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INTERIM REPORT
SMALL CENTRIFUGAL PUMPS FOR LOW-THRUST ROCKET ENGINES

by

R. B. Furst

Rockwell International
Rocketdyne Division

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16. Abstract

Six small, low specific speed centrifugal pump configurations were designed, fabricated, and tested. The configurations included shrouded, and 25 and 100% admission open face impellers with 2 inch tip diameters; 25, 50, and 100% emission vaned diffusers; and volutes with conical exits. Impeller tip widths varied from 0.030 inch to 0.052 inch. Design specific speeds (N_S = RPM*GPM**0.5/FT**0.75) were 430 (four configurations) and 215 (two configurations).

The six configurations were tested with water as the pumped fluid. Noncavitating performance results are presented for the design speed of 24,500 rpm over a flowrate range from 1 to 6 gpm for the N_S = 430 configurations and test speeds up to 29,000 rpm over a flowrate range from 0.3 to 1.2 gpm for the N_S = 215 configurations. Cavitating performance results are presented over a flowrate range from 60 to 120% of design flow. Fabrication of the small pump components is also discussed.

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SUMMARY

Six small (2-inch tip diameter) low specific speed centrifugal pump configurations were designed, fabricated, and tested pumping water. The configurations included shrouded, and 25 and 100% admission open face impellers, 25 to 100% emission vaned diffusers, and volutes with conical diffusers. Tip widths varied from 0.030 inch to 0.052 inch. Design specific speeds were 430 and 215.

Head, flow, efficiency, and cavitation tests were conducted in water at speeds up to 29,000 rpm.

Test efficiencies for the shrouded 430 specific speed configurations were 28 to 33%. The 215 specific speed configurations obtained efficiencies of only 5 to 10%.

Suction performance was largely better than predicted at 8000 to 11,000, while axial and radial loads were less than predicted.

Best performance was obtained by 430 specific speed configuration 2 with a shrouded impeller discharging into a volute with a conical diffuser.

There appeared to be no difference in the ability to cast the two different tip widths and the smallest (0.030 inch) does not appear to be a limit.

INTRODUCTION

Pump-fed, low-thrust chemical propulsion systems are being considered for transferring acceleration-limited structures from low earth orbit to geosynchronous or other high earth orbits. Engine systems for these applications will require small, relatively low flowrate, high head rise pumps that fall outside the design range of existing rocket engine turbopumps. In order to establish a technology base for future design of these systems, a program was initiated to experimentally evaluate low specific speed centrifugal pump stages and inlet-type stages over the flowrate range of interest. Funding for the program is being provided under NASA-Lewis Research Center contract NAS3-23164 and related effort is being provided by Rocketdyne internal sources.

Contract scope consists of design fabrication and test of six single-stage centrifugal pump test articles, and a conventional inducer. The tester and drive turbine were fabricated and tested as part of a prior company-funded effort. The shear force pump will be tested following completion of the contract effort. The test program was structured to first determine performance of each of the six centrifugal stages with water as the test fluid. Two of the stages will then be tested in liquid hydrogen to determine performance change due to differences in fluid properties such as viscosity and compressibility. The inducer and shear force stage will be tested in liquid hydrogen to determine relative suction performance capability.

The water test program has been completed. This interim report discusses the design and fabrication of the centrifugal stages and presents the water test performance results.

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PUMP CONFIGURATIONS

DESIGN

A design summary of the six centrifugal pump configurations is given in Table 1. Details of the pump geometries are given in Tables 2 and 3. Configurations 1, 2, 4, and 6 were designed for a specific speed of 430 ($rpm * gpm^{0.5}/FT^{0.75}$). Configurations 3 and 5 were designed for a specific speed of 215. All of the pumps incorporated impellers with 2-inch tip diameters. Discharge tip widths ranged from 0.030 to 0.052 inch.

Design details for Configuration 1 are given in Table 2. Pump hardware is shown in Fig. 1. This pump incorporates a 100% admission shrouded impeller discharging into a 100% emission vaned diffuser that discharges into a volute. The impeller is fully shrouded with backwardly curved blades. The vaned diffuser is the vane island type with eight straight mean line diffusing passages machined into the inlet housing rear face. The volute is designed with proportionately larger cross-section area than for a large pump to reduce friction loss. The area distribution is designed to minimize radial load through equalizing static pressure circumferentially. The use of a vaned diffuser produces a nearly constant radial load over a wide flowrange since the diffuser produces a volute velocity matching the flowrate down to the diffuser stall flowrate.

Configuration 2 (Table 2 and Fig. 2) utilizes the same impeller as Configuration 1 but discharges its flow directly into a volute. Diffusion is accomplished by a volute exit conical diffuser.

Configuration 3 (Table 3 and Fig. 3) utilizes the same impeller as Configurations 1 and 2. The impeller discharges through a 25% emission diffuser that has the same diffuser passage geometry as Configuration 1. The diffuser differs in that only two opposite passages were machined as compared to eight for Configuration 1. The intent is to reduce the design flowrate to one-fourth and the specific speed to one-half of that for 100% emission diffuser.

Configuration 4 (Table 2 and Fig. 4) incorporates a 0.035-inch tip width open face impeller with 100% admission that discharges directly into a volute. The diffusion is accomplished by a conical diffuser at the volute exit. The impeller tip width was increased above that for the shrouded impeller to compensate for the open face tip clearance leakage flow.

Configuration 5 (Table 3 and Fig. 5) incorporates a 25% admission open face impeller that discharges directly into a volute-shaped passage to minimize hydrodynamic radial loads. The impeller passage geometry is the same as for Configuration 4. The impeller geometry differs in that only two opposite passages are machined as compared with eight for Configuration 4. This modification was intended to reduce the design flowrate to one-fourth and the specific speed to one-half of that for a 100% admission impeller (Fig. 5, Table 3).

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TABLE 1. DESIGN SUMMARY OF CENTRIFUGAL PUMP TEST CONFIGURATIONS

CONFIGURATION	IMPELLER		TIP WIDTH, INCHES	DIFFUSER TYPE	FLUID	SPEED, rpm	FLOW, gpm	HEAD, FEET	SPECIFIC SPEED, rpm $rpm*gpm^{0.5}/ft^{0.75}$
	TYPE	DISCHARGE DIAMETER, INCHES							
1	SHROUDED 100% ADMISSION	2.00	0.030	VANED 100% EMISSION	WATER	24,500	5.0	637	430
					HYDROGEN	77,000	15.7	6,300	430
2	SAME AS CONFIGURATION 1	2.00	0.030	VOLUTE EXIT	WATER	24,500	5.0	637	430
					HYDROGEN	77,000	15.7	6,300	430
3	SAME AS CONFIGURATION 1	2.00	0.030	VANED 25% EMISSION	WATER	39,200	2.0	1,630	215
					HYDROGEN	125,000	6.38	16,600	215
4	OPEN FACE 100% ADMISSION	2.00	0.035	VOLUTE EXIT	WATER	24,500	5.0	637	430
					HYDROGEN	77,000	15.7	6,300	430
5	OPEN FACE 25% ADMISSION	2.00	0.035	VOLUTE EXIT	WATER	39,200	2.0	1,711	215
					HYDROGEN	125,000	6.78	17,400	215
6	SHROUDED 100% ADMISSION	2.00	0.052	VANED 50% EMISSION	WATER	24,500	5.0	637	430
					HYDROGEN	77,000	15.7	6,300	430

TABLE 2. PUMP DESIGN GEOMETRY SPECIFIC SPEED = 430

CONFIGURATION NO.	1	2	4	6
IMPELLER				
TYPE	SHROUDED	SHROUDED	OPEN FACE	SHROUDED
DISCHARGE DIAMETER, INCHES	2.0	2.0	2.0	2.0
INLET EYE DIAMETER, INCHES	0.75	0.75	0.80	0.81
INLET HUB DIAMETER, INCHES	0.50	0.50	0.50	0.50
DISCHARGE TIP WIDTH, INCHES	0.030	0.030	0.035	0.052
NUMBER OF BLADES	7	7	8	7
DISCHARGE BLADE ANGLE, DEGREES	33	33	20	33
WEAR RING DIAMETER, INCHES	1.00	1.00	1.00	1.00
FRONT WEAR RING RADIAL CLEARANCE, INCHES (MAXIMUM DESIGN)	0.002	0.002	--	0.002
IMPELLER FACE CLEARANCE, INCHES	--	--	0.004	--
REAR WEAR RING RADIAL CLEARANCE, INCHES (MAXIMUM DESIGN)	0.002	0.002	0.002	0.002
INLET EYE BLADE ANGLE, DEGREES	21.9	21.9	21.25	20
INLET FLOW COEFFICIENT (10% BLOCKAGE)	0.134	0.134	0.107	0.174
PERCENT ADMISSION	100	100	100	100
DISCHARGE FLOW COEFFICIENT	0.074	0.074	0.080	0.085
DIFFUSER				
INLET DIAMETER, INCHES	2.1	--	--	2.1
DISCHARGE DIAMETER, INCHES	2.7	--	--	2.7
PASSAGE WIDTH, INCHES	0.030	--	--	0.052
NUMBER OF PASSAGES	8	--	--	4
INLET ANGLE, DEGREES	6	--	--	6
AREA RATIO, OUT/IN	1.84	--	--	1.84
PERCENT EMISSION	100	--	--	50
VOLUTE				
MAXIMUM AREA AT 360 DEGREES, $IN.^2$	0.0468	0.0267	0.035	0.0468
CONTINUITY AREA/ACTUAL AREA	0.60	0.60	0.83	0.60
CONICAL DIFFUSER EXIT AREA, $IN.^2$	0.096	0.096	0.096	0.096

TABLE 3. PUMP DESIGN GEOMETRY SPECIFIC SPEED = 215

CONFIGURATION NO.	3	5
IMPELLER		
TYPE	SHROUDED	OPEN FACE
DISCHARGE DIAMETER, INCHES	2.0	2.0
INLET EYE DIAMETER, INCHES	0.75	0.8
INLET HUB DIAMETER, INCHES	0.5	0.5
DISCHARGE TIP WIDTH, INCHES	0.030	0.035
NUMBER OF BLADES	7	2
DISCHARGE BLADE ANGLE, DEGREES	33	20
IMPELLER FACE CLEARANCE, INCHES	--	0.004
WEAR RING DIAMETER, INCHES	1.00	1.00
FRONT WEAR RING RADIAL CLEARANCE, INCHES (MAXIMUM DESIGN)	0.002	--
REAR WEAR RING RADIAL CLEARANCE, INCHES (MAXIMUM DESIGN)	0.002	0.002
INLET EYE BLADE ANGLE, DEGREES	21.9	21.25
INLET FLOW COEFFICIENT (10% BLOCKAGE)	0.134	0.107
PERCENT ADMISSION	100	25
DISCHARGE FLOW COEFFICIENT	0.074	0.08
DIFFUSER		
INLET DIAMETER, INCHES	2.1	--
DISCHARGE DIAMETER, INCHES	2.7	--
PASSAGE WIDTH, INCHES	0.030	--
NUMBER OF PASSAGES	2	--
INLET ANGLE, DEGREES	6	--
AREA RATIO, OUT/IN	1.84	--
PERCENT EMISSION	25	--
VOLUTE		
MAXIMUM AREA AT 360 DEGREES, IN.^{2}	0.0146	0.011
CONTINUITY AREA/ACTUAL AREA	0.50	0.833
CONICAL DIFFUSER EXIT AREA, IN.^{2}	0.096	0.026

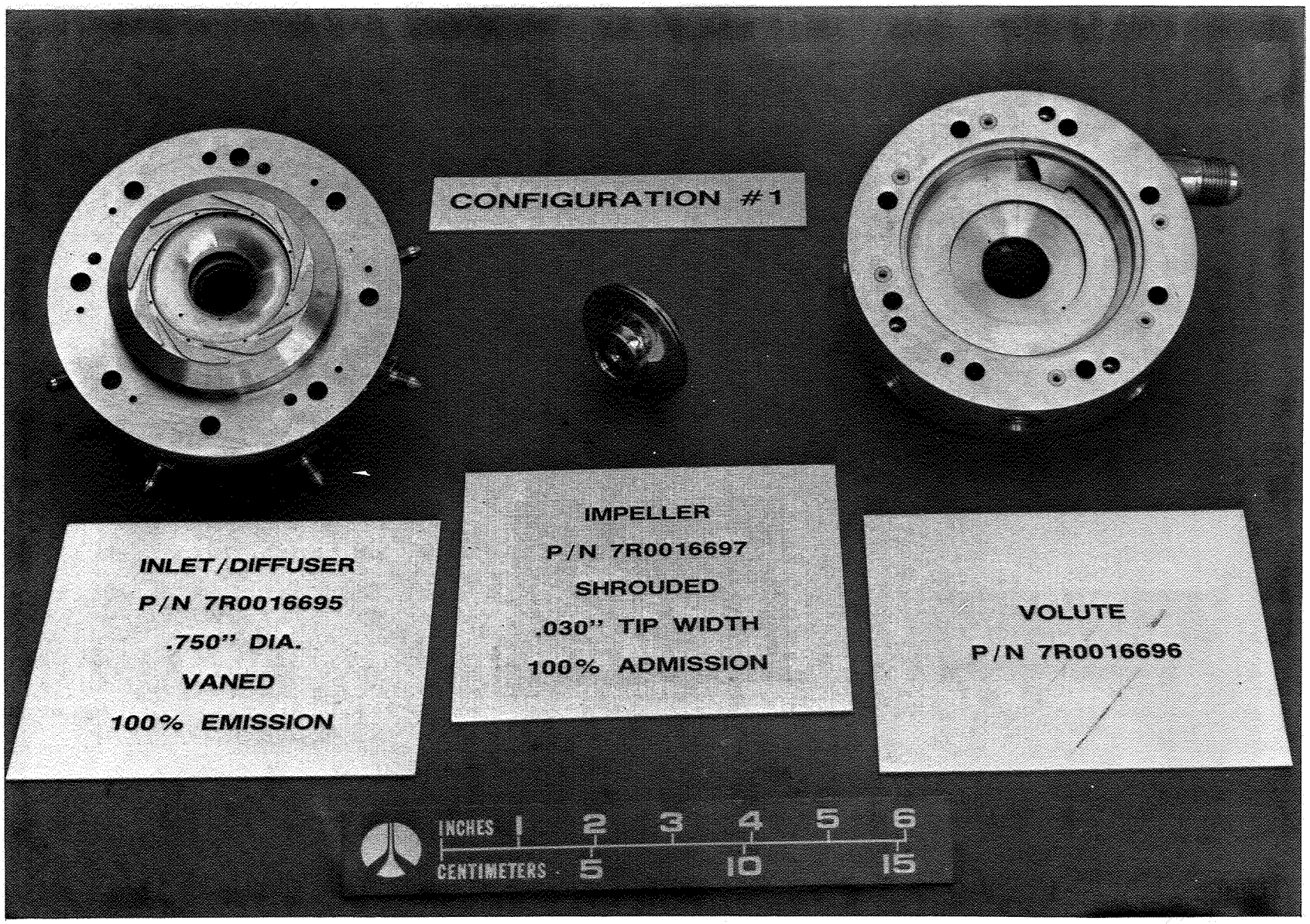

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Figure 1. Shrouded Impeller Vaned Diffuser Pump

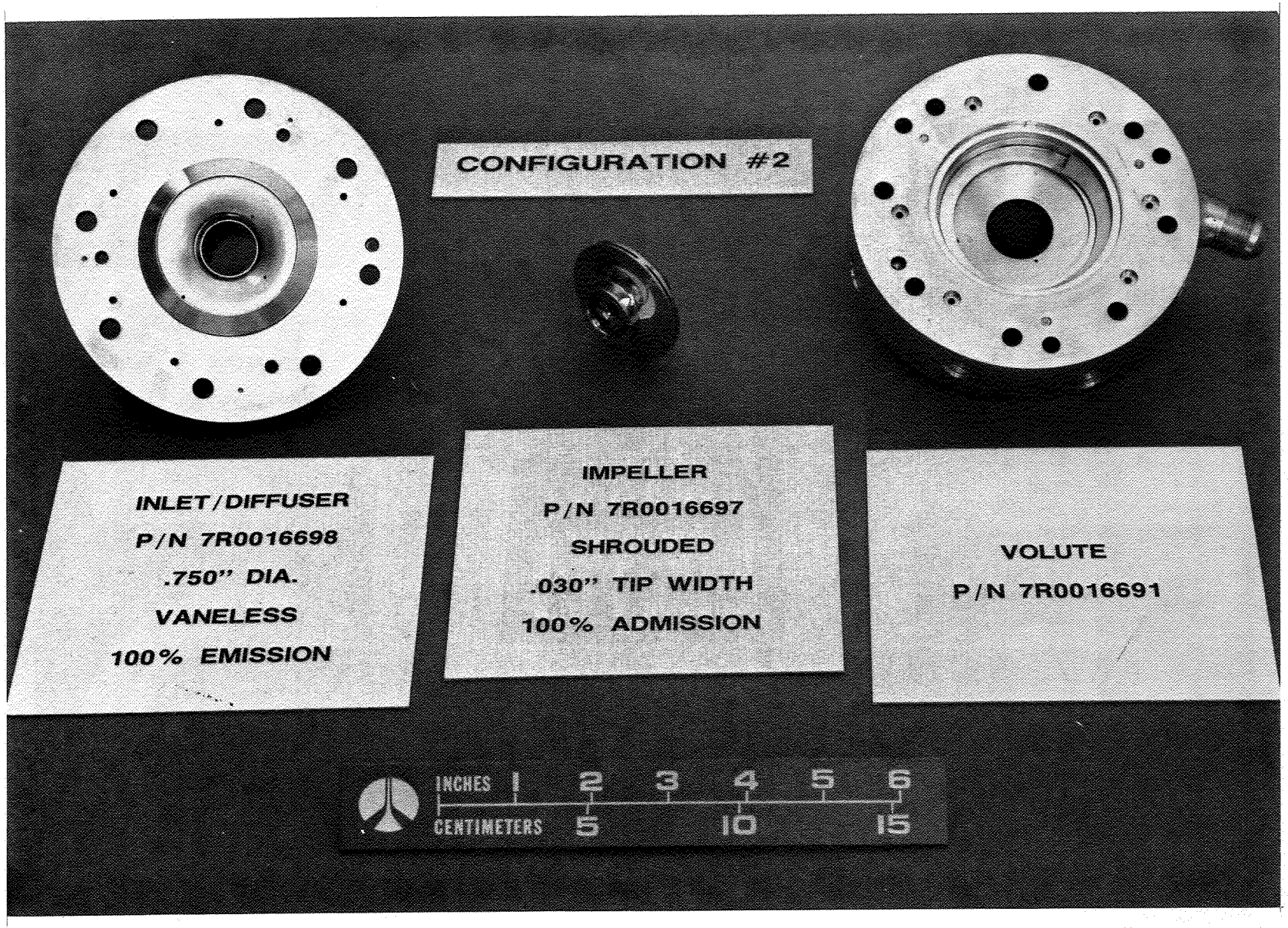

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Figure 2. Shrouded Impeller Volute Pump

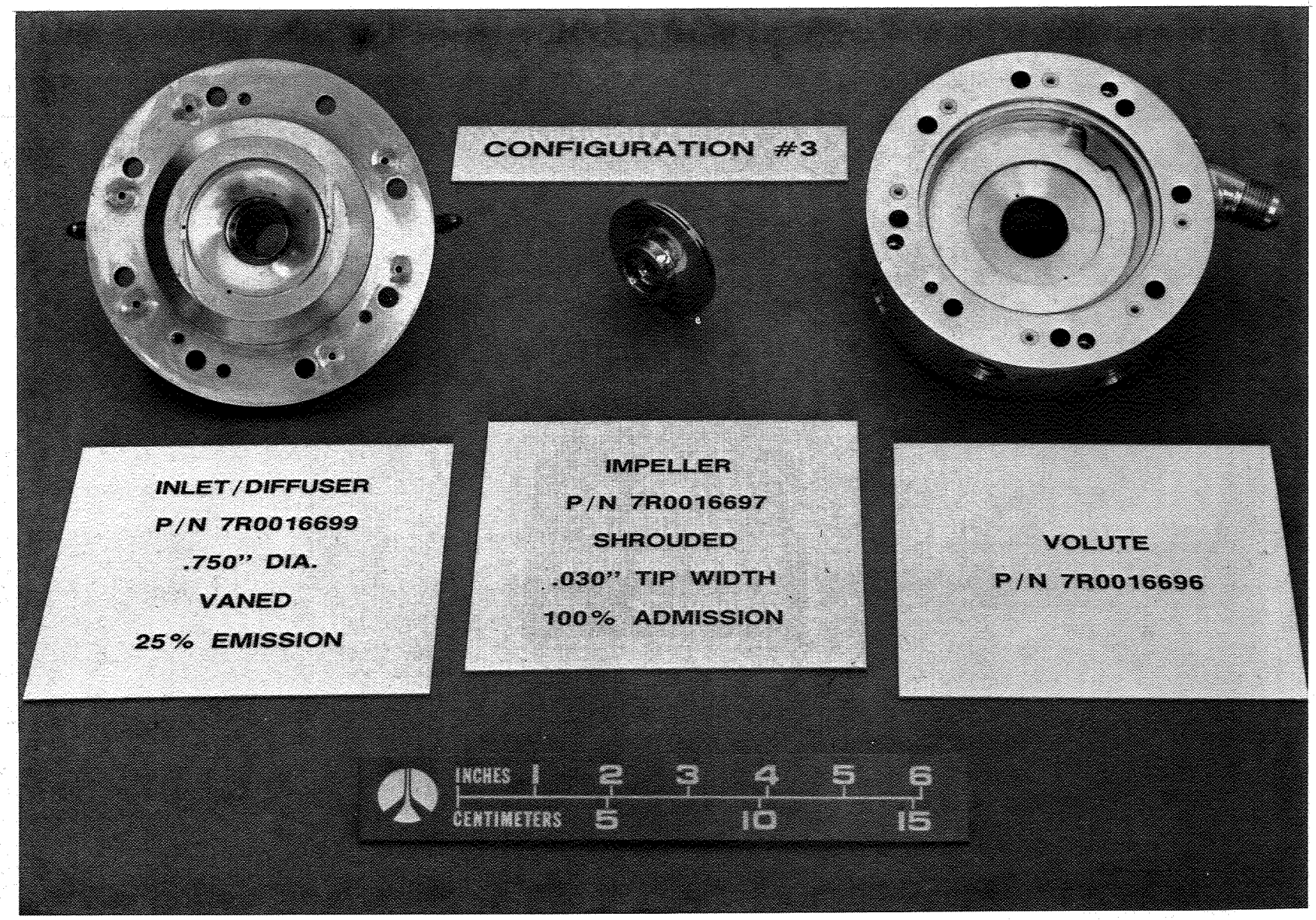

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Figure 3. Shrouded Impeller 25% Emission Diffuser Pump

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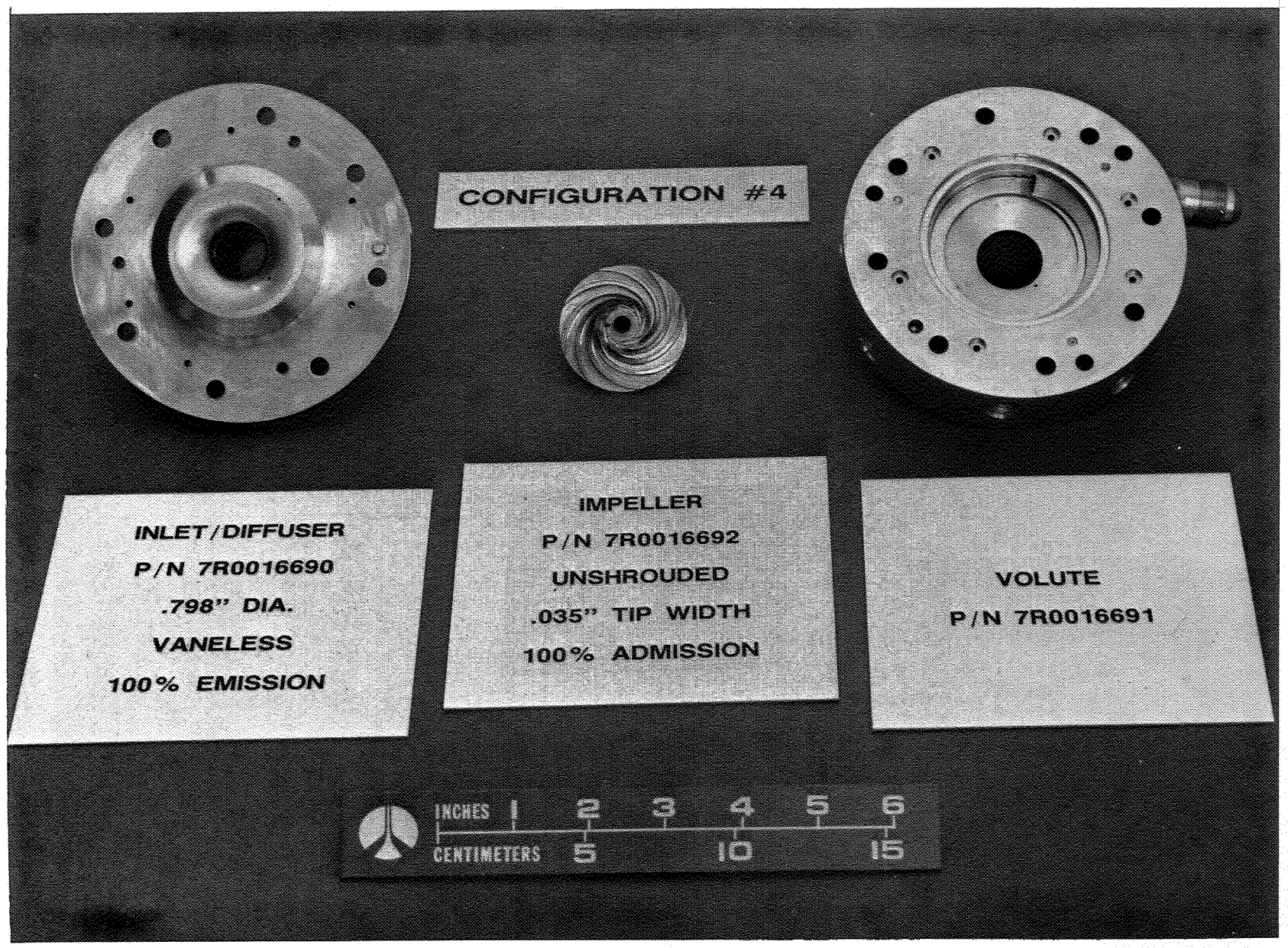

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Figure 4. Open Face Impeller Volute Pump

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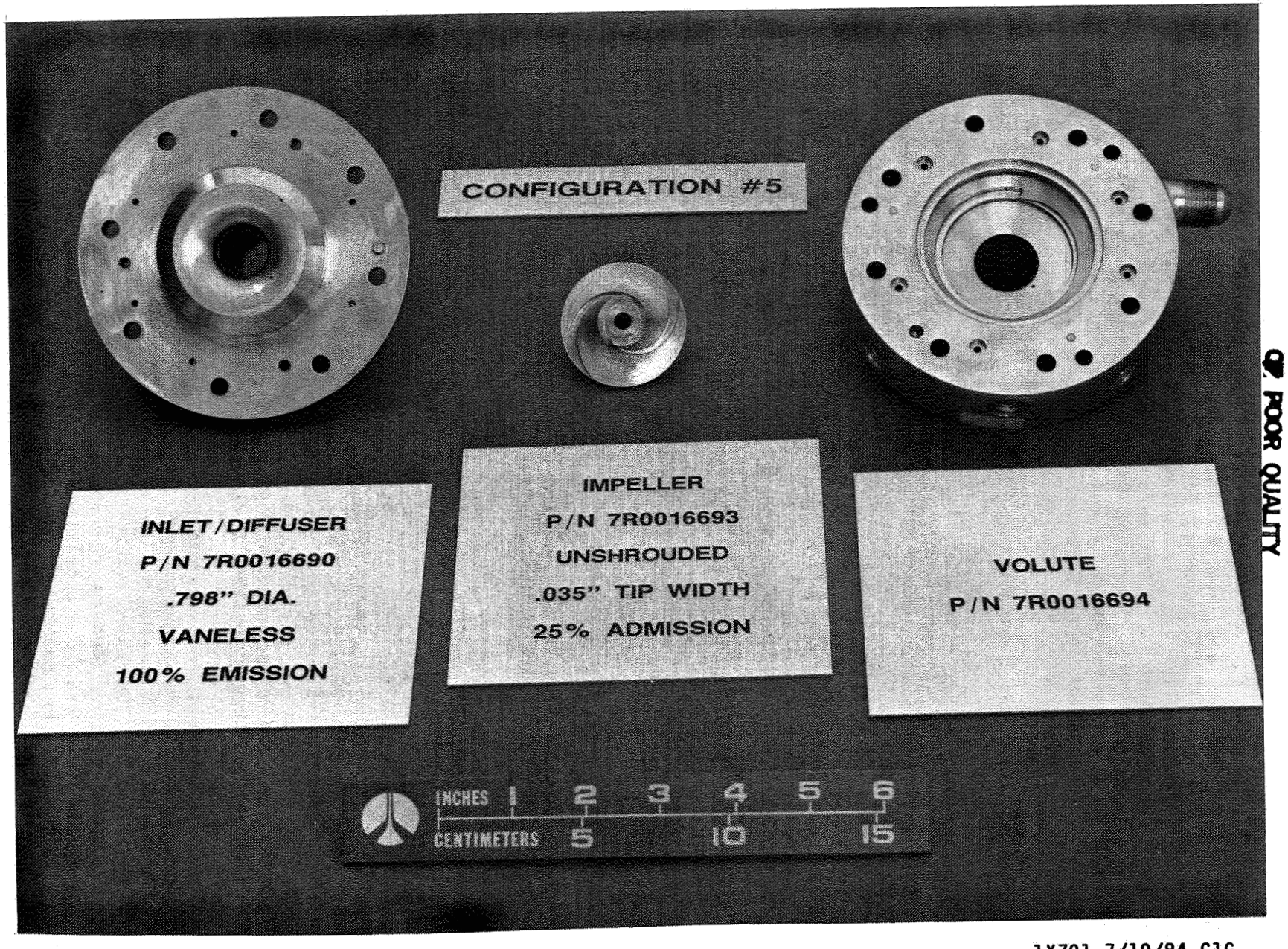

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Figure 5. Open Face 25% Admission Impeller Volute Pump

Configuration 6 (Table 2 and Fig. 6) incorporates a 100% admission shrouded impeller with the same blade shape as for Configurations 1, 2, and 3 with the exception that the impeller passage height is increased from inlet to exit to give a discharge tip width of 0.052 inch. The impeller discharges into a 50% emission vaned diffuser with increased passage height but otherwise the same passage shape as for Configurations 1 and 3. This configuration is intended to operate at the same design point flow and specific speed as for Configuration 1. The larger flow passages were used to simplify fabrication.

FABRICATION

Machined Parts

A very real problem with small diameter low specific speed pumps as investigated in this program, is the successful fabrication of very small flow passages and tip width. The process selected for manufacture of the open flow passages of the vaned diffusers, volutes, and open face impellers was machining. This method produced a smooth and repeatable surface finish required for low pressure and friction losses with minimum variation and risk. Shrouded impellers were cast due to the difficulty associated with machining the very small enclosed passages.

The machined open face impellers had the advantage of superior surface finish control but suffered an efficiency penalty due to impeller to housing clearance. The cast shrouded impellers had front wear rings with more easily controlled radial clearance.

Impeller Casting

A casting development effort was conducted to determine the optimum casting procedures for the Inconel 718 shrouded impellers.

The ceramic core design consisted of individual ceramic cores of the impeller passages assembled on a fixture to form a one piece core assembly. Because the core assembly was fragile due to the very small impeller passage dimensions, the impeller body wax pattern was not injected around the core in one piece. Upper and lower wax impeller halves were injection molded separately and booked to the core assembly. In order to meet the close dimensional requirements for the impeller blades and flow passages and the tight ceramic-to-wax fitup desired for the booking process, trial core assemblies were dimensionally inspected before being booked to the impeller patterns. A single iteration to fine tune the core assembly techniques and minor rework of the wax pattern dies resulted in the desired results for subsequent casting of impellers.

Inconel 718 was selected for casting the impellers because of its excellent strength, and corrosion resistance and its good castability. Inconel 718 does present a known potential problem of metal reaction with a ceramic core during the casting process. The alloy strength properties are not reduced but an unacceptable rough casting surface can result. Since the very small impeller flow passages are not readily accessible for surface finish improvement effort was made to produce the smooth as cast surface required for high impeller performance.

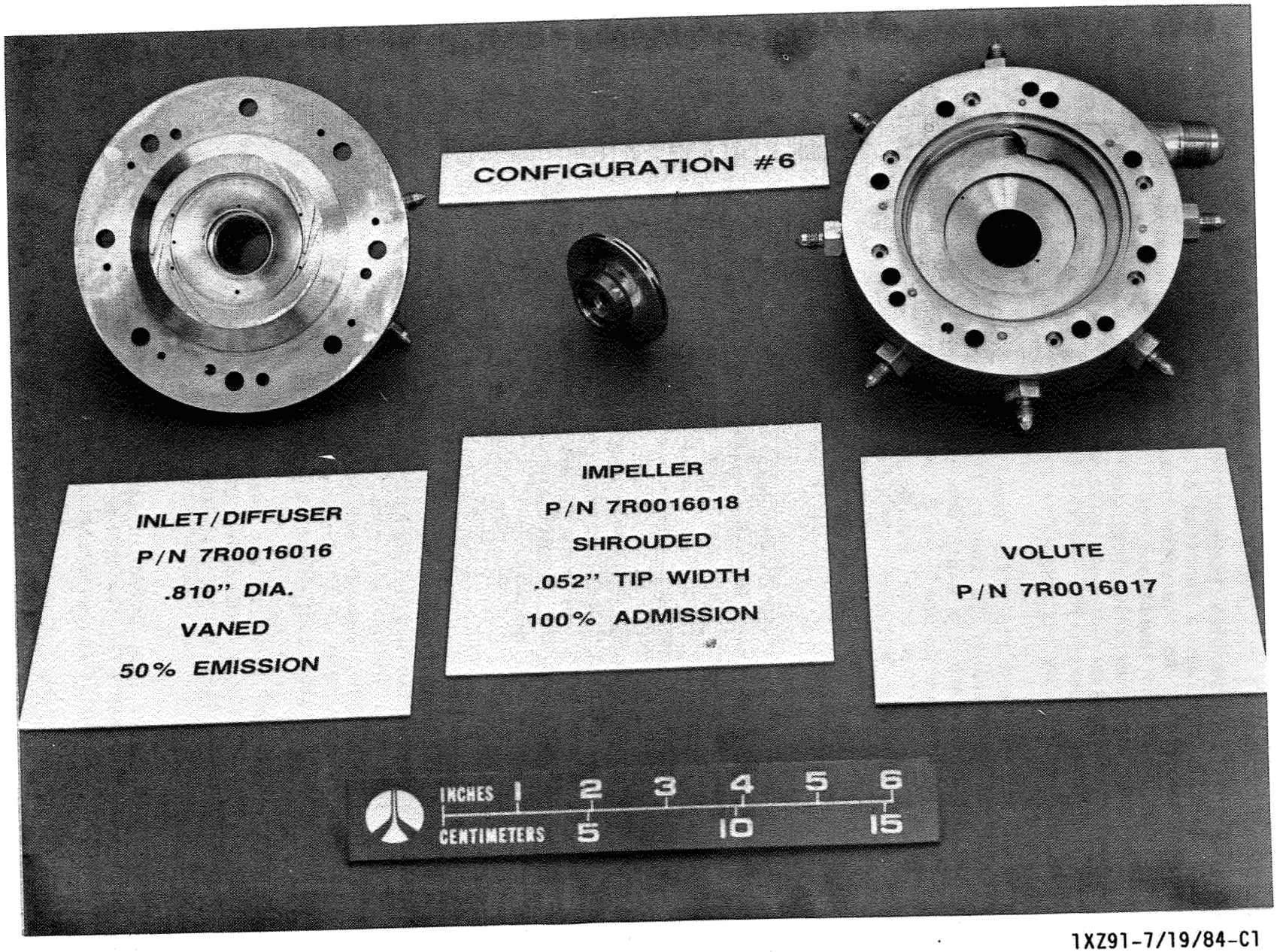

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Figure 6. Shrouded Impeller 50% Emission Diffuser Pump

Experience in this program with Inconel 718 ceramic core reaction indicated the severity of the reaction was a function of the time molten metal was in contact with the core material. An iterative procedure was followed to arrive at the metal pour temperature and investment shell temperature that would result in complete mold filling, sound metallurgical quality, and smooth surface finish. After each trial pour the impeller was cut up to evaluate the flow passage surface finish. The third test temperatures resulted in acceptable impeller quality, therefore, it was adopted for the test impeller castings.

Photographs of a 0.052-inch tip width impeller are shown in Fig. 7 and 8. There was no significant difference in the ability to cast the 0.030-inch tip width impeller and the 0.052-inch tip width impeller. Consequently, the tip width of future designs can be made as small as 0.030 inch with minimum casting problems, particularly if less reactive metal can be used. Even smaller tip widths may be feasible as 0.030 inch does not appear to be a limit.

TEST PROGRAM

Facility Description

The water test program was conducted in Rocketdyne's Engineering Development Laboratory in a closed loop water test facility shown schematically in Fig. 9. The test facility was capable of conducting tests over a wide range of speed, flow, and inlet pressure. Inlet pressure within the test loop can be lowered by dropping water tank pressure by means of a vacuum source or increased by pressurizing the tank with gaseous nitrogen. The test pumps are installed in the pump tester and are driven by a calibrated axial flow turbine with gaseous nitrogen as the working fluid. A cross-sectional view of the pump tester is shown in Fig. 10. The pump tester assembly and the installation of the assembly in the test facility are shown in Fig. 11, 12, and 13.

Instrumentation

Typical pump and tester instrumentation is shown in Fig. 14 and 15. Overall (flange to flange) head rise was determined by measuring the difference in pressure between a four-hole static pressure piezometer ring located 5 diameters upstream of the pump inlet and a four-hole static pressure piezometer ring located 10 diameters downsteam of the pump discharge. The velocity heads calculated from the pump flowrate and respective cross-sectional areas at the measurement stations were added to the inlet and discharge static heads to obtain the total head rise. The pump flowrate was measured by means of a flowmeter located in the pump discharge line. Pump speed was measured by a tester-mounted eddy current proximity probe that sensed the rotation of two flats machined on the tester shaft.

Instrumentation accuracies are listed in Table 4. All instrumentation was calibrated by standards traceable to the Bureau of Standards prior to testing of each pump configuration. Calibrations were checked pretest and posttest.

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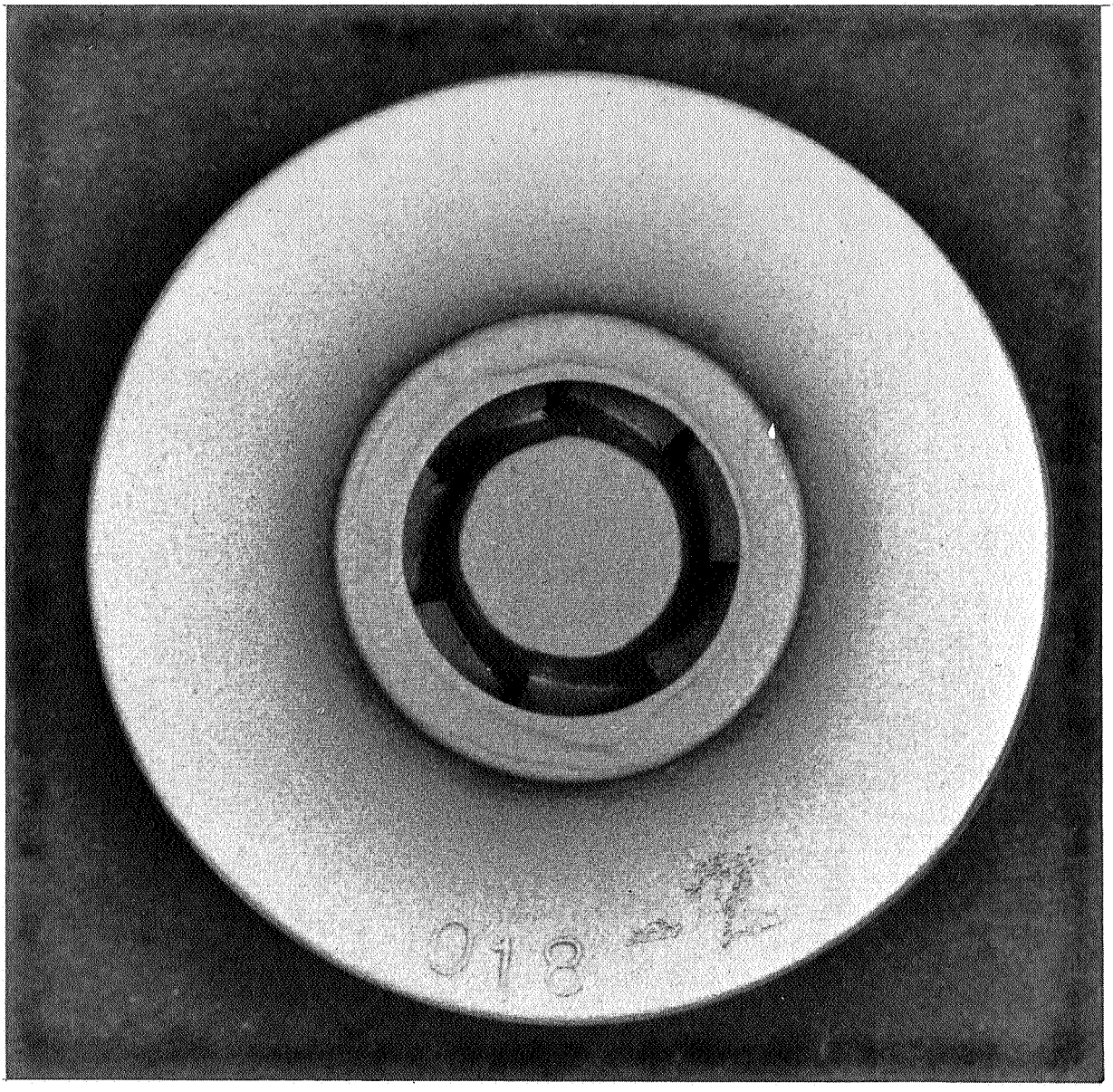

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Figure 7. 2-Inch Diameter Impeller Casting (Inlet)

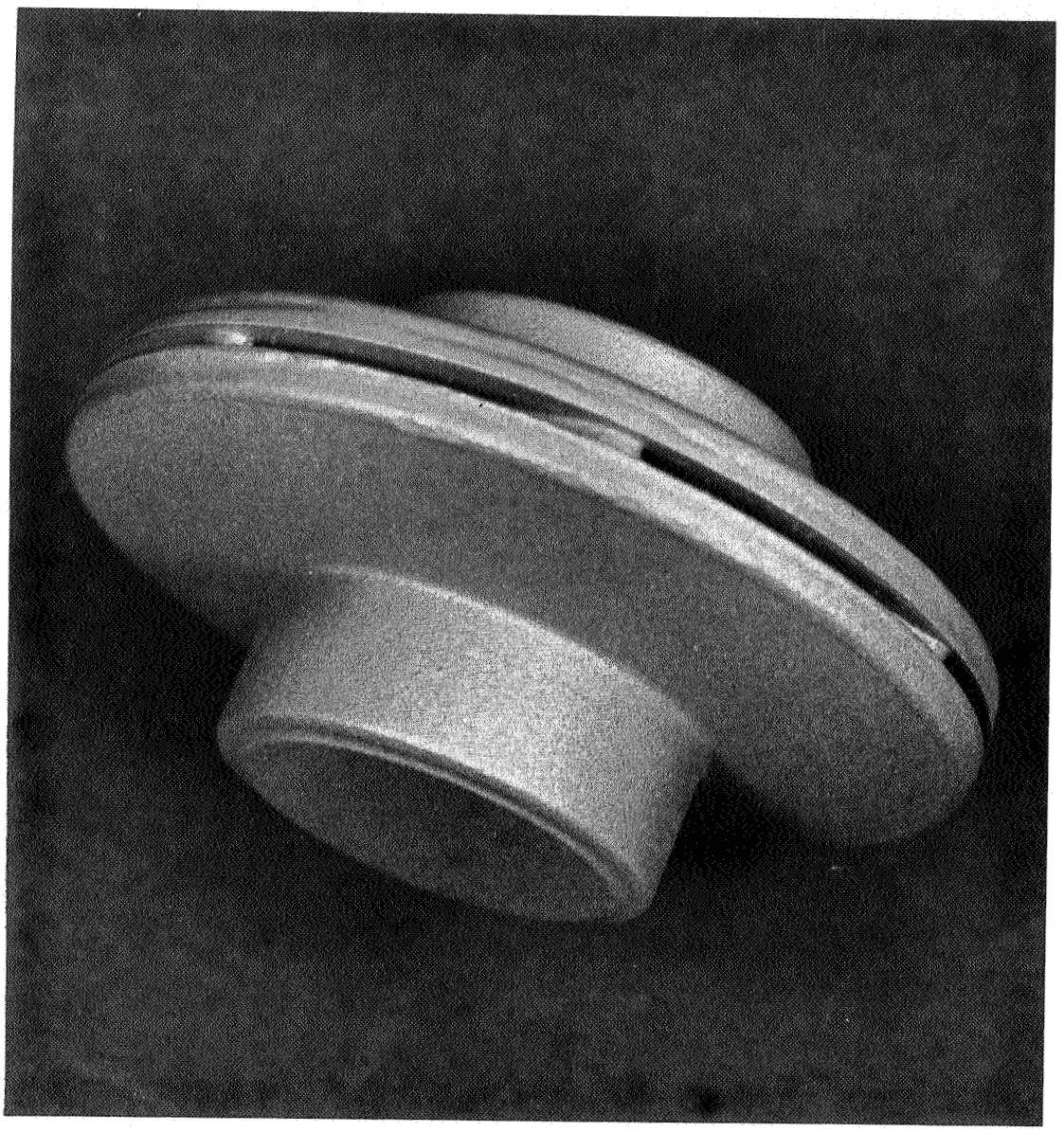

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Figure 8. 2-Inch Diameter Impeller Casting (Discharge)

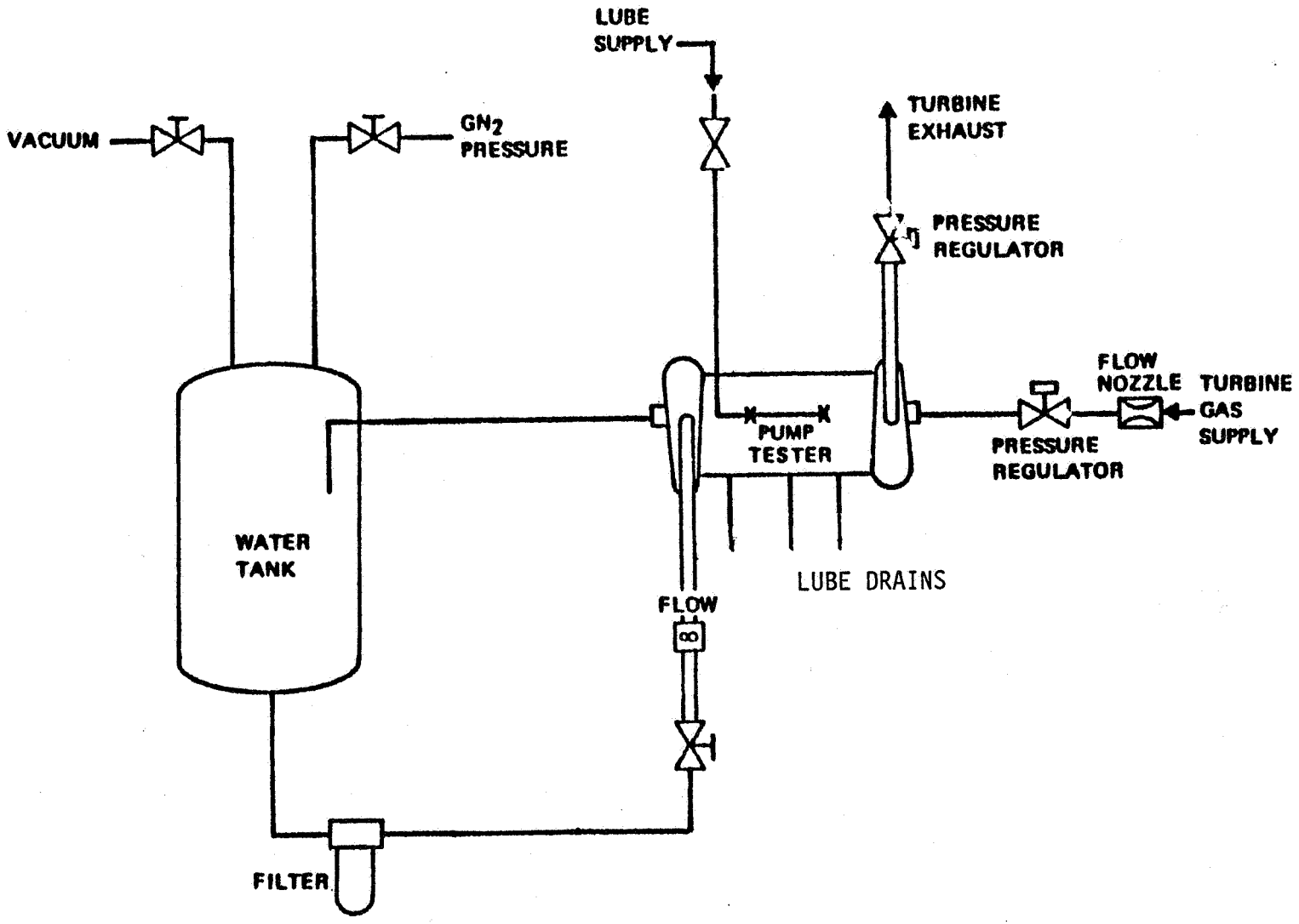

Figure 9. Water Test Facility Schematic

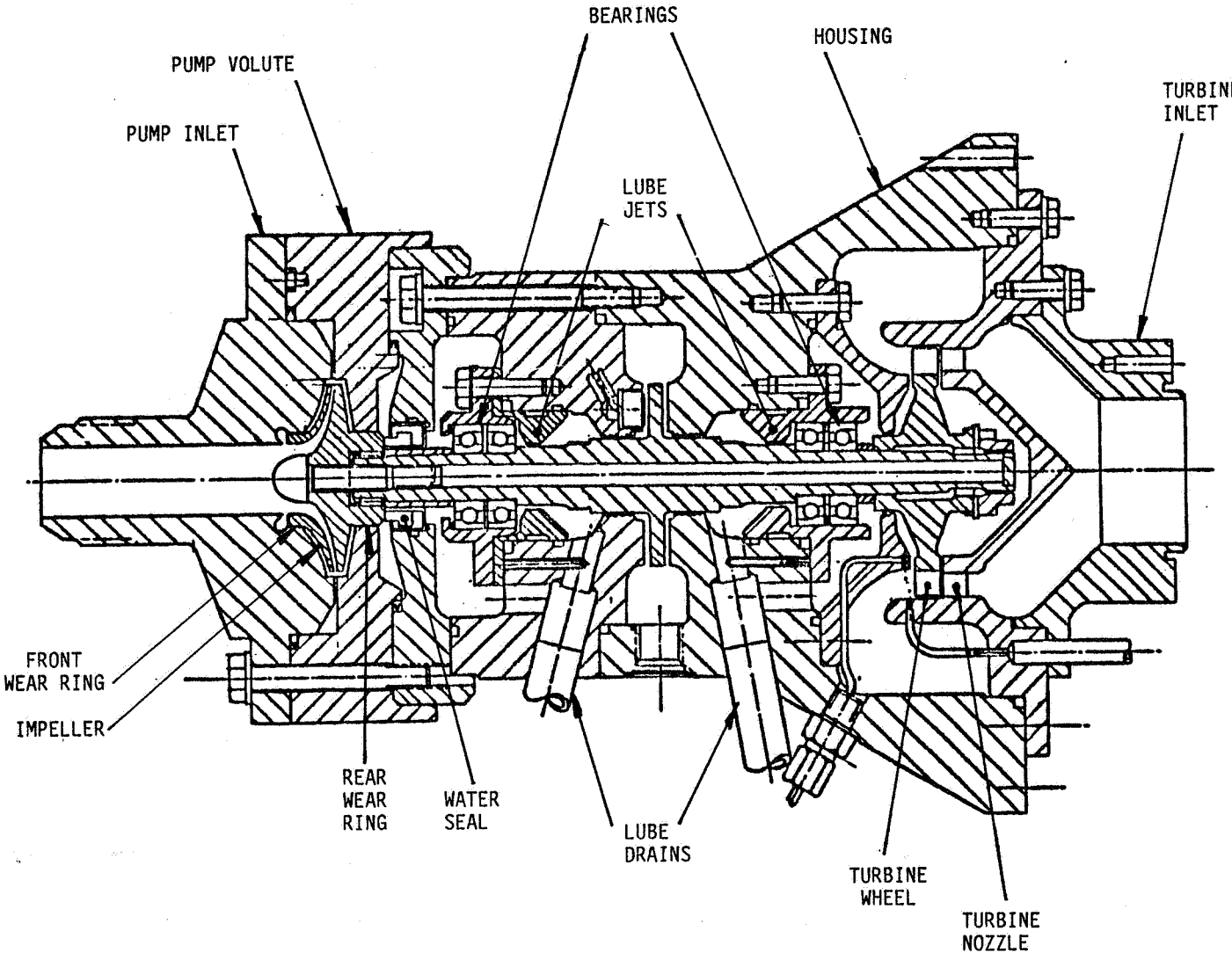

Figure 10. Pump/Tester Cross Section

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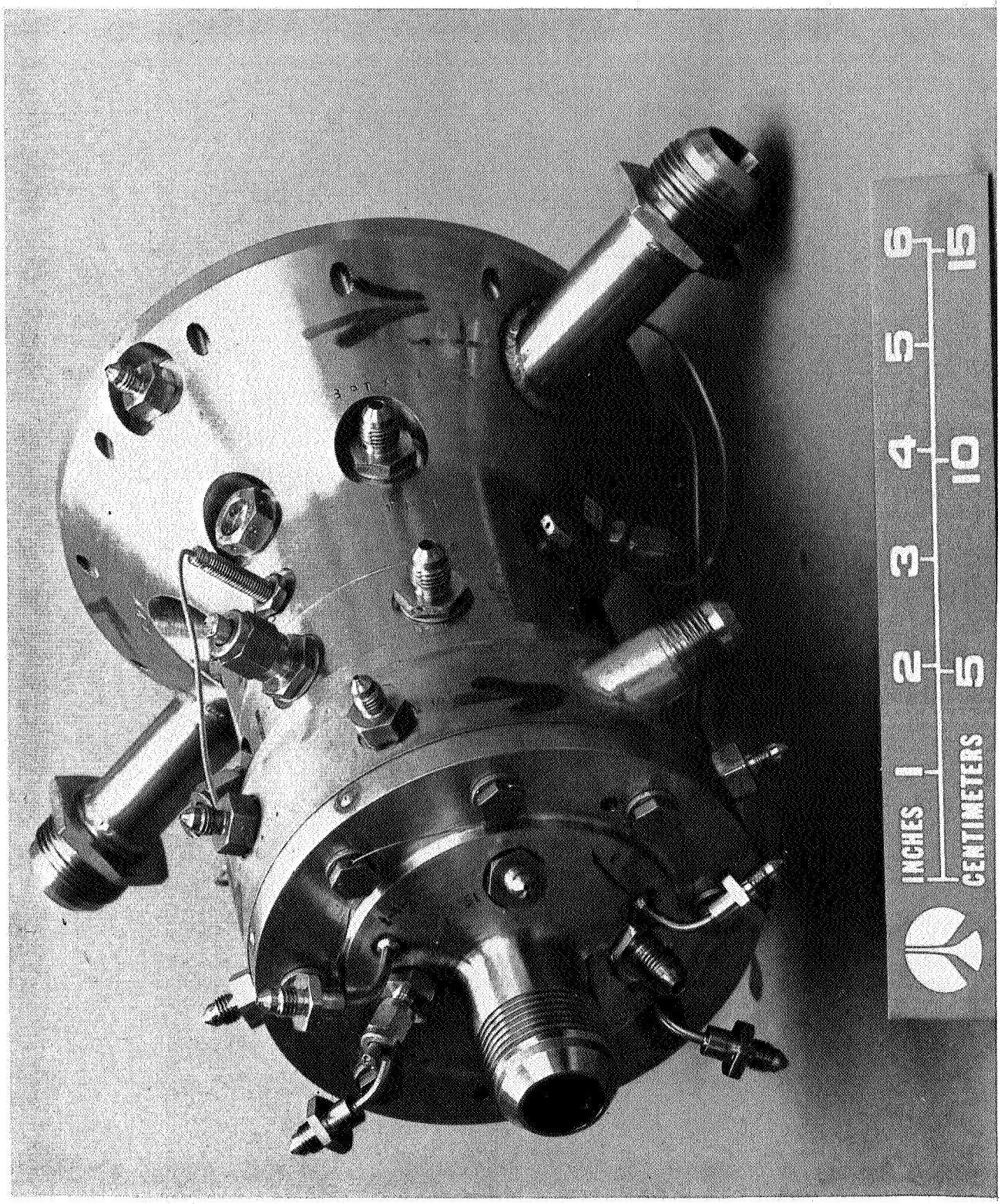

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Figure 11. Pump/Tester Assembly

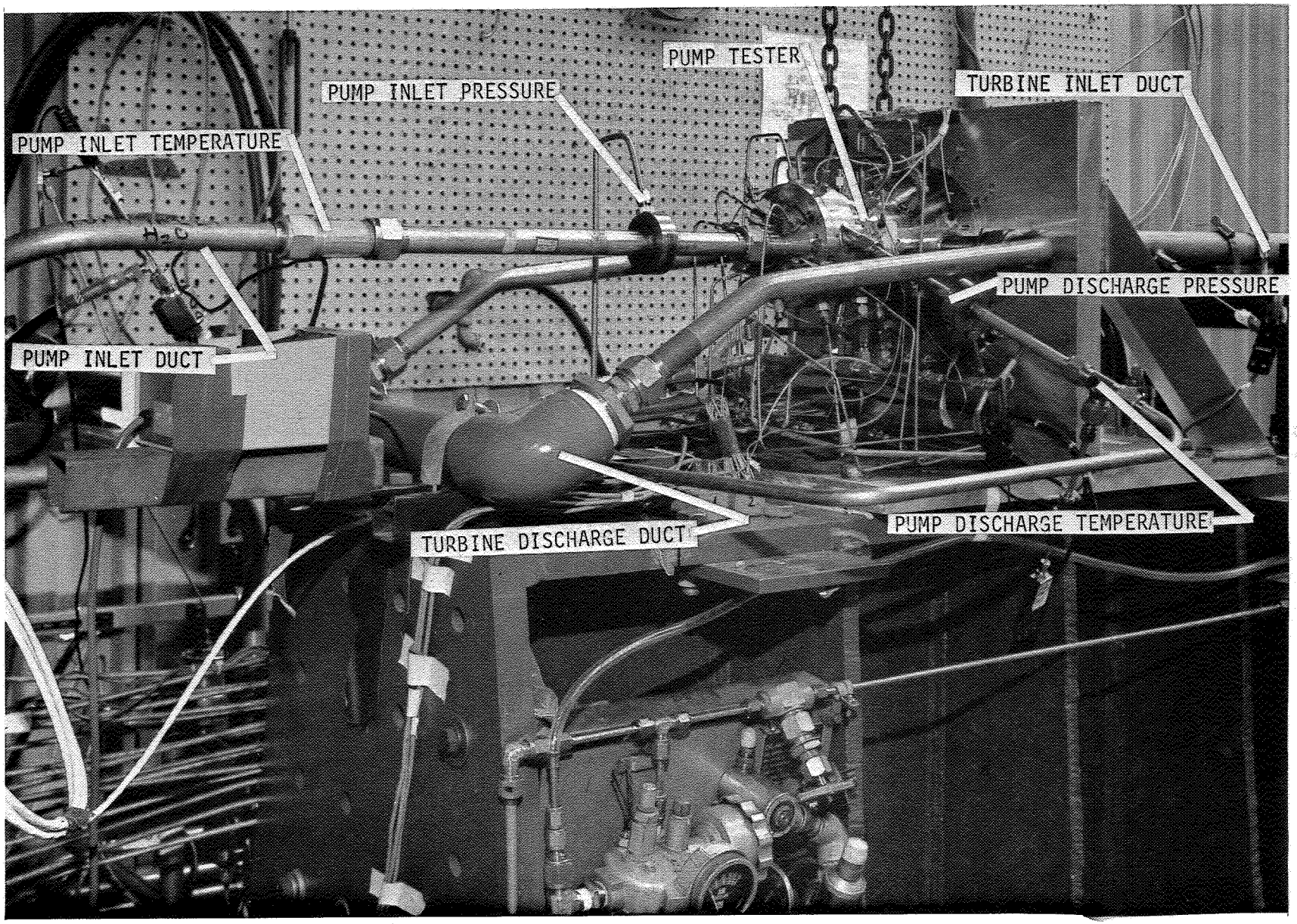

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Figure 12. Pump Test Facility

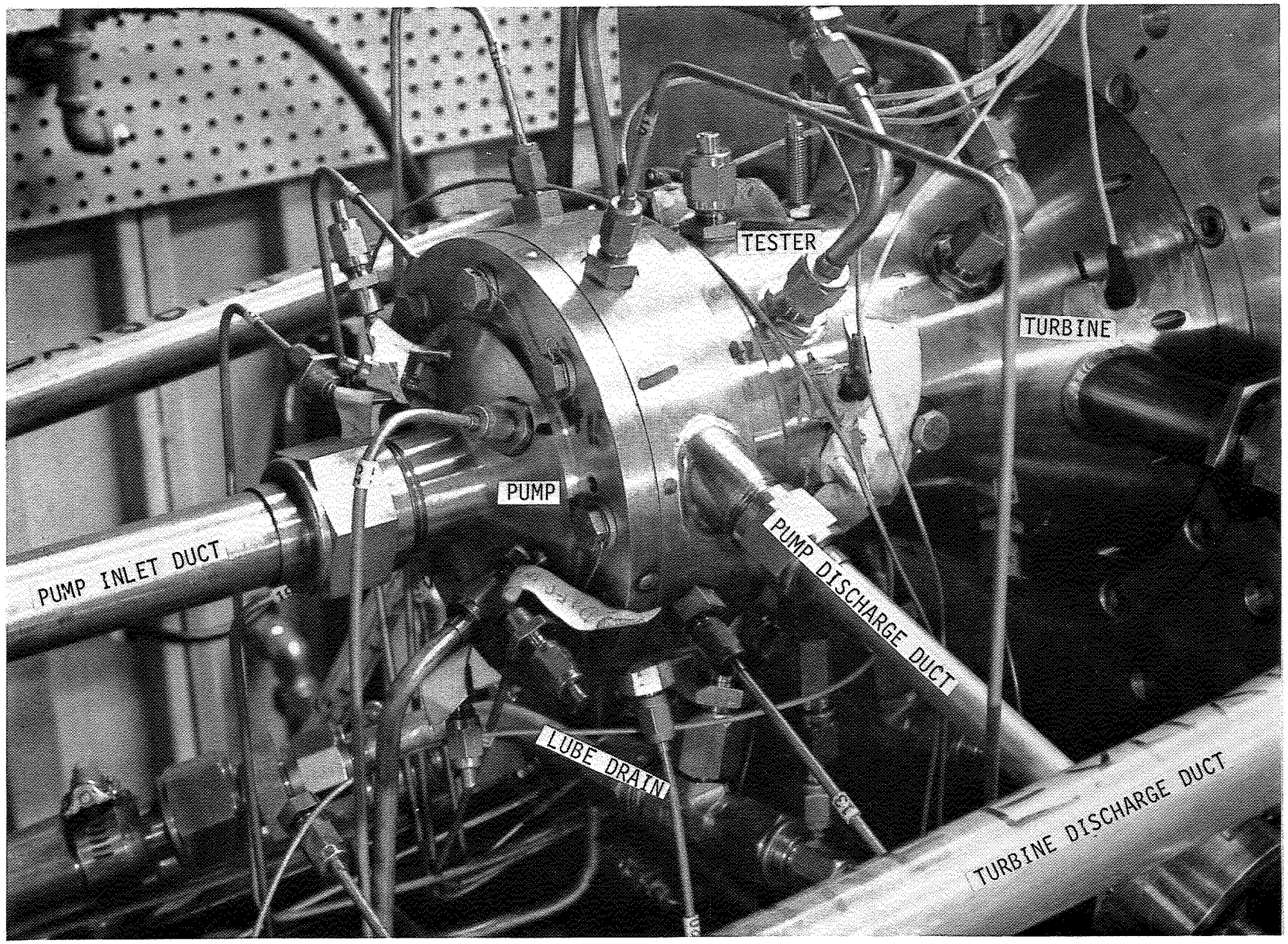

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Figure 13. Pump/Tester Installed in Test Facility

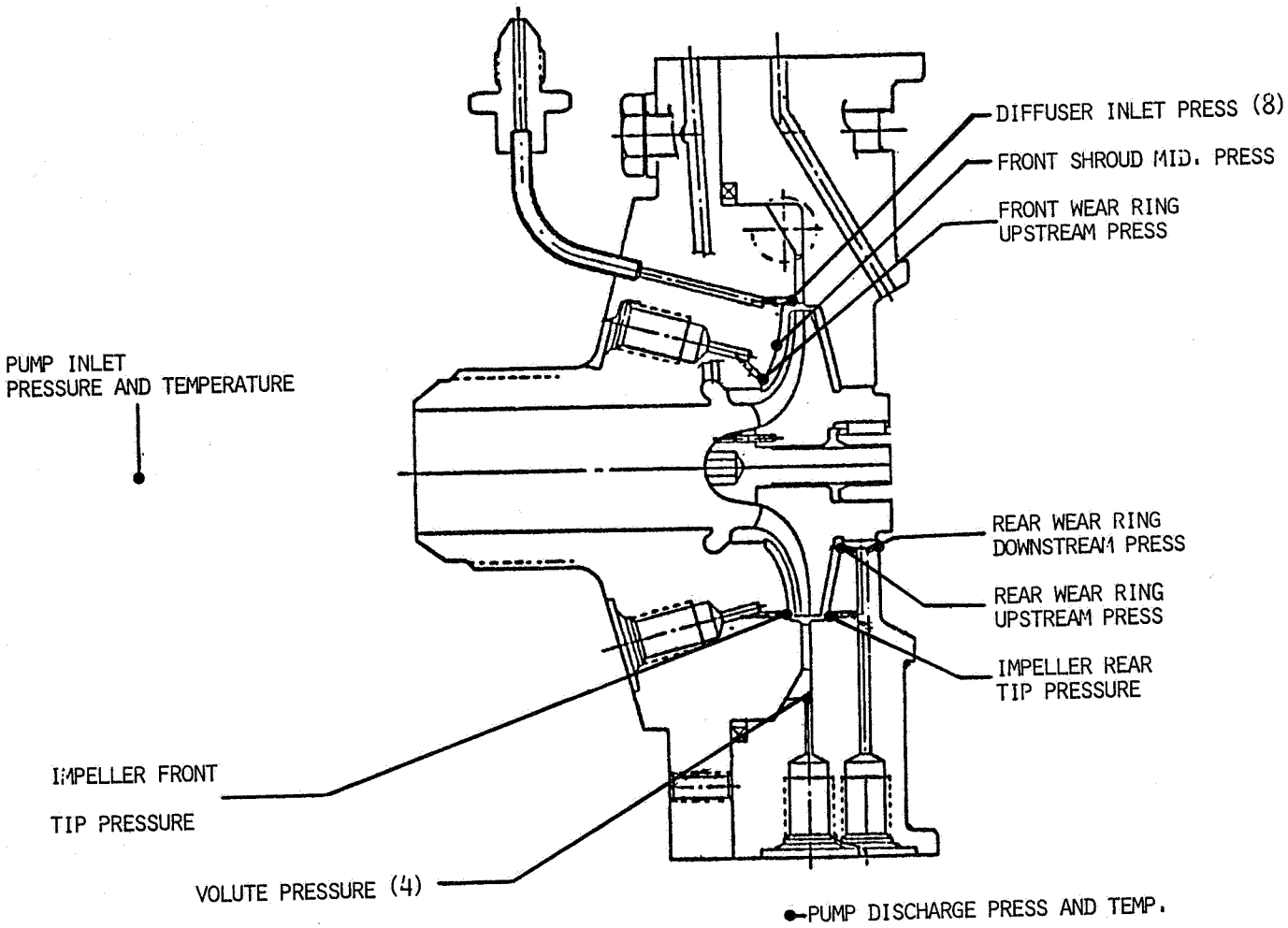

Figure 14. Typical Pump Instrumentation

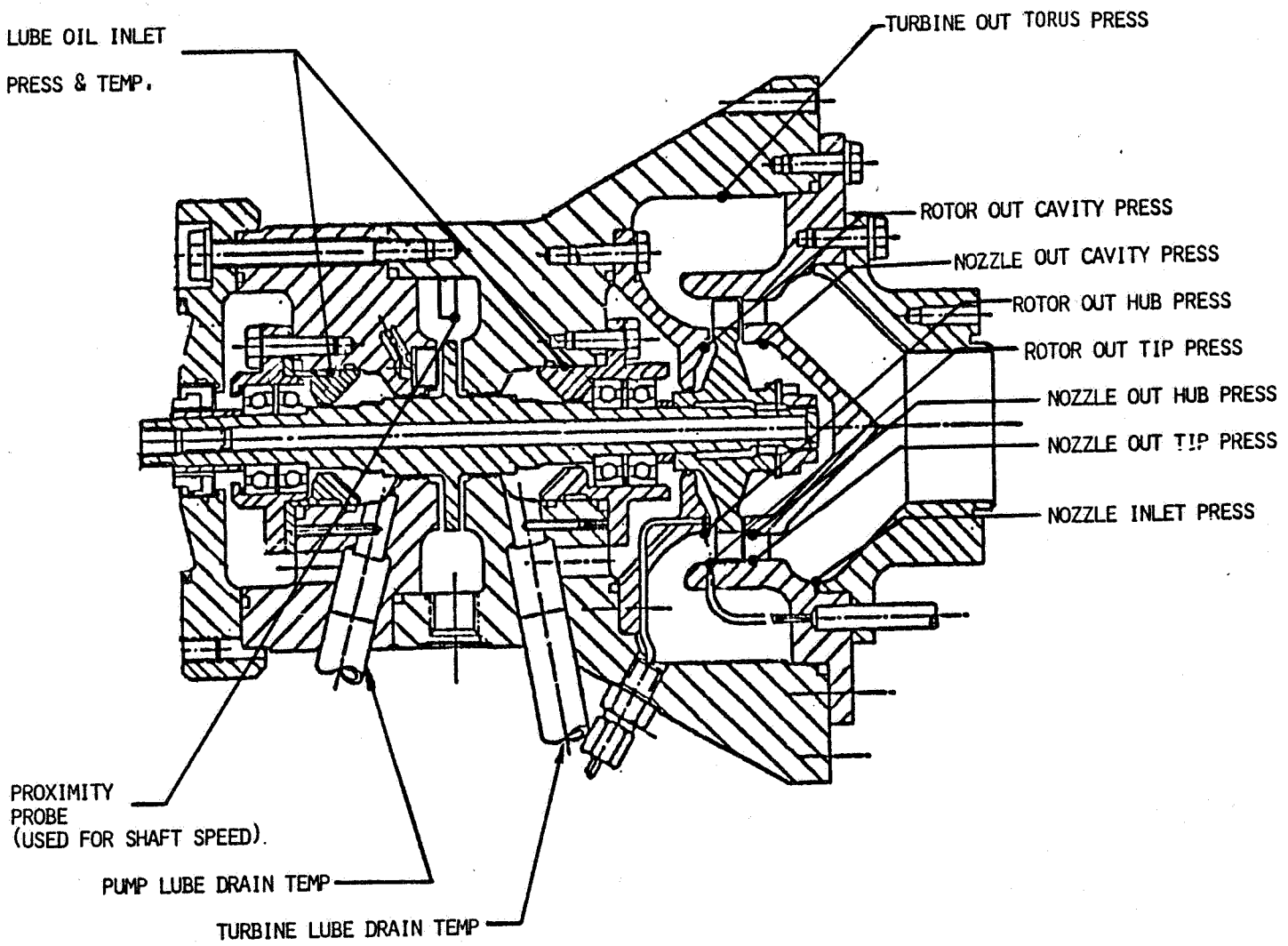

Figure 15. Tester and Turbine Instrumentation

TABLE 4. INSTRUMENTATION ACCURACIES

PUMP INLET PRESSURE	± 0.5 PSI
PUMP INLET AND DISCHARGE TEMPERATURE	± 0.2 DEGREE R
PUMP DISCHARGE PRESSURE AND ALL OTHER INTERNAL PRESSURES SHOWN IN FIG. 14	± 2.5 PSI
FLOWRATE	± 0.5%
SHAFT SPEED	± 0.5%

Test Procedures

The tests evaluated head rise versus flow at shaft speeds of 24,500, 19,600, 14,700, and 9350 rpm for Configurations 1, 2, 4, and 6 and at shaft speeds of 29,000, 23,520, and 11,760 rpm for Configurations 3 and 5. The flowrate was controlled by a valve located downstream of the flowmeter. Pump speed was controlled by varying the turbine inlet and discharge pressure to control the power input to the pump. Sufficient turbine measurements were made to permit calculation of the power input to the pump based on turbine calibration data obtained subsequent to the pump tests.

Sufficient pressure measurements were made in the pump to permit calculation of the pump axial and radial loads and internal performance at test operating conditions.

Suction performance tests were conducted by operation at a constant pump rotating speed and flowrate with the pump inlet pressure gradually lowered from a high to a low value. The higher test speeds produced consistent suction specific speed values and were, therefore, used to determine the pump suction performance. Suction performance data were not obtained for Configuration 1 due to damage to the volute wear-ring during the head versus flow test. Since the same impeller was used for Configuration 2 the suction performance capability of the impeller was evaluated by test of Configuration 2.

The pump power was determined by computing the power generated by the drive turbine based on test measurements and turbine calibration data. The turbine was calibrated after the pump test program using a water dynamometer. The power available to the pump was determined by connecting the turbine mounted on the pump tester to the dynamometer. The turbine was driven by dry gaseous nitrogen during the calibration. The turbine measurements during the calibration were the same as those obtained during the pump tests to provide a direct relationship of calibration information.

The dynamometer replaced the pump as the power absorber. Therefore, the turbine calibration includes the rotating assembly bearing and seal power losses up to the pump and the dynamometer absorbed horsepower was directly the pump input horsepower.

TEST RESULTS

HEAD AND EFFICIENCY PERFORMANCE VERSUS FLOW

Table 5 summarizes the pump design point head and efficiency at the design point flowrates while Fig. 16 through 21 present the head, flow, efficiency data for each if the 6 configurations. Figure 22 presents a comparison of efficiency data from all 6 configurations. Similary, Fig. 23 presents a comparison of delivered head. The wear ring radial clearances and open face impeller axial clearances are listed in Table 2 and 3.

Pump Configurations 1, 2, 4, and 6 were designed to operate at a design point specific speed (N_S) of 430. The highest efficiency, 32.5%, and head rise, 750 feet at 24,500 rpm, was achieved by Configuration 2, which utilized a shrouded impeller with a 0.030-inch exit tip width discharging into a volute with a conical diffuser at the exit. The lowest efficiency, 23%, and head rise 445 feet, of the four configurations was produced by Configuration 4, which was similar to Configuration 2 except for the use of an open face impeller rather than a shrouded impeller. The second highest efficiency 31% and third highest head rise, 725 feet, was achieved by Configuration 1, which used the same impeller as Configuration 2 but discharging through a vaned diffuser followed by a volute and exit diffuser. The third highest efficiency, 28.5%, and second highest head rise, 745 feet, was achieved by Configuration 6, which used a shrouded impeller with a 0.052-inch exit tip width discharging through a 50% emission vaned diffuser into a volute. The head rise and efficiency results are influenced by the wear ring clearances and the axial clearance of the open face impeller. Test Configuration 1 operated with wear ring clearances within the pretest design values while the other configurations were tested with clearances that were slightly larger than design (Tables 1, 2, and 3) to avoid rubbing. The efficiencies would have been higher if the pumps had been operated with the design clearances. This topic is discussed in more detail in a later section. Configuration 3 was designed to operate at a design point specific speed of 215. At the test speed of 29,000 rpm Configuration 3 achieved the higher efficiency of 9.6% and head of 1125 feet. This configuration incorporated the same shrouded impeller as Configurations 1 and 2 and discharged through a 25% emission diffuser and volute. Configuration 5 incorporated a 25% admission open face impeller with the same passage configuration as Configuration 4. This impeller discharged directly into a volute. It obtained a head rise of 340 feet at 29,000 rpm at an efficiency of 5.1%. The low efficiency of Configurations 3 and 5 result from the very low flowrate, one-fourth that of Configurations 1, 2, 4, and 6, at the same speed. At one-fourth the delivered flow the hydraulic power output is reduced to one-fourth. The input power, however, is only slightly reduced resulting in the low efficiency. Configuration 5 has a lower efficiency than Configuration 3 because of the high loss in the impeller to housing axial clearance space.

Figures 24 through 29 compare the impeller static pressure rise with the overall pump static pressure rise. The difference in the two indicates the conversion of the impeller exit velocity pressure into static pressure. Table 6 summarizes the design point diffusion system performance. Configuration 2 with a volute exit conical diffuser achieved the highest diffusing system performance. Configuration 2, as well as the vaned Configurations 1 and 6, were not affected by changes in flowrate. However, the 25% emission vaned diffuser affected Configuration 3 output head as its ability to recover velocity head declined as the flowrate was increased.

TABLE 5. DESIGN POINT PUMP PERFORMANCE SUMMARY
WATER TEST

TEST CONFIGURATION				TEST RESULTS			
CONFIGURATION NO.	FRONT WEAR RING RADIAL CLEARANCE, INCHES	REAR WEAR RING RADIAL CLEARANCE, INCHES	IMPELLER FACE AXIAL CLEARANCE, INCHES	SHAFT SPEED, RPM	FLOWRATE, GPM	HEAD, FEET	EFFICIENCY, %
1	0.0015	0.0020	-	24,500	5.0	725*	31**
2	0.0025	0.0020	-	24,500	5.0	750	32.5
3	0.0026	0.0020	-	29,000	1.48	1130	9.6
4	-	0.0045	0.010	24,500	5.0	445	23.0
5	-	0.0038	0.008	29,000	1.48	342	5.1
6	0.0031	0.0030	-	24,500	5.0	745+	28.5++

* HEADRISE DATA - TEST 84L007
** EFFICIENCY DATA - TEST 84L008 (SAME TURBOPUMP BUILD)
\+ HEADRISE DATA - TEST 84L005
++ EFFICIENCY DATA FOR CLEARANCES SHOWN - TEST 84L015

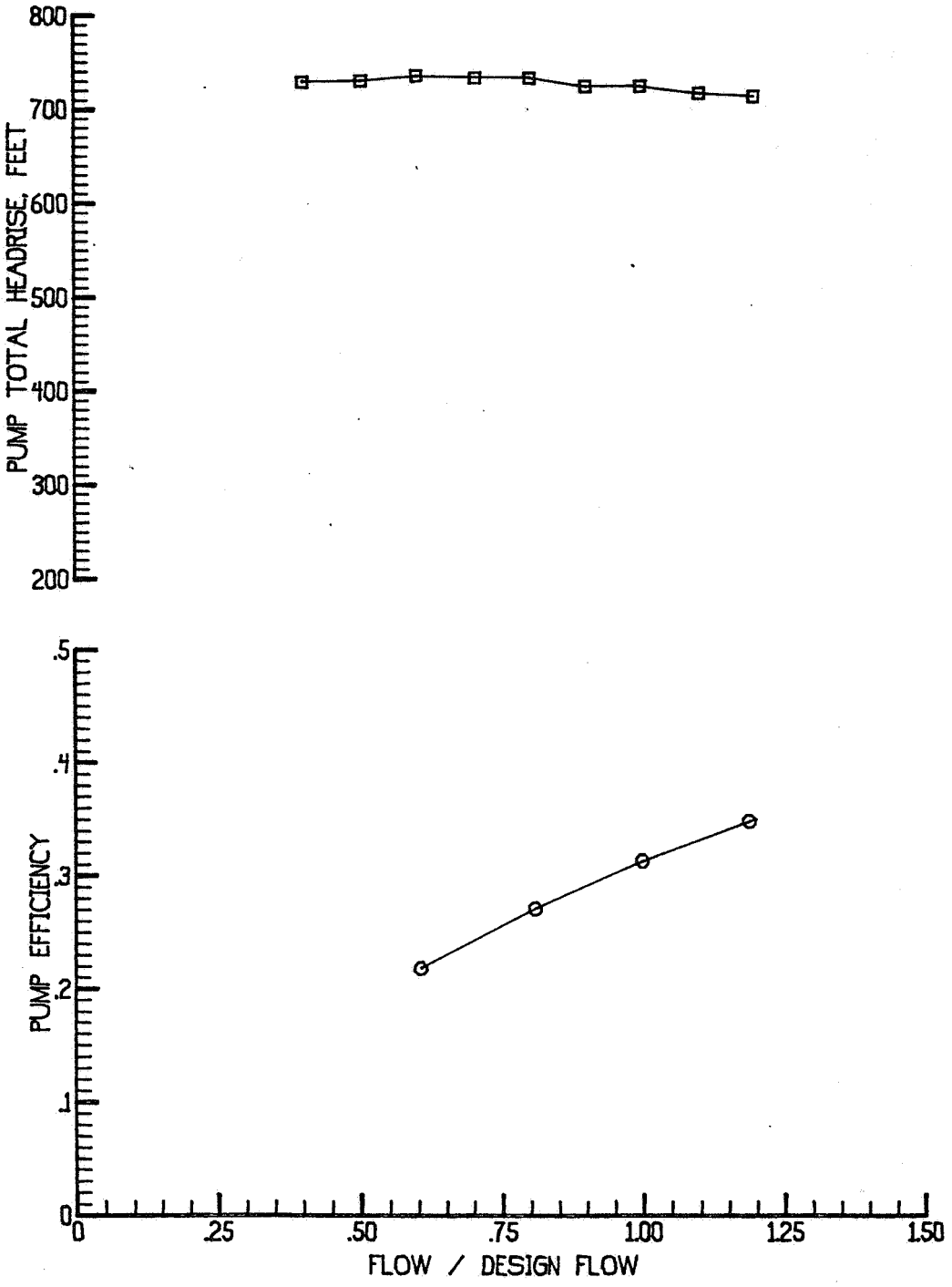

Figure 16. Low-Thrust Water Testing
Configuration 1
Test and Curve Speed - 24,500 rpm
Specific Speed - 430

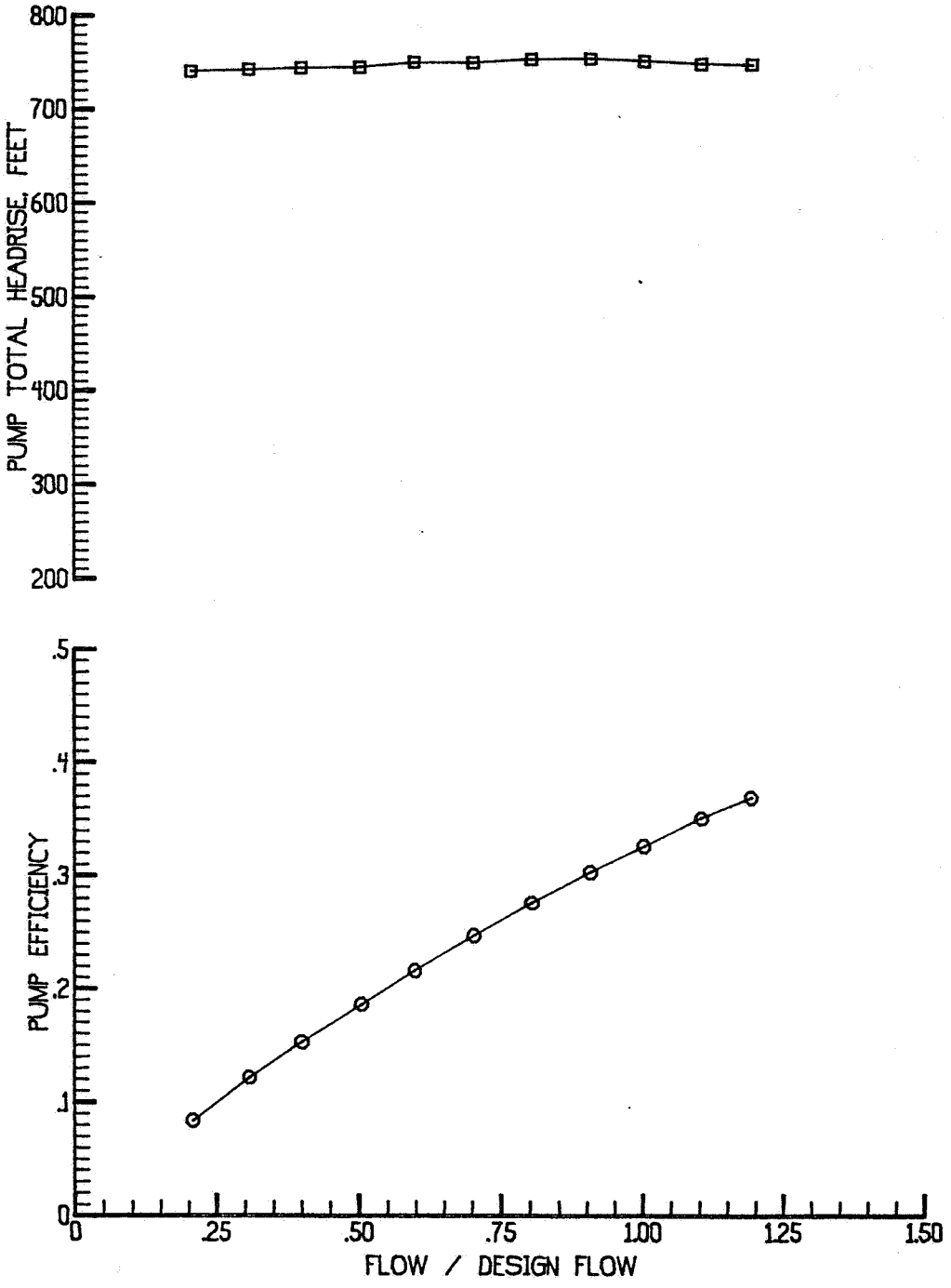

Figure 17. Low-Thrust Water Testing
Configuration 2
Test and Curve Speed - 24,500 rpm
Specific Speed - 430

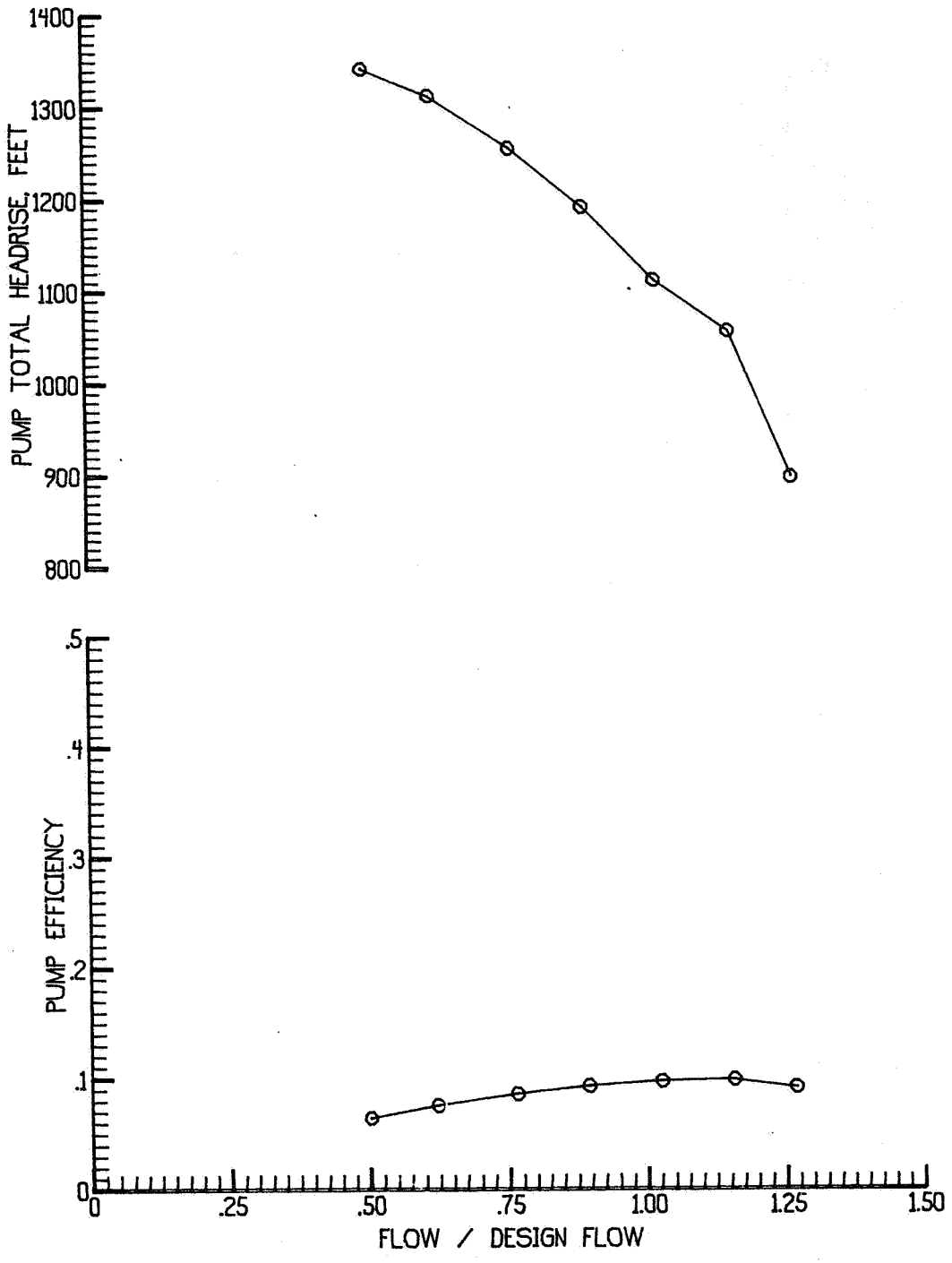

Figure 18. Low-Thrust Water Testing
Configuration 3
Test and Curve Speed – 29,000 rpm
Specific Speed - 215

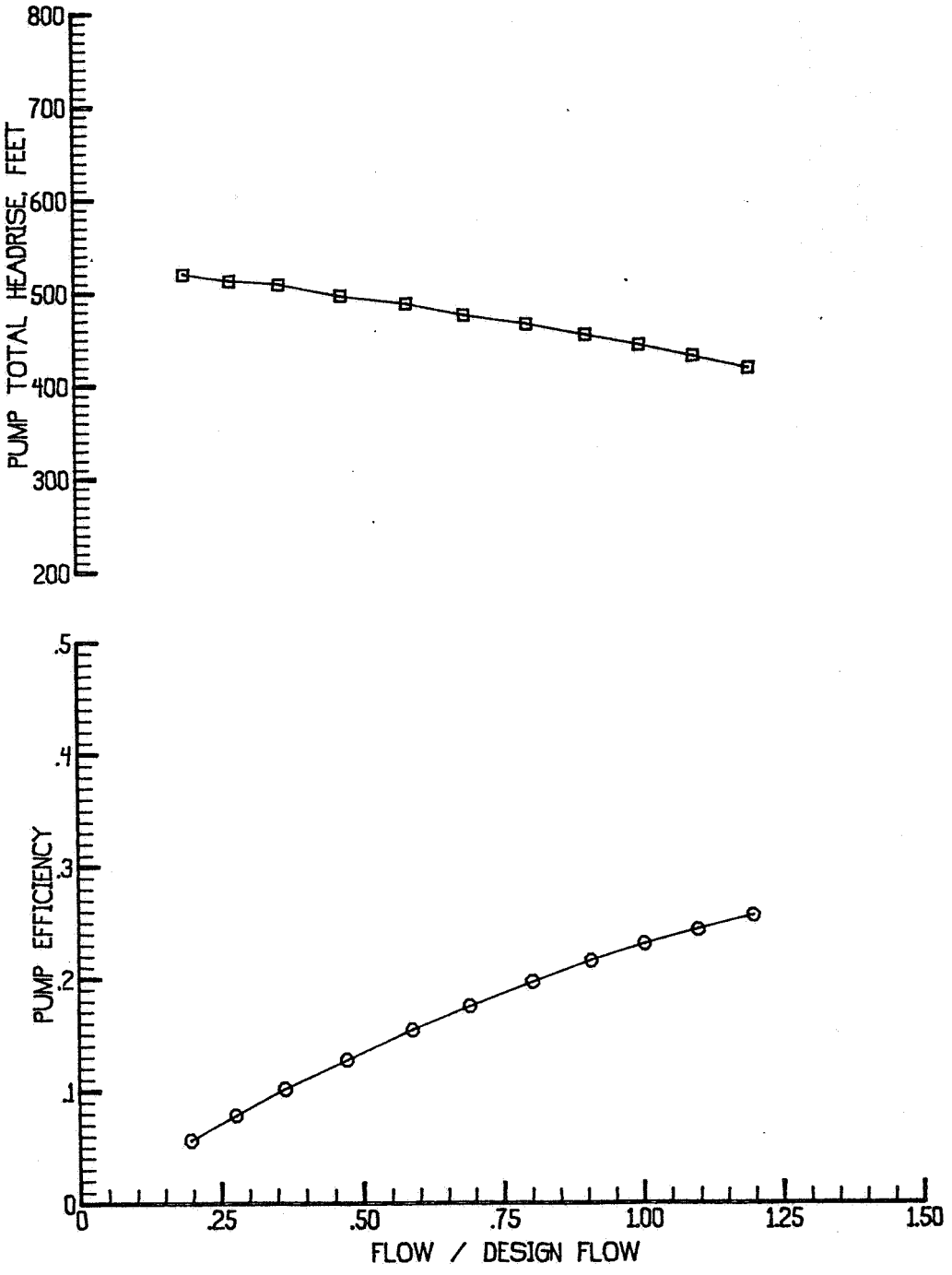

Figure 19. Low-Thrust Water Testing
Configuration 4
Test and Curve Speed - 24,500 rpm
Specific Speed - 430

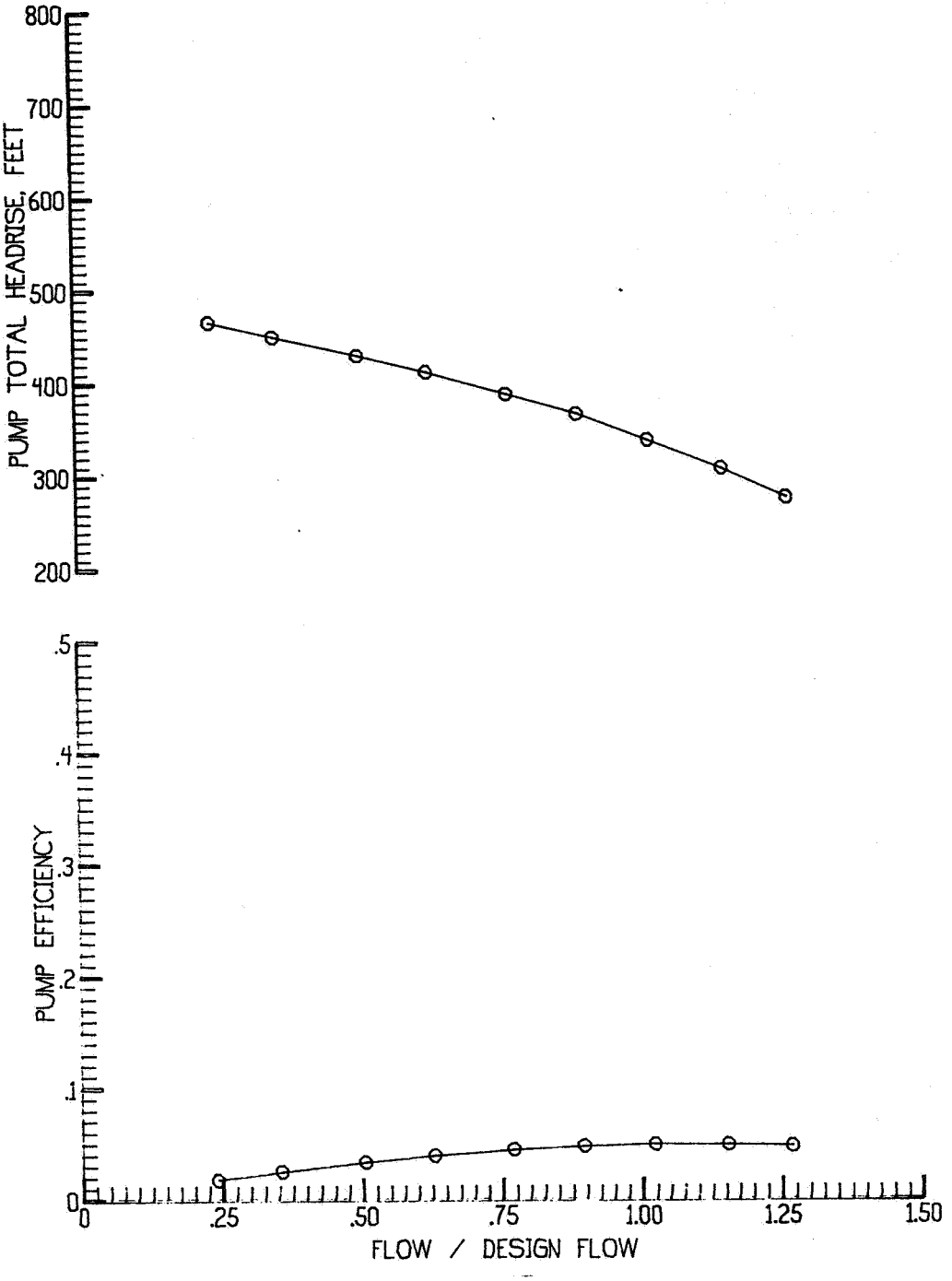

Figure 20. Low-Thrust Water Testing
Configuration 5
Test and Curve Speed - 29,000 rpm
Specific Speed - 215

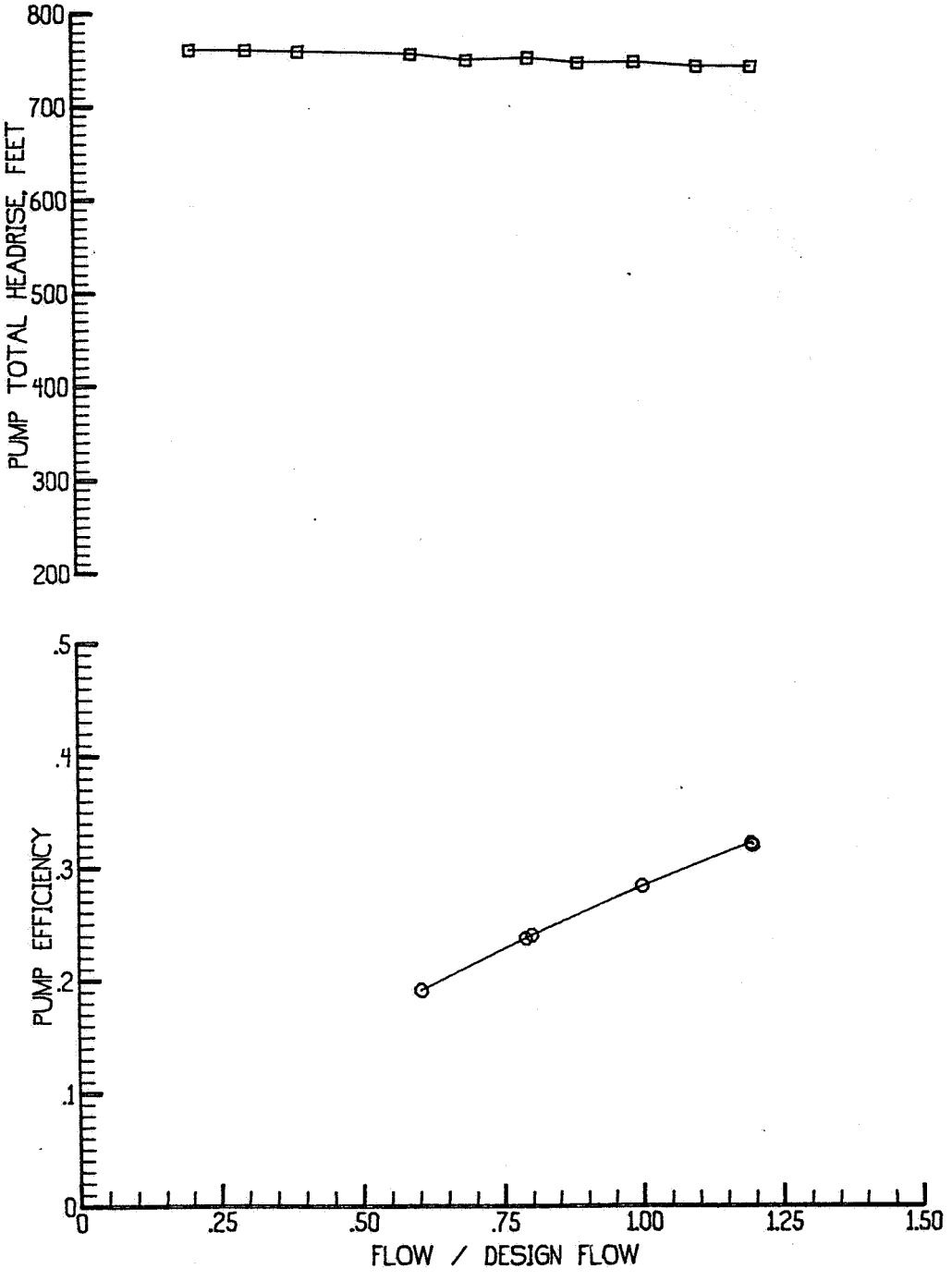

Figure 21. Low-Thrust Water Testing
Configuration 6
Test and Curve Speed - 24,500 rpm
Specific Speed - 430

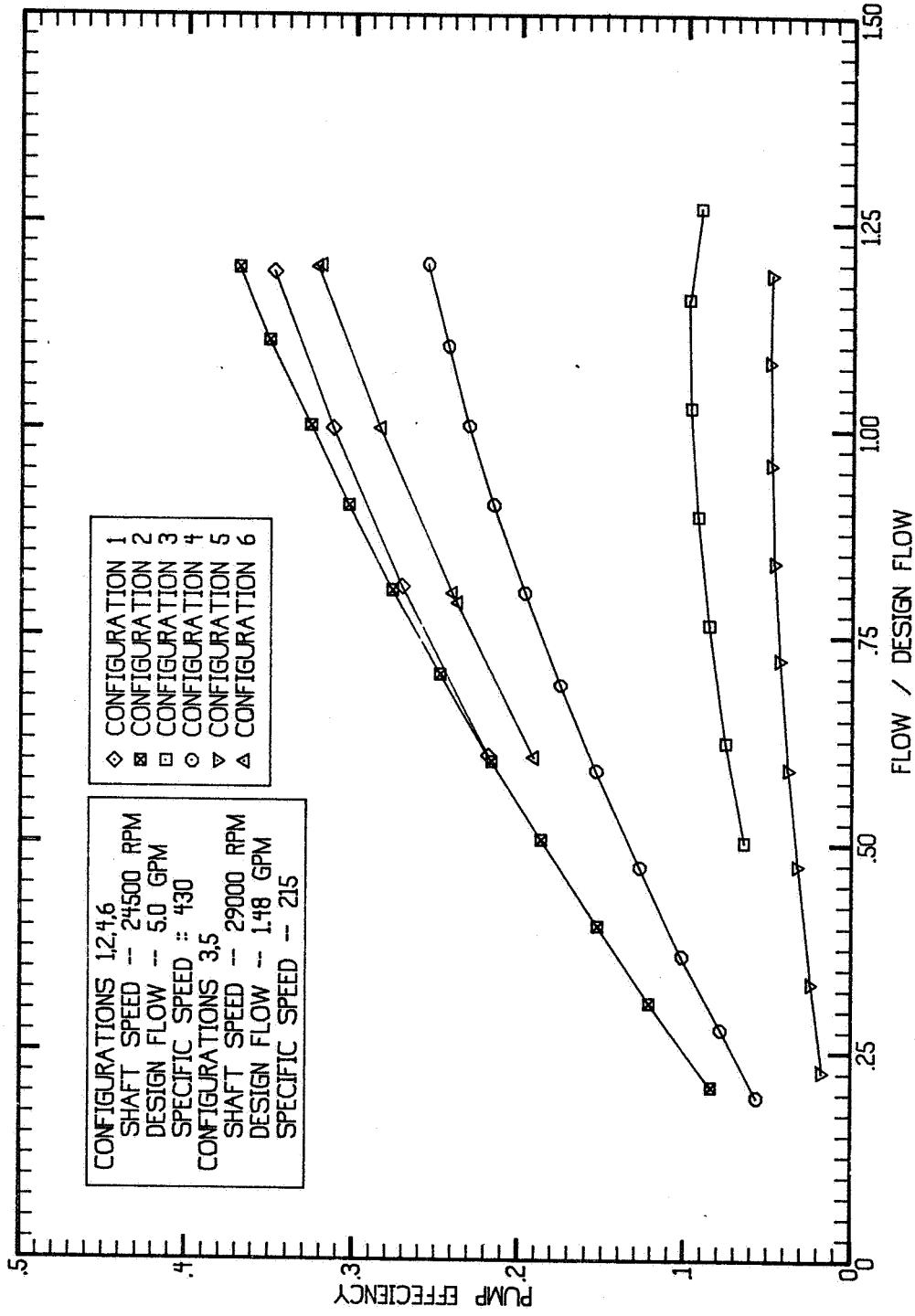

Figure 22. Low-Thrust Water Test Efficiency

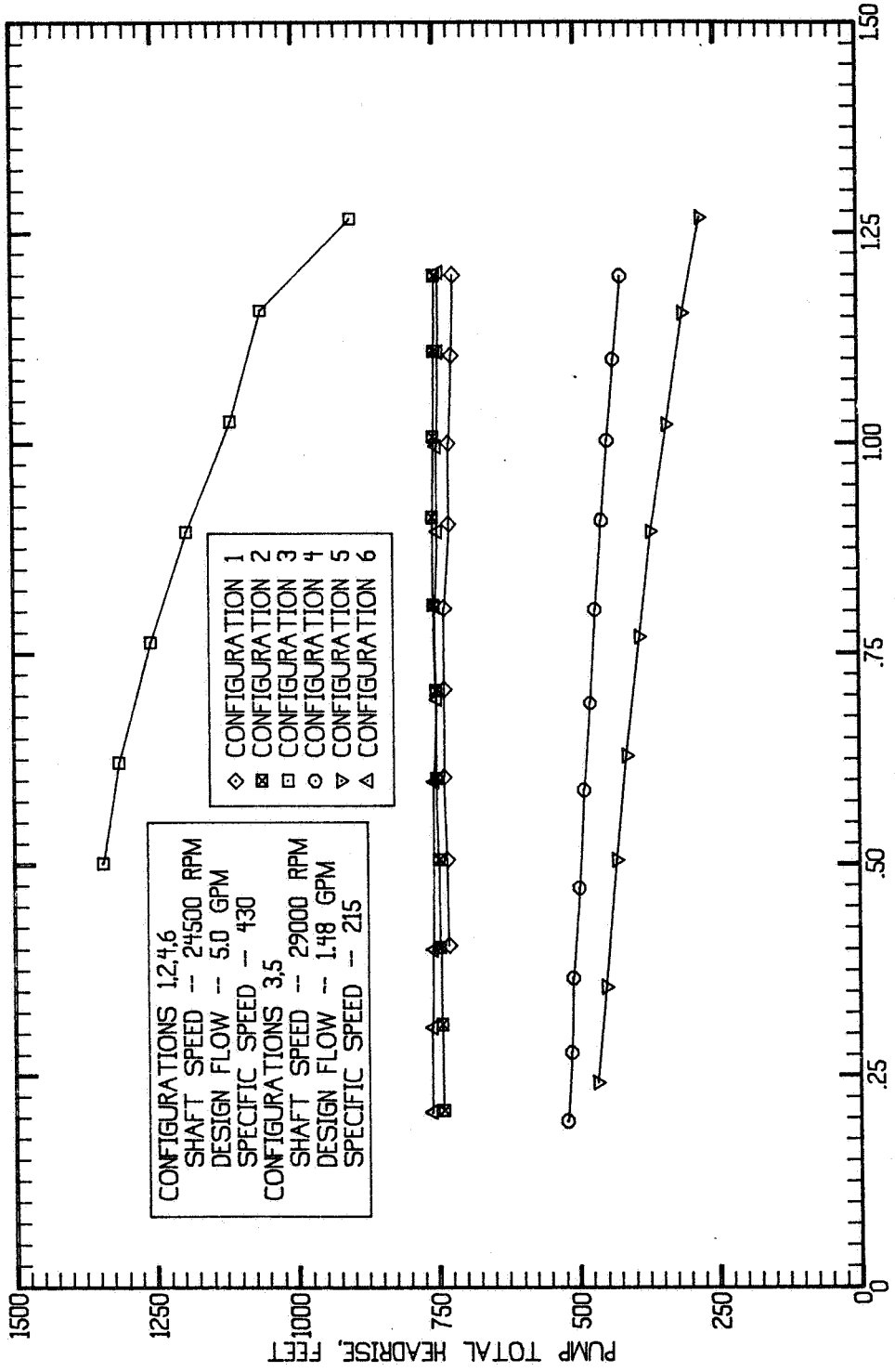

Figure 23. Low-Thrust Water Test Head

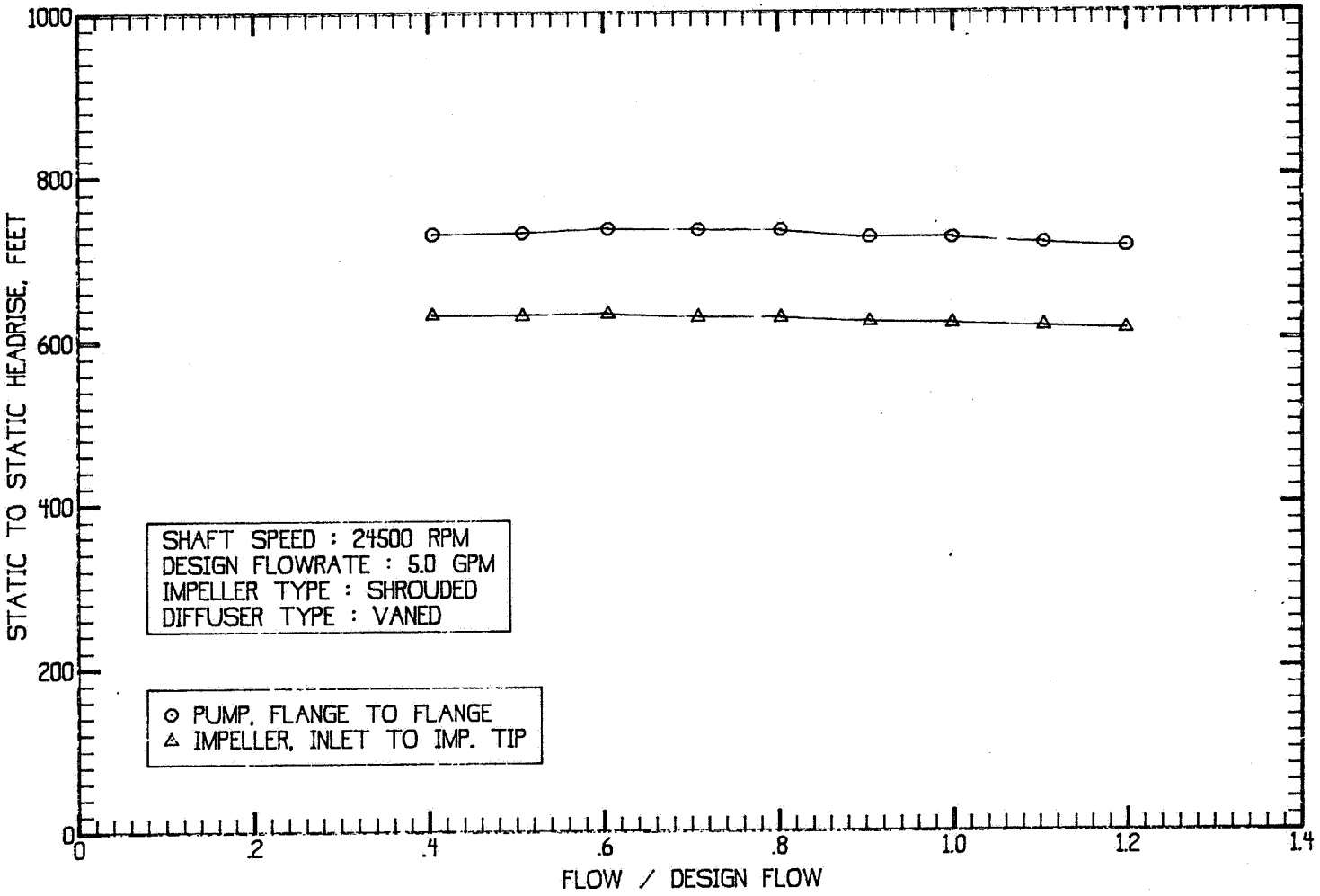

Figure 24. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 1

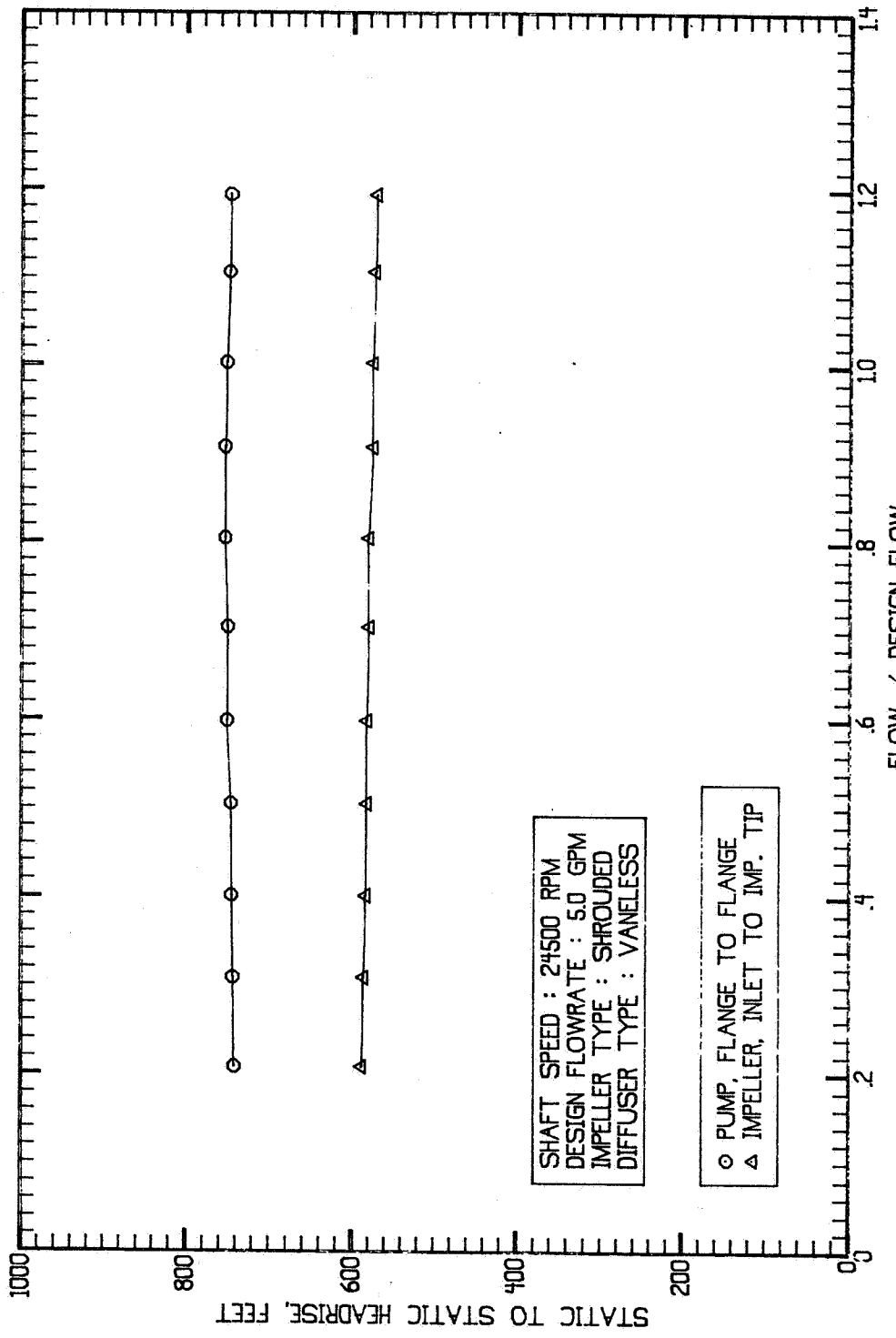

Figure 25. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 2

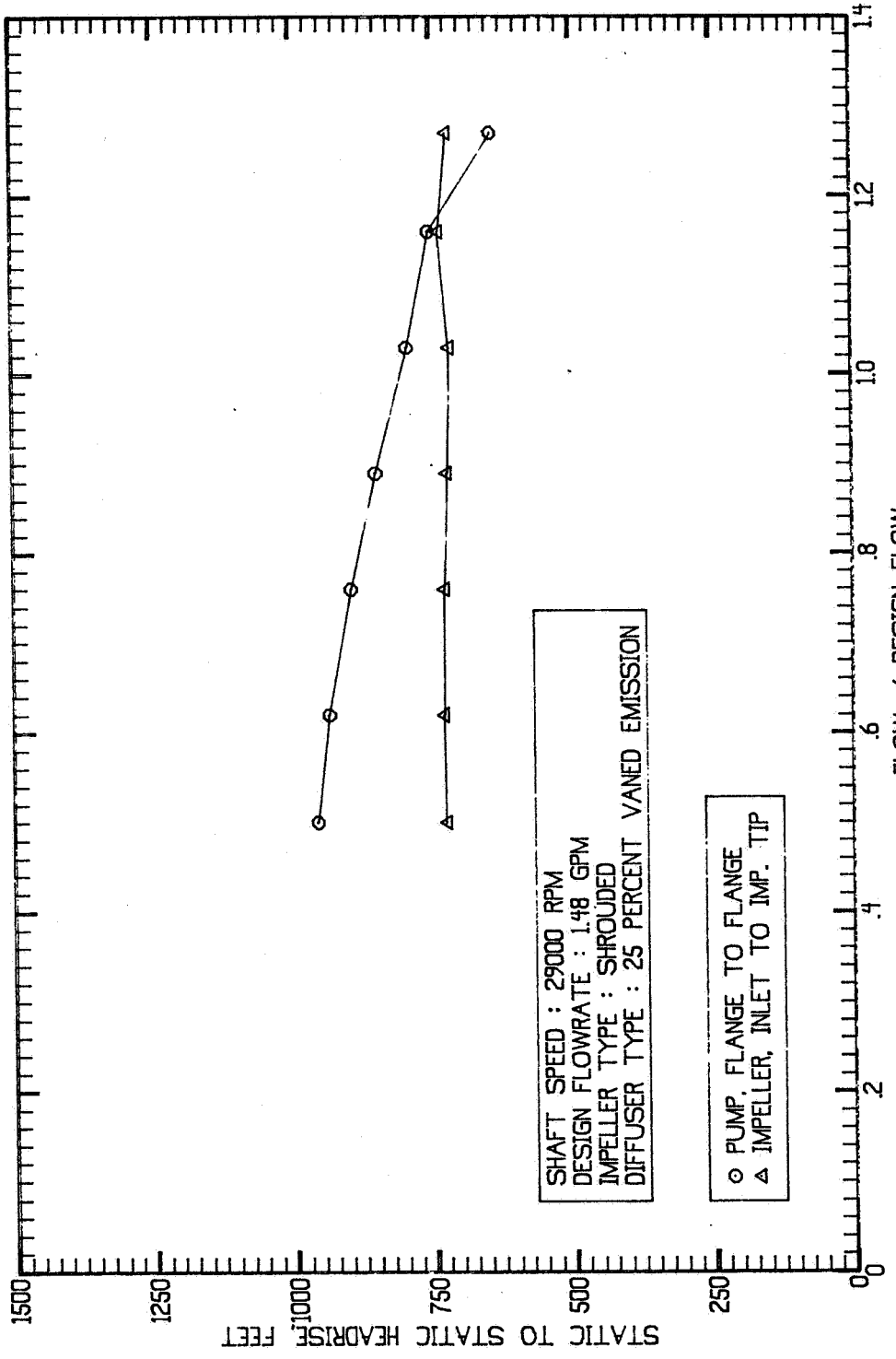

Figure 26. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 3

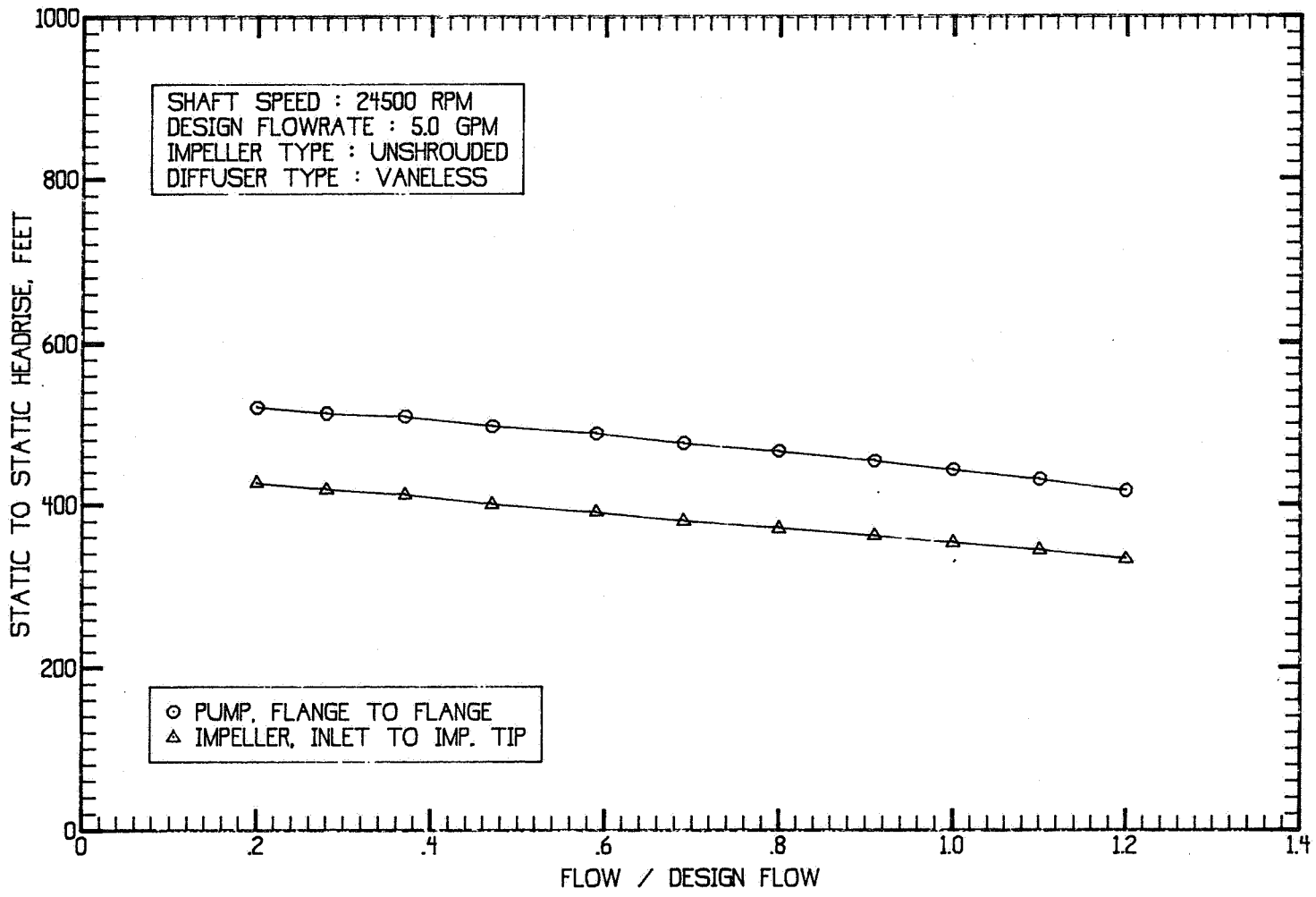

Figure 27. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 4

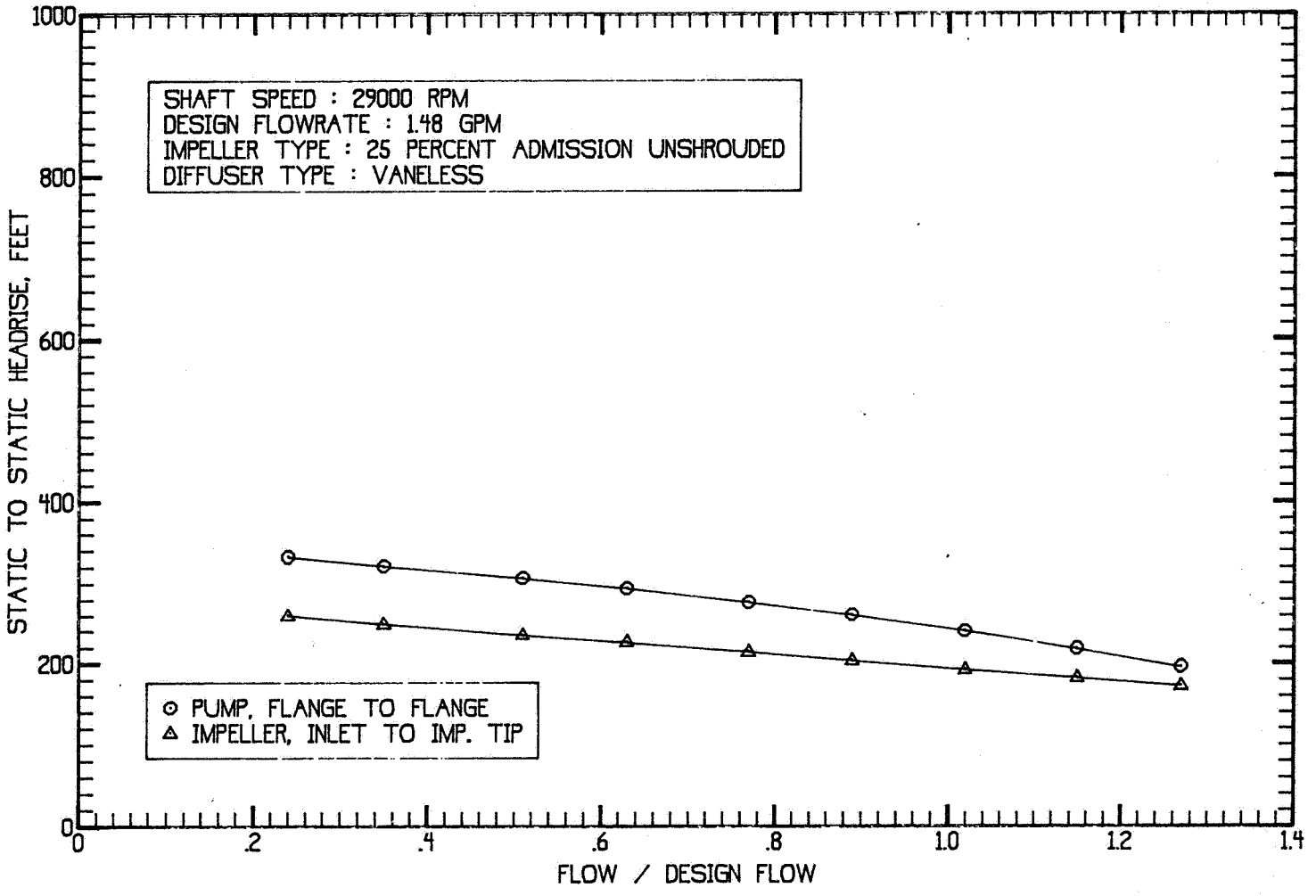

Figure 28. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 5

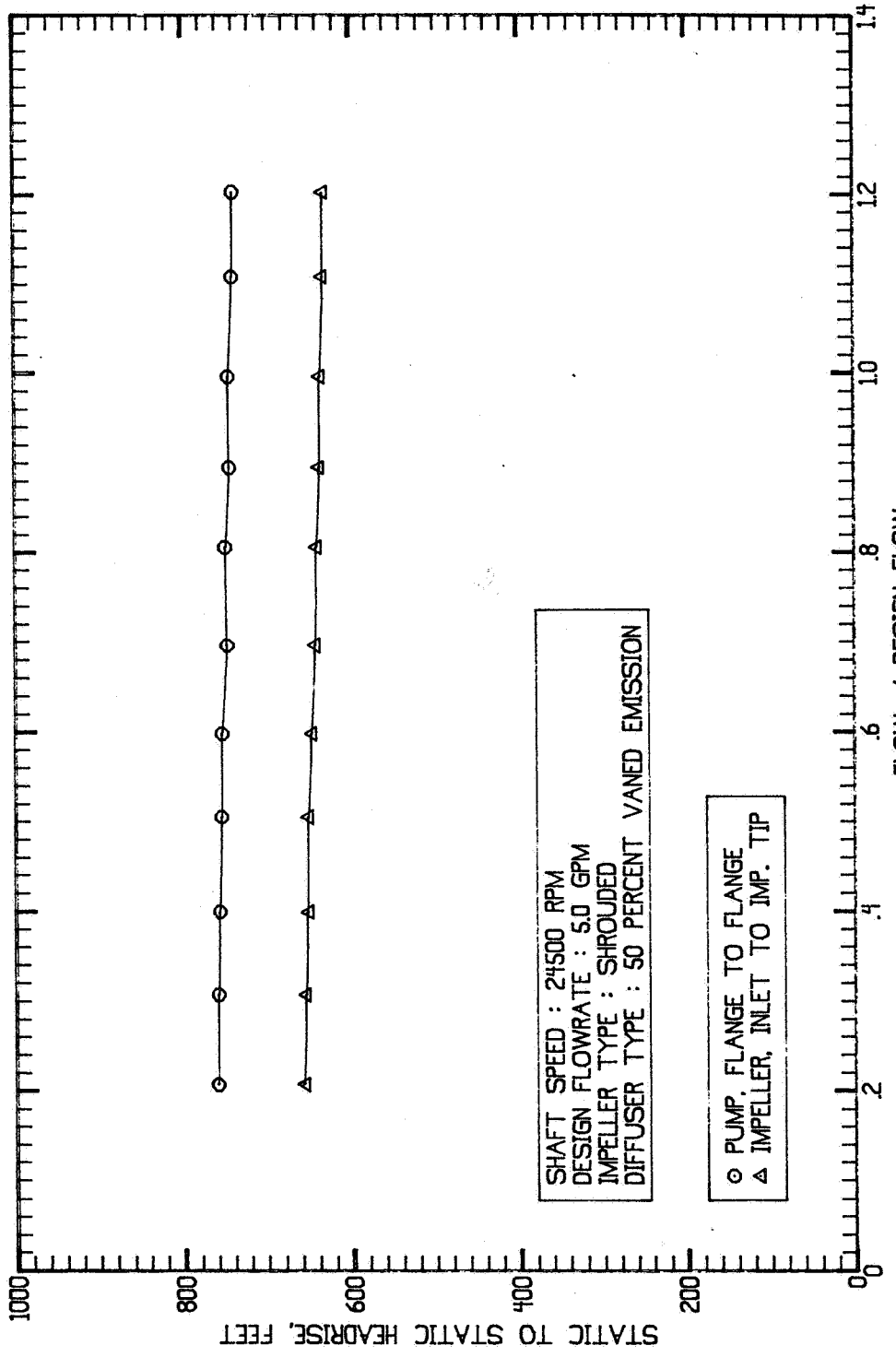

Figure 29. Pump and Impeller Static Headrise
Low-Thrust Water Testing, Configuration 6

TABLE 6. DIFFUSION SYSTEM STATIC PRESSURE DISTRIBUTION

CONFIGURATION	IMPELLER STATIC HEADRISE, FEET H_{IMP}	OVERALL PUMP STATIC HEADRISE, FEET H_{OV}	DIFFUSER STATIC HEADRISE, FEET H_{D-P}	H_{D-P}/H_{OV}
1	620	724	104	0.14
2	576	752	176	0.23
3*	720	805	85	0.11
4	354	440	86	0.20
5*	192	243	51	0.21
6	638	744	106	0.14

*TEST SPEED 29,000 RPM
RESULTS SCALED TO 24,500 RPM

$H_{D-P} = H_{OV} - H_{IMP}$

SUCTION PERFORMANCE

Cavitation tests were run at constant pump speed and flowrate for pump Configurations 2, 3, 4, 5, and 6. Pump Configuration 1 was not run because it contains the same impeller as Configuration 2 and, therefore, would have the same suction performance. All suction performance data are presented at 5% overall pump head loss. The design point predicted and test suction performance is compared for the six configurations in Table 7. The predicted cavitation performance at the design point is based on the procedure developed by Gongwer and presented by Wislicenus in Ref. 1. For the partial admission and emission pumps, the impeller inlet area was determined by multiplying the geometric area by emission or admission ratio. The calculated leakage flowrate for each configuration was added to the through flowrate in computing the impeller inlet flow coefficient. As shown in Table 7, Configurations 4 and 5 (open face impellers) exhibited higher suction specific speed capability than predicted. A probable explanation is that the influence of the backflow leakage is lower than originally accounted for in the predicted values. The shrouded impeller Configurations 3 and 6 (25 and 50% emission, respectively) both performed better than predicted, indicating that the partial emission influence is not as severe as predicted.

Figure 30 presents the test Configuration 2 pump total headrise versus NPSH for 80, 100, and 120% of design flowrate at a test speed of 24,500 rpm. The test results show that the head rise is constant over a wide NPSH range for each flowrate. The suction specific speed versus flow ratio is shown on Fig. 31.

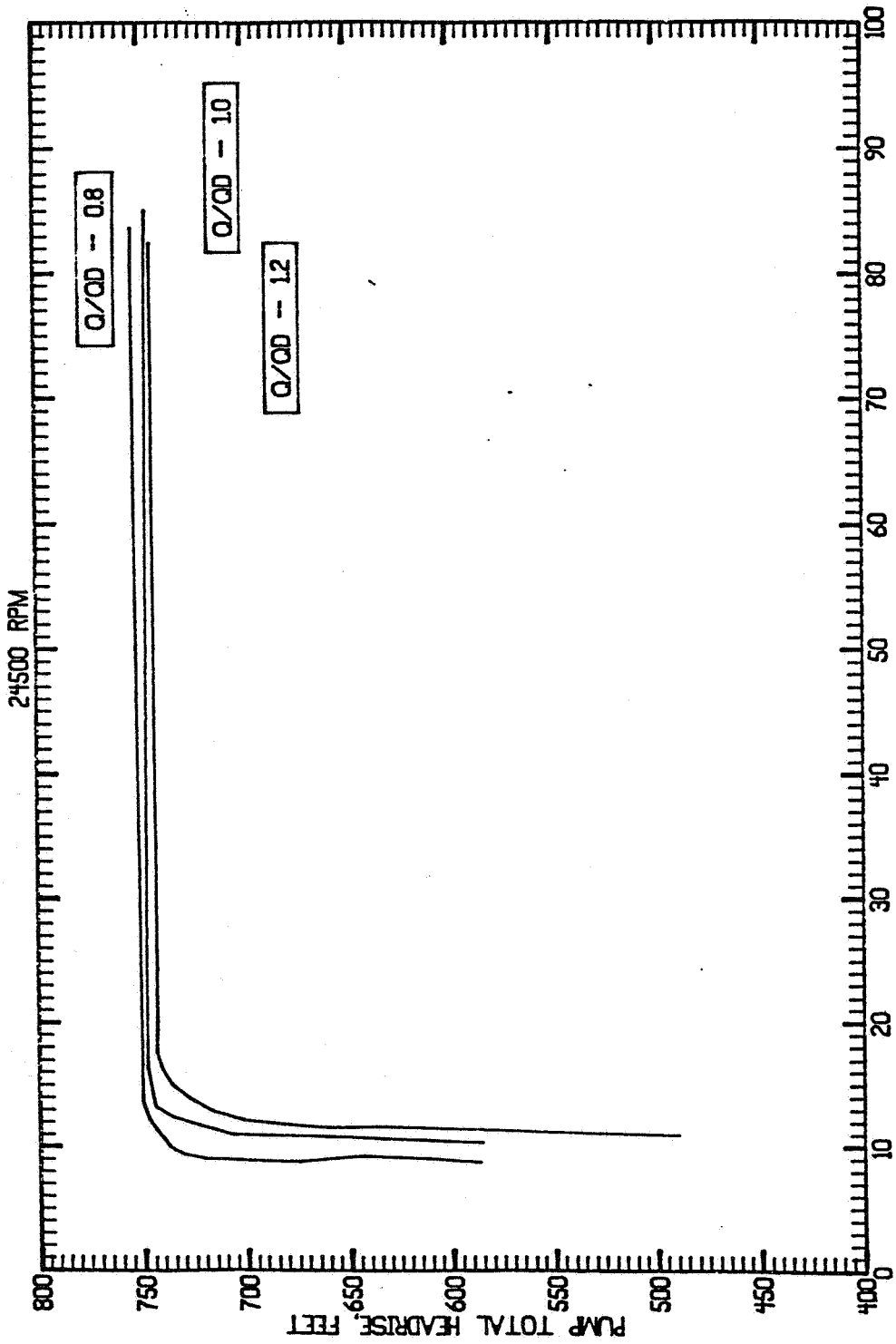

Figure 30. Cavitation Test, Configuration 2

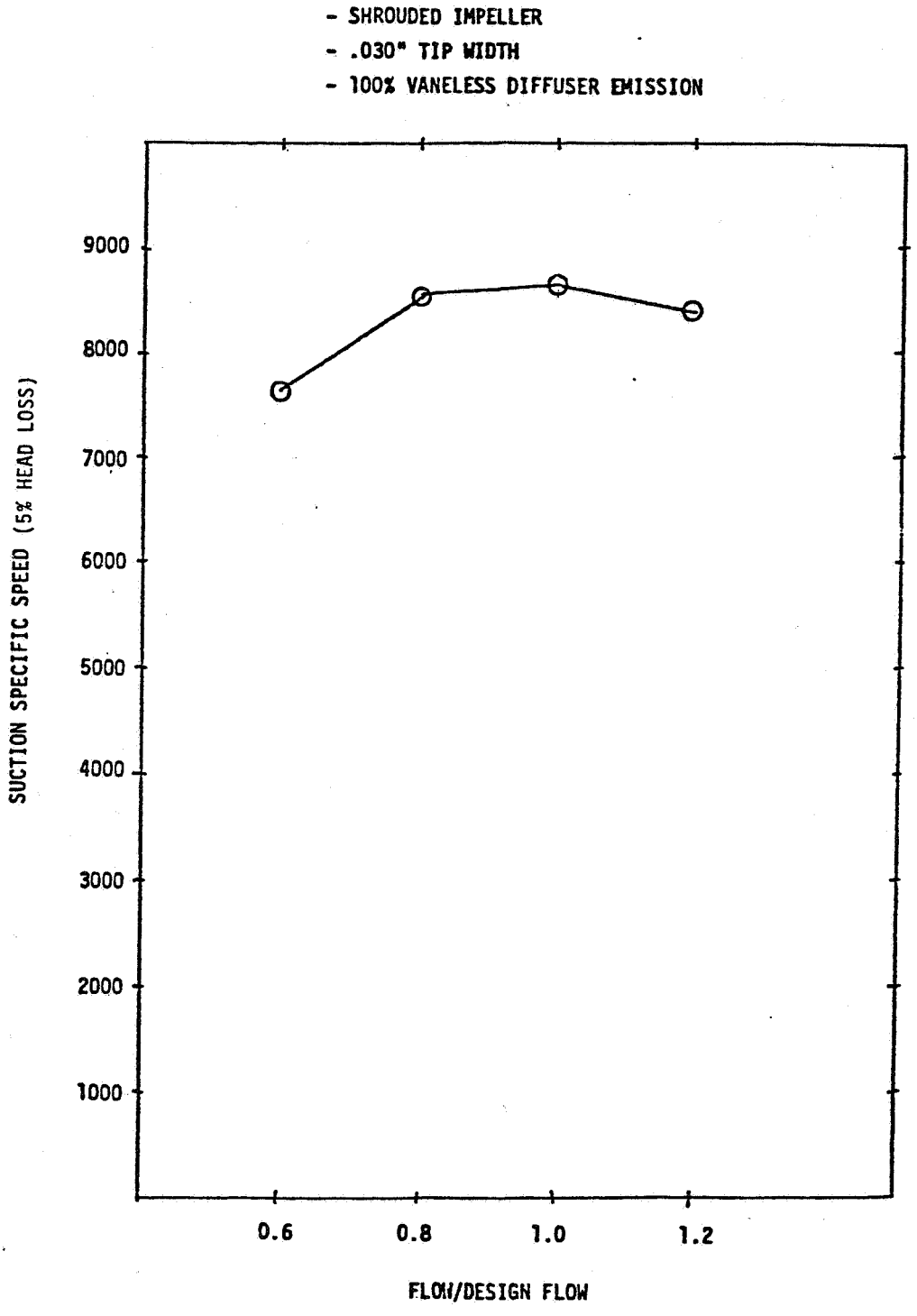

Figure 31. Suction Performance Configuration 2

TABLE 7. SUMMARY OF CENTRIFUGAL STAGE DESIGN POINT SUCTION PERFORMANCE

TEST CONFIGURATION	TEST SPEED, RPM	DESIGN FLOW AT TEST SPEED, GPM	INLET NPSH AT 5% HEAD FALLOFF, FEET	SUCTION SPECIFIC SPEED (TEST)	SUCTION SPECIFIC SPEED (PREDICTED)	$\frac{N_{ss}\ (TEST)}{N_{ss}\ (PRED)}$
1	24,500	5.0	11.6	8,700	9235	0.94
2	24,500	5.0	11.6	8,700	9370	0.93
3	27,440	1.4	6.7	7,800	4345	1.80
4	24,500	5.0	8.8	10,700	7440	1.44
5	29,000	1.48	13.2	5,100	4370	1.17
6	24,500	5.0	10.8	9,200	7120	1.29

Figure 32 indicates that the head rise versus NPSH is constant for Configuration 3 over a wide NPSH range at 80 and 100% of the design flowrate. At 120% of design flowrate the head rise begins to drop as NPSH is decreased below approximately 100 feet at 27,440 test rpm. The test results presented on Fig. 26 indicate that the diffuser static pressure recovery continuously decreases as the flowrate is increased until at 120% of design flowrate the recovery is zero. This along with the 120% head versus NPSH characteristic indicates the vaned diffuser may be cavitating. This may be a function of the percent emission since the 50% emission Configuration 6 demonstrated a constant head rise over a wide flow range of 120% flow as well as a constant diffusing system static pressure rise over a wide flow range. Suction specific speed versus flowrate for Configuration 3 is shown on Fig. 33.

Configuration 4 cavitation performance shown in Fig. 34 as head versus NPSH for 80, 100, and 120% of design flowrate indicates a wide NPSH range at constant headrise. The suction specific speed versus flow ratio at 5% head loss is shown on Fig. 35.

Configuration 5 head versus NPSH is shown for flow ratios Q/Q_D of 0.8, 1.0, and 1.2 on Fig. 36. Suction specific speed versus flow ratio is shown in Fig. 37. This partial admission impeller demonstrated the lowest suction specific speed of the six test configurations.

Configuration 6 head versus NPSH is presented on Fig. 38 for the flow ratios 0.8, 1.0, and 1.2. Constant head was generated over a wide NPSH range for the three flowrates. Suction specific speed versus flow ratio is plotted on Fig. 39.

HYDRODYNAMIC SHAFT LOADING

Each pump was instrumented to measure pressures required to calculate axial and radial forces produced by the impeller.

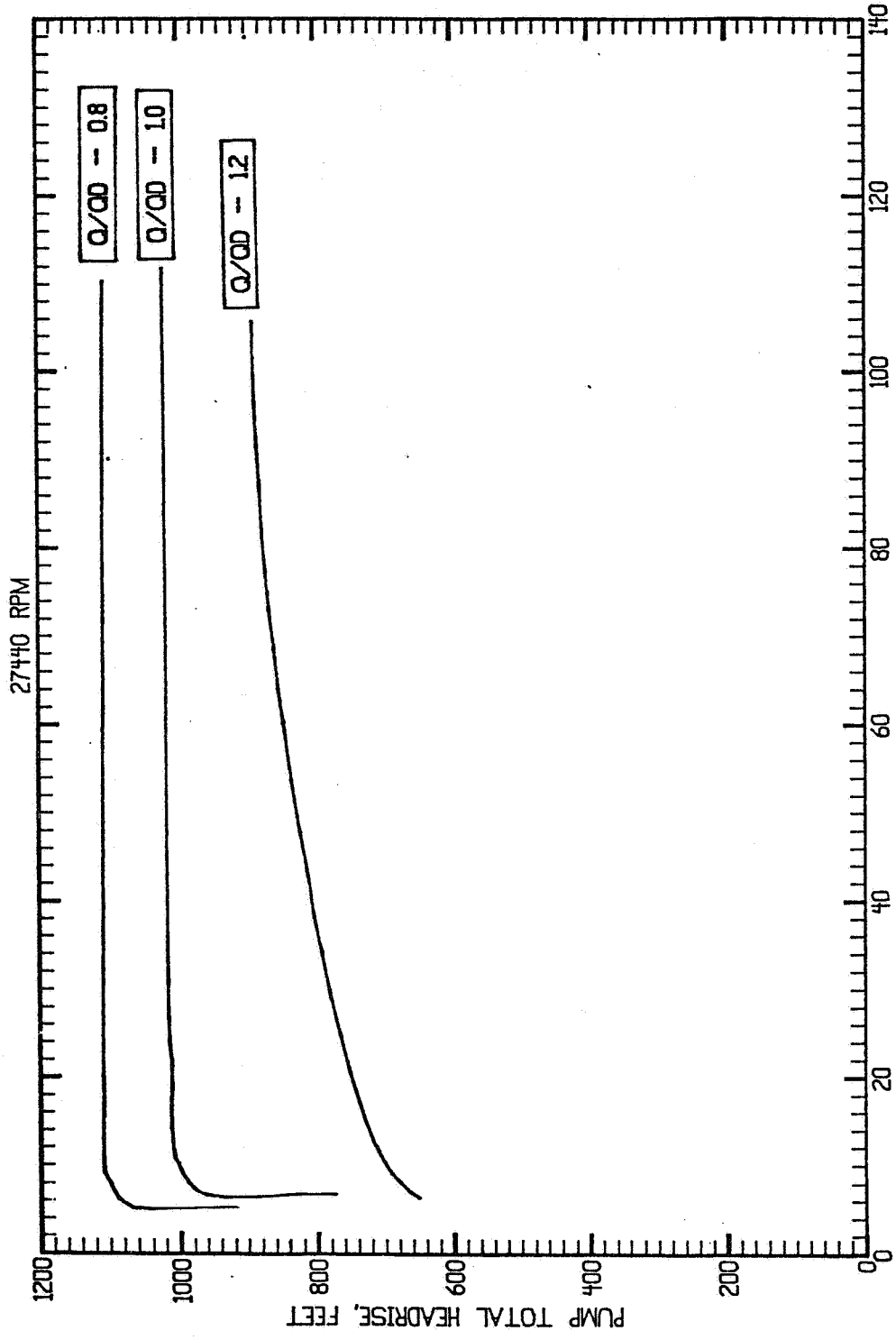

Figure 32. Cavitation Test, Configuration 3

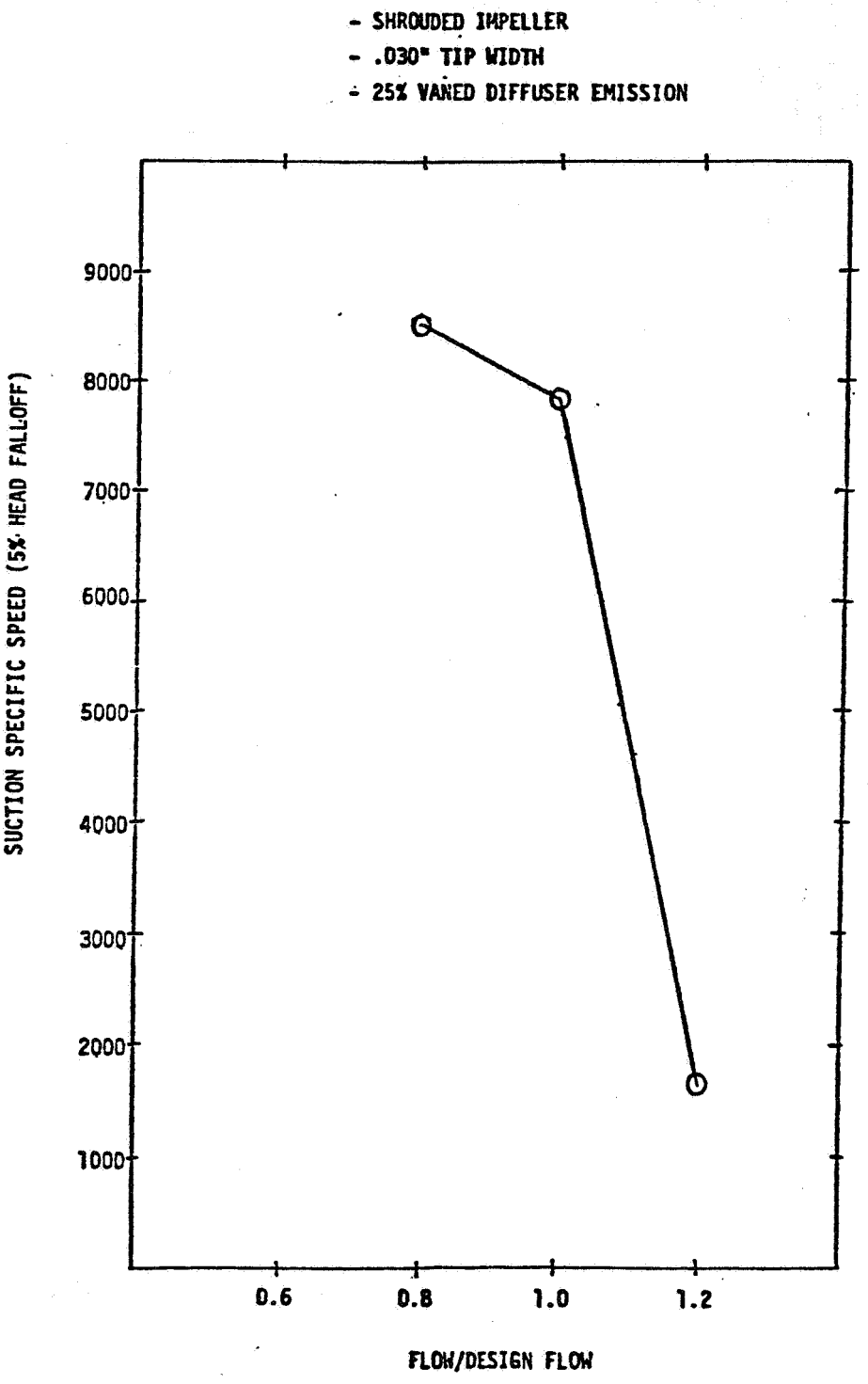

Figure 33. Suction Performance
Configuration 3

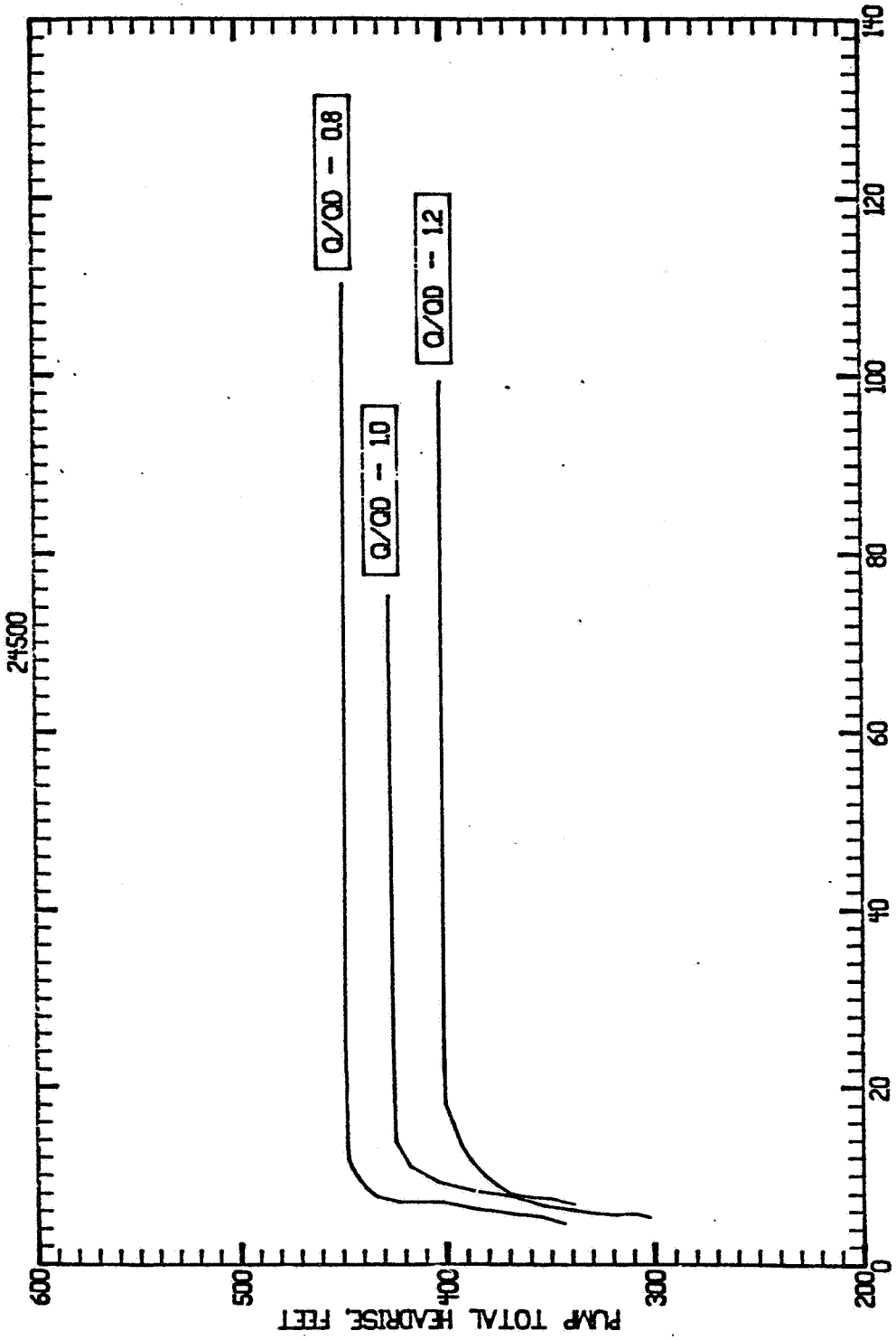

Figure 34. Cavitation Test, Configuration 4

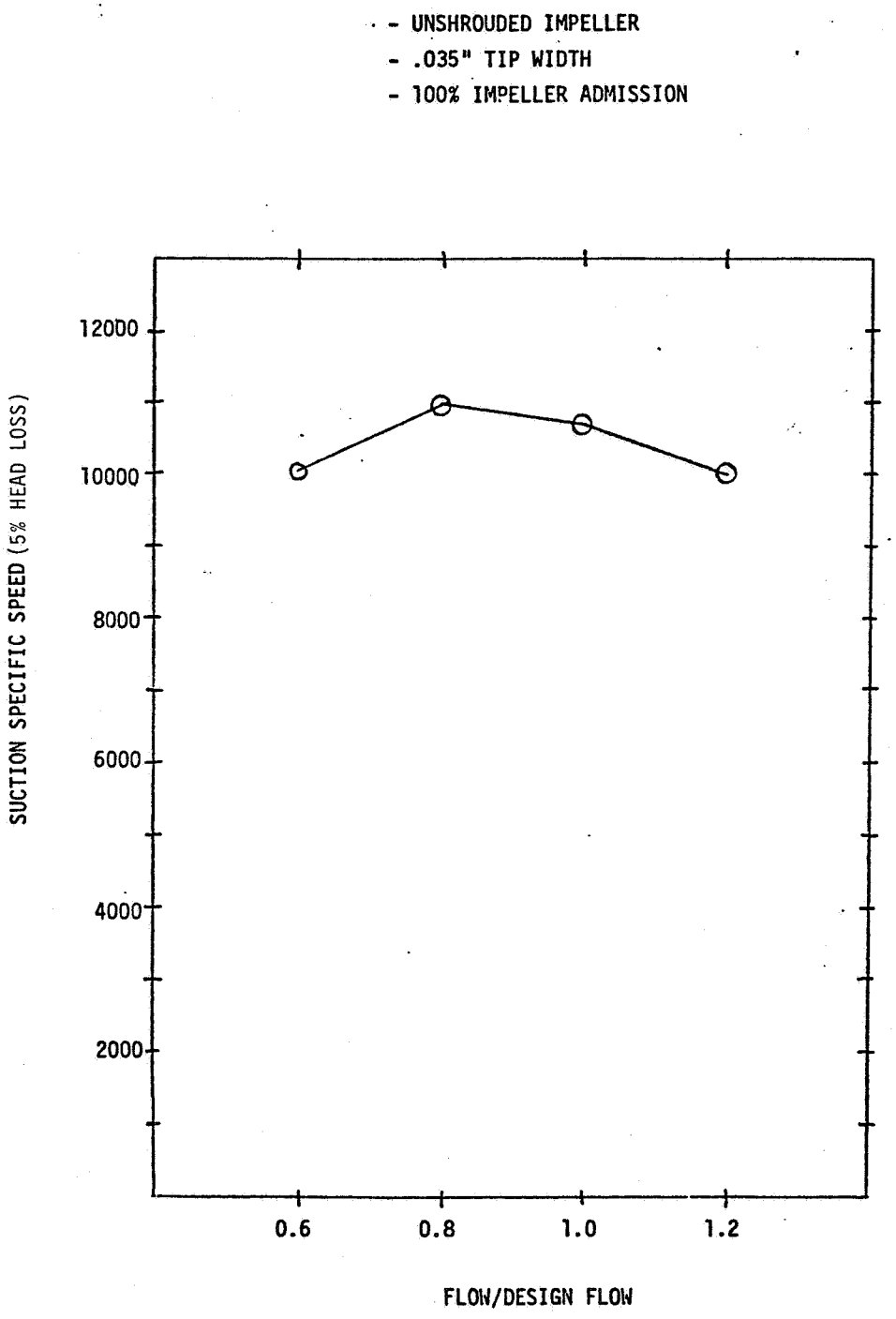

Figure 35. Suction Performance
Configuration 4

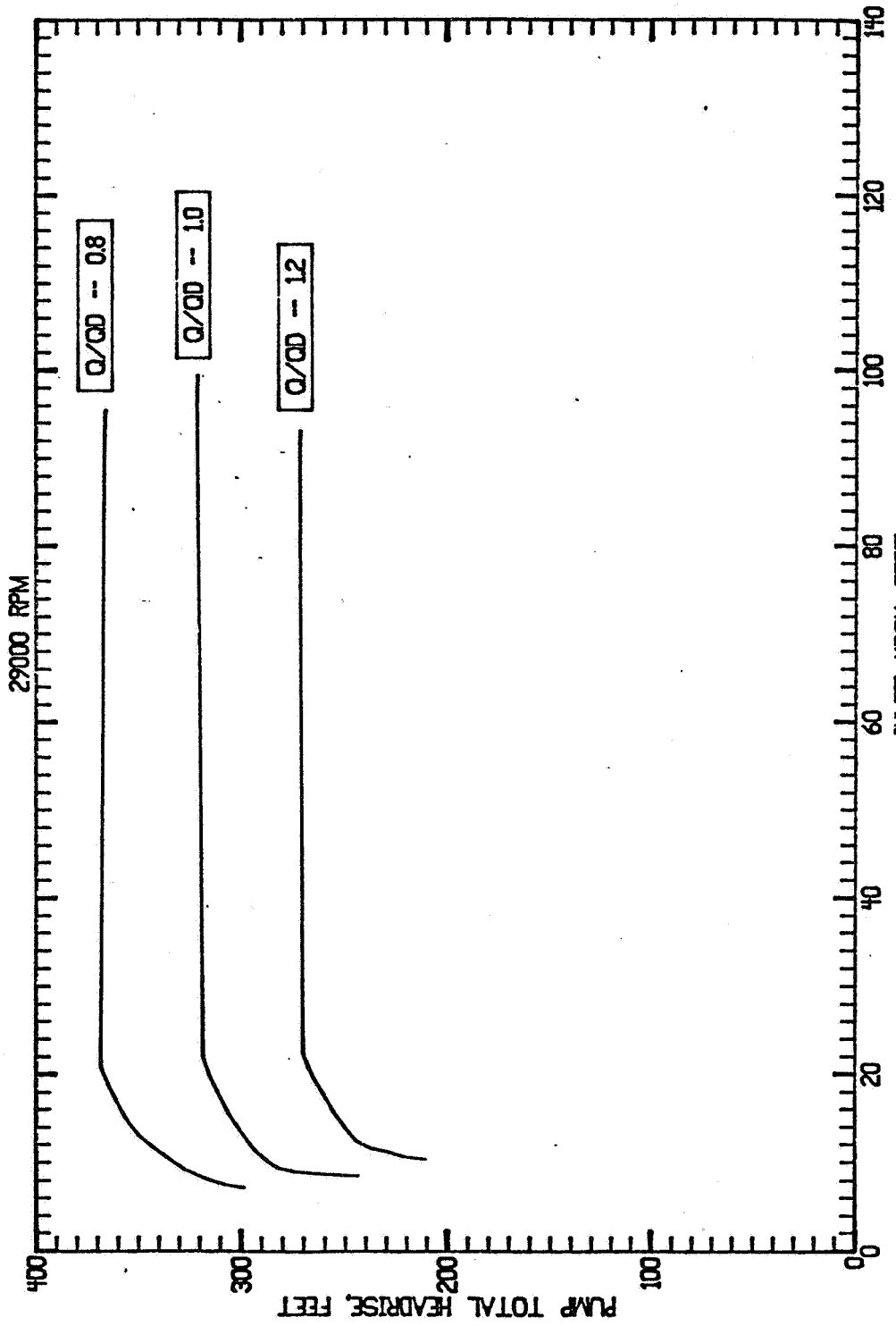

Figure 36. Cavitation Test, Configuration 5

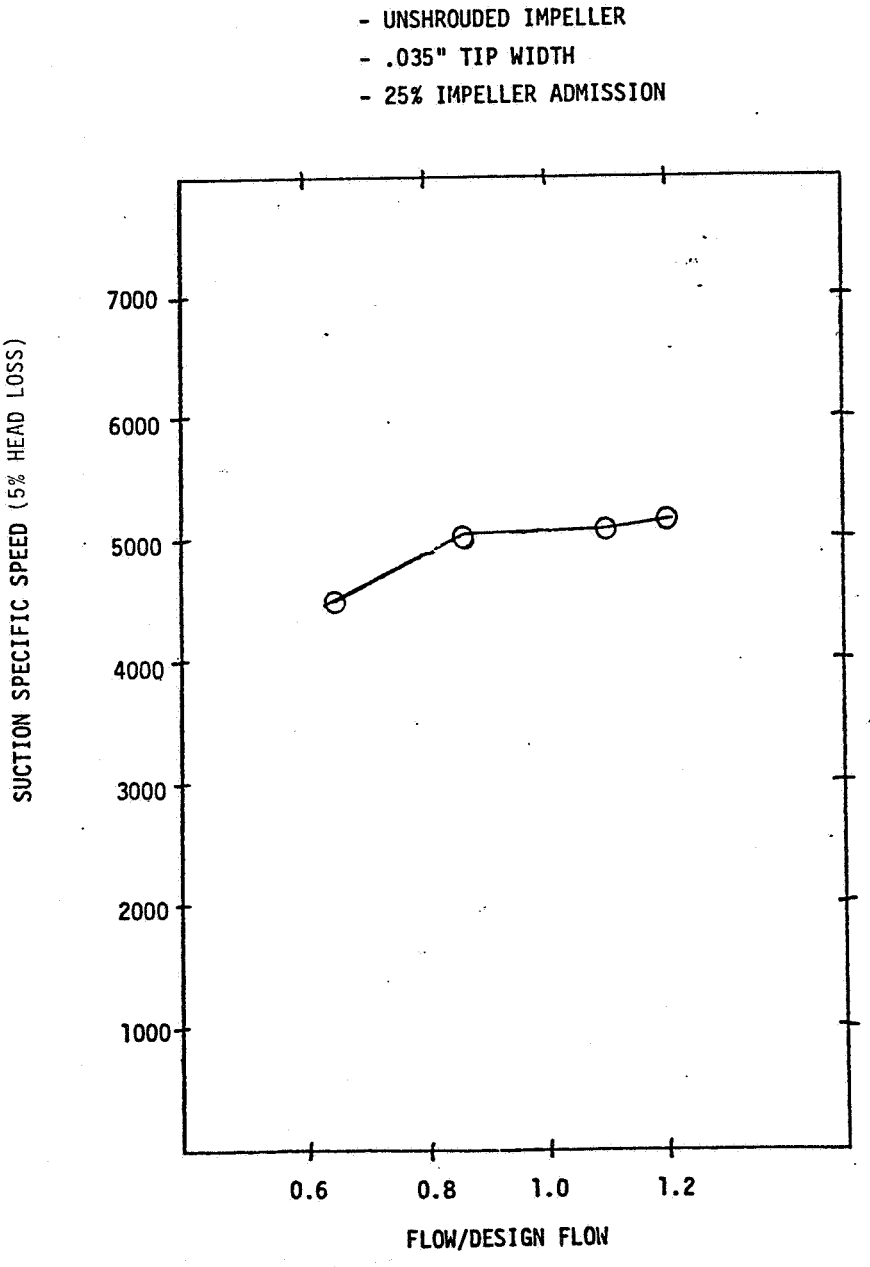

Figure 37. Suction Performance
Configuration 5

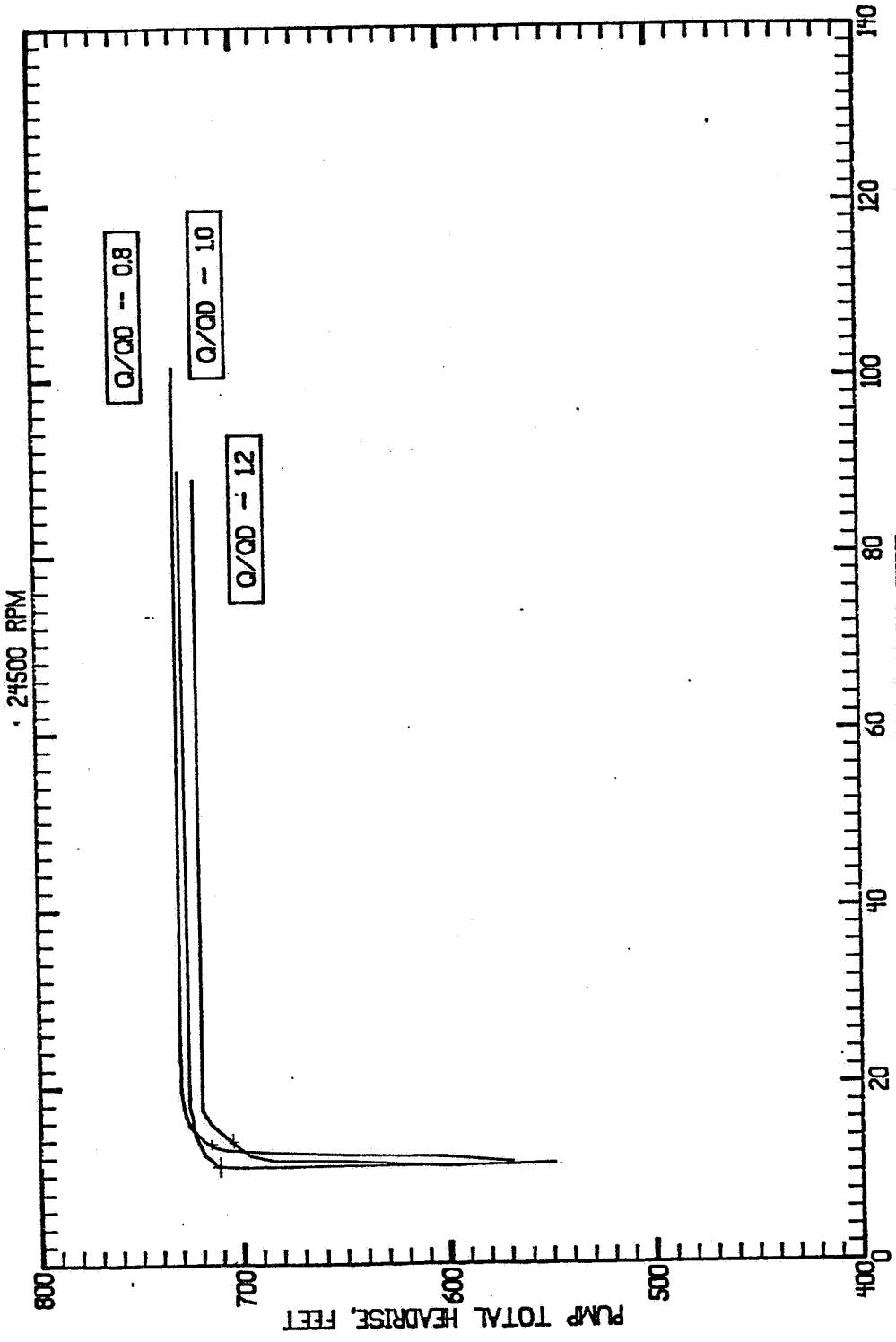

Figure 38. Cavitation Test, Configuration 6

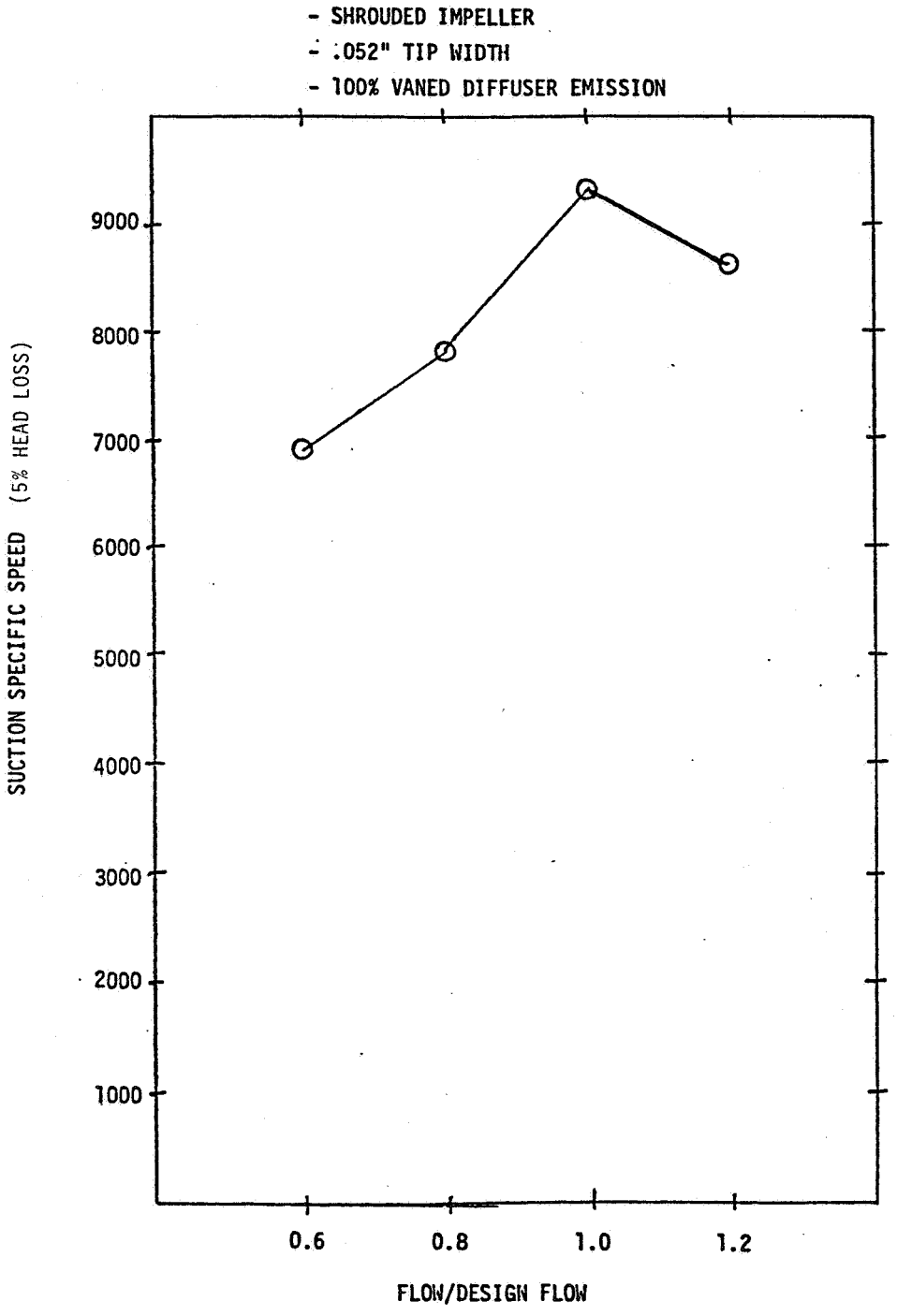

Figure 39. Suction Performance
Configuration 6

Radial Load. The radial loads are determined from the static pressure distribution downstream of the impeller. For the vaned diffuser pumps the static pressure taps are located in the diffuser passage inlet. The number of diffuser passages and, therefore, the number of static pressure taps depends on the configuration. For volute pumps four taps are located equally spaced in the volute. From these pressures the static pressure at the impeller tip is determined by assuming a free vortex flow from the impeller discharge diameter to the pressure tap location.

Using the pressures at the impeller tip and assuming the pressure distribution is linear between pressure taps, the incremental forces may be calculated. The resultant force is found by summing force components vectorially.

Radial loads over the test flow range are shown in Fig. 40. The two pumps showing the smallest radial loads are Configurations 1 and 6. Both of these configurations have vaned diffusers. The only other pump with a vaned diffuser, Configuration 3, showed larger radial loads than 1 and 6. However, the radial loads for Configuration 3 were calculated using the two diffuser inlet pressure taps and, therefore, are not as accurate as the other results. The test speed for Configurations 3 and 5 were 29,000 rpm, compared with 24,500 rpm for Configurations 1, 2, 4, and 6. Therefore, the Configuration 3 and 5 radial loads should be divided by 1.4 before comparison with the other configurations. The vaned diffuser configurations exhibit radial loads which do not depend strongly on flowrate. This is in contrast to the volute pumps, which show higher radial loads with a large dependence on flowrate. These characteristics agree with those predicted for the vaned diffuser and volute pumps. Vaned diffuser pumps are more desireable when wide flow range operation is required.

Axial Loads. The axial load is determined from the static pressure distribution on the front and rear impeller face and by the impeller inlet pressure. The front face has three static pressure taps located at the shroud hub, midpoint, and tip. The rear face has two static pressure taps located at the shroud hub and tip.

The axial load versus flow/design flow is plotted in Fig. 41 and 42 for the shrouded and open face impellers, respectively. The shrouded impellers show design point axial loads in the range of 2.6 to 42.5 pounds in a direction toward the turbine. The open face impellers show design point values of 8.7 and 22.2 pounds. However, the direction is away from the turbine. All axial and radial loads are well within bearing load capability in the design flow region. With vaned diffusers load margin exists over a very wide flow range.

ANALYSIS OF PUMP LOSSES

After completion of the water test program, Configurations 2 and 6 were selected for further tests and will be tested with liquid hydrogen as the pumped fluid. Predicted losses for these configurations when pumping water or liquid hydrogen are given in Tables 8 and 9, respectively. The losses presented are a percent of the total power input. The types of loss noted in the tables are typical of those considered in performance prediction of pumps incorporating shrouded impellers.

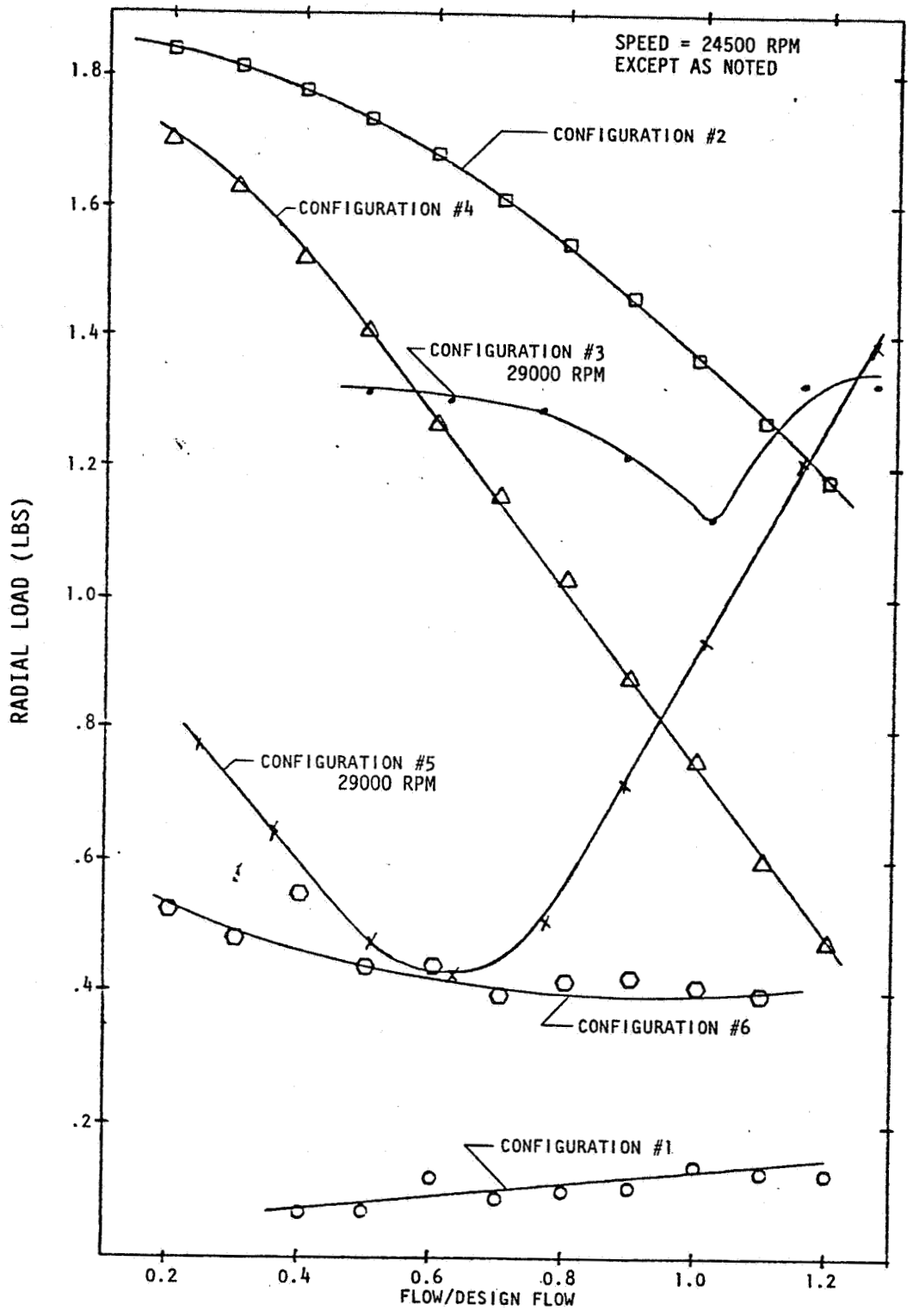

Figure 40. Radial Loads, Test Data

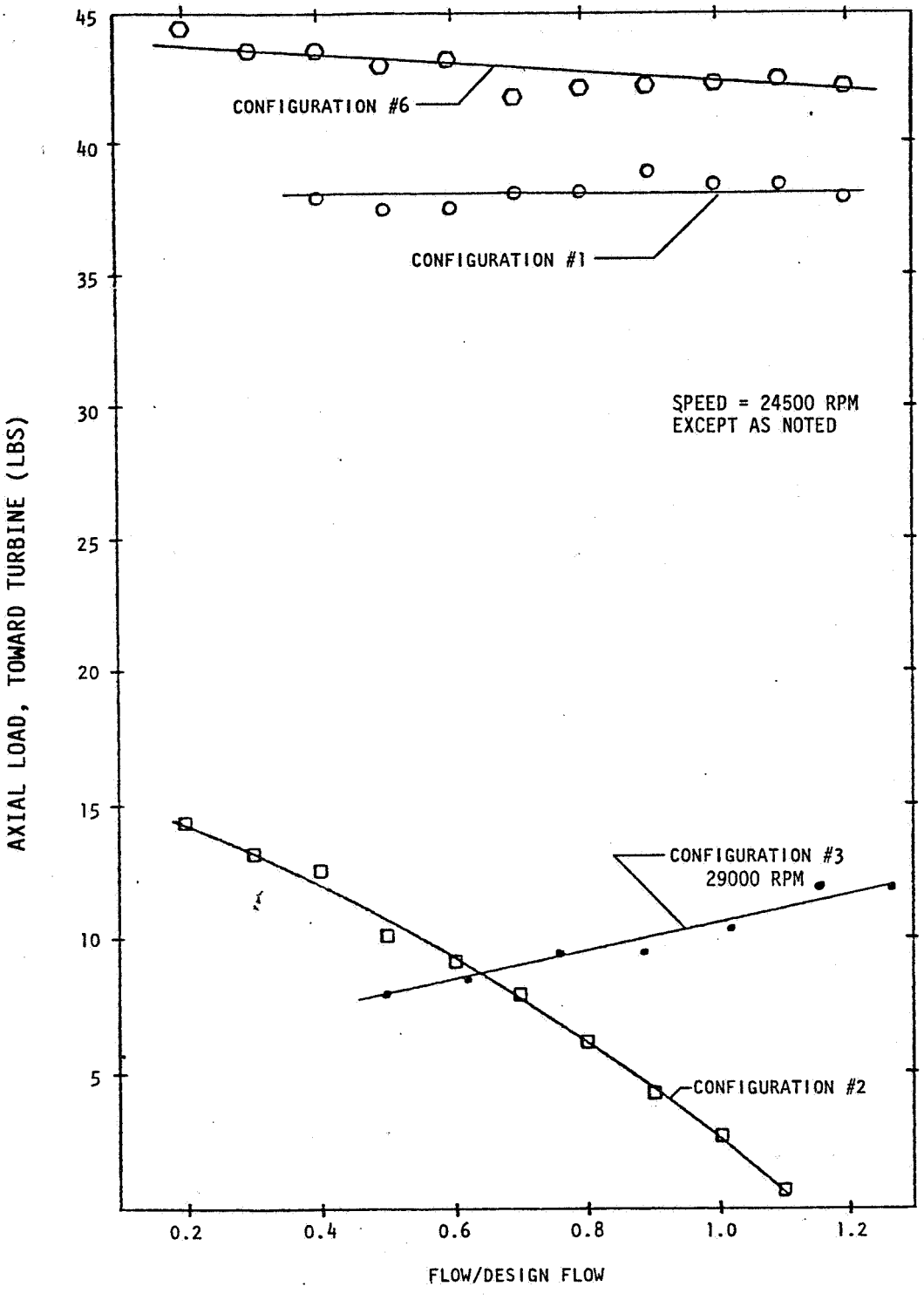

Figure 41. Axial Load, Shrouded Impellers, Test Data

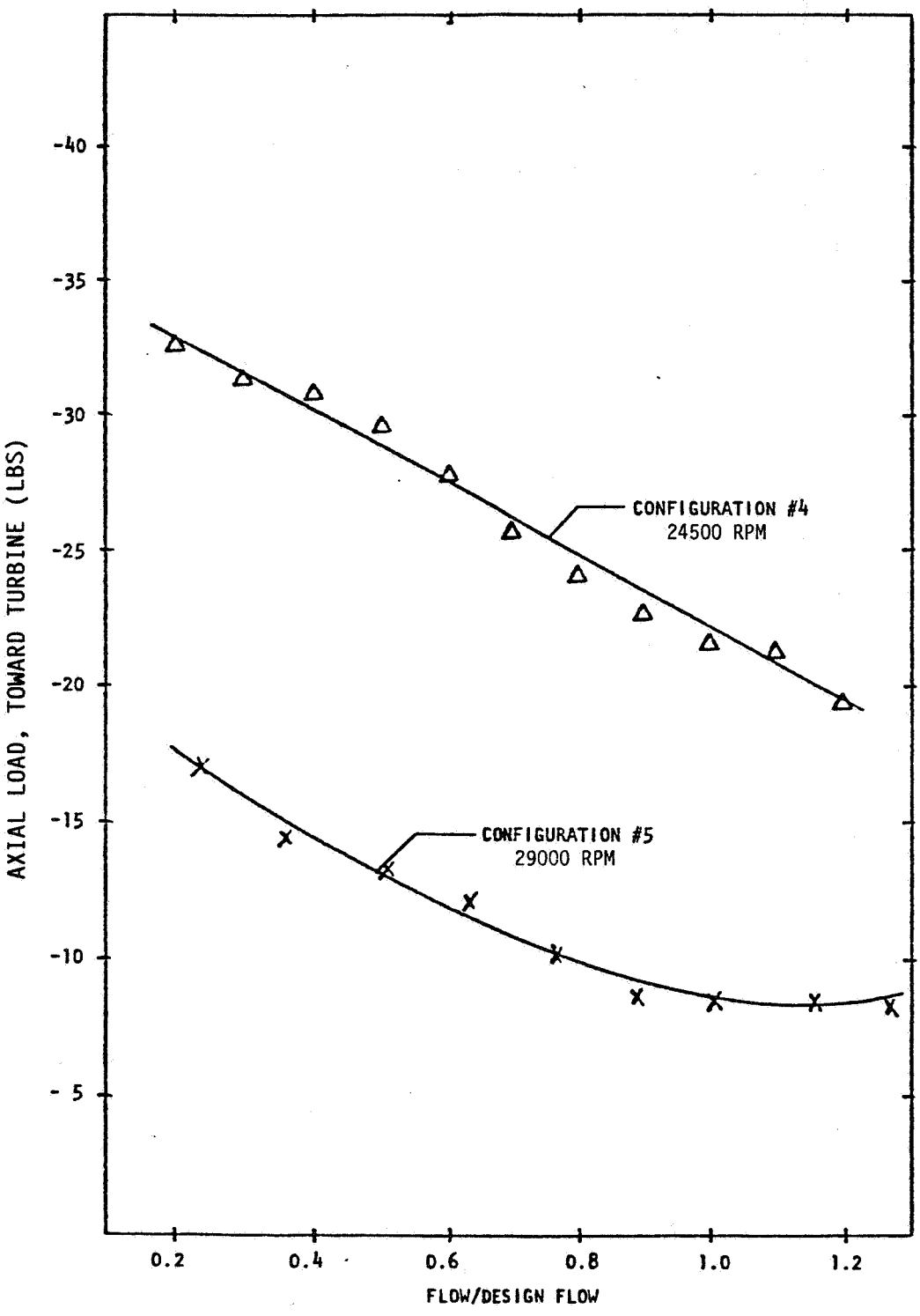

Figure 42. Axial Load, Open Face Impellers, Test Data

TABLE 8. PREDICTED LOSSES PERCENT OF INPUT POWER PUMPING
WATER SPECIFIC SPEED = 430

	PUMP CONFIGURATION	
	2	6
SPEED, RPM	24,500	24,500
FLOWRATE, GPM	5.0	5.0
WEAR RING CLEARANCE, INCHES	0.002	0.002
TOTAL WEAR RING LEAKAGE	23.9	25.2
DISK FRICTION	23.3	21.2
IMPELLER INTERNAL FRICTION	5.69	4.02
IMPELLER DIFFUSION	0.98	2.3
IMPELLER INCIDENCE	0.50	0.51
IMPELLER EXIT RECIRCULATION	0	0.34
VANELESS SPACE FRICTION	0.90	0.84
VANED DIFFUSER INCIDENCE	-	1.38
VANED DIFFUSER FRICTION	-	2.79
VANED DIFFUSER DIFFUSION	-	4.62
VOLUTE MOMENTUM	1.44	0.15
VOLUTE FRICTION	3.99	1.77
VOLUTE DIFFUSION	0.27	0.07
TOTAL	60.97	65.2
PREDICTED EFFICIENCY, PERCENT	39.03	34.8

TABLE 9. PREDICTED LOSSES PERCENT OF INPUT POWER PUMPING
LIQUID HYDROGEN SPECIFIC SPEED = 430

	PUMP CONFIGURATION		
	2	6	
PUMP SPEED, RPM	77,000	77,000	
FLOWRATE, GPM	15.7	15.7	
WEAR RING, CLEARANCE, INCHES	0.002	0.002	0.003
TOTAL WEAR RING LEAKAGE	27	28.3	37.4
DISK FRICTION	14.4	13.0	11.7
IMPELLER INTERNAL FRICTION	5.4	3.4	3.3
IMPELLER DIFFUSION	1.36	2.5	1.82
IMPELLER INCIDENCE	0.56	0.56	0.41
IMPELLER EXIT RECIRCULATION	0	0.34	0.03
VANELESS SPACE FRICTION	0.8	0.79	0.57
VANED DIFFUSER INCIDENCE	-	1.55	1.28
VANED DIFFUSER FRICTION	-	2.40	2.06
VANED DIFFUSER DIFFUSION	-	5.08	4.52
VOLUTE MOMENTUM	1.65	0.16	0.14
VOLUTE FRICTION	3.48	1.45	1.33
VOLUTE DIFFUSION	0.3	0.08	0.07
TOTAL	55.0	59.6	64.6
PREDICTED EFFICIENCY, PERCENT	45.0	40.4	35.4

Partial emission pump performance was evaluated assuming that the flow velocity in the flowing impeller passages was equal to the impeller through flow divided by the percent emission plus wear ring leakage flow. This fluid quantity was then used to calculate impeller friction diffusion and incidence loss in the flowing passages. No unsteady flow loss was computed and, because of the low impeller flow coefficient for these low specific speed pumps, this loss is small. For higher specific speed pumps and compressors with higher impeller passage velocities, this loss would be significant.

Comparison of the results for pumping water (Table 8) with results for pumping liquid hydrogen (Table 9) shows that flow friction and, in particular, disk friction losses are significantly lower when pumping liquid hydrogen. This is due to the much lower viscosity of hydrogen and results in higher efficiency. The losses associated with leakage, diffusion, and momentum are a higher percentage of the power input as a result of the reduced input power resulting from the lower disk friction.

By far, the highest individual losses in either fluid are the disk friction loss and the impeller wear ring (seal) leakage loss. With wear ring radial clearances of only 0.002 inch, the total of these two losses account for approximately 47% of total power input when pumping water and 40% when pumping liquid hydrogen. With low specific speed pumps, the clearance must be small to reduce leakage loss. This is illustrated in Table 9 which shows the influence of a clearance change on Configuration 6 when pumping liquid hydrogen. An increase in radial clearance from 0.002 to 0.003 inch results in a decrease in predicted efficiency from 40.4 to 35.4%, which would require a 14% increase in input power.

The leakage loss for the shrouded impellers includes the front (impeller inlet) and rear wear ring flows. The rear wear ring flow is returned to the impeller inlet through passages in the component. The leakage flow through the impeller inlet wear ring, however, has a tangential velocity approximately equal to half wheel speed at the impeller inlet prior to mixing with the incoming flow. This produces prewhirl at the impeller inlet, which drops the change of angular momentum produced by the impeller and, therefore, reduces the pump head rise. As the delivered pump flow is reduced from its normal operating flowrate, the ratio of the impeller total flow to the whirling front wear ring flow is decreased. This results in increasing prewhirl as the flow is reduced. The increased prewhirl acts to reduce pump head rise at reduced delivered flow while the increased tangential velocity at the backwardly curved impeller blade exit acts to increase the pump head rise. The result at low specific speeds is a nearly constant head rise as delivered flow is reduced.

PUMP SEAL CLEARANCE EFFECTS

The impeller seals are smooth faced wear ring-type seals. Clearances vary from configuration to configuration due to manufacturing differences. An adjusted efficiency is determined, which reflects the expected efficiency at the designed 0.002 inch radial wear ring clearance.

The four shrouded impeller configurations (1, 2, 3, and 6) have wear rings sealing against both front and rear shroud cavity leakage. The smooth-faced seals are located at a mean diameter of 1.002 inch. The as-tested radial wear ring clearances are presented in Table 10. The clearance influence on efficiency is

TABLE 10. DESIGN POINT PUMP EFFICIENCY SUMMARY
WATER TEST

TEST CONFIGURATION				TEST RESULTS			
CONFIGURATION NO.	FRONT WEAR RING RADIAL CLEARANCE, INCHES	REAR WEAR RING RADIAL CLEARANCE, INCHES	IMPELLER FACE AXIAL CLEARANCE, INCHES	SHAFT SPEED, RPM	FLOWRATE, GPM	EFFICIENCY, %	ADJUSTED EFFICIENCY TO 0.002 INCH RADIAL SEAL CLEARANCE, %
1	0.0015	0.0020	-	24,500	5.0	31*	30.1
2	0.0025	0.0020	-	24,500	5.0	32.5	33.5
3	0.0026	0.0020	-	29,000	1.48	9.6	11.2
4	-	0.0045	0.010	24,500	5.0	23.0	-
5	-	0.0038	0.008	29,000	1.48	5.1	-
6	0.0031	0.0030	-	24,500	5.0	28.5**	32.9

*EFFICIENCY DATA - TEST 84L008
**EFFICIENCY DATA - TEST 84L015

computed by the centrifugal pump loss isolation program. A sample output from the program is presented in Table 9 for a 0.002 to 0.003 inch change in radial wear ring clearance. The program output presents the individual component losses as a percentage of input power. By changing only the seal clearance, the input power is affected. The magnitude of the remaining component losses show a change in the percentage of the input power, their absolute magnitudes are essentially unchanged.

Using the Loss Isolation Program the four shrouded pump efficiencies are adjusted to the design radial wear ring clearance of 0.002 inch. These efficiencies are presented in Table 10. The Configuration 6 efficiency is better than the Configuration 1 efficiency, thus indicating the potential of partial emission pumps for low specific speeds.

The turbopump efficiencies for the open-faced impellers are not adjusted. The losses due to impeller blade tip leakages are not accurately known. The lower efficiencies for the open-faced impellers compared to the shrouded pumps is attributed to the face clearance being large compared to the impeller blade height.

The seal clearance will also have an effect on the delivered pump head. The leakage flowrate through the front impeller wear ring will have a large tangential component. Mixing of whirling leakage flow with the nonwhirling inlet flow will increase the inlet prewhirl. The effect on headrise is measured for two Configuration 6 pump builds (and is shown in Fig. 43). A 4% change in headrise is the result of a large change in wear ring clearance. Preliminary calculations agree with these measured results, further analysis on the effect of leakage flowrate on pump head output is suggested.

CONCLUSIONS

Tests were successfully completed to evaluate small centrifugal pumps operating at specific speeds well below those previously reported. The tests demonstrate successful pump operation is possible in the specific speed range from 215 to 430. At the lower specific speed range a severe efficiency penalty occurs since the hydraulic output power is substantially lower than the parasitic power.

The Configuration 6 partial emission diffuser concept has demonstrated the ability to use one impeller to cover a wide flow range by merely changing diffusers. The partial admission impeller concept resulted in low efficiency with an open face impeller.

Open face impellers resulted in low efficiency due to large axial clearance to passage height ratio. The control of axial clearance to the close tolerances required by small open face impellers for good performance is very difficult for small low specific speed pumps.

The maximum efficiency occurred for a volute-type pump (Configuration 2). The simplicity resulting from the absence of a vaned diffuser makes this configuration highly desirable when the engine operation permits single-point operation. Single-point operation permits volute design for a minimum radial load. When wide flow range operation is required a vaned diffuser is desired to produce a low radial load over a wide flow range such as exhibited by Configurations 1 and 6.

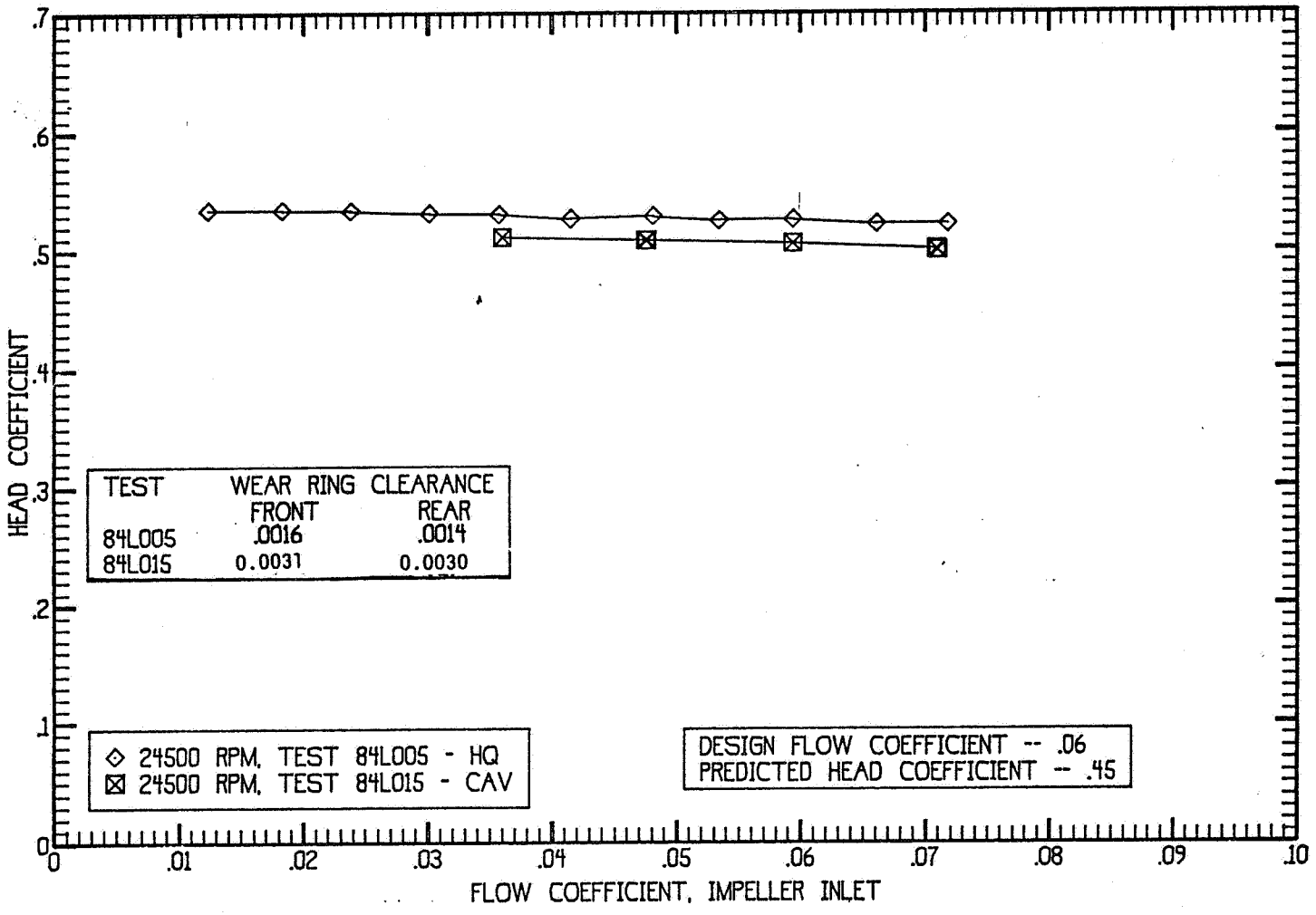

Figure 43. Low-Thrust Pump Head Coefficient Versus Flow Coefficient Configuration 6, Wear Ring Clearance Effect

APPENDIX

SAMPLE DATA

The data presented in the Appendix includes noncavitating results for each of the six configurations tested. The test number for each corresponding configuration is as follows:

SECTION	CONFIGURATION	TEST NUMBER
A1	1	84L007
A2	2	84L012
A3	3	84L010
A4	4	84L009
A5	5	84L011
A6	6	84L005

Each data slice represents the average of 10 scans taken during steady state-operating conditions. Included with the data is a copy of the constant file input for each configuration. The Data Table 11 shows the turbopump Configuration Geometries. The tabulated data format changed from test to test as the data reduction program was being updated.

TABLE 11. TURBOPUMP GEOMETRY

	Configuration					
	1	2	3	4	5	6
Pressure Tap Radial Location (Inches)						
34 Front Wear Ring Upstream	0.580	0.540	0.580	0.4025*	0.4025*	0.570
39 Front MidShroud	0.790	0.700	0.790	0.65	0.65	0.780
38 Impeller Front Tip	1.0	1.0	1.0	1.0	1.0	0.980
40 Impeller Rear Tip	0.970	1.0	0.970	1.0	1.0	0.970
36 Rear Wear Ring Upstream	0.580	0.580	0.580	0.580	0.580	0.580
37 Rear Wear Ring Downstream	0.580	0.600	0.580	0.600	0.600	0.580
26 Diffuser Inlet	1.07	-	1.07	-	-	1.07
18 Volute 0°	1.7037	1.308	1.7037	1.308	1.1611	1.6722
19 Volute 90	1.5091	1.142	1.5091	1.142	1.0971	1.4835
20 Volute 180°	1.5889	1.209	1.5889	1.209	1.1096	1.5599
21 Volute 270°	1.6510	1.263	1.6510	1.263	1.1422	1.6205
Wear Ring Dimensions (Inches)						
Mean Diameter	1.002	1.002	1.002	1.002	1.002	1.002
Front Radial Clearance	0.0015	0.0025	0.0026	-	-	0.0031
Rear Radial Clearance	0.0020	0.0020	0.0020	0.0045	0.0038	0.0030
Front Face Axial Clearance (Inches)	-	-	-	0.010	0.008	-

TEST 64L007 2-27-64 LOW THRUST PUMP H-Q & CAV TESTS

C	DESCRIPTION	CONSTANT
1	WALL DIAMETER AT INLET PRESS TAP, IN.	1.00000E+00
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER, IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.65000E-01
10	IND/IMP INLET AREA, SQ. IN.	3.12608E-01
11	DESIGN FLOW, GPM	5.00000E+00
12	AMBIENT PRESSURE, PSIA	1.43600E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	2.45000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR P(7)	1.00000E+00
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	1.34271E+01
31	CONFIGURATION NUMBER	1.00000E+00
35	FRONT WEAR RING UPSTREAM PRESSURE, RADIAL LOCATION	5.80000E-01
36	IMPELLER FRONT MID PRESSURE, RADIAL LOCATION	7.90000E-01
37	IMPELLER FRONT TIP PRESSURE, RADIAL LOCATION	1.00000E+00
38	IMPELLER REAR TIP PRESSURE, RADIAL LOCATION	9.70000E-01
39	REAR WEAR RING UPSTREAM PRESSURE, RADIAL LOCATION	5.80000E-01
40	IMPELLER LEADING EDGE TIP RADIUS	5.00000E-01
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80100E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00
99	PERCENT TURBINE ADMISSION	1.00000E+02

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PUMP CALIBRATION TEST FACILITY

TEST 84L007 TEST DATE 27 FEB 1984 PROCESS DATE 9 NOV 1984 PAGE 1

TEST 84L007 2-27-84 LOW INDUST PUMP H-Q & CAV TESTS

TIME	-1 WATER SP.WGT. LBM/FT3	-2 VAPOR HEAD (FT)	-3 INLET VELOCITY (FPS)	-15 IMPELLER IN FLOW COEF	-16 FLOW/ DES FLOW	-6 AMBIENT PRESS (PSIA)	-17 PUMP STA DELTA HEAD FT	-18 PUMP DIS VELOCITY (FPS)
24.00A	62.272	.87206	.79576	.74209E-01	1.2446	14.360	57.120	6.0136
501.50A	62.264	.82636	.62967	.61999E-01	1.0398	14.360	59.679	2.5174
809.67A	62.263	.82913	.49164	.48621E-01	.81542	14.360	59.949	1.5064
962.00A	62.264	.82495	1.4740	.71862E-01	1.2052	14.360	246.95	5.8932
1097.00A	62.264	.82634	1.3054	.66534E-01	1.1158	14.360	251.65	5.4587
1203.67A	62.262	.83194	1.2361	.60243E-01	1.0103	14.360	253.15	4.9420
1309.00A	62.262	.83052	1.1096	.54097E-01	.90726	14.360	254.92	4.4360
1427.00A	62.260	.83697	.99587	.46617E-01	.81535	14.360	255.37	3.9814
1523.50A	62.262	.83331	.86453	.42181E-01	.70741	14.360	256.05	3.4564
1615.83A	62.279	.84321	.75010	.36583E-01	.61354	14.360	256.56	2.9969
1734.00A	62.278	.84746	.62085	.30600E-01	.51319	14.360	254.07	2.5061
1842.00A	62.278	.84606	.49894	.24356E-01	.40851	14.360	252.93	1.9948
2000.67A	62.276	.84796	1.9756	.72327E-01	1.2130	14.360	444.43	7.6911
2196.00A	62.279	.84521	1.7991	.65883E-01	1.1049	14.360	449.85	6.1927
2325.00A	62.278	.84750	1.6577	.59962E-01	1.0056	14.360	451.54	5.5476
2442.00A	62.275	.85753	1.4642	.54254E-01	.90989	14.360	455.70	5.0236
2595.83A	62.276	.85404	1.3249	.48346E-01	.81081	14.360	463.96	5.2971
2710.00A	62.276	.85464	1.1484	.41960E-01	.70371	14.360	463.76	4.5913
2812.00A	62.276	.85609	.99121	.36240E-01	.60778	14.360	466.24	3.9826
2910.00A	62.274	.86186	.85353	.30436E-01	.51044	14.360	464.79	3.3324
3000.50A	62.275	.86042	.69406	.23872E-01	.40035	14.360	464.67	2.6173
3105.00A	62.274	.86475	.50299	.18370E-01	.30808	14.360	465.56	2.0109
3558.83A	62.276	.85612	2.4434	.71502E-01	1.1992	14.360	707.97	9.7666
3662.00A	62.275	.86619	2.2564	.65824E-01	1.1039	14.360	712.78	8.9971
3759.00A	62.271	.87497	2.0361	.55596E-01	.99948	14.360	716.39	8.1405
3893.00A	62.271	.87497	1.8436	.53953E-01	.90484	14.360	719.33	7.3705
4048.67A	62.269	.88256	1.6343	.47902E-01	.80336	14.360	726.09	6.5539
4164.83A	62.269	.88376	1.4588	.42189E-01	.70756	14.360	725.85	5.7521
4271.00A	62.267	.88569	1.2561	.36056E-01	.60469	14.360	726.33	4.9160
4391.00A	62.268	.88674	1.0537	.30225E-01	.50691	14.360	726.59	4.1326
4506.00A	62.266	.89567	.82410	.24072E-01	.40372	14.360	721.02	3.2947

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PUMP CALIBRATION TEST FACILITY

TEST 84L007 TEST DATE 27 FEB 1984 PROCESS DATE 9 NOV 1984 PAGE 4

TEST 84L007 2-27-84 LOW THRUST PUMP H-G & CAV TESTS

TIME	-23 PUMP DIS HEAD COEF	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
24.00A	.46735	.11961	.97090E-01	2.0645	2.0655	365.31	76.044	2.8815
501.50A	.46739	.12565	.93676E-01	2.1084	2.0496	364.25	76.034	2.8511
609.67A	.49306	.12509	.95937E-01	2.1029	2.0373	363.38	75.732	2.8965
962.00A	.49242	.20413	.72757E-01	2.7002	5.4344	521.65	153.57	5.8018
1097.00A	.49705	.20093	.73249E-01	2.6831	5.3859	519.31	153.64	5.7584
1203.67A	.49992	.19821	.73603E-01	2.6699	5.2929	514.81	153.62	5.6544
1309.00A	.50361	.19546	.74150E-01	2.6538	5.2239	511.45	153.56	5.6001
1427.00A	.50567	.19272	.74585E-01	2.6562	5.1882	509.69	153.35	5.5241
1523.50A	.50626	.18966	.75148E-01	2.6162	5.1540	508.01	153.45	5.4787
1613.83A	.50637	.18676	.75740E-01	2.5989	5.0464	502.68	153.51	5.4006
1734.00A	.50268	.18495	.76141E-01	2.5860	5.0138	501.05	153.36	5.3563
1842.00A	.50042	.18185	.76753E-01	2.5647	4.9017	495.42	153.35	5.2243
2086.67A	.49574	.27035	.67092E-01	2.9169	7.1803	599.61	204.31	7.6038
2196.00A	.50090	.26514	.67462E-01	2.9026	7.0980	596.17	204.44	7.5203
2325.00A	.50284	.26064	.67793E-01	2.8883	7.0165	592.74	204.46	7.4135
2442.00A	.50521	.25616	.68147E-01	2.8725	6.9339	589.23	204.81	7.3202
2595.83A	.51257	.25190	.66512E-01	2.8600	6.8400	585.23	205.17	7.2423
2710.00A	.51332	.24648	.68926E-01	2.8411	6.6751	578.13	204.90	7.0453
2812.00A	.51664	.24159	.69389E-01	2.8222	6.6433	576.75	204.77	7.0097
2916.00A	.51363	.23645	.69689E-01	2.8040	6.4606	568.76	205.03	6.8322
3006.50A	.51221	.23146	.70465E-01	2.7823	6.3743	564.96	205.31	6.7420
3105.00A	.51230	.22686	.71022E-01	2.7628	6.2841	560.94	204.99	6.6595
3558.83A	.50518	.36348	.63919E-01	3.0446	8.6337	657.50	255.84	9.0769
3682.00A	.50592	.35548	.64136E-01	3.0367	8.5076	652.69	255.96	8.9407
3799.00A	.51035	.34759	.64462E-01	3.0253	8.4677	651.16	255.79	8.6974
3893.00A	.51074	.34027	.64705E-01	3.0110	8.3966	648.41	255.82	8.8148
4048.67A	.51695	.33273	.64930E-01	3.0007	8.2169	641.44	255.42	8.6206
4164.83A	.51712	.32535	.65214E-01	2.9895	8.1264	637.90	255.31	8.5359
4271.00A	.51629	.31747	.65546E-01	2.9765	8.0219	633.78	255.42	8.4375
4391.00A	.51442	.30979	.65909E-01	2.9586	7.8950	628.75	256.05	8.2885
4508.00A	.51364	.30166	.66275E-01	2.9452	7.8265	626.01	256.30	8.2231

SECTION A1

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PUMP CALIBRATION TEST FACILITY

TEST 84L007 TEST DATE 27 FEB 1984 PROCESS DATE 9 NOV 1984 PAGE 5

TEST 84L007 2-27-84 LOW THRUST PUMP H-6 & CAV TESTS

TIME	-21 PUMP TOT HEADRISE (FT)	-115 TURBINE PRESSURE RATIO	6 PUMP INLET TEMP (F)	14 PUMP OUTLET TEMP (F)	105 TURBINE INLET TEMP (F)	-22 PUMP INL FLOW COEF	1 PUMP INL ET PRESS (PSIG)	8 PUMP DIS PRESS (PSIG)
24.00A	56.305	1.0767	71.120	71.865	54.787	.29552E-01	34.905	60.045
501.50A	60.604	1.0796	69.546	69.918	34.067	.24690E-01	35.043	61.291
609.67A	61.025	1.0790	69.644	69.967	34.065	.19362E-01	35.193	61.557
962.00A	250.63	1.1701	69.496	70.213	39.362	.28618E-01	34.393	142.52
1097.00A	253.24	1.1680	69.546	70.656	40.514	.26496E-01	34.508	143.80
1203.67A	254.63	1.1645	69.742	70.852	41.400	.23990E-01	34.746	144.68
1309.00A	256.30	1.1621	69.695	70.754	41.499	.21543E-01	34.813	145.51
1427.00A	256.68	1.1610	69.988	71.000	41.255	.19361E-01	34.955	145.64
1523.50A	257.28	1.1596	69.792	71.590	41.255	.16797E-01	35.310	146.49
1615.83A	257.54	1.1582	70.136	71.787	40.957	.14568E-01	35.296	146.61
1734.00A	255.20	1.1554	70.283	72.279	40.071	.12166E-01	35.191	145.51
1842.00A	254.01	1.1518	70.234	73.016	39.579	.97000E-02	35.254	145.08
2000.67A	446.65	1.2336	70.283	71.344	37.168	.26602E-01	33.756	226.42
2196.00A	451.66	1.2362	70.136	71.639	36.163	.26236E-01	34.037	229.05
2325.00A	453.76	1.2272	70.283	71.885	36.054	.23879E-01	34.167	230.09
2442.00A	457.39	1.2245	70.626	72.279	37.512	.21605E-01	34.367	231.89
2595.83A	465.51	1.2213	70.529	72.328	36.922	.19253E-01	34.498	235.59
2710.00A	465.17	1.2155	70.529	72.967	36.526	.16710E-01	34.722	235.73
2812.00A	467.55	1.2145	70.579	73.459	36.163	.14432E-01	34.933	237.01
2916.00A	466.60	1.2080	70.775	74.049	35.868	.12120E-01	35.019	236.46
3006.50A	466.01	1.2050	70.726	74.934	35.544	.95064E-02	35.248	236.72
3105.00A	464.66	1.2018	70.674	76.066	35.297	.75153E-02	35.348	236.26
3556.83A	710.84	1.2895	70.579	72.918	37.020	.26474E-01	33.102	339.75
3682.00A	715.57	1.2844	70.923	73.410	37.217	.26213E-01	33.600	342.31
3794.00A	720.69	1.2835	71.218	73.705	36.183	.23733E-01	33.666	344.96
3893.00A	721.40	1.2817	71.218	73.852	34.707	.21465E-01	34.159	345.66
4048.67A	727.93	1.2758	71.464	74.492	33.034	.19076E-01	34.540	346.97
4164.83A	727.50	1.2732	71.513	75.229	31.506	.16801E-01	35.232	349.55
4271.00A	729.80	1.2698	71.710	75.771	30.474	.14358E-01	35.735	351.11
4391.00A	727.93	1.2654	71.612	76.652	29.687	.12036E-01	36.136	350.77
4506.00A	728.23	1.2631	71.907	78.082	29.047	.95863E-02	36.346	351.15

SECTION A1

PUMP CALIBRATION TEST FACILITY

TEST 84L007 TEST DATE 27 FEB 1984 PROCESS DATE 9 NOV 1984 PAGE 6

TEST 84L007 2-27-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	18 VOLUTE PRESS CDE G(PSIG)	19 VOLUTE PRESS 90D EG(PSIG)	20 VOLUTE PRES 180D EG(PSIG)	21 VOLUTE PRES 270D EG(PSIG)	26 DIFF IN PRESS 1 (PSIG)	34 FRONT WR RING UP R (PSIG)	36 REAR WR RING UP R (PSIG)	37 REAR WR RINT UP R (PSIG)
24.00A	59.044	60.754	59.459	61.237	58.941	53.072	53.191	34.443
501.50A	60.434	61.916	60.026	62.235	59.791	53.692	53.774	34.592
609.67A	60.957	62.293	61.004	62.489	60.151	53.986	54.130	34.725
962.00A	138.22	141.50	139.25	138.02	133.94	106.33	107.04	35.406
1097.00A	139.87	142.50	140.47	139.07	134.43	106.92	107.41	35.522
1203.67A	141.32	143.61	141.27	140.19	135.30	107.52	108.09	35.772
1309.00A	142.58	144.57	142.66	141.22	135.89	108.11	108.75	35.938
1427.00A	143.45	145.15	142.49	141.95	136.35	108.40	109.11	36.120
1523.50A	144.33	145.69	142.95	142.69	136.86	108.86	109.85	36.552
1613.83A	144.97	146.15	143.51	143.76	137.47	109.38	110.55	36.752
1734.00A	143.52	144.80	141.72	142.82	136.61	109.27	111.05	36.735
1842.00A	143.91	144.10	140.93	142.33	136.61	109.91	111.81	37.100
2086.67A	218.71	223.19	220.06	217.74	209.55	159.25	159.23	36.386
2196.00A	222.13	225.65	223.11	220.14	211.20	160.44	160.36	36.802
2325.00A	224.06	226.66	224.23	221.30	211.93	160.99	160.67	37.117
2442.00A	226.82	229.15	226.46	223.68	213.60	162.14	162.11	37.383
2595.83A	230.99	233.52	232.07	231.78	215.78	163.61	161.66	37.698
2710.00A	231.69	234.06	232.71	232.35	215.61	163.69	162.20	38.081
2812.00A	233.87	235.35	233.96	233.95	216.60	164.60	163.20	38.429
2916.00A	233.84	235.35	233.93	233.79	216.27	164.68	163.43	38.926
3006.50A	234.62	235.84	234.44	234.79	217.15	165.83	164.64	39.343
3105.00A	234.58	235.37	234.08	234.33	217.22	166.45	165.35	39.974
3558.83A	326.91	332.57	332.66	329.94	309.42	227.18	222.99	38.064
3682.00A	331.26	336.45	336.42	333.03	311.88	228.87	224.62	38.695
3799.00A	335.25	339.67	338.75	335.17	313.05	229.88	225.74	39.127
3893.00A	337.77	340.95	340.64	337.25	314.10	231.07	227.02	39.625
4048.67A	342.23	344.68	343.72	339.94	315.67	232.31	228.71	40.406
4164.83A	343.51	345.17	344.41	341.29	315.78	233.10	230.37	41.170
4271.00A	346.11	347.19	346.70	343.98	317.76	234.91	232.62	42.206
4391.00A	346.78	347.74	346.97	344.36	318.19	235.58	233.65	42.981
4508.00A	347.81	348.27	347.90	345.41	318.91	237.03	234.99	43.761

SECTION A1

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PUMP CALIBRATION TEST FACILITY

TEST 64L007 TEST DATE 27 FEB 1964 PROCESS DATE 9 NOV 1964 PAGE 7

TEST 64L007 2-27-64 LOW THRUST PUMP H-6 & CAV TESTS

TIME	36 IMP PR T IP PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC PR (PSIG)	111 TURB NOZ IN PR (PSIG)	114 ROTOR OU T TIP PR (PSIG)
24.00A	57.535	57.635	3.3069	3.2861	1.5079
501.50A	56.392	56.397	3.4345	3.4205	1.9710
609.67A	56.039	56.029	3.4165	3.3719	1.9268
962.00A	129.28	126.68	8.3309	8.2807	4.7335
1097.00A	129.90	127.43	8.1557	8.0929	4.6073
1203.67A	130.00	128.15	7.9741	7.9180	4.5127
1309.00A	131.19	128.69	7.8138	7.7465	4.3613
1427.00A	131.60	129.22	7.6175	7.5746	4.2667
1523.50A	132.31	130.00	7.4310	7.3932	4.1343
1615.83A	132.81	130.71	7.2543	7.1956	4.0208
1734.00A	132.26	130.44	7.1283	7.0742	3.9766
1842.00A	132.54	130.71	6.9206	6.8762	3.8189
2066.67A	201.93	196.20	13.422	13.335	7.6284
2196.00A	203.00	197.62	13.047	12.961	7.3761
2325.00A	204.19	198.07	12.695	12.629	7.1554
2442.00A	205.94	199.81	12.357	12.297	6.9599
2595.83A	207.97	201.15	12.026	11.952	6.7644
2710.00A	208.26	201.73	11.598	11.547	6.4931
2812.00A	208.99	202.01	11.244	11.194	6.2850
2916.00A	209.00	202.89	10.861	10.806	6.0390
3006.50A	210.15	204.29	10.513	10.457	5.8120
3105.00A	210.37	204.79	10.194	10.130	5.6165
3556.83A	297.05	285.00	21.416	21.308	12.428
3682.00A	299.79	287.81	20.718	20.622	11.967
3799.00A	301.44	289.45	20.032	19.936	11.526
3893.00A	302.74	290.66	19.409	19.324	11.129
4048.67A	304.37	292.55	18.707	18.636	10.719
4164.83A	305.44	293.41	18.054	17.975	10.322
4271.00A	307.72	296.07	17.382	17.295	9.8801
4391.00A	306.56	296.96	16.759	16.691	9.4953
4506.00A	309.56	298.04	16.066	15.996	9.0160

SECTION A1

TEST 84L007 2-27-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	4 SHAFT SPEED (RPM)	-21 PUMP TOT HEADRISE (FT)	3 PUMP DIS FLOW (GPM)	-16 FLOW/DES FLOW	-30 PUMP SCALED HEAD RISE (FT	-31 PUMP SCALED FLOW (GPM)	-32 PUMP HYD PWR HP
24.00A	7201.7	56.305	1.0444	1.2446	663.96	6.2228	.27125E-01
501.50A	7260.7	60.804	1.5407	1.0398	692.46	5.1989	.23635E-01
609.67A	7231.9	61.025	1.2035	.81542	700.53	4.0771	.18529E-01
962.00A	14004.	250.65	3.0009	1.2052	699.01	6.0260	.22807
1097.00A	14071.	253.24	3.3409	1.1156	706.24	5.5792	.21345
1203.67A	14069.	254.63	3.0247	1.0103	710.27	5.0517	.19430
1309.00A	14004.	250.20	2.7150	.90726	715.52	4.5363	.17556
1427.00A	14644.	256.66	2.4308	.81535	716.44	4.0768	.15780
1523.50A	14653.	257.20	2.1154	.70741	719.27	3.5370	.13731
1613.83A	14659.	257.54	1.8354	.61354	719.43	3.0677	.11925
1734.00A	14645.	255.20	1.5538	.51319	714.20	2.5660	.98747E-01
1842.00A	14644.	254.01	1.2269	.40851	710.96	2.0425	.78233E-01
2086.67A	19510.	446.65	4.8297	1.2150	704.33	6.0649	.54419
2196.00A	19523.	451.16	4.4022	1.1049	711.67	5.5246	.50162
2325.00A	19526.	453.78	4.0074	1.0056	714.41	5.0281	.45874
2442.00A	19558.	457.39	3.6317	.90969	717.76	4.5494	.41903
2595.83A	19593.	465.51	3.2420	.81081	727.95	4.0541	.38072
2710.00A	19567.	465.17	2.8100	.70371	729.31	3.5185	.32975
2812.00A	19554.	467.55	2.4454	.60778	734.62	3.0389	.28606
2916.00A	19579.	466.00	2.0396	.51044	729.74	2.5522	.23976
3008.50A	19606.	466.01	1.6019	.40035	727.72	2.0018	.18831
3105.00A	19575.	464.66	1.2306	.30606	727.66	1.5404	.14426
3558.83A	24431.	710.84	5.9766	1.1992	714.91	5.9958	1.0721
3662.00A	24442.	715.57	5.5066	1.1039	716.79	5.5197	.99367
3799.00A	24426.	726.69	4.9863	.99946	725.09	4.9974	.90571
3893.00A	24429.	721.40	4.5110	.90484	725.64	4.5242	.82085
4048.67A	24391.	727.93	3.9990	.80336	734.47	4.0168	.73425
4164.83A	24381.	727.50	3.5205	.70756	734.70	3.5376	.64601
4271.00A	24391.	729.80	3.0106	.60469	736.37	3.0234	.55407
4391.00A	24451.	727.93	2.5294	.50691	730.87	2.5345	.46442
4506.00A	24475.	728.23	2.0165	.40372	729.75	2.0186	.37036

TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

C	DESCRIPTION	CONSTANT
1	WALL DIAMETER AT INLET PRESS TAP,IN.	1.00000E+00
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER,IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.85000E-01
10	IND/IMP INLET AREA,SQ.IN.	3.12608E-01
11	DESIGN FLOW, GPM	5.00000E+00
12	AMBIENT PRESSURE, PSIA	1.42490E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	2.45000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR F(7)	0.0
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	0.0
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00
99	PERCENT TURBINE ADMISSION	1.00000E+02

PUMP CALIBRATION TEST FACILITY

TEST 84L012 TEST DATE 27 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 5

TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

TIME	-17 PUMP STA DELTA HEAD FT	-18 PUMP DIS VELOCITY (FPS)	-1 WATER SP.WGT. LBM/FT3	-2 VAPOR HEAD (FT)	-21 PUMP TOT HEADRISE (FT)	-22 PUMP INL FLOW COEF	-23 PUMP DIS HEAD COEF	-3 INLET VELOCITY (FPS)
21.50A	-4.2802	12.254	62.225	1.0583	-1.3326	.36384E-01	-.97880E-03	3.0850
532.00A	62.705	2.9352	62.268	.88652	62.874	.28344E-01	.48896	.73367
743.00A	62.559	2.5044	62.266	.89396	62.682	.24240E-01	.48995	.62643
885.50A	63.328	1.9644	62.266	.89545	63.403	.19077E-01	.49953	.49134
1109.50A	264.42	5.8686	62.265	.89696	265.09	.28391E-01	.51693	1.4679
1212.00A	265.30	5.4021	62.263	.90448	265.87	.26198E-01	.52096	1.3512
1302.50A	266.00	4.9763	62.264	.90146	266.49	.24125E-01	.52181	1.2447
1390.50A	267.58	4.4303	62.262	.91052	267.96	.21470E-01	.52427	1.1081
1507.50A	266.61	3.9903	62.261	.91356	266.92	.19364E-01	.52369	.99808
1606.50A	265.62	3.4433	62.260	.91663	265.85	.16688E-01	.52028	.86127
1694.00A	266.39	2.9989	62.259	.91969	266.57	.14543E-01	.52226	.75011
1858.50A	265.82	2.5373	62.257	.92891	265.94	.12309E-01	.52144	.63465
1962.50A	263.89	2.0816	62.256	.93206	263.97	.97099E-02	.51755	.50067
2190.00A	474.01	7.8258	62.251	.95236	475.22	.28397E-01	.52132	1.7574
2272.50A	476.71	7.2141	62.249	.96194	477.73	.26183E-01	.52432	1.8044
2366.50A	477.39	6.6132	62.245	.97474	478.84	.24000E-01	.52541	1.6541
2450.00A	477.98	5.9323	62.243	.98279	478.67	.21509E-01	.52428	1.4638
2550.50A	477.57	5.2652	62.240	.99421	478.11	.19150E-01	.52696	1.3170
2634.00A	478.58	4.5591	62.239	.99915	478.99	.16686E-01	.52533	1.1503
2729.00A	478.13	3.9844	62.236	1.0108	478.45	.14453E-01	.52448	.99661
2830.50A	475.86	3.3241	62.235	1.0174	476.02	.12049E-01	.52107	.83146
2940.50A	475.35	2.6222	62.231	1.0326	475.49	.95237E-02	.52259	.65588
3059.50A	472.60	1.9840	62.230	1.0343	472.67	.71990E-02	.51851	.49625
3419.50A	739.61	9.7512	62.212	1.1096	741.48	.28482E-01	.52705	2.4390
3555.00A	742.97	9.0326	62.203	1.1463	744.57	.26337E-01	.52742	2.2593
3634.50A	744.25	8.1925	62.201	1.1556	745.57	.23921E-01	.52963	2.0491
3745.50A	747.18	7.4167	62.193	1.1897	748.26	.21645E-01	.53104	1.8551
3847.50A	747.79	6.5794	62.186	1.2168	748.64	.19193E-01	.53083	1.6457
3952.50A	745.82	5.7479	62.181	1.2385	744.47	.16771E-01	.52803	1.4377
4037.50A	743.77	4.8968	62.179	1.2505	744.24	.14295E-01	.52847	1.2248
4116.50A	740.03	4.1232	62.177	1.2586	740.37	.12026E-01	.52476	1.0313
4221.50A	740.29	3.2721	62.174	1.2687	740.50	.95365E-02	.52406	.81845
4321.50A	736.15	2.5270	62.169	1.2912	736.27	.73762E-02	.52266	.63207
4495.00A	734.93	1.7000	62.168	1.2974	734.99	.49597E-02	.52133	.42521

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TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

TIME	-6 AMBIENT PRESS (PSIA)	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
21.50A	14.249	.92315E-02	.98849	.20161	-.30387E-01	52.378	251.15	.30135E-01
532.00A	14.249	.11741	.94593E-01	2.1125	2.6837	366.47	77.164	2.9375
743.00A	14.249	.11966	.93386E-01	2.1327	2.6807	366.32	77.033	2.9481
885.50A	14.249	.11902	.93715E-01	2.1236	2.6510	364.25	76.772	2.9124
1109.50A	14.249	.19450	.70029E-01	2.8222	5.8316	540.37	154.14	6.2384
1212.00A	14.249	.19325	.70191E-01	2.8134	5.7790	537.93	153.77	6.1852
1302.50A	14.249	.19219	.70376E-01	2.8063	5.7590	536.99	153.82	6.1733
1390.50A	14.249	.18952	.70974E-01	2.7882	5.6432	531.57	153.88	6.0609
1507.50A	14.249	.18838	.71070E-01	2.7771	5.5953	529.31	153.67	5.9740
1606.50A	14.249	.18559	.71673E-01	2.7545	5.5229	525.88	153.87	5.9039
1694.00A	14.249	.18388	.71979E-01	2.7412	5.4909	524.34	153.78	5.8423
1850.50A	14.249	.18094	.72634E-01	2.7202	5.3646	518.28	153.72	5.7533
1962.50A	14.249	.17956	.72853E-01	2.7107	5.3348	516.83	153.73	5.7030
2190.00A	14.249	.24971	.63585E-01	3.0935	8.0264	633.96	205.51	8.5237
2272.50A	14.249	.24699	.63792E-01	3.0833	8.0354	634.32	205.46	8.5133
2366.50A	14.249	.24413	.64009E-01	3.0707	7.9415	630.60	205.48	8.4141
2490.00A	14.249	.24078	.64359E-01	3.0560	7.8276	626.06	205.68	8.3096
2550.50A	14.249	.23703	.64742E-01	3.0393	7.7005	620.95	205.03	8.1783
2634.00A	14.249	.23420	.65040E-01	3.0228	7.6439	618.67	205.53	8.0838
2729.00A	14.249	.23098	.65423E-01	3.0084	7.5098	613.22	205.58	7.9659
2830.50A	14.249	.22746	.65862E-01	2.9875	7.4141	609.30	205.74	7.8508
2946.50A	14.249	.22388	.66304E-01	2.9657	7.3193	605.39	205.32	7.7340
3059.50A	14.249	.22101	.66680E-01	2.9523	7.1888	599.97	205.51	7.6202
3419.50A	14.249	.32040	.59835E-01	3.2699	10.223	715.47	255.31	10.731
3535.00A	14.249	.31567	.60015E-01	3.2577	10.100	711.16	255.75	10.600
3634.50A	14.249	.31093	.60190E-01	3.2476	9.9941	707.41	255.39	10.485
3745.50A	14.249	.30584	.60485E-01	3.2341	9.9032	704.19	255.52	10.388
3847.50A	14.249	.30103	.60741E-01	3.2225	9.7519	698.78	255.63	10.242
3952.00A	14.249	.29532	.61036E-01	3.2071	9.6235	694.17	255.58	10.104
4037.50A	14.249	.29023	.61338E-01	3.1906	9.5193	690.40	255.45	9.9840
4116.50A	14.249	.28606	.61579E-01	3.1830	9.3299	683.50	255.67	9.8220
4221.50A	14.249	.28026	.61929E-01	3.1636	9.1951	678.54	255.87	9.6590
4321.50A	14.249	.27467	.62375E-01	3.1448	9.0089	671.63	255.48	9.4957
4495.00A	14.249	.26975	.62700E-01	3.1300	8.8925	667.29	255.60	9.3872

TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

TIME	4 SHAFT SPEED (RPM)	-21 PUMP TOT HEADRISE (FT)	3 PUMP DIS FLOW (GPM)	-30 PUMP SCALED HEAD RISE (FT	-31 PUMP SCALED FLOW (GPM)	-32 PUMP HYD PWR HP
						-.25191E-02
21.50A	23983.	-1.3326	7.4999			
532.00A	7368.6	62.874	1.7952	5.97	694.7	.28495E-01
745.00A	7356.1	62.682	1.5328	5.10	696.1	.24253E-01
885.50A	7331.2	63.403	1.2023	4.02	709.7	.19229E-01
1109.50A	14719.	265.09	3.5418	5.98	734.5	.24016
1212.00A	14684.	265.87	3.3063	5.52	740.2	.22171
1302.50A	14689.	266.47	3.0157	5.08	741.4	.20471
1390.50A	14695.	267.96	2.7115	4.52	744.9	.18326
1507.50A	14674.	266.92	2.4422	4.08	744.0	.16440
1606.50A	14694.	265.85	2.1075	3.51	739.2	.14130
1694.00A	14685.	266.57	1.8355	3.06	742.0	.12340
1856.50A	14679.	265.94	1.5529	2.59	740.9	.10416
1962.50A	14680.	265.97	1.2291	2.04	735.3	.81558E-01
2190.00A	19625.	475.22	4.7997	5.98	740.7	.57396
2272.50A	19620.	477.73	4.4153	5.51	744.9	.53189
2388.50A	19622.	478.84	4.0475	5.05	746.5	.48869
2450.00A	19641.	478.67	3.6308	4.53	744.9	.43821
2550.50A	19579.	478.11	3.2225	4.03	748.7	.38844
2634.00A	19627.	478.99	2.8148	3.51	746.4	.33992
2729.00A	19632.	478.45	2.4386	3.04	745.2	.29414
2830.50A	19648.	478.02	2.0345	2.54	740.3	.24415
2940.50A	19607.	475.49	1.6049	2.01	742.5	.19236
3059.50A	19625.	472.67	1.2143	1.52	736.7	.14468
3419.50A	24380.	741.48	5.9681	6.00	748.8	1.1132
3555.00A	24422.	744.57	5.5283	5.55	749.3	1.0371
3634.50A	24388.	745.57	5.0140	5.04	752.5	.94189
3745.50A	24400.	748.26	4.5393	4.56	754.5	.85567
3867.50A	24411.	748.64	4.0268	4.04	754.2	.75938
3952.00A	24406.	744.47	3.5179	3.53	750.2	.65968
4037.50A	24393.	744.24	2.9970	3.01	750.8	.56180
4116.50A	24415.	740.37	2.5236	2.53	745.5	.47057
4221.50A	24434.	740.50	2.0027	2.01	744.6	.37350
4321.50A	24396.	736.27	1.5406	1.55	742.6	.28676
4423.00A	24408.	734.99	1.0404	1.04	740.7	.19257

PUMP CALIBRATION TEST FACILITY

TEST 84L012 TEST DATE 27 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 31

TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

TIME	-190 TURB TESTER EFF	-191 TURB TESTER WORK	-192 TURB TESTER HP	-193 TURB TESTER TORQUE	-194 EQUIV WORK BTU/LB	-195 ACTUAL PUMP EFF	
21.50A	.23160E+07	-71379.	-934.75	-2456.6	-66472.	.14261E-05	
532.00A	.40105	1.2367	.20562	1.7579	1.2463	.13848	
743.00A	.40051	1.2345	.20914	1.7910	1.2603	.11581	7350 RPM
885.50A	.40134	1.2226	.20604	1.7708	1.2518	.93220E-01	
1109.50A	.56989	3.3233	.91462	3.9162	3.4527	.26258	
1212.00A	.57069	3.2979	.90184	3.8708	3.4323	.24584	
1302.50A	.57147	3.2910	.89497	3.8400	3.4265	.22874	
1390.50A	.57546	3.2474	.87087	3.7351	3.3801	.21043	
1507.50A	.57655	3.2259	.85989	3.6931	3.3588	.19120	14,700 RPM
1606.50A	.57950	3.2005	.84053	3.6052	3.3313	.16811	
1694.00A	.58039	3.1868	.82921	3.5586	3.3146	.14882	
1856.50A	.58464	3.1364	.80307	3.4478	3.2589	.12969	
1962.50A	.58573	3.1246	.79394	3.4084	3.2417	.10272	
2190.00A	.61815	4.9014	1.7551	5.6300	5.1811	.32740	
2272.50A	.61785	4.7646	1.7351	5.5734	5.1760	.30654	
2366.50A	.62007	4.9243	1.7011	5.4638	5.1297	.28728	
2450.00A	.62305	4.8773	1.6617	5.3322	5.0765	.26371	
2550.50A	.62496	4.8124	1.6141	5.1958	5.0054	.24068	19600 RPM
2634.00A	.62721	4.7942	1.5888	5.1017	4.9871	.21395	
2729.00A	.63055	4.7352	1.5477	4.9684	4.9242	.19007	
2830.50A	.63314	4.6942	1.5109	4.8468	4.8835	.16159	
2940.50A	.63474	4.6458	1.4717	4.7308	4.8337	.13070	
3059.50A	.63832	4.5888	1.4350	4.6085	4.7743	.10082	
3419.50A	.65270	6.6725	3.0251	7.8202	7.0461	.36865	
3555.00A	.65536	6.6191	2.9566	7.6300	6.9933	.35081	
3634.50A	.65668	6.5928	2.8875	7.4621	6.9324	.32622	
3745.50A	.65838	6.5200	2.8217	7.2884	6.8728	.30326	
3847.50A	.66111	6.4469	2.7462	7.0902	6.7909	.27655	
3952.00A	.66323	6.3825	2.6672	6.8876	6.7252	.24733	24500 RPM
4037.50A	.66484	6.3288	2.5992	6.7153	6.6678	.21615	
4116.50A	.66837	6.2357	2.5241	6.5158	6.5630	.18644	
4221.50A	.67093	6.1693	2.4467	6.3108	6.4877	.15267	
4321.50A	.67364	6.0686	2.3589	6.0935	6.3845	.12158	
4495.00A	.67577	6.0092	2.2938	5.9230	6.3129	.83956E-01	

SECTION A@

TIME	-15 IMPELLER IN FLOW COEF	-115 TURBINE PRESSURE RATIO	6 PUMP INLET TEMP (F)	14 PUMP OUTLET TEMP (F)	105 TURBINE INLET TEMP (F)	106 TURBINE OUTLET TEMP (F)	1 PUMP INLET PRESS (PSIG)	8 PUMP DIS PRESS (PSIG)
21.50A	.91366E-01	.99920	76.871	77.610	78.308	76.682	35.206	33.419
532.00A	.71177E-01	1.0800	71.605	71.844	37.586	39.726	29.493	56.612
743.00A	.60870E-01	1.0810	71.651	71.942	31.188	32.197	28.429	55.483
885.50A	.47906E-01	1.0803	71.900	72.189	29.760	29.638	28.231	55.615
1109.50A	.71295E-01	1.1911	71.949	72.830	22.669	10.348	25.752	140.10
1212.00A	.65786E-01	1.1895	72.195	73.027	21.832	8.1335	25.644	140.37
1302.50A	.60581E-01	1.1889	72.097	73.421	21.635	7.5430	25.672	140.70
1396.50A	.53913E-01	1.1846	72.392	73.667	21.783	7.3954	25.845	141.55
1507.50A	.48625E-01	1.1829	72.490	73.963	21.635	7.3954	25.835	141.11
1606.50A	.41906E-01	1.1802	72.589	74.308	21.783	7.8383	26.065	140.91
1694.00A	.36519E-01	1.1789	72.687	74.702	22.128	8.1827	26.265	141.45
1856.50A	.30910E-01	1.1742	72.983	75.294	22.620	8.6256	26.420	141.35
1962.50A	.24383E-01	1.1728	73.081	75.934	23.359	9.4130	26.872	140.96
2190.00A	.71308E-01	1.2767	73.721	75.146	20.207	-4.5132	23.496	228.44
2272.50A	.65750E-01	1.2766	74.016	75.639	20.995	-4.3656	23.869	229.97
2366.50A	.60267E-01	1.2725	74.410	76.181	21.389	-3.9719	24.280	230.91
2450.00A	.54012E-01	1.2677	74.656	76.723	21.783	-3.4306	24.789	231.41
2550.50A	.48089E-01	1.2625	75.001	77.166	22.128	-2.7909	25.163	231.59
2634.00A	.41902E-01	1.2603	75.148	77.955	22.079	-2.3480	25.664	232.52
2729.00A	.36293E-01	1.2549	75.493	78.497	22.226	-1.8559	26.017	232.67
2830.50A	.30257E-01	1.2513	75.689	79.384	22.029	-1.6591	26.434	232.07
2940.50A	.23915E-01	1.2476	76.132	80.665	21.980	-1.1178	27.041	232.47
3059.50A	.18078E-01	1.2426	76.182	82.292	21.980	-.92096	28.037	232.27
3419.50A	.71522E-01	1.3743	78.298	80.370	14.890	-20.851	22.088	341.66
3525.00A	.66136E-01	1.3690	79.282	81.454	14.644	-21.195	22.348	343.32
3634.50A	.60069E-01	1.3642	79.528	82.439	14.742	-20.801	23.058	344.57
3745.50A	.54355E-01	1.3593	80.414	83.129	15.727	-19.916	23.366	346.09
3847.50A	.48197E-01	1.3524	81.103	84.312	16.071	-19.128	24.037	346.99
3952.00A	.42114E-01	1.3469	81.645	85.248	15.924	-16.390	24.622	345.83
4037.50A	.35897E-01	1.3423	81.940	86.135	15.973	-17.898	25.540	346.71
4116.50A	.30200E-01	1.3337	82.137	87.515	16.465	-17.209	26.520	346.06
4221.50A	.23947E-01	1.3276	82.383	89.043	16.859	-16.077	27.584	347.22
4321.50A	.18523E-01	1.3199	82.924	91.704	16.662	-15.684	28.838	346.66
4495.00A	.12455E-01	1.3144	83.072	96.090	17.352	-14.355	30.269	347.56

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PUMP CALIBRATION TEST FACILITY

TEST 84L012 TEST DATE 27 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 11

TEST 84L012, 3-26-1984 LOW THRUST PUMP HQ & CAV TESTS

TIME	18 VOLUTE P RESS 0DE G(PSIG)	19 VOLUTE P RESS 90D EG(PSIG)	20 VOLUTE P RES 180D EG(PSIG)	21 VOLUTE P RES 270D EG(PSIG)	34 FRONT WR RING UP R (PSIG)	36 REAR WR RING UP R (PSIG)	37 REAR WR RINT DP R (PSIG)
21.50A	33.771	34.145	32.789	35.309	35.153	35.360	32.558
532.00A	55.255	53.353	52.385	55.828	47.708	47.753	27.710
743.00A	54.208	52.060	51.054	54.592	46.859	46.636	26.664
865.50A	54.617	52.224	51.119	54.719	47.365	46.960	26.498
1109.50A	132.28	122.62	122.98	128.87	93.441	93.394	29.404
1212.00A	133.00	122.74	123.13	129.17	94.290	93.782	29.487
1302.50A	133.90	122.72	123.18	129.30	95.171	94.106	29.520
1390.50A	135.32	123.26	123.65	130.07	96.690	95.077	29.802
1507.50A	135.47	122.82	123.29	129.68	97.180	95.222	29.835
1606.50A	136.38	122.82	123.39	130.03	98.404	95.934	30.167
1694.00A	137.43	123.36	123.77	130.58	99.776	96.856	30.549
1856.50A	137.84	123.41	124.11	130.99	100.92	97.568	30.732
1962.50A	138.18	123.34	124.16	131.06	101.96	98.442	31.296
2190.00A	213.69	195.23	197.19	205.07	138.88	139.97	34.218
2272.50A	216.11	196.18	198.54	206.56	141.62	141.38	34.683
2366.50A	218.10	196.69	198.90	207.40	143.50	142.58	35.264
2450.00A	219.74	196.97	199.54	208.12	145.67	143.76	35.995
2550.50A	221.01	196.71	199.39	208.44	147.99	144.78	36.476
2634.00A	223.56	197.93	200.69	209.80	150.72	146.69	37.190
2729.00A	224.80	198.11	200.98	210.34	152.51	147.59	37.672
2830.50A	225.51	197.80	201.03	210.75	154.81	148.92	38.203
2946.50A	227.04	198.59	202.02	211.85	157.69	150.88	39.133
3059.50A	228.06	198.87	202.46	212.80	160.04	152.69	40.312
3419.50A	317.85	287.92	293.01	302.73	197.22	198.75	40.876
3553.00A	321.32	288.69	294.31	304.22	200.32	200.24	41.225
3634.50A	324.02	289.24	294.63	305.20	203.60	202.10	42.188
3745.50A	327.22	289.73	295.40	306.04	206.67	203.49	42.985
3847.50A	330.20	290.45	296.61	307.79	210.96	205.97	44.014
3952.00A	331.31	289.49	296.09	307.29	213.61	206.83	44.662
4037.50A	334.09	290.57	297.39	309.12	217.97	209.67	45.824
4116.50A	335.49	290.55	298.01	310.50	221.17	211.78	47.036
4221.50A	338.62	292.64	299.72	312.13	225.27	214.17	48.580
4321.50A	339.48	292.60	300.12	313.14	228.43	216.84	50.124
4495.00A	341.67	294.28	301.86	315.23	232.19	219.82	52.033

TIME	38 IMP FR T IP PR (PSIG)	39 IMP FR M ID PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC PR (PSIG)	111 TURB NOZ IN PR (PSIG)	114 ROTOR OU T TIP PR (PSIG)
21.50A	34.691	34.294	35.601	.10635E-01	-.11323E-01	.15741E-01
532.00A	51.818	47.799	52.979	2.4018	2.3641	1.0986
743.00A	50.664	46.851	51.821	2.4590	2.4143	1.1301
885.50A	50.879	47.227	51.937	2.4149	2.3722	1.0734
1109.50A	115.00	97.307	116.45	6.1119	6.0414	2.6410
1212.00A	115.35	97.863	116.80	6.0286	5.9572	2.6158
1362.50A	115.55	98.451	116.95	5.9697	5.8924	2.5655
1390.50A	116.34	99.596	117.74	5.8259	5.7451	2.5088
1507.50A	116.44	99.956	117.71	5.7589	5.7014	2.4962
1606.50A	116.60	100.87	118.16	5.6314	5.5702	2.4396
1694.00A	117.44	101.85	118.90	5.5334	5.4892	2.3577
1856.50A	117.64	102.65	119.35	5.4026	5.3338	2.3074
1962.50A	117.95	103.50	119.96	5.3241	5.2674	2.2885
2190.00A	181.48	148.40	182.90	9.5720	9.4564	4.1205
2272.50A	183.03	150.25	184.20	9.3955	9.2945	4.0198
2366.50A	183.99	151.80	185.02	9.2255	9.1277	3.9569
2450.00A	184.78	153.37	186.08	9.0327	8.9269	3.8498
2550.50A	185.67	155.09	186.96	8.8038	8.7002	3.7491
2634.00A	187.02	157.29	188.75	8.6257	8.5480	3.6924
2729.00A	187.32	158.28	188.99	8.4361	8.3456	3.5917
2830.50A	187.88	159.78	190.00	8.2318	8.1529	3.4784
2946.50A	189.25	161.92	191.59	8.0259	7.9602	3.4217
3059.50A	190.12	164.10	193.20	7.8542	7.7756	3.3273
3419.50A	267.04	214.13	267.35	14.493	14.366	6.2862
3555.00A	268.80	216.02	269.07	14.163	14.042	6.0910
3634.50A	270.05	218.79	270.52	13.820	13.707	5.9148
3745.50A	270.75	220.21	271.00	13.500	13.393	5.7700
3847.50A	273.45	223.97	274.07	13.178	13.066	5.6252
3952.00A	273.30	225.25	274.30	12.777	12.672	5.4426
4037.50A	274.65	228.35	276.40	12.439	12.347	5.2600
4116.50A	275.87	230.58	278.17	12.156	12.041	5.1404
4221.50A	277.70	234.31	280.31	11.769	11.676	4.9641
4321.50A	278.91	236.41	282.24	11.419	11.306	4.8004
4495.00A	280.90	239.68	285.14	11.105	10.985	4.6305

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PUMP CALIBRATION TEST FACILITY

TEST 84L010 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 0

TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

C	DESCRIPTION	CONSTANT
1	WALL DIAMETER AT INLET PRESS TAP,IN.	1.00000E+00
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER,IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.85000E-01
10	IND/IMP INLET AREA,SQ.IN.	3.12608E-01
11	DESIGN FLOW, GPM	2.00000E+00
12	AMBIENT PRESSURE, PSIA	1.43470E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	3.92000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR F(7)	0.0
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	1.34271E+01
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

PUMP CALIBRATION TEST FACILITY

TEST 84L010 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 1

TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	4 SHAFT SPEED (RPM)	-16 FLOW/ DES FLOW	3 PUMP DIS FLOW (GPM)	-21 PUMP TOT HEADRISE (FT)	-3 INLET VELOCITY (FPS)
21.58A	4.8004	-1.1253	.58795E-04	-1.0456	.24028E-04
12091.58A	11742.	1.2454	.74605	96.019	.30490
12229.58A	11688.	.87318	.52069	155.12	.21280
12337.58A	11643.	.64504	.38317	177.10	.15659
12649.58A	23391.	1.2101	1.4441	395.91	.59018
12790.58A	23388.	1.0556	1.2596	559.10	.51478
12899.58A	23392.	.88527	1.0566	641.25	.43179
12998.58A	23401.	.71702	.85606	698.80	.34985
13095.58A	23388.	.54825	.65422	746.74	.26736
13219.58A	23361.	.35799	.42668	778.23	.17437
13858.58A	28971.	1.2676	1.8736	896.16	.76571
14018.58A	28996.	1.1574	1.7122	1056.3	.69975
14153.58A	28979.	1.0256	1.5163	1110.7	.61969
14443.58A	28981.	.89488	1.3232	1190.6	.54076
14558.58A	28971.	.76415	1.1295	1253.2	.46161
14676.58A	28974.	.62161	.91891	1309.9	.37554
14846.58A	28974.	.50178	.74176	1339.5	.30314
15756.58A	28967.	1.0770	1.5916	1048.3	.65047
16291.58A	28944.	.87475	1.2918	1175.3	.52793
16823.58A	11713.	1.2090	.72253	48.833	.29528
17664.00A	11685.	1.1739	.69933	78.926	.28600
17986.00A	11704.	1.0370	.61924	131.62	.25307

SECTION A3

PUMP CALIBRATION TEST FACILITY

TEST 84L010 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 4

TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	-17 PUMP STA DELTA HEAD FT	-18 PUMP DIS VELOCITY (FPS)	-9 IND IN VELOCITY (FPS)	-15 IMPELLER IN FLOW COEF	-21 PUMP TOT HEADRISE (FT)	-22 PUMP INL FLOW COEF	-23 PUMP DIS HEAD COEF
21.58A	-1.0456	.96065E-04	.60338E-04	-.15656E-02	-1.0456	-.66799E-02	-24654.
12091.58A	95.990	1.2190	.76563	.18565E-01	96.019	.73929E-02	.29427
12229.58A	155.11	.85075	.53436	.13016E-01	155.12	.51834E-02	.47993
12337.58A	177.09	.62605	.39323	.96155E-02	177.10	.38291E-02	.55197
12649.58A	395.80	2.3595	1.4820	.18038E-01	395.91	.71832E-02	.30572
12790.58A	559.02	2.0581	1.2927	.15736E-01	559.10	.62663E-02	.43186
12899.58A	641.19	1.7263	1.0843	.13196E-01	641.25	.52552E-02	.49516
12998.58A	698.77	1.3987	.87853	.10688E-01	698.80	.42564E-02	.53920
13095.58A	746.71	1.0689	.67139	.81727E-02	746.74	.32546E-02	.57682
13219.58A	778.22	.69714	.43789	.53365E-02	778.23	.21251E-02	.60260
13858.58A	895.98	3.0613	1.9228	.18895E-01	896.16	.75246E-02	.45109
14018.58A	1056.1	2.7976	1.7572	.17253E-01	1056.3	.68705E-02	.53077
14153.58A	1110.5	2.4775	1.5561	.15288E-01	1110.7	.60881E-02	.55876
14443.58A	1190.5	2.1619	1.3579	.13340E-01	1190.6	.53122E-02	.59890
14558.58A	1253.1	1.8455	1.1592	.11391E-01	1253.2	.45362E-02	.63079
14676.58A	1309.8	1.5014	.94303	.92662E-02	1309.9	.36900E-02	.65919
14846.58A	1339.5	1.2120	.76123	.74798E-02	1339.5	.29787E-02	.67413
15756.58A	1048.2	2.6005	1.6334	.16054E-01	1048.3	.63931E-02	.52783
16291.58A	1175.2	2.1107	1.3257	.13040E-01	1175.3	.51927E-02	.59257
16823.58A	48.805	1.1805	.74150	.18023E-01	48.833	.71772E-02	.15033
17664.00A	78.900	1.1434	.71820	.17499E-01	78.926	.69686E-02	.24416
17986.00A	131.60	1.0118	.63550	.15458E-01	131.62	.61558E-02	.40596

TIME	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
21.58A	.93901E-02	.98372	.20301	-.31983E-01	32.608	.50269E-01	.88081E-02
12091.58A	.16027	.77616E-01	2.5637	4.4906	474.18	122.96	4.8304
12229.58A	.15704	.78455E-01	2.5246	4.2960	463.79	122.40	4.6225
12337.58A	.15622	.78652E-01	2.5175	4.2184	459.60	121.92	4.5713
12649.58A	.27255	.62144E-01	3.1515	9.0795	674.27	244.95	9.5424
12790.58A	.26680	.62594E-01	3.1302	8.9818	670.62	244.92	9.4393
12899.58A	.26114	.63075E-01	3.1102	8.8132	664.31	244.96	9.2885
12998.58A	.25586	.63522E-01	3.0844	8.6662	658.74	245.05	9.0827
13095.58A	.25152	.63943E-01	3.0691	8.5377	653.84	244.92	8.9717
13219.58A	.24551	.64482E-01	3.0447	8.3223	645.53	244.63	8.7626
13858.58A	.39394	.58193E-01	3.3414	12.186	781.14	303.39	12.689
14018.58A	.39306	.58246E-01	3.3396	12.233	782.66	303.65	12.742
14153.58A	.37724	.58602E-01	3.3211	11.996	775.02	303.47	12.489
14443.58A	.37163	.58725E-01	3.3144	11.862	770.70	303.49	12.346
14558.58A	.36472	.58958E-01	3.3020	11.747	766.93	303.39	12.222
14676.58A	.35751	.59222E-01	3.2895	11.540	760.15	303.42	12.019
14846.58A	.35308	.59655E-01	3.2674	11.310	752.54	303.42	11.792
15756.58A	.38323	.58524E-01	3.3239	11.943	773.33	303.34	12.430
16291.58A	.36995	.58837E-01	3.3060	11.663	764.15	303.10	12.139
16823.58A	.15158	.80193E-01	2.4679	4.0910	452.50	122.66	4.3972
17664.00A	.15143	.80430E-01	2.4629	4.0587	450.71	122.36	4.3605
17986.00A	.14964	.81003E-01	2.4450	4.0173	448.37	122.57	4.3157

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PUMP CALIBRATION TEST FACILITY

TEST 84L010 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 6

TEST 84L010 3-14-84 LOW THRUST PUMP H-G & CAV TESTS

TIME	-6 AMBIENT PRESS (PSIA)	6 PUMP INLET TEMP (F)	14 PUMP OUTLET TEMP (F)	105 TURBINE INLET TEMP (F)	106 TURBINE OUTLET TEMP (F)	1 PUMP INLET PRESS (PSIG)	8 PUMP DIS PRESS (PSIG)	-2 VAPOR HEAD (FT)	-3 INLET VELOCITY (FPS)
21.58A	14.347	75.734	76.765	76.384	74.308	35.123	34.671	1.0190	
12091.58A	14.347	74.552	76.421	33.651	29.068	33.329	74.822	.97935	.30430
12229.58A	14.347	74.798	76.766	28.131	21.725	34.052	101.10	.98750	.21290
12337.58A	14.347	74.749	77.702	26.948	19.803	34.448	110.99	.98587	.15659
12649.58A	14.347	74.995	79.574	26.751	-4.9364	31.903	202.98	.99406	.59018
12790.58A	14.347	75.291	79.968	28.180	-3.2608	32.382	274.00	1.0039	.51478
12899.58A	14.347	75.291	80.757	28.328	-2.6694	32.941	310.07	1.0039	.43179
12998.58A	14.347	75.439	81.939	28.624	-1.9795	33.507	335.52	1.0089	.34935
13095.58A	14.347	75.291	83.762	28.624	-1.4374	34.080	356.82	1.0039	.26736
13219.58A	14.347	75.242	87.655	27.983	-1.2896	34.785	371.14	1.0023	.17437
13858.58A	14.347	75.981	83.220	23.399	-24.895	31.250	418.47	1.0273	.76571
14018.58A	14.347	76.178	83.959	24.237	-24.403	31.612	488.03	1.0341	.69975
14153.58A	14.347	76.178	84.630	24.779	-22.727	32.202	512.13	1.0342	.61969
14443.58A	14.347	76.129	85.388	25.026	-22.037	32.584	547.07	1.0324	.54076
14558.58A	14.347	75.784	86.867	24.829	-21.495	33.093	574.66	1.0206	.46161
14676.58A	14.347	76.030	88.936	24.237	-21.446	33.830	599.89	1.0290	.37554
14846.58A	14.347	76.178	92.188	23.054	-21.495	34.367	613.25	1.0342	.30314
15756.58A	14.347	77.613	85.920	20.454	-26.965	-8.7104	444.17	1.0847	.65347
16291.58A	14.347	77.446	87.000	19.289	-26.807	1.0598	508.84	1.0787	.52793
16823.58A	14.347	77.767	79.421	27.321	16.374	-4.1640	16.924	1.0903	.29528
17664.00A	14.347	77.824	79.395	25.654	17.643	-4.0471	30.043	1.0923	.28600
17986.00A	14.347	77.805	79.529	26.221	18.283	-4.0517	52.806	1.0917	.25307

TIME	18 VOLUTE PRESS ODEG(PSIG)	19 VOLUTE PRESS 90DEG(PSIG)	20 VOLUTE PRES 180DEG(PSIG)	21 VOLUTE PRES 270DEG(PSIG)	26 DIFF INLET 0 DEG (PSIG)	34 FRONT WR RING UP R (PSIG)	36 REAR WR RING UP R (PSIG)	37 REAR WR RINT DP R (PSIG)
21.58A	34.691	35.406	34.120	35.597	34.237	35.462	35.710	34.635
12091.58A	73.076	74.086	67.887	70.514	92.764	75.609	79.612	35.530
12229.58A	99.732	101.08	97.077	99.283	95.203	76.309	80.612	36.458
12337.58A	110.08	111.35	108.51	110.32	96.850	76.651	81.032	36.955
12649.58A	197.32	197.62	176.83	182.36	276.92	190.77	206.26	45.011
12790.58A	268.38	268.63	254.21	256.31	280.28	191.22	206.94	45.525
12899.58A	305.17	305.63	294.91	295.41	284.17	191.88	208.17	46.403
12998.58A	331.73	332.11	325.05	324.29	289.13	193.18	210.06	47.066
13095.58A	353.42	353.70	348.56	347.34	292.47	194.08	211.03	47.862
13219.58A	368.37	368.80	365.43	364.49	297.70	195.17	212.48	48.873
13858.58A	408.30	406.70	376.12	379.51	481.75	312.64	341.62	55.835
14018.58A	478.30	476.74	450.61	450.29	494.08	319.24	349.06	57.095
14153.58A	503.83	502.18	480.84	478.28	485.25	311.04	340.60	57.177
14443.58A	539.38	537.72	520.30	516.02	490.93	312.79	343.33	57.907
14558.58A	568.32	566.80	553.21	547.61	496.62	315.28	346.09	59.133
14676.58A	594.10	591.75	581.42	574.88	501.50	315.41	347.09	59.780
14846.58A	608.94	607.23	600.89	592.95	502.72	315.46	347.20	60.758
15756.58A	435.72	434.69	410.43	411.05	428.24	260.48	288.28	15.499
16291.58A	501.47	500.52	482.85	480.01	449.46	275.07	304.61	25.732
16823.58A	15.289	15.697	12.169	9.3847	55.719	37.445	41.061	3.6679
17664.00A	28.473	29.326	25.393	25.106	55.503	37.282	40.908	3.5806
17986.00A	31.423	32.705	47.002	49.505	56.280	37.500	41.279	3.2291

PUMP CALIBRATION TEST FACILITY

TEST 84L010 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 8

TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	38 IMP FR T IP PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC PR (PSIG)	114 ROTOR OUT TIP PR (PSIG)	115 ROTOR CUT HUB PR (PSIG)
21.58A	35.265	35.932	.23725E-01	.22049E-01	.25629E-01
12091.58A	94.264	92.671	4.3151	1.8677	1.9735
12229.58A	95.152	93.711	4.1172	1.7669	1.9095
12337.58A	95.448	94.190	4.0665	1.7984	1.8774
12649.58A	274.80	263.60	11.306	4.7717	5.2030
12790.58A	275.93	265.78	10.971	4.6205	5.0364
12899.58A	277.13	266.75	10.615	4.4567	4.8826
12998.58A	279.37	269.46	10.279	4.2929	4.7160
13095.58A	279.96	270.47	9.9981	4.1544	4.5494
13219.58A	281.69	272.73	9.5991	3.9843	4.3572
13858.58A	472.04	448.84	20.520	8.8851	9.7204
14018.58A	482.70	458.65	20.498	8.8788	9.6691
14153.58A	470.83	448.61	19.286	8.3182	9.0732
14443.58A	474.28	452.19	18.852	8.0851	8.8361
14558.58A	477.93	455.91	18.344	7.8331	8.5798
14676.58A	479.15	457.57	17.806	7.6316	8.3171
14846.58A	477.70	456.76	17.591	7.6693	8.2786
15756.58A	416.85	395.02	19.635	8.4414	9.2049
16291.58A	433.50	412.09	18.587	7.9568	8.6792
16823.58A	55.996	54.197	3.8604	1.6679	1.7671
17664.00A	55.689	53.919	3.8452	1.6694	1.7594
17986.00A	56.151	54.426	3.7724	1.6356	1.7321

C	DESCRIPTION	CONSTANT
1	WALL DIAMETER AT INLET PRESS TAP, IN.	1.00000E+00
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER, IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.85000E-01
10	IND/IMP INLET AREA, SQ. IN.	3.12608E-01
11	DESIGN FLOW, GPM	5.00000E+00
12	AMBIENT PRESSURE, PSIA	1.43960E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	2.45000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR F(7)	0.0
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	1.34271E+01
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

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PUMP CALIBRATION TEST FACILITY

TEST 84L009 TEST DATE 10 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 1

TEST 84L009, 3-9-1984 LOW THRUST PUMP H-Q & CAV TESTS

TIME	4 SHAFT SPEED (RPM)	-16 FLOW/ DES FLOW	3 PUMP DIS FLOW (GPM)	-21 PUMP TOT HEADRISE (FT)	-3 INLET VELOCITY (FPS)
21.50A	-.95927	1.5321	.29994E-03	.65010E-01	.12258E-03
941.00A	-2.8778	.0	.0	-1.8766	.0
1490.00A	7419.0	1.1752	1.7786	35.742	.72689
1657.00A	7351.9	1.0391	1.5591	36.824	.63717
1782.00A	7302.0	.81476	1.2142	38.451	.49620
2011.00A	14716.	1.1930	3.5831	148.94	1.4643
2090.50A	14703.	1.0994	3.2987	151.90	1.3481
2172.50A	14681.	.99591	2.9838	155.77	1.2194
2271.50A	14684.	.88611	2.6554	160.33	1.0852
2343.00A	14696.	.79416	2.3818	163.73	.97340
2427.00A	14676.	.68709	2.0579	167.79	.84101
2546.50A	14685.	.57629	1.7271	172.40	.70581
2624.00A	14690.	.48652	1.4586	175.10	.59610
2719.00A	14677.	.38563	1.1551	177.77	.47205
3202.00A	19353.	1.2144	4.7963	257.89	1.9602
3308.00A	19338.	1.1181	4.4124	265.25	1.8033
3429.00A	19365.	1.0195	4.0291	273.81	1.6466
3513.00A	19338.	.91764	3.6215	280.31	1.4800
3661.50A	19376.	.81602	3.2031	288.39	1.3090
3913.50A	19415.	.68480	2.7133	297.05	1.1088
4097.50A	19389.	.57541	2.2744	303.83	.92952
4199.00A	19404.	.46892	1.8569	309.11	.75889
4304.00A	19404.	.37417	1.4817	313.38	.60554
4554.00A	19406.	.26993	1.1479	317.66	.46911
4836.00A	24564.	1.1983	6.0072	420.67	2.4550
4976.50A	24529.	1.0985	5.4991	433.15	2.2474
5070.00A	24497.	1.0025	5.0120	443.88	2.0483
5214.00A	24508.	.90791	4.5411	455.20	1.8558
5358.00A	24511.	.80245	4.0141	467.22	1.6405
5578.00A	24558.	.69086	3.4625	478.56	1.4151
5695.00A	24527.	.58645	2.9454	489.36	1.2037
5799.50A	24550.	.47235	2.3665	499.24	.96715
5905.50A	24499.	.36534	1.8266	509.30	.74651
6067.00A	24524.	.27736	1.3881	513.98	.56730

TEST 84L009, 3-9-1984 LOW THRUST PUMP H-G & CAV TESTS

TIME	-17 PUMP STA DELTA HEAD FT	-18 PUMP DIS VELOCITY (FPS)	-1 WATER SP.WGT. LBM/FT3	-2 VAPOR HEAD (FT)	-21 PUMP TOT HEADRISE (FT)	-22 PUMP INL FLOW COEF	-23 PUMP DIS HEAD COEF	-6 AMBIENT PRESS (PSIA)
21.50A	.65019E-01	.49007E-03	62.422	.20469	.65010E-01	.36380E-01	50929.	14.396
941.00A	-1.8766	.0	62.221	1.0732	-1.8766	.0	-.60745E+06	14.396
1490.00A	35.576	2.9061	62.290	.80193	35.742	.27904E-01	.28033	14.396
1657.00A	36.697	2.5474	62.283	.82952	36.824	.24674E-01	.28784	14.396
1782.00A	38.374	1.9838	62.280	.84080	38.451	.19347E-01	.30467	14.396
2011.00A	148.26	5.8543	62.275	.85793	148.94	.28329E-01	.29055	14.396
2090.50A	151.33	5.3898	62.274	.86376	151.90	.26105E-01	.29687	14.396
2172.50A	155.30	4.8752	62.274	.86231	155.77	.23648E-01	.30535	14.396
2271.50A	159.96	4.3386	62.273	.86809	160.33	.21041E-01	.31417	14.396
2343.00A	163.43	3.8916	62.272	.86954	163.73	.18857E-01	.32031	14.396
2427.00A	167.57	3.3624	62.271	.87396	167.79	.16315E-01	.32914	14.396
2546.50A	172.24	2.8218	62.272	.87103	172.40	.13684E-01	.33781	14.396
2624.00A	174.99	2.3832	62.270	.87692	175.10	.11553E-01	.34281	14.396
2715.00A	177.70	1.8872	62.270	.87692	177.77	.91568E-02	.34868	14.396
3202.00A	256.65	7.8367	62.269	.88281	257.89	.28835E-01	.29094	14.396
3306.00A	264.23	7.2094	62.267	.88874	265.25	.26548E-01	.29970	14.396
3429.00A	272.96	6.5831	62.267	.89171	273.81	.24208E-01	.30852	14.396
3515.00A	279.63	5.9171	62.267	.89022	280.31	.21789E-01	.31670	14.396
3661.50A	287.85	5.2334	62.265	.89617	288.39	.19234E-01	.32461	14.396
3913.50A	296.67	4.4331	62.266	.89320	297.05	.16261E-01	.33299	14.396
4097.50A	303.56	3.7162	62.265	.89920	303.83	.13663E-01	.34219	14.396
4199.00A	308.93	3.0340	62.264	.90067	309.11	.11134E-01	.34686	14.396
4304.00A	313.27	2.4209	62.264	.90217	313.38	.88846E-02	.35168	14.396
4554.00A	317.59	1.8755	62.264	.90221	317.66	.68843E-02	.35661	14.396
4336.00A	418.76	9.8151	62.262	.90823	420.67	.28454E-01	.29454	14.396
4976.50A	431.57	8.9849	62.261	.91127	433.15	.26085E-01	.30417	14.396
5070.00A	442.56	8.1890	62.260	.91735	443.88	.23805E-01	.31252	14.396
5211.00A	454.12	7.4196	62.260	.91894	455.20	.21558E-01	.32017	14.396
5358.00A	466.37	6.6586	62.258	.92507	467.22	.19054E-01	.32856	14.396
5578.00A	477.93	5.6573	62.257	.92812	478.56	.16404E-01	.33525	14.396
5695.00A	488.90	4.8125	62.258	.92658	489.36	.13973E-01	.34369	14.396
5799.50A	498.95	3.8666	62.258	.92661	499.24	.11216E-01	.34998	14.396
5905.50A	509.13	2.9845	62.258	.92507	509.30	.86751E-02	.35852	14.396
6067.00A	513.88	2.2680	62.259	.92197	513.98	.65858E-02	.36105	14.396

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TIME	-15 IMPELLER IN FLOW COEF	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
21.50A	.91355E-01	.97301E-02	.98812	.20096	-.83917E-01	58.510	-.10045E-01	.21391E-02
941.00A	.0	.93235E-02	.99046	.20145	-.49067E-01	53.182	-.30136E-01	.10824E-01
1490.00A	.70071E-01	.13419	.86693E-01	2.2988	3.1814	398.98	77.692	3.4083
1657.00A	.61959E-01	.11735	.95386E-01	2.0816	2.5459	357.04	76.988	2.7382
1782.00A	.48582E-01	.11932	.94185E-01	2.1060	2.5942	360.40	76.466	2.7652
2011.00A	.71138E-01	.18585	.71808E-01	2.7445	5.4537	522.57	154.11	5.7610
2090.50A	.65552E-01	.18565	.71838E-01	2.7432	5.4887	524.25	153.97	5.8062
2172.50A	.59383E-01	.18523	.71912E-01	2.7414	5.4435	522.08	153.74	5.7731
2271.50A	.52836E-01	.18469	.72008E-01	2.7364	5.4236	521.13	153.77	5.7364
2343.00A	.47353E-01	.18370	.72155E-01	2.7294	5.3835	519.20	153.90	5.6864
2427.00A	.40969E-01	.18326	.72208E-01	2.7257	5.3903	519.52	153.69	5.7003
2546.50A	.34363E-01	.18198	.72544E-01	2.7178	5.3513	517.64	153.78	5.6778
2624.00A	.29010E-01	.18241	.72424E-01	2.7206	5.3598	518.05	153.84	5.6820
2715.00A	.22994E-01	.18084	.72723E-01	2.7086	5.3116	515.72	153.70	5.6284
3202.00A	.72410E-01	.22453	.66124E-01	2.9669	7.2712	603.40	202.67	7.6205
3308.00A	.66666E-01	.22293	.66291E-01	2.9617	7.2104	600.87	202.51	7.5831
3429.00A	.60791E-01	.22167	.66447E-01	2.9540	7.1461	598.19	202.79	7.5095
3515.00A	.54716E-01	.22147	.66442E-01	2.9551	7.1726	599.29	202.51	7.5413
3661.50A	.48299E-01	.22053	.66584E-01	2.9476	7.1114	596.73	202.91	7.4687
3913.50A	.40832E-01	.21987	.66665E-01	2.9444	7.1241	597.26	203.31	7.4850
4097.50A	.34310E-01	.21918	.66815E-01	2.9392	7.1161	596.93	202.83	7.4782
4199.00A	.27960E-01	.21842	.66901E-01	2.9346	7.0663	594.83	203.20	7.4172
4304.00A	.22310E-01	.21768	.67051E-01	2.9284	7.0749	595.20	203.20	7.4220
4554.00A	.17287E-01	.21687	.67120E-01	2.9254	7.0384	593.66	203.16	7.3887
4838.00A	.71451E-01	.28149	.61664E-01	3.1671	9.3403	683.88	257.23	9.7271
4976.50A	.65503E-01	.27980	.61747E-01	3.1622	9.3085	682.72	256.86	9.6800
5070.00A	.59778E-01	.27735	.61888E-01	3.1562	9.2468	680.45	256.53	9.6292
5211.00A	.54136E-01	.27679	.61982E-01	3.1550	9.1903	678.37	256.65	9.5956
5358.00A	.47848E-01	.27522	.62067E-01	3.1460	9.1869	678.24	256.68	9.5517
5578.00A	.41194E-01	.27361	.62174E-01	3.1427	9.1539	677.02	257.17	9.5364
5695.00A	.35087E-01	.27261	.62230E-01	3.1390	9.0918	674.72	256.84	9.4646
5799.50A	.28165E-01	.27129	.62312E-01	3.1336	9.0351	672.61	257.08	9.3960
5905.50A	.21784E-01	.26910	.62495E-01	3.1282	8.9639	669.96	256.55	9.3617
6067.00A	.16538E-01	.26786	.62577E-01	3.1235	8.9924	671.02	256.81	9.3686

TEST 84L009, 3-9-1984 LOW THRUST PUMP H-Q & CAV TESTS

TIME	-3 INLET VELOCITY (FPS)	6 PUMP INLET TEMP (F)	14 PUMP OUTLET TEMP (F)	105 TURBINE INLET TEMP (F)	106 TURBINE OUTLET TEMP (F)	1 PUMP INLET PRESS (PSIG)	8 PUMP DIS PRESS (PSIG)
21.50A	.12258E-03	32.084	31.828	31.975	32.025	.50598E-02	.33245E-01
941.00A	.0	77.291	78.266	79.568	76.690	35.246	34.435
1490.00A	.72689	68.673	69.155	33.353	36.161	33.634	49.027
1657.00A	.63717	69.658	69.894	28.087	29.562	33.701	49.575
1782.00A	.49620	70.052	70.387	27.152	27.445	34.057	50.656
2011.00A	1.4643	70.643	71.372	22.624	10.307	31.842	95.976
2090.50A	1.3481	70.840	71.519	22.723	9.6180	32.299	97.755
2172.50A	1.2194	70.791	71.962	22.427	9.1256	32.626	99.799
2271.50A	1.0852	70.988	72.110	22.821	9.1748	32.911	102.09
2343.00A	.97340	71.037	72.455	22.870	9.0763	33.089	103.77
2427.00A	.84101	71.184	72.652	23.067	9.2733	33.412	105.88
2546.50A	.70581	71.086	73.144	23.756	9.5195	33.670	108.16
2624.00A	.59610	71.283	73.735	23.805	9.8150	33.965	109.64
2715.00A	.47205	71.283	74.474	24.544	10.455	34.388	111.23
3202.00A	1.9602	71.480	72.750	25.331	2.1328	31.237	142.26
3308.00A	1.8033	71.677	72.947	25.676	2.6252	31.804	146.08
3429.00A	1.6466	71.776	73.144	25.626	2.5760	31.826	149.87
3515.00A	1.4800	71.726	73.588	26.365	3.2654	32.418	153.35
3661.50A	1.3090	71.923	73.883	26.315	3.2654	32.756	157.24
3913.50A	1.1088	71.825	74.375	26.463	3.6101	33.019	161.31
4097.50A	.92952	72.022	75.163	26.709	4.0533	33.402	164.66
4199.00A	.75889	72.071	75.951	26.315	3.7579	33.907	167.49
4304.00A	.60554	72.120	77.133	26.611	3.8563	34.376	169.83
4554.00A	.46911	72.120	78.561	26.463	4.0041	34.621	171.94
4838.00A	2.4550	72.317	74.228	25.725	-7.8148	30.004	211.11
4976.50A	2.2474	72.416	74.572	26.119	-7.4208	30.682	217.31
5070.00A	2.0483	72.613	74.720	26.512	-7.0269	31.157	222.53
5211.00A	1.8558	72.662	75.163	26.562	-7.0269	31.452	227.82
5358.00A	1.6405	72.859	75.410	26.168	-7.0761	31.880	233.53
5578.00A	1.4151	72.957	76.542	26.168	-6.7314	32.191	238.84
5695.00A	1.2037	72.908	76.986	25.873	-7.0761	32.736	244.12
5799.50A	.96715	72.908	78.414	25.823	-6.8299	33.582	249.31
5905.50A	.74651	72.859	80.236	25.626	-6.9284	34.234	254.36
6067.00A	.56730	72.760	82.452	26.020	-6.3867	34.570	256.75

PUMP CALIBRATION TEST FACILITY

TEST 84L009 TEST DATE 10 MAR 1984 PROCESS DATE 9 NOV 1984 PAGE 13

TEST 84L009, 3-9-1984 LOW THRUST PUMP H-O & CAV TESTS

TIME	18 VOLUTE P RESS ODL G(PSIG)	19 VOLUTE P RESS 90D EG(PSIG)	20 VOLUTE P RES 180D EG(PSIG)	21 VOLUTE P RES 270D EG(PSIG)	34 FRONT WR RING DP R (PSIG)	36 REAR WR RING DP R (PSIG)	37 REAR WR RING DP R (PSIG)	38 IMP FR T IP PR (PSIG)
21.50A	.13901	.73633E-01	.98228E-05	.23791E-01	.10625	.40540E-01	.14119	.10727
941.00A	34.482	35.179	33.660	35.329	35.296	35.071	34.527	34.887
1490.00A	47.924	48.108	47.099	48.947	34.544	41.513	33.929	46.760
1657.00A	48.497	48.419	47.395	49.264	34.708	41.789	34.128	47.139
1782.00A	49.772	49.270	48.118	50.247	35.132	42.582	34.593	48.096
2011.00A	90.656	88.663	88.606	91.497	35.459	60.243	35.141	84.063
2090.50A	92.831	90.087	89.988	93.066	36.079	61.052	35.756	85.563
2172.50A	95.350	91.609	91.353	94.984	36.602	62.153	36.487	87.212
2271.50A	97.770	93.050	92.718	96.791	37.124	63.545	37.168	89.125
2343.00A	100.12	94.113	94.050	98.266	37.631	64.937	37.816	90.758
2427.00A	102.50	95.554	95.513	100.07	38.121	66.523	38.513	92.572
2546.50A	105.03	97.207	97.174	102.20	38.578	68.142	39.277	94.815
2624.00A	106.55	98.303	98.523	103.64	39.035	69.567	39.709	96.431
2715.00A	108.84	99.514	99.822	105.42	39.786	70.959	40.424	98.327
3202.00A	132.65	128.24	129.29	133.30	37.255	77.531	36.802	120.66
3308.00A	136.50	131.12	131.92	136.23	38.251	79.085	37.915	123.48
3429.00A	141.45	133.60	134.54	139.40	39.002	80.720	38.978	126.26
3515.00A	145.65	135.93	136.81	142.58	39.802	83.116	40.224	129.46
3601.50A	149.95	138.48	139.45	145.90	40.619	85.787	41.321	132.96
3713.50A	154.91	141.23	142.38	149.42	41.435	88.603	42.433	136.85
4097.50A	159.01	143.51	145.24	152.82	42.138	91.274	43.546	140.73
4199.00A	162.63	145.58	147.43	155.61	43.036	93.654	44.527	143.81
4304.00A	165.90	147.55	149.62	158.33	44.015	95.856	45.523	146.78
4554.00A	168.58	149.19	151.80	160.90	44.848	97.733	46.487	149.63
4838.00A	195.07	186.52	189.23	194.80	40.243	102.04	39.676	174.80
4970.50A	202.40	190.72	193.79	199.88	41.631	104.86	41.453	179.64
5070.00A	208.99	194.06	196.91	204.31	42.742	107.69	43.148	184.23
5211.00A	215.11	197.55	200.43	208.68	43.689	110.42	44.443	188.52
5358.00A	221.70	201.03	204.35	213.84	44.685	114.16	46.088	193.69
5578.00A	228.11	204.44	208.13	218.35	45.518	117.77	47.433	198.86
5695.00A	234.76	208.32	212.67	223.43	46.824	121.72	49.277	204.33
5799.50A	241.65	212.23	216.94	228.59	48.196	125.82	50.988	210.22
5905.50A	247.72	215.65	221.10	233.45	49.943	129.51	52.766	215.64
6067.00A	251.58	217.71	223.32	236.95	51.249	132.29	54.211	219.68

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TEST 84L009, 2-9-1984 LOW THRUST PUMP H-Q & CAV TESTS

TIME	39 IMP FR M ID PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC PR (PSIA)	114 ROTOR OUT TIP PR (PSIG)	115 ROTOR OUT HUB PR (PSIG)	116 TURB NOZ OUT (PSIG)
21.50A	.24890E-01	.15732	.40096E-01	.28386E-01	.28829E-01	.60472E-01
941.00A	33.916	35.562	.33554E-01	.22078E-01	.22422E-01	.28645E-01
1490.00A	38.478	47.667	2.9900	1.3719	1.4255	.84341
1657.00A	38.694	47.998	2.3077	1.0376	1.0860	.63428
1782.00A	39.241	48.776	2.3617	1.0818	1.1180	.67155
2011.00A	55.299	84.893	5.5570	2.4253	2.5403	1.7791
2090.50A	56.195	86.797	5.5528	2.4379	2.5595	1.7473
2172.50A	57.006	88.337	5.5227	2.3874	2.5403	1.7346
2271.50A	57.655	89.827	5.4998	2.3811	2.5659	1.7537
2343.00A	58.319	91.301	5.4392	2.3622	2.5339	1.7282
2427.00A	59.181	92.841	5.4278	2.3423	2.5339	1.7155
2546.50A	60.011	94.646	5.3705	2.3370	2.5019	1.6964
2624.00A	60.459	96.004	5.3951	2.3370	2.5403	1.7155
2715.00A	61.338	97.594	5.3247	2.3054	2.4762	1.7027
3202.00A	72.320	121.62	7.9638	3.4408	3.6551	2.6575
3308.00A	73.630	124.85	7.8689	3.3966	3.6103	2.6321
3429.00A	74.858	127.58	7.7936	3.3462	3.5590	2.6130
3515.00A	76.318	130.05	7.7854	3.3651	3.5782	2.6257
3661.50A	77.694	133.06	7.7412	3.3462	3.5654	2.6003
3913.50A	78.972	136.28	7.7052	3.3146	3.5334	2.5875
4097.50A	80.150	139.29	7.6807	3.2957	3.5206	2.5939
4199.00A	81.460	142.04	7.6218	3.2831	3.4885	2.5684
4304.00A	82.472	144.62	7.5989	3.2768	3.4949	2.5684
4554.00A	83.418	148.92	7.5384	3.2453	3.4629	2.5493
4838.00A	96.954	175.54	11.874	5.1123	5.5131	4.2998
4976.50A	99.260	180.90	11.756	5.0492	5.4426	4.2616
5070.00A	101.20	184.58	11.596	4.9546	5.3657	4.1725
5211.00A	102.88	188.21	11.575	4.9609	5.3657	4.1725
5358.00A	104.85	192.36	11.458	4.8978	5.3145	4.1534
5578.00A	106.58	196.64	11.349	4.8474	5.2376	4.0834
5695.00A	108.58	201.31	11.270	4.8032	5.1992	4.0579
5799.50A	110.41	206.01	11.180	4.7906	5.1671	4.0388
5905.50A	112.38	210.53	11.043	4.7023	5.0838	3.9561
6067.00A	113.78	213.41	10.958	4.6518	5.0454	3.9497

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C	DESCRIPTION	CONSTANT
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER,IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.85000E-01
10	IND/IMP INLET AREA,SQ.IN.	3.12608E-01
11	DESIGN FLOW, GPM	2.00000E+00
12	AMBIENT PRESSURE, PSIA	1.42680E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	3.92460E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR F(7)	0.0
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	0.0
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

PUMP CALIBRATION TEST FACILITY

TEST 84L011 TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984

TEST 84L011 3-21-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	4 SHAFT SPEED (RPM)	-16 FLOW/DES FLOW	3 PUMP DIS FLOW (GPM)	-21 PUMP TOT HEADRISE (FT)	-3 INLET VELOCITY (FPS)	-15 IMPELLER IN FLOW COEF
		.31349	-.56819E-04	-.34505E-05	-.24036E-04	.0
22.50A	-8.1638	1.2357	.72665	34.608	.29776	.18399E-01
1398.50A	11571.	.87546	.51502	46.054	.21048	.13035E-01
1568.50A	11544.	.64410	.37873	52.041	.15478	.95901E-02
1659.50A	11536.	1.2257	1.4682	152.27	.60004	.18250E-01
2062.50A	23506.	1.0504	1.2575	180.23	.51391	.15640E-01
2156.50A	23492.	.87219	1.0412	204.33	.42550	.12986E-01
2263.50A	23425.	.72164	.86123	221.79	.35196	.10745E-01
2356.50A	23419.	.53956	.64607	239.06	.26403	.80337E-02
2454.50A	23497.	.35792	.42658	255.64	.17507	.53292E-02
2552.50A	23466.	.24132	.35791	469.39	.14627	.35931E-02
3067.50A	29104.	.35475	.52608	453.67	.21506	.52820E-02
3151.50A	29100.	.50511	.74671	432.18	.30598	.75207E-02
3233.50A	29087.	.62886	.93199	413.83	.38086	.93632E-02
3314.50A	29062.	.76962	1.1404	369.48	.46607	.11459E-01
3401.50A	29076.	.89477	1.3250	367.05	.54150	.13322E-01
3508.50A	29059.	1.0219	1.5129	337.94	.61628	.15215E-01
3587.50A	29051.	1.1540	1.7080	307.19	.69802	.17183E-01
3667.50A	29042.	1.2679	1.8754	275.19	.76643	.18878E-01
3787.50A	29025.	1.2211	1.8048	256.63	.73758	.18182E-01
3937.50A	29030.	1.2476	1.8516	255.78	.75681	.18575E-01
4236.50A	29136.	1.2407	1.8552	265.26	.75816	.18473E-01
4586.50A	29342.	1.0830	1.5974	274.85	.65284	.16125E-01
5054.00A	28945.	1.0275	1.5257	294.07	.62270	.15299E-01
5349.00A	29112.	.88875	1.3307	348.82	.54382	.13233E-01
5521.00A	29380.	.64253	.96126	374.82	.39285	.95668E-02
5632.00A	29364.	1.0135	1.5174	336.49	.62011	.15090E-01
5976.50A	29379.	1.1502	1.3906	149.57	.56833	.17125E-01
6425.00A	23740.	.97057	1.1703	178.62	.47827	.14457E-01
6562.00A	23629.	.81906	.98609	197.00	.40299	.12195E-01
6720.50A	23627.	.79986	.96396	196.22	.39395	.11909E-01
6842.00A	23644.	.66064	.79700	205.95	.32596	.98393E-02
6986.00A	23695.	.66827	.80615	200.52	.32946	.99500E-02
7123.00A	23671.	1.1536	1.3940	143.91	.56970	.17176E-01
7295.00A	23696.					

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PUMP CALIBRATION TEST FACILITY

TEST 84L011 TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984 PAGE 7

TEST 84L011 3-21-84 LOW THRUST PUMP H-G & CAV TESTS

TIME	-17 PUMP STA DELTA HEAD FT	-18 PUMP DIS VELOCITY (FPS)	-2 VAPOR HEAD (FT)	-3 INLET VELOCITY (FPS)	-21 PUMP TOT HEADRISE (FT)	-22 PUMP INL FLOW COEF	-23 PUMP DIS HEAD COEF	-6 AMBIENT PRESS (PSIA)
22.50A	-.34506E-05	-.96103E-04	-.94232E+06	-.24638E-04	-.34505E-05	.18588E-02	-.22747	14.268
1396.50A	34.580	1.1905	1.0214	.29778	34.608	.73268E-02	.10926	14.268
1568.50A	46.040	.84148	1.0296	.21048	46.054	.51909E-02	.14606	14.268
1659.50A	52.034	.61881	1.0349	.15478	52.041	.38190E-02	.16522	14.268
2062.50A	152.15	2.3989	1.0624	.60004	152.27	.72675E-02	.11646	14.268
2156.50A	180.15	2.0546	1.0746	.51391	180.23	.62281E-02	.13800	14.268
2263.50A	204.28	1.7011	1.0870	.42550	204.33	.51715E-02	.15735	14.268
2356.50A	221.75	1.4071	1.0834	.35196	221.79	.42788E-02	.17088	14.268
2454.50A	239.04	1.0556	1.1012	.26403	239.06	.31992E-02	.18295	14.268
2552.50A	255.03	.69992	1.1139	.17507	255.04	.21222E-02	.19536	14.268
3067.50A	469.39	.56479	1.1981	.14627	469.39	.14309E-02	.23413	14.268
3151.50A	453.05	.65955	1.2028	.21500	453.07	.21034E-02	.22604	14.268
3233.50A	432.15	1.2233	1.2097	.30598	432.18	.29949E-02	.21582	14.268
3314.50A	413.79	1.5226	1.2274	.38088	413.83	.37287E-02	.20673	14.268
3401.50A	389.41	1.8635	1.2694	.46607	389.48	.45633E-02	.19461	14.268
3508.50A	366.96	2.1649	1.3022	.54150	367.05	.53053E-02	.18365	14.268
3587.50A	337.82	2.4719	1.3295	.61828	337.94	.60592E-02	.16917	14.268
3667.50A	307.04	2.7906	1.3637	.69802	307.19	.68426E-02	.15387	14.268
3787.50A	275.00	3.0642	1.3943	.76643	275.19	.75177E-02	.13800	14.268
3937.50A	257.85	2.9488	1.4353	.73758	256.03	.72405E-02	.12963	14.268
4236.50A	255.60	3.0257	1.5159	.75681	255.78	.73971E-02	.12754	14.268
4586.50A	265.08	3.0311	1.5928	.75816	265.26	.73566E-02	.13018	14.268
5054.00A	274.72	2.6100	1.7262	.65284	274.85	.64213E-02	.13857	14.268
5349.00A	293.94	2.4695	1.8303	.62270	294.07	.60926E-02	.14682	14.268
5521.00A	348.73	2.1742	1.8716	.54382	348.82	.52697E-02	.17072	14.268
5632.00A	374.77	1.5706	1.9042	.39285	374.82	.38098E-02	.18370	14.268
5976.50A	336.37	2.4792	2.0228	.62011	336.49	.60093E-02	.16471	14.268
6425.00A	149.47	2.2722	2.1319	.56833	149.57	.68197E-02	.11230	14.268
6562.00A	178.54	1.9121	2.1401	.41627	178.62	.57571E-02	.13482	14.268
6720.50A	196.95	1.6112	2.1644	.40259	197.00	.48564E-02	.14894	14.268
6842.00A	190.17	1.5750	2.1751	.39395	190.22	.47426E-02	.14330	14.268
6986.00A	205.92	1.3052	2.1806	.32596	205.95	.39183E-02	.15509	14.268
7123.00A	200.49	1.3172	2.1863	.32946	200.52	.39624E-02	.15126	14.268
7295.00A	143.81	2.2776	2.2308	.56970	143.91	.68399E-02	.10827	14.268

TIME	-1 WATER SP.WGT. LBM/FT3	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
				.20106	-.77503E-01	59.307	-.85491E-01	-.15847E-01
22.50A	.87317E+06	.91102E-02	.98450					
1398.50A	62.234	.14021	.83402E-01	2.3620	3.9140	442.70	121.17	4.2570
1568.50A	62.232	.14086	.83066E-01	2.3698	3.8754	440.50	120.89	4.2340
1659.50A	62.230	.14029	.83350E-01	2.3794	3.8653	439.93	120.83	4.2371
2062.50A	62.224	.21069	.88131E-01	2.8934	7.4249	609.74	246.16	7.9137
2156.50A	62.220	.20948	.88220E-01	2.8898	7.4463	610.62	246.01	7.9224
2263.50A	62.218	.20835	.88370E-01	2.8828	7.3984	608.65	245.30	7.8603
2356.50A	62.218	.20737	.88579E-01	2.8748	7.3462	606.49	245.24	7.8183
2454.50A	62.214	.20606	.88892E-01	2.8665	7.2549	602.70	246.06	7.7815
2552.50A	62.211	.20511	.89018E-01	2.8576	7.3041	604.76	245.95	7.7834
3067.50A	62.191	.25968	.84229E-01	3.0581	9.4526	687.98	304.77	9.9517
3151.50A	62.189	.26138	.84109E-01	3.0655	9.4494	687.86	304.73	9.9793
3233.50A	62.188	.26307	.83986E-01	3.0721	9.5494	691.50	304.59	10.076
3314.50A	62.184	.26491	.83886E-01	3.0774	9.5765	692.47	304.54	10.121
3401.50A	62.174	.26677	.83761E-01	3.0834	9.6544	695.28	304.50	10.190
3508.50A	62.167	.26839	.83661E-01	3.0890	9.6754	696.04	304.30	10.227
3567.50A	62.160	.26954	.83497E-01	3.0892	9.7636	699.21	304.22	10.240
3667.50A	62.153	.27078	.83557E-01	3.0941	9.7782	699.73	304.13	10.333
3787.50A	62.146	.27158	.83454E-01	3.0956	9.7959	700.36	303.95	10.331
3937.50A	62.137	.26055	.84171E-01	3.0641	9.4846	688.68	304.00	10.017
4238.50A	62.119	.26213	.84144E-01	3.0663	9.5264	690.48	305.11	10.069
4586.50A	62.102	.26574	.83834E-01	3.0793	9.6061	693.53	307.27	10.138
5054.00A	62.074	.26151	.84124E-01	3.0648	9.5084	690.01	303.11	10.026
5349.00A	62.054	.26040	.84456E-01	3.0506	9.4395	687.29	304.86	9.9295
5521.00A	62.045	.26084	.84232E-01	3.0590	9.5028	689.80	307.67	10.003
5632.00A	62.039	.25369	.84671E-01	3.0392	9.2924	681.98	307.50	9.7870
5976.50A	62.016	.26665	.84354E-01	3.0515	9.4195	686.77	307.65	9.9130
6425.00A	61.996	.20104	.89586E-01	2.8175	7.0173	592.71	248.61	7.4517
6562.00A	61.994	.19656	.70719E-01	2.7904	6.6652	586.28	247.44	7.2929
6720.50A	61.990	.19674	.70753E-01	2.7885	6.6656	586.26	247.43	7.2905
6842.00A	61.988	.19847	.70424E-01	2.8019	6.9235	588.75	247.60	7.3610
6986.00A	61.987	.19604	.70867E-01	2.7850	6.7999	583.42	248.14	7.2327
7123.00A	61.985	.19500	.71064E-01	2.7777	6.7802	582.61	247.88	7.2129
7295.00A	61.976	.19967	.70231E-01	2.8093	6.9452	589.57	248.15	7.3803

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PUMP CALIBRATION TEST FACILITY

TEST 84L011 TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984 PAGE 11

TEST 84L011 3-21-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	-16 FLOW/ DES FLOW	6 PUMP INL ET TEMP (F)	14 PUMP OUT LET TEMP (F)	105 TURBINE INLET TE MP (F)	106 TURBINE OUTLET T EMP (F)	1 PUMP INL ET PRESS (PSIG)	8 PUMP DIS PRESS (PSIG)
42.50A	.31349	-3766.1	67.951	50.395	88.386	34.341	32.257
1396.50A	1.2357	75.806	77.671	46.593	41.426	28.221	43.167
1568.50A	.87546	76.052	78.006	44.378	37.981	28.019	47.916
1659.50A	.64410	76.200	78.092	43.836	36.799	28.119	50.606
2062.50A	1.2257	76.987	79.626	45.805	19.473	25.790	91.539
2156.50A	1.0504	77.332	80.517	46.139	20.309	26.052	103.89
2263.50A	.87219	77.676	81.502	46.740	20.654	26.293	114.55
2356.50A	.72164	77.578	82.535	46.396	20.457	26.511	122.33
2454.50A	.53956	78.070	84.455	46.602	20.309	26.806	130.08
2552.50A	.35792	78.414	87.655	45.805	20.309	27.225	137.40
3067.50A	.24132	80.629	101.00	40.884	4.5578	27.842	230.56
3151.50A	.35475	80.776	95.286	41.031	4.4594	26.582	222.24
3233.50A	.50511	80.924	91.151	41.671	4.7055	26.165	212.79
3314.50A	.62886	81.367	89.723	41.720	4.5086	25.836	204.52
3401.50A	.76962	82.400	89.034	41.819	4.0656	25.495	193.63
3508.50A	.89477	83.188	88.788	42.015	3.8195	25.144	183.57
3587.50A	1.0219	83.627	88.640	42.114	4.1148	24.886	170.72
3667.50A	1.1540	84.615	88.788	42.262	4.1640	24.523	157.05
3787.50A	1.2679	85.303	89.280	41.819	3.6718	24.230	142.92
3937.50A	1.2211	86.208	90.006	42.452	5.2347	16.352	127.62
4236.50A	1.2476	87.679	91.763	42.141	5.0774	13.155	123.42
4586.50A	1.2407	89.479	93.448	42.411	4.6401	7.7793	122.10
5054.00A	1.0830	92.074	96.429	41.762	4.7661	-6.7773	111.65
5349.00A	1.0275	93.919	98.544	40.883	4.1405	9.7576	136.43
5521.00A	.88875	94.643	100.07	40.509	3.9376	17.075	167.33
5632.00A	.64253	95.200	102.19	40.365	4.5967	5.8256	167.29
5976.50A	1.0135	97.163	101.93	39.112	3.3272	28.189	173.06
6425.00A	1.1502	98.883	101.50	40.520	15.826	8.8400	73.192
6562.00A	.97097	99.009	101.66	40.613	17.039	9.3309	86.198
6720.50A	.81906	99.381	102.81	40.166	16.643	7.8627	92.649
6842.00A	.79986	99.545	103.10	39.679	16.342	8.6200	90.483
6986.00A	.66084	99.627	104.16	39.865	16.482	6.3918	95.034
7123.00A	.66827	99.744	104.22	39.972	16.727	5.5759	91.878
7295.00A	1.1536	100.38	102.97	39.355	15.711	9.5264	71.423

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TEST 84L011 3-21-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	18 VOLUTE PRESS ODE G(PSIG)	19 VOLUTE PRESS 90D EG(PSIG)	20 VOLUTE PRES 180D EG(PSIG)	21 VOLUTE PRES 270D EG(PSIG)	34 FRONT WR RING UP R (PSIG)	36 REAR WR RING UP R (PSIG)	37 REAR WR RINT DP R (PSIG)	38 IMP FR T IP PR (PSIG)
22.50A	32.781	31.726	32.847	34.322	34.202	34.102	31.398	33.754
1398.50A	40.351	41.495	43.405	45.464	28.356	33.697	25.251	42.673
1568.50A	45.076	44.044	45.809	48.015	28.748	35.202	25.351	45.146
1659.50A	48.117	45.866	47.609	49.933	29.025	36.416	25.617	47.042
2062.50A	79.852	86.674	88.917	93.635	25.890	45.350	22.012	83.936
2156.50A	89.596	92.447	95.185	99.811	27.474	48.426	22.809	89.591
2263.50A	100.22	98.302	101.40	106.04	29.172	51.922	24.022	95.625
2356.50A	109.60	103.53	106.67	111.55	30.332	55.337	25.484	100.87
2454.50A	119.04	109.05	112.27	117.53	31.769	59.561	26.879	107.05
2552.50A	129.03	114.81	117.67	123.95	33.320	63.979	28.623	113.12
3067.50A	218.58	167.86	192.30	200.52	40.505	94.197	33.009	185.97
3151.50A	207.67	180.65	185.31	192.47	37.974	87.642	30.202	178.38
3233.50A	194.64	173.17	177.93	185.73	35.932	81.621	27.976	168.56
3314.50A	183.66	167.08	172.32	177.08	34.316	77.284	26.331	162.64
3401.50A	170.04	160.04	164.64	169.36	32.356	72.379	24.636	154.58
3508.50A	159.62	153.74	158.59	162.67	30.577	68.301	23.224	147.82
3587.50A	146.15	146.06	150.80	155.05	28.699	64.028	21.779	140.14
3667.50A	133.40	138.94	143.56	147.98	26.690	60.079	20.400	133.44
3787.50A	122.41	132.46	136.25	141.08	24.878	56.567	19.719	126.62
3937.50A	106.71	116.11	119.68	123.75	17.825	42.919	15.738	107.03
4238.50A	101.11	112.06	115.92	121.36	14.391	39.315	12.665	105.41
4586.50A	99.866	111.23	114.54	119.73	8.4379	37.845	6.7563	105.30
5054.00A	83.515	83.328	85.916	94.473	.29589	8.2444	1.1360	78.558
5549.00A	112.10	113.46	117.83	121.86	13.305	40.092	10.516	107.31
5521.00A	141.55	136.56	141.96	145.76	22.324	54.867	16.868	130.73
5632.00A	144.16	124.91	131.49	134.77	13.507	44.068	9.6502	120.58
5976.50A	147.65	141.74	152.73	157.01	31.883	66.067	24.919	142.71
6425.00A	59.502	65.672	68.166	71.948	10.565	26.187	10.068	63.142
6562.00A	71.405	71.698	74.608	77.945	11.441	28.939	11.085	68.340
6720.50A	76.294	74.275	77.648	80.657	12.569	29.620	10.516	71.738
6842.00A	75.977	72.520	75.222	78.950	13.499	28.900	11.154	69.195
6986.00A	82.185	73.958	77.469	80.563	12.107	27.544	10.441	71.423
7123.00A	79.111	70.990	74.443	77.383	10.036	26.769	9.5805	67.641
7295.00A	57.977	64.027	66.516	69.915	9.3305	24.722	9.7901	60.750

SECTION A5

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PUMP CALIBRATION TEST FACILITY

TEST 84L011 TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984 PAGE 15

TEST 84L011 3-21-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	39 IMP FR M ID PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC P R (PSIG)	114 ROTOR OU T TIP PR (PSIG)	115 ROTOR OU T HUB PR (PSIG)	116 TURB NOZ OUT (PSIG)
22.50A	33.727	54.809	.17071E-04	.25322E-01	.64035E-02	.54072E-01
1398.50A	33.743	44.047	3.5477	1.5256	1.6593	1.0910
1568.50A	35.067	46.382	3.5412	1.5446	1.6144	1.1291
1659.50A	36.098	48.286	3.5444	1.5636	1.5952	1.1355
2062.50A	49.359	86.926	7.7902	3.2347	3.4595	2.8531
2156.50A	52.450	92.110	7.7052	3.1651	3.4403	2.7577
2263.50A	55.966	98.004	7.6264	3.1461	3.4210	2.7704
2356.50A	58.795	103.20	7.5659	3.1461	3.3698	2.7449
2454.50A	62.061	109.13	7.5417	3.1144	3.3249	2.7449
2552.50A	65.450	115.12	7.4714	3.0828	3.3506	2.6622
3067.50A	98.187	187.77	11.340	4.7413	5.1316	4.4371
3151.50A	93.723	179.96	11.452	4.8173	5.1764	4.5134
3233.50A	89.275	171.74	11.575	4.8869	5.2341	4.5579
3314.50A	85.923	166.25	11.725	4.9565	5.2789	4.6406
3401.50A	81.999	158.45	11.851	5.0262	5.3494	4.6661
3508.50A	77.976	151.15	11.980	5.0515	5.4006	4.7360
3587.50A	73.675	144.05	12.031	5.0831	5.4711	4.7233
3667.50A	69.440	137.57	12.178	5.1338	5.4967	4.8060
3787.50A	65.957	131.38	12.216	5.1971	5.5288	4.8124
3937.50A	46.842	113.59	11.414	4.7888	5.1011	4.4935
4236.50A	45.291	109.65	11.551	4.8574	5.1750	4.5311
4586.50A	45.156	109.29	11.797	4.9917	5.3418	4.6406
5054.00A	9.5327	81.771	11.479	4.8299	5.1503	4.5109
5349.00A	47.519	110.66	11.430	4.8101	5.1544	4.5231
5521.00A	62.480	133.44	11.417	4.7869	5.1239	4.4790
5632.00A	49.442	125.04	10.867	4.5247	4.8267	4.2405
5976.50A	75.621	146.45	12.015	5.2730	5.6441	4.9714
6425.00A	30.634	65.479	7.2074	2.9578	3.2241	2.6313
6562.00A	32.917	70.459	6.9416	2.8453	3.0766	2.5308
6720.50A	35.386	74.417	6.9592	2.8686	3.1045	2.5467
6842.00A	32.647	71.368	7.0434	2.9131	3.1353	2.5706
6966.00A	30.766	73.545	6.9074	2.8510	3.0718	2.5227
7123.00A	29.705	69.726	6.8535	2.8235	3.0573	2.5308
7295.00A	28.718	63.138	7.1199	2.9422	3.1847	2.6167

C	DESCRIPTION	CONSTANT
1	WALL DIAMETER AT INLET PRESS TAP,IN.	1.00000E+00
2	HUB DIAMETER AT INLET PRESS TAP, IN	0.0
5	IMPELLER INLET TIP DIAMETER,IN	8.05000E-01
6	IMPELLER INLET HUB DIAMETER, IN	5.00000E-01
7	IMPELLER DISH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	7.85000E-01
10	IND/IMP INLET AREA,SQ.IN.	3.12608E-01
11	DESIGN FLOW, GPM	5.00000E+00
12	AMBIENT PRESSURE, PSIA	1.43810E+01
13	DESIGN SPEED FOR DESIGN FLOW, RPM	2.45000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FOR F(7)	1.00000E+00
23	K FACTOR	0.0
24	WATER TANK ELEVATION, FT	1.34271E+01
31	CONFIGURATION NUMBER	6.00000E+00
35	FRONT WEAR RING UPSTREAM PRESSURE, RADIAL LOCATION	5.70000E-01
36	IMPELLER FRONT MID PRESSURE, RADIAL LOCATION	7.80000E-01
37	IMPELLER FRONT TIP PRESSURE, RADIAL LOCATION	9.80000E-01
38	IMPELLER REAR TIP PRESSURE, RADIAL LOCATION	9.70000E-01
39	REAR WEAR RING UPSTREAM PRESSURE, RADIAL LOCATION	5.80000E-01
40	IMPELLER LEADING EDGE TIP RADIUS	5.00000E-01
91	NOZZLE INLET DIAMETER, IN	1.00000E+00
92	NOZZLE THROAT DIAMETER, IN	1.91000E-01
93	NOZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

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PUMP CALIBRATION TEST FACILITY

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TEST 84L005 2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	-2 VAPOR HEAD (FT)	-101 NOZZLE FLOWRATE (LB/SEC)	-102 FLOW NOZZLE PR RATIO	-103 FLOW PARAM	-104 TURB AVL ENERGY, BTU/LBM	-105 CSUBO ISEN VEL FT/S	-106 TURBINE MEAN VEL FT/S	-107 TURB AVL ENER PIP BTU/LBM
19.79A	.68831	.11946	.96195E-01	2.1245	.68694	182.48	76.993	1.6758
528.79A	.73360	.21110	.69830E-01	2.9630	1.9920	315.30	153.85	3.9536
723.79A	.74752	.28147	.64141E-01	3.2370	3.3736	410.96	208.18	5.7022
1012.79A	.77088	.38308	.61176E-01	3.3436	5.2072	510.60	257.00	7.3336
1377.79A	.78016	.37252	.61375E-01	3.3479	5.1068	505.66	257.41	7.3535
1525.79A	.78418	.36120	.61603E-01	3.3589	4.8133	490.93	256.88	7.2663
1803.00A	.79082	.35518	.61793E-01	3.3473	4.7657	488.44	258.37	7.1992
2027.00A	.79621	.34461	.61974E-01	3.3409	4.6066	480.24	256.09	7.0316
2215.79A	.79762	.33751	.62211E-01	3.3226	4.5345	476.43	256.84	6.8856
2319.79A	.79487	.33042	.62419E-01	3.3229	4.3854	468.54	256.67	6.8202
2501.79A	.80028	.31994	.62647E-01	3.2971	4.2687	462.28	254.72	6.5453
2656.79A	.80299	.31833	.62848E-01	3.2925	4.2643	462.03	258.82	6.5948
2799.79A	.79758	.30583	.63130E-01	3.2721	4.1157	453.90	254.22	6.3807
3033.79A	.79897	.30224	.63613E-01	3.2407	4.2362	460.53	257.77	6.3985
3474.00A	.81802	.32984	.70935E-01	3.1140	4.2408	433.12	206.57	6.0605
3960.79A	.82490	.37289	.61055E-01	3.3874	4.5948	476.95	226.24	7.0154
4676.58A	.91021	.13834	.40285	1.9875	.51116	149.53	-.34078E-01	1.7145

PUMP CALIBRATION TEST FACILITY

TEST 84L005 TEST DATE 15 FEB 1984 PROCESS DATE 9 NOV 1984

TEST 84L005 2-15-84 LOW THRUST PUMP HC & CAV. TESTS

TIME	-1 WATER SP.WGT. LBM/FT3	-115 TURBINE PRESSURE RATIO	6 PUMP INLET TEMP (F)	14 PUMP OUTLET TEMP (F)	105 TURBINE INLET TEMP (F)	106 TURBINE OUTLET TEMP (F)	1 PUMP INLET PRESS (PSIG)	8 PUMP DISCHARGE PRESS (PSIG)
19.79A	62.320	1.0202	64.273	64.465	27.119	31.532	39.266	66.676
528.79A	62.308	1.0620	66.098	67.080	12.131	2.0484	38.437	153.32
723.79A	62.304	1.1087	66.640	68.511	8.5317	-12.693	38.164	249.66
1012.79A	62.298	1.1716	67.528	69.745	14.744	-17.032	37.188	358.35
1377.79A	62.296	1.1657	67.373	70.238	20.710	-11.263	38.389	360.88
1525.79A	62.295	1.1551	68.021	70.731	21.005	-10.524	38.936	362.29
1803.00A	62.293	1.1539	68.268	71.323	19.871	-11.263	39.274	365.99
2027.00A	62.292	1.1487	68.465	71.669	18.540	-11.904	39.667	363.00
2215.79A	62.291	1.1466	68.514	72.261	17.160	-12.693	39.835	364.12
2319.79A	62.292	1.1415	68.416	72.853	16.617	-12.743	40.168	366.90
2501.79A	62.290	1.1378	68.613	73.642	15.483	-13.137	40.304	362.45
2656.79A	62.290	1.1379	68.711	75.221	14.645	-13.975	40.545	374.13
2799.79A	62.291	1.1328	68.514	76.751	14.399	-13.482	40.649	363.42
3033.79A	62.291	1.1373	68.563	80.796	13.610	-13.975	40.819	372.85
3474.00A	62.286	1.1395	69.250	72.024	15.261	-13.519	10.223	217.21
3960.79A	62.284	1.1503	69.478	71.681	14.113	-14.210	8.6249	289.54
4676.58A	62.261	1.0151	72.380	71.990	28.045	29.175	39.999	38.784

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PUMP CALIBRATION TEST FACILITY

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TEST 84L005 2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	18 VOLUTE PRESS ODEG(PSIG)	19 VOLUTE PRESS 90DEG(PSIG)	20 VOLUTE PRES 180DEG(PSIG)	21 VOLUTE PRES 270DEG(PSIG)	26 DIFFUSER IN PRESS (PSIG)	34 FRONT WR RING UP R (PSIG)	36 REAR WR RING UP R (PSIG)	37 REAR WR RINT DP R (PSIG)
19.79A	65.847	67.225	64.367	65.995	64.539	59.121	60.273	38.413
528.79A	150.43	151.60	147.74	144.31	140.15	115.82	118.99	39.492
723.79A	244.62	245.06	239.57	229.83	223.88	177.12	182.64	41.236
1012.79A	348.82	348.85	342.34	324.57	318.56	244.64	252.46	40.737
1377.79A	352.38	352.11	344.93	327.45	320.96	246.47	254.62	42.846
1525.79A	354.79	354.47	346.94	329.31	321.66	247.27	255.82	44.307
1803.00A	359.41	358.57	351.32	333.86	325.51	250.55	259.36	45.586
2027.00A	357.56	356.36	349.25	331.87	322.59	248.91	257.46	46.715
2215.79A	359.36	358.02	351.50	334.36	324.41	250.94	260.23	47.861
2319.79A	362.63	361.14	355.58	337.64	326.70	252.90	261.38	49.787
2501.79A	358.69	357.44	352.44	335.34	324.03	251.71	260.23	50.949
2656.79A	370.58	368.94	364.27	346.91	333.45	259.44	268.17	53.124
2799.79A	359.97	358.59	354.53	339.61	324.49	253.62	261.71	54.220
3033.79A	369.74	368.80	364.16	350.30	333.43	260.52	268.72	56.113
3474.00A	206.15	204.45	206.27	204.81	215.04	158.80	155.27	11.529
3960.79A	278.90	279.58	275.44	260.79	251.75	185.67	197.64	12.961
4676.58A	38.821	39.609	38.178	39.947	39.612	39.924	40.219	38.631

PUMP CALIBRATION TEST FACILITY

TEST 84L005 TEST DATE 15 FEB 1984 PROCESS DATE 9 NOV 1984

TEST 84L005 2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	38 IMP FR T IP PR (PSIG)	39 IMP FR M ID PR (PSIG)	40 IMP REAR TIP PR (PSIG)	110 TURB IN STATIC PR (PSIG)	111 TURB NOZ IN PR (PSIG)	112 TURB NOZ OUT TIP PR PSIG	113 TURB NOZ OUT HUB PR PSIG	114 ROTOR OUT TIP PR (PSIG)
19.79A	62.436	58.815	63.484	2.6547	2.2504	1.0948	1.0454	1.7976
528.79A	133.21	122.00	135.61	7.4534	6.3654	3.6921	3.8488	4.9530
723.79A	211.80	192.16	215.42	12.468	10.843	6.7901	7.0206	8.0446
1012.79A	300.58	270.30	304.46	20.976	19.073	12.660	12.675	13.463
1377.79A	302.67	272.22	307.14	20.273	18.313	12.124	12.224	12.972
1525.79A	303.77	273.17	308.15	19.331	17.226	11.461	11.558	12.315
1803.00A	307.65	276.68	312.21	18.832	16.770	11.123	11.226	11.933
2027.00A	304.53	274.21	309.62	17.856	15.858	10.494	10.632	11.315
2215.79A	307.51	277.18	311.88	17.255	15.355	10.086	10.216	10.894
2319.79A	309.39	278.60	313.92	16.654	14.712	9.6902	9.8003	10.492
2501.79A	307.17	277.15	311.67	15.724	13.976	9.0380	9.2657	9.9123
2656.79A	316.50	285.70	320.99	15.644	13.847	8.9797	9.2657	9.7912
2799.79A	308.01	278.70	312.66	14.578	12.900	8.2926	8.6005	9.1282
3033.79A	316.38	286.36	321.29	14.408	12.818	8.1761	8.4223	8.9816
3474.00A	193.95	157.24	208.71	17.047	15.442	10.106	10.069	10.839
3960.79A	236.02	207.37	239.44	19.892	17.759	11.650	11.730	12.794
4676.58A	39.325	38.006	39.741	4.5497	3.8898	2.0407	2.0680	3.4298

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PUMP CALIBRATION TEST FACILITY

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TEST 84L005 2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	4 SHAFT SPEED (RPM)	-21 PUMP TOT HEADRISE (FT)	3 PUMP DIS FLOW (GPM)	-16 FLOW/ DES FLOW	-30 PUMP SCALED HEAD RISE (FT	-31 PUMP SCALED FLOW (GPM)	-32 PUMP HYD PWR HP	-23 PUMP DIS HEAD COEF
19.79A	7352.3	63.446	1.4939	.99902	705.02	4.9951	.24007E-01	.49623
528.79A	14691.	265.94	2.9756	.99247	739.62	4.9624	.19973	.52058
723.79A	19880.	489.62	4.0311	.99362	743.67	4.9681	.49813	.52343
1012.79A	24542.	744.17	6.0269	1.2033	741.64	6.0166	1.1318	.52200
1377.79A	24581.	746.98	5.5574	1.1078	742.11	5.5392	1.0475	.52234
1525.79A	24531.	748.70	4.9855	.99586	746.83	4.9793	.94190	.52565
1803.00A	24673.	756.27	4.5055	.89480	745.75	4.4740	.85978	.52490
2027.00A	24455.	748.26	4.0233	.80616	751.06	4.0308	.75963	.52864
2215.79A	24527.	750.25	3.4857	.69638	748.65	3.4819	.65986	.52694
2319.79A	24511.	755.76	2.9930	.59836	755.11	2.9918	.57079	.53148
2501.79A	24324.	745.04	2.5076	.50515	755.85	2.5257	.47141	.53200
2656.79A	24716.	771.37	2.0123	.39854	757.98	1.9947	.39166	.53351
2799.79A	24276.	746.26	1.5190	.30661	760.12	1.5331	.28604	.53501
3033.79A	24615.	767.62	1.0378	.20659	760.45	1.0329	.20102	.53524
3474.00A	19726.	479.81	4.4655	-87.343	-.22504E+09	-436.72	.70097	-.15839E+06
3960.79A	21604.	650.89	5.0943	-112.06	.20180E+09	-560.30	.93927	.14204E+06
4676.58A	-3.2542	-2.8090	-.11034E-03	.20297	-.13989E+10	1.0149	.92293E-07	-.98464E+06

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