



INTERIM REPORT  
SMALL CENTRIFUGAL PUMPS FOR  
LOW-THRUST ROCKET ENGINES

by  
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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 vaneed 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 vaneed 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 ( $\text{rpm} * \text{gpm}^{0.5}/\text{ft}^{0.75}$ ). 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).

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

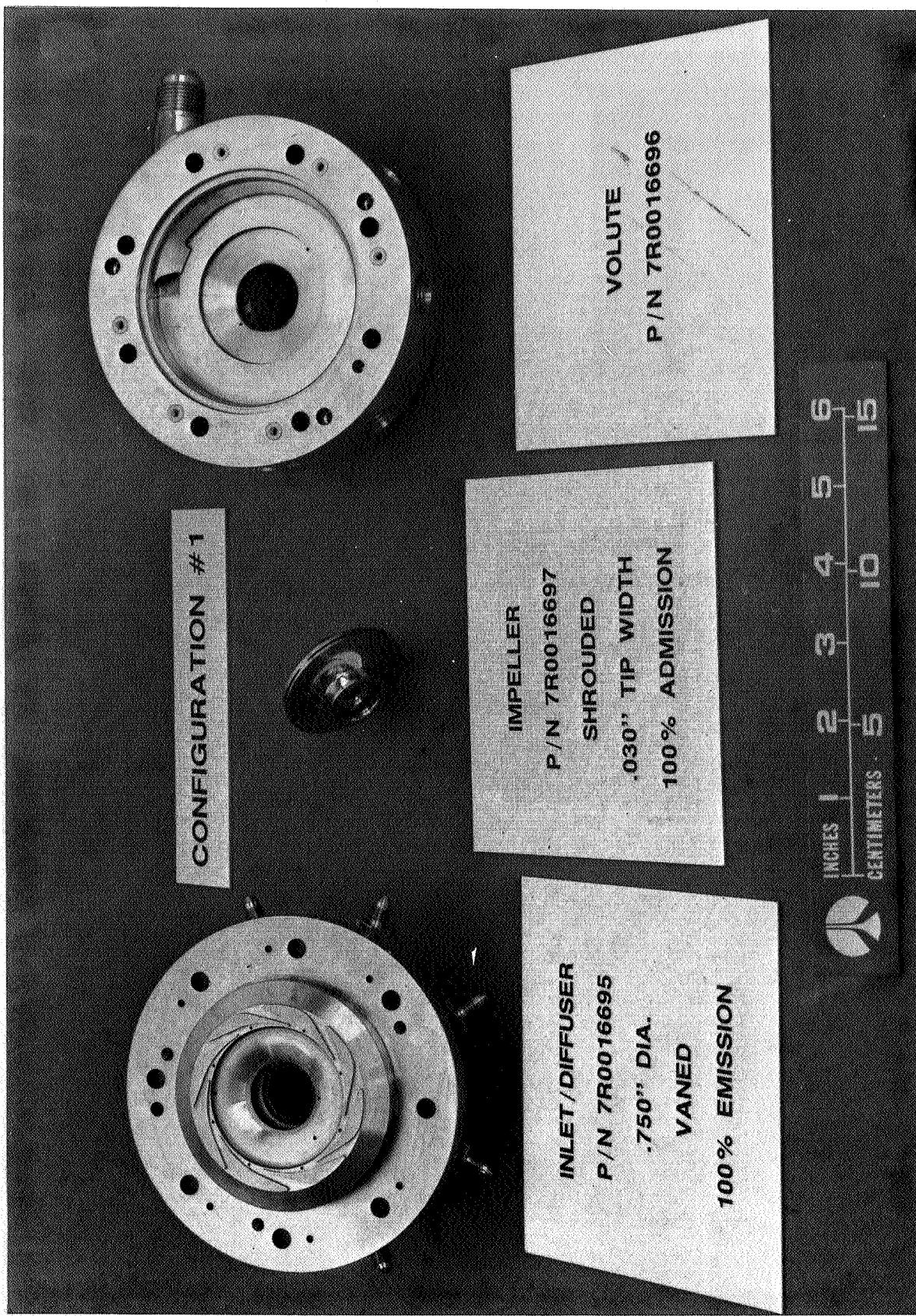
TABLE 2. PUMP DESIGN GEOMETRY SPECIFIC SPEED = 430

CONFIGURATION NO.	1	2	4	6
<b>IMPELLER</b>				
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
<b>DIFFUSER</b>				
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
<b>VOLUTE</b>				
MAXIMUM AREA AT 360 DEGREES, IN. <sup>2</sup>	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. <sup>2</sup>	0.096	0.096	0.096	0.096

TABLE 3. PUMP DESIGN GEOMETRY SPECIFIC SPEED = 215

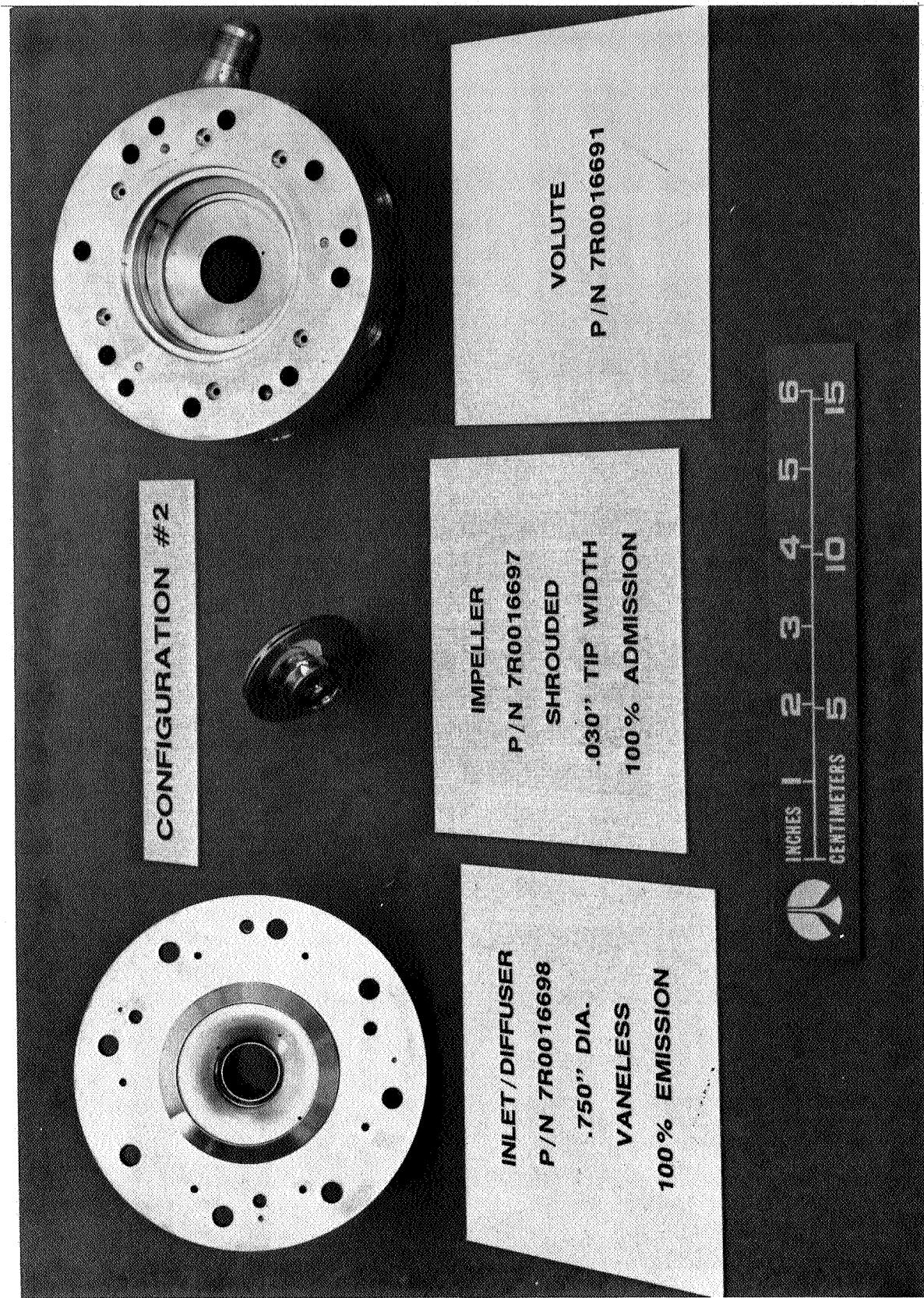
CONFIGURATION NO.	3	5
<b>IMPELLER</b>		
TYPE	SHROUDED	OPEN FACE
DISCHARGE DIAMETER, INCHES	2.0	2.0
INLET EYE DIAMETER, INCHES	0.75	0.8
INLET HUB DIAMETER, INCHES	0.5	0.5
DISCHARGE TIP WIDTH, INCHES	0.030	0.035
NUMBER OF BLADES	7	2
DISCHARGE BLADE ANGLE, DEGREES	33	20
IMPELLER FACE CLEARANCE, INCHES	--	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
<b>DIFFUSER</b>		
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	--
<b>VOLUTE</b>		
MAXIMUM AREA AT 360 DEGREES, IN. <sup>2</sup>	0.0146	0.011
CONTINUITY AREA/ACTUAL AREA	0.50	0.833
CONICAL DIFFUSER EXIT AREA, IN. <sup>2</sup>	0.096	0.026

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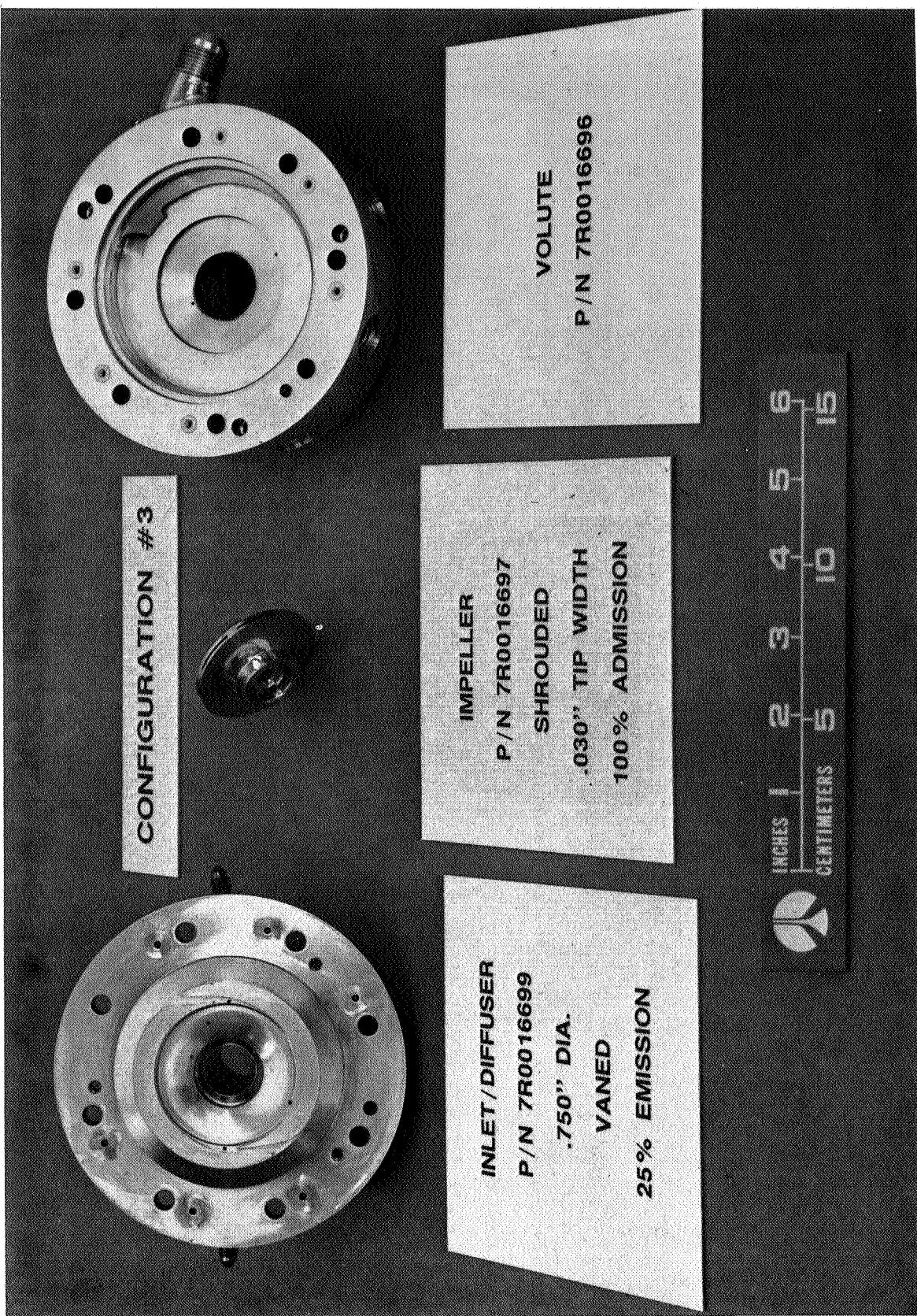
Figure 1. Shrouded Impeller Vaned Diffuser Pump



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Figure 2. Shrouded Impeller Volute Pump

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Figure 3. Shrouded Impeller 25% Emission Diffuser Pump

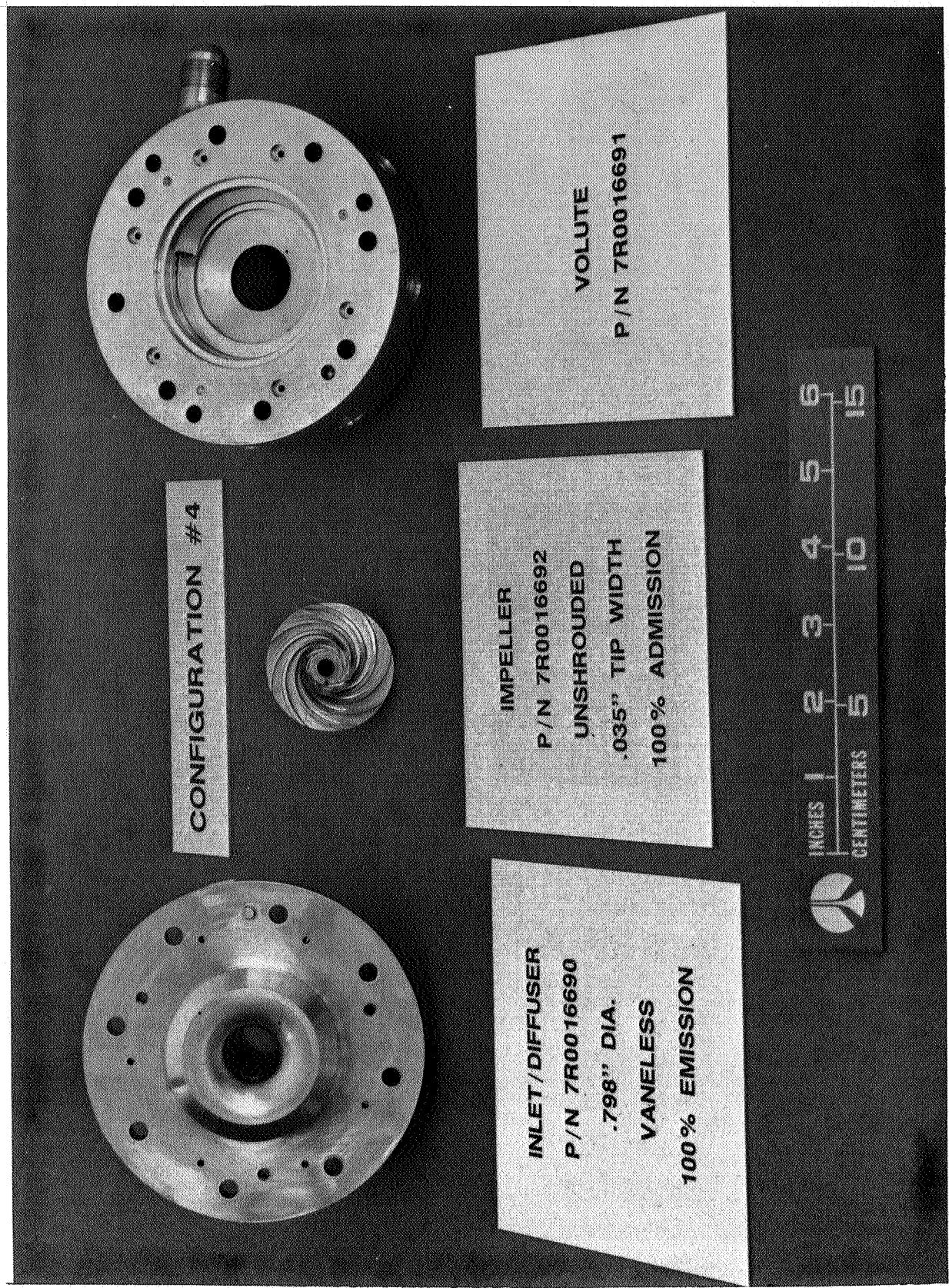
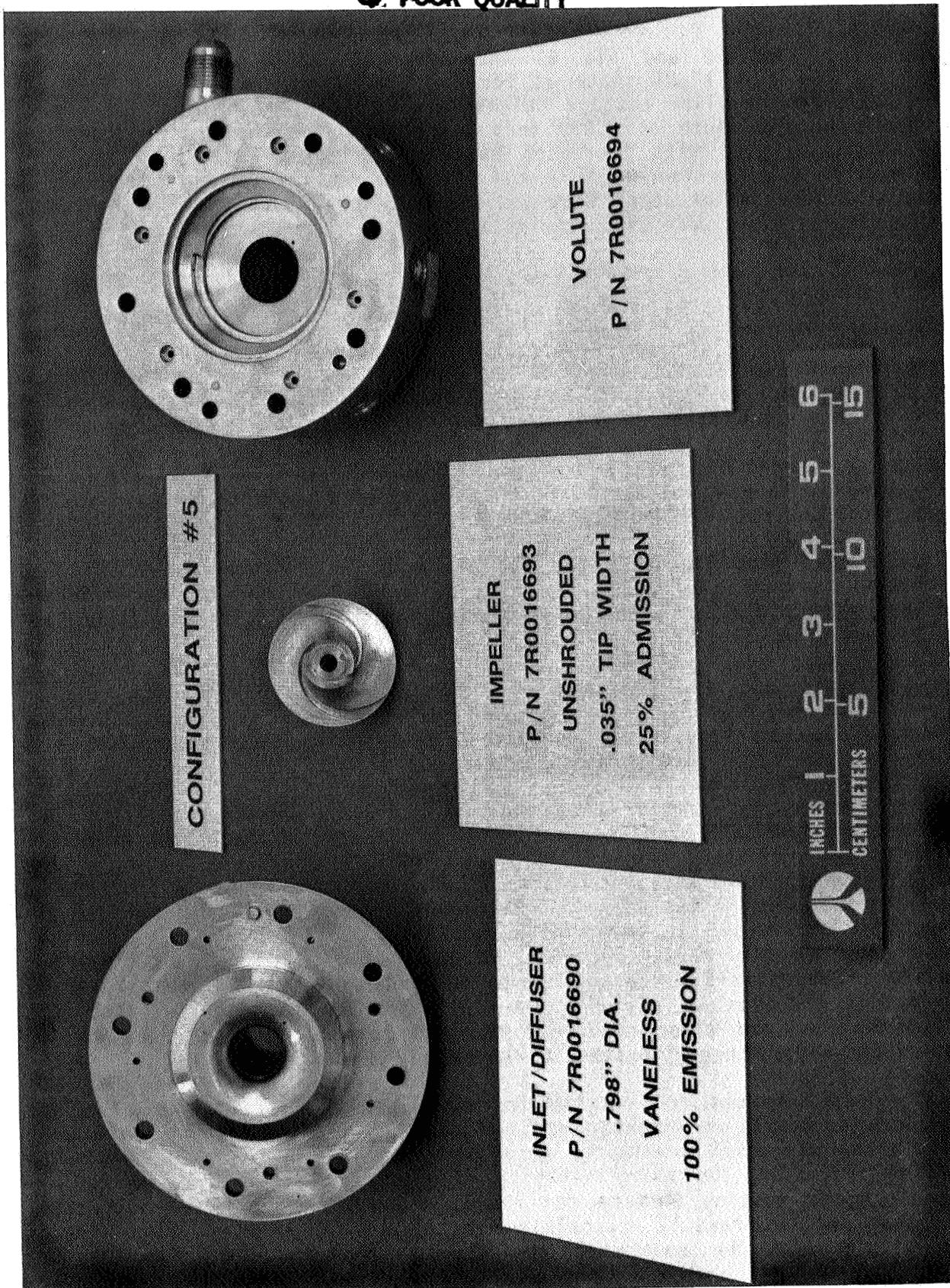


Figure 4. Open Face Impeller Volute Pump

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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.

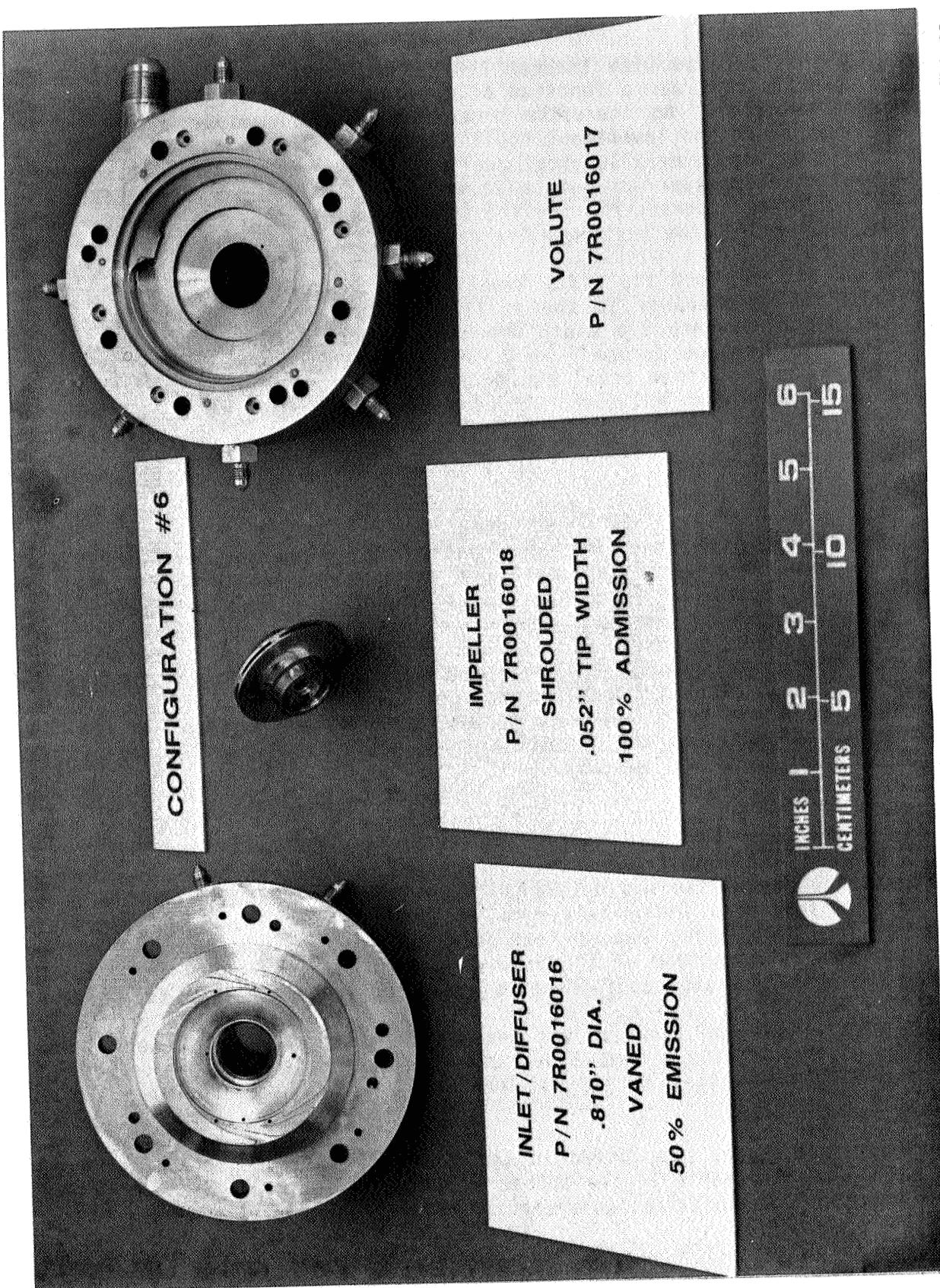
### Impeller Casting

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

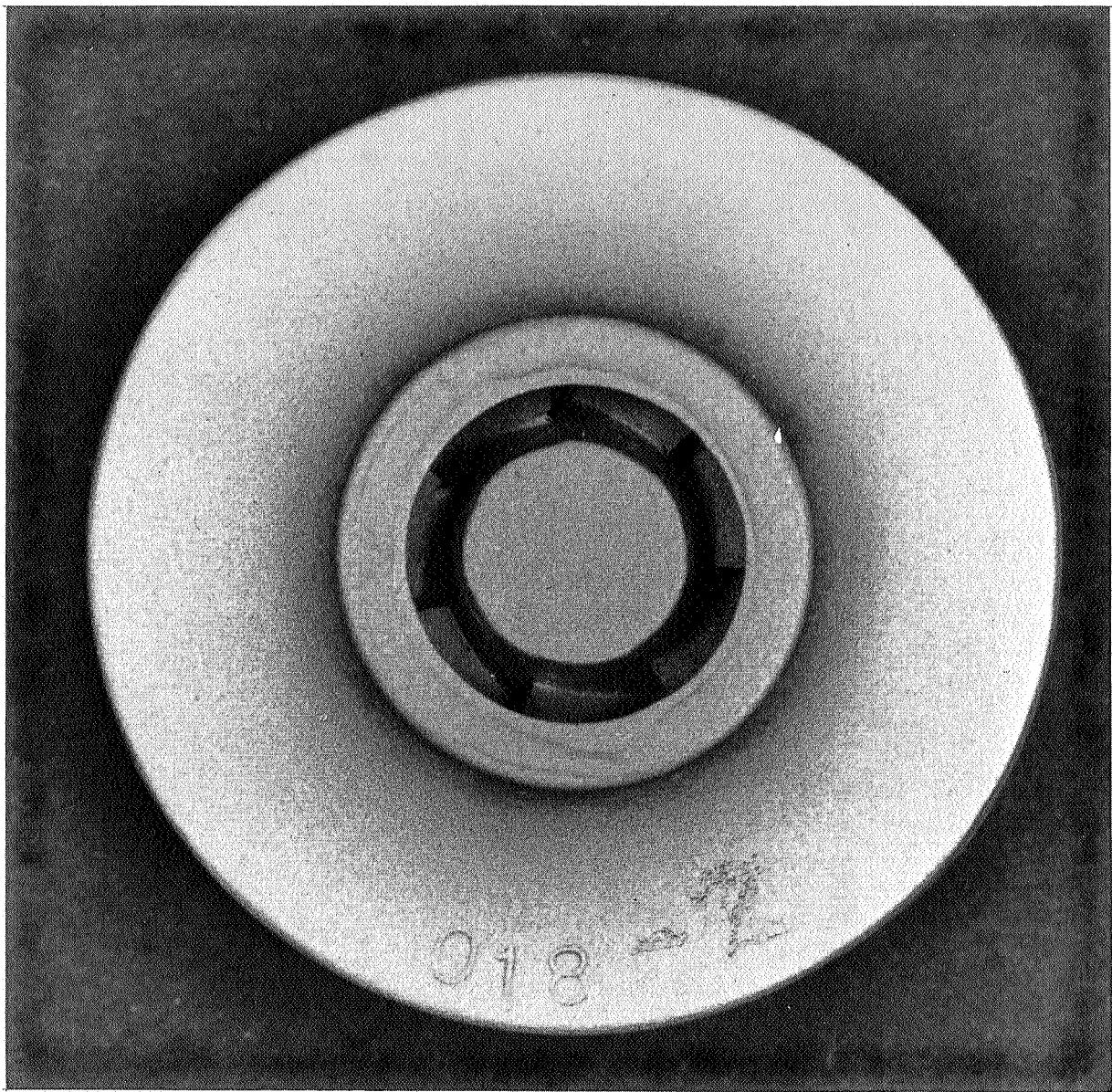
The water test program was conducted in Rocketdyne's Engineering Development Laboratory in a closed loop water test facility shown schematically in Fig. 9. The test facility was capable of conducting tests over a wide range of speed, flow, and inlet pressure. Inlet pressure within the test loop can be 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 downstream 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.

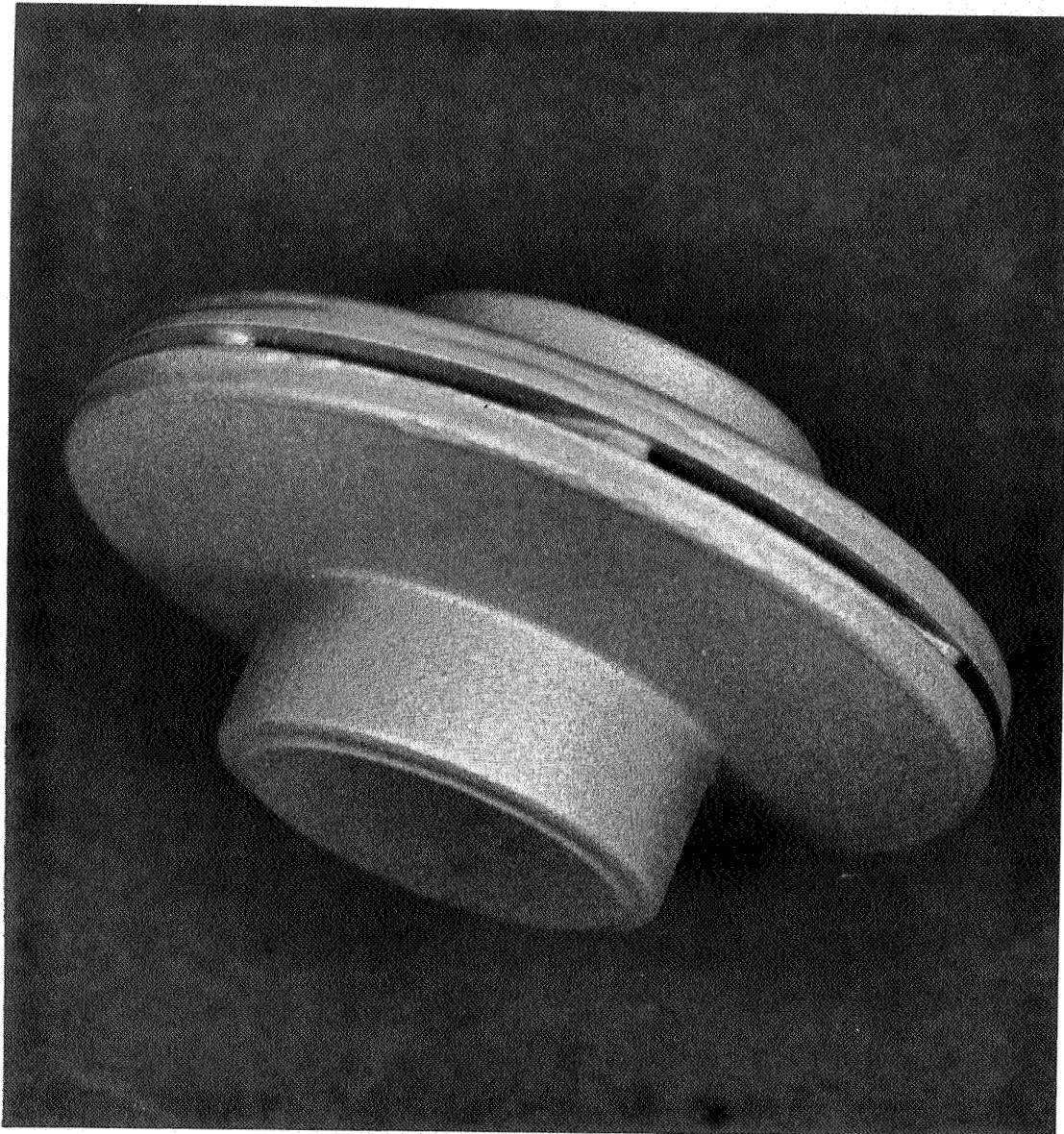
Instrumentation accuracies are listed in Table 4. All instrumentation was calibrated by standards traceable to the Bureau of Standards prior to testing of each pump configuration. Calibrations were checked pretest and posttest.

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



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

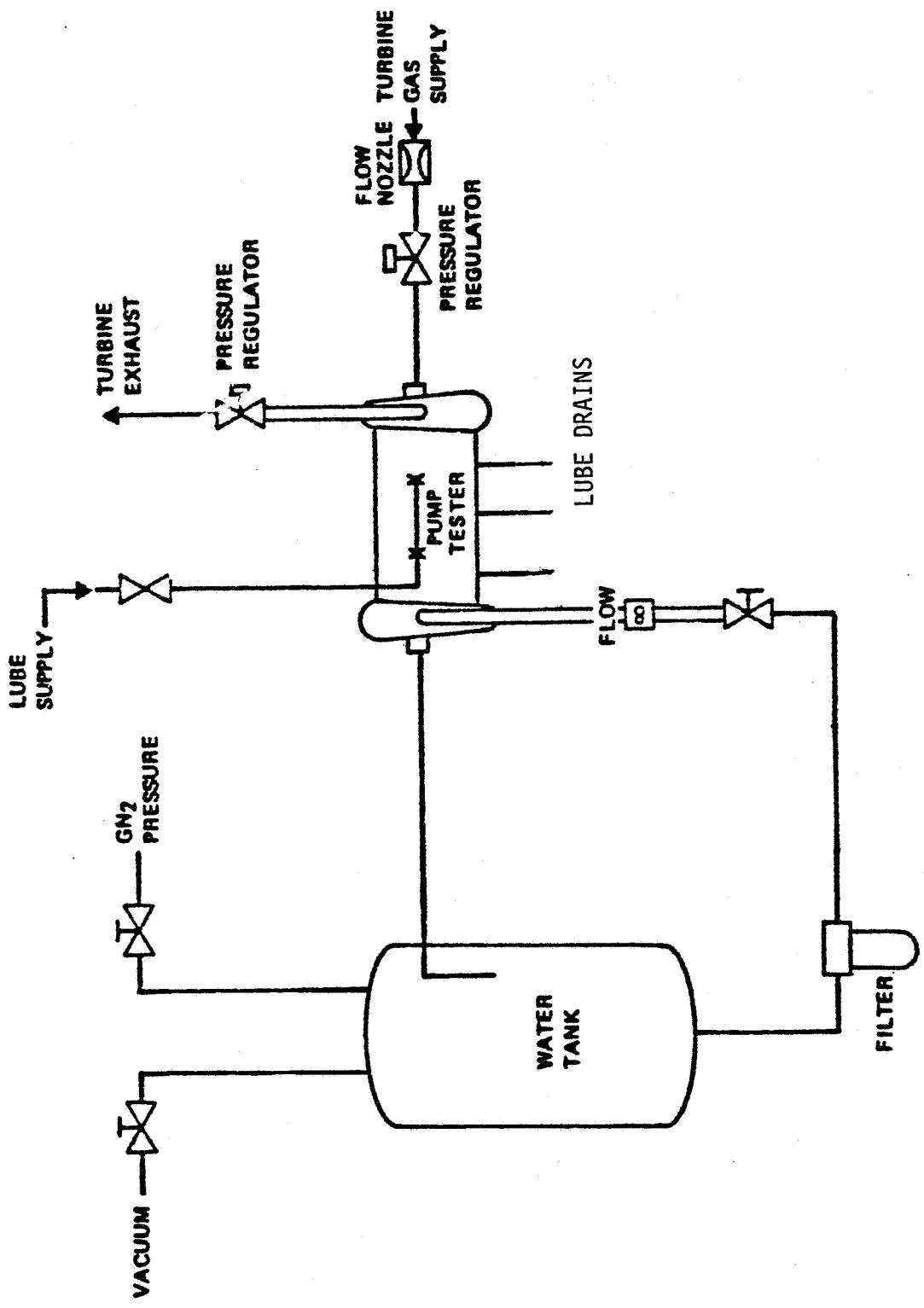


Figure 9. Water Test Facility Schematic

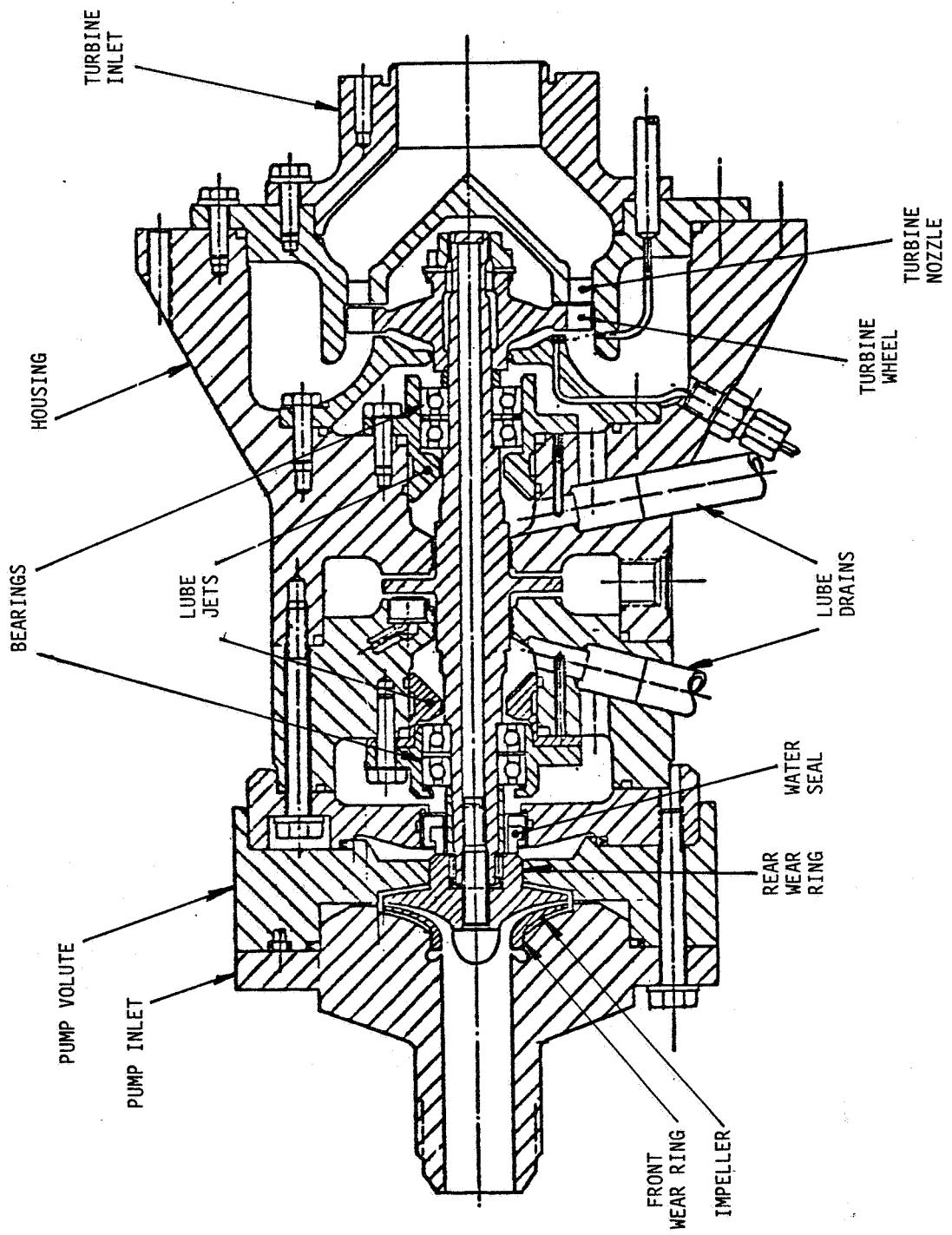
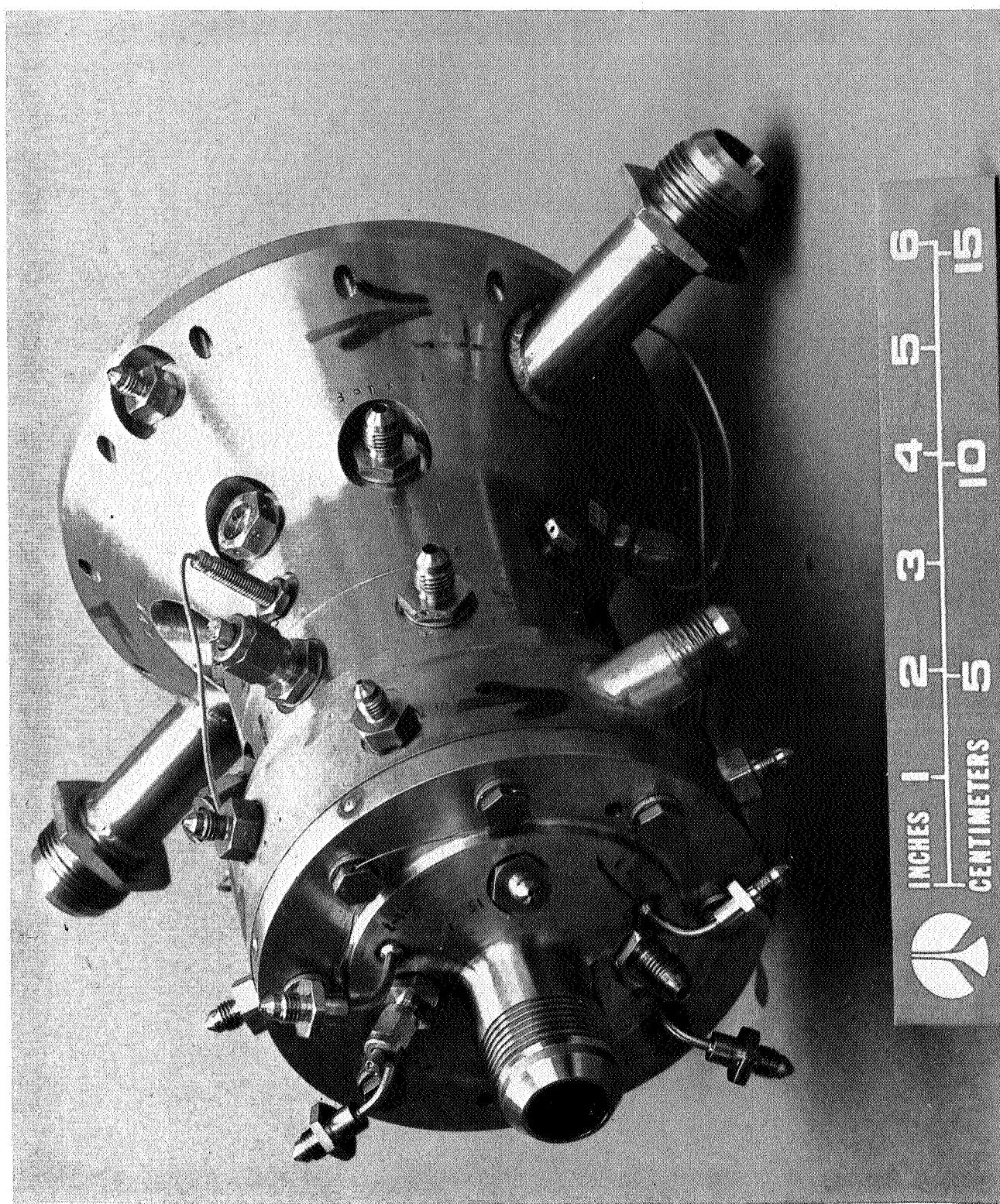


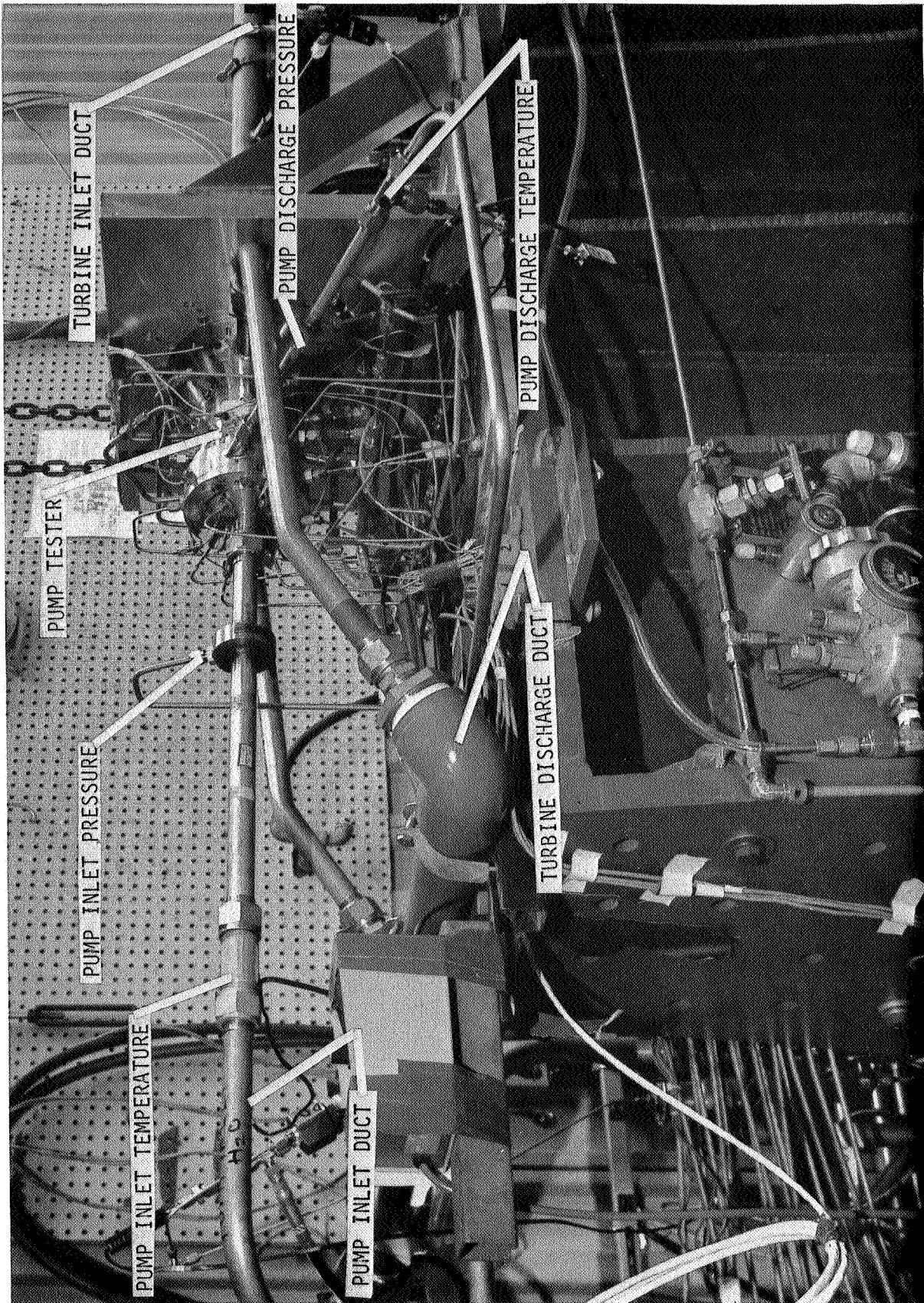
Figure 10. Pump/Tester Cross Section

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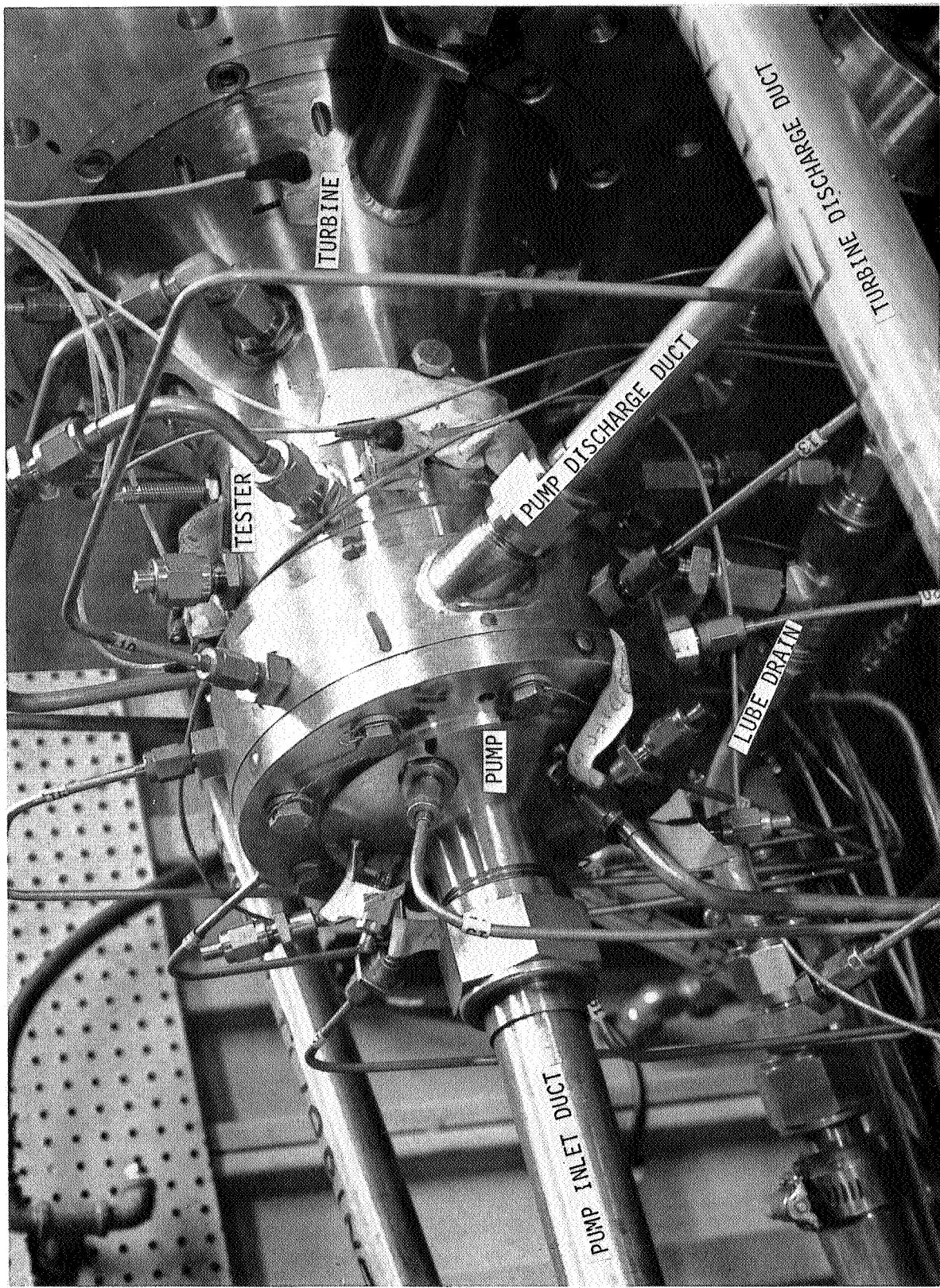
Figure 11. Pump/Tester Assembly



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Figure 12. Pump Test Facility

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Figure 13. Pump/Tester Installed in Test Facility

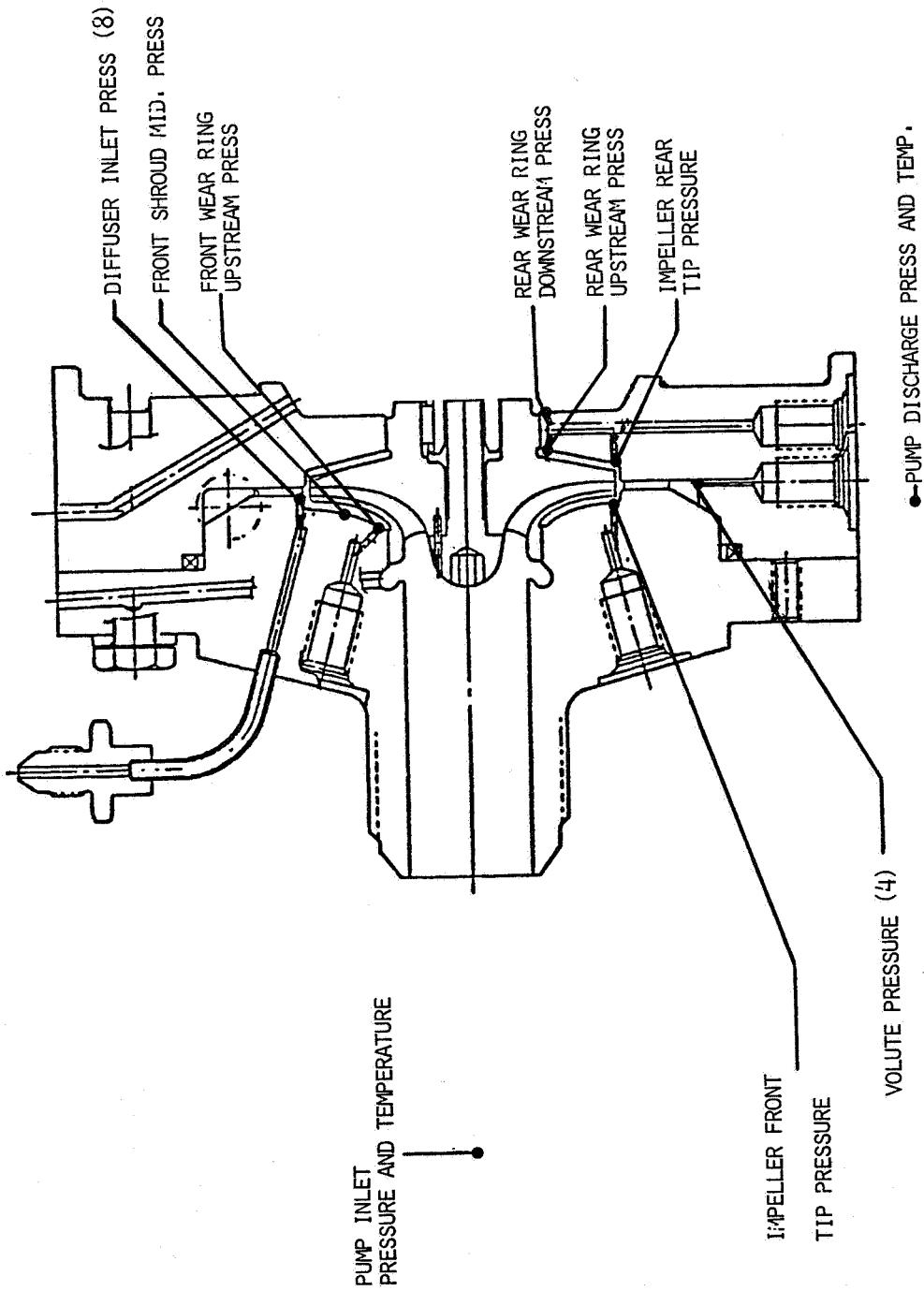


Figure 14. Typical Pump Instrumentation

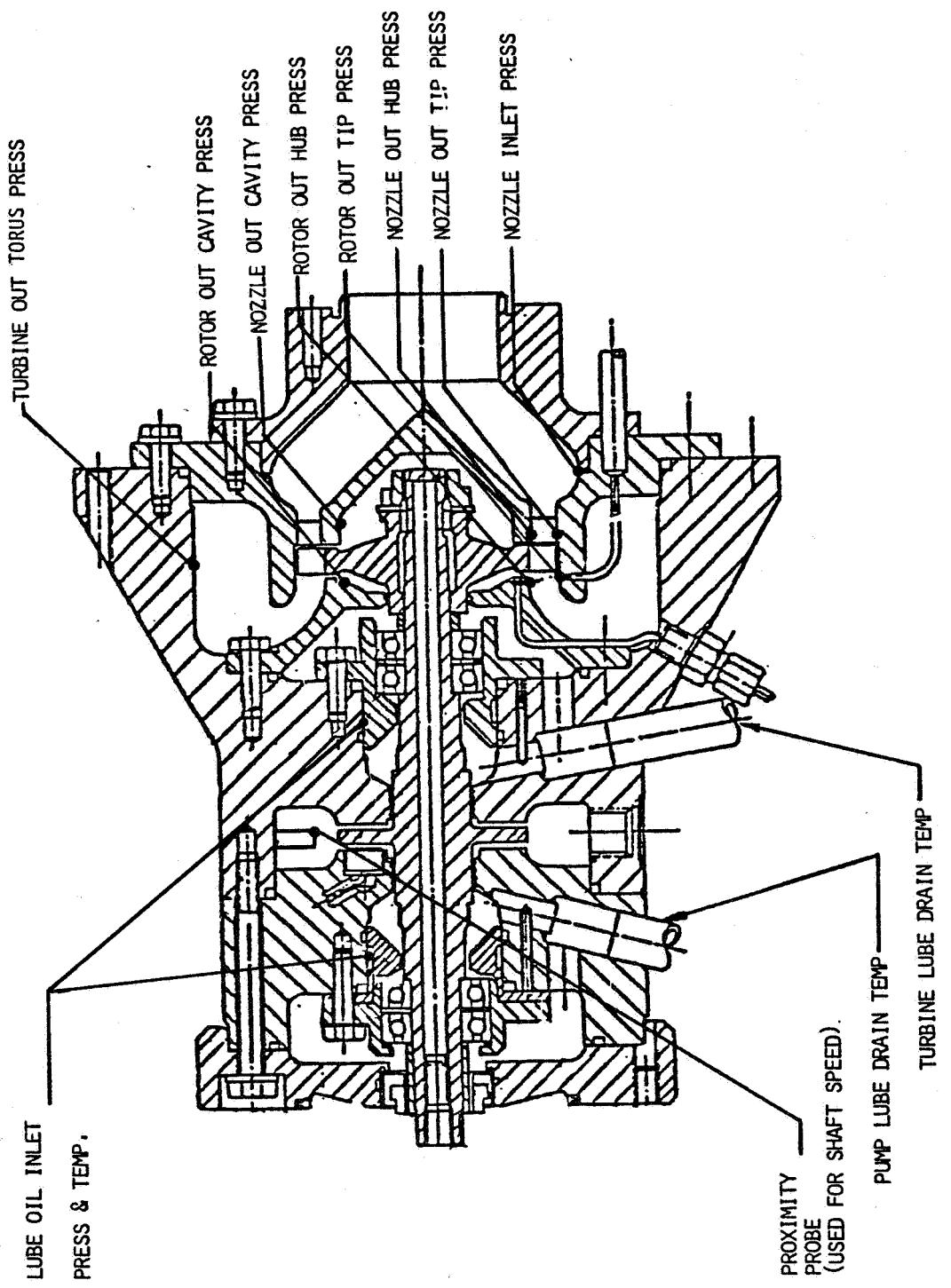


Figure 15. Tester and Turbine Instrumentation

TABLE 4. INSTRUMENTATION ACCURACIES

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

#### 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 of the 6 configurations. Figure 22 presents a comparison of efficiency data from all 6 configurations. Similarly, 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

CONFIGURATION NO.	TEST CONFIGURATION			TEST RESULTS			
	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 <sup>+</sup>	28.5 <sup>++</sup>

\* HEADRISE DATA - TEST 84L007

\*\* EFFICIENCY DATA - TEST 84L008 (SAME TURBOPUMP BUILD)

+ HEADRISE DATA - TEST 84L005

++ EFFICIENCY DATA FOR CLEARANCES SHOWN - TEST 84L015

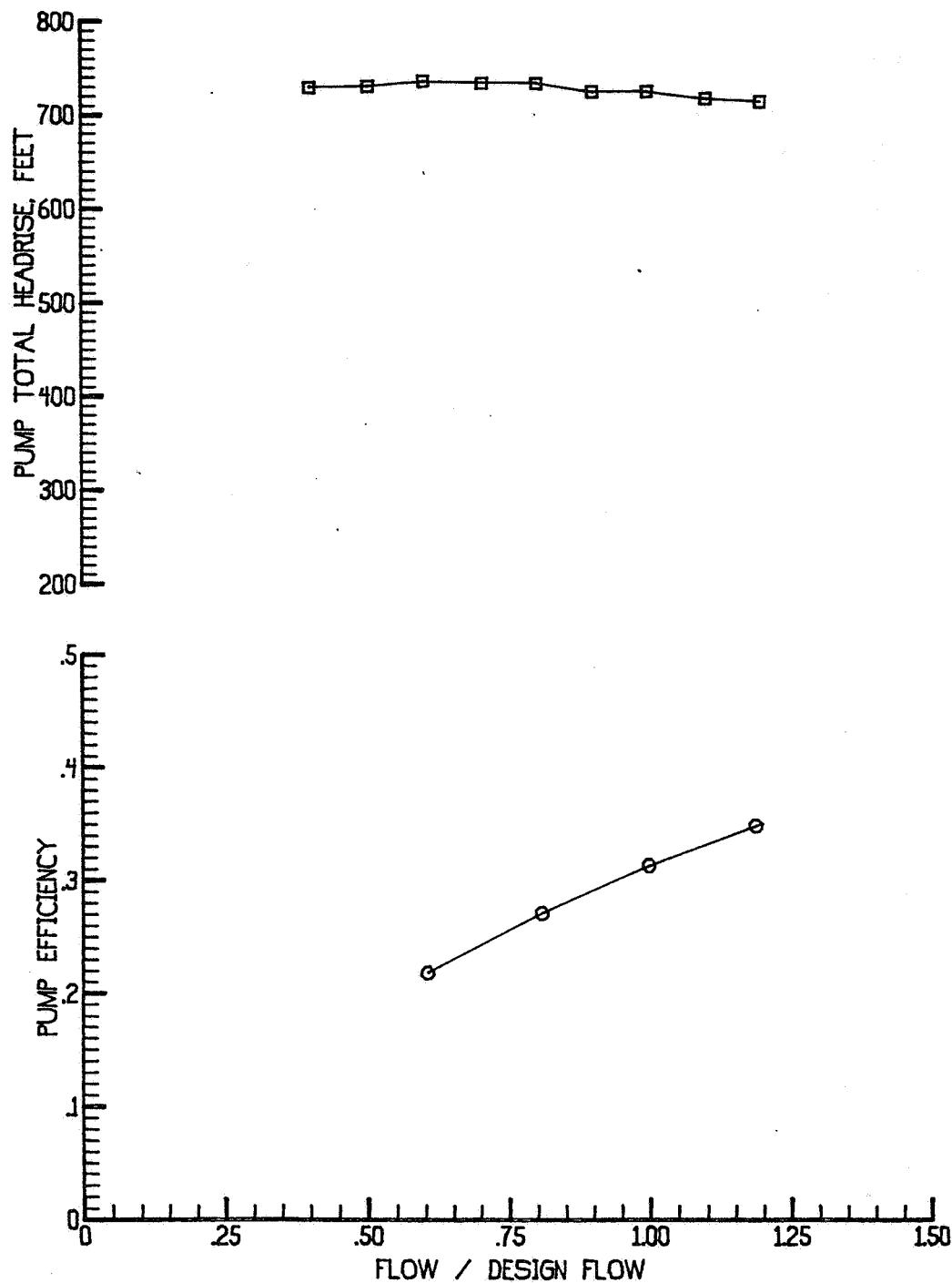


Figure 16. Low-Thrust Water Testing  
Configuration 1  
Test and Curve Speed - 24,500 rpm  
Specific Speed - 430

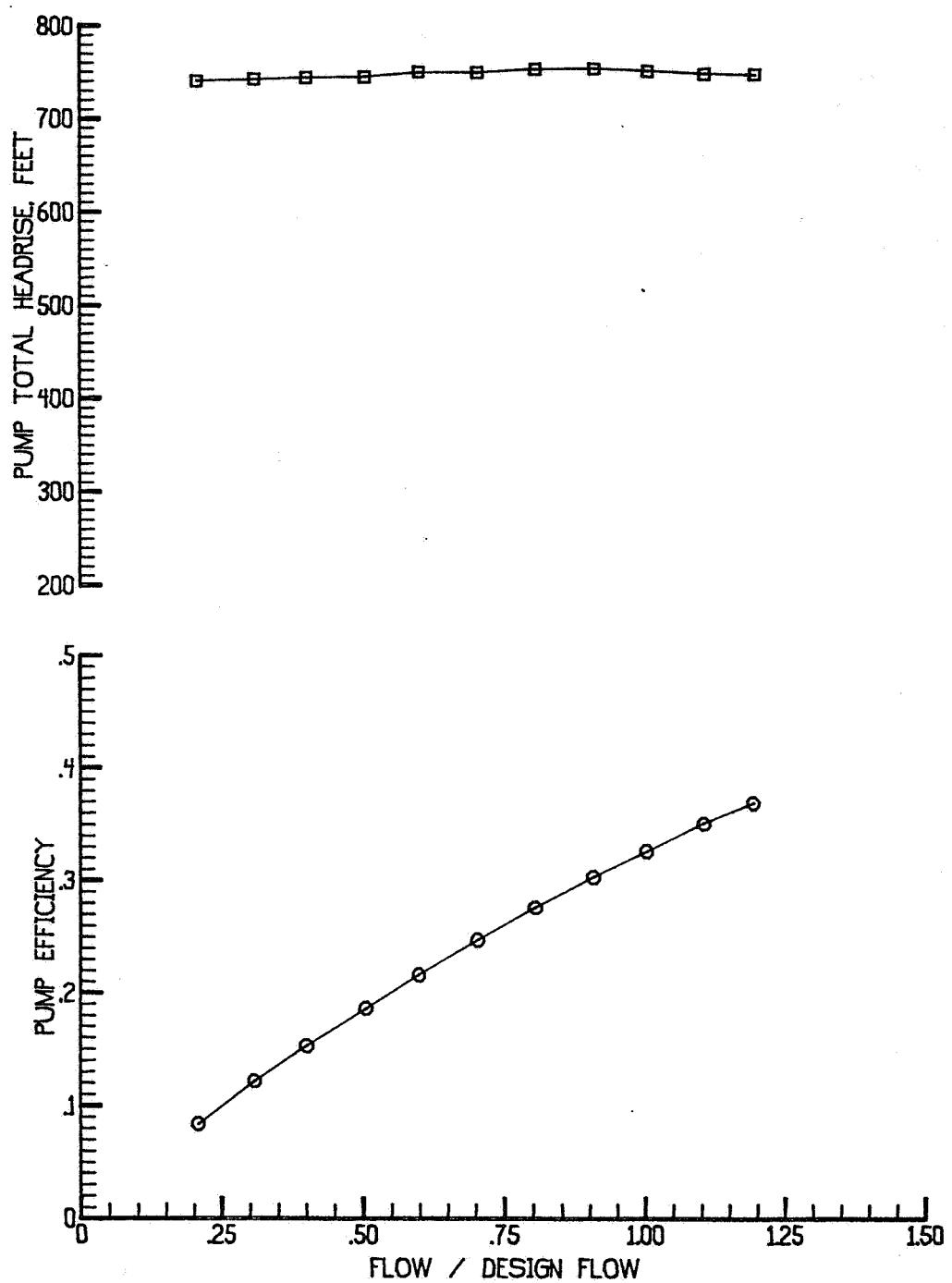


Figure 17. Low-Thrust Water Testing  
Configuration 2  
Test and Curve Speed - 24,500 rpm  
Specific Speed - 430

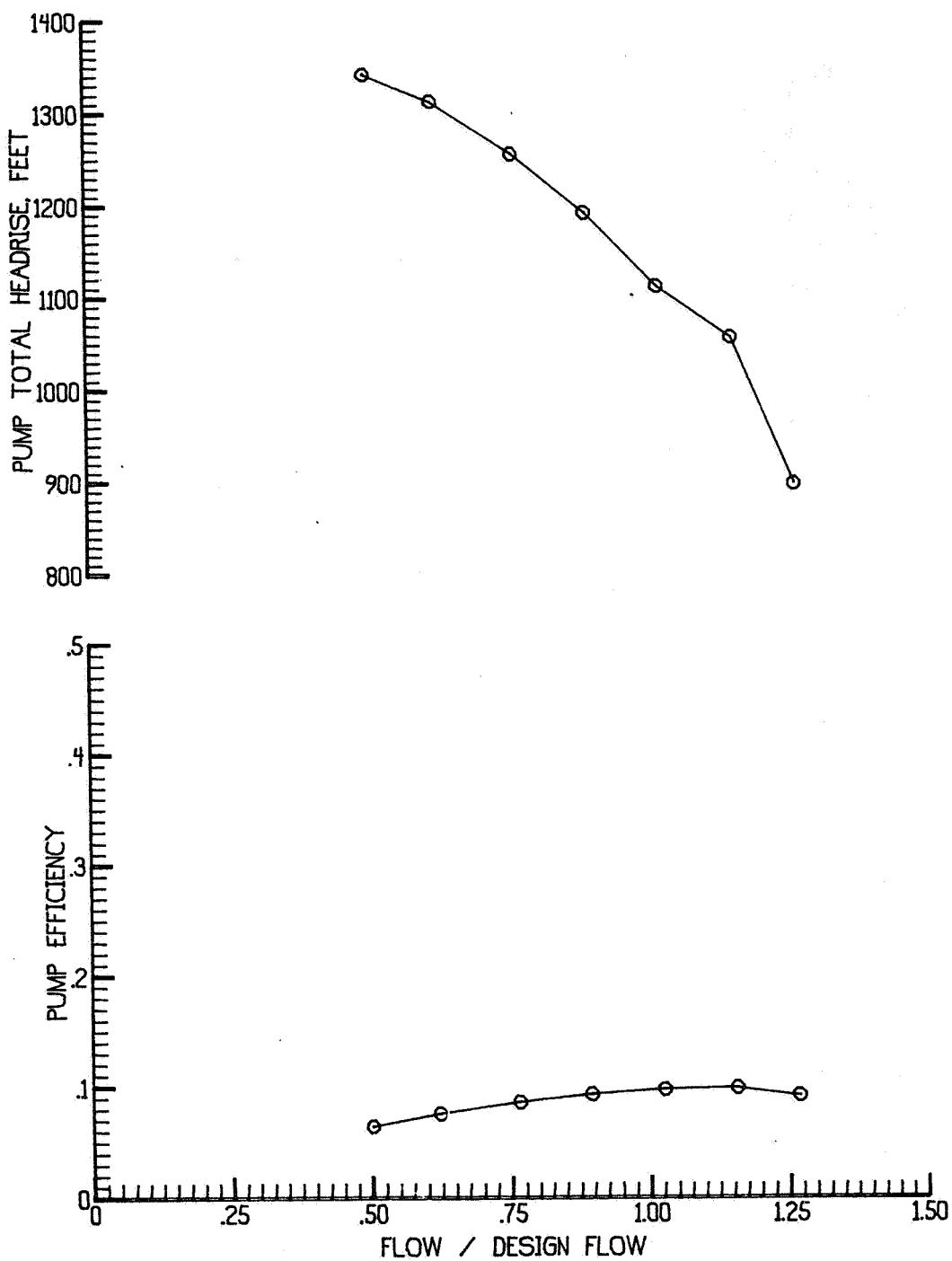


Figure 18. Low-Thrust Water Testing  
Configuration 3  
Test and Curve Speed - 29,000 rpm  
Specific Speed - 215

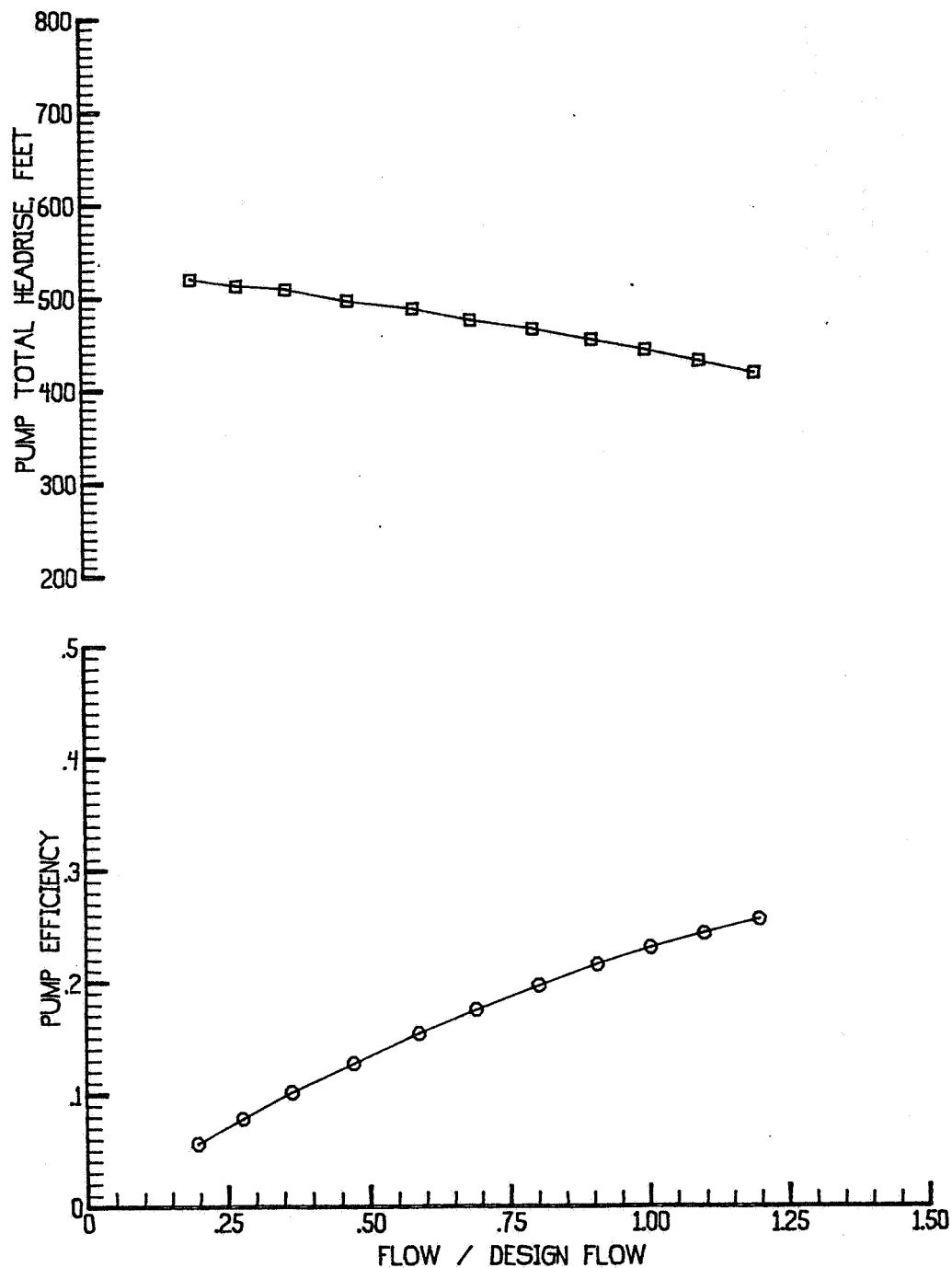


Figure 19. Low-Thrust Water Testing  
Configuration 4  
Test and Curve Speed - 24,500 rpm  
Specific Speed - 430

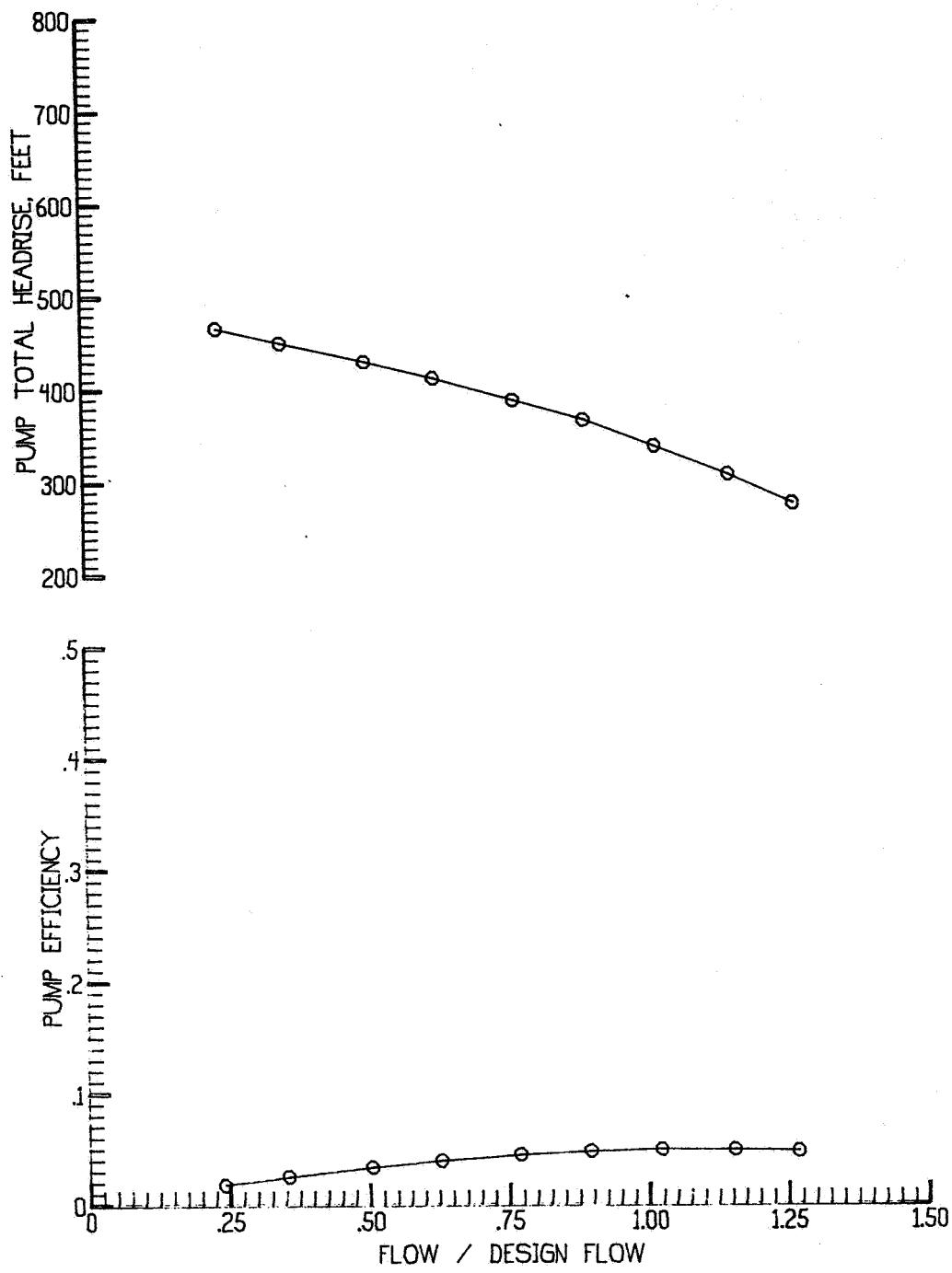


Figure 20. Low-Thrust Water Testing  
Configuration 5  
Test and Curve Speed - 29,000 rpm  
Specific Speed - 215

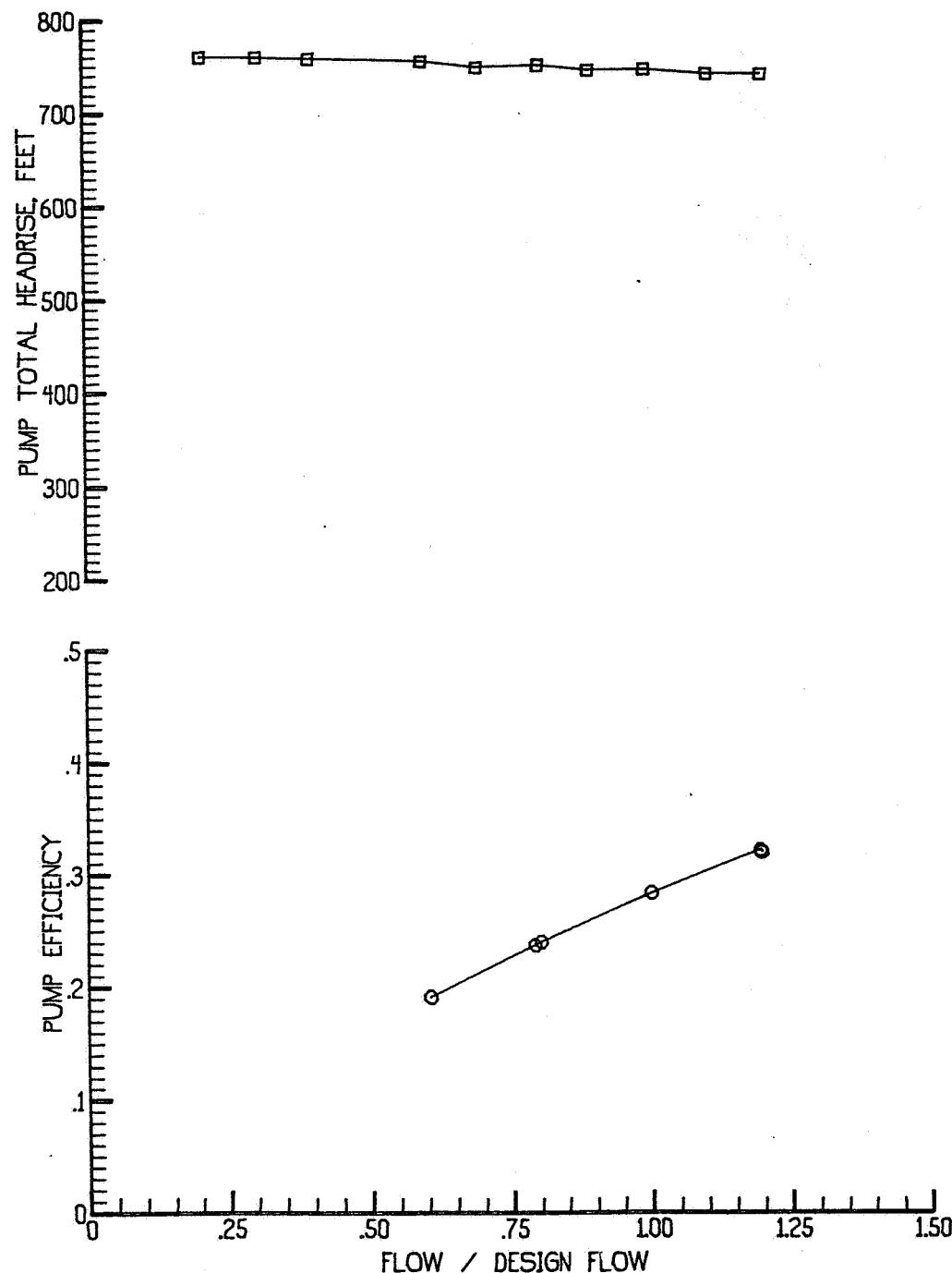


Figure 21. Low-Thrust Water Testing  
Configuration 6  
Test and Curve Speed - 24,500 rpm  
Specific Speed - 430

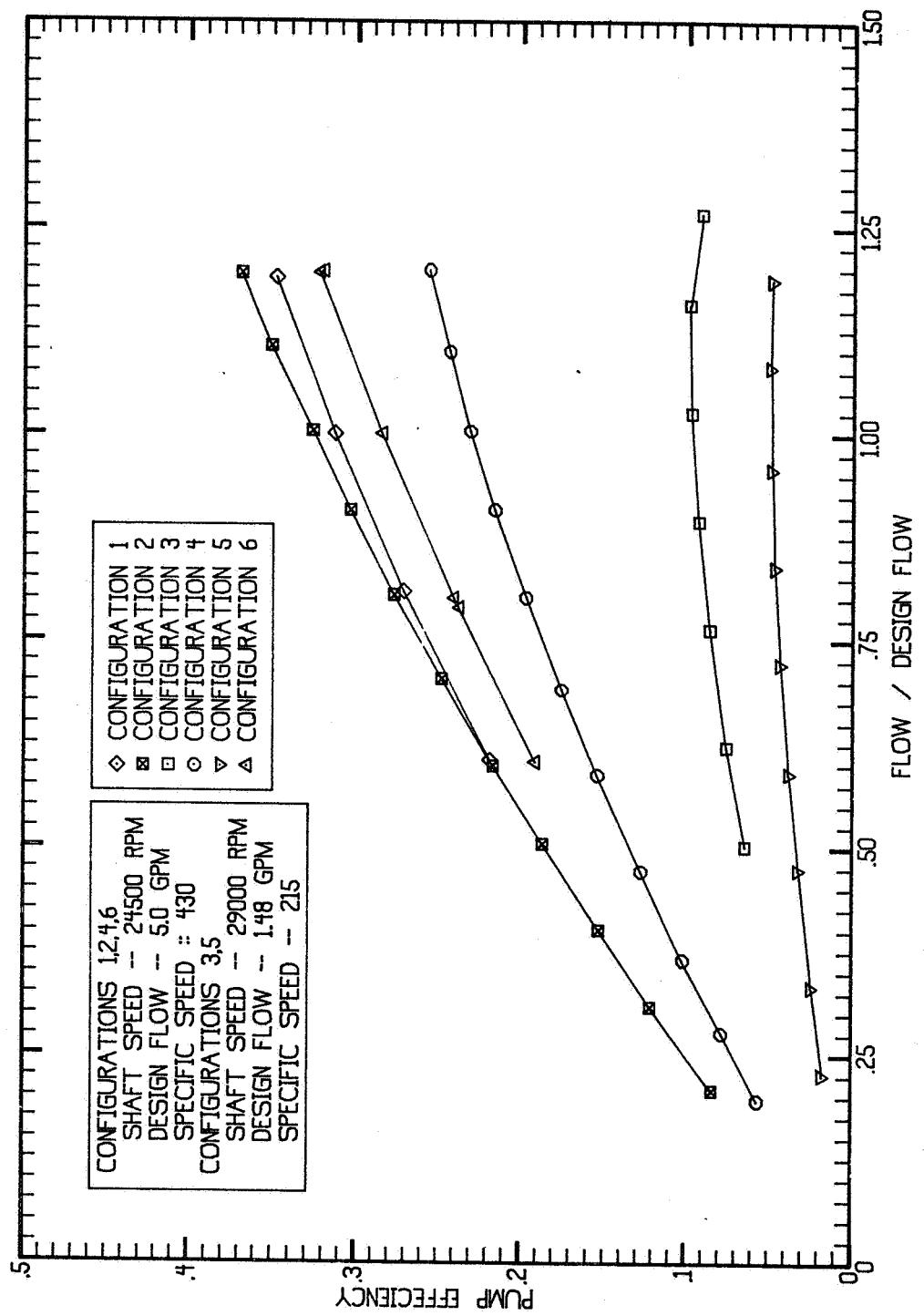


Figure 22. Low-Thrust Water Test Efficiency

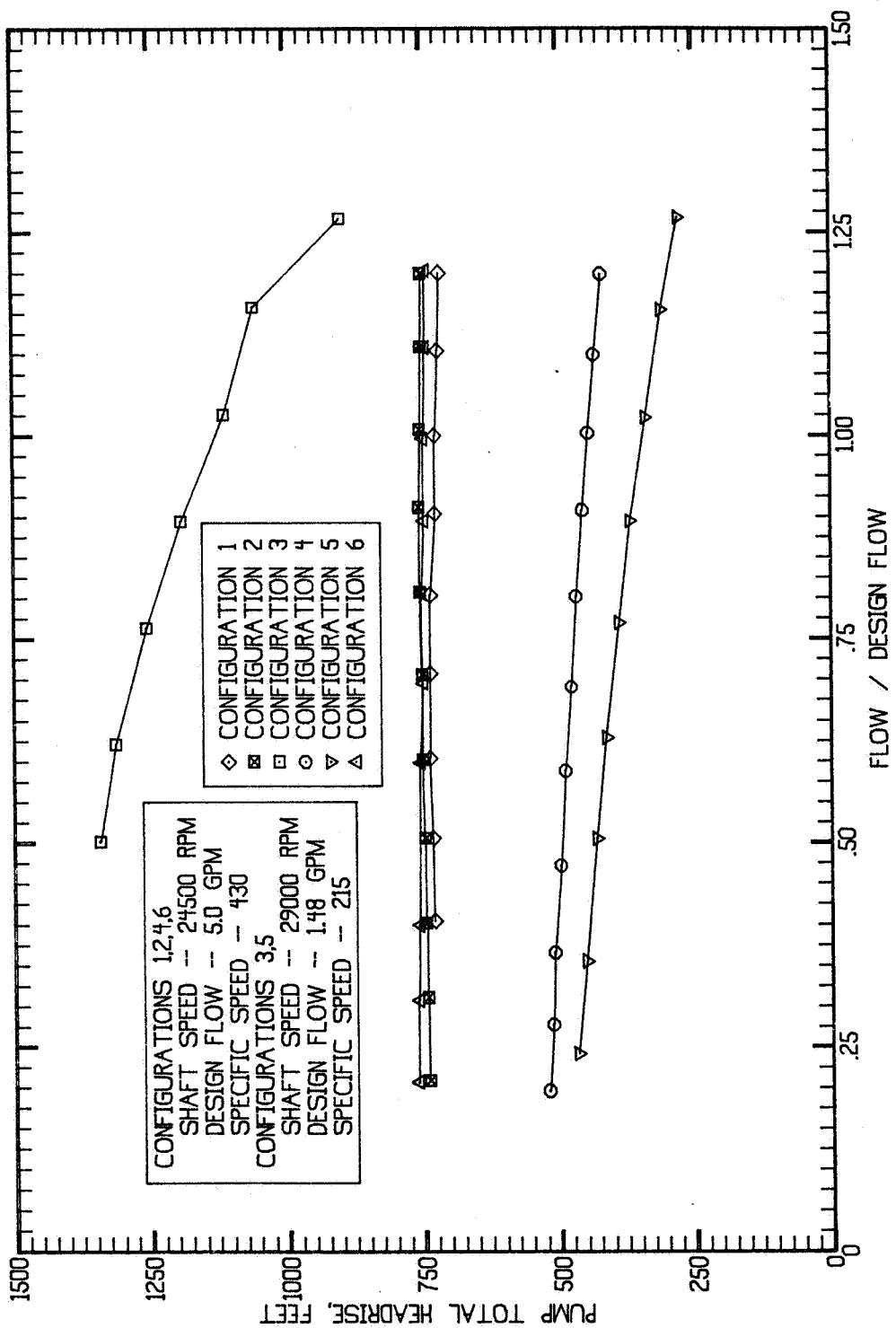


Figure 23. Low-Thrust Water Test Head

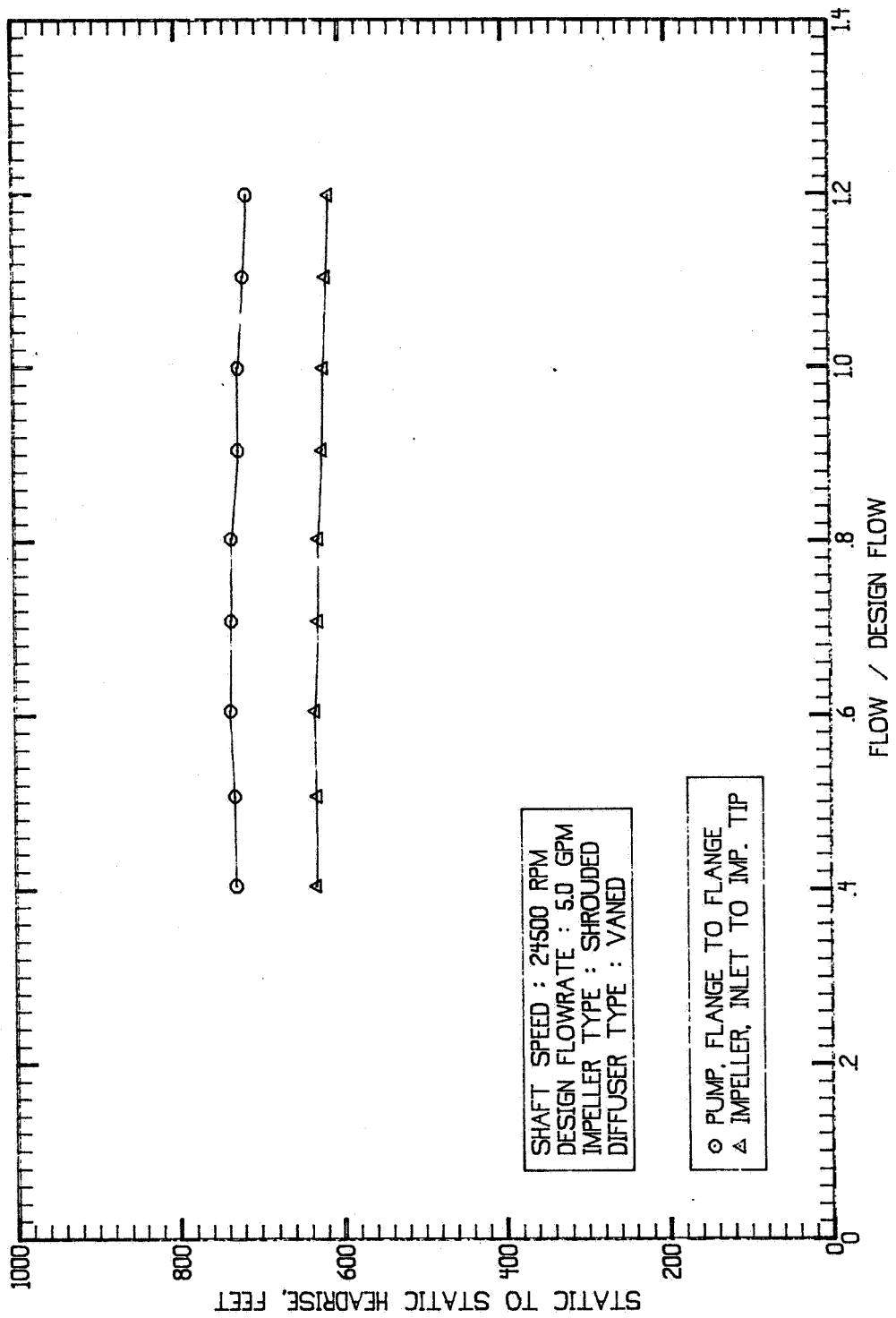


Figure 24. Pump and Impeller Static Headrise  
Low-Thrust Water Testing, Configuration 1

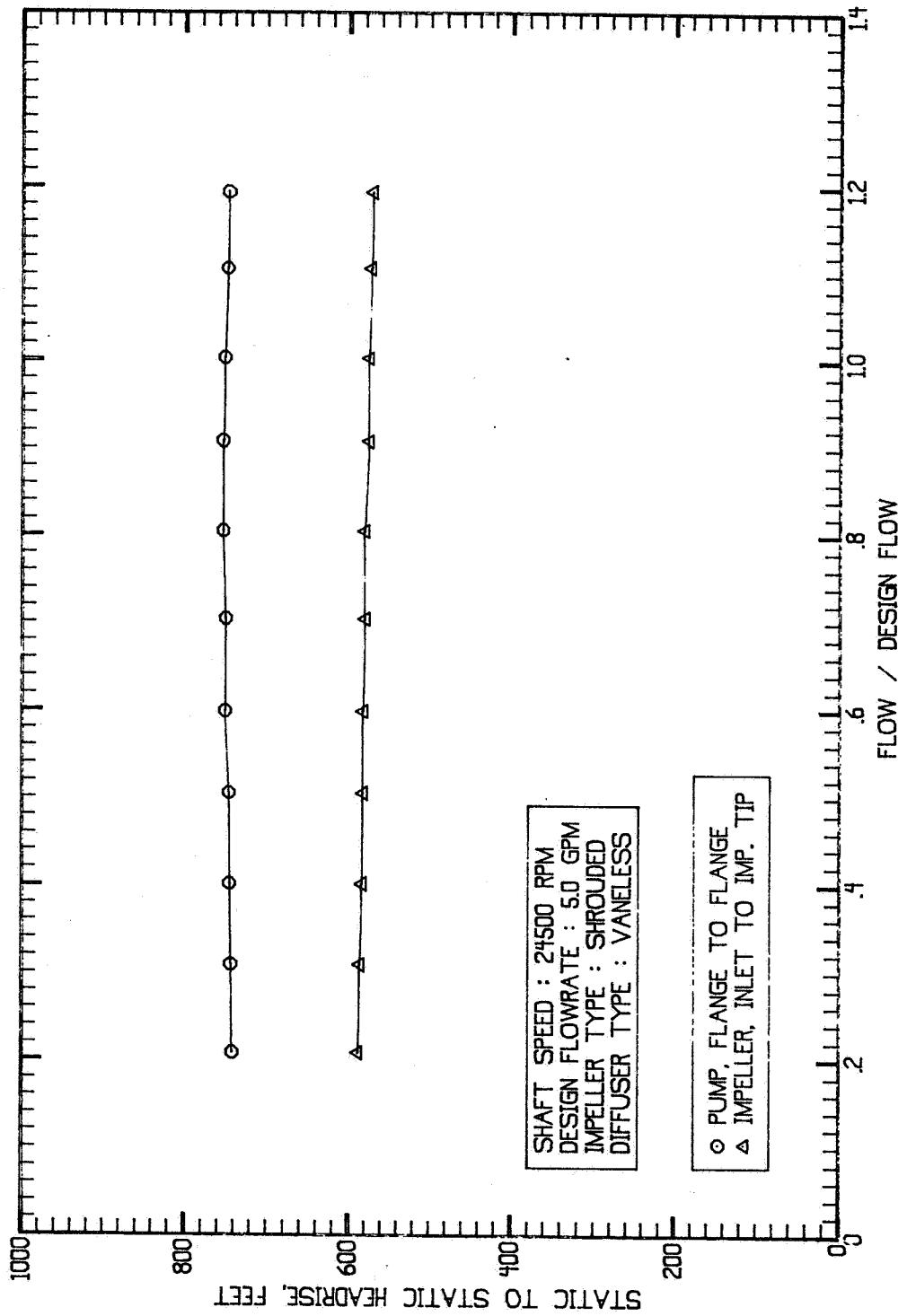


Figure 25. Pump and Impeller Static Headrise  
Low-Thrust Water Testing, Configuration 2

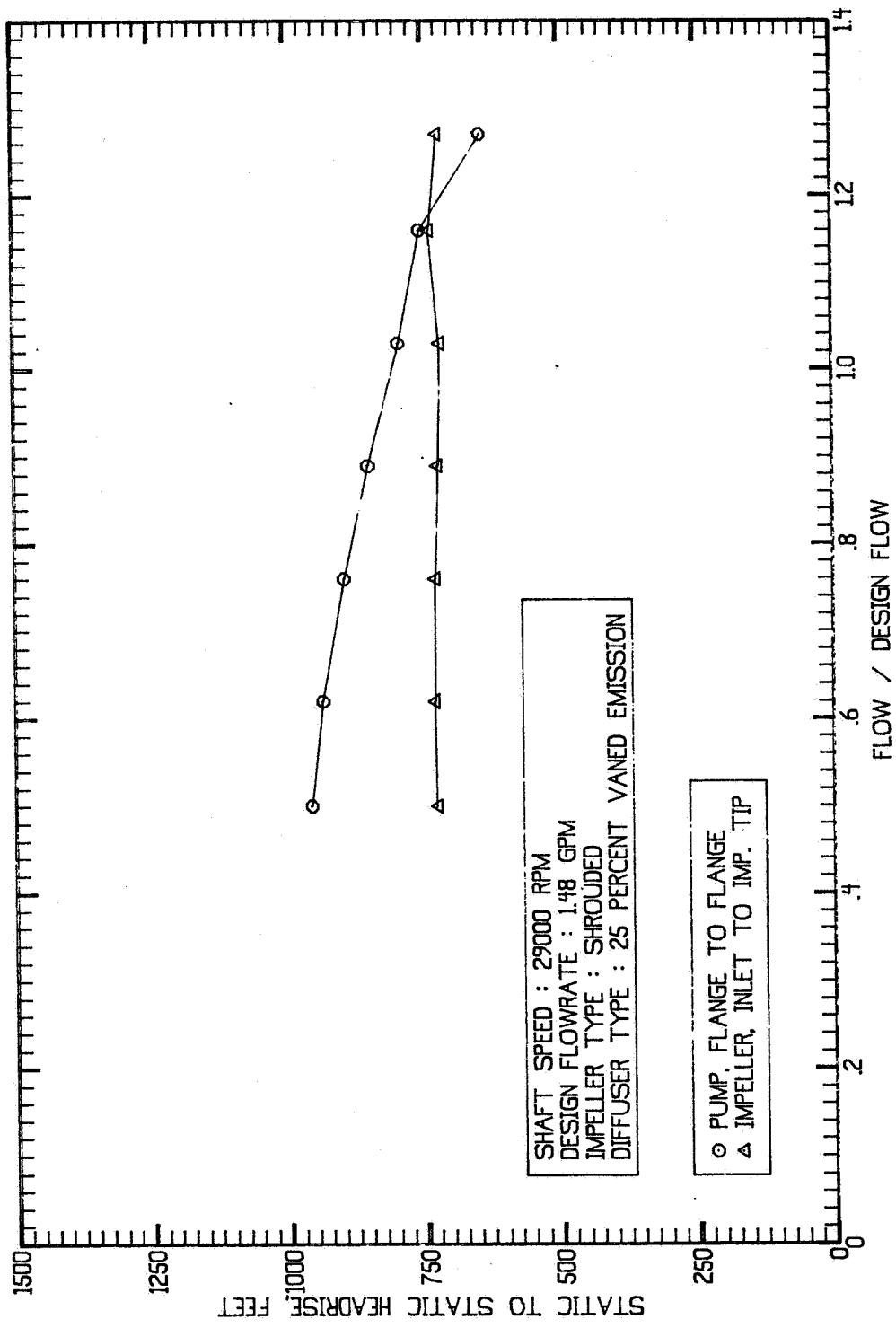


Figure 26. Pump and Impeller Static Headrise  
 Low-Thrust Water Testing, Configuration 3

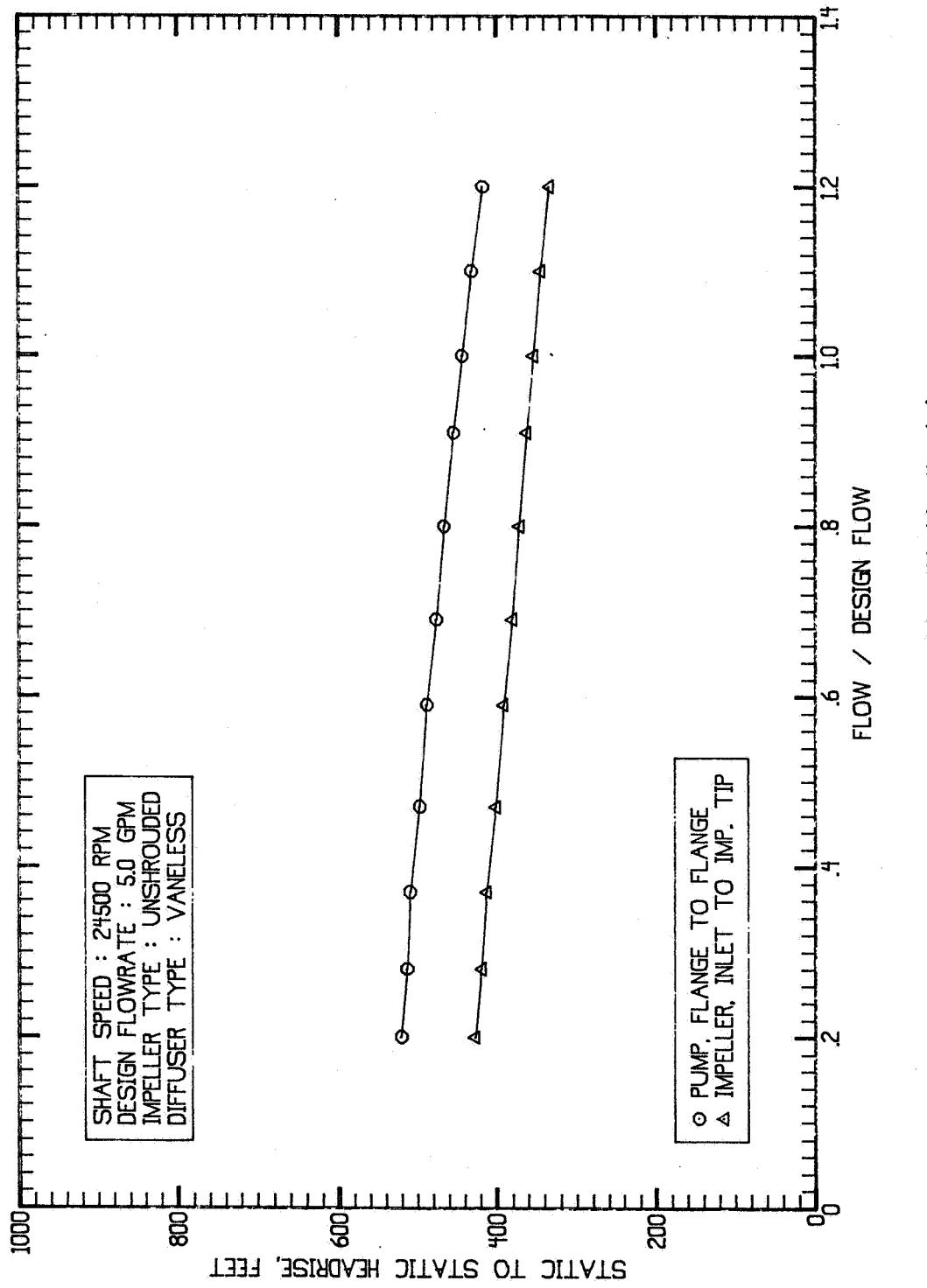


Figure 27. Pump and Impeller Static Headrise  
Low-Thrust Water Testing, Configuration 4

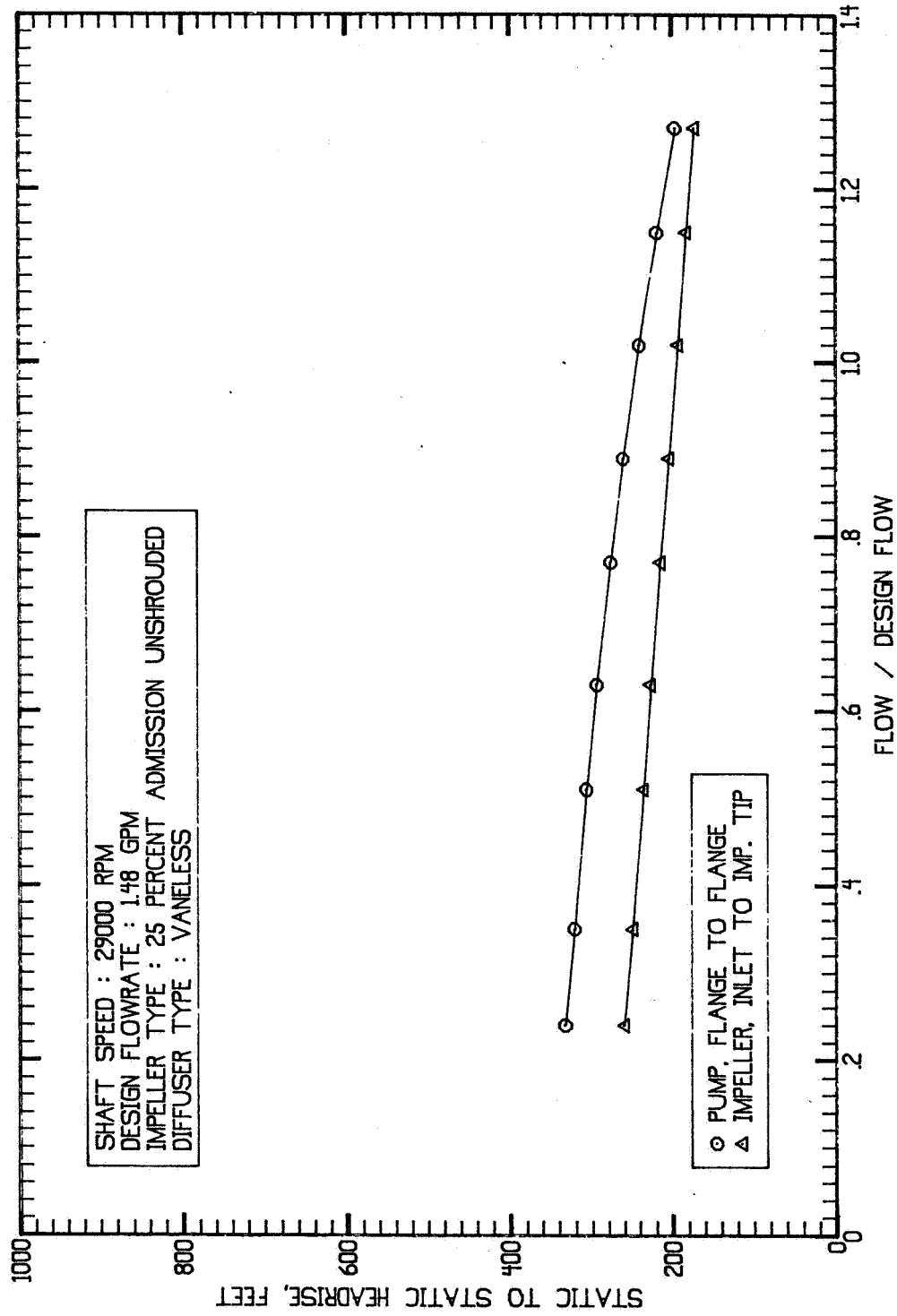


Figure 28. Pump and Impeller Static Headrise  
Low-Thrust Water Testing, Configuration 5

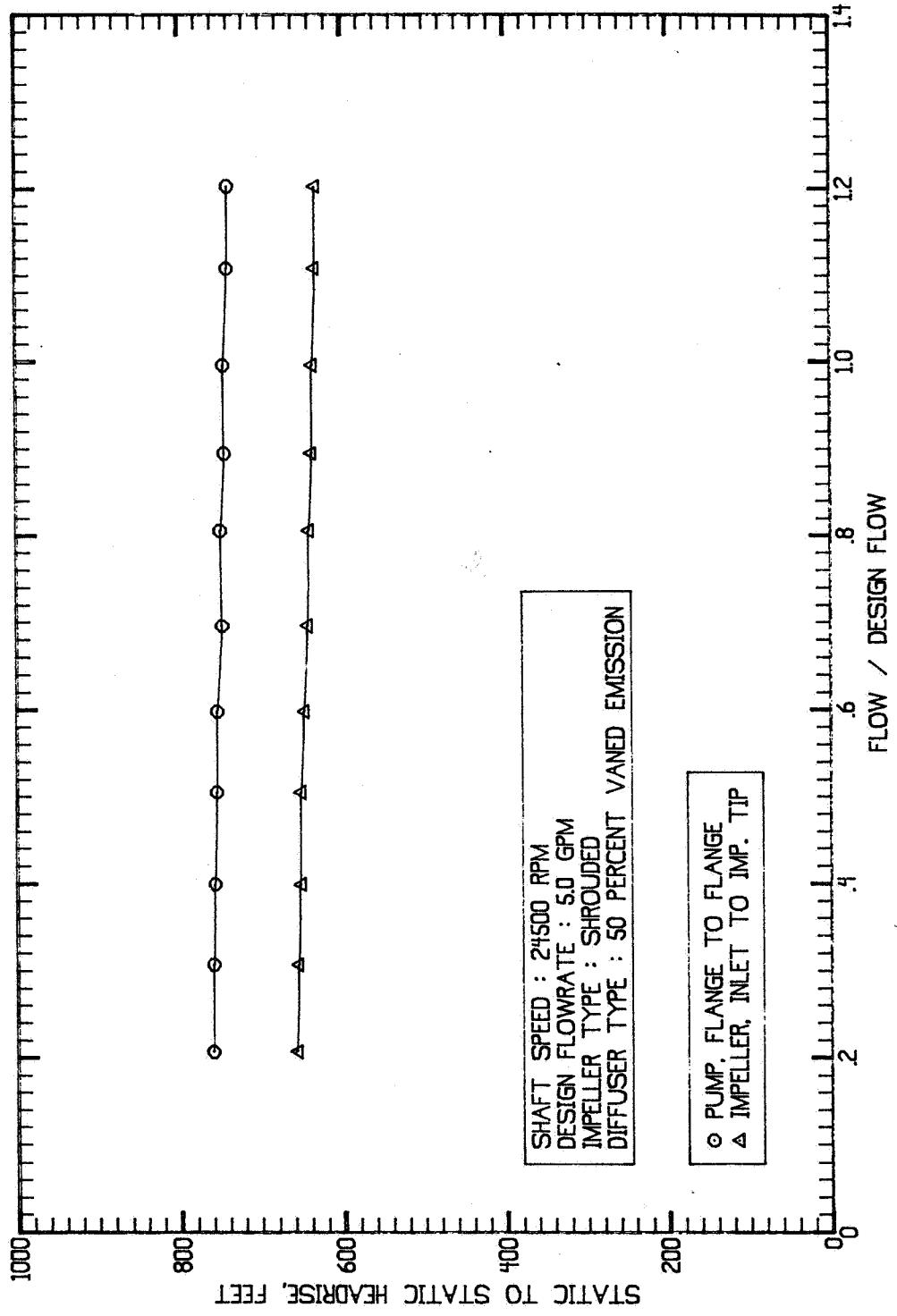


Figure 29. Pump and Impeller Static Headrise  
Low-Thrust Water Testing, Configuration 6

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.

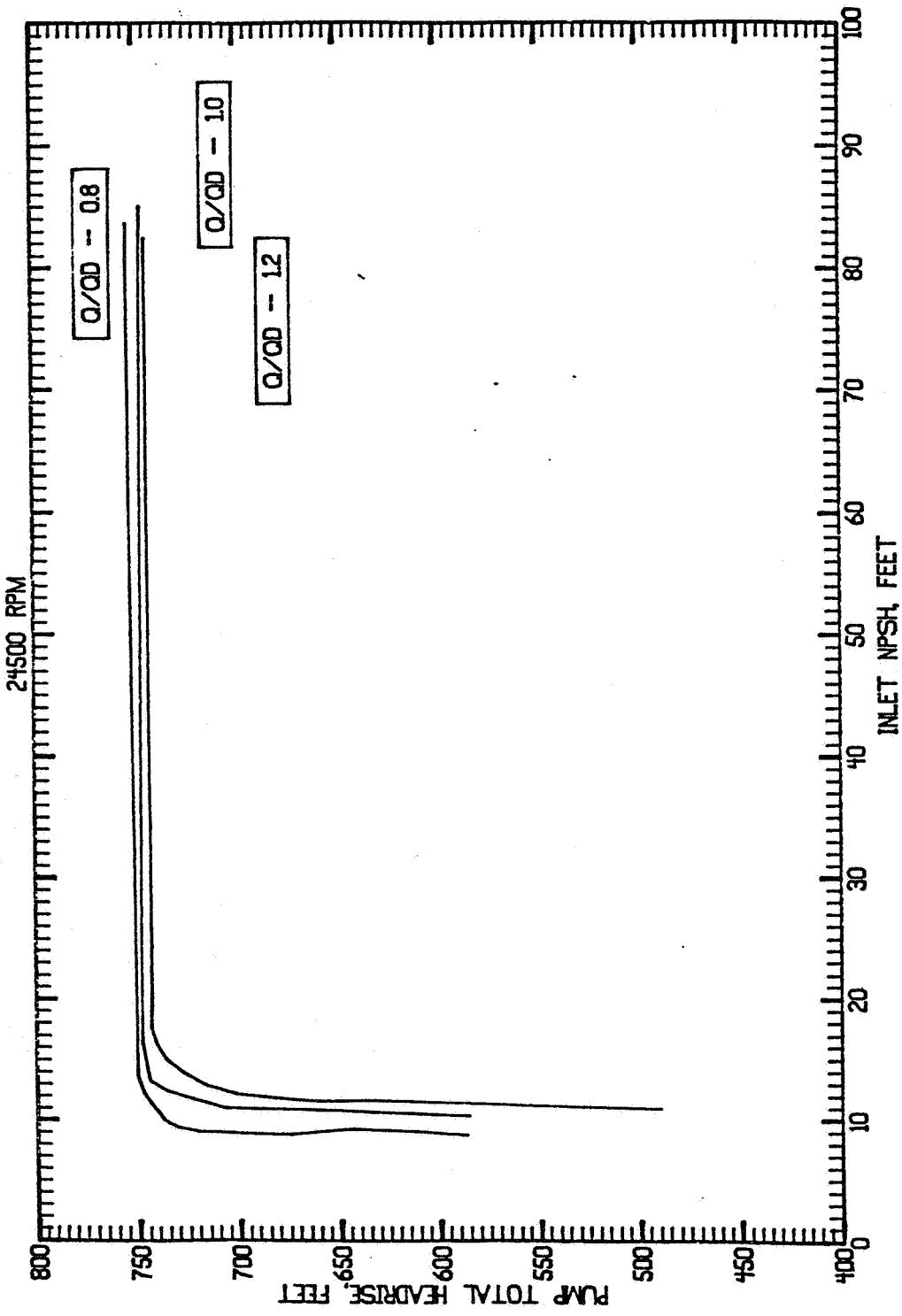


Figure 30. Cavitation Test, Configuration 2

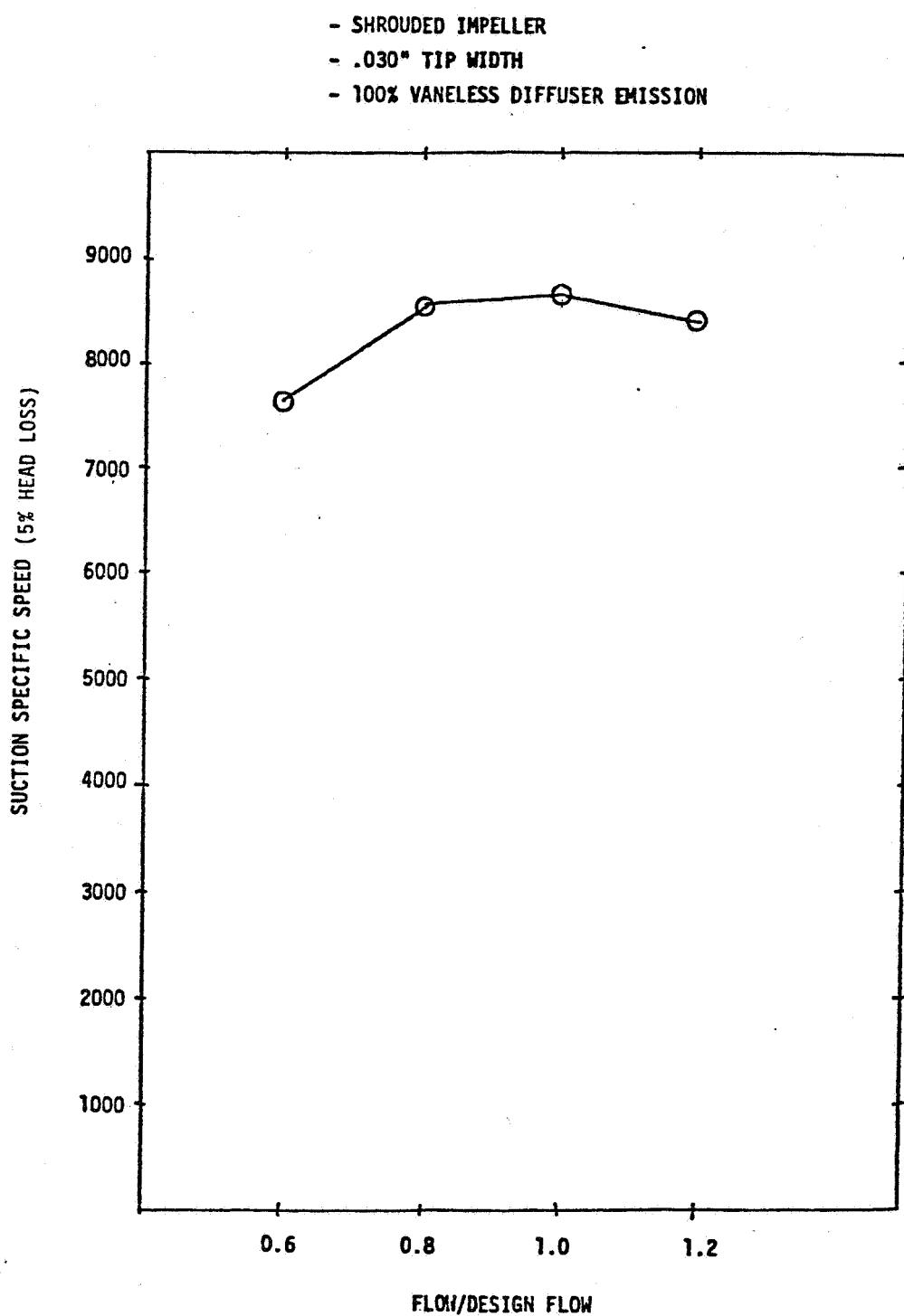


Figure 31. Suction Performance Configuration 2

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)	$\frac{N_{SS} \text{ (TEST)}}{N_{SS} \text{ (PRED)}}$
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.

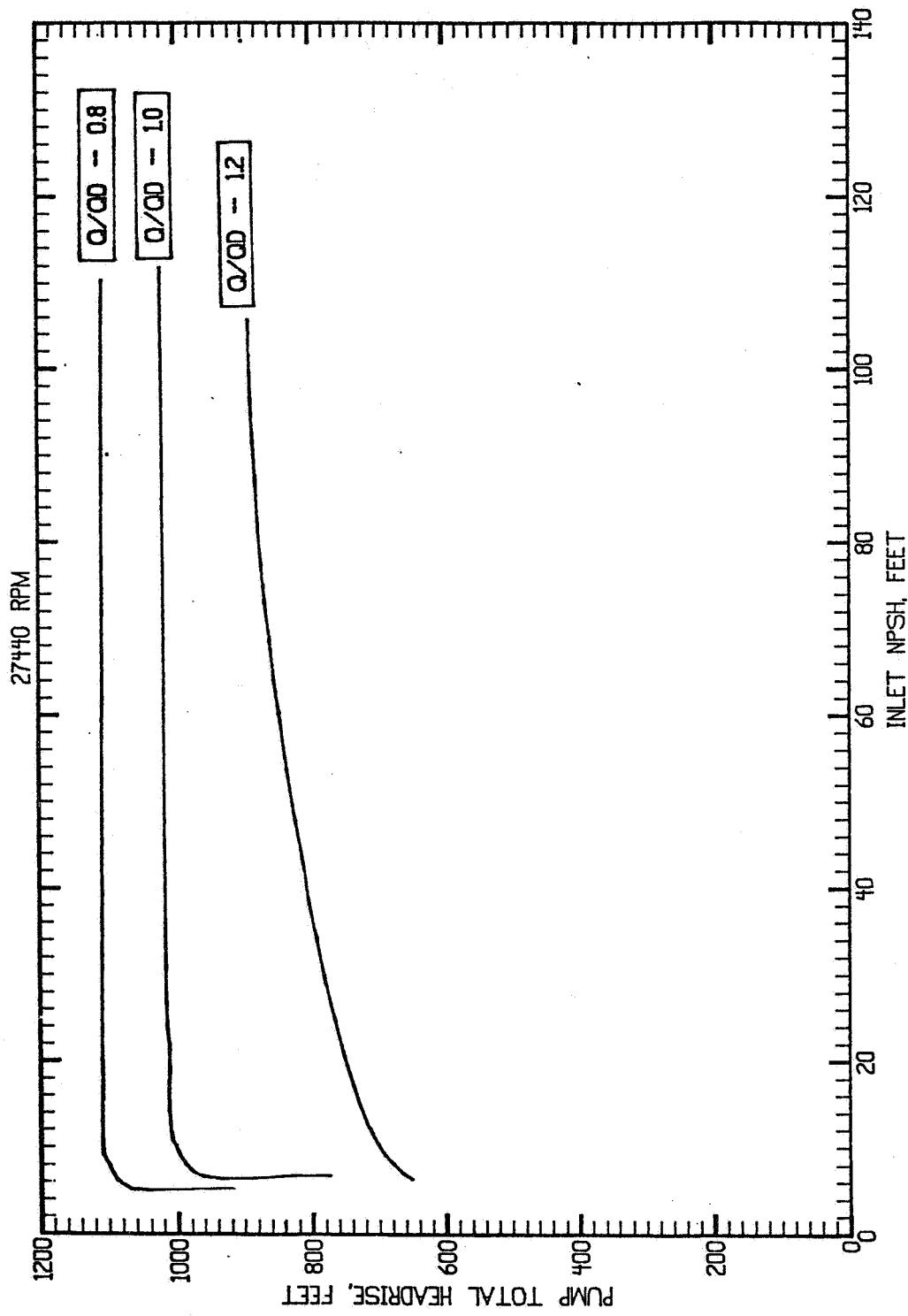


Figure 32. Cavitation Test, Configuration 3

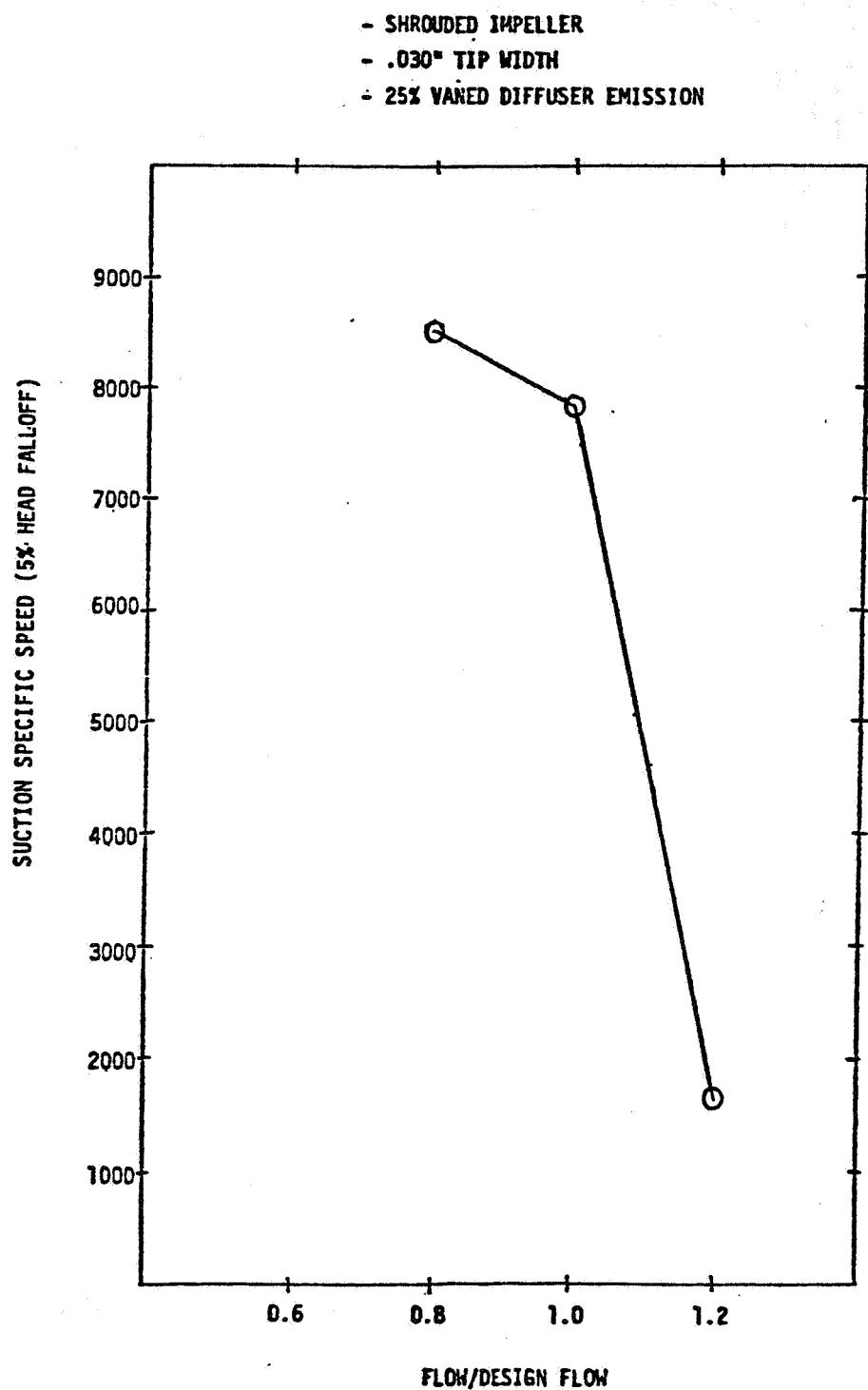


Figure 33. Suction Performance  
Configuration 3

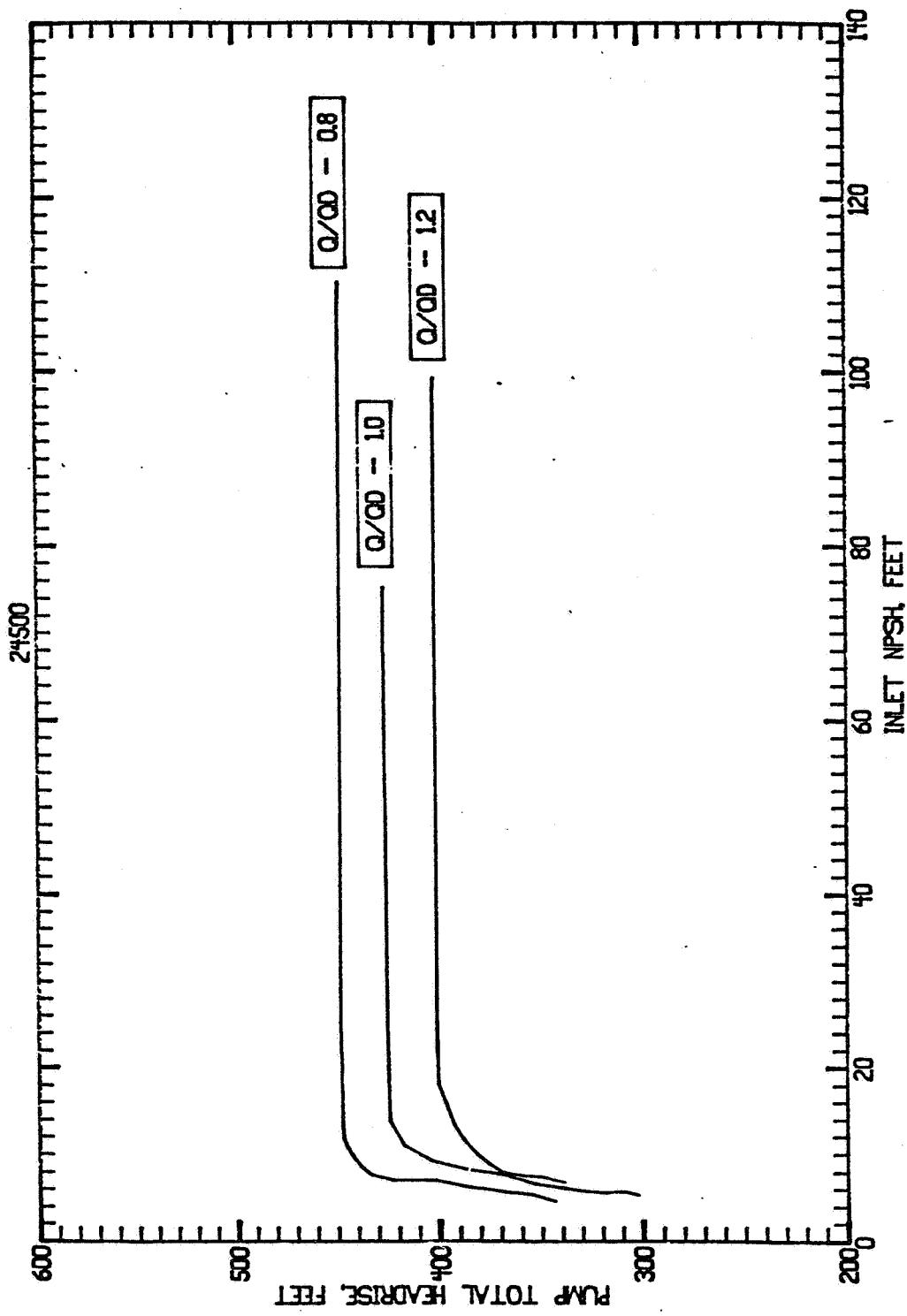


Figure 34. Cavitation Test, Configuration 4

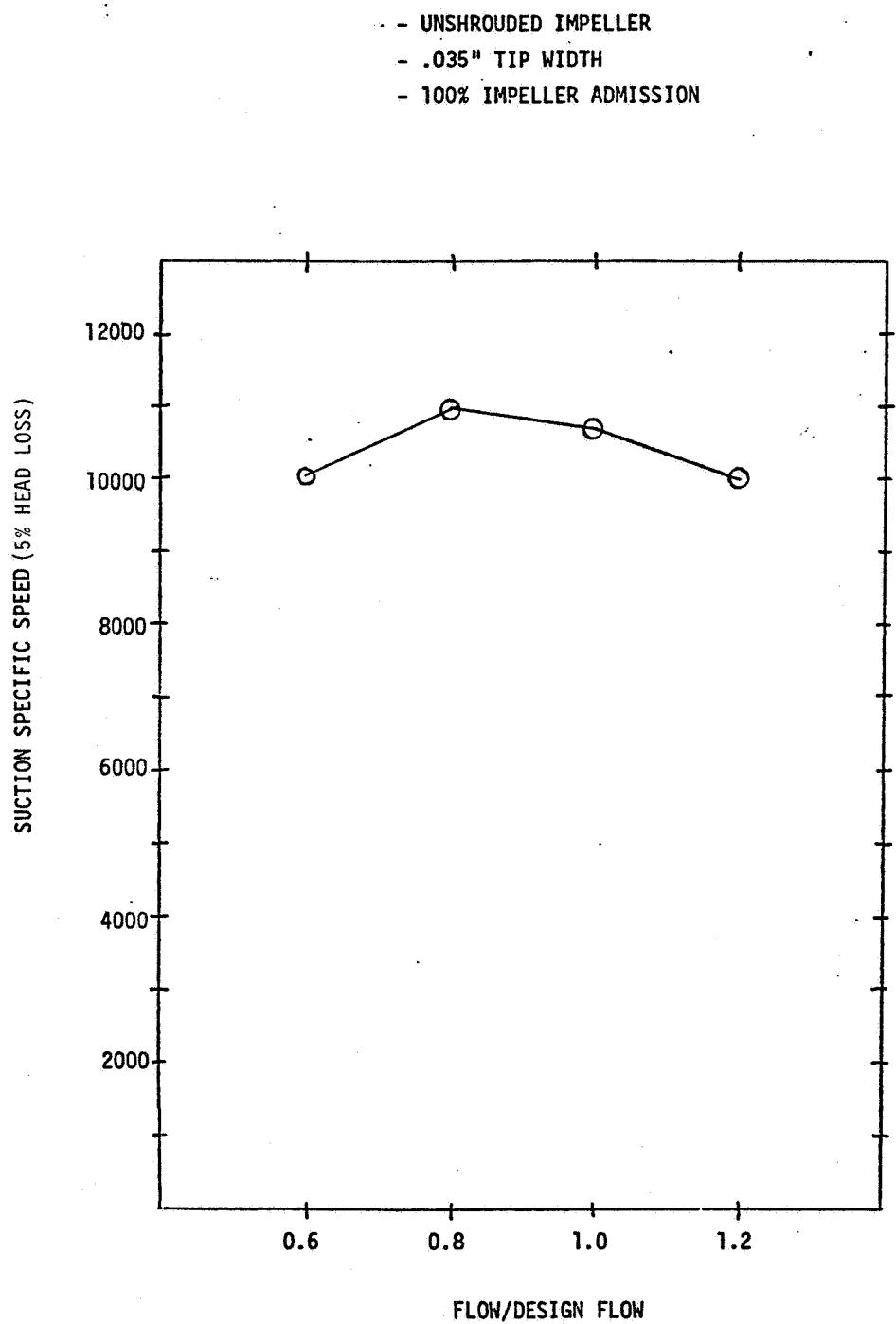


Figure 35. Suction Performance  
Configuration 4

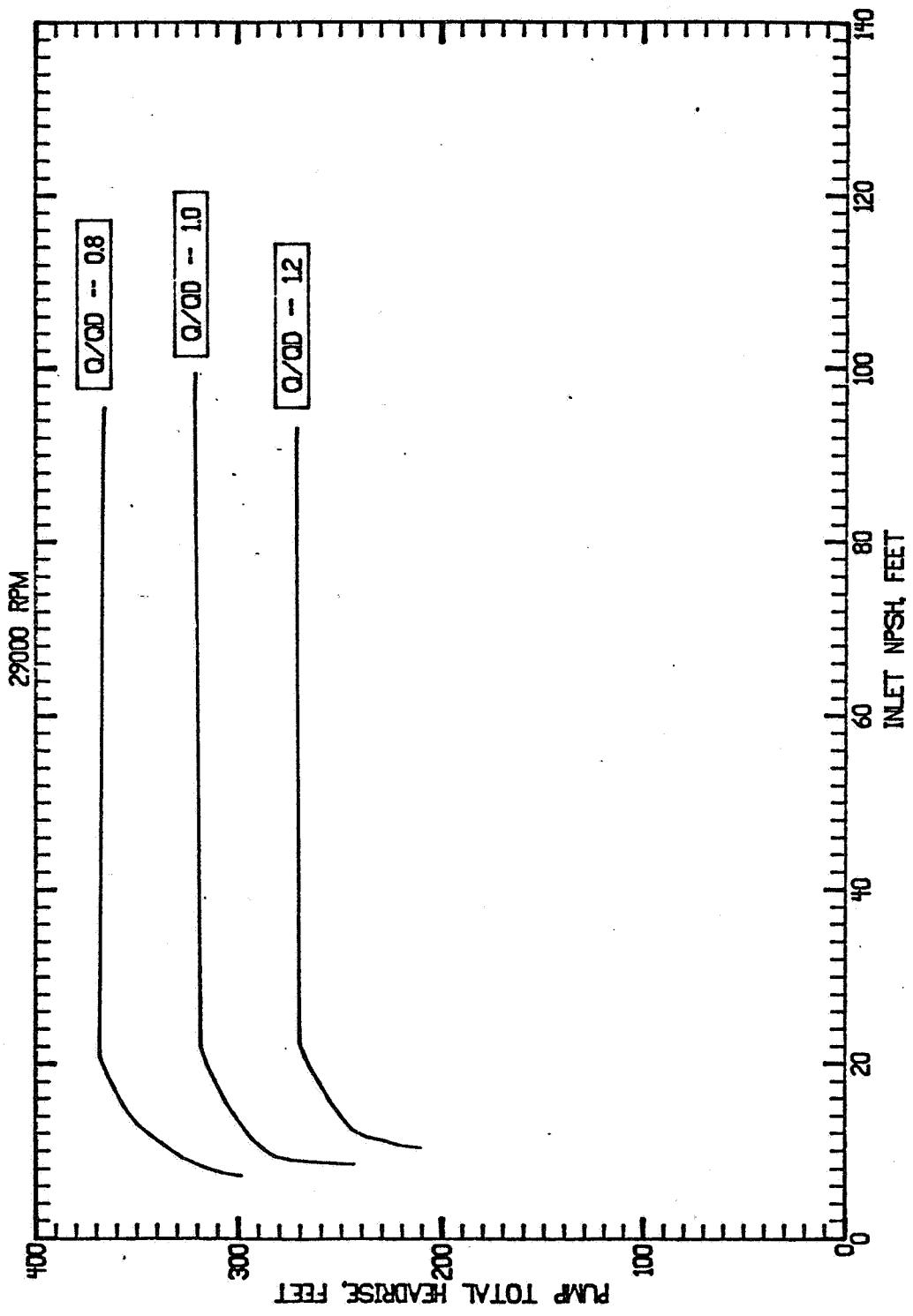


Figure 36. Cavitation Test, Configuration 5

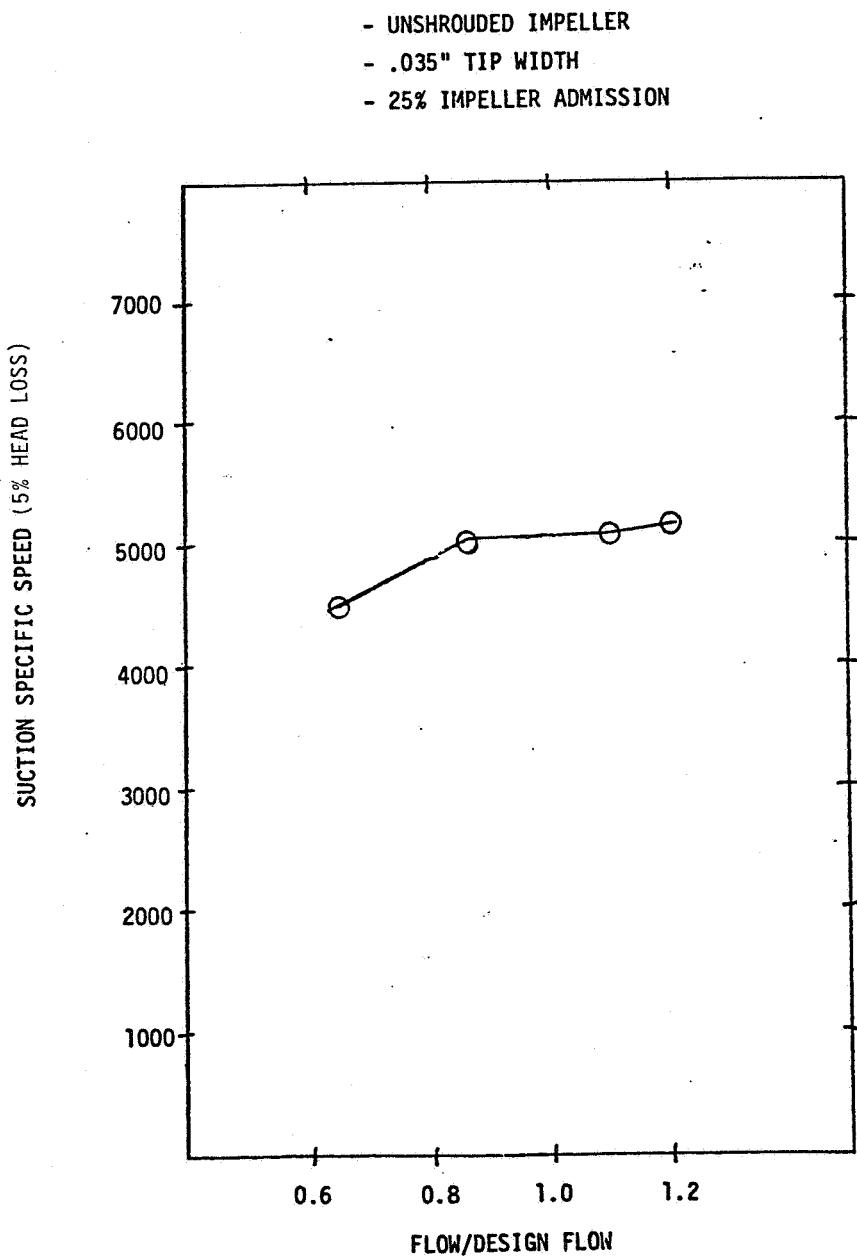


Figure 37. Suction Performance Configuration 5

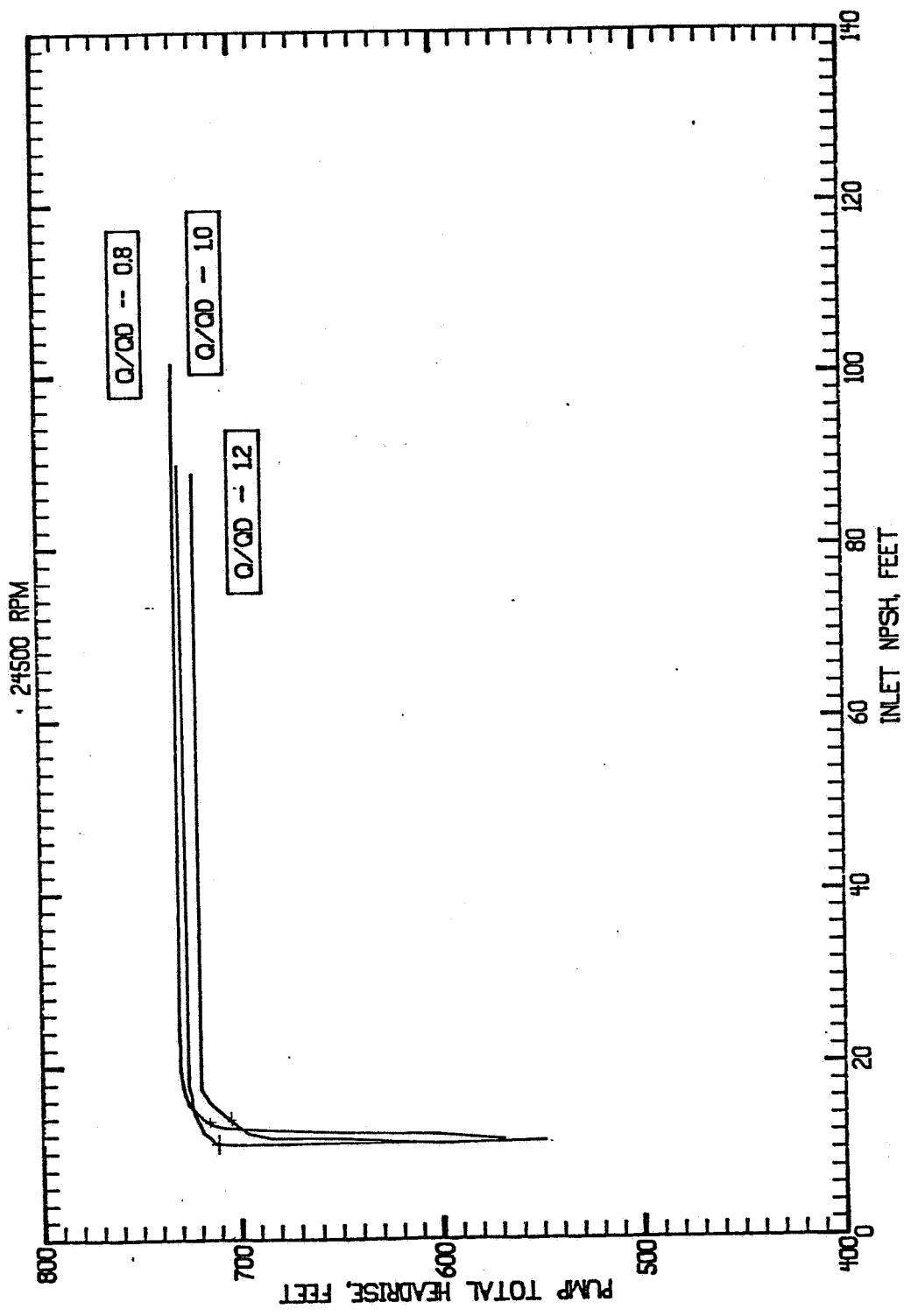


Figure 38. Cavitation Test, Configuration 6

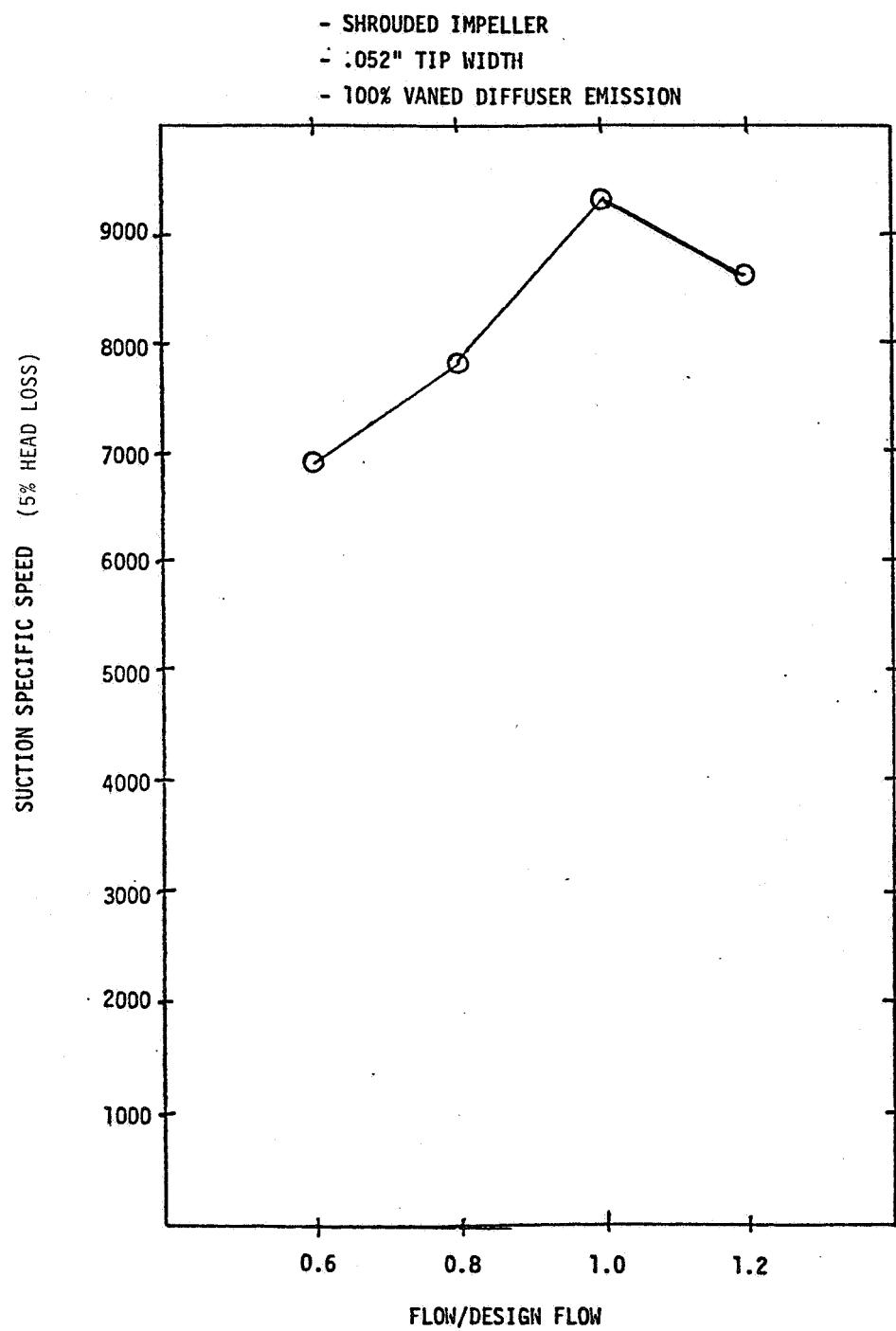


Figure 39. Suction Performance Configuration 6

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 desirable 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.

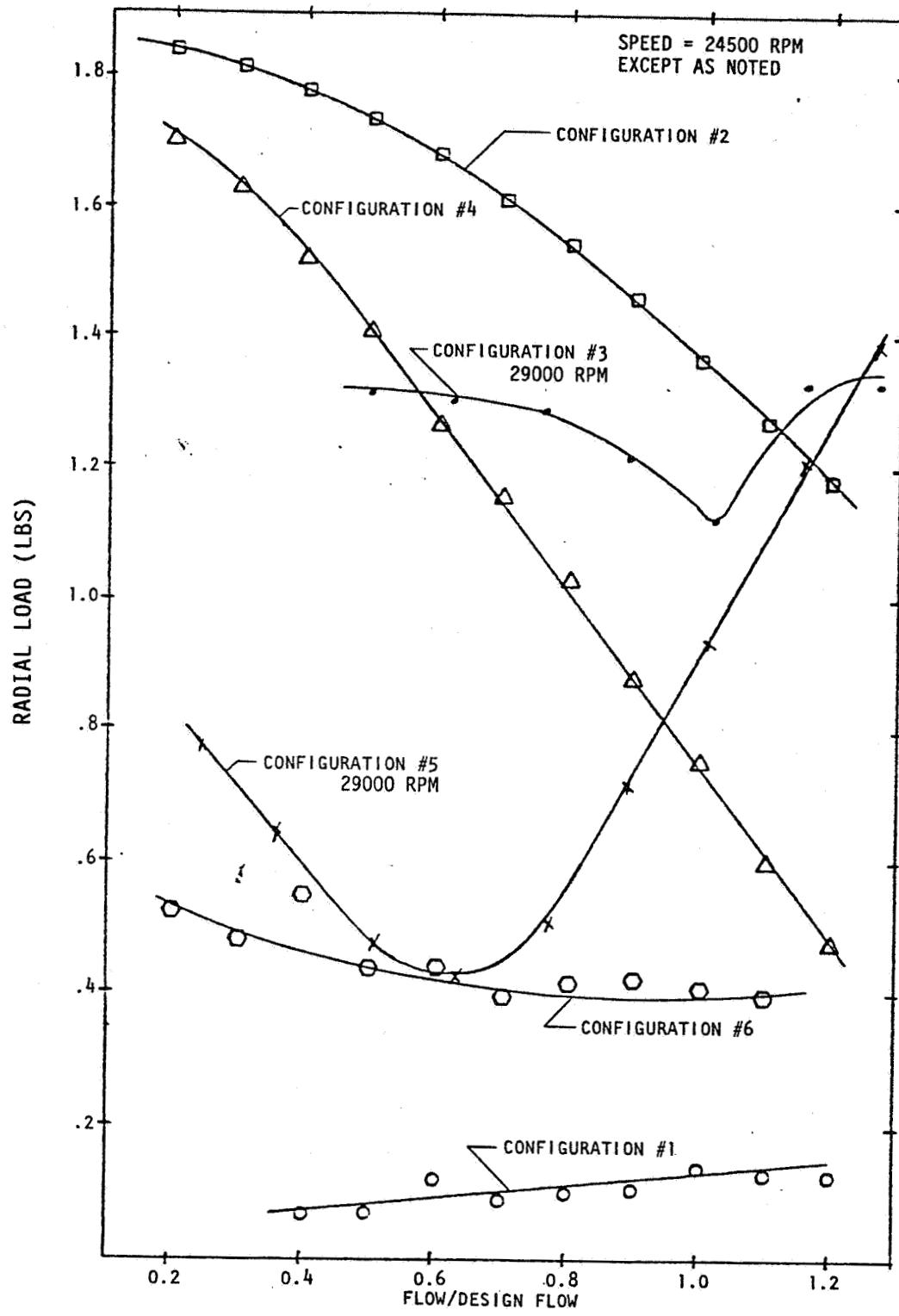


Figure 40. Radial Loads, Test Data

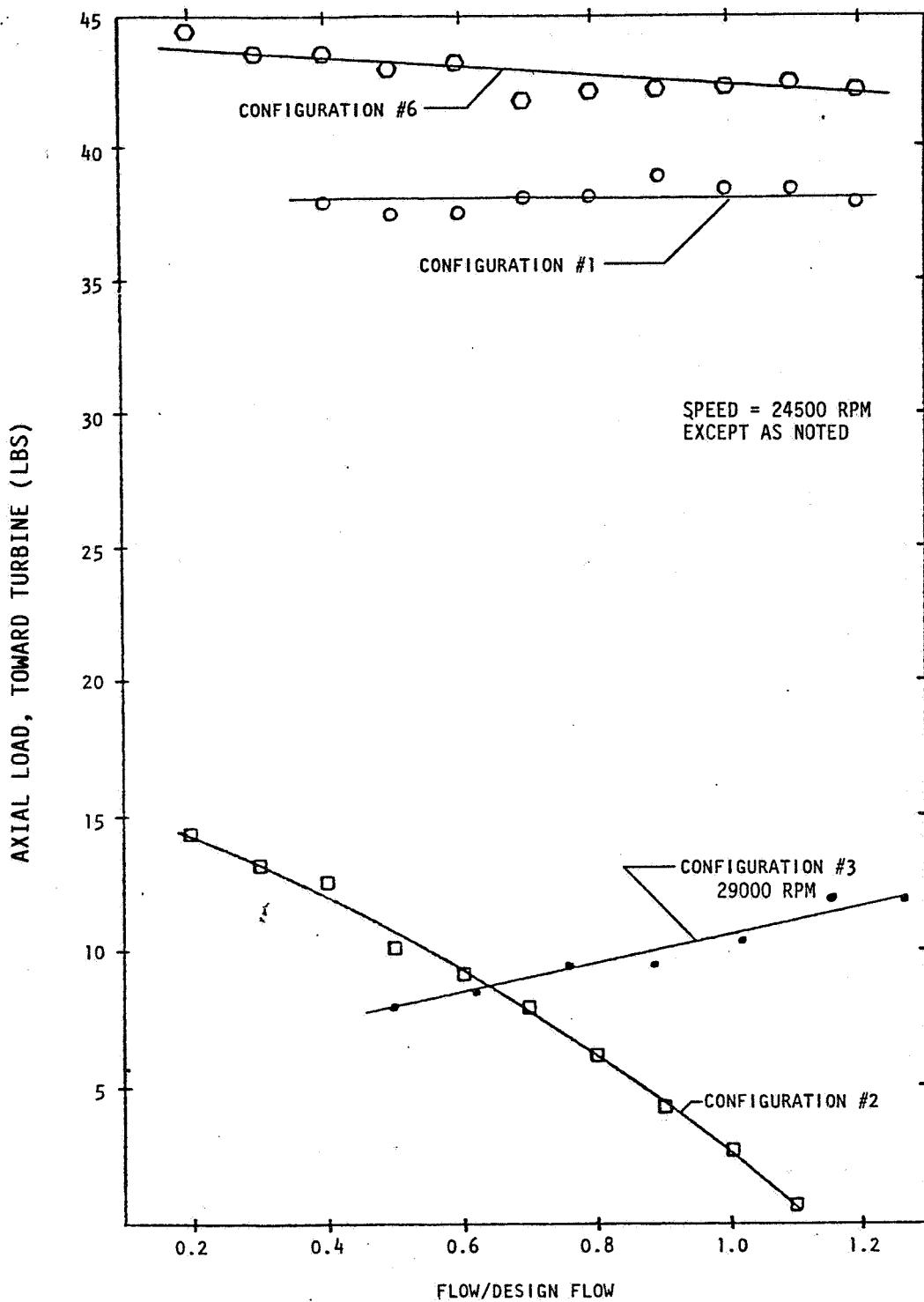


Figure 41. Axial Load, Shrouded Impellers, Test Data

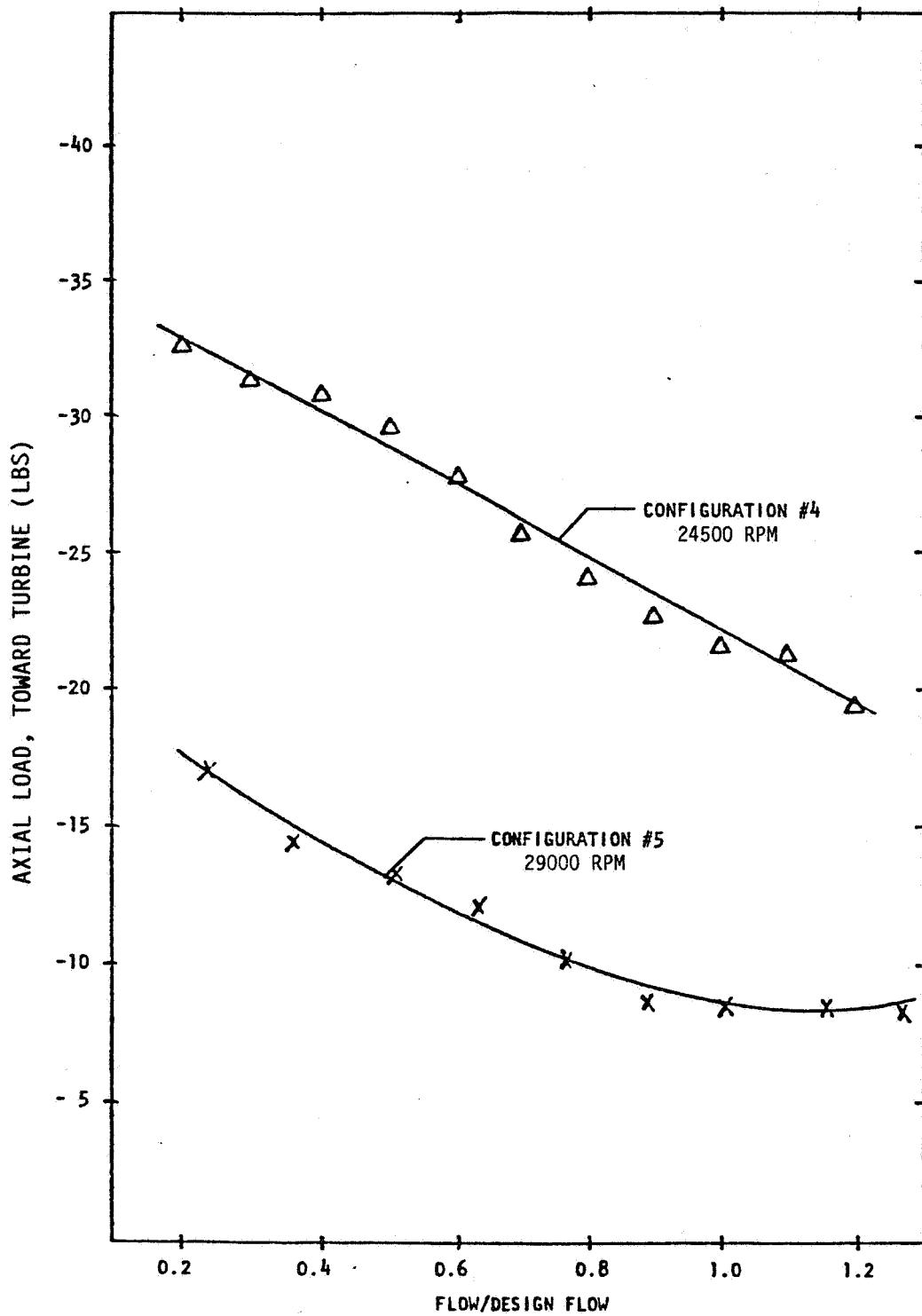


Figure 42. Axial Load, Open Face Impellers, Test Data

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

CONFIGURATION NO.	TEST CONFIGURATION				TEST RESULTS			
	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.

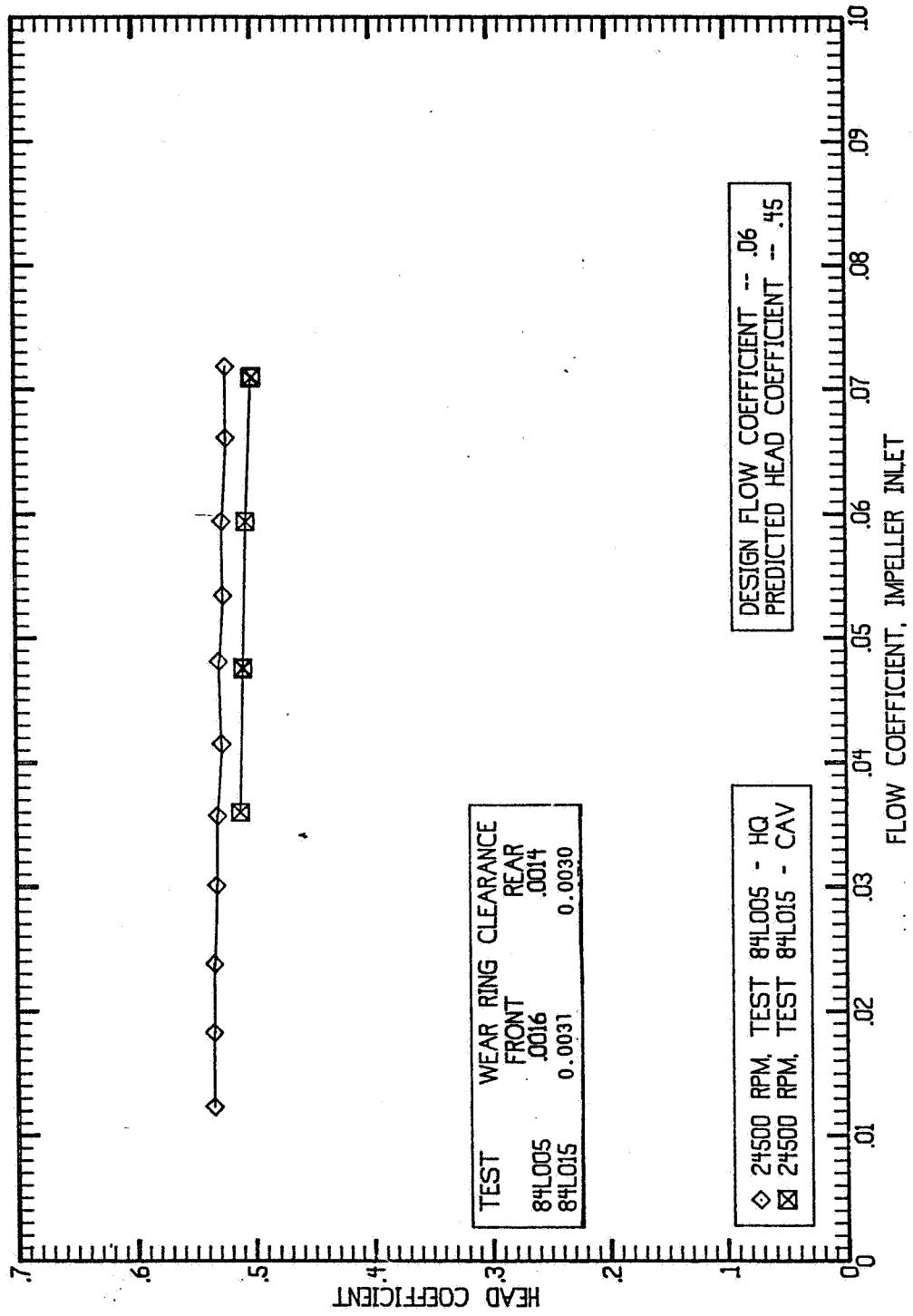


Figure 43. Low-Thrust Pump Head Coefficient Versus Flow Coefficient Configuration 6, Wear Ring Clearance Effect

## 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:

<u>SECTION</u>	<u>CONFIGURATION</u>	<u>TEST NUMBER</u>
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
<u>Pressure Tap Radial Location (Inches)</u>						
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
<u>Wear Ring Dimensions (Inches)</u>						
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	-

PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 FEB 1984  
PROCCESS DATE 9 NUV 1984  
TEST 64L007 2-27-84, LOW THRUST SUMP H-8 L CAVITIES

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 DISCH TIP DIAMETER, IN	2.00000E+00
9 INLET AREA AT PRESS TAP, SQ. IN	7.65000E-01
10 IN/IMP INLET AREA, SQ. IN	3.12600E-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
14 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	1.00000E+01
35 FRONt WEAK KING UPSTREAM PRESSURE, RADIAL LOCATION	5.66000E-01
36 IMPELLER FRONT MID PRESSURE, RADIAL LOCATION	7.50000E-01
37 IMPELLER FRONT TIP PRESSURE, RADIAL LOCATION	1.00000E+00
38 IMPELLER REAR TIP PRESSURE, RADIAL LOCATION	9.70000E-01
39 REAR WEAK KING 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 SPL. HT. KVAL	1.40000E+00
95 MWL OF GAS	2.801e-01
96 TURB MEAN DIAMETER, IN	2.40000E+00
97 TURB NLZ AREA, IN <sup>2</sup>	5.54000E-01
98 TURB PIPE IN DIAMETER, IN	1.61600E+00
99 PERCENT TURLINE ADMISSION	1.00000E+02

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SECTION A1

PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 FEB 1984  
TEST E4LC07 <-> T-4 LOW INKUST PUMP H-Q & CAV TESTS

PAGE 1

TIME	-1	-2	-3	-4	-5	-6	-15	-16	-17	-18
	WATER	VAPOR	INLET	IMPELLER	FLOW/	AMBIENT	PUMP STA	PUMP STA	PUMP STA	PUMP STA
	SP.WGT.	HEAD	VELOCITY	IN FLW	DES FLOW	PRESS	LEVEL	HEAD FT	LEVEL	VEL. LITY
24.0.0UA	02.0.272	0.72000	0.62036	0.62961	0.61999E-01	1.0396	14.360	57.120	57.120	0.0136
501.0UA	02.0.264	0.62513	0.62576	0.62614	0.62621E-01	0.61542	14.360	59.649	59.649	0.5174
069.0UA	02.0.263	0.62453	0.62453	0.62474	0.71862E-01	1.2052	14.360	246.85	246.85	5.0532
462.0UA	02.0.264	0.62434	0.62434	0.62454	0.66534E-01	1.1158	14.360	251.65	251.65	5.4587
1097.0UA	02.0.264	0.62454	0.62454	0.62454	0.60243E-01	1.0103	14.360	253.15	253.15	4.9420
1203.67A	02.0.262	0.62456	0.62456	0.62456	0.59097E-01	0.90726	14.360	254.92	254.92	4.4260
1509.0UA	02.0.262	0.62457	0.62457	0.62457	0.46617E-01	0.81355	14.360	255.37	255.37	3.4814
1427.00A	02.0.260	0.62458	0.62458	0.62458	0.42181E-01	0.70741	14.360	256.05	256.05	3.4264
1525.0UA	02.0.262	0.62431	0.62431	0.62431	0.36583E-01	0.61354	14.360	256.20	256.20	4.9869
1045.03A	02.0.279	0.62432	0.72010	0.62432	0.30600E-01	0.51319	14.360	259.07	259.07	2.5061
1739.00A	02.0.278	0.62474	0.62474	0.62474	0.24356E-01	0.40851	14.360	259.93	259.93	1.9546
1842.00A	02.0.278	0.62466	0.62466	0.62466	0.49894	0.49894	14.360	259.93	259.93	1.9546
2400.07A	02.0.276	0.62476	0.62476	0.62476	0.72327E-01	1.2130	14.360	444.43	444.43	1.6911
2149.00A	02.0.279	0.62424	0.62424	0.62424	0.65863E-01	1.1049	14.360	449.05	449.05	1.1927
2325.00A	02.0.276	0.62476	0.62476	0.62476	0.59962E-01	1.0056	14.360	451.94	451.94	0.5476
2444.00A	02.0.275	0.62473	0.62473	0.62473	0.54254E-01	0.90989	14.360	455.70	455.70	0.5236
2595.03A	02.0.276	0.62464	0.62464	0.62464	0.48346E-01	0.81081	14.360	463.90	463.90	1.2971
2740.00A	02.0.276	0.62464	0.62464	0.62464	0.41960E-01	0.70371	14.360	465.76	465.76	0.5913
2612.00A	02.0.276	0.62465	0.62465	0.62465	0.36240E-01	0.60778	14.360	466.24	466.24	2.2626
2916.00A	02.0.274	0.62418	0.62418	0.62418	0.30436E-01	0.51044	14.360	464.79	464.79	3.3324
3060.00A	02.0.275	0.62402	0.62402	0.62402	0.23872E-01	0.40055	14.360	464.67	464.67	0.6173
3105.00A	02.0.274	0.62412	0.62412	0.62412	0.16370E-01	0.30808	14.360	465.56	465.56	0.0165
3555.b3A	02.0.276	0.62612	0.62612	0.62612	0.71502E-01	1.11992	14.360	107.57	107.57	50.7600
3612.00A	02.0.273	0.62615	0.62615	0.62615	0.65624E-01	1.1039	14.360	712.76	712.76	6.9511
3755.00A	02.0.271	0.61477	0.6361	0.6361	0.55596E-01	0.99948	14.360	716.39	716.39	6.1405
3893.60A	02.0.271	0.67457	0.67457	0.67457	0.53953E-01	0.90484	14.360	719.33	719.33	7.3705
4048.07A	02.0.209	0.68220	0.68220	0.68220	0.47902E-01	0.80336	14.360	720.09	720.09	0.5584
4104.03A	02.0.205	0.66376	0.66376	0.66376	0.42189E-01	0.70756	14.360	725.85	725.85	5.7524
4271.00A	02.0.267	0.68569	0.68569	0.68569	0.36056E-01	0.60469	14.360	726.33	726.33	4.9100
4391.00A	02.0.268	0.68674	0.68674	0.68674	0.30225E-01	0.50691	14.360	726.59	726.59	4.1326
4500.00A	02.0.206	0.69267	0.69267	0.69267	0.24672E-01	0.40372	14.360	721.02	721.02	2.2941

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 FEB 1984  
TEST 64L007 2-27-84 LOW THRUST PUMP H-C & CAV TESTS

TIME	-23	-101	-102	-103	-104	-105	-106	-107
PUMP DIS	NOZZLE	FLOW		TURB AVL	C SUBO	TURBINE		TURB AYL
HEAD	FLUVRATE	NUZZLE	PARAM	ENERGY	ISEN VEL	MEAN VEL	ENER PIP	BTU/LBM
COLF	(LB/SEC)	PR RATIO	BTU/LBM	FT/S	FT/S	FT/S	BTU/LBM	
24.00A	.46733	.11961	.97090E-01	2.0645	2.0655	3.65.31	76.044	2.8815
501.50A	.46739	.12565	.93676E-01	2.1084	2.0456	3.64.25	76.034	2.6511
609.67A	.49306	.12509	.93937E-01	2.1029	2.0573	3.63.38	75.732	2.8965
962.00A	.49242	.20415	.72757E-01	2.7002	5.4344	521.65	153.57	5.6016
1097.00A	.49705	.20093	.73244E-01	2.6631	5.3854	519.31	153.64	5.7584
1203.67A	.49992	.19021	.73603E-01	2.6699	5.2929	514.81	153.62	5.6544
1309.00A	.50361	.19541	.74132E-01	2.6536	5.234	511.45	153.56	5.6001
1427.00A	.50567	.15272	.74583E-01	2.6562	5.1882	509.69	153.35	5.5241
1523.50A	.50626	.16966	.75148E-01	2.6162	5.1540	508.01	153.45	5.4787
1613.83A	.50637	.16676	.75140E-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	.50642	.18185	.76753E-01	2.5647	4.9017	495.42	153.35	5.2243
2086.67A	.45574	.27035	.67092E-01	2.9169	7.1803	599.61	204.31	7.6038
2196.00A	.50090	.26514	.67462E-01	2.9066	7.0960	596.17	204.44	7.5203
2325.00A	.50284	.26004	.67793E-01	2.6803	7.0165	592.74	204.46	7.4135
2442.00A	.50521	.25616	.68147E-01	2.8725	6.5339	585.23	204.21	7.3202
2595.83A	.51237	.25190	.66512E-01	2.8660	6.8400	585.23	205.17	7.2423
2710.00A	.51352	.24648	.68926E-01	2.8411	6.6751	578.13	204.9	7.0453
2812.00A	.51664	.24159	.69328E-01	2.8422	6.6433	576.75	204.77	7.0097
2916.00A	.51363	.23645	.69089E-01	2.8040	6.4606	568.76	205.03	6.8322
3006.50A	.51221	.23146	.70463E-01	2.7623	6.3743	564.96	205.31	6.7420
3105.00A	.51436	.24286	.71022E-01	2.7648	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	.64130E-01	3.0367	8.5076	652.69	255.96	8.9407
3799.00A	.51035	.24759	.64446E-01	2.0253	8.4677	651.16	255.79	6.6974
3893.00A	.51074	.34027	.64705E-01	3.0110	6.3966	648.41	255.82	8.8148
4048.67A	.51695	.33213	.64930E-01	3.007	8.2169	641.44	255.42	8.6206
4164.83A	.51714	.32532	.65249E-01	2.9895	8.1264	637.20	255.31	8.5355
4271.00A	.51629	.31747	.65546E-01	2.9765	8.0219	633.78	255.42	8.4375
4391.00A	.51442	.30975	.65599E-01	2.9506	7.8950	628.75	256.05	8.2885
4508.00A	.51364	.30160	.66473E-01	2.9524	7.8265	626.01	256.30	8.2231

SECTION A1

TEST 64L007 TEST DATE 27 FEB 1984 PROCESS DATE 5 NOV 1984 PAGE 5  
 LSII 64L007 4-27-84 LOW THRUST PUMP H-C & CAV TESTS

TIME	-21	-115	6	14	105	-22	1	6
PUMP JCT	TURBINE	PUMP INL	PUMP OUT	TURBINE	PUMP INL	PUMP INL	PUMP INL	PUMP DIS
(F1)	PRESSURE	ET TEMP	ET TEMP	INLET TIE	FLW	ET PRESS	ET PRESS	PRESS
(PSIG)	(PSIG)	(F)	(F)	MP	COEF	(PSIG)	(PSIG)	(PSIG)
24.00A	56.309	1.0707	71.120	71.802	54.767	24690E-01	35.043	61.291
501.50A	60.804	1.0726	69.520	69.520	34.067	19362E-01	35.193	61.557
609.67A	61.025	1.0790	69.644	69.667	34.005	26618E-01	34.393	142.52
962.00A	250.63	1.1701	65.496	70.213	34.302	26496E-01	34.508	143.80
1097.00A	253.24	1.1680	65.540	70.650	40.514	23590E-01	34.746	144.68
1203.67A	254.63	1.1645	69.742	70.852	41.400	21543E-01	34.813	145.51
1305.00A	256.30	1.1661	92.093	70.754	41.499	19361E-01	34.555	145.84
1427.00A	256.06	1.1610	69.288	71.000	41.255	16797E-01	35.310	146.49
1523.50A	257.26	1.1598	69.792	71.550	41.255	14568E-01	35.296	146.61
1613.00A	257.54	1.1502	70.430	71.767	40.557	12166E-01	35.191	145.51
1734.00A	255.20	1.1554	70.283	72.279	40.071	97000E-02	35.254	145.08
1842.00A	254.01	1.1518	70.234	73.016	35.579	26602E-01	33.756	226.42
2060.00A	446.65	1.2236	70.422	71.344	37.168	26236E-01	34.037	229.05
2196.00A	451.66	1.2302	70.136	71.635	36.102	23879E-01	34.167	230.09
2325.00A	453.76	1.2272	70.463	71.855	36.054	21605E-01	34.367	231.89
2442.00A	457.35	1.2245	70.628	72.219	37.512	19253E-01	34.498	235.59
2592.00A	465.51	1.2213	70.529	72.328	36.922	16710E-01	34.722	235.73
2710.00A	465.17	1.2155	70.524	72.467	36.526	14432E-01	34.833	237.01
2812.00A	461.55	1.2145	70.575	73.495	36.183	12120E-01	35.019	236.46
2916.00A	466.60	1.2080	70.775	74.049	35.888	95.064E-02	35.248	236.72
3000.00A	466.04	1.2059	70.720	74.934	35.544	75.153E-02	35.348	236.26
3105.00A	464.06	1.2016	70.674	76.066	35.297	26474E-01	33.102	339.75
3556.00A	710.64	1.2895	70.579	72.916	37.020	26213E-01	33.066	342.31
3602.00A	715.37	1.2844	70.523	73.410	37.217	23733E-01	33.066	344.96
3712.00A	720.69	1.2835	71.648	73.705	36.183	21465E-01	34.159	345.66
3833.00A	721.40	1.2817	71.216	73.852	34.767	19076E-01	34.540	346.97
4046.00A	727.53	1.2755	71.048	74.492	33.034	16801E-01	35.232	349.55
4164.00A	727.50	1.2732	71.513	75.229	31.508	14358E-01	35.735	351.11
4271.00A	729.00	1.2696	71.710	75.771	30.474	12056E-01	36.136	350.77
4351.00A	727.93	1.2654	71.612	76.652	29.007	12056E-02	36.346	351.15
4504.00A	728.03	1.2631	71.307	78.082	22.047	45863E-02	36.346	

### SECTION A1

**PUMP CALIBRATION TEST FACILITY**  
**TEST 84L007 TEST DATE 27 FEB 1984 PROCESS DATE 9 NCV 1984**  
**TEST 84L007 4-27-84 LUM THRUS1 PUMP H-Q L CAV 1LSIS**

TIME	16		19		20		21		22		23		24		25		26		27	
	VOLUME P KES5 CDE G(PSIG)	VOLUME P RES 900 E(G(PSIG))	VOLUME P RES 1600 E(G(PSIG))	DIF IN PRESS 1 R (PSIG)	FRONT WR RING UP	FRONT WR RING UP	REAR WR RING UP	REAR WR RING UP												
24.000	59.044	60.434	61.916	60.026	62.435	59.791	53.072	53.191	34.443								34.592			
501.50A	60.434	60.957	62.493	61.004	62.469	60.151	53.986	54.130	34.725								34.406			
609.67A	60.957	62.493	64.150	59.625	63.862	53.94	106.33	107.04									35.522			
962.00A	136.422	139.677	142.50	140.47	135.07	124.43	106.92	107.41									35.522			
1097.00A	139.677	141.34	143.61	141.27	140.19	135.30	107.52	108.09									35.772			
1203.67A	141.34	144.57	145.05	144.95	141.95	126.35	108.40	109.11									35.938			
1427.00A	144.57	144.53	145.69	144.95	142.69	135.89	108.11	108.75									36.120			
1523.50A	144.53	146.52	146.15	146.51	141.62	135.89	108.66	109.85									36.552			
1427.00A	144.57	144.53	145.69	144.95	142.69	136.86	108.66	109.85									36.552			
1613.63A	144.97	146.80	146.15	146.51	143.76	137.47	109.38	110.55									36.752			
1734.00A	143.52	143.91	144.80	141.72	142.62	136.61	109.27	111.05									36.735			
1842.00A	143.91	144.10	144.93	140.93	142.33	136.61	109.91	111.81									37.106			
2086.67A	216.71	223.19	220.98	217.74	209.95	159.25	159.25	159.63									36.386			
2196.00A	222.13	225.65	223.11	226.14	221.20	160.44	160.38	160.38									36.802			
2325.00A	224.06	226.66	224.23	221.30	211.93	160.99	160.67	160.67									37.117			
2442.00A	226.62	229.15	226.46	223.68	215.60	162.14	162.14	162.14									37.363			
2595.63A	230.99	233.52	232.07	231.76	215.78	163.61	163.61	163.61									37.698			
2710.00A	231.69	234.06	232.71	232.35	215.61	163.69	162.20	162.20									38.061			
2812.00A	233.87	235.35	233.90	233.95	216.60	164.60	163.20	163.20									38.429			
2916.00A	235.84	237.35	233.93	233.79	216.27	164.68	163.43	163.43									38.926			
3006.50A	234.62	235.64	234.44	234.79	217.15	165.83	164.64	164.64									39.343			
3105.00A	234.58	235.37	234.08	234.33	217.22	166.45	165.35	165.35									39.574			
3258.83A	320.91	322.57	322.68	329.94	309.42	227.18	222.99	222.99									38.064			
3682.00A	331.26	330.45	330.42	333.03	311.88	228.87	224.62	224.62									36.695			
3799.00A	335.25	332.67	336.72	335.17	312.05	229.88	225.74	225.74									39.127			
3893.00A	337.77	340.95	340.64	337.25	314.10	231.07	227.02	227.02									39.625			
4046.61A	342.23	344.68	343.12	335.94	315.67	232.31	228.71	228.71									40.406			
4164.83A	343.51	345.17	344.41	341.29	315.78	233.10	230.37	230.37									41.170			
4271.00A	346.11	347.15	346.70	343.98	317.76	234.91	232.62	232.62									42.206			
4391.00A	346.78	347.74	346.97	344.36	316.19	235.56	233.65	233.65									42.981			
4508.00A	347.81	348.27	347.90	345.41	316.91	237.03	234.99	234.99									43.761			

TEST 64007 TLSI 64007 PUMP CALIBRATION TEST FACILITY  
TEST DATE 2-7-84 FLB 1984 PROCESS DATE 5 NOV 1984  
TUMPLUMPH-6 CAV TESTS

TEST B4 LOG TEST DATE 27 FEB 1984 TEST LOCATION 100' ACCL. PROCESS DATE 5 NOV 1984 PAGE 7

TIME	3t		IMP HS 1		IMP REAK		TURB IN		LURG NCZ		ROTUR QU	
	TP	PK	TP PR		STATIC P		IN PK		T TIP PR		(PSIG)	
			(PSIG)	(PSIG)	K	(PSIG)	K	(PSIG)	T	PR	(PSIG)	(PSIG)
24.000A	37.555		57.635		3.3689		3.3681		1.9079			
501.50A	38.342		58.397		3.4345		3.4205		1.9710			
600.67A	38.059		58.029		3.4165		3.0719		1.9268			
502.00A	124.028		126.68		6.2569		6.2867		4.7335			
1057.00A	125.550		127.43		8.1557		8.0525		4.6073			
1203.07A	130.060		128.13		7.9741		7.9160		4.5127			
1309.00A	131.119		128.89		7.8138		7.7463		4.3613			
1427.00A	131.000		129.22		7.6175		7.5746		4.2667			
1543.50A	132.31		130.00		7.4310		7.3534		4.1343			
1611.00A	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			
2066.07A	131.93		136.20		13.462		13.335		7.0284			
2196.00A	203.06		197.62		13.047		12.961		7.3761			
2345.00A	207.19		198.07		12.645		12.625		7.1554			
2442.00A	205.24		199.81		12.357		12.257		6.9299			
2595.00A	207.97		201.15		12.050		11.954		6.7644			
2710.00A	206.26		201.73		11.598		11.547		6.4931			
2812.00A	205.47		202.01		11.1244		11.114		6.2850			
2916.00A	209.00		202.89		10.661		10.660		6.0390			
3066.50A	210.15		204.29		10.513		10.457		5.8120			
3165.00A	210.37		204.79		10.194		10.130		5.6165			
3556.63A	297.05		285.00		21.416		21.308		12.426			
3012.00A	259.75		287.61		20.718		20.622		11.967			
3722.00A	301.44		289.42		20.032		19.936		11.526			
3693.00A	302.74		290.66		19.409		19.324		11.129			
4646.67A	304.37		292.53		18.767		18.656		10.715			
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	305.56		298.04		16.066		15.996		9.0160			

SECTION A

TEST 84L607 TEST DATE 27 Feb 1984 PROCESS DATE 9 NOV 1984  
 TEST 84L607 PUMP CALIBRATION TEST FACILITY  
 TEST 84L607 <--> 7-34 LOW THRUST PUMP H-4 & CAV TESTS PAGE 11

TIME	SHATL SP.	PUMP TUL.	PUMP DIS.	FLWN	PUMP SCA.	PUMP SCA.	PUMP SCA.	PUMP SCA.
LID	HEADSL (FT)	FLWN (GPM)	DIS. FLWN (GPM)	LED HEAD RISE (FT)	LED FLOW (GPM)	HYD. PWR. HP	HYD. PWR. HP	
240.00A	7201.7	60.604	1.0444	1.2449	692.40	5.1969	23635t-01	27125t-01
501.50A	7260.7	61.025	1.05407	1.0356	692.40	5.1969	23635t-01	27125t-01
609.67A	7231.9	50.625	1.2035	61542	700.53	4.0771	18529E-01	22807
762.00A	14004.0	250.65	3.0005	1.2052	692.01	6.0260	2.1345	2.1345
1047.00A	14071.0	253.24	3.3409	1.1156	706.24	5.5792	1.9430	1.9430
-1203.67A	14069.0	154.63	3.0247	1.0103	710.27	5.0117	1.7556	1.7556
-1304.00A	14084.0	256.20	2.1150	9072.6	710.52	4.5363	1.5780	1.5780
1427.00A	14644.0	456.06	2.4308	61555	718.44	4.0768	1.3731	1.3731
1523.50A	14053.0	27.20	2.1154	70741	719.27	3.5370	1.1425	1.1425
1613.63A	14059.0	237.54	3.0294	61354	719.43	3.0677	96747t-01	96747t-01
1734.00A	14645.0	255.20	1.0538	51319	714.20	2.5660	78233t-01	78233t-01
1842.00A	14644.0	254.01	1.2209	40651	710.98	2.0425	544414	544414
2196.00A	19510.0	446.65	4.6297	1.150	706.33	6.0649	50162	50162
2325.00A	19523.0	451.6	4.7022	1.1049	711.67	5.5246	45674	45674
2325.00A	19526.0	453.76	4.6074	1.0056	714.41	5.0281	41903	41903
2442.00A	19538.0	47.35	3.6517	90689	711.76	4.5494	38072	38072
2595.63A	19593.0	465.51	3.2420	61081	727.95	4.0541	32975	32975
2710.00A	19507.0	465.17	2.8100	70371	725.31	3.5185	2.6606	2.6606
2812.00A	19554.0	367.55	6.6257	60778	724.06	3.0385	90571	90571
2916.00A	19579.0	466.00	2.0346	51044	729.74	2.5522	18631	18631
3006.50A	19608.0	466.01	1.6019	46055	727.72	2.0018	14426	14426
3105.00A	19575.0	464.66	1.2306	30806	727.86	1.5404	1.0721	1.0721
350b.63A	24431.0	710.84	5.4766	1.1992	714.91	5.9958	5.5197	5.5197
500c.00A	24442.0	710.37	5.5066	1.1034	718.79	5.99367	5.99367	5.99367
3722.00A	24546.0	726.09	5.5262	99446	725.09	4.9974	82085	82085
3893.00A	24429.0	721.40	4.5110	90464	725.64	4.5242	73425	73425
4046.67A	24391.0	724.93	5.9450	60336	734.47	4.0168	64601	64601
4164.63A	24381.0	727.50	3.5405	70756	734.70	3.5376	55407	55407
4271.00A	24391.0	729.60	3.0100	60465	736.37	3.0234	46442	46442
4391.00A	24451.0	727.53	2.5244	50691	730.67	2.5345	37036	37036
4506.00A	24475.0	726.23	2.0165	40372	729.75	2.0186		

SECTION A1

TEST 84L012

PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 NOV 1984 PROCESS DATE 9 NOV 1984  
TEST 84L012 1-26-1984 JUN THRUST PUMP HQ-LAY JESIS

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
8	INLET AREA AT PRESS TAP, SQ. IN	7.35000E-01
10	ANNU/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 THRUST DIAMETER, IN	1.91000E-01
93	NOZZLE CFS/CH COEFF	9.85000E-01
94	SPEC. HT. RATIC	1.40000E+00
95	MW/LB OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN <sup>2</sup>	5.54000E-01
98	TURB PIPE IN. DIAMETER, IN	1.61000E+00
99	PERCENT TURBINE ADMISSION	1.00000E+02

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OF POOR QUALITY

PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 MAR 1984  
TEST 34L012, 26-1384 LUN THRUST PUMP HQ & LAV TESTS

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TIME	PUMP STA	PUMP DIS	AFTER	VAPOR	PUMP IGT	PUMP LIN.	PUMP DIS	INLET
RELATIA	VELOCITY	SP.WGT.	HEAD	HEADRISE	FLOW	HEAD	COEF	VELOCITY
HLAU FT	(FPS)	LBM/FT <sup>3</sup>	(FT)	(FT)	COEF	COEF	(PSI)	(FPS)
21.50A	4.2802	1.2*254	62.225	1.0583	-1.3326	.36384E-01	-97880E-03	3.0550
332.00A	02.705	2.9352	62.266	.88652	62.874	.28344E-01	.48896	.73367
143.00A	62.359	2.5044	62.266	.89396	62.682	.24240E-01	.48995	.62643
885.50A	03.428	1.9644	62.266	.89545	63.403	.19077E-01	.49953	.49134
1109.50A	264.42	5.8686	62.265	.89696	65.049	.28391E-01	.51693	1.4679
1212.00A	265.30	5.4021	62.263	.90448	65.47	.20198E-01	.52096	1.3512
1302.50A	269.00	4.9763	62.264	.90146	66.49	.24125E-01	.52181	1.2447
1390.50A	267.5d	4.4303	62.262	.91052	67.96	.21470E-01	.52427	1.1081
1207.50A	266.0d	3.9903	62.261	.91356	66.92	.19364E-01	.52369	.9808
1006.50A	265.62	3.4433	62.260	.91663	65.85	.16638E-01	.52028	.6127
1694.00A	266.39	2.9989	62.259	.91569	66.57	.14543E-01	.52226	.75011
1650.50A	265.02	2.5573	62.251	.92891	65.94	.12309E-01	.52144	.03465
492.50A	243.85	2.0016	62.256	.93206	63.97	.97099E-02	.51755	.20067
2190.50A	474.01	7.8258	52.251	.95236	475.22	.28397E-01	.52132	1.1574
2212.50A	476.71	7.2141	52.247	.96194	477.13	.26183E-01	.52432	1.8044
2306.50A	477.09	6.9132	62.245	.97474	478.84	.24000E-01	.52541	1.9541
2450.00A	477.98	5.9423	62.243	.96279	478.07	.21509E-01	.52428	1.4838
2550.50A	477.21	5.2652	32.242	.99421	478.11	.19150E-01	.52696	1.3170
2634.00A	478.28	4.5391	62.239	.99915	478.99	.16686E-01	.52533	1.1503
2729.00A	478.13	3.9844	32.236	1.0108	478.45	.1453E-01	.52448	.9061
2820.50A	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	.65246
3059.50A	472.60	1.97840	62.230	1.0343	472.67	.71990E-02	.51851	.49625
3119.50A	739.61	9.7512	62.212	1.1396	741.48	.28482E-01	.52705	2.4390
3255.00A	742.51	9.0226	62.203	1.1403	744.57	.26337E-01	.52742	2.2593
3634.50A	744.25	8.1923	52.201	1.1256	745.57	.23921E-01	.52963	2.0491
3745.50A	747.18	7.4167	62.193	1.1897	748.26	.21645E-01	.53104	1.4551
3847.50A	747.75	6.2794	62.186	1.2169	748.04	.19193E-01	.53083	1.6457
3952.00A	744.82	5.7479	62.181	1.2385	744.47	.16771E-01	.52803	1.4377
4037.50A	743.17	4.8568	62.175	1.2505	744.24	.14295E-01	.52847	1.2248
4110.50A	740.03	4.1232	62.177	1.2586	740.37	.12020E-01	.52476	1.0313
4221.50A	740.25	3.7271	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
4492.00A	734.93	1.1000	62.168	1.2974	734.99	.49597E-02	.52133	.42221

SECTION A2

PUMP CALIBRATION TEST FACILITY  
TEST BOROLE 1-26-1984  
TEST DATE 27 MAR 1984  
PROCESSES DATE 2 NUV 1984  
THRUST PUMP HQ & CAV TESTS

TIME	-6	-101	-102	-103	-104	-105	-106	-107
PRESS	AMBIENT	NOZZLE	FLOW	TURB	AVL	C SUB	TURBINE	TURB
4PSIA	FLW RATE	PR	PARAM	ENERGY	ISEN VEL	MEAN VEL	ENKE PIP	AVL
41.50A	14.249	*92315E-04	*98349	*20161	*30387E-01	52.378	251.15	*30135E-01
532.00A	14.249	*1741	*94593E-01	2.1125	2.6837	366.47	77.164	2.9375
745.00A	14.249	*11960	*93386E-01	2.1327	2.6807	366.32	77.033	2.9481
882.50A	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	54.037	154.14	6.2384
1212.00A	14.249	*19325	*70141E-01	2.8134	5.7790	537.93	153.77	6.1852
1302.50A	14.249	*19219	*70276E-01	2.8063	5.7590	536.99	153.82	6.1733
1340.50A	14.249	*18952	*70374E-01	2.7882	5.6432	531.57	153.88	6.0609
1407.50A	14.249	*18838	*71070E-01	2.7771	5.5953	529.31	153.67	5.9740
1506.50A	14.249	*18557	*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
1856.50A	14.249	*18044	*72624E-01	2.7202	5.3646	518.28	153.72	5.7533
1992.50A	14.249	*17956	*72953E-01	2.7107	5.3348	516.83	153.73	5.7030
2190.00A	14.249	*24971	*63585E-01	3.0935	8.0264	633.96	205.91	8.5237
2272.50A	14.249	*24679	*63792E-01	3.0893	8.0354	634.32	205.46	8.5133
2366.50A	14.249	*24413	*64009E-01	3.0707	7.9415	630.60	202.48	8.4141
2450.00A	14.249	*24078	*64359E-01	3.0560	7.8276	626.06	205.48	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	*23096	*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	*66450E-01	2.9657	7.3193	605.39	205.32	7.7340
3029.50A	14.249	*22101	*66680E-01	2.9523	7.1888	599.97	205.51	7.6202
3419.50A	14.249	*32049	*59835E-01	3.2999	10.223	715.47	255.31	10.731
3532.50A	14.249	*31367	*60015E-01	3.2577	10.100	711.16	255.75	10.600
3634.50A	14.249	*31093	*60190E-01	2.2476	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	3.2245	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
4119.50A	14.249	*28696	*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
4449.50A	14.249	*26975	*62700E-01	3.1300	8.8925	667.29	255.60	9.3872

## TEST 84L012

TEST 84L012, 3-26-1984 LUM THRUST PUMP HQ &amp; CAV TESTS

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 21 MAR 1984  
PROCESS DATE 9 NOV 1984

TIME	SHAFT SP LED	PUMP TOT (RPM)	HEURIST (F/F)	PUMP DIS FLU <sub>m</sub> (GPM)	PUMP SCA LED FLOW (GPM)	PUMP SCA LED HEAD RISE (FT)	PUMP SCA LED FLOW (GPM)	PUMP P HYD PWR HP	PUMP P HYD PWR HP
-21.50A	43.983.	-1368.0	-1.312.	1.4299	1.4299	5.97	6.94.7	.28495E-01	
-532.00A	7356.1	62.874	1.1932	5.5328	5.5328	5.19	6.96.1	.24253E-01	
742.00A	631.4	62.682	1.2023	4.92	4.92	769.7	.19229E-01		
845.50A	1471.9	63.403	3.5749	5.98	5.98	734.5	.24016		
1109.50A	14584.	265.87	3.3503	5.52	5.52	740.2	.22171		
1212.00A	14989.	266.42	3.0457	5.98	5.98	741.4	.20471		
1312.20A	14992.	257.96	2.7115	4.52	4.52	744.9	.16326		
1390.50A	14395.	265.92	2.4422	4.08	4.08	744.0	.16440		
1557.50A	14674.	255.85	2.1075	3.51	3.51	739.2	.14130		
1600.50A	14894.	266.57	1.8325	3.06	3.06	742.6	.12340		
1694.00A	14508.	265.94	1.5529	2.59	2.59	740.9	.10416		
1856.50A	14679.	265.97	1.2291	2.04	2.04	735.3	.81558E-01		
1962.50A	14680.	475.22	4.7597	5.98	5.98	740.7	.57396		
2140.00A	19625.	477.73	4.4153	5.51	5.51	744.9	.53189		
2212.50A	19320.	478.84	4.0775	5.05	5.05	746.5	.48869		
2300.50A	19622.	478.67	3.6508	4.53	4.53	744.9	.43821		
2450.00A	19591.	478.11	3.2225	4.63	4.63	748.7	.38844		
2520.50A	19579.	479.99	2.8148	3.51	3.51	746.4	.33992		
2624.00A	19627.	470.42	2.4386	3.04	3.04	745.2	.29414		
2729.00A	19032.	470.42	2.0145	2.54	2.54	740.3	.24415		
2830.50A	19545.	476.02	1.6049	2.01	2.01	742.5	.19236		
2949.50A	19607.	475.49	1.2143	1.52	1.52	736.7	.14468		
3059.50A	19525.	472.67	5.9681	6.00	6.00	748.8	.11132		
3419.50A	24380.	741.48	5.5203	5.55	5.55	749.3	.10371		
3555.00A	24422.	744.57	5.0140	5.04	5.04	752.5	.94184		
3634.50A	24388.	745.27	4.5393	4.56	4.56	754.5	.85567		
3745.50A	24400.	746.26	4.0208	4.04	4.04	754.2	.75938		
3817.50A	24414.	748.67	3.5179	3.53	3.53	750.2	.65968		
3952.00A	24406.	744.47	2.9970	3.61	3.61	750.8	.56180		
4051.50A	24393.	744.24	2.5236	2.53	2.53	745.5	.47057		
4116.50A	24415.	740.50	2.0027	2.01	2.01	744.6	.37350		
4221.50A	24434.	726.27	1.5406	1.55	1.55	742.6	.28676		
4221.50A	24396.	734.93	1.0594	1.04	1.04	740.7	.19657		
4473.00A	24408.	734.93							

SECTION A2

TEST 84LO12		TEST DATE 27 MAR 1984		PUMP CALIBRATION TEST FACILITY		PROCESS DATE 9 NOV 1984		PAGE 31	
TEST 84LO12		TEST 3-26-1984 LOH THRUST PUMP HQ & CAV TESTS							
LINE	TIME	TURB TESTER	TURB TESTER	TURB TESTER	TURB TESTER	TURB TESTER	EQUIP WORK	ACTUAL PUMP EFF	
		EFF	WHRK	HP	BTU/LB	BTU/LB	BTU/LB	BTU/LB	
21.50A	-231.65E+07	-713.79.	-934.75	-2456.6	-664.12.	-1426.1E-05	-194	-195	
532.50A	-4.6105	1.2367	.20502	1.7279	1.2463	1.3d48			
743.50A	-6.6051	1.2345	.20914	1.7910	1.2603	1.11581			
635.50A	-6.6134	1.2226	.20604	1.708	1.2518	.93220E-01			
1109.50A	-5.5989	3.3233	.91462	3.9162	3.4527	.26258			
1212.50A	-5.5706	3.2979	.90184	3.8708	3.4323	.24584			
1302.50A	-5.5714	3.2910	.89497	3.8430	3.4265	.22874			
1390.50A	-5.7545	3.2474	.87087	3.7351	3.3801	.21043			
1507.50A	-5.7655	3.2257	.85989	3.6931	3.3588	.19120			
1606.50A	-5.7950	3.2005	.84023	3.6052	3.3313	.16811			
1694.50A	-5.8039	3.1868	.82921	3.5586	3.3146	.14882			
1856.50A	-5.8464	3.1364	.80307	3.4478	3.2589	.12969			
1902.50A	-5.8573	3.1246	.79394	3.4084	3.2417	.10272			
2190.00A	-6.1815	4.9614	1.7531	5.6300	5.1811	.32740			
2272.50A	-6.1785	4.1646	1.7351	5.5734	5.1760	.30654			
2366.50A	-6.2007	4.9243	1.7011	5.4638	5.1297	.28728			
2450.00A	-6.2305	4.8773	1.6617	5.3322	5.0765	.26371			
2530.50A	-6.2456	4.8124	1.6141	5.1958	5.0054	.24068			
2634.00A	-6.2721	4.7942	1.5888	5.1017	4.9871	.21395			
2729.50A	-6.3055	4.7352	1.5477	4.9684	4.9242	.19007			
2830.50A	-6.3314	4.6942	1.5109	4.8468	4.8835	.16159			
2946.50A	-6.3474	4.6458	1.4717	4.7308	4.8337	.13070			
3059.50A	-6.3832	4.5888	1.4350	4.6885	4.7743	.10082			
3419.50A	-6.6270	6.6125	3.0251	7.8202	7.0461	.36865			
3592.50A	-6.6536	6.6191	2.9566	7.6300	6.9933	.35081			
3634.50A	-6.6688	6.5928	2.8875	7.4621	6.9324	.332622			
3745.50A	-6.6838	6.5200	2.8217	7.4084	6.8728	.30326			
3847.50A	-6.6111	6.4999	2.7462	7.0902	6.7909	.21655			
3952.50A	-6.6323	6.3825	2.6672	6.8376	6.7252	.24733			
4037.50A	-6.6434	6.3288	2.5992	6.7153	6.6678	.21615			
4116.50A	-6.6837	6.2357	2.5241	6.5158	6.5630	.18644			
4221.50A	-6.7093	6.1693	2.4467	6.3108	6.4877	.15267			
4321.50A	-6.7364	6.0666	2.3539	6.0935	6.3845	.12158			
4425.50A	-6.7517	6.0092	2.2938	5.9230	6.3129	.03956E-01			

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TEST 84L012

PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 MAR 1984  
PROCESS DATE 9 NOV 1984  
TEST 84L012, 3-26-1984, LUM, INKUSI, PUMP Hq & CAV TESTS

PAGE 9

TIME	-15	-115	6	14	105	106	1	8
IMPELLER COEF	IN FLOW	JURBINE PRESSURE	PUMP LINL EI TEMP	PUMP OUT EI TEMP	TURBINE INLET MP (F)	TURBINE OUTLET MP (F)	PUMP INL ET PRESS	PUMP DIS PRESS
21.50A	.91366E-01	.99920	76.871	77.610	78.308	76.682	35.206	33.419
22.00A	.71177E-01	1.0800	71.005	71.844	37.506	39.726	29.493	56.612
22.50A	.60870E-01	1.0810	71.051	71.942	31.188	32.197	28.429	55.483
23.00A	.47906E-01	1.0803	71.900	72.189	29.760	29.638	28.231	55.615
23.50A	.41395E-01	1.1911	71.949	72.830	22.669	10.348	25.752	140.10
24.00A	.712495E-01	1.1911	71.949	72.830	22.669	10.348	25.644	140.37
24.50A	.65786E-01	1.1895	72.195	73.027	21.832	8.1335	25.644	140.37
25.00A	.60581E-01	1.1889	72.097	73.421	21.635	7.5430	25.672	140.70
25.50A	.53913E-01	1.1846	72.392	73.667	21.783	7.3954	25.845	141.55
26.00A	.48625E-01	1.1829	72.420	73.963	21.635	7.3954	25.835	141.11
26.50A	.41906E-01	1.1802	72.569	74.308	21.783	7.8383	25.065	140.91
27.00A	.36519E-01	1.1789	72.687	74.702	22.128	8.1827	26.265	141.45
27.50A	.30910E-01	1.1742	72.983	75.294	22.620	8.6256	26.420	141.35
28.00A	.243683E-01	1.1728	73.081	75.934	23.359	9.4130	26.872	140.96
28.50A	.71308E-01	1.2707	72.721	72.146	20.207	-4.5132	23.496	228.44
29.00A	.62750E-01	1.2766	74.016	75.639	20.995	-4.3656	23.869	229.97
29.50A	.60267E-01	1.2725	74.410	76.184	21.589	-3.9719	24.280	230.91
30.00A	.54012E-01	1.2677	74.656	76.723	21.783	-3.4306	24.789	231.41
30.50A	.48089E-01	1.2625	75.001	77.166	22.128	-2.7909	25.163	231.59
31.00A	.41902E-01	1.2603	75.148	77.955	22.079	-2.3480	25.664	232.52
31.50A	.36293E-01	1.2549	75.493	78.497	22.226	-1.8959	26.017	232.67
32.00A	.30257E-01	1.2513	75.689	79.384	22.029	-1.6591	26.434	232.07
32.50A	.23915E-01	1.2476	76.132	80.665	21.980	-1.1178	27.041	232.47
33.00A	.18078E-01	1.2426	76.182	82.292	21.980	-9.92096	28.037	232.27
33.50A	.71522E-01	1.3743	78.298	80.370	14.890	-20.851	22.088	341.66
34.00A	.66136E-01	1.3690	79.282	81.454	14.644	-21.195	22.348	343.32
34.50A	.60069E-01	1.3642	79.528	82.439	14.742	-20.801	23.058	344.57
35.00A	.54355E-01	1.3593	80.414	83.129	15.727	-19.916	23.366	346.09
35.50A	.48197E-01	1.3524	81.103	84.312	16.071	-19.128	24.037	346.99
36.00A	.42114E-01	1.3469	81.645	85.248	15.924	-16.390	24.622	345.83
36.50A	.35897E-01	1.3422	81.940	86.135	12.973	-17.898	25.540	346.71
37.00A	.30200E-01	1.3377	82.127	87.515	16.465	-17.209	26.520	346.06
37.50A	.23947E-01	1.3276	82.383	89.043	16.859	-16.077	27.584	347.22
38.00A	.18523E-01	1.3199	82.924	91.704	16.662	-15.684	28.838	346.66
38.50A	.12455E-01	1.3144	83.072	96.090	17.352	-14.355	30.269	347.56

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TEST 64L012 TEST DATE 27 MAR 1984 PROCESS DATE 9 NUV 1984  
TEST 84L012 TEST 3-26-1984 LNU THRUST PUMP HQ & CAV TESTS

TIME	18		19		20		21		34		36		37	
	VOLUME P RES 0C GIPSIG)	VOLUME P RES 90C EGIPSIG)	VOLUME P RES 180C EGIPSIG)	VOLUME P RES 180C EGIPSIG)	VOLUME P RES 2700 EGIPSIG)	VOLUME P RES 2700 EGIPSIG)	VOLUME P RES 2700 EGIPSIG)	VOLUME P RES 2700 EGIPSIG)	FRONT WK R (PSIG)	FRONT WK R (PSIG)	REAR MR R (PSIG)	REAR MR R (PSIG)	REAR MR R (PSIG)	REAR MR R (PSIG)
532.50A	55.255	53.353	52.385	55.828	47.708	47.753	27.710							
743.50A	54.208	52.360	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							
1212.50A	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	29.602							
1507.50A	136.47	122.82	123.29	129.68	97.180	95.222	29.835							
1608.50A	136.38	122.82	123.39	130.03	98.404	95.934	30.167							
1694.50A	137.43	123.36	123.77	130.58	99.776	96.856	30.549							
1856.50A	137.84	122.41	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	138.82	139.97	34.218							
2212.50A	216.41	196.18	198.54	206.26	141.82	141.38	34.683							
2368.50A	218.10	196.09	198.90	207.40	143.50	142.58	35.264							
2420.50A	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							
2654.00A	223.56	197.93	200.59	209.80	150.12	146.69	37.190							
2729.50A	224.40	198.11	200.98	210.34	152.51	147.59	37.672							
2830.50A	225.51	197.80	201.03	210.75	154.84	148.92	38.203							
2946.20A	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	297.92	293.01	302.73	197.22	198.75	40.876							
3222.00A	321.32	288.67	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	330.26	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							
4146.20A	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	341.61	294.28	301.86	315.23	232.19	219.82	52.033							

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 27 MAR 1984  
PROCESS DATE 9 NOV 1984  
TEST 84L012, 3-26-1984, LUM THRUST PUMP Hq & CAV TESTS

TIME	IMP FR T	IMP FR M	IMP REAR	TURB IN	TURB NOZ	KNOX QU	KNOX PR	F TIP PK	F TIP PR
	IP PR	ID PR	TIP PK	STATIC P	IN PR	(PSIG)	(PSIG)	(PSIG)	(PSIG)
21.50A	34.671	34.294	35.601	1063.5E-01	11323E-01	1.5741E-01			
532.00A	51.81d	47.799	52.979	2.401.8	2.3641	1.0986			
743.00A	50.664	46.351	51.321	2.4590	2.4143	1.1301			
885.50A	50.875	47.227	51.937	2.4149	2.3722	1.0734			
1109.50A	115.00	97.307	116.45	6.111.9	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			
1207.50A	116.44	99.650	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	2.3677			
1636.50A	117.64	102.65	119.35	5.4026	5.3338	2.3074			
1962.50A	117.95	103.50	119.96	2.3241	5.2674	2.2685			
2190.00A	181.49	148.40	182.90	9.5720	9.4504	4.1205			
2272.50A	183.03	150.25	184.20	9.3955	9.2945	4.0198			
2306.50A	183.99	151.80	185.02	9.2255	9.1277	3.9663			
2450.00A	184.18	153.37	186.08	9.0327	8.9269	3.8498			
2530.50A	185.67	155.09	186.96	8.8033	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	8.2314	8.1529	3.4784			
2940.50A	189.22	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	207.04	214.13	207.35	14.493	14.306	6.2862			
3555.00A	238.80	216.02	269.07	14.163	14.042	6.0910			
3634.50A	270.05	218.79	270.22	13.820	13.707	5.9148			
3745.50A	270.75	220.21	271.50	13.50	13.393	5.7700			
3847.50A	273.45	223.97	274.07	13.173	13.066	5.6252			
3952.50A	273.50	225.25	274.30	12.777	12.672	5.4426			
4037.50A	274.65	228.55	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	234.01	280.34	11.769	11.676	4.9641			
4321.50A	278.91	236.41	282.24	11.419	11.306	4.8004			
4445.50A	280.90	239.68	285.14	11.105	10.985	4.6305			

SECTION A2

PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 MAR 1984    PROCESS DATE 9 NCV 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 FLCH, RPM	3.92000E+04
19	PUMP DISCHARGE LINE DIAMETER, IN.	5.00000E-01
21	HEAD ELEVATION (FT) CORRECTION FCR 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	WT OF GAS	2.80160E+01
96	TURB MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN <sup>2</sup>	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

SECTION A3

PUMP CALIBRATION TEST FACILITY  
 TEST DATE 15 MAR 1984 PROCESS DATE 9 NOV 1984  
 PAGE 1  
 TEST 84L010 TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	SHAFT SP FED	SP DES FLOW	FLOW / (RPM)	PUMP DIS (GPM)	PUMP JOT (FT)	INLET HEADRISE (FT)	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
13212.58A	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.	1.2050		.72253	48.833		.29528
17664.00A	11685.	1.1739		.65933	78.926		.28600
17986.00A	11704.	1.0370		.61924	131.62		.25307

PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 MAR 1984  
PROCESS DATE 9 NOV 1984  
TEST 84L010 3-14-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	-17	-18	-9	-15	-21	-22	-23
PUMP STA	PUMP DIS	IND IN	IMPELLER	PUMP TOT	PUMP INL	PUMP DIS	
DELTA	VELOCITY	VELOCITY	IN FLOW	HEADRISE	FLOW	HEAD	COEF
HEAD FT	(FPS)	(FPS)	COEF	(FT)	COEF	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	•5876	
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	

SECTION A3

TEST 84L010		TEST 84L010		TEST DATE 15 MAR 1984		PROCESS DATE 9 NOV 1984		PAGE 5	
				3-14-84 LOW THRUST PUMP H-Q & CAV TESTS					
TIME		-101	-102	-103	-104	-105	-106	-107	
	NOZZLE FLOW		NOZZLE FLOW		TURB AVL	CSURO	TURBINE	TURB AVL	
FLOWRATE (LB/SEC)	PR RATIO	PARAM	ENERGY*	ISEN VEL	MEAN VEL	ENER PIP FT/S	BTU/LBM	BTU/LBM	
21.58A 12091.58A 12229.58A 12337.58A 12649.58A 12790.58A 12899.58A 12998.58A 13095.58A 13219.58A 13858.58A 14018.58A 14153.58A 14443.58A 14558.58A 14676.58A 14846.58A 15756.58A 16291.58A 16823.58A 17664.00A 17986.00A	.93901E-02 1.6027 1.5704 .15622 .27255 .26680 .22114 .25586 .25152 .24551 .39394 .39306 .37724 .37163 .36472 .35751 .35308 .38323 .36995 .15158 .15143 .14964	.58372 77616E-01 78455E-01 78652E-01 62144E-01 62594E-01 63075E-01 63522E-01 63943E-01 644932E-01 58193E-01 50246E-01 58502E-01 58725E-01 58958E-01 59222E-01 .59655E-01 .58524E-01 .58837E-01 .80193E-01 .80430E-01 .81003E-01	.20301 2.5637 2.5246 2.5175 3.1515 3.1302 3.1102 3.0844 3.0691 3.0447 3.3414 3.3396 3.3211 3.3144 3.3020 3.2895 3.2674 3.3239 3.3060 2.4679 2.4629 2.4450 31.983E-01 32.608	4.4906 4.2960 4.2184 9.0795 8.9818 8.9132 8.8132 8.6662 8.5377 8.3223 8.3223 12.186 12.233 11.996 11.862 11.747 11.540 11.310 11.943 11.663 4.0910 4.0587 4.0173	474.18 463.79 459.60 674.27 670.62 664.31 664.31 658.74 653.84 645.53 781.14 782.66 775.02 770.70 766.93 760.15 752.54 773.33 764.15 452.50 450.71 448.37	122.96 122.40 121.92 244.95 244.92 244.96 244.96 245.05 244.92 244.63 303.39 303.65 303.47 303.49 303.39 303.42 303.42 303.34 303.10 122.66 122.36 122.57	4.8304 4.6225 4.5713 9.5424 9.4393 9.2885 9.0827 8.9717 8.7626 12.689 12.742 12.489 12.346 12.222 12.019 11.792 12.430 12.139 4.3972 4.3605 4.3157		

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## TEST 84L010

TEST DATE 15 MAR 1984

3-14-84

LOW THRUST PUMP H-G &amp; CAV TESTS

PUMP CALIBRATION TEST FACILITY  
PROCESS DATE 9 NCV 1984

PAGE 6

TIME	-6		6		14		105		106		TURBINE		OUTLET T		PUMP INL		PUMP DIS VAPOR		INLET HEAD VELOCITY	
	AMBIENT PRESS (PSIA)	PUMP INL (F)	PUMP OUT (F)	BT TEMP (F)	BT TEMP (F)	TURBINE INLET TEMP MP (F)	TURBINE INLET TEMP MP (F)	TURBINE OUTLET TEMP MP (F)	TURBINE OUTLET TEMP MP (F)	TURBINE PRESS (PSIG)	TURBINE PRESS (PSIG)	TURBINE HEAD (FT)	TURBINE HEAD (FT)	TURBINE PRESS (PSIG)	TURBINE PRESS (PSIG)	TURBINE HEAD (FT)	TURBINE HEAD (FT)	PUMP DIS VAPOR (PSIG)	PUMP DIS VAPOR (PSIG)	INLET HEAD (FT)
21.58A	14.347	75.734	76.765	76.364	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	76.736	2R.131	21.725	34.052														
12337.58A	14.347	74.745	77.792	26.948	19.803	34.448	110.99	98587	15659											
12649.58A	14.347	74.955	79.574	26.751	-4.9364	31.903	202.98	99406	59318											
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	43175											
12998.58A	14.347	75.439	81.939	28.624	-1.9795	33.507	335.52	1.0089	34235											
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	23.359	-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	5476											
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			29528											
17664.00A	14.347	77.824	79.395	25.654	17.643	-4.0471			28600											
17986.00A	14.347	77.805	79.529	26.221	18.283	-4.0517	52.806	1.0917	25307											



PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 MAR 1984  
PROCESS DATE 9 NCV 1984  
PAGE 8

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

TIME	38	40	40	110	114	115
IMP FR T		IMP REAR	TURB IN	ROTOR DU	ROTOR CU	
IP PR		TIP PR	STATIC P	TIP PR	HUR PR	
(PSIG)	(PSIG)	(PSIG)	R (PSIG)	(PSIG)	(PSIG)	
21.58A	35.265	35.932	23725E-31	.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	11.3C6	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	448.34	20.520	8.8851	9.7204	
14018.58A	482.70	458.65	20.458	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.COA	56.151	54.426	3.7724	1.6356	1.7321	

SECTION A3

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TEST 84L004            TEST DATE 10 MAR 1984            PROCESS DATE 9 NOV 1984            PAGE 0  
TEST 84L005, 3-9-1984 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 DISCH TIP DIAMETER, IN	2.00000E+00
9	INLET AREA AT PRESS TAP, SQ. IN	1.85000E-01
10	INUIMP INLET AREA, SQ. IN.	3.12608E-01
11	DESIGN FLOh, 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	NUZZLE INLET DIAMETER, IN	1.00000E+00
92	NUZZLE THROAT DIAMETER, IN	1.91000E-01
93	NUZZLE DISCH COEFF	9.85000E-01
94	SPEC. HT. RATIO	1.40000E+00
95	MWT OF GAS	2.80160E+01
96	TURB MWN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN2	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

SECTION A4

PUMP CALIBRATION TEST FACILITY TEST 84L009 TEST 84L009, 3-9-1984 LOW THRUST PUMP H-Q & CAV TESIS								
TIME	SHFTL SP	FLOW / DES FLOW	PUMP DIS	PUMP TUT	INLET	VELCITY		
EEU	(RPM)	EEU	FLOW	(CPM)	HEADRISE	(FPI)	(FPPS)	
21.50A	-2.95927	1.5321	• 29944E-03	• 65010E-01	• 12258E-03			
941.0UA	-2.0718	• 0	• 0	-1.8766	• 0			
1490.0UA	1419.0	1.1752	1.7786	35.742	• 72689			
1657.00A	1351.5	1.0391	1.5591	36.824	• 63717			
1732.00A	1302.0	• 81476	1.2142	38.451	• 49620			
2011.00A	14716.	1.1530	3.5831	148.94	• 1.4643			
2990.50A	1+703.	1.0694	3.2987	151.90	• 1.3481			
2172.50A	14581.	• 99531	2.9838	455.77	• 1.2194			
2271.50A	14684.	• 88611	2.6524	160.33	• 1.0852			
2343.00A	14696.	• 79416	2.3818	163.73	• 97340			
2421.00A	14676.	• 66709	2.0579	467.74	• 64101			
2540.50A	14685.	• 57629	1.7271	172.40	• 70581			
2624.00A	14690.	• 48652	1.4586	175.10	• 59610			
2715.00A	14677.	• 38563	1.1251	177.77	• 47205			
3202.00A	19253.	1.2144	4.7963	257.89	• 1.9602			
3503.00A	19338.	1.1181	4.4124	265.25	• 1.8033			
3429.00A	19365.	1.0195	4.0291	273.81	• 1.6466			
3515.00A	19338.	• 91164	3.6215	280.31	• 1.4800			
3601.50A	12316.	• 81602	3.2031	268.39	• 1.3090			
3913.00A	19415.	• 68480	2.7113	297.05	• 1.1086			
4096.00A	19569.	• 57541	2.2744	303.83	• 92952			
4199.00A	19404.	• 46892	1.8569	309.11	• 75889			
4304.00A	17404.	• 37417	1.4817	313.38	• 60554			
4534.00A	19400.	• 20693	1.1479	317.66	• 46911			
4936.00A	24564.	1.1983	6.0072	420.67	• 2.4220			
4976.00A	24525.	1.0985	5.4991	433.15	• 2.474			
5070.00A	24497.	1.0025	5.0120	443.88	• 2.0483			
5211.00A	24508.	• 90791	4.5411	455.20	• 1.8558			
5353.00A	24511.	• 80245	4.0141	467.22	• 1.6405			
2578.00A	24558.	• 69CB6	3.4625	478.56	• 1.4151			
2692.00A	24527.	• 58645	2.9454	489.36	• 1.2037			
5799.50A	24550.	• 47232	2.3665	499.24	• 96715			
5902.50A	24499.	• 36534	1.8266	509.30	• 74651			
6067.00A	24524.	• 27136	1.3881	513.98	• 56730			

TEST 84L009 TEST 84L009 TEST FACILITY  
DATE 10 MAR 1984 PROCESS DATE 9 MUL 1984  
3-9-1984 LOW INLET PUMP H-Q & CAV TESTS

TIME	-17	-18	-1	-2	-21	-22	-23	-6
PUMP STA	PUMP DIS	WATER	VAPOR	PUMP TOT	PUMP INL	PUMP DIS	PUMP DIS	AMBIENT
DELT A	VELOCITY	SP. WT.	HEAD	HEADRISE	FLUX	HEAD	COEF	PRESS (PSIA)
H/L/L FT	(FPS)	LBM/FT <sup>3</sup>	FT-F	FT-F	COEF	HEAD	COEF	
21.50A	6.65019E-01	*49007E-03	62.422	.20469	.65010E-01	.36380E-01	.50929*	14.396
141.00A	-1.8766	*0	62.224	1.0732	-1.8766	*0	*60745E+06	14.396
141.00A	32.376	2.9061	62.290	.80193	35.742	*27904E-01	*28033	14.396
1657.00A	36.697	2.2474	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
201.100A	148.26	2.8543	62.275	.85793	148.94	*28329E-01	*29055	14.396
2950.50A	151.33	5.3898	62.274	.86376	151.90	*26105E-01	*29687	14.396
2172.50A	195.30	*8752	52.274	.86231	153.77	*23648E-01	*20535	14.396
2271.50A	159.96	4.3386	62.273	.86809	160.33	*21044E-01	*31417	14.396
2343.00A	153.43	3.8916	62.272	.86954	163.73	*18957E-01	*32031	14.396
2427.00A	167.57	3.3624	62.271	.87396	167.79	*16315E-01	*32914	14.396
2546.50A	172.24	2.9218	62.272	.87103	172.40	*13684E-01	*33781	14.396
2624.00A	174.95	2.3832	62.270	*87092	175.10	*1553E-01	*34281	14.396
2711.00A	177.70	1.8872	62.270	*87692	177.77	*91568E-02	*34868	14.396
3202.00A	256.65	7.8367	62.264	.88281	257.89	*28835E-01	*29094	14.396
3306.00A	264.29	7.2034	62.261	.89874	265.25	*26548E-01	*29970	14.396
3429.00A	272.46	6.5831	62.267	.89111	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	308.92	3.0340	62.264	.90067	309.11	*1134E-01	*34686	14.396
4304.00A	313.27	2.4209	62.264	.90217	313.38	*88846E-02	*35168	14.396
4554.00A	317.59	1.6725	62.264	.90221	317.66	*68843E-02	*35661	14.396
-4333.00A	418.76	9.8151	62.262	.90823	420.67	*2.8454E-01	*29454	14.396
4916.50A	431.57	8.9849	62.261	.91127	433.15	*26085E-01	*30417	14.396
5070.00A	442.56	3.1890	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	6.9586	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
5792.00A	488.90	4.8125	62.256	.92658	489.36	*13973E-01	*34369	14.396
5799.50A	498.95	3.6666	62.258	.92661	499.24	*14216E-01	*34998	14.396
2905.50A	509.13	2.9345	62.258	.92507	509.30	*86751E-02	*35852	14.396
6067.00A	513.88	2.2680	62.259	.92497	513.98	*65858E-02	*36105	14.396

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TEST 84L009

TEST DATE 10 MAR 1984  
PROCESS DATE 9 NOV 1984

PAGE 9

PUMP CALIBRATION TEST FACILITY  
 2-9-19d4 L04 THRUST PUMP H-Q & CAN TESTS

TIME	-15	-101	-102	-103	-104	-105	-106	-107
IMPELLER COEF	IN FLOW	NOZZLE FLOWRATE	NOZZLE PARAM	TURB AVL ENERGY	TURB AVL ISEN VEL	TURB AVL MEAN VEL	TURB AVL ENER PIP	TURB AVL BTU/LBM
PK RATIO	PK RATIO	PK RATIO	PK RATIO	BTU/LBM	FT/S	FT/S	FT/S	BTU/LBM
21.50A .91355E-01	.97361E-02	.98812	.20096	-.83917E-01	58.510	-.1045E-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	
1651.00A .61959E-01	.14735	.95386E-01	2.0816	2.5459	357.04	76.988	2.7382	
1782.00A .48582E-01	.11932	.94132E-01	2.1060	2.5942	360.40	76.466	2.7652	
2011.00A .71138E-01	.18585	.71898E-01	2.7445	5.4537	522.57	154.11	5.7610	
2090.50A .65552E-01	.18562	.71838E-01	2.7432	5.4887	524.25	153.97	5.8062	
2172.50A .59383E-01	.18523	.71912E-01	2.7414	5.4435	522.06	153.74	5.7731	
2271.50A .52836E-01	.18464	.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	.18199	.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	
2715.50A .22994E-01	.18034	.72723E-01	2.7086	5.3116	517.72	153.70	5.6205	
3202.00A .72410E-01	.22453	.66124E-01	2.9669	7.2712	603.40	202.67	7.5831	
3308.00A .66666E-01	.22293	.66291E-01	2.9617	7.2104	600.87	202.51	7.5095	
3429.00A .60791E-01	.22167	.66447E-01	2.9540	7.1461	598.19	202.79	7.5413	
3515.00A .54716E-01	.22147	.66442E-01	2.9551	7.1726	599.29	202.51		
3691.50A .48229E-01	.22052	.66564E-01	2.9476	7.1114	596.73	202.91	7.4687	
3913.50A .40832E-01	.21967	.66665E-01	2.9444	7.1241	597.26	203.31	7.4850	
4097.50A .34310E-01	.21918	.66615E-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	.21766	.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	
4638.00A .71451E-01	.28149	.61664E-01	3.1671	9.3403	683.88	257.23	9.7271	
4776.50A .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	.62571E-01	3.1235	8.9924	671.02	256.81	9.3686	

PUMP CALIBRATION TEST FACILITY  
TEST DATE 10 MAR 1984  
PROCESSED DATE 4 NOV 1984  
PAGE 11  
TEST 84L009 TEST 84L009, 3-9-1984 LOW THRUST PUMP H-Q & GAV TESTS

TIME	-3	6	14	105	106	1	8
INLET	PUMP INL	PUMP OUT	TURBINE	TURBINE	OUTLET	PUMP INL	PUMP DIS
VELOCITY	ET TEMP	ET TEMP	INLET TE	OUTLET TE	ET PRESS	PRESS	PRESS
(FPS)	(F)	(F)	(F)	(F)	(PSIG)	(PSIG)	(PSIG)
21.50A .12258E-03	32.084	31.828	31.975	32.025	•50598E-02	•33245E-01	
941.00A 0	77.291	78.266	79.558	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 •49020	1 70.052	70.387	27.152	27.445	34.057	50.656	
2011.00A 1.4643	70.043	71.372	22.624	10.307	31.842	95.976	
2090.30A 1.3481	70.640	71.519	22.723	9.0180	32.299	97.755	
2172.50A 1.2194	70.791	71.962	22.427	9.1256	32.626	99.799	
2271.50A 1.0852	70.588	72.110	22.821	9.1748	32.941	102.09	
2343.00A •97340	71.637	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	
2715.20A •47205	71.4283	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	71.720	73.588	26.365	3.2654	32.418	153.35	
3661.20A 1.3090	71.923	73.883	26.315	3.2654	32.756	157.24	
3943.20A 1.1088	71.625	74.375	26.463	3.6101	33.019	161.31	
4097.30A •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 •90554	72.120	77.133	26.011	3.8563	34.376	169.83	
4524.00A •46911	72.120	78.564	26.463	4.0041	34.621	171.94	
4838.00A 2.4550	72.317	74.428	25.725	-7.8148	30.004	211.11	
4976.50A 2.2474	72.416	74.572	26.519	-7.4208	30.682	217.31	
5010.00A 2.0483	72.613	74.720	26.512	-7.0269	31.157	222.53	
5211.00A 1.8258	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	
557d.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	
5905.20A •74651	72.859	80.236	25.626	-6.9284	34.234	254.36	
6007.00A •56730	72.760	82.452	26.020	-6.3867	34.570	256.75	

PUMP CALIBRATION TEST FACILITY  
TEST DATE 10 MAR 1984  
PROCESS DATE 9 NOV 1984  
TEST 84L009, 3-9-1984 LUN THRSI PUMP H-Q & CAV TESTS

TIME	18	19	20	21	34	36	37	38
	VOLUME P	VOLUME P	VOLUME P	VOLUME P	FRONT WR	REAR WR	REAR WR	IMP FR I
RESS	RESS 900	RESS 900	RESS 1800	RESS 2700	KING UP	KING UP	RINT DP	IP PR
S (PSIG)	E (PSIG)	E (PSIG)	E (PSIG)	E (PSIG)	R (PSIG)	R (PSIG)	R (PSIG)	(PSIG)
21.50A	21.901	•73233E-C1	.98223E-05	.23791E-01	.10625	.40540E-01	.14119	.10727
941.00A	34.482	35.179	33.860	35.329	35.290	35.071	34.527	34.887
1490.00A	47.924	48.108	47.094	48.947	44.544	41.513	33.929	46.760
1657.00A	48.497	48.419	47.395	45.264	34.708	41.789	36.128	47.139
1782.00A	49.712	49.270	48.118	50.247	35.132	42.582	34.593	48.096
2011.00A	50.656	88.663	88.606	91.497	35.459	60.243	35.141	84.063
2050.50A	92.831	90.087	89.986	93.066	36.079	61.052	35.756	85.563
2172.50A	95.350	91.009	91.353	94.984	26.602	62.153	36.487	87.212
2271.50A	97.770	93.020	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	107.50	95.554	95.513	100.07	38.121	66.523	38.513	92.572
2546.20A	105.03	97.307	97.174	102.20	38.578	68.142	39.277	94.815
2624.00A	106.55	98.303	98.523	103.04	39.035	69.567	39.709	96.431
2715.00A	108.84	99.514	99.622	105.42	39.786	70.959	40.424	98.327
3202.00A	132.65	128.24	125.29	133.30	37.255	77.531	36.802	120.66
3308.00A	136.50	121.12	131.92	136.23	28.251	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	142.33	149.42	41.435	88.603	42.433	136.85
4097.70A	159.04	143.51	145.24	152.82	42.138	91.274	43.546	140.73
4199.00A	162.63	145.56	147.43	152.61	43.036	93.654	44.527	143.81
4304.00A	165.90	147.55	149.62	153.33	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
4d3B.00A	195.07	166.52	189.43	194.80	40.243	102.04	39.676	174.80
4970.50A	202.40	190.12	193.79	199.86	41.631	104.86	41.453	179.64
5070.00A	208.95	194.06	196.91	204.31	42.742	107.69	43.148	184.23
5211.00A	215.11	197.55	200.43	208.68	43.089	110.42	44.443	188.52
5558.00A	221.70	201.03	204.35	213.84	44.685	114.16	46.068	193.69
5578.00A	226.11	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	48.496	125.82	50.988	210.22
5905.00A	247.72	215.63	221.10	233.45	49.943	129.51	52.766	215.64
6067.00A	251.58	217.71	225.32	236.95	51.249	132.29	54.211	219.68

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## TEST 84L009

TEST DATE 2-9-1984 LUN\_100ST\_PUMP\_H-Q &amp; CAV\_IESIS

PUMP CALIBRATION TEST FACILITY PROCESS DATE 9 NOV 1984

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TIME	IMP FR M	AMP REAK	TURB IN	ROTOR QW	ROTOR QU	TURB NOZ
ID PR	TIP PR	STATIC P	T TIP PR	T HUB PR	T HUB PR	OUT
21.50A	.24840E-01	.12762	.40096E-01	.28466E-01	.28829E-01	.60472E-01
941.00A	33.916	32.902	.33954E-01	.22078E-01	.22422E-01	.28645E-01
1490.00A	38.478	47.667	2.7900	1.3719	1.4225	.84341
1657.00A	38.694	47.998	2.3077	1.0376	1.0800	.63428
1782.00A	39.241	48.775	2.3617	1.0818	1.1180	.67155
2011.00A	57.299	64.893	5.5570	2.4255	2.5403	1.7791
2090.20A	56.192	66.797	2.5543	2.4379	2.5595	1.7473
2172.50A	57.000	88.337	5.5227	2.3874	2.5403	1.7346
2211.50A	57.055	89.827	5.4998	2.3811	2.5659	1.7537
2243.00A	58.319	91.301	2.4352	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	60.455	96.604	5.3924	2.3370	2.5403	1.7155
2715.00A	61.358	97.594	5.3247	2.3054	2.4762	1.7027
3202.00A	72.320	121.62	7.9636	3.4408	3.6551	2.6575
3306.00A	73.630	124.85	7.8689	3.3906	3.6103	2.6321
3429.00A	74.858	127.28	7.7936	3.3462	3.5590	2.6130
3515.00A	76.318	130.05	7.7954	3.3651	3.5782	2.6257
3691.50A	17.934	133.06	1.7442	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	146.92	7.5364	3.2453	3.4629	2.5493
4828.00A	96.454	173.54	11.374	5.1123	5.5131	4.2998
4976.50A	99.266	180.20	11.756	5.0492	5.4426	4.2616
5010.00A	101.20	184.58	11.526	4.9546	5.3657	4.1725
5211.00A	102.86	189.21	11.515	4.9609	5.3657	4.1725
5358.30A	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	109.28	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	113.76	213.41	10.958	4.6218	5.0424	3.9497

TEST 84L011	TEST 84L011	TEST DATE 22 MAR 1984	PUMP CALIBRATION TEST FACILITY	PROCESS DATE 17 NOV 1984	PAGE 0
		3-21-84	LGW THRUST PUMP	H-Q & CAV TESTS	
C DESCRIPTION	CONSTANT				
2 HUB DIAMETER AT INLET PRESS TAP, IN	0.0				
5 IMPELLER INLET TIP DIAMETER, IN	8.0500E-01				
6 IMPELLER INLET HUB DIAMETER, IN	5.0000E-01				
7 IMPELLER DISH TIP DIAMETER, IN	2.0000E+00				
9 INLET AREA AT PRESS TAP, SQ. IN.	7.8500E-01				
10 IND/IMP INLET AREA, SQ.IN.	3.12608E-01				
11 DESIGN FLOW, GPM	2.0000E+00				
12 AMBIENT PRESSURE, PSIA	1.42268E+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 FACTUR	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 CUFF	9.85000E-01				
94 SPEC. WT. RATIO	1.40000E+00				
95 MWT OF GAS	2.80160E+01				
96 TURB MEAN DIAMETER, IN	2.40000E+00				
97 TURB NOZ AREA, IN <sup>2</sup>	5.54000E-01				
98 TURB PIPE IN DIAMETER, IN	1.61000E+00				

SECTION A5

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984  
TEST 84L011 TEST 84L011 3-21-84 LOW THKUST PUMP H-Q & CAV TESTS

TIME	SHFT1 SP	FLUW/ DES FLOW	PUMP DIS	PUMP TUT	HEADRISE	VELCITY	INLET	-3	-15	IMPELLER
EEU	(RPM)	(GPM)	(FPM)	(FPM)	(FPM)	(FPM)	(FPM)	IN FLOW	IN FLOW	COEF
24.50A	-8.1638	.31349	-•56615E-04	-•34505E-05	-•24036E-04	-•24036E-04	-•24036E-04	-•24036E-04	-•24036E-04	-•24036E-04
1598.50A	11571.	1.2357	•72605	•34.608	•29778	•18399E-01	•18399E-01	•18399E-01	•18399E-01	•18399E-01
1508.50A	11544.	•67546	•51502	46.054	•21048	•13035E-01	•13035E-01	•13035E-01	•13035E-01	•13035E-01
1655.50A	11536.	•64410	•31613	52.041	•15476	•95901E-02	•95901E-02	•95901E-02	•95901E-02	•95901E-02
2062.50A	23506.	1.2257	•1.4062	152.27	•60004	•18250E-01	•18250E-01	•18250E-01	•18250E-01	•18250E-01
2156.50A	23492.	•60504	•1.2575	160.23	•51391	•15640E-01	•15640E-01	•15640E-01	•15640E-01	•15640E-01
2263.50A	23425.	•67119	1.0412	204.33	•42550	•12986E-01	•12986E-01	•12986E-01	•12986E-01	•12986E-01
2356.50A	23419.	•72164	•60123	221.79	•35196	•10745E-01	•10745E-01	•10745E-01	•10745E-01	•10745E-01
2454.50A	23497.	•53556	•64667	234.06	•26403	•80337E-02	•80337E-02	•80337E-02	•80337E-02	•80337E-02
2552.50A	23466.	•35792	•42638	255.04	•17507	•53292E-02	•53292E-02	•53292E-02	•53292E-02	•53292E-02
3067.50A	29104.	•24132	•32791	469.39	•14627	•35931E-02	•35931E-02	•35931E-02	•35931E-02	•35931E-02
3151.50A	29100.	•35475	•52608	453.67	•21506	•52820E-02	•52820E-02	•52820E-02	•52820E-02	•52820E-02
3233.50A	29087.	•50511	•74671	432.18	•30598	•75207E-02	•75207E-02	•75207E-02	•75207E-02	•75207E-02
3314.50A	29076.	•62886	•53199	413.83	•38086	•93632E-02	•93632E-02	•93632E-02	•93632E-02	•93632E-02
3401.50A	29076.	•16962	•1.1404	369.48	•46607	•11459E-01	•11459E-01	•11459E-01	•11459E-01	•11459E-01
3508.50A	29054.	•69477	1.03650	367.05	•54150	•13322E-01	•13322E-01	•13322E-01	•13322E-01	•13322E-01
3567.50A	29051.	1.0219	1.5129	337.94	•61626	•15215E-01	•15215E-01	•15215E-01	•15215E-01	•15215E-01
3667.50A	25042.	•1.1540	1.7080	307.19	•69802	•17183E-01	•17183E-01	•17183E-01	•17183E-01	•17183E-01
3787.50A	29025.	1.2679	1.6754	275.19	•76643	•18878E-01	•18878E-01	•18878E-01	•18878E-01	•18878E-01
3937.50A	29030.	1.2211	1.0448	256.63	•73758	•10182E-01	•10182E-01	•10182E-01	•10182E-01	•10182E-01
4236.50A	29136.	1.2476	1.0516	255.78	•75681	•16575E-01	•16575E-01	•16575E-01	•16575E-01	•16575E-01
4586.50A	29342.	1.2407	1.6552	265.26	•75816	•18473E-01	•18473E-01	•18473E-01	•18473E-01	•18473E-01
5054.00A	28945.	•1.0630	•1.5914	274.85	•65284	•16125E-01	•16125E-01	•16125E-01	•16125E-01	•16125E-01
5349.00A	29112.	1.6275	1.5257	294.07	•62270	•15299E-01	•15299E-01	•15299E-01	•15299E-01	•15299E-01
5521.00A	29380.	•88875	1.3307	348.82	•54382	•13233E-01	•13233E-01	•13233E-01	•13233E-01	•13233E-01
5632.00A	29364.	•64223	•96126	374.62	•39265	•95668E-02	•95668E-02	•95668E-02	•95668E-02	•95668E-02
5776.50A	25374.	1.0135	•1.5114	336.49	•62011	•15090E-01	•15090E-01	•15090E-01	•15090E-01	•15090E-01
6425.00A	23740.	1.1502	1.3906	149.57	•56833	•17125E-01	•17125E-01	•17125E-01	•17125E-01	•17125E-01
6562.00A	23629.	•97057	1.1703	178.62	•47827	•14457E-01	•14457E-01	•14457E-01	•14457E-01	•14457E-01
6720.50A	23627.	•81906	•56609	197.00	•40299	•12195E-01	•12195E-01	•12195E-01	•12195E-01	•12195E-01
6842.00A	23644.	•79986	•96376	190.22	•39395	•11909E-01	•11909E-01	•11909E-01	•11909E-01	•11909E-01
6966.00A	23695.	•66064	•75700	205.93	•32596	•98393E-02	•98393E-02	•98393E-02	•98393E-02	•98393E-02
7123.00A	23671.	•66627	•60615	200.52	•32946	•99500E-02	•99500E-02	•99500E-02	•99500E-02	•99500E-02
7295.00A	23690.	1.1536	1.3940	143.91	•56970	•17176E-01	•17176E-01	•17176E-01	•17176E-01	•17176E-01

TEST 641011 TEST DATE 22 MAR 1984 PROCESS DATE 1  
TEST 641011 3-21-84 LOW THRUST PUMP H-C & GAV TESTS

PAGE 7  
TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984  
3-21-84 LOW THRUST PUMP H-C & CAV TESTS  
PUMP CALIBRATION TEST FACILITY

TIME	-17			-18			-2			-3			-21			-22			-23			
	PUMP STA	PUMP DIS	VAPOR	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	VELLCITY	HEAD	
HLD FT	1.1450E-03	-9.6103E-04	-9.4234E+06	1.1905	1.0214	2.4778	3.4606	-2.4036E-04	-3.4505E-05	1.8588E-02	-2.2274E-02	7.3266E-02	-1.0926	1.1646E-02	-1.1646	7.2675E-02	-1.1646	1.1646E-02	-1.1646	1.1646E-02	-1.1646	
1.1596.5UA	34.580	1.1568.5UA	46.040	8.4148	1.0296	2.1048	4.6054	1.0214	2.1048	5.1909E-02	1.14606	1.1646E-02	1.14606	1.1646E-02	1.14606	1.1646E-02	1.14606	1.1646E-02	1.14606	1.1646E-02	1.14606	
1.1639.5UA	52.034	1.1616.1	1.0349	1.15478	5.2041	1.15478	5.2041	1.0349	1.15478	1.1650E-02	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	1.16522	
2.062.5UA	152.15	2.056.50A	160.15	2.0546	1.0746	2.1591	1.8023	1.0624	2.0550	6.2281E-02	1.13800	1.14268	6.2281E-02	1.13800	1.14268	6.2281E-02	1.13800	1.14268	6.2281E-02	1.13800	1.14268	
2.063.50A	204.26	2.07011	1.0870	4.2550	2.0433	2.0433	2.0433	1.0870	2.0433	5.1715E-02	1.15735	1.14268	5.1715E-02	1.15735	1.14268	5.1715E-02	1.15735	1.14268	5.1715E-02	1.15735	1.14268	
2.356.50A	221.75	2.361.75	1.0634	3.5196	2.2174	4.2788E-02	1.17088	1.0634	3.5196	2.2174	4.2788E-02	1.17088	1.14268	2.2174	4.2788E-02	1.17088	1.14268	2.2174	4.2788E-02	1.17088	1.14268	
2.354.50A	236.04	1.0556	1.0102	2.6403	2.3906	3.1992E-02	1.18295	1.0556	1.0102	2.3906	3.1992E-02	1.18295	1.14268	2.3906	3.1992E-02	1.18295	1.14268	2.3906	3.1992E-02	1.18295	1.14268	
2.552.50A	255.03	0.9992	1.1139	1.7507	2.5504	2.1222E-02	1.19536	0.9992	1.1139	1.7507	2.5504	2.1222E-02	1.19536	1.14268	1.7507	2.5504	2.1222E-02	1.19536	1.7507	2.5504	2.1222E-02	1.19536
3.067.50A	409.29	5.6479	1.1981	1.14627	4.6934	1.4309E-02	2.3413	409.29	5.6479	1.1981	1.14627	4.6934	1.4309E-02	2.3413	4.6934	1.14627	4.6934	1.14627	4.6934	1.14627	4.6934	
3.151.50A	453.05	0.85955	1.2038	2.1500	4.5307	2.1034E-02	2.22604	3.151.50A	453.05	0.85955	1.2038	2.1500	4.5307	2.1034E-02	2.22604	4.5307	2.1500	4.5307	2.1034E-02	2.22604	4.5307	
3.233.50A	432.15	1.0233	1.0497	3.0598	4.3218	2.0594E-02	2.15882	3.233.50A	432.15	1.0233	1.0497	3.0598	4.3218	2.0594E-02	2.15882	4.3218	3.0598	4.3218	2.0594E-02	2.15882	4.3218	
3.314.50A	413.79	1.0522t	1.0274	3.6066	4.1363	3.7287E-02	2.0673	3.314.50A	413.79	1.0522t	1.0274	3.6066	4.1363	3.7287E-02	2.0673	4.1363	3.6066	4.1363	3.7287E-02	2.0673	4.1363	
3.401.50A	389.41	1.0833	1.0494	4.6607	3.8948	4.5633E-02	1.19461	3.401.50A	389.41	1.0833	1.0494	4.6607	3.8948	4.5633E-02	1.19461	3.8948	4.6607	3.8948	4.5633E-02	1.19461	3.8948	
3.508.50A	366.96	2.1649	1.3022	5.4150	3.6705	5.3053E-02	1.18365	3.508.50A	366.96	2.1649	1.3022	5.4150	3.6705	5.3053E-02	1.18365	3.6705	5.4150	3.6705	5.3053E-02	1.18365	3.6705	
3.687.50A	337.82	2.4719	1.5295	6.1628	3.3794	6.0592E-02	1.16917	3.687.50A	337.82	2.4719	1.5295	6.1628	3.3794	6.0592E-02	1.16917	3.3794	6.1628	3.3794	6.0592E-02	1.16917	3.3794	
3.667.50A	307.04	2.7406	1.5637	6.9602	3.0719	6.8427E-02	1.15387	3.667.50A	307.04	2.7406	1.5637	6.9602	3.0719	6.8427E-02	1.15387	3.0719	6.9602	3.0719	6.8427E-02	1.15387	3.0719	
3.767.50A	275.00	3.0642	1.5943	7.6643	2.7519	7.5177E-02	1.13800	3.767.50A	275.00	3.0642	1.5943	7.6643	2.7519	7.5177E-02	1.13800	2.7519	7.6643	2.7519	7.5177E-02	1.13800	2.7519	
3.937.50A	257.65	2.5468	1.4353	7.3758	2.5603	7.2405E-02	1.12963	3.937.50A	257.65	2.5468	1.4353	7.3758	2.5603	7.2405E-02	1.12963	2.5603	7.3758	2.5603	7.2405E-02	1.12963	2.5603	
4.23b.50A	255.60	3.0251	1.5159	7.5681	2.5578	7.3971E-02	1.12754	4.23b.50A	255.60	3.0251	1.5159	7.5681	2.5578	7.3971E-02	1.12754	2.5578	7.5681	2.5578	7.3971E-02	1.12754	2.5578	
4.286.50A	265.08	3.0311	1.5926	7.5681	2.6226	7.3566E-02	1.13016	4.286.50A	265.08	3.0311	1.5926	7.5681	2.6226	7.3566E-02	1.13016	2.6226	7.5681	2.6226	7.3566E-02	1.13016	2.6226	
5.054.00A	274.74	2.6100	1.7202	6.5284	2.7465	6.4213E-02	1.13857	5.054.00A	274.74	2.6100	1.7202	6.5284	2.7465	6.4213E-02	1.13857	2.7465	6.5284	2.7465	6.4213E-02	1.13857	2.7465	
5.349.00A	253.94	2.4645	1.6303	6.2270	2.9407	6.0926E-02	1.14682	5.349.00A	253.94	2.4645	1.6303	6.2270	2.9407	6.0926E-02	1.14682	2.9407	6.2270	2.9407	6.0926E-02	1.14682	2.9407	
5.521.00A	348.73	2.1742	1.6716	5.4282	3.4882	5.2697E-02	1.17072	5.521.00A	348.73	2.1742	1.6716	5.4282	3.4882	5.2697E-02	1.17072	3.4882	5.4282	3.4882	5.2697E-02	1.17072	3.4882	
5.632.00A	374.77	1.5706	1.9042	3.9263	3.7462	3.6098E-02	1.16370	5.632.00A	374.77	1.5706	1.9042	3.9263	3.7462	3.6098E-02	1.16370	3.7462	3.9263	3.7462	3.6098E-02	1.16370	3.7462	
5.976.50A	336.37	2.4792	2.0228	6.2011	3.3649	6.0093E-02	1.16471	5.976.50A	336.37	2.4792	2.0228	6.2011	3.3649	6.0093E-02	1.16471	3.3649	6.2011	3.3649	6.0093E-02	1.16471	3.3649	
6.425.00A	149.47	2.2722	2.1319	5.6633	1.4957	6.8197E-02	1.11230	6.425.00A	149.47	2.2722	2.1319	5.6633	1.4957	6.8197E-02	1.11230	1.4957	5.6633	1.4957	6.8197E-02	1.11230	1.4957	
6.562.00A	178.54	1.9121	2.1401	4.1027	1.7662	5.7571E-02	1.13482	6.562.00A	178.54	1.9121	2.1401	4.1027	1.7662	5.7571E-02	1.13482	4.1027	1.7662	5.7571E-02	1.13482	4.1027		
6.720.50A	196.95	1.6112	2.1644	4.0559	1.9700	4.8564E-02	1.14894	6.720.50A	196.95	1.6112	2.1644	4.0559	1.9700	4.8564E-02	1.14894	4.0559	1.9700	4.8564E-02	1.14894	4.0559		
6.842.00A	196.17	1.5750	2.1751	3.9395	1.9022	4.7426E-02	1.14330	6.842.00A	196.17	1.5750	2.1751	3.9395	1.9022	4.7426E-02	1.14330	1.9022	3.9395	1.9022	4.7426E-02	1.14330	1.9022	
7.063.00A	205.92	1.3032	2.1806	3.2596	2.0595	3.9183E-02	1.15509	7.063.00A	205.92	1.3032	2.1806	3.2596	2.0595	3.9183E-02	1.15509	2.0595	3.2596	2.0595	3.9183E-02	1.15509	2.0595	
7.313.00A	200.49	1.3172	2.1862	3.2546	2.0052	3.9624E-02	1.15126	7.313.00A	200.49	1.3172	2.1862	3.2546	2.0052	3.9624E-02	1.15126	2.0052	3.2546	2.0052	3.9624E-02	1.15126	2.0052	
7.295.00A	143.81	2.2776	2.2308	2.6970	1.4351	6.8399E-02	1.10827	7.295.00A	143.81	2.2776	2.2308	2.6970	1.4351	6.8399E-02	1.10827	1.4351	2.6970	1.4351	6.8399E-02	1.10827	1.4351	

SECTION A5

ORIGINAL PAGE IS  
OF POOR QUALITY

PUMP CALIBRATION TEST FACILITY  
TEST DAIL 22 MAJ 1984 PROCESS DATE 17 NOV 1984  
TEST 64L011 3-21-84 LOW THRUST PUMP H-Q & CAV TESTS

TIME	-1	-101	-102	-103	-104	-105	-106	-107
WATER	NOZZLE	FLOW RATE	NOZZLE	PARAM	ENERGY,	ISEN VEL	MEAN VEL	TURB AVL
SP-WGT	Lbm/FT <sup>3</sup>	(LB/SEC)	PR KATIG		BTU/LBM	FT/S	FT/S	ENER PIP
22.50A	.67317E+0b	.91162E-02	.98450	.20106	-.77503E-01	.59.307	-.85491E-01	-.15847E-01
1.96.50A	62.234	.14021	.83402E-01	2.3620	3.9140	442.70	121.17	4.2570
1568.50A	62.432	.14086	.85066E-01	2.3698	3.8754	440.50	120.89	4.2340
1659.50A	62.290	.14029	.63550E-01	2.3794	3.8653	439.93	120.83	4.2371
2062.50A	62.224	.21069	.66131E-01	2.8534	7.4249	609.74	246.16	7.9137
2156.50A	62.220	.20948	.66220E-01	2.6658	7.4463	610.62	246.01	7.9224
2263.50A	62.216	.20835	.66370E-01	2.6826	7.3984	608.65	245.30	7.8603
2356.50A	62.218	.20737	.68279E-01	2.8748	7.3462	606.49	245.24	7.8183
2454.50A	62.214	.20606	.68892E-01	2.8665	7.2549	602.70	246.06	7.7815
2552.50A	62.211	.20511	.69016E-01	2.8576	7.3041	604.76	245.95	7.7834
3067.50A	62.194	.25966	.64229E-01	3.0581	9.4526	687.98	304.77	9.9517
3151.50A	62.185	.26138	.64109E-01	3.0655	9.4494	687.86	304.73	9.9793
3233.50A	62.168	.26307	.63486E-01	3.0721	9.5494	691.50	304.59	10.076
3314.50A	62.164	.26491	.63686E-01	3.0774	9.5765	692.47	304.54	10.121
3401.50A	62.174	.26677	.63761E-01	3.0834	9.6544	695.28	304.50	10.190
3506.50A	62.167	.26634	.63661E-01	3.0890	9.6754	696.04	304.30	10.227
3567.50A	62.160	.26954	.63457E-01	3.0852	9.6336	699.21	304.22	10.240
3667.50A	62.153	.27078	.63557E-01	3.0941	9.7762	699.73	304.13	10.333
3767.50A	62.146	.27156	.63454E-01	3.0956	9.7959	700.36	303.95	10.331
3857.50A	62.137	.26655	.6417AE-01	3.0641	9.4646	688.88	304.00	10.017
4238.50A	62.114	.26212	.64144E-01	3.0663	9.5264	690.48	305.11	10.069
4580.50A	62.102	.26574	.63634E-01	3.0793	9.6061	693.53	307.27	10.138
5054.00A	62.074	.26151	.64124E-01	3.0648	9.5084	690.01	303.11	10.026
5349.00A	62.054	.26040	.64456E-01	3.0506	9.4395	687.29	304.86	9.9295
5521.00A	62.045	.26084	.64432E-01	3.0590	9.5028	689.80	307.67	10.003
5632.00A	62.034	.25369	.64671E-01	3.0592	9.4924	681.98	307.50	9.7870
5576.50A	62.016	.26665	.64354E-01	3.0515	9.4195	686.77	307.65	9.9130
6425.00A	61.996	.20104	.69566E-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
6120.50A	61.990	.19674	.70753E-01	2.7685	6.6656	586.26	247.43	7.2905
6644.00A	61.988	.19847	.70424E-01	2.6019	6.9235	588.75	247.60	7.3610
6986.00A	61.987	.19604	.70867E-01	2.7650	6.7994	583.42	248.14	7.2327
7123.00A	61.985	.19500	.71064E-01	2.7777	6.7602	582.61	247.86	7.2129
7295.00A	61.976	.19967	.70251E-01	2.8053	6.5452	585.57	248.15	7.3803

TEST 04L011 TEST DATE 22 MAY 1984  
TEST 04L011 PROCESS DATE 17 NOV 1984  
3-21-64 LOW THRUST PUMP H-Q & CAV TESTS

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TIME	-16	6	14	105	106	1	8
DES FLOW	FLOW/	PUMP INL	PUMP OUT	TURBINE	TURBINE	PUMP INL	PUMP DIS
	ET TEMP	ET TEMP	ET TEMP	INLET TE	OUTLET T	ET PRESS	PRESS
	(F)	(F)	(F)	(F)	(F)	(PSIG)	(PSIG)
2.2-50A	.31349	-3766.1	67.951	50.395	88.386	34.341	32.257
1398.50A	1.2357	75.806	77.071	46.593	41.426	28.221	43.167
1568.50A	.87546	76.052	78.066	44.376	37.981	28.019	47.916
1655.50A	.64410	70.200	78.052	43.836	36.799	28.119	50.606
2462.50A	1.2257	76.287	72.045	45.805	19.473	25.790	91.539
2156.50A	1.0504	77.332	60.517	46.129	20.309	26.052	103.89
2263.50A	.87219	71.670	61.502	46.740	20.654	26.293	114.55
2350.50A	.72164	77.578	62.535	46.396	20.457	26.511	122.33
2454.50A	.53956	78.070	64.459	46.002	20.309	26.806	130.08
2552.50A	.35792	78.414	67.625	45.805	20.309	27.225	137.40
3067.50A	.24132	60.624	101.016	40.684	4.5578	27.642	230.56
3151.50A	.35475	60.776	55.286	41.031	4.4594	26.582	222.24
3233.50A	.50511	60.924	51.151	41.671	4.7055	26.165	212.79
3314.50A	.62886	61.367	69.723	41.720	4.5066	25.836	204.52
3401.50A	.76962	82.400	65.034	41.819	4.0656	25.495	193.63
3508.50A	.89477	63.188	66.768	42.015	3.61195	25.164	183.57
3667.50A	1.02119	63.627	68.640	42.114	4.1148	24.886	170.72
3787.50A	1.1540	64.615	66.766	42.262	4.1640	24.523	157.05
3787.50A	1.26779	65.303	62.260	41.619	3.6718	24.230	142.92
3937.50A	1.2211	66.208	50.006	42.452	5.2347	16.352	127.62
4430.50A	1.2476	67.679	51.763	42.141	5.0774	13.155	123.42
4586.50A	1.2407	65.479	53.448	42.411	4.6401	7.7793	122.10
5054.00A	1.0830	52.074	56.429	41.762	4.7661	-6.7773	111.65
5349.00A	1.0275	93.919	58.544	40.663	4.1405	9.7576	136.43
2521.00A	.88875	94.643	100.07	40.569	3.9376	17.075	167.33
5632.00A	.64253	95.200	102.19	40.365	4.5967	5.8256	167.29
5476.50A	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	6.8400	73.192
6562.00A	.97097	99.009	101.66	40.613	17.039	9.3309	86.198
6720.50A	.81906	99.361	102.81	40.166	16.643	7.8627	92.649
6842.00A	.79866	99.542	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	100.36	102.97	39.355	15.711	9.5264	71.423

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TEST 64L011 TEST 64L011 PUMP CALIBRATION TEST FACILITY  
TEST DATE 22 MAR 1984 PROCESS DATE 17 NOV 1984  
3-21-84 LCN THRUST PUMP H-Q & CAV TESTS

TIME	18	19	20	21	24	36	37	38
	VOLUME P	VOLUME P	VOLUME P	VOLUME P	FRONT WR	REAR WR	WR	IMP FR T
RES UD 6PSIG)	RES 900 E6(PSIG)	RES 1600 E6(PSIG)	RES 2100 E6(PSIG)	RES 2100 E6(PSIG)	RING UP R (PSIG)	RING UP R (PSIG)	RINT DP	IP PR (PSIG)
22.50A	32.761	31.726	32.847	34.322	34.202	34.102	31.398	33.754
1366.50A	40.351	41.495	43.403	45.464	26.356	33.697	25.251	42.673
1566.50A	45.076	44.044	45.009	46.015	26.746	35.202	25.351	45.146
1655.50A	48.117	45.866	46.664	49.535	29.025	36.416	25.617	47.042
2062.50A	75.852	66.674	68.517	53.635	25.650	45.350	22.012	83.936
2156.50A	69.556	52.447	55.165	99.811	27.474	46.426	22.805	89.591
2463.50A	100.22	98.362	101.40	106.04	24.172	51.922	24.022	95.625
2556.50A	109.60	105.53	106.67	111.05	30.332	55.337	25.484	100.87
2454.50A	119.04	106.03	112.27	117.53	31.769	59.561	26.879	107.05
2152.50A	123.03	114.81	117.67	123.95	33.320	63.979	26.623	113.12
3067.50A	218.56	167.86	192.30	200.52	40.905	94.197	33.009	165.97
3151.50A	207.67	180.65	182.31	192.47	37.974	87.642	30.202	178.38
3233.50A	199.64	172.17	177.93	183.73	35.932	81.621	27.976	168.56
3314.50A	163.66	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	156.55	162.67	30.517	68.301	23.224	147.82
3587.50A	146.15	146.06	150.80	155.05	28.699	64.028	21.779	140.14
3607.50A	133.40	138.94	143.56	147.98	26.690	60.079	20.400	133.44
3787.50A	144.41	132.46	136.25	141.08	24.878	56.567	19.719	126.62
3937.50A	106.71	116.11	119.68	123.75	17.625	42.919	15.738	107.03
4238.50A	101.11	112.06	115.92	121.36	14.391	39.315	12.665	105.30
4586.50A	99.866	111.63	114.54	119.73	8.4379	37.845	6.7563	105.30
5054.00A	63.515	63.326	65.916	64.473	29.649	8.2444	1.1360	78.558
5349.00A	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	12.507	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	59.302	65.672	66.166	71.948	10.565	26.187	10.068	63.142
6562.00A	71.405	71.698	74.616	77.945	11.441	28.939	11.085	68.340
6720.50A	74.294	74.475	77.646	80.657	12.569	29.620	10.516	71.738
6842.00A	75.977	72.520	75.222	78.550	13.499	28.900	11.154	69.195
6986.00A	82.185	73.958	71.469	80.563	12.107	27.544	10.441	71.423
7123.00A	79.111	76.990	74.443	77.363	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

TEST 84LC011		TEST DATE 22 MAR 1984		PROCESS DATE 17 NOV 1984		PUMP CALIBRATION TEST FACILITY	
TEST 84LC011		3-21-84 LGW THRUST PUMP H-Q & CAV TESTS				PAGE 15	
TIME	IMP FK N	40	11C	114	115	116	
IMP FK N	IMP REAK	TURB IN	RUTUR QU	RUTUR QU	RUTUR QU	RUTUR QU	TURB NOZ
10 00A	110 PK (PSIG)	711P PK (PSIG)	STATIC P (PSIG)	711P PK (PSIG)	711P PR (PSIG)	711P PR (PSIG)	OUT
12 50A	33.0747	34.0804	1.7071E-04	2.5322E-01	.64035E-02	.54072E-01	
1300 50A	33.0743	44.047	2.5477	1.5256	1.6553	1.0910	
1500 50A	35.067	46.362	3.5412	1.5446	1.6144	1.1291	
1650 50A	36.0098	46.286	3.5444	1.5636	1.5952	1.1355	
2002 50A	45.3559	66.926	7.1402	3.2347	3.4595	2.8531	
2150 50A	52.450	92.110	7.7052	3.1651	3.4403	2.7577	
2263 50A	53.5066	96.064	7.6664	3.1461	3.4210	2.7704	
2356 50A	56.795	103.20	7.5659	3.1461	3.3698	2.7449	
2454 50A	62.061	105.13	7.5417	3.1144	3.3249	2.7449	
2552 50A	65.450	115.12	7.4714	3.0826	3.3506	2.6622	
3067 50A	98.187	164.77	11.440	4.7413	5.1316	4.4371	
3151 50A	53.723	179.56	11.452	4.8173	5.1764	4.5134	
3233 50A	89.475	171.74	11.375	4.8669	5.2341	4.5579	
3314 50A	63.923	166.25	11.745	4.9565	5.2789	4.6406	
3401 50A	61.699	158.45	11.651	5.0262	5.3494	4.6661	
3508 50A	77.476	151.15	11.960	5.0515	5.4006	4.7360	
3567 50A	73.675	144.05	12.034	5.0631	5.4711	4.7233	
3667 50A	69.440	157.57	12.178	5.1338	5.4967	4.8060	
3767 50A	65.957	131.38	12.416	5.1971	5.5288	4.8124	
3937 50A	46.642	113.59	11.414	4.7688	5.1011	4.4935	
4236 50A	45.241	105.65	11.551	4.8574	5.1750	4.5311	
4586 50A	45.156	109.25	11.497	4.9917	5.3418	4.6406	
5054 00A	5.5327	81.71	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	11.447	4.7659	5.1235	4.4790	
5632 00A	49.442	125.04	10.467	4.5247	4.6267	4.2405	
5476 50A	75.621	146.45	12.015	5.2730	5.6441	4.9714	
6425 00A	30.634	65.475	7.6074	2.5578	3.2241	2.6313	
6502 00A	32.917	70.459	6.9416	2.6453	3.0766	2.5308	
6720 50A	33.386	74.417	6.9592	2.6686	3.1045	2.5467	
6L42 00A	32.647	71.366	7.0434	2.9131	3.1353	2.5706	
6506 00A	30.766	73.545	6.9074	2.6510	3.0718	2.5227	
7123 00A	29.705	69.726	6.6535	2.6235	3.0573	2.5308	
7295 00A	28.718	63.138	7.1154	2.5422	3.1647	2.6167	

ST 84L005

TEST DATE 15 FEB 1984 PROCESS DATE 9 NCV 1984

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TEST 84L005 2-15-84 LOW THRUST PUMP HC &amp; 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	1.43810E+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 FCR 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	TUBE MEAN DIAMETER, IN	2.40000E+00
97	TURB NOZ AREA, IN <sup>2</sup>	5.54000E-01
98	TURB PIPE IN DIAMETER, IN	1.61000E+00

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PUMP CALIBRATION TEST FACILITY  
 TEST DATE 15 FEB 1984 PROCESS DATE 9 NOV 1984  
 PAGE 4  
 TEST 84L05 TEST 84L05 2-15-84 LOW THRUST PUMP HQ E GAV. TESTS

TIME	-2	-101	-102	-103	-104	-105	-106	-107
VAPOR HEAD (FT)	NOZZLE FLOWRATE (LB/SEC)	FLUID NOZZLE PR RATIO	FLOW PARAM	TURB AYL ENERGY, BTU/LBM	CSUBO ISEN VEL FT/S	TURBINE MEAN VEL FT/S	TURB AYL ENERGY, 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	3.2736	+10.96	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	.61374E-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 .60028	.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 .79857	.30224	.62612E-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	

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 FEB 1984      PROCESS DATE 9 NOV 1984  
PAGE 5  
TEST 84L005      TEST 84L005      2-15-94 LOW THRUST PUMP HC & CAV. TESTS

TIME	-1	-115	6	14	105	106	1	8
WATER	TURBINE	PUMP INL	PUMP OUT	TURBINE	TURBINE	PUMP INL	PUMP DIS.	PUMP DIS.
SP.WGT.	PRESSURE	ET TEMP	LET TEMP	INLET TEMP	OUTLET TEMP	ET PRESS	PRESS	PRESS
LBM/FT <sup>3</sup>	RATIO	(F)	(F)	(F)	(F)	(PSIG)	(PSIG)	(PSIG)
19.79A	52.320	1.0202	64.273	64.465	27.119	31.532	39.266	66.676
528.79A	62.308	1.0620	66.198	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	68.321	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	68.495	71.569	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	39.784

SECTION A6

PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 FEB 1984 PROCESS DATE 9 NOV 1984  
TEST 84L005 TEST 84L005 2-15-84 LOW THRUST PUMP HQ E CAV. TESTS

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TIME	18			19			20			21			22			23			24			25			26			
	VOLUME P RES. JOE	VOLUME P RFSS 90D	VOLUME P RES 1300	VOLUME P EG(PSIG)	VOLUME P RES 1300	VOLUME P EG(PSIG)	VOLUME P RES 270D	VOLUME P EG(PSIG)	DIFFUSER IN PRES	FRONT WR R (PSIG)	REAR WR R (PSIG)																	
19.79A	65.847	67.225	64.367	65.955	64.367	65.955	64.367	65.955	64.367	144.31	140.15	115.82	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99	118.99		
522.79A	150.43	151.60	147.74	147.74	147.74	147.74	147.74	147.74	147.74	229.83	223.88	177.12	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	182.64	
723.79A	244.62	245.06	239.57	239.57	239.57	239.57	239.57	239.57	239.57	324.57	318.56	244.64	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	252.46	
1012.79A	348.82	348.85	342.34	342.34	342.34	342.34	342.34	342.34	342.34	327.45	320.96	246.47	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	254.62	
1377.79A	352.38	352.11	344.93	344.93	344.93	344.93	344.93	344.93	344.93	329.31	321.66	247.27	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	
1525.79A	354.79	354.47	346.94	346.94	346.94	346.94	346.94	346.94	346.94	329.31	321.66	247.27	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	255.82	
1803.00A	359.41	358.57	351.32	351.32	351.32	351.32	351.32	351.32	351.32	333.86	325.51	250.55	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	259.36	
2027.00A	357.56	356.36	349.25	349.25	349.25	349.25	349.25	349.25	349.25	331.87	322.59	248.91	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	257.46	
2215.79A	359.36	358.02	351.50	351.50	351.50	351.50	351.50	351.50	351.50	334.36	324.41	250.94	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	
2319.79A	362.63	361.14	355.58	355.58	355.58	355.58	355.58	355.58	355.58	337.64	326.70	252.90	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	261.38	
2501.79A	358.69	357.44	352.44	352.44	352.44	352.44	352.44	352.44	352.44	335.34	324.03	251.71	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	260.23	
2656.79A	370.58	368.94	364.27	364.27	364.27	364.27	364.27	364.27	364.27	346.91	333.45	259.44	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	268.17	
2799.79A	359.97	358.59	354.53	354.53	354.53	354.53	354.53	354.53	354.53	339.61	324.49	253.62	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	261.71	
3033.79A	369.74	368.80	364.16	364.16	364.16	364.16	364.16	364.16	364.16	350.30	333.43	260.52	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	268.72	
3474.00A	206.15	204.45	206.27	206.27	206.27	206.27	206.27	206.27	206.27	204.81	215.04	158.80	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	155.27	
3960.79A	278.90	279.58	275.44	275.44	275.44	275.44	275.44	275.44	275.44	260.79	251.75	185.67	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	197.64	
4676.58A	38.821	39.609	38.178	38.178	38.178	38.178	38.178	38.178	38.178	39.947	39.612	39.924	40.219	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631	38.631

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PUMP CALIBRATION TEST FACILITY  
TEST DATE 15 FEB 1984      PROCESS DATE 9 NCV 1984  
TEST 84L005      2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	38		39		40		110		111		112		113		114	
	IMP FR T	IMP FR M	IMP QEAR	TURB IN	TURB NCZ	TURB NCZ	OUT TIP	OUT TIP	OUT HUB	OUT HUB	ROTOR NOZ	ROTOR DU	T TIP	PR	T TIP	PR
IP PR	ID PR	(PSIG)	(PSIG)	(PSIG)	R (PSIG)	STATIC P	IN PR	PR PSIG	PR PSIG	PR PSIG	PR PSIG	PR PSIG	(PSIG)	(PSIG)	(PSIG)	(PSIG)
19.79A	62.436	58.815	63.484	2.6547	2.2504	1.0948	1.0454	1.0454	1.0454	1.0454	1.0454	1.0454	1.0454	1.0454	1.0454	1.0454
528.79A	133.21	122.00	135.51	7.4534	6.3654	3.6921	3.8488	3.8488	3.8488	3.8488	3.8488	3.8488	3.8488	3.8488	3.8488	3.8488
723.79A	211.80	192.16	215.42	12.468	10.843	6.7901	7.0206	7.0206	7.0206	7.0206	7.0206	7.0206	7.0206	7.0206	7.0206	7.0206
1012.79A	300.58	270.30	304.46	20.976	19.073	12.663	12.663	12.663	12.663	12.663	12.663	12.663	12.663	12.663	12.663	12.663
1377.79A	302.67	272.22	307.14	20.273	18.313	12.124	12.124	12.124	12.124	12.124	12.124	12.124	12.124	12.124	12.124	12.124
1525.79A	303.77	273.17	308.15	19.331	17.226	11.461	11.558	11.558	11.558	11.558	11.558	11.558	11.558	11.558	11.558	11.558
1803.00A	307.65	276.68	312.21	18.832	16.770	11.123	11.226	11.226	11.226	11.226	11.226	11.226	11.226	11.226	11.226	11.226
2027.00A	304.53	274.21	309.62	17.856	15.858	10.494	10.632	10.632	10.632	10.632	10.632	10.632	10.632	10.632	10.632	10.632
2215.79A	307.51	277.18	311.88	17.255	15.355	10.086	10.216	10.216	10.216	10.216	10.216	10.216	10.216	10.216	10.216	10.216
2319.79A	309.39	278.60	313.92	16.654	14.712	9.6902	9.8093	9.8093	9.8093	9.8093	9.8093	9.8093	9.8093	9.8093	9.8093	9.8093
2501.79A	307.17	277.15	311.67	15.724	13.976	9.0380	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657
2656.79A	316.50	285.70	320.99	15.644	13.847	8.9797	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657	9.2657
2799.79A	308.01	278.70	312.56	14.578	12.900	8.2926	8.6005	8.6005	8.6005	8.6005	8.6005	8.6005	8.6005	8.6005	8.6005	8.6005
3033.79A	316.38	286.36	321.29	14.408	12.818	8.1761	8.4223	8.4223	8.4223	8.4223	8.4223	8.4223	8.4223	8.4223	8.4223	8.4223
3474.00A	193.95	157.24	208.71	17.047	15.442	10.106	10.069	10.069	10.069	10.069	10.069	10.069	10.069	10.069	10.069	10.069
3960.79A	236.02	207.37	239.44	19.892	17.759	11.650	11.730	11.730	11.730	11.730	11.730	11.730	11.730	11.730	11.730	11.730
4676.58A	39.325	38.006	39.741	4.5457	3.8898	2.0407	2.0680	2.0680	2.0680	2.0680	2.0680	2.0680	2.0680	2.0680	2.0680	2.0680

SECTION A6

PUMP CALIBRATION TEST FACILITY  
 TEST DATE 15 FEB 1984    PROCESS DATE 9 NOV 1984  
 TEST 94L005    2-15-84 LOW THRUST PUMP HQ & CAV. TESTS

TIME	SHAFT SPEED	PUMP HEAD	TOT HEAD	PUMP DISCHARGE	DES. FLOW	FLOW / LED HEAD	PUMP SCALED FLOW	PUMP HEAD	PUMP HEAD	-31		-32		-23		
										(RPM)	(FT)	(GPM)	(GPM)	HP	CCEF	
19.79A	7352.3	63.446	63.446	1.4339	0.9902	705.02	4.9951	0.24007E-01	0.49623	528.79A	14691.	2.9756	0.99247	4.9624	0.52058	
528.79A	14691.	265.94	265.94	4.0311	0.9362	739.62	4.9624	0.19973	0.52343	723.79A	19880.	489.62	4.0269	4.9681	0.49813	
723.79A	19880.	744.17	744.17	6.0269	1.2033	743.67	4.9681	0.0166	0.52290	1012.79A	24542.	746.98	5.5574	741.64	1.1318	
1012.79A	24542.	748.70	748.70	4.9855	1.1078	742.11	5.5392	5.5392	0.52234	1377.79A	24581.	748.70	0.9986	746.83	4.9793	
1377.79A	24581.	756.27	756.27	4.5055	0.99480	745.75	4.4740	0.85978	0.52565	1525.79A	24531.	748.70	4.9855	746.83	0.94190	
1525.79A	24531.	756.27	756.27	4.0233	0.80616	751.06	4.9308	0.75963	0.52490	1803.00A	24673.	748.26	4.0233	746.83	0.52864	
2027.00A	24455.	750.25	750.25	3.4857	0.69638	748.65	3.4819	0.65986	0.52694	2215.79A	24527.	750.25	2.9330	0.59836	0.53148	
2215.79A	24527.	755.76	755.76	2.5076	0.50515	755.11	2.9918	0.57079	0.53200	2319.79A	24511.	755.76	2.5076	755.85	2.5257	
2319.79A	24511.	745.04	745.04	2.5076	0.50515	755.85	2.5257	0.47141	0.53351	2501.79A	24324.	745.04	2.5076	755.85	0.47141	
2501.79A	24324.	771.37	771.37	2.0123	0.39864	757.98	1.9947	0.39166	0.53351	2656.79A	24716.	746.26	1.5130	0.30661	0.53501	
2799.79A	24276.	767.62	767.62	1.0378	0.20659	760.12	1.5331	0.28604	0.53501	3033.79A	24615.	767.62	1.0378	0.20659	0.53524	
3474.30A	19726.	479.81	479.81	4.4655	-0.87343	760.45	1.0329	0.20180E+09	0.436072	3960.79A	21604.	650.89	5.0943	0.20180E+09	-0.15839E+06	
3960.79A	21604.	650.89	650.89	-0.11034E-03	-2.8090	-1.1206	-0.20297	-0.13989E+10	0.93927	4676.58A	-3.2542	-0.11034E-03	-2.8090	1.0149	-0.14204E+06	
4676.58A	-3.2542	-0.11034E-03	-2.8090	-0.11034E-03	-2.8090	-0.20297	-0.13989E+10	1.0149	-0.22293E-07	-0.98464E+06	92293E-07	-0.98464E+06				

SECTION A6

#### REFERENCES

1. Wislicenus, G. F.: "Fluid Mechanics of Turbomachinery," Dover Publications, Inc., New York, 1965.