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AIR BUBBLER SYSTEM DESIGN
FOR THE 140-FOOT WYTM



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16. Abstract

The 140' class of Coast Guard Cutters are equipped with an air bubbler hull lubrication system for ice breaking. The air bubbler system reduces ice friction against the cutter's hull plating. This report describes the air bubbler system on this class cutter, gives its operating characteristics, and its design history.

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AIR BUBBLER
SYSTEM DESIGN
FOR THE 140-FOOT WYTM

By

E.J. Lecourt

January 1976

FINAL REPORT

CONTRACT NO. DOT-CG-50383-A

Prepared for

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NOMENCLATURE

- d = manifold diameter
 f = friction coefficient
 l = manifold length between orifices
 q = flow rate from orifice
 A_0 = orifice area
 C_D = discharge coefficient
 K = manifold flow coefficient
 Q_1 = flow rate approaching orifice location
 V_1 = fluid velocity approaching orifice location
 ΔP = change in pressure
 ΔP_0 = pressure differential across orifice
 ρ = mass density

I. DESCRIPTION OF THE SYSTEM

The air bubbler system designed for the 140-foot WYTM consists of four manifolds, an air compressor driven by a diesel engine, and the necessary piping and valves.

The two forward or bow manifolds consist of two 6" x 4" rectangular tubes which are located on the center line below the molded keel line from the forefoot at about Frame 9 to Bulkhead 32. Six orifices are located in the outboard side of each tube. The location and the size of each orifice is listed in Table I.

The two aft manifolds consist of two air ducts located within the hull, outboard of the 9' Buttock, and extending from Bulkhead 32 to Bulkhead 61. The width of the duct is 8 inches and the height of the inboard side is approximately 8 inches. The hull plating forms the bottom of the duct. The dimensions of the inboard and outboard sides of the duct vary with the slope of the hull. These manifolds each have eight orifices through the hull plating; the location and size of each orifice is listed in Table II.

The spacing of the orifices in the manifolds described above is 6 feet. An alternate design with orifices located every 4-1/2 feet was also prepared. The number, size, and location of the orifices for these alternate manifolds are listed in Tables A-1 and A-2 of Appendix A.

The air for the bubbler system is supplied by an air compressor with a capacity of 7500 SCFM at 9 psig. The compressor will be driven by a diesel engine rated at 350 HP. The diesel-compressor will be located in a van on the main deck above the motor room.

The piping system consists of a 12" main which divides in the engineroom into two 10" mains. The branches to each manifold are 8" pipe. A schematic of the piping system is shown in Figure 1.

In each branch, a straight run has been provided with fittings for a flowmeter, pressure gage, and thermometer. These will be utilized for installing instruments for testing the effectiveness of the bubbler system.

The design of the system provides four modes of operation:

1. all four manifolds
2. two bow manifolds only
3. two starboard side manifolds only
4. two port side manifolds only.

Motor operated butterfly valves are located at each manifold to permit changing the mode of operation.

The first mode is the normal mode for operations in ice. The second mode allows all of the air to be supplied to the bow manifolds if this should prove to be more effective. The third and fourth modes are for maneuvering in restricted waters, providing the capability of moving the bow to the right or left. The characteristics of the system for each mode of operation are explained in the following section.

TABLE I.
FORWARD MANIFOLDS, PORT AND STARBOARD
6-FOOT ORIFICE SPACING

<u>Orifice No.</u>	<u>Location (Frame No.)</u>	<u>Diameter (inches)</u>
1	10 - 11	1.875
2	14 - 15	1.875
3	18 - 19	2.000
4	22 - 23	2.000
5	26 - 27	2.125
6	30 - 31	2.125

SUPPLY AT AFT END OF MANIFOLD.

TABLE II.
AFT MANIFOLDS, PORT AND STARBOARD
6-FOOT ORIFICE SPACING

<u>Orifice No.</u>	<u>Location (Frame No.)</u>	<u>Diameter (inches)</u>
1	32 - 33	1.438
2	36 - 37	1.562
3	40 - 41	1.562
4	44 - 45	1.562
5	48 - 49	1.562
6	52 - 53	1.562
7	56 - 57	1.562
8	60 - 61	1.438

SUPPLY BETWEEN ORIFICES NO. 4 AND 5.

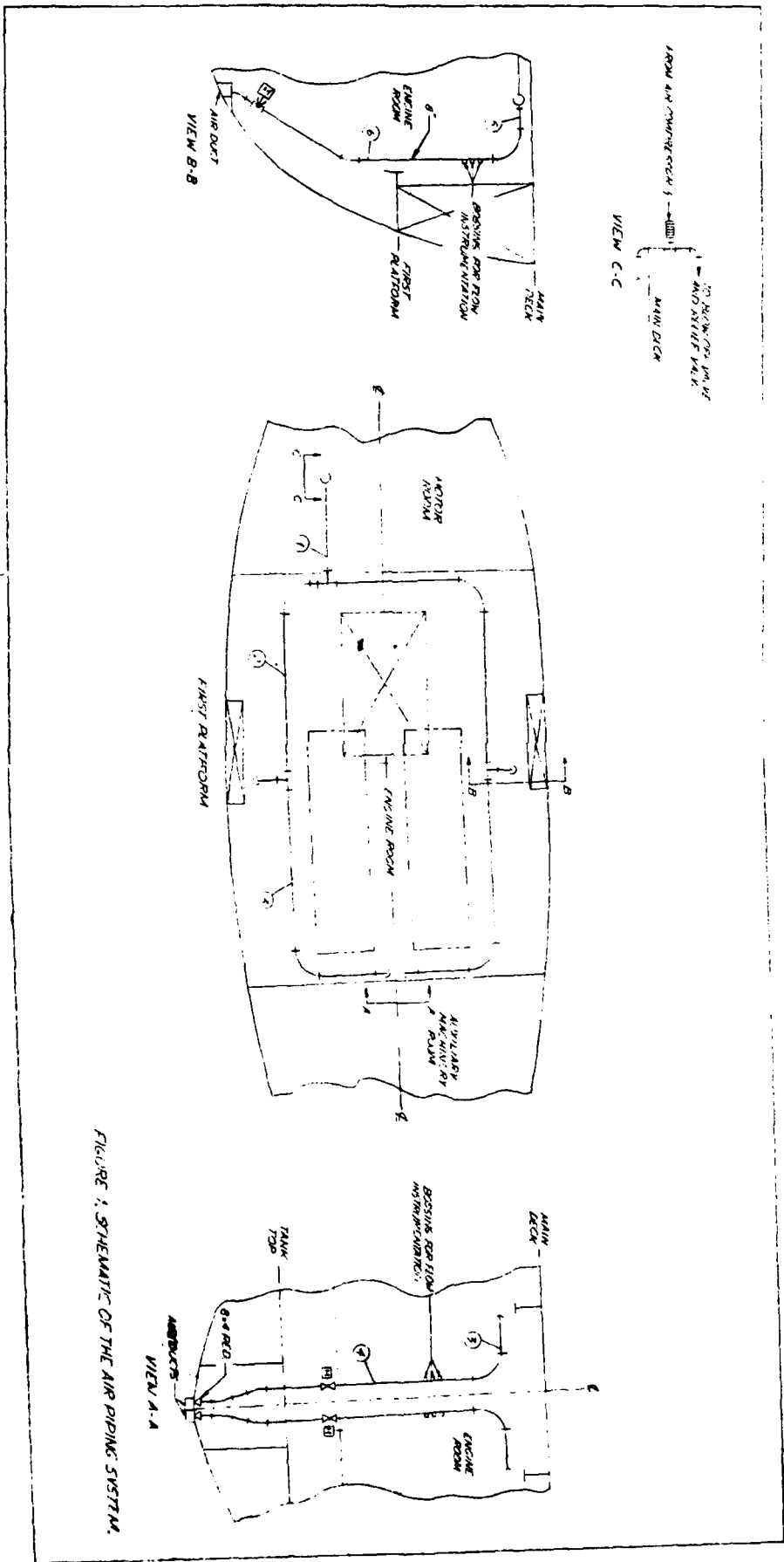


FIGURE 1. SCHEMATIC OF THE AIR PIPING SYSTEM.

II. OPERATING CHARACTERISTICS

The characteristics of the air bubbler system for each mode of operation are summarized in Table III. The air flow and pressure at the compressor are determined by the characteristics of the compressor, the piping system, and the manifolds.

Typical compressor characteristics are shown in Figures 2 and 3. Air flow versus discharge pressure is shown in Figure 2, and power versus discharge pressure is shown in Figure 3. The operating pressure of the system is limited by the power of the diesel engine.

The air flow through each orifice is a function of the pressure in the manifold, the hydrostatic pressure outside the manifold, and the diameter of the orifice. Calculations have been performed to determine the air flow characteristic versus manifold pressure, and the results are presented in graphical form in Figures 4, 5, 6, 7, and 8. A computer program was used to perform the calculation, and the printout is included in Appendix B.

The pressure drop in the piping system has been calculated for each mode of operation and is tabulated in Table III.

In modes 3 and 4, the total air flow cannot be supplied to the manifolds on one side of the ship without exceeding the 9 psig pressure limit imposed by the torque limit of the diesel engine. It is, therefore, necessary to provide a blow-off of 750 SCFM through a special valve in order to keep the pressure at 9 psig.

The characteristics of the alternate manifolds with 4-1/2-foot spacing are almost identical. Graphs of the characteristics are included in Appendix A, and the supporting calculations are included in Appendix B.

TABLE III
OPERATING CHARACTERISTICS FOR EACH MODE

MODE	AIR FLOW (SCFM)					PRESSURE (PSIG)			POWER (HP)
	Bow Manifold Stbd Side	Bow Manifold Port Side	Aft Manifold Stbd Side	Aft Manifold Port Side	Total Air Flow	Bow Manifold	Aft Manifold	Air Compressor	Diesel Engine
1.	1700	1700	2050	2050	7500	5.7	5.7	6.4	250
2.	3750	3750	—	—	7500	7.8		9.0	325
3.	3550	—	3200	—	6750*	7.5	7.7	8.9	325
4.	—	3550	—	3200	6750*	7.5	7.7	8.9	325

* Blow-off required equal to 750 scfm

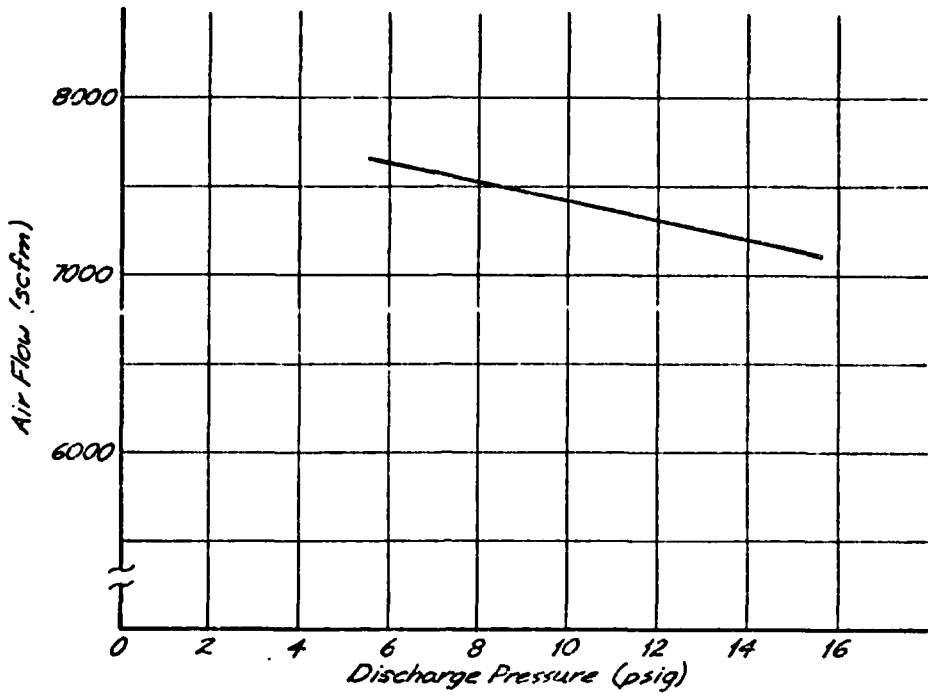


FIGURE 2
 AIR FLOW VS DISCHARGE PRESSURE
 FOR INGERSOLL-RAND TYPE L Axz 138 x 28 COMPRESSOR AT 1770 RPM

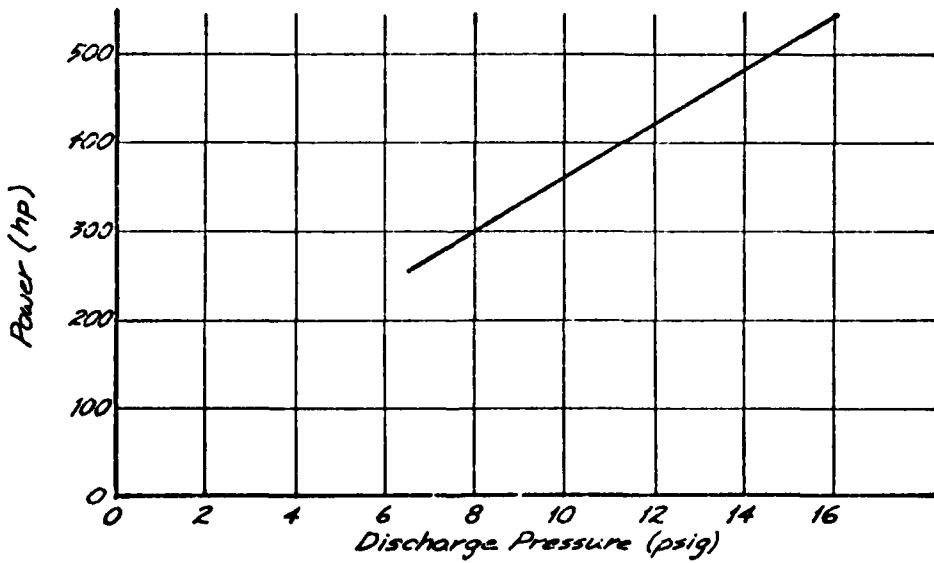


FIGURE 3
 POWER VS DISCHARGE PRESSURE
 FOR INGERSOLL-RAND TYPE L Axz 138 x 28 COMPRESSOR AT 1770 RPM

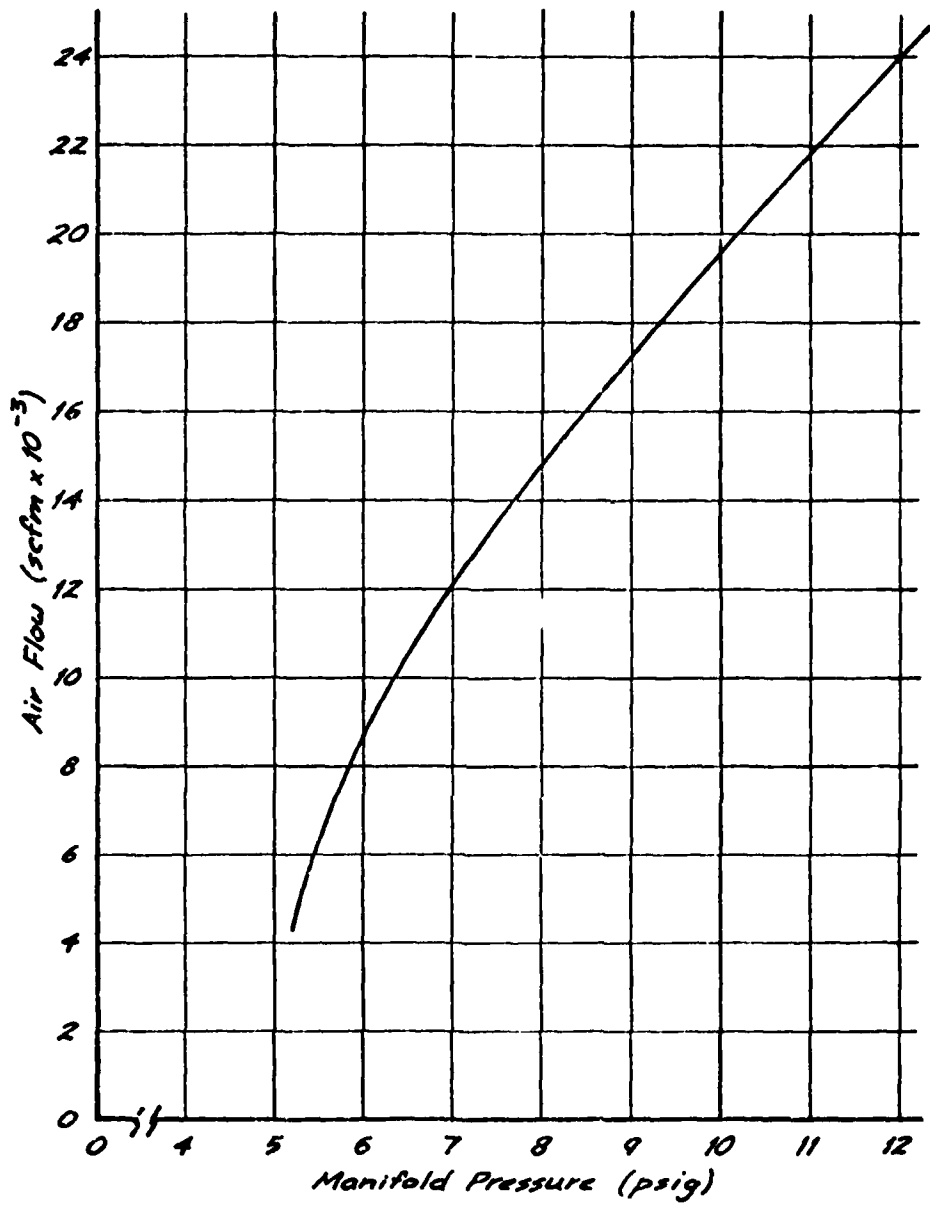


FIGURE 4
AIR FLOW CHARACTERISTIC WITH ALL MANIFOLDS

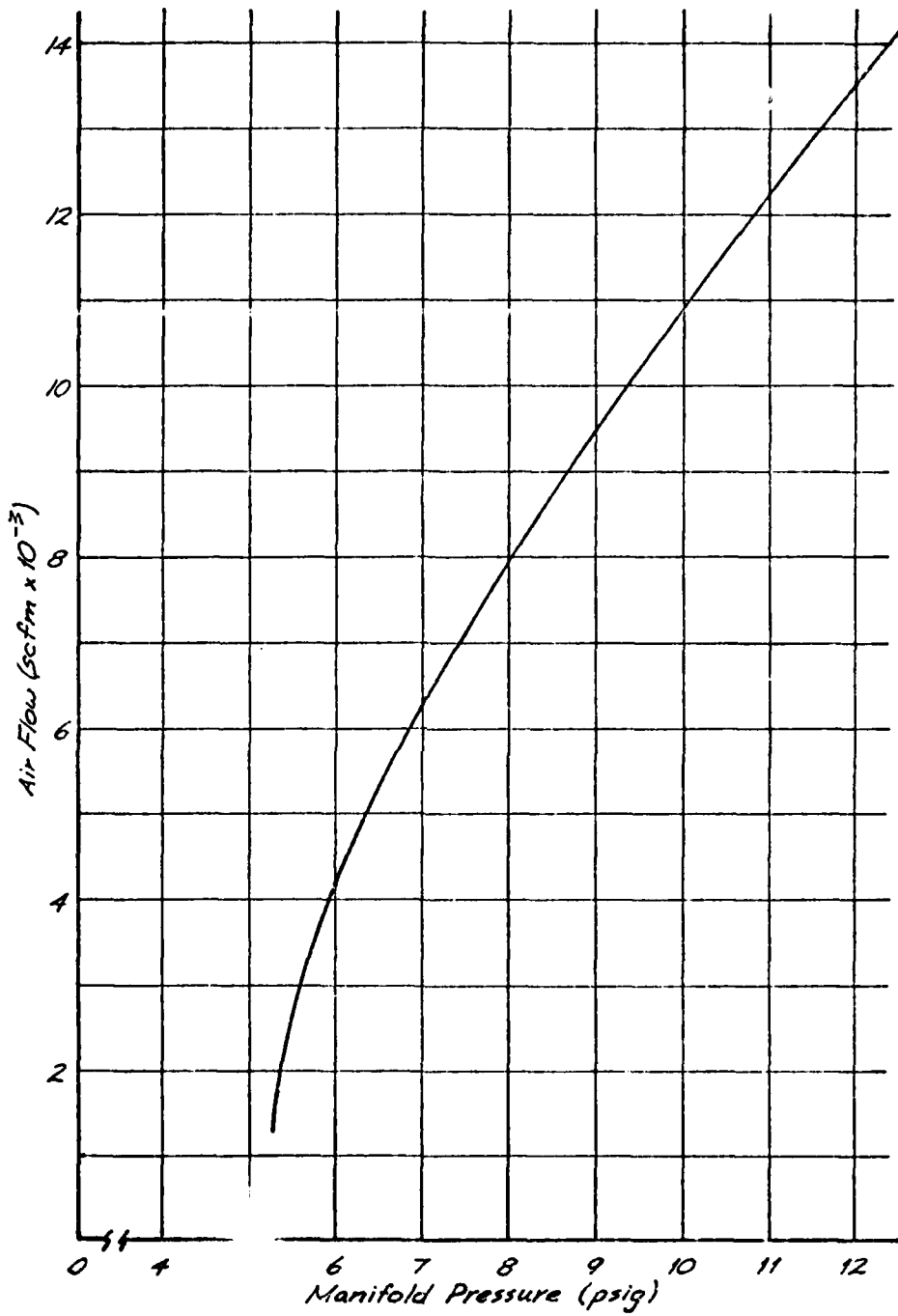


FIGURE 5
AIR FLOW CHARACTERISTIC WITH TWO EOW MANIFOLDS

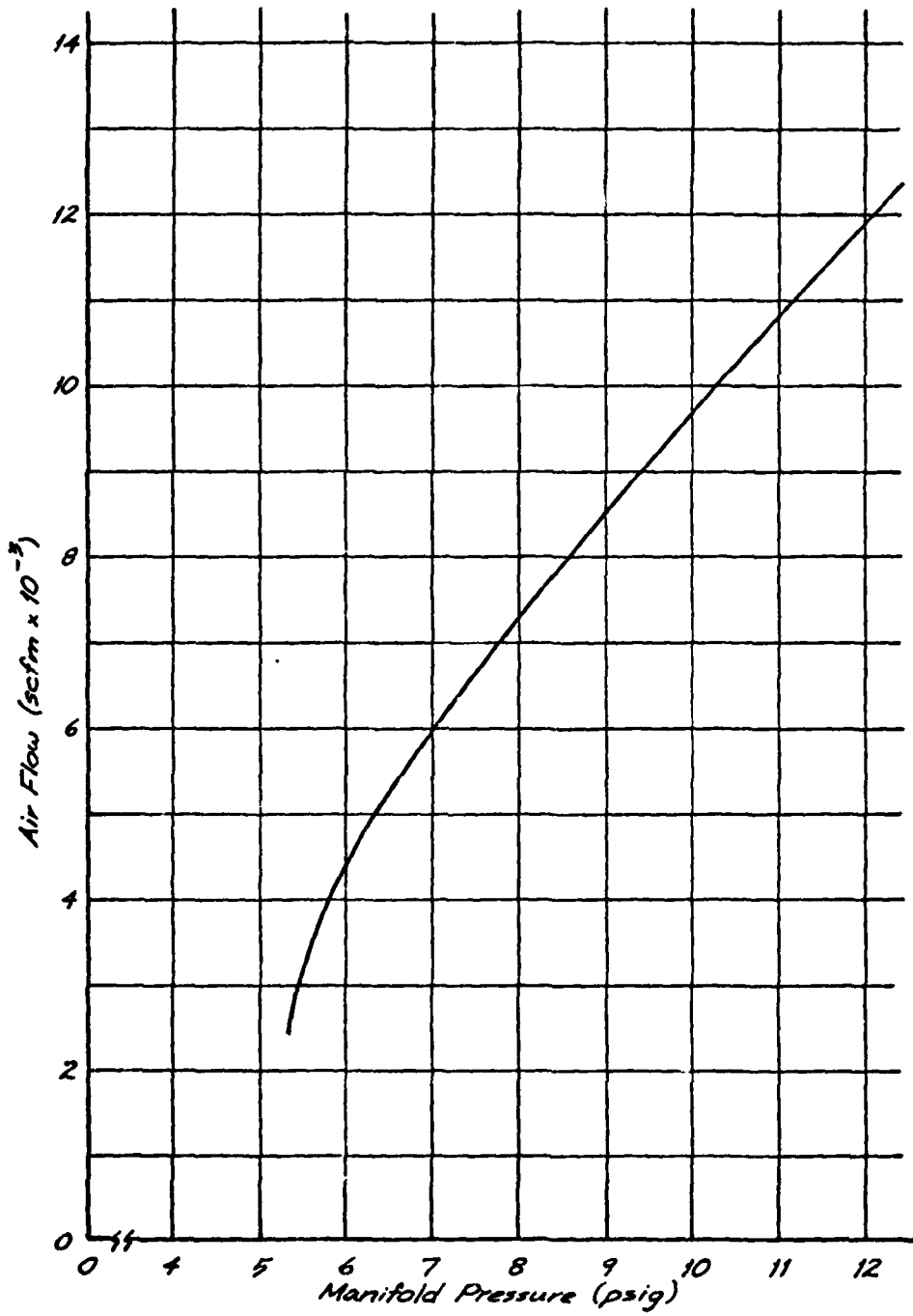


FIGURE 6
AIR FLOW CHARACTERISTIC WITH PORT OR STARBOARD MANIFOLDS

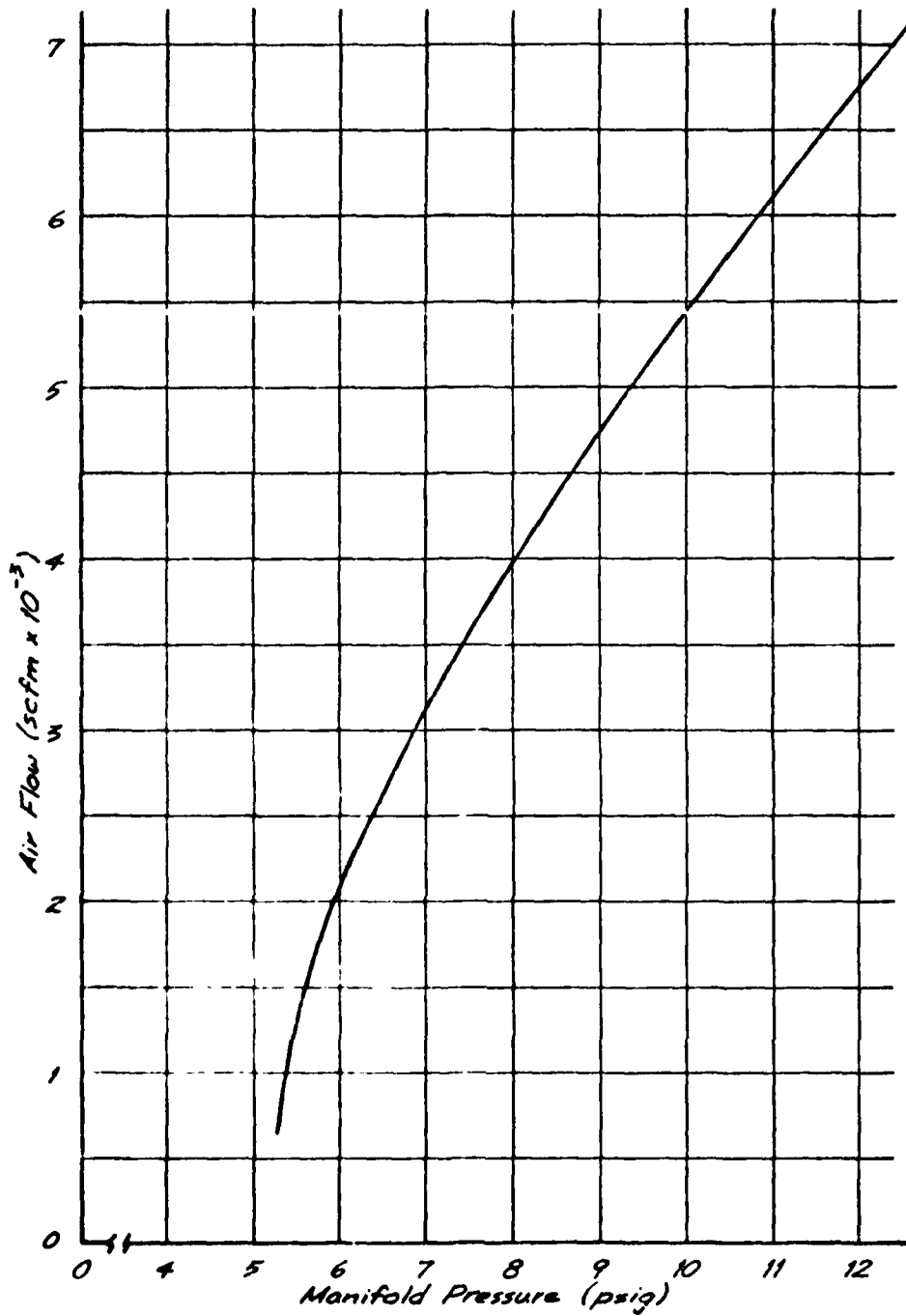


FIGURE 7
AIR FLOW CHARACTERISTIC OF ONE BOW MANIFOLD

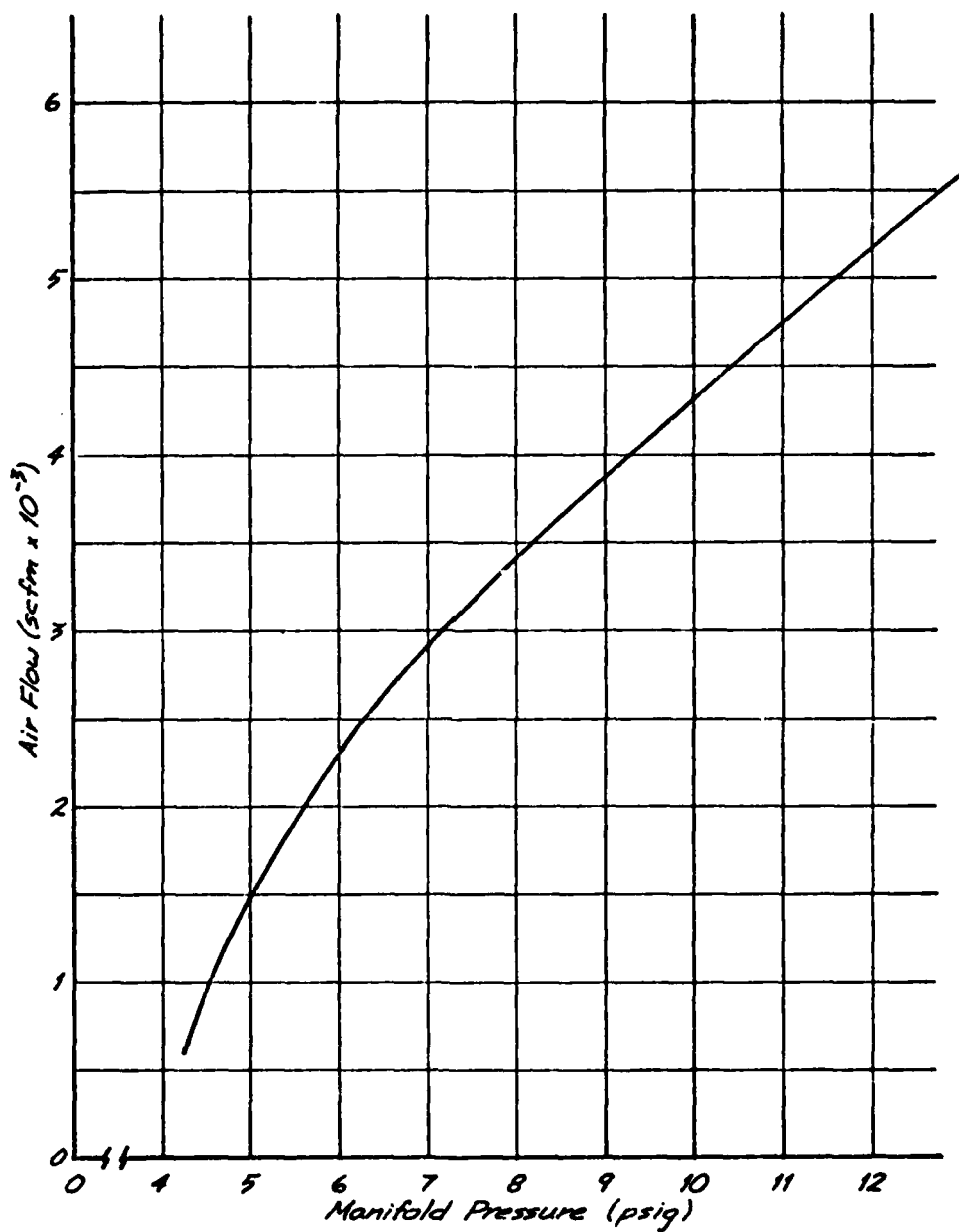


FIGURE 8
AIR FLOW CHARACTERISTIC OF ONE AFT MANIFOLD

III. DESIGN HISTORY

System Capacity

The only published data of operating experience with air bubbler systems has been from two experimental programs. The first was the U.S. Coast Guard testing program with the USCGC SUNDEW and the second was the MARAD testing program with the SS LEON FRASER (Reference 1). Neither program resulted in a specific criterion for establishing the capacity of a system; however, engineering judgement has led to a rule-of-thumb which sets the minimum capacity as one SCFS per foot of ship covered by the manifolds. The manifolds on the WYTM will extend for about 80 feet of the length of the ship. Using this rule-of-thumb, the minimum capacity would be approximately 5000 SCFM.

Other factors which must be considered are the operating pressure of the system, the capacity of air compressors available, and the ratings of diesel engines which are candidates as prime movers. Taking these factors into consideration and allowing a margin for test purposes, the system capacity was set at 7500 SCFM at 9 psig with a prime mover of 350 HP.

Size and Spacing of Orifices

The air flow rate, system pressure, and the size and spacing of the orifices are all interrelated. To solve this problem, two computer programs are available. The first determines the orifice diameter for a given flow rate, and the second calculates the flow rate for a manifold with given orifice diameters.

The programs are written utilizing three fundamental equations. The flow through an orifice is calculated using the following relationship:

$$q = C_D A_0 \sqrt{\frac{2}{\rho} \Delta P_0} \quad (1)$$

The pressure at any point in the manifold is a function of friction losses and head gain due to reduced velocities in the manifold between orifices (References 2 and 3). The equation for friction loss is:

$$\Delta P \text{ friction} = f \frac{\rho L V_1^2}{2d} \quad (2)$$

and the equation for the head increase due to deceleration is:

$$\Delta P \text{ deceleration} = \frac{\rho}{2} v_1^2 \left[2 \frac{q}{Q_1} - (1 + K) \times \left(\frac{q}{Q_1} \right)^2 \right] \quad (3)$$

Starting at the dead end of the manifold and working towards the supply end, the flow at each orifice is calculated knowing the pressure in the manifold at that orifice and the hydrostatic pressure outside the manifold at that orifice. Summing the flows from each orifice gives the total flow, and the pressure at the last orifice is the supply pressure.

Initial investigations for this design considered orifice spacing of 1, 2, 6, and 10 feet. The spacing on the SUNDEW was 12, 14-1/2, and 16 inches, depending on the manifold location. The spacing on the LEON FRASER was every 2 feet, and this spacing resulted in a very uniform distribution. Greater spacing on the WYTM was considered to reduce the number of orifices. Calculations for spacing of 4-1/2 feet and 6 feet were performed in the final design stages. The results of these calculations are in Appendix B. Orifice spacing of 6 feet was the final selection for the WYTM.

The manifold pressure is a function of the total orifice area. Small orifices with higher manifold pressures result in a very uniform flow distribution which is not very sensitive to changes in pressure; however, this requires more horsepower to achieve a given flow rate. In this design for the WYTM a large, total orifice area was utilized to keep the compressor power requirements within limits.

Piping System Design

For analysis of the pressure drop in the air piping system, the system was divided into the six sections listed in Table IV and indicated in Figure 1. Air flow calculations were performed for each mode of operation with the results tabulated in Tables V, VI, and VII. An absolute roughness of .005 feet for galvanized pipe was used in all of the calculations.

TABLE IV
AIR PIPING SYSTEM DESCRIPTION

Section No.	Description	I.D. (inches)	Length (feet)	Fittings	L/D
1	12" SCH 40	12.00	16	TEE (branch) ELL (LR)	60 20
2	10" SCH 40	10.02	30	TEE (branch) ELL (LR)	60 20
3	8" SCH 40	7.981	30	TEE (run) ELL (LR) ELL (LR)	20 20 20
4	8" SCH 80	7.625	15	45° ELL 45° ELL Butterfly Valve	16 16 20
5	8" SCH 40	7.981	2	TEE (branch) ELL (LR)	60
6	8" SCH 80	7.625	16	45° ELL 45° ELL Butterfly Valve	16 16 20

TABLE V
PRESSURE DROP IN PIPING FOR MODE 1 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	7500	180	6	.28
2	3750	180	6	.18
3	1700	180	6	.10
4	1700	120	6	.08
5	2050	180	6	.10
6	2050	120	6	.11

TABLE VI
PRESSURE DROP IN PIPING FOR MODE 2 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	7500	180	9	.26
2	3750	180	9	.18
3	3750	180	9	.41
4	3750	120	8	.34

TABLE VII

PRESSURE DROP IN PIPING FOR MODE 3 AND 4 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	6750	180	9	.21
2	6750	180	9	.56
3	3550	180	9	.37
4	3550	120	9	.30
5	3200	180	9	.21
6	3200	120	8	.25

REFERENCES

1. Levine, G.H., Voelker, R.P., Mentz, P.B., "Advances in the Development of Commercial Ice-Transiting Ships," SNAME Transactions, Volume 82, 1974.
2. Keller, J.D., "The Manifold Problem," Journal of Applied Mechanics, March, 1949.
3. McNown, J.S., "Mechanics of Manifold Flow," Trans. ASCE, 1953.

APPENDIX A

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TABLE A-1.

ALTERNATE FORWARD MANIFOLDS, PORT AND STARBOARD
4-1/2-FOOT ORIFICE SPACING

<u>Orifice No.</u>	<u>Location (Frame No.)</u>	<u>Diameter (inches)</u>
1	10 - 11	1.750
2	13 - 14	1.750
3	16 - 17	1.750
4	19 - 20	1.875
5	22 - 23	1.875
6	25 - 28	1.875
7	28 - 29	1.875

SUPPLY AT AFT END OF MANIFOLD.

TABLE A-2.

ALTERNATE AFT MANIFOLDS, PORT AND STARBOARD
4-1/2-FOOT ORIFICE SPACING

<u>Orifice No.</u>	<u>Location (Frame No.)</u>	<u>Diameter (inches)</u>
1	32 - 33	1.315
2	35 - 36	1.438
3	38 - 39	1.438
4	41 - 42	1.438
5	44 - 45	1.438
6	47 - 48	1.438
7	50 - 51	1.438
8	53 - 54	1.438
9	56 - 57	1.438
10	59 - 60	1.315

SUPPLY BETWEEN ORIFICES NO. 5 AND 6.

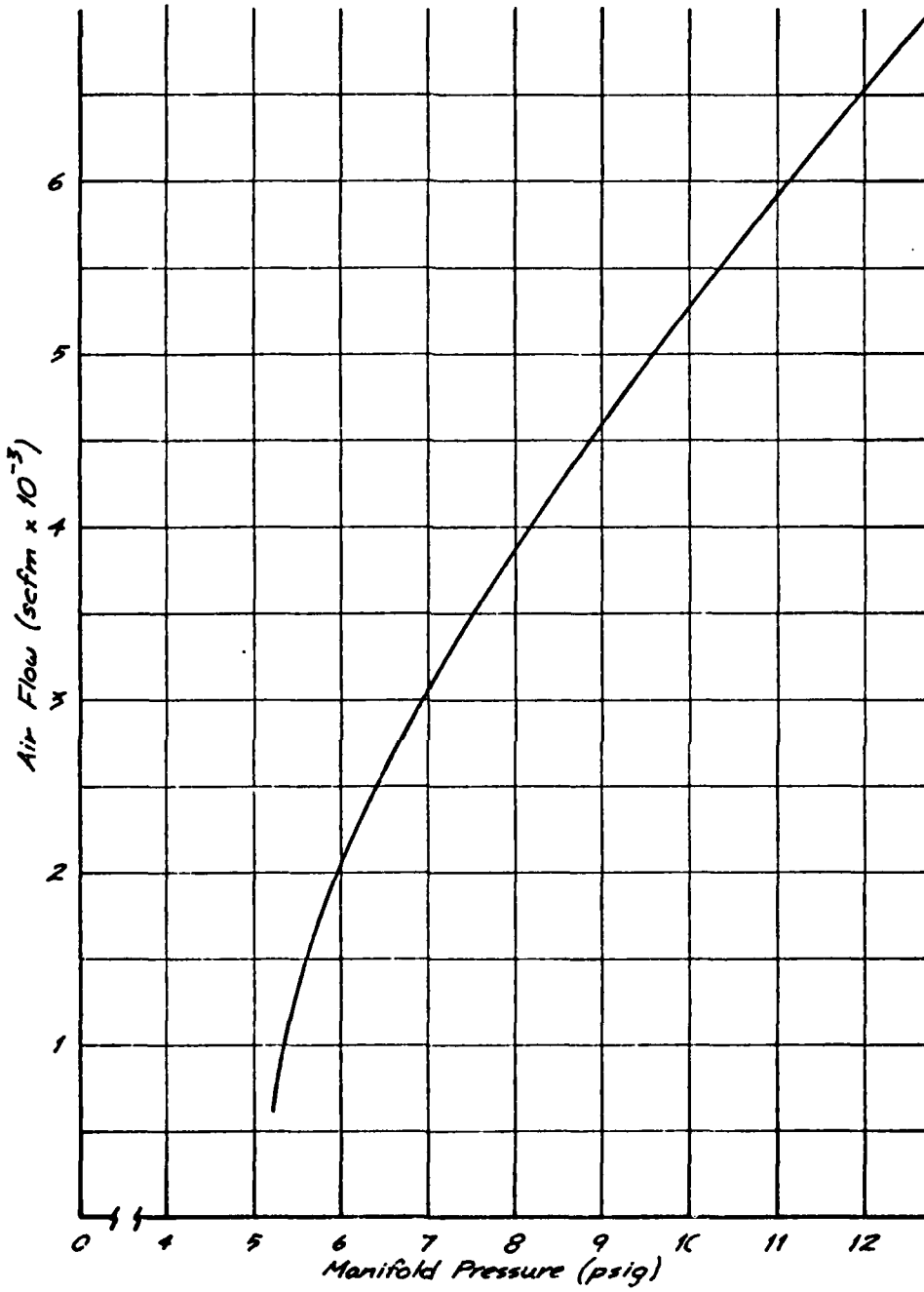


FIGURE A-1
ALTERNATE BOW MANIFOLD AIR FLOW CHARACTERISTIC

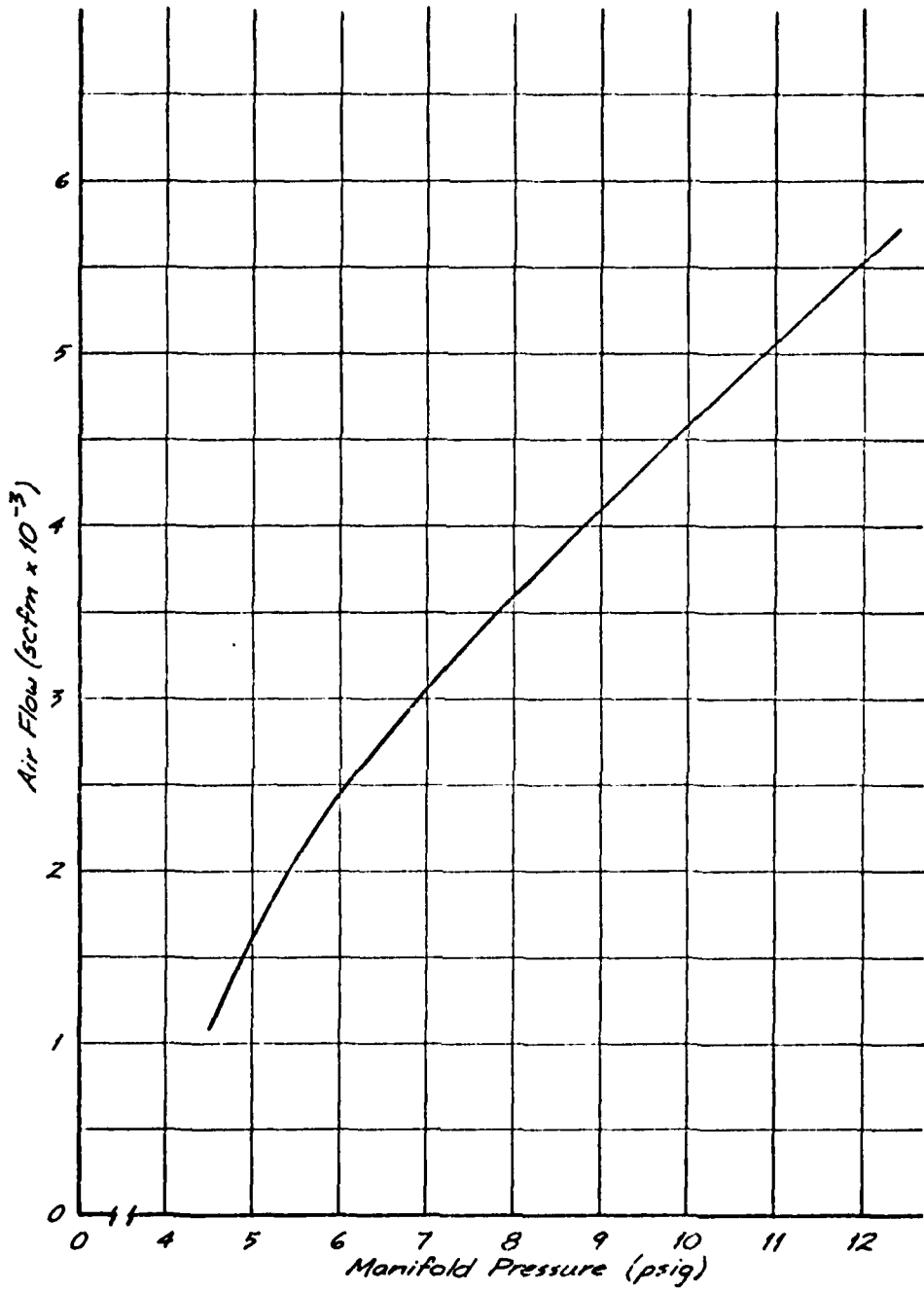


FIGURE A-2
ALTERNATE AFT MANIFOLD AIR FLOW CHARACTERISTIC

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TABLE B-1 FORWARD MANIFOLD, 6-FOOT ORIFICE SPACING

CALCULATION OF MANIFOLD FLOW		3/ 5/75
SPECIFIED ORIFICE DIAMETERS		
SUPPLY RT ORIFICE	6	
NUMBER OF ORIFICES	6	
ORIFICE SPACING	6.0	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	30.0	FT
MANIFOLD AREA	15.0	SQ IN
MANIFOLD HYDRAULIC DIA	3.7	IN
ROUGHNESS	0.00015	FT
AREA RATIO	1.260	
LENGTH/DIAMETER RATIO	97.3	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC ♦ 10000
PRESS/FT OF WATER	0.433	PSI/FT
DRI DIAMETER	DEPTH	
NO.	(INCHES)	(FEET)
1	1.875	11.8
2	1.875	11.8
3	2.000	11.8
4	2.000	11.9
5	2.125	12.0
6	2.125	12.0

TABLE B-1 (continued)

LOCATION 1 IS IN MANIFOLD REPRESENTING ORIFICE
 LOCATION 2 IS IN MANIFOLD REPRESENTING ORIFICE
 LOCATION 3 IS OUTSIDE OF ORIFICE

ORF NO.	W1 (FPS)	Q3 (SCFS)	Q2 NORMAL	P1 (PSI)	P3 (PSI)	AIR TEN (SLUGS/FT ³)	F FACT	REF NO.
1	14.52	2.1272	1.0000	5.295	5.113	0.00336	0.0334	0.4042 05
2	28.04	2.1068	0.9858	5.293	5.113	0.00329	0.0309	0.2032 05
3	44.73	2.3079	1.0089	5.295	5.113	0.00329	0.0181	0.1534 05
4	59.17	1.9750	0.9745	5.275	5.175	0.00329	0.0192	0.1332 05
5	70.17	1.7291	0.9294	5.275	5.200	0.00329	0.0198	0.1332 05
6	82.61	1.7770	0.9384	5.275	5.200	0.00329	0.0195	0.1332 05

TOTAL AIR FLOW 295.56 SCFM

ORF NO.	W1 (FPS)	Q3 (SCFS)	Q2 NORMAL	P1 (PSI)	P3 (PSI)	AIR TEN (SLUGS/FT ³)	F FACT	REF NO.
1	95.74	5.5295	1.0000	6.250	5.113	0.00346	0.0302	0.1042 05
2	70.94	5.4991	0.9851	6.250	5.113	0.00315	0.0197	0.2032 05
3	110.18	2.0077	1.0019	6.203	5.113	0.00344	0.0181	0.1534 05
4	147.57	5.7095	1.0330	6.144	5.156	0.00343	0.0172	0.1332 05
5	182.51	5.1111	1.1067	6.033	5.200	0.00343	0.0175	0.1332 05
6	226.53	5.9171	1.0004	6.044	5.200	0.00342	0.0174	0.1332 05

TOTAL AIR FLOW 2027.29 SCFM

TABLE B-1 (continued)

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	F1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FACT	REV NO.
1	47.40	7.6687	1.0000	7.283	5.113	0.00352	0.0194	0.145E 06
2	94.20	7.5491	0.9844	7.221	5.113	0.00361	0.0182	0.267E 06
3	146.25	8.3559	1.0897	7.118	5.113	0.00354	0.0177	0.444E 06
4	196.40	8.0124	1.0448	7.009	5.156	0.00358	0.0174	0.593E 06
5	250.58	8.6074	1.1224	6.887	5.200	0.00356	0.0173	0.753E 06
6	303.47	8.3692	1.0913	6.801	5.200	0.00354	0.0172	0.903E 06

TOTAL AIR FLOW 2913.82 SCFM

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FACT	REV NO.
1	55.98	9.4640	1.0000	8.275	5.113	0.00378	0.0190	0.179E 06
2	111.27	9.3105	0.9838	8.185	5.113	0.00377	0.0179	0.354E 06
3	172.81	10.2981	1.0379	8.034	5.113	0.00375	0.0175	0.547E 06
4	232.37	9.8935	1.0454	7.873	5.156	0.00372	0.0173	0.730E 06
5	297.01	10.6512	1.1254	7.691	5.200	0.00369	0.0172	0.926E 06
6	360.13	10.3399	1.0924	7.560	5.200	0.00367	0.0171	0.112E 07

TOTAL AIR FLOW 3597.26 SCFM

TABLE B-1 (continued)

ERI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LBS/FT ³)	F FRACT	KEY NO.
1	63.82	11.0793	1.0000	9.267	5.113	0.00395	0.0137	0.2105 04
2	124.90	10.8428	0.9833	9.149	5.113	0.00393	0.0128	0.4152 06
3	194.06	12.0355	1.0503	8.950	5.113	0.00390	0.0174	0.5202 08
4	261.17	11.5732	1.0448	8.737	5.156	0.00386	0.0172	0.8532 09
5	334.21	12.4308	1.1252	8.464	5.200	0.00382	0.0171	0.1932 07
6	405.54	12.0503	1.0502	8.514	5.200	0.00379	0.0170	0.1302 07

TOTAL RIP FLOW: 4202.04 SCFM

ERI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LBS/FT ³)	F FRACT	KEY NO.
1	68.52	12.5341	1.0000	10.259	5.113	0.00411	0.0135	0.2332 04
2	138.86	12.3673	0.9833	10.113	5.113	0.00409	0.0176	0.4702 06
3	211.74	13.6518	1.0349	9.884	5.113	0.00405	0.0173	0.7342 08
4	285.21	12.1291	1.0423	9.501	5.156	0.00400	0.0171	0.8532 09
5	362.21	14.1129	1.1252	9.259	5.200	0.00395	0.0170	0.1232 07
6	442.23	12.1291	1.0502	9.077	5.200	0.00392	0.0170	0.1142 07

TOTAL RIP FLOW: 4774.12 SCFM

TABLE B-1 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	73.39	14.0140	1.0000	11.252	5.113	0.00427	0.0183	0.265E 06
2	145.98	13.7663	0.9823	11.076	5.113	0.00425	0.0175	0.524E 06
3	226.97	15.1844	1.0835	10.782	5.113	0.00420	0.0172	0.805E 06
4	305.83	14.6009	1.0419	10.465	5.156	0.00415	0.0171	0.107E 07
5	391.99	15.7236	1.1220	10.101	5.200	0.00409	0.0170	0.135E 07
6	476.24	15.2101	1.0854	9.835	5.200	0.00404	0.0169	0.153E 07

TOTAL AIR FLOW 5309.95 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	77.64	15.3894	1.0000	12.244	5.113	0.00444	0.0182	0.291E 06
2	154.45	13.1116	0.9819	12.040	5.113	0.00440	0.0175	0.575E 06
3	240.21	16.6563	1.0923	11.793	5.113	0.00435	0.0172	0.882E 06
4	323.82	15.0119	1.0314	11.303	5.156	0.00429	0.0170	0.117E 07
5	415.32	17.2373	1.1200	10.969	5.200	0.00422	0.0170	0.148E 07
6	504.83	16.5578	1.0824	10.593	5.200	0.00417	0.0169	0.173E 07

TOTAL AIR FLOW 5923.89 SCFM

TABLE B-1 (continued)

DPI NO.	V1 (FPS)	O2 (CLFS)	O3 NORMAL	F1 (PSI)	P3 (PSI)	HIF IEN (CLUG/ET3)	F FEET	REV NO.
1	81.98	16.7251	1.0000	13.236	5.113	0.00450	0.0131	0.318E 06
2	151.92	15.4153	0.9815	13.074	5.113	0.00456	0.0174	0.684E 06
3	251.90	16.0814	1.0011	12.614	5.113	0.00490	0.0171	0.532E 06
4	339.73	17.3770	1.0990	12.142	5.156	0.00443	0.0170	0.127E 07
5	435.96	18.4978	1.1179	11.708	5.200	0.00433	0.0159	0.159E 07
6	530.16	18.0542	1.0795	11.351	5.200	0.00439	0.0159	0.153E 07

TOTAL RIP FLOW 6321.12 SCFN

TABLE B-2 AFT MANIFOLD 6-FOOT ORIFICE SPACING, ORIFICES NO. 1-4

CALCULATION OF MANIFOLD FLOW 3/ 6/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 4

NUMBER OF ORIFICES 4 FT
 ORIFICE SPACING 6.0 FT
 DISCHARGE COEFFICIENT 0.620

MANIFOLD LENGTH 18.0 FT
 MANIFOLD AREA 37.7 SQ IN
 MANIFOLD HYDRAULIC DIA 5.8 IN
 ROUGHNESS 0.00015 FT

AREA RATIO 0.196
 LENGTH/DIAMETER RATIO 37.2
 K 0.400

AIR TEMPERATURE 50.0 DEGREES F
 AIR VISCOSITY 0.0365 SLUGS/FT-SEC+10000
 PRESSURE OF WATER 0.433 PSI/FT

ORI DIAMETER DEPTH

NO. (INCHES) (FEET)
 1 1.438 8.8
 2 1.562 9.3
 3 1.562 9.6
 4 1.562 9.8

TABLE B-2 (continued)

LOCATION 1 IS IN MANHOLE 2 APPROXIMATE CRIPICE
 LOCATION 2 IS IN MANHOLE 3 APPROXIMATE CRIPICE
 LOCATION 3 IS OUTSIDE OF CRIPICE

DEI NO.	V1 (FPS)	D3 (SCFS)	D3 NORMAL	F1 (PSI)	P3 (PSI)	RIP DEM (SLUG-FT ³)	F FACT	REV NO.
1	5.90	2.6304	1.0000	4.345	3.813	0.00314	0.0254	0.245E 05
2	11.27	1.2910	0.3090	4.345	4.050	0.00314	0.0252	0.188E 05
3	15.08	1.4473	0.6557	4.345	4.150	0.00314	0.0210	0.609E 05
4	18.37	1.0530	0.5061	4.345	4.245	0.00314	0.0304	0.753E 05

TOTAL RIP FLOW 388.30 SCFM

DEI NO.	V1 (FPS)	D3 (SCFS)	D3 NORMAL	F1 (PSI)	P3 (PSI)	RIP DEM (SLUG-FT ³)	F FACT	REV NO.
1	2.76	3.6190	1.0000	5.345	3.813	0.00300	0.0336	0.427E 05
2	20.40	3.2604	1.0005	5.345	4.050	0.00300	0.0124	0.098E 05
3	30.84	3.7480	1.0560	5.329	4.150	0.00300	0.0187	0.134E 05
4	40.25	3.5082	0.9949	5.314	4.245	0.00300	0.0181	0.175E 05

TOTAL RIP FLOW 895.31 SCFM

TABLE B-2 (continued)

DPI NO.	V1 (FPS)	V3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FRCT	REY NO.
1	12.24	4.7549	1.0000	6.345	3.813	0.00347	0.0215	0.552E 05
2	26.06	5.3769	1.1285	6.340	4.030	0.00347	0.0190	0.120E 06
3	39.45	5.2131	1.0941	6.333	4.160	0.00347	0.0180	0.181E 06
4	52.56	5.0954	1.0594	6.323	4.246	0.00346	0.0174	0.241E 06

TOTAL AIR FLOW 1227.01 SCFM

DPI NO.	V1 (FPS)	V3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FRCT	REY NO.
1	14.12	5.7592	1.0000	7.345	3.813	0.00363	0.0209	0.679E 05
2	30.28	6.5642	1.1432	7.338	4.030	0.00363	0.0185	0.145E 06
3	46.09	6.4404	1.1183	7.326	4.160	0.00363	0.0176	0.221E 06
4	61.65	6.3351	1.1000	7.312	4.246	0.00363	0.0171	0.292E 06

TOTAL AIR FLOW 1507.13 SCFM

TABLE B-2 (continued)

CDI NO.	VI (\$)	OS (\$)	OS (%)	PI (%)	PS (%)	ATP (M) (PLUS FTS)	F FBT	REV NO.
1	15.45	1.000	1.000	3.244	3.244	0.0000	0.0000	0.0000
2	20.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
3	25.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
4	30.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
5	35.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
6	40.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
7	45.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
8	50.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
9	55.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
10	60.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
TOTAL FOR FLD		1750.00	100%	100%				

CDI NO.	VI (\$)	OS (\$)	OS (%)	PI (%)	PS (%)	ATP (M) (PLUS FTS)	F FBT	REV NO.
1	10.00	1.000	1.000	3.244	3.244	0.0000	0.0000	0.0000
2	15.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
3	20.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
4	25.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
5	30.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
6	35.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
7	40.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
8	45.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
9	50.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
10	55.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
11	60.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
12	65.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
13	70.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
14	75.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
15	80.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
16	85.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
17	90.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
18	95.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
19	100.00	1.000	1.000	3.244	4.178	0.0000	0.0000	0.0000
TOTAL FOR FLD		1750.00	100%	100%				

TABLE B-2 (continued)

QPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIP DEN (CLUS/FT ³)	F FACT	REV NO.
1	18.02	9.2463	1.0000	10.244	3.813	0.00413	0.0196	0.0145 05
2	38.94	9.8831	1.1602	10.270	4.030	0.00412	0.0177	0.0136 06
3	59.62	9.5514	1.1456	10.308	4.160	0.00412	0.0169	0.0127 07
4	80.11	9.4525	1.1342	10.289	4.246	0.00411	0.0165	0.0113 08
TOTAL AIP FLOW			2223.45	SCFM				

QPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIP DEN (CLUS/FT ³)	F FACT	REV NO.
1	18.58	9.1292	1.0000	11.243	3.813	0.00422	0.0123	0.1182 06
2	41.06	10.5268	1.1629	11.228	4.030	0.00424	0.0175	0.2309 06
3	62.91	10.5078	1.1497	11.302	4.160	0.00422	0.0149	0.2372 06
4	84.59	10.4103	1.1394	11.279	4.246	0.00422	0.0164	0.4122 06
TOTAL AIP FLOW			2441.20	SCFM				

TABLE B-2 (continued)

DEI NO.	M1 (WFO)	Q3 (SCFD)	Q3 NORMAL	P1 (R1)	P2 (R2)	PIP DEN (SLUG-FT3)	F FRACT	REV NO.
1	19.98	9.9119	1.0000	13.341	1.113	0.00449	0.019	0.117E 06
2	43.98	11.5445	1.1848	13.328	1.113	0.00449	0.0173	0.253E 06
3	65.91	11.4772	1.1869	13.324	1.113	0.00449	0.0167	0.385E 06
4	86.85	11.3897	1.1893	13.321	1.113	0.00449	0.0161	0.521E 06

TOTAL HIP FLOW 2652.93 SCFM

DEI NO.	M1 (WFO)	Q3 (SCFD)	Q3 NORMAL	P1 (R1)	P2 (R2)	PIP DEN (SLUG-FT3)	F FRACT	REV NO.
1	20.97	10.9879	1.1796	13.322	1.113	0.00449	0.0199	0.135E 06
2	44.99	12.4422	1.1863	13.323	1.113	0.00449	0.0173	0.273E 06
3	68.40	12.3352	1.1854	13.320	1.113	0.00449	0.0169	0.413E 06
4	93.07	12.2326	1.1844	13.323	1.113	0.00449	0.0163	0.551E 06

TOTAL HIP FLOW 2659.91 SCFM

TABLE B-3 AFT MANIFOLD, 6-FOOT ORIFICE SPACING, ORIFICES NO. 5-8

CALCULATION OF MANIFOLD FLOW		34 6475
SPECIFIED ORIFICE DIAMETERS		
SUPPLY AT ORIFICE	4	
NUMBER OF ORIFICES	4	
ORIFICE SPACING	6.0	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	18.0	FT
MANIFOLD AREA	37.7	SQ IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.196	
LENGTH DIAMETER RATIO	37.2	
	0.499	
AIR TEMPERATURE	59.0	DEGREES F
AIR VISCOSITY	0.0385	SLUGS/FT-SEC * 10000
APPROX OF WATER	0.433	FT/FT
ORIF. DIAMETER	DEPTH	
NO.	MANIFOLD	(FEET)
1	1.438	8.9
2	1.543	9.5
3	1.562	9.8
4	1.562	9.9

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
 LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
 LOCATION 3 IS OUTSIDE OF ORIFICE

TABLE B-3 (continued)

DEI NO.	V1 (FPS)	P2 (CICF)	O3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	5.90	2.0827	1.0000	4.389	3.850	0.00315	0.0234	0.2445 05
2	10.68	1.7526	0.8444	4.389	4.114	0.00315	0.0234	0.4332 05
3	14.47	1.2690	0.6092	4.388	4.249	0.00315	0.0212	0.6032 05
4	17.46	1.0553	0.5057	4.388	4.290	0.00315	0.0202	0.7272 05

TOTAL AIR FLOW 369.94 CFM

DEI NO.	V1 (FPS)	P2 (CICF)	O3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	3.75	2.8219	1.0000	5.389	3.850	0.00331	0.0226	0.4272 05
2	20.29	3.2929	1.0754	5.377	4.116	0.00331	0.0129	0.6175 05
3	24.14	2.5233	1.0129	5.382	4.249	0.00331	0.0127	0.7123 05
4	29.05	2.4134	0.9449	5.377	4.250	0.00331	0.0131	0.1792 05

TOTAL AIR FLOW 893.19 CFM

TABLE B-3 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMPL	P1 (PSID)	P3 (PSID)	AIR DEN (CLUG/FT ³)	F FACT	REY NO.
1	12.23	4.7698	1.0000	6.389	3.856	0.00347	0.0215	0.563E 05
2	25.90	5.3318	1.1178	6.324	4.116	0.00347	0.0190	0.114E 06
3	39.15	5.1665	1.0932	6.375	4.246	0.00347	0.0190	0.130E 06
4	52.24	5.1009	1.0694	6.367	4.290	0.00347	0.0174	0.240E 06

TOTAL AIR FLOW 1222.14 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMPL	P1 (PSID)	P3 (PSID)	AIR DEN (CLUG/FT ³)	F FACT	REY NO.
1	14.11	5.7648	1.0000	7.328	3.856	0.00364	0.0208	0.580E 05
2	30.14	6.5474	1.1358	7.381	4.116	0.00364	0.0185	0.145E 06
3	45.83	6.4027	1.1106	7.370	4.246	0.00364	0.0176	0.221E 06
4	61.37	6.3416	1.1001	7.356	4.290	0.00363	0.0171	0.295E 06

TOTAL AIR FLOW 1503.39 SCFM

TABLE B-3 (continued)

DPI NO.	W1 (FPS)	D3 (CFPS)	D3 NORMAL	P1 (PSI)	P3 (PSI)	RIP TEM (LOG/FT)	F FRACT	REV NO.
1	15.53	6.6753	1.0000	8.399	3.899	0.00399	0.0203	U.737E 15
2	33.55	7.5473	1.1456	8.379	4.116	0.00379	0.0131	0.149E 16
3	51.17	7.5149	1.1357	8.364	4.046	0.00364	0.0173	0.257E 16
4	68.86	7.4549	1.1167	8.345	4.290	0.00345	0.0153	0.349E 16
TOTAL RIP FLOW		1797.58	CCFM					

DPI NO.	W1 (FPS)	D3 (CFPS)	D3 NORMAL	P1 (PSI)	P3 (PSI)	RIP TEM (LOG/FT)	F FRACT	REV NO.
1	15.91	7.5932	1.0000	9.397	3.896	0.00397	0.0193	0.589E 05
2	34.40	8.6772	1.1519	9.379	4.116	0.00379	0.0174	0.121E 06
3	53.62	8.5508	1.1351	9.368	4.346	0.00368	0.0171	0.292E 06
4	74.22	8.4304	1.1271	9.305	4.290	0.00364	0.0193	0.592E 06
TOTAL RIP FLOW		1923.12	CCFM					

TABLE B-3 (continued)

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	RIP DEN (CLUG/FT3)	F FACT	REY NO.
1	18.01	8.3535	1.0000	10.387	3.256	0.00413	0.0196	0.285E 06
2	38.84	9.6581	1.1562	10.374	4.116	0.00413	0.0177	0.212E 06
3	59.42	9.5361	1.1416	10.352	4.246	0.00413	0.0169	0.235E 06
4	79.89	9.4751	1.1343	10.324	4.290	0.00412	0.0165	0.435E 06

TOTAL AIR FLOW 2221.37 SCFM

B-18

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	RIP DEN (CLUG/FT3)	F FACT	REY NO.
1	18.96	9.1468	1.0000	11.395	3.256	0.00430	0.0193	0.108E 06
2	40.96	10.6041	1.1593	11.371	4.116	0.00429	0.0175	0.233E 06
3	62.73	10.4849	1.1463	11.346	4.246	0.00429	0.0168	0.256E 06
4	84.38	10.4632	1.1394	11.313	4.290	0.00428	0.0164	0.479E 06

TOTAL AIR FLOW 2439.47 SCFM

TABLE B-3 (continued)

CPI NO.	VI (FPS)	03 (CFPS)	03 NORMAL	P1 (in)	P2 (FPS)	P3 (FPS)	RIP ISH (SLUG-FT ³)	F FRIT	REV NO.
1	19.81	9.9190			3.856	0.00445		0.0141	0.117E 06
2	48.88	11.5637			4.116	0.00445		0.0142	0.233E 06
3	55.64	11.4060	1.1477	16.305	4.249	0.00445		0.0147	0.337E 06
4	86.26	11.2414	1.1473	12.302	4.290	0.00445		0.0153	0.520E 06
TOTAL RIP FLOW				2951.44	117PM				

CPI NO.	VI (FPS)	03 (CFPS)	03 NORMAL	P1 (in)	P2 (FPS)	P3 (FPS)	RIP ISH (SLUG-FT ³)	F FRIT	REV NO.
1	20.56	10.6768	1.0000	13.206	3.876	0.00445		0.0133	0.125E 06
2	50.00	12.2289	1.1607	13.245	4.116	0.00445		0.0139	0.273E 06
3	78.24	12.1001	1.1527	13.213	3.846	0.00445		0.0133	0.431E 06
4	91.08	12.2391	1.1484	13.252	4.290	0.00445		0.0132	0.531E 06
TOTAL RIP FLOW				2956.14	117PM				

TABLE B-4 ALTERNATE FORWARD MANIFOLD, 4½-FOOT ORIFICE SPACING

CALCULATION OF MANIFOLD FLOW		3/4" EDS
SPECIFIED ORIFICE DIAMETERS		
SUPPLY AT ORIFICE	7	
NUMBER OF ORIFICES	7	FT
ORIFICE SPACING	4.5	
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	27.0	FT
MANIFOLD AREA	15.0	SQ IN
MANIFOLD HYDRAULIC DIA	3.7	IN
ROUGHNESS	0.00015	FT
AREA RATIO	1.217	
LENGTH/DIAMETER RATIO	87.6	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC
PRESS/FT OF WATER	0.433	PSI/FT
DRI DIAMETER	DEPTH	
NO.	(INCHES)	(FEET)
1	1.750	11.8
2	1.750	11.8
3	1.750	11.8
4	1.875	11.9
5	1.875	11.9
6	1.875	12.0
7	1.875	12.0

TABLE B-4 (continued)

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
 LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
 LOCATION 3 IS OUTSIDE OF ORIFICE

ORF. NO.	V1 (FPS)	O3 (SCFS)	O3 NORMAL	P1 (PSID)	P2 (PSID)	HIP DEN (SLUG/FT ³)	F FRACT	REV NO.
1	42.26	1.8525	1.0000	5.298	5.113	0.00330	0.0240	0.3522 05
2	57.18	1.8435	0.9879	5.294	5.113	0.00325	0.0213	0.7012 05
3	57.49	1.8114	0.9720	5.289	5.113	0.00329	0.0232	0.1042 06
4	46.47	1.7800	0.9469	5.282	5.158	0.00329	0.0195	0.1262 06
5	61.14	1.7169	0.9213	5.275	5.156	0.00329	0.0191	0.1702 05
6	40.38	1.6773	0.7364	5.274	5.274	0.00329	0.0193	0.1942 06
7	73.52	1.6564	0.7290	5.271	5.269	0.00329	0.0184	0.2212 06

ORF. NO.	V1 (FPS)	O3 (SCFS)	O3 NORMAL	P1 (PSID)	P2 (PSID)	HIP DEN (SLUG/FT ³)	F FRACT	REV NO.
1	61.18	4.8128	1.0000	6.293	5.113	0.00345	0.0205	1.9102 05
2	61.68	4.7559	0.9879	6.286	5.113	0.00345	0.0199	1.1912 05
3	56.31	4.6719	0.9719	6.281	5.113	0.00340	0.0195	0.2402 06
4	123.22	5.1144	1.0329	6.172	5.173	0.00349	0.0179	1.3202 06
5	163.02	4.9134	1.0313	6.113	5.159	0.00349	0.0172	1.2002 05
6	133.67	4.7559	0.9817	6.072	5.200	0.00349	0.0173	1.5912 04
7	213.69	4.6514	0.9615	6.112	5.200	0.00349	0.0173	1.4112 05

TOTAL HIP FLOW 700.65 CFPM

TOTAL HIP FLOW 2020.91 CFPM

TABLE B-4 (continued)

DR1 NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (LBS/FT ³)	F FACT	REV NO.
1	41.93	6.6873	1.0000	7.281	5.113	0.00370	0.0197	0.1252 05
2	82.24	6.6045	0.9876	7.281	5.113	0.00370	0.0197	0.3192 06
3	122.51	6.4806	0.9691	7.195	5.113	0.00370	0.0179	0.5033 06
4	167.18	7.1546	1.0629	7.052	5.154	0.00373	0.0175	0.5033 06
5	210.71	8.2321	1.0774	6.972	5.154	0.00371	0.0173	0.5033 06
6	252.66	8.6592	0.9987	6.894	5.200	0.00368	0.0173	0.5033 05
7	293.79	8.5070	0.9736	6.757	5.200	0.00367	0.0172	0.5033 06

TOTAL AIR FLOW 2821.76 SCFM

DR1 NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (LBS/FT ³)	F FACT	REV NO.
1	48.80	8.2521	1.0000	8.281	5.113	0.00370	0.0192	0.1522 06
2	97.19	8.1471	0.9872	8.281	5.113	0.00370	0.0181	0.3192 06
3	144.74	7.9884	0.9679	8.184	5.113	0.00370	0.0177	0.4822 06
4	197.76	8.8298	1.0711	7.953	5.154	0.00373	0.0174	0.6532 06
5	249.47	8.5609	1.0370	7.798	5.154	0.00371	0.0173	0.7312 06
6	299.53	8.3201	0.9982	7.651	5.200	0.00368	0.0172	0.8032 05
7	348.43	8.0402	0.9742	7.552	5.200	0.00367	0.0171	0.1012 07

TOTAL AIR FLOW 3484.05 SCFM

TABLE B-4 (continued)

QRT NO.	V1 (PPS)	P3 (CCFS)	Q3 (NORMAL)	P1 (PPS)	P3 (PPS)	RIR (DN (SLUB-FT))	F FACT	REF NO.
1	54.77	9.3320	1.0000	9.2079	9.113	0.00399	0.0183	0.1813 09
2	109.46	9.5339	0.9997	9.331	9.113	0.00399	0.0173	0.2058 09
3	163.50	9.3421	0.9999	9.142	9.113	0.00391	0.0179	0.1829 09
4	217.22	10.1155	1.0738	9.343	9.159	0.00399	0.0171	0.1829 09
5	270.91	10.1155	1.0000	9.533	9.159	0.00399	0.0171	0.1829 09
6	324.64	9.2113	0.9999	9.409	9.200	0.00391	0.0171	0.1829 09
7	378.59	9.3336	0.9728	9.314	9.200	0.00399	0.0171	0.1829 09

TOTAL RIR FLOW 4072.10 CFM

QRT NO.	V1 (PPS)	P3 (CCFS)	Q3 (NORMAL)	P1 (PPS)	P3 (PPS)	RIR (DN (SLUB-FT))	F FACT	REF NO.
1	59.74	10.2749	1.0000	10.259	9.113	0.00411	0.0181	0.2058 09
2	118.53	10.2341	0.9998	10.158	9.113	0.00409	0.0179	0.4113 09
3	177.31	10.1109	0.9999	9.990	9.113	0.00401	0.0174	0.2058 09
4	236.59	11.7409	1.0000	9.233	9.159	0.00401	0.0172	0.2058 09
5	295.48	11.7409	1.0000	9.409	9.159	0.00409	0.0171	0.1829 09
6	354.43	10.2113	0.9999	9.209	9.200	0.00401	0.0171	0.1829 09
7	413.37	10.2113	0.9728	9.314	9.200	0.00409	0.0171	0.1829 09

TOTAL RIR FLOW 4420.79 CFM

TABLE B-4 (continued)

CPI NO.	V1 (FPS)	Q3 (SCFM)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT ³)	F FRACT	REY NO.
1	53.98	12.2220	1.0000	11.263	5.113	0.00422	0.0185	0.231E 06
2	127.41	12.0506	0.9860	11.124	5.113	0.00425	0.0177	0.453E 06
3	189.98	11.7951	0.9651	10.918	5.113	0.00422	0.0173	0.677E 06
4	240.10	13.0541	1.0589	10.623	5.156	0.00417	0.0172	0.917E 06
5	328.64	15.6125	1.0324	10.518	5.156	0.00412	0.0171	0.114E 07
6	395.41	12.1558	0.9946	10.044	5.200	0.00408	0.0170	0.126E 07
7	480.56	11.8309	0.9580	9.829	5.200	0.00404	0.0169	0.157E 07

TOTAL AIR FLOW 5144.16 SCFM

CPI NO.	V1 (FPS)	Q3 (SCFM)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT ³)	F FRACT	REY NO.
1	67.68	13.4223	1.0000	12.257	5.113	0.00444	0.0184	0.254E 06
2	134.78	13.2299	0.9857	12.096	5.113	0.00441	0.0176	0.503E 06
3	201.03	12.9427	0.9643	11.856	5.113	0.00437	0.0173	0.743E 06
4	275.34	14.3324	1.0578	11.513	5.156	0.00432	0.0171	0.109E 07
5	348.05	13.8217	1.0305	11.158	5.156	0.00426	0.0170	0.123E 07
6	418.95	13.0520	0.9926	10.828	5.200	0.00421	0.0170	0.149E 07
7	488.60	12.9573	0.9554	10.506	5.200	0.00417	0.0169	0.172E 07

TOTAL AIR FLOW 5642.36 SCFM

TABLE B-5 ALTERNATE AFT MANIFOLD, 4½'-FOOT ORIFICE SPACING, ORIFICES NO. 1-5

CALCULATION OF MANIFOLD FLOW		3/ 8/75
SPECIFIED ORIFICE DIAMETERS		
SUPPLY AT ORIFICE	5	
NUMBER OF ORIFICES	5	
ORIFICE SPACING	4.5	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	19.0	FT
MANIFOLD AREA	97.7	SQ IN
MANIFOLD HYDRAULIC DIP	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.208	
LENGTH/DIAMETER RATIO	97.2	
	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESSURE OF WATER	0.433	PSI/FT
ORIFICE DIAMETER	DEPTH	
NO.	(INCHES)	(FEET)
1	1.315	8.7
2	1.438	9.2
3	1.450	9.5
4	1.452	9.7
5	1.453	9.9

TABLE B-5 (continued)

DEI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FACT	REY NO.
1	10.33	4.0216	1.0000	6.346	3.770	0.00347	0.0222	0.474E 05
2	22.14	4.5952	1.1426	6.342	3.986	0.00347	0.0155	0.102E 06
3	33.40	4.4600	1.1099	6.336	4.116	0.00347	0.0184	0.154E 06
4	44.82	4.3634	1.0850	6.328	4.203	0.00346	0.0177	0.206E 06
5	55.90	4.3066	1.0714	6.319	4.246	0.00346	0.0173	0.256E 06

TOTAL AIR FLOW 1304.93 SCFM

DEI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FACT	REY NO.
1	11.89	4.8492	1.0000	7.345	3.770	0.00363	0.0214	0.572E 05
2	25.66	5.6115	1.1572	7.340	3.986	0.00363	0.0189	0.123E 06
3	34.14	5.4932	1.1328	7.331	4.116	0.00363	0.0179	0.188E 06
4	50.42	5.4074	1.1151	7.320	4.203	0.00363	0.0173	0.252E 05
5	65.53	5.3568	1.1047	7.307	4.246	0.00363	0.0170	0.315E 06

TOTAL AIR FLOW 1503.09 SCFM

TABLE B-5 (continued)

ERI NO.	V1 (FPS)	Q3 (CCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	13.18	5.6052	1.0000	8.345	3.770	0.00280	0.0205	0.5622 05
2	23.50	6.5352	1.1653	8.338	3.956	0.00320	0.0135	0.4733 05
3	43.59	6.4252	1.1454	8.277	4.116	0.00379	0.0175	0.3195 05
4	33.50	6.3452	1.1217	8.312	4.208	0.00379	0.0171	0.2342 05
5	73.31	6.2573	1.1223	8.233	4.243	0.00379	0.0167	0.2642 05

TOTAL AIR FLOW 1372.85 SCFM

ERI NO.	V1 (FPS)	Q3 (CCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	14.22	6.7234	1.0000	9.345	3.770	0.00324	0.0205	0.7462 05
2	20.87	7.3111	1.1704	9.332	3.956	0.00346	0.0182	0.7622 05
3	47.20	7.2623	1.1542	9.170	4.133	0.00379	0.0174	0.2733 05
4	23.57	7.2220	1.1421	9.304	4.203	0.00379	0.0167	0.2733 05
5	74.74	7.1326	1.1342	9.233	4.243	0.00379	0.0167	0.2733 05

TOTAL AIR FLOW 2125.07 SCFM

TABLE B-5 (continued)

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FRACT	REY NO.
1	15.13	7.0981	1.0000	10.344	3.770	0.00412	0.0201	0.827E 05
2	32.90	8.2275	1.1740	10.335	3.986	0.00412	0.0180	0.180E 06
3	50.47	8.1293	1.1600	10.318	4.116	0.00412	0.0172	0.275E 06
4	67.90	8.0542	1.1493	10.296	4.203	0.00412	0.0167	0.370E 06
5	85.23	8.0042	1.1421	10.270	4.246	0.00411	0.0164	0.464E 06

TOTAL AIR FLOW 2365.40 SCFM

DRI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FRACT	REY NO.
1	15.93	7.6705	1.0000	11.344	3.770	0.00429	0.0198	0.905E 05
2	34.68	9.0253	1.1766	11.333	3.986	0.00429	0.0178	0.197E 06
3	52.24	8.9096	1.1642	11.313	4.116	0.00429	0.0170	0.302E 06
4	71.67	8.8556	1.1545	11.298	4.203	0.00429	0.0166	0.406E 06
5	90.01	8.8043	1.1478	11.258	4.246	0.00429	0.0163	0.510E 06

TOTAL AIR FLOW 2597.13 SCFM

TABLE B-5 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FACT	REY NO.
1	16.63	8.3160	1.0000	12.344	3.770	0.00445	0.0196	0.981E 05
2	36.24	9.8013	1.1766	12.331	3.986	0.00445	0.0177	0.214E 06
3	55.68	9.7078	1.1674	12.309	4.116	0.00445	0.0169	0.328E 06
4	74.99	9.6337	1.1585	12.280	4.203	0.00444	0.0165	0.441E 06
5	94.22	9.5810	1.1531	12.245	4.245	0.00444	0.0162	0.554E 06

TOTAL AIR FLOW 2822.39 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUGS/FT ³)	F FACT	REY NO.
1	17.26	8.9483	1.0000	13.343	3.770	0.00462	0.0194	0.108E 06
2	37.63	10.5005	1.1802	13.329	3.986	0.00462	0.0175	0.230E 06
3	57.85	10.4682	1.1699	13.304	4.116	0.00461	0.0168	0.353E 06
4	77.95	10.3939	1.1616	13.272	4.202	0.00461	0.0164	0.472E 06
5	97.96	10.3395	1.1555	13.233	4.246	0.00460	0.0162	0.597E 06

TOTAL AIR FLOW 3042.62 SCFM

TABLE B-6 ALTERNATE AFT MANIFOLD, 4 1/2 - FOOT ORIFICE SPACING, ORIFICES NO. 6-10

CALCULATION OF MANIFOLD FLOW		30 6/75
SPECIFIED ORIFICE DIAMETERS		
SUPPLY AT ORIFICE	5	
NUMBER OF ORIFICES	5	
ORIFICE SPACING	4.5	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	18.0	FT
MANIFOLD POWER	27.7	90 IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.208	
LENGTH/DIAMETER RATIO	32.2	
	0.400	
AIR TEMPERATURE	59.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESSURE OF WATER	0.430	PSI/FT
ORI NO.	DIAMETER (FEET)	DEPTH (FEET)
1	1.315	9.1
2	1.438	9.5
3	1.438	9.8
4	1.438	9.8
5	1.438	9.9

TABLE B-6 (continued)

LOCATION 1 IS IN MAINFOLD APPROXIMATE DRIFICE
 LOCATION 2 IS IN MAINFOLD IMMEDIATELY UPSTREAM OF DRIFICE
 LOCATION 3 IS OUTSIDE OF DRIFICE

DRIFICE NO.	V1 (FPS)	Q1 (SCFM)	Q2 (NORMAL)	P1 (PSID)	P2 (PSID)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	4.52	1.5950	1.0000	4.390	3.943	0.00315	0.0239	0.192E 05
2	8.73	1.4994	0.9338	4.389	4.116	0.00315	0.0234	0.364E 05
3	11.78	1.0757	0.9744	4.389	4.246	0.00315	0.0230	0.491E 05
4	14.82	1.0739	0.6731	4.388	4.246	0.00315	0.0211	0.517E 05
5	17.35	0.8928	0.5597	4.388	4.290	0.00315	0.0216	0.723E 05

TOTAL AIR FLOW 367.59 SCFM

DRIFICE NO.	V1 (FPS)	Q1 (SCFM)	Q2 (NORMAL)	P1 (PSID)	P2 (PSID)	AIR DEN (SLUG/FT ³)	F FRCT	REV NO.
1	7.92	2.9446	1.0500	5.389	3.943	0.00331	0.0205	0.347E 05
2	16.80	3.2980	1.1200	5.387	4.116	0.00331	0.0205	0.735E 05
3	25.20	3.1203	1.0597	5.384	4.246	0.00331	0.0192	0.119E 04
4	33.58	3.1144	1.0577	5.380	4.246	0.00331	0.0185	0.147E 04
5	41.79	3.0475	1.0350	5.375	4.290	0.00331	0.0180	0.163E 04

TOTAL AIR FLOW 931.49 SCFM

TABLE B-6 (continued)

DPI NO.	V1 (FPS)	D3 (SCFS)	D3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FACT	REY NO.
1	10.06	3.9239	1.0000	6.389	3.943	0.00347	0.0223	0.463E 05
2	21.53	4.5148	1.1509	6.363	4.116	0.00347	0.0195	0.995E 05
3	32.96	4.3771	1.1158	6.350	4.246	0.00347	0.0184	0.151E 06
4	44.07	4.3685	1.1136	6.372	4.246	0.00347	0.0178	0.203E 06
5	55.14	4.3137	1.0956	6.363	4.290	0.00347	0.0173	0.253E 06

TOTAL AIR FLOW 1299.82 SCFM

DPI NO.	V1 (FPS)	D3 (SCFS)	D3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT ³)	F FACT	REY NO.
1	11.66	4.7650	1.0000	7.389	3.943	0.00364	0.0215	0.562E 05
2	25.24	5.5441	1.1625	7.334	4.116	0.00364	0.0130	0.122E 06
3	38.52	5.4244	1.1364	7.325	4.246	0.00364	0.0179	0.186E 06
4	51.79	5.4134	1.1361	7.364	4.246	0.00364	0.0174	0.249E 06
5	64.94	5.3627	1.1254	7.351	4.290	0.00363	0.0170	0.312E 06

TOTAL AIR FLOW 1590.57 SCFM

TABLE B-6 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	RIP DEN (SLUG/FT ³)	F FACT	REV NO.
1	12.96	5.5322	1.0000	3.388	3.943	0.00380	0.0209	0.650E 05
2	28.10	6.4760	1.1704	3.302	4.116	0.00360	0.0192	0.142E 05
3	43.05	6.2666	1.1502	3.271	4.245	0.00320	0.0176	0.217E 05
4	57.95	6.3533	1.1482	3.256	4.246	0.00380	0.0171	0.291E 05
5	73.74	6.3032	1.1352	3.234	4.250	0.00380	0.0163	0.363E 05

TOTAL RIP FLOW 1861.96 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	RIP DEN (SLUG/FT ³)	F FACT	REV NO.
1	14.04	6.2504	1.0000	3.392	3.943	0.01397	0.0205	0.702E 05
2	29.54	7.2471	1.1747	3.390	4.116	0.00397	0.0199	0.149E 05
3	46.22	7.2240	1.1523	3.366	4.245	0.00397	0.0171	0.249E 05
4	63.07	7.2040	1.1507	3.348	4.245	0.00395	0.0169	0.331E 05
5	79.23	7.1294	1.1479	3.326	4.250	0.00395	0.0164	0.415E 05

TOTAL RIP FLOW 2115.25 SCFM

TABLE B-6 (continued)

DPI NO.	V1 (FPS)	O3 (CFPS)	O3 NORMAL	P1 (PSID)	P2 (PSID)	AIR DEN (GLUS/FT3)	F FRACT	PEY NO.
1	14.97	8.9445	1.0000	10.393	3.943	0.00413	0.0201	0.819E 05
2	38.60	8.1784	1.1777	10.378	4.116	0.00413	0.0180	0.178E 06
3	50.04	8.0795	1.1635	10.362	4.246	0.00413	0.0172	0.574E 06
4	57.45	8.0617	1.1609	10.349	4.246	0.00413	0.0167	0.353E 06
5	84.77	8.0116	1.1537	10.314	4.290	0.00412	0.0164	0.463E 06

TOTAL AIR FLOW 2356.55 SCFM

DST NO.	V1 (FPS)	O3 (CFPS)	O3 NORMAL	P1 (PSID)	P2 (PSID)	AIR DEN (GLUS/FT3)	F FRACT	PEY NO.
1	15.78	7.6108	1.0000	11.307	3.943	0.00430	0.0199	0.893E 05
2	34.40	8.9795	1.1798	11.376	4.116	0.00430	0.0178	0.192E 06
3	52.84	8.8606	1.1672	11.357	4.246	0.00430	0.0170	0.300E 06
4	71.25	8.8634	1.1646	11.332	4.246	0.00430	0.0166	0.405E 06
5	89.57	8.8122	1.1579	11.302	4.290	0.00430	0.0163	0.503E 06

TOTAL AIR FLOW 2538.96 SCFM

TABLE B-6 (continued)

DFI NO.	VI (FEET)	D3 (FEET)	D3 NORMAL	P1 (FEET)	P3 (FEET)	RIP DEN (CLUSTERS)	F FRCT	REV NO.
1	16.48	6.5734	1.1509	18.387	3.840	0.00448	0.0126	0.2749
2	26.28	9.7513	1.1915	16.324	4.115	0.00426	0.0172	0.2136
3	25.10	9.4644	1.1771	12.283	4.240	0.00409	0.0168	0.2292
4	14.20	4.2419	1.1374	16.332	4.248	0.00442	0.0159	0.2242
5	23.81	9.2028	1.1519	3.808	4.280	0.00418	0.0159	0.2200

TOTAL RIP FLOW 2814.79 100%

DFI NO.	VI (FEET)	D3 (FEET)	D3 NORMAL	P1 (FEET)	P3 (FEET)	RIP DEN (CLUSTERS)	F FRCT	REV NO.
1	17.13	6.3042	1.0900	13.387	3.848	0.00449	0.0124	0.1052
2	27.39	10.5157	1.1398	13.373	4.119	0.00468	0.0173	0.2270
3	27.50	10.2071	1.1281	13.373	4.248	0.00449	0.0168	0.2292
4	17.58	4.2419	1.1374	16.332	4.248	0.00441	0.0163	0.2102
5	27.58	10.2470	1.1418	13.377	4.280	0.00441	0.0163	0.2166

TOTAL RIP FLOW 3025.43 100%