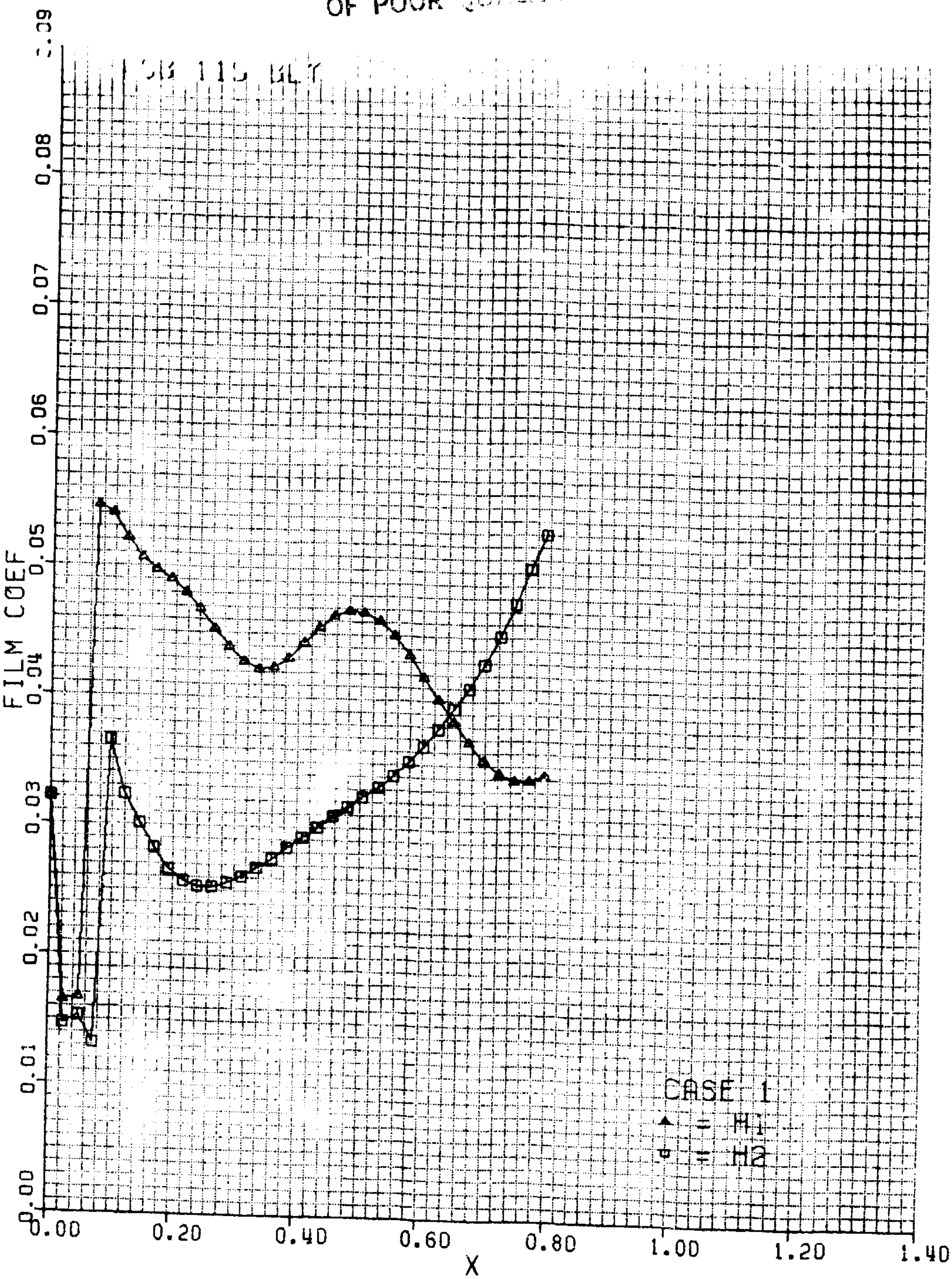

HSB TPL BLT
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
= H1
= H2

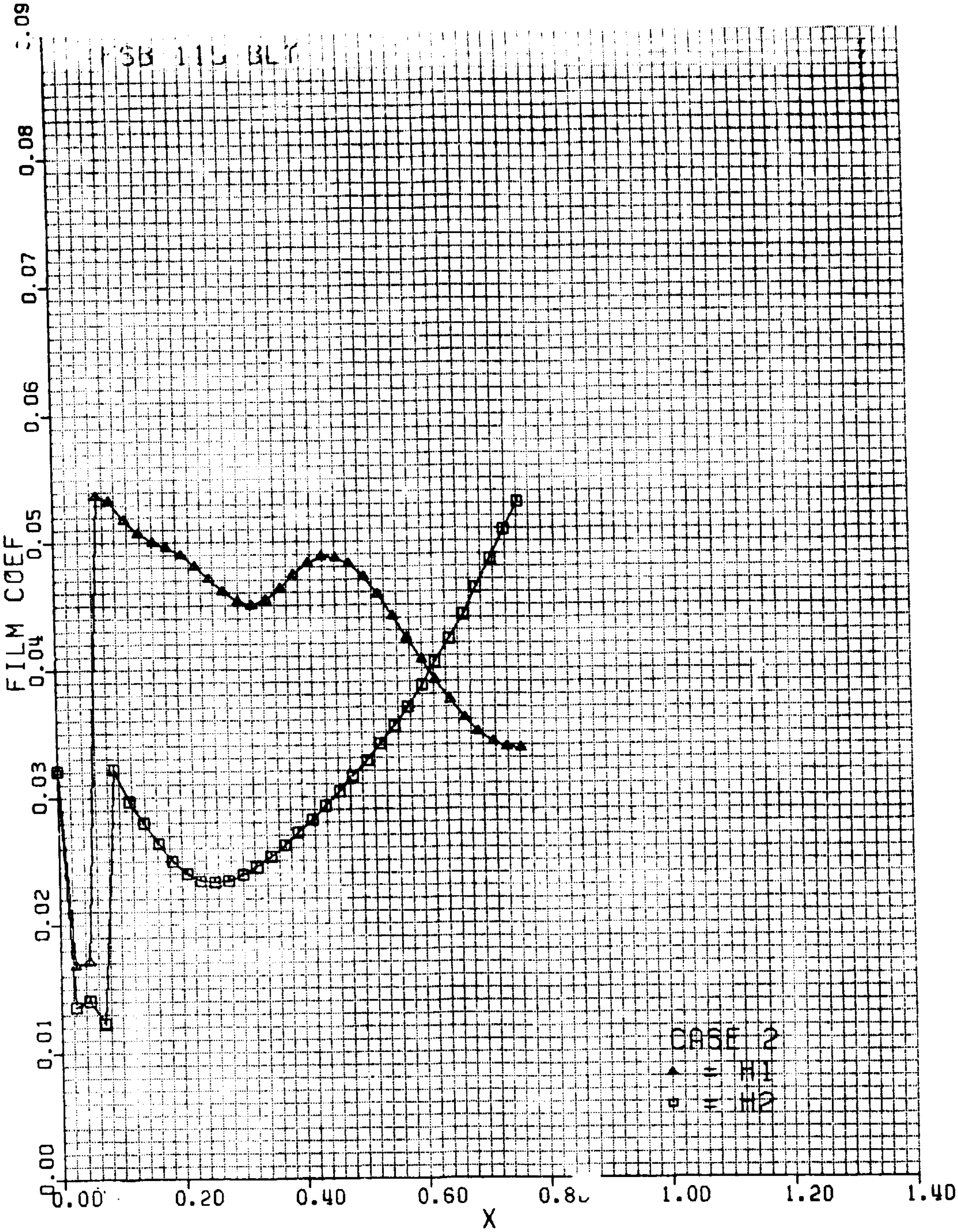

FSB FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
= H1
= H2


FSB FPL BLY
FILM COEF
X
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 3
= H1
= H2


FSB FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
= H1
= H2


FSB FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
▲ = H1
□ = H2


FILM COEF
X
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 1
▲ = H1
□ = H2


FSB 11D BLT
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.00
0.20
0.40
0.60
0.8
1.00
1.20
1.40
X
CASE 2
▲ = H1
□ = H2

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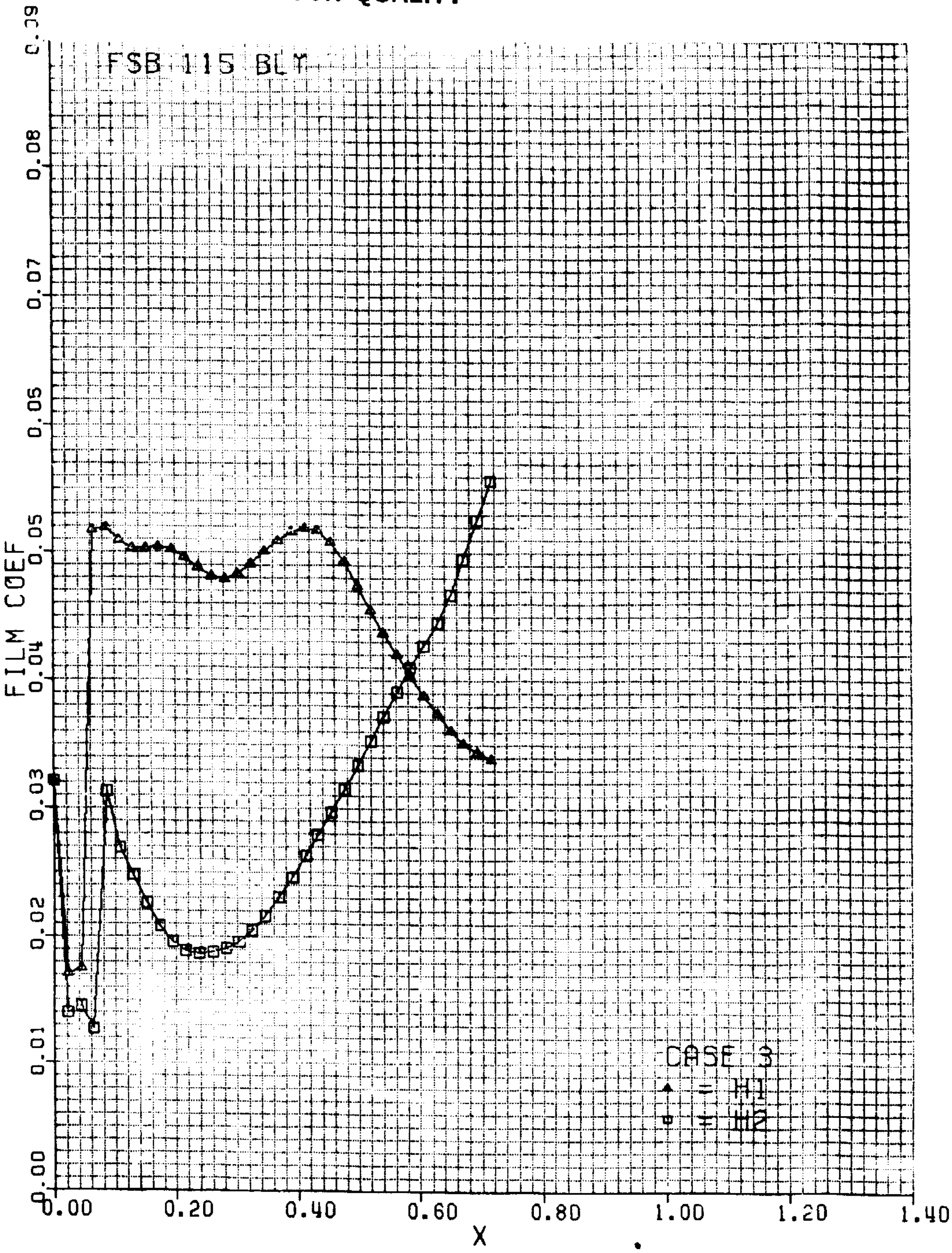
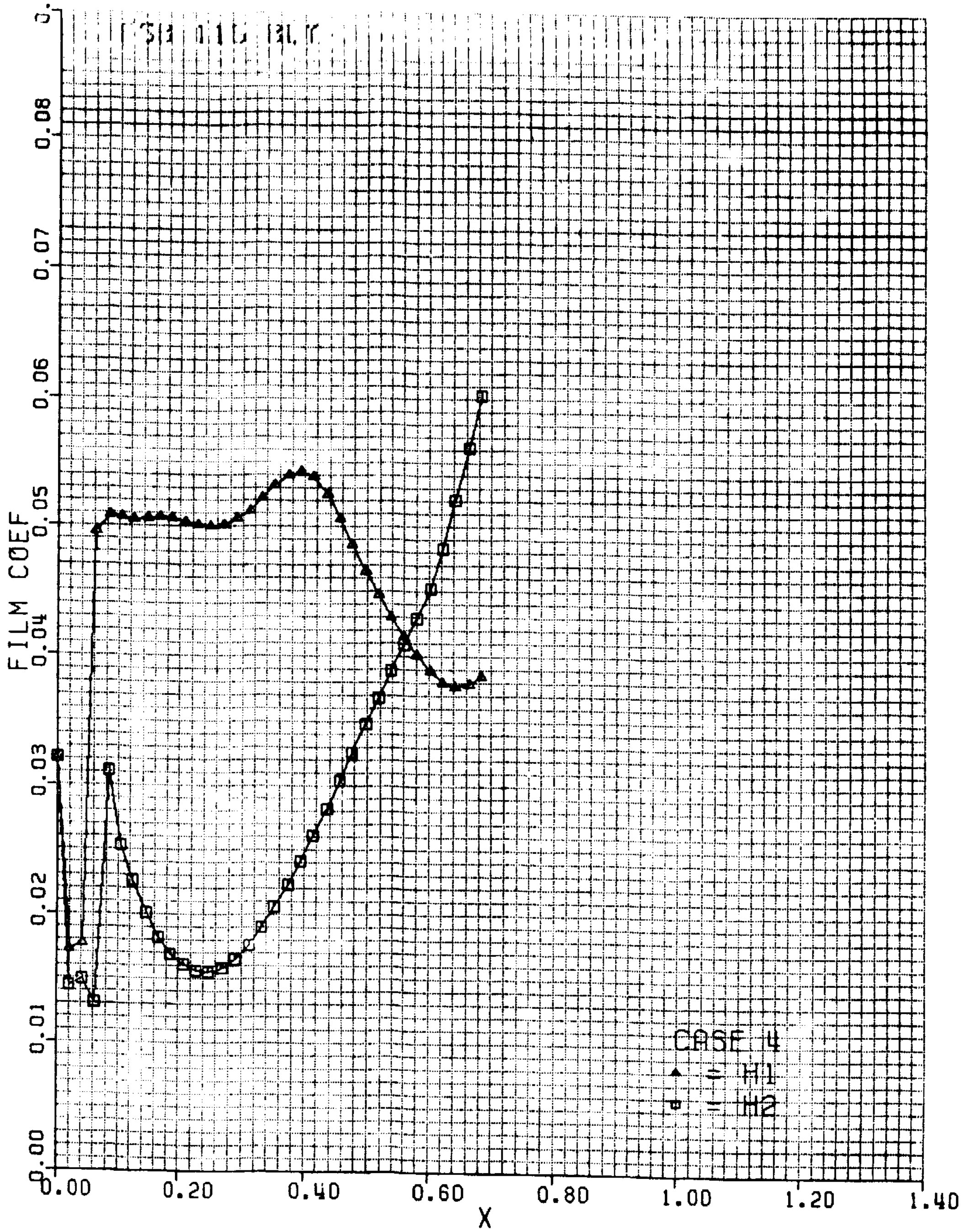
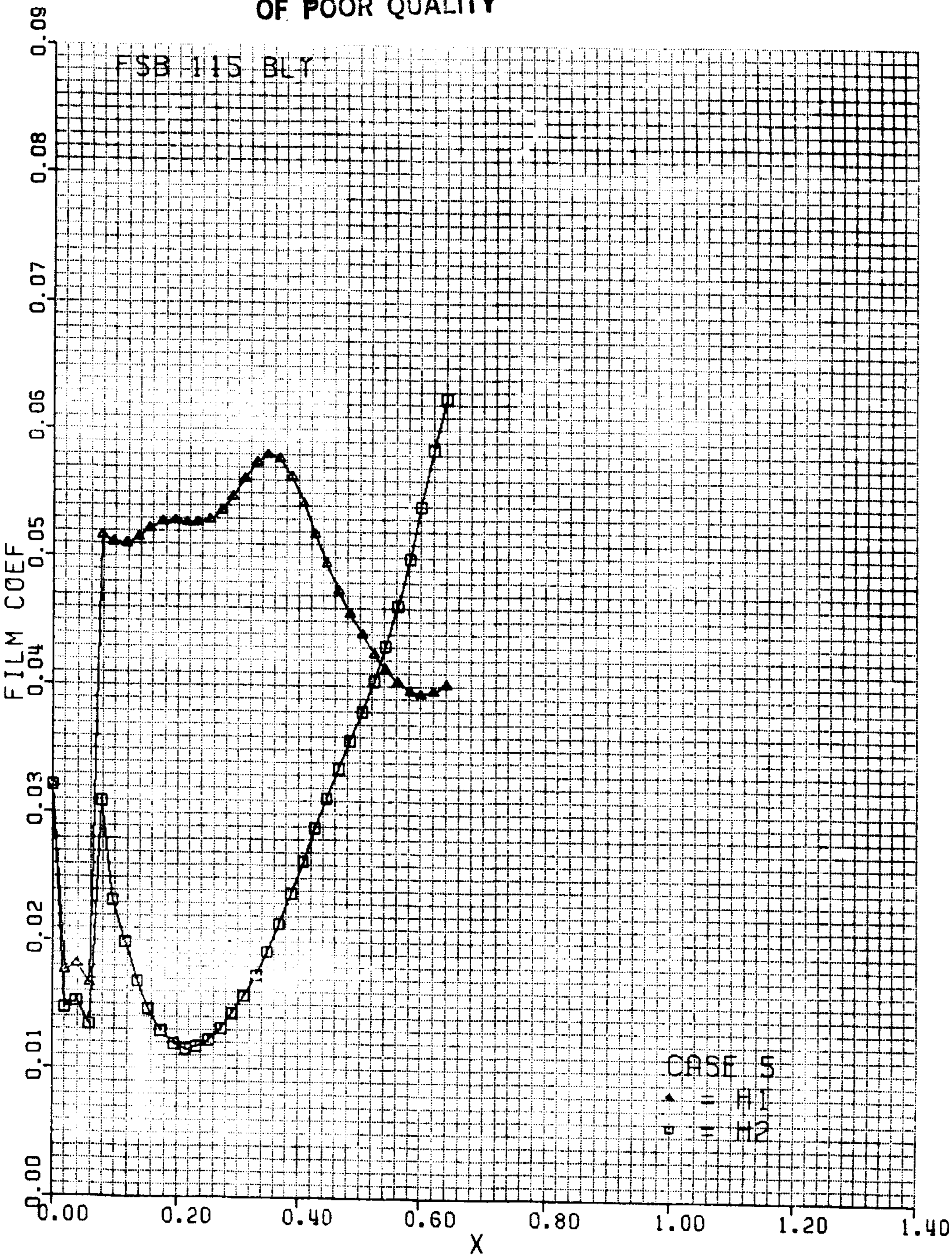



FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
▲ = H1
□ = H2


FSB 115 BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
= H1
= H2

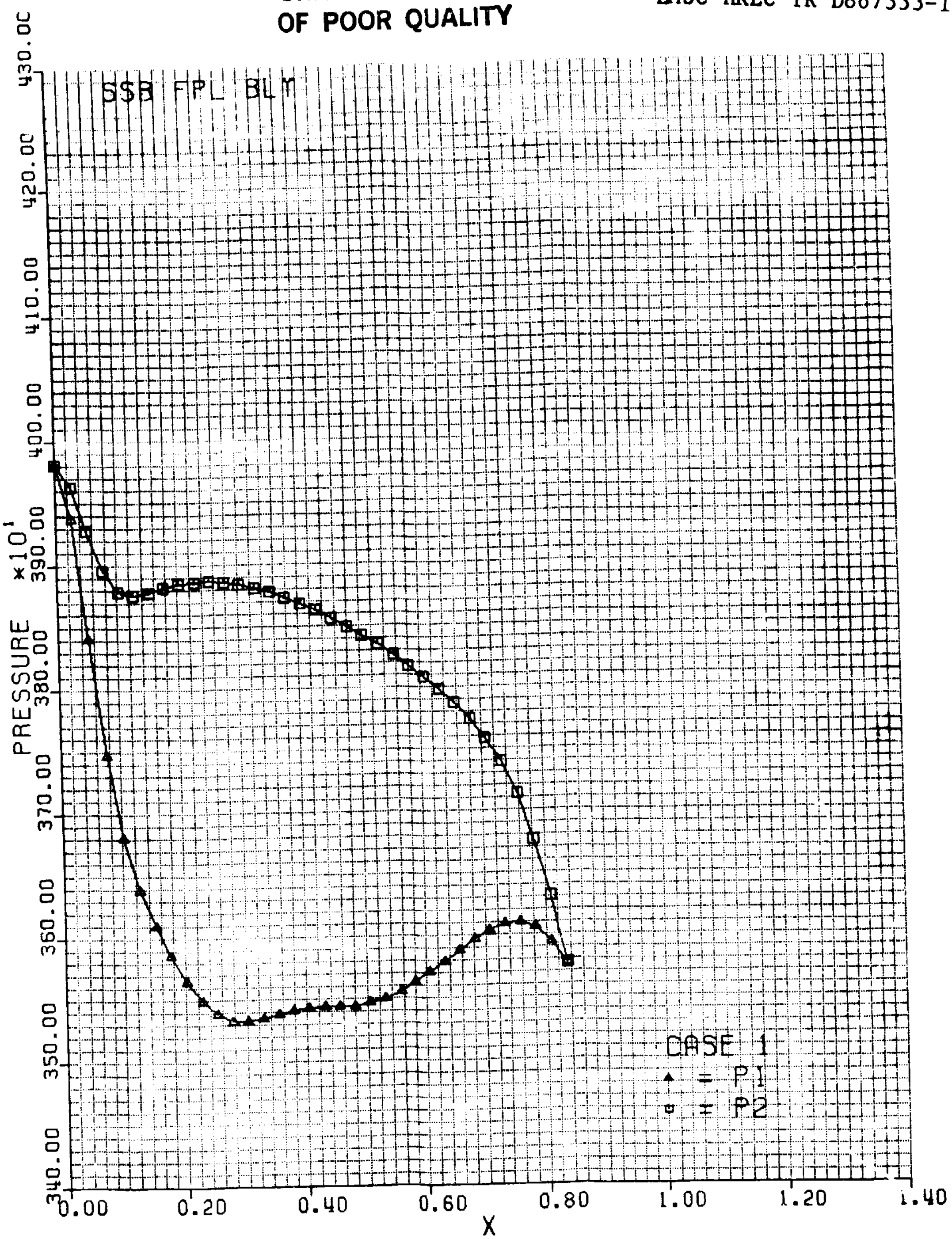
Appendix C

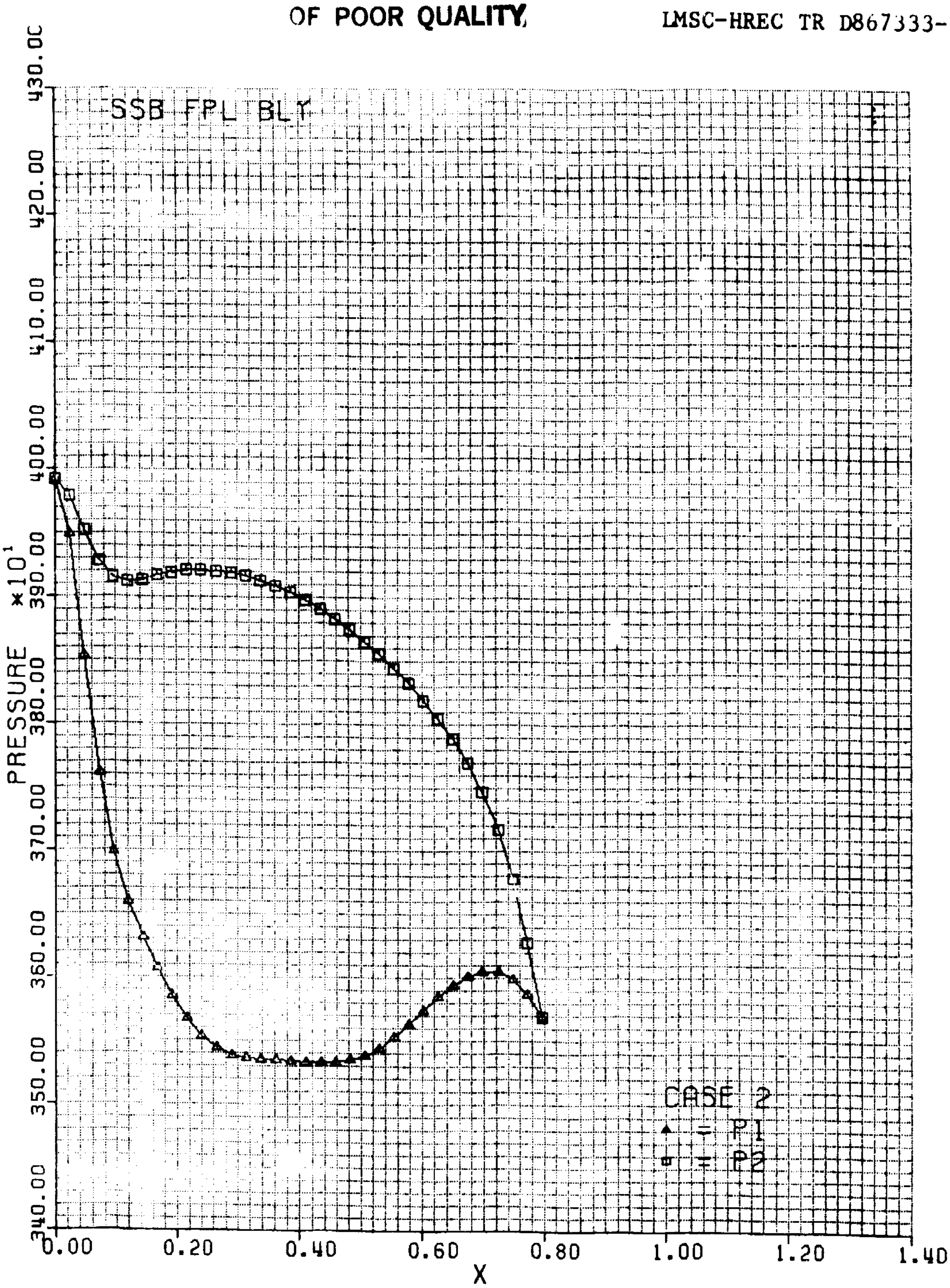
HPFTP SECOND STAGE BLADE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

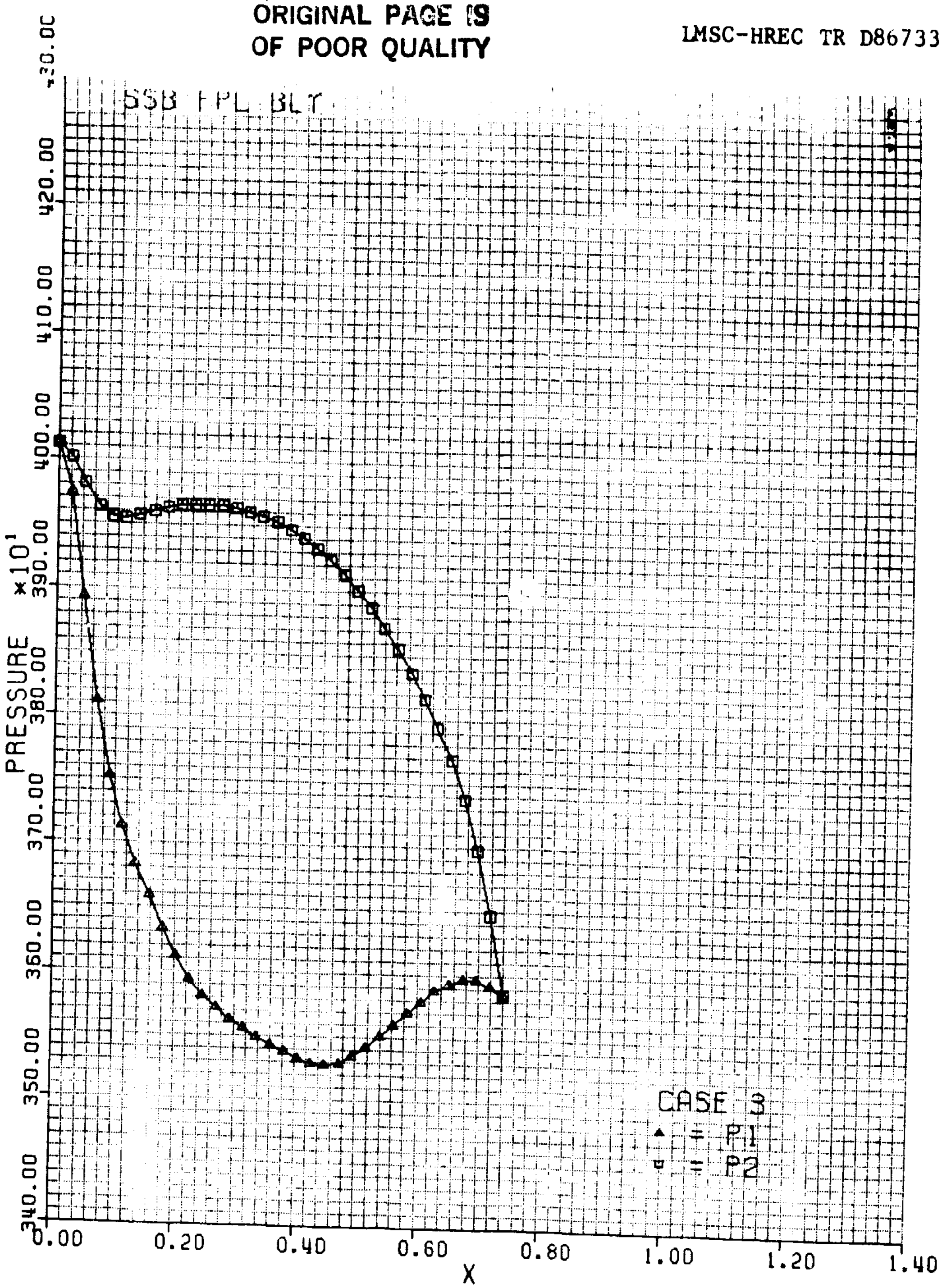
C.1 FPL Pressure Distributions
C.2 115 Percent Power Level Pressure Distributions
C.3 FPL Heat Transfer Coefficients
C.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Suction Surface △
Surface 2 - Pressure Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Case 1 - R = 4.5936 Hub	1390	1340
Case 2 - R = 4.80 Intermediate	↓	↓
Case 3 - R = 5.0795 Mean	↓	↓
Case 4 - R = 5.29 Intermediate	↓	↓
Case 5 - R = 5.5655 Tip	↓	↓


SSB FPL BLM
PRESSURE ×10[1]
430.00
420.00
410.00
400.00
390.00
380.00
370.00
360.00
350.00
340.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = P1
□ = P2


SSB FPL BLY
PRESSURE ×10[1]
340.00
350.00
360.00
370.00
380.00
390.00
400.00
410.00
420.00
430.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
= P1
= P2


SSB FPL BLT
PRESSURE ×10[1]
340.00
350.00
360.00
370.00
380.00
390.00
400.00
410.00
420.00
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 3
▲ = P1
▫ = P2

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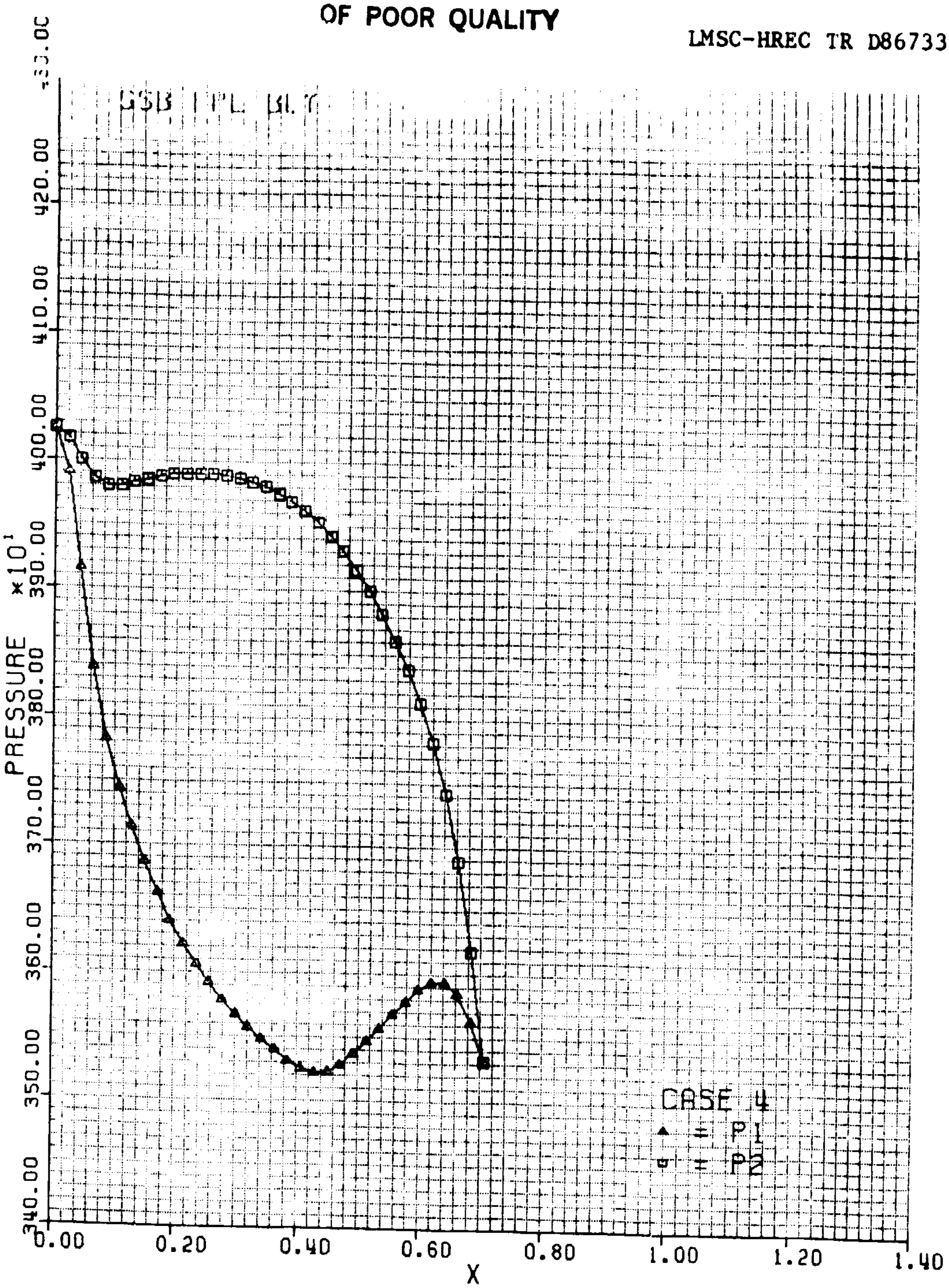
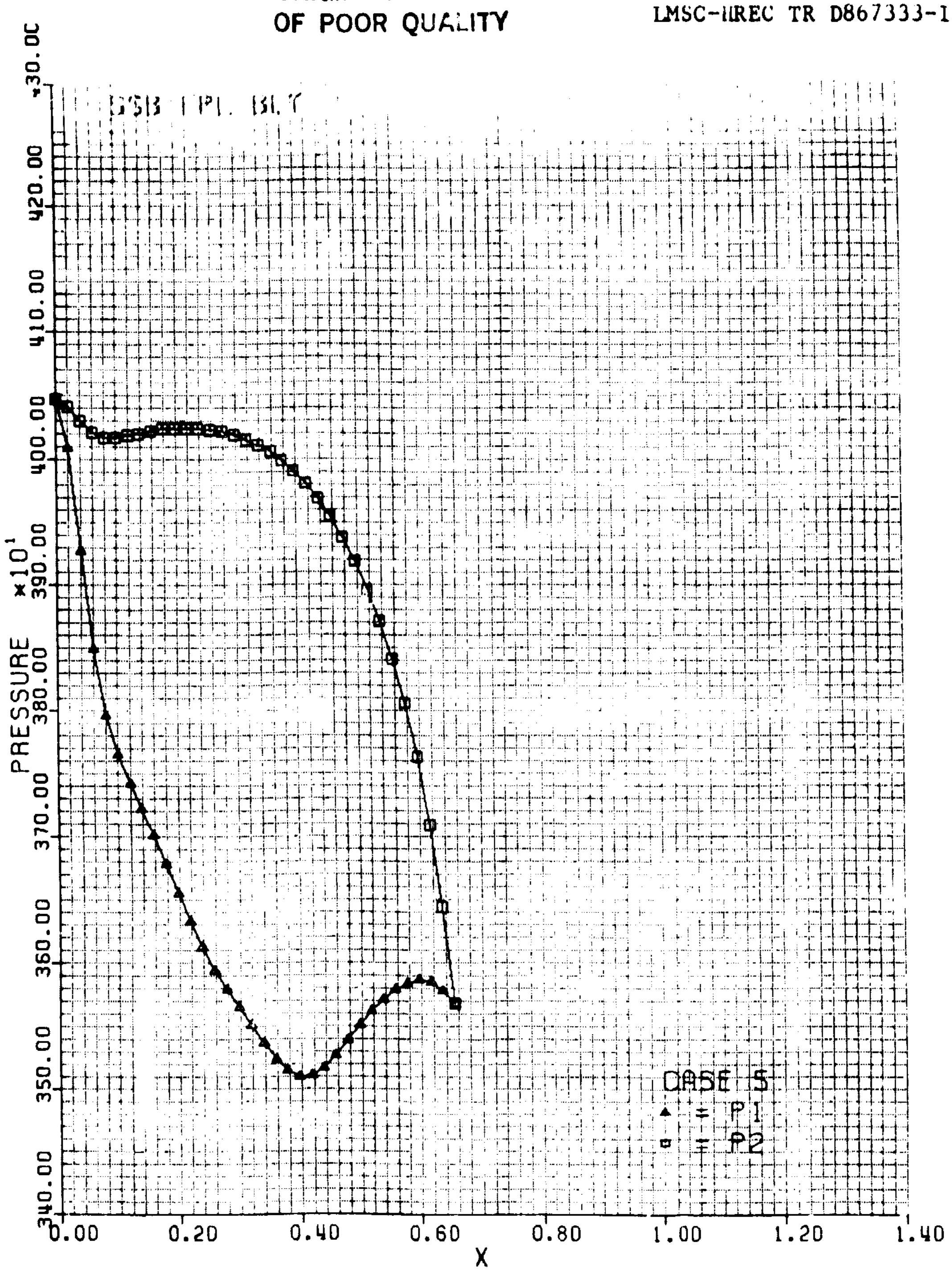
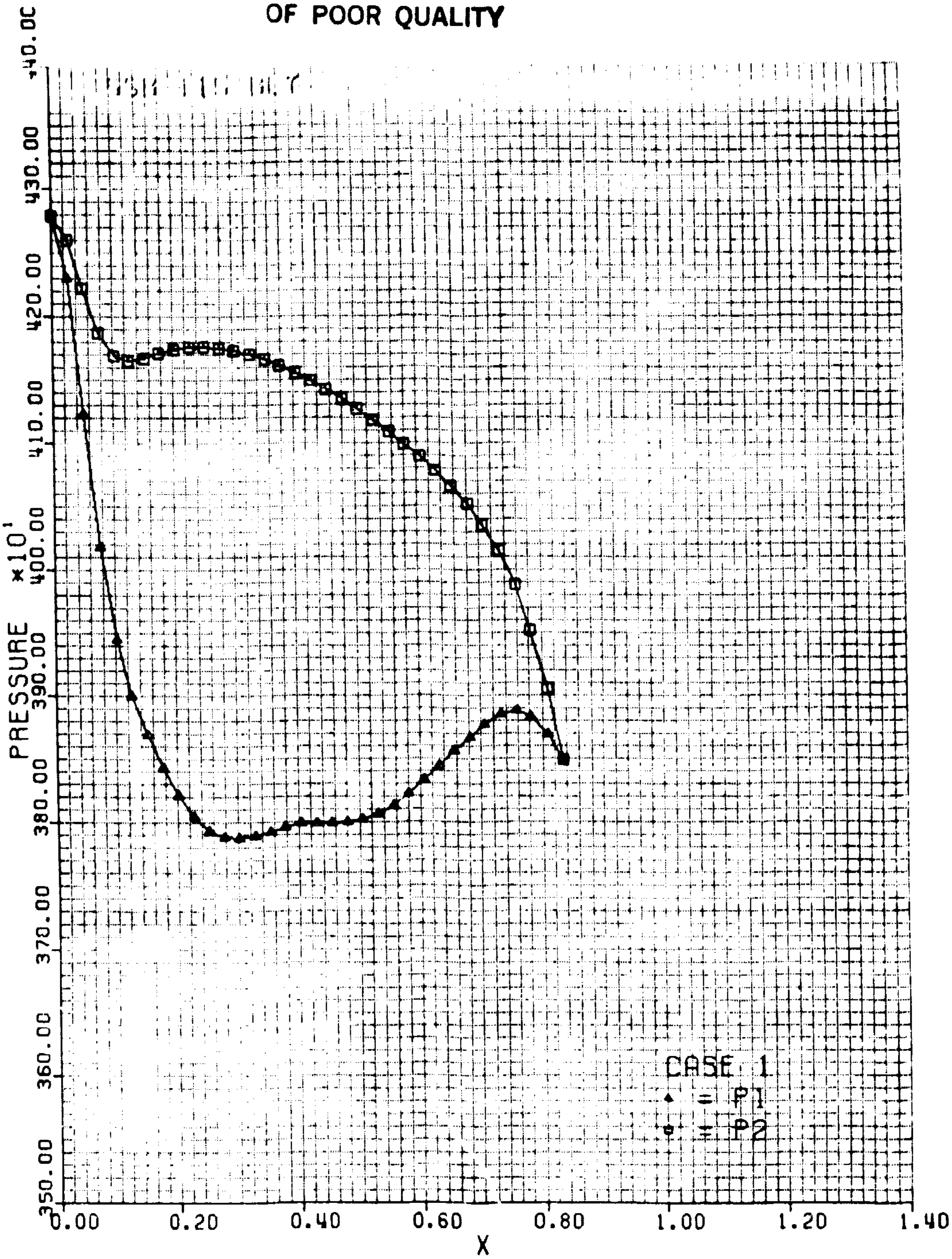
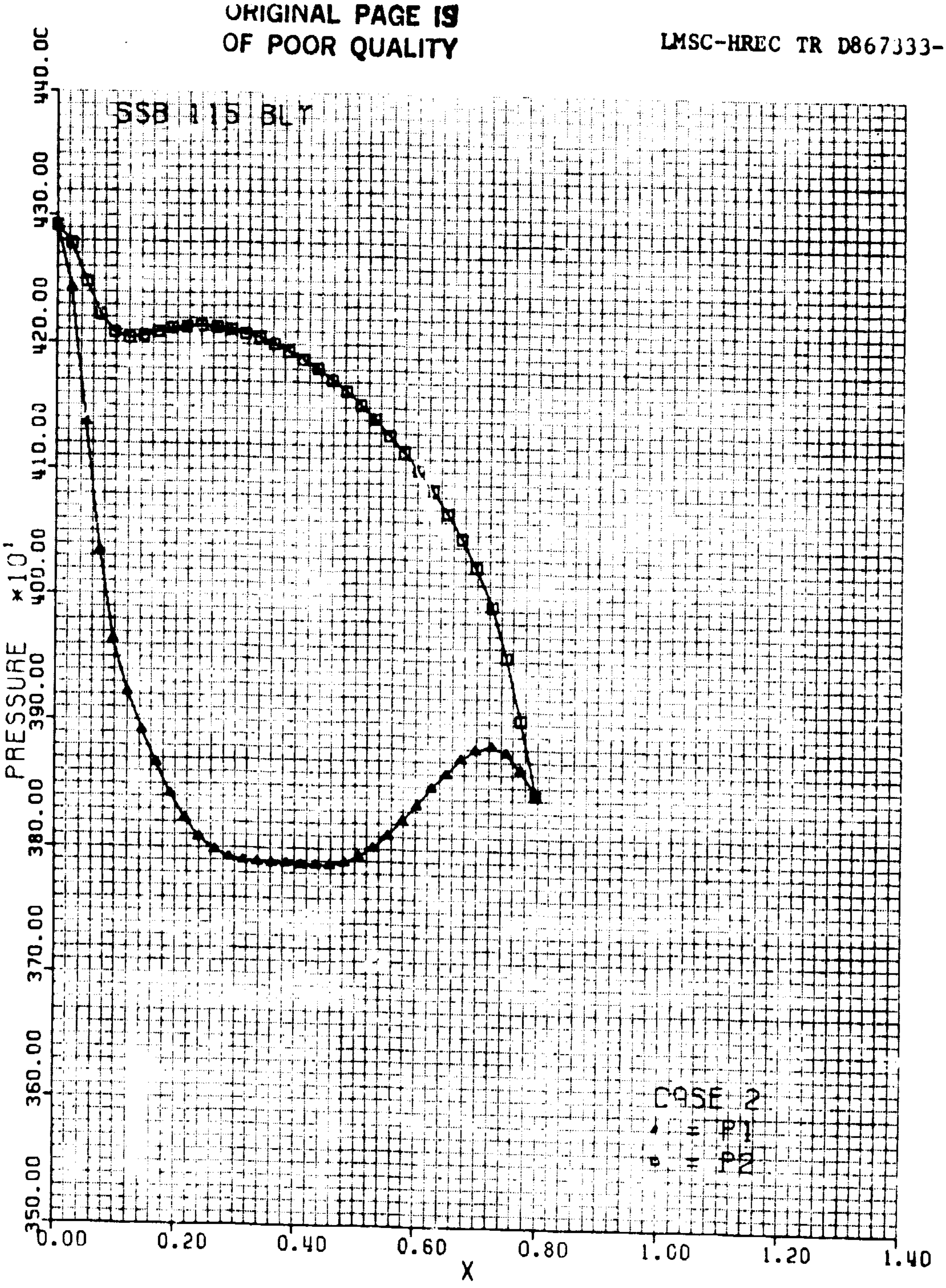
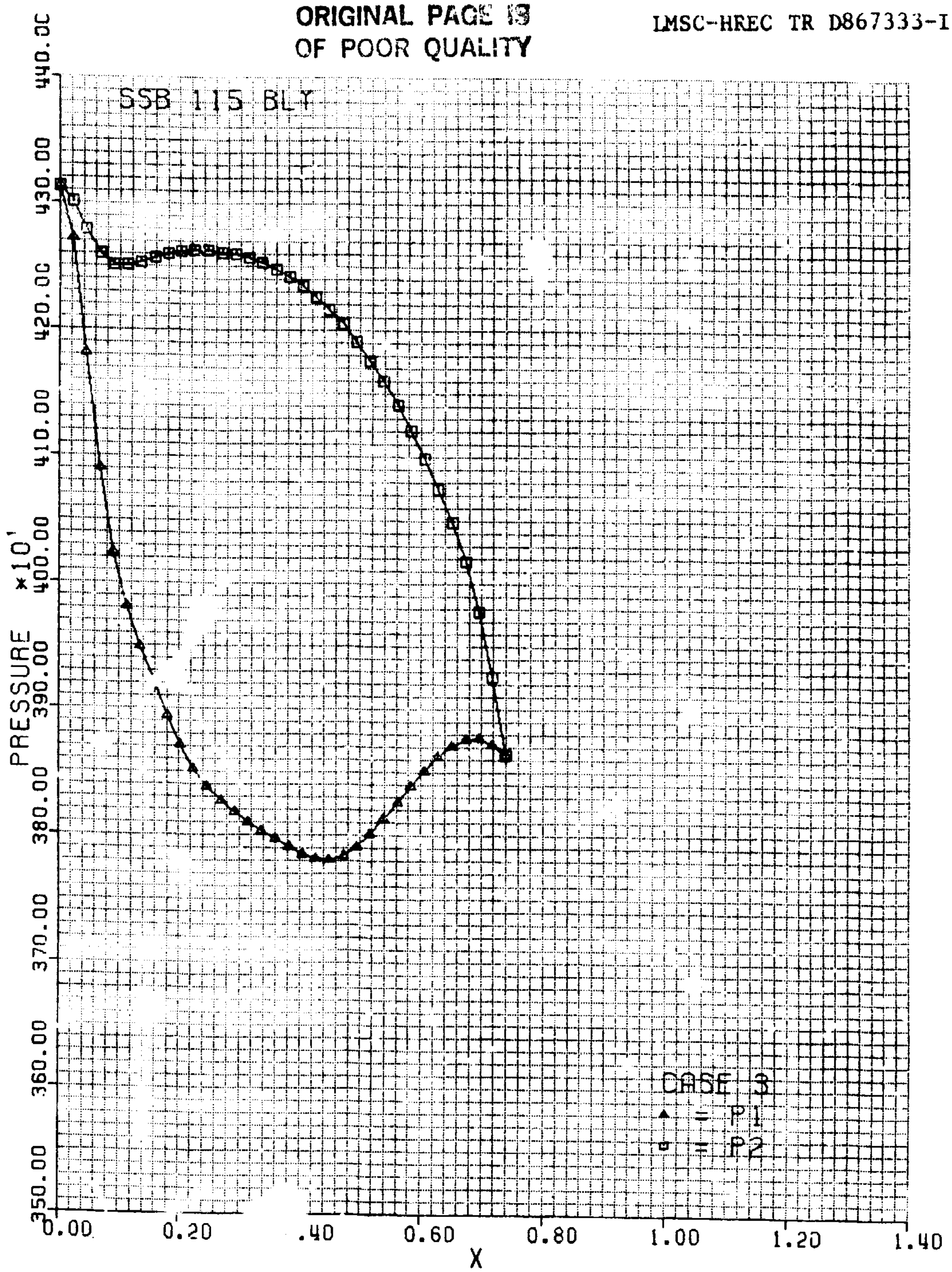



PRESSURE ×10[1]
340.00
350.00
360.00
370.00
380.00
390.00
400.00
410.00
420.00
430.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
▲ = P1
▫ = P2


440.00
430.00
420.00
410.00
400.00
390.00
380.00
370.00
360.00
350.00
PRESSURE ×10[1]
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
▲ = P1
□ = P2


SSB 115 BLT
440.00
430.00
420.00
410.00
400.00
390.00
380.00
370.00
360.00
350.00
PRESSURE *10¹
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
= P1
= P2


SSB 115 BLT
PRESSURE *10¹
440.00
430.00
420.00
410.00
400.00
390.00
380.00
370.00
360.00
350.00
0.00
0.20
.40
0.60
0.80
1.00
1.20
1.40
X
CASE 3
▲ = P1
□ = P2

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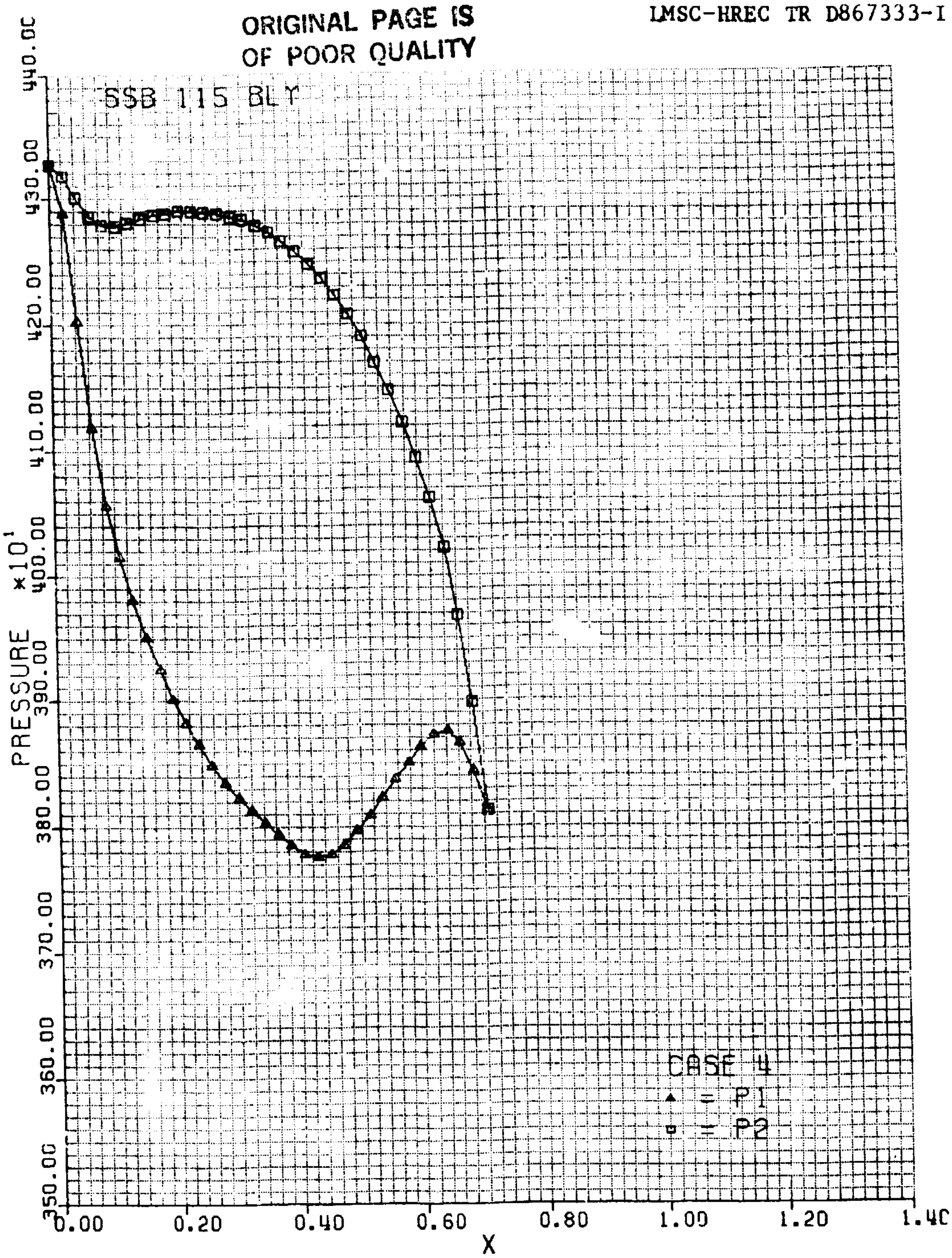

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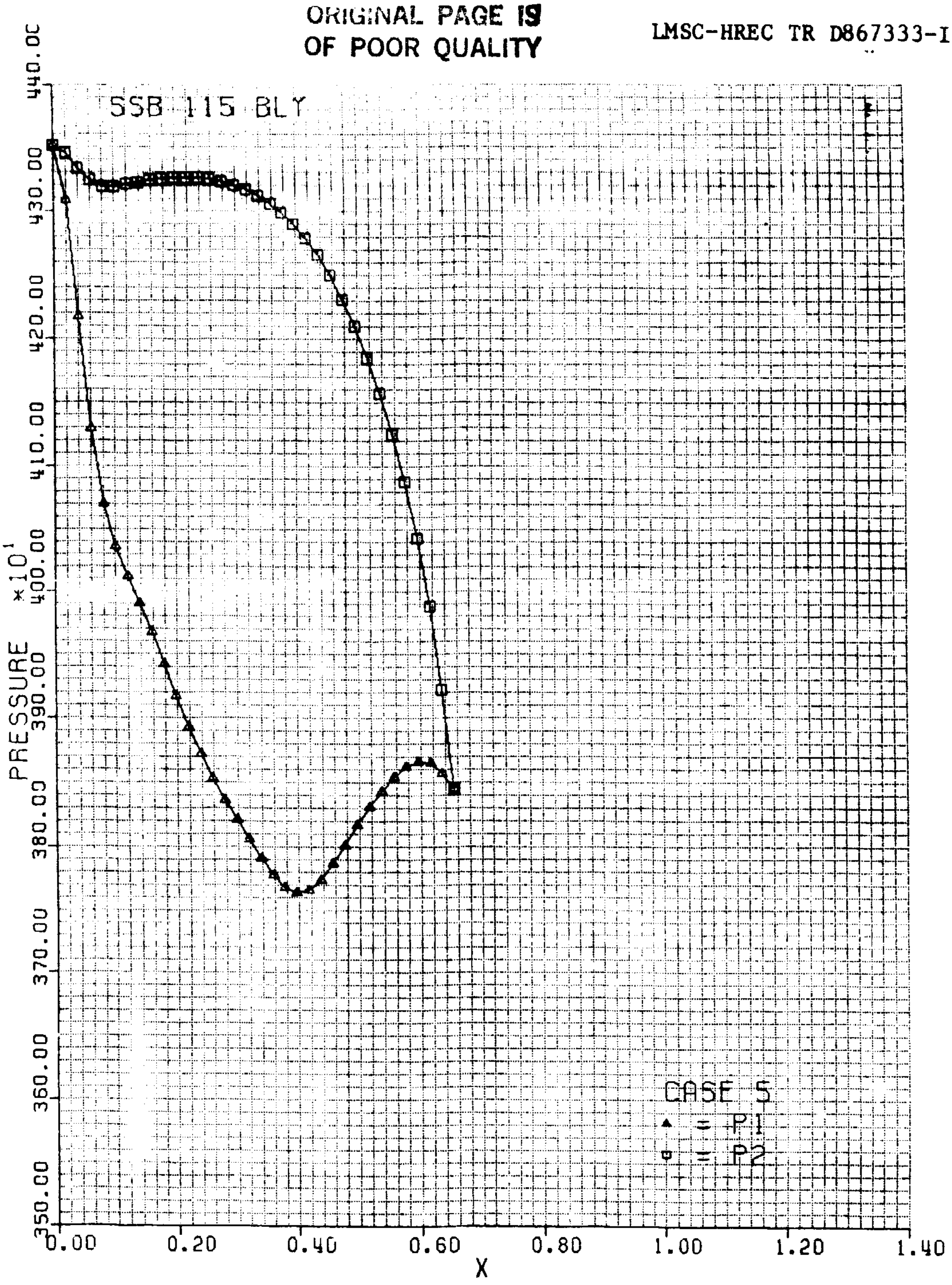
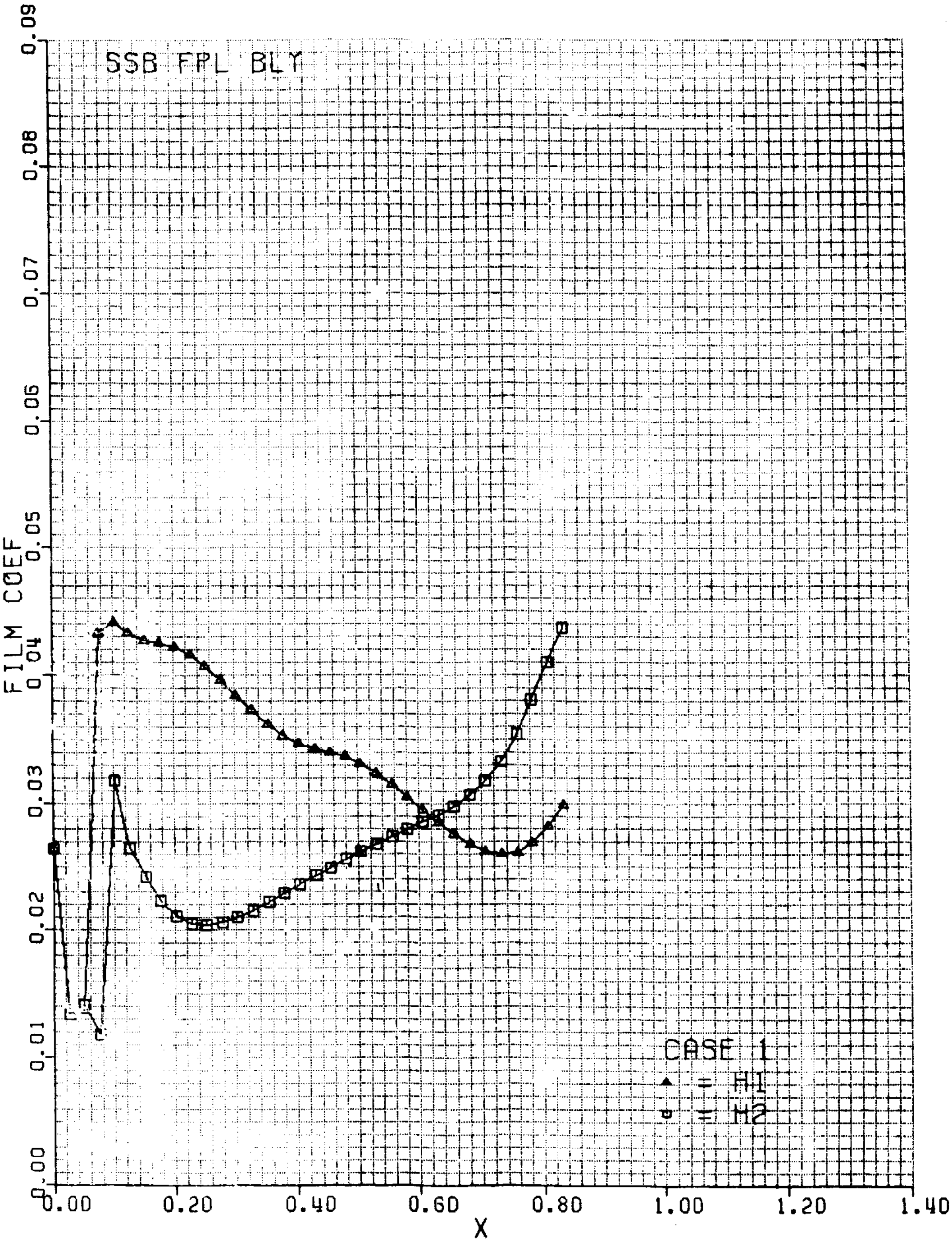
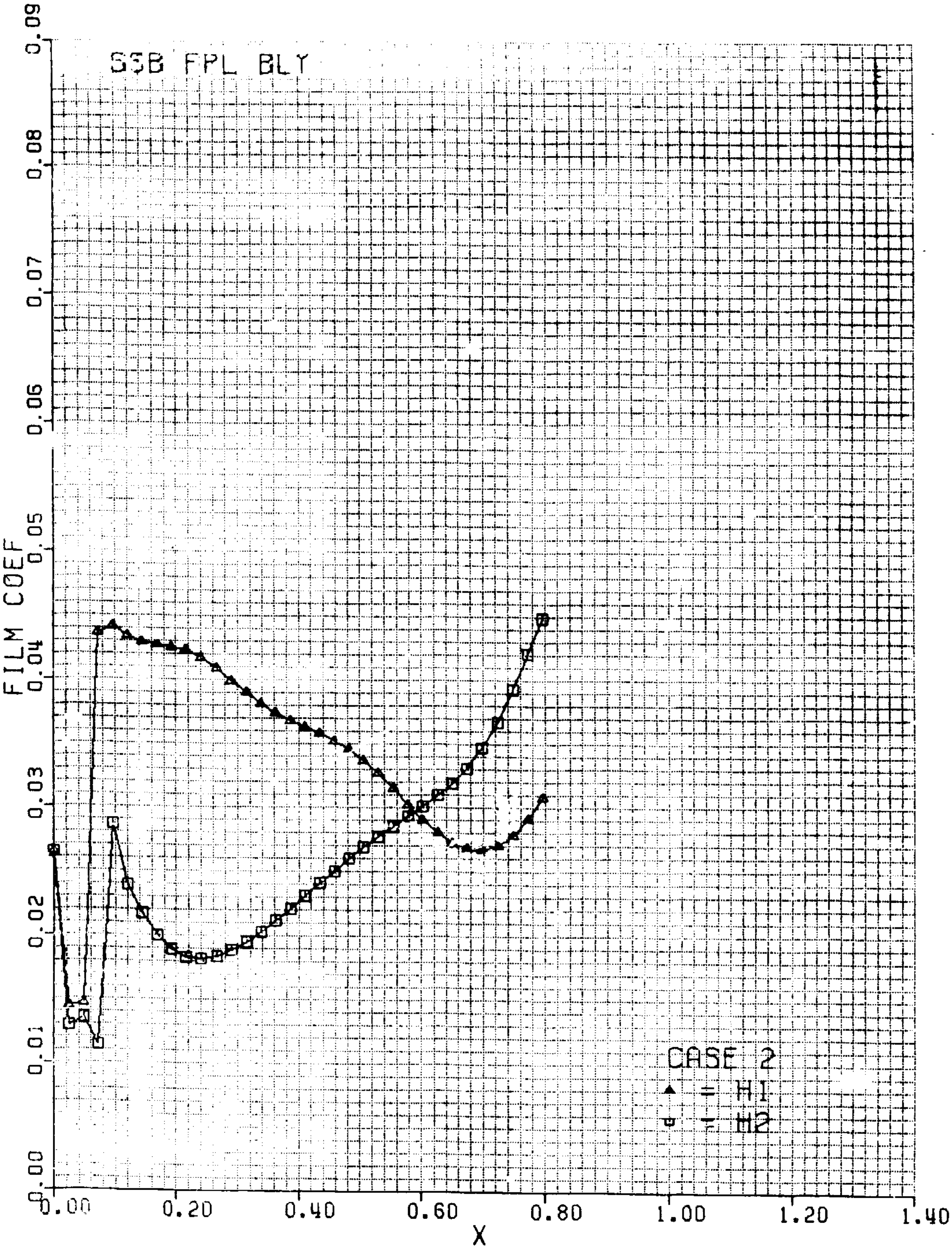
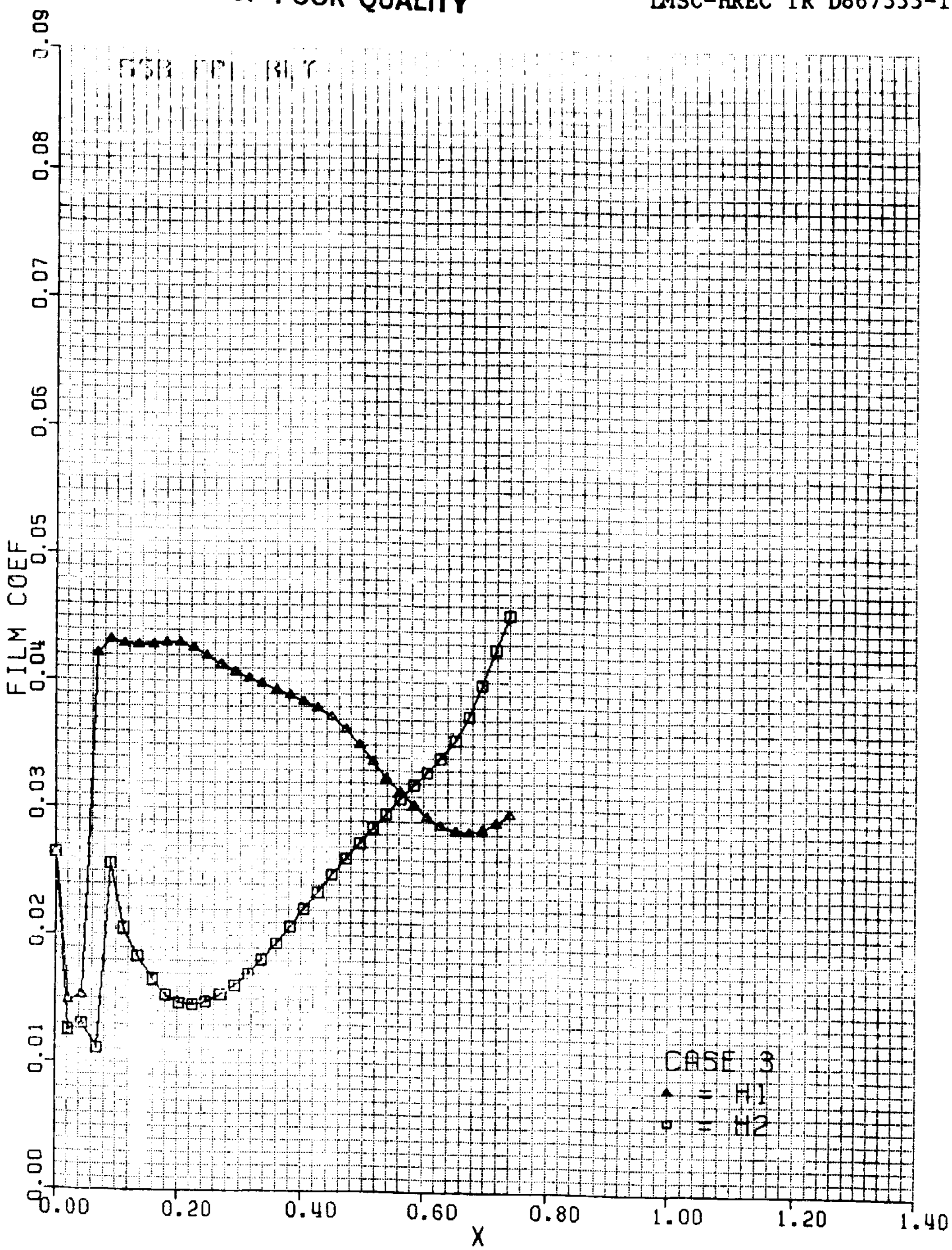
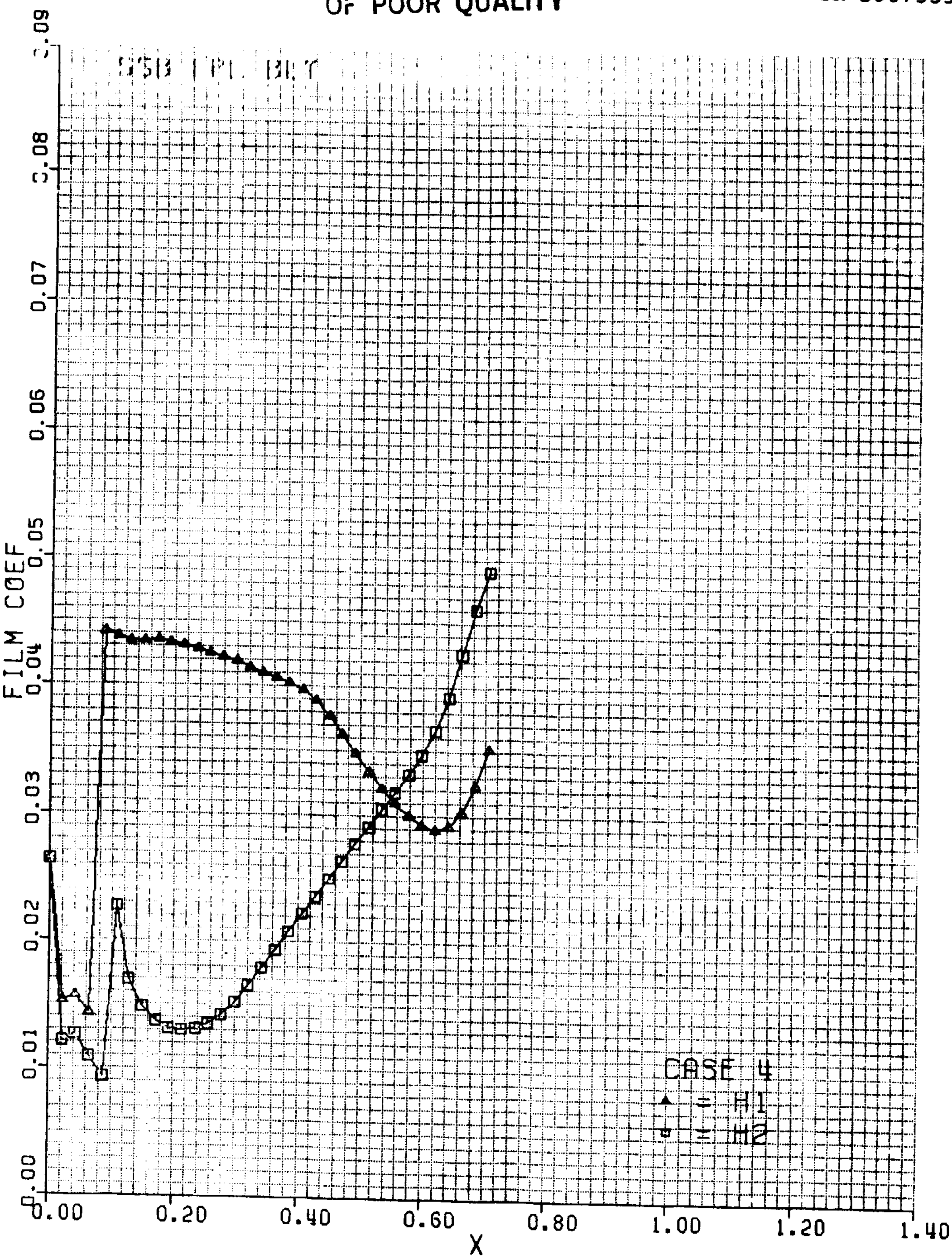


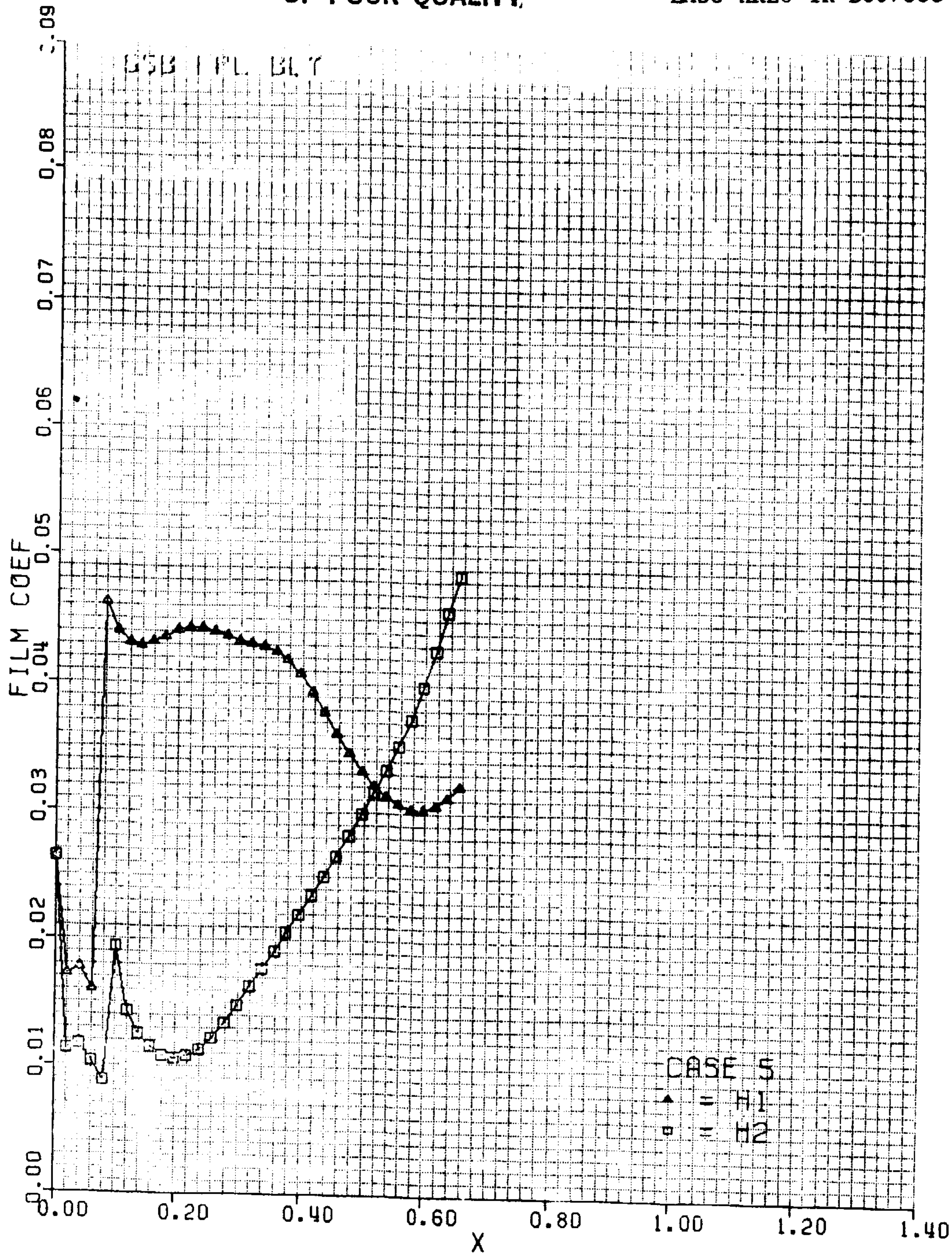

SSB FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
= H1
= H2


S3B FPL BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
▲ = H1
□ = H2

C.3.2


FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 3
▲ = H1
□ = H2


SSB FPL BET
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 4
= H1
= H2


SSB I FL BLT
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 5
= H1
= H2

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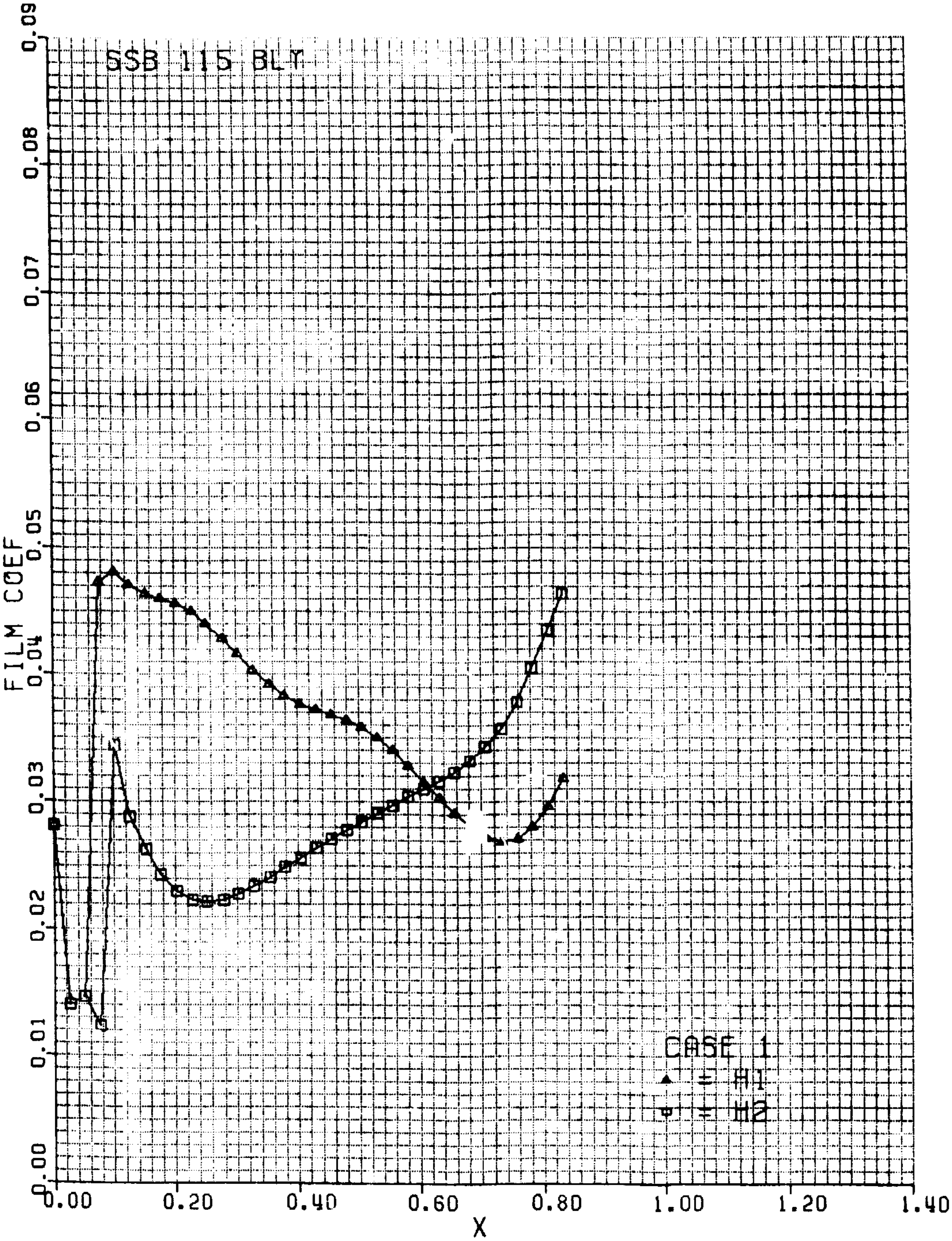

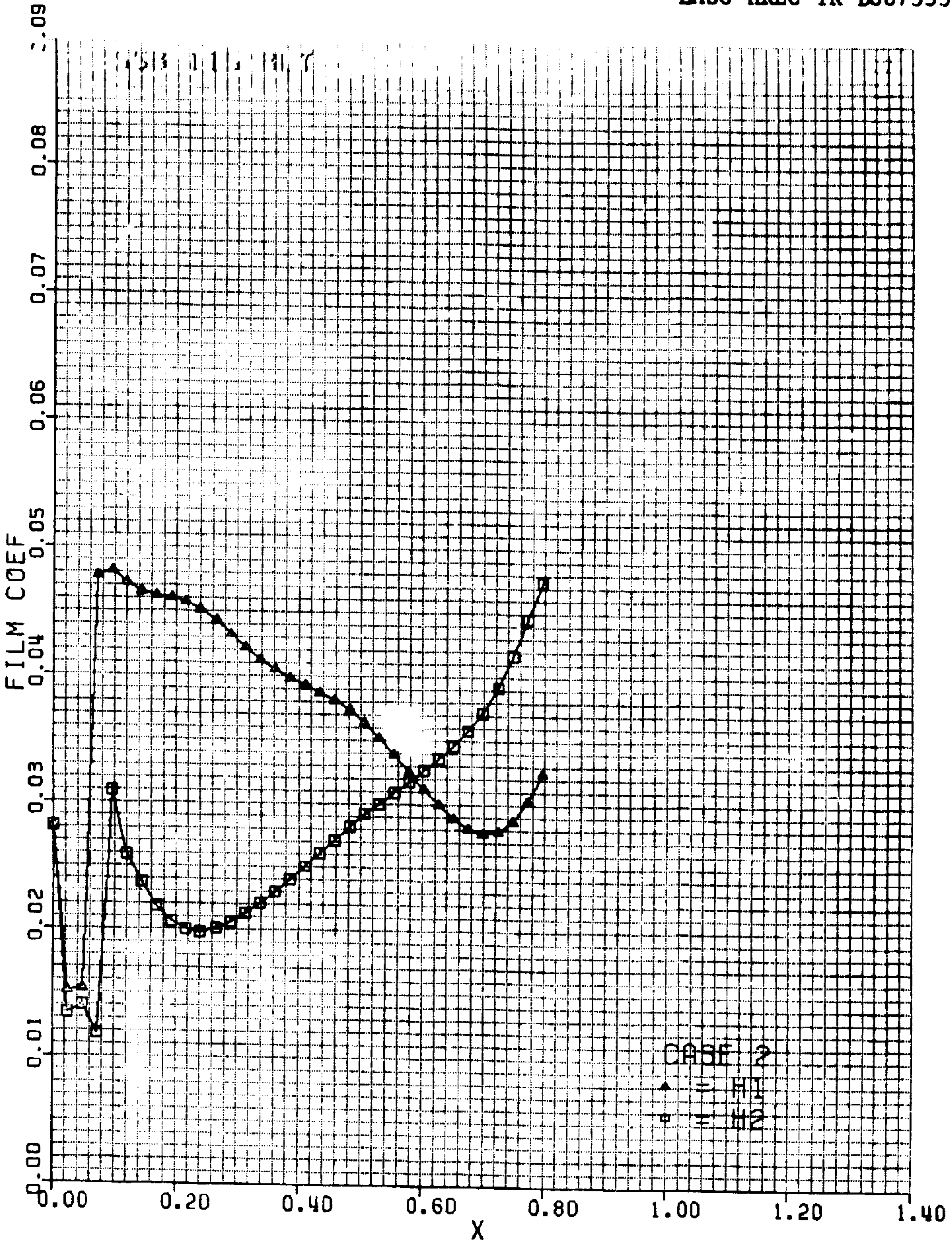
FILM COEF
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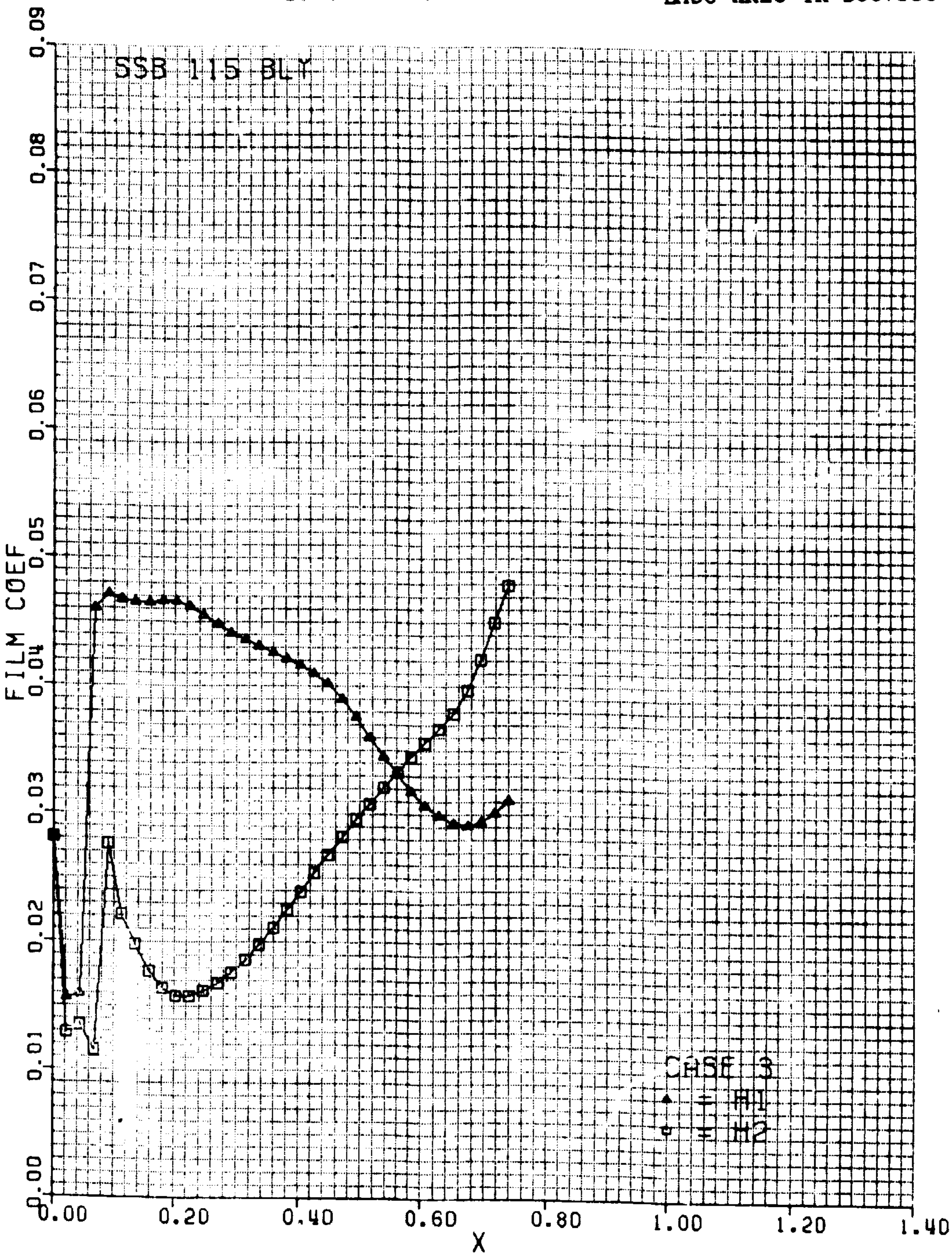
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 2
= H1
= H2


SSB 115 BLY
FILM COEF
X
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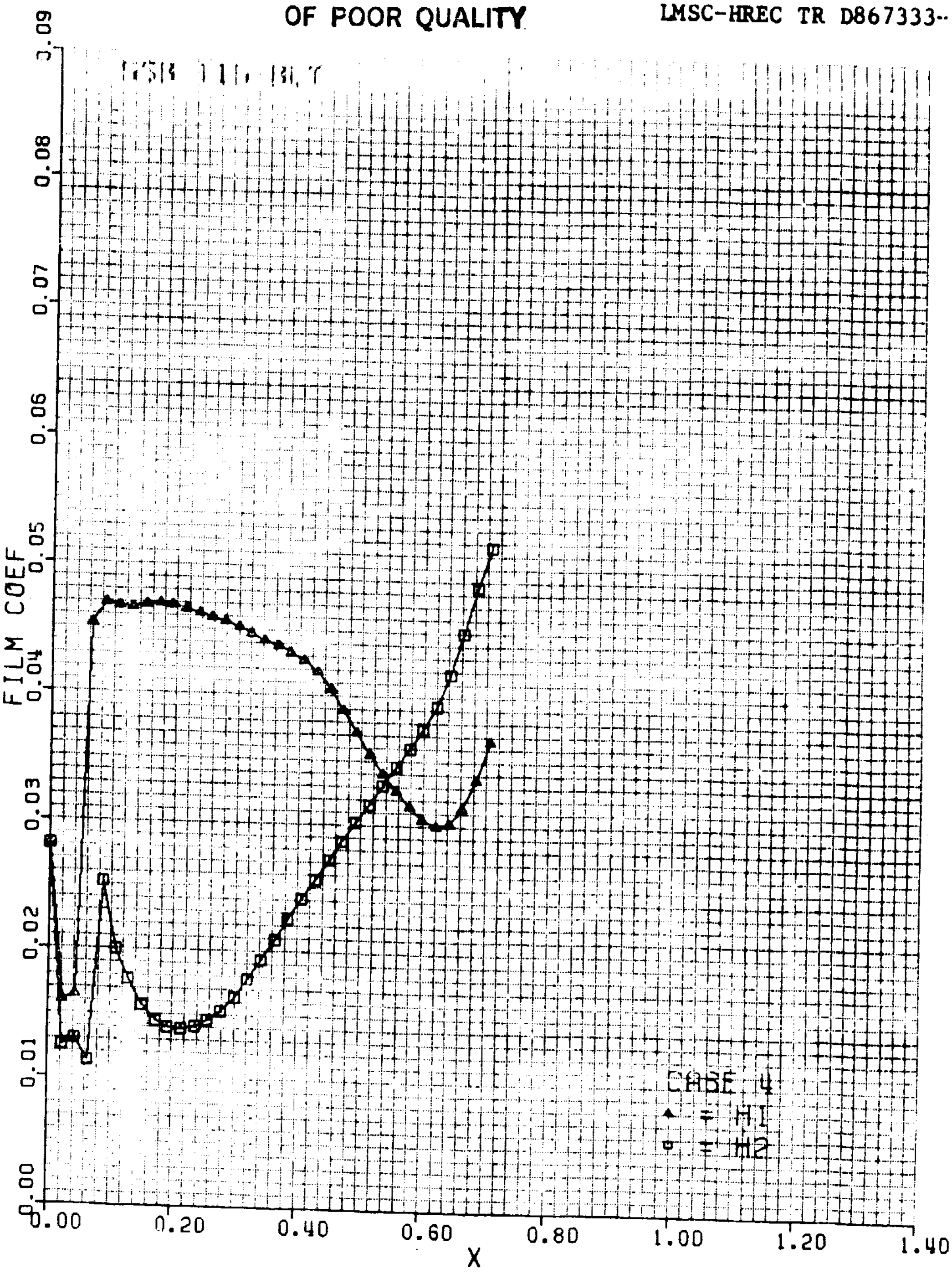
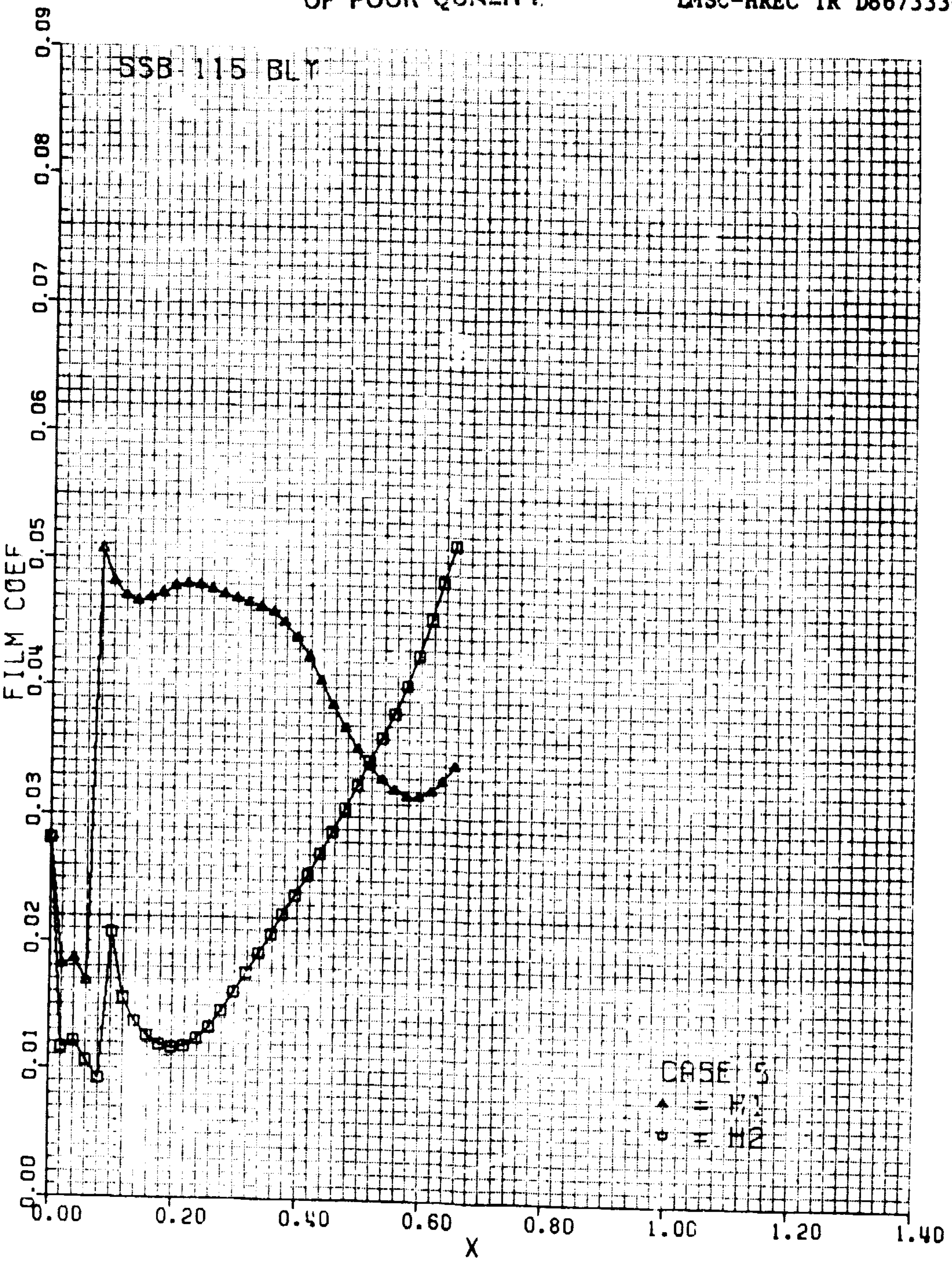
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 3
= H1
= H2


FILM COEF
X
CASE 4
▲ = H1
□ = H2
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.20
0.40
0.60
0.80
1.00
1.20
1.40


SSB 115 BLY
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 5
= H1
= H2

Appendix D

HPFTP SECOND STAGE NOZZLE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

D.1 FPL Pressure Distributions
D.2 115 Percent Power Level Pressure Distributions
D.3 FPL Heat Transfer Coefficients
D.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Pressure Surface △
Surface 2 - Suction Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Case 1 - R = 4.55 Hub	1445	1400
Case 2 - R = 4.76 Intermediate	↓	↓
Case 3 - R = 5.037 Mean	↓	↓
Case 4 - R = 5.25 Intermediate	↓	↓
Case 5 - R = 5.523 Tip	↓	↓

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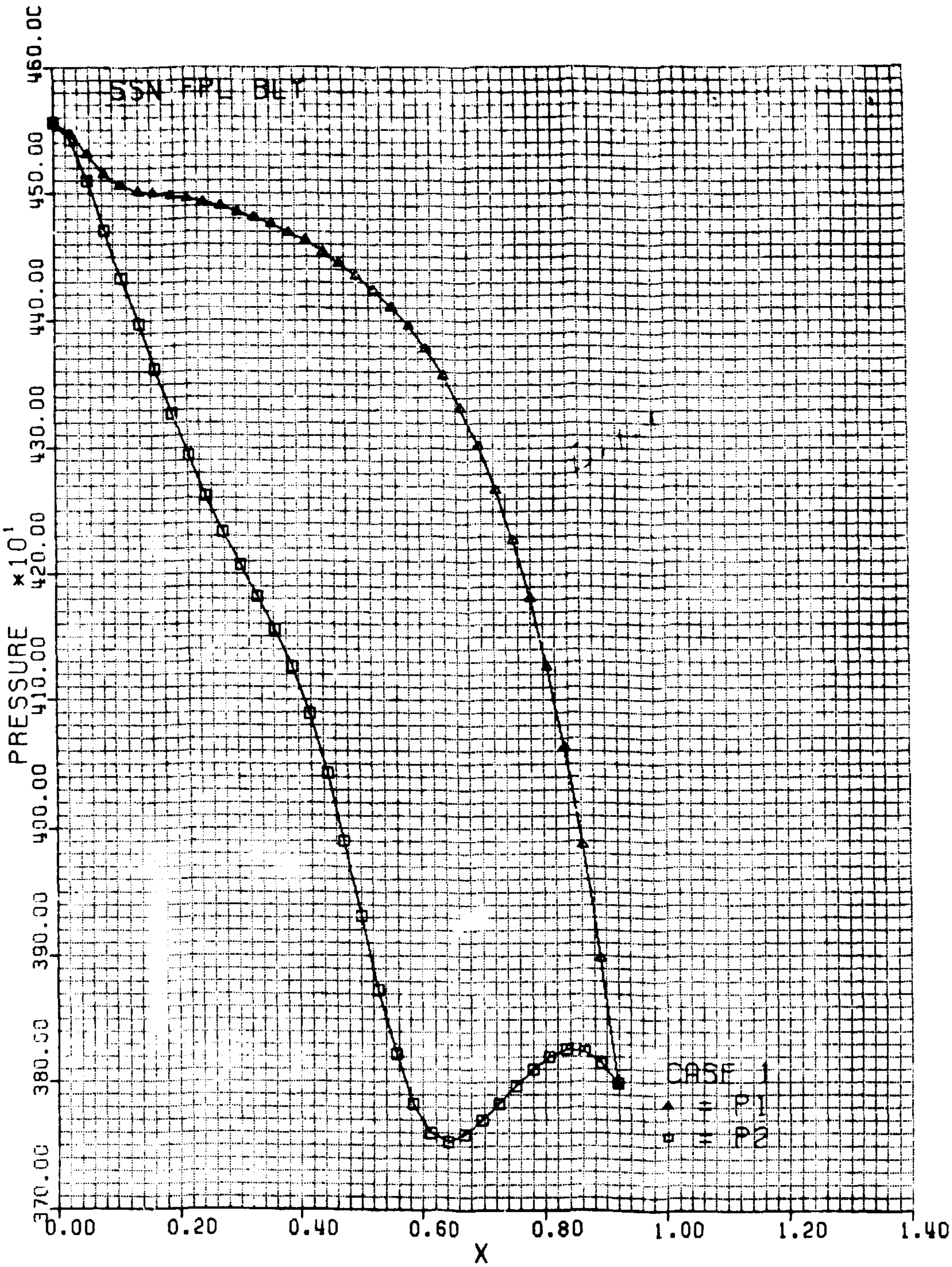

C-2

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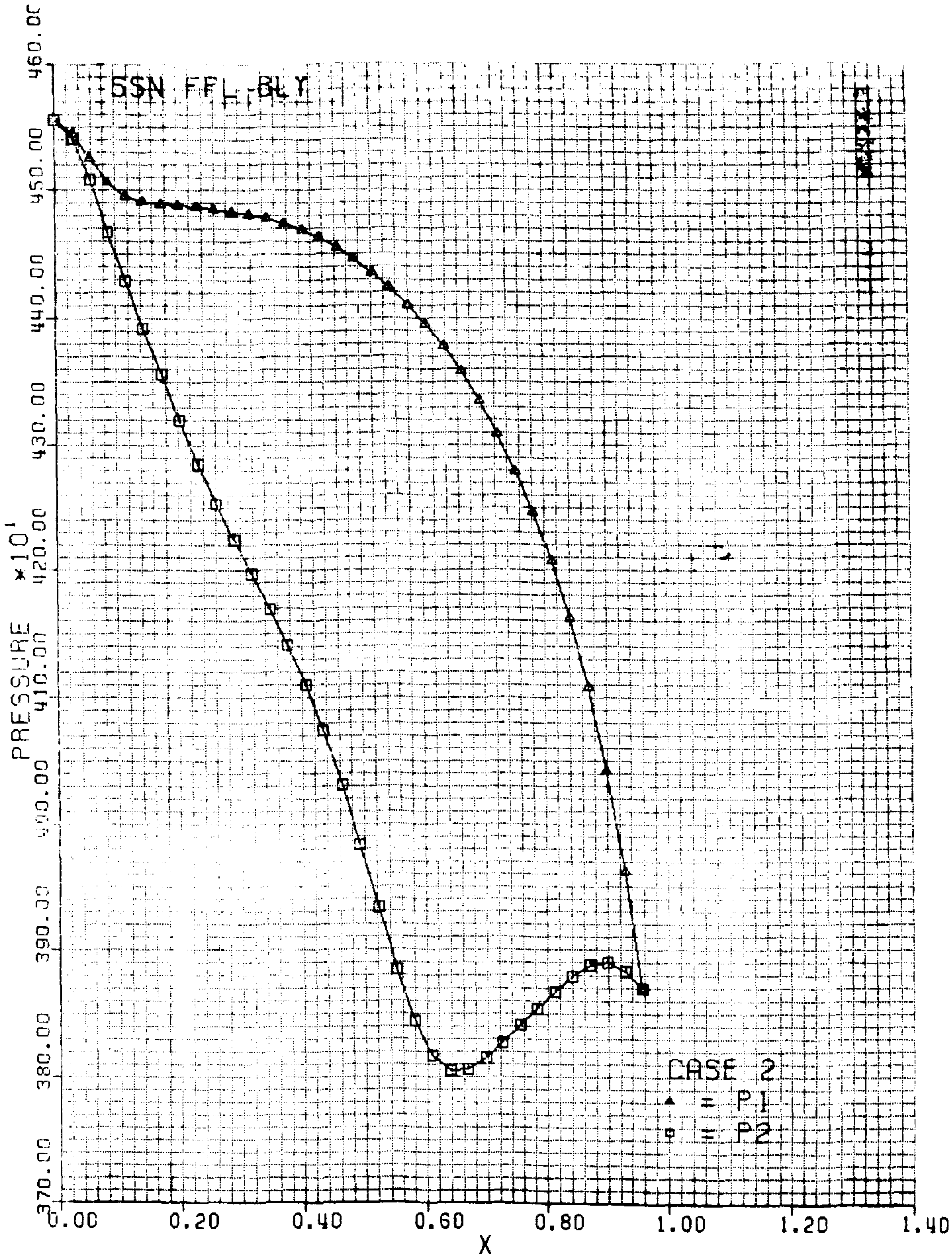

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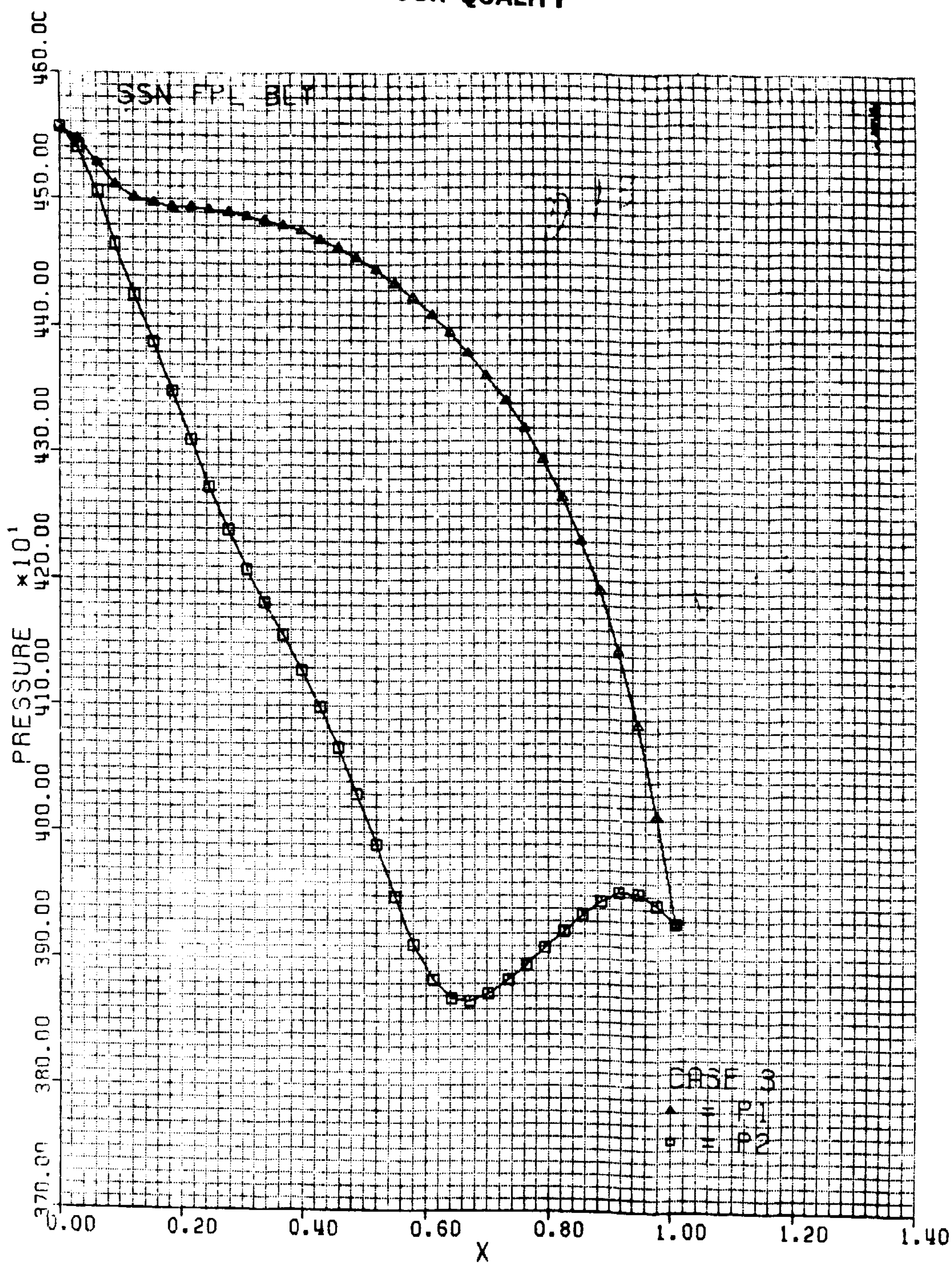

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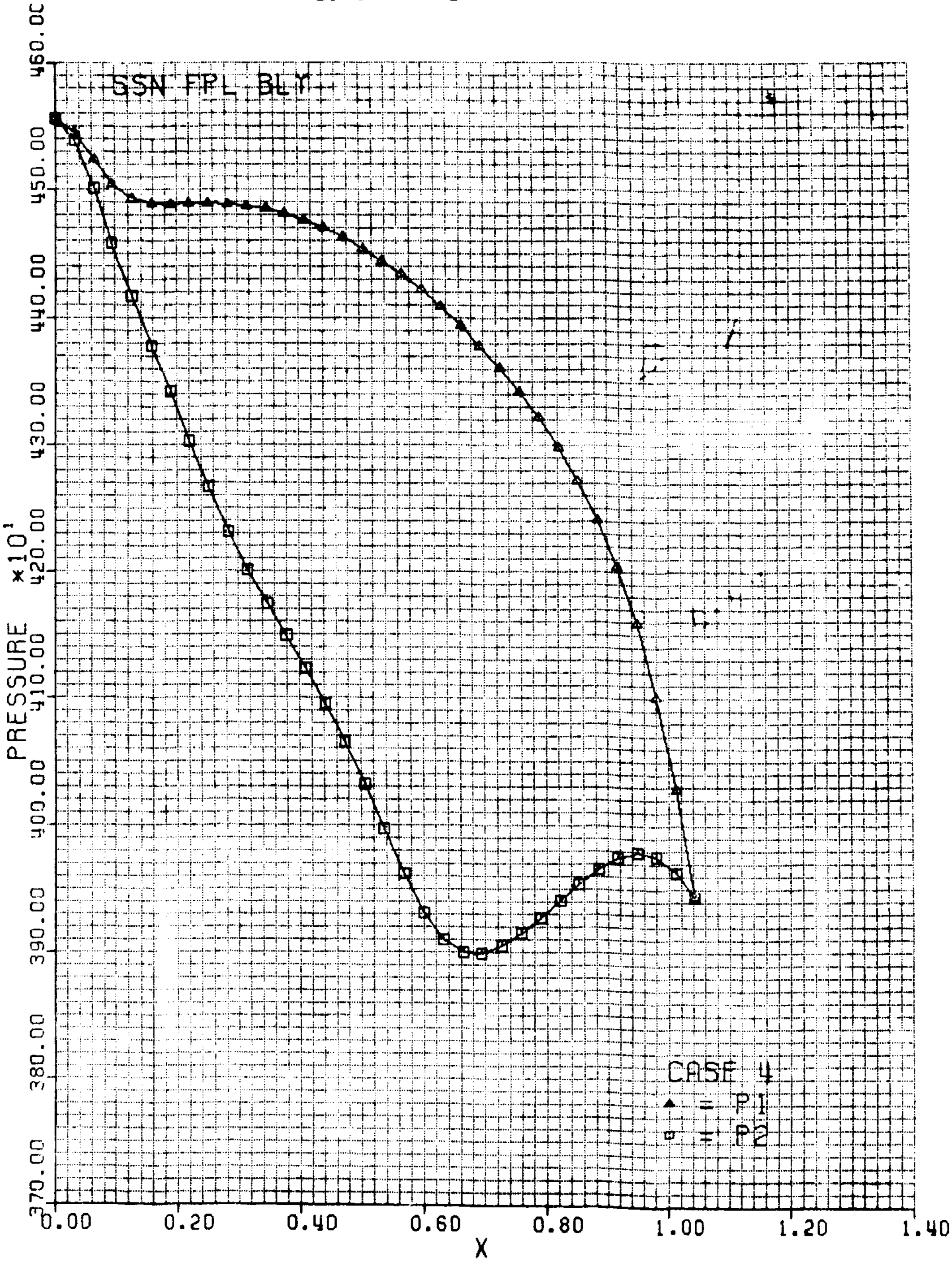

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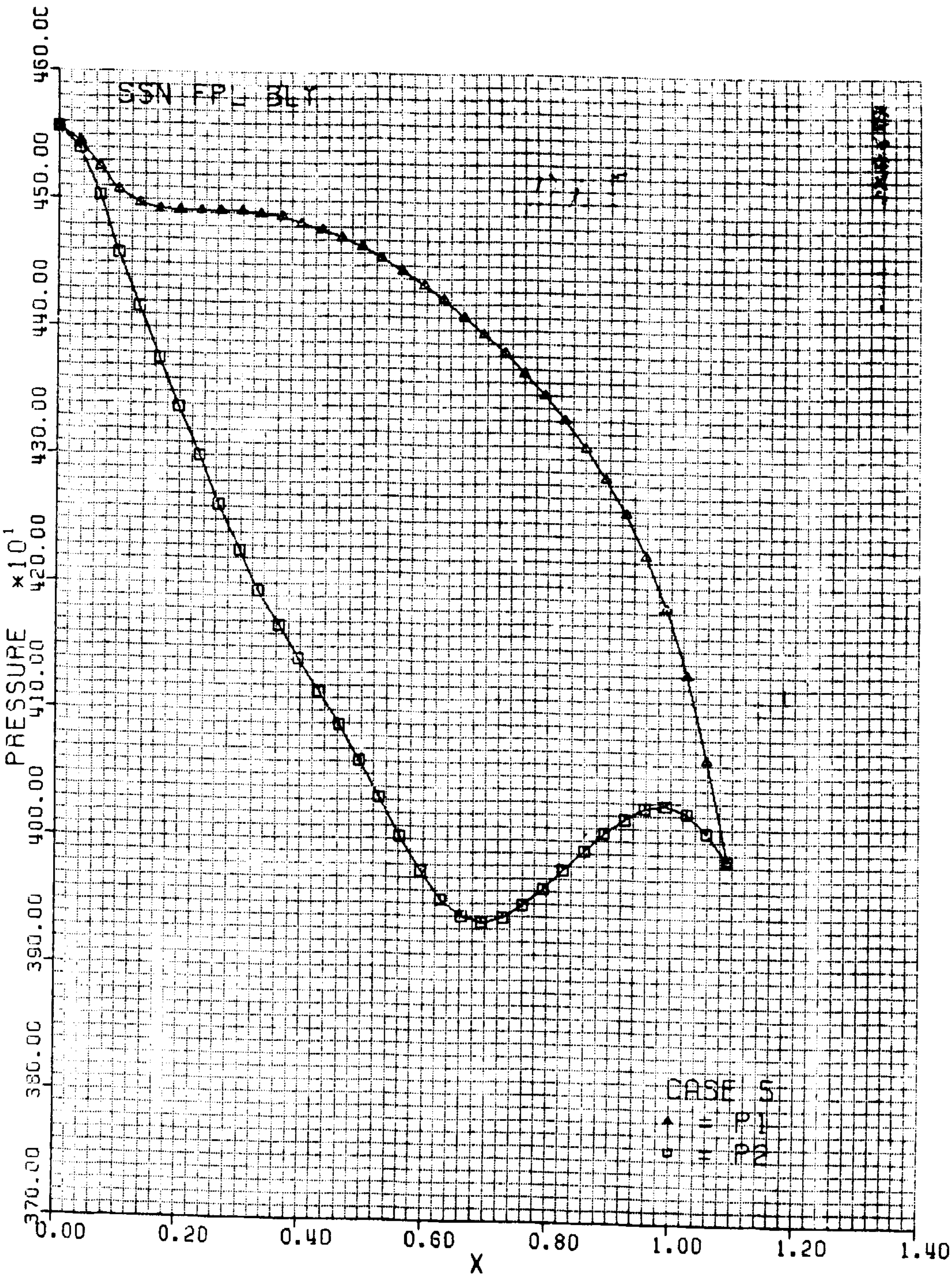

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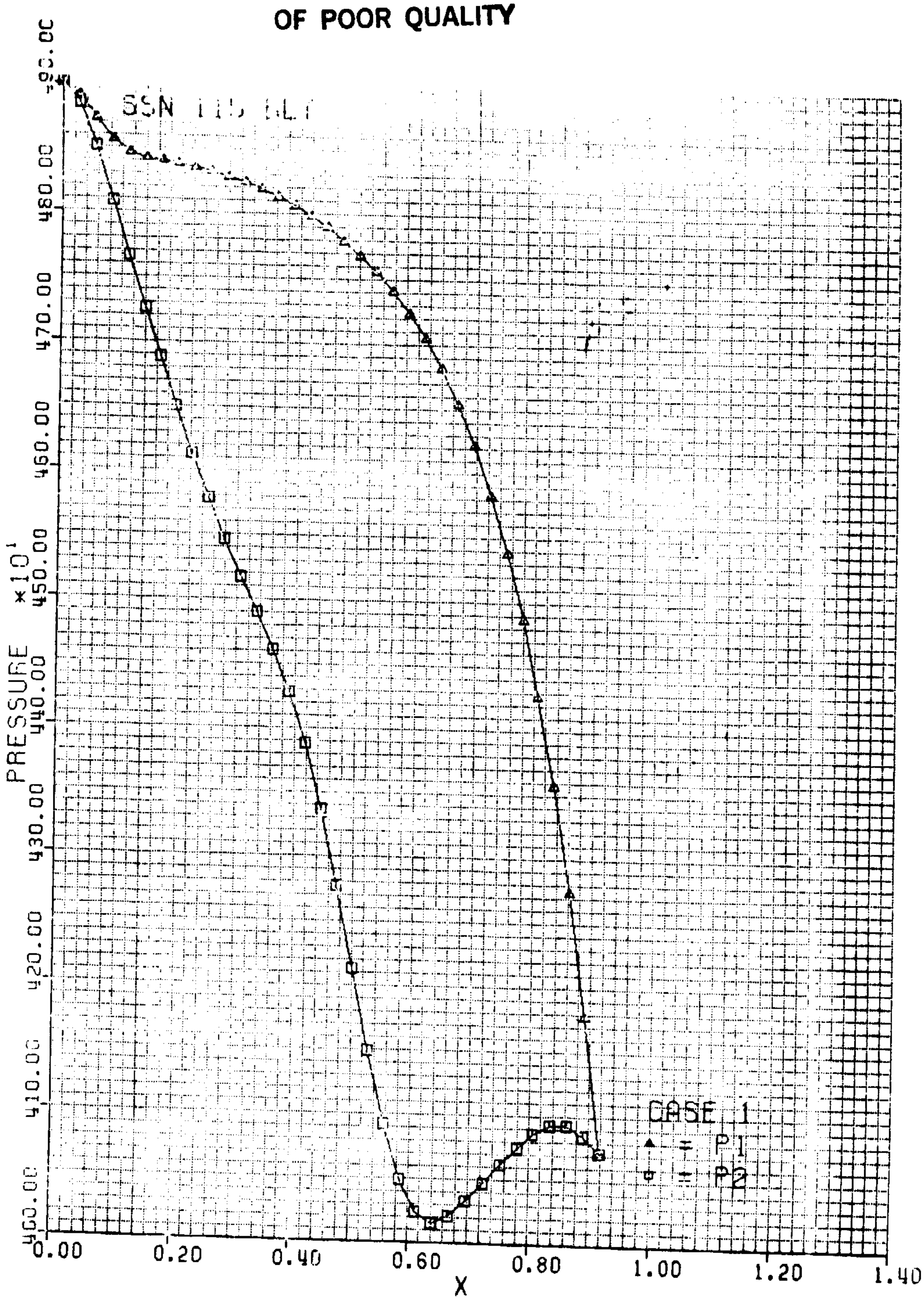

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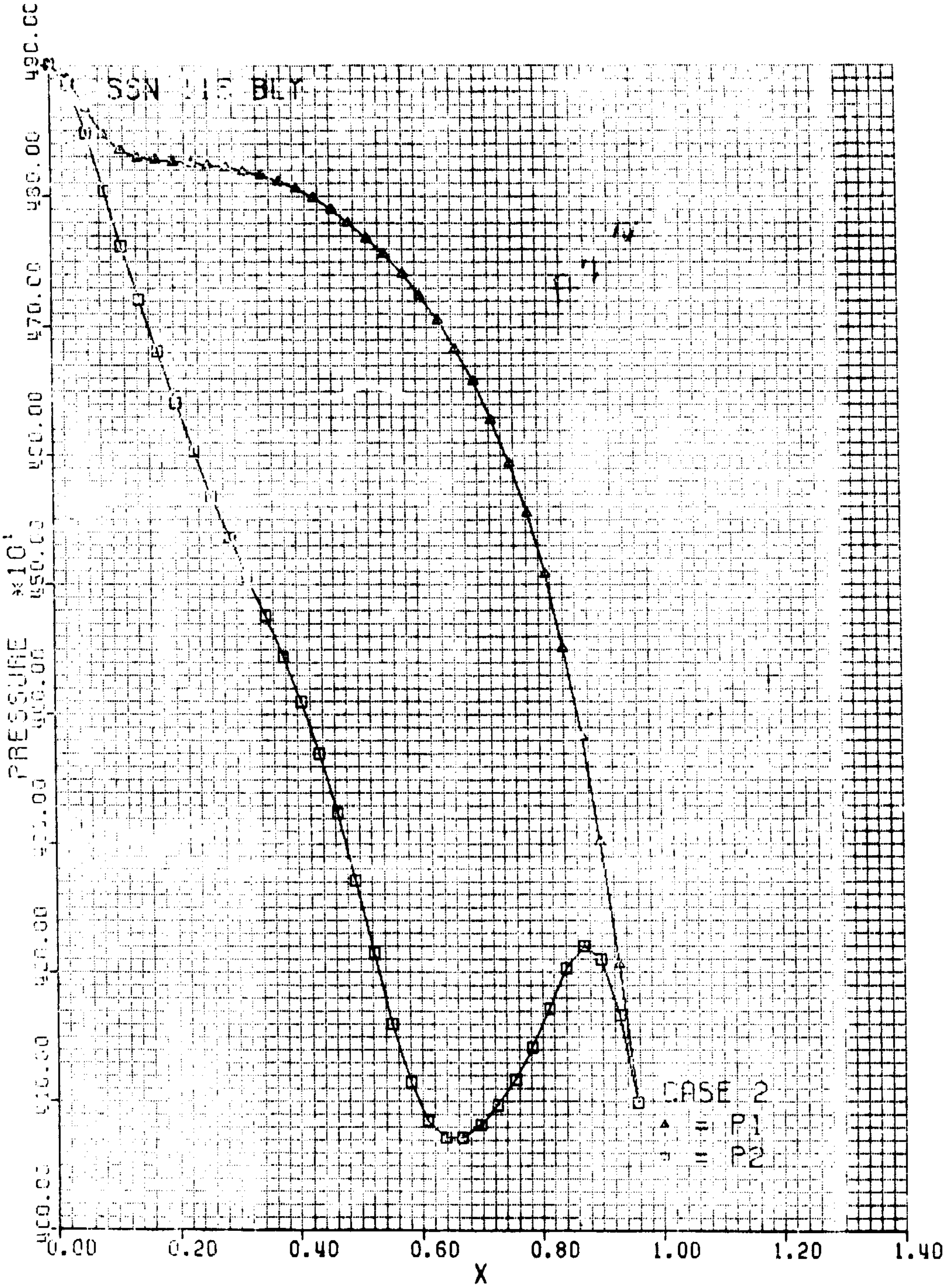

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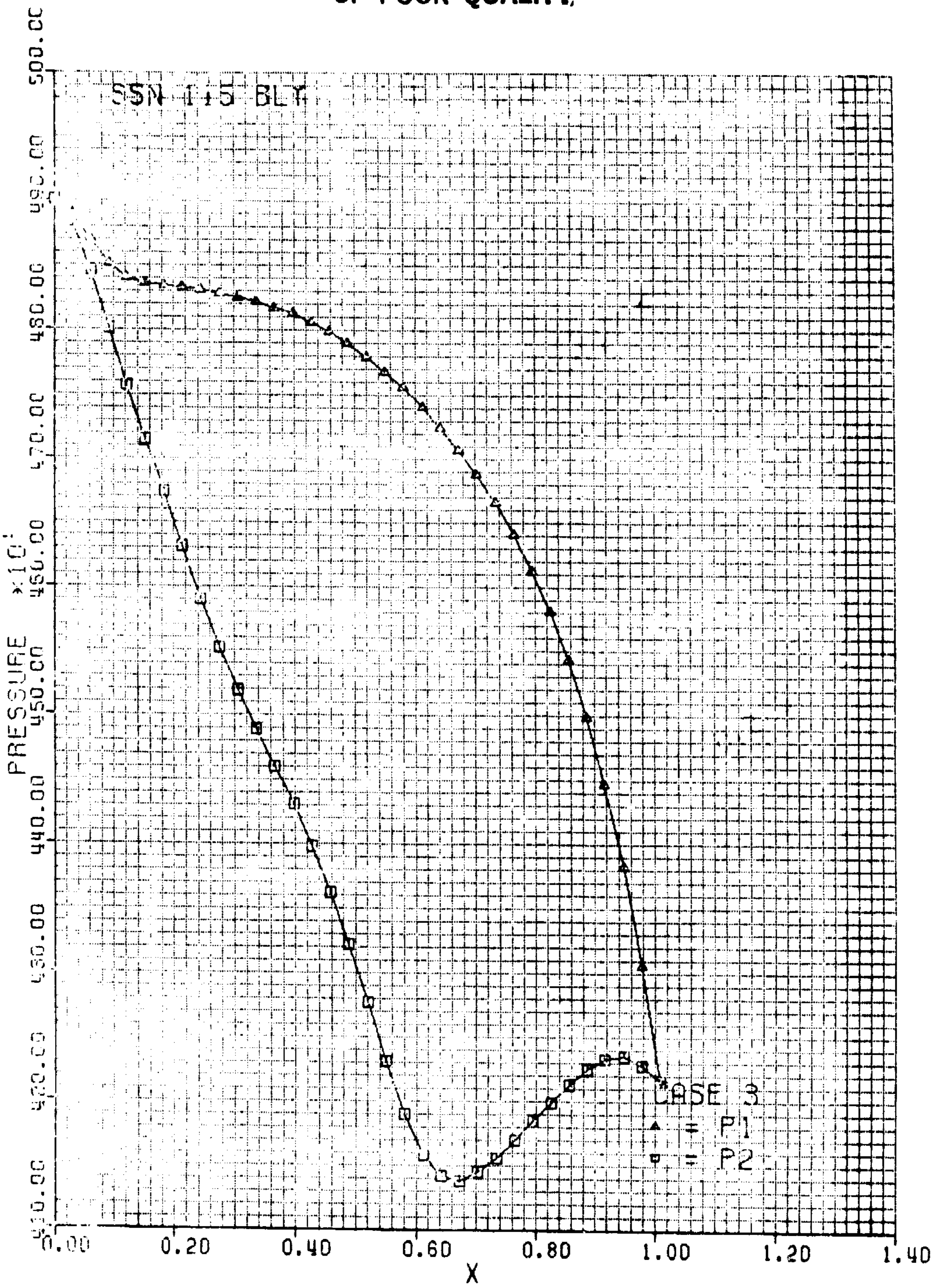

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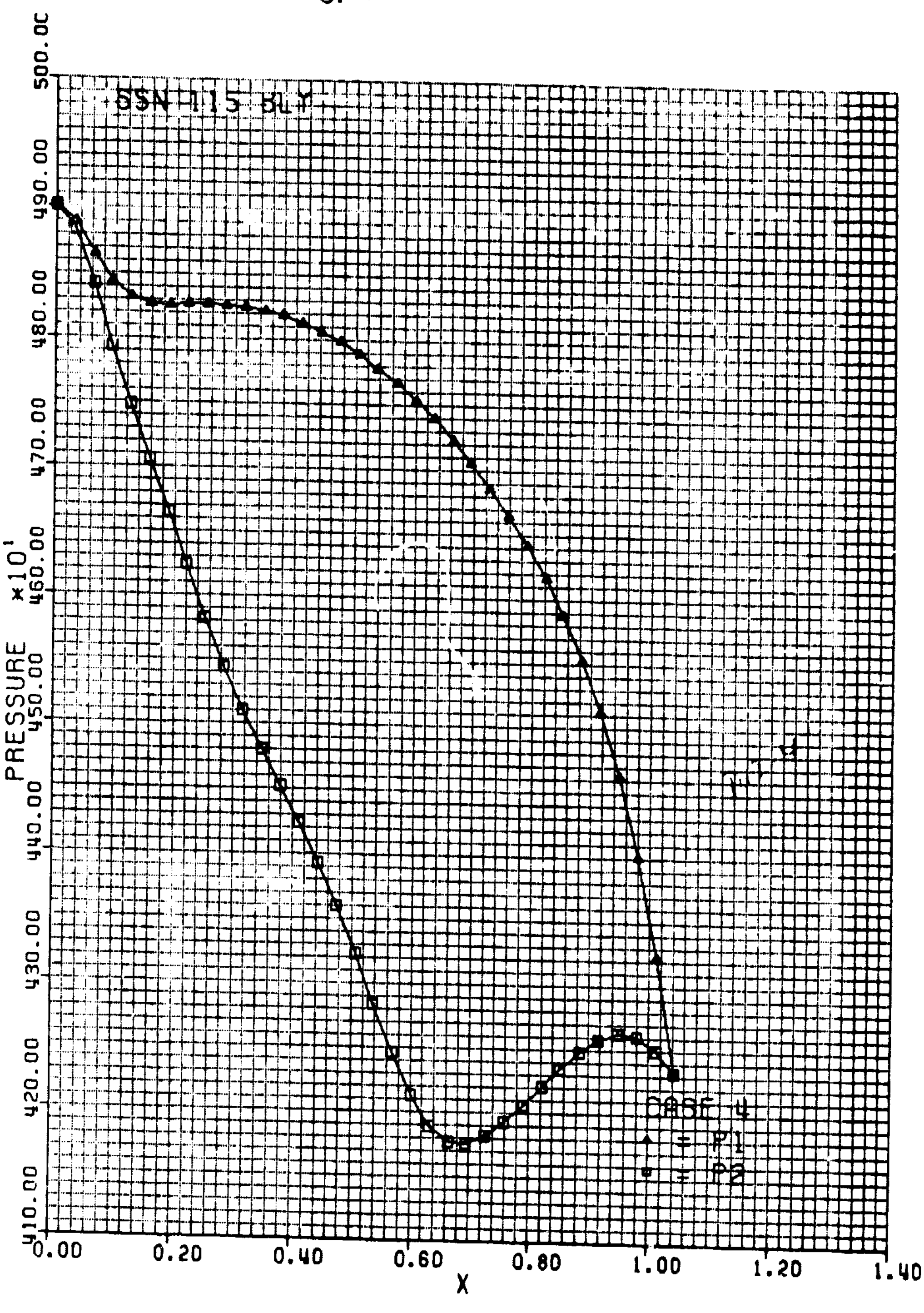

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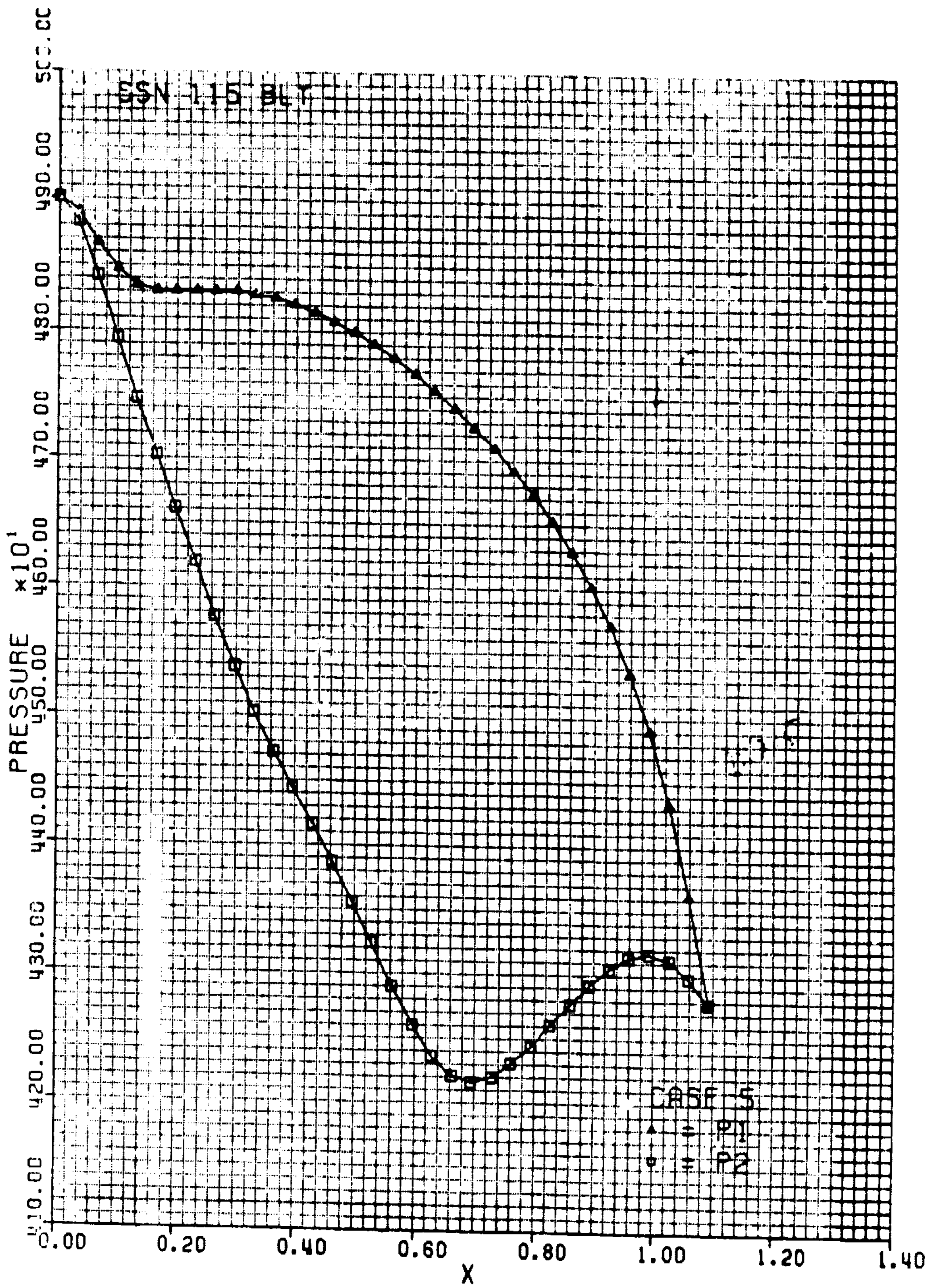

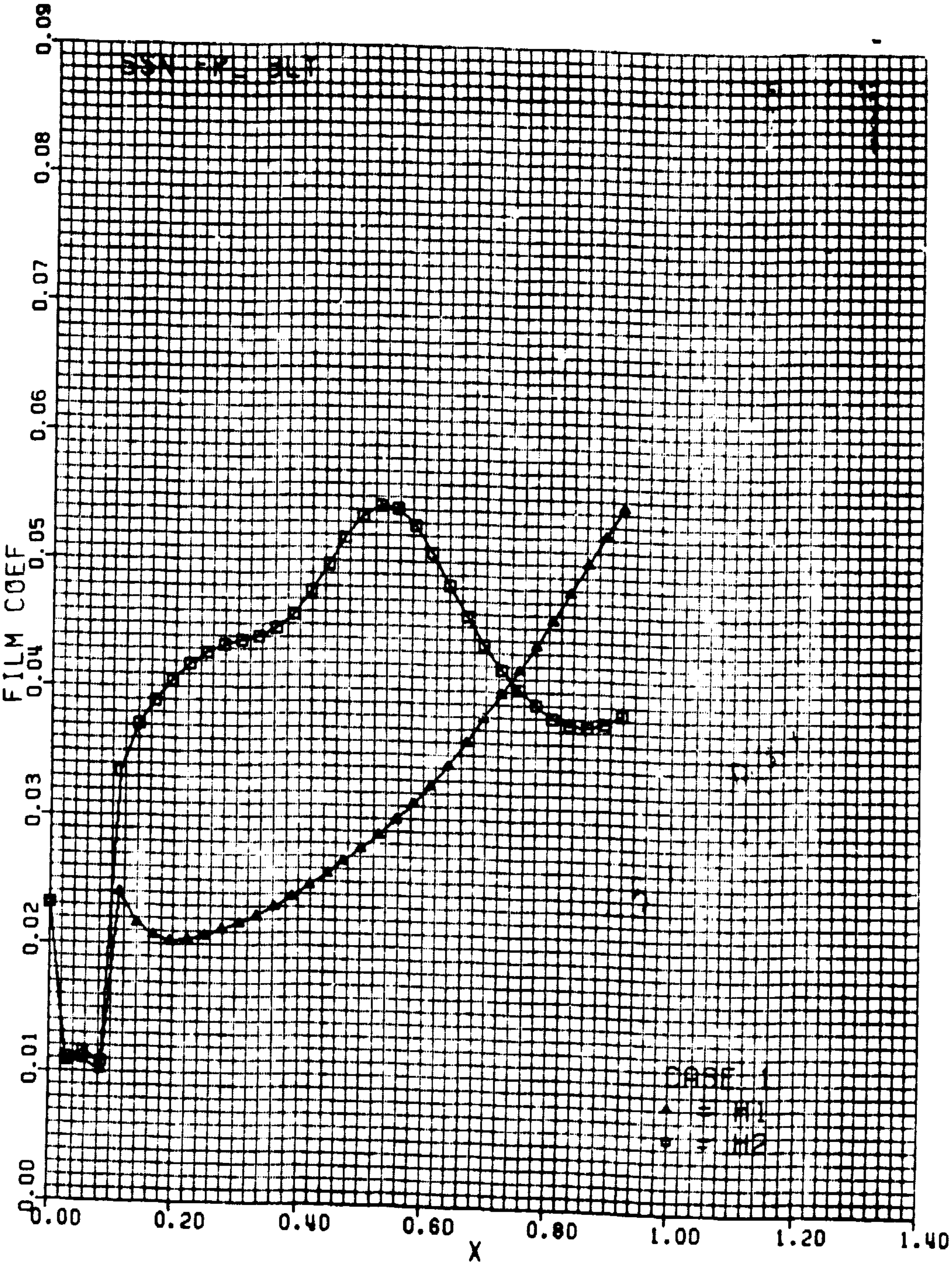
SSN FM 3LT
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
CASE 1
= M1
= M2

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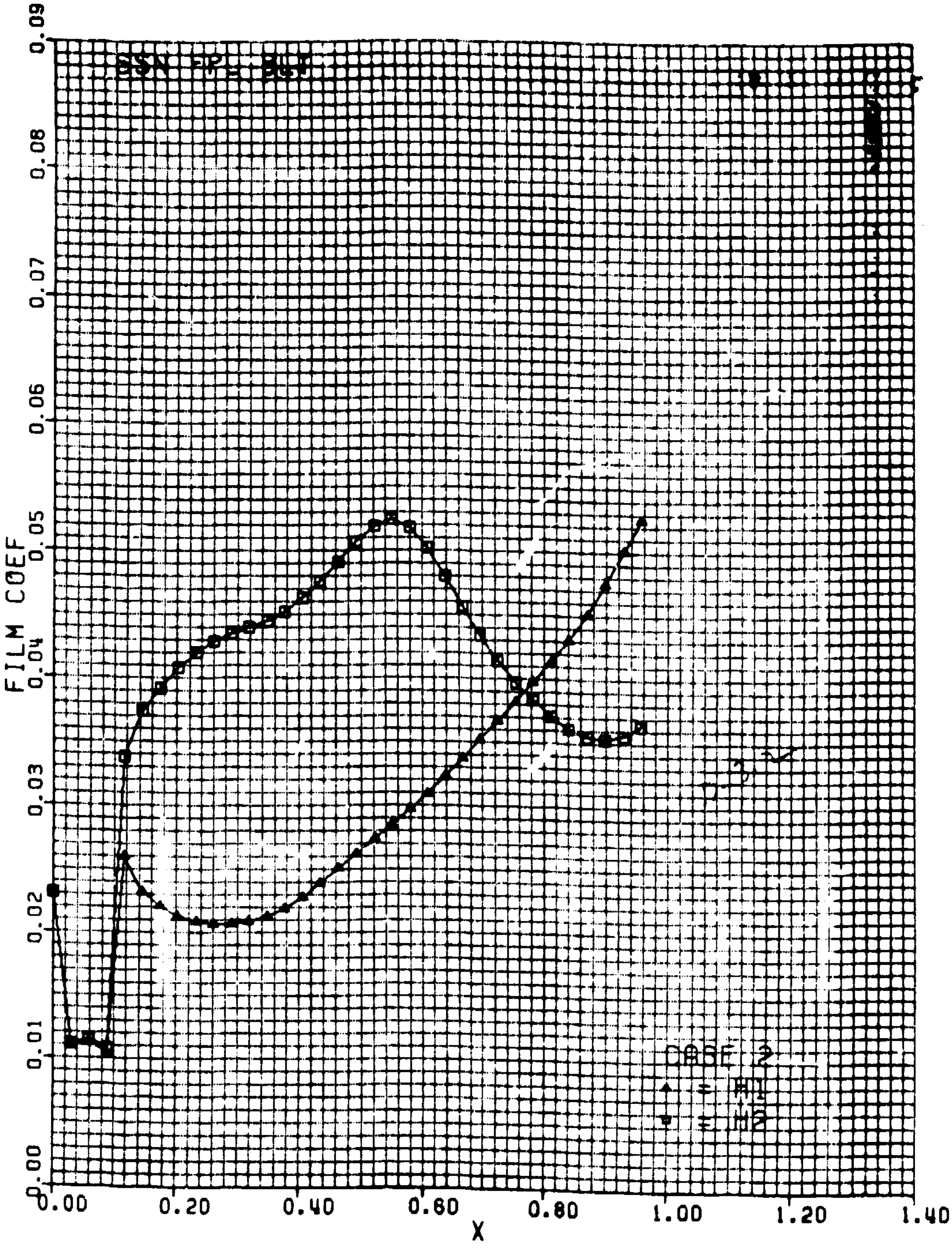

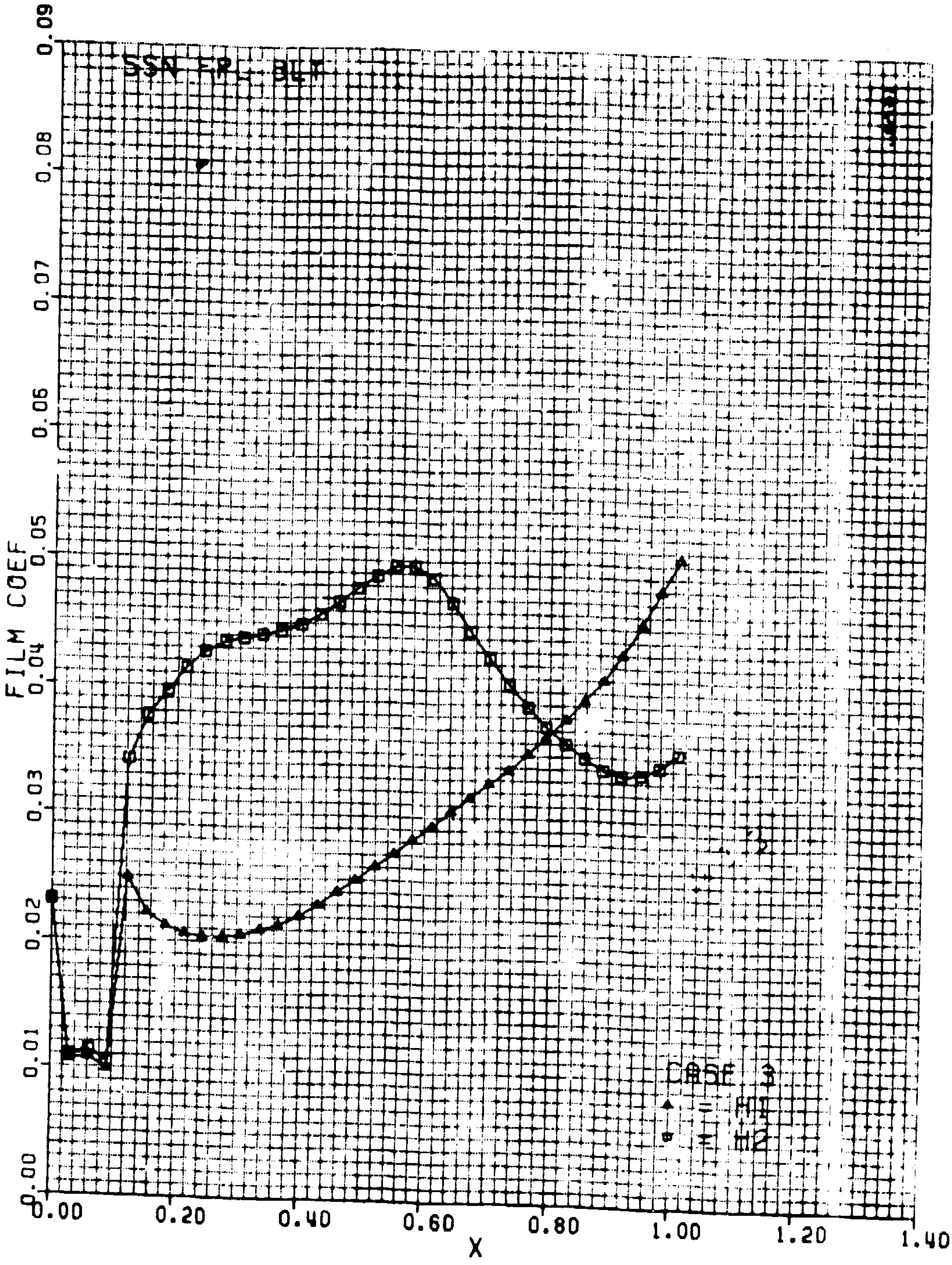
SSN FRL BLT
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
CASE 3
= H1
= H2

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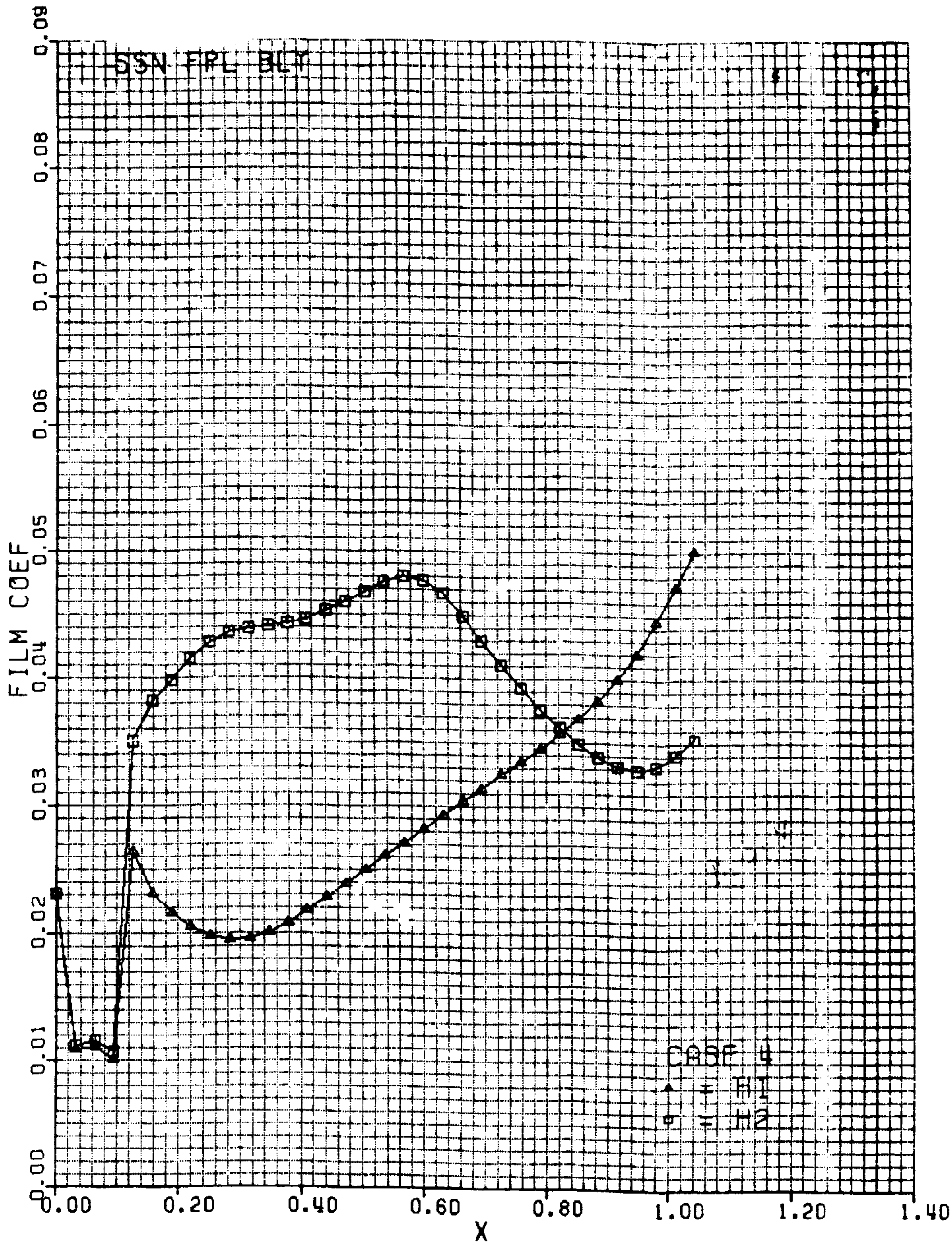

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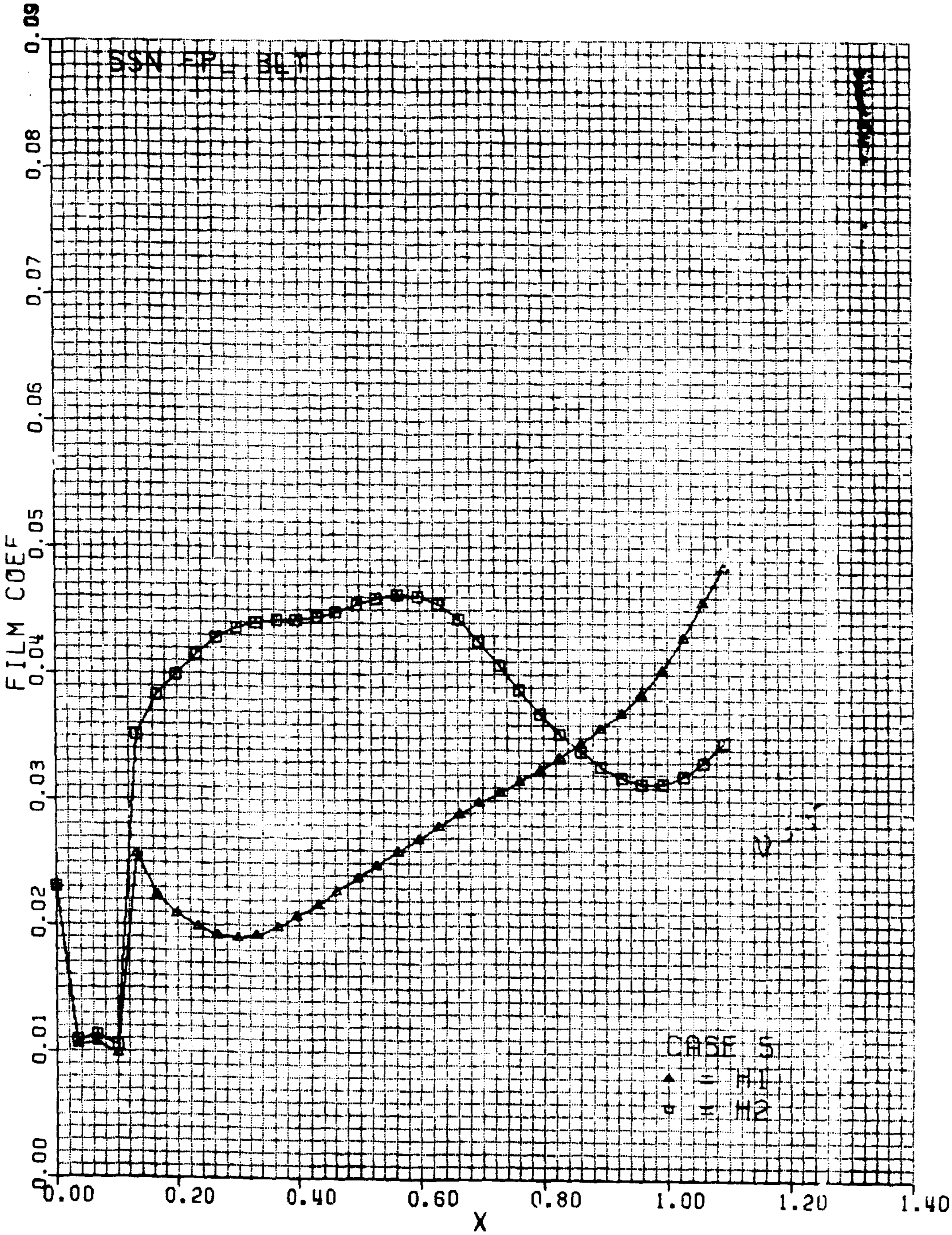

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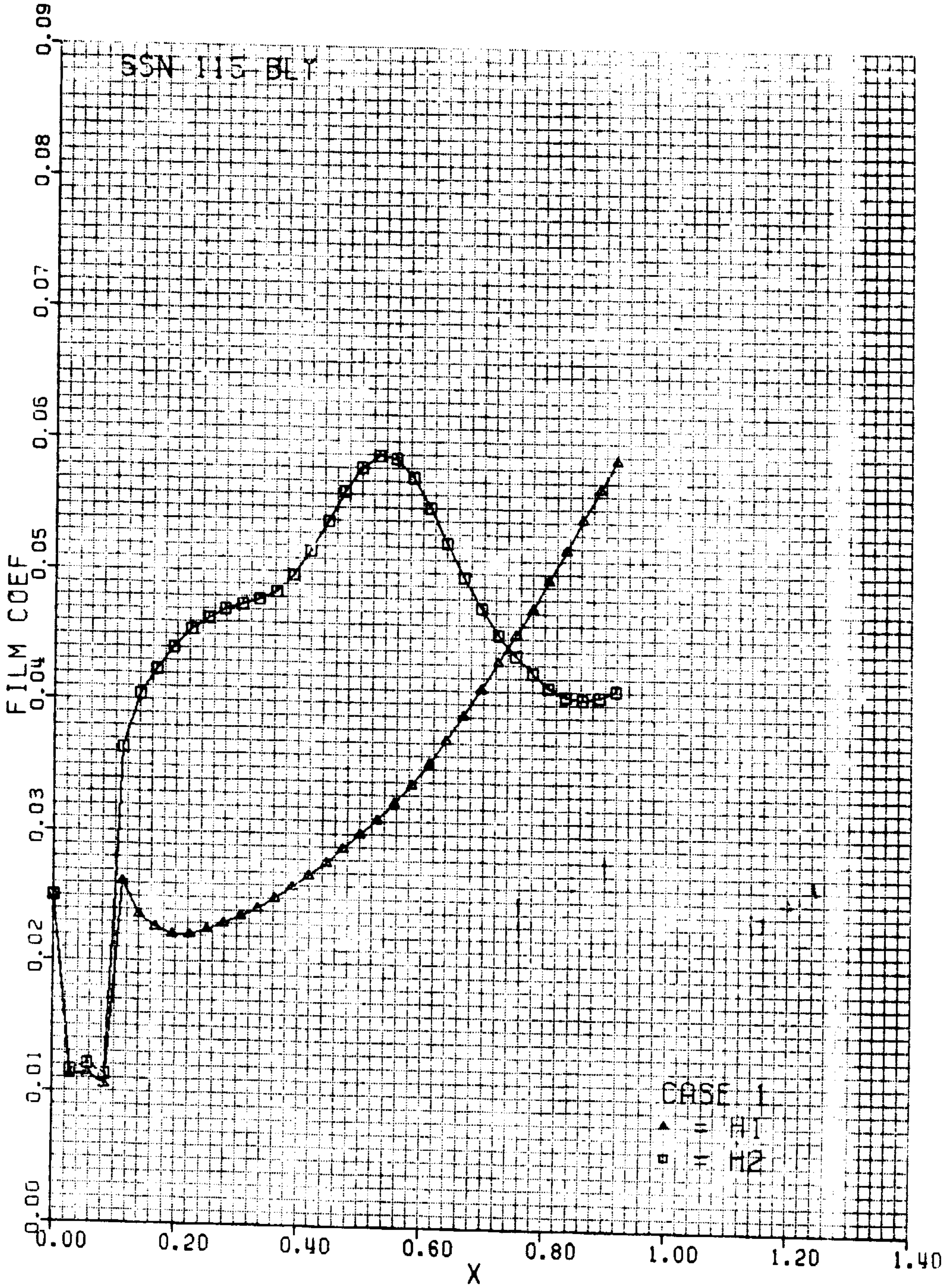

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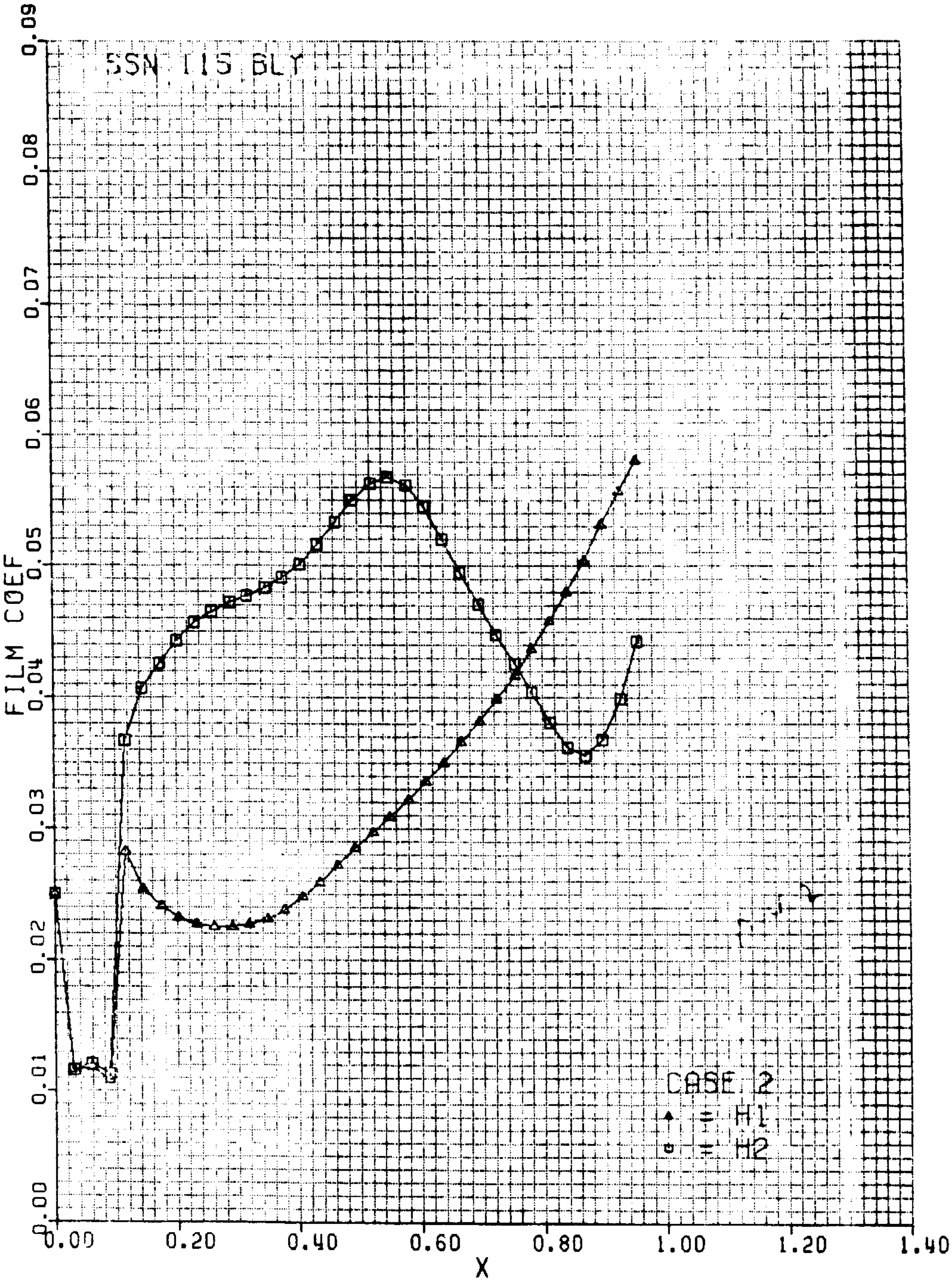

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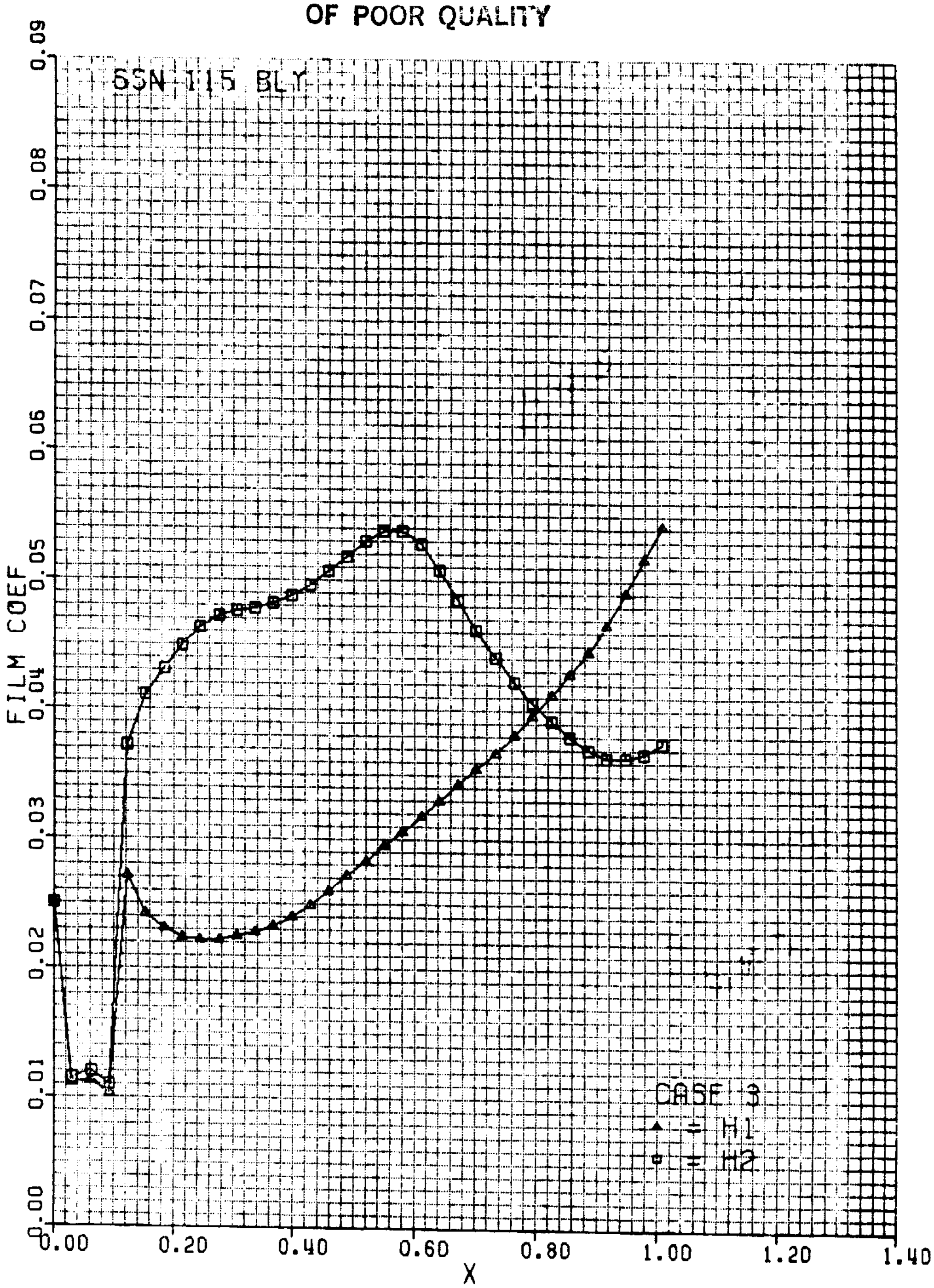

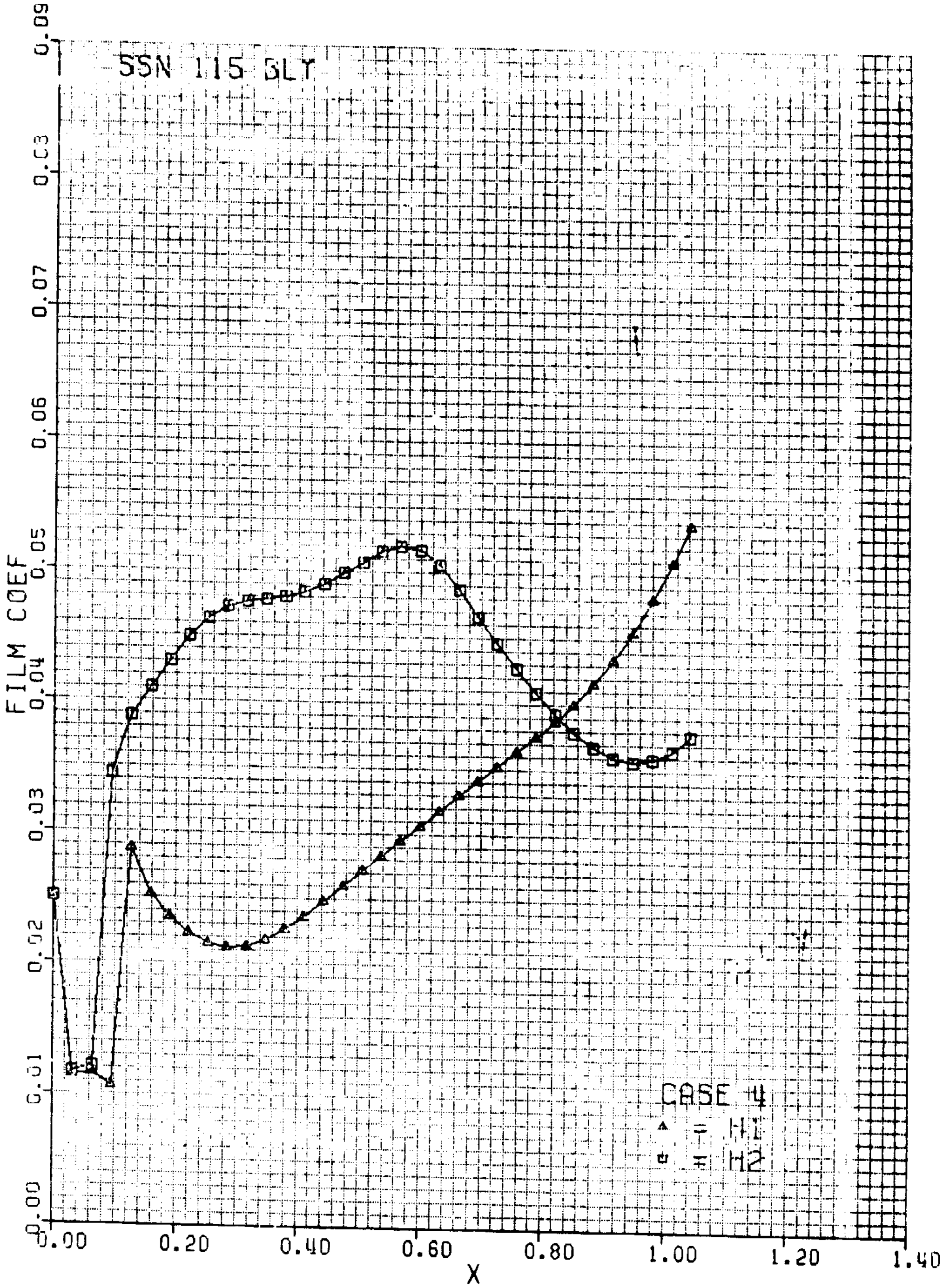
SSN 115 BLT
FILM COEF
X
CASE 4
= H1
= H2
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40

ORIGINAL PAGE IS
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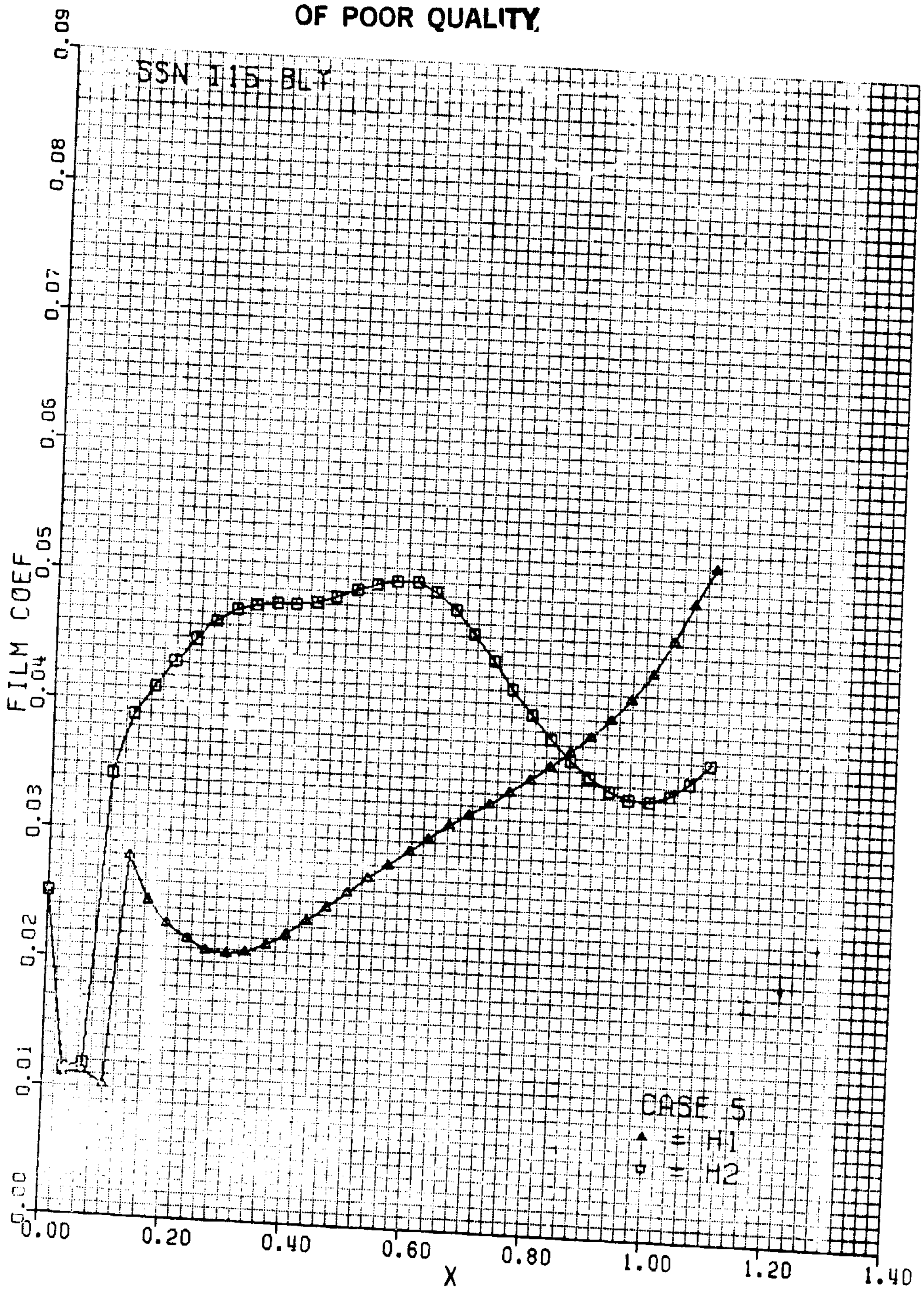

Appendix E

HPOTP FIRST STAGE NOZZLE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

E.1 FPL Pressure Distributions

E.2 115 Percent Power Level Pressure Distributions

E.3 FPL Heat Transfer Coefficients

E.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Suction Surface △

Surface 2 - Pressure Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	Percent
Streamline 1 - R = 4.795	1030	1215
Streamline 6 - R = 5.04	1030	1215
Streamline 11 - R = 5.285	1030	1215

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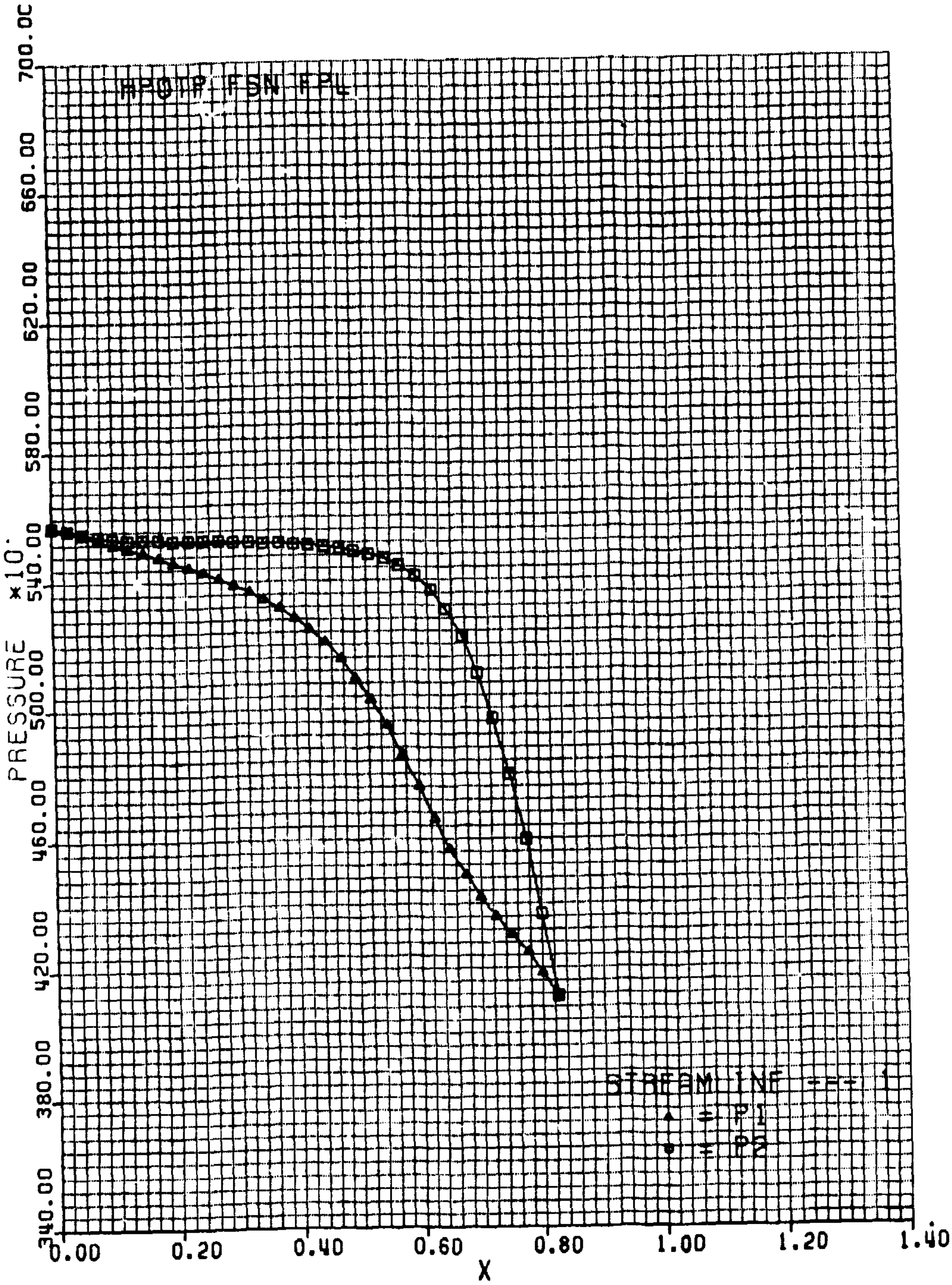

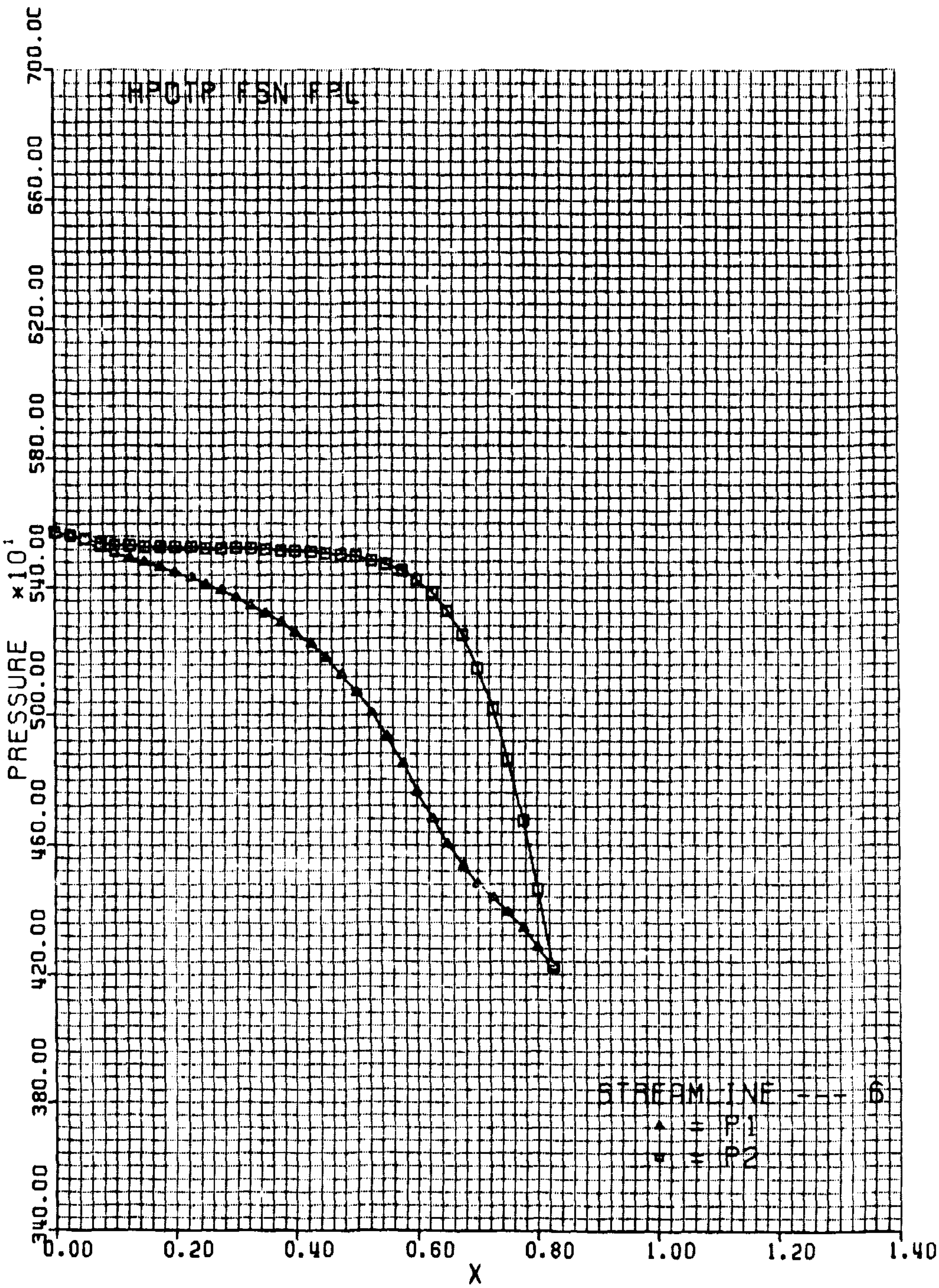
HPOTP FSN FPL
PRESSURE *10[1]
700.00
660.00
620.00
580.00
540.00
500.00
460.00
420.00
380.00
340.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
STREAMLINE --- 6
= P1
= P2

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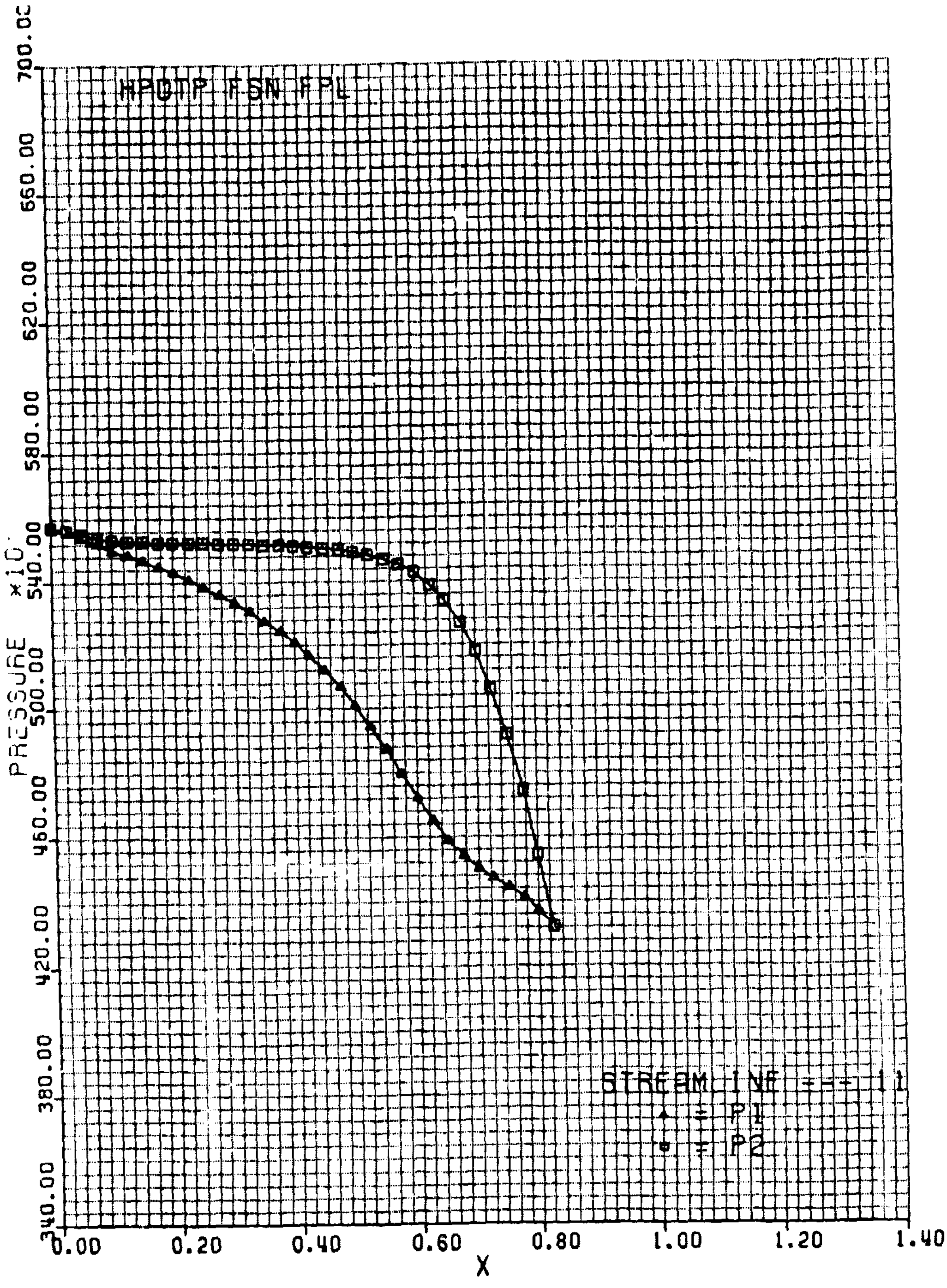

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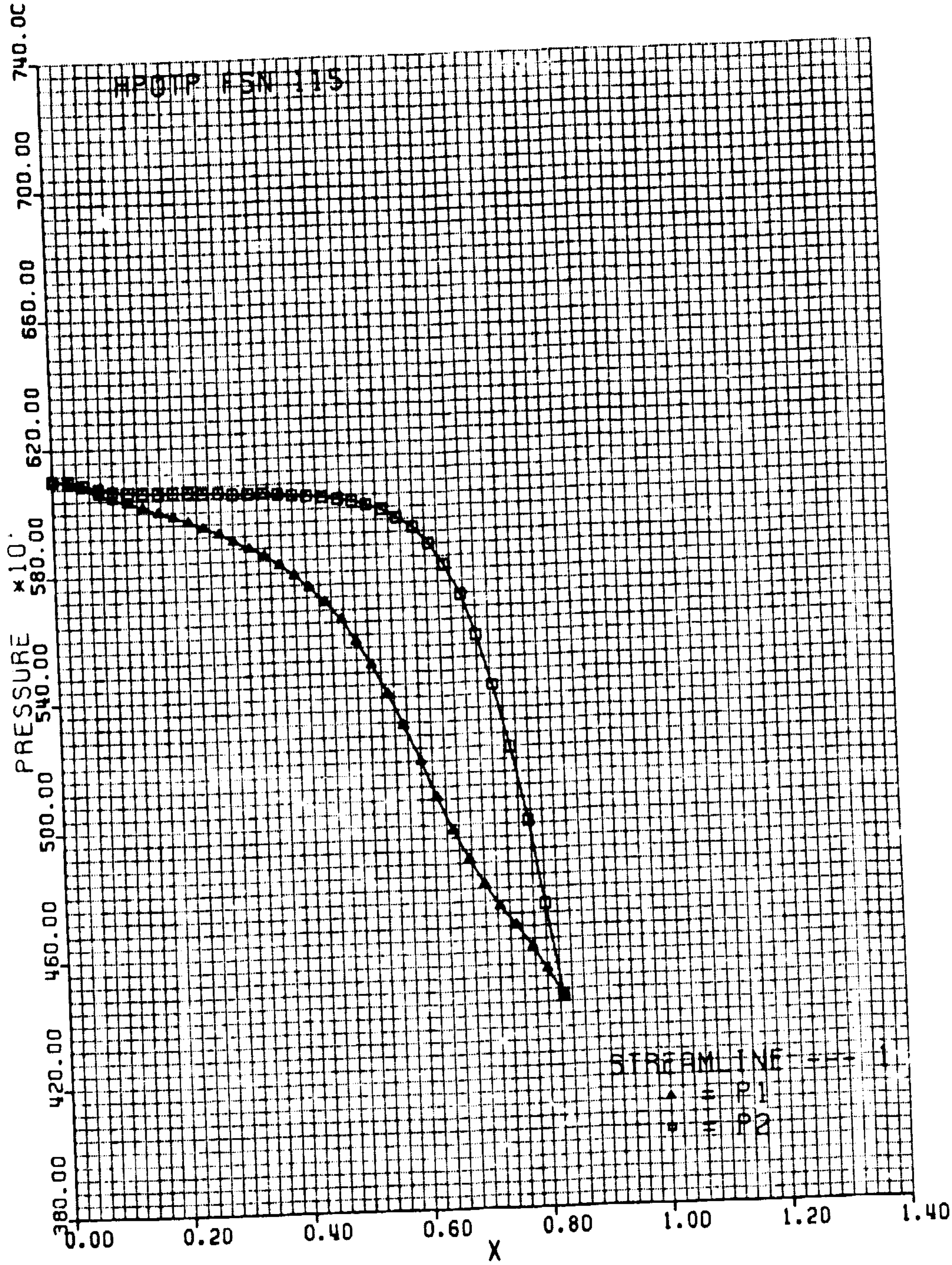

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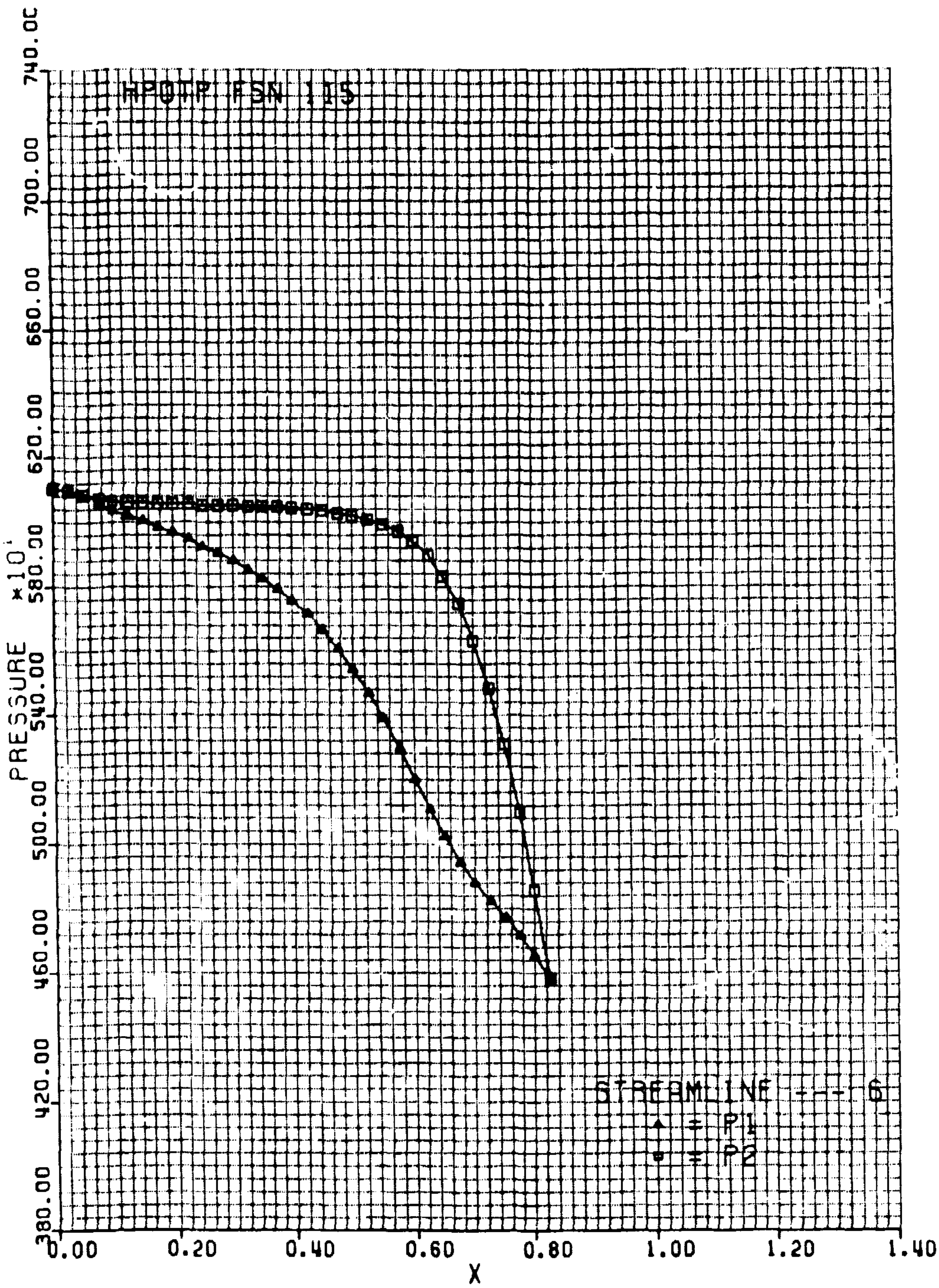

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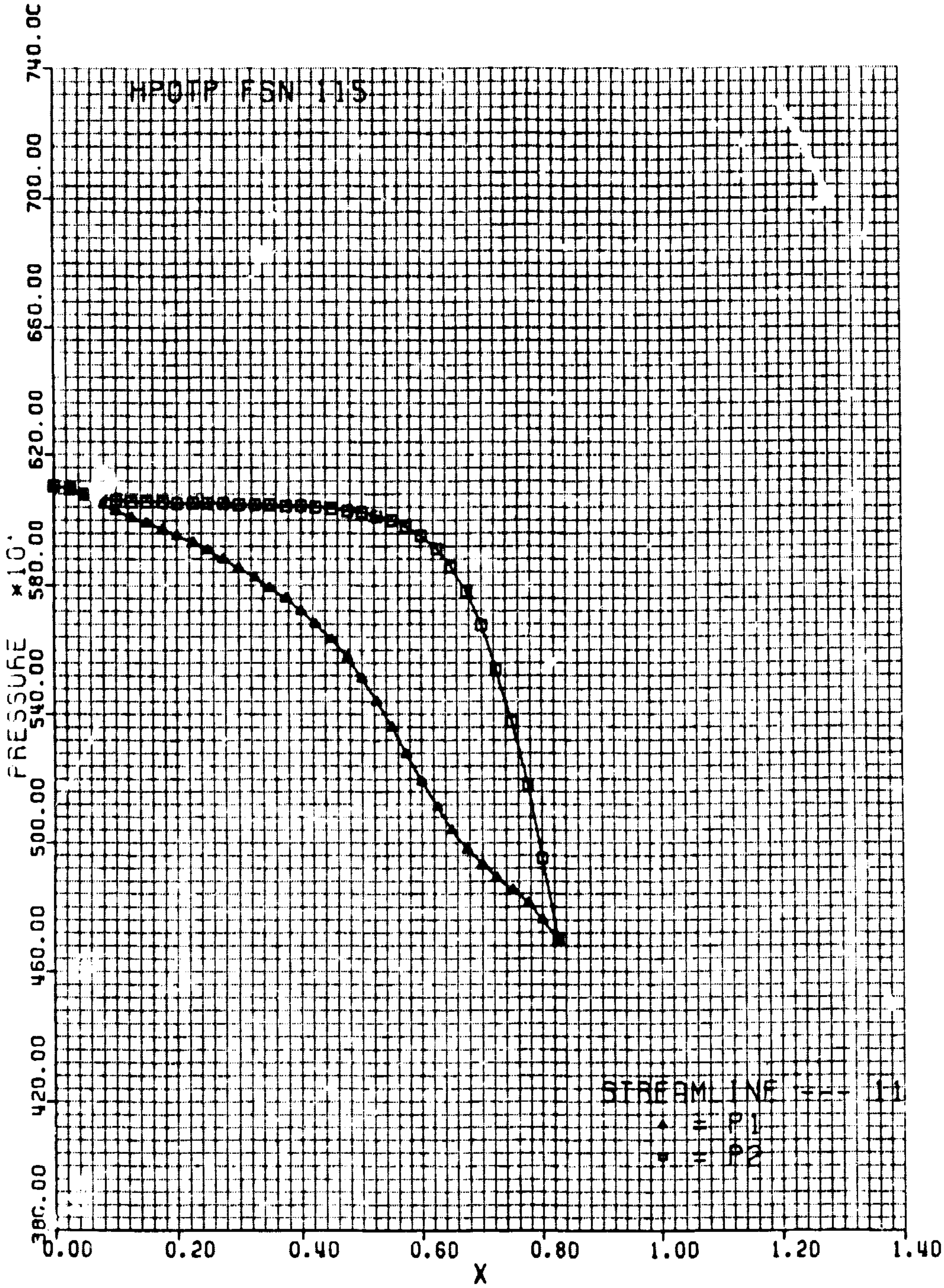

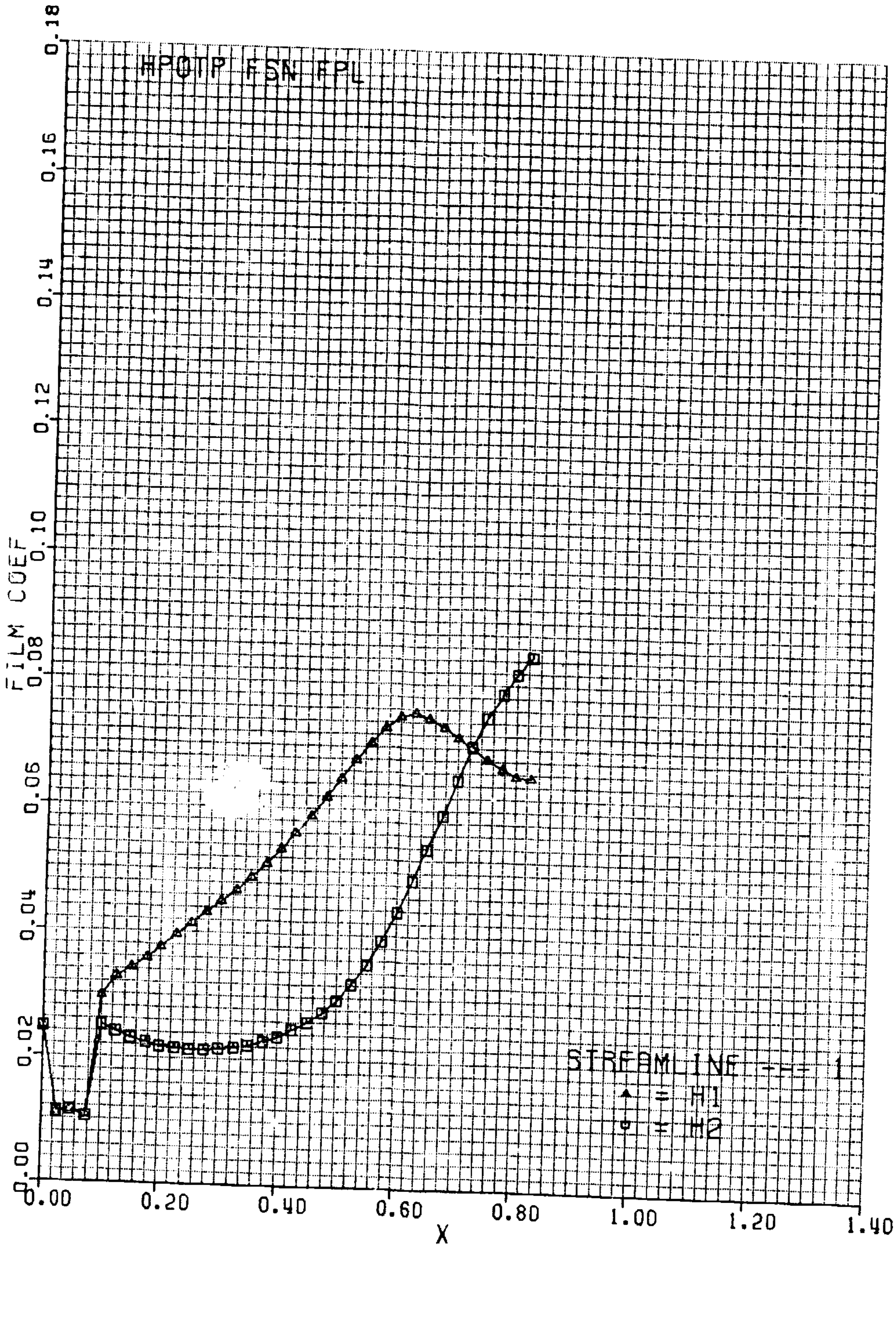
HPOTP FSN FPL
FILM COEF
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
STREAMLINE --- 1
= H1
= H2

ORIGINAL PAGE IS
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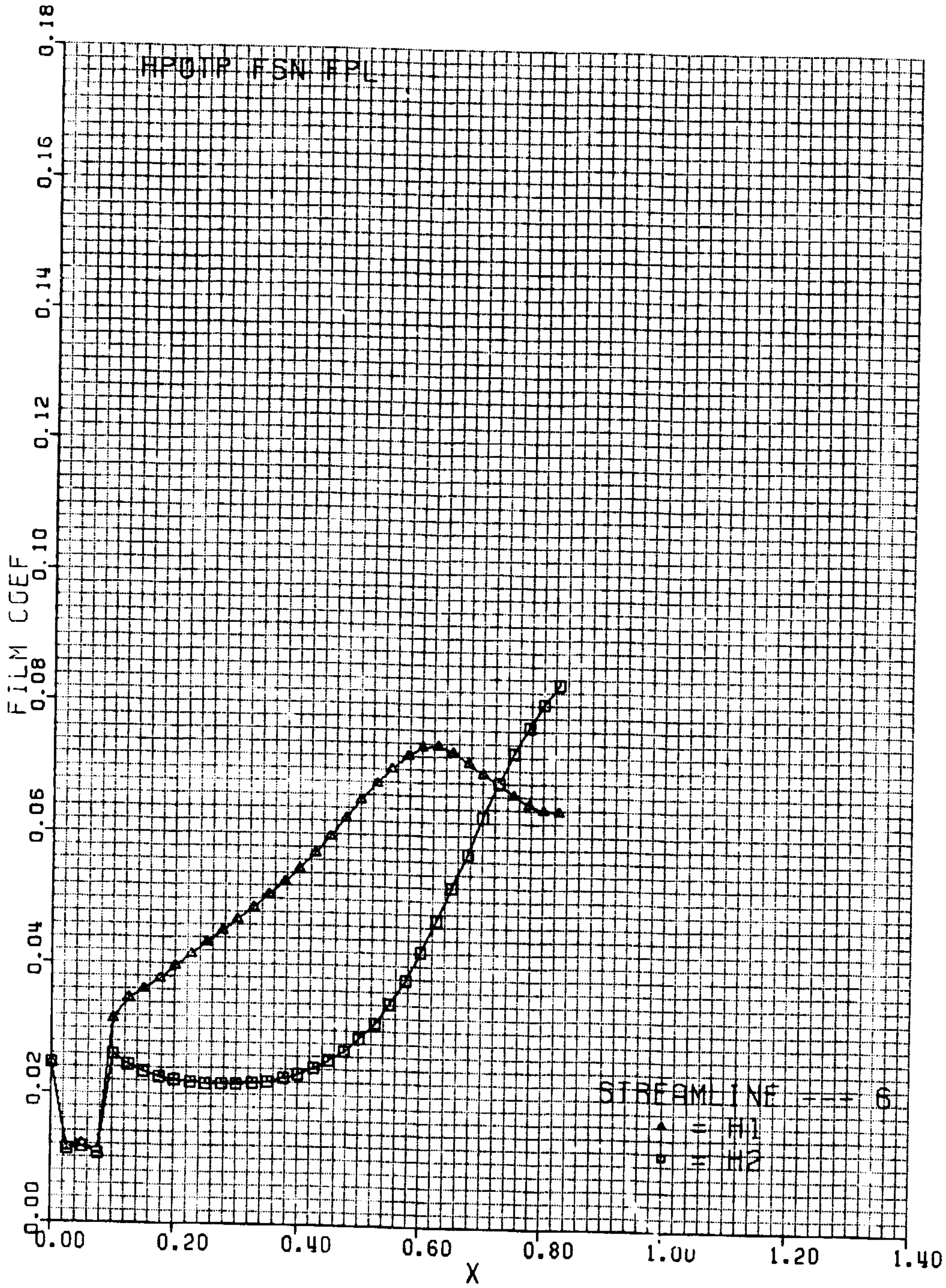

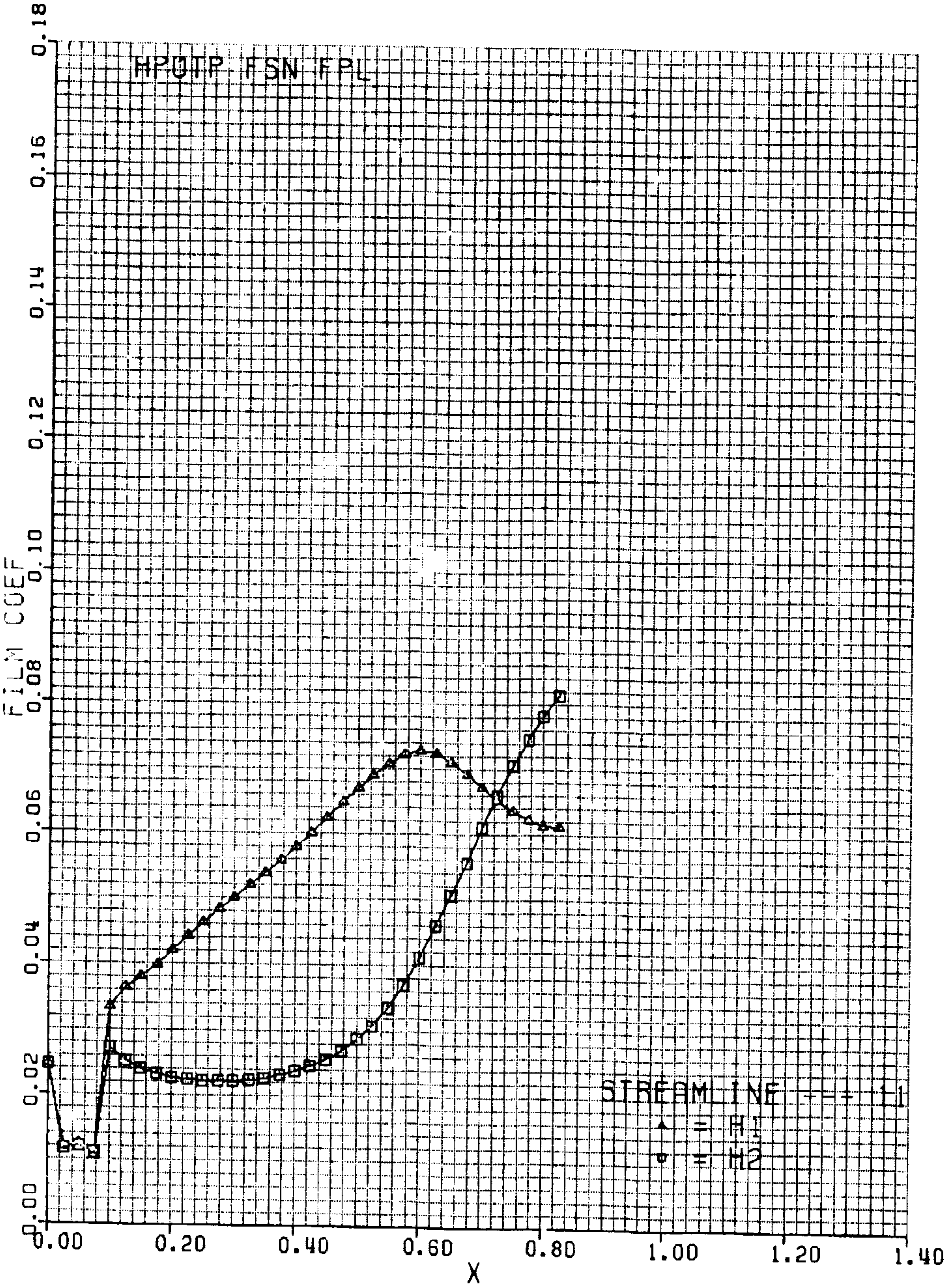
HPOTP FSN FPL
FILM COEF
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
STREAMLINE --- 11
= H1
= H2

ORIGINAL PAGE IS
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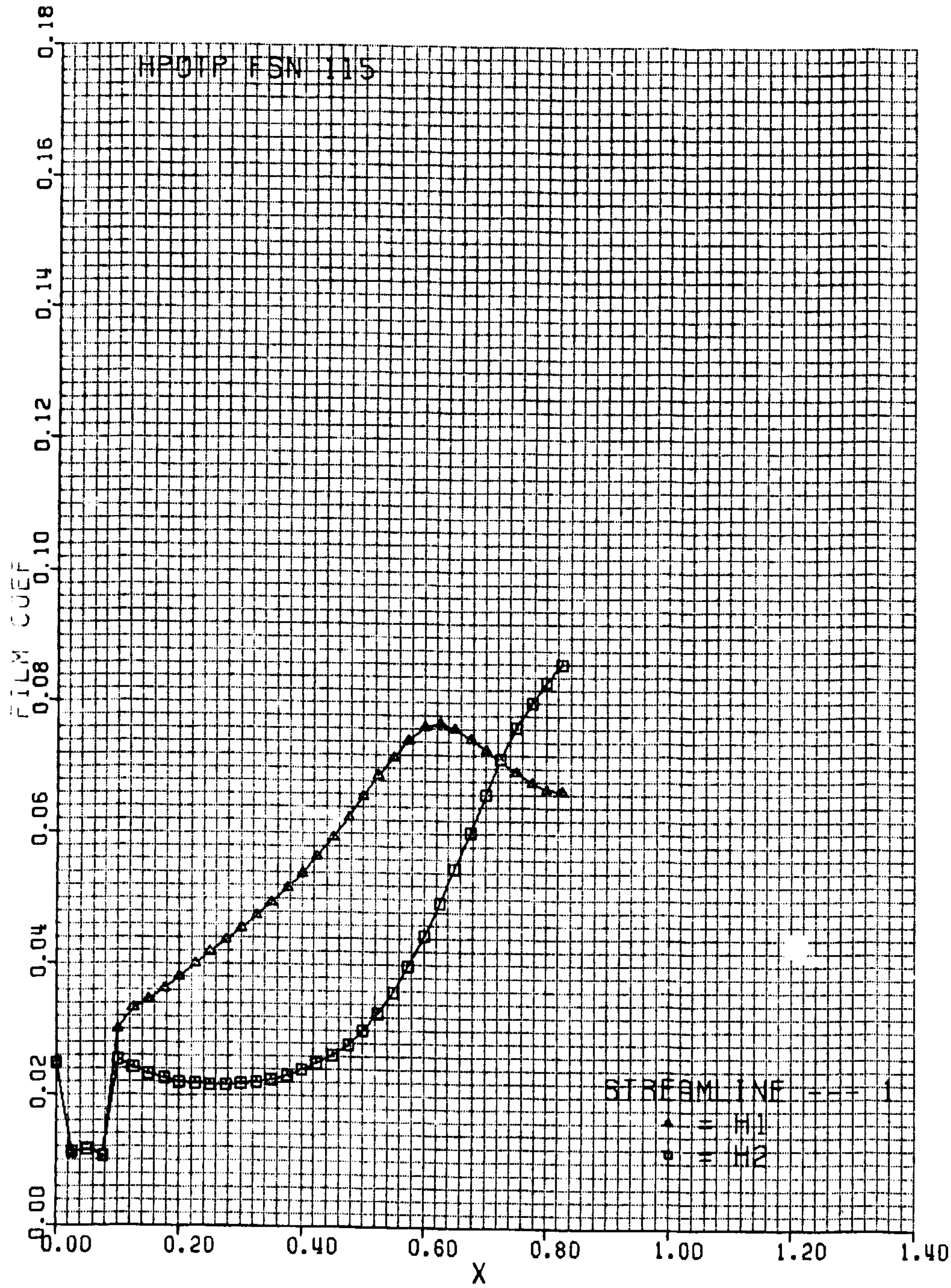
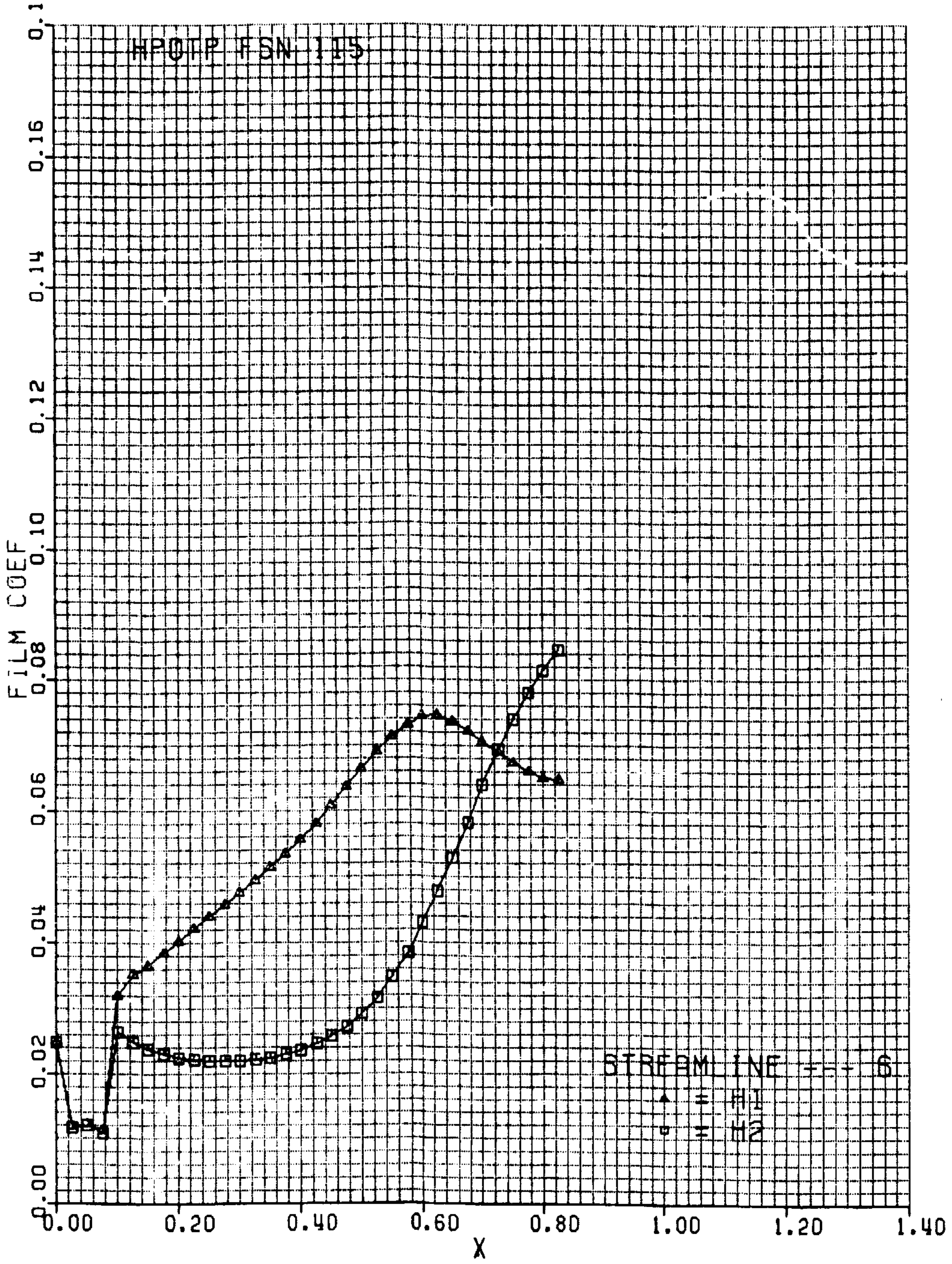
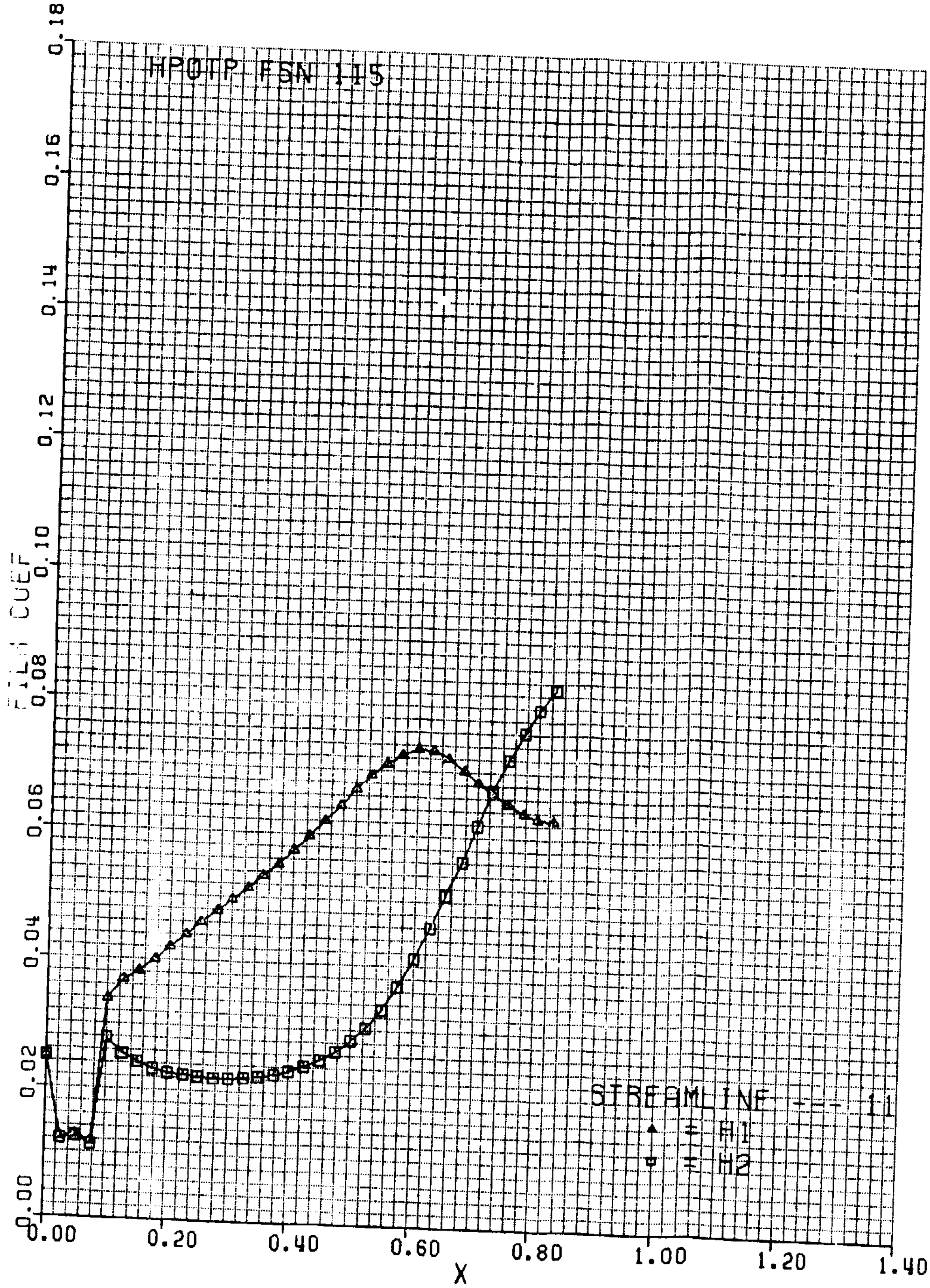



HPOTP FSN 115
FILM COEF
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
STREAMLINE --- 6
= H1
= H2

ORIGINAL PAGE IS
OF POOR QUALITY



Appendix F

HPOTP FIRST STAGE BLADE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

F.1 FPL Pressure Distributions

F.2 115 Percent Power Level Pressure Distributions

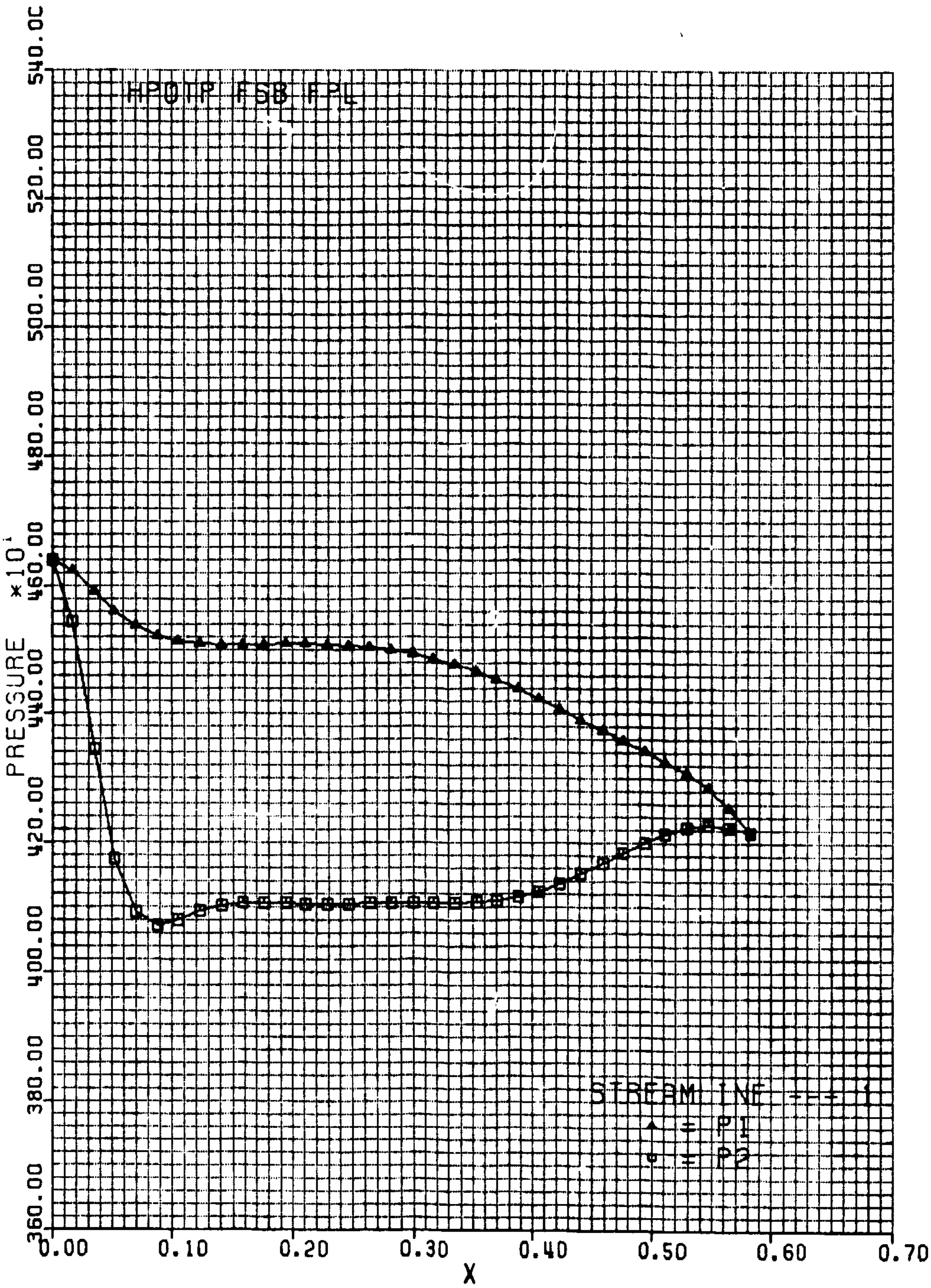
F.3 FPL Heat Transfer Coefficients

F.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Pressure Surface △

Surface 2 - Suction Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Streamline 1 - R = 4.7915	975	1150
Streamline 6 - R = 5.04	975	1150
Streamline 11 - R = 5.2885	975	1150


HPOTP FSB FPL
PRESSURE ×10¹
540.00
520.00
500.00
480.00
460.00
440.00
420.00
400.00
380.00
360.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE --- 1
▲ = P1
◻ = P2

F.1.1

ORIGINAL PAGE IS
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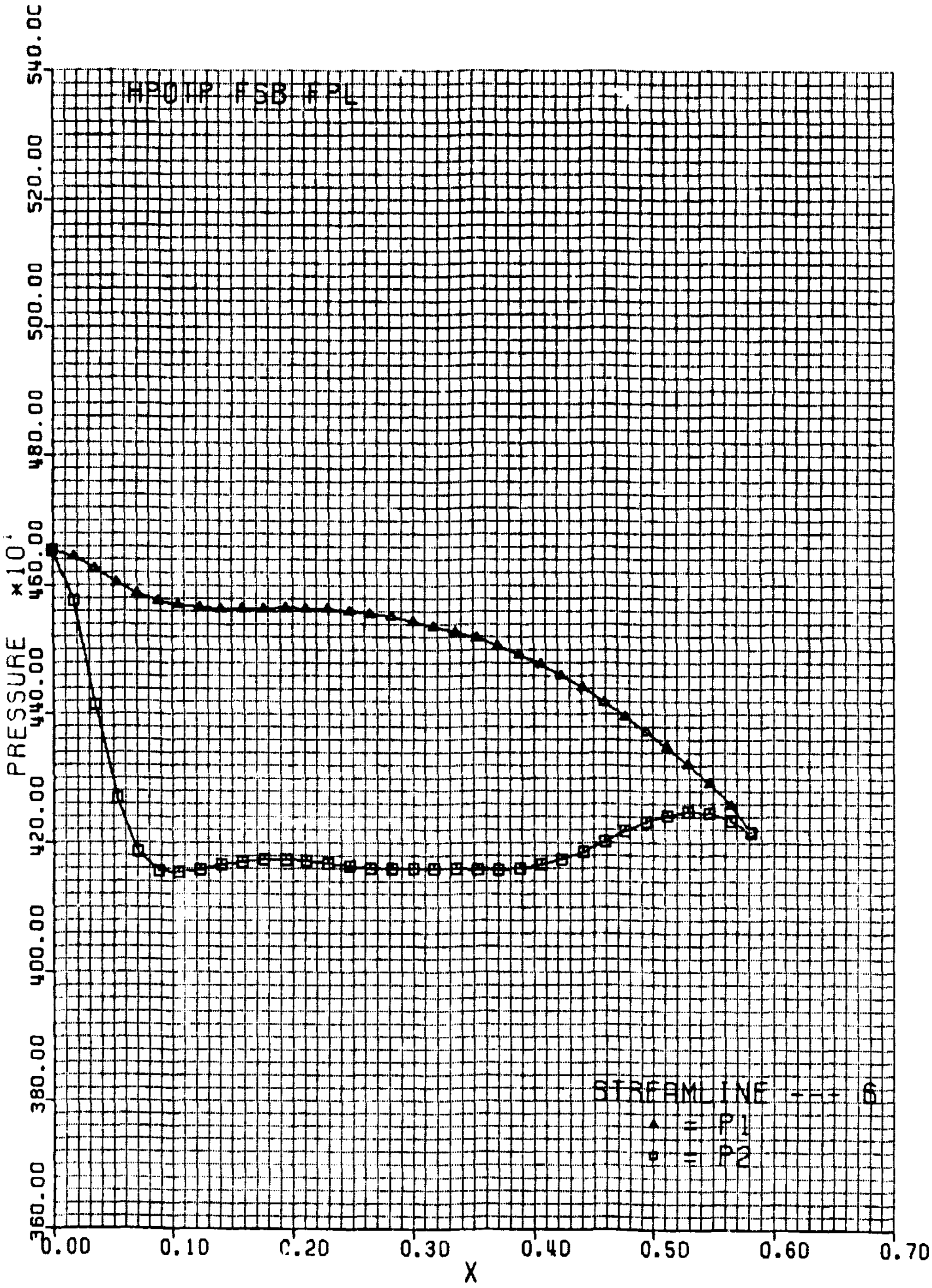
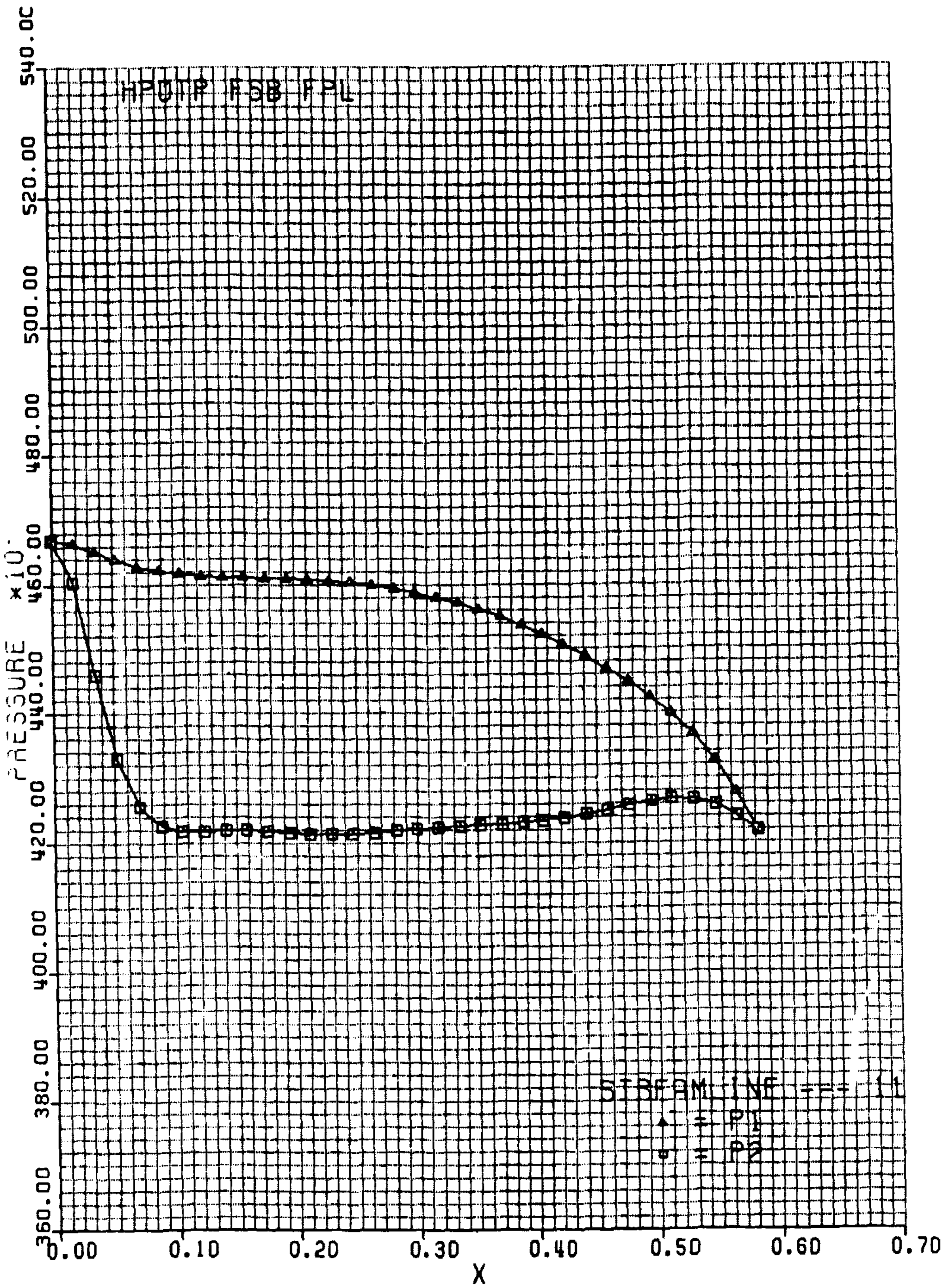
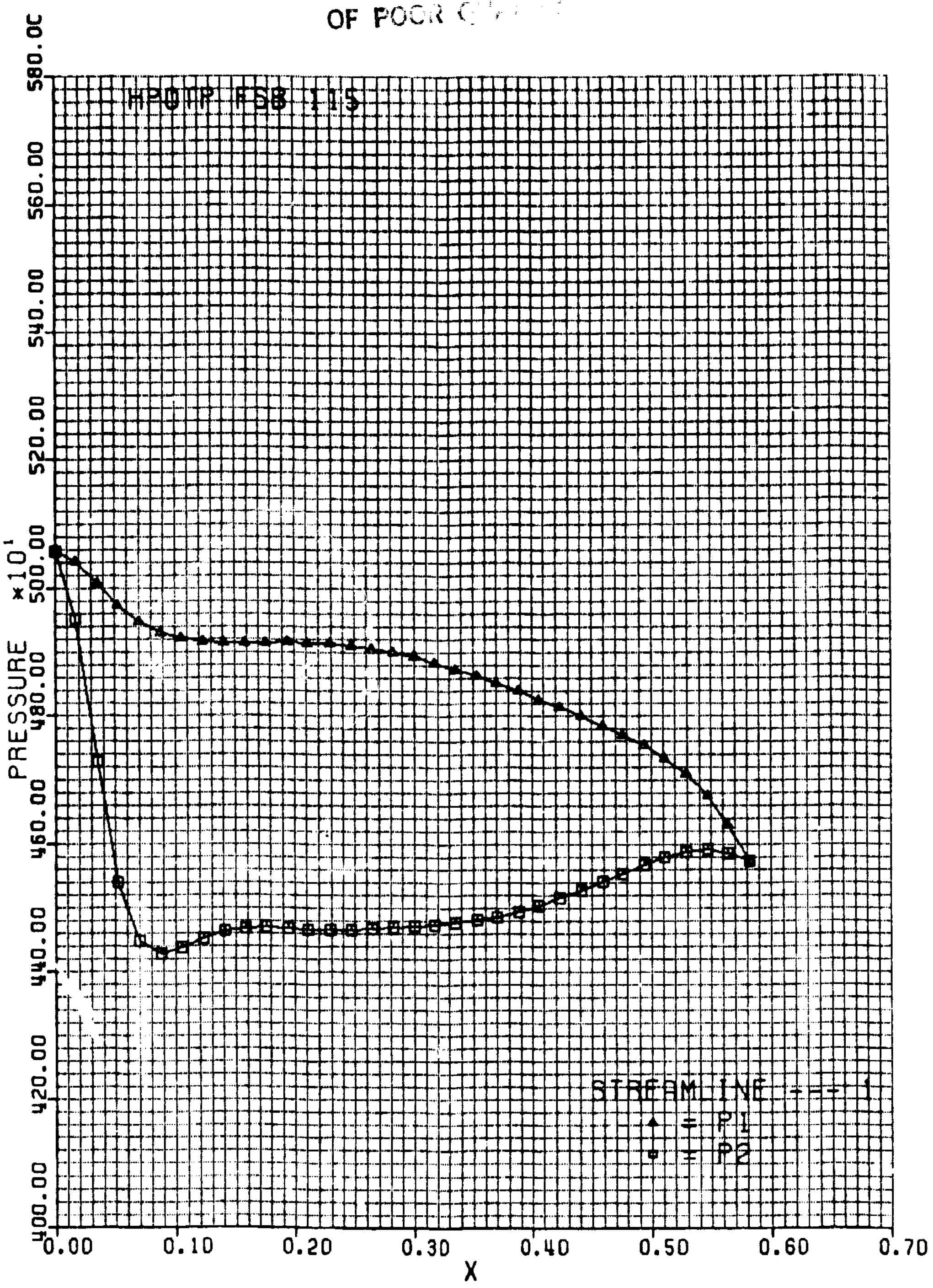



HPOTP FSB FPL
PRESSURE *10¹
540.00
520.00
500.00
480.00
460.00
440.00
420.00
400.00
380.00
360.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE === 11
▲ = P1
⊡ = P2

F.1.3


HPOTP FSB 115
PRESSURE ×10¹
580.00
560.00
540.00
520.00
500.00
480.00
460.00
440.00
420.00
400.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE === 1
= P1
= P2

F.2.1

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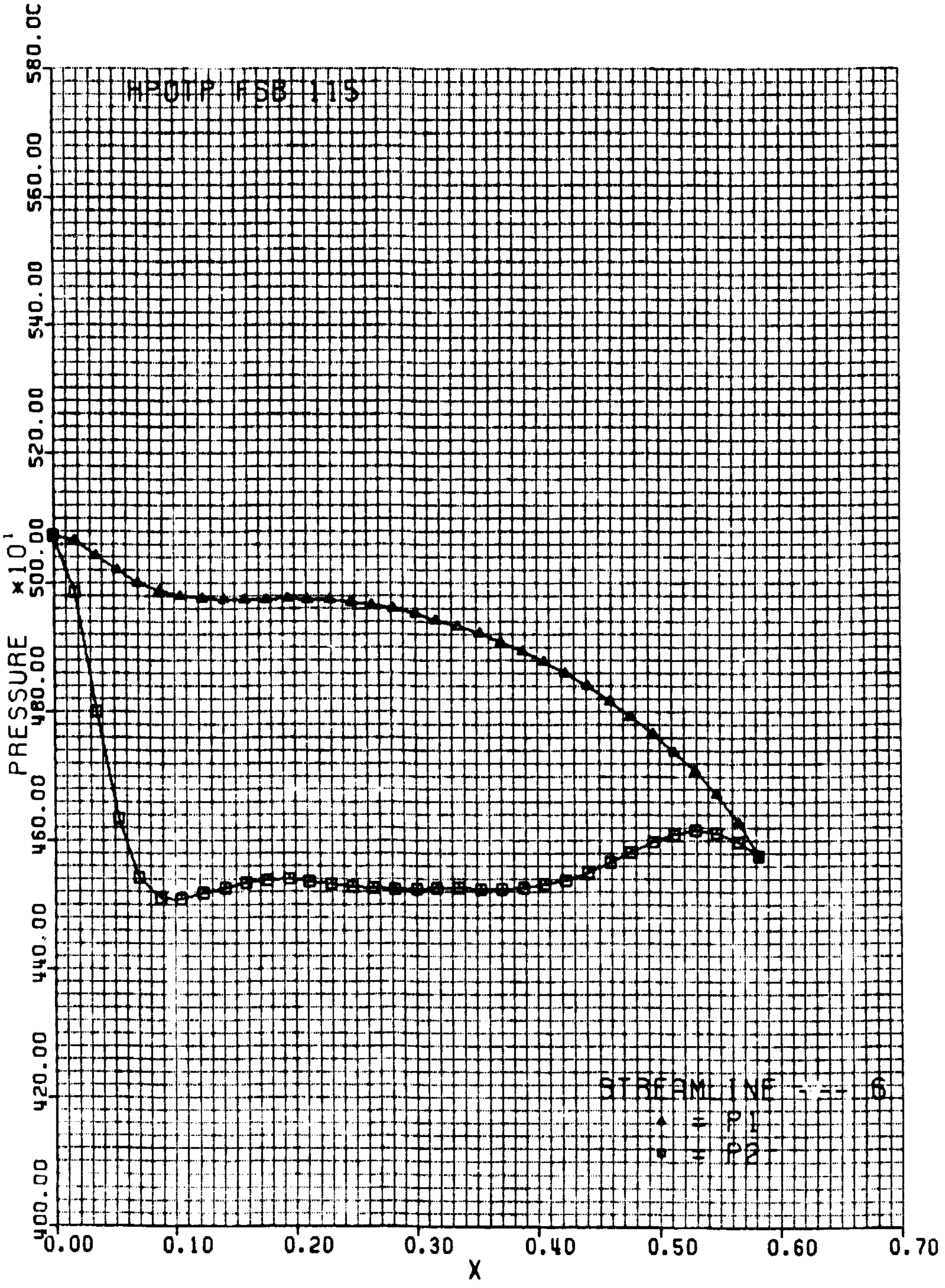
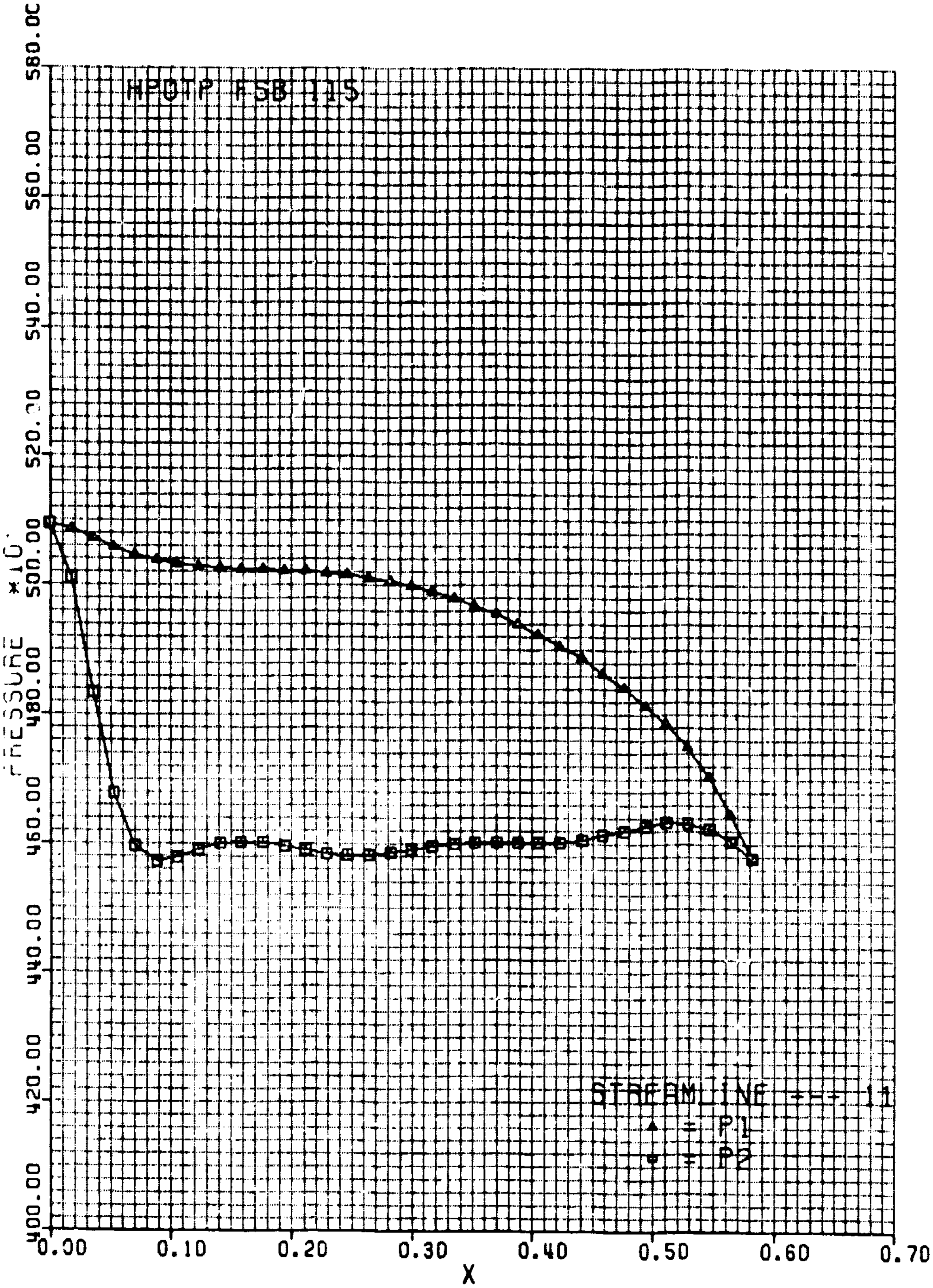
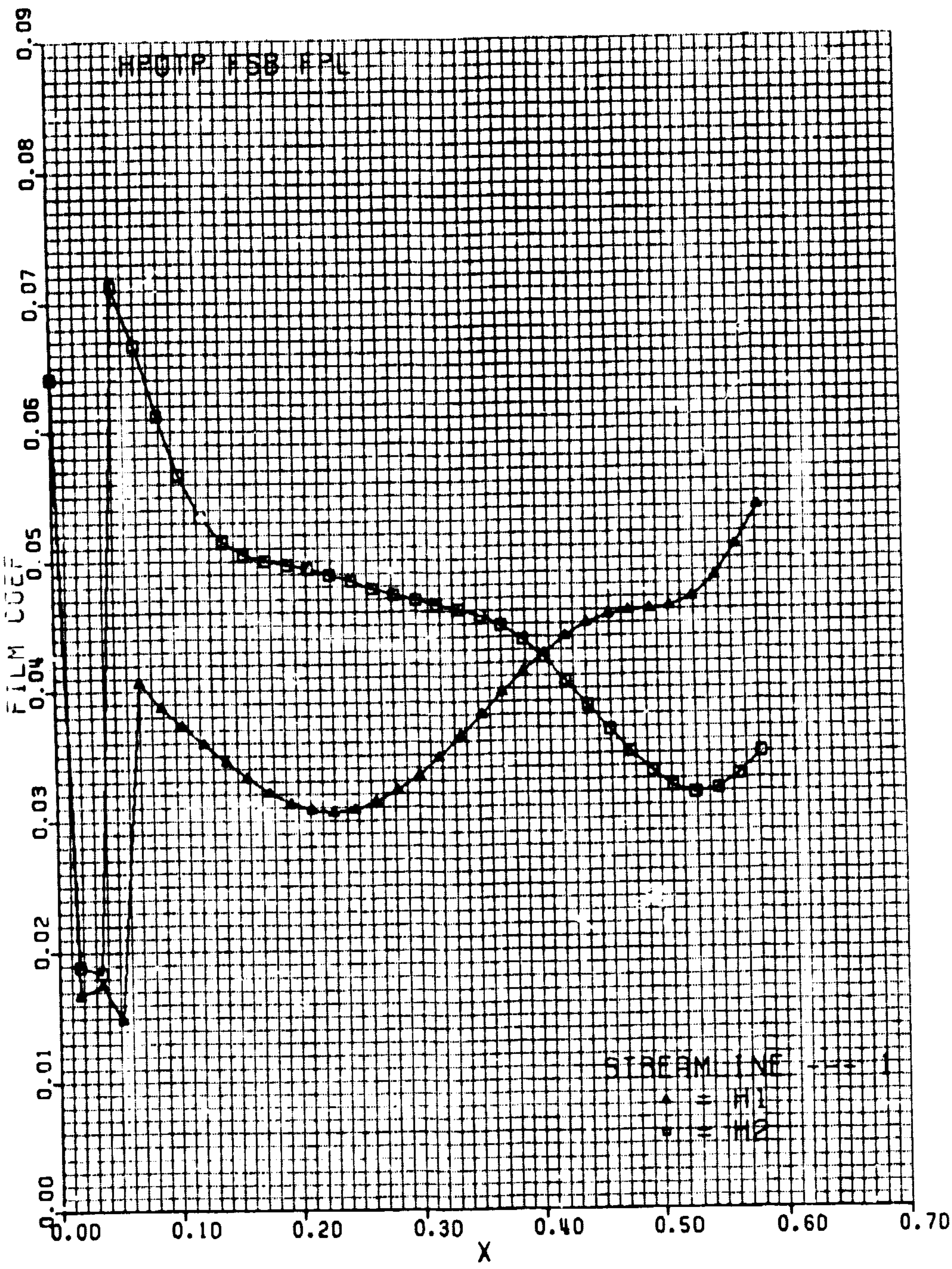



HPOTP FSB 115
PRESSURE *10
580.00
560.00
540.00
520.00
500.00
480.00
460.00
440.00
420.00
400.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE --- 11
= P1
= P2

ORIGINAL PAGE IS
OF POOR QUALITY



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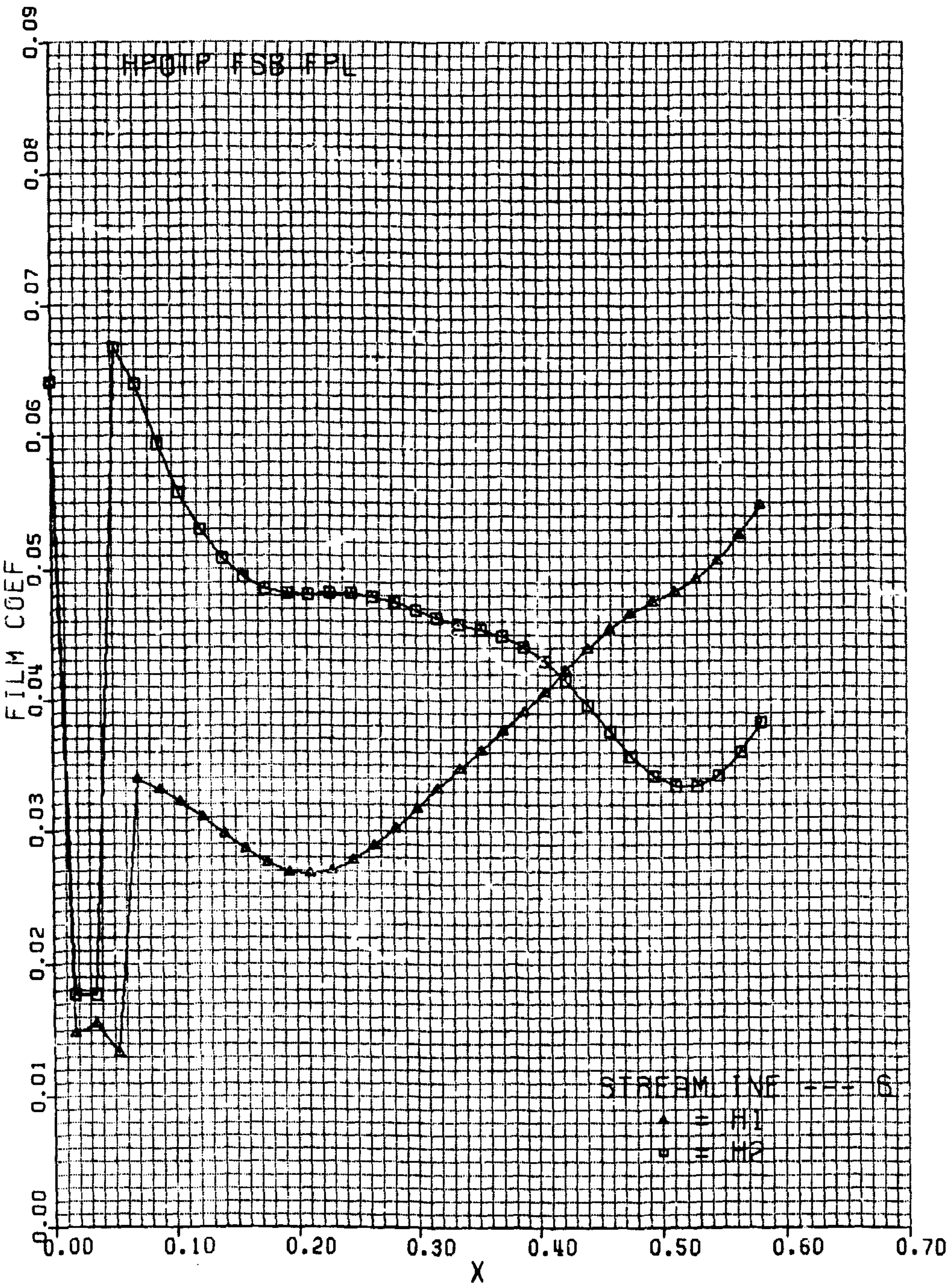

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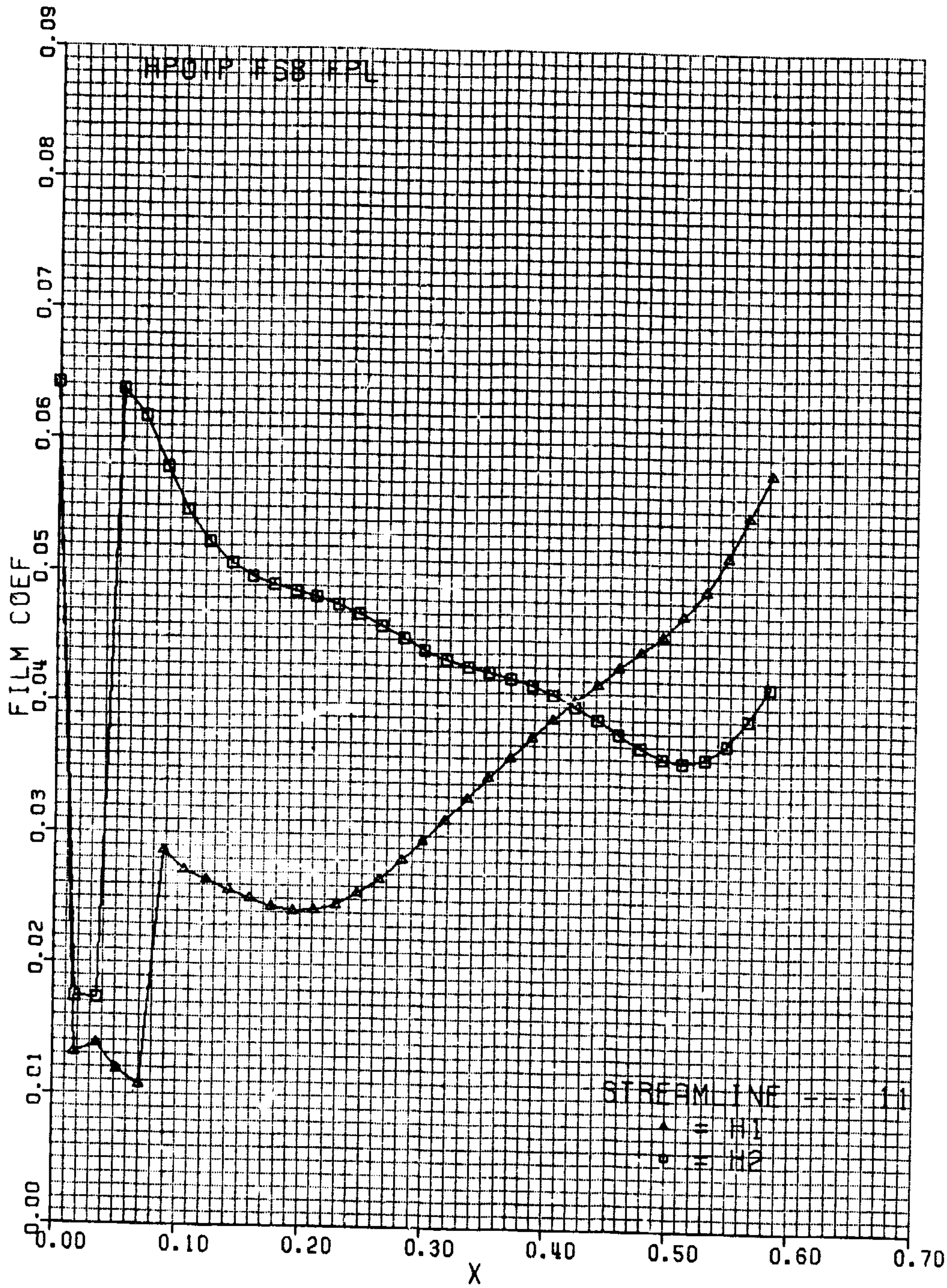
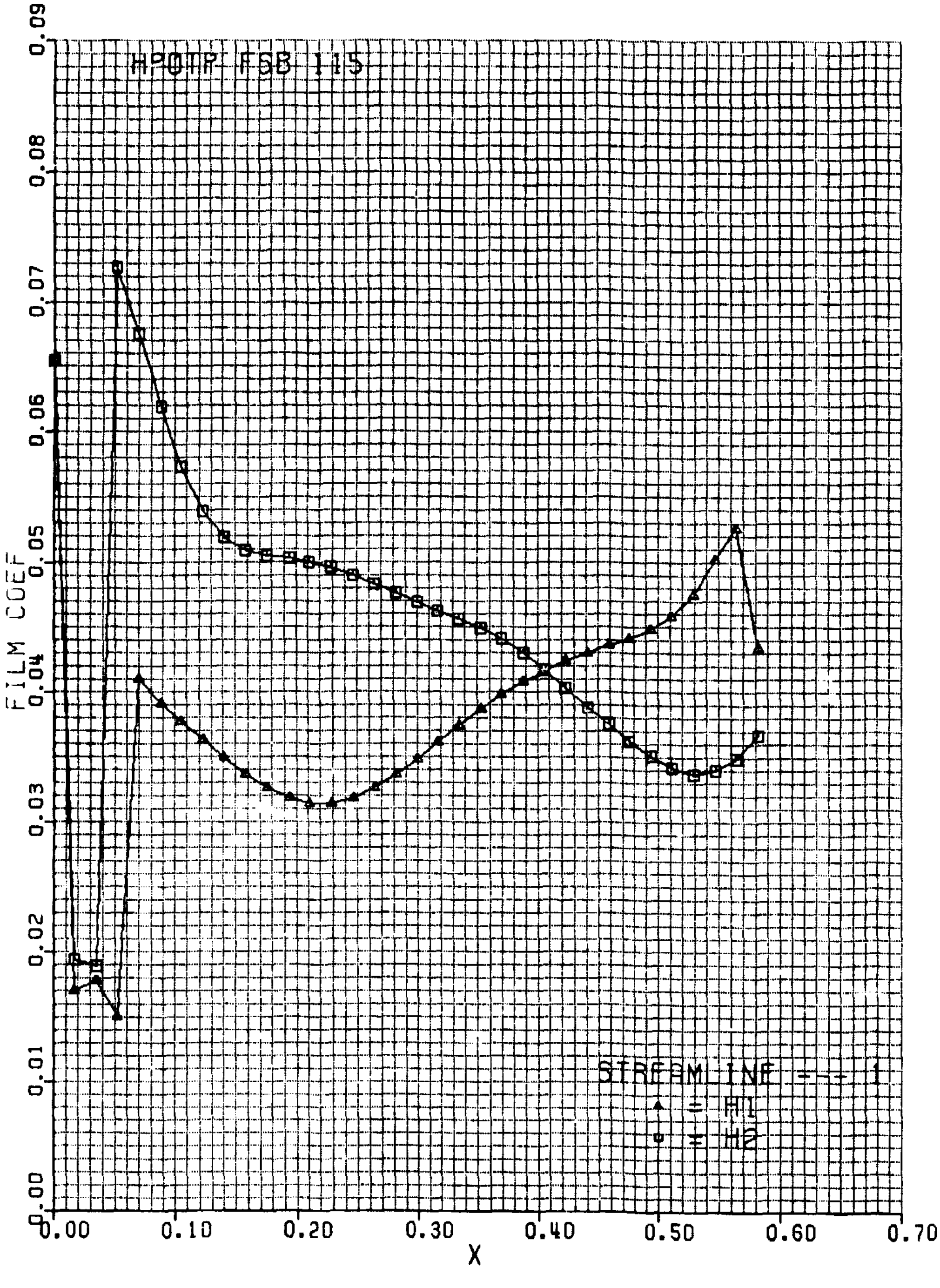
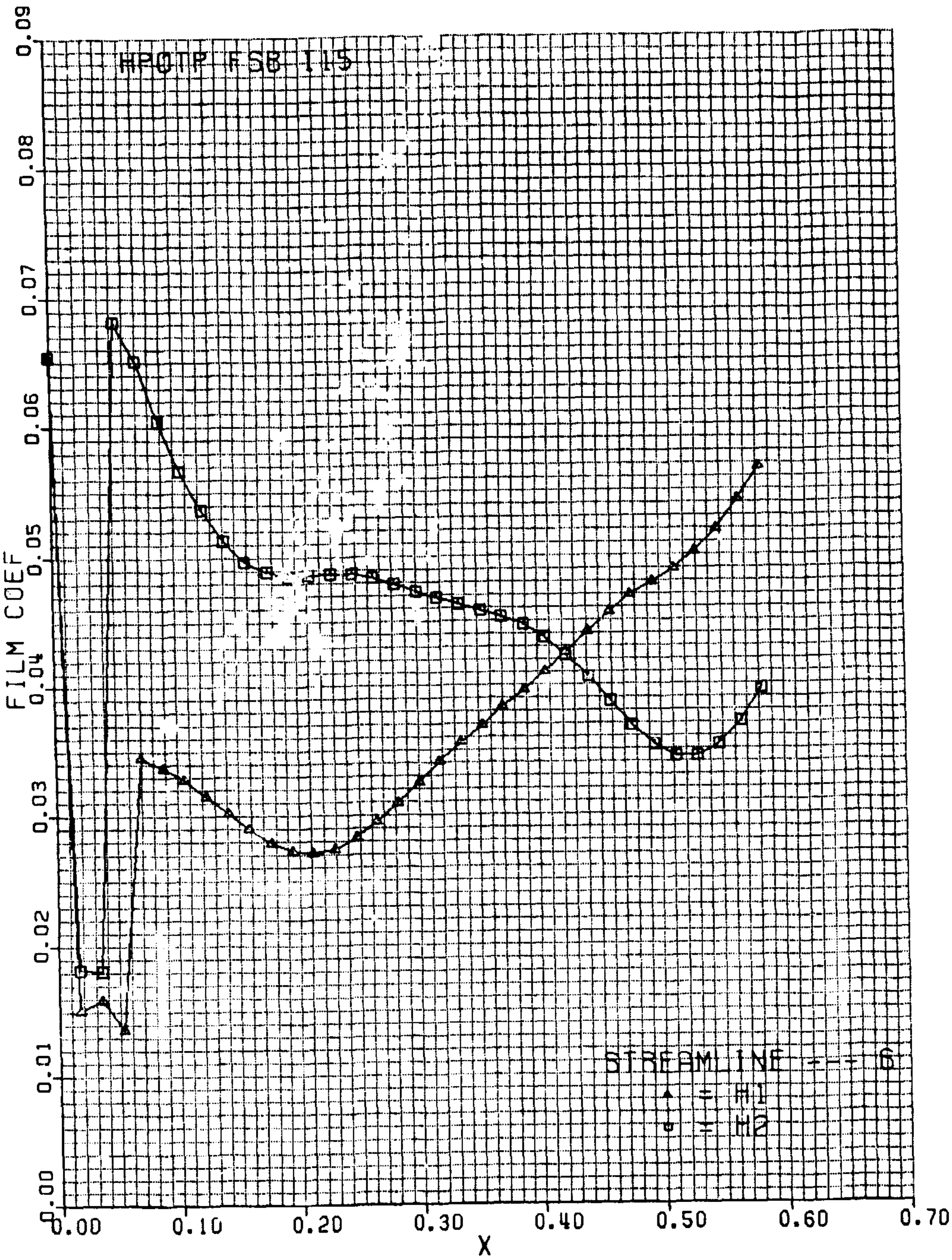



HPOTP FSB 115
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE = 1
▲ = H1
□ = H2

F.4.1


HPOTP FSB 115
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
X
STREAMLINE --- 6
= H1
= H2

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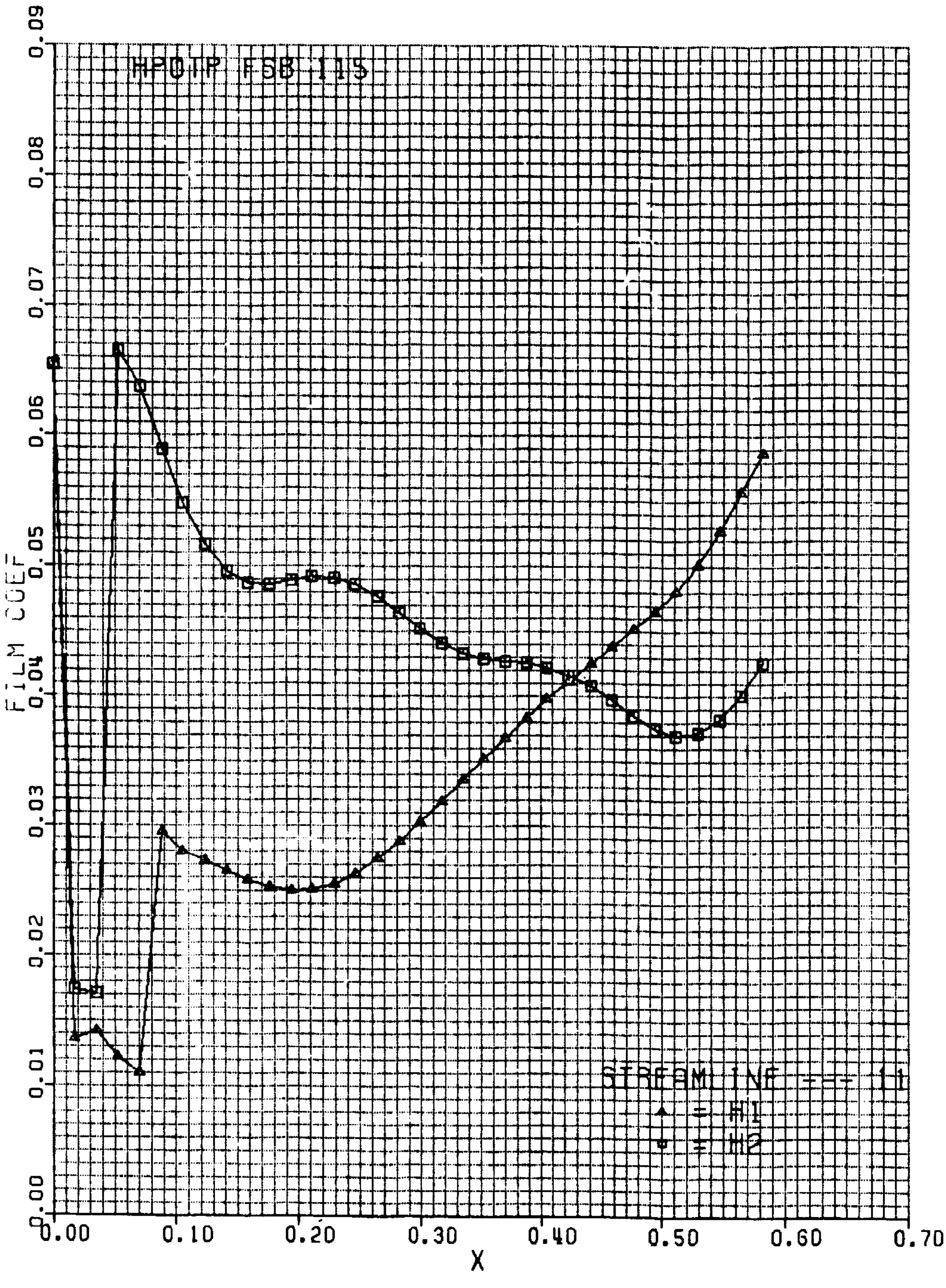

F.4.3

Appendix G

HPOTP SECOND STAGE NOZZLE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

G.1 FPL Pressure Distributions

G.2 115 Percent Power Level Pressure Distributions

G.3 FPL Heat Transfer Coefficients

G.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Suction Surface △

Surface 2 - Pressure Surface □

	Approximate Adiabatic Wall Temperatures (F)	
	FPL	115 Percent
Streamline 1 - R = 4.705	945	1120
Streamline 6 - R = 5.04	945	1120
Streamline 11 - R = 5.375	945	1120

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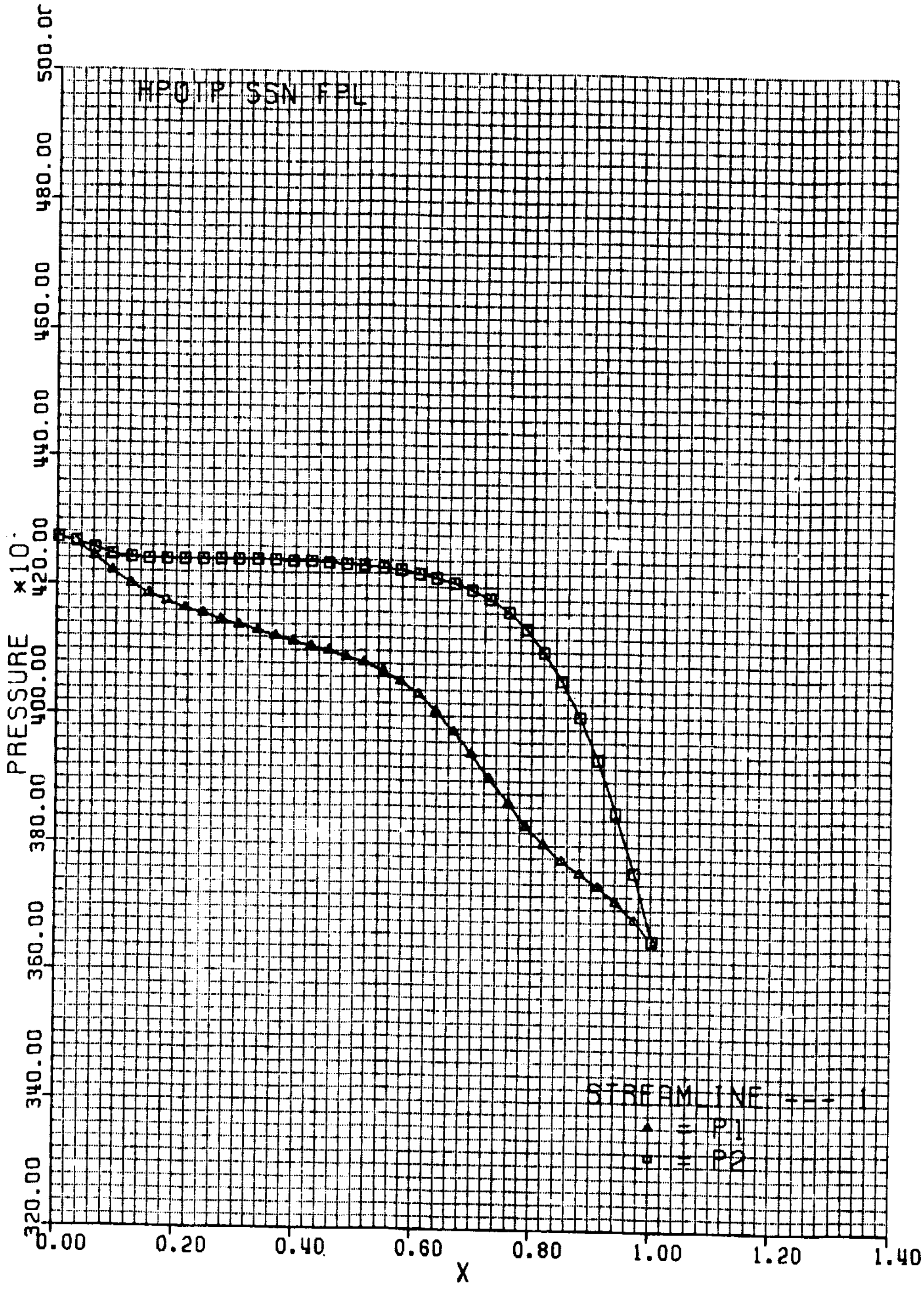

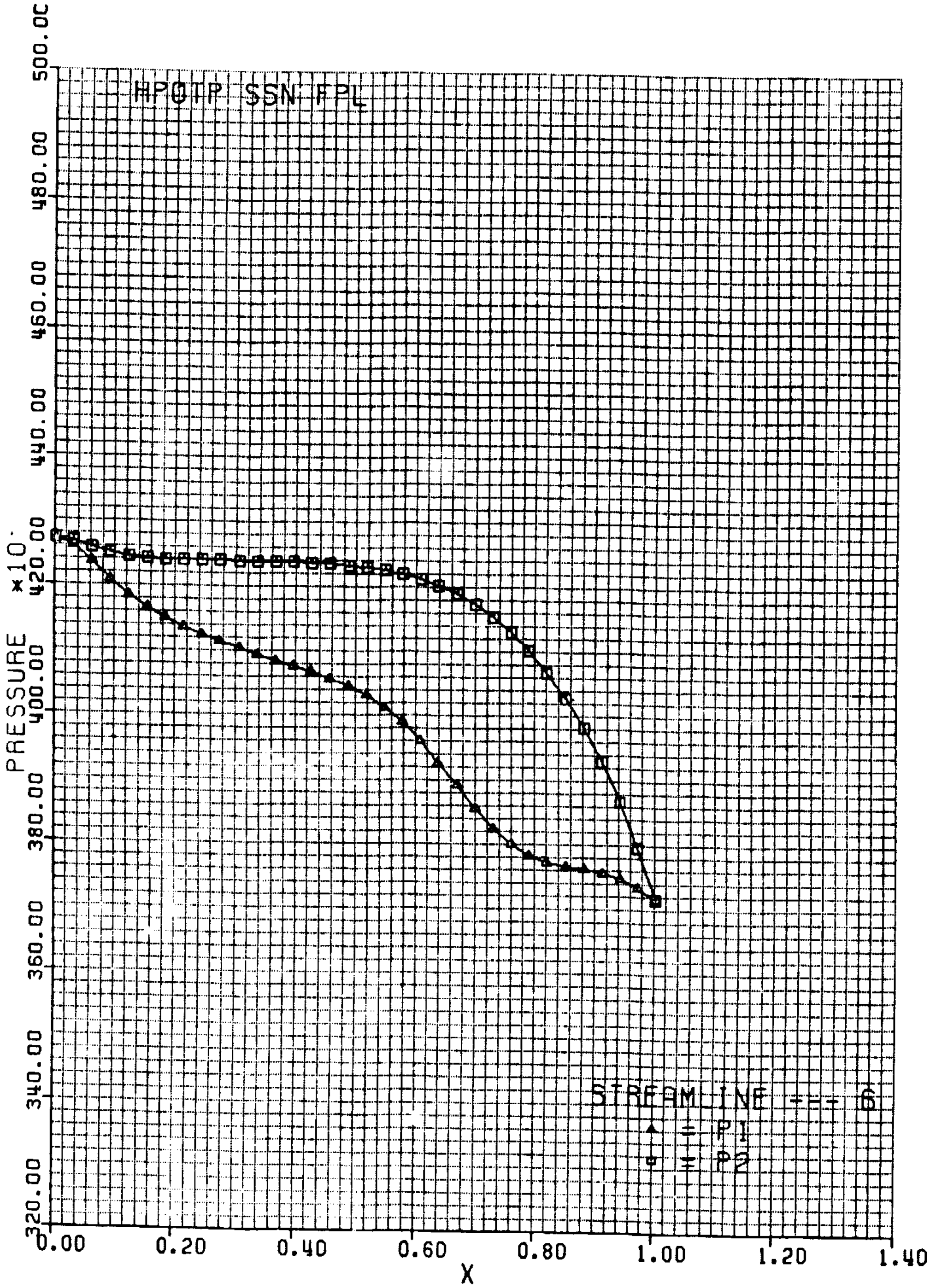
HPOTP SSN FPL
PRESSURE ×10
500.00
480.00
460.00
440.00
420.00
400.00
380.00
360.00
340.00
320.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
STREAMLINE --- 6
= P1
= P2

ORIGINAL PAGE IS
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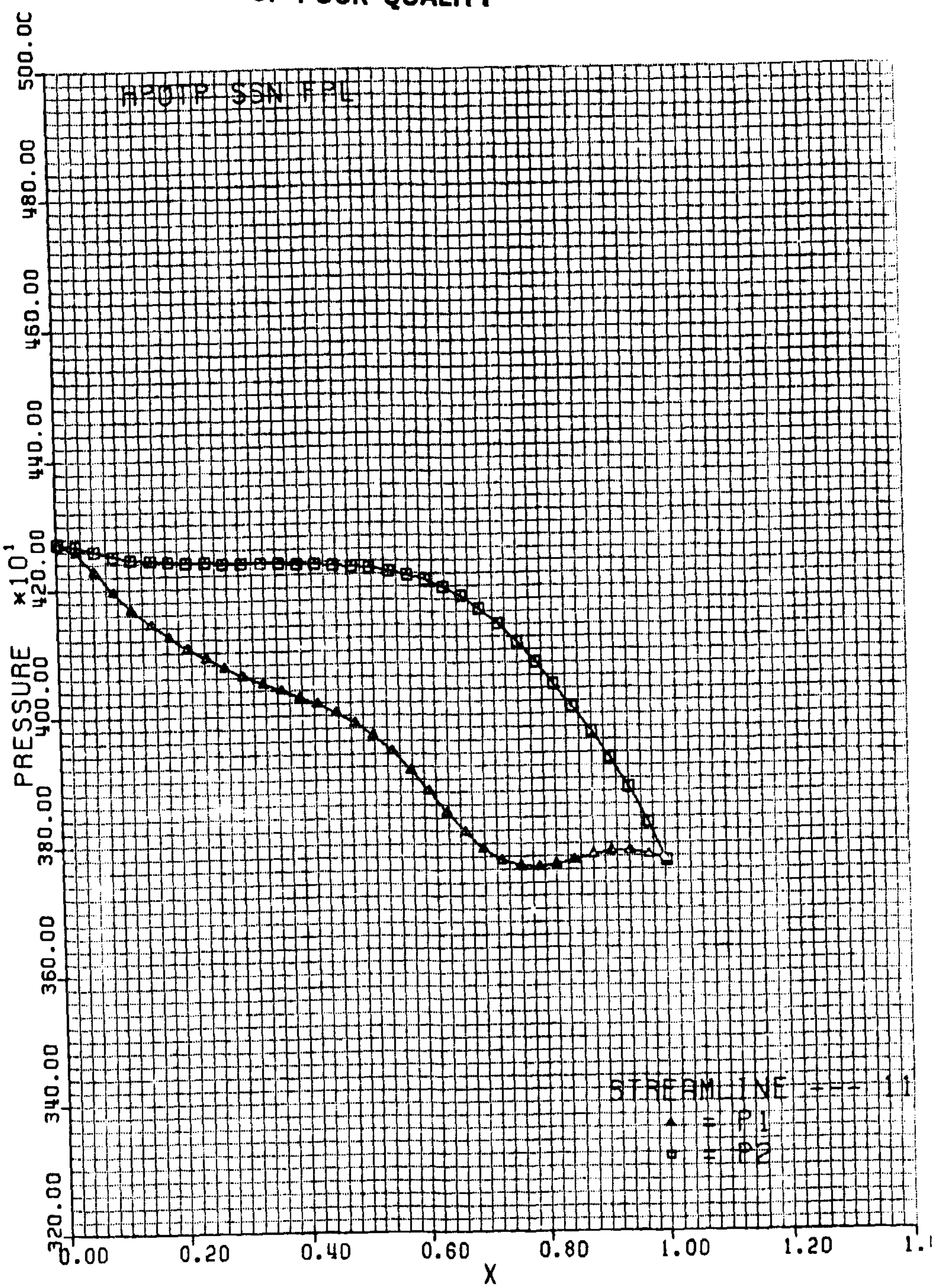

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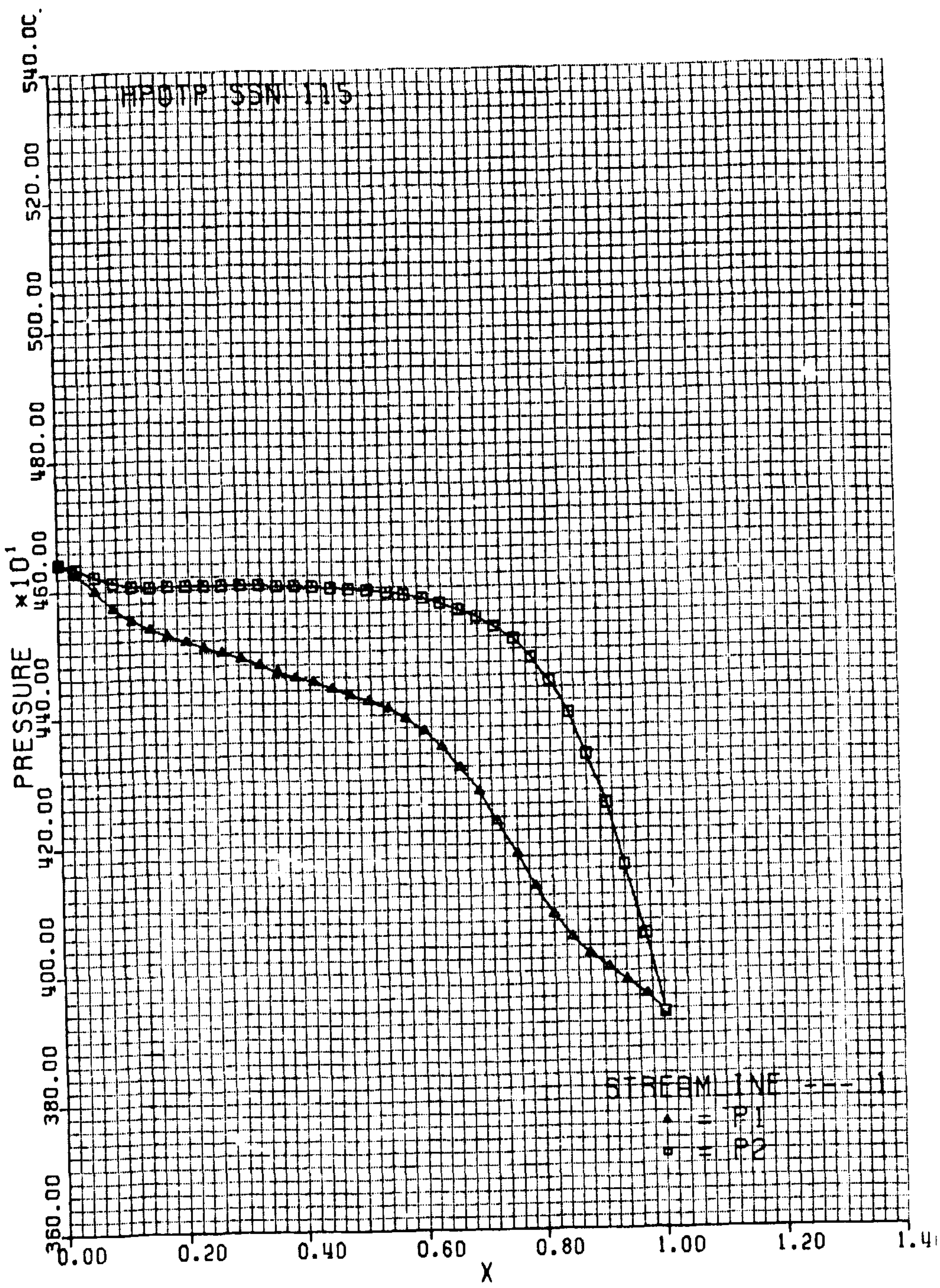

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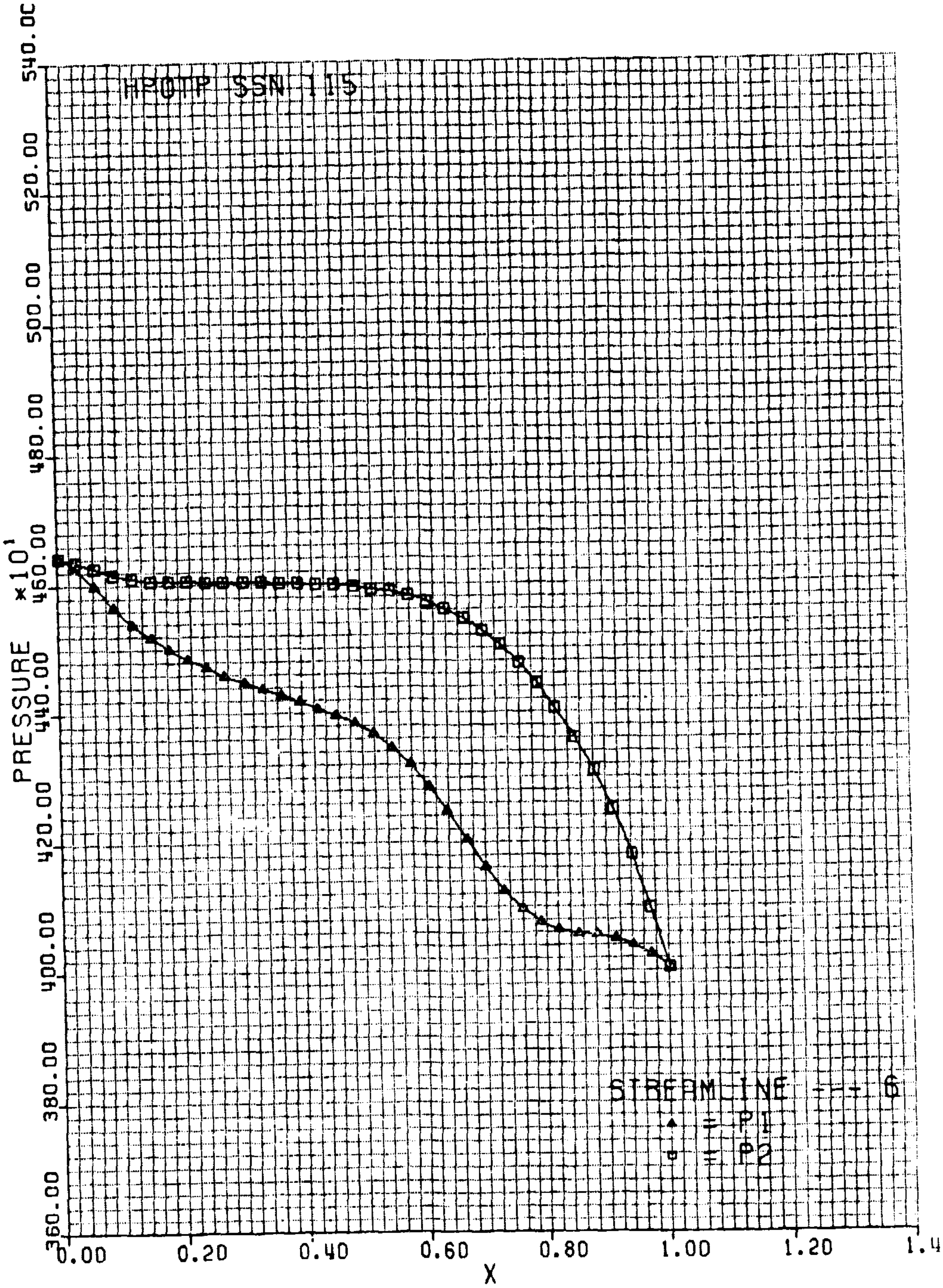
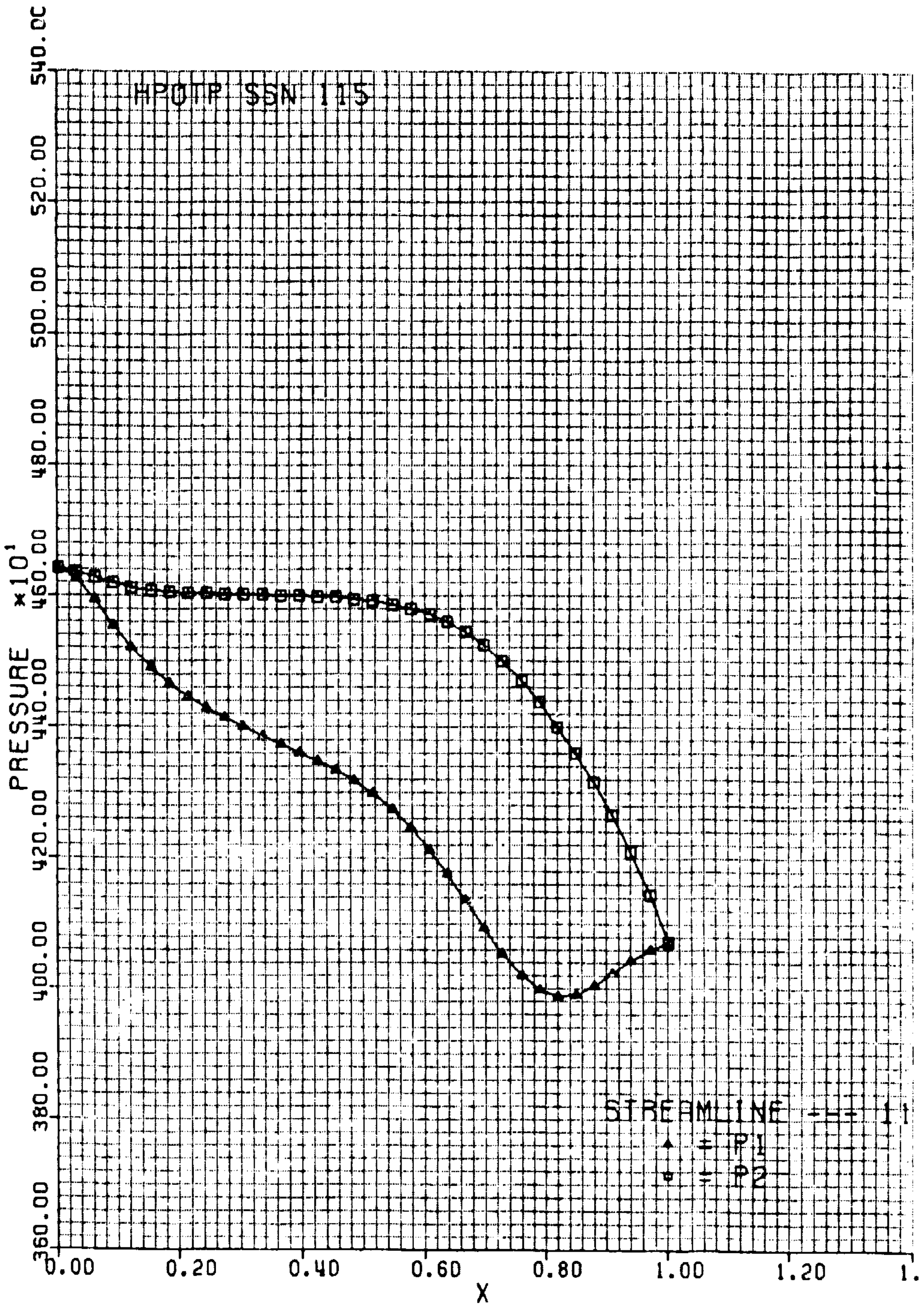
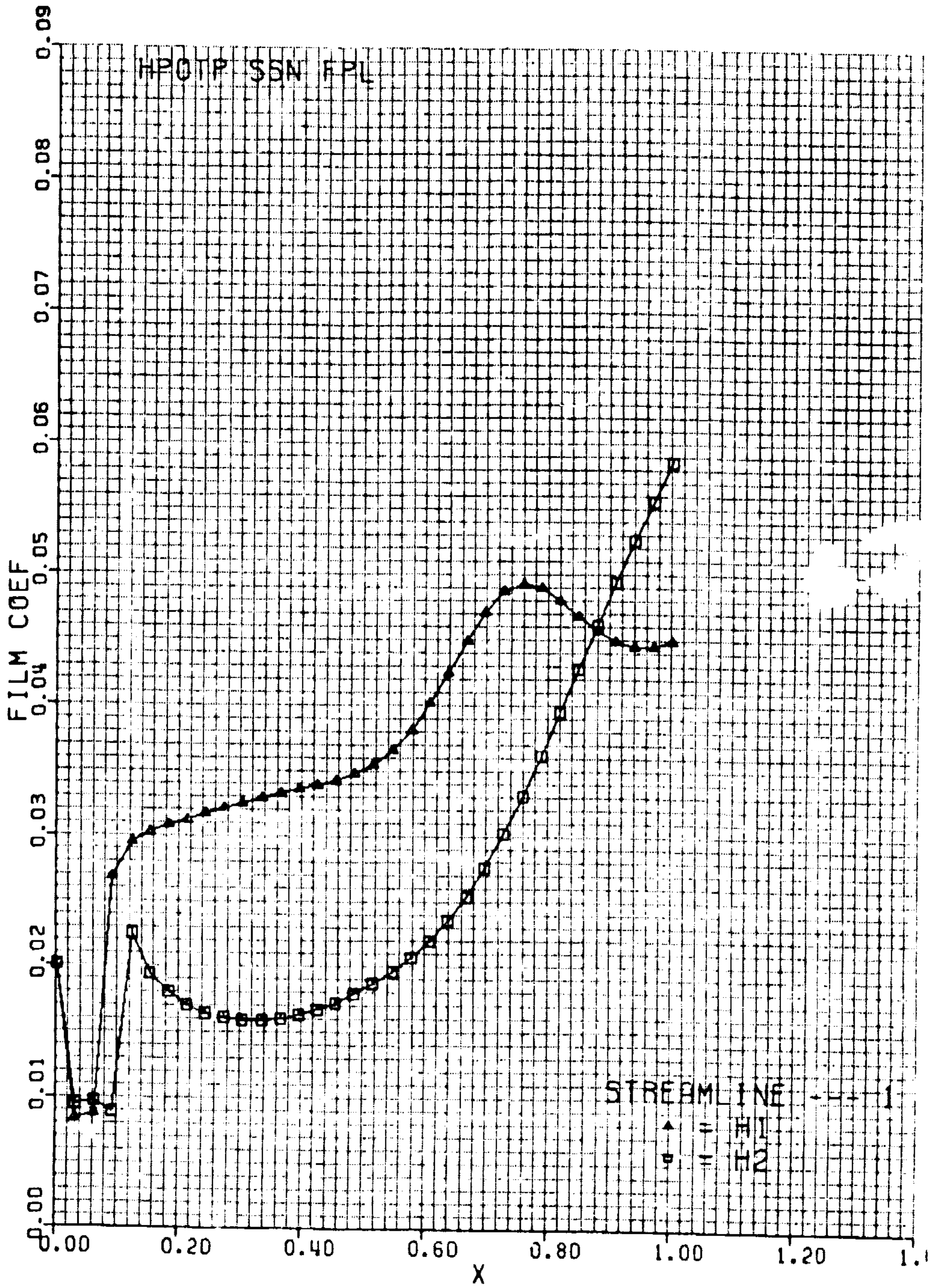
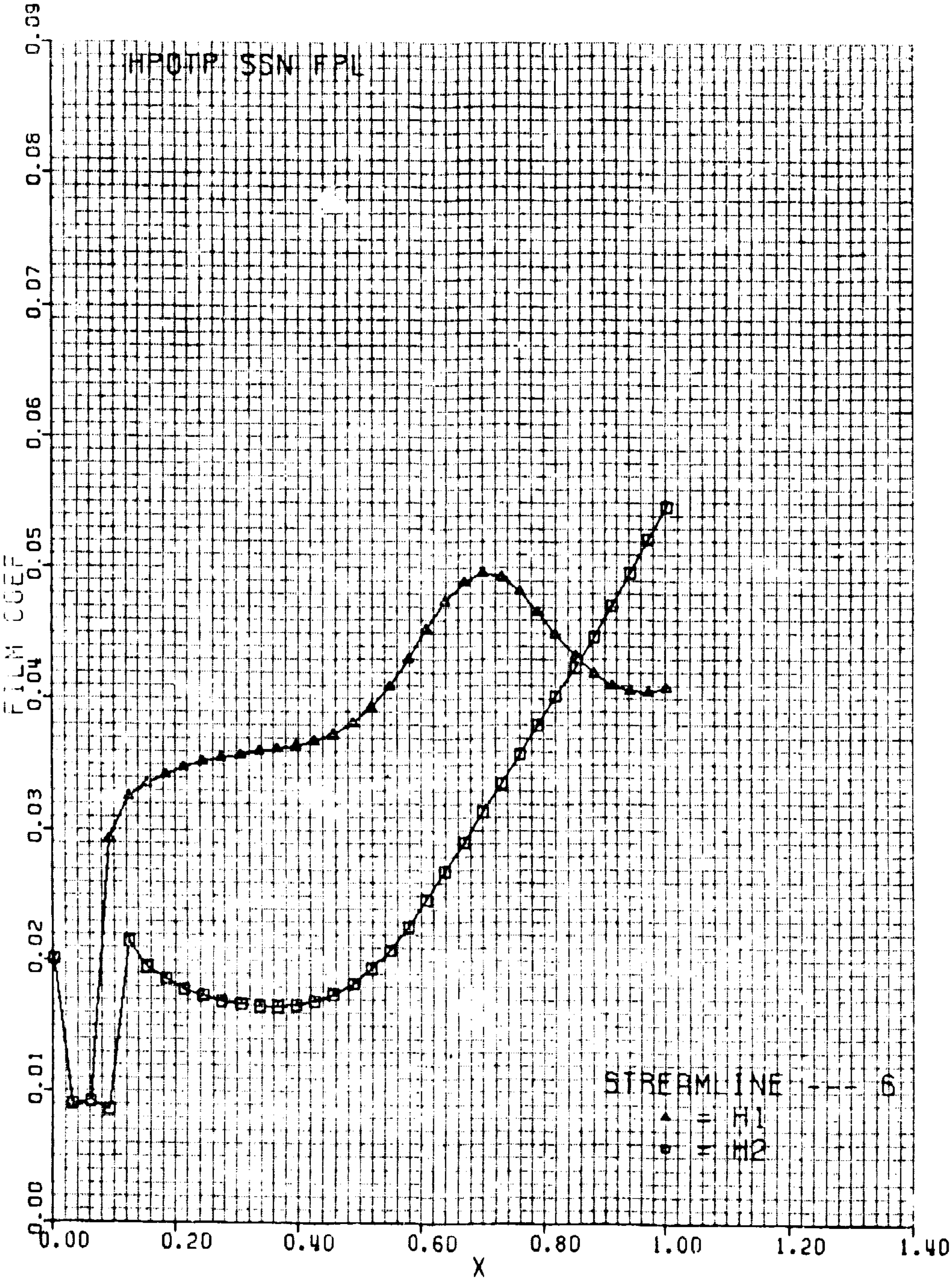
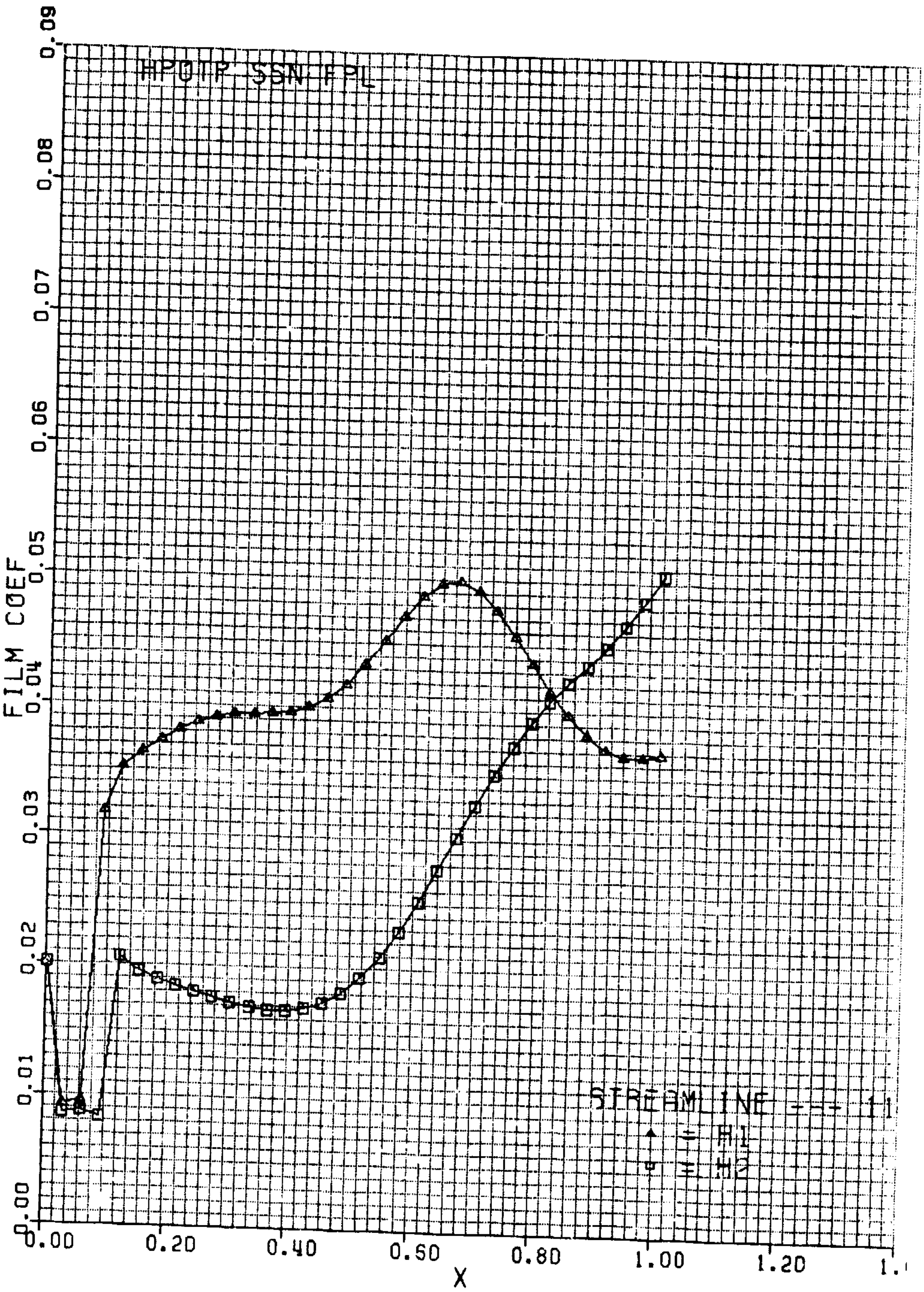



HPOTP SSN 115
PRESSURE ×10[1]
540.00
520.00
500.00
480.00
460.00
440.00
420.00
400.00
380.00
360.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
X
STREAMLINE --- 11
▲ = P1
□ = P2

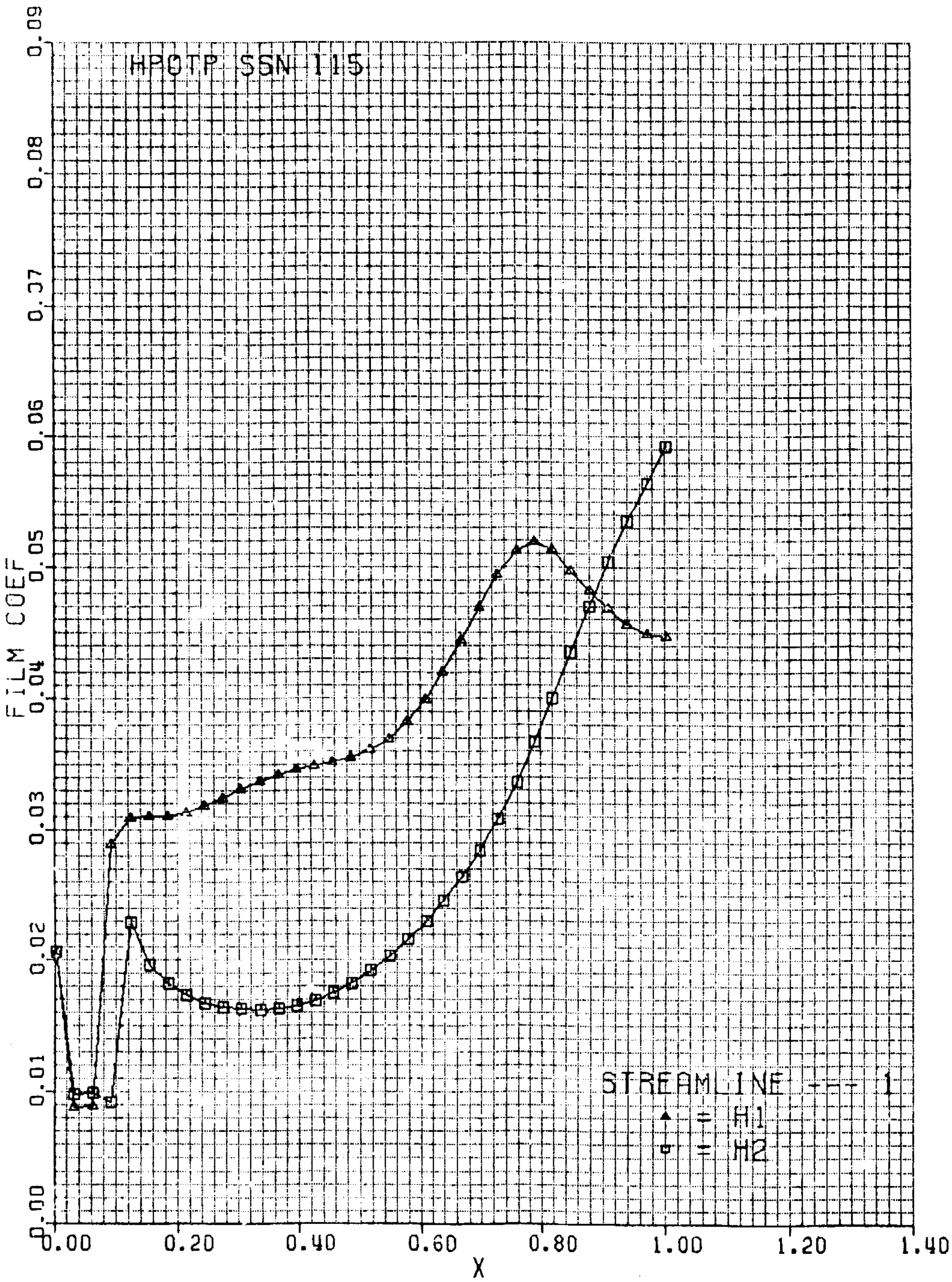

HPOTP SSN FPL
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
X
0.00
0.20
0.40
0.60
0.80
1.00
1.20
STREAMLINE -- 1
= H1
= H2

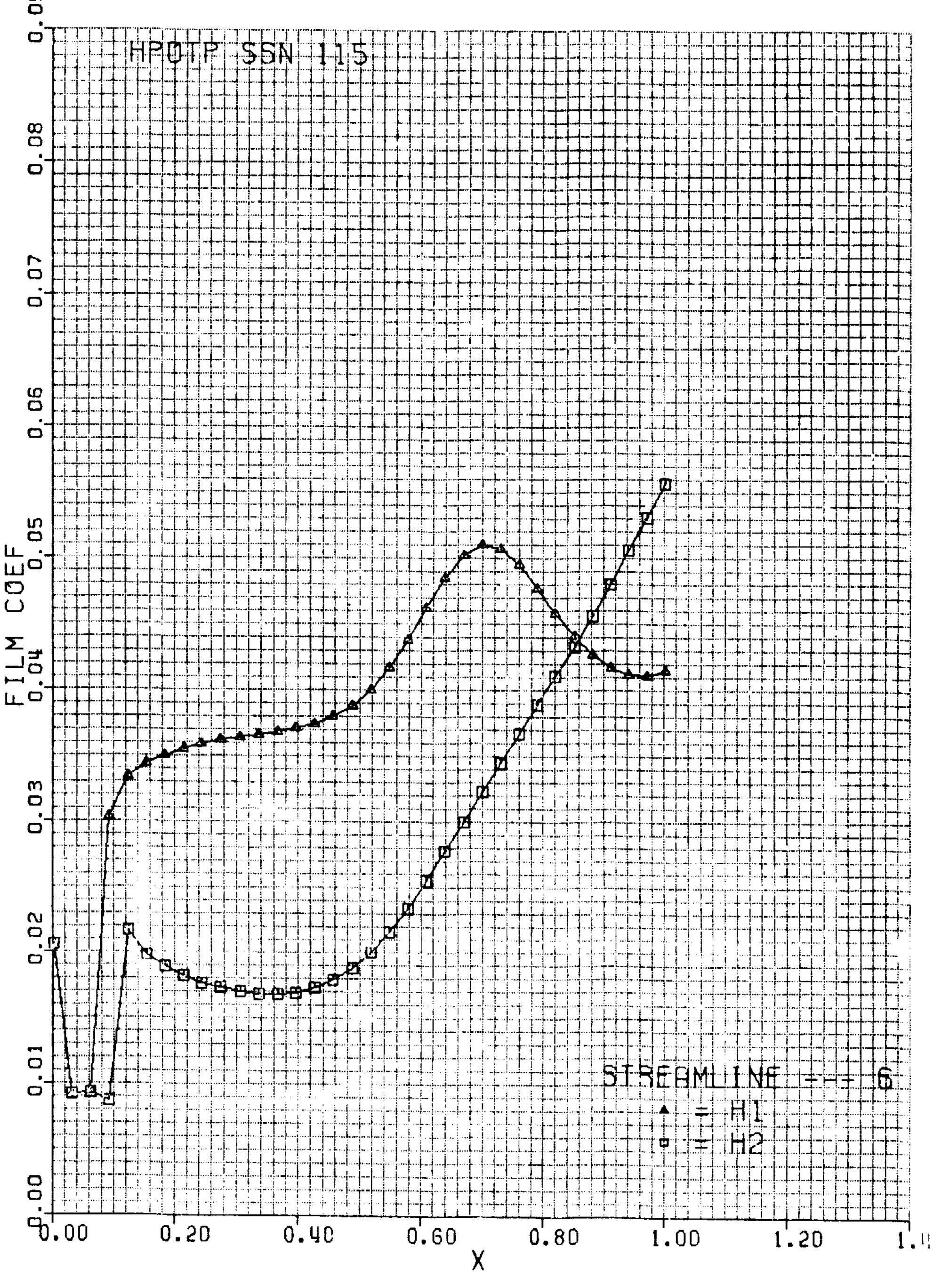
G.3.1


HPOTP SSN FPL
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
X
STREAMLINE --- 6
= H1
= H2

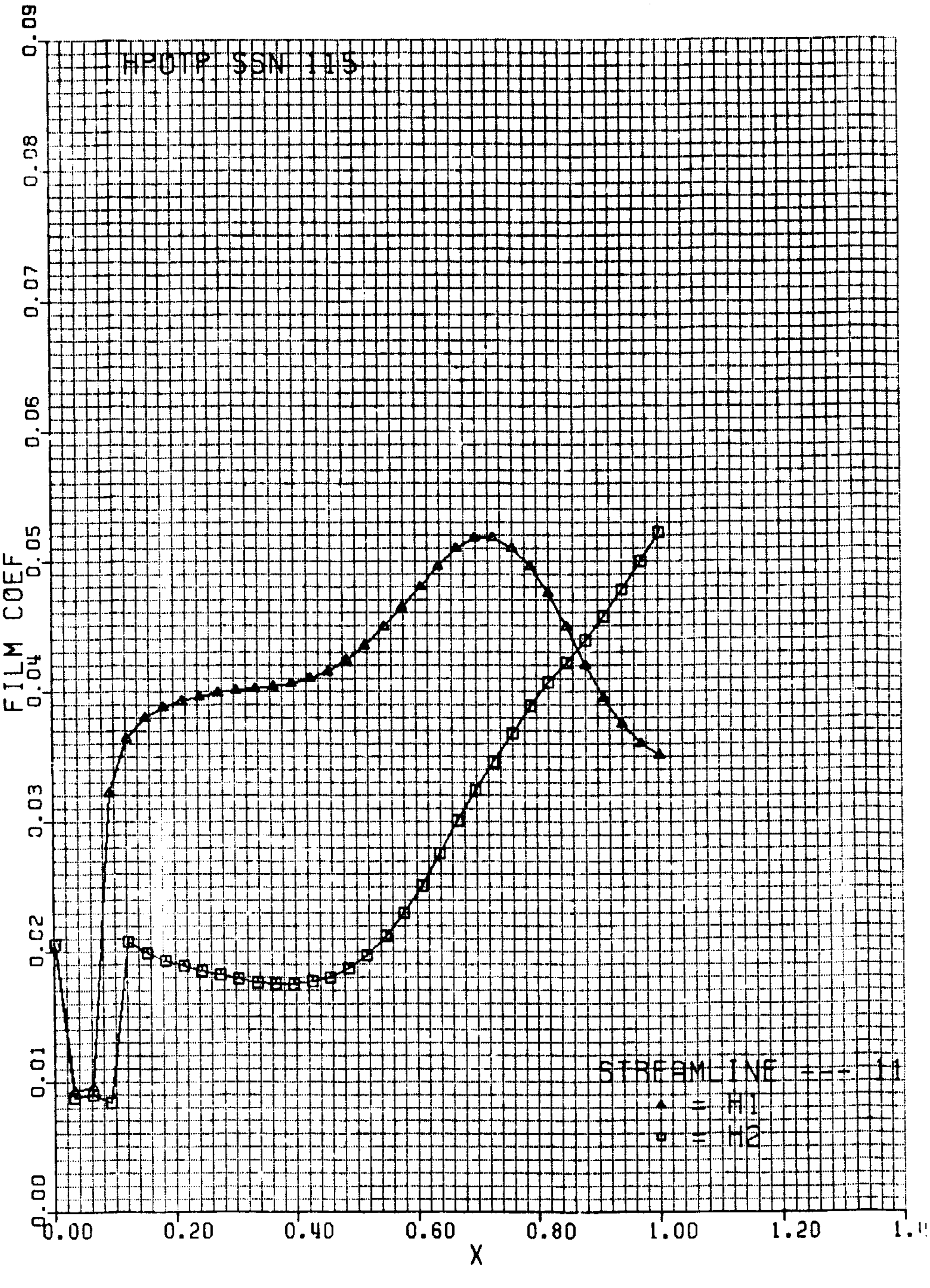

HPOTP SSN FPL
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
X
STREAMLINE --- 11
= H1
= H2

ORIGINAL PAGE IS
OF POOR QUALITY




HPOTP SSN 115
FILM COEF
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.00
0.20
0.40
0.60
0.80
1.00
1.20
X
STREAMLINE --- 6
= H1
= H2

ORIGINAL PAGE IS
OF POOR QUALITY



Appendix H
HPOTP SECOND STAGE BLADE PRESSURE, ADIABATIC WALL TEMPERATURE AND HEAT TRANSFER COEFFICIENT DISTRIBUTIONS

H.1 FPL Pressure Distributions

H.2 115 Percent Power Level Pressure Distributions

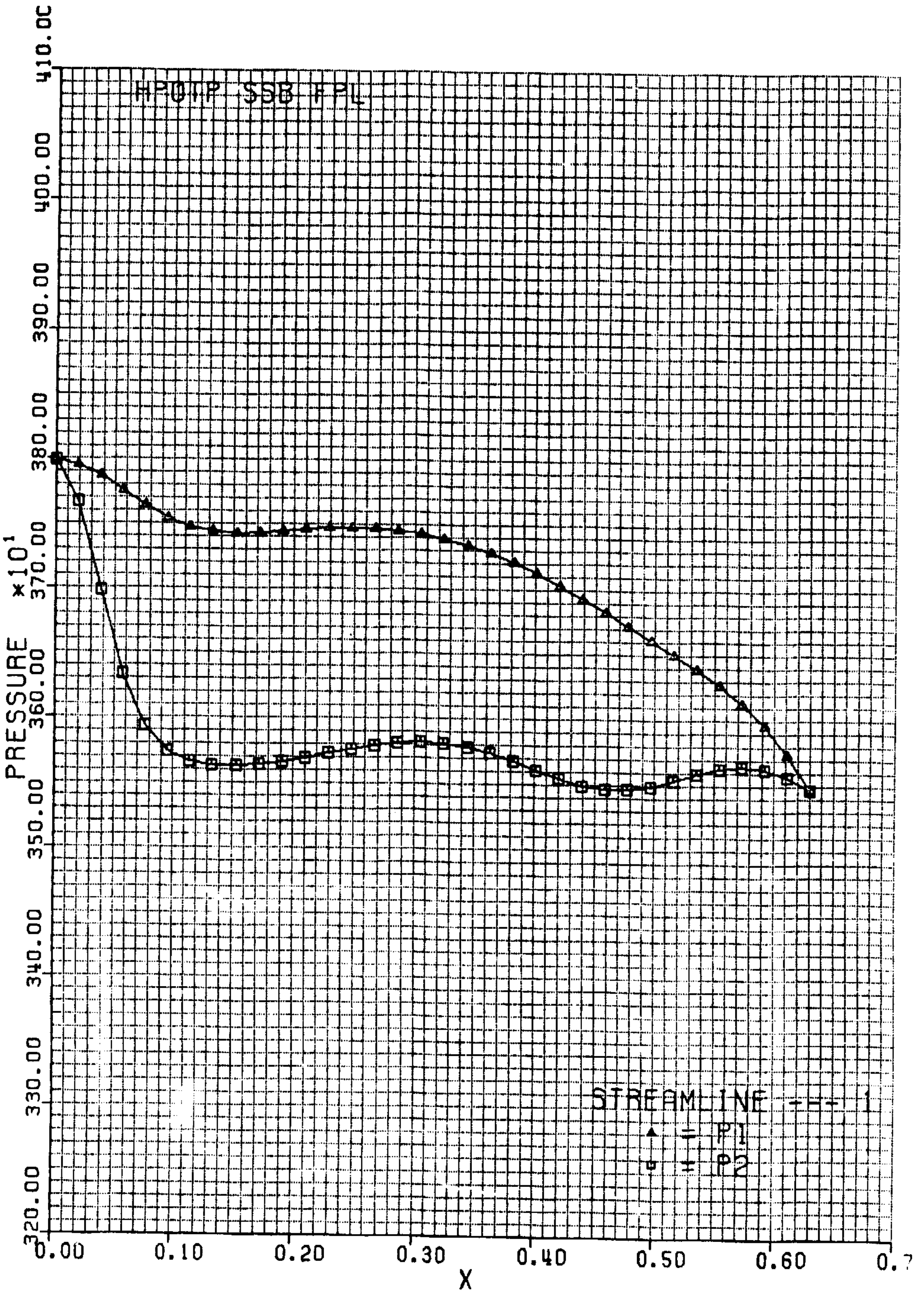
H.3 FPL Heat Transfer Coefficients

H.4 115 Percent Power Level Heat Transfer Coefficients

Surface 1 - Pressure Surface △

Surface 2 - Suction Surface □

	Approximate Adiabatic Wall Temperature (F)	
	FPL	115 Percent
Streamline 1 - R = 4.703	910	1080
Streamline 6 - R = 5.039	910	1080
Streamline 11 - R = 5.375	910	1080


HPOTP SSB FPL
PRESSURE ×10[1]
410.00
400.00
390.00
380.00
370.00
360.00
350.00
340.00
330.00
320.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
X
STREAMLINE --- 1
= P1
= P2

H.1.1

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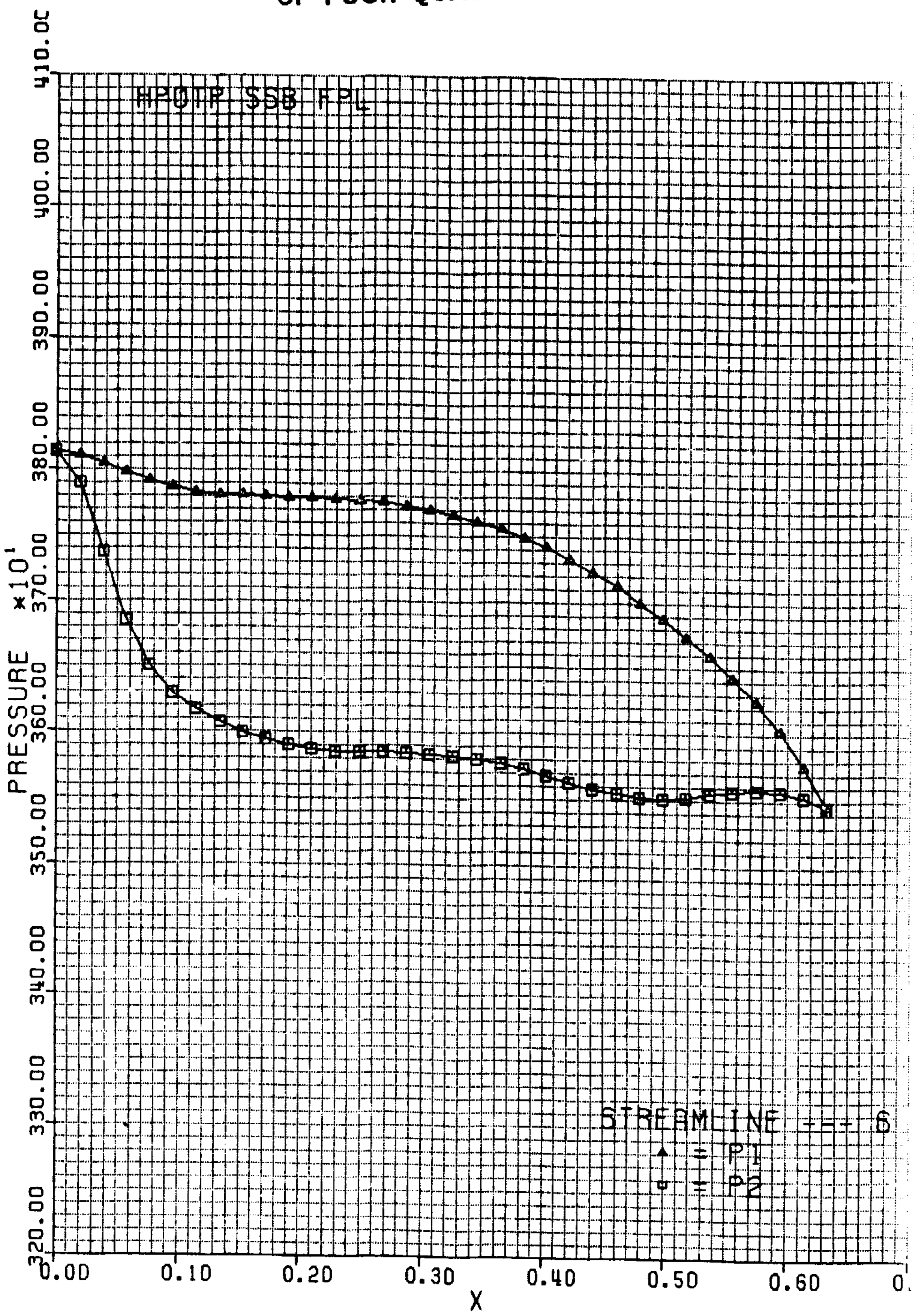

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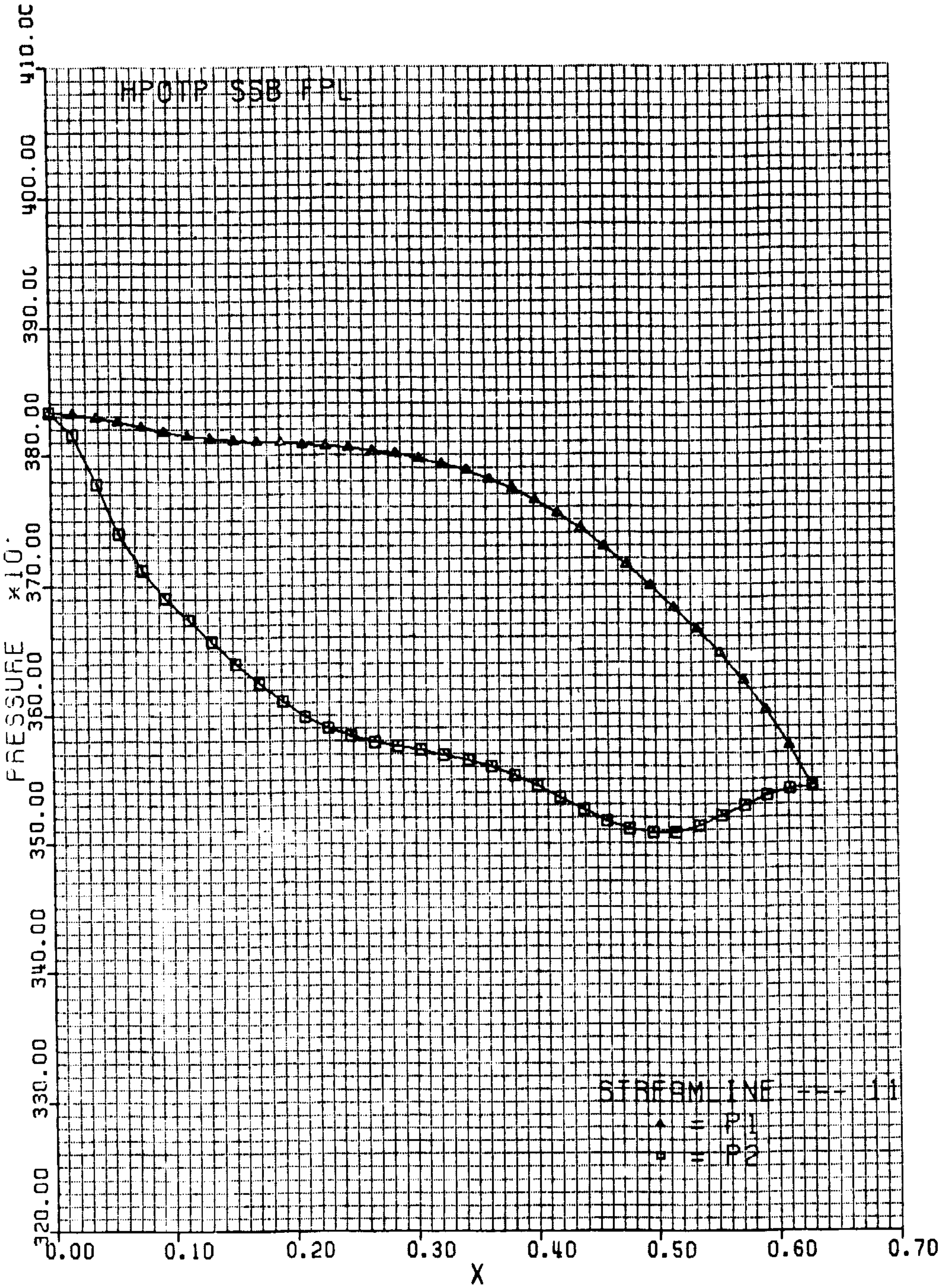

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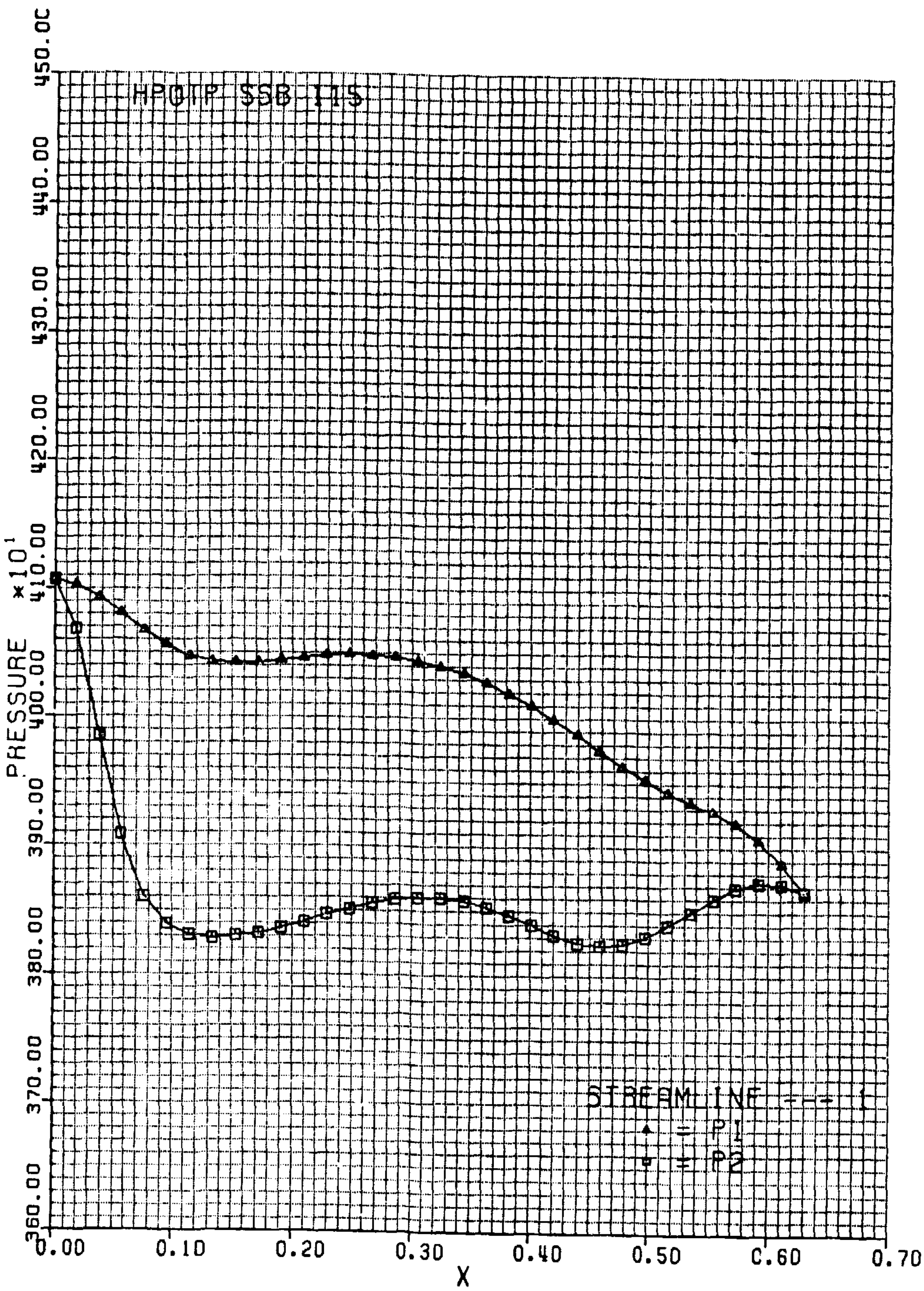

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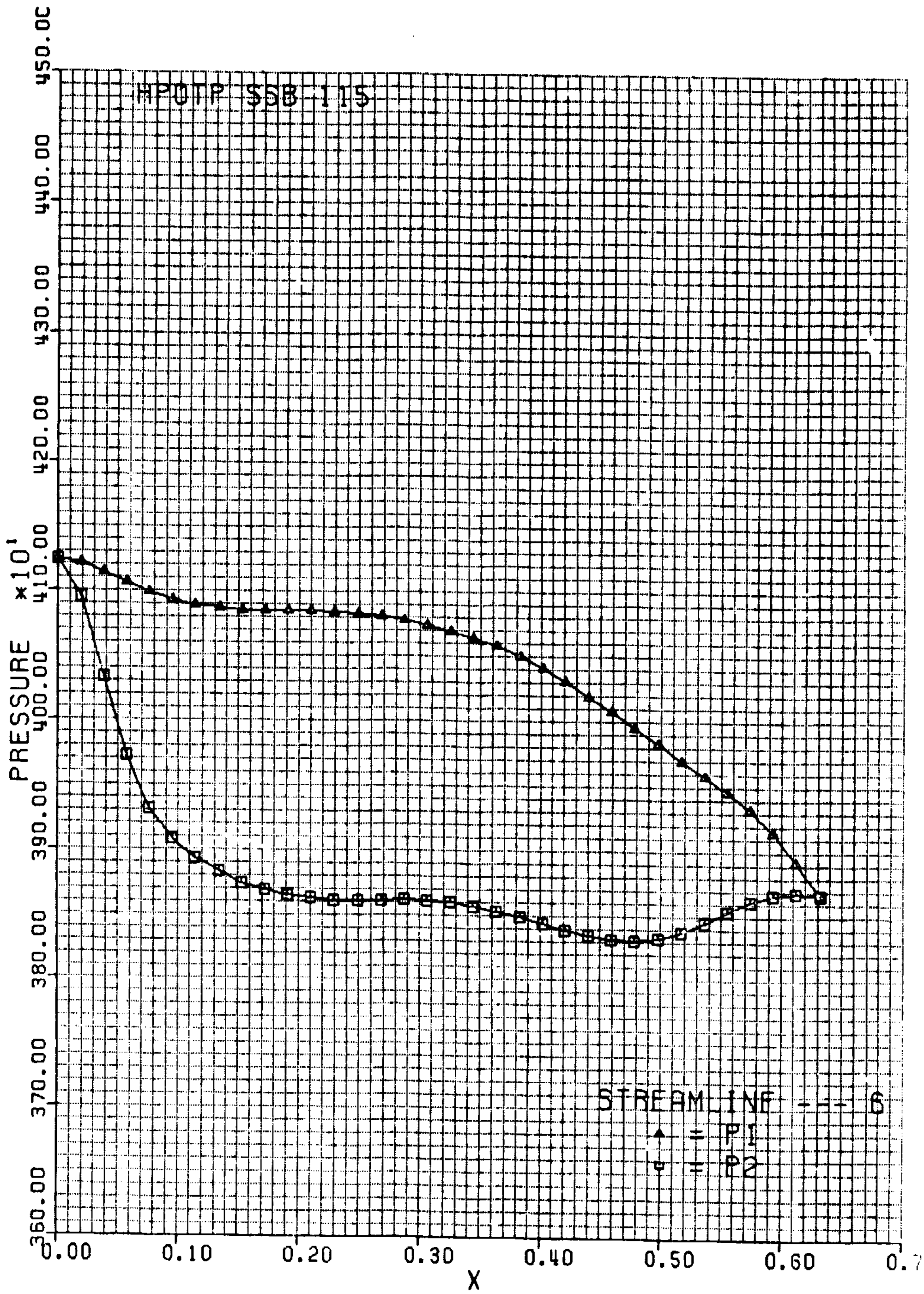

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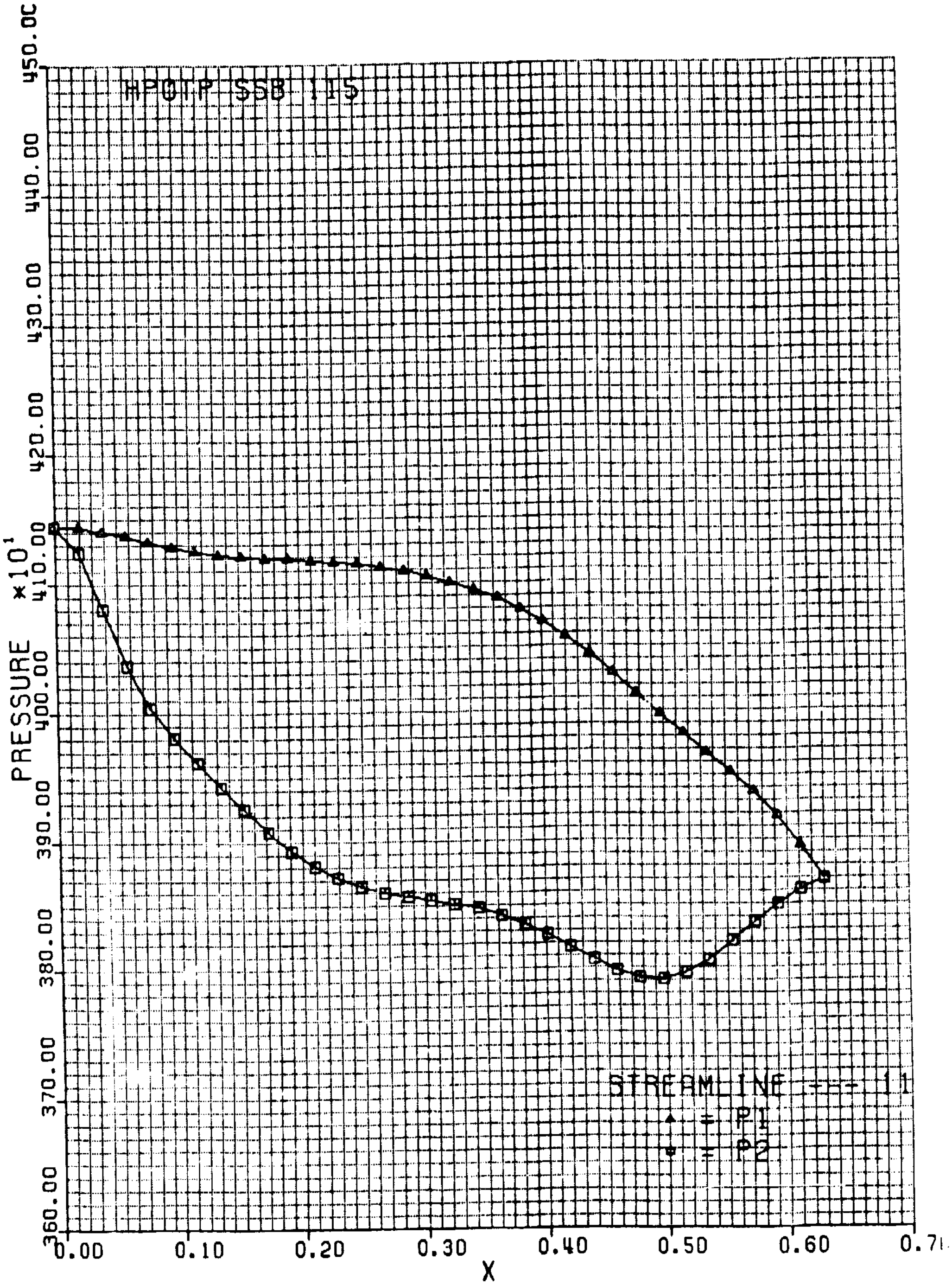

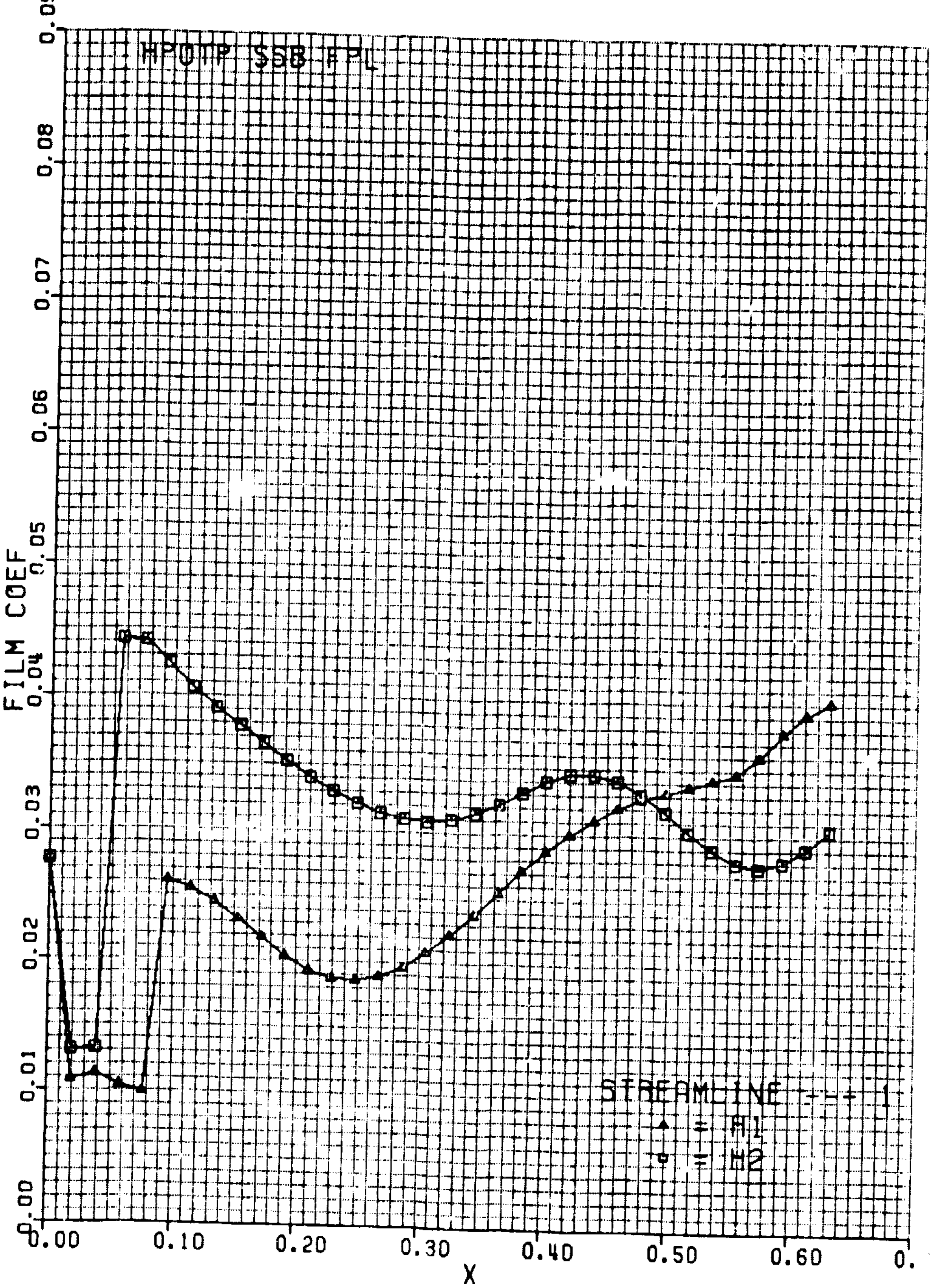
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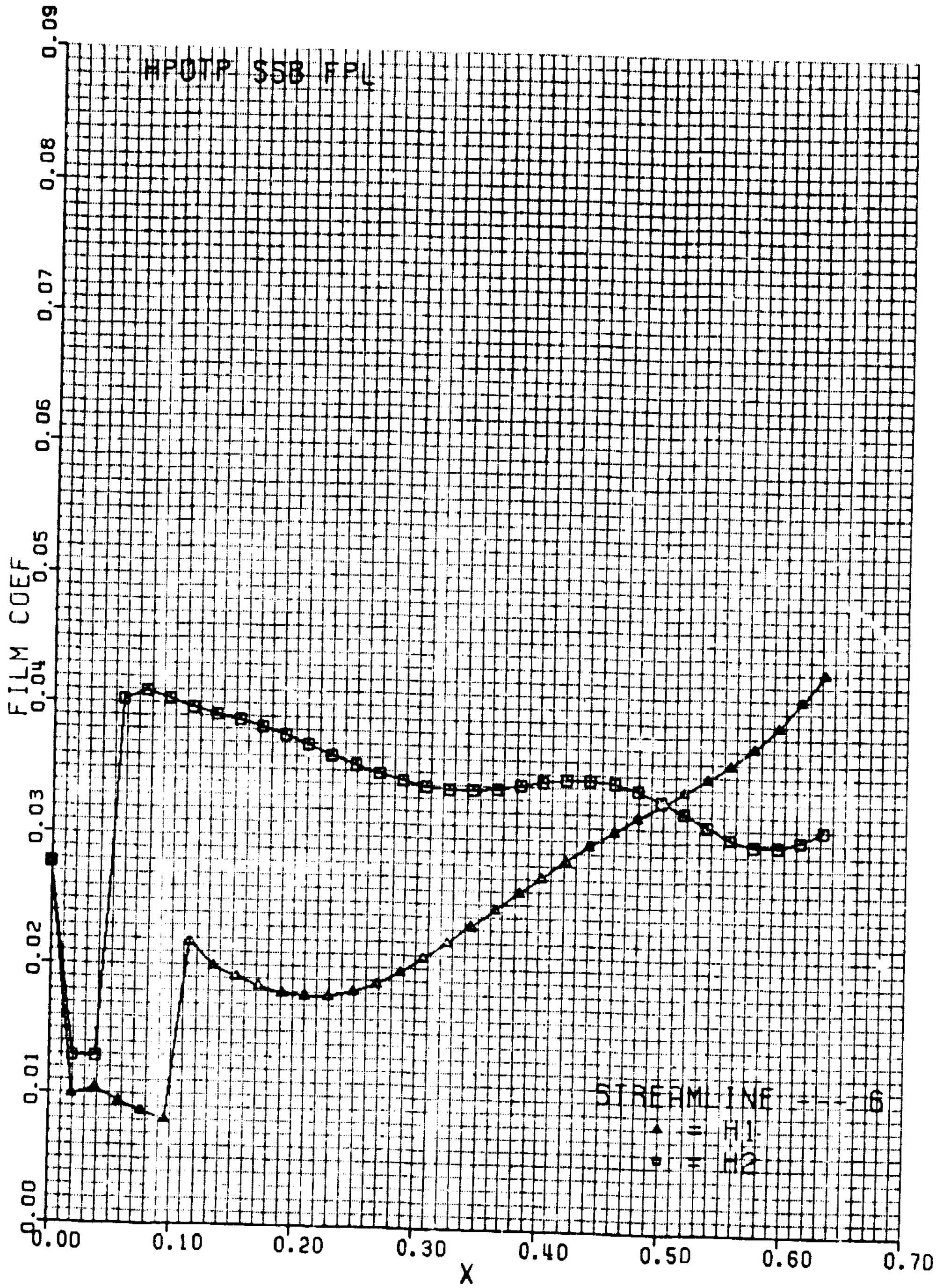

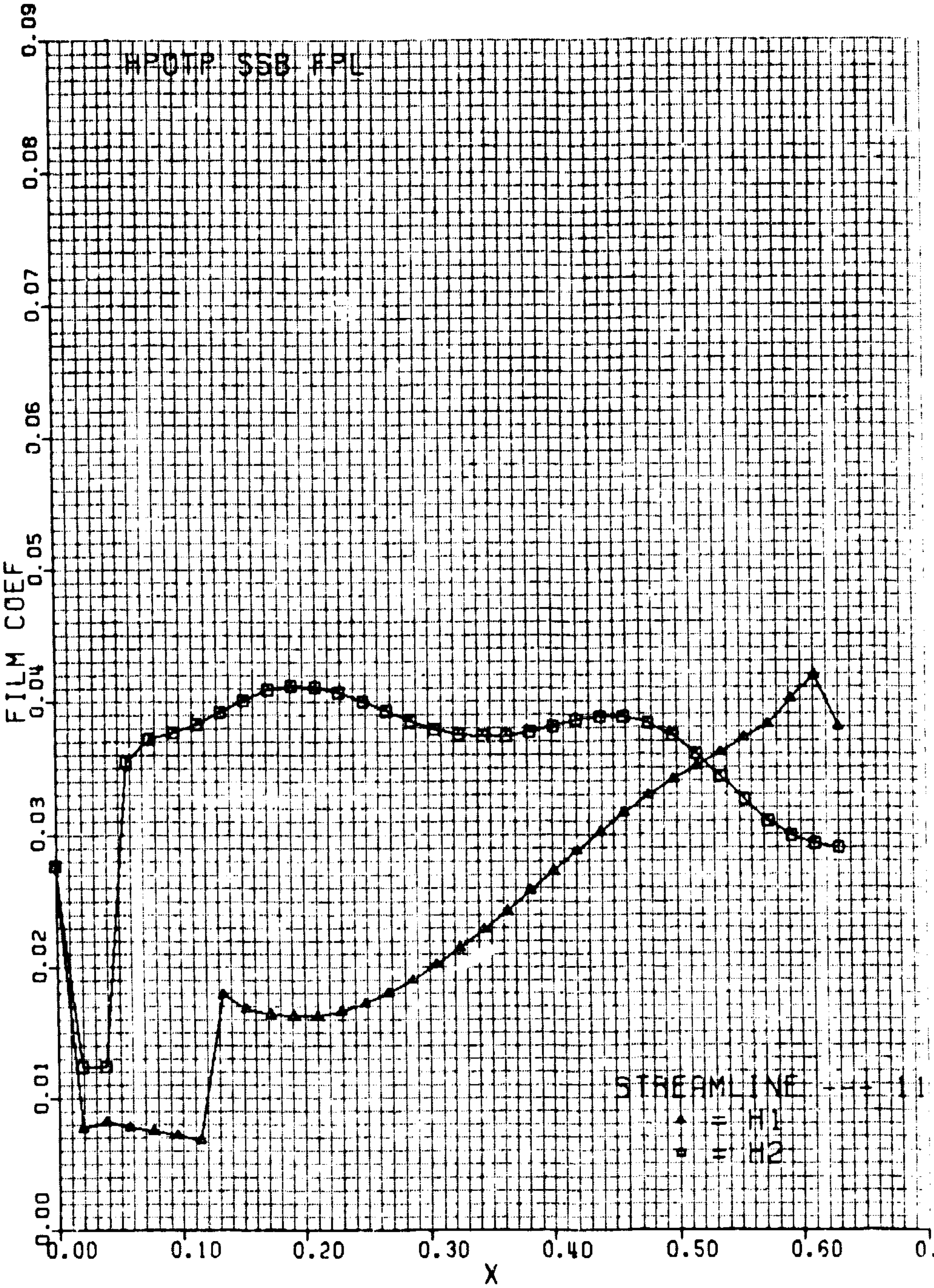
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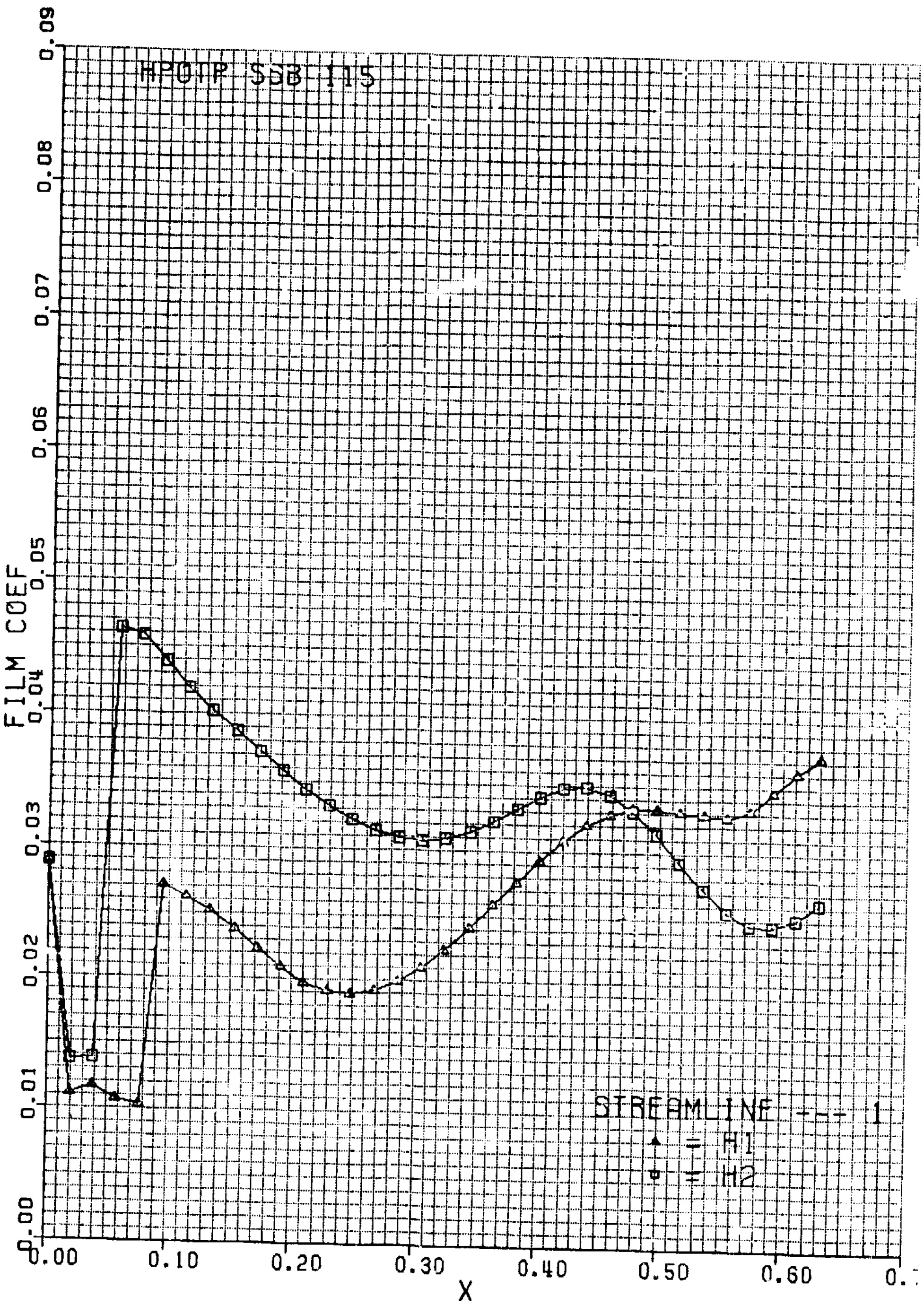

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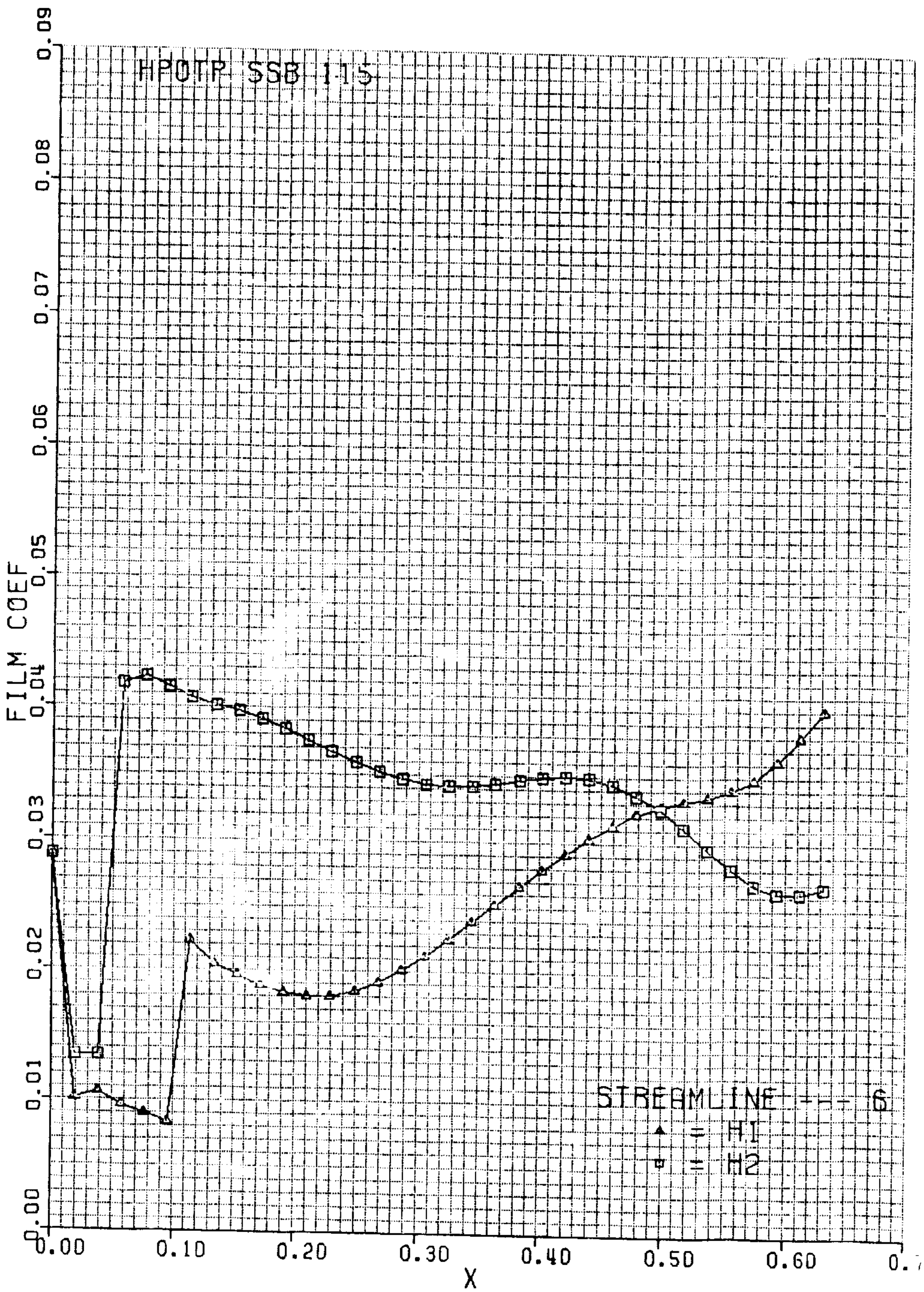

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