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NASA-CR-132232) LH2 PUMP COMPONENT DEVELOPMENT TESTING IN THE ELECTRIC PUMP ROOM AT TEST CELL C INDUCER NO. 1 Final (Aerojet-General Corp., Sacramento, Calif.) ~~400~~ 405 p HC $22.00 CSCL 13K G3/15

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ENGINEERING OPERATIONS REPORT

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FINAL REPORT

LH_2 PUMP COMPONENT DEVELOPMENT TESTING IN THE ELECTRIC PUMP ROOM AT TEST CELL "C" INDUCER NO. 1

PROJECT 121

MAY 1972

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I. INTRODUCTION

The NERVA Engine requirements dictates the turbopumps within the system shall have certain performance characteristics. To ascertain the performance of the pump characteristics and to identify any problems associated with its performance, early component testing of various pump configurations was desirable and was accomplished to support the design selection of the pump for the NERVA Turbopump.

The NERVA Pump will be a two stage centrifugal pump with both stages having backswept impellers and an inducer upstream of the first stage impeller.

The component tests conducted at Test Cell "C" investigated the performance of the first stage components. The first stage configuration tested consisted of an inducer, impeller and a vaned diffuser followed by a pump volute.

The test program completed on 22 December 1971 provided demonstration of the ability of the design selected for the NERVA Turbopump to meet the requirement imposed by the NERVA Engine.

All testing was conducted at the Nuclear Rocket Development Station, Jackass Flats, Nevada

II. SUMMARY AND CONCLUSIONS

The LH_2 Pump Component Development Testing was conducted during the first quarter of Contract 1972. All objectives of the program were successfully accomplished in the three experimental plans including:

1. Provision of performance data of various pump components under consideration for the NERVA turbopump.

2. Provision of cavitating performance data of the initial configuration inducer.

During the test program the following was demonstrated:

1. The non-cavitating performance of the overall test article and individual components agreed with the pretest prediction and met or exceeded the design requirements. The predicted overall head coefficient (ψ_{ov}) at design was .54. The actual value at design was .565.

2. The cavitation performance agreed with the pretest predictions and exceeded the design requirements. The empirical relationship for Net Positive Suction Pressure (NPSP) at breakdown for the LH_2 pump was:

$$NPSP = \left[\frac{P_V}{130} - 0.076\right]\left[\frac{N}{1000} - 153.1 + 525\left(\frac{Q}{N}\right) - 450\left(\frac{Q}{N}\right)^2\right]$$

where:

N	=	pump speed
Q	=	volumetric flow rate
P_V	=	vapor pressure

3. The test rig shaft critical speed of 29,250 rpm agreed with the pretest predicted critical speed of 30,000 rpm.

4. The radial thrust agreed with pretest predicted value of .18 for the radial force parameter $\left(\frac{\text{Radial Force}}{\text{Ave Impeller Static Pressure Rise}}\right)$.

5. The axial thrust was within the capabilities of the bearings. It reached momentary peak magnitudes of 3400 lbs toward pump inlet at the highest speed, lowest Q/N value and lowest suction pressures tested. High thrust magnitudes of approximately 1000 lbs toward coupling were obtained at high scution pressures, high values of Q/N, and low speed.

III. PROGRAM OBJECTIVES

The overall objective of the LH_2 Pump Component Development Program was to investigate performance characteristics of various pump components and configurations under consideration for the NERVA Turbopump.

The main objective of this program was to investigate inducer performance. It also provided a means to establish the performance characteristics of the first stage impeller, pump volute, and a portion of the internal instrumentation being considered for use on the NERVA Turbopump.

The test article was limited to the first stage of the NERVA Turbopump by the available power of the electric drive system. It was felt that the performance of the crossover and the second stage housing could be accurately predicted from the results of the Pump Air Test Program (Reference 1*).

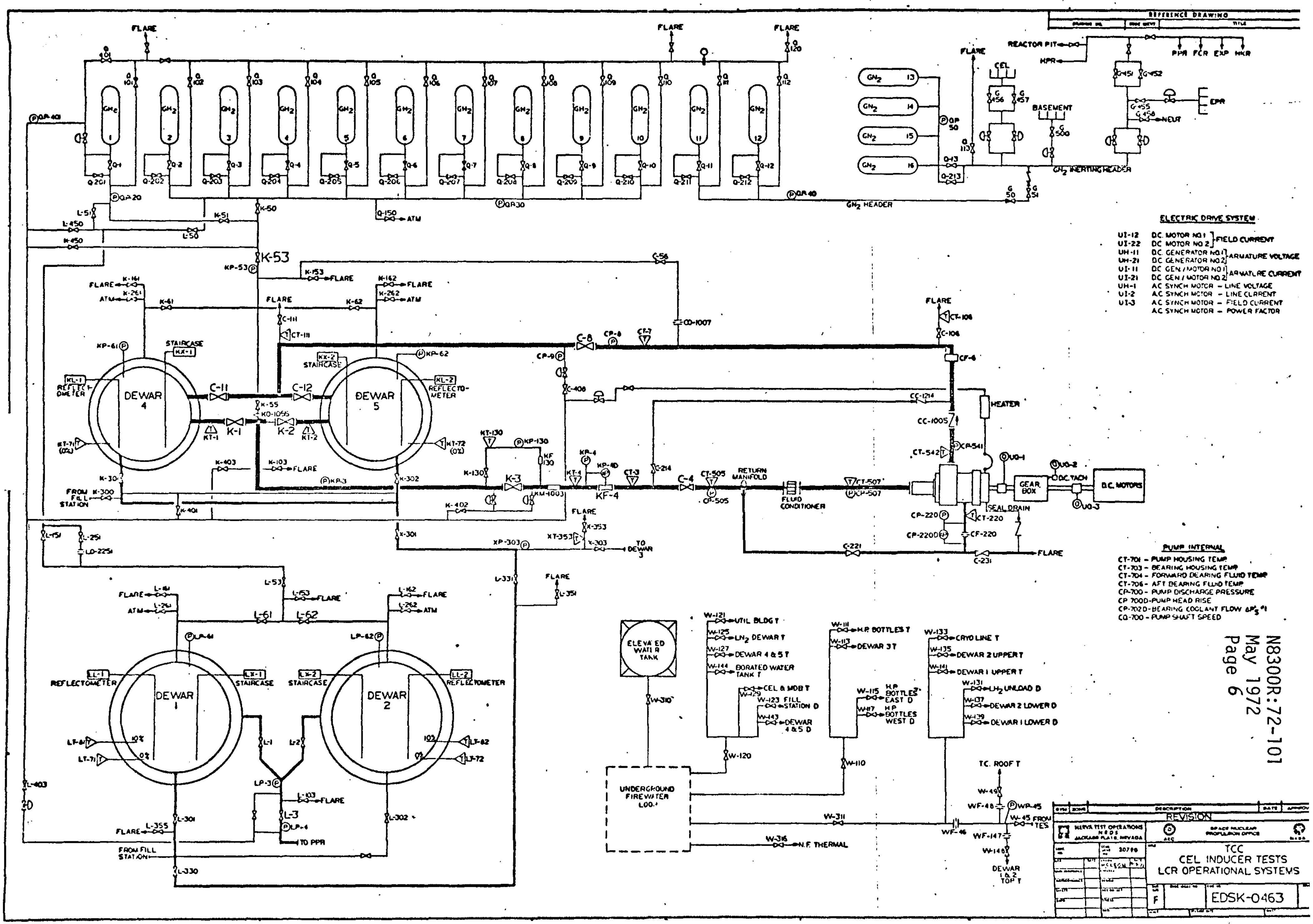
*References are listed in Section XII.

IV. FLOW SYSTEM

The electric pump room schematic for the pump test program is shown in Figure 1. Liquid hydrogen was provided to the pump from either Dewar 4 or 5. The inlet flow to the pump was measured by a Venturi, KF-4. Low flow rate measurements, less than five pounds per second, were measured by diverting the suction flow through Valve K-130 and measuring the flow through a turbine type Flow Meter KF-130A during chilldown. Provisions were provided to either divert the liquid hydrogen flow around or through the pump rig by Valves C-4 and C-214. The inlet line as shown in Figure 1, had provisions to use a fluid conditioner for suction pressure throttling. Valve K-3 was utilized to control the upstream pressure of the fluid conditioner. The pump inlet line also had a bellows with a removable liner which permitted investigating the effect of the bellows on suction performance.

The pump discharge line had a turbine type flow meter, CF-6, to measure discharge flow rate. The pump impedence was controlled by Valve C-8 in the pump discharge line. The bypass line was teed off the pump discharge line and Valve C-106 controlled the bypass flow. The pump rig bearing coolant flow was either diverted out through the flare stack utilizing Valve C-231 or returned to the suction line through the return manifold utilizing Valve C-221.

The pump rig was powered by the electric motors located adjacent to the electric pump room in the motor drive building.



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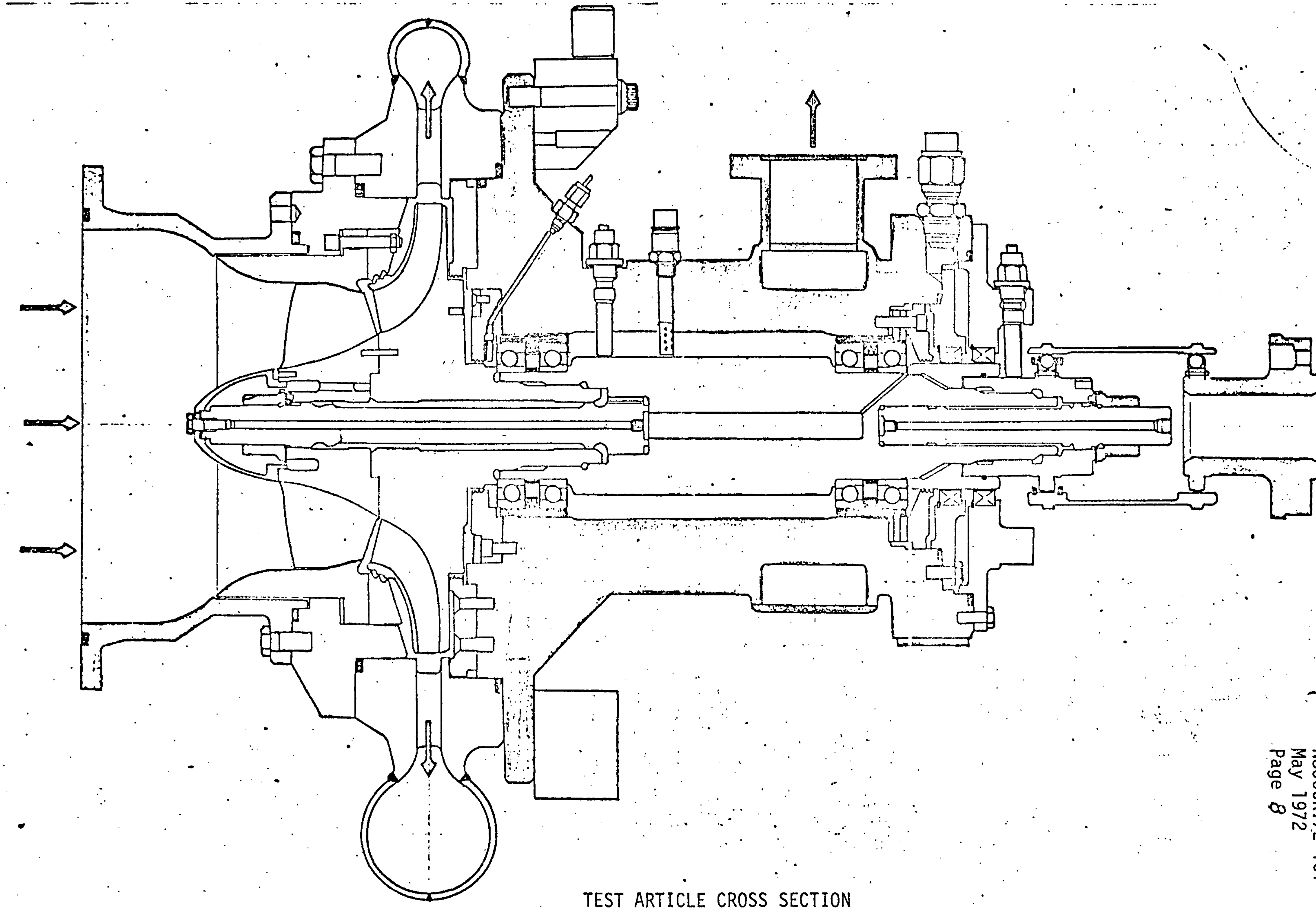
V. TEST ARTICLE DESCRIPTION

The Test Article was a single stage centrifugal pump assembly. It was mounted on a heavy steel support frame which had adjusting screws for precision alignment of the pump shaft with the gear box high speed drive shaft. The pump support frame was bolted to the concrete and steel pedestal in the Electric Pump Room (EPR). The test article was mechanically connected to the gear box drive shaft by a ball spline coupling which allowed for a small amount of misalignment, such as that due to dimensional changes from ambient conditions to cryogenic operation conditions.

The first stage pump assembly is shown in cross section by Figure 2. The assembly drawing for the pump was ANSC Drawing 1139300, "LH_2 Test Rig Assembly - 1st Stage." (Reference 3) The major parts of the pump rig are described below:

INLET SPOOL HOUSING - This spool had a 9.5 inch inside diameter flange at the facility interface which was the inlet line bellows. There were two spool housings which were interchangeable; one had four internal strutts, two of which housed displacement probes that sense the position of the inducer spinner in the vertical and horizontal planes. The inducer spinner used with the strutted inlet spool had a truncated conical cross section rather than the elliptical cross section shown in Figure 2. The spinner sides were perpendicular to the displacement probes and had a known depth spotface machined into it to allow calibration of the displacement probes during operation at LH_2 temperatures. The strutted spool was part number 1138562-1 (Reference 4), and the non-strutted spool was part number 1138561-1 (Reference 5).



TEST ARTICLE CROSS SECTION

FIGURE 2

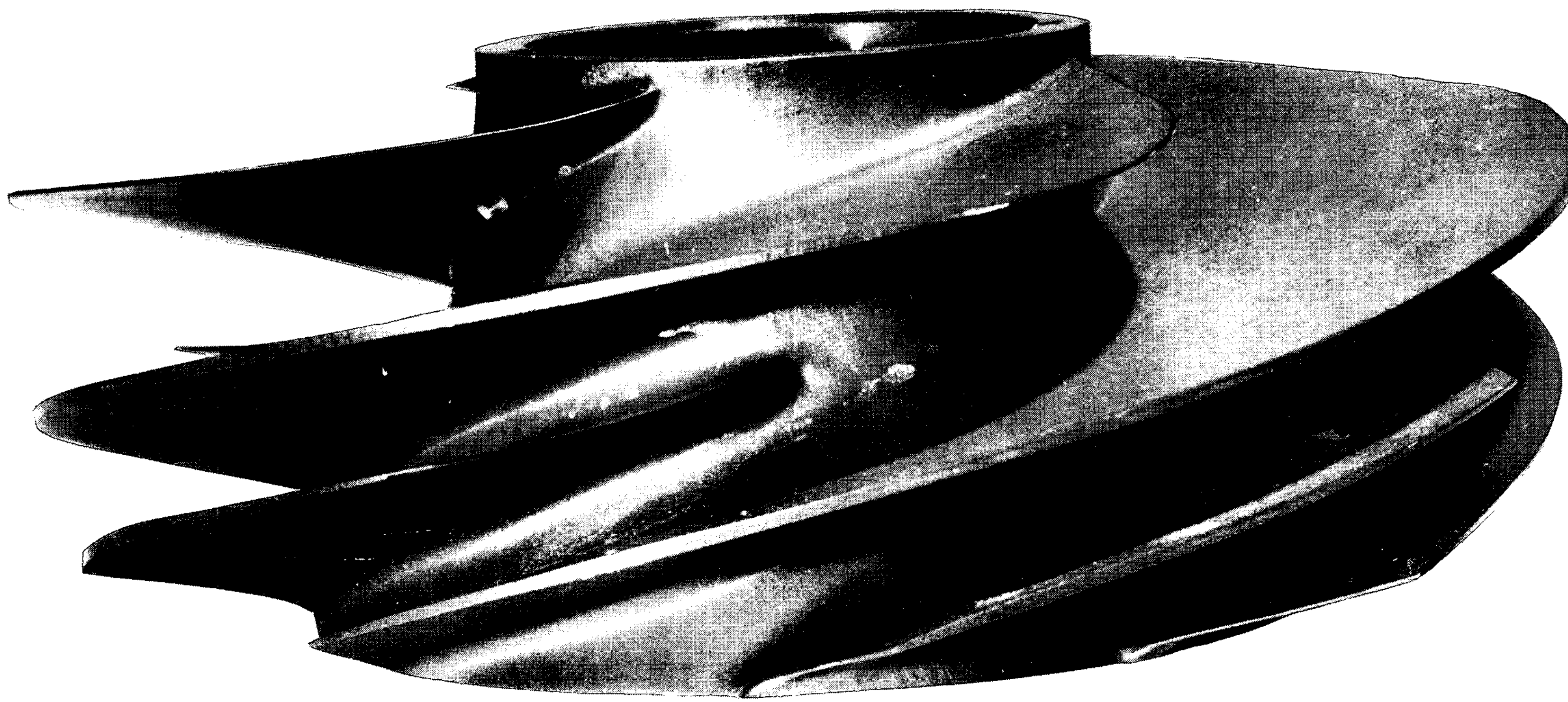
INDUCER - The inducer was part number 1138588-1 (Reference 6) and is shown in Figure 3 without the spinner. The inducer design parameters are:

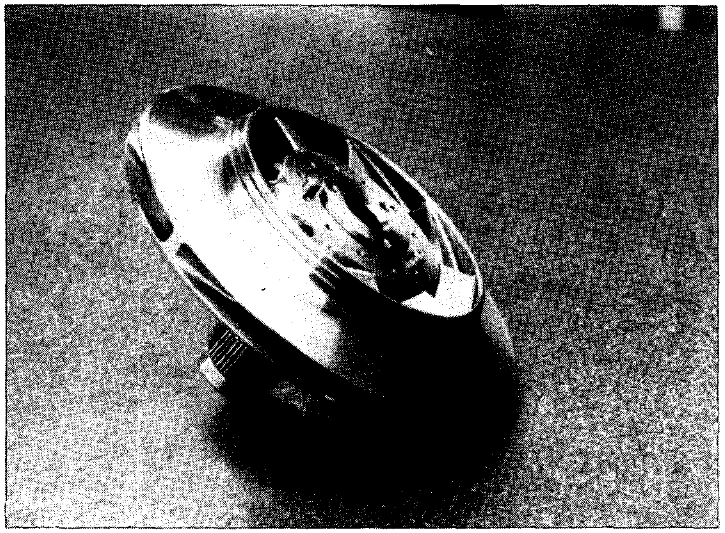
Inlet Tip Diameter	6.86 in.
Inlet Hub/Tip Ratio	0.398 in.
Inlet Tip Blade Angle (Camber line)	8.2°
Discharge Tip Diameter	6.46 in.
Discharge Hub/Tip Ratio	0.683 in.
Discharge Blade Angle	
Tip	16°
Mean	18.3°
Hub	24°
Blade Number	4 + 4
Inlet Tip Flow Coefficient	0.076
Discharge Tip Head Coefficient (Based on η_h = 0.85)	0.210

IMPELLER - The impeller was part number 1138550-1 (Reference 7) and is shown in Figure 4. The unshrouded tooling verification piece is also shown. This first stage impeller is backswept and shrouded with the following design parameters:

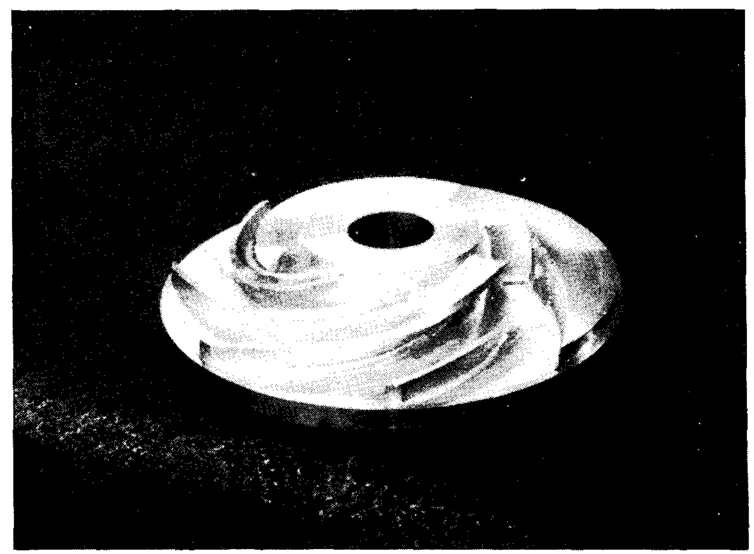
Discharge Diameter	10.75 in.
Discharge Part Width	0.52 in.
Discharge Blade Angle	30°
Blade Number	8
Inlet Tip Diameter	6.53
Hub/Tip Ratio	0.70
Blade Inlet Angle	
Tip	16°
Mean	21°
Hub	26°
Discharge Flow Coefficient	0.105

INDUCER





Impeller



Unshrouded Tooling
Verification Piece

PUMP DISCHARGE HOUSING VOLUTE - The volute was part number 1138600-4 (Reference 8) and has internal vanes. There were three housings built onto the volute near the discharge flange. Two of these contained filters and orifices that were used to externally route pump discharge pressure LH_2 back to the two sets of pump bearings for bearing coolant. The volute design parameters are:

Volute Base Circle Diameter	16.0 in.
Volute Throat Area	11.45 sq. in.
Discharge Line Inside Diameter	4.75 in.

POWER TRANSMISSION - The power transmission was composed of many parts as shown on assembly drawing 1139300 (Reference 3). The main housing supported the bearing cartridges, each of which held the two sets of preloaded 65mm duplex ball bearings that supported the main shaft. The inducer and impeller were cantilever mounted with respect to the two sets of bearings. There was no balance piston arrangements on this first stage assembly pump nor a separate thrust bearing. All axial loads were carried by the aft ball bearing assembly. The bearings were cooled by LH_2 from the pump discharge. The coolant was controlled and contained by a series of labyrinths and dynamic seals.

PUMP/FACILITY INTERFACES - The LH_2 that flowed around the back side of the impeller, as well as both bearing coolant LH_2 flows, discharged from the pump assembly at the 2.125-inch inside diameter flange known as the Main Drain Line. The main pump shaft had two dynamic seals on the aft end that had a drain line connection between them. This was to route any seal leakage hydrogen to the flare stack through the 3/4 inch tubing line known as the Seal Drain Line.

VI. FACILITY DESCRIPTION

The LH_2 Pump Component Development Program was conducted within the Test Cell "C" complex at NRDS. The test program required the use of the Motor Drive Building (MDB), the Electric Pump Room (EPR), the Cryogenic Evaluation Laboratory (CEL), the Local Control Room (LCR) and their associated support systems.

The Electric Drive System (ELD) provided rotational energy and speed control for the test article. The ELD could drive the pump from a low speed of a few rpm to the pump limit of 30,000.

The ELD was rated at 5,000 horsepower at its design speed of 514 rpm which corresponds to a pump speed of 34,645 rpm. After allowing for electrical losses in the D.C. generators/D.C. motors and mechanical losses the gear box, there was approximately 4,400 horsepower available at the pump shaft. At reduced speeds, the ELD was limited by the D. C. motor armature current. The ELD was rated at 100% load for continuous operation and at 125% load for a 2-hour duration.

The Test Cell "C" Electric Drive System was an eight-machine electro mechanical rotary converter capable of providing variable output shaft speeds to the test article in the Electric Pump Room (EPR). The eight machines of the Electric Drive system were permanently mounted in a metal-type building known as the Motor Drive Building (MDB). The machines were arranged in two ranks of equipment that form two common shaft systems. The first rank of five machines consisted of a constant speed synchronous motor driving two separately excited D.C. generators through rigid flange couplings on either side of the motor. Outboard of each large D.C. generator on the main shaft, a smaller generator was connected through flexibile couplings. The rotating members of this first rank of 5 machines were supported on four bearings in large pedestal supports which contained oil sumps for self lubrication of the bearings. The second rank of three machines consisted of two D.C. motors and a speed increasing gear box. The two motors and the gear box were connected goether by means of rigid flange couplings and the rotors were supported on three bearings in large pedestal supports similar to the first rank of machines.

The gear box was manufactured by the General Electric Generator and Gear Department and was designated type DT-383-A Speed Increasing Gear. The 6 1/2-ton gear box was rated for 6000 horsepower and 514 rpm input shaft speed with 2,481 rpm intermediate shaft speed and 34,645 rpm output shaft speed, or overall ratio of 1:67.4. This gear unit was a double stage speed increasing gear with twin intermediate power branches. Input and output shafts were in line and the intermediate shafts were symmetrically located in the same horizontal plane on either side of the input and output shaft centerline.

The test program used basically the existing CEL flow loop. The required modifications of the facility were accomplished so that the least amount of effort would be required to restore the system to its original configuration. The flow loop is described in Section IV.

The Dewar 4 and 5 system was used with one dewar (Run) storing and supplying LH_2 to the pump inlet at the required pressure and temperature while the other dewar (Catch) was collecting and storing the recovered LH_2 from the pump discharge.

Dewars 4 and 5 were identical in construction and were spherical, double walled, vacuum-jacketed, pearlite insulated LH_2 storage vessels. The inner vessel had a total volume of 55,000 gallons, while the 100% level point was 50,000 gallons of LH_2 which allowed for a 10% ullage gas volume. The maximum allowable working pressure was 100 psig.

The LH_2 supply line from the dewars to the pump inlet was vacuum-jacketed and foam-insulated and included remotely-operated valves (K-1, K-2, K-103, K-3, K-130, C-4), branch line remotely-operated valves (K-55, K-403, K-402, C-214, C-221), relief valves (KS-1055, KS-1004), LH_2 flowmeters (KF-130, KF-4), filter (KM-1003), and associated pressure and temperature instrumentation.

The main LH_2 filter, KM-1003, was located in the LH_2 supply line downstream of K-3 and K-130. This filter was a ten-inch, 150 lb ASA, in-line, cone-type filter by Capital Westward. The filtration specifications were: 100% removal of all particulates greater than 150 microns in size and 98% removal of 100 micron size particulates. The filter was designed to flow 200 lbs/sec of LH_2 with a 5 psid pressure drop.

There was a flange location 53 inches upstream of the pump inlet flange where a fluid conditioner was installed for pump cavitation tests to drop the pump inlet NPSP. Two fluid conditioners (47 hole and 21 hole) and an open spool section were fabricated to fit in this location. The fluid conditioners had the following part numbers: 47 Hole, 1440038 (Reference 9); 21 Hole, 1440037 (Reference 10).

The pump discharge piping provides the flow path back to Dewar 4 and 5 catch and storage system and provided a pump back pressure impedance source with valve C-8 and a pump discharge vent line to the flare stack with valve C-106.

The pump discharge line was vacuum-jacketed and foam-insulated and included remotely-operated valve (C-8), branch line remotely-operated valves (C-106, C-56), relief valves (CS-1200, CS-1056), LH_2 flowmeter (CF-6), and associated pressure and temperature instrumentation.

The LH_2 return line from the pump and CEL piping from C-8 to Dewars 4 and 5 was vacuum-jacketed and included remotely-operated valves (C-111, C-11, C-12), branch line remotely-operated valve (C-408), relief valves (CS-1111, CS-1201, CS-1202), and associated pressure and temperature instrumentation.

The operation of the system was accomplished from the LCR which was located approximately 500 feet from the EPR. The LCR required some modification to accommodate the instrumentation necessary to conduct this test.

A more detailed description of the facility can be found in Section 2.3 of Reference 2.

VII. CONTROL SYSTEMS

The controls for the CEL tests originated in the LCR; none come from the R-CP Control Room. The R-CP powerhouse still had the normal controls for the ELR air conditioning, the pumps for makeup water to the elevated water tank, and TCC diesel generator and electrical switchgear.

The general types of control valves used for the CEL Inducer Tests were as follows:

a. Analog valve with sero-hydraulic actuator (typically Moog)

b. Analog valve with servo-pneumatic actuator (typically Mason-Neillan)

c. Analog jog valve with electric motor actuator (typically Limitorque)

d. Binary valve with solenoid pilot valve which utilized hydraulic actuating fluid

e. Binary valve with solenoid pilot valve which utilized pneumatic actuating fluid

f. Binary valve with electric motor actuator

g. Binary valve which was a solenoid valve

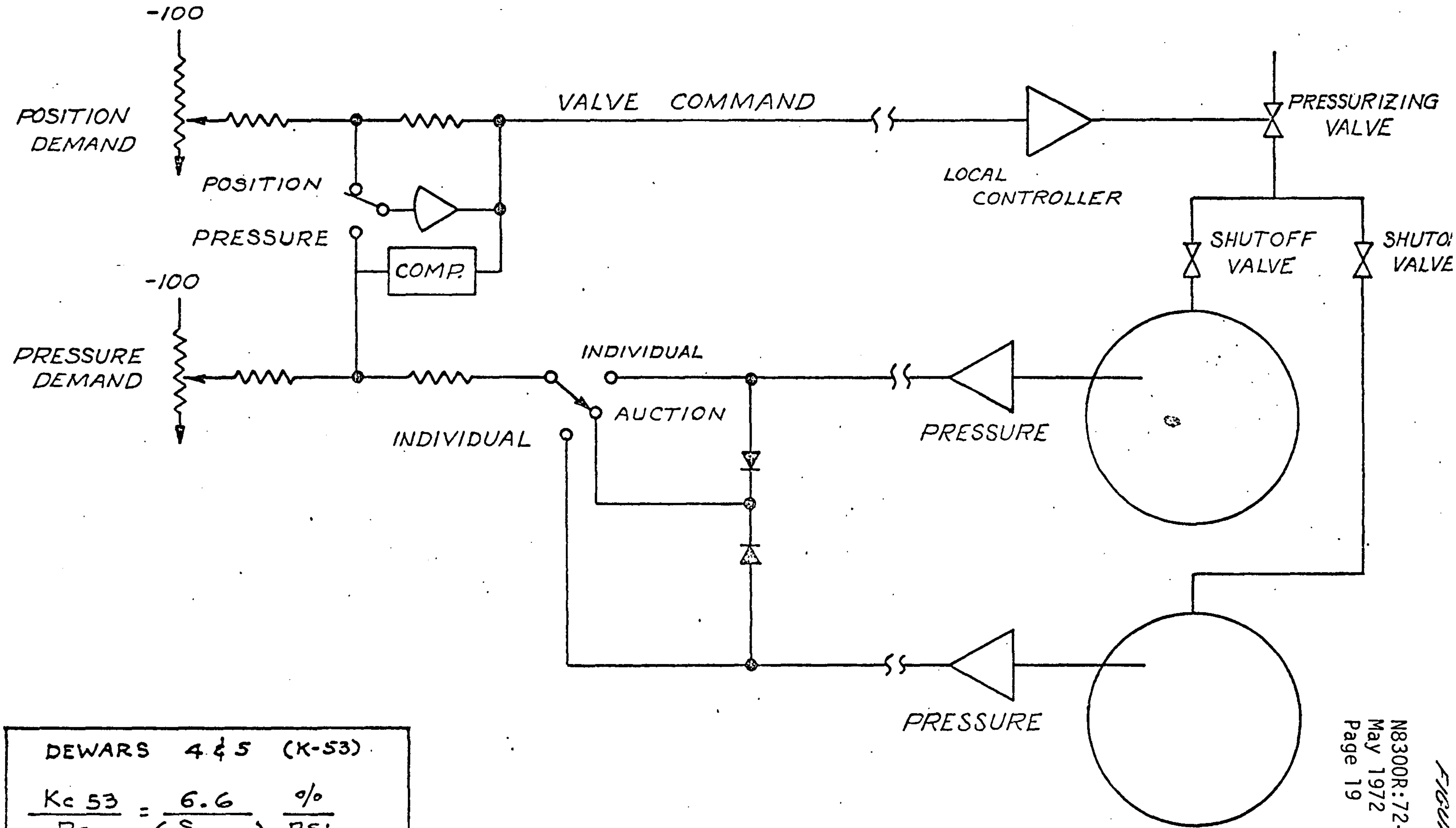
h. Generator field current control which indirectly controlled pump speed.

Pressurization was performed with an analog control system, where the controlled parameter was the pressure in the vessel and the control element was an analog valve which controlled the flow rate from the tank farm to the vessel. All of these systems used the simplest possible controller compensation. It consisted of amplification of the error signal. This lead to a pressure with an error which was proportional to the liquid flow rate and inversely proportional to tank farm pressure and controller amplification. In all cases, the amplification could be made large enough so that the steady-state error did not compromise the effective utilization of the system with the attainable values of liquid flow rate and tank farm pressure. Pressurization systems of the type described were used to pressurize Dewars 4 and 5. Dewars 4 and 5 were pressurized by analog control valve K-53. Figure 5 is a functional block diagram of the dewar pressurization control system. The two modes of operation were Position and Pressure. L-53 was operated in Position Control Mode to a nominal pressure of 40 to 70 psig. K-53 was operated in Pressure Control Mode with a nominal pressure demand of 40 to 100 psig.

In position mode, L-53 and K-53 were operated with position feedback only. In Pressure Control, the measured pressure (KP-61 or KP-62) was compared to the manually demanded pressure to generate the actuating signal. A selector switch in the feedback loop allowed selection of Dewar 4, Dewar 5 or auctioneered pressure as the measured parameter. The auctioneer selected the higher output of the two as the measured feedback pressure, but was not used for CEL testing.

The other valve which had a control feedback for closed loop operation, as well as Position Control, was C-8 (Q/N control). C-8 was a six-inch Annin plug valve with flow under the plug of the 240 C_v equal percentage trim valve. The Q/N controller was located at the CTO console and had the Q/N demand as well as the position demand potentiometer.

In Q/N control, the valve maintained the position required to keep the measured Q/N signal equal to the demanded Q/N. The Q signal was obtained from the turbine flowmeter, CF-6, which was really a volumetric flow measurement (gpm) which had been signal conditioned for 0 to 10 volts to be expressed as 0-100 lbs per second LH_2 (at a density of 4.3 lbs/ft^3). The N signal was



DEWARS 4 & 5 (K-53)

$$\frac{Kc\ 53}{Pe} = \frac{6.6}{\left(\frac{S}{200}+1\right)} \ \frac{\%}{PSI}$$

TYPICAL DEWAR PRESSURIZATION CONTROLLER

FIGURE 5

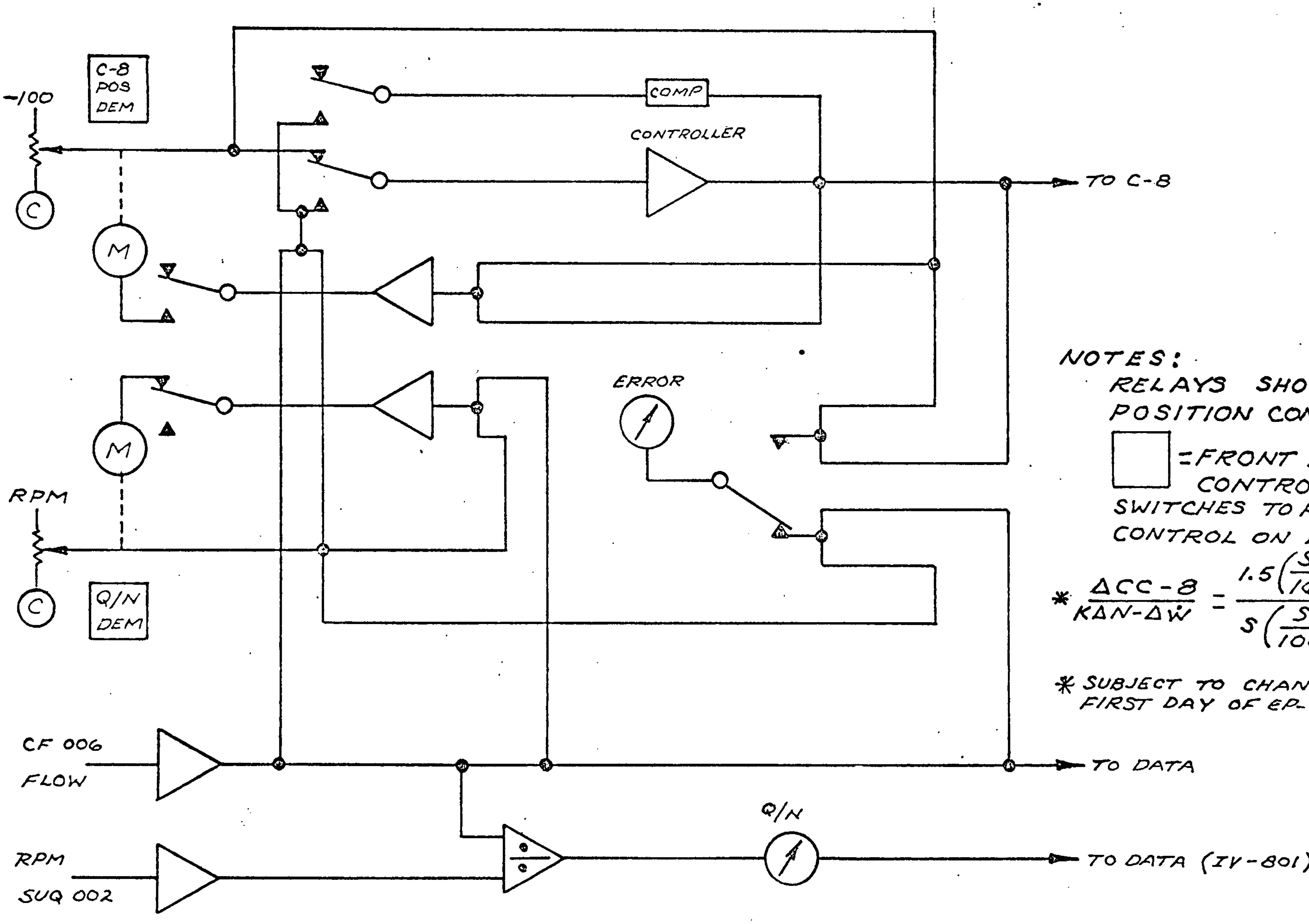
obtained from the DC tachometer, SUQ-002, driven from the gear box intermediate speed shaft and was signal conditioned to be expressed as 0-40,000 rpm. The generated Q/N (from the Q/N chassis) was ranged for 0-1 gpm/rpm Q/N, but the controller responded within a Q/N range of only .1 to .5. The C-8 Q/N controller circuit is shown in Figure 6.

The pump controller controlled the field current of the D.C. generators which indirectly controlled the pump speed as shown in Figure 7. This was the RPM controller and was located at the CTO console and contained the RPM demand and the Manual demand potentiometers.

The local controller in the MDB had a demand potentiometer and provided a signal to the Silicon Controlled Rectifiers (SCR) which was the power source for the generator field windings and maintained the field current at the required steady level. The SCR had inherent closed loop control of the generator field current of which it was an integral part.

In the Manual Control Mode, the LCR Generator Armature Voltage controller provided the demand signal to the local controller rather than the local demand potentiometer. The VGA signal was displayed on the RPM chassis meter and was obtained from channel UH-011 which was the measured voltage generator #1 field and was ranged -500 vdc to +600 vdc.

In the RPM mode, the LCR Speed Controller put out a demand to the Generator Armature Voltage Controller until the measured speed was equal to the demanded speed; this was a closed loop controller using RPM as the feedback signal. The feedback RPM signal was the value of speed channel SUQ-002, which was the D.C. tachometer driven from the intermediate speed shaft of the gear box. This channel was ranged for 0-40,000 rpm.



NOTES:

RELAYS SHOWN IN POSITION CONTROL.

☐ = FRONT PANEL CONTROL

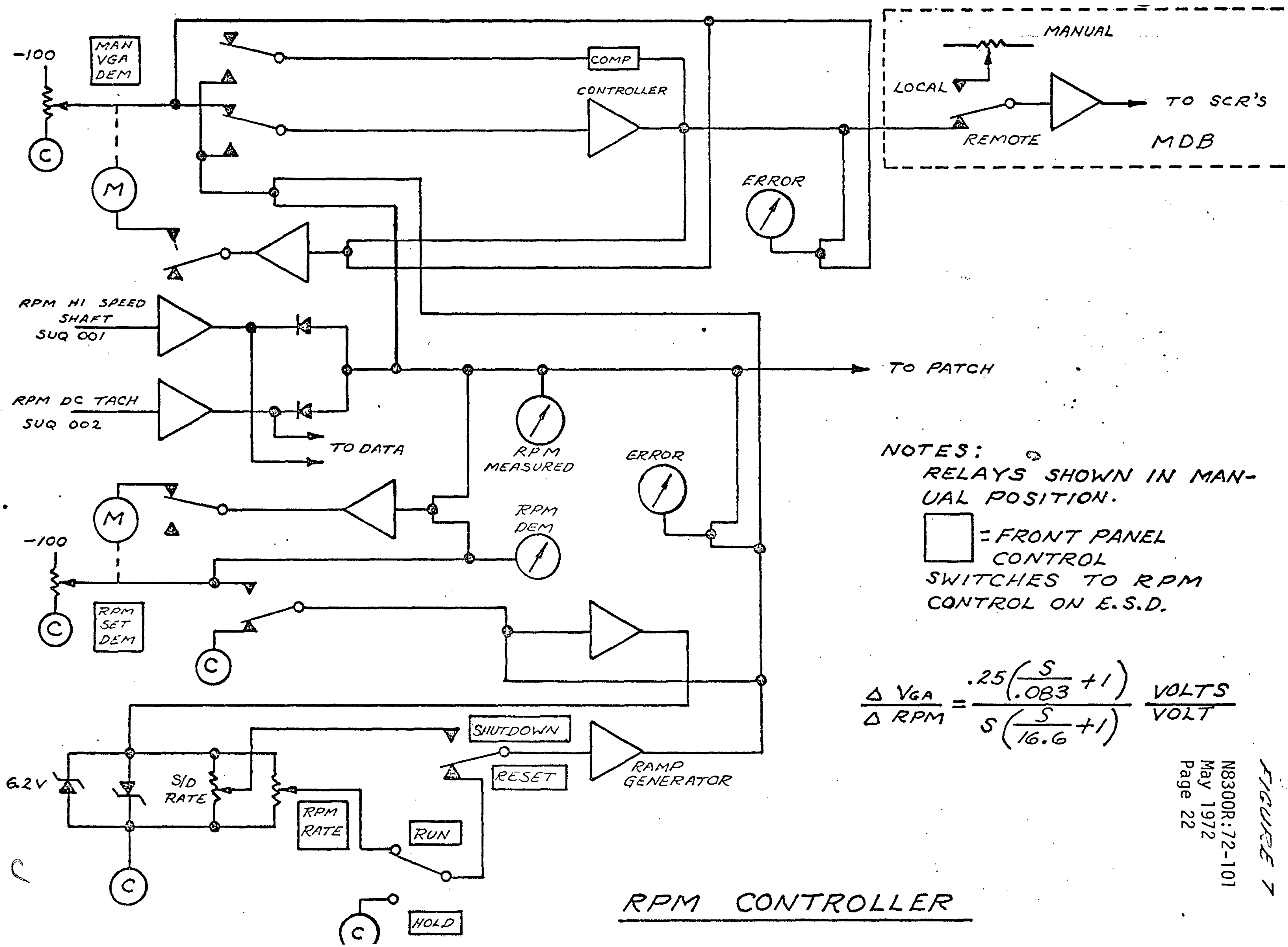
SWITCHES TO POSITION CONTROL ON E.S.D.

$$* \frac{\Delta CC\text{-}8}{K\Delta N - \Delta\dot{W}} = \frac{1.5\left(\frac{S}{16}+1\right)}{S\left(\frac{S}{100}+1\right)} \frac{\%}{\#/SEC}$$

* SUBJECT TO CHANGE ON FIRST DAY OF EP-1

Q/N CONTROLLER (C-8)

FIGURE 6



NOTES:
RELAYS SHOWN IN MANUAL POSITION.
☐ = FRONT PANEL CONTROL
SWITCHES TO RPM CONTROL ON E.S.D.

$$\frac{\Delta V_{GA}}{\Delta RPM} = \frac{.25\left(\frac{S}{.083}+1\right)}{S\left(\frac{S}{16.6}+1\right)} \quad \frac{VOLTS}{VOLT}$$

RPM CONTROLLER

FIGURE 7

The RPM controller was a closed loop controller which was closed around an open loop controller, VGA (Generator Armature Voltage), which was the demand for the closed loop MDB local controller, IGF (Generator Field Current).

The RPM controller speed demand had an additional circuit within it which limited the rate of change of the RPM demand potentiometer signal seen by the RPM controller. This limiter was a ramp rate generator which had a potentiometer to adjust the rate from 0 rpm/sec to 5,000 rpm/sec for both increasing and decreasing speed demands. When an emergency shutdown occurred, relays were set up so that the RPM controller mode was automatically selected, even if Manual Generator Armature voltage mode had been manually selected. A preset decreasing ramp rate was switched to become the demanded input to the RPM controller. This preset value was adjustable from inside the chassis, but was set at a nominal 4,000 rpm/sec. This rate was adjusted to provide a maximum deceleration rate for the pump without exceeding the armature current which would trip the D.C. breakers.

Valve C-106 operated normally in Position Control from a potentiometer in the Q/N controller chassis at the CTO console. C-106 was a 3 1/2-inch Rocketdyne LHBV butterfly valve which had a throat diameter of 3.46 inches and had a servo-hydraulic actuator. In addition to the Manual Position Control mode, there was a special Q/N sensing circuit and relays which allowed the valve to be switched to a preset open demand whenever the measured Q/N became less than the set point of the special Q/N sensing circuit. The preset opening potentiometer was inside of the Q/N chassis, but there were two front panel switch/lights which controlled this special Q/N sensing circuit: One was a lamp indication "LOW Q/N" which illuminated whenever the measured Q/N was less than the adjustable set point Q/N. The other was a split screen switch labeled "RUN" and "RESET". "RESET" allowed resetting of the low Q/N trip and allowed normal Position Control of C-106. "RUN" allowed the low Q/N sensing circuit to step C-106 to the preset position when measured Q/N dropped below the sensing point Q/N. For normal operation the circuit was in RESET until significant pump speed and flow were obtained to have a steady and larger than .15 value of Q/N, at which time it was switched to RUN. At the end of a run when pump speed and flow was decreasing, the switch was placed to RESET so that C-106 could not step open as the Q/N signal became unreliable. While C-106 was in the RUN mode, the manual demand potentiometer was normally demanding the valve to 0% but should a C-8 failure occur and the measured Q/N decrease to the set point, C-106 would step to the preset demand, and provide a liquid hydrogen bypass flow to prevent stalling the pump.

Valve C-231 operated in Position Control from a potentiometer located in the Q/N controller chassis at the CTO console in the LCR. C-231 was a four-inch Annin plug valve with flow under the plug of the 195 C_v linear trim valve.

Valve K-3 operated in Position Control from a potentiometer located in the RPM Controller chassis at the CTO console. K-3 was a eight-inch Hadley Butterfly with a 3400 C_v.

Valve K-130 operated in Position Control from a potentiometer located at the FLO console. K-130 was a two-inch Annin plug valve with the flow over the plug of the 46 C_v linear trim valve.

VIII. INSTRUMENTATION

A. General

The measurements related to the test article are shown in Table I and Table II, Pump Instrumentation and Facility Instrumentation. Table I and Table II reflects the instrumentation required by the test article supplier for EP-1. Figure 8 shows the location of the instrumentation on the test article and Figure 1 shows the relative location of instrumentation on the facility flow loop.

The following revisions or changes were made for EP-2:

1. Ranges on CP 706 and CP 710 were changed to 0 to 750 psig.
2. The following channels were relocated to measure diffuser inlet conditions and with the range of the measurement of 0 to 1000 psig.

Parameter	Location
CP 718	Θ = 65°
CP 719	Θ = 345°
CP 720	Θ = 225°
CP 721	Θ = 145°

3. Parameter CT 702 was deleted due to temperature transducer failure.
4. Range of UQ 003 was changed to 0 to 40000 rpm.

The following revision or changes were made for EP-2A:

1. Parameter CT 700 and CT 701 were deleted due to temperature transducer failure.
2. Range on CT 508 was changed to 35°R - 590°R.
3. Range on KF 130 flow measurement was changed to 0-15 pounds per second.

TABLE I

PUMP INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
		+ CD 700.-C	± .010; 0-10KHZ	Displacement, Radial, Spinner, θ = 0°; Bently 304QB-7102-01 (05324-1138565-2)	X		
		+ CD 701.-C	± .010; 0-10KHZ	Displacement, Radial, Spinner, θ = 90°, Bently 304QB-7102-01 (05324-1138565-2)	X		
		CD 702.-C	± .010; 0-10KHZ	Displacement, Shaft Bearing Cavity θ = 0°; Kaman KD 1100-23	X		
		CD 703.-C	± .010; 0-10KHZ	Displacement, Shaft Bearing Cavity θ = 90°; Kaman KD 1100-23	X		
		CD 704.-C	± .010; 0-10KHZ	Displacement, Shaft Bearing Cavity θ = 270°; Bently 304QB-7101-01 (5324-1138565-1)	X		
		CD 705.-C	± .010; 0-10KHZ	Displacement, Shaft Aft End, θ = 0°; Kaman KD 1100-23	X		
		CD 706.-C	± .010; 0-10KHZ	Displacement, Shaft Aft End, θ = 90°, Kaman KD 1100-23	X		
		+ CD 707.-C	± .010; 0-10KHZ	Displacement, Shaft Aft End, θ = 180°, Bently 204QB-7101-01	X		
		+ CD 708.-C	± .010; 0-10KHZ	Displacement, Shaft Aft End, θ = 270°, Bently 304QB-7101-01	X		
		CA 700.-C	± 50g's, 0-2KHZ	Acceleration, Radial θ = 175°			
		CA 701.-C	± 50g's, 0-2KHZ	Acceleration, Radial θ = 265°			
		CA 702.-C	± 50g's, 0-2KHZ	Acceleration, Axial θ = 225°			
CT 700.-C	35-590°R			Temperature, Pump housing .20, θ = 288°; Mod. 108 MA 4A		X	
CT 701.-C	35-590°R			Temperature, Pump housing .30, θ = 270°; Mod. 108 MA 4A		X	X
CT 702.-C	35-590°R			Temperature, Pump housing,.40, θ = 252°; Mod. 108 MA 4A		X	

PUMP INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
CT 703.-C	35-590°R			Temperature, Bearing housing		X	X
CT 704.-C	35-100°R			Temperature, Fluid forward bearing, θ = 0°, Mod. 150 LM S/N 880001			X
CT 705.-C	35-100°R			Temperature, Fluid forward bearing, θ = 180°, Mod. 150 LM		X	
CT 706.-C	35-100°R			Temperature, Fluid aft bearing, θ = 135°, Mod. 150 LM			X
CT 707.-C	35-100°R			Temperature, Fluid aft bearing, θ = 315°, Mod. 150 LM		X	
CP 700.-C	0-1000 psig			Pressure, Pump discharge flange suction side			X
CP 701.-C	0-1000 psig			Pressure, Pump discharge flange motor side		X	
CP 702.-C	0-1000 psig			Pressure, Filter exit bearing feed			
CP 703.-C	0-1000 psig			Pressure, Bearing housing		X	
CP 704.-C	0-100 psig			Pressure, Bearing aft cavity			
CP 705.-C	0-200 psig			Pressure, Impeller contour, inducer discharge θ = 85°		X	
CP 706.-C	0-500 psig			Pressure, Impeller contour, R = 4.0, θ = 65°			
CP 707.-C	0-750 psig			Pressure, Impeller contour, R = 4.8, θ = 45°			
CP 708.-C	0-1000 psig			Pressure, Impeller contour, impeller tip θ = 25°			
CP 709.-C	0-200 psig			Pressure, Impeller contour, inducer discharge θ = 345°			
CP 710.-C	0-500 psig			Pressure, Impeller contour, R = 4.0, θ = 325°			
CP 711.-C	0-750 psig			Pressure, Impeller contour, R = 4.8, θ = 305°			
CP 712.-C	0-1000 psig			Pressure, Impeller contour, impeller tip, θ = 105°		X	
CP 713.-C	0-1000 psig			Pressure, Diffuser vane inlet, θ = 25°			
CP 714.-C	0-1000 psig			Pressure, Diffuser vane inlet, θ = 305°			
CP 715.-C	0-1000 psig			Pressure, Diffuser vane inlet, θ = 265°			

PUMP INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
CP 716.-C	0-1000 psig			Pressure, Diffuser vane inlet, θ = 185°			
CP 717.-C	0-1000 psig			Pressure, Diffuser vane inlet, θ = 105°			
CP 718.-C	0-1000 psig			Pressure, Diffuser vane discharge, θ = 125°			
CP 719.-C	0-1000 psig			Pressure, Diffuser vane discharge, θ = 45°			
CP 720.-C	0-1000 psig			Pressure, Diffuser vane discharge, θ = 325°			
CP 721.-C	0-1000 psig			Pressure, Diffuser vane discharge, θ = 285°			
CP 722.-C	0-1000 psig			Pressure, Diffuser vane discharge, θ = 205°			
CP 723.-C	0-200 psig			Pressure, Impeller back cavity, θ = 90°		X	
CP 724.-C	0-1000 psig			Pressure, Impeller back distribution R = 4.1 θ = 65°			
CP 725.-C	0-1000 psig			Pressure, Impeller back distribution R = 4.8 θ = 45°			
CP 726.-C	0-1000 psig			Pressure, Impeller back tip θ = 25°		X	
CP 727.-C	0-1000 psig			Pressure, Impeller back distribution, R = 4.1 θ = 325°			
CP 728.-C	0-1000 psig			Pressure, Impeller back distribution, R = 4.8 θ = 305°			
CP 729.-C	0-1000 psig			Pressure, Impeller back tip θ = 105°			
CP 702.D.-C	0-750 psi			Differential pressure, bearing feed orifice #1		X	
CP 730.D.-C	0-750 psi			Differential pressure, bearing feed orifice #2			
CP 700.D.-C	0-1000 psi			Differential pressure, pump pressure rise, from CP 700.-C to CP 508.-C		X	X*
CQ 700.-C	0-40,000 RPM			Pump shaft speed		X	
CP 701N-C	0-250 psig			Pressure Pump Discharge Flange Motor Side, Narrow Range		X	

*Visual readout on the X-Y plotter (the y coordinate)

+CD 707.-C and CD 708.-C to be connected when CD 700.-C and CD 701.C is not being used.

TABLE II

FACILITY INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
		CP 511.W.-C	0-100 psi, 0-5000 HZ	Pressure, Pump Suction Kistler, High Freq			
		CP 542.W.-C	0-1000 psi 0-5000 HZ	Pressure, Pump Discharge, Kistler, High Freq			
KT 071.-C	35-49°R			Temperature, Dewar 4		X	
KT 072.-C	35-49°R			Temperature, Dewar 5		X	
KT 130.-C	35-54°R			Temperature, Flowmeter Inlet KF 130			
KT 004.-C	35-54°R			Temperature, Pump Suction Venturi KF-4			
CT 003.-C	35-590°R			Temperature, Chill Line Inlet		X	
CT 505.-C	35-54°R			Temperature, Fluid Conditioner Inlet		X	X
CT 505.A.-C	35-45°R			Temperature, Fluid Conditioner Inlet, Special Channel			
CT 506.-C	35-45°R			Temperature, Pump Suction θ = 45°, Special Channel			
CT 507.-C	35-54°R			Temperature, Pump Suction θ = 135°		X	X
CT 508.-C	35-54°R			Temperature, Pump Suction θ = 225°			
CT 509.-C	35-590°R			Temperature, Pump Suction θ = 315°			
CT 542.-C	35-100°R			Temperature, Pump Discharge		X	X
CT 006.-C	35-100°R			Temperature, Flowmeter, Pump Discharge CF-6			
CT 220.-C	35-590°R			Temperature, Main Leakage Oriface			
IP 101.-C	25-28 in Hg			Pressure Barametric (Req. to obtain absolute)			
SKP 061.-C	0-150 psig			Pressure, Dewar 4		X	
SKP 062.-C	0-150 psig			Pressure, Dewar 5		X	

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
KP 130.-C	0-100 psig			Pressure, Chill Flowmeter Inlet KF 130		X	
KP 004.-C	0-150 psig			Pressure, Venturi, Pump Suction KF 004			
CP 003.-C	0-100 psig			Pressure, Chill Line Inlet			
CP 505.-C	0-100 psig			Pressure, Fluid Conditioner Inlet		X	X
CP 505.A.-C	0-50 psig			Pressure, Fluid Conditioner Inlet, Special Channel			
CP 506. [illegible].-C	0-50 psig			Pressure, Pump Suction θ = 0°, Special Channel			
CP 507.-C	0-100 psig			Pressure, Pump Suction θ = 90°		X	X*
CP 508.-C	0-100 psig			Pressure, Pump Suction θ = 180°			
CP 509.-C	0-100 psig			Pressure, Pump Suction θ = 270°			
SCP 220.-C	0-200 psig			Pressure, Main Leakage Oriface		X	
CP 541.-C	0-1000 psig			Pressure, Pump discharge line		X	X
KP 004.D.-C	0-25 psi			Differential Pressure, Pump Suction Venturi			
CP 220.D.-C	0-10 psi			Differential Pressure, Main Leakage Oriface			
SCF 006.-C	0-100 P/S			Flow, Pump Discharge		X	X*
KF 130.-C	0-5 P/S			Flow, Chilldown		X	
CR 106A.-C	0-100%			Stem Position, Pump bypass valve			
CB 221.-C	(a)			Open/closed indication (OBV), main leakage line			
CR 231A.-C	0-100%			Stem Position, Main Leakage to flare valve (ACV)		X	
CR 008A.-C	0-100%			Stem Position, Flow Control Valve (ACV)		X	

FACILITY INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	Description	Oscilloscope	Sanborn	Meter
KR 003A.-C	0-100%			Stem Position, Suction line impedance valve		X	
CB 214.-C	(a)			Open/close indication (OBV), chill line			
KR 130.-C	0-100%			Stem position, chill Bypass Valve			
SUQ 001.-C	0-40000 RPM			Electric Drive High Speed Pinion Rotation		X	
SUI 011.-C	± 10000 ADC			Current Electric Motor Armature, Motor #1			
UI 021.-C	0-50000 ADC			Current Electric Motor Armature, Motor #2			
CP 006.-C	0-1000 psig			Pressure Pump Discharge Flowmeter			
CP 008.-C	0-1000 psig			LH_2 Recirculation Pressure Upstream of C-8			X
CP 009.-C	0-1000 psig			LH_2 Pressure Downstream of C-8			X
CR 011A-CJ	0-100%			C-11 Stem Position			X
CR 012A-CJ	0-100%			C-12 Stem Position			X
CT 007.-C	35-54°R			LH_2 Temperature Between Vacuum Vessels & FE-24			X
CT 106.-6	35-590°R			C-106, LH_2 Line Vent Temperature			X
CT 111.-C	35-590°R			C-109, LH_2 Return Line Vent Temperature			X
KL 001.-C	1.0-31.6 KPH			Dewar 4, Level - Reflectometer			X
KL 002.-C	1.0-31.6 KPH			Dewar 5, Level - Reflectometer			X
KP 003.-C	0-150 psig			Pressure Upstream of K-3			X
KP 053.-C	0-3500 psig			Dewar Pressurization Control Pressure		X	X
KR 053A-CH	0-100%			K-53 stem position			X
KT 001.-C	35-54°R			Dewar 4, Outlet Temperature			X
KT 002	35-54°R			Dewar 5, Outlet Temperature			X
IV 801U-C	0-1.0 GPM/RPM			Measured Q/N			X
KX 001.-C	2.9-29 KPH			Dewar 4 Level, Carbon Resistor			
KX 002.-C	.73-29 KPH			Dewar 5 Level, Carbon Resistor			

FACILITY INSTRUMENTATION

Narrow Band Channel	Range Narrow Band	Wide Band Channel	Range Wide Band	DESCRIPTION	Oscilloscope	Sanborn	Meter
QP 020.-CE	0-3500 psig			H_e Header Supply Pressure			
QP 030.-CE	0-3500 psig			GH_2 Upstream of K-50 pressure			
QP 040.-CE	0-3500 psig			N_2 Run Supply Header Pressure			
QP-050.-CE	0-3500 psig			GN_2 Room Inerting header supply pressure			
UH 001.-C	0-15K VAC			AC Input Line Voltage Monitor			X
SUH 011.-C	± 600 VAC			DC Generator #1, Armature Voltage		X	X
UH 021.-C	± 600 VAC			DC Generator #2, Armature Voltage		X	X
UI 002.-C	0-300 amp			Syne Motor AC Current Monitor & Alarm			X
UI 003.-C	0-200 amp			Syne Motor DC Field Current Monitor			X
UI 012.-C	0-20 amp			DC Motor #1 Field Current Monitor			X
UI 022.-C	0-20 amp			DC Motor #2 Field Current Monitor			X
UI 031.-C	± 50 amp			DC Generator #1 & #2 Field Current Feedback			
SUQ 002.-C	0-40000 rpm			Intermediate Gear, DC Tach			
UQ 003.-C	0-593.45 rpm			Electric Drive Input Gear Speed			
UT 551.-C	460-853.3°R			Gear Box Inboard Output Shaft Bearing Temperature			
UT 552.-C	460-853.3°R			Gear Box Outboard Output Shaft Bearing Temperature			

*Visual readout on X-Y plotter (SCF 006.-C reflects meter also).

(a) On digital printout parameter noted as VALV with range from 0 to 3.

Digit	0	1	2	3
C-221	Open	Closed	Open	Closed
C-214	Open	Open	Closed	Closed

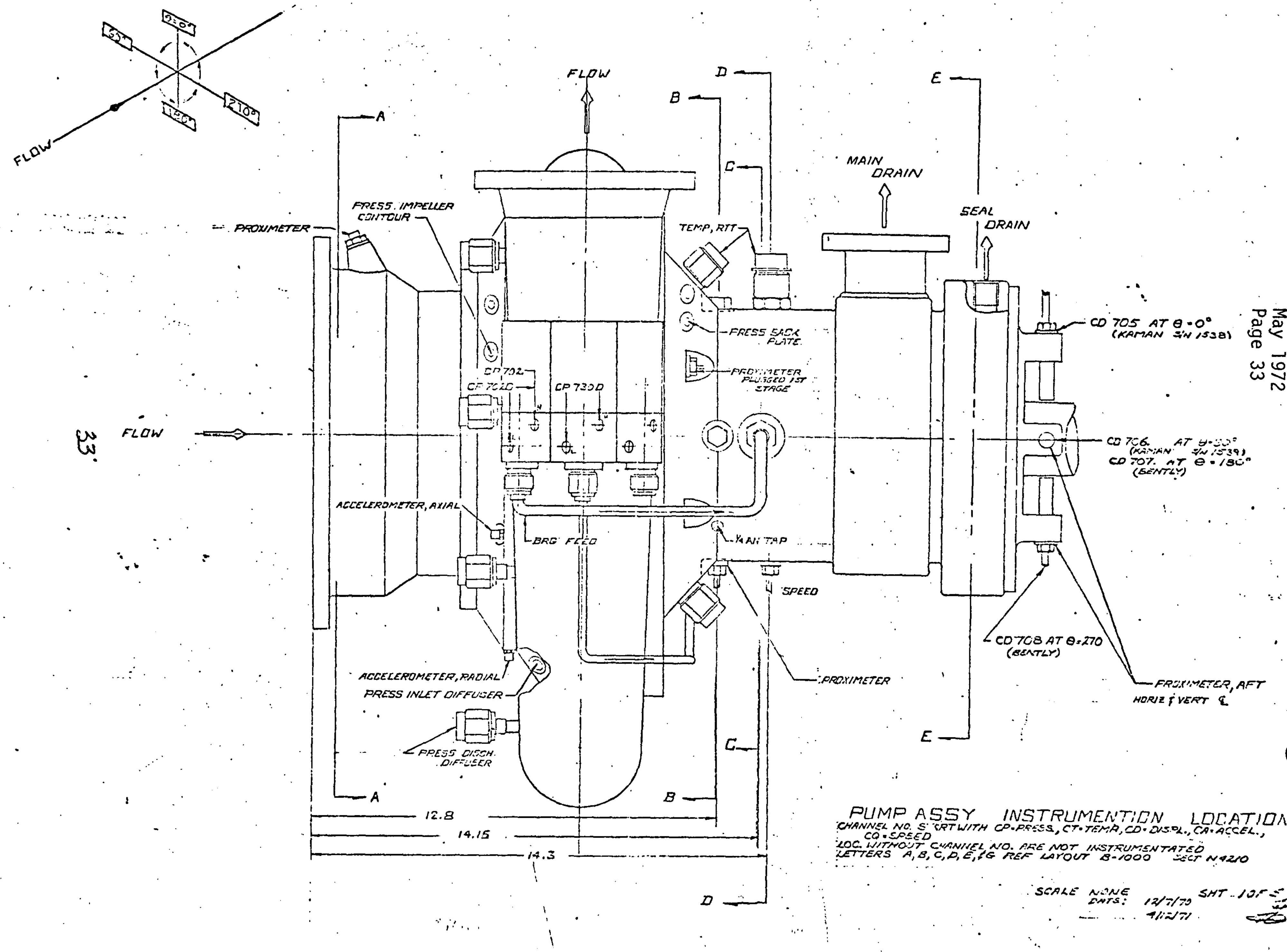
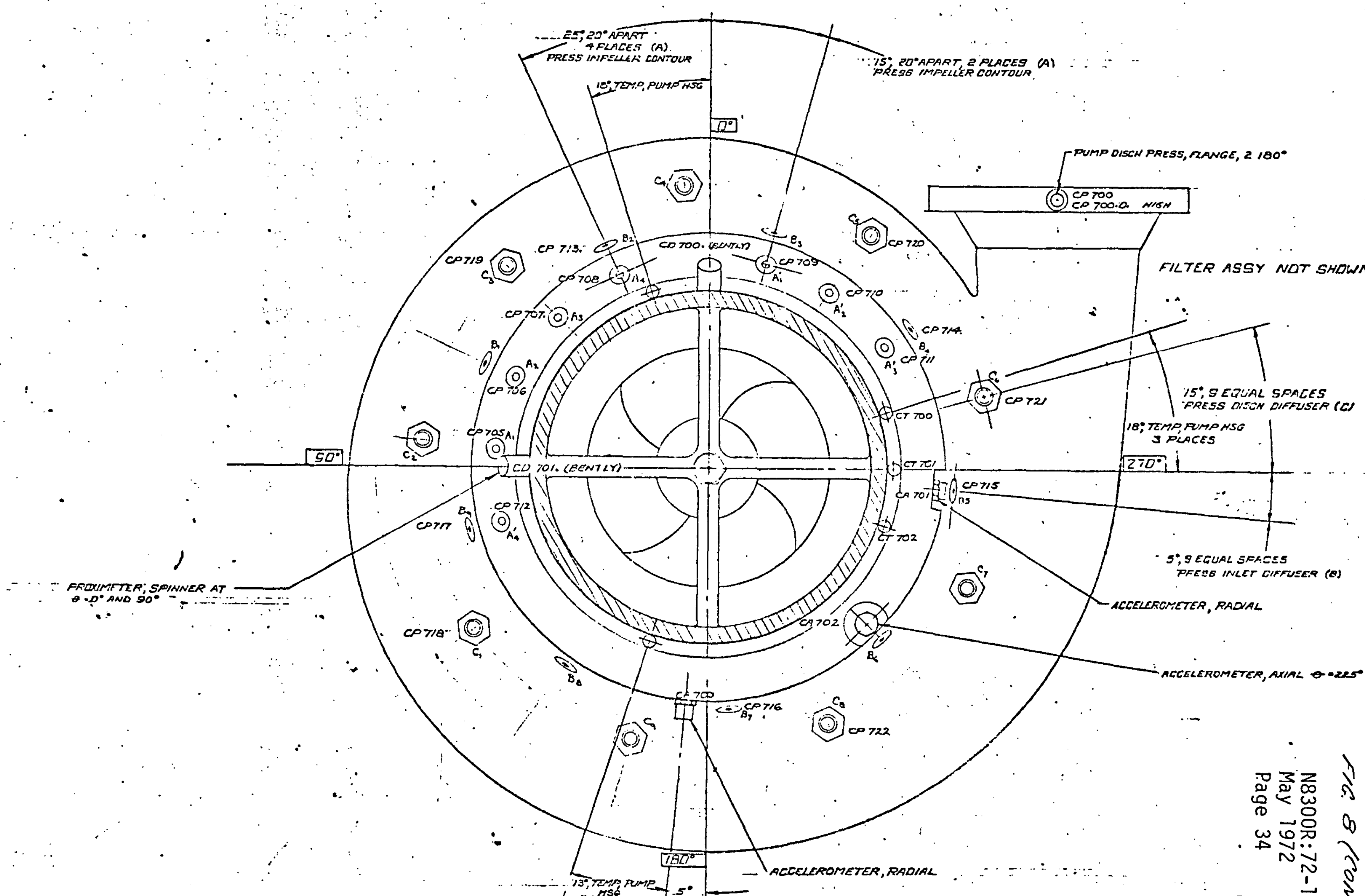

FLOW
0=0°
210°
FLOW
A
B
C
D
E
MAIN DRAIN
SEAL DRAIN
PROXIMETER
PRESS. IMPELLER CONTOUR
TEMP, RTT
PRESS BACK PLATE
PROXIMETER PLUGGED 1ST STAGE
CP 702
CP 730D
CD 705 AT θ = 0°
(KAMAN S/N 1538)
CD 706 AT θ = 90°
(KAMAN S/N 1539)
CD 707 AT θ = 180°
(BENTLY)
ACCELEROMETER, AXIAL
BRG FEED
1/4 AN TAP
SPEED
CD 708 AT θ = 270
(BENTLY)
ACCELEROMETER, RADIAL
PRESS INLET DIFFUSER
PROXIMETER
PROXIMETER, AFT
HORIZ & VERT ℄
PRESS DISCH. DIFFUSER
12.8
14.15
14.3
PUMP ASSY INSTRUMENTION LOCATION
CHANNEL NO. START WITH CP = PRESS., CT = TEMP, CD = DISPL., CA = ACCEL., CQ = SPEED
LOC. WITHOUT CHANNEL NO. ARE NOT INSTRUMENTATED
LETTERS A, B, C, D, E, & G REF LAYOUT B-1000 SECT N4210
SCALE NONE
DATES: 12/7/70
4/12/71
SHT 1 OF 3

FIGURE 8

33

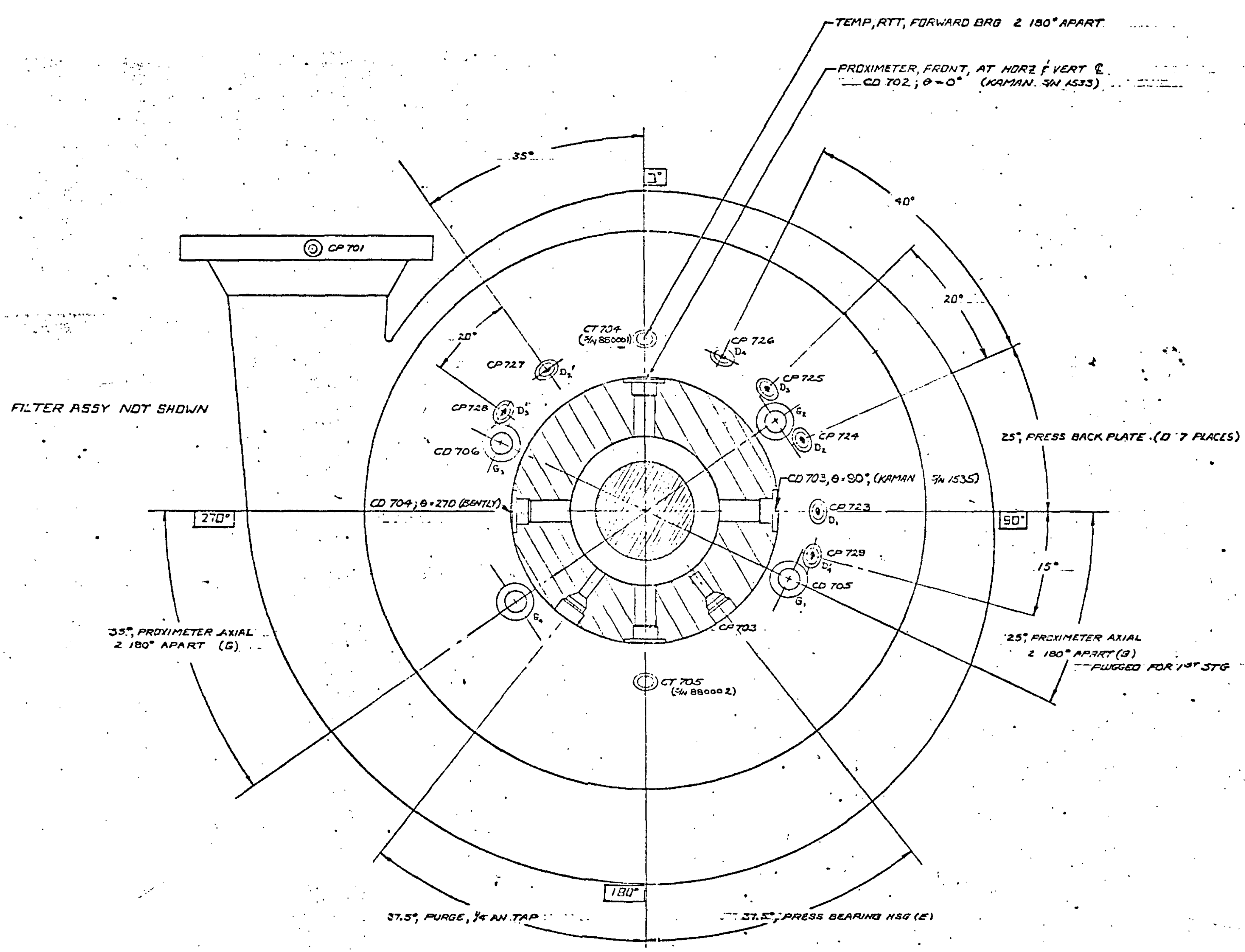
Fig. 2



SECTION A-A

FIG. 8 (CONT'D)

SHT 2 OF 5



SECTION B-B

SHT 3 OF 5

FIG 8 (CONT'D)

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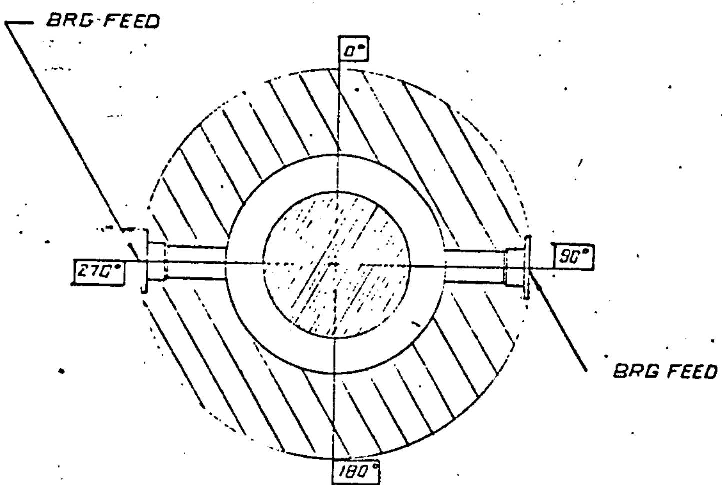
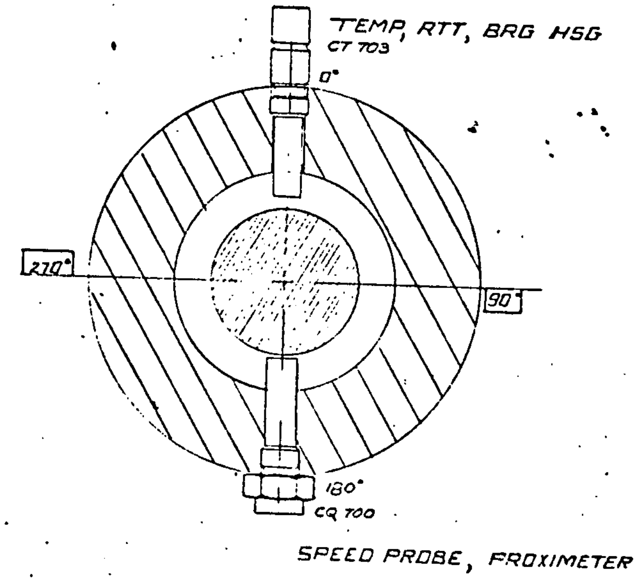
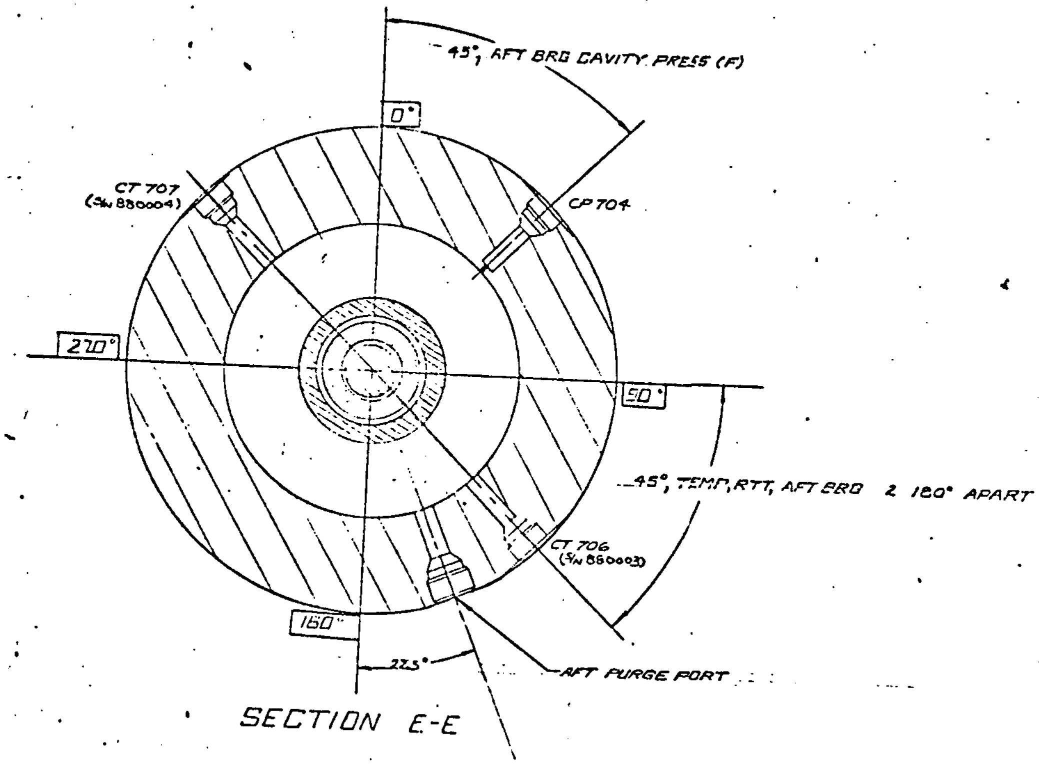


SECTION C-C



SECTION D-D

FIG 8 (CONT'D)



SECTION E-E

FIG 8 (CONT'D)

SHT 5 OF 5

B. Discrepancies

In the review of the data, the following discrepancies were noted during the test series:

1. Parameters CT 700, CT 701, and CT 702 showed intermittent radical performance due to transducer failure; however, prior to the failure it provided accurate measurements.
2. Parameter UQ 700 and UQ 003 initially for EP-1 were not registering. This was caused by VIDAR adjustment. For all performance calculations, SUQ 002 should be used.
3. Parameter CP 006 measurement was incorrect until EP-2A.
4. Accelerometer CA 701 data shows indication of grounding of the transducer during EP-2.
5. Displacement measurement CD 706 has a drifting problem during EP-2A.

C. Wide Band

The wide band measurements were recorded on a fourteen track recorder. Twelve tracks were used to record data (1 channel/track), one channel for F.M. Servo-Control, and the other was used for direct record time code.

The twelve measurements on the wide band tape were three accelerometers, two high frequency pressure (piezoelectric type), and at any given time seven of the nine displacement measurements. If CD 700 and CD 701 were being recorded, than CD 707 and CD 708 were not recorded.

The associated conditioning equipments, charge amplifiers, proximeters (Bentley) and modulator/demodulators (Kaman) were located inside the Electric Pump Room.

D. Narrow Band

The narrow band data were recorded through the DDP-116 at ten sample per second and also through the multiplex system. Within the narrow band measurements certain parameters were considered accurate and certain parameters were considered "special channels".

The following channels were considered accurate parameters and received their final set up, including the DDP-116 computer system, no earlier than seven days prior to EP-1:

CP-006.-C	CP-701.-C	SKP-061.-CE	KT-071.-C
CP-700.-C	CP-703.-C	SKP-062.-CE	KT-072.-C
CP-700D-C	CP-723.-C	KP-130.-C	

The"special channel" or high accurate channels received their final set up, including the DDP-116 computer system, no earlier than one day prior to test date. The parameters and the accuracy are as follows:

CP-505A-C	$\pm$ 0.5%
CP-506.-C	$\pm$ 0.5%
CT-505A-C	0.1°R
CT-506.-C	0.1°R

The stimulus applied to the above pressure transducers were at 0%, 20%, 40%, 60%, 80%, and 100% of the required full scale reading and the results were recorded and checked by NRTO personnel.

The temperature measurements, platinum resistance type, were set up at 37.5°R and the results recorded and checked at 0% and 100%.

Post check of three temperature transducers, CT-505A-C, CT-506.-C, and CT-542.-C, were accomplished at NRTO Laboratory. The transducers were checked at the liquid nitrogen point and at ice point and found to be within $\pm$ 0.03°R.

E. Pump Instrumentation - Internal

1. Proximity Probes

Proximity probes (displacement) were used in the test article to measure shaft dynamics. Proximity systems from two manufacturers were utilized during the program, Kaman Nuclear and Bentley Nevada. For better resolution, both systems required a zero bias circuit. The circuit used are shown in Figures 9 and Figure 10.

KAMAN NUCLEAR SYSTEM

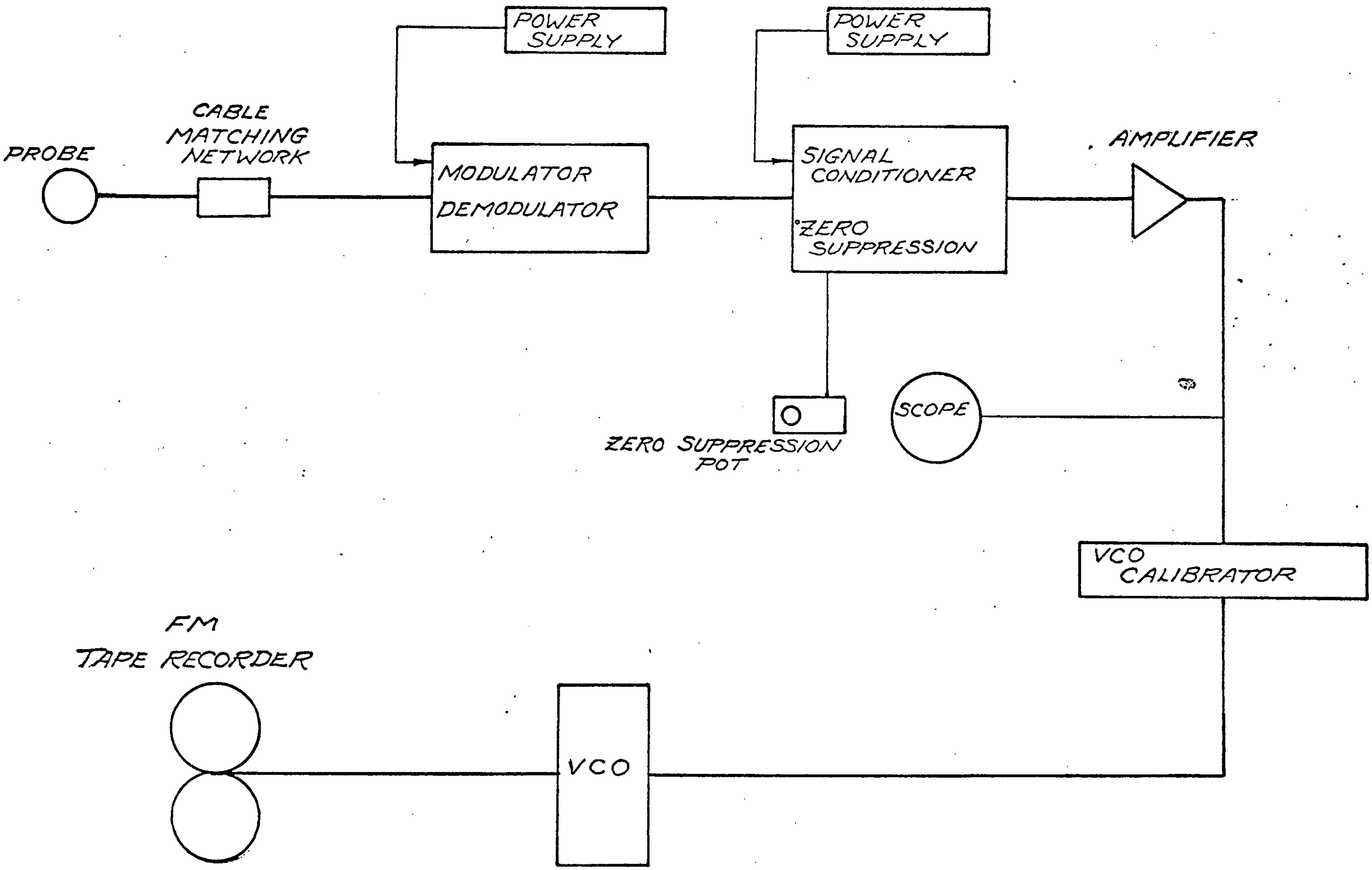


FIGURE 9

TAD

BENTLY NEVADA SYSTEM

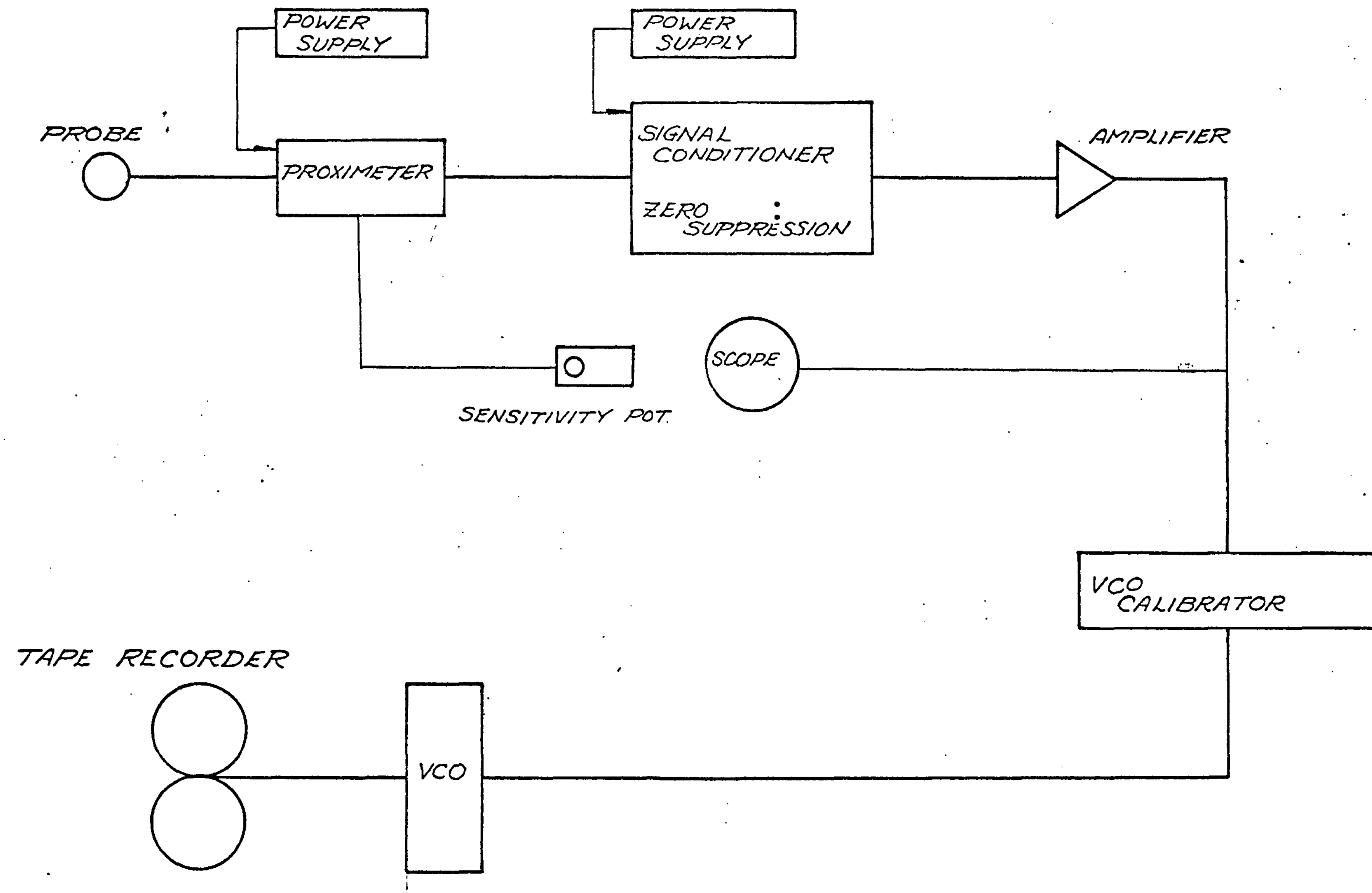


FIGURE 10

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TAD

Both systems use the eddy current concept to measure displacement; however, each uses different conditioning equipment that are not interchangeable. The carrier frequency used in both systems is one mega hertz, with a system frequency response capable to one hundred kilo hertz.

The proximity systems, Bentley and Kaman, do not have a temperature compensation network which would compensate for the large temperature differential from ambient to liquid hydrogen. The zero shift was compensated by adjusting the zero suppression or sensitivity protiometer at operating temperature by viewing the output through an oscilloscope.

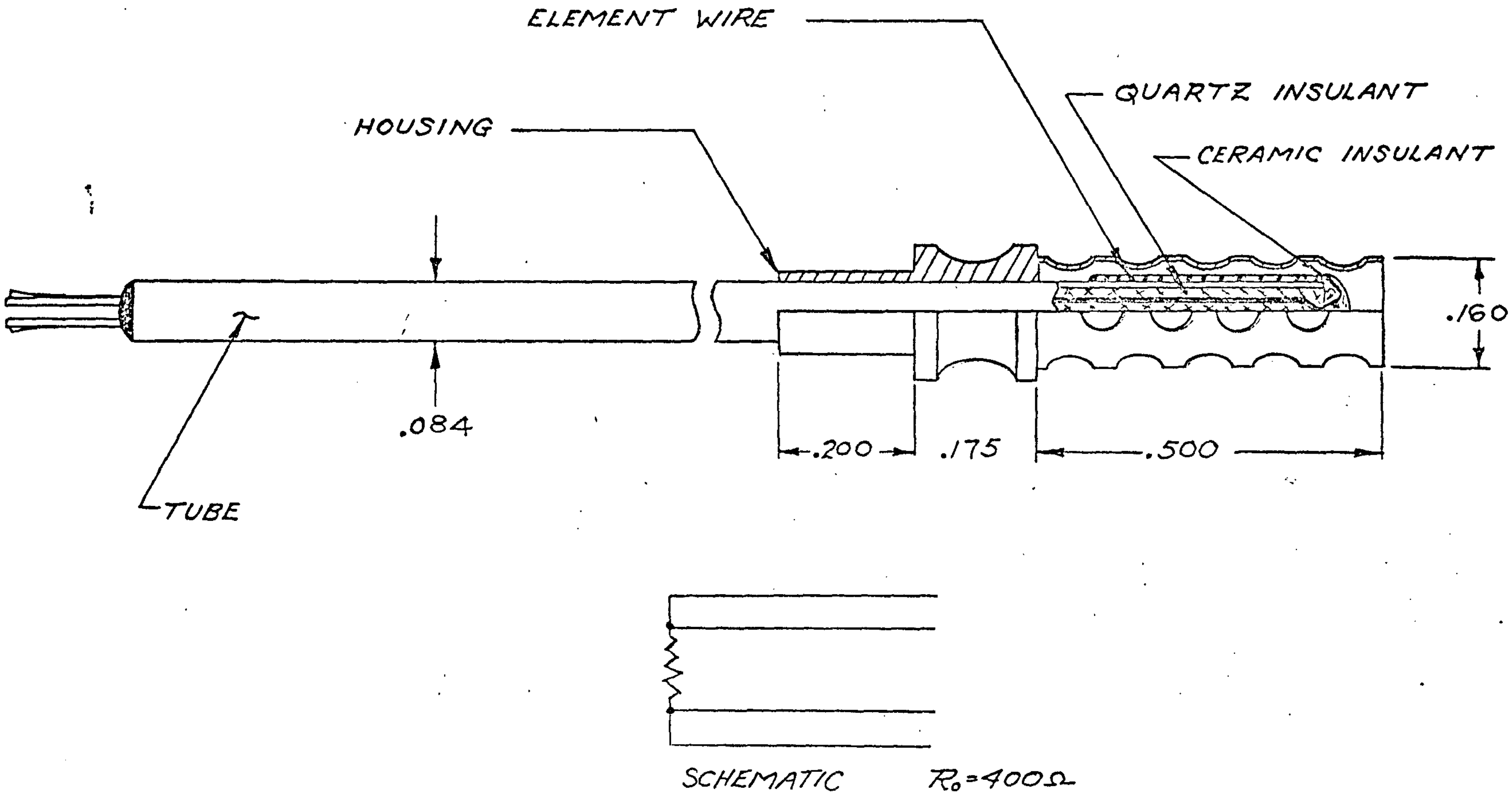
The conditioning equipment of both systems did suffer from malfunction. Two Kaman modulators and demodulators showed erratic behavior and had to be replaced. The S/8-4 power supply supplied for the Bentley system had voltage fluctuations that were too great and had to be replaced with a more constant power supply.

2. Temperature Probes

Platinum resistance temperature sensors were installed downstream of the support bearings. These temperature sensors were used to measure the fluid temperature discharging from the bearings as an indication of incipient bearing failure. The sensor, as shown in Figure 11, is 0.875 inches in length 0.16 inches in diameter, 9.0 inches of 0.085 diameter sheath cabling.

These sensors could not readily be assemblied and disassemblied into the test article due to the necessity of sweglocking, for the purpose of sealing, on to the sheath. This necessitated the sensor be assembled into the test article just once.

Platinum resistance surface temperature sensors were installed into the pump housing to measure housing metal temperature. These sensors were 0.30 inches in length and 0.25 inches in diameter with one foot of teflon covered cabling. (Rosemount Model Number 108MA-4A).



RTT, BEARING FLUID

FIGURE 11

The surface temperature sensors failed during the test series. All the sensors failed due to the thermal stresses going from ambient to liquid hydrogen temperature. Reviewing the specification from the vendor, the sensors should have been used down to liquid nitrogen and not to liquid hydrogen temperatures.

All the sensors mentioned in the foregoing paragraphs had ice point resistance of four hundred ohms.

3. Speed Probe

The shaft rotational speed in the test article was monitored by the usage of a Kaman Nuclear proximity probe. The results from this probe was very favorable. The probes correlation of shaft speed with the data from the D.C. tachometer, on the drive shaft, was very good and were within $\pm$ 50 rpm. The data as indicated from the Sanborn chart shows that the resolution of shaft speed was very good at low speeds.

F. Data Acquisition

The data acquired was recorded either on wide-band tape or narrow band tape. The data recorded on X-Y plotters and strip charts (Sanborn) not considered permanent records.

The flow of data from measurement to recording for the narrow band data is depicted in Figure 12. The narrow-band tape in this case is the engineering units tape. In a parallel system, not depicted, the data was also recorded on the multiplex system as a backup to the DDP-116 recording system.

The engineering units tape was than used as data input to a performance analysis program in Sacramento.

The flow of data from measurement to recording for the wide-band data is depicted in Figure 13. As shown, the system after a given test, can be played back into the oscilloscope for a "quick look" analysis.

NARROW BAND DATA

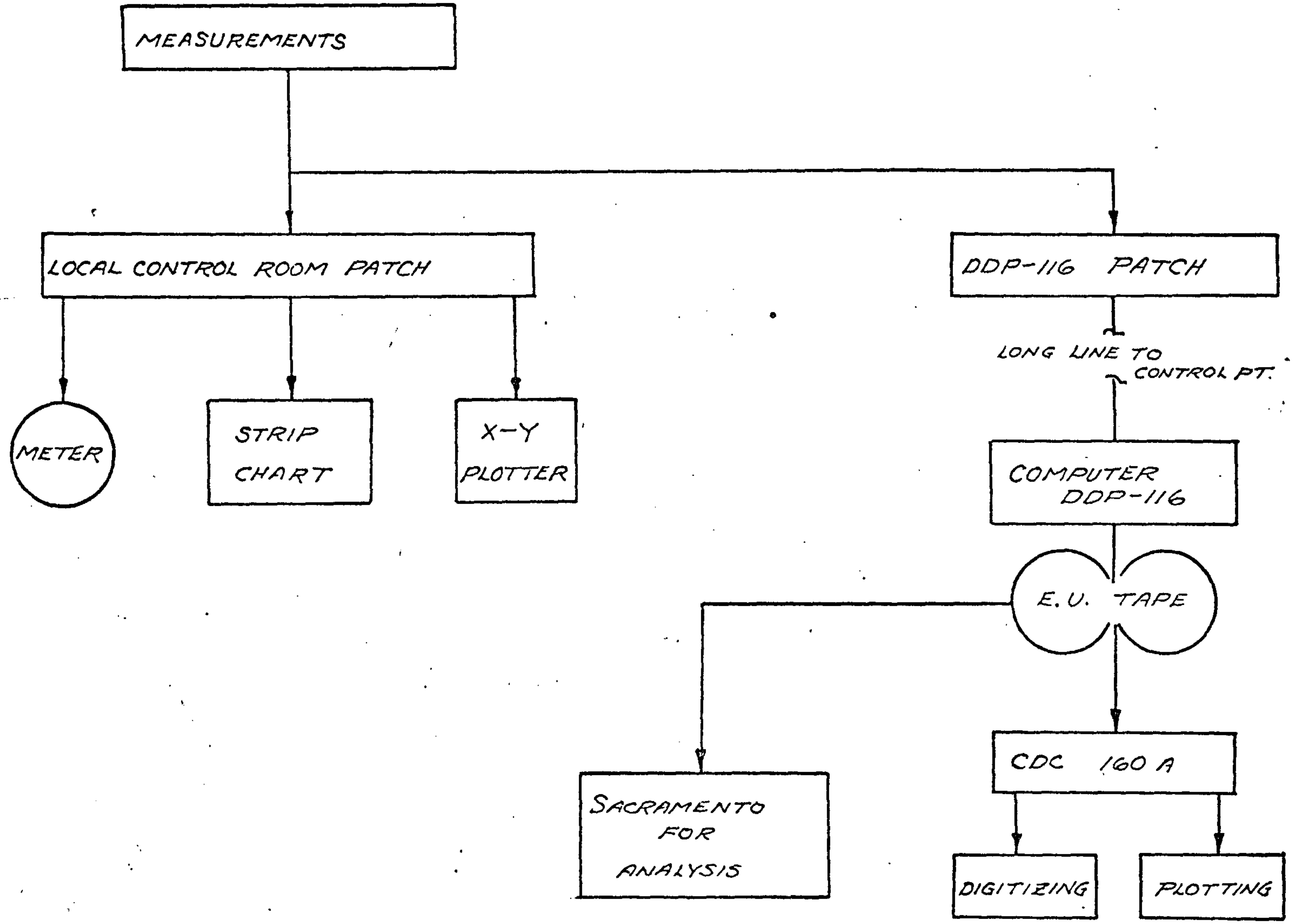


FIGURE 12

TAD

WIDE BAND DATA

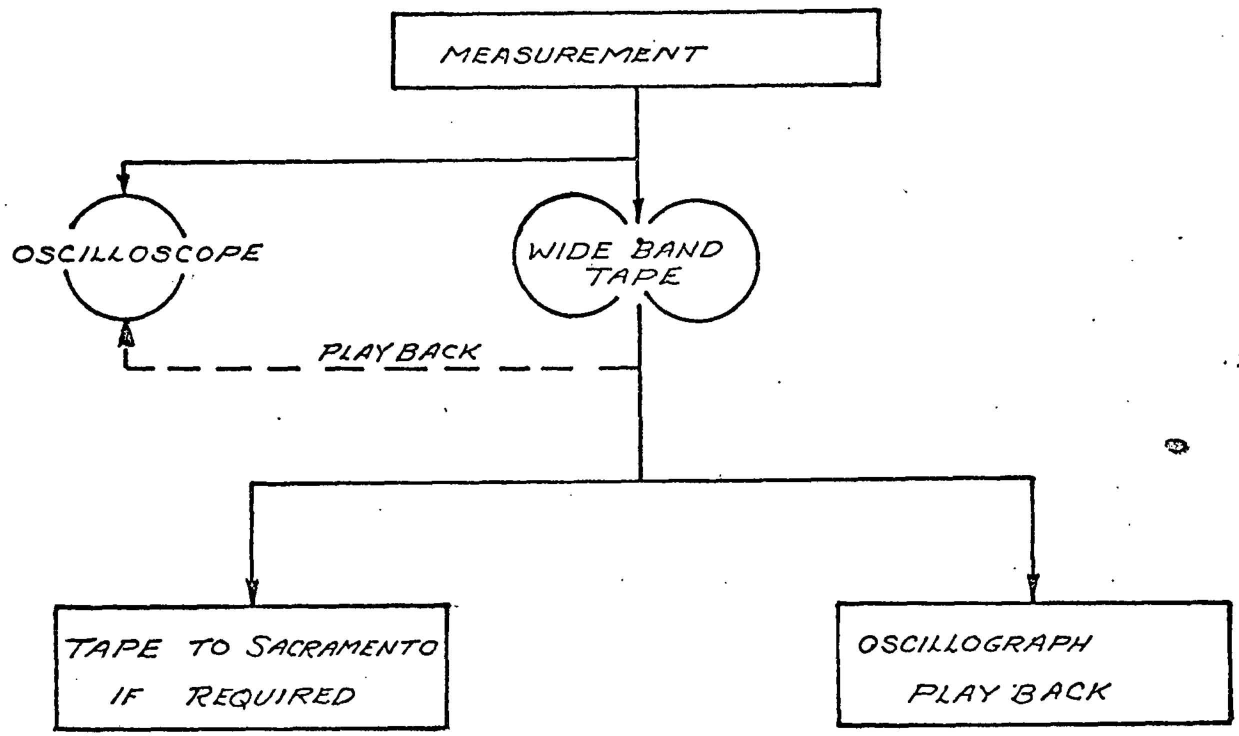


FIGURE 13

TAD

IX. DATA PROCESSING

A. DATA REDUCTION

Analog data from the LH_2 pump test was digitized during testing and stored on mangetic tape using the DDP-116 computer at NRDS. The data on these tapes was converted into unformated records compatible with UNIVAC 1108 FORTRAN. These converted tapes were utilized as the source of data for the data reduction program described here. The converted data tapes contained one unformated record, with time as the first data item, for each time point of the test. The sampling rate for all of the low band LH_2 pump test data was ten samples per second.

Essentially two types of data were processed from the LH_2 pump tests. The first type of data processed was that from the head-capacity mapping tests. Data from these tests covered a relatively short (approximately two second) steady state time span. The second type of data processed was that from the cavitation tests. Cavitation data was of a transient nature covering a longer (approximately thirty sec.) time span.

Provisions were made in the data reduction program for averaging redundant data channels and for averaging input data over a specified time period. For both the cavitation and mapping tests, input data was averaged over a one second time interval (ten data samples) and where possible, redundant channels were averaged. Justification for averaging the transient cavitation data was that the rate of change of control parameters was slow compared to the averaging period.

Computed information provided by the data reduction program may be divided into the following categories:

1. Suction Performance
2. Pump Performance
   a. Isentropic Head
   b. Impeller Discharge Flow Coefficient
   c. Stage Head Coefficient
   d. Impeller Discharge Total Head Coefficient
   e. Housing Losses
3. Radial Load

The details of each of these sections of the data reduction program are discussed below.

A listing of the data reduction program together with an example case appears in Appendix A.

1. <u>Suction Performance</u>

Cavitating and noncavitating suction performance of the pump as discussed in this report is based on the following test data and method of analysis.

Shown in Figure 14 is a sketch of the LH_2 pump supply system and the data measurement points used in the suction performance calculations.

The thermodynamic process from Station 1 to Station 2 is shown on the T-S diagram of Figure 15. It is assumed that from Station 1 to Station 2 the fluid undergoes adiabatic throttling.

LH_2 PUMP SUPPLY SYSTEM

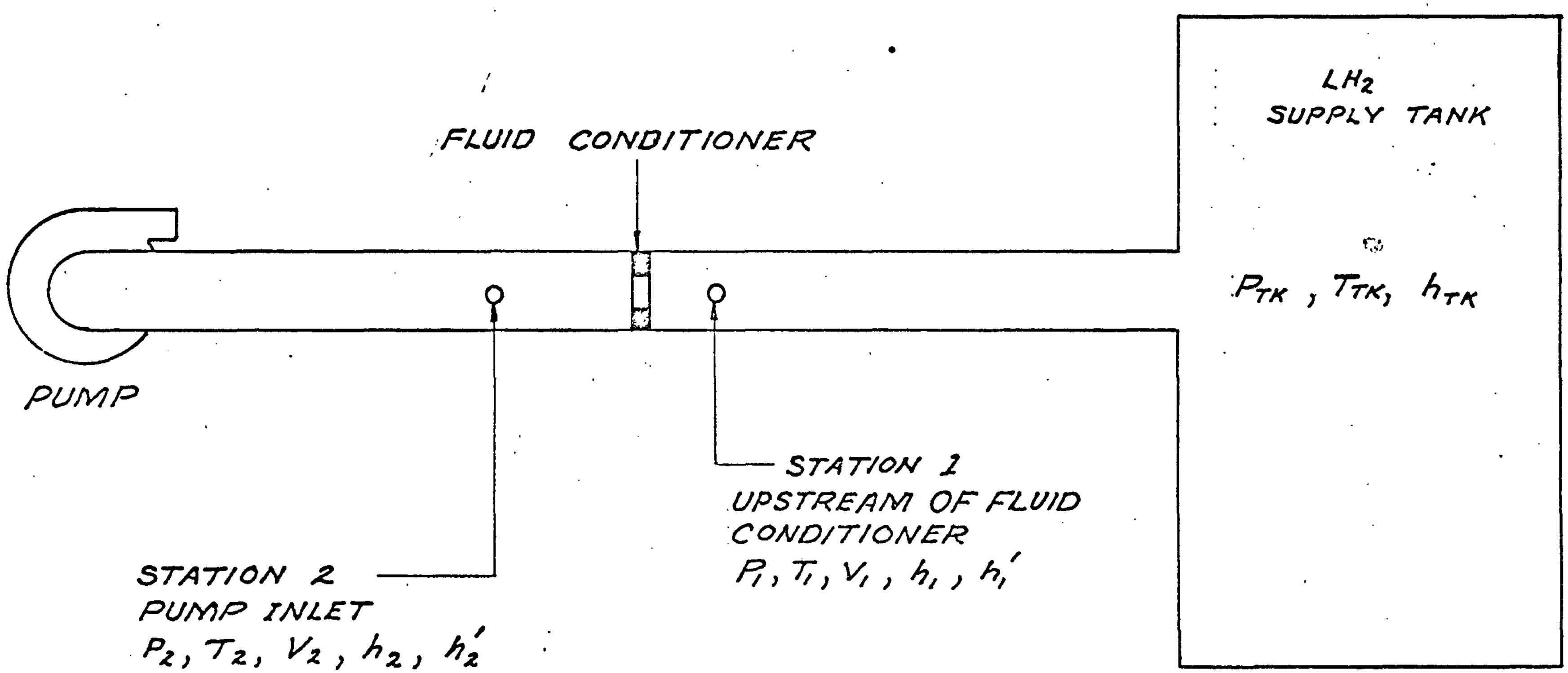


FIGURE 14

FLUID CONDITIONER THROTTLING PROCESS

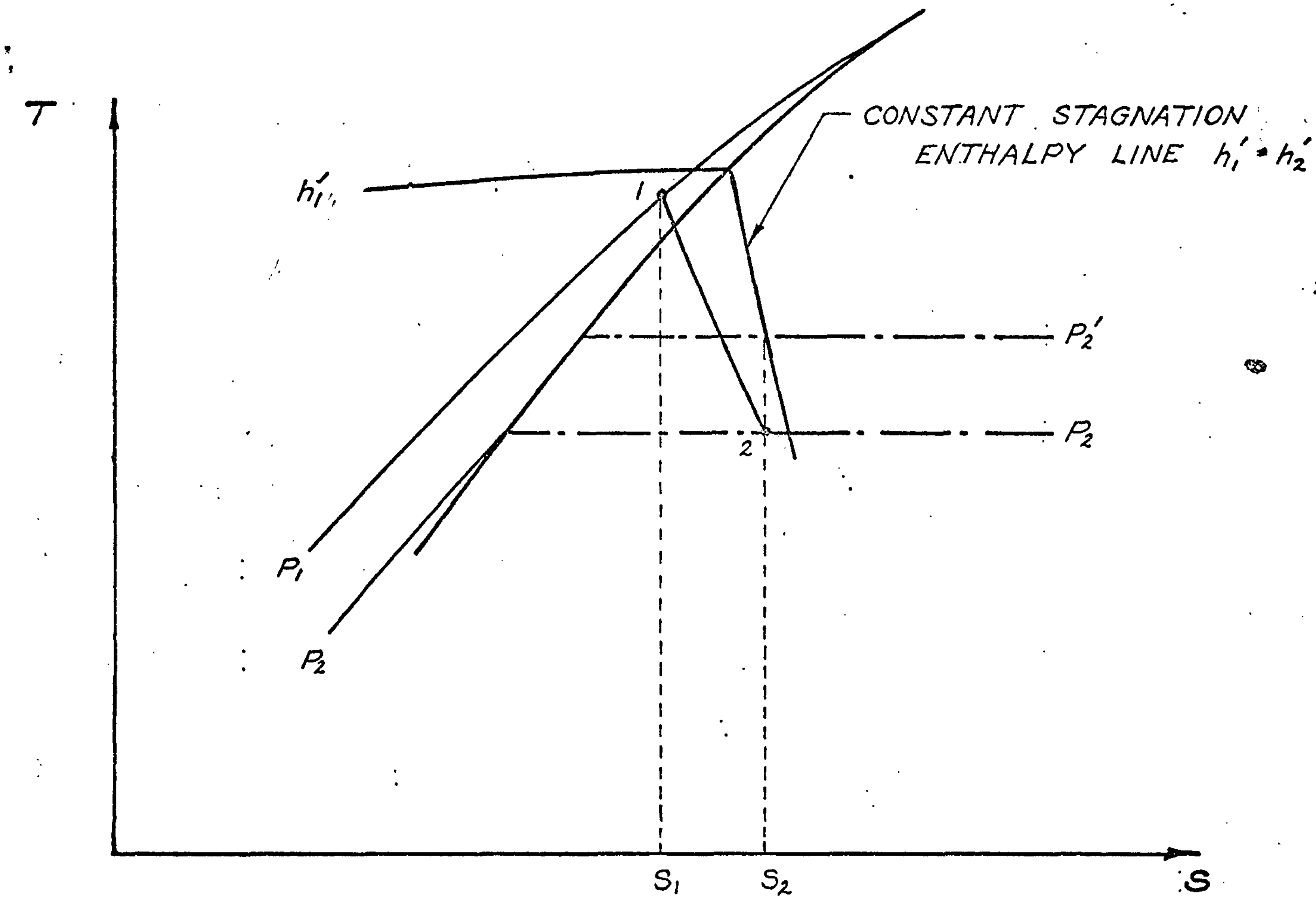


FIGURE 15

Then from the first law, i.e., conservation of energy

$$h_1' = h_1 + \frac{V_1^2}{2gJ} = h_2 + \frac{V_2^2}{2gJ}$$

In some cases it may also be assumed that the flow from the tank to Station 1 is adiabatic. In this case

$$h_2' = h_1' = h_{TK}$$

In reality $h_1' \neq h_{TK}$ due to measurement errors in pressure and/or temperature and due to some small heat leak in the suction line. For two-phase calculations at the pump inlet, either h_{TK} or h_1' may be selected for the reference stagnation enthalpy. For the results presented in this report, h_1' was used as the reference enthalpy for two phase pump inlet conditions, i.e.

$$h_2' \overset{\text{Set}}{=} h_1'$$

Fluid conditions upstream of the fluid conditioner are determined as follows:

$$\rho_1 = f(P_1, T_1) \qquad \text{(hydrogen property tables)}$$

$$V_1 = \frac{(144)\dot{W}}{\rho_1 A_1}$$

$$h_1 = f(P_1, T_1) \qquad \text{(hydrogen property tables)}$$

$$h_1' = h_1 + \frac{V_1^2}{2gJ}$$

If the fluid downstream of the fluid conditioner (pump inlet) is single phase, then

$$\rho_2 = f(P_2, T_2) \qquad \text{(hydrogen property tables)}$$

$$h_2 = f(P_2, T_2) \qquad \text{(hydrogen property tables)}$$

$$V_2 = \frac{144\,\dot{W}}{\rho_2 A_2}$$

$$h_2' = h_2 + \frac{V_2^{\,2}}{2gJ}$$

For two phase pump inlet conditions, fluid properties are determined as follows:

$$h_2' \overset{\text{set}}{=} h_1' \qquad \text{(or } h_{TK} \text{ depending on which option is selected)}$$

Initially it is assumed that

$$h_2 = h_1$$

Then $T_2 = f(P_2, h_2)$

$$\rho_2 = f(P_2, h_2)$$

$$V_2 = \frac{144\,\dot{W}}{\rho_2 A_2}$$

A new value for h_2 can now be computed

$$h_2 = h_2' - \frac{V_2^{\,2}}{2gJ}$$

Calculations are then repeated from the table look-up for T_2 until successive values of h_2 satisfy the following criteria:

$$\left| 1 - \frac{h_{2,\ new}}{h_{2,\ old}} \right| \leq 0.00001$$

The state point of the fluid at the pump inlet is now defined by P_2, h_2. Entropy of the fluid entering the pump is then found from the property tables

$$S_2 = f\ (P_2,\ H_2)$$

From saturation properties corresponding to P_2, the following mixture properties are found:

$$\text{Quality} = X_2 = \frac{h_2 - h_L}{h - h_L}$$

$$\frac{\text{Vapor Volume}}{\text{Liquid Volume}} = \beta = \frac{\rho_L\ X_2}{\rho_2\ (1 - X_2)}$$

$$\frac{\text{Vapor Volume}}{\text{Total Volume}} = \alpha = \frac{\beta}{\beta + 1}$$

Various methods of computing NPSP (net positive suction performance) have been used in the evaluation of pump suction performance. The method used for the LH_2 pump tests is described here.

It is assumed that the fluid initially is at the hypothetical tank condition shown on the T-S diagram of Figure 16. Also, it is assumed that the fluid undergoes an isentropic expansion from the hypothetical tank condition to P_2, passing through the saturation state corresponding to S_2. The logical definition for NPSP is then

$$NPSP \equiv P_2' - P_{sat}$$

where

P_2' is the total pressure corresponding to S_2, h_2'

P_{sat} is the saturation pressure corresponding to S_2.

It should be noted that negative values of NPSP result from this method for sufficiently high vapor content in the pump suction line.

Net positive suction head (NPSH) was computed by two methods. The first is based on constant density using saturation density corresponding to S_2, i.e.

$$NPSH = \frac{144\ NPSP}{\rho_{sat}}$$

The second is based on the enthalpy difference

$$NPSH = 778.16\ (h_2' - h_{sat})$$

The above calculated parameters establish pump suction conditions which provide the basis for suction performance and overall pump performance.

HYPOTHETICAL TANK CONDITION

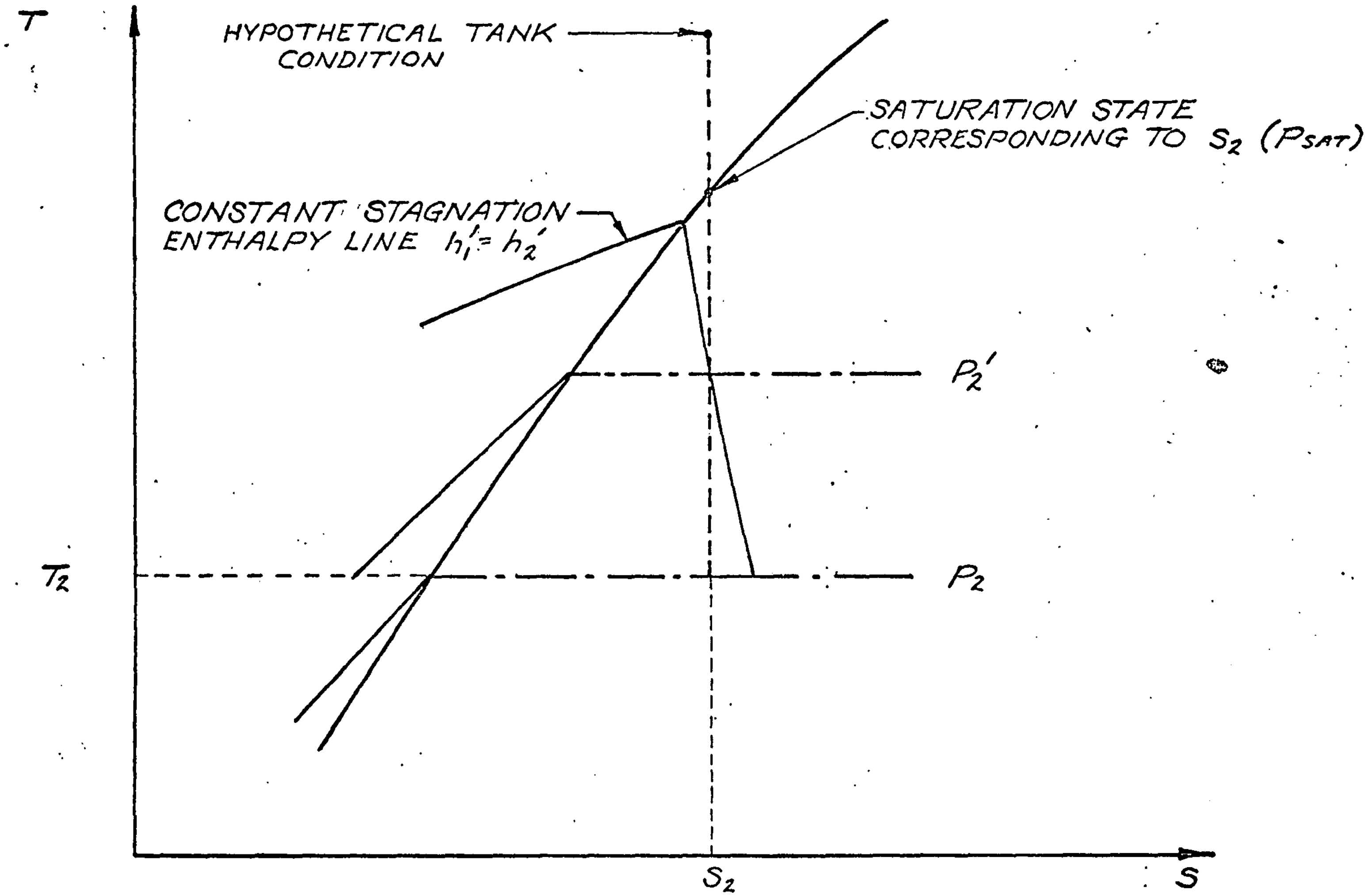


FIGURE 16

2. Pump Performance

Overall performance is presented in normalized parameters (H/N^2, Q_D/N) as well as in dimensionless form (ψ, ϕ_2).

a. Isentropic Head

The isentropic head is defined by inlet conditions (pressure, temperature and entropy) and measured discharge pressure. The discharge velocity head is added to obtain the correct total head.

b. Impeller Discharge Flow Coefficient

The labyrinth leakage flow $\dot{W}_{lb}$ was considered in the computation of the discharge flow coefficient ϕ_2.

$$\phi_2 = 144 \frac{\dot{W}_s + \dot{W}_{lb}}{\rho A_2 \cdot U_2}$$

where:

A_2 = impeller discharge area blocked, (sq in)

U_2 = D_2 N/229 (ft/s)

$\dot{W}_s$ = weight flow, inlet (lb/s)

ρ = fluid density in lb/ft^3

The recirculating shroud labyrinth flow was estimated as follows:

$$W_{lb} = C_{lb} \frac{A_{lb}}{144} \left(2g\,(144)\,\rho\,\Delta P_{lb}\right)^{1/2}$$

$$= 0.66847\, C_{lb}\, A_{lb} \left(\rho\,\Delta P_{lb}\right)^{1/2}$$

where:

A_{lb} = labyrinth flow area

ΔP_{lb} = pressure drop in lb/sq in across labyrinth

C_{lb} = labyrinth flow coefficient = 0.5

c. Stage Head Coefficient

$$\psi = \frac{g \, \Delta H_{is}}{U_2^2}$$

d. Impeller Discharge Total Head Coefficient (One-Dimensional)

This coefficient is based on an average static pressure determined from several wall static pressures measured around the impeller periphery between diffuser inlet and impeller discharge at radius R_M.

Since the static head (ψ_s) is based on measurements outside the impeller discharge the absolute velocity is reduced by the ratio of the impeller discharge radius R_2 to the radius of the pressure tap R_M. The velocity head therefore is multiplied by the radius ratio squared.

$$\psi_t = \psi_s + \left(\frac{R_2}{R_M}\right)^2 \frac{\phi_2^2 + \psi_2^2}{2}$$

The theoretical head coefficient ψ_i based on Stodola's slip correction is defined as:

$$\psi_i = 1 - \frac{\phi_2}{\tan \beta_2} - \frac{\Pi \sin \beta_2}{Z}$$

where:

β_2 = discharge blade angle

Z = number of blades

e. Housing Losses

Diffusion housing losses are expressed in head coefficient form as:

$$\Delta\psi_{\ell(\mathrm{Housing})} = \psi_{t(\mathrm{Impeller})} - \psi_{t(\mathrm{Stage})}$$

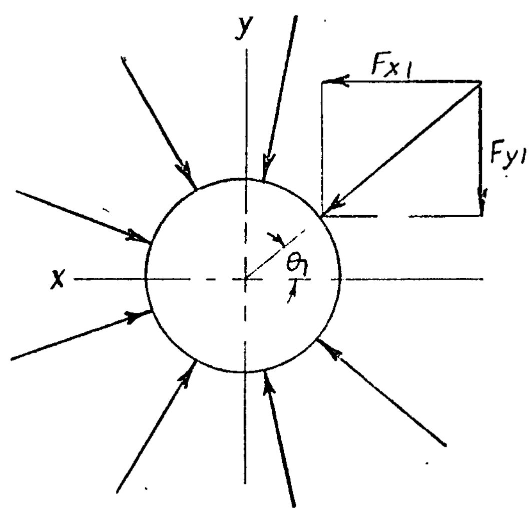
3. Radial Thrust

Radial thrust is determined from the wall static pressures measured around the impeller periphery. Each measured pressure multiplied by its effective area (circumferential increment x effective width) results in a force vector F shown below. The force components of F are:

$$F_y = F \sin\theta$$

and

$$F_x = F \cdot \cos\theta$$



The radial force $\overline{F}$ then is the resultant of the algebraic sums of the force components F_y and F_x.

$$\overline{F} = \sqrt{\Sigma F_y + \Sigma F_x}$$

The direction of the resultant force is determined by the angle

$$\theta = \tan^{-1} \left(\frac{\Sigma F_y}{\Sigma F_x}\right)$$

θ is measured from the pressure tap nearest to the volute tongue in direction of impeller rotation.

The radial thrust parameter used in the data presentation is defined as the ratio of the resultant radial force $\overline{F}$ to the average impeller static pressure rise.

$$RFP = \frac{\overline{F}}{P_{2m} - P_s}$$

B. HYDROGEN PROPERTIES

Hydrogen property routines were required for the data reduction program to evaluate pump performance. Early attempts to use the National Bureau of Standards (NBS) tab decks for parahydrogen proved unsatisfactory for the two phase suction performance calculations. This was due to an apparently ill-defined saturation line between the super-cooled liquid and two-phase regions. As a result of the problems associated with using the NBS tab decks, new hydrogen properties routines were developed.

The new parahydrogen routines are based on the hydrogen properties data of Reference 11. In the single phase region, linear interpolation of the tabulated data of Reference 11 is used. In the interpolation scheme pressure and one other property; temperature, enthalpy, etc; are used as the independent variables. Saturation data used to define the saturation line and to evaluate two-phase properties was the data on page 23 of Reference 11. Saturation properties are determined using spline fits of this data.

Use of these routines in the data reduction program to evaluate hydrogen properties, both in the single phase and two-phase regions yielded consistent results. The accuracy of hydrogen properties data derived from these routines is governed by the experimental accuracy of the data of Reference 11 and the limitations of linear interpolation of that data.

X. TEST PROGRAM

The NERVA LH_2 Pump Component Development tests were performed on the first stage pump rig at the NRDS test Cell "C" facility using the CEL test loop and the electric drive system. The tests were performed on six separate days utilizing the following test operating procedures:

Test Designation	Date	TOP
EP-1 First Day	8 December 1971	NRTO-TOP-0044 (Reference 12)
EP-1 Second Day	10 December 1971	NRTO-TOP-0044* (Reference 12)
EP-2 First Day	15 December 1971	NRTO-TOP-0045 (Reference 13)
EP-2 Second Day	16 December 1971	NRTO-TOP-0045* (Reference 13)
EP-2 Third Day	17 December 1971	NRTO-TOP-0045* (Reference 13)
EP-2A	22 December 1971	NRTO-TOP-0045* (Reference 13)

*Red-line revision with Test Requirement Engineer (TRE) approval.

All objectives of the planned tests were accomplished and several additional tests were performed.

The following sections (A through F) list the pertinent hardware configuration for a test or the changes made between successive tests as well as a brief statement of the tests performed each day.

A. EP-1, FIRST DAY

1. The test article and facility configuration were setup as follows for testing on 8 December 1971:

   a. The 47 hole fluid conditioner was installed.

   b. The pump inlet spool with displacement probes and the inducer spinner with calibration spotfaces were installed.

c. The pump inlet bellows liner was installed.

d. Electrical clamps were installed on valves C-8 and C-106 and were setup to limit their opening to 68% and 30% respectively.

e. The controllers for C-8 (Q/N) and C-231 (PRES) were not setup; and RPM speed control was setup.

2. The following tests were completed on 8 December 1971: (Wednesday)

a. The green run to 19K rpm was made in Manual speed control with C-8 and C-106 in Position control to a Q/N of .25. C-221 was left open and C-231 was left closed throughout the green run.

b. Before the coastdown test, two attempts were made to switch into RPM speed control but the system was unstable. The system coastdown time, with the drive motors off, was performed by opening the D.C. breakers when armature current reached approximately zero as the speed was manually decreased from a steady state 19K rpm. The pump and electric drive system coasted from 18K to 0 rpm in approximately 50 seconds. This compared with a coastdown time of approximately 200 seconds without the pump connected to the electric drive system as reported in Appendix A of Reference 2.

c. Frequency response measurements on the Manual (V_{GA}) speed control loop were performed at 19K rpm with C-8 in position control at a Q/N of .25. C-221 was closed and C-231 adjusted to maintain 45 psig at CP-220.

d. Frequency response measurements on C-231 in position control were performed at 19K rpm with speed in manual control, C-8 in position control at a Q/N of .25, C-221 closed, and C-231 set to establish 45 psig at CP-220. After the frequency response measurements were completed, CTO initiated a shutdown with the Emergency Shutdown (ESD) preset ramp rate at its slowest rate (approximately 2000 rpm/sec). The flow rate vs pump delta P trace on the X-Y plotter for the ESD was almost identical to the trace for the startup to 19K rpm.

e. Frequency response measurements on C-8 in position control were performed at 16K rpm with speed in manual control, C-8 set for a Q/N of .22 and C-231 set for 45 psig with C-221 closed. After the frequency responses were completed, an ESD was initiated with the preset ramp rate increased to approximately 4000 rpm/sec. This shutdown rate produced a maximum drive motor armature current of approximately 6000 amps and a flow rate vs pump delta P trace on the X-Y plotter which was almost identical to the startup trace.

f. C-8 and C-106 valve mapping tests were performed at 19K rpm with speed in manual control and C-231 manually adjusted to maintain 50 psig at CP-220 with C-221 closed. With C-106 closed and C-8 opened to the electrical clamp (68%) the maximum Q/N was .32. With C-8 closed and C-106 opened to the electrical clamp (30%) the maximum Q/N was .13. When using C-8 and then C-106 alone to decrease toward a Q/N of .1, the pump exhibited indications of stall around .10 to .11 Q/N at 19K rpm. A planned ESD was taken from 19K rpm while operating at a Q/N of .25 at a ramp rate $\approx$ - 4000 rpm/sec. (700 pot divisions on the Shutdown Ramp Rate potentiometer). This ramp rate appeared to be quite satisfactory from the standpoint of both the Test Article and the Facility.

B. EP-1, SECOND DAY

1. The following test article and facility changes were made on 9 December 1971 in preparation for testing on 10 December 1971:

a. Removed the 47 hole fluid conditioner and installed the open spacer in its place.

b. Installed mechanical valve blocks on C-8 and C-106 to limit C-106 to 29% and C-8 to 68%. The electrical clamps on C-8 and C-106 were removed.

c. Installed new compensation networks for the Q/N controller to permit C-8 to operate in Q/N control.

d. Modified the RPM controller compensation to permit stable operation in RPM control.

e. It was decided that a pressure controller for C-231 was not required; C-231 position control was acceptable.

2. The following tests were performed on 10 December 1971 (Friday):

a. A green run to 26K rpm was performed in manual speed control and C-8 position control at a Q/N of .25. C-231 was manually opened at 10K rpm (before C-221 was closed) and adjusted to maintain 40 psig at CP-220 while increasing to 26K rpm. Because of questionable supply dewar LH_2 level instrumentation, an ESD was initiated at 26K. This shutdown demonstrated that an ESD was the most desirable way to terminate pump operation.

b. Frequency response on the RPM speed control mode were performed at an indicated 19K rpm. Subsequent investigation determined that, based on pump delta P and flow rate, the true speed was more like 13K rpm. The higher speed indication was due to noise on speed channel UQ-1 and the design feature of the speed controller which utilizes the higher of the two speed channels. The frequency response measurements were made with C-8 in position

F

control at a Q/N of .25 and C-221 closed with C-231 adjusted for 60 psig at CP-220. A planned ESD was initiated by the CTO.

c. Frequency response measurements were made on the Q/N control system at 19K rpm with the speed controller in RPM control and C-221 closed with C-231 adjusted for 20 psig at CP-220. The test was terminated by a planned ESD.

d. Frequency response measurements were repeated on the RPM speed control loop at 19K rpm with C-8 in position control and C-221 closed with C-231 full open. The supply dewar was pressurized to 49 psig, and after completing the response measurements, C-8 was used in position control to map the 19K rpm speed line from Q/N of .25 out to .35 (the C-8 block) and to a minimum Q/N of .14 before returning to ~ .2Q/N where a planned ESD was initiated. During the shutdown, C-8 opening was continued to the 60% position (~.25 Q/N).

e. Mapping of the 23K and 26K rpm speed lines with 40 psig supply dewar pressure was performed in the RPM speed control mode with C-8 in position control and C-221 closed with C-231 opened. The sequence which was used to get to 23K rpm was: C-221 open and C-231 closed with C-8 set to 60%; manual speed control from 0 to 10K rpm; switch C-106 to AUTO: Open C-231 to 4% and close C-221 then adjust C-231 for 20 psig at EP-220; Switch to RPM speed control; Switch to Hold and set Ramp Rate pot to 800 rpm/sec and RPM demand to 19K rpm; Switch to Run and open C-231 to 100% as speed increased to 19K rpm; at 19K switch to Hold and reset RPM demand to 23K; Switch to Run and monitor Q/N and rpm as it approached 23K rpm. At 23K rpm, the Q/N was first increased to .35 (C-8 Block) and then decreased to .14 before returning to .25. The speed then ramped to 26K rpm where the Q/N was decreased to .17 and increased to .35 before returning to .25 Q/N where a planned ESD was initiated.

f. Mapping of the 23K rpm speed line with 60 psig dewar pressure was performed in RPM speed control with C-8 in Q/N control and C-231 opened with C-221 closed. Mapping was limited to Q/N values of .33 and .17. After the Q/N was returned to .25, the supply dewar pressure was increased from 60 to 80 psig. The 80 psig dewar mapping of the 23K speed line was limited to Q/N value of .33 and .16 and the planned ESD was initiated at a Q/N of .20.

C. EP-2, FIRST DAY

1. The following test article and facility changes were made on Monday and Tuesday (13 and 14 December 1971) in preparation for testing on 15 December 1971:

a. The pump inlet spool with the displacement probes was replaced with a spool which had no obstructions.

b. The inducer spinner with the calibration spotfaces was replaced with the normal spinner.

c. The bellows liner was not removed.

d. The spacer was removed and the 21 hole fluid conditioner was installed.

e. Hot GHe pump purges and leak checks were completed.

f. The C-8 mechanical block was examined and determined that a brass collar had extruded from between the mechanical block and the actuator body allowing the valve to open to 84% - this was deemed acceptable.

2. The following 17 cavitation data points were obtained on 15 December 1971 (Wednesday):

RUN NUMBER	SPEED, RPM	Q/N	DEWAR TEMP. °R
1	19K	.17	39
1	19K	.24	39
2	19K	.30	41
3	22K	.17	41
3	19K	.17	41
4	24K	.24	37.5
5	19K	.24	41
5	22K	.24	41
6	24K	.24	41
6	24K	.17	41
7	24K	.17	39
7	22K	.17	39
8	19K	.30	37.5
8	19K	.24	37.5
8	19K	.17	37.5
9	19K	.30	39
9	22K	.24	39

D. EP-2, SECOND DAY

1. The following test article changes were made during the night of 15 December 1971 in preparation for testing on 16 December 1971:

a. The 21 hole fluid conditioner was removed and the 47 hole fluid conditioner was installed.

2. The data points listed below were performed on 16 December 1971 (Thursday); 13 cavitation points and two mapping tests.

a. Cavitation Points

RUN NUMBER	SPEED, RPM	Q/N	DEWAR TEMP. °R
10	22K	.30	37.5
10	24K	.30	37.5
11	22K	.30	41
11	24K	.30	41
11	26K	.30	41
12	22K	.30	39
12	24K	.30	39
12	26K	.30	39
13	22K	.30	43
13	24K	.30	43
14	26K	.30	37.5
15	26K	.30	43
15	24K	.24	43

b. A mapping test of the 23K rpm speed line was performed with 37.5°R LH_2 from Q/N values of .28 to .37 (where C-8 was open to the mechanical block) after cavitation run #14.

c. The low speed mapping tests were performed with 39°R LH_2 and a supply dewar pressure of 40 psig. The speed was increased to 12K rpm in rpm speed control with C-8 in Q/N control at .22. Q/N (using only C-8) was increased to .35 while at 12K rpm and then decreased to .14. The speed was then reduced to 9K rpm (in RPM control) and the Q/N increased from .14 (in Q/N control) toward .35, C-8 was switched to position control to reach the .35 value. At Q/N of .35, the speed was reduced to 6K rpm (in speed control) and C-8 (in position control) was reduced to .14 Q/N with good control. At Q/N of .14, the speed was reduced to 3K (in speed control) and C-8 was opened (in position control) to increase toward Q/N of .35.

E. EP-2, THIRD DAY

1. The following test article changes were made during the night of 16 December 1971 in preparation for testing on 17 December 1971:

a. The 47 hole fluid conditioner was removed and the 21 hole fluid conditioner was installed.

2. The following 19 cavitation data points were obtained on 17 December 1971 (Friday):

RUN NUMBER	SPEED, RPM	Q/N	DEWAR TEMP. °R
16	24K	.17	37.5
16	22K	.17	37.5
16	22K	.24	37.5
17	24K	.17	43
17	22K	.17	43
17	22K	.24	43
17	19K	.24	43
17	19K	.17	43
18	26K	.17	41
18	26K	.21	41
19	26K	.17	43
19	26K	.21	43
20	26K	.17	37.5
20	26K	.21	37.5
21	26K	.17	39
21	26K	.21	39
21	24K	.21	39
22	19K	.30	43
23	24K	.24	39

F. EP-2A

1. The following test article changes were made on Monday and Tuesday (20 and 21 December) in preparation for testing on 22 December 1971:

a. The 21 hole fluid conditioner was removed.

b. The pump inlet bellows liner was removed.

c. The 47 hole fluid conditioner was installed.

2. The final tests were completed on 22 December 1971 (Wednesday) and include 8 cavitation points, 2 mapping tests and a high speed test to determine the critical speed of the pump assembly.

a. Cavitation Points

RUN NUMBER	SPEED, RPM	Q/N	DEWAR TEMP. °R
24	26K	.26	37.5
25	27K	~.28 (73 pps)	39
26	26K	.26	39
26	24K	.30	39
26	22K	.30	39
27	26K	.26	41
28	26K	.26	43
29	27K	~.28 (73 pps)	37.5

b. A mapping test of the 23K rpm speed line was performed between cavitation runs #24 and #25 using 41°R LH_2 and a supply dewar pressure of 60 psig. The pump startup ramp to 23K rpm was made along the .14 Q/N line and then C-8 (in Q/N control) was used to move to the .34 Q/N point on the 23K rpm line where a planned ESD was initiated for a shutdown along the .34 Q/N line.

c. The high speed test was performed to locate the critical speed of the pump as indicated by a rapid increase in pump shaft displacement. This test was performed between cavitation runs #26 and #27 using 39°R LH_2 with a supply dewar pressure of 100 psig. The pump was started up in RPM speed control with C-8 in Q/N control to 26K rpm and a Q/N of .30. Then the speed demand was slowly increased while C-8 maintained a Q/N of .30 and the SCOPE operator monitored the shaft displacement instrumentation. The pump speed was reduced several hundred rpm after the displacement instruments showed a step increase; the maximum speed was approximately 29.2K rpm. The speed was slowly increased again and at approximately 29K, the shaft displacement began to increase and the speed was reduced before a planned ESD was initiated to terminate this test.

d. A low speed mapping test was performed between cavitation runs #28 and #29 using 37.5°R LH_2 with a supply dewar pressure of 50 psig. This test utilized pump inlet flow through K-130 (rather than the normal K-3) so that low flow rates could be measured by the turbine flowmeter KF-130 which had been re-ranged from 0-5 pps to 0-15 pps. The pump was operated at 3K and 6K rpm with K-130 open and C-8 used in position control to limit the KF-130 flow from dewar flow up to 15 pps. The pump discharge pressure for this test indicated very questionable data; it was suspected that the K-130 leg was offering too large a pressure drop creating a two-phase hydrogen condition at the pump inlet.

e. Another low speed mapping test was performed after cavitation run #29 using 39°R LH_2 and a supply dewar pressure of 40 psig. This test utilized pump inlet flow through K-3 rather than K-130. The 6K rpm speed line was mapped in RPM speed control from a Q/N of .20 to .1 with C-8 in position control. Then the 9K rpm speed line was mapped from a Q/N of .20 to .06 with RPM speed control and C-8 position control before a planned ESD was used to terminate the test.

The operating conditions are summarized in Figure 17.

The chronologies for the six experimental plans are included as Appendices B through G.

LH_2 PUMP COMPONENT DEVELOPMENT TEST OPERATING CONDITIONS

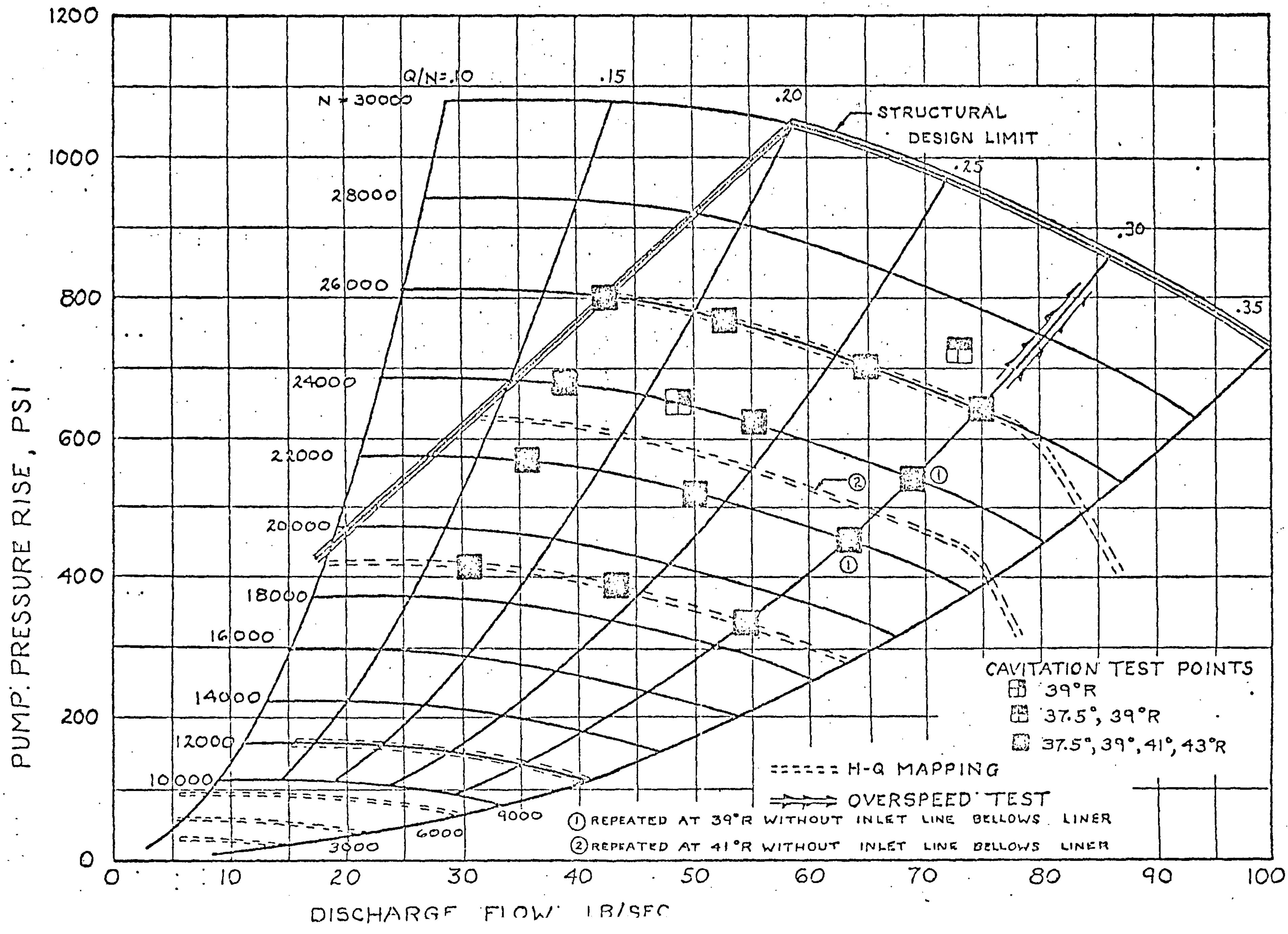


FIGURE 17

XI. RESULTS

The test program consisted of six run days as described in Section X. During the program a large amount of operational data was acquired. This section discusses the significant results of the tests conducted. The data acquired has been divided into three general categories: Non-cavitating Performance, Cavitating Performance, and High Speed Test results.

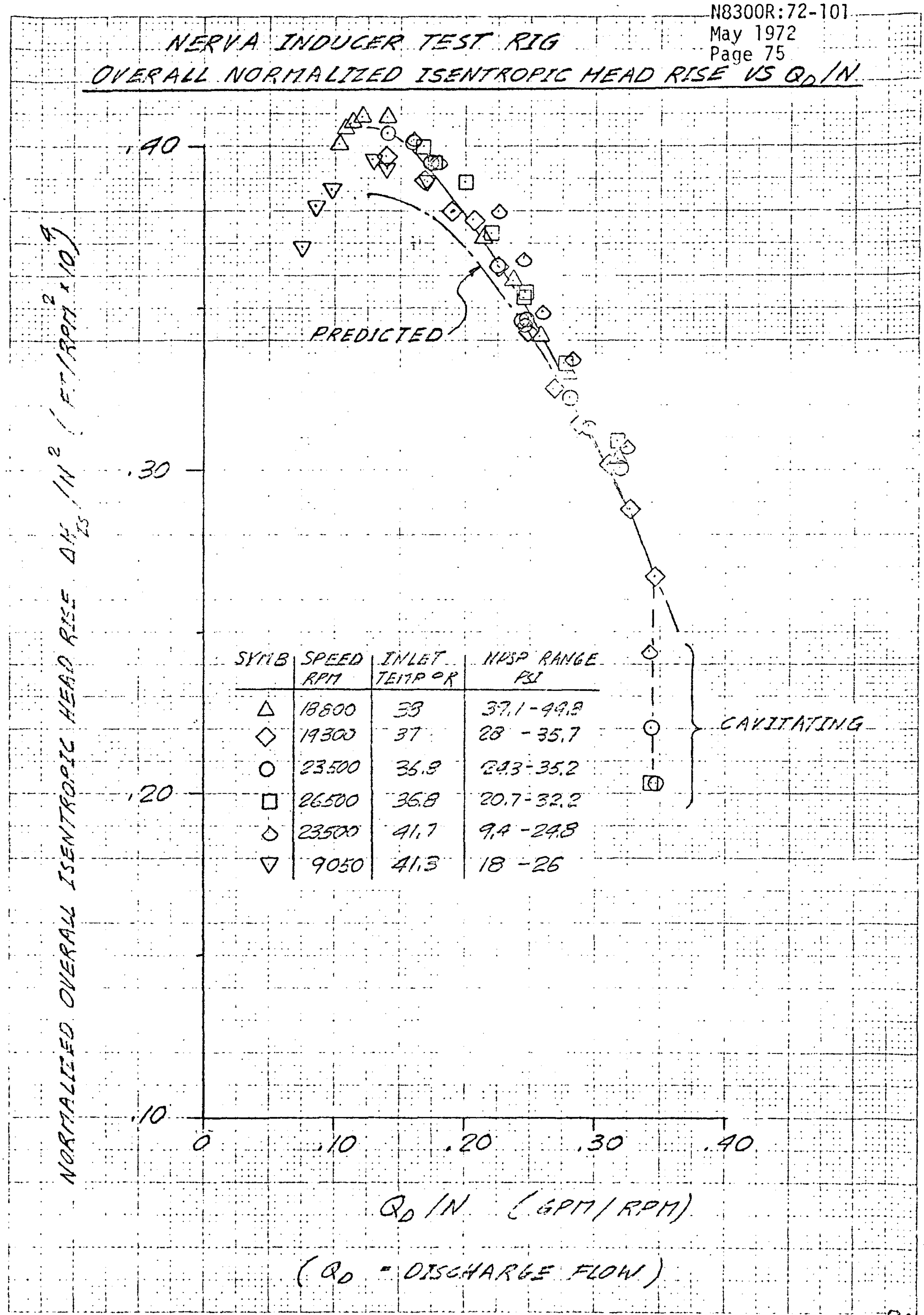
A. NON-CAVITATING PERFORMANCE

The following non-cavitating performance was evaluated:

1. Overall Performance
2. Inducer Performance
3. Impeller Performance
4. Housing Losses
5. Axial Thrust
6. Radial Thrust

1. Overall Performance

The overall head capacity curve is presented in Figure 18 in terms of normalized isentropic head rise ($\Delta H/N^2$) and normalized flow (Q_D/N). The discharge flow rate Q_D used in this presentation is 5 to 15% lower than the inlet flow Q_S because both the impeller rear labyrinth leakage and the bearing coolant flow were tapped off and directed to the burn stack. All data points plotted in Figure 18 were taken from mapping tests conducted at constant speeds and high suction pressure.


NERVA INDUCER TEST RIG
OVERALL NORMALIZED ISENTROPIC HEAD RISE VS Q_D/N
NORMALIZED OVERALL ISENTROPIC HEAD RISE $\Delta H_{IS}/N^2$ ($FT/RPM^2 \times 10^9$)
.40
.30
.20
.10
0
.10
.20
.30
.40
Q_D/N (GPM/RPM)
(Q_D = DISCHARGE FLOW)
PREDICTED
CAVITATING
SYMB | SPEED RPM | INLET TEMP °R | NPSP RANGE PSI
△ | 18800 | 38 | 37.1 - 49.8
◇ | 19300 | 37 | 28 - 35.7
○ | 23500 | 36.8 | 24.3 - 35.2
□ | 26500 | 36.8 | 20.7 - 32.2
23500 | 41.7 | 9.4 - 24.8
▽ | 9050 | 41.3 | 18 - 26

12-29-71

Overall head rise was approximately four percent higher than predicted at the low Q_D/N value of 0.125. At higher capacity-speed ratios however the measured head agreed quite well with the predicted head curve.

Maximum head rise was measured at a Q_D/N value of approximately 0.125, which falls between that of the first stage and that of the second stage of the two-stage pump tested in air (Reference 1). This value was expected since the test rig consisted of a first stage rotor and a second stage housing.

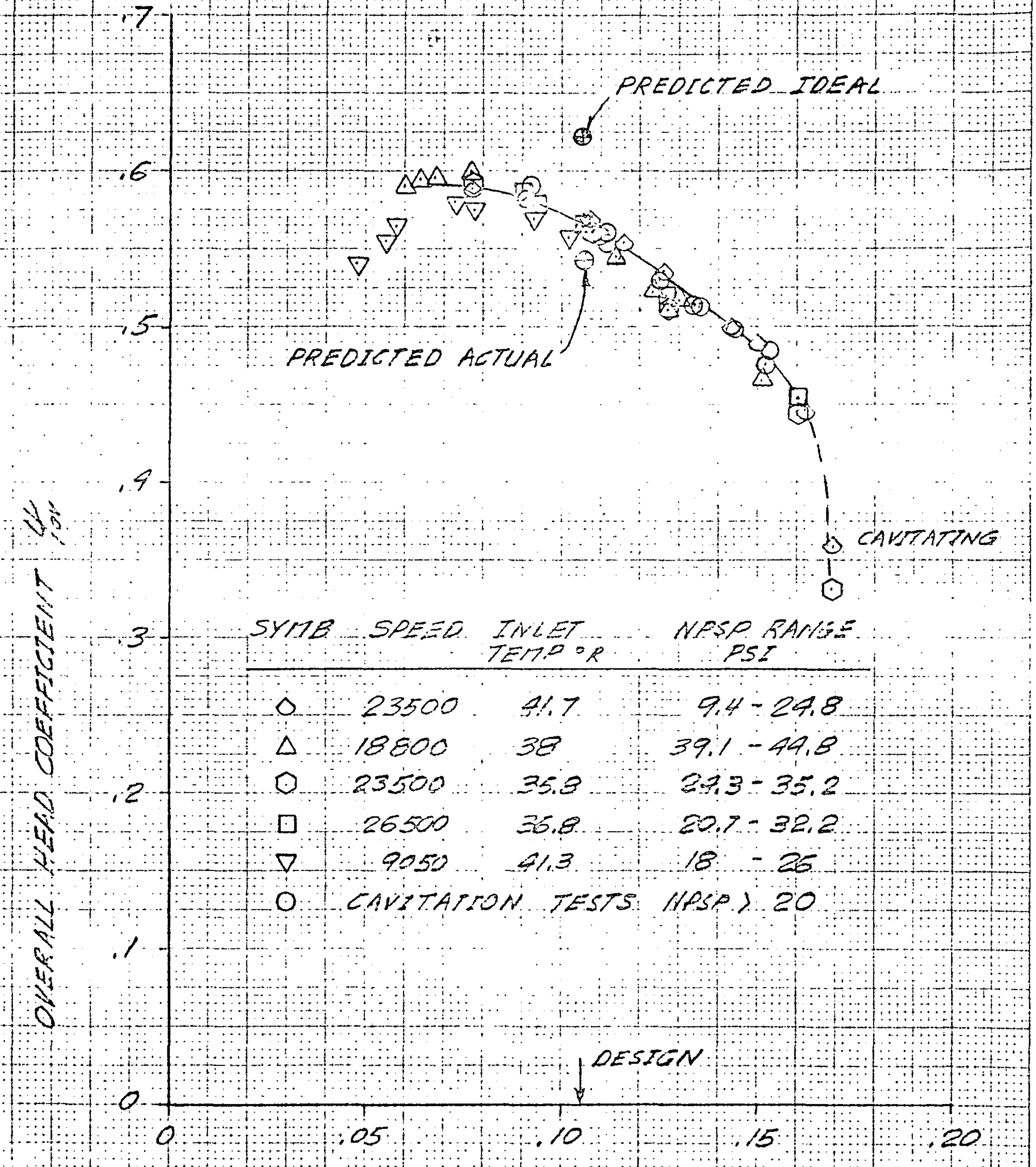
The apparent discontinuity in the positive slope region of the head curve is primarily due to data scatter resulting from large differences in speed between the low flow test conducted at 9000 rpm and the regular mapping tests conducted at speeds above 18000 rpm. Stall as evidenced on the pump air test rig is not well defined in Figure 18 mainly because of data scatter and a lack of data at lower values of Q_D/N.

The high flow limit or the cut-off capacity at head breakdown due to cavitation ($Q_D/N = .345$) is well defined by data points taken at two operating speeds. This operating limit is also confirmed by the cavitation test results.

Figure 19 depicts the overall head coefficient plotted as a function of the discharge flow coefficient. Data points from cavitation tests at NPSP values greater than 20 psi agree well with data from mapping tests.

NERVA INDUCER TEST RIG

OVERALL HEAD COEFFICIENT VS. DISCHARGE FLOW COEFFICIENT



SYMB	SPEED	INLET TEMP °R	NPSP RANGE PSI
⬠	23500	41.7	9.4 - 24.8
△	18800	38	39.1 - 44.8
⬡	23500	35.8	27.3 - 35.2
□	26500	36.8	20.7 - 32.2
▽	9050	41.3	18 - 26
○	CAVITATION TESTS NPSP > 20		

DISCHARGE FLOW COEFFICIENT ϕ_2
(BASED ON BLOCKED IMPELLER DISCHARGE AREA A_2 = 14.13 IN^2)

3-7-72

Pump efficiency presented in Figure 20 is expressed as the ratio of ideal enthalpy rise to actual enthalpy rise. The actual enthalpy rise was determined from measured temperature rise. Values of efficiency based on discharge flow (lower curve) account for impeller rear labyrinth and bearing coolant flow losses. These values were obtained by downgrading the upper values (based on inlet flow) in accordance to the ratio of discharge flow to inlet flow. Disc friction losses are not accounted for in the values presented because the frictional heat was dissipated by the labyrinth flow.

The peak efficiency of 82% based on inlet flow agrees with values measured on the air test rig when operated without flow recirculation.

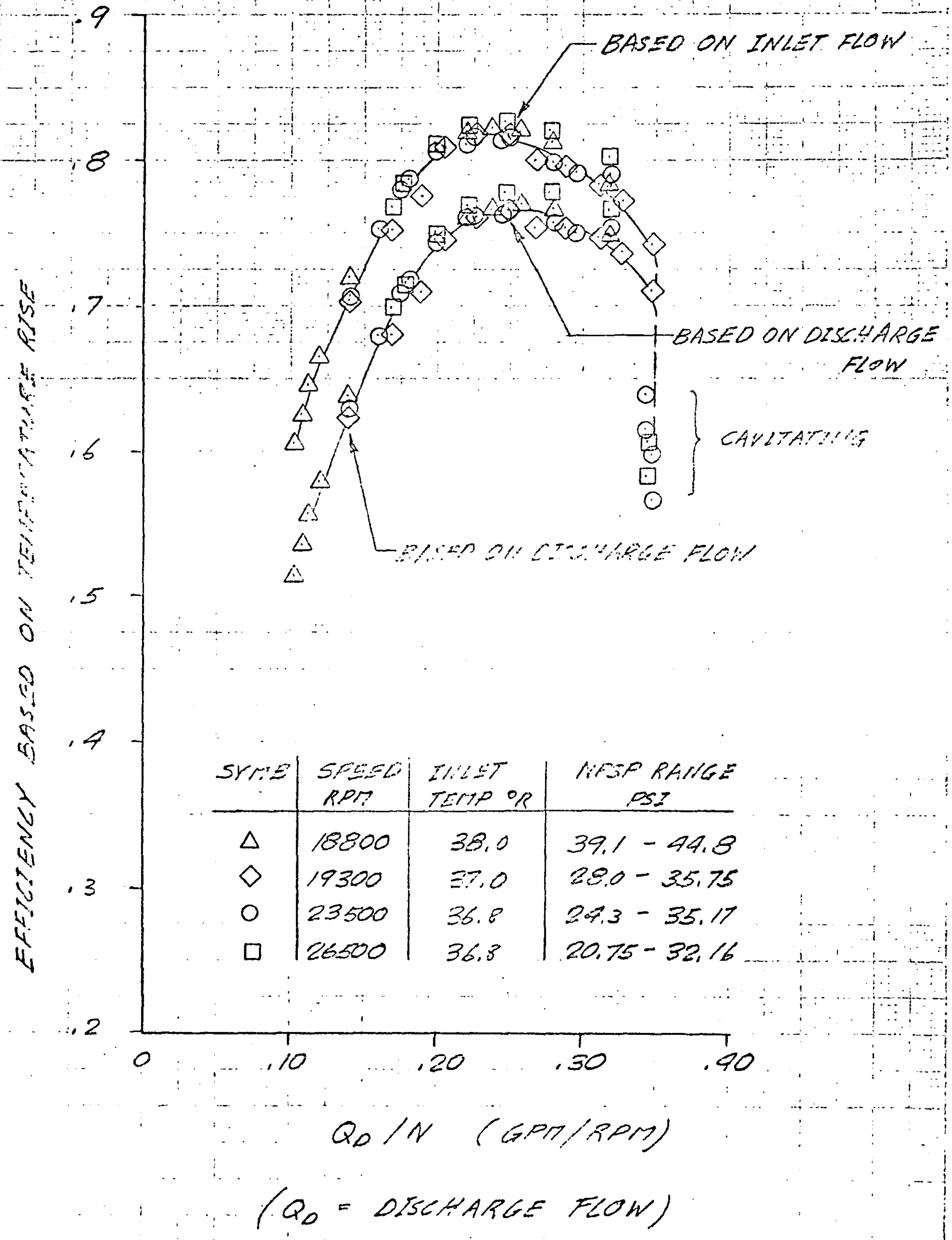
2. Inducer Performance

The measured static head at the inducer discharge based on two wall static taps located between inducer exit and impeller inlet is presented in Figure 21 as a function of inlet flow. Measurements made on the air test rig at a similar location slightly inward of that of the inducer test rig are represented by the dashed line. The higher head obtained in liquid hydrogen was mainly attributed to differences in orientation and location of pressure taps between the two rigs rather than discrepancies in flow measurements. The slopes of the two characteristics are identical.

FIGURE 20

NERVA INDUCER TEST RIG

EFFICIENCY VERSUS FLOW PARAMETER Q_D/N

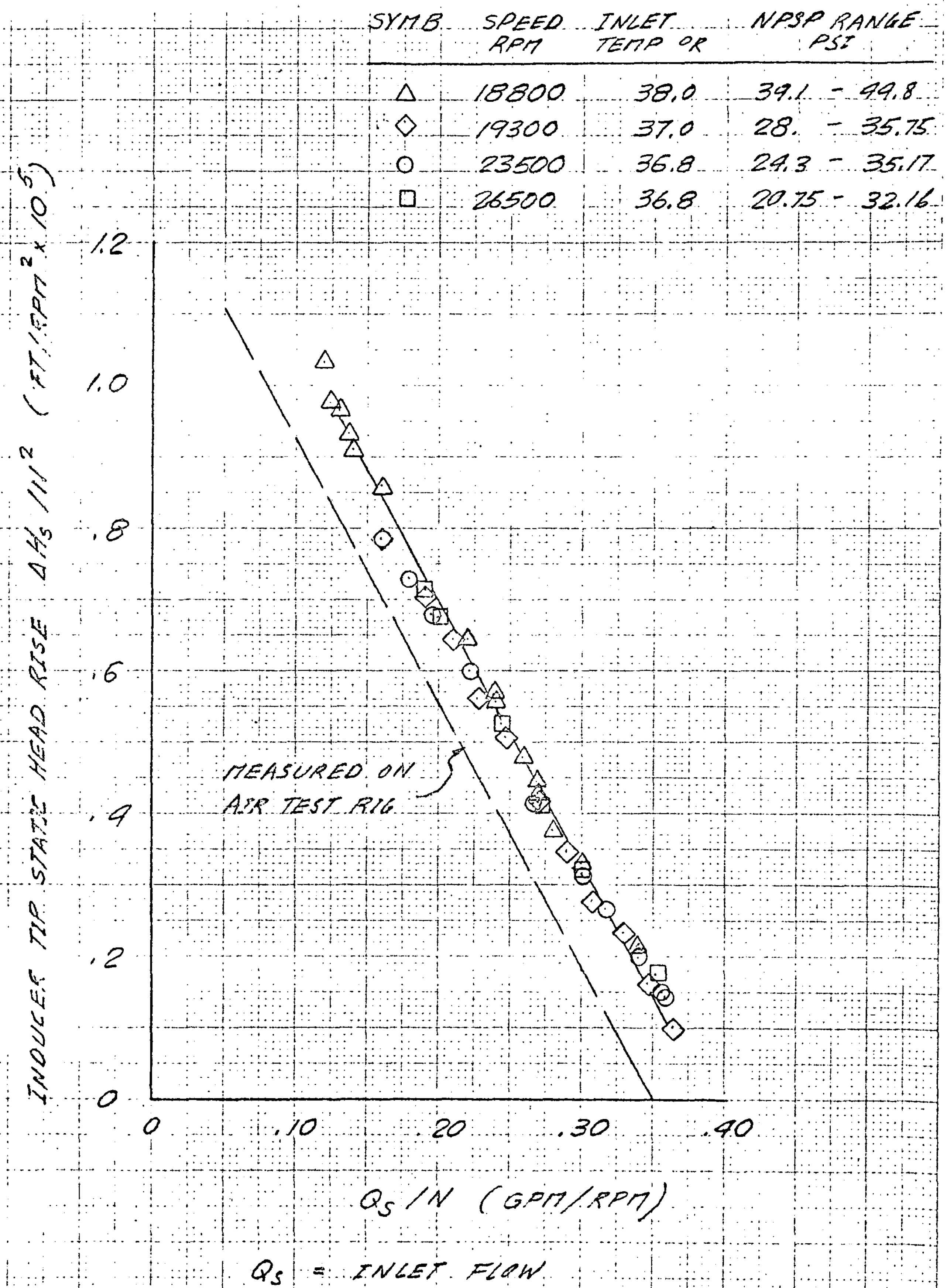


12-29-71

FIGURE 21

NERVA INDUCER TEST RIG

INDUCER TIP STATIC HEAD RISE VS FLOW PARAMETER Q_s/N



12-29-7 83

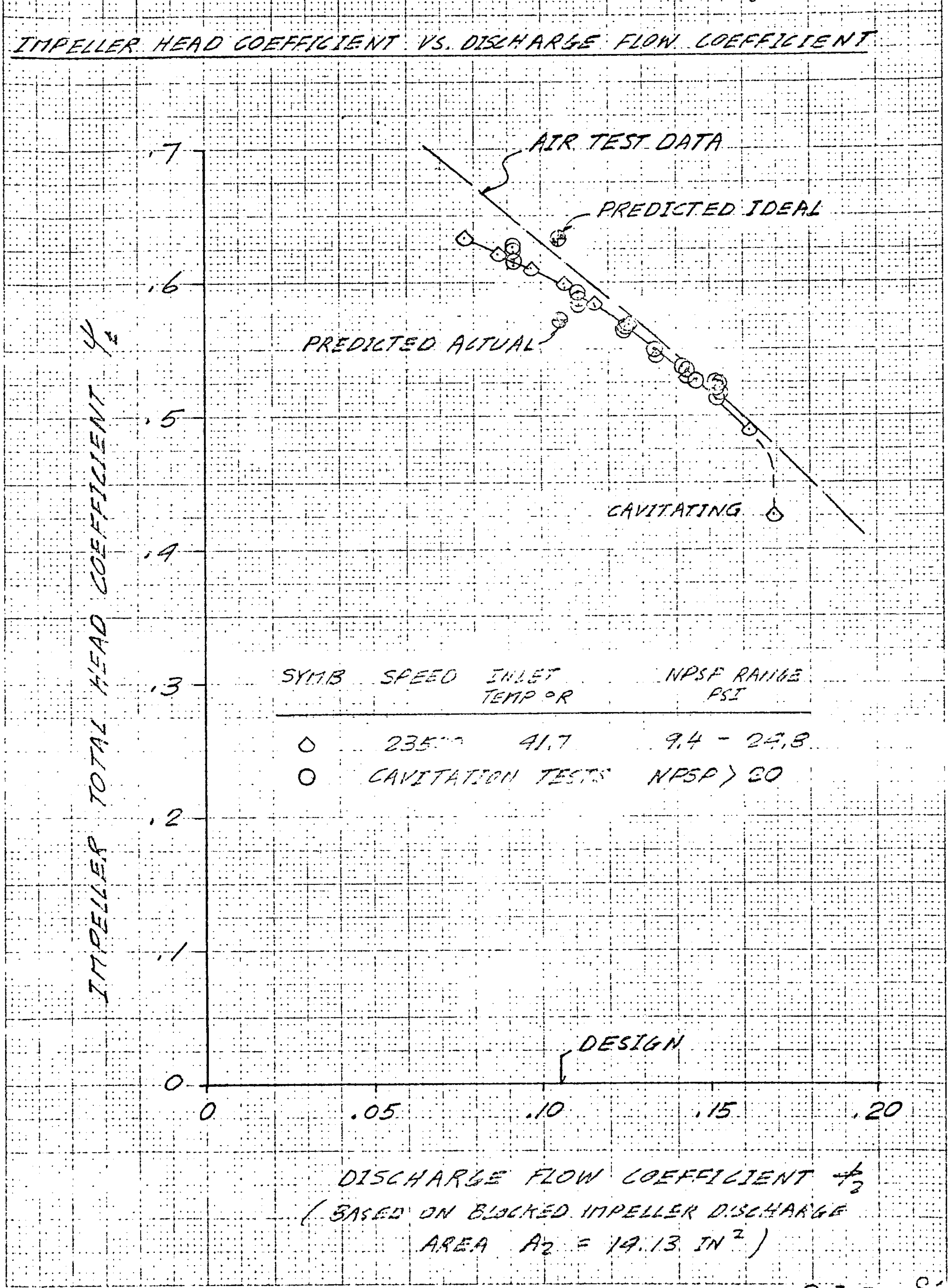
3. Impeller Performance

The impeller head coefficient is plotted as a function of discharge flow coefficient in Figure 22. The data is compared with air test data and the predicted actual and ideal head coefficient at the design flow coefficient. The values presented were computed for axial inlet flow (no prewhirl) and thus include the inducer head. The velocity head, which is added to the measured static head, was calculated from the fluid tangential velocity component based on the Stodola correction for slip. The meridional component of velocity was obtained from continuity considerations. Equations used in the computation of the impeller head coefficient are presented in Section IX.

Air test and hydrogen test data agree quite well at flow coefficients above design. At low flow coefficients, however, the impeller head obtained in liquid hydrogen is somewhat less than that measured on the air test rig. The difference in performance at low flow could be related to the following causes:

a. Changes in interaction effects resulting from different housings.

b. Effect of backvanes with outward flow on air test impeller. Impeller of inducer test rig had smooth disc with inward flow through labyrinth.


NERVA INDUCER TEST RIG
IMPELLER HEAD COEFFICIENT VS. DISCHARGE FLOW COEFFICIENT
AIR TEST DATA
PREDICTED IDEAL
PREDICTED ACTUAL
CAVITATING
IMPELLER TOTAL HEAD COEFFICIENT
0
.1
.2
.3
.4
.5
.6
.7
SYMB SPEED INLET TEMP °R NPSP RANGE PSI
23500 41.7 9.4 - 24.8
CAVITATION TESTS NPSP > 20
DESIGN
0
.05
.10
.15
.20
DISCHARGE FLOW COEFFICIENT
(BASED ON BLOCKED IMPELLER DISCHARGE AREA A2 = 14.13 IN²)
3-7-72

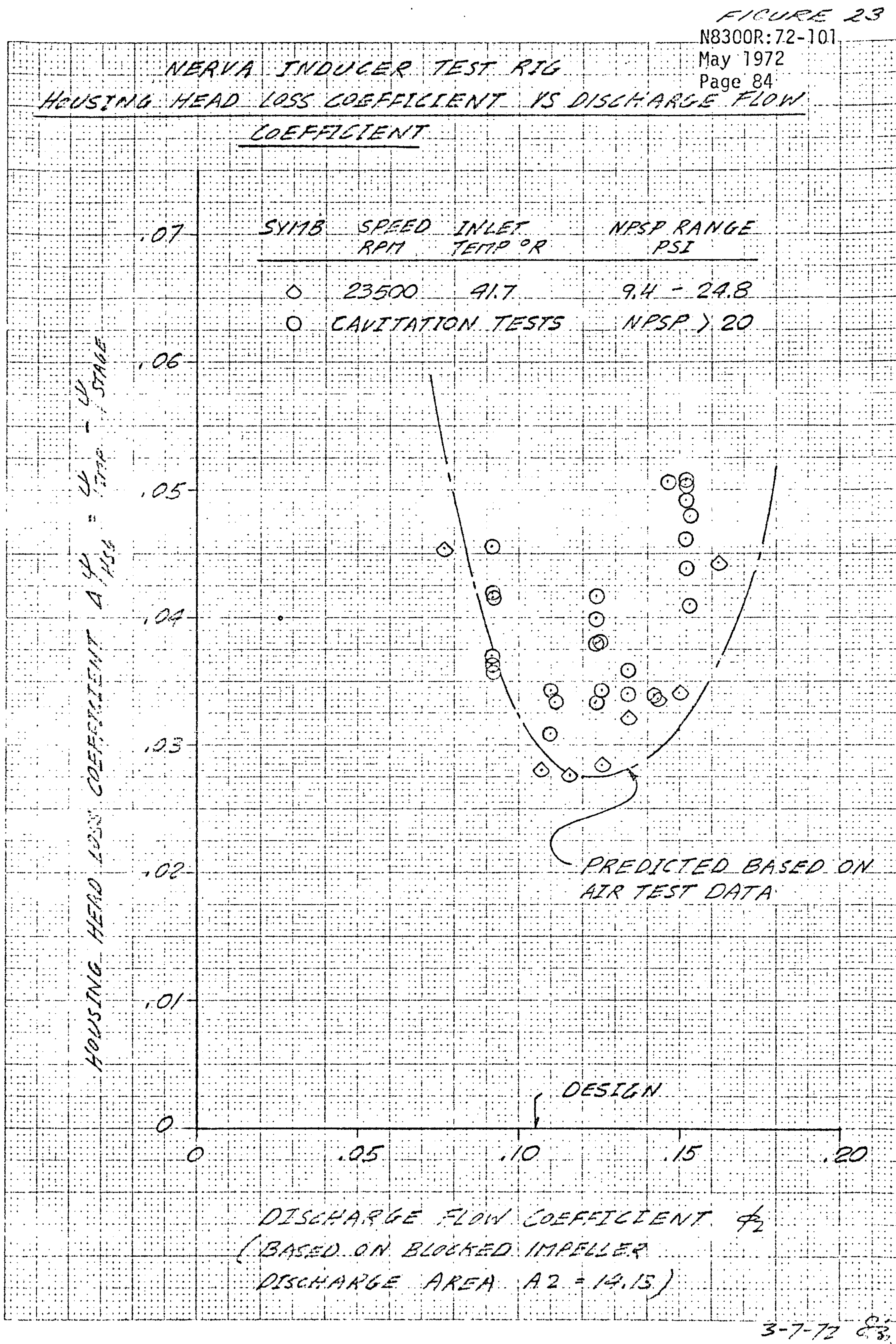
4. Housing Losses

Housing losses are presented in Figure 23 in terms of head loss coefficient and discharge flow coefficient. The head loss coefficient is defined as the difference between the impeller head coefficient and the stage head coefficient and therefore, includes volute losses as well as diffuser vane losses. The static head used in the computation of the total head at the impeller discharge is based on an average circumferential pressure determined from equally spaced wall taps at identical locations with respect to the housing vanes. The average circumferential pressure thus does not necessarily represent an average value of pressure variations from vane to vane at the same radius.

The relatively large variation in housing loss coefficients results from general data scatter reflected on impeller head and overall pump head and the small difference in the magnitudes of these parameters. Minimum housing losses amounted to approximately 6% of the pump head rise and agree quite well with predictions based on air test data.

5. Axial Thrust

The net axial thrust was computed from the pressure forces acting upon the front face and the backface of the impeller. These pressure forces were determined through numerical integration of the respective pressure profiles. Axial thrust considered as positive in direction towards pump inlet, reached momentary peak magnitudes of approximately 3400 lbs at the highest speed, lowest Q/N value and lowest suction pressures tested. High negative thrust magnitudes of approximately 1000 lbs were obtained at high suction pressures, high values of Q/N and low speed. Thrust reversals were experienced during start and shutdown transients.


NERVA INDUCER TEST RIG
HOUSING HEAD LOSS COEFFICIENT VS DISCHARGE FLOW COEFFICIENT
SYMB SPEED RPM INLET TEMP °R NPSP RANGE PSI
◇ 23500 41.7 9.4 - 24.8
○ CAVITATION TESTS NPSP > 20
HOUSING HEAD LOSS COEFFICIENT
.07
.06
.05
.04
.03
.02
.01
0
PREDICTED BASED ON AIR TEST DATA
DESIGN
0
.05
.10
.15
.20
DISCHARGE FLOW COEFFICIENT
(BASED ON BLOCKED IMPELLER DISCHARGE AREA A2 = 14.15)
3-7-72

6. Radial Thrust

The radial force acting upon the impeller shown in Figure 24 as a function of Q_D/N is expressed as the ratio of radial force to the average static pressure rise measured at the periphery of the impeller. The radial force was obtained by integrating the circumferential pressure profile based on 9 static pressure taps located between impeller tip and diffuser inlet. The effective impeller tip width was assumed to be one inch.

The radial force parameter of this single stage pump is about twice as high as that of the two stage air test pump (Reference 1) because the average impeller discharge pressure of the single stage pump would only be approximately half of that of the second stage of the air test pump under the same operating conditions.

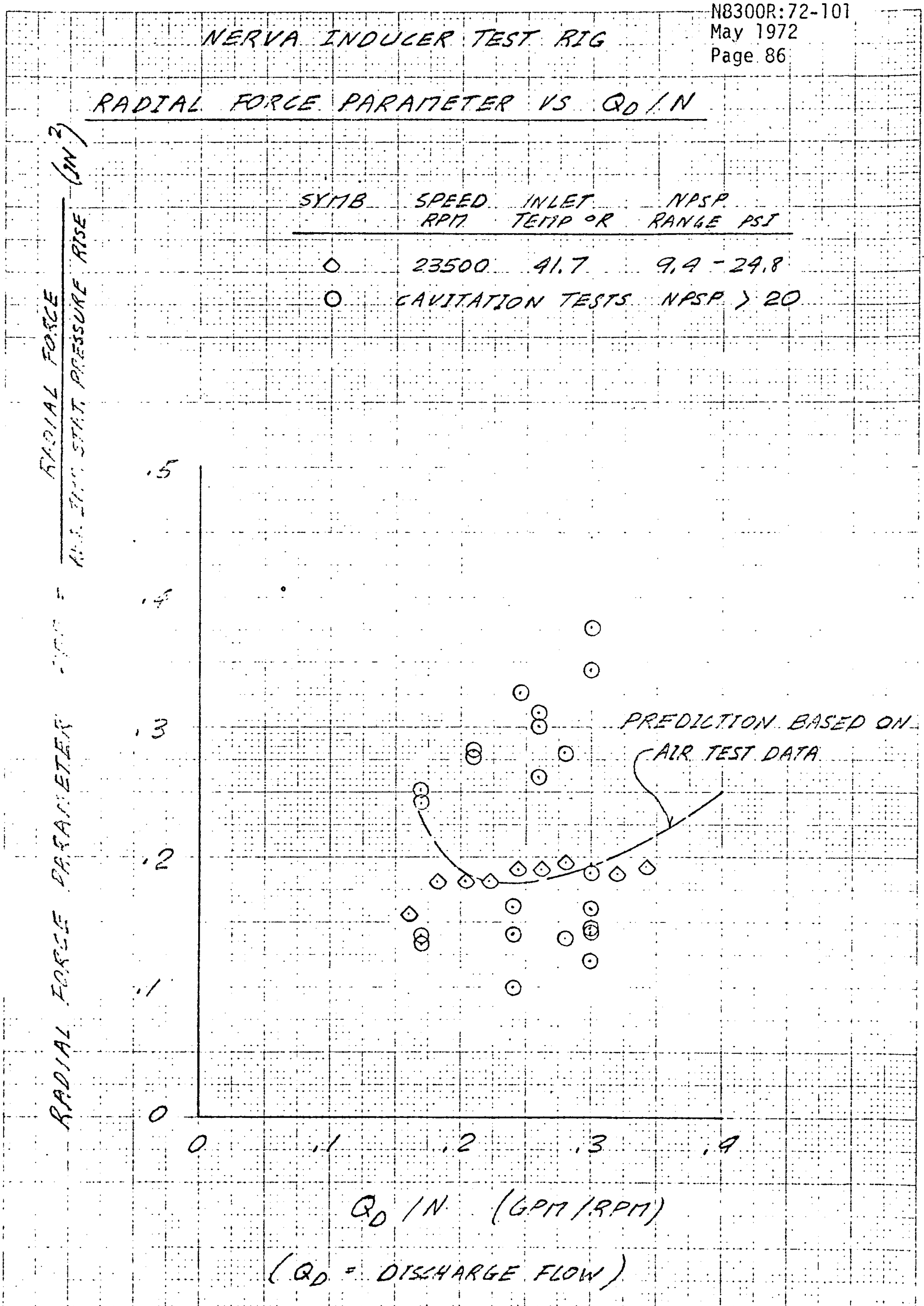
Data points from mapping tests agree well with the minimum predicted value indicated by the dashed line in Figure 24 between the Q_D/N values of 0.2 and 0.3. The large scatter in data points taken from cavitation tests at high starting values of NPSP reflects instrumentation accuracy and non-steady state conditions.

B. CAVITATING PERFORMANCE

The following performance aspects were evaluated:

1. Suction Performance
2. Axial Thrust
3. Radial Thrust
4. High Frequency Pressure Measurements
5. Cavitation Data Correlation
6. Flow Limit

FIGURE 24


NERVA INDUCER TEST RIG
RADIAL FORCE PARAMETER VS Q_D/N
SYMB
SPEED RPM
INLET TEMP °R
NPSP RANGE PSI
23500
41.7
9.4 - 24.8
CAVITATION TESTS NPSP > 20
PREDICTION BASED ON AIR TEST DATA
.5
.4
.3
.2
.1
0
0
.1
.2
.3
.4
Q_D/N (GPM/RPM)
(Q_D = DISCHARGE FLOW)
2-25-72

1. Suction Performance

The reduced data for the cavitation tests are shown in Appendix H. These plots show the performance of the pump as the suction pressure was reduced to induce cavitation.

2. Axial Thrust

Axial thrust was very sensitive to suction pressure. During cavitation runs, the net thrust toward suction increased with decreasing suction pressure and reached a maximum value at the point where head breakdown occurred. At this limiting value of NPSP, thrust decreased as head dropped off. A typical axial thrust - NPSP characteristic is shown in Figure 25.

3. Radial Thrust

Radial thrust expressed in terms of the radial force parameter defined in Section IX is also plotted in Figure 25 as a function of NPSP. In contrast to axial thrust, radial thrust was only little affected by changes in suction pressure. A minor thrust peak occurred near the NPSP value at incipient cavitation. The drop off in radial thrust parameter in the region of head breakdown was minor.

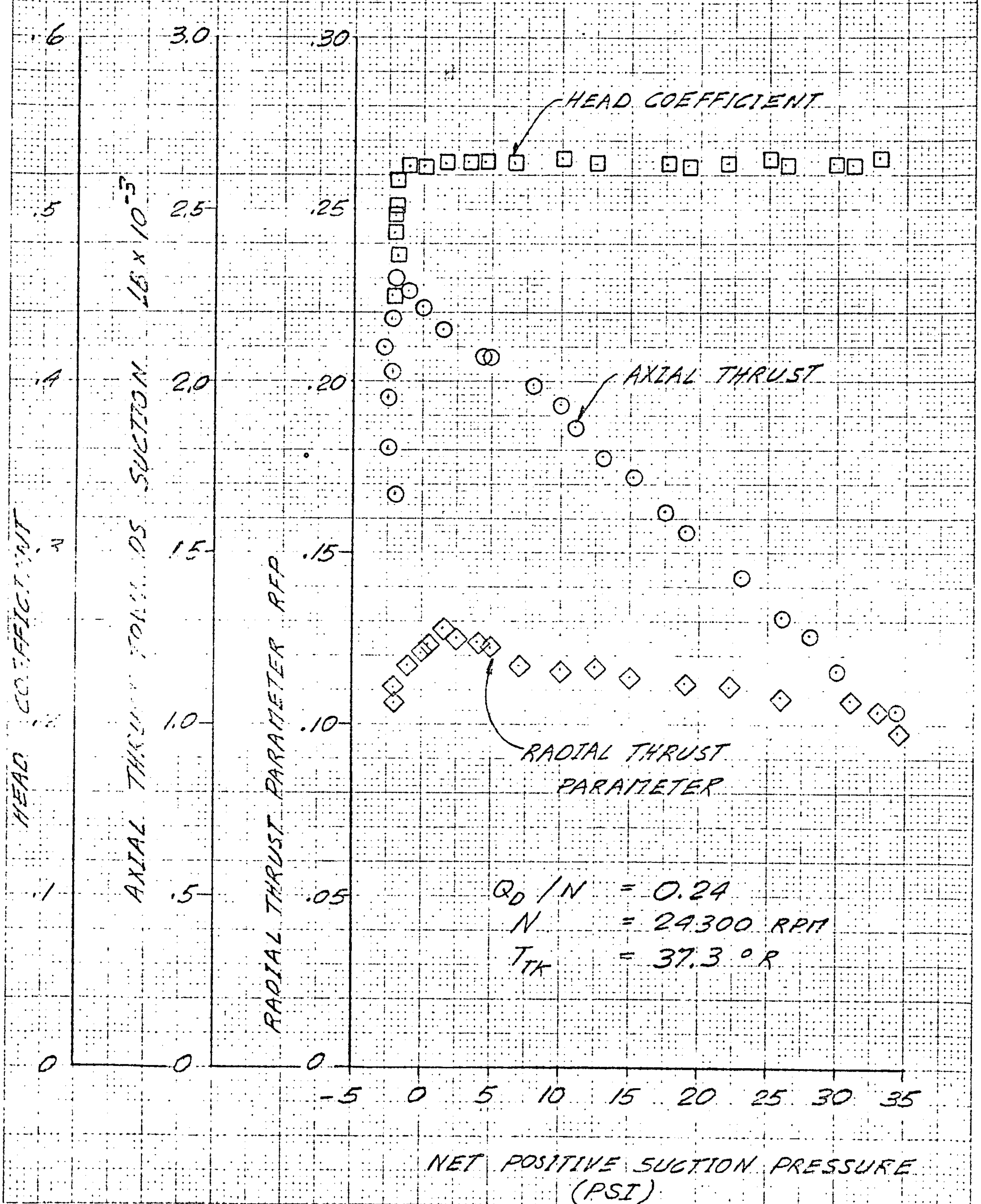
4. High Frequency Pressure Measurements

Two Kistler high frequency (0-5000 Hz) pressure transducers were installed in the test facility system to monitor inlet and discharge pressure. The inlet pressure transducer, CP 511W (Range 0-100 psi) was located 1.5 inches upstream of the test article inlet and the discharge pressure transducer, CP-542W (Range 0-1000 psi) was located 3.5 inches downstream of the test article discharge flange. The signal conditioned transducer outputs were

FIGURE 25

NERVA INDUCER TEST RIG

RADIAL THRUST PARAMETER, AXIAL THRUST & HEAD COEFFICIENT VERSUS NET SUCTION PRESSURE



3-6-72

recorded on wide band tape during all test runs. Playbacks of the data tape were recorded on oscillograph at a 1 inch per second rate for preliminary review. Selected portions of cavitation tests were recorded at 40 inches per second to permit observance of possible pressure wave forms.

Inspection of the high frequency pressure data showed the amplitude of pressure oscillation to be less than 1.0 psi and 50 psi for the inlet (CP 511W) and discharge (CP 542W) pressure measurements respectively and no discernable pressure wave form was observed.

5. Cavitation Data Correlation

Cavitation performance of the pump, in terms of net positive suction pressure (NPSP), is known to be a function of pump speed (N), pump volumetric flow rate (Q), and vapor pressure (P_V). An attempt was made to find an empirical relation for the NPSP at breakdown for the LH_2 pump. The derived relation was based on the cavitation data of Appendix H.

Preliminary plots of this data revealed the following trends regarding breakdown NPSP:

a. NPSP is linear in speed (N) and vapor pressure (P_V)

b. $\frac{\partial NPSP}{\partial N}$ is independent of flow coefficient (Q/N)

c. NPSP is not linear in flow coefficient (Q/N)

The above information lead to the following form of the empirical relation

$$NPSP = \left[\frac{P_V}{a} + b\right]\left[\frac{N}{1000} + c + d\left(\frac{Q}{N}\right) + e\left(\frac{Q}{N}\right)^2\right]$$

The coefficients a, b, c, d, and e were found using the data of Appendix H and least square techniques. The resulting values were

$a = 130$

$b = -0.076$

$c = -153.1$

$d = 525$

$e = -450$

Using this empirical relation, breakdown NPSP was computed for each cavitation test and compared with established test values. The results of this comparison are shown in Table III. The maximum difference was found to be 0.6 psi.

6. Flow Limit

Figure 26 presents maximum values of estimated vapor fractions (gas to liquid volume ratios) and flow to speed ratios (Q_S/N) for a series of 35 cavitation tests. It is interesting to note that the limiting Q_S/N values, which account for vapor in the suction line, fall within a rather narrow band of values from 0.33 to 0.38. The average value of Q_S/N agrees well with the cut-off capacity to speed ratio defined by mapping tests in Figure 18. The corresponding incidence to blade angle ratio at the inducer tip for the limiting Q_S/N value of 0.35 is approximately 0.21, when the fluid density at the inducer inlet is assumed to be the same as at the instrumentation location downstream of the vapor generator.

TABLE III

CAVITATION DATA CORRELATION

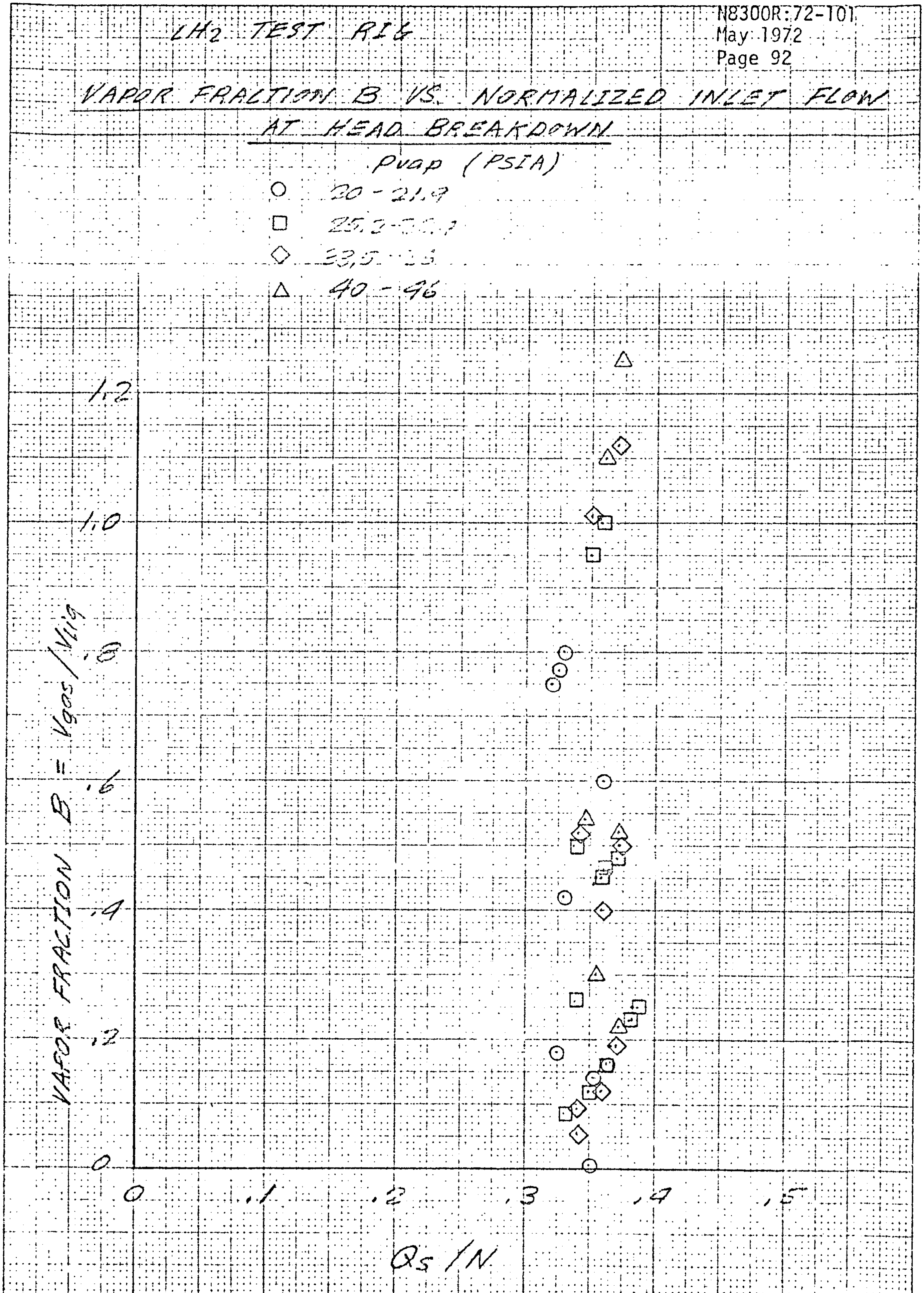
Q/N	N	PV	NPSP	CNPSP	DEV
.190	19200.	20.2	-4.30	-4.00	.30
.190	19300.	21.6	-4.50	-4.53	-.03
.190	19000.	36.0	-10.40	-10.16	.24
.190	18850.	46.8	-14.60	-14.41	.19
.190	22200.	20.1	-3.40	-3.72	-.32
.190	22200.	24.6	-5.60	-5.36	.24
.190	22500.	35.5	-9.20	-9.28	-.08
.190	22200.	45.5	-13.00	-12.98	.02
.190	24300.	19.8	-3.20	-3.46	-.26
.190	24400.	24.5	-5.30	-5.08	.22
.190	24300.	34.0	-8.80	-8.40	.40
.190	24400.	45.0	-12.30	-12.21	.09
.190	26400.	19.0	-3.10	-3.03	.07
.190	26500.	27.9	-5.70	-5.97	-.27
.190	26500.	35.7	-8.40	-8.56	-.16
.190	26500.	40.9	-10.30	-10.28	.02
.260	19200.	19.7	-2.30	-2.10	.20
.260	19300.	21.2	-2.40	-2.41	-.01
.260	19200.	34.7	-5.10	-5.31	-.21
.260	18800.	45.0	-7.40	-7.62	-.22
.260	22300.	19.9	-1.80	-1.90	-.10
.260	22500.	28.1	-3.20	-3.43	-.23
.260	22400.	34.3	-4.50	-4.62	-.12
.260	22200.	44.5	-6.30	-6.61	-.31
.260	24400.	18.9	-1.90	-1.57	.33
.260	24200.	27.5	-3.00	-3.09	-.09
.260	24300.	32.9	-4.00	-4.02	-.02
.260	24100.	42.4	-5.50	-5.73	-.23
.240	26400.	19.2	-2.20	-1.91	.29
.240	26400.	27.5	-3.40	-3.61	-.21
.240	26500.	35.3	-5.20	-5.18	.02
.240	26500.	40.2	-6.50	-6.18	.32
.320	19200.	19.4	-1.40	-.88	.52
.320	19200.	28.0	-1.70	-1.67	.03
.320	19300.	33.1	-2.30	-2.12	.18
.320	19100.	43.2	-3.40	-3.09	.31
.320	22500.	21.6	-.60	-.78	-.18
.320	22500.	25.7	-.90	-1.05	-.15
.320	22100.	26.1	-1.00	-1.13	-.13
.320	22500.	33.3	-1.70	-1.56	.14
.320	24300.	21.8	-.40	-.63	-.23
.320	24400.	25.8	-.80	-.83	-.03
.320	24200.	26.0	-.80	-.86	-.06
.320	24400.	33.4	-1.20	-1.22	-.02
.320	26500.	18.3	.30	-.30	-.60
.320	26500.	26.8	-.50	-.61	-.11
.320	26500.	33.7	-1.00	-.85	.15
.320	26400.	41.6	-1.50	-1.16	.34

A= 130.0 B= -.076 C= -153.1 D= 525.00E= -450.000

MAX. DEVIATION = .60 SUM DEV. SQ. = 2.51

$$NPSP = \left(P_v - 0.076\right)\left[\frac{N}{\ldots} - 153.1 + 525\left(\frac{Q}{N}\right) - 450.0\left(\frac{Q}{N}\right)^2\right]$$

FIGURE 26



1-28-72

C 2

C. HIGH SPEED TEST RESULTS

A high speed test of the test article was conducted during EP-2A to establish the critical speed experimentally.

1. Measurement and Data Display

Proximity measuring probes (Channels CD-702 through CD-708) radially located around the rotor at 90 degree intervals adjacent each rotor bearing, were used to detect both rotor rotation and radial rotor movement. A local step change in rotor shaft diameter (approximately .0003 in depth spotface) over an approximate arc of 12 degrees rotation provided a momentary proximeter to shaft distance step change. The resulting proximeter signal output step change for each revolution of the rotor shaft could be observed on oscilloscope monitor and subsequently on the oscillograph record. A pretest proximeter-to-rotor shaft distance calibration established the spotface depth in relation to signal output voltage value. The step change in proximeter signal output was a known distance based on the pretest calibration thereby allowing disregard for output sensitivity changes caused by temperature variation. The scale factor could likewise be used to measure, directly from the oscillograph record, the amplitude of rotor radial movement.

The signal conditioned proximeter output was tape recorded and patched on line to oscilloscope display during all tests. Off-line playback of the data through a CEC oscillograph recorder provided oscillograph data displayed at a paper speed of 1 inch per second with selected portions at 40 inches per second.

2. Test Results

A high speed run of the test article was conducted during the December 22nd EP-2A using inlet conditions of 100 psia inlet pressure and 39°R inlet fluid temperature. Discharge flow system impedance was controlled to maintain a Q/N of 0.30.

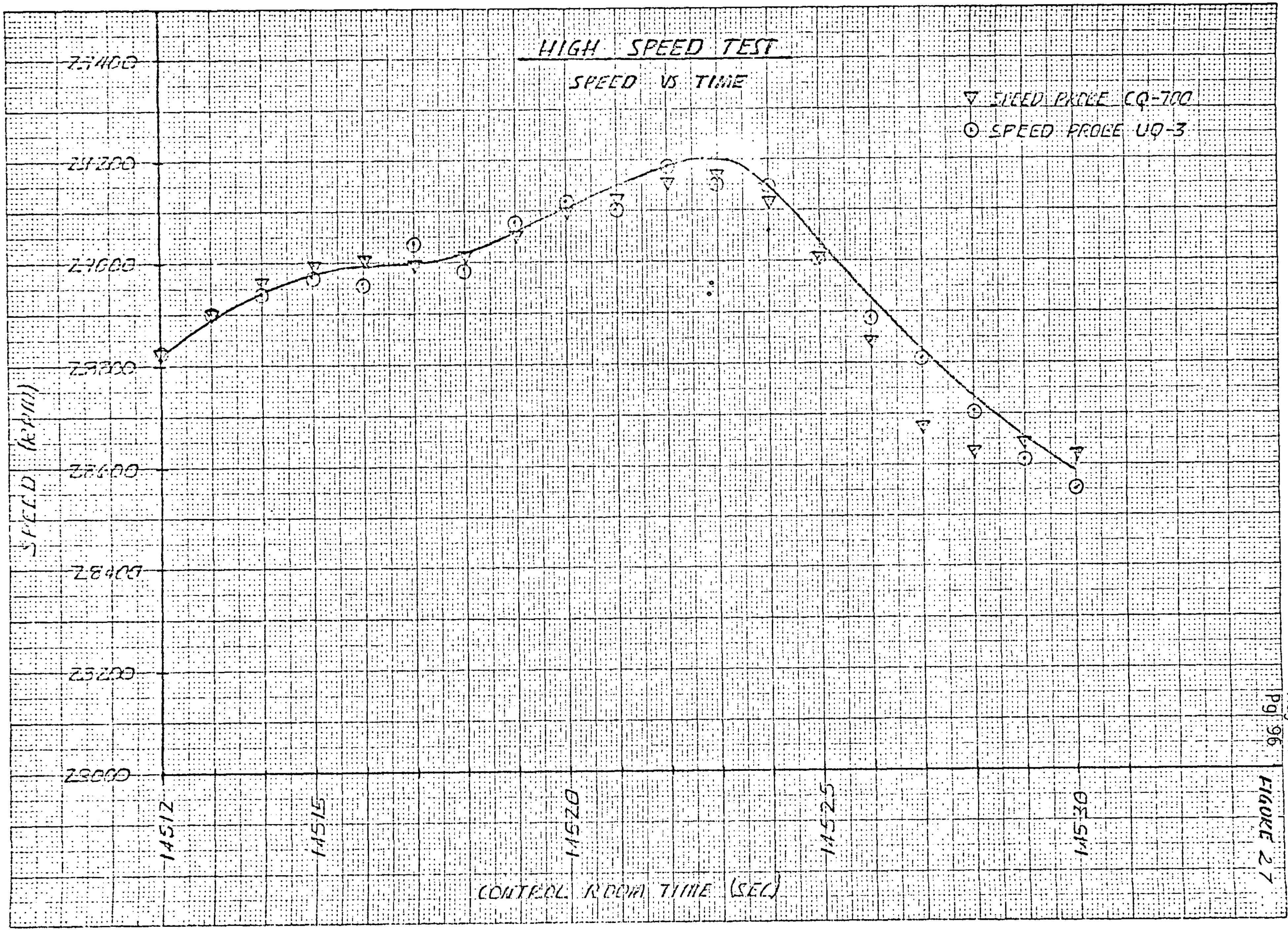
For the high speed test, rotational speed was adjusted to approximately 26,000 rpm and then slowly increased while observing the rotor dynamics displayed on the oscilloscopes. Figure 27 presents a plot of speed versus time at the maximum speed condition. The rotor radial displacement amplitude rapidly increased at approximately 29,200 rpm.

A maximum radial displacement of 6.0 mils double amplitude was measured at the 90 degree aft end bearing location at the time period of maximum speed. Corresponding forward rotor radial displacement (CD 703) was 3.6 mils double amplitude. The displacement amplitudes include shaft rotation eccentricity estimated at less than 0.05 mils double amplitude.

The peak speed achieved was 29,245 rpm based on the displacement probe shaft spotface frequency count.

Figure 28 presents a plot of shaft radial displacement (CD 703 and CD 706) and beat frequency versus speed. The beat frequency, characterized by sudden change in amplitude of the speed frequency, was observed at indefinite intervals in time at speeds in excess of 28,000 rpm. However a definite beat frequency between 90 and 100 Hz was noted between 28000 rpm and 29000 rpm. Additional speed increase reduced the beat frequency as noted on Figure 28.

The maximum radial displacements resulted when the beat frequency decreased to zero which was simultaneous with the maximum speed. Given the relationship $\omega_N = \omega_S \pm \omega_B$ (where ω_N = natural frequency, ω_S = speed frequency and ω_B = beat frequency) the data presented in Figure 28 shows the critical speed to occur at approximately 29,250 rpm which agrees well with the predicted critical speed of 30,000 rpm.


HIGH SPEED TEST
SPEED VS TIME
▽ SPEED PROBE CQ-700
⊙ SPEED PROBE UQ-3
SPEED (RPM)
1451Z
1451б
1452O
1452S
1453O
CONTROL ROOM TIME (SEC)
FIGURE 27

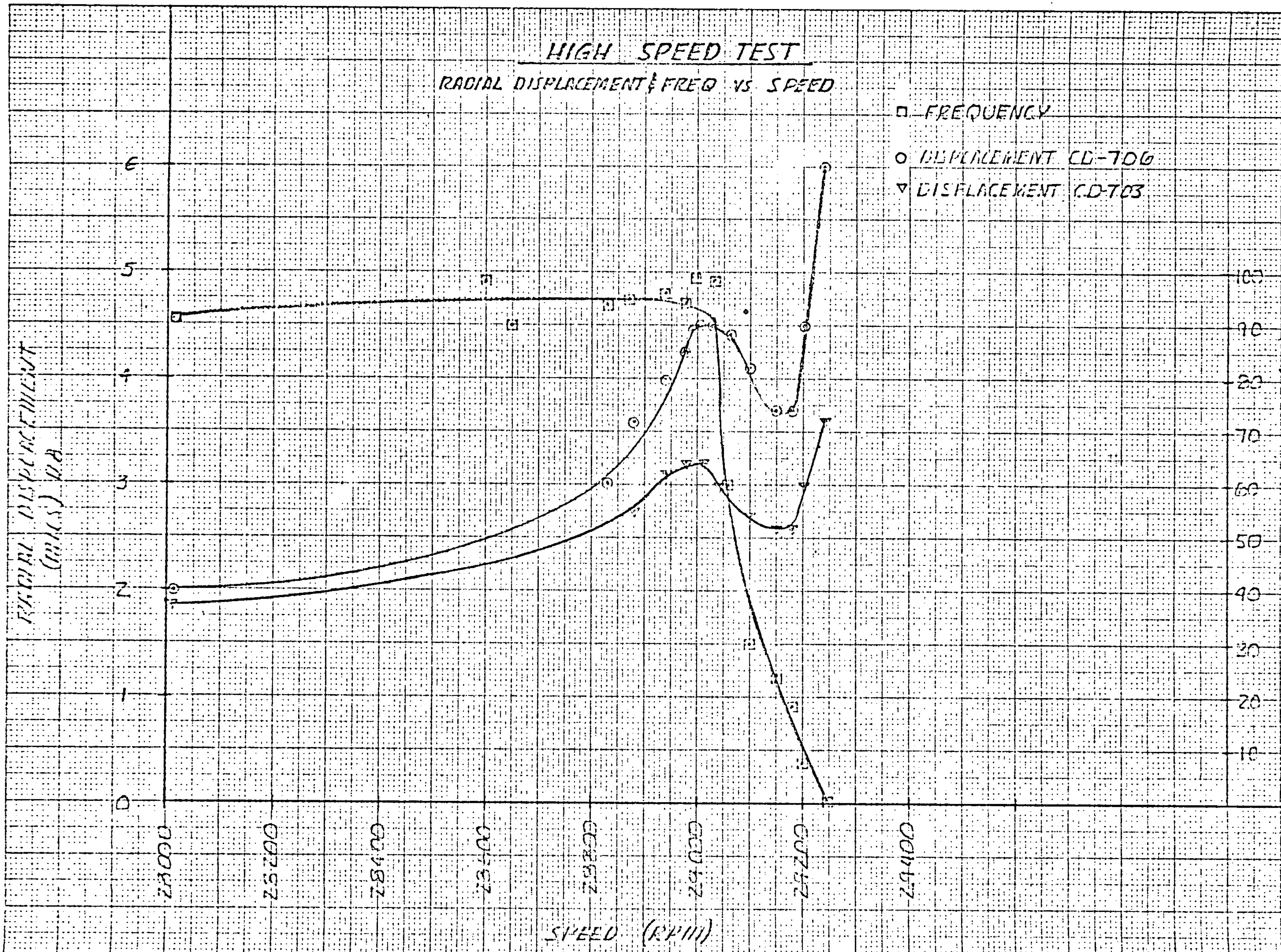

HIGH SPEED TEST
RADIAL DISPLACEMENT & FREQ VS SPEED
□ FREQUENCY
○ DISPLACEMENT CD-706
▽ DISPLACEMENT CD-703
6
5
4
3
2
1
0
100
90
80
70
60
50
40
30
20
10
SPEED (RPM)

FIGURE 28

XII. REFERENCES

1. N8300R:71-090, "Performance of a Two-Stage Centrifugal NERVA Pump Tested with Air as the Working Fluid", dated 9 December 1971

2. NRTO-R-0213, "Test Description for NERVA LH_2 Pump Component Development Test at Test Cell "C", dated 11 November 1971

3. ANSC Drawing 1139300, "LH_2 Test Rig Assembly-First Stage"

4. ANSC Drawing 1138562, "Vaned Inlet Spool-LH_2 Test Rig"

5. ANSC Drawing 1138561, "Inlet Spool - LH_2 Test Rig"

6. ANSC Drawing 1138588, "Inducer - LH_2 Test Rig"

7. ANSC Drawing 1138550, "Impeller,First Stage LH_2 Rig"

8. ANSC Drawing 1138600, "Housing, LH_2 Test Rig"

9. NRTO Drawing 1440038, "Fluid Conditioner, FC-47, CEL Inducer Pump Testing"

10. NRTO Drawing 1440037, "Fluid Conditioner, FC-21, CEL Inducer Pump Testing"

11. NBS Monograph 94, Thermodynamic and Related Properties of Parahydrogen from the Triple Point to 100°K at Pressures to 340 Atmospheres, dated 10 August 1965

12. NRTO-TOP-0044, Test Operating Procedure for NERVA Turbopump Inducer Tests (CEL), EP-I

13. NRTO-TOP-0045, Test Operating Procedure for NERVA Turbopump Inducer Tests (CEL), EP-II

APPENDIX A

LH_2 PUMP TEST DATA REDUCTION PROGRAM

@ EL. DATA,1,720405, 41895

000001	9 10 11 13 15 16 16 17 17 18 19 20 43 43 43 43 43 42 42 42 42 42 41 41 41							
000002	40 40 39 39 38							
000003	24.9029	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000004	36.4823							
000005	0.20788	0.20828	0.21058	0.21305	0.21575	0.21869	0.22187	0.22528
000006	0.22632							
000007	-132.27	-131.80	-128.88	-125.77	-122.46	-118.96	-115.25	-111.28
000008	-110.18							
000009	1.186	1.205	1.316	1.427	1.539	1.650	1.761	1.874
000010	1.905							
000011	24.9336	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000012	37.8000	39.0995						
000013	0.20780	0.20812	0.21042	0.21289	0.21559	0.21853	0.22163	0.22512
000014	0.22894	0.23196						
000015	-131.97	-131.55	-128.65	-125.53	-122.25	-118.75	-115.02	-111.07
000016	-106.85	-103.63						
000017	1.186	1.202	1.314	1.425	1.536	1.648	1.759	1.872
000018	1.985	2.070						
000019	24.9641	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000020	37.8000	39.6000	41.1497					
000021	0.20772	0.20804	0.21026	0.21281	0.21543	0.21829	0.22147	0.22489
000022	0.22870	0.23291	0.23697					
000023	-131.67	-131.31	-128.39	-125.30	-122.01	-118.51	-114.80	-110.86
000024	-106.66	-102.16	-98.04					
000025	1.186	1.201	1.312	1.424	1.534	1.645	1.757	1.869
000026	1.983	2.099	2.201					
000027	25.0254	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000028	37.8000	39.6000	41.4000	43.2000	44.3376			
000029	0.20756	0.20780	0.21003	0.21249	0.21511	0.21797	0.22107	0.22449
000030	0.22814	0.23236	0.23705	0.24237	0.24618			
000031	-131.10	-130.82	-127.92	-124.83	-121.54	-118.07	-114.38	-110.45
000032	-106.27	-101.79	-96.99	-91.85	-88.38			
000033	1.187	1.197	1.309	1.420	1.530	1.641	1.752	1.863
000034	1.977	2.092	2.211	2.333	2.412			
000035	25.0865	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000036	37.8000	39.6000	41.4000	43.2000	45.0000	46.8000	46.8414	
000037	0.20740	0.20756	0.20979	0.21225	0.21479	0.21766	0.22067	0.22401
000038	0.22767	0.23180	0.23641	0.24157	0.24769	0.25493	0.25508	
000039	-130.52	-130.35	-127.45	-124.36	-121.10	-117.62	-113.95	-110.03
000040	-105.87	-101.43	-96.67	-91.56	-86.03	-79.95	-79.80	
000041	1.187	1.194	1.305	1.415	1.526	1.636	1.747	1.859
000042	1.971	2.086	2.203	2.324	2.450	2.581	2.585	
000043	25.1459	25.2000	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000
000044	37.8000	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	48.9365
000045	0.20724	0.20732	0.20955	0.21193	0.21456	0.21734	0.22036	0.22362
000046	0.22719	0.23124	0.23577	0.24086	0.24674	0.25381	0.26232	0.26414
000047	-129.95	-129.86	-126.96	-123.89	-120.63	-117.17	-113.50	-109.60
000048	-105.46	-101.05	-96.33	-91.26	-85.80	-79.80	-73.17	-71.85
000049	1.188	1.192	1.302	1.412	1.522	1.631	1.743	1.853
000050	1.965	2.079	2.196	2.316	2.439	2.570	2.709	2.737
000051	25.2071	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000052	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	50.7564
000053	0.20709	0.20931	0.21162	0.21424	0.21694	0.21996	0.22322	0.22679
000054	0.23069	0.23514	0.24014	0.24587	0.25262	0.26089	0.27130	0.27368
000055	-129.37	-126.49	-123.44	-120.18	-116.72	-113.08	-109.19	-105.06
000056	-100.68	-95.99	-90.96	-85.54	-79.65	-73.13	-65.75	-64.15

000057	1.188	1.298	1.408	1.517	1.628	1.738	1.848	1.959
000058	2.073	2.189	2.308	2.430	2.559	2.695	2.844	2.876
000059	25.2665	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000060	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000061	52.3745							
000062	0.20693	0.20907	0.21138	0.21392	0.21662	0.21956	0.22282	0.22632
000063	0.23021	0.23450	0.23943	0.24507	0.25159	0.25945	0.26923	0.28242
000064	0.28401							
000065	-128.79	-126.02	-122.97	-119.71	-116.28	-112.63	-108.77	-104.65
000066	-100.30	-95.63	-90.66	-85.29	-79.48	-73.09	-65.90	-57.50
000067	-56.58							
000068	1.189	1.295	1.405	1.514	1.623	1.733	1.843	1.953
000069	2.067	2.182	2.299	2.421	2.547	2.682	2.827	2.990
000070	3.008							
000071	25.3278	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000072	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000073	53.8380							
000074	0.20677	0.20883	0.21114	0.21360	0.21630	0.21924	0.22242	0.22584
000075	0.22965	0.23395	0.23871	0.24420	0.25055	0.25810	0.26748	0.27964
000076	0.29561							
000077	-128.22	-125.53	-122.48	-119.26	-115.83	-112.18	-108.34	-104.25
000078	-99.92	-95.29	-90.34	-85.03	-79.29	-73.00	-65.98	-57.92
000079	-48.92							
000080	1.189	1.291	1.401	1.510	1.619	1.728	1.837	1.949
000081	2.060	2.175	2.291	2.412	2.538	2.669	2.810	2.968
000082	3.137							
000083	25.3871	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000084	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000085	54.0000	55.1717						
000086	0.20661	0.20860	0.21082	0.21336	0.21599	0.21893	0.22203	0.22544
000087	0.22918	0.23339	0.23808	0.24340	0.24960	0.25683	0.26573	0.27710
000088	0.29315	0.30896						
000089	-127.64	-125.06	-122.01	-118.79	-115.38	-111.75	-107.91	-103.84
000090	-99.53	-94.93	-90.02	-84.77	-79.10	-72.89	-66.05	-58.24
000091	-48.84	-41.01						
000092	1.189	1.289	1.407	1.506	1.615	1.724	1.833	1.943
000093	2.054	2.168	2.284	2.404	2.527	2.657	2.795	2.948
000094	3.124	3.267						
000095	25.4465	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000096	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000097	54.0000	55.8000	56.4029					
000098	0.20645	0.20836	0.21058	0.21305	0.21567	0.21853	0.22163	0.22505
000099	0.22870	0.23283	0.23744	0.24261	0.24865	0.25564	0.26414	0.27487
000100	0.28933	0.31238	0.32525					
000101	-127.07	-124.59	-121.54	-118.32	-114.91	-111.31	-107.49	-103.44
000102	-99.15	-94.56	-89.70	-84.50	-78.87	-72.79	-66.07	-58.48
000103	-49.56	-37.94	-32.54					
000104	1.190	1.285	1.394	1.502	1.611	1.719	1.828	1.938
000105	2.048	2.162	2.277	2.394	2.517	2.644	2.780	2.929
000106	3.096	3.308	3.404					
000107	25.5960	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000108	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000109	54.0000	55.8000	57.6000	59.1047				
000110	0.20613	0.20772	0.20995	0.21241	0.21495	0.21773	0.22075	0.22401
000111	0.22751	0.23148	0.23585	0.24078	0.24642	0.25294	0.26057	0.26994
000112	0.28186	0.29847	0.32597	0.41744				
000113	-125.62	-123.40	-120.37	-117.17	-113.78	-110.20	-106.42	-102.41
000114	-98.17	-93.65	-88.87	-83.77	-78.29	-72.40	-65.96	-58.86
000115	-50.78	-41.12	-28.19	-1.36				
000116	1.192	1.277	1.385	1.492	1.600	1.708	1.816	1.925

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000117	2.034	2.145	2.259	2.374	2.49[illegible]	2.617	2.747	2.886
000118	3.038	3.214	3.442	3.900				
000119	25.7435	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000120	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000121	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000122	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000123	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000124	97.2000	99.0000	100.8000					
000125	0.20574	0.20717	0.20939	0.21170	0.21424	0.21694	0.21980	0.22298
000126	0.22640	0.23021	0.23442	0.23911	0.24436	0.25040	0.25747	0.26581
000127	0.27614	0.28941	0.30825	0.34011	0.44994	0.75143	0.90298	1.01590
000128	1.11047	1.19573	1.27433	1.34799	1.41808	1.48531	1.55016	1.61310
000129	1.67436	1.73428	1.79301	1.85062	1.90728	1.96315	2.01830	2.07265
000130	2.12653	2.17978	2.23238					
000131	-124.19	-122.20	-119.20	-116.02	-112.65	-109.09	-105.33	-101.37
000132	-97.17	-92.73	-88.02	-83.00	-77.65	-71.91	-65.73	-58.97
000133	-51.44	-42.82	-32.46	-18.36	12.47	61.59	80.53	93.62
000134	104.16	113.40	121.76	129.52	136.84	143.81	150.53	157.01
000135	163.32	169.47	175.50	181.41	187.21	192.95	198.60	204.19
000136	209.73	1.94	7.40					
000137	1.193	1.269	1.376	1.483	1.591	1.697	1.804	1.912
000138	2.021	2.130	2.241	2.355	2.471	2.592	2.717	2.849
000139	2.990	3.147	3.330	3.571	4.080	4.874	5.172	5.371
000140	5.527	5.660	5.778	5.884	5.982	6.073	6.159	6.240
000141	6.317	6.391	6.461	6.528	6.595	6.658	6.718	6.777
000142	6.835	6.891	6.945					
000143	26.0369	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000144	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000145	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000146	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000147	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000148	97.2000	99.0000	100.8000					
000149	0.20502	0.20605	0.20820	0.21042	0.21281	0.21535	0.21813	0.22107
000150	0.22433	0.22783	0.23172	0.23601	0.24078	0.24610	0.25214	0.25914
000151	0.26732	0.27726	0.28957	0.30570	0.32851	0.36491	0.43071	0.53719
000152	0.64455	0.73618	0.81533	0.88589	0.95058	1.01082	1.06636	1.12072
000153	1.17293	1.22339	1.27234	1.31994	1.36651	1.41204	1.45670	1.50065
000154	1.54388	1.58647	1.62835					
000155	-121.33	-119.82	-116.83	-113.69	-110.37	-106.87	-103.16	-99.26
000156	-95.14	-90.81	-86.22	-81.38	-76.24	-70.76	-64.94	-58.67
000157	-51.86	-44.42	-36.06	-26.48	-14.92	0.00	20.68	45.94
000158	66.65	82.43	95.16	106.04	115.70	124.49	132.55	140.29
000159	147.67	154.75	161.60	168.23	174.69	181.03	187.21	193.29
000160	199.26	205.17	211.04					
000161	1.196	1.253	1.360	1.465	1.571	1.676	1.782	1.888
000162	1.994	2.102	2.209	2.320	2.431	2.546	2.664	2.786
000163	2.914	3.049	3.198	3.361	3.552	3.792	4.117	4.501
000164	4.808	5.037	5.215	5.365	5.494	5.609	5.712	5.808
000165	5.898	5.983	6.063	6.140	6.212	6.281	6.348	6.412
000166	6.474	6.534	6.594					
000167	26.3268	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000168	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000169	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000170	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000171	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000172	97.2000	99.0000	100.8000					
000173	0.20430	0.20502	0.20701	0.20915	0.21146	0.21392	0.21654	0.21940
000174	0.22242	0.22568	0.22934	0.23323	0.23760	0.24237	0.24777	0.25381
000175	0.26073	0.26875	0.27821	0.28965	0.30396	0.32239	0.34719	0.38160
000176	0.42943	0.48888	0.55324	0.61602	0.67499	0.73006	0.78163	0.03568

000177	0.08208	0.12651	0.16934	0.21074	0.25[illegible]	0.29013	0.32843	0.36602
000178	0.40281	0.43897	0.47433					
000179	-118.47	-117.41	-114.46	-111.37	-108.06	-104.61	-100.96	-97.12
000180	-93.09	-88.83	-84.37	-79.66	-74.66	-69.42	-63.85	-57.92
000181	-51.59	-44.81	-37.40	-29.30	-20.24	-9.96	1.98	16.01
000182	32.24	49.35	65.54	79.83	92.37	103.48	113.55	122.80
000183	131.44	139.59	147.33	154.77	161.94	168.89	175.65	182.29
000184	188.75	195.10	201.42					
000185	1.199	1.238	1.343	1.449	1.553	1.657	1.761	1.865
000186	1.969	2.074	2.180	2.288	2.395	2.506	2.618	2.733
000187	2.853	2.976	3.106	3.246	3.395	3.561	3.749	3.962
000188	4.202	4.449	4.676	4.873	5.041	5.186	5.315	5.430
000189	5.535	5.634	5.724	5.809	5.890	5.966	6.039	6.109
000190	6.176	6.242	6.304					
000191	26.6130	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000192	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000193	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000194	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000195	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000196	97.2000	99.0000	100.8000					
000197	0.20367	0.20407	0.20597	0.20804	0.21019	0.21257	0.21503	0.21773
000198	0.22060	0.22369	0.22711	0.23077	0.23474	0.23911	0.24396	0.24936
000199	0.25540	0.26224	0.27002	0.27916	0.28981	0.30268	0.31834	0.33789
000200	0.36236	0.39280	0.42936	0.47092	0.51518	0.55984	0.60379	0.64614
000201	0.68699	0.72624	0.76415	0.00611	0.04164	0.07620	0.10982	0.14272
000202	0.17490	0.20645	0.23744					
000203	-115.64	-115.02	-112.09	-109.02	-105.78	-102.35	-98.74	-94.97
000204	-90.98	-86.82	-82.45	-77.84	-73.00	-67.92	-62.55	-56.90
000205	-50.90	-44.53	-37.72	-30.41	-22.50	-13.86	-4.37	6.14
000206	17.78	30.52	44.02	57.71	70.95	83.37	94.82	105.42
000207	115.25	124.44	133.15	141.40	149.31	156.91	164.26	171.39
000208	178.32	185.10	191.86					
000209	1.201	1.224	1.329	1.432	1.535	1.638	1.741	1.843
000210	1.946	2.049	2.152	2.257	2.362	2.469	2.578	2.688
000211	2.801	2.917	3.036	3.162	3.292	3.432	3.580	3.740
000212	3.913	4.097	4.287	4.475	4.653	4.814	4.961	5.093
000213	5.213	5.323	5.425	5.519	5.608	5.692	5.771	5.847
000214	5.918	5.988	6.056					
000215	26.8955	27.0000	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000
000216	39.6000	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000
000217	54.0000	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000
000218	68.4000	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000
000219	82.8000	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000
000220	97.2000	99.0000	100.8000					
000221	0.20295	0.20311	0.20494	0.20693	0.20899	0.21130	0.21368	0.21622
000222	0.21893	0.22187	0.22505	0.22846	0.23220	0.23625	0.24070	0.24555
000223	0.25095	0.25691	0.26367	0.27122	0.27996	0.28997	0.30165	0.31548
000224	0.33177	0.35116	0.37397	0.40035	0.42983	0.46186	0.49539	0.52948
000225	0.56358	0.59703	0.62985	0.66196	0.69319	0.72370	0.75350	0.78267
000226	0.01652	0.04458	0.07199					
000227	-112.80	-112.63	-109.73	-106.68	-103.46	-100.09	-96.53	-92.79
000228	-88.87	-84.77	-80.47	-75.97	-71.25	-66.30	-61.10	-55.66
000229	-49.90	-43.87	-37.45	-30.66	-23.43	-15.69	-7.40	1.53
000230	11.17	21.51	32.54	44.06	55.85	67.63	79.08	90.08
000231	100.54	110.43	119.82	128.73	137.26	145.45	153.32	160.94
000232	168.34	175.55	182.67					
000233	1.205	1.210	1.314	1.417	1.519	1.620	1.722	1.823
000234	1.924	2.026	2.128	2.230	2.333	2.436	2.541	2.647
000235	2.756	2.866	2.978	3.094	3.214	3.339	3.469	3.605
000236	3.747	3.897	4.052	4.210	4.368	4.522	4.668	4.806

000237	4.933	5.052	5.161	5.264	5.[illegible]	5.449	5.534	5.615
000238	5.692	5.765	5.836					
000239	27.1745	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000240	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000241	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000242	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000243	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000244	99.0000	100.8000						
000245	0.20232	0.20399	0.20589	0.20788	0.21003	0.21233	0.21479	0.21742
000246	0.22020	0.22322	0.22640	0.22989	0.23363	0.23776	0.24221	0.24706
000247	0.25238	0.25834	0.26494	0.27233	0.28067	0.29013	0.30094	0.31325
000248	0.32740	0.34369	0.36213	0.38287	0.40575	0.43047	0.45653	0.48355
000249	0.51097	0.53846	0.56580	0.59290	0.61952	0.64574	0.67157	0.69692
000250	0.72179	0.74635						
000251	-109.96	-107.36	-104.33	-101.15	-97.81	-94.29	-90.60	-86.74
000252	-82.70	-78.46	-74.05	-69.44	-64.60	-59.54	-54.25	-48.73
000253	-42.91	-36.81	-30.39	-23.63	-16.46	-8.89	-0.85	7.67
000254	16.69	26.21	36.19	46.51	57.07	67.69	78.23	88.55
000255	98.53	108.17	117.43	126.34	134.92	143.19	151.21	158.97
000256	166.52	173.99						
000257	1.207	1.299	1.401	1.503	1.603	1.703	1.803	1.904
000258	2.003	2.103	2.203	2.304	2.405	2.507	2.610	2.714
000259	2.821	2.927	3.038	3.150	3.265	3.384	3.506	3.632
000260	3.763	3.897	4.033	4.172	4.309	4.445	4.577	4.704
000261	4.822	4.935	5.041	5.141	5.236	5.325	5.410	5.490
000262	5.567	5.642						
000263	27.4500	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000264	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000265	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000266	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000267	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000268	99.0000	100.8000						
000269	0.20168	0.20303	0.20486	0.20677	0.20891	0.21106	0.21344	0.21591
000270	0.21861	0.22139	0.22449	0.22775	0.23124	0.23506	0.23919	0.24364
000271	0.24849	0.25381	0.25969	0.26613	0.27336	0.28131	0.29021	0.30022
000272	0.31151	0.32406	0.33821	0.35386	0.37103	0.38978	0.40981	0.43102
000273	0.45304	0.47561	0.49849	0.52154	0.54450	0.56731	0.58996	0.61237
000274	0.63454	0.65639						
000275	-107.13	-104.99	-101.99	-98.83	-95.52	-92.03	-88.40	-84.56
000276	-80.59	-76.43	-72.08	-67.56	-62.83	-57.90	-52.74	-47.36
000277	-41.76	-35.89	-29.75	-23.33	-16.59	-9.51	-2.06	5.73
000278	13.92	22.50	31.43	40.71	50.22	59.93	69.72	79.51
000279	89.17	98.68	107.94	116.96	125.70	134.19	142.44	150.46
000280	158.27	165.99						
000281	1.209	1.286	1.387	1.487	1.587	1.686	1.785	1.884
000282	1.982	2.080	2.179	2.277	2.376	2.476	2.577	2.677
000283	2.780	2.884	2.988	3.094	3.204	3.315	3.427	3.544
000284	3.661	3.782	3.905	4.028	4.153	4.277	4.399	4.519
000285	4.635	4.746	4.852	4.954	5.050	5.141	5.229	5.311
000286	5.391	5.469						
000287	27.7235	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000288	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000289	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000290	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000291	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000292	99.0000	100.8000						
000293	0.20105	0.20208	0.20391	0.20574	0.20772	0.20987	0.21217	0.21456
000294	0.21710	0.21980	0.22266	0.22576	0.22910	0.23267	0.23649	0.24062
000295	0.24507	0.24992	0.25524	0.26096	0.26732	0.27424	0.28186	0.29037
000296	0.29967	0.31000	0.32136	0.33392	0.34758	0.36236	0.37834	0.39526

000297	0.41298	0.43150	0.45057	0.46996	0.4895[illegible]	0.50938	0.52909	0.54879
000298	0.56834	0.58781						
000299	-104.33	-102.63	-99.64	-96.50	-93.22	-89.79	-86.18	-82.41
000300	-78.46	-74.37	-70.10	-65.64	-60.99	-56.17	-51.14	-45.89
000301	-40.45	-34.78	-28.87	-22.71	-16.27	-9.55	-2.55	4.75
000302	12.37	20.28	28.51	37.00	45.74	54.70	63.79	72.98
000303	82.17	91.30	100.34	109.24	117.96	126.49	134.83	142.96
000304	150.91	158.80						
000305	1.213	1.272	1.373	1.472	1.571	1.669	1.767	1.865
000306	1.962	2.059	2.155	2.252	2.349	2.448	2.546	2.644
000307	2.744	2.843	2.944	3.047	3.150	3.256	3.362	3.470
000308	3.580	3.692	3.804	3.918	4.033	4.147	4.260	4.373
000309	4.482	4.590	4.693	4.792	4.888	4.981	5.069	5.154
000310	5.234	5.314						
000311	28.2617	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000312	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000313	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000314	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000315	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000316	99.0000	100.8000						
000317	0.19985	0.20033	0.20200	0.20383	0.20566	0.20764	0.20971	0.21193
000318	0.21432	0.21678	0.21940	0.22218	0.22520	0.22838	0.23172	0.23538
000319	0.23919	0.24332	0.24777	0.25262	0.25771	0.26335	0.26931	0.27582
000320	0.28290	0.29053	0.29879	0.30769	0.31731	0.32764	0.33860	0.35029
000321	0.36268	0.37564	0.38914	0.40313	0.41759	0.43230	0.44724	0.46241
000322	0.47767	0.49309						
000323	-98.72	-97.87	-94.95	-91.88	-88.63	-85.24	-81.70	-78.03
000324	-74.17	-70.19	-66.01	-61.70	-57.20	-52.55	-47.71	-42.69
000325	-37.51	-32.11	-26.55	-20.77	-14.71	-8.59	-2.17	4.45
000326	11.30	18.38	25.70	33.20	40.90	48.79	56.83	65.00
000327	73.28	81.60	89.96	98.32	106.63	114.91	123.08	131.14
000328	139.10	147.05						
000329	1.218	1.247	1.346	1.444	1.541	1.637	1.733	1.829
000330	1.924	2.019	2.112	2.207	2.301	2.395	2.489	2.584
000331	2.679	2.773	2.868	2.964	3.060	3.157	3.256	3.354
000332	3.452	3.552	3.653	3.752	3.853	3.954	4.054	4.155
000333	4.253	4.351	4.446	4.540	4.633	4.721	4.808	4.891
000334	4.973	5.052						
000335	28.7910	28.8000	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000
000336	41.4000	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000
000337	55.8000	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000
000338	70.2000	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000
000339	84.6000	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000
000340	99.0000	100.8000						
000341	0.19874	0.19874	0.20033	0.20200	0.20375	0.20558	0.20756	0.20963
000342	0.21177	0.21408	0.21646	0.21909	0.22179	0.22465	0.22767	0.23085
000343	0.23434	0.23792	0.24181	0.24595	0.25032	0.25500	0.26001	0.26534
000344	0.27106	0.27718	0.28369	0.29069	0.29808	0.30594	0.31429	0.32311
000345	0.33241	0.34218	0.35235	0.36292	0.37389	0.38517	0.39669	0.40853
000346	0.42061	0.43277						
000347	-93.13	-93.11	-90.26	-87.21	-84.03	-80.70	-77.22	-73.60
000348	-69.82	-65.92	-61.85	-57.64	-53.27	-48.75	-44.06	-39.24
000349	-34.23	-29.07	-23.73	-18.23	-12.58	-6.71	-0.70	5.50
000350	11.87	18.42	25.14	32.03	39.09	46.30	53.63	61.10
000351	68.69	76.35	84.09	91.88	99.70	107.53	115.34	123.12
000352	130.86	138.67						
000353	1.224	1.224	1.321	1.417	1.513	1.607	1.702	1.796
000354	1.888	1.981	2.073	2.166	2.257	2.348	2.439	2.530
000355	2.622	2.713	2.804	2.894	2.987	3.078	3.169	3.262
000356	3.353	3.445	3.538	3.630	3.722	3.814	3.906	3.997

000357	4.087	4.178	4.266	4.354	4.4[illegible]	4.524	4.606	4.687
000358	4.766	4.845						
000359	29.3093	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000360	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000361	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000362	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000363	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000364	100.8000							
000365	0.19763	0.19866	0.20025	0.20192	0.20367	0.20550	0.20748	0.20947
000366	0.21162	0.21384	0.21622	0.21869	0.22131	0.22409	0.22703	0.23013
000367	0.23339	0.23681	0.24046	0.24428	0.24833	0.25262	0.25723	0.26208
000368	0.26716	0.27257	0.27837	0.28441	0.29076	0.29752	0.30459	0.31198
000369	0.31969	0.32780	0.33614	0.34488	0.35385	0.36308	0.37254	0.38223
000370	0.39216							
000371	-87.59	-85.54	-82.56	-79.42	-76.14	-72.72	-69.16	-65.45
000372	-61.61	-57.62	-53.51	-49.24	-44.83	-40.09	-35.57	-30.73
000373	-25.74	-20.60	-15.31	-9.87	-4.28	1.45	7.33	13.37
000374	19.55	25.89	32.35	38.96	45.68	52.55	59.52	66.60
000375	73.77	81.02	88.34	95.72	103.12	110.56	118.00	125.45
000376	133.00							
000377	1.228	1.297	1.392	1.487	1.579	1.673	1.765	1.856
000378	1.946	2.038	2.126	2.216	2.305	2.394	2.483	2.571
000379	2.658	2.747	2.835	2.923	3.009	3.097	3.185	3.271
000380	3.359	3.445	3.532	3.618	3.704	3.790	3.875	3.959
000381	4.044	4.127	4.208	4.290	4.369	4.449	4.526	4.602
000382	4.678							
000383	29.8187	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000384	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000385	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000386	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000387	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000388	100.8000							
000389	0.19660	0.19715	0.19866	0.20025	0.20192	0.20367	0.20542	0.20732
000390	0.20939	0.21146	0.21368	0.21599	0.21837	0.22091	0.22362	0.22640
000391	0.22934	0.23252	0.23577	0.23919	0.24277	0.24658	0.25055	0.25477
000392	0.25922	0.26390	0.26875	0.27392	0.27924	0.28488	0.29084	0.29696
000393	0.30340	0.31008	0.31699	0.32414	0.33153	0.33916	0.34695	0.35497
000394	0.36316							
000395	-82.09	-80.85	-77.91	-74.81	-71.57	-68.20	-64.68	-61.04
000396	-57.26	-53.36	-49.31	-45.15	-40.82	-36.38	-31.80	-27.06
000397	-22.22	-17.23	-12.11	-6.84	-1.47	4.05	9.70	15.48
000398	21.41	27.42	33.59	39.86	46.26	52.76	59.37	66.07
000399	72.85	79.74	86.67	93.69	100.75	107.85	114.97	122.14
000400	129.41							
000401	1.234	1.274	1.368	1.462	1.553	1.645	1.735	1.825
000402	1.914	2.003	2.092	2.180	2.266	2.353	2.439	2.526
000403	2.611	2.696	2.782	2.866	2.950	3.034	3.118	3.201
000404	3.284	3.367	3.450	3.532	3.613	3.694	3.776	3.855
000405	3.935	4.014	4.092	4.169	4.245	4.320	4.394	4.468
000406	4.540							
000407	30.3191	30.6000	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000
000408	43.2000	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000
000409	57.6000	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000
000410	72.0000	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000
000411	86.4000	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000
000412	100.8000							
000413	0.19556	0.19580	0.19715	0.19866	0.20025	0.20192	0.20359	0.20542
000414	0.20732	0.20923	0.21130	0.21344	0.21575	0.21805	0.22060	0.22314
000415	0.22584	0.22870	0.23164	0.23474	0.23800	0.24142	0.24499	0.24873
000416	0.25262	0.25675	0.26104	0.26549	0.27018	0.27503	0.28004	0.28536

000417	0.29084	0.29649	0.30237	0.30841	0.3146	0.32112	0.32780	0.33455
000418	0.34146							
000419	-76.61	-76.16	-73.26	-70.21	-67.01	-63.68	-60.20	-56.62
000420	-52.91	-49.05	-45.08	-40.97	-36.74	-32.37	-27.89	-23.29
000421	-18.55	-13.69	-8.70	-3.58	1.64	6.99	12.45	18.04
000422	23.73	29.53	35.44	41.48	47.60	53.83	60.14	66.56
000423	73.06	79.63	86.29	92.99	99.77	106.59	113.46	120.35
000424	127.39							
000425	1.239	1.253	1.346	1.437	1.528	1.618	1.708	1.797
000426	1.885	1.972	2.059	2.144	2.231	2.315	2.400	2.484
000427	2.567	2.650	2.733	2.815	2.897	2.978	3.060	3.141
000428	3.220	3.299	3.379	3.458	3.536	3.613	3.692	3.768
000429	3.843	3.919	3.994	4.067	4.141	4.213	4.284	4.354
000430	4.425							
000431	31.2983	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000
000432	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000
000433	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000
000434	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000
000435	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000
000436	0.19366	0.19366	0.19580	0.19723	0.19866	0.20025	0.20184	0.20359
000437	0.20534	0.20717	0.20907	0.21106	0.21313	0.21527	0.21750	0.21988
000438	0.22226	0.22481	0.22743	0.23021	0.23299	0.23601	0.23903	0.24221
000439	0.24555	0.24897	0.25254	0.25628	0.26009	0.26406	0.26820	0.27241
000440	0.27678	0.28131	0.28600	0.29076	0.29569	0.30070	0.30586	0.31111
000441	-65.71	-63.96	-60.97	-57.86	-54.62	-51.22	-47.73	-44.10
000442	-40.37	-36.51	-32.52	-28.43	-24.22	-19.89	-15.46	-10.89
000443	-6.22	-1.45	3.41	8.40	13.50	18.68	23.97	29.34
000444	34.82	40.39	46.04	51.78	57.60	63.53	69.52	75.58
000445	81.72	87.93	94.20	100.54	106.91	113.35	119.84	126.47
000446	1.248	1.304	1.393	1.482	1.571	1.657	1.744	1.830
000447	1.914	1.998	2.083	2.164	2.247	2.329	2.410	2.490
000448	2.570	2.649	2.727	2.805	2.882	2.959	3.036	3.111
000449	3.187	3.262	3.335	3.408	3.481	3.554	3.625	3.696
000450	3.766	3.836	3.905	3.974	4.041	4.108	4.174	4.240
000451	32.2487	32.4000	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000
000452	45.0000	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000
000453	59.4000	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000
000454	73.8000	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000
000455	88.2000	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000
000456	0.19183	0.19191	0.19318	0.19445	0.19588	0.19731	0.19874	0.20025
000457	0.20184	0.20351	0.20526	0.20701	0.20891	0.21082	0.21281	0.21487
000458	0.21702	0.21916	0.22147	0.22385	0.22632	0.22886	0.23148	0.23418
000459	0.23697	0.23991	0.24285	0.24595	0.24912	0.25246	0.25580	0.25930
000460	0.26287	0.26653	0.27026	0.27416	0.27813	0.28218	0.28631	0.29061
000461	-54.94	-54.70	-51.78	-48.73	-45.55	-42.22	-38.81	-35.27
000462	-31.60	-27.85	-23.97	-19.98	-15.88	-11.68	-7.37	-2.96
000463	1.55	6.16	10.87	15.67	20.58	25.57	30.64	35.78
000464	41.03	46.34	51.76	57.22	62.78	68.42	74.11	79.87
000465	85.69	91.60	97.55	103.59	109.64	115.78	121.95	128.28
000466	1.258	1.265	1.353	1.440	1.527	1.612	1.696	1.780
000467	1.863	1.945	2.027	2.107	2.187	2.266	2.344	2.423
000468	2.500	2.576	2.651	2.727	2.802	2.875	2.949	3.021
000469	3.093	3.164	3.236	3.305	3.374	3.443	3.512	3.579
000470	3.645	3.712	3.777	3.842	3.906	3.970	4.033	4.097
000471	33.1758	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000
000472	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000
000473	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000
000474	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000
000475	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000	
000476	0.19016	0.19080	0.19199	0.19326	0.19461	0.19596	0.19739	0.19882

000477	0.20033	0.20192	0.20351	0.20518	0.20693	.20875	0.21058	0.21249
000478	0.21448	0.21646	0.21861	0.22075	0.22298	0.22528	0.22767	0.23013
000479	0.23259	0.23522	0.23784	0.24062	0.24340	0.24626	0.24920	0.25222
000480	0.25532	0.25850	0.26176	0.26510	0.26851	0.27193	0.27551	
000481	-44.27	-42.61	-39.62	-36.49	-33.25	-29.88	-26.40	-22.84
000482	-19.15	-15.35	-11.45	-7.46	-3.34	0.85	5.14	9.53
000483	14.01	18.59	23.26	28.02	32.84	37.77	42.76	47.81
000484	52.95	58.16	63.42	68.78	74.20	79.68	85.22	90.83
000485	96.50	102.22	108.00	113.84	119.73	125.66	131.76	
000486	1.266	1.316	1.401	1.485	1.570	1.652	1.735	1.816
000487	1.897	1.976	2.054	2.132	2.209	2.286	2.362	2.437
000488	2.512	2.585	2.658	2.731	2.803	2.873	2.944	3.013
000489	3.081	3.150	3.218	3.284	3.350	3.416	3.481	3.545
000490	3.609	3.672	3.734	3.796	3.856	3.917	3.978	
000491	34.0793	34.2000	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000
000492	46.8000	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000
000493	61.2000	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000
000494	75.6000	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000
000495	90.0000	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000	
000496	0.18857	0.18865	0.18976	0.19095	0.19215	0.19342	0.19469	0.19604
000497	0.19747	0.19890	0.20041	0.20192	0.20351	0.20518	0.20685	0.20860
000498	0.21034	0.21217	0.21408	0.21599	0.21805	0.22012	0.22218	0.22433
000499	0.22656	0.22886	0.23124	0.23363	0.23609	0.23855	0.24118	0.24380
000500	0.24650	0.24920	0.25206	0.25493	0.25787	0.26081	0.26383	
000501	-33.69	-33.48	-30.54	-27.47	-24.27	-20.96	-17.55	-14.03
000502	-10.40	-6.69	-2.87	1.04	5.05	9.17	13.37	17.65
000503	22.05	26.51	31.07	35.70	40.41	45.19	50.05	54.98
000504	59.97	65.02	70.14	75.35	80.59	85.90	91.28	96.72
000505	102.20	107.74	113.35	118.98	124.70	130.44	136.34	
000506	1.276	1.280	1.365	1.449	1.530	1.612	1.693	1.773
000507	1.852	1.930	2.007	2.084	2.160	2.234	2.308	2.381
000508	2.455	2.526	2.597	2.668	2.738	2.807	2.875	2.943
000509	3.009	3.076	3.141	3.206	3.270	3.334	3.397	3.458
000510	3.520	3.581	3.642	3.701	3.760	3.820	3.879	
000511	34.9613	36.0000	37.8000	39.6000	41.4000	43.2000	45.0000	46.8000
000512	48.6000	50.4000	52.2000	54.0000	55.8000	57.6000	59.4000	61.2000
000513	63.0000	64.8000	66.6000	68.4000	70.2000	72.0000	73.8000	75.6000
000514	77.4000	79.2000	81.0000	82.8000	84.6000	86.4000	88.2000	90.0000
000515	91.8000	93.6000	95.4000	97.2000	99.0000	100.8000		
000516	0.18706	0.18770	0.18881	0.18992	0.19111	0.19231	0.19358	0.19485
000517	0.19620	0.19755	0.19898	0.20049	0.19405	0.20351	0.20510	0.20669
000518	0.20844	0.21011	0.21193	0.21368	0.21559	0.21750	0.21940	0.22147
000519	0.22346	0.22560	0.22775	0.22989	0.23212	0.23442	0.23681	0.23919
000520	0.24157	0.24404	0.24658	0.24920	0.25183	0.25445		
000521	-23.18	-21.49	-18.47	-15.31	-12.05	-8.70	-5.22	-1.66
000522	1.98	5.73	9.59	13.52	17.55	21.69	25.89	30.17
000523	34.57	39.03	43.55	48.15	52.85	57.58	62.40	67.28
000524	72.21	77.20	82.28	87.40	92.58	97.81	103.09	108.45
000525	113.84	119.30	124.81	130.35	135.94	141.70		
000526	1.284	1.331	1.413	1.495	1.575	1.655	1.733	1.811
000527	1.887	1.963	2.039	2.112	2.186	2.259	2.330	2.401
000528	2.472	2.542	2.611	2.680	2.747	2.814	2.880	2.945
000529	3.009	3.073	3.136	3.200	3.262	3.322	3.384	3.443
000530	3.502	3.561	3.619	3.677	3.734	3.792		

000531	-8.0377310E-07	1.2281445E-06	-2.1050322E-06	-3.8373024E-06	-8.7732374E-06
000532	-1.5259414E-05	-2.6335328E-05	-4.1334596E-05	-6.5248416E-05	-9.56112215-05
000533	-1.3180607E-04	-1.7026696E-04	-2.1873437E-04	-2.5922335E-04	-3.1173105E-04
000534	-3.6397233E-04	-4.2257714E-04	-4.5541749E-04	-5.0527305E-04	-5.48521585 04
000535	-5.8049584E-04	-6.1718419E-04	-6.4380987E-04	-6.5827104E-04	-6.5781804E-04
000536	-6.4924148E-04	-6.2883272E-04	-5.9352177E-04	-5.5021366E-04	-4.9570493E-04

000537	-4.3643903E-04	-3.7869989E-04	-3.2988888E-04	[illegible].9135311E-04	-2.7009731E-04
000538	-2.7696572E-04	-2.9812312E-04	-3.5004592E-04	[illegible].2455082E-04	-5.2401202E-04
000539	-6.4125592E-04	-7.8212495E-04	-9.3448052E-04	-1.0934784E-03	-1.2559322E-03
000540	-1.3698538E-03	-1.5478358E-03	-1.7219023E-03	-1.8920438E-03	-2.0561721E-03
000541	-2.2143473E-03	-2.4177387E-03	-2.6272401E-03	-2.8407149E-03	-2.9235301E-03
000542	-3.2097408E-03	-3.4133869E-03	-3.4292715E-03	-4.0583221E-03	-4.0351868E-03
000543	-5.2023678E-03	-5.5757572E-03	-6.2069722E-03	-6.8678927E-03	-7.1803709E-03
000544	-7.6073285E-03	-7.9515444E-03	-9.1273819E-03	-9.5657506E-03	-1.1015059E-02
000545	-1.1959132E-02	-1.3886189E-02	-1.5505519E-02	-1.7400006E-02	-2.0124586E-02
000546	-2.2408441E-02	-2.3006439E-02	-2.3612257E-02	-2.1131850E-02	-1.5787078E-02
000547	-7.2297747E-03	-1.1157932E-02	2.0572108E-04	9.1201507E-03	-3.6886842E-02
000548	-2.5967306E-01	2.0399673E-02	4.1266163E-02	6.8570651E-02	1.4766631E-01
000549	4.1671141E-02	8.3815085E-02	1.2820967E-01	1.7331713E-01	2.2031547E-01
000550	2.6879575E-01	3.1955518E-01	3.7255940E-01	4.2889084E-01	4.8814042E-01
000551	5.5015638E-01	6.1401927E-01	6.8175290E-01	7.4882307E-01	8.2030192E-01
000552	8.9316323E-01	9.6889537E-01	1.0395381E+00	1.1158471E+00	1.1918611E+00
000553	1.2680118E+00	1.3436317E+00	1.4195863E+00	1.4938576E+00	1.5657673E+00
000554	1.6369293E+00	1.7064442E+00	1.7737101E+00	1.8403582E+00	1.9056878E+00
000555	1.9713662E+00	2.0390411E+00	2.1107021E+00	2.1868961E+00	2.2692860E+00
000556	2.3605869E+00	2.4577571E+00	2.5647236E+00	2.6795942E+00	2.8029003E+00
000557	2.9331360E+00	3.0713863E+00	3.2149294E+00	3.3623746E+00	3.5129883E+00
000558	3.6532274E+00	3.8122308E+00	3.9723517E+00	4.1335542E+00	4.2953206E+00
000559	4.4572955E+00	4.6326102E+00	4.8109381E+00	4.9917539E+00	5.1482192E+00
000560	5.3505627E+00	5.5385032E+00	5.6917803E+00	5.9679756E+00	6.1196071E+00
000561	6.4955823E+00	6.7236159E+00	7.0008332E+00	7.2845818E+00	7.5091781E+00
000562	7.7573489E+00	7.9939722E+00	8.3571042E+00	8.6083924E+00	9.0096826E+00
000563	9.3389942E+00	9.8044979E+00	1.0229200E+01	1.0686035E+01	1.1241795E+01
000564	1.1740489E+01	1.2016333E+01	1.2275667E+01	1.2205924E+01	1.1833711E+01
000565	1.1143704E+01	1.1728386E+01	1.0774412E+01	1.0186019E+01	1.4999411E+01
000566	3.7406308E+01	1.0508182E+01	9.6191112E+00	8.3929369E+00	4.3831287E+00
000567	-5.7318471E-02	-1.8093034E-01	-4.9784230E-01	-8.8737394E-01	-1.4439885E+00
000568	-2.1308185E+00	-3.0135132E+00	-4.0968010E+00	-5.4553331E+00	-7.0653434E+00
000569	-8.9079311E+00	-1.0891583E+01	-1.3194912E+01	-1.5409693E+01	-1.7982500E+01
000570	-2.0641264E+01	-2.3494803E+01	-2.5827529E+01	-2.8601520E+01	-3.1270310E+01
000571	-3.3868301E+01	-3.6312903E+01	-3.8676869E+01	-4.0770123E+01	-4.2521120E+01
000572	-4.4057432E+01	-4.5291856E+01	-4.6171278E+01	-4.6823811E+01	-4.7185354E+01
000573	-4.7400820E+01	-4.7608307E+01	-4.7991765E+01	-4.8607001E+01	-4.9585045E+01
000574	-5.1154888E+01	-5.3068125E+01	-5.5648849E+01	-5.8727770E+01	-6.2332962E+01
000575	-6.6339776E+01	-7.0798392E+01	-7.5474072E+01	-8.0216248E+01	-8.4945172E+01
000576	-8.8378554E+01	-9.3209590E+01	-9.7775742E+01	-1.0205513E+02	-1.0598185E+02
000577	-1.0947043E+02	-1.1370972E+02	-1.1770864E+02	-1.2139729E+02	-1.2287832E+02
000578	-1.2737635E+02	-1.3032203E+02	-1.3031157E+02	-1.3843027E+02	-1.3730741E+02
000579	-1.5065102E+02	-1.5333181E+02	-1.5864047E+02	-1.6366492E+02	-1.6426362E+02
000580	-1.6578472E+02	-1.6593847E+02	-1.7221788E+02	-1.7159915E+02	-1.7825786E+02
000581	-1.8042763E+02	-1.8864278E+02	-1.9410328E+02	-2.0004923E+02	-2.0932852E+02
000582	-2.1504047E+02	-2.0928329E+02	-2.0118944E+02	-1.7942589E+02	-1.4498536E+02
000583	-9.8067031E+01	-9.7440413E+01	-3.8944428E+01	2.2018214E+00	-1.5324378E+02
000584	-9.6215597E+02	3.6778774E+01	7.2762252E+01	1.1458652E+02	1.9525322E+02
000585	-3.4852970E-01	-2.3328599E+00	-2.0682478E+00	-3.2165717E+00	-2.6094543E+00
000586	-1.2407244E+00	3.2160865E+00	1.1342612E+01	2.5378825E+01	4.4994254E+01
000587	6.9446852E+01	9.5141850E+01	1.2866170E+02	1.5495204E+02	1.9055501E+02
000588	2.2540166E+02	2.6281975E+02	2.7566446E+02	3.0073723E+02	3.1701581E+02
000589	3.2576079E+02	3.2333676E+02	3.1249379E+02	2.8602308E+02	2.4109665E+02
000590	1.8228715E+02	1.0647765E+02	1.1968543E+01	-9.6472164E+01	-2.2083220E+02
000591	-3.5521484E+02	-4.9429203E+02	-6.3011102E+02	-7.5967443E+02	-8.7793619E+02
000592	-9.7611348E+02	-1.0620580E+03	-1.1236298E+03	-1.1665448E+03	-1.1896026E+03
000593	-1.1965205E+03	-1.1861179E+03	-1.1663516E+03	-1.1427383E+03	-1.1180923E+03
000594	-1.1428658E+03	-1.1103218E+03	-1.0857529E+03	-1.0696396E+03	-1.0641185E+03
000595	-1.0733223E+03	-1.0504141E+03	-1.0340018E+03	-1.0264770E+03	-1.0823485E+03
000596	-1.0365624E+03	-1.0349302E+03	-1.1172453E+03	-9.5022563E+02	-1.0518802E+03

000597	-7.3317710E+02	-7.1729678E+02	-6.1916306E+02	[illegible]2271128E+02	-5.3825987E+02
000598	-5.1531466E+02	-5.1639302E+02	-3.6579871E+02	[illegible].6543501E+02	-1.8416297E+02
000599	-8.7846858E+01	1.5419294E+02	3.5588009E+02	5.7942490E+02	8.7722455E+02
000600	1.1212214E+03	1.1541824E+03	1.1518611E+03	9.4203092E+02	5.4030442E+02
000601	-3.5545003E+01	1.5041468E+02	-5.6987252E+02	-8.9772310E+02	1.9715175E+03
000602	1.5643871E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000603	1.0761355E+00	9.0125519E+00	-1.6858820E+01	-3.7102804E+01	-8.6642049E+01
000604	-1.5703564E+02	-2.7513041E+02	-4.5130837E+02	-7.0776183E+02	-1.0446450E+03
000605	-1.4487078E+03	-1.8692702E+03	-2.3880154E+03	-2.8067078E+03	-3.3410802E+03
000606	-3.8559030E+03	-4.3843916E+03	-4.5542515E+03	-4.8694049E+03	-5.0390446E+03
000607	-5.0769555E+03	-4.9279847E+03	-4.6275005E+03	-4.0775766E+03	-3.2393895E+03
000608	-2.1710548E+03	-8.3495872E+02	7.8810918E+02	2.6316170E+03	4.7142330E+03
000609	6.9491255E+03	9.2604127E+03	1.1524025E+04	1.3685515E+04	1.5672403E+04
000610	1.7362219E+04	1.8840761E+04	1.9943022E+04	2.0737451E+04	2.1205585E+04
000611	2.1388423E+04	2.1278368E+04	2.0977596E+04	2.0559050E+04	2.0065004E+04
000612	2.0212248E+04	1.9492025E+04	1.8829911E+04	1.8237987E+04	1.7749108E+04
000613	1.7442580E+04	1.6669838E+04	1.5978421E+04	1.5412988E+04	1.5529079E+04
000614	1.4476561E+04	1.3941732E+04	1.4340021E+04	1.2070660E+04	1.2720182E+04
000615	9.0641995E+03	8.6428251E+03	7.4271301E+03	6.3105084E+03	6.3673451E+03
000616	6.0708932E+03	6.0532802E+03	4.8294821E+03	4.9320575E+03	3.5624987E+03
000617	2.9059444E+03	1.1351017E+03	-3.1705787E+02	-1.8692257E+03	-3.8552011E+03
000618	-5.4197643E+03	-5.4462613E+03	-5.1573924E+03	-3.6215951E+03	-9.1656659E+02
000619	2.7670921E+03	2.0174573E+03	6.5948069E+03	8.2338889E+03	-9.3307466E+03
000620	-9.3572403E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00

000621	0.0005	0.0010	0.0015	0.0020	0.0025	0.0030	0.0035	0.0040	0.0045	0.0050
000622	0.0055	0.0060	0.0065	0.0070	0.0075	0.0080	0.0085	0.0090	0.0095	0.0100
000623	0.0105	0.0110	0.0115	0.0120	0.0125	0.0130	0.0135	0.0140	0.0145	0.0150
000624	0.0155	0.0160	0.0165	0.0170	0.0175	0.0180	0.0185	0.0190	0.0195	0.0200
000625	0.0205	0.0210	0.0215	0.0220	0.0225	0.0230	0.0235	0.0240	0.0245	0.0250
000626	0.0255	0.0260	0.0265	0.0270	0.0275	0.0280	0.0285	0.0290	0.0295	0.0300
000627	0.0305	0.0310	0.0315	0.0320	0.0325	0.0330	0.0335	0.0340	0.0345	0.0350
000628	0.0355	0.0360	0.0365	0.0370	0.0375	0.0380	0.0385	0.0390	0.0395	0.0400
000629	0.0405	0.0410	0.0415	0.0420	0.0425	0.0430	0.0435	0.0440	0.0445	0.0450

000630	0.73234603E-02	-0.44074261E-03	0.66207946E-03	-0.29226363E-03
000631	0.40084907E-04	0.0E+00	0.0E+00	0.0E+00
000632	-0.27176666E+02	0.21129340E+03	0.13364318E+02	-0.19311670E+04
000633	0.67461013E+04	0.0E+00	0.0E+00	0.0E+00
000634	-0.71967724E-02	0.14495527E-02	0.32403130E-02	-0.44640177E-02
000635	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000636	0.17724540E+01	-0.44368880E+02	0.20554680E-01	0.0E+00
000637	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000638	0.20006200E+01	-0.50097080E+02	0.10044000E+01	0.17484950E-01
000639	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000640	-0.87239000E+03	0.26248000E+02	-0.09787200E+01	0.00271270E+01
000641	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000642	0.10111000E+04	-0.29485000E+02	0.25312000E+01	-0.00666590E+01
000643	0.0E+00	0.0E+00	0.0E+00	0.0E+00
000644	-0.22172000E+02	0.52157000E+01	-0.02737800E+01	0.58282000E-02
000645	0.04826500E+01	-0.29189000E-01	0.0E+00	0.0E+00
000646	-0.06839500E+01	0.18552000E+01	-0.00378920E+01	0.40527000E+02
000647	0.54573000E+01	-0.32436000E+01	-0.01769100E+01	0.00641000E+01

W EL1 , IST,1,720405, 41892

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      COMPILER (DATA=SHORT)
      COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
      COMMON /TAPEIN/ CHAN1(100),CHAN2(100),CHAN3(100),CHAN4(100),
     1PARID(100),CHANID(200),UNITS(200),DEC(200),NPAR
      COMMON /TAPE/ TSTART,TSTOP,INT1,INT2,IAVE,NSETS,INPUT(100,50),
     1ATIME(50),TIME,IEND
      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
      INTEGER TESTID,DAY,PARID,CHAN1,CHAN2,CHAN3,CHAN4,CHANID,UNITS,DEC,
     1TAPEIN,TAPEOT
      REAL INPUT,INPT
      DIMENSION OUTPUT(120,50)
      DATA NSAT,NPAR,MPAR /22,33,95/
      CALL INPROP
      CALL SATUR(NSAT)
      CALL CHINPT(TAPEIN,TAPEOT)
      CALL GEOMT
      CALL OUTNOM(MPAR)
      NSETS=0
      IFILE=0
   10 READ (5,1000) TSTART,TSTOP,INT1,INT2,IAVE,IFLAG,NRTHR,IEND
 1000 FORMAT(F10.0,F10.0,6I5)
      GO TO 50
   20 CALL TAPE2
      GO TO 55
   50 CALL TAPE1
   55 IF (NSETS.GE.50) GO TO 60
      IF (IEND.EQ.0) GO TO 10
   60 DO 540 I=1,NSETS
      DO 100 J=1,NPAR
  100 INPT(J)=INPUT(J,I)
      CALL FLOW(JFLG)
      IF (JFLG.GT.1) GO TO 540
      CALL SUCTON (IFLAG,JFLG)
      IF (JFLG.GT.1) GO TO 540
      CALL RADTHR (NRTHR)
      CALL AXFOR
      CALL PERFOR(JFLG)
      IF (JFLG.GT.1) GO TO 540
      DO 500 J=1,36
  500 OUTPUT(J,I)=OUT(J)
      DO 510 J=40,75
      K=J-3
  510 OUTPUT(K,I)=OUT(J)
      DO 520 J=80,83
      K=J-7
  520 OUTPUT(K,I)=OUT(J)
      DO 530 J=85,103
      K=J-8
  530 OUTPUT(K,I)=OUT(J)
  540 CONTINUE
      CALL OUTPT (OUTPUT,ATIME,MPAR,NSETS,IFILE,TAPEIN,TAPEOT)
      NSETS=0
      IF (TIME.LT.TSTOP) GO TO 20
      IF (IEND.EQ.0) GO TO 10
      END FILE 2
      IFILE=0
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      IF (IEND.EQ.1) GO TO 10
      STOP
      END
      SUBROUTINE CHINPT(TAPEIN,TAPEOT)
      COMPILER (DATA=SHORT)
      COMMON /TAPEIN/ CHAN1(100),CHAN2(100),CHAN3(100),CHAN4(100),
     1PARID(100),CHANID(200),UNITS(200),DEC(200),NPAR
      COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
      INTEGER CHAN1,CHAN2,CHAN3,CHAN4,PARID,CHANID,UNITS,DEC,END,
     1PARCK(100),TAPEIN,TAPEOT
      DIMENSION DEF(100,10),ICHAN(4),IDN(4),DEFIN(10)
      DATA BLANK /'      '/
      DATA PARID /'PATM  ','PSD   ','TD    ','PLFI  ','PLFO  ','PLRI  ',
     1'PLRO  ','WREF  ','DPORF1','DPORF2','PORF  ','PTK   ','TTK   ',
     2'P1    ','T1    ','P2    ','T2    ','PID   ','P708  ','P726  ',
     3'PDIFI1','PDIFI2','PDIFI3','PDIFI4','PDIFI5','PDIFI6','PDIFI7',
     4'PDIFI8','PDIFI9','PDIFO ','N     ','P707  ','P725  '/
      DATA END/'END   '/
      LINE=0
      IPAGE=1
      READ (1) DAY,RUNTME,TESTID,TAPEIN,TAPEOT
      READ (1) MWORDS,(CHANID(I),I=1,MWORDS)
      READ (1) MWORDS,(UNITS(I),I=1,MWORDS)
      READ(1) MWORDS,(DEC(I),I=1,MWORDS)
      TAPEIN=TAPEOT
      DO 100 I=1,2
      DAY(I)=BLANK
  100 RUNTME(I)=BLANK
      CALL DATE (9,DAY)
      CALL TOD (8,RUNTME)
      IFLAG=0
      DO 210 I=1,NPAR
  210 PARCK(I)=0
      READ (5,20) TAPEOT
  240 READ (5,20)IDENT,(DEFIN(J),J=1,10),(ICHAN(I),I=1,4)
   20 FORMAT (A6,1X,10A6,1X,4I3)
      K=0
  250 K=K+1
      IF (IDENT.EQ.END) GO TO 270
      IF (PARID(K).EQ.IDENT) GO TO 260
      IF (K.GE.NPAR) GO TO 255
      GO TO 250
  255 WRITE (6,1000) IDENT
 1000 FORMAT (//10X,A6,' IS AN UNRECOGNIZABLE PARAMETER IDENTIFICATION')
      GO TO 240
  260 PARCK(K)=1
      CHAN1(K)=ICHAN(1)
      CHAN2(K)=ICHAN(2)
      CHAN3(K)=ICHAN(3)
      CHAN4(K)=ICHAN(4)
      N=1
      DO 265 I=2,4
      IF (ICHAN(I).EQ.0) GO TO 266
  265 N=I
  266 DO 267 I=1,N
      J=ICHAN(I)
  267 IDN(I)=CHANID(J)
      DO 268 I=1,10
  268 DEF(K,I)=DEFIN(I)
      IF (LINE.NE.0) GO TO 269
```

```
      WRITE (6,1100) IPAGE
 1100 FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
 1110 FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6)
      WRITE (6,1110) TESTID,DAY,RUNTME
 1130 FORMAT (/' INPUT TAPE = ',A6,5X,'OUTPUT TAPE = ',A6/)
      WRITE (6,1130) TAPEIN,TAPEOT
      WRITE (6,1120)
 1120 FORMAT (1X,'PARAMETER',20X,'DEFINITION',38X,'CHANNELS USED'/)
  269 WRITE (6,1010) PARID(K),(DEF(K,L),L=1,10),(ICHAN(I),IDN(I),I=1,N)
 1010 FORMAT (1X,A6,2X,10A6,4(2X,I3,1X,A6))
      LINE=LINE+1
      IF (LINE.LT.50) GO TO 240
      LINE=0
      IPAGE=IPAGE+1
      GO TO 240
  270 DO 300 I=1,NPAR
      IF (PARCK(I).EQ.1)  GO TO 300
      WRITE (6,1020) PARID(I)
 1020 FORMAT (//10X,' NO CHANNEL IDENTIFICATION FOR ',A6)
      IFLAG=1
  300 CONTINUE
      IF (IFLAG.NE.0) STOP
      RETURN
      END
      SUBROUTINE OUTNOM(MPAR)
      COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
      COMMON /NOMEN/ HED(120),DEC(120),UN(120)
      DIMENSION DEF(10)
      INTEGER HED,DEC,UN,BLANK,TESTID,DAY,RUNTME
      DATA BLANK /'      '/
      LINE=0
      DO 100 I=1,MPAR
  100 UN(I)=BLANK
      DO 200 I=1,MPAR
      READ (5,1000) HED (I),DEF,UN(I),DEC(I)
      IF (LINE.GT.0) GO TO 150
      IPAGE=IPAGE+1
      WRITE (6,2000) IPAGE
      WRITE (6,2010) TESTID,DAY,RUNTME
  150 LINE=LINE+1
      WRITE (6,1010) HED(I),DEF,UN(I)
      IF (LINE.LT.50) GO TO 200
      LINE=0
  200 CONTINUE
 1000 FORMAT (A6,1X,10A6,1X,A6,5X,A1)
 1010 FORMAT (1X,A6,1X,10A6,1X,A6)
 2000 FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
 2010 FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6/)
      RETURN
      END
      SUBROUTINE OUTPT (OUTPUT,ATIME,MPAR,NSETS,IFILE,TAPEIN,TAPEOT)
      COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
      COMMON /NOMEN/ HED(120),DEC(120),UN(120)
      INTEGER HED,DEC,UN,TESTID,DAY,RUNTME,F(22),G(22),V(14),BLANK,
     1TAPEIN,TAPEOT
      DIMENSION OUTPUT(120,50),ATIME(50),NUM(10)
      DATA F(1),F(2),F(4),F(6),F(8),F(10),F(12),F(14),F(16),F(18),F(20),
     1F(22) /'(F9.1,',10*'F11.',')'/
      DATA V(1),V(3),V(4),V(5),V(6),V(8),V(9),V(10),V(11),V(13),V(14)
     1/'(8X,',  '(8X,I3',  6H)/3X,',  6HTIME',,  '3X',,  '(5X,A6',
```

```
         26H)/4X,',  6HSEC',3,  'X,',  '(5X,A6',  ',)/)
          DATA G(22) /')'/
          DATA NUM/'1','2','3','4','5','6','7','8','9','10'/
          DATA BLANK /'      '/
          IF (IFILE.GT.0) GO TO 100
          WRITE(2) DAY,RUNTME,TESTID,TAPEIN,TAPEOT
          WRITE (2) MPAR,(HED(I),I=1,MPAR)
          WRITE (2) MPAR,(UN(I),I=1,MPAR)
          WRITE (2) MPAR,(DEC(I),I=1,MPAR)
      100 DO 200 K=1,MPAR,10
          IPAGE=IPAGE+1
          L=K+9
          NCOL=10
          IF (L.LE.MPAR) GO TO 150
          L=MPAR
          NCOL=MPAR-K+1
      150 V(2)=NUM(NCOL)
          V(7)=NUM(NCOL)
          V(12)=NUM(NCOL)
          WRITE (6,2000) IPAGE
          WRITE (6,2010) TESTID,DAY,RUNTME
          WRITE (6,V) (I,I=K,L),(HED(I),I=K,L),(UN(I),I=K,L)
          M=1
          DO 180 I=K,L
          M=M+2
      180 F(M)=DEC(I)
          DO 182 I=1,M
      182 G(I)=F(I)
          IF (M.EQ.21) GO TO 200
          M1=M+1
          DO 185 I=M1,21
      185 G(I)=BLANK
      200 WRITE (6,G) (ATIME(M),(OUTPUT(I,M),I=K,L),M=1,NSETS)
          DO 300 J=1,NSETS
      300 WRITE (2) MPAR,ATIME(J),(OUTPUT(I,J),I=1,MPAR)
          DO 400 I=1,MPAR
          DO 400 J=1,50
      400 OUTPUT(I,J)=0.0
          IFILE=1
     2000 FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
     2010 FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6/)
          RETURN
          END
          SUBROUTINE GEOMT
          COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
          COMMON /TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
          REAL INPT
          DATA NUM/30/
          EQUIVALENCE  (GEOM(1),DSL1),(GEOM(2),DSL2),(GEOM(3),ALBF),
         1             (GEOM(4),CLABF),(GEOM(5),ALBR),(GEOM(6),CLABR),
         2             (GEOM(7),AI2),(GEOM(8),DI2),(GEOM(9),BET2),
         3             (GEOM(10),Z2),(GEOM(11),RPTAP),(GEOM(12),ADFD),
         4             (GEOM(13),DDL),(GEOM(14),RHOREF),(GEOM(15),ORFD),
         5             (GEOM(16),ORFCOE),(GEOM(17),ORFBTA),(GEOM(18),W),
         6             (GEOM(19),R706),(GEOM(20),R707),(GEOM(21),R708),
         7             (GEOM(22),R724),(GEOM(23),R725),(GEOM(24),R726),
         8             (GEOM(25),RLF),(GEOM(26),RLM),(GEOM(27),RLI),
         9             (GEOM(28),RIN),(GEOM(29),RLD),(GEOM(30),RLS)
          IPAGE=IPAGE+1
          WRITE (6,1010) IPAGE
```

```
1010 FORMAT('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
     WRITE (6,1020) TESTID,DAY,RUNTME
1020 FORMAT(12A6,12X,'DATE ',2A6,'TIME ',2A6)
     READ (5,1000) (GEOM(I),I=1,NUM)
1000 FORMAT(8F10.0)
     WRITE(6,2000) DSL1
2000 FORMAT (' DSL1       SUCTION LINE DIAMETER UPSTREAM FLOW COND.',30X
    1,F6.3,' IN')
     WRITE(6,2010) DSL2
2010 FORMAT (' DSL2       SUCTION LINE DIAMETER DOWNSTREAM FLOW COND.',
    128X,F6.3,' IN')
     WRITE(6,2020) ALBF
2020 FORMAT (' ALBF       FRONT LABYRINTH FLOW AREA',46X,F6.3,' SQ-IN')
     WRITE(6,2030) CLABF
2030 FORMAT (' CLABF      FRONT LABYRINTH COEFFICIENT',44X,F6.4)
     WRITE(6,2040) ALBR
2040 FORMAT (' ALBR       REAR LABYRINTH FLOW AREA',47X,F6.3,' SQ-IN')
     WRITE(6,2050) CLABR
2050 FORMAT (' CLABR      REAR LABYRINTH COEFFICIENT',45X,F6.4)
     WRITE (6,2060) AI2
2060 FORMAT (' AI2        IMPELLER DISCHARGE BLOCKED AREA',40X,F6.2
    1' SQ-IN')
     WRITE (6,2070) DI2
2070 FORMAT (' DI2        IMPELLER DISCHARGE DIAMETER',44X,F6.3,' IN')
     WRITE (6,2080) BET2
2080 FORMAT (' BET2       IMPELLER DISCHARGE BLADE ANGLE',41X,F6.2,
    1' DEG')
     WRITE (6,2080) Z2
2090 FORMAT('Z2         NUMBER OF IMPELLER BLADES',50X,I2)
     WRITE (6,3000) RPTAP

3000 FORMAT('RPTAP      DIFFUSER INLET PRESSURE TAP RADIAL LOCATION',
    127X,F6.3,' IN')
     WRITE (6,3010) ADFD
3010 FORMAT(' ADFD       DIFFUSER DISCHARGE FLOW AREA',42X,F6.2,
    1'SQ-IN')
     WRITE (6,3020) DDL
3020 FORMAT(' DDL        DISCHARGE LINE DIAMETER',48X,F6.3,' IN')
     WRITE (6,3030) RHOREF
3030 FORMAT(' RHOREF     REFERENCE DENSITY',54X,F6.4,' LB/CU-FT')
     WRITE (6,3040) ORFD
3040 FORMAT (' ORFD       BEARING COOLANT ORIFICE DIAMETER',39X,F6.4,
    1' IN')
     WRITE (6,3050) ORFCOE
3050 FORMAT (' ORFCOE     BEARING COOLANT ORIFICE COEFFICIENT',36X,
    1F6.4)
     WRITE (6,3060) ORFBTA
3060 FORMAT (' ORFBTA     BEARING COOLANT ORIFICE BETA',43X,F6.4)
3070 FORMAT (' R707        RADIAL LOCATION OF PRESSURE TAP 707',35X,
    1F6.4,' IN')
     WRITE (6,3070) R707
3080 FORMAT (' W           DIFFUSER VANE INLET WIDTH',45X,F6.4,' IN')
     WRITE (6,3080) W
3090 FORMAT (' R706        RADIAL LOCATION OF PRESSURE TAP 706',35X,
    1F6.4,' IN')
     WRITE (6,3090) R706
4000 FORMAT (' R708        RADIAL LOCATION OF PRESSURE TAP 708',35X,
    1F6.4,' IN')
     WRITE (6,4000) R708
4010 FORMAT (' R724        RADIAL LOCATION OF PRESSURE TAP 724',35X,
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              1F6.4,' IN')
               WRITE (6,4010) R724
          4020 FORMAT (' R725        RADIAL LOCATION OF PRESSURE TAP 725',35X,
              1F6.4,' IN')
               WRITE (6,4020) R725
          4030 FORMAT (' R726        RADIAL LOCATION OF PRESSURE TAP 726',35X,
              1F6.4,' IN')
               WRITE (6,4030) R726
          4040 FORMAT (' RLF         LABYRINTH LAND RADIUS',49X,F6.4,' IN')
               WRITE (6,4040) RLF
          4050 FORMAT (' RLM         LABYRINTH LAND RADIUS',49X,F6.4,' IN')
               WRITE (6,4050) RLM
          4060 FORMAT (' RLI         LABYRINTH LAND RADIUS',49X,F6.4,' IN')
               WRITE (6,4060) RLI
          4070 FORMAT (' RIN         INDUCER RADIUS',56X,F6.4, ' IN')
               WRITE (6,4070) RIN
          4080 FORMAT (' RLD         LABYRINTH LAND RADIUS',49X,F6.4,' IN')
               WRITE (6,4080) RLD
          4090 FORMAT (' RLS         SHAFT RADIUS',58X,F6.4,' IN')
               WRITE (6,4090) RLS
               RETURN
               END
               SUBROUTINE SUCTON (IFLAG,JFLG)
         C-----------------------SYMBOLS----------------------------------------------
         C  A1=FLOW AREA UPSTREAM OF FLOW CONDITIONER---SQ-IN
         C A2=FLOW AREA DOWNSTREAM OF FLOW CONDITIONER---SQ-IN
         C  ALPHA=VAPOR VOLUME/TOTAL VOLUME DOWNSTREAM OF FLOW CONDITIONER
         C  B=VAPOR VOLUME/LIQUID VOLUME DOWNSTREAM OF FLOW CONDITIONER
         C H1=ENTHALPY UPSTREAM OF FLUID CONDITIONER---BTU/LB
         C  H1T=STAGNATION ENTHALPY UPSTREAM OF FLUID CONDITIONER---BTU/LB
         C  H2=ENTHALPY DOWNSTREAM OF FLUID CONDITIONER---BTU/LB
         C  H2T=STAGNATION ENTHALPY DOWNSTREAM OF FLUID CONDITIONER---BTU/LB
         C  HLIQ2=SATURATION ENTHALPY CORRESPONDING TO S2---BTU/LB
         C  HTK=ENTHALPY IN TANK---BTU/LB
         C  NPSHA=NET POSITIVE SUCTION HEAD USING NPSP AND RHOSAT---FT
         C  NPSHB=NET POSITIVE SUCTION HEAD USING (H2-HLIQ2)---FT
         C  NPSP=NET POSITIVE SUCTION PRESSURE=P2T-PVAP2---PSI
         C  P1=PRESSURE UPSTREAM OF FLOW CONDITIONER---PSIA
         C  P2=PRESSURE DOWNSTREAM OF FLOW CONDITIONER---PSIA
         C  P2T=STAGNATION PRESSURE DOWNSTREAM OF FLOW CONDITIONER---PSIA
         C  PTK=TANK PRESSURE ---PSIA
         C  PVAP1=VAPOR PRESSURE UPSTREAM OF FLOW CONDITIONER---PSIA
         C  PVAP2=VAPOR PRESSURE CORRESPONDING TO S2---PSIA
         C  PVAPTK=VAPOR PRESSURE IN TANK---PSIA
         C  RHO1=FLUID DENSITY UPSTREAM OF FLOW CONDITIONER---LB/CU-FT
         C RHO2=FLUID DENSITY DOWNSTREAM OF FLOW CONDITIONER---LB/CU-FT
         C  RHOLIQ=LIQUID DENSITY DOWNSTREAM OF FLOW CONDITIONER---LB/CU-IN
         C  RHOSAT=SATURATION DENSITY CORRESPONDING TO S2---LB/CU-FT
         C  RHOVAP=VAPOR DENSITY DOWNSTREAM OF FLOW CONDITIONER---LB/CU-IN
         C  S2=ENTROPY DOWNSTREAM OF FLUID CONDITIONER---BTU/LB-DEG R
         C  T1=TEMPERATURE UPSTREAM OF FLOW CONDITIONER---DEG R
         C  T2=MEASURED TEMPERATURE DOWNSTREAM OF FLOW CONDITIONER DEG R
         C  T2CALC=VAPOR TEMPERATURE CORRESPONDING TO S2---DEG R
         C  TTK=TANK TEMPERATURE---DEG R
         C  V1=AVERAGE FLUID VELOCITY UPSTREAM OF FLUID CONDITIONER---FT/SEC
         C  V2=AVERAGE FLUID VELOCITY DOWNSTREAM OF FLUID CONDITIONER---FT/SEC
         C  WDOT=SUCTION WEIGHT FLOW RATE---LB/SEC
         C  X2=QUALITY DOWNSTREAM OF FLUID CONDITIONER
         C-----------------------------------------------------------------------------
               REAL NPSP,NPSHA,NPSHB
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      COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),S[illegible]25),RHOSAT(25),
     1EMPT(25),EMPS(25),EMTS(25),EMHS(25),EMRHOS(25)
      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
      REAL INPT
      EQUIVALENCE (INPT(12),PTK),(INPT(13),TTK),(INPT(14),P1),
     1            (INPT(15),T1),(INPT(16),P2),(INPT(17),T2)
      EQUIVALENCE (OUT(11),WDOT),(OUT(12),QS),(OUT(13),PVAPTK),
     1            (OUT(14),HTK),(OUT(15),RHO1),(OUT(16),V1),
     2            (OUT(17),H1),(OUT(18),H1T),(OUT(19),PVAP1),
     3            (OUT(20),RHO2),(OUT(21),V2),(OUT(22),H2),
     4            (OUT(23),H2T),(OUT(24),PVAP2),(OUT(25),S2),
     5            (OUT(26),X2),(OUT(27),P2T),(OUT(28),NPSP),
     6            (OUT(29),NPSHA),(OUT(30),NPSHB),(OUT(31),B),
     7            (OUT(32),ALPHA),(OUT(33),T2CALC),(OUT(34),RHOLIQ),
     8            (OUT(35),RHOL2),(OUT(36),HLIQ2)
      EQUIVALENCE (GEOM(1),DSL1),(GEOM(2),DSL2)
      A1=3.14159*DSL1**2/4.
      A2=3.14159*DSL2**2/4.
      N=22
C*** COMPUTE TANK CONDITIONS
      CALL PTENTH(PTK,TTK,1,HTK,JFLG)
      IF (JFLG.GT.1) RETURN
      CALL SPLNT (N,TSAT,PSAT,EMPT,TTK,PVAPTK)
C*** CHECK FOR VAPOR UPSTREAM OF FLOW CONDITIONER
      IF (P1.GT.PVAPTK) GO TO 90
      WRITE (6,1020)
 1020 FORMAT (' POSSIBLE VAPOR UPSTREAM OF FLOW CONDITIONER')
   90 CALL PTDENS(P1,T1,1,RHO1,JFLG)
      IF (JFLG.GT.1) RETURN
      V1=144.*WDOT/(RHO1*A1)
      CALL PTENTH(P1,T1,2,H1,JFLG)
      IF (JFLG.GT.1) RETURN
      H1T=H1+V1**2/(2.*32.174*778.16)
      CALL SPLNT (N,TSAT,PSAT,EMPT,T1,PVAP1)
      IF (P2.LE.(PVAP1+3.)) GO TO 100
C *** SINGLE PHASE DOWNSTREAM OF FLOW CONDITIONER
      CALL PTDENS(P2,T2,2,RHO2,JFLG)
      IF (JFLG.GT.1) RETURN
      CALL PTENTH(P2,T2,3,H2,JFLG)
      IF (JFLG.GT.1) RETURN
      V2=144.*WDOT/(RHO2*A2)
      H2T=H2+V2**2/(2.*32.174*778.16)
      CALL PTENTR(P2,T2,1,S2,JFLG)
      IF (JFLG.GT.1) RETURN
      RHOLIQ=RHO2
      X2=0.0
      B=0.
      ALPHA=0.
      RHOVAP=0.
      GO TO 160
C*** POSSIBLE TWO PHASE DOWNSTREAM OF FLOW CONDITIONER
  100 H2=H1
      IF (IFLAG.NE.0) GO TO 105
      HTOT=H1T
      GO TO 106
  105 HTOT=HTK
  106 ICOUNT=0
  110 ICOUNT=ICOUNT+1
      CALL PHTEMP(P2,H2,1,T2CALC,X2,JFLG)
      IF (JFLG.GT.1) RETURN
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               CALL PHDENS(P2,H2,1,RHO2,RHOLIQ,X2,JFLG)
               IF (JFLG.GT.1) RETURN
               IF (RHOLIQ.GT.0.0) GO TO 120
               RHOLIQ=RHO2
           120 V2=144.*WDOT/(RHO2*A2)
               H2NEW=HTOT-V2**2/(2.*32.174*778.16)
               IF (ABS(1.-H2/H2NEW).LE.0.00001) GO TO 150
               H2=H2NEW
               IF (ICOUNT.LE.20) GO TO 110
               WRITE (6,1000)
          1000 FORMAT (' SOLUTION FOR ENTHALPY DOWNSTREAM OF FLOW CONDITIONER DID
              1 NOT CONVERGE IN 20 ITERATIONS')
           150 CALL PHENTR(P2,H2,1,S2,JFLG)
               IF (JFLG.GT.1) RETURN
               H2T=H2+V2**2/(2.*32.174*778.16)
               RHOVAP=X2*RHOLIQ/(RHOLIQ/RHO2+X2-1.0)
               B=X2*RHOLIQ/((1.-X2)*RHOVAP)
               ALPHA=B/(B+1.)
         C *** FIND SATURATION PRESSURE CORRESPONDING TO S2
           160 CALL SPLNT (N,SSAT,TSAT,EMTS,S2,T2CALC)
               CALL SPLNT (N,SSAT,PSAT,EMPS,S2,PVAP2)
               CALL SPLNT (N,SSAT,HSAT,EMHS,S2,HLIQ2)
               CALL SPLNT (N,SSAT,RHOSAT,EMRHOS,S2,RHOL2)
               QS=448.86*WDOT/RHO2
           300 P2T=P2+RHO2*V2**2/(2.*32.174*144.)
               PTEST=P2T+0.5
               CALL PHENTR(PTEST,H2T,2,S11,JFLG)
               IF (JFLG.GT.1) RETURN
               DP=PTEST-P2T
               ICOUNT=1
           315 CALL PHENTR(P2T,H2T,3,STEST,JFLG)
               IF (JFLG.GT.1) RETURN
               DS=S11-STEST
               DPDS=DP/DS
               IF (ABS(1.-STEST/S2)-1.0E-05) 350,350,320
           320 IF (ICOUNT-30) 330,340,340
           330 ICOUNT=ICOUNT+1
               S11=STEST
               DP=DPDS*(STEST-S2)
               P2T=P2T-DP
               GO TO 315
           340 WRITE (6,1030)
          1030 FORMAT (' NO SOLUTION FOR P2T')
           350 NPSP=P2T-PVAP2
               NPSHA=144.*NPSP/RHOL2
           450 NPSHB=778.16*(H2T-HLIQ2)
           500 RETURN
               END
               SUBROUTINE FLOW(JFLG)
               COMMON / CALC/ INPT(100),GEOM(50),OUT(120)
               REAL INPT
               EQUIVALENCE(GEOM(3),ALBF),(GEOM(4),CLABF),(GEOM(5),ALBR),
              1            (GEOM(6),CLABR),(GEOM(13),DDL),(GEOM(14),RHOREF),
              2            (GEOM(15),ORFD),(GEOM(16),ORFCOE),(GEOM(17),ORFBTA)
               EQUIVALENCE (INPT(2),PSD),(INPT(3),TD),(INPT(4),PLFI),
              1            (INPT(5),PLFO),(INPT(6),PLRI),(INPT(7),PLRO),
              2            (INPT(8),WREF),(INPT(9),DPORF1),(INPT(10),DPORF2),
              3            (INPT(11),PORF)
               EQUIVALENCE (OUT(1),RHOD),(OUT(2),WD),(OUT(3),QD),(OUT(4),HSDB),
              1            (OUT(5),RHOFL),(OUT(6),WLBF),(OUT(7),RECF),
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     2              (OUT(8),RHORL),(OUT(9),WLBR),(OU[illegible]),BLDR),
     3              (OUT(11),WS),(OUT(103),WBRG)
      CALL PTDENS(PSD,TD,3,RHOD,JFLG)
      IF (JFLG.GT.1) RETURN
      WD=WREF*RHOD/RHOREF
      QD=448.86*WD/RHOD
      CALL PTENTH(PSD,TD,4,HSDB,JFLG)
      IF (JFLG.GT.1) RETURN
      CALL PHDENS(PORF,HSDB,2,RHOBRG,RHOLBG,QUAL,JFLG)
      IF (JFLG.GT.1) RETURN
      WB1=0.5252*ORFCOE*ORFBTA**2*ORFD**2*SQRT(RHOBRG*DPORF1)
      WB2=0.5252*ORFCOE*ORFBTA**2*ORFD**2*SQRT(RHOBRG*DPORF2)
      WBRG=WB1+WB2
C     FRONT LABYRINTH FLOW
      CALL PHDENS(PLFO,HSDB,3,RHOFL,RHOLFL,QUAL,JFLG)
      IF (JFLG.GT.1) RETURN
      DPLBF=PLFI-PLFO
      WLBF=0.66847*CLABF*ALBF*SQRT(RHOFL*DPLBF)
C     REAR LABYRINTH FLOW
      DPLBR=PLRI-PLRO
      CALL PHDENS(PLRO,HSDB,4,RHORL,RHOLRL,QUAL,JFLG)
      IF (JFLG.GT.1) RETURN
      WLBR=0.66847*CLABR*ALBR*SQRT(RHORL*DPLBR)
C     BEARING HOUSING FLOW
C     SUCTION FLOW
      WS=WD+WBRG+WLBR
      RECF=WLBF/WS
      BLDR=WLBR/WS
      RETURN
      END
      SUBROUTINE AXFOR
      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
      REAL INPT
      EQUIVALENCE (GEOM(8),D2),(GEOM(19),R706),(GEOM(20),R707),
     1              (GEOM(21),R708),(GEOM(22),R724),(GEOM(23),R725),
     2              (GEOM(24),R726),(GEOM(25),RLF),(GEOM(26),RLM),
     3              (GEOM(27),RLI),(GEOM(28),RIN),(GEOM(29),RLD),
     4              (GEOM(30),RLS)
      EQUIVALENCE (INPT(16),PS),(INPT(19),P708),(INPT(20),P726),
     1              (INPT(4),P706),(INPT(5),P705),(INPT(6),P724),
     2              (INPT(7),P723),(INPT(32),P707),(INPT(33),P725),
     3              (INPT(31),SN)
      EQUIVALENCE (OUT(11),VWIN),(OUT(34),RHOSL),(OUT(85),P2F),
     1              (OUT(86),PLF),(OUT(87),XKSOU),(OUT(88),XKSOV),
     2              (OUT(89),FF),(OUT(90),FFLB),(OUT(91),FIN),
     3              (OUT(92),FFOV),(OUT(93),FMT),(OUT(94),P2R),
     4              (OUT(95),PLD),(OUT(96),XKDOU),(OUT(97),XKDOV),
     5              (OUT(98),FR),(OUT(99),F723),(OUT(100),FAS),
     6              (OUT(101),FROV),(OUT(102),FAX),(OUT(20),RHO2)
      PAMB=INPT(1)/2.036
C-CONSTANTS
      R2 = D2/2.
      R708Q = R708**2
      R707Q = R707**2
      R706Q = R706**2
      R726Q = R726**2
      R725Q = R725**2
      R724Q = R724**2
      R2Q   = R2**2
      RLFQ  = RLF**2
```

```
      RLMQ  = RLM**2
      RLIQ  = RLI**2
      RINQ  = RIN**2
      R726Q = R726**2
      R725Q = R725**2
      R724Q = R724**2
      RLDQ  = RLD**2
      RLSQ=RLS**2
C-PRESSURE EXTRAPOLATIONS SHROUD
      P2F = (R2Q-R707Q)*(P708-P707)/(R708Q-R707Q)+P707
      PLF = P706-(R706Q-RLFQ)*(P707-P706)/(R707Q-R706Q)
C-K-VALUES SHROUD
      XKK = 11028./SN/SQRT(RHO2)
      XKSOU = XKK * SQRT((P708-P707)/(R708Q-R707Q))
      XKSOV = XKK * SQRT((P708-P706)/(R708Q-R706Q))
C-SHROUD PRESSURE FORCES
      FF27 = 1.5708*(R2Q-R707Q)*(P2F+P707)
      FF7L = 1.5708*(R707Q-RLFQ)*(P707+PLF)
      FF  = FF27 + FF7L
C-LABYRINTH PRESSURES
      PLFI = P705 + (PLF - P705)/3.
      PLFM = PLF - (PLF - P705)/3.
C-PRESSURE FRONT LABYRINTH
      FLFM = 3.1417*(RLFQ - RLMQ)*PLFM
      FLFI = 3.1417*(RLMQ - RLIQ)*PLFI
      F705 = 3.1417*(RLIQ - RINQ)*P705
      FFLB = FLFM + FLFI + F705
C-PRESSURE FORCE INDUCER
      FIN = 3.1417 * RINQ * PS
C-MOMENTUM FORCE
      FMT = 0.145 * VWIN**2/RHOSL
C-FRONT SIDE PRESSURE FORCE
      FFOV = FF + FFLB + FIN
C-PRESSURE EXTRAPOLATIONS DISK
      P2R = (R2Q-R725Q)*(P726-P725)/(R726Q-R725Q)+P725
      PLD = P725 - (R725Q-RLDQ)*(P725-P724)/(R725Q-R724Q)
C-K-VALUES DISK
      XKDOU = XKK * SQRT((P726-P725)/(R726Q-R725Q))
      XKDOV = XKK * SQRT((P726-P724)/(R726Q-R724Q))
C-DISK PRESSURE FORCES
      FR25  = 1.5708*(R2Q - R725Q)*(P2R+P725)
      FR5L  = 1.5708*(R725Q - RLDQ)*(P725+PLD)
      FR    = FR25 + FR5L
      F723  = 3.1417*(RLDQ-RLSQ)*P723
      FAS   = 3.1417* RLS**2* PAMB
C-BACKSIDE PRESSURE FORCE
      FROV  = FR + F723 + FAS
C-AXIAL THRUST POSITIVE TOWARDS SUCTION
      FAX=FROV-FFOV-FMT
      RETURN
      END
      SUBROUTINE RADTHR(N)
      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
      DIMENSION P(9),THETA(10),FX(9),FY(9)
      EQUIVALENCE (INPT(21),P(1))
      EQUIVALENCE (GEOM(8),DI2),(GEOM(18),W)
      EQUIVALENCE (OUT(80),RUSL),(OUT(81),BETA),(OUT(82),RFP),
     1(OUT(83),PAVE)
      DTHETA=360./N
      THETA(1)=-DTHETA/2.
```

```
      DO 10 I=2,N
   10 THETA(I)=THETA(I-1)+DTHETA
      THETA(N+1)=THETA(1)+360.
      SUMFX=0.0
      SUMFY=0.0
      DO 110 I=1,N
      PHI = (THETA,I+1)-THETA(I)) / 2.+ THETA(I)
      IF (PHI.LT.0.0) GO TO 40
      IF (PHI.LE.90.0) GO TO 50
      IF (PHI.LE.180.0) GO TO 60
      IF (PHI.LE.270.0) GO TO 70
      IF (PHI.LE.360.0) GO TO 80
   40 WRITE (6,1000)
 1000 FORMAT (' ANGLE LESS THAN 0 OR GREATER THAN 360 DEG, RADIAL THRUST
     1CALCULATION TERMINATED')
      RETURN
   50 PSI=PHI
      SIGNY=-1.
      SIGNX=-1.
      GO TO 100
   60 PSI=180.-PHI
      SIGNY=-1.
      SIGNX=1.
      GO TO 100
   70 PSI=PHI-180.0
      SIGNY=1.
      SIGNX=1.0
      GO TO 100
   80 PSI=360.-PHI
      SIGNY=1.
      SIGNX=-1.
  100 F=P(I)*W*DI2*ABS(SIN((THETA(I+1)-THETA(I))/(2.*57.296)))
      FX(I)=F*SIGNX*COS(PSI/57.296)
      FY(I)=F*SIGNY*SIN(PSI/57.296)
      SUMFX=SUMFX+FX(I)
  110 SUMFY=SUMFY+FY(I)
      IF (SUMFX.LE.0.0) GO TO 150
      IF (SUMFY.LE.0.0) GO TO 130
      BETA=57.296*ATAN(SUMFY/SUMFX)
      GO TO 200
  130 BETA=57.296*ATAN(SUMFY/SUMFX)+360.
      GO TO 200
  150 BETA=57.296*ATAN(SUMFY/SUMFX)+180.0
  200 RUSL=SQRT(SUMFX**2+SUMFY**2)
      SUMP=0.0
      DO 300 I=1,N
  300 SUMP=SUMP+P(I)
      PAVE=SUMP/N
      RFP=RUSL/PAVE
      RETURN
      END
      SUBROUTINE PERFOR(JFLG)
      COMMON /CALC/ INPT(100),GEOM(50),OUT(120)
      REAL INPT,N
      EQUIVALENCE (GEOM(9),BET2),(GEOM(10),Z2),(GEOM(13),DDL),
     1            (GEOM(8),DI2),(GEOM(7),AI2),(GEOM(11),RPTAP),
     2            (GEOM(12),ADFD)
      EQUIVALENCE (INPT(2),PSD),(INPT(3),TD),(INPT(18),PID),
     1            (INPT(19),PTIP),(INPT(20),PBTIP),(INPT(21),PDIFI1),
     2            (INPT(22),PDIFI2),(INPT(23),PDIFI3),(INPT(24),PDIFI4),
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     3              (INPT(25),PDIFI5),(INPT(26),PD[illegible]),(INPT(27),PDIFI7),
     4              (INPT(28),PDIFI8),(INPT(29),PDI[illegible]9),(INPT(30),PDIF0),
     5(INPT(31),N),(INPT(16),PS)
      EQUIVALENCE (OUT(1),RHOD),(OUT(2),WD),(OUT(3),QD),(OUT(4),HSDB),
     1              (OUT(6),WLBF),(OUT(9),WLBR),(OUT(11),WS),(OUT(12),QS),
     2              (OUT(25),SS),(OUT(40),U2),(OUT(41),VDIS),
     3              (OUT(42),HTDB),(OUT(43),DPTD),(OUT(44),PTD),
     4              (OUT(45),DHISO),(OUT(46),HN20),(OUT(47),HCO),
     5              (OUT(48),QND),(OUT(49),DHTAB),(OUT(50),DHTI),
     6              (OUT(51),EFTD),(OUT(52),EFTDO),(OUT(53),DPSIN),
     7              (OUT(54),DHSIN),(OUT(55),HSIN2),(OUT(56),QNS),
     8              (OUT(57),PHI2),(OUT(58),PSITH),(OUT(59),HBIMP),
     9              (OUT(60),RHOID),(OUT(61),HISTB),(OUT(62),DHISI),
     1              (OUT(63),HN2IS),(OUT(64),HCIS),(OUT(65),HCIT),
     2              (OUT(66),DHITI),(OUT(67),HN2IT),(OUT(68),EFIMP),
     3              (OUT(69),DHCHG),(OUT(70),DHISD),(OUT(71),HN2DS),
     4              (OUT(72),DHITD),(OUT(73),HCTD),(OUT(74),DHCDF),
     5              (OUT(75),DHCVO)
      EQUIVALENCE (OUT(83),PDIFIA)
      EQUIVALENCE (OUT(23),HTSB),(OUT(22),HSB),(OUT(27),PTS),
     1              (OUT(34),RHOSL)
C     CONSTANTS
      BET2R=BET2/57.296
      TBE2=TAN(BET2R)
      SLP=3.14159*SIN(BET2R)/Z2
      ADL=3.14159/4.*DDL**2
C     PUMP OVERALL PERFORMANCE
      U2=3.14159*DI2*N/720.
      CALL PTENTR(PSD,TD,2,SD,JFLG)
      IF (JFLG.GT.1) RETURN
      VDIS=QD*144./(ADL*448.86)
      HDVEL=VDIS**2/2./32.174
      PTD=PSD+RHOD*HDVEL/144.
      HTDB=HSDB+HDVEL/778.16
      DH=HTDB-HTSB
      DPTD=PTD-PTS
      CALL PSENTH(PTD,SS,1,HISOB,JFLG)
      IF (JFLG.GT.1) RETURN
      DHISO=(HISOB-HTSB)*778.16
      HN20=DHISO/N**2
      HCO=DHISO*32.174/U2**2
      QND=QD/N
      DHTAB=(HTDB-HTSB)
      DHTI=(HISOB-HTSB)
      EFTD=DHTI/DHTAB
      EFTDO=EFTD*WD/WS
C     INDUCER PERFORMANCE
      DPSIN=PID-PS
      DHSIN=144.*DPSIN/RHOSL
      HSIN2=DHSIN/N**2
      QNS=QS/N
C     IMPELLER FLOW COEFFICIENT
      WSIMP=WS+WLBF
      PIMP=(PTIP+PBTIP)/2.
      RHOID=RHOD
  100 PHI2=144.*WSIMP/(RHOID*AI2*U2)
      PSITH=1.-PHI2/TBE2-SLP
      HVEL2=0.015547*U2**2*(PSITH**2+PHI2**2)
      HBIMP=HTDB-HVEL2/778.16
      RHOLD=RHOID
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      CALL PHDENS(PIMP,HBIMP,2,RHOID,RHOL,QUAL,JFL
      IF (JFLG.GT.1) RETURN
      IF (ABS(1.-RHOLD/RHOID)-1.0E-05) 150,150,100
C     IMPELLER STATIC HEAD COEFFICIENT
  150 CALL PHTEMP(PDIFIA,HBIMP,2,TID,QI2,JFLG)
      IF (JFLG.GT.1) RETURN
      CALL PSENTH(PDIFIA,SS,2,HISIB,JFLG)
      IF (JFLG.GT.1) RETURN
      DHISI=(HISIB-HSB)*778.16
      HN2IS=DHISI/N**2
      HCIS=32.174*DHISI/U2**2
C     IMPELLER TOTAL HEAD COEFFICIENT
      HCIT=HCIS+(DI2/2./KPTAP)**2*(PSITH**2+PHI2**2)/2.
      DHITI=U2**2*HCIT/32.174
      HN2IT=DHITI/N**2
      EFIMP=HCIT/PSITH
C     HOUSING HEAD LOSS COEFFICIENT
      DHCHG=HCIT-HCO
C     DIFFUSER AND VOLUTE LOSSES
      CALL PSENTH(PDIFO,SS,3,HISDB,JFLG)
      IF (JFLG.GT.1) RETURN
      DHISD=(HISDB-HSB)*778.16
      HN2DS=DHISD/N**2
C     DIFFUSER DISCHARGE ANGLE BASED ON PFLEIDERS DEVIATION CRITERION
      CM52=144.*(WS-WLBR)/RHOD/ADFD
      CUTH2=U2*PSITH
      AL52R=ATAN(1./(2.01+0.245*CUTH2/CM52))
      HVDF=.975*(CM52/SIN(AL52R))**2/(2.*32.174)
      DHITD=DHISD+HVDF
      HCTD=32.174*DHITD/U2**2
      DHCDF=HCIT-HCTD
      DHCVO=HCTD-HCO
      RETURN
      END
      SUBROUTINE TAPE1
      COMMON / TITLE/ TESTID(12),DAY(2),RUNTME(2),IPAGE
      COMMON /TAPEIN/ CHAN1(100),CHAN2(100),CHAN3(100),CHAN4(100),
     1PARID(100),CHANID(200),UNITS(200),DEC(200),NPAR
      COMMON /TAPE/ TSTART,TSTOP,INT1,INT2,IAVE,NSETS,INPUT,ATIME,TIME,
     1IEND
      INTEGER CHAN1,CHAN2,CHAN3,CHAN4,PARID,CHANID,UNITS,UN(100),D(100)
      REAL INPUT
      DIMENSION INPUT(100,50),ATIME(50),DATA(200),NUM(10)
      INTEGER PGAGE
      INTEGER BLANK,F(22),G(22),V(14)
      INTEGER DEC,DAY,RUNTME,TESTID
      DATA BLANK /'      '/
      DATA PGAGE /'PSIG  '/
      DATA F(1),F(2),F(4),F(6),F(8),F(10),F(12),F(14),F(16),F(18),F(20),
     1F(22) /'(F9.1,','10*'F11.',')'/
      DATA V(1),V(3),V(4),V(5),V(6),V(8),V(9),V(10),V(11),V(13),V(14)
     1/'(8X,',  '(8X'I3',  6H)/3X,',  6HTIME',,  '3X','  '(5X,A6',
     26H)/4X,',  6HSEC','3,  'X','  '(5X,A6',  ')/)'/
      DATA G(22) /')'/
      DATA NUM/'1','2','3','4','5','6','7','8','9','10'/
      KENTR=1
  100 READ(1) NCHAN,TIME, (DATA(I),I=1,NCHAN)
      IF (TIME.LT.TSTART) GO TO 100
      BACKSPACE 1
      GO TO 250
```

```
      ENTRY TAPE2
  250 KENTR=2
  260 NSETS=NSETS+,
      DO 270 J=1,NPAR
  270 INPUT(J,NSETS)=0.0
      ATIME(NSETS)=0.0
      DO 300 I=1,INT1
      READ(1) NCHAN,TIME,(DATA(J),J=1,NCHAN)
      IF (KENTR.EQ.1) GO TO 310
      IF (TIME.GE.TSTOP) GO TO 310
  300 CONTINUE
  310 NAVE=1
  320 ATIME(NSETS)=ATIME(NSETS)+TIME
      DO 350 J=1,NPAR
      N=1
      K=CHAN1(J)
      PAR=DATA(K)
      UN(J)=UNITS(K)
      D(J)=DEC(K)
      IF (CHAN2(J).EQ.0) GO TO 350
      N=2
      K=CHAN2(J)
      PAR=PAR+DATA(K)
      IF (CHAN3(J).EQ.0) GO TO 350
      N=3
      K=CHAN3(J)
      PAR=PAR+DATA,K)
      IF (CHAN4(J),EQ,0) GO TO 350
      N=4
      K=CHAN4(J)
      PAR=PAR+DATA,K)
  350 INPUT(J,NSETS)=INPUT(J,NSETS)+PAR/N
      IF (NAVE.GE.IAVE.OR.TIME.GE.TSTOP) GO TO 450
      DO 400 I=1,INT2
      READ (1) NCHAN,TIME,(DATA(J),J=1,NCHAN)
      IF (TIME.GE.TSTOP) GO TO 410
  400 CONTINUE
  410 NAVE=NAVE+1
      GO TO 320
  450 DO 500 J=1,NPAR
      INPUT (J,NSETS)=INPUT(J,NSETS)/NAVE
      IF (UN(J).NE.PGAGE) GO TO 500
      INPUT(J,NSETS)=INPUT(J,NSETS)+INPUT(1,NSETS)/2.036
      UN(J)='PSIA'
  500 CONTINUE
      ATIME(NSETS)=ATIME(NSETS)/NAVE
      IF (NSETS.LT.50.AND.TIME.LT.TSTOP) GO TO 260
      IF (IEND.EQ.0) RETURN
      DO 600 K=1,NPAR,10
      IPAGE=IPAGE+1
      L=K+9
      NCOL=10
      IF (L.LE.NPAR) GO TO 550
      L=NPAR
      NCOL=NPAR-K+1
  550 V(2)=NUM(NCOL)
      V(7)=NUM(NCOL)
      V(12)=NUM(NCOL)
      WRITE (6,6050) IPAGE
      WRITE (6,6000) TESTID,DAY,RUNTME
```

```
                WRITE (6,V) (I,I=K,L),(PARID(I),I=K,L),(U[illegible]),I=K,L)
                M=1
                DO 580 I=K,L
                M=M+2
          580   F(M)=D(I)
                DO 582 I=1,M
          582   G(I)=F(I)
                IF (M.EQ.21) GO TO 600
                M1=M+1
                DO 585 I=M1,21
          585   G(I)=BLANK
          600   WRITE (6,G) (ATIME(M),(INPUT(I,M),I=K,L),M=1,NSETS)
         6000   FORMAT (12A6,12X,'DATE ',2A6,'TIME ',2A6)
         6050   FORMAT ('1',52X,'LH2 PUMP TEST',44X,'PAGE ',I4)
                RETURN
                END
      C
      C  SPLINT CALCULATES INTERPOLATED POINTS AND DERIVATIVES
      C  FOR A SPLINE CURVE
                SUBROUTINE SPLNT (N,X,Y,EM,XX,YINT)
                DIMENSION Z(10),X(25),Y(25),EM(25)
         1000   FORMAT (' SPLNT USED FOR EXTRAPOLATION',3E20.7/)
                MAX=1
                Z(1)=XX
                DO140I=1,MAX
                K=2
                IF(Z(I)-X(1),70,60,90
           60   YINT   =Y(1)
                SK=X(K)-X(K-1)
                GO TO 130
           70   IF (Z(I)-(1.1*X(1)-0.1*X(2))) 75,120,120
           75   WRITE (6,1000) Z(I),X(1),X(2)
                SRW=16
                GO TO 120
           80   K=N
                IF (Z(I)-(1.1*X(N)-0.1*X(N-1))) 120,120,85
           85   WRITE (6,1000) Z(I),X(N-1),X(N)
                SRW=16
                GO TO 120
           90   IF(Z(I)-X(K))120,100,110
          100   YINT   =Y(K)
                SK=X(K)-X(K-1)
                GO TO 130
          110   K=K+1
                IF(K-N)90,90,80
          120   CONTINUE
                SK=X(K)-X(K-1)
                YINT   =EM(K-1)*(X(K)-Z(I))**3/6.  /SK+EM(K)*(Z(I)-X(K-1))**3/6.
               1/SK+(Y(K)/SK-EM(K)*SK/6.  )*(Z(I)-X(K-1))+(Y(K-1)/SK-EM(K-1)*SK/6.
               2  )*(X(K)-Z(I))
          130   DYDX   =-EM(K-1)*(X(K)-Z(I))**2/2.0  /SK+EM(K)*(X(K-1)-Z(I))** 2/2
               1  /SK+(Y(K)-Y(K-1))/SK-(EM(K)-EM(K-1))*SK/6.
                D2YDX=(X(K)-Z(I))*EM(K-1)/SK+(Z(I)-X(K-1))*EM(K)/SK
                RCURV=((1.+DYDX**2)**1.5)/ABS(D2YDX)
          140   CONTINUE
          500   RETURN
                END
                SUBROUTINE SPLNE (N,X,Y,EM)
                INTEGER SRW
      C
```

```
      C  SPLINE CALCULATES FIRST AND SECOND DERIVATIVES [illegible] SPLINE POINTS     3K
      C  END CONDITION-SECOND DERIVATIVES ARE THE SAME , [illegible]END POINT AND
      C  ADJACENT POINT
      C
         DIMENSION X(25),Y(25),EM(25),G(25),SB(25),SLOPE(25),CURV(25)
         SRW=0
         SB(1)=-1.0
         G(1)=0.
         NO=N-1
         IF (NO-2) 20,7,7
       7 DO10I=2,NO
         A=(X(I)-X(I-1))/6.
         C=(X(I+1)-X(I))/6.
         W=2.  *(A+C)-A*SB(I-1)
         SB(I)=C/W
         F=(Y(I+1)-Y(I))/(X(I+1)-X(I))-(Y(I)-Y(I-1))/(X(I)-X(I-1))
      10 G(I)=(F-A*G(I-1))/W
      20 EM(N)=G(N-1)/(1.  +SB(N-1))
         DO30I=2,N
         K=N+1-I
      30 EM(K)=G(K)-SB(K)*EM(K+1)
         SLOPE(1)=(X(1)-X(2))/6.  *(2.  *EM(1)+EM(2))+(Y(2)-Y(1))/(X(2)-X(1
        1))
         DO40I=2,N
      40 SLOPE(I)=(X(I)-X(I-1))/6.  *(2.  *EM(I)+EM(I-1))+(Y(I)-Y(I-1))/(X(
        1I)-X(I-1))
         DO 45 I=1,N
      45 CURV(I)=((1.+SLOPE(I)**2)**1.5)/ABS(EM(I))
         IF (SRW) 50,100,50
      50 WRITE (6,1000) N, (X(I),Y(I),SLOPE(I),EM(I),CURV(I),I=1,N)
     100 RETURN
    1000 FORMAT ('1',15HNO. OF POINTS =,I3/10X,1HX,19X,1HY,19X,5HSLOPE,15X,
        A2HEM,15X,4HCURV/(5E20.8))
         END
         SUBROUTINE SATUR(N)
         COMPILER (DATA=SHORT)
         COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),SSAT(25),RHOSAT(25),
        1EMPT(25),EMPS(25),EMTS(25),EMHS(25),EMRHOS(25),EMTP(25),
        2HSATV(25),SSATV(25),RHOSTV(25),EMHLP(25),EMHVP(25),EMSLP(25),
        3EMSVP(25),EMROLP(25),EMROVP(25),EMPH(25)
      C*** SATURATION DATA
         DATA HSAT /-132.81,-132.25,-129.29,-126.13,-122.78,-119.2,-115.38,
        1-111.31,-110.18,-106.96,-102.31,-97.32,-91.966,-86.208,-79.959,
        2-73.176,-65.733,-57.436,-48.009,-36.876,-22.458,16.550/
         DATA PSAT /1.0214,1.1433,1.9546,3.1302,4.7762,6.9953,9.8904,13.564
        1,14.296,18.120,23.705,30.406,38.371,47.688,58.519,70.967,85.149,
        2101.21,119.30,139.63,162.40,187.51/
         DATA TSAT /24.845,25.2,27.0,28.8,30.6,32.4,34.2,36.0,36.482,37.8,
        139.6,41.4,43.2,45.0,46.8,48.6,50.4,52.2,54.0,55.8,57.6,59.3568/
         DATA SSAT /1.18491,1.20743,1.31999,1.43138,1.54157,1.65296,1.76315
        1,1.87572,1.90534,1.98828,2.10204,2.21816,2.33665,2.45751,2.58193,
        22.71227,2.84853,2.99428,3.15306,3.33553,3.56422,4.19696/
         DATA RHOSAT/4.8086,4.7975,4.7434,4.6884,4.6298,4.5693,4.5055,
        14.4371,4.4185,4.3664,4.2889,4.2086,4.1205,4.0256,3.9226,3.8086,
        23.6805,3.5358,3.3664,3.1578,2.8711,1.9619/
         DATA HSATV / 60.315,61.104,64.965,68.612,72.045,75.223,78.103,
        180.683,81.408,82.987,84.800,86.207,87.124,87.530,87.316,86.357,
        284.480,81.472,76.866,69.891,58.502,16.358 /
         DATA SSATV / 8.9615,8.8821,8.5147,8.1936,7.9093,7.6545,7.4223,
        17.2102,7.1581,7.0159,6.8298,6.6533,6.4850,6.3203,6.1592,5.9968,
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     25.8310,5.6568,5.4672,5.2492,4.9707,4.1946/
      DATA RHOSTV /.007837,.008666,.07390,.021130,.030722,.043083,
     1.05864,.077866,.08351,.10105,.12927,.16304,.20317,.25074,
     2.3072,.3745,.4555,.5547,.6795,.8452,1.0422,1.9619 /
      CALL SPLNE(N,TSAT,PSAT,EMPT)
      CALL SPLNE(N,HSAT,PSAT,EMPH)
      CALL SPLNE(N,SSAT,PSAT,EMPS)
      CALL SPLNE(N,PSAT,TSAT,EMTP)
      CALL SPLNE(N,SSAT,TSAT,EMTS)
      CALL SPLNE(N,SSAT,HSAT,EMHS)
      CALL SPLNE(N,SSAT,RHOSAT,EMRHOS)
      CALL SPLNE (N,PSAT,HSAT,EMHLP)
      CALL SPLNE (N,PSAT,HSATV,EMHVP)
      CALL SPLNE (N,PSAT,SSAT,EMSLP)
      CALL SPLNE (N,PSAT,SSATV,EMSVP)
      CALL SPLNE (N,PSAT,RHOSAT,EMROLP)
      CALL SPLNE (N,PSAT,RHOSTV,EMROVP)
      RETURN
      END
      SUBROUTINE PARAH
      COMMON /PROP/ T(30,50),SV(30,50),H(30,50),S(30,50),NUM(30),P(30),
     1AA(5,90),RHOX(90),B(9,8)
      COMMON /SAT/ HSAT(25),PSATUR(25),TSAT(25),SSAT(25),RHOSAT(25),
     1EMPT(25),EMPS(25),EMTS(25),EMHS(25),EMRHOS(25),EMTP(25),
     2HSATVP(25),SSATV(25),RHOSTV(25),EMHLP(25),EMHVP(25),EMSLP(25),
     3EMSVP(25),EMROLP(25),EMROVP(25),EMPH(25)
      DATA PCRIT /187.55/
      DATA N/22/
C     ENTRY POINT FOR DENSITY(PP,TT)
C
      ENTRY PTDENS(PP,TT,K,RHO,JFLG)
      ENTR='PTDENS'
      IF (PP.GT.PCRIT) GO TO 100
      CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
      IF (PP.LT.PSAT) GO TO 160
  100 CALL HPROP(PP,TT,SV,T,1,2,C,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 110
      RHO=1./C
      RETURN
C     ENTRY FOR ENTHALPY(PP,TT)
C
      ENTRY PTENTH(PP,TT,K,ENTH,JFLG)
      ENTR='PTENTH'
      IF (PP.GT.PCRIT) GO TO 101
      CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
      IF (PP.LT.PSAT) GO TO 160
  101 CALL HPROP(PP,TT,H,T,1,3,ENTH,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 110
      RETURN
C     ENTRY FOR ENTROPY(PP,TT)
C
      ENTRY PTENTR(PP,TT,K,ENTRO,JFLG)
      ENTR='PTENTR'
      IF (PP.GT.PCRIT) GO TO 102
      CALL SPLNT(N,TSAT,PSATUR,EMPT,TT,PSAT)
      IF (PP.LT.PSAT) GO TO 160
  102 CALL HPROP(PP,TT,S,T,1,4,ENTRO,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 110
  105 RETURN
  110 GO TO (105,120,130,140,150),JFLG
```

```
  120 WRITE (6,2000) XMIN,XMAX,PP,ENTR,K
 2000 FORMAT (' MINIMUM TABULATED PRESSURE IS GREATER THAN P'/
     1' PMIN=',F10.2,5X,'PMAX=',F10.2,5X,'P=',F10.2,5X,A6,I2)
      RETURN
  130 WRITE (6,2010) XMIN,XMAX,PP,ENTR,K
 2010 FORMAT (' MAXIMUM TABULATED PRESSURE IS LESS THAN P'/
     1' PMIN=',F10.2,5X,'PMAX=',F10.2,5X,'P=',F10.2,5X,A6,I2)
      RETURN
  140 WRITE (6,2020) XMIN,XMAX,TT,ENTR,K
 2020 FORMAT (' MINIMUM TABULATED TEMPERATURE IS GREATER THAN T'/
     1' TMIN=',F10.2,5X,'TMAX=',F10.2,5X,'T=',F10.2,5X,A6,I2)
      RETURN
  150 WRITE (6,2030) XMIN,XMAX,TT,ENTR,K
 2030 FORMAT (' MAXIMUM TABULATED TEMPERATURE IS LESS THAN T'/
     1' TMIN=',F10.2,5X,'TMAX=',F10.2,5X,'T=',F10.2,5X,A6,I2)
      RETURN
  160 WRITE (6,2040) PSAT,PP,ENTR,K
 2040 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO T'/
     1' PSAT=',F10.2,5X,'P=',F10.2,5X,A6,I2)
      JFLG=6
      RETURN
C     ENTRY FOR TEMPERATURE(PP,HH)
C
      ENTRY PHTEMP(PP,HH,K,TEMP,X,JFLG)
      ENTR='PHTEMP'
      IF (PP.GT.PCRIT) GO TO 200
      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
      IF (PP.LT.PSAT) GO TO 260
  200 CALL HPROP(PP,HH,T,H,3,1,TEMP,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 210
      X=0.0
      RETURN
C     ENTRY FOR DENSITY(PP,HH)
C
      ENTRY PHDENS(PP,HH,K,RHO,RHOL,X,JFLG)
      ENTR='PHDENS'
      IF (PP.GT.PCRIT) GO TO 201
      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
      IF (PP.LT.PSAT) GO TO 280
  201 CALL HPROP(PP,HH,SV,H,3,2,C,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 210
      RHO=1./C
      X=0.0
      RHOL=0.0
      RETURN
C     ENTRY FOR ENTROPY(PP,HH)
C
      ENTRY PHENTR(PP,HH,K,ENTRO,JFLG)
      ENTR='PHENTR'
      IF (PP.GT.PCRIT) GO TO 202
      CALL SPLNT(N,HSAT,PSATUR,EMPH,HH,PSAT)
      IF (PP.LT.PSAT) GO TO 290
  202 CALL HPROP(PP,HH,S,H,3,4,ENTRO,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 210
  205 RETURN
  210 GO TO (205,120,130,240,250),JFLG
  240 WRITE (6,3000) XMIN,XMAX,HH,ENTR,K
 3000 FORMAT (' MINIMUM TABULATED ENTHALPY IS GREATER THAN H'/
     1' HMIN=',F10.4,5X,'HMAX=',F10.4,5X,'H=',F10.4,5X,A6,I2)
      RETURN
```

```
  250 WRITE (6,3010) XMIN,XMAX,HH,ENTR,K
 3010 FORMAT (' MAXIMUM TABULATED ENTHALPY IS LESS THAN H'/
     1' HMIN=',F10.4,5X,'HMAX=',F10.4,5X,'H=',F10.4,5X,A6,I2)
      RETURN
  260 CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
      CALL SPLNT(N,PSATUR,TSAT,EMTP,PP,TEMP)
      IF (HH.GT.HSATV) GO TO 270
      X=(HH-HSATL)/(HSATV-HSATL)
      RETURN
  270 WRITE (6,3020) PSAT,PP,HSATV,HH,ENTR,K
 3020 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO H AND H IS G
     1REATER THAN H SATURATED VAPOR'/' PSAT=',F10.2,5X,'P=',F10.2,5X,
     2'HSATV=',F10.4,5X,'H=',F10.4,5X,A6,I2)
      JFLG=6
      RETURN
  280 CALL SPLNT(N,PSATUR,RHOSAT,EMROLP,PP,RHOL)
      CALL SPLNT(N,PSATUR,RHOSTV,EMROVP,PP,RHOV)
      CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
      IF (HH.GT.HSATV) GO TO 270
      X=(HH-HSATL)/(HSATV-HSATL)
      RHO=RHOL*RHOV/(X*RHOL+ (1.-X)*RHOV)
      RETURN
  290 CALL SPLNT(N,PSATUR,SSAT,EMSLP,PP,SL)
      CALL SPLNT(N,PSATUR,SSATV,EMSVP,PP,SVP)
      CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
      IF (HH.GT.HSATV) GO TO 270
      XS=(HH-HSATL)/(HSATV-HSATL)
      ENTRO=XS*SVP+(1.-XS)*SL
      RETURN
C     ENTRY FOR ENTHALPY(PP,SS)
C
      ENTRY PSENTH(PP,SS,K,ENTH,JFLG)
      ENTR='PSENTH'
      IF (PP.GT.PCRIT) GO TO 300
      CALL SPLNT(N,SSAT,PSATUR,EMPS,SS,PSAT)
      IF (PP.LT.PSAT) GO TO 360
  300 CALL HPROP(PP,SS,H,S,4,3,ENTH,JFLG,XMIN,XMAX)
      IF (JFLG.GT.1) GO TO 310
  305 RETURN
  310 GO TO (305,120,130,340,350), JFLG
  340 WRITE (6,4000) XMIN,XMAX,SS,ENTR,K
 4000 FORMAT (' MINIMUM TABULATED ENTROPY IS GREATER THAN S'/
     1' SMIN=',F10.5,5X,'SMAX=',F10.5,5X,'S=',F10.5,5X,A6,I2)
      RETURN
  350 WRITE (6,4010) XMIN,XMAX,SS,ENTR,K
 4010 FORMAT (' MAXIMUM TABULATED ENTROPY IS LESS THAN S'/
     1' SMIN=',F10.5,5X, 'SMAX=',F10.5,5X,'S=',F10.5,5X,A6,I2)
      RETURN
  360 CALL SPLNT(N,PSATUR,HSAT,EMHLP,PP,HSATL)
      CALL SPLNT(N,PSATUR,HSATVP,EMHVP,PP,HSATV)
      CALL SPLNT(N,PSATUR,SSAT,EMSLP,PP,SL)
      CALL SPLNT(N,PSATUR,SSATV,EMSVP,PP,SVP)
      IF (SS.GT.SVP) GO TO 370
      XS=(SS-SL)/(SVP-SL)
      ENTH=XS*HSATV+(1.-XS)*HSATL
      RETURN
  370 WRITE (6,4020) PSAT,PP,SVP,SS,ENTR,K
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 4020 FORMAT (' P IS LESS THAN SAT. PRESS. CORRESPONDING TO S AND S IS G
     1REATER THAN S SATURATED VAPOR'/' PSAT=',F10.2,5X,'P=',F10.2,5X,
     2'SV=',F10.5,5X,'S=',F10.5,5X,A6,I2)
      JFLG=6
      RETURN
      END
C**** THIS SUBROUTINE READS IN THE HYDROGEN PROPERTIES DATA TO BE USED  FILE 001
C**** IN SUBROUTINE HPROP                                                FILE 002
C                                                                        FILE 003
      SUBROUTINE INPROP
      DIMENSION A(30)
      COMMON /PROP/ T(30,50),SV(30,50),H(30,50),S(30,50),NUM(30),P(30),
     1AA(5,90),RHOX(90),B(9,8)
   10 FORMAT (8F10.0)                                                    FILE 009
   20 FORMAT (25I3)                                                      FILE 010
C                                                                        FILE 011
C**** READ NUMBER OF DATA POINTS FOR EACH ISOBAR                         FILE 012
C                                                                        FILE 013
      READ (5,20) (NUM(I),I=1,30)
      DO 50 I=1,30
      M=NUM(I)                                                           FILE 016
C                                                                        FILE 017
C**** READ TEMPERATURES FOR ISOBAR I                                     FILE 018
C                                                                        FILE 019
      READ (5,10) (T(I,J),J=1,M)
C                                                                        FILE 021
C**** READ SPECIFIC VOLUMES FOR ISOBAR I                                 FILE 022
C                                                                        FILE 023
      READ (5,10) (SV(I,J),J=1,M)
C                                                                        FILE 025
C**** READ ENTHALPYS FOR ISOBAR I                                        FILE 026
C                                                                        FILE 027
      READ (5,10) (H(I,J),J=1,M)
C                                                                        FILE 029
C**** READ ENTROPYS FOR ISOBAR I                                         FILE 030
C                                                                        FILE 031
   50 READ (5,10) (S(I,J),J=1,M)
C                                                                        FILE 037
C**** CONVERT PRESSURES FROM ATMOSPHERES TO PSIA                         FILE 038
C                                                                        FILE 039
      A(1)=1.                                                            FILE 040
      A(2)=1.5                                                           FILE 041
      DO 55 I=2,10                                                       FILE 042
   55 A(I+1)=I                                                           FILE 043
      A(12)=12.5                                                         FILE 044
      DO 60 I=1,8                                                        FILE 045
   60 A(I+12)=10+5*I                                                     FILE 046
      DO 65 I=1,5                                                        FILE 047
   65 A(I+20)=50+10*I                                                    FILE 048
      DO 70 I=1,5
   70 A(I+25)=100+20*I
      DO 80 I=1,30
   80 P(I)=14.696*A(I)                                                   FILE 050
   25 FORMAT (5E16.7)                                                    FILE 057
   30 FORMAT (10F8.4)                                                    FILE 058
   35 FORMAT (4E20.8)                                                    FILE 059
C                                                                        FILE 060
C**** READ EMPIRICAL COEFFICIENTS                                        FILE 061
C                                                                        FILE 062
      READ (5,25) ((AA(I,J),J=1,90),I=1,5)
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      READ (5,30) (RHOX(I),I=1,90)
      READ (5,35) ((B(I,J),J=1,8),I=1,9)
      RETURN                                                            FILF 066
      END
C**** SUBROUTINE HPROP ****                                             HPROP000
C**** THIS SUBROUTINE PROVIDES THE FOLLOWING HYDROGEN PROPERTIES DATA TOHPROP001
C**** THE MAIN PROGRAM:                                                 HPROP002
C**** SUCTION LINE SPNIC VELOCITY AS A FUNCTION OF TEMPERATURE AND      HPROP003
C**** PRESSURE                                                          HPROP004
C**** INDUCER INLET SPECIFIC VOLUME AS A FUNCTION OF TEMPERATURE AND    HPROP005
C**** PRESSURE                                                          HPROP006
C**** PUMP INLET SPECIFIC VOLUME AS A FUNCTION OF TEMPERATURE AND       HPROP007
C**** PRESSURE                                                          HPROP008
C                                                                       HPROP009
      SUBROUTINE HPROP(A,B,Y,X,KJ,K,C,JFLG,XMIN,XMAX)
      DIMENSION X(30,50),Y(30,50),CP(2)
      COMMON /PROP/ T(30,50),SV(30,50),H(30,50),S(30,50),N(30),P(30),
     1AA(5,90),RHOX(90),D(9,8)
      COMMON /SAT/ HSAT(25),PSAT(25),TSAT(25),SSAT(25),RHOSAT(25),
     1EMPT(25),EMPS(25),EMTS(25),EMHS(25),EMRHOS(25),EMTP(25),
     2HSATV(25),SSATV(25),RHOSTV(25),EMHLP(25),EMHVP(25),EMSLP(25),
     3EMSVP(25),EMROLP(25),EMROVP(25),EMPH(25)
C                                                                       HPROP012
C**** P IS THE PRESSURE ARRAY                                           HPROP013
C**** X IS THE INDEPENDENT PROPERTY ARRAY                               HPROP014
C**** Y IS THE DEPENDENT PROPERTY ARRAY                                 HPROP015
C**** N IS THE OF DATA POINTS FOR EACH ISOBAR ARRAY                     HPROP016
C**** A IS PRESSURE                                                     HPROP017
C**** B IS THE SECOND INDEPENDENT VARIABLE                              HPROP018
C**** KJ DETERMINES THE INDEPENDENT PARAMETER USED                      HPROP019
C**** KJ=1,B IS TEMPERATURE                                             HPROP020
C**** KJ NOT=1,B IS SPECIFIC VOLUME,ENTHALPY,ENTROPY OR SONIC VELOCITY  HPROP021
C**** K DETERMINES THE DEPENDENT PARAMETER REQUESTED                    HPROP022
C**** K=1,C IS TEMPERATURE                                              HPROP023
C**** K=2,C IS SPECIFIC VOLUME                                          HPROP024
C**** K=3,C IS ENTHALPY                                                 HPROP025
C**** K=4,C IS ENTROPY                                                  HPROP026
C**** K=5,C IS SONIC VELOCITY                                           HPROP027
C**** C IS THE REQUESTED DEPENDENT PROPERTY                             HPROP028
C**** D IS THE ARRAY OF EMPIRICAL CONSTANTS USED IN THE SATURATED       HPROP029
C**** PRESSURE SUBPROGRAM SVSL                                          HPROP030
C                                                                       HPROP031
      NSAT=22
      JFLG=1                                                            HPROP032
      I=0                                                               HPROP033
      LIMIT=0                                                           HPROP034
C                                                                       HPROP035
C**** SET XMIN=MINIMUM TABULATED PRESSURE                               HPROP036
C                                                                       HPROP037
      XMIN=P(1)                                                         HPROP038
C                                                                       HPROP039
C**** SET XMAX=MAXIMUM TABULATED PRESSURE                               HPROP040
C                                                                       HPROP041
      XMAX=P(25)                                                        HPROP042
   50 I=I+1                                                             HPROP043
C                                                                       HPROP044
C**** SEARCH PRESSURE TABLE FOR VALUE CORRESPONDING TO A                HPROP045
C                                                                       HPROP046
      IF(P(I)-A) 60,80,55                                               HPROP047
C                                                                       HPROP048
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C**** TABULATED PRESSURE IS GREATER THAN A,TEST F[illegible]INIMUM TABLE VALUE HPROP049
C                                                                 HPROP050
   55 IF (I-1) 200,200,150                                        HPROP051
C                                                                 HPROP052
C**** TABULATED PRESSURE IS LESS THAN A,TEST FOR MAXIMUM TABLE VALUE  HPROP053
C                                                                 HPROP054
   60 IF (I-25) 50,250,250                                        HPROP055
C                                                                 HPROP056
C**** TABULATED PRESSURE=A                                        HPROP057
C                                                                 HPROP058
   80 M=N(I)                                                      HPROP059
C                                                                 HPROP060
C**** SET XMIN=MINIMUM TABULATED INDEPENDENT PROP.                HPROP061
C                                                                 HPROP062
      XMIN=X(I,1)                                                 HPROP063
C                                                                 HPROP064
C**** SET XMAX=MAXIMUM TABULATED INDEPENDENT PROP.                HPROP065
C                                                                 HPROP066
      XMAX=X(I,M)                                                 HPROP067
      J=0                                                         HPROP068
   85 J=J+1                                                       HPROP069
C                                                                 HPROP070
C**** SEARCH INDEPENDENT PROPERTY TABLE FOR VALUE CORRESPONDING TO B  HPROP071
C                                                                 HPROP072
      IF (X(I,J)-B) 95,100,90                                     HPROP073
C                                                                 HPROP074
C**** TABULATED PROP. IS GREATER THAN B,TEST FOR MINIMUM TABLE VALUE  HPROP075
C                                                                 HPROP076
   90 IF (J-1) 300,300,110                                        HPROP077
C                                                                 HPROP078
C**** TABULATED PROP. IS LESS THAN B,TEST FOR MAXIMUM TABLE VALUE HPROP079
C                                                                 HPROP080
   95 IF (J-M) 85,350,350
C                                                                 HPROP082
C**** TABULATED PROP=B,SET C=TABULATED VALUE                      HPROP083
C                                                                 HPROP084
  100 C=Y(I,J)                                                    HPROP085
      GO TO 500                                                   HPROP086
C                                                                 HPROP087
C**** INTERPOLATE ALONG ISOBAR I FOR C                            HPROP088
C                                                                 HPROP089
  110 C=Y(I,J-1)+(B-X(I,J-1))/(X(I,J)-X(I,J-1))*(Y(I,J)-Y(I,J-1)) HPROP090
      GO TO 500                                                   HPROP091
C                                                                 HPROP092
C**** A LIES BETWEEN TWO TABULATED ISOBARS,INTERPOLATE ALONG EACH ISOBARHPROP093
C**** FOR PROPER B                                                HPROP094
C                                                                 HPROP095
  150 NM=I-1                                                      HPROP096
      DO 180 IK=NM,I                                              HPROP097
      M=N(IK)                                                     HPROP098
      JK=IK-I+2                                                   HPROP099
      J=0
C                                                                 HPROP101
C**** SET XMIN=MINIMUM TABULATED INDEPENDENT PROP.                HPROP102
C                                                                 HPROP103
      XMIN=X(IK,1)                                                HPROP104
C                                                                 HPROP105
C**** SET XMAX=MAXIMUM TABULATED INDEPENDENT PROP.                HPROP106
C                                                                 HPROP107
      XMAX=X(IK,M)                                                HPROP108
```

```
  155 J=J+1                                                            HPROP109
C                                                                      HPROP110
C**** SEARCH INDEPENDENT PROPERTY TABLE FOR VALUE CORRESPONDING TO B    HPROP111
C                                                                      HPROP112
      IF (X(IK,J)-B) 165,170,160                                       HPROP113
C                                                                      HPROP114
C**** TABULATED PROP. IS GREATER THAN B,TEST FOR MINIMUM TABLE VALUE    HPROP115
C                                                                      HPROP116
  160 IF (J-1) 300,300,550                                             HPROP117
C                                                                      HPROP118
C**** TABULATED PROP. IS LESS THAN B,TEST FOR MAXIMUM TABLE VALUE       HPROP119
C                                                                      HPROP120
  165 IF (J-N(IK)) 155,510,510                                         HPROP121
C                                                                      HPROP122
C**** TABULATED VALUE=B,SET CP=TABULATED VALUE                          HPROP123
C                                                                      HPROP124
  170 CP(JK)=Y(IK,J)                                                   HPROP125
      GO TO 180                                                        HPROP126
C                                                                      HPROP127
C**** MAXIMUM TABULATED VALUE IS LESS THAN B,IF ISOBAR LESS THAN A SET  HPROP128
C**** LIMIT=1 AND CONTINUE,IF ISOBAR GREATER THAN A SET ERROR FLAG AND  HPROP129
C**** RETURN                                                           HPROP130
C                                                                      HPROP131
  510 IF (JK-1) 520,520,350                                            HPROP132
  520 LIMIT = 1                                                        HPROP133
      GO TO 180
C                                                                      HPROP135
C**** CHECK LIMIT SET=1                                                 HPROP136
C                                                                      HPROP137
  550 IF (LIMIT) 175,175,600                                           HPROP138
C                                                                      HPROP139
C**** LIMIT=0,NORMAL INTERPOLATION SEQUENCE ON ISOBAR                   HPROP140
C                                                                      HPROP141
  175 CP(JK)=Y(IK,J-1)+(B-X(IK,J-1))/(X(IK,J)-X(IK,J-1))*              HPROP142
     1(Y(IK,J)-Y(IK,J-1))                                              HPROP143
  180 CONTINUE                                                         HPROP144
C                                                                      HPROP145
C**** NORMAL INTERPOLATION FOR C                                        HPROP146
C                                                                      HPROP147
      C=CP(1)+(A-P(I-1))/(P(I)-P(I-1))*(CP(2)-CP(1))                   HPROP148
      GO TO 500                                                        HPROP149
C                                                                      HPROP150
C**** LIMIT=1,CHECK FOR TEMPERATURE AS INDEPENDENT PROPERTY             HPROP151
C                                                                      HPROP152
  600 IF (KJ.EQ.1) GO TO 610
      IF (KJ.EQ.3) GO TO 611
      IF (KJ.EQ.4) GO TO 612
      GO TO 350
C                                                                      HPROP154
C**** TEMPERATURE ,S INDEPENDENT PROPERTY,FIND CORRESPONDING VAPOR      HPROP155
C**** PRESSURE                                                         HPROP156
C                                                                      HPROP157
  610 CALL SPLNT(NSAT,TSAT,PSAT,EMPT,B,PSL)
      GO TO 615
  611 CALL SPLNT(NSAT,HSAT,PSAT,EMPH,B,PSL)
      GO TO 615
  612 CALL SPLNT(NSAT,SSAT,PSAT,EMPS,B,PSL)
  615 GO TO (620,620,630,640,645),K
C                                                                      HPROP160
C**** FIND STAURATED LIQUID SPEC. VOL. CORRESPONDING TO TEMPERATURE=B   HPROP161
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      C                                                                 HPROP162
  620 CALL SPLNT(NSAT,PSAT,RHOSAT,EMROLP,PSL,C[illegible]))
      CP(2)=1./CP(2)
      GO TO 650                                                         HPROP164
      C                                                                 HPROP165
      C**** FIND SATURATED LIQUID ENTHALPY CORRESPONDING TO TEMPERATURE=B HPROP166
      C                                                                 HPROP167
  630 CALL SPLNT(NSAT,PSAT,HSAT,EMHLP,PSL,CP(2))
      GO TO 650                                                         HPROP169
      C                                                                 HPROP170
      C**** FIND SATURATED LIQUID ENTROPY CORRESPONDING TO TEMPERATURE=B  HPROP171
      C                                                                 HPROP172
  640 CALL SPLNT(NSAT,PSAT,SSAT,EMSLP,PSL,CP(2))
      GO TO 650                                                         HPROP174
      C                                                                 HPROP175
      C**** SET SATURATED LIQUID SONIC VELOCITY                          HPROP176
      C                                                                 HPROP177
  645 CP(2)=3940.                                                       HPROP178
      C                                                                 HPROP179
      C**** INTEPOLATE FOR CP ON ISOBAR GREATER THAN A                   HPROP180
      C                                                                 HPROP181
  650 CP(1)=Y(I,J-1)+(B-X(I,J-1))*(Y(I,J)-Y(I,J-1))/(X(I,J)-X(I,J-1))   HPROP182
      C                                                                 HPROP183
      C**** INTEPOLATE FOR C USING SATURATED CONDITIONS                  HPROP184
      C                                                                 HPROP185
      C=CP(1)+(A-P(I))*(CP(2)-CP(1))/(PSL-P(I))                         HPROP186
      GO TO 500                                                         HPROP187
      C                                                                 HPROP188
      C**** MINIMUM TABULATED PRESSURE IS GREATER THAN A,SET ERROR FLAG  HPROP189
      C                                                                 HPROP190
  200 JFLG=2                                                            HPROP191
      GO TO 500                                                         HPROP192
      C                                                                 HPROP193
      C**** MAXIMUM TABULATED PRESSURE IS LESS THAN A,SET ERROR FLAG     HPROP194
      C                                                                 HPROP195
  250 JFLG=3                                                            HPROP196
      GO TO 500                                                         HPROP197
      C                                                                 HPROP198
      C**** MINIMUM TABULATED INDEPENDENT PROP. IS GREATER THAN B,SET ERROR HPROP199
      C**** FLAG                                                        HPROP200
      C                                                                 HPROP201
  300 JFLG=4                                                            HPROP202
      GO TO 500                                                         HPROP203
      C                                                                 HPROP204
      C**** MAXIMUM TABULATED INDEPENDENT PROP. IS LESS THAN B,SET ERROR FLAG HPROP205
      C                                                                 HPROP206
  350 JFLG=5                                                            HPROP207
  500 RETURN                                                            HPROP208
      END                                                               HPROP20
  NTABS  10
  TAPE 1,'B'     . KEN KIRK 'S TAPE
  TAPE 2,'K'     . OUTPUT TAPE FOR KIRK.
  READ 5
  PRINT 6
  END
```

2.   11:38:20

END CUR

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN I

08 DECEMBER 1971

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I. PRE-OPERATIONAL PHASE

During this phase verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switched to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

12007	Turn off the HPR, EPR and MER fans.
12012	Close Q-113.
12022	Pressurize the room inerting header (Bottles 13, 14, 15, and 16). a. Open Q-213 CEL valve.
12140	Begin inerting the following areas: HPR (G-451/452) CEL (G-456) EPR (G-455) a. Report when concentrations reach 3%. b. Maintain 0_2 concentrations between 3 and 5%.

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G. CHECK THE SHUTDOWN CHAIN.

12167	Bypass all the inputs to the Shutdown Chain.
12169	Reset the Shutdown Chain.
12172	Switch the following valves to Normal:
	C-221 C-8
12176	Close C-221.
12210	C-8 switched to override.
12214	Push the Emergency Shutdown Button.
	a. Report valve action.
12221	Reset the Shutdown Chain.
12228	Switch C-8 to POSITION Control and Close.
12232	Switch C-231 to POSITION Control and Close.
12240	Switch the shutdown outputs to Override.
12278	Close Q-213.

H. PERFORM A VOLTAGE CALIBRATION.

12681-12781	Calibration interval.
13201-13301	Recalibration interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4/5 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 40 psig.

A. PROCEED WITH HEADER PRESSURIZATION

14676	Report on room inerting.
14679	Open K-50, K-153.
14686	Open L-50.
14691	Close Q-120, Q-150, Q-101 thru Q-112.

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14718 Pressurize the helium header.

a. QP-20: 3050 psig.

14764 Pressurize the hydrogen header.

a. QP-30: 3050 psig.

B. PROCEED WITH THE CHILLDOWN

14927 Issue the ready order.
14930 Close K-153, K-262, K-403, C-221.
14983 Open K-2, K-62.
15003 Open C-214, K-3, C-8, C-231.
15050 Select Dewar 5 pressure feedback.
15055 In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
15186 Use C-111 to chill CT-111.

a. Monitor CF-6.

15371 When CT-3 is chilled, close K-3.
15492 Open K-130.
15900 When CT-111 is chilled, set C-111 to maintain CP-9 < 60 psig.
15907 Use C-106 to chill CT-106.

a. Vary KF-130 between 1 and 5 lbs/sec.

15978 When CT-106 is chilled, Open C-106.
16021 Close K-130.
16055 When CP-8 is less than 10 psig Close C-106, C-214; Open C-4.

a. PMP: Report CP-8.

16122 Open K-130.
16170 Open C-111.
16178 Use C-8 to chill the pump.

a. Vary KF-130 between 1 and 5 lbs/sec.

16253	When CT-220 is chilled, open C-221.
	a. PMP: Report CT-220.
16347	Close C-231.
16418	At TD command, set C-111 to maintain CP-9 $<$ 60 psig.
16527	Start 900 second timer.
16537	Switch K-53 to POSITION Control and Close.
16575	Close K-62.
16580	Open K-153.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

16664	Report electric drive alarm status.
16667	Start synchronous motor.
16742	Start blowers.
16750	Establish and maintain unity power factor. (120 Amps
16800	Increase D. C. motor field to 13 amps, then decrease to 5 amps.
16810	Raise and lower armature voltage.
16890	D. C. motor field reduced to 5 amps.

D. PROCEED WITH OVERSPEED TRIP CHECK.

17460	Set the overspeed trip pot to 105 divisions (4,000 rpm).
17472	Raise synchronous motor field to 120 amps.
17474	Raise D. C. motor field to 13 amps.
17492	Close K-153.
17498	Select Dewar 5 pressure feedback.
17510	Open K-62.
17514	In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
17556	Switch the following shutdown output to NORMAL:
	Speed Rate
17566	Activate the following inputs to the shutdown chain:

UQ-2	CP-220
JP-101/201	CP-505

17583	Open K-3.
17594	Close K-130.
17607	Open C-11.
17624	Close C-111.
17637	Open K-161.
17654	Open C-221.
17656	Close C-231.
17664	Use C-8 to chill the pump.
17666	Set C-8 to 50%. (Q/N = .22)
17673	Set C-106 to 30%.
17690	When the pump is chilled, close the D. C. breakers.
	a. PMP: Report pump chill.
17708	Activate CT-507 input to the shutdown chain.
17716	Speed increased to 3,000 rpm.
17785	Speed decreased to 0 rpm.
17860	Dewar transfer.
18000	Remove pressure off line.
18900	Entry on MDB for oil lube temperature check and leak surveillance.
19340	Re-entry crew returned to LCR.
19504	Set the overspeed trip pot to 105 divisions (4,000 rpm).
19508	Raise synchronous motor field to 120 amps.
19510	Raise D. C. motor field to 13 amps.
19516	Close K-153.
19520	Select Dewar 4 pressure feedback.
19525	Open K-61.
19530	In K-53 PRESSURE Control, establish 40 psig in Dewar 4.
19540	Switch the following shutdown output to NORMAL: Speed Rate
19550	Activate the following inputs to the shutdown chain: UQ-2 CP-220 JP-101/201 CP-505

19556	Open K-3.
19560	Close K-130.
19563	Open C-12.
19578	Close C-111.
19580	Open K-162.
19586	Open C-221.
19590	Close C-231.
19597	Use C-8 to chill the pump.
19598	Set C-8 to 50%. (Q/N = .22)
19638	Set C-106 to 30%.
19684	When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

19690	Activate CT-507 input to the shutdown chain.
19699	Speed increased to 3,000 rpm.
19780	Reset the shutdown chain.
19781	Bypass UQ-2 shutdown input.
19782	Activate UQ-3 shutdown input.
19840	In MANUAL Control, increase speed to produce overspeed trip (5,500 rpm).
19848	When speed is zero, open the D.C. breakers.
19854	Bypass all the shutdown inputs.
19858	Reset the shutdown chain.
19861	Close C-106.
19867	Open K-130.
19892	Close K-3.
19907	When KF-130 is stable, close K-130 in 10% steps.
19960	60%
19970	50%
19980	40%
20000	30%
20010	20%
20030	10%
20045	5%
20055	0%

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20058	Open and close K-3 in 10% steps.
20070	10%
20080	20%
20090	30%
20100	40%
20110	50%
20120	60%
20130	70%
20135	80%
20145	90%
20150	100%
20205	0%
20207	Open K-3.
20211	Use C-111 to maintain CP-9 between 60 and 100 psig.
20220	Close C-12.
20224	Close K-162.
20238	Switch K-53 to POSITION Control and close.
20250	Close K-61.
20255	Open K-153.
20262	Decrease D. C. motor field to less than 5 amps.
20267	Switch the shutdown outputs to OVERRIDE.

III. GREEN RUN

During this phase, the pump will be operated along a Q/N of .22 to a maximum speed of 19,000 rpm.

A. PROCEED WITH THE GREEN RUN.

20960	Issue the ready order.
20966	Set the overspeed trip pot to 550 divisions (21,000 rpm).
20982	Raise the synchronous motor field to 120 amps.
20987	Raise the D. C. motor field to 13 amps.
20988	Close K-153.
21004	Select Dewar 4 pressure feedback.
21013	Open K-61.
21024	Switch the following shutdown outputs to NORMAL: Speed Rate C-221

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21031 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

21040 In K-53 PRESSURE Control, establish 40 psig in Dewar 4.

21060 Use C-106 to chill CT-106.

21090 At CTO command, Open C-12; Close C-111.

21100 Open K-162.

21107 Open C-221.

21108 Close C-231.

21112 Set C-8 to 50% (Q/N = .22).

21176 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

21182 Activate the following inputs to the shutdown chain:

D. C. Breakers
CT-507

21240 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

21280 Meter not indicating true Q/N.

21350 Decrease speed to 0 rpm.

21360 Open D. C. breakers.

21370 Outputs to shutdown chain bypassed.

21375 Shutdown chain reset.

21380 Use C-111 to maintain CP-9 between 60 and 100 psig.

21385 Close C-12.

21395 Switch K-53 to POSITION Control and close.

21400 Close K-61.

21410 Open K-153.

21415 Decrease D. C. motor field to less than 5 amps.

21420 Switch the shutdown outputs to OVERRIDE.

21470 Data hold (UQ-1 giving false reading).

B. PROCEED WITH THE GREEN RUN.

22234	Set the overspeed trip pot to 550 divisions (21,000 rpm).
22240	Raise the synchronous motor field to 120 amps.
22244	Raise the D.C. motor field to 13 amps.
22248	Close K-153.
22252	Select Dewar 4 pressure feedback.
22256	Open K-61.
22271	Switch the following shutdown outputs to NORMAL: Speed Rate C-221
22276	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-62
22290	In K-53 PRESSURE Control, establish 40 psig in Dewar 4.
22310	Use C-106 to chill CT-106.
22328	At CTO command Open C-12; Close C-111.
22336	Open K-162.
22343	Open C-221.
22346	Close C-231.
22350	Set C-8 to 50% (Q/N = .22).
22434	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.
22476	Activate the following inputs to the shutdown chain: D.C. Breakers CT-507

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22540	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
22570	Use C-8 to decrease Q/N = .15.
22600	Use C-8 to increase Q/N = .25.
22604	Switch Speed Rate Control to HOLD.
22612	Set Speed Rate pot to 80 divisions (400 rpm/sec).
22710	Remain in Manual Control and demand 19,000 rpm.
22770	Bypass the following shutdown inputs:
	CT-507
22780	Decrease speed to zero.
22781	Open D.C. breakers.
22796	Bypass all the shutdown inputs.
22797	Reset the shutdown chain.
22800	Use C-111 to maintain CP-9 between 60 and 100 psig.
22804	Close C-12.
22810	Switch K-53 to POSITION Control and close.
22824	Close K-61.
22833	Open K-153.
22837	Decrease D.C. motor field to less than 5 amps.
22848	Switch the shutdown outputs to OVERRIDE.
22880	Data hold and lunch break.
23000	Liquid transfer.

IV. BREAKER TRIP COASTDOWN

During this phase, a pump operating point of 19,000 rpm and Q/N of .22 will be established. Speed will be ramped to 17,000 rpm at various rates. When it is determined which rate gives a D.C. Motor Armature current close to 0 amps, 19,000 rpm will again be established, a down-ramp initiated, then the D.C. breakers opened to initiate an emergency shutdown. The breakers will be opened when the armature current is close to zero.

This phase will provide the non-powered coastdown time required for the D.C. Motors with the pump providing a load.

A. PROCEED WITH COASTDOWN

28570	Rechill system and bring Dewar 5 back on line.
28630	Close K-153.
28638	Select Dewar 5 pressure feedback.
28643	Open K-62.
28650	In K-53 PRESSURE Control, establish 70 psig in Dewar 5.
28710	Use C-111 to rechill system.
29002	Set the overspeed trip pot to 550 divisions (21,000 rpm).
29004	Raise the synchronous motor field to 120 amps.
29010	Raise the D. C. motor field to 13 amps.
29020	In K-53 PRESSURE Control, establish 70 psig in Dewar 5.
29026	Switch the following shutdown outputs to NORMAL: Speed Rate
29031	Activate the following inputs to the shutdown chain: UQ-2 CP-505 UQ-3 CP-220 JP-101/201 KP-61
29050	Use C-106 to chill CT-106.
29076	At CTO command Open C-11; Close C-111.
29096	Open K-161.
29100	Open C-221.
29101	Close C-231.
29106	Set C-8 to 50% (Q/N = .22).
29116	When the pump is chilled, close the D. C. breakers. a. PMP: Report pump chill.
29130	Breaker two opens on close command.
29135	Use C-111 to maintain CP-9 between 80 - 90 psig.

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29140	Close C-11.
29250	Re-entry for checking breakers.
30984	Pressure reduced on lines to standby condition.
33052	Set the overspeed trip pot to 550 divisions (21,000 rpm).
33060	Raise the synchronous motor field to 120 amps.
33064	Raise the D.C. motor field to 13 amps.
33068	Close K-153.
33070	Select Dewar 5 pressure feedback.
33081	Open K-62.
33087	In K-53 PRESSURE Control, establish 50 psig in Dewar 5.
33091	Switch the following shutdown outputs to NORMAL: Speed Rate
33098	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
33135	Use C-106 to chill CT-106.
33155	At CTO command Open C-11; Close C-111.
33180	Open K-161.
33183	Open C-221.
33184	Close C-231.
33188	Set C-8 to 50% (Q/N = .22).
33438	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.
33452	Activate the following inputs to shutdown chain: D.C. Breakers CT-507

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33500	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
33510	Switch C-106 to AUTO.
33516	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
33528	Switch to SPEED Control.
33530	Oscillations in SPEED Control.
33630	Switch to SPEED Control (still have oscillations).
33700	Increase speed to 19,000 rpm in MANUAL Control.
33754	Demand 17,000 rpm in MANUAL Control.
33765	Increase speed to 19,000 rpm in MANUAL Control.
33789	When armature current is zero, open the D.C. breakers.
33806	Bypass all the shutdown inputs.
33808	Reset the shutdown chain.
33810	After reset, set MANUAL Speed Control pot to 50 divisions.
33818	When speed is zero, switch C-106 to RESET.
33834	Use C-111 to maintain CP-9 between 60 and 100 psig.
33836	Close C-11.
33843	Switch K-53 to POSITION Control and close.
33857	Close K-62.
33863	Open K-153.
33866	Decrease D.C. motor field to less than 5 amps.
33870	Switch the shutdown outputs to OVERRIDE.

V. K-3 MAPPING

During this phase, K-3 will be operated with dewar pressures of 60 and 80 psig. The D.C. Breakers will be open and flow will be to the flare through C-106 and C-111. This phase will investigate the ability of K-3 to provide the necessary ΔP's for cavitation testing.

A. PROCEED WITH K-3 MAPPING.

33940	Close K-153.
33945	Select Dewar 5 pressure feedback.
33950	Open K-62.
33960	Close K-162.
33990	In K-53 PRESSURE Control, establish 60 psig in Dewar 5.
34030	Open C-11, Close C-111.
34138	Proceed with K-3 mapping.
34268	Increase KP-62 to 80 psig.
34272	Proceed with K-3 mapping.
34376	Use C-111 to maintain CP-9 between 80 and 100 psig.
34400	Close C-11.
34408	Switch K-53 to POSITION Control and close.
34418	Close K-62.
34427	Open K-153.
34433	Open K-161.

VI. FREQUENCY RESPONSE MEASUREMENTS

During this phase, the pump speed will be increased to 19,000 rpm at a Q/N of .25. C-231 will be set to maintain CP-220 at 45 psig and C-221 will be closed. Frequency response measurements will then be made on Manual VGA Control. C-8 will be set to maintain a Q/N of .25 and the pump speed decreased to zero.

A. PROCEED WITH THE FREQUENCY RESPONSE MEASUREMENTS.

34580	Dewar transfer.
35945	Patch the oscillator to Manual VGA loop.
35950	Set the oscillator amplitude to 2 volts.
35956	Set the overspeed trip pot to 550 divisions (21,000 rpm).
35959	Raise the synchronous motor field to 120 amps.
35968	Raise the D.C. motor field to 13 amps.
35986	Close K-153.
35990	Select Dewar 4 pressure feedback.
35994	Open K-61.

36009 Switch the following shutdown outputs to NORMAL:

Speed Rate
C-221

36014 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

36030 In K-53 PRESSURE Control, establish 50 psig in Dewar 4.
36031 Use C-106 to chill CT-106.
36070 At CTO command Open C-12; Close C-11.
36073 Open K-162.
36077 Open C-221.
36080 Close C-231.
36087 Set C-8 to 55% (Q/N = .25).
36161 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

36166 Activate the following inputs to the shutdown chain:

D.C. Breakers
CT-507

36190 In MANUAL Control, establish 10,000 rpm at a Q/N = .25.
36196 Switch C-106 to AUTO.
36200 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

36206 Open C-231.
36226 Close C-221.

36250	Use C-231 to establish and maintain 45 psig at CP-220.
36260	Establish 19, 000 rpm in Manual Control.
36266	Use C-8 to maintain Q/N = .25.
36302	Proceed with frequency response measurements. (Manual VGA)
36474	Unpatch the oscillator from Manual VGA loop.
36504	Open C-221.
36506	Close C-231.
36511	Bypass the following shutdown inputs: CT-507 Q/N High Q/N Low
36518	Switch C-106 to RESET.
36523	Decrease speed to zero.
36531	Open the D. C. breakers.
36543	Bypass all the shutdown inputs.
36547	Reset the shutdown chain.
36550	Use C-111 to maintain CP-9 between 60 and 100 psig.
36563	Close C-12.
36568	Switch K-53 to POSITION Control and close.
36572	Close K-61.
36576	Open K-153.
36580	Decrease D. C. motor field to below 5 amps.
36588	Switch the shutdown outputs to OVERRIDE.

VII. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

37120	Issue the ready order.
37122	Open L-251.
37130	Close L-261, L-153.
37136	Open L-61, L-301, L-330.
37158	Open L-331, X-301.
37191	Close K-401.

37210	Use K-161/162 to vent Dewar 4/5.
37235	Use L-53 in POSITION Control to establish and maintain 30 psig in Dewar 1.
37266	When LP-61 is greater than KP-61/62, Open K-301/302.
37301	When LH_2 transfer is complete, Close K-301/302.
41814	Transfer complete.

VIII. FREQUENCY RESPONSE MEASUREMENTS

During this phase, the pump speed will be increased to 19,000 rpm at a Q/N of .25. C-231 will be set to maintain CP-220 at 45 psig and C-221 will be closed. Frequency response measurements will then be made on C-231 POSITION. C-8 will be set to maintain a Q/N of .25 and the pump speed decreased to zero.

A. PROCEED WITH THE FREQUENCY RESPONSE MEASUREMENTS.

42330	Patch the oscillator to C-231 POSITION.
42336	Set the oscillator amplitude to 1 volt.
42350	Set the overspeed trip pot to 550 divisions (21,000 rpm).
42362	Raise the synchronous motor field to 120 amps.
42372	Raise the D. C. motor field to 13 amps.
42377	Close K-153.
42384	Select Dewar 5 pressure feedback.
42388	Open K-62.
42440	Switch the following shutdown outputs to NORMAL: Speed Rate C-221
42450	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61

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42480 In K-53 PRESSURE Control, establish 50 psig in Dewar 5.
42590 Use C-106 to chill CT-106.
42610 At CTO command, Open C-11, Close C-111.
42616 Open K-161.
42624 Open C-221.
42626 Close C-231.
42634 Set C-8 to 60% (Q/N = .25).
42770 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

42774 Activate the following inputs to the shutdown chain:

D.C. Breakers
CT-507

42818 In MANUAL Control, establish 10,000 rpm at a Q/N = .25.
42820 Switch C-106 to AUTO.
42828 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

42832 Open C-231 to 10%.
42846 Close C-221.
42858 Use C-231 to establish and maintain 45 psig at CP-220.
42920 In Manual Control, demand 19,000 rpm.
42925 Use C-8 to maintain Q/N = .25.
42978 Proceed with frequency response measurements. (C-231 POSITION)

B. EMERGENCY SHUTDOWN CHECK

43143 Controlled shutdown CTO Manual from 19,000 rpm at approximately 2,000 rpm/sec.

IX. FREQUENCY RESPONSE MEASUREMENTS

During this phase, the pump speed will be increased to 16,000 rpm at a Q/N of .22. C-231 will be set to maintain CP-220 at 45 psig and C-221 will be closed. Frequency response measurements will then be made on C-8 POSITION. C-8 will be set to maintain a Q/N of .25 and the pump speed decreased to zero.

A. PROCEED WITH THE FREQUENCY RESPONSE MEASUREMENTS.

43550	Dewar transfer.
44293	Patch the oscillator to C-8 POSITION.
44303	Set the oscillator amplitude to 1 volt.
44312	Set the overspeed trip pot to 550 divisions (21,000 rpm).
44317	Raise the synchronous motor field to 120 amps.
44334	Raise the D. C. motor field to 13 amps.
44340	Close K-153.
44344	Select Dewar 4 pressure feedback.
44348	Open K-61.
44362	Switch the following shutdown outputs to NORMAL: Speed Rate C-221
44366	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-62
44380	In K-53 PRESSURE Control, establish 50 psig in Dewar 4.
44395	Use C-106 to chill CT-106.
44410	At CTO command Open C-12, Close C-111.
44416	Open K-162.
44418	Open C-221.
44426	Close C-231.
44434	Set C-8 to 55% (Q/N = .22).

44510	When the pump is chilled, close the D. C. breakers.
	a. PMP: Report pump chill.
44514	Activate the following inputs to the shutdown chain:
	D. C. Breakers CT-507
44555	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
44559	Switch C-106 to AUTO.
44563	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
44576	Open C-231 to 50 pot divisions.
44584	Close C-221.
44586	Use C-231 to establish and maintain 45 psig at CP-220.
44638	In Manual Control, demand 16,000 rpm.
44640	Use C-8 to maintain Q/N = .22.
44672	Proceed with frequency response measurements. (C-8 POSITION)

B. EMERGENCY SHUTDOWN CHECK

44941	Controlled shutdown CTO Manual from 21,000 rpm at approximately 4,000 rpm/sec.
44961	Switch C-106 to RESET.
44967	Open the D. C. breakers.
44972	Bypass all the shutdown inputs.
44975	Reset the shutdown chain.
44978	Use C-111 to maintain CP-9 between 60 and 100 psig.
44982	Close C-12.
44984	Switch K-53 to POSITION Control and close.

45000	Close K-61.
45006	Open K-153.
45012	Decrease D. C. motor field to below 5 amps.
45014	Switch the shutdown outputs to OVERRIDE.

X. C-8 AND C-106 MAPPING

During this phase, a pump operating condition of 19,000 rpm and .22 Q/N will be established. C-231 will be set to maintain 50 psig at CP-220 and C-221 will be closed. C-8 POSITION will be increased to increase the Q/N to .35 or to C-8 maximum position. C-8 will then be closed to provide a Q/N of .10 and opened to a Q/N of .22. C-8 will be closed and C-106 opened simultaneously. C-106 will be mapped between a Q/N of approximately .15 (electrical clamp) to .10. C-8 will then be opened to provide a Q/N of .25 while C-106 is being closed. Pump speed will then be decreased to zero.

A. PROCEED WITH VALVE MAPPING.

45400 Dewar transfer.

45983 Set the overspeed trip pot to 550 divisions (21,000 rpm).

45994 Raise the synchronous motor field to 120 amps.

45997 Raise the D. C. motor field to 13 amps.

45998 Close K-153.

46004 Select Dewar 5 pressure feedback.

46007 Open K-62.

46020 Switch the following shutdown outputs to NORMAL:

Speed Rate
C-221

46024 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

46040 In K-53 PRESSURE Control, establish 60 psig in Dewar 5.

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46050 Use C-106 to chill CT-106.
46062 At CTO command, Open C-11, Close C-111.
46072 Open K-161.
46075 Open C-221.
46080 Close C-231.
46082 Set C-8 to 55% (Q/N = .22).
46113 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

46117 Activate the following inputs to the shutdown chain:

D.C. Breakers
CT-507

46150 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
46153 Switch C-106 to AUTO.
46157 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

46160 Open C-231 to 52 pot divisions.
46168 Close C-221.
46190 Use C-231 to maintain 50 psig at CP-220.
46250 In Manual Control, demand 19,000 rpm.
46253 Use C-8 to maintain Q/N = .22.
46340 Use C-8 to increase Q/N to .35 or the C-8 clamp. (Clamp at .32)

a. Use .02 increments.

46400 Use C-8 to decrease Q/N to .20.

a. Use .03 increments.

46406 Switch C-106 to RESET.
46410 Bypass Q/N Low.

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46455	Use C-8 to decrease Q/N to .10.
	a. Use .03 increments.
46490	Use C-106 to increase Q/N to .25. (Clamp at .22)
46540	Close C-8.
46580	Use C-106 to decrease Q/N to .10.
	a. Use .01 increments.
46590	Open C-106 (Q/N = .15).
	a. Use .02 increments.
46630	Use C-8 to increase Q/N to .25.
46640	Close C-106.
46699	Switch C-106 to AUTO.
46704	Activate Q/N Low.

B. CONTROLLED SHUTDOWN

46723	CTO Manual from 19,000 rpm at approximately 4,000 rpm/sec.
46726	Open C-221.
46737	Bypass the following shutdown inputs:
	CT-507 Q/N High Q/N Low
46745	Close C-231.
46746	Switch C-106 to RESET.
46748	Open the D.C. breakers.
46750	Bypass all the shutdown inputs.
46756	Reset the shutdown chain.
46757	Use C-111 to maintain CP-9 between 60 and 100 psig.
46764	Close C-11.
46768	Switch K-53 in POSITION Control and close.

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46786	Close K-62.
46790	Open K-153.
46795	Decrease D.C. motor field to below 5 amps.
46798	Switch the shutdown outputs to OVERRIDE.

XI. MINIMUM SHUTDOWN PHASE

46910

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A. POST VOLTAGE CALIBRATION

47681-47781 Calibration Interval

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END

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APPENDIX C

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN I

10 DECEMBER 1971

I. PRE-OPERATIONAL PHASE

During this phase verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switched to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

04787	Turn off the HPR, EPR and MER fans.
04930	Close Q-113.
04940	Pressurize the room inerting header (Bottles 13, 14, 15, and 16).
	a. Report QP-50 1650 psig.
	b. Open CEL valve, use Q-213.
04994	Begin inerting the following areas:
	HPR (G-451/452)
	CEL (G-456) (G-457)
	EPR (G-455)

F

a. Report when concentrations reach 3%.
b. Maintain O_2 concentrations between 3 and 5%.

B. CHECK THE SHUTDOWN CHAIN.

05012	Bypass all the inputs to the Shutdown Chain.
05018	Reset the Shutdown Chain.
05021	Switch the following valves to Normal:
	C-221
	C-8
05026	Close C-221.
05031	Switch C-8 to Q/N Control.
05057	Push the Emergency Shutdown Button.
	a. Report valve action.
05062	Reset the Shutdown Chain.
05074	Switch C-8 to POSITION Control and CLOSE.
05075	Switch the shutdown outputs to Override.
05076	Close C-221.

H. PERFORM A VOLTAGE CALIBRATION.

05222-05322 Calibration Interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4/5 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 60 psig.

A. PROCEED WITH HEADER PRESSURIZATION.

07739	Report on room inerting.
07746	Open K-50, K-153.
07754	Open L-50.
07760	Close Q-120, Q-150, Q-101 thru Q-112.
07783	Pressurize the helium header.
	a. QP-20: 2900 psig.
08023	Pressurize the hydrogen header with Bottle 4.
	a. QP-30: 3000 psig.

B. PROCEED WITH THE CHILLDOWN.

08020	Close K-153, K-262, K-403, K-402, C-221.
08058	Open K-2, K-62.
08087	Open C-214, C-8.
08113	Select Dewar 5 pressure feedback.
08150	In K-53 PRESSURE Control, establish 60 psig in Dewar 5.
08158	Open C-111.
08217	Use K-130 to chill KT-130.
	a. Monitor CF-6.
08610	When KT-130 is chilled, close K-130.
08613	Close K-130.
08630	Open K-3 to chill CT-3 to 100°R.
08920	Close K-3.
08931	Switch K-53 to POSITION Control and close.
08940	Close K-62.
08946	Open K-153.
08960	Standby for re-entry (Hydrogen decay check).
09211	Valves closed on helium, nitrogen and hydrogen header.
10120	Pressurize the hydrogen header with Bottle 5.
	a. QP-30: 3100 psig.

10213 Repressure helium and nitrogen header.

a. QP-20: 2900 psig.

10278 Close K-153.
10280 Open K-62.
10295 In K-53 PRESSURE Control, establish 60 psig in Dewar 5.
10420 Open K-3 to chill CT-3 to 100°R.
11050 Close K-3.
11060 Use K-130 to chill KT-130.

a. Monitor CF-6.

11086 When KT-130 is chilled, close K-130.
11424 Close K-130.
11527 When CP-8 is less than 10 psig, Open C-231, C-4; Close C-214.

a. PMP: Report CP-8.

11564 Use K-130 to chill the pump.

a. CTO monitor CF-6.

12168 When CT-220 is chilled, Open C-221 and Close C-231.
12251 Open C-231, Close C-221.
12390 Pump reported chilled.
12610 Use C-106 to chill CT-106.
12621 Open K-130.
12660 Close K-130
12670 Slowly Open K-3.
12771 When CT-111 is chilled, set C-111 to maintain CP-9 $<$ 70-80 psig.
12784 Start 900 second timer.
12791 Switch K-53 to Postion Control and Close.
12806 Close K-62.
12811 Open K-153.
12820 Open C-221, Close C-231.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

12889	Report electric drive alarm status.
12902	Start synchronous motor.
12986	Start blowers.
12994	Establish and maintain unity power factor. (120 Amps)
13020	Increase D.C. motor field to 13 amps, then decrease to 5 amps.
13060	Raise and lower armature voltage.
13153	5 Amps set on D.C. field.

D. PROCEED WITH OVERSPEED TRIP CHECK.

13867	Set the overspeed trip pot to 105 divisions (4,000 rpm).
13872	Raise synchronous motor field to 120 amps.
13876	Raise D.C. motor field to 13 amps.
13886	Select Dewar 5 pressure feedback.
13888	Close K-153.
13891	Open K-62.
13896	In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
13944	Switch the following shutdown output to NORMAL: Speed Rate
13948	Activate the following inputs to the shutdown chain: UQ-2 CP-220 JP-101/201 CP-505
13960	Open K-3.
13963	Close K-130.
13967	Open C-11.
13974	Close C-111.
13982	Open K-161.
14000	Open C-221.
14001	Close C-231.
14008	Use C-8 to chill the pump.

14020	Set C-8 to 55%. (Q/N = .22)
14068	Set C-106 to 20%.
14214	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
14220	Activate CT-507 input to the shutdown chain.
14280	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
14292	Reset the shutdown chain.
14294	Bypass UQ-2 shutdown input.
14295	Activate UQ-3 shutdown input.
14303	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm). (No trip).
14444	When speed is zero, open the D.C. breakers.
14452	Bypass all the shutdown inputs.
14456	Reset the shutdown chain.
14460	Close C-106.
14477	Use C-111 to maintain CP-9 between 60 and 100 psig.
14481	Close C-11.
14494	Close K-161.
14508	Switch K-53 to POSITION Control and close.
14520	Close K-62.
14525	Open K-153.
14528	Decrease D. C. motor field to less than 5 amps.
14531	Switch the shutdown outputs to OVERRIDE.

III. SPEED CONTROL FREQUENCY RESPONSES

A. PROCEED WITH THE GREEN RUN

15424	Set the overspeed trip pot to 105 divisions (4,000 rpm).
15432	Raise the synchronous motor field to 120 amps.
15434	Raise the D.C. motor field to 13 amps.
15438	Close K-153.

15443 Select Dewar 5 pressure feedback.

15447 Open K-62.

15453 In K-53 PRESSURE Control, establish 40 psig in Dewar 5.

15458 Switch the following shutdown outputs to NORMAL:

Speed Rate
C-221

15476 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

15500 Open C-111 to maintain CF-6 at 5 lb/sec.

15680 Use C-106 to chill CT-106.

15970 Dewar transfer.

16464 Patch the oscillator to the speed loop.

16488 Set the oscillator amplitude to 1 volt.

16493 Set the overspeed trip pot to 105 divisions (4,000 rpm).

16498 Raise the synchronous motor field to 120 amps.

16597 Raise the D. C. motor field to 13 amps.

16601 Close K-153.

16605 Select Dewar 4 pressure feedback.

16616 Open K-61.

16622 In K-53 PRESSURE Control, establish 40 psig in Dewar 4.

16640 Switch the following shutdown outputs to NORMAL:

Speed Rate
C-221

16644 Activate the following inputs to the shutdown chain:

JP-101/201	CP-505
CP-220	KP-62

16656	Use C-106 to chill CT-106.
16681	At CTO command Open C-12, Close C-111.
16704	Open K-162.
16708	Open C-221.
16710	Close C-231.
16714	Set C-8 to 60% (Q/N = .25).
16870	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
16876	Activate the following inputs to the shutdown chain:
	D.C. Breakers CT-507
16939	Activate UQ-2 and UQ-3 inputs.
16940	Set overspeed trip pot to 28,000 rpm (730 pot divisions).
16945	In MANUAL Control, establish 10,000 rpm at a Q/N = .25.
16947	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
16950	Switch C-106 to AUTO.
16951	Open C-231 to 60 pot divisions.
16958	Close C-221.
16963	Use C-231 to establish and maintain 60 psig at CP-220.
17030	Increase speed to 19,000 rpm.
17070	CP-220 reduced to 12 psig.
17160	Increase speed to 23,000 rpm.
17170	Use C-8 to maintain Q/N = .25.
17235	Increase speed to 26,000 rpm.
17255	Controlled CTO-ESD (Dewar level in Dewar 4 not indicating properly).

IV. SPEED CONTROL FREQUENCY RESPONSE

A. PROCEED WITH THE GREEN RUN

19776	Set the overspeed trip pot to 550 divisions (21,000 rpm).
19786	Patch oscillator input to speed loop.
19796	Set oscillator amplitude to 1 volt.
19800	Raise the synchronous motor field to 120 amps.
19805	Raise the D.C. motor field to 13 amps.
19806	Close K-153.
19810	Select Dewar 5 pressure feedback.
19815	Open K-62.
19820	In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
19824	Switch the following shutdown outputs to NORMAL: Speed Rate C-221
19830	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
19920	Use C-106 to chill CT-106.
19942	At CTO command Open C-11, Close C-111.
19961	Open K-161.
19968	Open C-221.
19969	Close C-231.
19976	Set C-8 to 60% (Q/N = .25).
20102	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.

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20108	Activate the following inputs to the shutdown chain: D.C. Breakers CT-507
20155	In MANUAL Control, establish 10,000 rpm at a Q/N = .25.
20158	Switch C-106 to AUTO.
20162	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
20166	Open C-231 to 60 pot divisions.
20174	Close C-221.
20180	Use C-231 to establish and maintain 60 psig at CP-220.
20245	Increase speed to 19,000 rpm.
20262	Use C-8 to maintain Q/N = .25.
20268	Switch speed rate control to RUN.
20270	Switch to speed control.
20280	Frequency response measurements.
20438	Push shutdown button.
20454	Open D. C. breakers.
20461	Bypass all the shutdown inputs.
20464	Reset the shutdown chain.
20473	Switch C-106 to RESET.
20478	Use C-111 to maintain CP-9 between 60 and 100 psig.
20480	Close C-11.
20482	Switch K-53 to POSITION Control and close.
20496	Close K-62.
20501	Open K-153.
20506	Decrease D. C. motor field to less than 5 amps.
20510	Switch the shutdown outputs to OVERRIDE.
20630	Liquid transfer.

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V. FREQUENCY RESPONSE MEASUREMENTS

During this phase, the pump speed will be increased to 19,000 rpm at a Q/N of .25. C-231 will be set to maintain CP-220 at 20 psig and C-221 will be closed. Frequency response measurements will then be made on C-8 Q/N Control. C-8 will be set to maintain a Q/N of .25 and the pump speed decreased to zero.

A. PROCEED WITH THE FREQUENCY RESPONSE MEASUREMENTS.

21632	Patch the oscillator to C-8 Q/N.
21638	Set the oscillator amplitude to 1 volt.
21644	Set the overspeed trip pot to 550 divisions (21,000 rpm).
21648	Raise the synchronous motor field to 120 amps.
21651	Raise the D.C. motor field to 13 amps.
21662	Close K-153.
21667	Select Dewar 4 pressure feedback.
21673	Open K-61.
21677	In K-53 PRESSURE Control, establish 40 psig in Dewar 4.
21688	Switch the following shutdown outputs to NORMAL: Speed Rate C-221 C-8
21704	Activate the following inputs to the shutdown chain: UQ-2 CP-505 UQ-3 KP-62 JP-101/201 CP-220
21750	Use C-106 to chill CT-106.
21757	At CTO command Open C-12, Close C-111.
21767	Open K-162.
21773	Open C-221.
21776	Close C-231.
21781	Set C-8 to 60% (Q/N = .25).

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21865	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
21876	Activate the following inputs to the shutdown chain: D.C. Breakers CT-507
21920	In MANUAL Control, establish 10,000 rpm at Q/N = .25.
21923	Switch C-106 to AUTO.
21927	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
21933	Open C-231 to 70 pot divisions.
21935	Close C-221.
21940	Use C-231 to establish and maintain 20 psig at CP-220.
22010	Increase speed to 19,000 rpm.
22030	Switch to Speed Control.
22069	Switch to Q/N Control.
22078	Proceed with frequency response measurements. (C-8 Q/N)
22098	Unpatch the oscillator.
22203	Shutdown.
22240	Liquid transfer.

B. PUMP MAPPING AND SPEED CONTROL FREQUENCY RESPONSE.

23380	Patch the oscillator to the speed loop.
23387	Set the oscillator amplitude to 1 volt.
23396	Set the overspeed trip pot to 550 divisions (21,000 rpm).
23400	Raise the synchronous motor field to 120 amps.
23405	Raise the D.C. motor field to 13 amps.
23412	Close K-153.
23420	Select Dewar 5 pressure feedback.
23424	Open K-62.

23430 In K-53 PRESSURE Control, establish 40 psig in Dewar 5.

23442 Switch the following shutdown outputs to NORMAL:

Speed Rate
C-221

23446 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

23468 Use C-106 to chill CT-106.
23471 At CTO command Open C-11, Close C-111.
23484 Open K-161.
23488 Open C-221.
23490 Close C-231.
23494 Set C-8 to 60% (Q/N = .25)
23566 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

23572 Activate the following inputs to the shutdown chain:

D.C. Breakers
CT-507

23610 In MANUAL Control, establish 10,000 rpm at a Q/N = .25.
23616 Switch C-106 to AUTO.
23619 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

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23626	Open C-231 to 70 pot divisions.
23630	Close C-221.
23632	Use C-231 to establish and maintain 20 psig at CP-220.
23646	Switch C-8 to Q/N.
23666	Switch to Speed Control.
23668	Switch to Hold.
23670	Set Speed Rate pot to 80 divisions (400 rpm/sec).
23690	Demand 19,000 rpm.
23693	Switch to RUN.
23732	Open C-231.
23744	Q/N to POSITION Control.
23774	Frequency response.
23790	Unpatch oscillator.
23843	Use C-8 to increase Q/N to .35.
	a. Use .02 increments.
23870	Use C-8 to decrease Q/N to .25.
23900	Bypass Q/N Low.
23930	Use C-8 to decrease Q/N to .14.
23934	Shutdown - Dewar transfer.

VI. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

23945	Issue the ready order.
23978	Open L-251.
24042	Close L-261, L-153.
24095	Open L-61, L-301, L-330.
24104	Open L-331, X-301.
24116	Close K-401.
24126	Use L-53 in POSITION Control to establish and maintain 65 psig in Dewar 1.
24140	When LP-61 is greater than KP-61/62, Open K-301/302.

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24146	When LH_2 transfer is complete, Close K-301/302.
28220	Transfer complete.

VII. PUMP MAPPING #1

During this phase, an initial pump operating condition of 19,000 rpm and .25 Q/N will be established. Using C-8 in Q/N Control to vary the system impedance, the pump will be mapped at the following:

SPEED	Q/N
23,000	.14 to .35
26,000	.17 to .35

At 26,000 rpm an emergency shutdown will be initiated. Dewar pressure will be maintained at 40 psig.

A. PROCEED WITH PUMP MAPPING.

28388	Bottle six on line.
28542	Issue the ready order.
28550	Set the overspeed trip pot to 730 divisions (28,000 rpm).
28554	Raise the synchronous motor field to 120 amps.
28557	Raise the D.C. motor field to 13 amps.
28588	Close K-153.
28594	Select Dewar 4 pressure feedback.
28600	Open K-61.
28604	In K-53 PRESSURE Control, establish 40 psig in Dewar 4.
28617	Switch the following shutdown outputs to NORMAL:

Speed Rate C-8
C-221

28619	Activate the following inputs to the shutdown chain:

UQ-2 CP-505
UQ-3 KP-62
JP-101/201
CP-220

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29126	Use C-8 to decrease Q/N to .20.
29129	Bypass Q/N Low.
29160	Use C-8 to decrease Q/N to .14.
	a. Use .02 increments.
29185	Use C-8 to increase Q/N to .25.
29188	Activate Q/N Low.
29191	Switch Speed Rate Control to HOLD.
29196	Demand 26,000 rpm.
29200	Switch Speed Rate Control to RUN.
29240	Use C-8 to decrease Q/N to .17.
	a. Use .02 increments.
29290	Use C-8 to increase Q/N to .35.
	a. Use .02 increments.
29308	Close C-106 and decrease Q/N to .25.
29314	At TD command, push the shutdown button.
29334	Open D.C. Breakers.
29338	Bypass all the shutdown inputs.
29344	Switch C-231 to POSITION Control and close.
29348	Switch C-106 to RESET.
29350	Reset the shutdown chain.
29354	Use C-111 to maintain CP-9 between 60 and 100 psig.
29360	Close C-12.
29374	Switch K-53 to POSITION Control and close.
29380	Close K-61.
29384	Open K-153.
29388	Decrease D.C. motor field to less than 5 amps.
29393	Switch the shutdown outputs to OVERRIDE.

VIII. PUMP MAPPING #2

During this phase, an initial pump operating condition of 23,000 rpm and .25 Q/N will be established. Using C-8 in Q/N Control to vary the system impedance, the pump will be mapped at the following:

SPEED	Q/N
23,000	.14 to .35

A. PROCEED WITH PUMP MAPPING.

29567	Dewar 5 boil off.
30950	Set the overspeed trip pot to 660 divisions (25,000 rpm).
30956	Raise the synchronous motor field to 120 amps.
30958	Raise the D.C. motor field to 13 amps.
30960	Close K-153.
30969	Select Dewar 5 pressure feedback.
30970	Open K-62.
30977	In K-53 PRESSURE Control, establish 60 psig in Dewar 5.
30981	Switch the following shutdown outputs to NORMAL: Speed Rate C-8 C-221
30986	Activate the following inputs to the shutdown chain: UQ-2 CP-505 UQ-3 KP-61 JP-101/201 CP-220
31010	Use C-106 to chill CT-106.
31017	At CTO command Open C-11, Close C-111.
31032	Open K-161.
31036	Open C-221.
31038	Close C-231.
31040	Set C-8 to 60% (Q/N = .25).
31125	When the pump is chilled, close the D.C. Breakers. a. PMP: Report pump chill.
31130	Activate the following inputs to the shutdown chain: D.C. Breakers CT-507

31165 In MANUAL Control, establish 10,000 rpm at a Q/N = .25.

31167 Switch C-106 to AUTO.

31170 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

31176 Open C-231 to 70 pot divisions.

31178 Close C-221.

31187 In C-231 POSITION Control, establish 20 psig at CP-220.

31197 Q/N Control switched.

31206 Switch to SPEED Control.

31210 Switch Speed Rate Control to HOLD.

31215 Set Speed Rate pot to 160 divisions (800 rpm/sec).

31228 Demand 23,000 rpm.

31233 Switch Speed Rate Control to RUN.

31285 Use C-8 to increase Q/N to .33.

a. Use .02 increments.

31340 Use C-8 to decrease Q/N to .17.

31370 Use C-8 to increase Q/N to .25.

31383 80 psig set in Dewar 5.

31420 Use C-8 to increase Q/N to .33.

a. Use .02 increments.

31490 Use C-8 to decrease Q/N to .17.

31505 Use C-8 to increase Q/N to .20.

31510 Shutdown (CTO MANUAL).

31516 Switch C-231 to POSITION Control and close.

31526 Switch C-106 to RESET.

31530 Open D.C. Breakers.

31549 Use C-111 to maintain CP-9 between 60 and 100 psig.

31553 Close C-12.

31554 Bypass all the shutdown inputs.

31562	Reset the shutdown chain.
31566	Switch K-53 to POSITION Control and close.
31568	Close K-62.
31584	Open K-153
31586	Decrease D.C. motor field to less than 5 amps.
31590	Switch the shutdown outputs to OVERRIDE.
31800	Maximum Shutdown Phase.

END

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APPENDIX D

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN II

15 DECEMBER 1971

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I. PRE-OPERATIONAL PHASE

During this phase verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switched to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

01080	Turn off the HPR, EPR and MER fans.
01085	Close Q-113.
01095	Pressurize the room inerting header (Bottles 13, 14, 15, and 16).
01158	Begin inerting the following areas:

HPR (G-451/452)
CEL (G-456)
EPR (G-455)

a. Report when concentrations reach 3%.
b. Maintain 0_2 concentrations between 3 and 5%.

G. CHECK THE SHUTDOWN CHAIN.

H. PERFORM A VOLTAGE CALIBRATION.

04201-04301 Calibration interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4/5 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 40 psig.

A. PROCEED WITH HEADER PRESSURIZATION.

04524	Report on room inerting.
04530	Open K-50, K-153.
04537	Open L-50.
04546	Close Q-120, Q-150, Q-101 thru Q-112.
04580	Pressurize the helium header.
	a. QP-20: 1400 psig.
04713	Pressurize the hydrogen header with Bottle 2.
	a. QP-30: 3000 psig.

B. PROCEED WITH THE CHILLDOWN.

04738	Close K-153, K-403, K-402, K-261, C-408.
04768	Close C-221.
04787	Open K-1, K-61.
04815	Open C-214, C-8.
04822	Select Dewar 4 pressure feedback.
04827	Open C-111.
04877	In K-53 PRESSURE Control, establish 60 psig in Dewar 4.
05647	Use K-3 to chill CT-3 to $100^{o}R$.
	a. PMP: Report CT-3.
05947	Use K-130 to chill KT-130.
	a. DSO: Report KT-130.
05962	Close K-130.
05990	When CP-8 is less than 10 psig, Open C-4, C-231; Close C-214.

06020	Close C-111.
06583	Use C-106 to establish and maintain CP-505 between 10-20 psig.
06584	Use K-130 to maintain 3 lbs/sec at KF-130.
06590	When pump is chilled, slowly open K-3.
06610	Close K-130.
06654	Use C-111 to chill CT-111.
06820	When CT-111 is chilled, set C-111 to maintain CP-9 between 80 and 100 psig.
06821	Open C-221.
06840	Close C-231.
06841	Start 900 second timer.
06845	Switch K-53 to POSITION Control and close.
06854	Close K-61.
06860	Open K-153.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

06873	Report electric drive alarm status.
06880	Start synchronous motor. (UI-2 not reading properly)
06960	Start blowers.
06987	Establish and maintain unity power factor. (120 amps)
07026	Increase D.C. motor field to 13 amps, then decrease to 5 amps.
07090	Raise and lower armature voltage.
07130	5 Amps field set.

D. PROCEED WITH OVERSPEED TRIP CHECK.

07944	Set the overspeed trip pot to 105 divisions (4,000 rpm).
07953	Raise synchronous motor field to 120 amps.
07960	Close K-153.
07964	Select Dewar 4 pressure feedback.
07968	Open K-61.
07986	Raise D.C. motor field to 13 amps.
07990	In K-53 PRESSURE Control, establish 45 psig in Dewar 4.
07992	Switch the following shutdown output to NORMAL:

Speed Rate

07995	Activate the following inputs to the shutdown chain:
	UQ-2 JP-101/201
	CP-220 CP-505
08008	Open K-3.
08013	Close K-130.
08048	Open C-111.
08032	Open C-221.
08034	Close C-231.
08065	Use C-8 to chill the pump.
08082	Set C-8 to 55%. (Q/N = .22)
08090	Set C-106 to 15%.
08358	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
08364	Activate CT-507 input to the shutdown chain.
08416	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
08420	Reset the shutdown chain.
08425	Bypass UQ-2 shutdown input.
08426	Activate UQ-3 shutdown input.
08460	In MANUAL Control, increase speed to produce overspeed trip (6,000 rpm -- 1 Trip).
08474	When speed is zero, open the D.C. breakers.
08475	Bypass all the shutdown inputs.
08480	Reset the shutdown chain.
08484	Close C-106.
08500	Use C-111 to maintain CP-9 between 60 and 100 psig.
08508	Switch K-53 to POSITION Control and close.
08516	Close K-61.
08520	Open K-153.
08528	Switch the shutdown outputs to OVERRIDE.
08570	Decrease D.C. motor field to less than 5 amps.

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III. CAVITATION TEST PHASE RUN #1A - 37.5°R

The following points will be investigated:

Speed	Q/N
19,000	.07, .24

The supply dewar pressure will be maintained at 45 psig.

A. PROCEED WITH CAVITATION TEST.

09187	Set the overspeed trip pot to 550 divisions (21,000 rpm).
09203	Raise the synchronous motor field to 120 amps.
09217	Close K-153.
09218	Select Dewar 5 pressure feedback.
09224	Open K-62.
09230	In K-53 PRESSURE Control, establish 45 psig in Dewar 5
09236	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

09240	Raise the D. C. motor field to 13 amps.
09246	Activate the following inputs to the shutdown chain:

UQ-2	CP-505
UQ-3	CP-220
JP-101/201	KP-61

09272	Use C-106 to chill CT-106.
09322	At CTO command, Open C-11, Close C-111.
09342	Use K-161 to maintain KP-61 between 20 and 25 psig.
09361	Open C-221.
09374	Close C-231.
09430	Set C-8 to 55% (Q/N = .22).
09648	When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

09654	Activate the following inputs to the shutdown chain: D.C. Breakers, CT-507
09697	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
09701	Switch C-106 to AUTO.
09706	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
09713	Open C-231 to 70 pot divisions.
09716	Close C-221.
09730	Use C-231 to establish and maintain 20 psig at CP-220.
09739	Switch C-8 to Q/N control and establish Q/N = .22.
09767	Switch to SPEED Control.
09780	Switch Speed Rate Control to HOLD.
09781	Set Speed Rate pot to 160 divisions (800 rpm/sec).
09787	Demand 19,000 rpm.
09800	Switch Speed Rate Control to RUN.
09830	Open C-231.
09848	CTO Manual Shutdown (Speed not indicating properly).
09855	Open D.C. breakers.
09860	Bypass all the shutdown inputs.
09865	Switch C-106 to RESET.
09868	Switch C-231 to POSITION Control and close.
09870	Reset the shutdown chain.
09880	Use C-111 to maintain CP-9 between 60 and 100 psig.
09890	Close C-11.
09905	Switch K-53 to POSITION Control and close.
09912	Close K-62.
09915	Open K-153.
09918	Decrease D.C. motor field to less than 5 amps.
09922	Switch the shutdown outputs to OVERRIDE.
10452	Dewar transfer.

IV. CAVITATION TEST PHASE RUN #1B - 39°R

The following points will be investigated:

Speed	Q/N
19,000	.17, .24

The supply dewar pressure will be maintained at 75 psig.

A. PROCEED WITH CAVITATION TEST.

11296	Set the overspeed trip pot to 550 divisions (21,000 rpm).
00304	Raise the synchronous motor field to 120 amps.
11312	Close K-153.
11336	Raise the D.C. motor field to 13 amps.
11350	Select Dewar 5 pressure feedback.
11353	Open K-62.
11366	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
11372	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
11390	In K-53 PRESSURE Control, establish 75 psig in Dewar 5.
11400	Use C-106 to chill CT-106.
11410	At CTO command, Open C-11, Close C-111.
11425	Use K-161 to maintain KP-61 between 20 and 25 psig.
11430	Open C-221.
11434	Close C-231.
11455	Set C-8 to 530 pot divisions.
11475	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.

11480 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

11524 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

11526 Switch C-106 to AUTO.

11530 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

11537 Open C-231 to 70 pot divisions.

11540 Close C-221.

11550 Use C-231 to establish and maintain 20 psig at CP-220.

11554 Switch C-8 to Q/N control and establish Q/N

11573 Switch to Speed Control.

11577 Switch Speed Rate Control to HOLD.

11581 Set Speed Rate pot to 160 divisions (800 rpm/sec).

11590 Demand 19,000 rpm.

11609 Switch Speed Rate Control to RUN.

11646 Open C-231.

11680 Use C-8 in Q/N Cpntrol to establish a Q/N = .17.

11686 Report CP-700D. 475 psid.

11702 Slowly decrease K-3 position.

11745 CP-505 bypassed.

11856 Open K-3 (Q/N = .17 at 19,000 rpm -- K-3 minimum pot setting = 279 divisions).

11910 Use C-8 to increase Q/N to .24. (653 pot divisions).

11920 Report CP-700D. 430 psid,

11924 Slowly decrease K-3 position.

12054 Open K-3 (Q/N = .24 at 19,000 rpm -- K-3 minimum pot setting = 386 divisions).

12096 Increase Dewar 5 pressure to 85 psig.

12134 Use C-8 to increase Q/N to .30. (Reached approximately .29).

12143	At TD command, push the shutdown button.
12150	Open D.C. breakers.
12157	Bypass all the shutdown inputs.
12160	Switch C-231 to POSITION Control and close.
12162	Switch C-106 to RESET.
12165	Reset the shutdown chain.
12170	Use C-111 to maintain CP-9 between 60 and 100 psig.
12172	Close C-11.
12178	Switch K-53 to POSITION Control and close.
12190	Decrease D.C. motor field to less than 5 amps.
12194	Switch the shutdown outputs to OVERRIDE.
12198	Close K-62.
12200	Open K-153.
12520	Dewar 5 vented.

V. CAVITATION TEST PHASE RUN #2 - 41°R

The following points will be investigated:

Speed	Q/N
19,000	.30

The supply dewar pressure will be maintained at 90 psig.

A. PROCEED WITH CAVITATION TEST.

13880	Set the overspeed trip pot to 630 divisions (24,000 rpm).
13896	Raise the synchronous motor field to 120 amps.
13902	Close K-153.
13906	Select Dewar 4 pressure feedback.
13910	Open K-61.
13923	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
13936	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-62

C3

13938 Raise the D. C. motor field to 13 amps.

13950 In K-53 PRESSURE Control, establish 85 psig in Dewar 4.

13964 Use C-106 to chill CT-106.

13973 At CTO command, Open C-12, Close C-111.

13984 Use K-162 to maintain KP-62 between 20 and 25 psig.

13997 Open C-221.

14000 Close C-231.

14008 Set C-8 to 530 pot divisions.

14115 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

14118 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

14158 In MANUAL Control, establish 10, 000 rpm at a Q/N = . 22.

14159 Switch C-106 to AUTO.

14162 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

14174 Open C-231 to 80 pot divisions.

14178 Close C-221.

14193 Use C-231 to establish and maintain 30 psig at CP-220.

14202 Switch to Q/N Control and establish Q/N = . 20.

14219 Switch to SPEED Control.

14222 Switch Speed Rate Control to HOLD.

14228 Set Speed Rate pot to 160 divisions (800 rpm/sec).

14232 Demand 19, 000 rpm.

14238 Switch Speed Rate Control to RUN.

14254 Open C-231.

14340	Increase Dewar pressure to 90 psig.
14384	Use C-8 in Q/N Control to establish a Q/N = .30.
14392	Report CP-700D. 370 psid.
14398	Slowly decrease K-3 position.
14554	Open K-3 (Q/N = .30 at 19,000 rpm -- K-3 minimum pot setting = 585 divisions).
14567	At TD command, push the shutdown button.
14575	Open D.C. breakers.
14580	Switch C-231 to POSITION Control and close.
14582	Switch C-106 to RESET.
14584	Bypass all the shutdown inputs.
14588	Reset the shutdown chain.
14590	Use C-111 to maintain CP-9 between 60 and 100 psig.
14600	Close C-12.
14615	Switch K-53 to POSITION Control and close.
14620	Close K-61.
14626	Open K-153.
14635	Decrease D.C. motor field to less than 5 amps.
14638	Switch the shutdown outputs to OVERRIDE.
15150	Bottle 3 brought on line.

a. QP-30 = 3100 psi.

VI. CAVITATION TEST PHASE RUN #3 - 41°R

The following points will be investigated:

Speed	Q/N
19,000	.17
22,000	.17

The supply dewar pressure will be maintained at 85 psig.

A. PROCEED WITH CAVITATION TEST.

16090	Set the overspeed trip pot to 630 divisions (24,000 rpm).
16094	Raise the synchronous motor field to 120 amps.
16101	Close K-153.
16108	Select Dewar 5 pressure feedback.

16111 Open K-62.

16127 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

16130 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

16142 Raise the D.C. motor field to 13 amps.

16145 In K-53 PRESSURE Control, establish 85 psig in Dewar 5.

16158 Use C-106 to chill CT-106.

16169 At CTO command, Open C-11, Close C-111.

16184 Use K-161 to maintain KP-61 between 35 and 40 psig.

16186 Open C-221.

16188 Close C-231.

16192 Set C-8 to 530 pot divisions.

16262 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

16266 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

16303 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

16306 Switch C-106 to AUTO.

16310 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

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16316	Open C-231 to 85 pot divisions.
16318	Close C-221.
16324	Use C-231 to establish and maintain 30 psig at CP-220.
16334	Switch to Q/N Control and establish Q/N = .20.
16342	Switch to SPEED Control.
16346	Switch Speed Rate Control to HOLD.
16352	Set Speed Rate pot to 160 divisions (800 rpm/sec).
16356	Demand 19,000 rpm.
16358	Switch Speed Rate Control to RUN.
16370	Open C-231.
16397	Use C-8 in Q/N Control to establish a Q/N = .17.
16427	Increase speed to 22,000.
16440	Slowly decrease K-3 position.
16544	Open K-3 (Q/N = .17 at 22,000 rpm -- K-3 minimum pot setting = 313 divisions).
16574	Decrease speed to 19,000 rpm.
16580	Report CP-700D. 450 psid.
16590	Slowly decrease K-3 position.
16667	Open K-3 (Q/N = .17 at 19,000 rpm -- K-3 minimum pot setting = 268 divisions).
16683	At TD command, push the shutdown button.
16692	Open D.C. breakers.
16694	Switch C-106 to RESET.
16697	Switch C-231 to POSITION Control and close.
16698	Bypass all the shutdown inputs.
16700	Reset the shutdown chain.
16706	Use C-111 to maintain CP-9 between 60 and 100 psig.
16725	Close C-11.
16728	Switch K-53 to POSITION Control and close.
16734	Close K-62.
16741	Open K-153.
16750	Decrease D.C. motor field to less than 5 amps.
16756	Switch the shutdown outputs to OVERRIDE.

VII. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

17322	Open L-251.
17330	Close L-261, L-153.
17360	Open L-61 (Won't open -- investigate valve).
18418	Open L-61, L-301, L-330.
18461	Open L-331, X-301.
18467	Close K-401.
18482	Use K-161/162 to vent Dewar 4/5.
18490	Use L-53 in POSITION Control to establish and maintain psig in Dewar 1.
18510	When LP-61 is greater than KP-61/62, Open K-301/302.
23448	When LH_2 transfer is complete, Close K-301/302.

VIII. CAVITATION TEST PHASE RUN #4 - 37.5°R

The following points will be investigated:

Speed	Q/N
24,000	.24

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

23626	Bottle 4 brought on line.
	a. QP-30 = 3000 psi.
24428	Set the overspeed trip pot to 680 divisions (26,000 rpm).
24436	Raise the synchronous motor field to 120 amps.
24441	Close K-153.
24446	Select Dewar 4 pressure feedback.
24450	Open K-61.
24500	Raise the D.C. motor field to 13 amps.
24514	50 psi established in Dewar 5.

24546 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

24550 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

24586 In K-53 PRESSURE Control, establish 100 psig in Dewar 4.

24798 Use C-106 to chill CT-106.

24820 Dewar 5 pressure set at 60 psig.

24845 At CTO command, Open C-12, Close C-111.

24868 Use K-162 to maintain KP-62 between 50 and 60 psig.

24874 Open C-221.

24876 Close C-231.

24882 Set C-8 to 530 pot divisions.

25047 80 psig set in Dewar 4.

25051 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

25060 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

25081 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

25086 Switch C-106 to AUTO.

25092 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

25096	Open C-231 to 85 pot divisions
25098	Close C-221.
25113	Use C-231 to establish and maintain 30 psig at CP-220.
25116	Switch to Q/N Control and establish Q/N = .20.
25126	Switch to SPEED Control.
25129	Switch Speed Rate Control to HOLD.
25134	Set Speed Rate pot to 160 divisions (800 rpm/sec).
25140	Demand 19,000 rpm.
25164	Switch Speed Rate Control to RUN.
25180	Open C-231.
25216	Increase Dewar 4 pressure (85 psi).
25263	RPM increased to 24,000 rpm.
25266	90 psi in Dewar 4.
25310	95 psi in Dewar 4.
25340	100 psi in Dewar 4.
25344	Use C-8 in Q/N Control to establish a Q/N = .24.
25350	Slowly decrease K-3 position.
25468	Open K-3 (Q/N = .24 at 19,000 rpm -- K-3 minimum pot setting = 515 divisions).
25499	Use C-8 to decrease Q/N to .17.
25504	Slowly decrease K-3 position (Cavitation point not reached).
25540	At TD command, push the shutdown button.
25550	Open D.C. breakers.
25554	Switch C-231 to POSITION Control and close.
25558	Switch C-106 to RESET.
25560	Bypass all the shutdown inputs.
25562	Reset the shutdown chain.
25578	Use C-111 to maintain CP-9 between 60 and 100 psig.
25580	Close C-12.
25594	Switch K-53 to POSITION Control and close.
25598	Close K-61.
25605	Open K-153.
25611	Decrease D.C. motor field to less than 5 amps.
25615	Switch the shutdown outputs to OVERRIDE.
25830	Dewar transfer.

IX. CAVITATION TEST PHASE RUN #5 - 41°R

The following points will be investigated:

Speed	Q/N
19,000	.24
22,000	.24

The supply dewar pressure will be maintained at 85 psig.

A. PROCEED WITH CAVITATION TEST.

27386	Set the overspeed trip pot to 630 divisions (24,000 rpm).
27394	Raise the synchronous motor field to 120 amps.
27396	Close K-153.
27404	Select Dewar 5 pressure feedback.
27407	Open K-62.
27418	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
27426	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
27434	Raise the D.C. motor field to 13 amps.
27444	In K-53 PRESSURE Control, establish 85 psig in Dewar 5.
27451	Use C-106 to chill CT-106.
27458	At CTO command, Open C-11, Close C-111.
27478	Use K-161 to maintain KP-61 between 40 and 50 psig.
27480	Open C-221.
27482	Close C-231.
27487	Set C-8 to 530 pot divisions.

27560 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

27564 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

27592 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

27594 Switch C-106 to AUTO.

27596 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

27600 Open C-231 to 85 pot divisions.

27603 Close C-221.

27610 Use C-231 to establish and maintain 30 psig at CP-220.

27620 Switch to Q/N Control and establish Q/N = .22.

27630 Switch to SPEED Control.

27633 Switch Speed Rate Control to HOLD.

27640 Set Speed Rate pot to 160 divisions (800 rpm/sec).

27643 Demand 19,000 rpm.

27647 Switch Speed Rate Control to RUN.

27659 Open C-231.

27676 Use C-8 in Q/N Control to establish a Q/N = .24.

27684 Report CP-700D. 420 psid.

27688 Slowly decrease K-3 position.

27700 100 psi set in Dewar 5.

27736 Open K-3 (Q/N = .24 at 19,000 rpm -- K-3 minimum pot setting = 338 divisions).

27756 Increase speed to 22,000 rpm.

27764 Report CP-700D. 560 psid.

27768 Slowly decrease K-3 position.

27816 Open K-3 (Q/N = .24 at 22,000 rpm -- K-3 minimum pot setting = 416 divisions).

27836	At TD command, push the shutdown button
27848	Open D.C. breakers.
27850	Switch C-231 to POSITION Control and close.
27856	Switch C-106 to RESET.
27859	Bypass all the shutdown inputs.
27860	Reset the shutdown chain.
27868	Use C-111 to maintain CP-9 between 60 and 100 psig.
27872	Close C-11.
27878	Switch K-53 to POSITION Control and close.
27884	Close K-62.
27888	Open K-153.
27900	Decrease D.C. motor field to less than 5 amps.
27904	Switch the shutdown outputs to OVERRIDE.
28320	Dewar transfer.

X. CAVITATION TEST PHASE RUN #6 - 41°R

The following points will be investigated:

Speed	Q/N
24,000	.17, .24

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

29204	Select Dewar 4 pressure feedback.
29210	Open K-61.
29233	Set the overspeed trip pot to 680 divisions (26,000 rpm).
29240	Raise the synchronous motor field to 120 amps.
29250	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
29258	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-62

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29272	Use C-106 to chill CT-106.
29283	Raise the D.C. motor field to 13 amps.
29290	At CTO command, Open C-12, Close C-111.
29296	Use K-162 to maintain KP-62 between 50 and 60 psig.
29300	Open C-221.
29304	Close C-231.
29306	Set C-8 to 530 pot divisions.
29348	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
29352	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
29372	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
29374	Switch C-106 to AUTO.
29378	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High
	Q/N Low
29381	Open C-231 to 85 pot divisions.
29382	Close C-221.
29384	Use C-231 to establish and maintain 30 psig at CP-220.
29400	Switch to Q/N Control and establish Q/N = .20.
29406	Switch to SPEED Control.
29408	Switch Speed Rate Control to HOLD.
29416	Set Speed Rate pot to 160 divisions (800 rpm/sec).
29418	Demand 24,000 rpm.
29423	Switch Speed Rate Control to RUN.
29444	Open C-231.
29468	Use C-8 in Q/N Control to establish a Q/N = .24.
29476	Report CP-700D. 650 psid.
29480	Slowly decrease K-3 position.

29538	Open K-3 (Q/N = .24 at 24,000 rpm -- K-3 minimum pot setting = 540 divisions).
29576	Use C-8 to decrease Q/N to .17.
29581	Slowly decrease K-3 position.
29630	Open K-3 (Q/N = .17 at 24,000 rpm -- K-3 minimum pot setting = 312 divisions).
29640	At TD command, push the shutdown button.
29650	Open D.C. breakers.
29653	Switch C-231 to POSITION Control and close.
29656	Switch C-106 to RESET.
29659	Bypass all the shutdown inputs.
29660	Reset the shutdown chain.
29675	Use C-111 to maintain CP-9 between 60 and 100 psig.
29682	Close C-12.
29694	Switch K-53 to POSITION Control and close.
29698	Close K-61.
29704	Open K-153.
29708	Decrease D.C. motor field to less than 5 amps.
29714	Switch the shutdown outputs to OVERRIDE.
29830	Dewar transfer.

XI. CAVITATION TEST PHASE RUN #7 - 39°R

The following points will be investigated:

Speed	Q/N
22,000	.17
24,000	.17

The supply dewar pressure will be maintained at 80 psig.

A. PROCEED WITH CAVITATION TEST.

31118	Set the overspeed trip pot to 680 divisions (26,000 rpm).
31120	Raise the synchronous motor field to 120 amps.
31127	Close K-153.
31131	Select Dewar 5 pressure feedback.
31136	Open K-62.

201

31153 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

31157 Raise the D. C. motor field to 13 amps.

31162 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

31178 Use C-106 to chill CT-106.

31186 At CTO command, Open C-11, Close C-111.

31196 Use K-161 to maintain KP-61 between 30 and 40 psig.

31201 Open C-221.

31203 Close C-231.

31208 Set C-8 to 530 pot divisions.

31210 In K-53 PRESSURE Control, establish 80 psig in Dewar 5.

31317 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

31321 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

31340 In MANUAL Control, establish 10,000 rpm at a Q/N = . 17.

31342 Switch C-106 to AUTO.

31348 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

202

B

31351	Open C-231 to 85 pot divisions
31354	Close C-221.
31358	Use C-231 to establish and maintain 30 psig at CP-220.
31365	Switch to Q/N Control and establish Q/N = .17.
31374	Switch to SPEED Control.
31376	Switch Speed Rate Control to HOLD.
31380	Set Speed Rate pot to 160 divisions (800 rpm/sec).
31387	Demand 24,000 rpm.
31390	Switch Speed Rate Control to RUN.
31394	Open C-231.
31419	Use C-8 in Q/N Control to establish a Q/N = .17.
31428	Report CP-700D. 750 psid.
31431	Slowly decrease K-3 position.
31505	Open K-3 (Q/N = .17 at 24,000 rpm -- K-3 minimum pot setting = 339 divisions).
31523	Decrease Speed to 22,000 rpm.
31530	Report CP-700D. 630 psid.
31538	Slowly decrease K-3 position.
31587	Open K-3 (Q/N = .17 at 22,000 rpm -- K-3 minimum pot setting = 307 divisions).
31597	At TD command, push the shutdown button.
31608	Open D.C. breakers.
31610	Switch C-231 to POSITION Control and close.
31612	Switch C-106 to RESET.
31614	Bypass all the shutdown inputs.
31618	Reset the shutdown chain.
31627	Use C-111 to maintain CP-9 between 60 and 100 psig.
31632	Close C-11.
31643	Switch K-53 to POSITION Control and close.
31648	Close K-62.
31651	Open K-153.
31656	Decrease D.C. motor field to less than 5 amps.
31659	Switch the shutdown outputs to OVERRIDE.

XII. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

31875	Open L-251.
31894	Close L-261, L-153.
31920	Open L-61, L-301, L-330.
31928	Open L-331, X-301.
31931	Close K-401.
31940	Use K-161/162 to vent Dewar 4/5.
31946	When LP-61 is greater than KP-61/62, Open K-301/302.
36783	When LH_2 transfer is complete, Close K-301/302.

XIII. CAVITATION TEST PHASE RUN #8 - 37.5°R

The following points will be investigated:

Speed	Q/N
19,000	.17, .24, .30

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

37270	Bottle 5 brought on line.
	a. QP-30 = 3000 psi.
37456	Set the overspeed trip pot to 550 divisions (21,000 rpm).
37468	Raise the synchronous motor field to 120 amps.
37473	Close K-153.
37476	Select Dewar 4 pressure feedback.
37478	Open K-61.
37500	Switch the following shutdown outputs to NORMAL:
	Speed Rate, C-8, C-221

37505 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

37512 Raise the D. C. motor field to 13 amps.

37514 In K-53 PRESSURE Control, establish 90 psig in Dewar 4.

37527 Use C-106 to chill CT-106.

37540 At CTO command, Open C-12, Close C-111.

37568 Use K-162 to maintain KP-62 between 40 and 50 psig.

37571 Open C-221.

37577 Close C-231.

37581 Set C-8 to 530 pot divisions.

37754 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

37757 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

37774 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

37776 Switch C-106 to AUTO.

37778 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

37782 Open C-231 to 85 pot divisions.

37786 Close C-221.

37791 Use C-231 to establish and maintain 30 psig at CP-220.

37801 Switch to Q/N Control and establish Q/N = .25.

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37816	Switch to SPEED Control.
37818	Switch Speed Rate Control to HOLD.
37822	Set Speed Rate pot to 160 divisions (800 rpm/sec).
37828	Demand 19,000 rpm.
37832	Switch Speed Rate Control to RUN.
37837	Open C-231.
37874	Use C-8 in Q/N Control to establish a Q/N = .30.
37892	Increase Dewar 4 pressure to 100 psig.
37898	Report CP-700D. 390 psid.
37903	Slowly decrease K-3 position.
37974	Open K-3 (Q/N = .30 at 19,000 rpm -- K-3 minimum pot setting = 465 divisions).
38000	Use C-8 to decrease Q/N to .24.
38008	Report CP-700D. 430 psid.
38010	Slowly decrease K-3 position.
38068	Open K-3 (Q/N = .24 at 19,000 rpm -- K-3 minimum pot setting = 335 divisions).
38096	Use C-8 to decrease Q/N to .17.
38100	Report CP-700D. 480 psid.
38110	Slowly decrease K-3 position.
38156	Open K-3 (Q/N = .17 at 19,000 rpm -- K-3 minimum pot setting = 245 divisions).
38166	At TD command, push the shutdown button.
38174	Open D.C. breakers.
38178	Switch C-231 to POSITION Control and close.
38181	Switch C-106 to RESET.
38183	Bypass all the shutdown inputs.
38187	Reset the shutdown chain.
38193	Use C-111 to maintain CP-9 between 60 and 100 psig.
38198	Close C-12.
38210	Switch K-53 to POSITION Control and close.
38214	Close K-61.
38220	Open K-153.
38227	Decrease D.C. motor field to less than 5 amps.
38234	Switch the shutdown outputs to OVERRIDE.
38544	Dewar transfer.

XIV. CAVITATION TEST PHASE RUN #9 - 39°R

The following points will be investigated:

Speed	Q/N
19,000	.30
22,000	.24

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

39452	Set the overspeed trip pot to 630 divisions (24,000 rpm).
39460	Raise the synchronous motor field to 120 amps.
39470	Close K-153.
39474	Select Dewar 5 pressure feedback.
39478	Open K-62.
39486	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
39490	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
39508	Use C-106 to chill CT-106.
39516	Raise the D.C. motor field to 13 amps.
39521	At CTO command, Open C-11, Close C-111.
39530	Use K-161 to maintain KP-61 between 50 and 60 psig.
39535	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
39538	Open C-221.
39540	Close C-231.
39544	Set C-8 to 530 pot divisions.
39574	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.

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39578	Activate the following inputs to the shutdown chain: D.C. Breakers, CT-507
39603	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
39606	Switch C-106 to AUTO.
39611	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
39612	Open C-231 to 85 pot divisions.
39613	Close C-221.
39618	Use C-231 to establish and maintain 30 psig at CP-220.
39624	Switch to Q/N Control and establish Q/N = .25.
39636	Switch to SPEED Control.
39638	Switch Speed Rate Control to HOLD.
39641	Set Speed Rate pot to 160 divisions (800 rpm/sec).
39647	Demand 19,000 rpm.
39651	Switch Speed Rate Control to RUN.
39654	Open C-231.
39690	Use C-8 in Q/N Control to establish a Q/N = .30.
39692	Report CP-700D. 370 psid.
39693	Slowly decrease K-3 position.
39757	Open K-3 (Q/N = .30 at 19,000 rpm -- K-3 minimum pot setting = 445 divisions).
39786	Use C-8 to decrease Q/N to .24.
39801	Increase speed to 22,000 rpm.
39805	Report CP-700D. 570 psid.
39806	Slowly decrease K-3 position.
39860	Open K-3 (Q/N = .24 at 22,000 rpm -- K-3 minimum pot setting = 406 divisions).
39870	At TD command, push the shutdown button.
39881	Open D.C. breakers.
39883	Switch C-231 to POSITION Control and close.
39884	Switch C-106 to RESET.

39890	Bypass all the shutdown inputs.
39893	Reset the shutdown chain.
39900	Use C-111 to maintain CP-9 between 60 and 100 psig.
39912	Close C-11.
39926	Switch K-53 to POSITION Control and close.
39930	Close K-62.
39937	Open K-153.
39941	Decrease D.C. motor field to less than 5 amps.
39947	Switch the shutdown outputs to OVERRIDE.
40464	Minimum shutdown phase.

END

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APPENDIX E

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN II

16 DECEMBER 1971

I. PRE-OPERATIONAL PHASE

During this phase verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switched to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

G. CHECK THE SHUTDOWN CHAIN.

H. PERFORM A VOLTAGE CALIBRATION.

06441-06541 Calibration interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4/5 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 40 psig.

A. PROCEED WITH HEADER PRESSURIZATION.

06968	Open K-50, K-153.
06981	Open L-50.
06983	Report on room inerting.

06988	Close Q-120, Q-150, Q-101 thru Q-112.
07137	Pressurize the helium header.
	a. AP-20: 1250 psig.
07228	Pressurize the hydrogen header with Bottle 5.
	a. QP-30: 2550 psig.

B. PROCEED WITH THE CHILLDOWN.

07271	Close K-153, K-403, K-402, K-261, C-408.
07272	Close C-221.
07308	Open K-1, K-61.
07334	Open C-214, C-8.
07356	Select Dewar 4 pressure feedback.
07391	In K-53 PRESSURE Control, establish 60 psig in Dewar 4.
07433	Open C-111.
07674	Use K-3 to chill CT-3 to 100°R.
	a. PMP: Report CT-3.
07900	Use K-130 to chill KT-130.
	a. DSO: Report KT-130.
07956	When CP-8 is less than 10 psig, Open C-4, C-231; Close C-214.
07976	Close C-111.
08017	Use C-106 to establish and maintain CP-505 between 10 and 20 psig.
08604	Use K-130 to maintain 3 lbs/sec at KF-130.
	a. CTO: Monitor CF-6.
08610	When pump is chilled, slowly open K-3.
08632	Close K-130.
08757	Use C-111 to chill CT-111.
08778	When CT-111 is chilled, set C-111 to maintain CP-9 between 80 and 100 psig.
08781	Open C-221.
08804	Close C-231.
08810	Start 900 second timer.
08817	Switch K-53 to POSITION Control and close.
08824	Close K-61.
08831	Open K-153.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

08852	Report electric drive alarm status.
08874	Start synchronous motor.
08928	Start blowers.
08958	Establish and maintain unity power factor. (120 Amps)
08994	Increase D.C. motor field to 13 amps, then decrease to 5 amps.
09042	Raise and lower armature voltage.
09065	Set field to 5 amps.

D. PROCEED WITH OVERSPEED TRIP CHECK.

10116	Set the overspeed trip pot to 105 divisions (4,000 rpm).
10120	Raise synchronous motor field to 120 amps.
10128	Close K-153.
10133	Select Dewar 4 pressure feedback.
10136	Open K-61.
10147	Raise D.C. motor field to 13 amps.
10152	In K-53 PRESSURE Control, establish 40 psig in Dewar 4.
10156	Switch the following shutdown output to NORMAL: Speed Rate
10160	Activate the following inputs to the shutdown chain: UQ-2, JP-101/201, CP-220, CP-505
10164	Open K-3.
10168	Close K-130.
10193	Open C-111.
10208	Set C-8 to 55%. (Q/N = .22).
10214	Open C-221.
10216	Close C-231.
10527	Use C-8 to chill the pump.
10533	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.

10588	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
10596	Reset the shutdown chain.
10598	Bypass UQ-2 shutdown input.
10600	Activate UQ-3 shutdown input.
10632	In MANUAL Control, increase speed to produce overspeed trip (6,000 rpm).
10655	When speed is zero, open the D.C. breakers.
10664	Bypass all the shutdown inputs.
10668	Reset the shutdown chain.
10674	Close C-106.
10678	Use C-111 to maintain CP-9 between 60 and 100 psig.
10684	Switch K-53 to POSITION Control and close.
10688	Close K-61.
10697	Open K-153.
10704	Decrease D.C. motor field to less than 5 amps.
10710	Switch the shutdown outputs to OVERRIDE.

E. VOLTAGE CALIBRATION.

10951-11051 Recalibration interval.

III. CAVITATION TEST PHASE RUN #10 - 37.5°R

The following points will be investigated:

Speed	Q/N
22,000	.30
24,000	.30

The supply dewar pressure will be maintained at 60 psig.

A. PROCEED WITH CAVITATION TEST.

12220	Set the overspeed trip pot to 680 divisions (26,000 rpm).
12224	Raise the synchronous motor field to 120 amps.
12257	Raise the D.C. motor field to 13 amps.
12271	Close K-153.
12273	Select Dewar 5 pressure feedback.
12276	Open K-62.
12287	In K-53 PRESSURE Control, establish 60 psig in Dewar 5.

12292 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

12297 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

12313 Use C-106 to chill CT-106.

12362 Pressure rise in Dewar 5.

12376 Close K-62.

12430 Use K-161 to vent the Dewar 5 to 60 psi.

12468 At CTO command, Open C-11, Close C-111.

12486 Use K-161 to maintain KP-61 between 10 and 20 psig.

12567 Open K-62.

12572 In K-53 PRESSURE Control, establish 60 psig in Dewar 5.

12588 Open C-221.

12590 Close C-231.

12596 Set C-8 to 530 pot divisions.

12660 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

12664 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

12681 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

12684 Switch C-106 to AUTO.

12686 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

12692	Open C-231 to 85 pot divisions.
12696	Close C-221.
12708	Use C-231 to establish and maintain 30 psig at CP-220.
12710	Switch to Q/N Control and establish Q/N = .25.
12724	Switch to SPEED Control.
12728	Switch Speed Rate Control to HOLD.
12733	Set Speed Rate pot to 160 divisions (800 rpm/sec).
12744	Demand 22,000 rpm.
12747	Switch Speed Rate Control to RUN.
12751	On Ramp, open C-231.
12790	Use C-8 in Q/N Control to establish a Q/N = .30.
12794	Report CP-700D. 520 psid.
12797	Slowly decrease K-3 position.
12853	Open K-3 (Q/N = .30 at 22,000 rpm -- K-3 minimum pot setting = 434 divisions).
12878	Increase speed to 24,000 rpm.
12884	Report CP-700D. 610 psid
12892	Slowly decrease K-3 position.
12933	Open K-3 (Q/N = .30 at 24,000 rpm -- K-3 minimum pot setting = 458 divisions).
12941	At TD command, push the shutdown button.
12954	Open D.C. breakers.
12955	Switch C-231 to POSITION Control and close.
12956	Switch C-106 to RESET.
12957	Bypass all the shutdown inputs.
12960	Reset the shutdown chain.
12972	Use C-111 to maintain CP-9 between 60 and 100 psig.
12978	Close C-11.
12981	Switch K-53 to POSITION Control and close.
12986	Close K-62.
12998	Open K-153.
13004	Decrease D.C. motor field to less than 5 amps.
13008	Switch the shutdown outputs to OVERRIDE.
13140	Dewar transfer.

C

IV. CAVITATION TEST PHASE RUN #11 - 41^{o}R

The following points will be investigated:

Speed	Q/N
22,000	.30
24,000	.30
26,000	.30

The supply dewar pressure will be maintained at 75 psig.

A. PROCEED WITH CAVITATION TEST.

14124 Set the overspeed trip pot to 730 divisions (28,000 rpm).

14128 Raise the synchronous motor field to 120 amps.

14130 Close K-153.

14136 Select Dewar 4 pressure feedback.

14138 Open K-61.

14150 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

14156 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

14163 Raise the D.C. motor field to 13 amps.

14165 In K-53 PRESSURE Control, establish 75 psig in Dewar 4.

14170 Use C-106 to chill CT-106.

14174 At CTO command, Open C-12, Close C-111.

14181 Use K-162 to maintain KP-62 between 25 and 35 psig.

14184 Open C-221.

14186 Close C-231.

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14193 Set C-8 to 530 pot divisions.

14247 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

14252 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

14267 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

14269 Switch C-106 to AUTO.

14271 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

14276 Open C-231 to 85 pot divisions

14278 Close C-221.

14286 Use C-231 to establish and maintain 30 psig at CP-220.

14291 Switch to Q/N Control and establish Q/N = .25.

14307 Switch to SPEED Control.

14310 Switch Speed Rate Control to HOLD.

14316 Set Speed Rate pot to 160 divisions (800 rpm/sec).

14320 Demand 22,000 rpm.

14324 Switch Speed Rate Control to RUN.

14326 On Ramp, open C-231.

14362 Use C-8 in Q/N Control to establish a Q/N = .30.

14368 Report CP-700D. 500 psid.

14370 Slowly decrease K-3 position.

14421 Open K-3 (Q/N = .30 at 22,000 rpm -- K-3 minimum pot setting = 417 divisions).

14430 Increase Speed to 24,000 rpm.

14453 Report CP-700D. 600 psid.

14458 Slowly decrease K-3 position.

14503 Open K-3 (Q/N = .30 at 24,000 rpm -- K-3 minimum pot setting = 439 divisions).

14530 Increase Dewar 4 pressure to 80 psig.

14536	Increase speed to 26,000 rpm.
14540	Use C-8 to increase Q/N to .30.
14547	Report CP-700D. 710 psid.
14548	Slowly decrease K-3 position.
14597	Open K-3 (Q/N = .30 at 26,000 rpm -- K-3 minimum pot setting = 451 divisions).
14602	At TD command, push the shutdown button.
14618	Open D.C. breakers.
14622	Switch C-231 to POSITION Control and close.
14623	Bypass all the shutdown inputs.
14628	Switch C-106 to RESET.
14631	Reset the shutdown chain.
14636	Use C-111 to maintain CP-9 between 60 and 100 psig.
14640	Close C-12.
14650	Switch K-53 to POSITION Control and close.
14656	Close K-61.
14660	Open K-153.
14663	Decrease D.C. motor field to less than 5 amps.
14666	Switch the shutdown outputs to OVERRIDE.
15600	Liquid boil-off and transfer.

V. CAVITATION TEST PHASE RUN #12 - 39°R

The following points will be investigated:

Speed	Q/N
22,000	.30
24,000	.30
26,000	.30

The supply dewar pressure will be maintained at 65 psig.

A. PROCEED WITH CAVITATION TEST.

16060	Set the overspeed trip pot to 730 divisions (26,000 rpm).
16062	Raise the synchronous motor field to 120 amps.
16072	Close K-153.
16074	Select Dewar 5 pressure feedback.
16076	Open K-62.
16091	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

16093	Raise the D. C. motor field to 13 amps.
16102	Activate the following inputs to the shutdown chain:

UQ-2 CP-220
UQ-3 CP-505
JP-101/201 KP-61

16110	In K-53 PRESSURE Control, establish 65 psig in Dewar 5.
16116	Use C-106 to chill CT-106.
16120	At CTO command, Open C-11, Close C-111.
16128	Use K-161 to maintain KP-61 between 20 and 30 psig.
16138	Open C-221.
16140	Close C-231.
16144	Set C-8 to 530 pot divisions.
161250	When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

16253	Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

16276	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
16278	Switch C-106 to AUTO.
16280	At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

16282	Open C-231 to 85 pot divisions.
16283	Close C-221.
16289	Use C-231 to establish and maintain 30 psig at CP-220.
16296	Switch to Q/N Control and establish Q/N - .25.
16313	Switch to SPEED Control.
16316	Switch Speed Rate Control to HOLD.

16320	Set Speed Rate pot to 160 divisions (800 rpm/sec).
16327	Demand 22,000 rpm.
16329	Switch Speed Rate Control to RUN.
16334	On Ramp, Open C-231.
16369	Use C-8 in Q/N Control to establish a Q/N = .30.
16371	Report CP-700D. 500 psid.
16376	Slowly decrease K-3 position.
16450	Open K-3 (Q/N = .30 at 22,000 rpm -- K-3 minimum pot setting = 426 divisions).
16486	Increase speed to 24,000 rpm - maintain Q/N = .30.
16490	Report CP-700D. 600 psid.
16493	Slowly decrease K-3 position.
16546	Open K-3 (Q/N = .30 at 24,000 rpm -- K-3 minimum pot setting = 452 divisions).
16586	Increase speed to 26,000 rpm.
16588	Increase Dewar 5 pressure to 75 psig.
16591	Report CP-700D. 710 psid.
16597	Slowly decrease K-3 position.
16626	Open K-3 (Q/N = .30 at 26,000 rpm -- K-3 minimum pot setting = 460 divisions).
16628	At TD command, push the shutdown button.
16630	Switch C-231 to POSITION Control and close.
16640	Open D.C. breakers.
16645	Switch C-106 to RESET.
16646	Bypass all the shutdown inputs.
16647	Reset the shutdown chain.
16660	Use C-111 to maintain CP-9 between 60 and 100 psig.
16668	Close C-11.
16673	Switch K-53 to POSITION Control and close.
16678	Close K-62.
16682	Open K-153.
16686	Decrease D.C. motor field to less than 5 amps.
16690	Switch the shutdown outputs to OVERRIDE.
16800	Dewar transfer.

VI. CAVITATION TEST PHASE RUN #13 - 43°R

The following points will be investigated:

Speed	Q/N
22,000	.30
24,000	.30

The supply dewar pressure will be maintained at 70 psig.

A. PROCEED WITH CAVITATION TEST.

17750	Bottle 6 on line.
	a. QP-30: 3000 psig
17996	Set the overspeed trip pot to 730 divisions (28,000 rpm).
18010	Raise the synchronous motor field to 120 amps.
18015	Raise the D. C. motor field to 13 amps.
18016	Close K-153.
18023	Select Dewar 4 pressure feedback.
18027	Open K-61.
18041	Switch the following shutdown outputs to NORMAL:
	Speed Rate, C-8, C-221
18048	Activate the following inputs to the shutdown chain:
	UQ-2 CP-220 UQ-3 CP-505 Jp-101/201 KP-62
18051	In K-53 PRESSURE Control, establish 70 psig in Dewar 4.
18056	Use C-106 to chill CT-106.
18064	At CTO command Open C-12, Close C-111.
18071	Use K-162 to maintain KP-62 between 30 and 40 psig.
18076	Open C-221.
18078	Close C-231.
18080	Set C-8 to 530 pot divisions.
18207	When the pump is chilled, close the D. C. breakers.
	a. PMP: Report pump chill.
18214	Activate the following inputs to the shutdown chain:
	D. C. Breakers

222

18228	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
18230	Switch C-106 to AUTO.
18234	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
18238	Open C-231 to 85 pot divisions.
18240	Close C-221.
18243	Use C-231 to establish and maintain 30 psig at CP-220.
18251	Switch to Q/N Control and establish Q/N = .25.
18266	Switch to SPEED Control.
18268	Switch Speed Rate Control to HOLD.
18274	Set Speed Rate pot to 160 divisions (800 rpm/sec).
18278	Demand 22,000 rpm.
18282	Switch Speed Rate Control to RUN.
18287	On Ramp, Open C-231.
18316	Use C-8 in Q/N Control to establish a Q/N = .30.
18320	Report CP-700D. 480 psid.
18325	Slowly decrease K-3 position.
18362	Open K-3 (Q/N = .30 at 22,000 rpm -- K-3 minimum pot setting = 460 divisions).
18388	80 psig set in Dewar 4.
18396	Increase speed to 24,000 rpm and maintain Q/N = .30.
18400	Report CP-700D. 580 psid.
18402	Slowly decrease K-3 position.
18454	Open K-3 (Q/N = .30 at 24,000 rpm -- K-3 minimum pot setting = 440 divisions).
18464	At TD command, push the shutdown button
18481	Open D.C. breakers.
18486	Switch C-231 to POSITION Control and close.
18487	Switch C-106 to RESET.
18489	Bypass all the shutdown inputs.
18490	Reset the shutdown chain.
18496	Use C-111 to maintain CP-9 between 60 and 100 psig.
18497	Close C-12.

18508	Switch K-53 to POSITION Control and close.
18513	Close K-61.
18516	Open K-153.
18520	Decrease D. C. motor field to less than 5 amps.
18522	Switch the shutdown outputs to OVERRIDE.

VII. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

18922	Open L-251.
18930	Close L-261, L-153.
18940	Open L-61, L-301, L-330.
18953	Open L-331, X-301.
18983	Close K-401.
19004	Use L-53 in POSITION Control to establish and maintain 65 psig in Dewar 1.
19012	When LP-61 is greater than KP-61/62, Open K-301/302.
19024	Use K-161/162 to vent Dewar 4/5.
25830	When LH_2 transfer is complete, Close K-301/302.

VIII. CAVITATION TEST PHASE RUN #14 - 37.5°R

The following points will be investigated:

Speed	Q/N
26,000	.30

The supply dewar pressure will be maintained at 80 psig.

A. PROCEED WITH CAVITATION TEST.

27850	Nevada Power loop closed.
28087	Set the overspeed trip pot to 730 divisions (28,000 rpm).
28097	Raise the synchronous motor field to 120 amps.

224

28100 Close K-153.
28103 Select Dewar 5 pressure feedback.
28108 Open K-62.
28118 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

28127 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

28130 Raise the D.C. motor field to 13 amps.
28138 In K-53 PRESSURE Control, establish 80 psig in Dewar 5.
28202 Use C-106 to chill CT-106.
28218 At CTO command Open C-11, Close C-111.
28223 Use K-161 to maintain KP-61 between 30 and 40 psig.
28226 Open C-221
28228 Close C-231.
28232 Set C-8 to 530 pot divisions.
28490 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

28494 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

28512 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
28513 Switch C-106 to AUTO.
28516 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

28520	Open C-231 to 85 pot divisions.
28523	Close C-221.
28528	Use C-231 to establish and maintain 30 psig at CP-220.
28540	Switch to Q/N Control and establish Q/N = .30.
28556	Switch to SPEED Control.
28558	Switch Speed Rate Control to HOLD.
28564	Set Speed Rate pot to 160 divisions (800 rpm/sec).
28568	Demand 24,000 rpm.
28573	Switch Speed Rate Control to RUN.
28580	On Ramp, Open C-231.
28600	Use C-8 in Q/N Control to establish a Q/N = .30.
28603	Increase speed to 26,000 rpm.
28627	Report CP-700D. 740 psid.
28634	Slowly decrease K-3 position.
28710	Open K-3 (Q/N = .30 at 26,000 rpm -- K-3 minimum pot setting = 433 divisions).
28738	Increase KP-62 to 100 psig.
28741	Decrease speed to 23,000 rpm.
28744	Bypass Q/N High.
28748	Decrease Q/N to .28.
28810	Increase Q/N slowly (.36 maximum).
28816	At PMP Command, decrease Q/N to .25.
28831	At TD command, push the shutdown button.
28842	Open D.C. breakers.
28846	Bypass all the shutdown inputs.
28848	Switch C-231 to POSITION Control and close.
28850	Switch C-106 to RESET.
28852	Reset the shutdown chain.
28860	Use C-111 to maintain CP-9 between 60 and 100 psig.
28868	Close C-11.
28880	Switch K-53 to POSITION Control and close.
28884	Close K-62.
28888	Open K-153.
28891	Decrease D.C. motor field to less than 5 amps.
28892	Switch the shutdown outputs to OVERRIDE.
28980	Dewar transfer.

IX. CAVITATION TEST PHASE RUN #15 - 43°R

The following points will be investigated:

Speed	Q/N
24,000	.24
26,000	.30

The supply dewar pressure will be maintained at 90 psig.

A. PROCEED WITH CAVITATION TEST

30080 Set the overspeed trip pot to 730 divisions (28,000 rpm).

30086 Raise the synchronous motor field to 120 amps.

30094 Close K-153.

30100 Select Dewar 4 pressure feedback.

30101 Open K-61.

30114 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

30123 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

30130 Raise the D.C. motor field to 13 amps.

30134 In K-53 PRESSURE Control, establish 90 psig in Dewar 4.

30136 Use C-106 to chill CT-106.

30149 Use K-162 to maintain KP-62 between 50 and 60 psig.

30152 At CTO command Open C-12, Close C-111.

30154 Open C-221.

30156 Close C-231.

30159 Set C-8 to 530 pot divisions.

30226 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

227

30234	Activate the following inputs to the shutdown chain:
	D.C. Breakers
30249	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
30250	Switch C-106 to AUTO.
30251	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
30253	Open C-231 to 85 pot divisions.
30256	Close C-221.
30262	Use C-231 to establish and maintain 30 psig at CP-220.
30271	Switch to Q/N Control and establish Q/N = .30.
30293	Switch to SPEED Control.
30296	Switch Speed Rate Control to HOLD.
30301	Set Speed Rate pot to 160 divisions (800 rpm/sec).
30306	Demand 26,000 rpm.
30308	Switch Speed Rate Control to RUN.
30313	On Ramp, Open C-231.
30338	Use C-8 in Q/N Control to establish a Q/N = .30.
30342	Report CP-700D. 680 psid.
30350	Slowly decrease K-3 position.
30426	Open K-3 (Q/N = .30 at 26,000 rpm -- K-3 minimum pot setting = 443 divisions).
30446	Decrease speed to 24,000 rpm.
30468	Use C-8 to decrease Q/N to .24.
30474	Report CP-700D. 650 psid.
30480	Slowly decrease K-3 position.
30540	Open K-3 (Q/N = .24 at 24,000 rpm -- K-3 minimum pot setting = 367 divisions).
30550	At TD command, push the shutdown button.
30562	Open D.C. breakers.
30564	Switch C-231 to POSITION Control and close.
30574	Switch C-106 to RESET.

30576	Bypass all the shutdown inputs.
30579	Reset the shutdown chain.
30586	Use C-111 to maintain CP-9 between 60 and 100 psig.
30596	Close C-12.
30600	Switch K-53 to POSITION Control and close.
30611	Close K-61.
30617	Open K-153.
30620	Decrease D. C. motor field to less than 5 amps.
30623	Switch the shutdown outputs to OVERRIDE.
30642	Dewar transfer.

X. LOW SPEED MAPPING

During this phase, pump mapping will be performed at speed of 3,000, 6,000, 9,000 and 12,000 rpm at Q/N's of .14 to .35. Supply fluid temperature will be 39^{o}R. Dewar pressure will be maintained at 40 psig.

A. PROCEED WITH LOW SPEED MAPPING.

31968	Set the overspeed trip pot to 550 divisions (21,000 rpm).
31973	Raise the synchronous motor field to 120 amps.
31980	Close K-153.
31986	Select Dewar 5 pressure feedback.
31988	Open K-62.
32020	In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
32023	Raise the D. C. motor field to 13 amps.
32046	Bottles 5 and 6 on line.
32056	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
32064	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61

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32070 Use C-106 to chill CT-106.
32081 At CTO command Open C-11, Close C-111.
32100 Open K-161.
32103 Open C-221.
32106 Close C-231.
32112 Set C-8 to 530 pot divisions.
32274 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

32280 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

32307 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
32308 Switch C-106 to AUTO.
32316 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

32322 Switch to Q/N Control.
32328 Switch to SPEED Control.
32386 Increase speed to 12,000 rpm.
32394 Use C-8 to increase Q/N to .30.

a. Use .02 increments.

32433 Use C-8 to increase Q/N to .35.

a. Use .02 increments.

32476 Use C-8 to decrease Q/N to .25.
32478 Bypass Q/N Low input.
32480 Switch C-106 to RESET.
32538 Use C-8 to decrease Q/N to .14.
32567 Decrease speed to 9,000 rpm.

230

32630	Switch C-8 to POSITION Control.
32632	Use C-8 and C-106 to increase Q/N to .35.
32634	C-106 switched to RESET.
32636	Q/N High and Low bypassed.
32680	Decrease speed to 6,000 rpm.
32730	Use C-8 to decrease Q/N to .14. (40% on C-8)
32758	Decrease speed to 3,000 rpm.
32831	Use C-8 to increase Q/N to .35 (550 pot divisions).
32841	Bypass the following shutdown inputs: CT-507, Q/N High, Q/N Low
32853	Switch to MANUAL Control and decrease speed to zero.
32864	Open D.C. breakers.
32867	Bypass all the shutdown inputs.
32871	Reset the shutdown chain.
32876	Use C-111 to maintain CP-9 between 60 and 100 psig.
32888	Close C-11.
32904	Switch K-53 to POSITION Control and close.
32907	Close K-62.
32911	Open K-153.
32916	Decrease D.C. motor field to less than 5 amps.
32918	Switch the shutdown outputs to OVERRIDE.

XI. SHUTDOWN PHASE - MINIMUM

33800

A. POST CALIBRATION.

36551-36651 Calibration interval.

END

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APPENDIX F

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN II

17 DECEMBER 1971

I. PRE-OPERATIONAL PHASE

During this phase, verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switch to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

G. CHECK THE SHUTDOWN CHAIN.

H. PERFORM A VOLTAGE CALIBRATION.

03401-03501	Calibration interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4/5 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 40 psig.

A. PROCEED WITH HEADER PRESSURIZATION.

03742	Report on room inerting.
03750	Open K-50, K-153
03754	Open L-50.
03766	Close Q-120, Q-150, Q-101 thru Q-112.

	03812	Pressurize the helium header.
		a. QP-20: 1000 psig
	03893	Pressurize the hydrogen header with Bottle 6.
		a. QP-30: 3100 psig
B.	PROCEED WITH THE CHILLDOWN.	
	03916	Close K-153, K-403, K-402, K-261, C-408.
	03924	Close C-221.
	03941	Open K-1, K-61.
	03951	Open C-214, C-8.
	03956	Select Dewar 4 pressure feedback.
	03974	Slowly Open K-3.
	04026	In K-53 PRESSURE Control, establish 60 psig in Dewar 4.
	04196	Use C-111 to chill CT-3 to 100°R.
		a. PMP: Report CT-3.
	04200	Slowly Close K-3.
	04503	Use K-130 to chill KT-130.
		a. DSO: Report KT-130.
	04508	Close K-130.
	04595	When CP-8 is less than 10 psig, Open C-4, C-231; Close C-214.
	04597	Use C-106 to establish and maintain CP-505 between 10 and 20 psig.
	04600	Close C-111.
	04908	Use K-130 to maintain 3 lbs/sec at KF-130.
		a. CTO: Monitor CF-6.
	04910	When pump is chilled, slowly open K-3.
	04934	Close K-130.
	04944	Use C-111 to chill CT-111.
	04950	Close C-106.
	05000	When CT-111 is chilled, set C-111 to maintain CP-9 between 80 and 100 psig.
	05003	Open C-221.
	05006	Close C-231.

05017	Start 900 second timer.
05022	Switch K-53 to POSITION Control and close.
05031	Close K-61.
05034	Open K-153.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

05056	Report electric drive alarm status.
05060	Start synchronous motor.
05131	Start blowers.
05146	Establish synchronous motor field at 120 amps.
05178	Increase D.C. motor field to 13 amps, then decrease to 5 amps.
05230	Raise and lower armature voltage.
05321	D.C. motor field amps will not reduce (Field remains at 13 amps).

D. PROCEED WITH OVERSPEED TRIP CHECK.

06192	Set the overspeed trip pot to 105 divisions (4,000 rpm).
06201	Raise synchronous motor field to 120 amps.
06205	Raise D.C. motor field to 13 amps.
06208	Close K-153.
06214	Select Dewar 4 pressure feedback.
06228	Open K-61.
06230	In K-53 PRESSURE Control, establish 55 psig in Dewar 4.
06234	Switch the following shutdown output to NORMAL: Speed Rate.
06246	Activate the following inputs to the shutdown chain: UQ-2 JP-101/201 CP-220 CP-505
06248	Open K-3.
06250	Close K-130.

06257	Open C-11.
06261	Close C-111.
06266	Open K-161.
06268	Open C-221.
06270	Close C-231.
06272	Use C-8 to chill the pump.
06274	Set C-8 to 55%. (Q/N = .22)
06507	Set C-106 to 15%.
06511	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
06514	Activate CT-507 input to the shutdown chain.
06528	Establish 3,000 rpm.
06559	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
06567	Reset the shutdown chain.
06569	Bypass UQ-2 shutdown input.
06574	Activate UQ-3 shutdown input.
06626	In MANUAL Control, increase speed to produce overspeed trip (6,000 rpm).
06637	When speed is zero, open the D.C. breakers.
06640	Bypass all the shutdown inputs.
06643	Reset the shutdown chain.
06646	Close C-106.
06653	Use C-111 to maintain CP-9 between 60 and 100 psig.
06656	Switch K-53 to POSITION Control and close.
06660	Close K-61.
06662	Open K-153.
06672	Switch the shutdown outputs to OVERRIDE.

III. CAVITATION TEST PHASE RUN #16 - 37.5°R

The following points will be investigated:

Speed	Q/N
22,000	.17, .24
24,000	.17

The supply dewar pressure will be maintained at 85 psig.

236

A. PROCEED WITH CAVITATION TEST.

06740	Set the overspeed trip pot to 680 divisions (26,000 rpm).
06747	Raise the synchronous motor field to 120 amps.
06750	Raise the D. C. motor field to 13 amps.
06754	Close K-153.
06758	Select Dewar 5 pressure feedback.
06764	Open K-62.
06792	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

06808	In K-53 PRESSURE Control, establish 55 psig in Dewar 5.
06810	Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

06833	Use C-106 to chill CT-106.
06860	At CTO command Open C-11, Close C-111.
06877	Use K-161 to maintain KP-61 between 40 and 50 psig.
06881	Open C-221.
06884	Close C-231.
06886	Set C-8 to 530 pot divisions.
06958	Increase Dewar 5 pressure to 85 psig.
06964	When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

06970	Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

06982 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

06984 Switch C-106 to AUTO.

06990 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

06991 Open C-231 to 85 pot divisions.

06996 Close C-221.

06998 Use C-231 to establish and maintain 30 psig at CP-220.

07010 Switch to Q/N Control and establish Q/N = .20.

07020 Switch to SPEED Control.

07022 Switch Speed Rate Control to HOLD.

07025 Set Speed Rate pot to 160 divisions (800 rpm/sec).

07032 Demand 24,000 rpm.

07034 Switch Speed Rate Control to RUN.

07037 On Ramp, Open C-231.

07073 Use C-8 to establish a Q/N = .17.

07076 Report CP-700D. 750 psid.

07080 Slowly decrease K-3 position.

07163 Open K-3 (Q/N = .17 at 24,000 rpm -- K-3 minimum pot setting = 329 divisions).

07188 Decrease speed to 22,000 rpm.

07196 Use C-8 to maintain Q/N at .17.

07198 Report CP-700D. 640 psid.

07201 Slowly decrease K-3 position.

07260 Open K-3 (Q/N = .17 at 22,000 rpm -- K-3 minimum pot setting = 300 divisions).

07304 Use C-8 to increase Q/N to .24.

07307 Report CP-700D. 580 psid.

07316 Slowly decrease K-3 position.

07377 Open K-3 (Q/N = .24 at 22,000 rpm -- K-3 minimum pot setting = 510 divisions).

07391 At TD command, push the shutdown button.

07403 Open D.C. breakers.

07404 Switch C-231 to POSITION Control and close.

07406 Switch C-106 to RESET.

07410 Bypass all the shutdown inputs.

07413 Reset the shutdown chain.

07420	Use C-111 to maintain CP-9 between 60 and 100 psig.
07426	Close C-11.
07436	Switch K-53 to POSITION Control and close.
07444	Close K-62.
07447	Open K-153.
07457	Switch the shutdown outputs to OVERRIDE.
07480	Dewar transfer.

IV. CAVITATION TEST PHASE RUN #17 - 43°R

The following points will be investigated:

Speed	Q/N
19,000	.17, .24
22,000	.17, .24
24,000	.17

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

08468	Set the overspeed trip pot to 680 divisions (26,000 rpm).
08477	Raise the synchronous motor field to 120 amps.
08479	Raise the D.C. motor field to 13 amps.
08482	Close K-153.
08486	Select Dewar 4 pressure feedback.
08489	Open K-61.
08506	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
08520	Activate the following inputs to the shutdown chain: UQ-2, UQ-3, JP-101/201, CP-220, CP-505, KP-62
08530	Use C-106 to chill CT-106.
08531	In K-53 PRESSURE Control, establish 100 psig in Dewar 4.
08542	At CTO command Open C-12, Close C-111.

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08554 Use K-162 to maintain KP-62 between 50 and 60 psig.

08556 Open C-221.

08558 Close C-231.

08562 Set C-8 to 530 pot divisions.

08622 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

08626 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

08654 CT-507 high trip.

08680 CT-507 bypassed.

08706 Close Breaker.

08726 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

08730 Switch C-106 to AUTO.

08734 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

08736 Open C-231 to 85 pot divisions.

08740 Close C-221.

08746 Use C-231 to establish and maintain 30 psig at CP-220.

08750 Switch to Q/N Control and establish Q/N = .17.

08769 Switch to SPEED Control.

08771 Switch Speed Rate Control to HOLD.

08777 Set Speed Rate pot to 160 divisions (800 rpm/sec).

08782 Demand 24,000 rpm.

08784 Switch Speed Rate Control to RUN.

08786 On Ramp, Open C-231.

08810 Use C-8 in Q/N Control to establish a Q/N = .17.

08813	Report CP-700D. 710 psid.
08818	Slowly decrease K-3 position.
08892	Open K-3 (Q/N = .17 at 24,000 rpm -- K-3 minimum pot setting = 324 divisions).
08914	Decrease speed to 22,000 rpm.
08917	Use C-8 to maintain a Q/N of .17.
08920	Report CP-700D. 590 psid.
08927	Slowly decrease K-3 position.
08973	Open K-3 (Q/N = .17 at 22,000 rpm -- K-3 minimum pot setting = 298 divisions).
09000	Use C-8 to increase Q/N to .24.
09004	Report CP-700D. 540 psid.
09008	Slowly decrease K-3 position.
09056	Open K-3 (Q/N = .24 at 22,000 rpm -- K-3 minimum pot setting = 436 divisions).
09087	Decrease speed to 19,000 rpm.
09088	Use C-8 to maintain a Q/N = .24.
09091	Report CP-700D. 390 psid.
09096	Slowly decrease K-3 position.
09137	Open K-3 (Q/N = .24 at 19,000 rpm -- K-3 minimum pot setting = 350 divisions).
09170	Use C-8 to decrease Q/N to .17.
09177	Report CP-700D. 430 psid.
09180	Slowly decrease K-3 position.
09237	Open K-3 (Q/N = .17 at 19,000 rpm -- K-3 minimum pot setting = 253 divisions).
09246	At TD command, push the shutdown button.
09256	Open D.C. breakers.
09261	Switch C-231 to POSITION Control and close.
09263	Switch C-106 to RESET.
09266	Bypass all the shutdown inputs.
09268	Reset the shutdown chain.
09270	Use C-111 to maintain CP-9 between 60 and 100 psig.
09274	Close C-12.
09287	Close K-61.
09292	Switch K-53 to POSITION Control and close.
09298	Open K-153.
09306	Switch the shutdown outputs to OVERRIDE.
09700	Dewar transfer and boil-off.

V. CAVITATION TEST PHASE RUN #18 - 41°R

The following points will be investigated:

Speed	Q/N
26,000	.17, .21

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

10891	Set the overspeed trip pot to 730 divisions (28,000 rpm).
10900	Raise the synchronous motor field to 120 amps.
10905	Raise the D. C. motor field to 13 amps.
10906	Close K-153.
10908	Select Dewar 5 pressure feedback.
10913	Open K-62.
11004	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
11014	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
11028	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
11036	Use C-106 to chill CT-106.
11048	At CTO command Open C-11, Close C-111.
11056	Use K-161 to maintain KP-61 between 60 and 70 psig.
11061	Open C-221.
11063	Close C-231.
11065	Set C-8 to 530 pot divisions.

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11157 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

11164 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

11186 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

11196 Switch C-106 to AUTO.

11198 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

11202 Open C-231 to 85 pot divisions.

11204 Close C-221.

11206 Use C-231 to establish and maintain 30 psig at CP-220.

11216 Switch to Q/N Control and establish Q/N = .17.

11233 Switch to SPEED Control.

11236 Switch Speed Rate Control to HOLD.

11240 Set Speed Rate pot to 160 divisions (800 rpm/sec).

11246 Demand 26,000 rpm.

11251 Switch Speed Rate Control to RUN.

11259 On Ramp, Open C-231.

11280 Use C-8 in Q/N Control to establish a Q/N = .17.

11287 Report CP-700D. 860 psid.

11289 Slowly decrease K-3 position.

11381 Open K-3 (Q/N = .17 at 26,000 rpm -- K-3 minimum pot setting = 340 divisions).

11440 Use C-8 to increase Q/N to .24. (.21 max. reached)

11447 Report CP-700D. 810 psid.

11453 Slowly decrease K-3 position.

11516 Open K-3 (Q/N = .21 at 26,000 rpm -- K-3 minimum pot setting = 487 divisions).

11530	At TD command, push the shutdown button.
11544	Open D.C. breakers.
11546	Switch C-231 to POSITION Control and close.
11547	Switch C-106 to RESET.
11548	Bypass all the shutdown inputs.
11550	Reset the shutdown chain.
11558	Use C-111 to maintain CP-9 between 60 and 100 psig.
11568	Close C-11.
11578	Switch K-53 to POSITION Control and close.
11581	Close K-62.
11586	Open K-153.
11590	Switch the shutdown outputs to OVERRIDE.
11630	Dewar transfer.

VI. CAVITATION TEST PHASE RUN #19 - 43°R

The following points will be investigated:

Speed	Q/N
26,000	.17, .21

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

12910	Bottle 7 on line.
	a. QP-30: 3200 psi
13001	Set the overspeed trip pot to 730 divisions (28,000 rpm).
13008	Raise the synchronous motor field to 120 amps.
13011	Raise the D.C. motor field to 13 amps.
13014	Close K-153.
13019	Select Dewar 4 pressure feedback.
13026	Open K-61.
13035	Switch the following shutdown outputs to NORMAL:
	Speed Rate, C-8, C-221

E

13050 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

13060 Use C-106 to chill CT-106.

13080 In K-53 PRESSURE Control, establish 100 psig in Dewar 4.

13083 At CTO command Open C-12, Close C-111.

13085 Use K-162 to maintain KP-62 between 60 and 70 psig.

13086 Open C-221.

13090 Close C-231.

13094 Set C-8 to 530 pot divisions.

13156 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

13163 Activate the following inputs to the shutdown chain:

D. C. Breakers

13183 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

13187 Switch C-106 to AUTO.

13190 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

13192 Open C-231 to 85 pot divisions.

13194 Close C-221.

13201 Use C-231 to establish and maintain 30 psig at CP-220.

13208 Switch to Q/N Control and establish Q/N = .17.

13223 Switch to SPEED Control.

13225 Switch Speed Rate Control to HOLD.

13230	Set Speed Rate pot to 160 divisions (800 rpm/sec).
13232	Demand 26,000 rpm.
13238	Switch Speed Rate Control to RUN.
13243	On Ramp, Open C-231.
13273	Use C-8 in Q/N Control to establish a Q/N = .17.
13276	Report CP-700D. 840 psid.
13280	Slowly decrease K-3 position.
13353	Open K-3 (Q/N = .17 at 26,000 rpm -- K-3 minimum pot setting = 351 divisions).
13382	Use C-8 to increase Q/N to .21.
13388	Report CP-700D. 800 psid.
13389	Slowly decrease K-3 position.
13450	Open K-3 (Q/N = .21 at 26,000 rpm -- K-3 minimum pot setting = 520 divisions).
13456	At TD command, push the shutdown button.
13471	Open D.C. breakers.
13474	Switch C-231 to POSITION Control and close.
13475	Switch C-106 to RESET.
13477	Bypass all the shutdown inputs.
13478	Reset the shutdown chain.
13487	Use C-111 to maintain CP-9 between 60 and 100 psig.
13493	Close C-12.
13501	Switch K-53 to POSITION Control and close.
13507	Close K-61.
13510	Open K-153.
13516	Switch the shutdown outputs to OVERRIDE.
13594	D.C. motor field reduced less than 5 amps.

VII. DEWAR 1 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 1.

A. PROCEED WITH THE LH_2 TRANSFER.

13664	Open L-251.
13686	Close L-262, L-153.
13788	Open L-61/62, L-301, L-330; Close L-61.
13798	Open L-331, X-301.

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13808	Close K-401.
13880	Use L-53 in POSITION Control to establish and maintain 65 psig in Dewar 2.
13863	When LP-61 is greater than KP-61/62, Open K-301/302.
20330	When LH_2 transfer is complete, Close K-301/302.

VIII. CAVITATION TEST PHASE RUN #20 - 37.5°R

The following points will be investigated:

Speed	Q/N
26,000	.17, .24

The supply dewar pressure will be maintained at 90 psig.

A. PROCEED WITH CAVITATION TEST.

20881	Set the overspeed trip pot to 730 divisions (26,000 rpm).
20888	Raise the synchronous motor field to 120 amps.
20890	Raise the D. C. motor field to 13 amps.
20896	Close K-153.
20898	Select Dewar 5 pressure feedback.
20903	Open K-62.
20914	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
20924	Activate the following inputs to the shutdown chain: UQ-2, CP-220, UQ-3, CP-505, JP-101/201, KP-61
20951	In K-53 PRESSURE Control, establish 90 psig in Dewar 5.
20961	Use C-106 to chill CT-106.

20968	At CTO command Open C-11, Close C-111.
20981	Use K-161 to maintain KP-61 between 60 and 70 psig.
20984	Open C-221.
20986	Close C-231.
20990	Set C-8 to 530 pot divisions.
21186	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
21190	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
21207	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
21208	Switch C-106 to AUTO.
21212	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
21216	Open C-231 to 85 pot divisions.
21218	Close C-221.
21223	Use C-231 to establish and maintain 30 psig at CP-220.
21230	Switch to Q/N Control and establish Q/N = .17.
21246	Switch to SPEED Control.
21248	Switch Speed Rate Control to HOLD.
21254	Set Speed Rate pot to 160 divisions (800 rpm/sec).
21258	Demand 26,000 rpm.
21261	Switch Speed Rate Control to RUN.
21267	On Ramp, Open C-231.
21290	Use C-8 in Q/N Control to establish a Q/N = .17.
21294	Report CP-700D. 890 psid.
21298	Slowly decrease K-3 position.
21379	Open K-3 (Q/N = .17 at 26,000 rpm -- K-3 minimum pot setting = 355 divisions).

21438	Use C-8 to increase Q/N to .21.
21439	Increase dewar pressure to 100 psig.
21454	Slowly decrease K-3 position.
21541	Open K-3 (Q/N = .21 at 26,000 rpm -- K-3 minimum pot setting = 465 divisions).
21551	At TD command, push the shutdown button.
21566	Open D.C. breakers.
21575	Switch C-231 to POSITION Control and close.
21576	Switch C-106 to RESET.
21578	Bypass all the shutdown inputs.
21589	Reset the shutdown chain.
21581	Use C-111 to maintain CP-9 between 60 and 100 psig.
21586	Close C-11.
21596	Switch K-53 to POSITION Control and close.
21605	Close K-62.
21606	Open K-153.
21617	Switch the shutdown outputs to OVERRIDE.
21650	Dewar transfer.

IX. CAVITATION TEST PHASE RUN #21 - 39°R

The following points will be investigated:

Speed	Q/N
24,000	.21
26,000	.17, .21

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

22794	Set the overspeed trip pot to 730 divisions (26,000 rpm).
22800	Raise the synchronous motor field to 120 amps.
22803	Raise the D.C. motor field to 13 amps.
22810	Close K-153.
22850	Bottle 8 on line.

a. QP-30: 3200 psi

22894 Open K-61.
22896 Select Dewar 4 pressure feedback.
22902 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

22918 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

22922 Use C-106 to chill CT-106.
22941 At CTO command Open C-12, Close C-111.
22948 Use K-162 to maintain KP-62 between 60 and 70 psig.
22952 Open C-221.
22953 Close C-231.
22957 Set C-8 to 530 pot divisions.
22963 In K-53 PRESSURE Control, establish 100 psig in Dewar 4.
23017 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

23020 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

23033 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
23036 Switch C-106 to AUTO.
23038 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

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23041	Open C-231 to 85 pot divisions.
23044	Close C-221.
23051	Use C-231 to establish and maintain 30 psig at CP-220.
23056	Switch to Q/N Control and establish Q/N = .17.
23066	Switch to SPEED Control.
23068	Switch Speed Rate Control to HOLD.
23073	Set Speed Rate pot to 160 divisions (800 rpm/sec).
23082	Demand 26,000 rpm.
23084	Switch Speed Rate Control to RUN.
23086	On Ramp, Open C-231.
23112	Use C-8 in Q/N Control to establish a Q/N = .17.
23114	Report CP-700D. 880 psid.
23119	Slowly decrease K-3 position.
23177	Open K-3 (Q/N = .17 at 26,000 rpm -- K-3 minimum pot setting = 337 divisions).
23208	Use C-8 to increase Q/N to .21.
23213	Report CP-700D. 830 psid.
23216	Slowly decrease K-3 position.
23304	Open K-3 (Q/N = .21 at 26,000 rpm -- K-3 minimum pot setting = 468 divisions).
23322	Decrease speed to 24,000 rpm.
23330	Use C-8 to maintain a Q/N of .21.
23333	Report CP-700D. 690 psid.
23340	Slowly decrease K-3 position.
23375	Open K-3 (Q/N = .21 at 24,000 rpm -- K-3 minimum pot setting = 393 divisions).
23384	At TD command, push the shutdown button.
23397	Open D.C. breakers.
23398	Switch C-231 to POSITION Control and close.
23399	Switch C-106 to RESET.
23404	Bypass all the shutdown inputs.
23406	Reset the shutdown chain.
23412	Use C-111 to maintain CP-9 between 60 and 100 psig.
23426	Close C-12.
23428	Switch K-53 to POSITION Control and close.
23433	Close K-61.
23436	Open K-153.
23440	Switch the shutdown outputs to OVERRIDE.
23610	Dewar transfer.

X. CAVITATION TEST PHASE RUN #22 - 43°R

The following points will be investigated:

Speed	Q/N
19,000	.30

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

24293 Set the overspeed trip pot to 550 divisions (21,000 rpm).
24300 Raise the synchronous motor field to 120 amps.
24305 Raise the D. C. motor field to 13 amps.
24307 Close K-153.
24310 Select Dewar 5 pressure feedback.
24314 Open K-62.
24324 Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

24330 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-61

24349 In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
24352 Use C-106 to chill CT-106.
24362 At CTO command Open C-11, Close C-111.
24371 Use K-161 to maintain KP-61 between 60 and 70 psig.
24373 Open C-221.
24375 Close C-231.
24378 Set C-8 to 530 pot divisions.

24441	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
24447	Activate the following inputs to the shutdown chain:
	D.C. Breakers
24460	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
24462	Switch C-106 to AUTO.
24468	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
24470	Open C-231 to 85 pot divisions.
24472	Close C-221.
24475	Use C-231 to establish and maintain 30 psig at CP-220.
24480	Switch to Q/N Control and establish Q/N = .30.
24502	Switch to SPEED Control.
24504	Switch Speed Rate Control to HOLD.
24507	Set Speed Rate pot to 160 divisions (800 rpm/sec).
24512	Demand 19,000 rpm.
24518	Switch Speed Rate Control to RUN.
24520	On Ramp, Open C-231.
24537	Use C-8 in Q/N Control to establish a Q/N = .30.
24542	Report CP-700D. 350 psid.
24546	Slowly decrease K-3 position.
24598	Open K-3 (Q/N = .30 at 19,000 rpm -- K-3 minimum pot setting = 482 divisions).
24614	At TD command, push the shutdown button.
24630	Open D.C. breakers.
24631	Switch C-231 to POSITION Control and close.
24632	Switch C-106 to RESET.
24633	Bypass all the shutdown inputs.
24636	Reset the shutdown chain.

24652	Use C-111 to maintain CP-9 between 60 and 100 psig.
24658	Close C-11.
24662	Switch K-53 to POSITION Control and close.
24664	Close K-62.
24666	Open K-153.
24668	Switch the shutdown outputs to OVERRIDE.
24720	Dewar transfer.

XI. CAVITATION TEST PHASE RUN #23 - 39°R

The following points will be investigated:

Speed	Q/N
24,000	.24

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH CAVITATION TEST.

25616	Set the overspeed trip pot to 680 divisions (26,000 rpm).
25622	Raise the synchronous motor field to 120 amps.
25627	Raise the D.C. motor field to 13 amps.
25630	Close K-153.
25634	Select Dewar 5 pressure feedback.
25640	Open K-62.
25647	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
25640	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
25665	Use C-106 to chill CT-106.

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25668	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
25671	At CTO command Open C-11, Close C-111.
25682	Use K-161 to maintain KP-61 between 60 and 70 psig.
25690	Open C-221.
25692	Close C-231.
25694	Set C-8 to 530 pot divisions.
25762	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
25764	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
25780	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
25782	Switch C-106 to AUTO.
25786	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
25788	Open C-231 to 85 pot divisions.
25790	Close C-221.
25796	Use C-231 to establish and maintain 30 psig at CP-220.
25800	Switch to Q/N Control and establish Q/N = .24.
25816	Switch to SPEED Control.
25818	Switch Speed Rate Control to HOLD
25832	Set Speed Rate pot to 160 divisions (800 rpm/sec).
25841	Demand 24,000 rpm.
25846	Switch Speed Rate Control to RUN.
25852	On Ramp, Open C-231.
25868	Use C-8 in Q/N Control to establish a Q/N = .24.
25874	Report CP-700D. 660 psid.
25878	Slowly decrease K-3 position.

25964	Open K-3 (Q/N = .24 at 24,000 rpm -- K-3 minimum pot setting = 512 divisions).
25984	At TD command, push the shutdown button.
25988	Switch C-231 to POSITION Control and close.
25997	Open D.C. breakers.
26001	Bypass all the shutdown inputs.
26004	Reset the shutdown chain.
26008	Switch C-106 to RESET.
26013	Use C-111 to maintain CP-9 between 60 and 100 psig.
26028	Close C-11.
26029	Switch K-53 to POSITION Control and close.
26034	Close K-62.
26038	Open K-153.
26050	Switch the shutdown outputs to OVERRIDE.
26096	Decrease D.C. motor field to less than 5 amps.

POST VOLTAGE CALIBRATION

26541-26641 Calibration interval.

↓

MAXIMUM SHUTDOWN SECURE

26850

↓

END

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APPENDIX G

CHRONOLOGY FOR CEL INDUCER TEST

EXPERIMENTAL PLAN II A

22 DECEMBER 1971

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I. PRE-OPERATIONAL PHASE

During this phase, verification will be made of the Test Cell "C" readiness to conduct a test using the CEL and Electric Drive Systems. Facility setup checklists will be reviewed, personnel locations will be determined, the Operators communication net will be checked, and systems switched to LCR control. Valves and systems necessary for the test will then be operated, room inerting will be started, and a voltage calibration performed.

A. SETUP CHECKLISTS HAVE BEEN REVIEWED AND APPROVED.

B. REPORT ON STATUS OF PERSONNEL IN TEST CELL "C" AREA.

C. CHECK THE OPERATORS NET.

D. HAVE THE REQUIRED SYSTEMS SWITCHED TO LCR CONTROL.

E. EXERCISE THE VALVES IN THE ELECTRIC PUMP ROOM, CEL AND HIGH PRESSURE ROOM.

F. BEGIN INERTING THE TEST CELL.

G. CHECK THE SHUTDOWN CHAIN.

H. PERFORM A VOLTAGE CALIBRATION.

03361-03461 Calibration interval.

II. PRESSURIZATION, CHILLDOWN, OVERSPEED TRIP CHECK

During this phase, the helium and hydrogen headers will be pressurized, Dewar 4 will be pressurized, the CEL flow loop will be chilled and soaked, and the overspeed inputs to the shutdown chain will be checked. K-3 and K-130 will be calibrated at a dewar pressure of 40 psig.

A. PROCEED WITH HEADER PRESSURIZATION.

03700	Report on room inerting.
03710	Open K-50, K-153.

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03713 Open L-50.
03725 Close Q-120, Q-150, Q-101 thru Q-112.
03764 Pressurize the helium header.

a. QP-20: 2700 psig

03841 Pressurize the hydrogen header with Bottle 7.

a. QP-30: 1700 psig

B. PROCEED WITH THE CHILLDOWN.

03878 Close K-153, K-262, K-403, K-402, C-408.
03887 Close C-221.
03895 Open K-1, K-61.
03907 Open C-214, C-8.
03926 Select Dewar 4 pressure feedback.
03933 Open C-111.
03959 In K-53 PRESSURE Control, establish 60 psig in Dewar 4.
04667 Use K-3 to chill CT-3 for 100°R.
04680 Close K-3.
04914 Use K-130 to chill KT-130.
04919 Close K-130.
05030 When CP-8 is less than 10 psig Open C-4, C-231; Close C-214.

a. PMP: Report CP-8.

05048 Close C-111.
05053 Use C-106 to establish and maintain CP-505 between 10 and 20 psig.
05063 Use K-130 to maintain 3 lbs/sec at KF-130.
05341 When pump is chilled, slowly open K-3.
05355 Close K-130.
05370 Use C-111 to chill CT-111.
05410 When CT-111 is chilled, set C-111 to maintain CP-9 between 80 and 100 psig.
05412 Open C-221.
05419 Close C-231.
05423 Start 900 second timer.

05435	Switch K-53 to POSITION Control and close.
05448	Close K-61.
05451	Open K-153.

C. PROCEED WITH STARTUP OF A.C. MOTOR.

05457	Report electric drive alarm status.
05460	Start synchronous motor.
05535	Start blowers.
05568	Establish and maintain unity power factor. (120 Amps)
05578	Increase D.C. motor field to 13 amps, then decrease to 5 amps.
05617	Raise and lower armature voltage.
05631	5 Amps set on D.C. motor field.

D. PROCEED WITH OVERSPEED TRIP CHECK.

06550	Set the overspeed trip pot to 105 divisions (4,000 rpm).
06556	Close K-153.
06561	Select Dewar 4 pressure feedback.
06569	Raise synchronous motor field to 120 amps.
06572	Raise D.C. motor field to 13 amps.
06580	Open K-61.
06582	In K-53 PRESSURE Control, establish 60 psig in Dewar 4.
06585	Switch the following shutdown output to NORMAL: Speed Rate
06590	Activate the following inputs to the shutdown chain: UQ-2 CP-220 JP-101/201 CP-505
06600	Open K-3.
06605	Close K-130.
06611	Open C-111.
06616	Open C-221.
06620	Close C-231.

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06628	Use C-8 to chill the pump.
06858	Set C-8 to 55%. (Q/N = .22)
06860	Set C-106 to 15%.
06864	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
06868	Activate CT-507 input to the shutdown chain.
06907	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
06910	Reset the shutdown chain.
06915	Bypass UQ-2 shutdown input.
06918	Activate UQ-3 shutdown input.
06955	In MANUAL Control, increase speed to produce overspeed trip (4,000 rpm).
06957	When speed is zero, open the D.C. breakers.
06960	Bypass all the shutdown inputs.
06962	Reset the shutdown chain.
06964	Close C-106.
06984	Use C-111 to maintain CP-9 between 60 and 100 psig.
06990	Switch K-53 to POSITION Control and close.
06996	Close K-61.
06999	Open K-153.
07007	Switch the shutdown outputs to OVERRIDE.
07015	Decrease D.C. motor field to less than 5 amps.

III. CAVITATION TEST PHASE RUN #24 - 37.5°R

The following points will be investigated:

Speed	Q/N
26,000	.26

The supply dewar pressure will be maintained at 50 psig.

A. PROCEED WITH CAVITATION TEST.

07286	Set the overspeed trip pot to 730 divisions (28,000 rpm).

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07292	Raise the synchronous motor field to 120 amps.
07304	Close K-153.
07307	Select Dewar 5 pressure feedback.
07310	Open K-62.
07315	Raise the D. C. motor field to 13 amps.
07349	Switch the following shutdown outputs to NORMAL:
	Speed Rate, C-8, C-221
07356	Activate the following inputs to the shutdown chain:
	UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
07371	In K-53 PRESSURE Control, establish 50 psig in Dewar 5.
07384	Use C-106 to chill CT-106.
07410	At CTO command Open C-11, Close C-111.
07424	Use K-161 to maintain KP-61 between 30 and 40 psig.
07429	Open C-221.
07430	Close C-231.
07432	Set C-8 to 530 pot divisions.
07590	Critical power breaker tripped (Data hold).
07982	When the pump is chilled, close the D. C. breakers.
	a. PMP: Report pump chill.
07989	Activate the following inputs to the shutdown chain:
	D. C. Breakers, CT-507
08010	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
08013	Switch C-106 to AUTO.

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08015	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
08018	Open C-231 to 85 pot divisions.
08020	Close C-221.
08023	Use C-231 to establish and maintain 30 psig at CP-220.
08032	Switch to Q/N Control and establish Q/N = .26.
08051	Switch to SPEED Control.
08054	Switch Speed Rate Control to HOLD.
08058	Set Speed Rate pot to 160 divisions (800 rpm/sec).
08067	Demand 26,000 rpm.
08071	Switch Speed Rate Control to RUN.
08074	On Ramp, Open C-231.
08097	Use C-8 in Q/N Control to establish a Q/N = .26.
08103	Report CP-700D. 760 psid.
08106	Slowly decrease K-3 position.
08152	Close K-3 (Q/N = .26 at 26,000 rpm -- K-3 minimum pot setting = 484 divisions).
08162	At TD command, push the shutdown button.
08177	Open D.C. breakers.
08179	Bypass all the shutdown inputs.
08180	Switch C-231 to POSITION Control and close.
08182	Switch C-106 to RESET.
08184	Reset the shutdown chain.
08194	Use C-111 to maintain CP-9 between 60 and 100 psig.
08198	Close C-11.
08207	Switch K-53 to POSITION Control and close.
08211	Close K-62.
08213	Open K-153.
08219	Decrease D.C. motor field to less than 5 amps.
08225	Switch the shutdown outputs to OVERRIDE.
08240	Dewar transfer.

IV. PUMP MAPPING

During this phase, pump mapping will be performed at a speed of 23,000 rpm at Q/N's of .14 to .34. Supply fluid temperature will be 37.5°R. Dewar pressure will be maintained at 50 psig.

A. PROCEED WITH PUMP MAPPING.

08757	Set the overspeed trip pot to 680 divisions (26,000 rpm).
08762	Raise the synchronous motor field to 120 amps.
08770	Raise the D.C. motor field to 13 amps.
08793	Close K-153.
08800	Select Dewar 4 pressure feedback.
08808	Open K-61.
08818	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
08029	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-62
08835	In K-53 PRESSURE Control, establish 50 psig in Dewar 4.
08841	Use C-106 to chill CT-106.
08848	At CTO command Open C-12, Close C-111.
08854	Use K-162 to maintain KP-62 between 30 and 40 psig.
08860	Open C-221.
08863	Close C-231.
08868	Set C-8 to 530 pot divisions.
08949	When the pump is chilled, close the D.C. breakers. a. PMP: Report pump chill.

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08954	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
08973	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
09012	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High
09018	Open C-231 to 85 pot divisions.
09020	Close C-221.
09026	Use C-231 to establish and maintain 30 psig at CP-220.
09032	Switch to Q/N Control and establish Q/N = .14.
09054	Switch to SPEED Control.
09057	Switch Speed Rate Control to HOLD.
09062	Set Speed Rate pot to 160 divisions (800 rpm/sec).
09069	Demand 23,000 rpm.
09073	Switch Speed Rate Control to RUN.
09078	On Ramp, Open C-231.
09101	Use C-8 to establish Q/N = .14.
09136	Switch C-106 to AUTO.
09139	Q/N Low activated.
09205	Dewar 4 pressure increased to 60 psig.
09218	Use C-8 to increase Q/N to .34 in Q/N Control.
09221	At TD command, push the shutdown button.
09243	Open D.C. breakers.
09246	Switch C-231 to POSITION Control and close.
09249	Switch C-106 to RESET.
09250	Bypass all the shutdown inputs.
09252	Reset the shutdown chain.
09254	Use C-111 to maintain CP-9 between 60 and 100 psig.
09262	Close C-12.
09274	Switch K-53 to POSITION Control and close.
09276	Close K-61.

09280	Open K-153.
09288	Decrease D. C. motor field to less than 5 amps.
09290	Switch the shutdown outputs to OVERRIDE.
09360	Dewar transfer.

B. VOLTAGE CALIBRATION.

09831-09931	Calibration interval.

V. CAVITATION TEST PHASE RUN #25 - 39°R

The following points will be investigated:

Speed	Q/N
27,000	.28

The supply dewar pressure will be maintained at 80 psig.

A. PROCEED WITH CAVITATION TEST.

10397	Set the overspeed trip pot to 760 divisions (28,000 rpm).
10404	Raise the synchronous motor field to 120 amps.
10406	Raise the D. C. motor field to 13 amps.
10408	Close K-153.
10410	Select Dewar 5 pressure feedback.
10415	Open K-62.
10426	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
10434	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61

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10450 In K-53 PRESSURE Control, establish 80 psig in Dewar 5.

10457 Use C-106 to chill CT-106.

10465 At CTO command Open C-11, Close C-111.

10480 Use K-161 to maintain KP-61 between 30 and 40 psig.

10484 Open C-221.

10486 Close C-231.

10490 Set C-8 to 530 pot divisions.

10621 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

10626 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

10647 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

10650 Switch C-106 to AUTO.

10656 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

10661 Open C-231 to 85 pot divisions.

10663 Close C-221.

10668 Use C-231 to establish and maintain 30 psig at CP-220.

10672 Switch to Q/N Control and establish Q/N = .28.

10699 Switch to SPEED Control.

10700 Switch Speed Rate Control to HOLD.

10705 Set Speed Rate pot to 160 divisions (800 rpm/sec).

10720 Demand 27,000 rpm.

10723 Switch Speed Rate Control to RUN

10725 On Ramp, Open C-231.

10761 Use C-8 in Q/N Control to establish a Q/N = .17. (73 lbs/sec).

10769	Report CP-700D. 800 psid.
10774	Slowly decrease K-3 position.
10832	Open K-3 (Q/N = .28 at 27,000 rpm -- K-3 minimum pot setting = 430 divisions).
10840	At TD command, push the shutdown button.
10854	Open D.C. breakers.
10855	Switch C-231 to POSITION Control and close.
10856	Switch C-106 to RESET.
10868	Bypass all the shutdown inputs.
10870	Reset the shutdown chain.
10873	Use C-111 to maintain CP-9 between 60 and 100 psig.
10878	Close C-11.
10891	Switch K-53 to POSITION Control and close.
10895	Close K-62.
10900	Open K-153.
10910	Switch the shutdown outputs to OVERRIDE.
11105	Dewar transfer.

VI. CAVITATION TEST PHASE RUN #26 - 39°R

The following points will be investigated:

Speed	Q/N
24,000	.30
26,000	.26

The supply dewar pressure will be maintained at 75 psig.

A. PROCEED WITH CAVITATION TEST.

12261	Set the overspeed trip pot to 730 divisions (28,000 rpm).
12267	Raise the synchronous motor field to 120 amps.
12268	Raise the D.C. motor field to 13 amps.
12270	Close K-153.
12272	Select Dewar 4 pressure feedback.
12274	Open K-61.
12293	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

12294 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

12314 Use C-106 to chill CT-106.

12316 In K-53 PRESSURE Control, establish 75 psig in Dewar 4.

12329 At CTO command Open C-12, Close C-111.

12334 Use K-162 to maintain KP-62 between 30 and 40 psig.

12338 Open C-221.

12340 Close C-231.

12343 Set C-8 to 530 pot divisions.

12449 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

12452 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

12470 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

12471 Switch C-106 to AUTO.

12472 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

12476 Open C-231 to 85 pot divisions.

12479 Close C-221.

12484 Use C-231 to establish and maintain 30 psig at CP-220.

12488 Switch to Q/N Control and establish Q/N = .25.

12504 Switch to SPEED Control.

12506 Switch Speed Rate Control to HOLD.

12512	Set Speed Rate pot to 160 divisions (800 rpm/sec).
12518	Demand 26,000 rpm.
12521	Switch Speed Rate Control to RUN.
12525	On Ramp, Open C-231.
12555	Use C-8 in Q/N Control to establish a Q/N = .26.
12559	Report CP-700D. 770 psid.
12562	Slowly decrease K-3 position.
12625	Open K-3 (Q/N = .26 at 26,000 rpm -- K-3 minimum pot setting = 415 divisions).
12647	Decrease speed to 24,000 rpm.
12661	Use C-8 to increase Q/N to .30.
12665	Report CP-700D. 610 psid.
12668	Slowly decrease K-3 position.
12707	Open K-3 (Q/N = .30 at 24,000 rpm -- K-3 minimum pot setting = 428 divisions).
12731	Decrease speed to 22,000 rpm.
12735	Use C-8 to increase Q/N to .30.
12739	Report CP-700D. 510 psid.
12740	Slowly decrease K-3 position.
12789	Open K-3 (Q/N = .30 at 22,000 rpm -- K-3 minimum pot setting = 403 divisions).
12798	At TD command, push the shutdown button.
12809	Open D.C. breakers.
12810	Switch C-231 to POSITION Control and close.
12812	Switch C-106 to RESET.
12817	Bypass all the shutdown inputs.
12819	Reset the shutdown chain.
12824	Use C-111 to maintain CP-9 between 60 and 100 psig.
12828	Close C-12.
12841	Switch K-53 to POSITION Control and close.
12849	Close K-61.
12850	Open K-153.
12860	Decrease D.C. motor field to less than 5 amps.
12862	Switch the shutdown outputs to OVERRIDE.
12900	Dewar transfer.

VII. PUMP OVERSPEED TEST PHASE - 39°R

The following points will be investigated:

Speed	Q/N
26,000 to 28,500	.30

The supply dewar pressure will be maintained at 100 psig.

A. PROCEED WITH OVERSPEED.

14164	Set the overspeed trip pot to 830 divisions (32,000 rpm).
14173	Raise the synchronous motor field to 120 amps.
14176	Raise the D. C. motor field to 13 amps.
14180	Close K-153.
14183	Select Dewar 5 pressure feedback.
14186	Open K-62.
14196	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221
14198	Activate the following inputs to the shutdown chain: UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
14214	Use C-106 to chill CT-106.
14221	In K-53 PRESSURE Control, establish 100 psig in Dewar 5.
14228	At CTO command Open C-11, Close C-111.
14239	Use K-161 to maintain KP-61 between 30 and 40 psig.
14244	Open C-221.
14248	Close C-231.
14250	Set C-8 to 530 pot divisions.

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14347 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

14350 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

14366 In MANUAL Control, establish 10,000 rpm at a Q/N = .22.

14370 Switch C-106 to AUTO.

14373 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

14376 Open C-231 to 85 pot divisions.

14379 Close C-221.

14384 Use C-231 to establish and maintain 30 psig at CP-220.

14389 Switch to Q/N Control and establish Q/N = .29.

14417 Switch to SPEED Control.

14420 Switch Speed Rate Control to HOLD.

14423 Set Speed Rate pot to 160 divisions (800 rpm/sec).

14428 Demand 26,000 rpm.

14434 Switch Speed Rate Control to RUN.

14438 On Ramp, Open C-231.

14461 Use C-8 in Q/N Control to establish a Q/N = .30.

14475 Increase speed.

14496 Speed at 27,000 rpm.

14511 Speed at 28,000 rpm.

14521 Speed at 28,500 rpm.

14522 Decrease speed to 27,000 rpm.

14532 Slowly increase pump speed.

14540 Speed at 28,500 rpm.

14542 Decrease to 27,000 rpm.

14551 At TD command, push the shutdown button.

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14566	Open D.C. breakers.
14567	Switch C-231 to POSITION Control and close.
14568	Switch C-106 to RESET.
14570	Bypass all the shutdown inputs.
14572	Reset the shutdown chain.
14582	Use C-111 to maintain CP-9 between 60 and 100 psig.
14585	Close C-11.
14590	Switch K-53 to POSITION Control and close.
14595	Close K-62.
14604	Open K-153.
14610	Decrease D. C. motor field to less than 5 amps.
14615	Switch the shutdown outputs to OVERRIDE.
14650	Dewar transfer.

VIII. CAVITATION TEST PHASE RUN # 27 - 41°R

The following points will be investigated:

Speed	Q/N
26,000	.26

The supply dewar pressure will be maintained at 75 psig.

A. PROCEED WITH CAVITATION TEST.

15333	Set the overspeed trip pot to 730 divisions (28,000 rpm).
15340	Raise the synchronous motor field to 120 amps.
15344	Raise the D. C. motor field to 13 amps.
15346	Close K-153.
15350	Select Dewar 4 pressure feedback.
15356	Open K-61.
15362	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

15371 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

15379	Use C-106 to chill CT-106.
15386	In K-53 PRESSURE Control, establish 75 psig in Dewar 4.
15388	At CTO command Open C-12, Close C-111.
15396	Use K-161 to maintain KP-61 between 30 and 40 psig.
15400	Open C-221.
15402	Close C-231.
15406	Set C-8 to 530 pot divisions.
15517	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
15520	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
15534	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
15540	Switch C-106 to AUTO.
15543	At CTO command, activate the following inputs to the shutdown chain:
	Q/N High Q/N Low
15547	Open C-231 to 85 pot divisions.
15549	Close C-221.
15553	Use C-231 to establish and maintain 30 psig at CP-220.
15558	Switch to Q/N Control and establish Q/N = .25.
15577	Switch to SPEED Control.
15580	Switch Speed Rate Control to HOLD.
15584	Set Speed Rate pot to 160 divisions (800 rpm/sec).
15588	Demand 26,000 rpm.
15593	Switch Speed Rate Control to RUN.
15599	On Ramp, Open C-231.
15617	Use C-8 in Q/N Control to establish a Q/N = .26.

15623	Report CP-700D. 760 psid.
15626	Slowly decrease K-3 position.
15679	Open K-3 (Q/N = .26 at 26,000 rpm -- K-3 minimum pot setting = 426 divisions).
15697	At TD command, push the shutdown button.
15711	Open D.C. breakers.
15714	Switch C-231 to POSITION Control and close.
15719	Switch C-106 to RESET.
15721	Bypass all the shutdown inputs.
15722	Reset the shutdown chain.
15726	Use C-111 to maintain CP-9 between 60 and 100 psig.
15729	Close C-11.
15741	Switch K-53 to POSITION Control and close.
15746	Close K-62.
15749	Open K-153.
15760	Decrease D.C. motor field to less than 5 amps.
15736	Switch the shutdown outputs to OVERRIDE.
15820	Dewar transfer.

IX. CAVITATION TEST PHASE RUN #28 - 43°R

The following points will be investigated:

Speed	Q/N
26,000	.26

The supply dewar pressure will be maintained at 80 psig.

A. PROCEED WITH CAVITATION TEST.

16340	Set the overspeed trip pot to 730 divisions (28,000 rpm).
16350	Raise the synchronous motor field to 120 amps.
16354	Close K-153.
16356	Select Dewar 5 pressure feedback.
16359	Open K-62.
16364	Raise the D.C. motor field to 13 amps.
16366	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221

16378	Activate the following inputs to the shutdown chain:
	UQ-2 CP-220 UQ-3 CP-505 JP-101/201 KP-61
16383	In K-53 PRESSURE Control, establish 80 psig in Dewar 5.
16386	Use C-106 to chill CT-106.
16397	At CTO command Open C-11, Close C-111.
16402	Use K-161 to maintain KP-61 between 30 and 40 psig.
16406	Open C-221.
16408	Close C-231.
16412	Set C-8 to 530 pot divisions.
16477	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
16480	Activate the following inputs to the shutdown chain:
	D.C. Breakers, CT-507
16500	CT-507 tripped shutdown chain.
16543	CT-507 bypassed.
16549	When the pump is chilled, close the D.C. breakers.
	a. PMP: Report pump chill.
16551	Activate the following inputs to the shutdown chain:
	D.C. Breakers
16565	In MANUAL Control, establish 10,000 rpm at a Q/N = .22.
16567	Switch C-106 to AUTO.

16573	At CTO command, activate the following inputs to the shutdown chain: Q/N High Q/N Low
16576	Open C-231 to 85 pot divisions.
16578	Close C-221.
16582	Use C-231 to establish and maintain 30 psig at CP-220.
16587	Switch to Q/N Control and establish Q/N = .26.
16604	Switch to SPEED Control.
16606	Switch Speed Rate Control to HOLD.
16612	Set Speed Rate pot to 160 divisions (800 rpm/sec).
16615	Demand 26,000 rpm.
16622	Switch Speed Rate Control to RUN.
16625	On Ramp, Open C-231.
16648	Use C-8 in Q/N Control to establish a Q/N = .26.
16652	Report CP-700D. 730 psid.
16654	Slowly decrease K-3 position.
16699	Open K-3 (Q/N = .26 at 26,000 rpm -- K-3 minimum pot setting = 427 divisions).
16709	At TD command, push the shutdown button.
16724	Open D.C. breakers.
16729	Switch C-231 to POSITION Control and close.
16730	Switch C-106 to RESET.
16734	Bypass all the shutdown inputs.
16736	Reset the shutdown chain.
16737	Use C-111 to maintain CP-9 between 60 and 100 psig.
16746	Close C-11.
16751	Switch K-53 to POSITION Control and close.
16756	Close K-62.
16758	Open K-153.
16760	Decrease D.C. motor field to less than 5 amps.
16762	Switch the shutdown outputs to OVERRIDE.

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X. DEWAR 2 TO DEWAR 4/5 LH_2 TRANSFER

During this phase, Dewar 4/5 will be refilled by transferring LH_2 from Dewar 2.

A. PROCEED WITH THE LH_2 TRANSFER.

16850	Open L-251.
16856	Close L-261, L-153.
16864	Open L-62, L-302, L-330.
16885	Open L-331, X-301.
16892	Close K-401.
16899	Use K-161/162 to vent Dewar 4/5.
16913	Use L-53 in POSITION Control to establish and maintain 65 psig in Dewar 2.
16993	When LP-61 is greater than KP-61/62, Open K-301/302.
22810	When LH_2 transfer is complete, Close K-301/302.

XI. LOW SPEED MAPPING AND CAVITATION RUN #29 - 37.5°R

The following points will be investigated:

Speed	Q/N
27,000	.28

The supply dewar pressure will be maintained at 50 psig.

A. PROCEED WITH CAVITATION TEST.

22822	Set the overspeed trip pot to 315 divisions (12,000 rpm).
22837	Raise the synchronous motor field to 120 amps.
22839	Raise the D. C. motor field to 13 amps.
22905	Close K-153.
22915	Select Dewar 4 pressure feedback.
22926	Open K-61.
22928	Switch the following shutdown outputs to NORMAL:

Speed Rate, C-8, C-221

22930 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101/201	KP-62

22936 In K-53 PRESSURE Control, establish 50 psig in Dewar 4.
23002 Use C-106 to chill CT-106..
23015 At CTO command Open C-12, Close C-111.
23016 Open C-221.
23021 Close C-231.
23026 Set C-8 to 530 pot divisions.
23217 Open K-130.
23290 Slowly close K-3 (3-1/2 lbs/sec flow for dewar pressure alone).
23345 When the pump is chilled, close the D. C. breakers.

a. PMP: Report pump chill.

23351 Activate the following inputs to the shutdown chain:

D. C. Breakers, CT-507

23362 In MANUAL Control, establish 3,000 rpm with maximum KF-130 of 15 lbs/sec.
23424 Vary KF-130 between 4 and 15 lbs/sec with C-8 and C-106.
23450 Close C-106.
23469 Increase speed to 6,000 rpm.
23520 Use C-8 to decrease KF-130 to 4 lbs/sec (40% on C-8).
23556 Use C-8 to increase KF-130 to 6 lbs/sec.
23577 Demand 0 speed (plotters not reading correctly).
23590 Breakers open.
23610 Data hold.
23934 Set C-8 to 55% (Q/N = .22).

23937 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

23945 Activate the following inputs to the shutdown chain:

D.C. Breakers

23966 In MANUAL Control, establish 9,000 rpm.
23981 Demand 0 speed (pump inlet pressure falling).
24001 Reset the overspeed trip pot to 760 divisions (28,000 rpm).
24015 Open K-3.
24026 Close K-130.
24047 Increase Dewar 4 pressure to 80 psig.
24082 In MANUAL Control, demand 10,000 rpm.
24084 Switch C-106 to AUTO.
24088 At CTO command, activate the following inputs to the shutdown chain:

Q/N High
Q/N Low

24096 Open C-231 to 85 pot divisions.
24100 Close C-221.
24104 Use C-231 to establish and maintain 30 psig at CP-220.
24116 Switch to Q/N Control and establish Q/N = .27.
24140 Switch to SPEED Control.
24144 Switch Speed Rate Control to HOLD.
24150 Set Speed Rate pot to 160 divisions (800 rpm/sec).
24152 Demand 27,000 rpm.
24157 Switch Speed Rate Control to RUN.
24168 On Ramp, Open C-231.
24195 Use C-8 in Q/N Control to establish 73 lbs/sec.
24200 Report CP-700D. 820 psid.
24206 Slowly decrease K-3 position.
24269 Open K-3 (Q/N = .28 at 27,000 rpm -- K-3 minimum pot setting = 428 divisions).

24298	Switch Speed Rate Control to HOLD.
24300	Demand 9,000 rpm.
24311	Switch Speed Rate Control to RUN.
24348	At TD command, push the shutdown button.
24355	Open D.C. breakers.
24358	Bypass all the shutdown inputs.
24360	Reset the shutdown chain.
24368	Switch C-231 to POSITION Control and close.
24370	Switch C-106 to RESET.
24372	Use C-111 to maintain CP-9 between 60 and 100 psig.
24378	Close C-12.
24388	Switch K-53 to POSITION Control and close.
24395	Close K-61.
24398	Open K-153.
24400	Decrease D.C. motor field to less than 5 amps.
24402	Switch the shutdown outputs to OVERRIDE.
24470	Dewar transfer.

XII. LOW SPEED MAPPING

During this phase, pump mapping will be performed at speeds of 6,000, 9,000 rpm at Q/N's of .14 to .35. Supply fluid temperature will be 39°R. Dewar pressure will be maintained at 40 psig.

A. PROCEED WITH LOW SPEED MAPPING.

25288	Set the overspeed trip pot to 395 divisions (15,000 rpm).
25295	Raise the synchronous motor field to 120 amps.
25300	Raise the D.C. motor field to 13 amps.
25310	Close K-153.
25316	Select Dewar 5 pressure feedback.
25319	Open K-62.
25329	Switch the following shutdown outputs to NORMAL: Speed Rate, C-8, C-221

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25339 Activate the following inputs to the shutdown chain:

UQ-2	CP-220
UQ-3	CP-505
JP-101-201	KP-61

25340 In K-53 PRESSURE Control, establish 40 psig in Dewar 5.
25352 Use C-106 to chill CT-106.
25364 At CTO command Open C-11, Close C-111.
25366 Open K-161.
25368 Open C-221.
25370 Close C-231.
25373 Set C-8 to 530 pot divisions.
25390 Incoming line breaker tripped.
25465 When the pump is chilled, close the D.C. breakers.

a. PMP: Report pump chill.

25470 Activate the following inputs to the shutdown chain:

D.C. Breakers, CT-507

25496 In MANUAL Control, establish 6,000 rpm at a Q/N = .22.
25545 Switch to SPEED Control.
25606 Use C-8 to maintain Q/N = .10 (30% minimum on C-8).
25631 Bypass CP-507.
25646 Use C-8 to increase Q/N to .20.

a. Use .02 increments.

25667 Increase speed to 9,000 rpm.
25714 Use C-8 to decrease Q/N to .10 at 9 lbs/sec.
25739 Q/N = .06 (22% on C-8 minimum point).
25762 Use C-8 to increase Q/N to .20.

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25766	Shutdown CTO Manual.
25772	Open D.C. breakers.
25775	Bypass all the shutdown inputs.
25779	Reset the shutdown chain.
25788	Use C-111 to maintain CP-9 between 60 and 100 psig.
25792	Close C-11.
25806	Switch K-53 to POSITION Control and close.
25809	Close K-62.
25813	Open K-153.
25816	Decrease D.C. motor field to less than 5 amps.
25819	Switch the shutdown outputs to OVERRIDE.

POST VOLTAGE CALIBRATION

26091-26191 Calibration interval.

MAXIMUM SHUTDOWN SECURE

26300

END

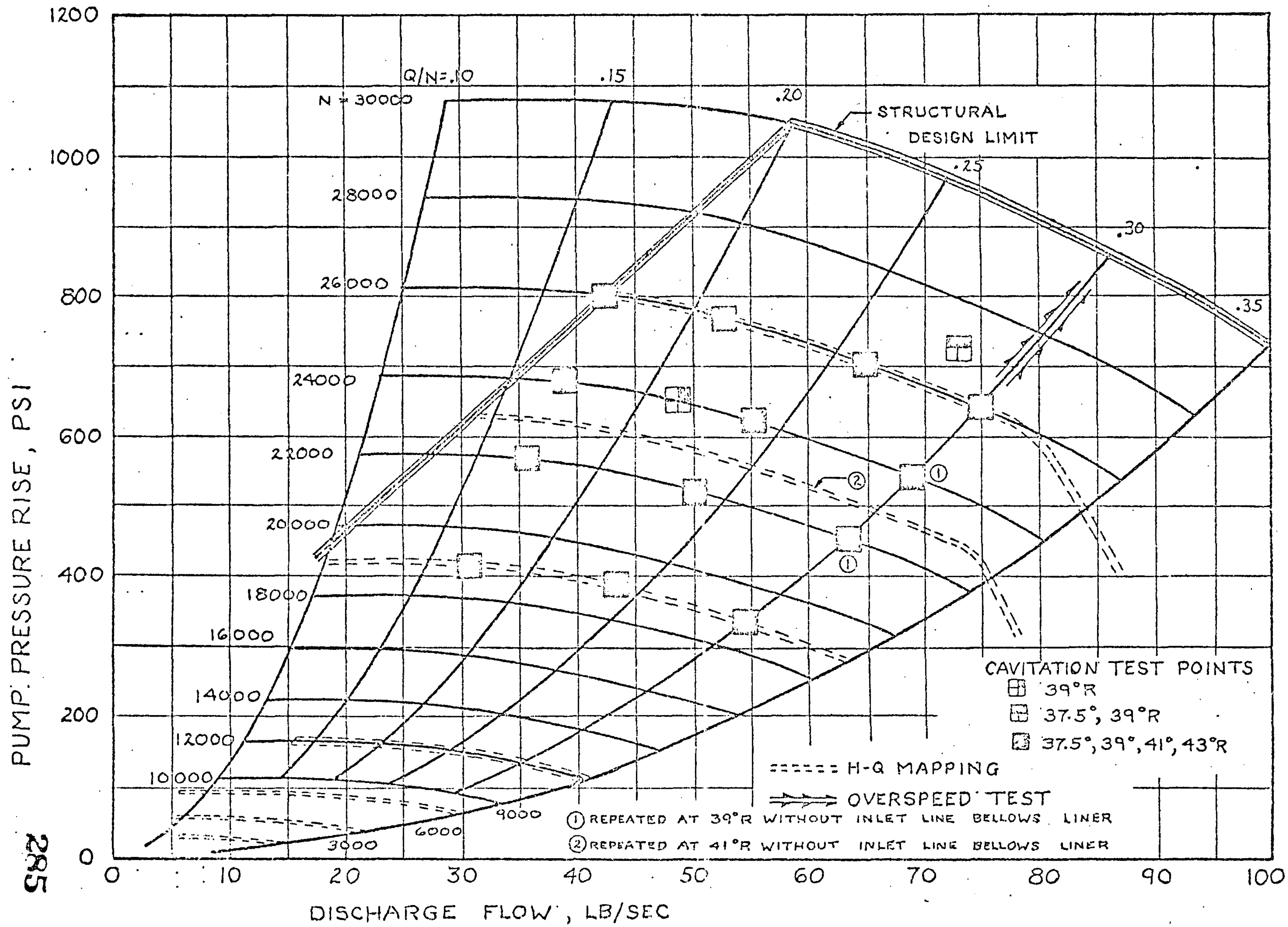
APPENDIX H

LH_2 PUMP COMPONENT DEVELOPMENT PROGRAM

INDUCER NO. 1

CAVITATION TEST DATA

LH_2 PUMP COMPONENT DEVELOPMENT TEST OPERATING CONDITIONS



Inducer I-LH$_2$ Pump Test - Cavitation Test Summary

Target				Actual					Cond. at Breakdown	
Speed	Q/N (Disch.)	Temp. (Dewar)	Cav. Run	Speed	Q/N (Suct.)	ω (Suct.)	Temp. (Dewar)	Vap. Press (Equil. Tank)	NPSP (Equil. Tank)	Vap. by Vol. (Suct. Line)
19k	.17	37.5	8C	19.2k	.19	35.4	36.6	20.2	-4.3	.50
		39	1A	19.3k	.19	35.5	37.5	21.6	-4.5	.48
		41	3B	19.0k	.19	33.5	41.5	36.0	-10.4	.54
		43	17E	18.85k	.19	32.4	43.4	46.8	-14.6	.55
	.24	37.5	8B	19.2k	.26	48.4	36.5	19.7	-2.3	.35
		39	1B	19.3k	.26	48.5	37.5	21.2	-2.4	.32
		41	5A	19.2k	.26	47	41.2	34.7	-5.1	.34
		43	17D	18.8k	.26	45	43.4	45.0	-7.4	.34
	.30	37.5	8A	19.2k	.32	60	36.5	19.4	-1.5	.28
		39	9A	19.2k	.32	58	39.5	28.0	-1.7	.19
		41	2	19.3k	.31	56.6	41.0	33.1	-2.3	.20
		43	22	19.1k	.32	56.3	43.4	43.2	-3.4	.19
22k	.17	37.5	16B	22.2k	.19	41.5	36.9	20.1	-3.4	.44
		39	7B	22.2k	.19	40.5	38.5	24.6	-5.6	.49
		41	3A	22.5k	.19	40	41.5	35.5	-9.2	.50
		43	17B	22.2k	.19	38	43.4	45.5	-13.0	.52
	.24	31.5	16C	22.3k	.26	57.5	36.9	19.9	-1.8	.29
		39	9B	22.5k	.26	55.8	39.5	28.1	-3.2	.30
		41	5B	22.4k	.26	54.9	41.2	34.3	-4.5	.30
		43	17C	22.2k	.26	53.2	43.4	44.5	-6.3	.31
	.30	37.5	10A	22.5k	.32	70	38.1	21.6	-.6	.14
		39	12A	22.5k	.32	69	39.3	25.7	-.9	.14
		39 ①	26C	22.1k	.32	68	39.3	26.1	-1.0	.15
		41	11A	22.5k	.32	68	41.3	33.3	-1.7	.16
		43	13A	22.5k	.32	67	42.8	39.8	-2.4	.16

① Without inlet line bellows liner

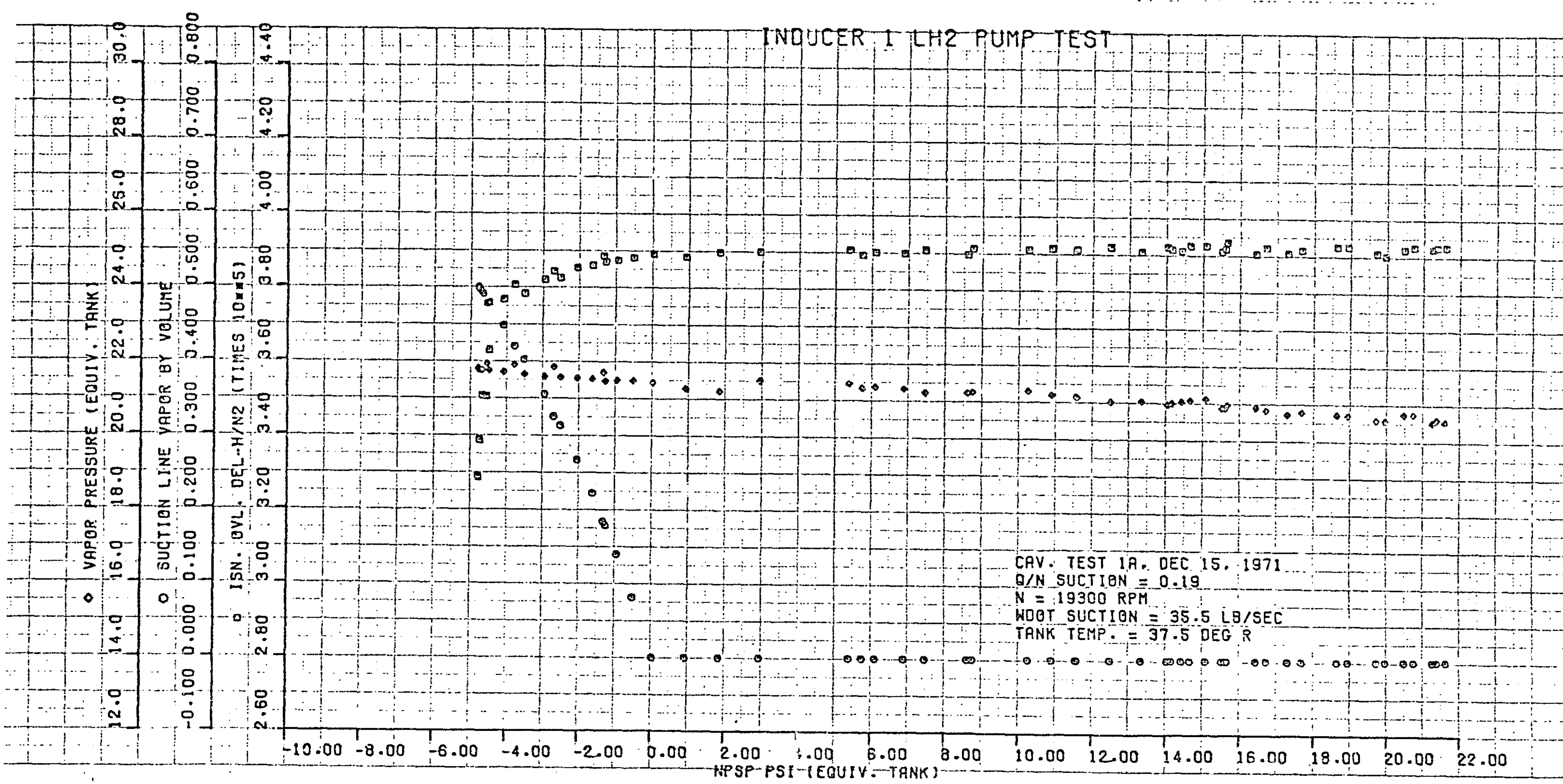
c4

INDUCER 1-LH_2 PUMP TEST - CAVITATION TEST SUMMARY (CONT'D)

TARGET				ACTUAL					COND. AT BREAKDOWN	
SPEED	Q/N (DISCH.)	TEMP. (DEWAR)	CAV. RUN	SPEED	Q/N (SUCT.)	W (SUCT.)	TEMP. (DEWAR)	VAP. PRESS (EQUIV. TANK)	NPSP (EQUIV. TANK)	VAP. BY VOL (SUCT. LINE)
24K	.17	37.5	16A	24.3K	.19	45.5	36.9	19.8	-3.2	.42
		39	7A	24.5K	.19	45	38.5	24.5	-5.3	.48
		41	6B	24.3K	.19	43.2	40.9	34.0	-8.8	.50
		43	17A	24.4K	.19	42.2	43.4	45.0	-12.3	.50
	.21	39	21C	24.1K	.23	53.5	39.4	27.7	-3.9	.35
	.24	37.5	4	24.4K	.26	62	36.3	18.9	-2.2	.36
		39	23	24.2K	.26	60.5	39.4	27.5	-3.0	.30
		41	6A	24.3K	.26	59.8	40.8	32.9	-4.0	.30
		43	15B	24.1K	.26	58	43.1	42.4	-5.5	.30
	.30	37.5	10B	24.3K	.32	75.2	38.1	21.8	-.4	.11
		39	12B	24.4K	.32	75	39.3	25.8	-.8	.13
		39 ①	26B	24.2K	.32	72	39.3	26.0	-.8	.12
		41	11B	24.4K	.32	73	41.3	33.4	-1.2	.13
		43	13B	24.4K	.32	72	42.9	40.5	-2.0	.14
26K	.17	37.5	20A	26.4K	.19	49	36.4	19.0	-3.1	.44
		39	21A	26.5K	.19	48	39.3	27.9	-5.7	.45
		41	18A	26.5K	.19	47.2	41.4	35.7	-8.4	.48
		43	19A	26.5K	.19	47	42.6	40.9	-10.3	.48
	.21	37.5	20B	26.4K	.23	60	36.5	19.2	-2.4	.37
		39	21B	26.4K	.23	59	39.3	27.5	-3.4	.32
		41	18B	26.5K	.24	58	41.4	35.3	-5.2	.34
		43	19B	26.5K	.24	57.5	42.6	40.2	-6.5	.35
	.26	37.5 ①	24	26.3K	.28	72	38.6	22.6	-.8	.14
		39 ①	26A	26.5K	.28	72	39.3	26.0	-1.4	.18
		41 ①	27	26.5K	.29	71	41.4	33.8	-2.4	.20
		43 ①	28	26.5K	.29	69.5	42.2	42.0	-3.8	.22
	.30	37.5	14	26.5K	.32	83	36.5	18.3	+.4	0
		39	12C	26.5K	.32	81.3	39.6	26.8	-.5	.10
		41	11C	26.5K	.32	80	41.3	33.7	-1.0	.12
		43	15A	26.4K	.32	78.3	43.1	41.6	-1.5	.11
27K	73 LB/SEC	37.5 ①	29	27.2K	.30	81.1	36.5	18.2	0	.10
		39 ①	25	②	②	②	②	②	②	②

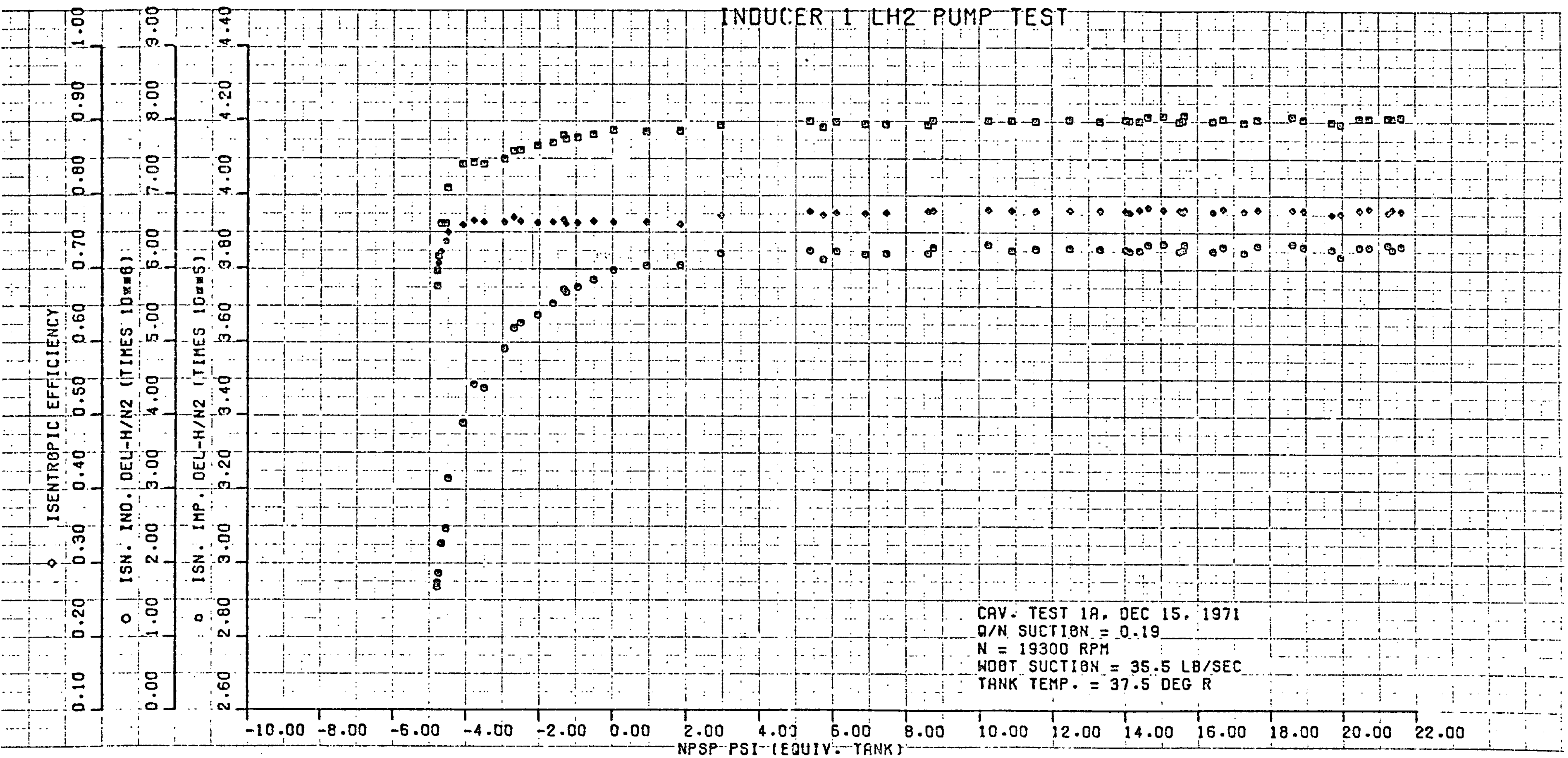
① WITHOUT INLET LINE BELLOWS LINER

② PERFORMANCE CALCULATIONS NOT COMPLETED DUE TO DATA STORAGE FORMAT



CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02



CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

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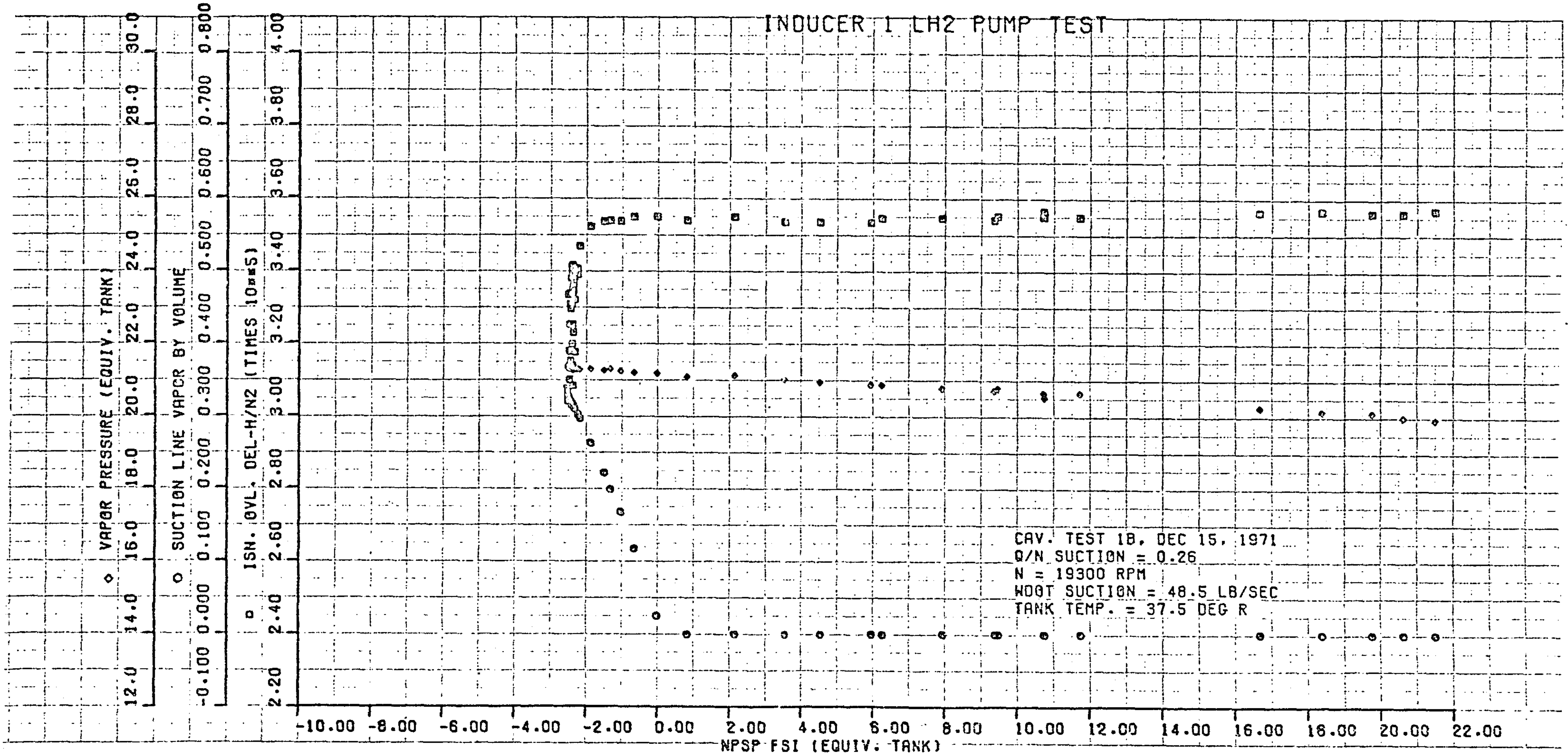

CHART No. 12-02

CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

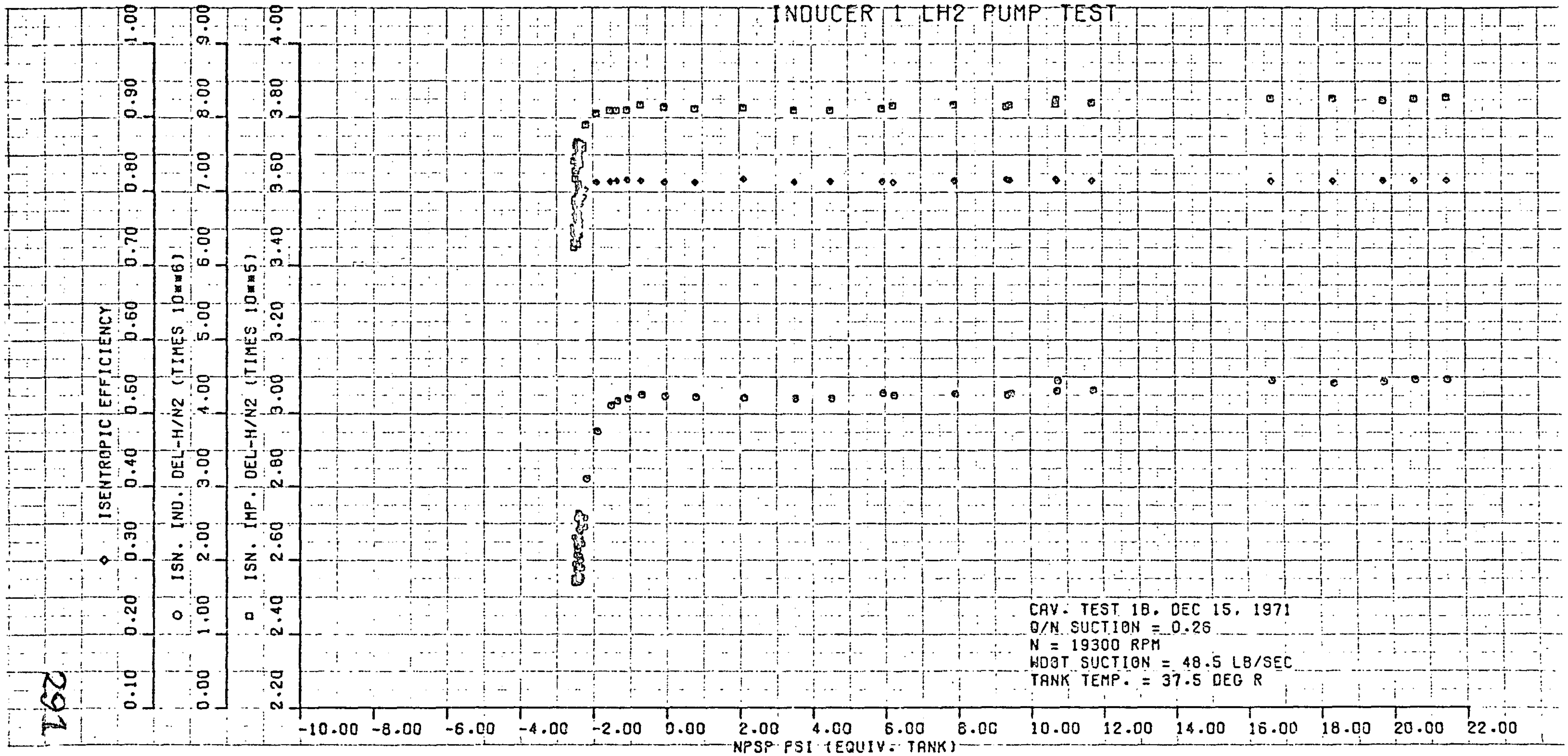

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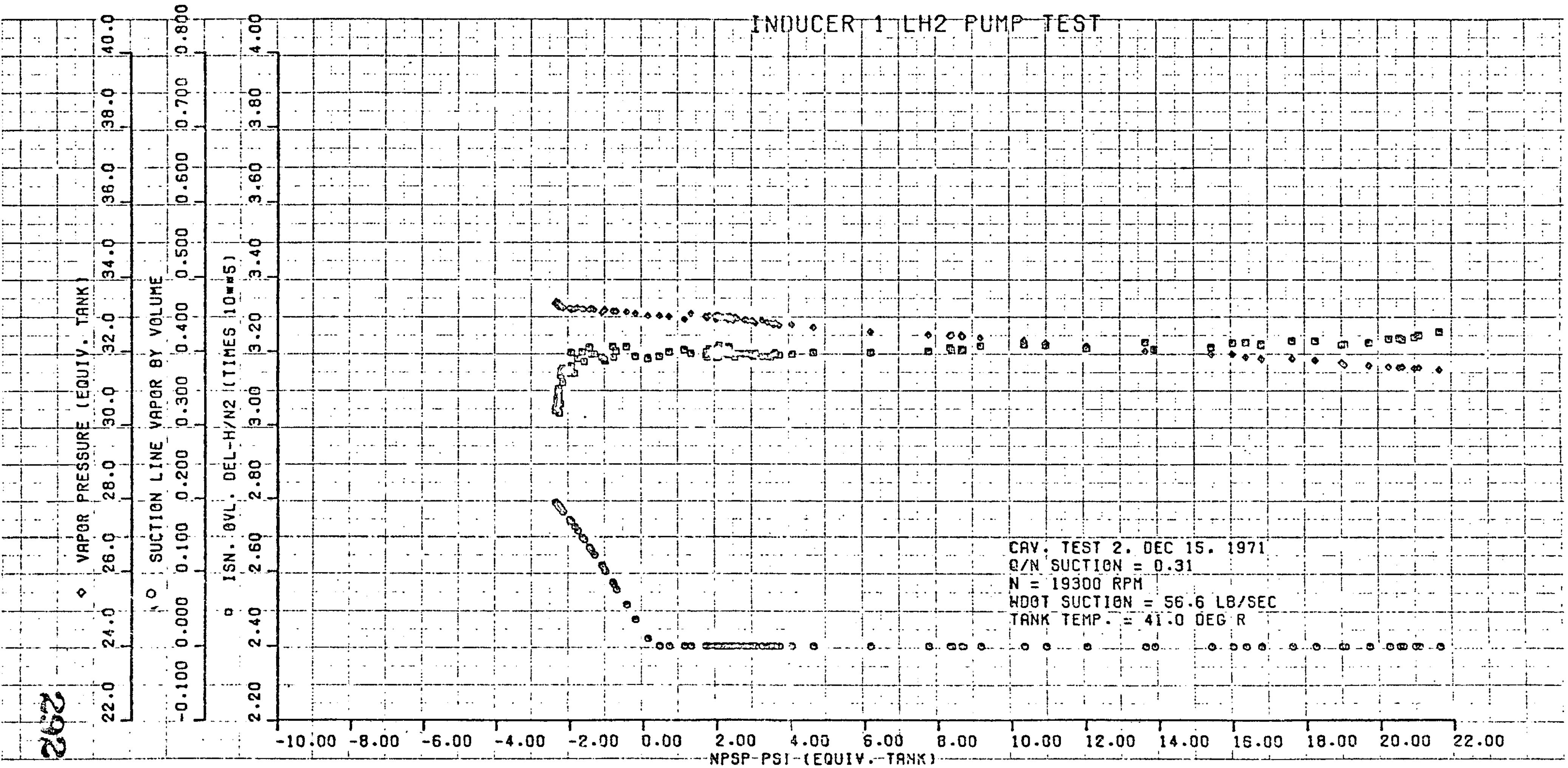
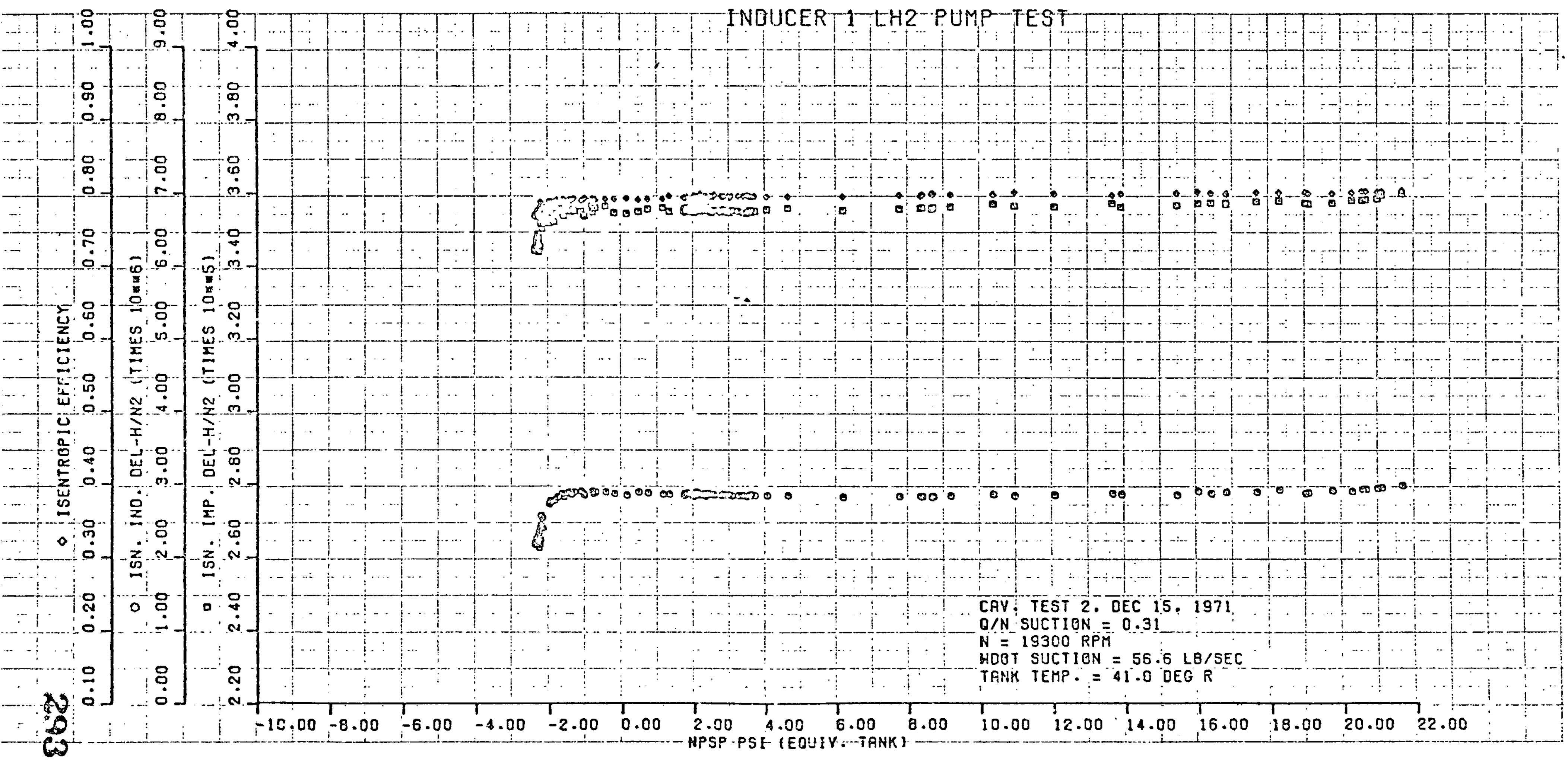
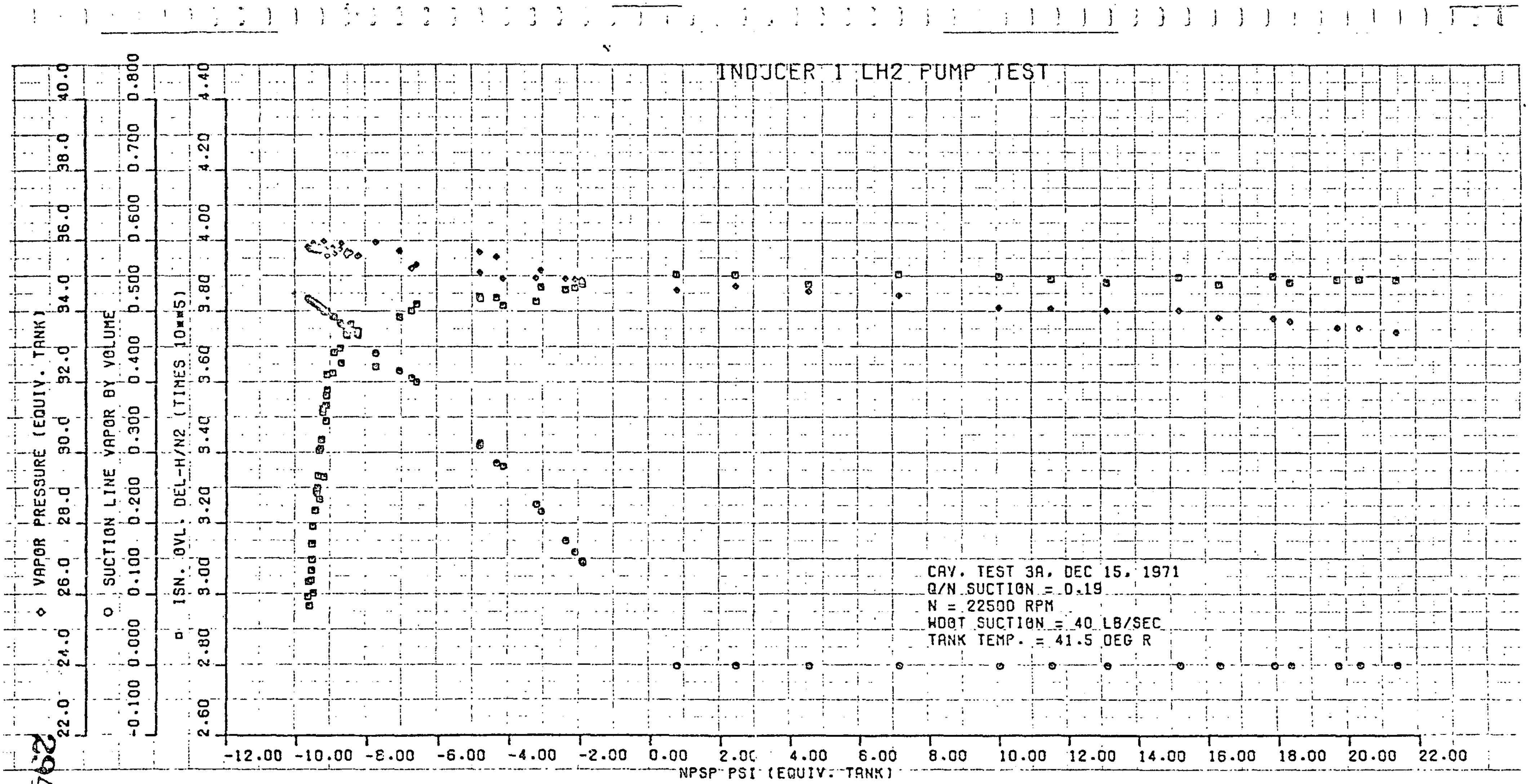
CHART No. 12-02



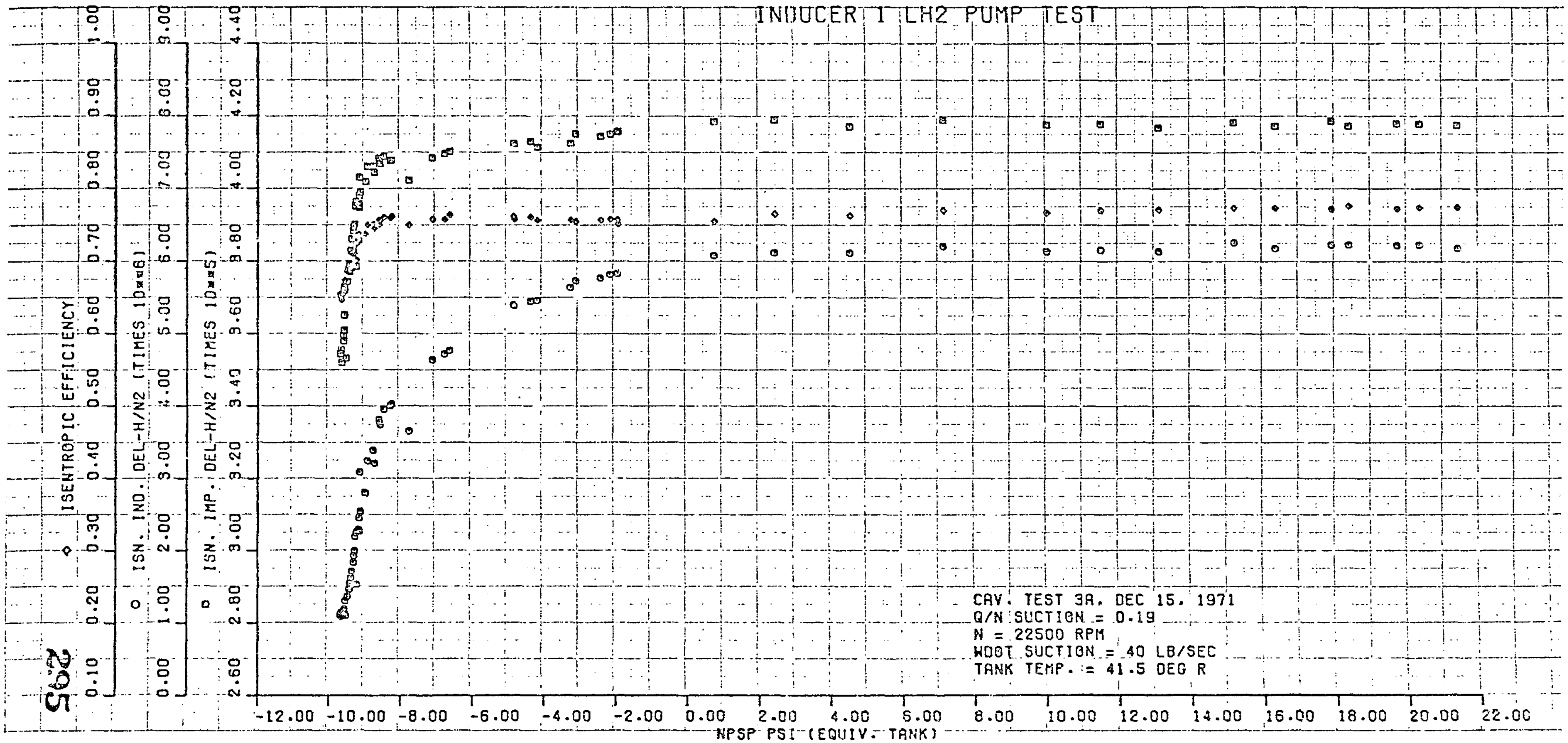
INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
CAV. TEST 2. DEC 15. 1971
Q/N SUCTION = 0.31
N = 19300 RPM
WDOT SUCTION = 56.6 LB/SEC
TANK TEMP. = 41.0 DEG R
NPSP-PSI-(EQUIV.-TANK)



INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 2. DEC 15. 1971
Q/N SUCTION = 0.31
N = 19300 RPM
WDOT SUCTION = 56.6 LB/SEC
TANK TEMP. = 41.0 DEG R



INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 3A, DEC 15, 1971
Q/N SUCTION = 0.19
N = 22500 RPM
WDOT SUCTION = 40 LB/SEC
TANK TEMP. = 41.5 DEG R



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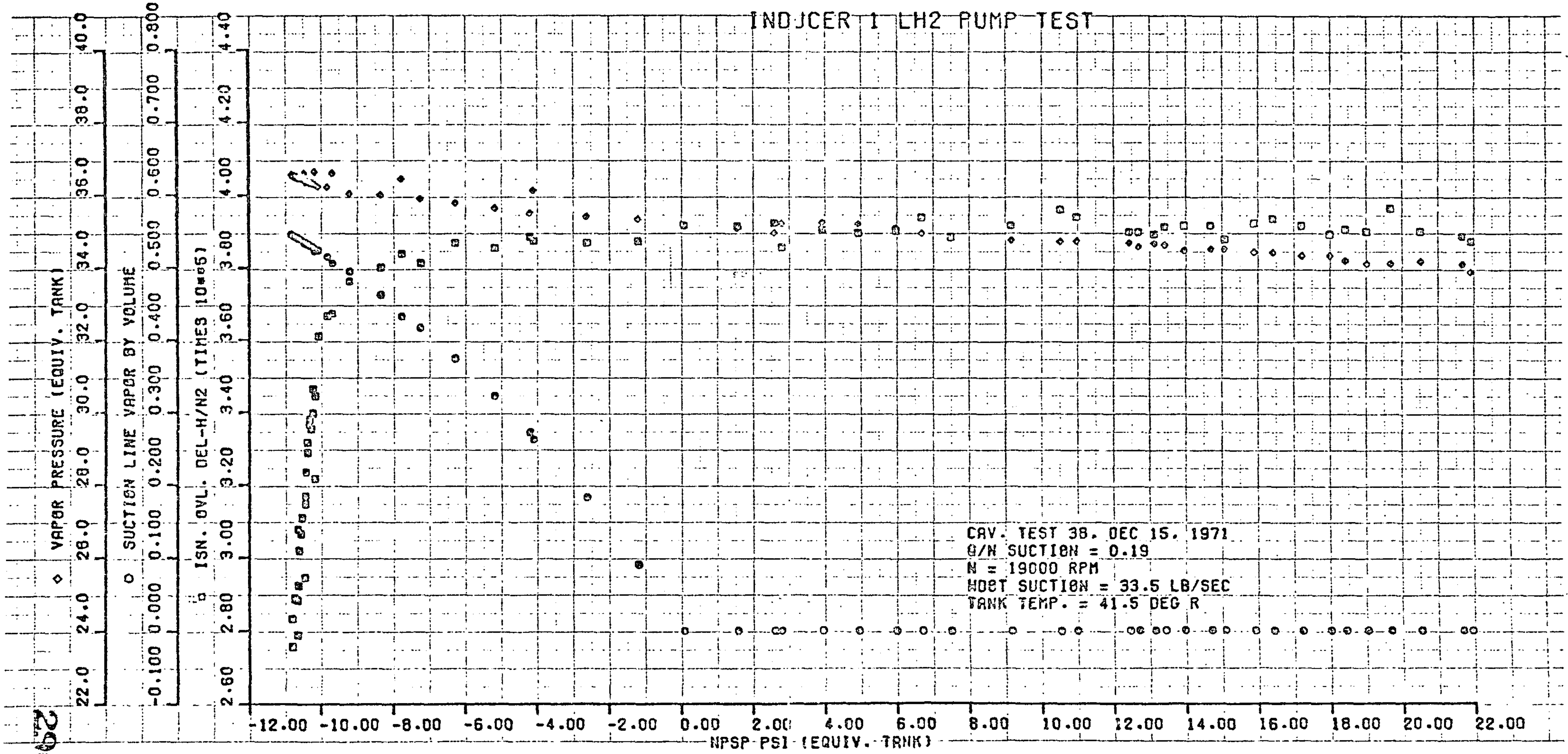
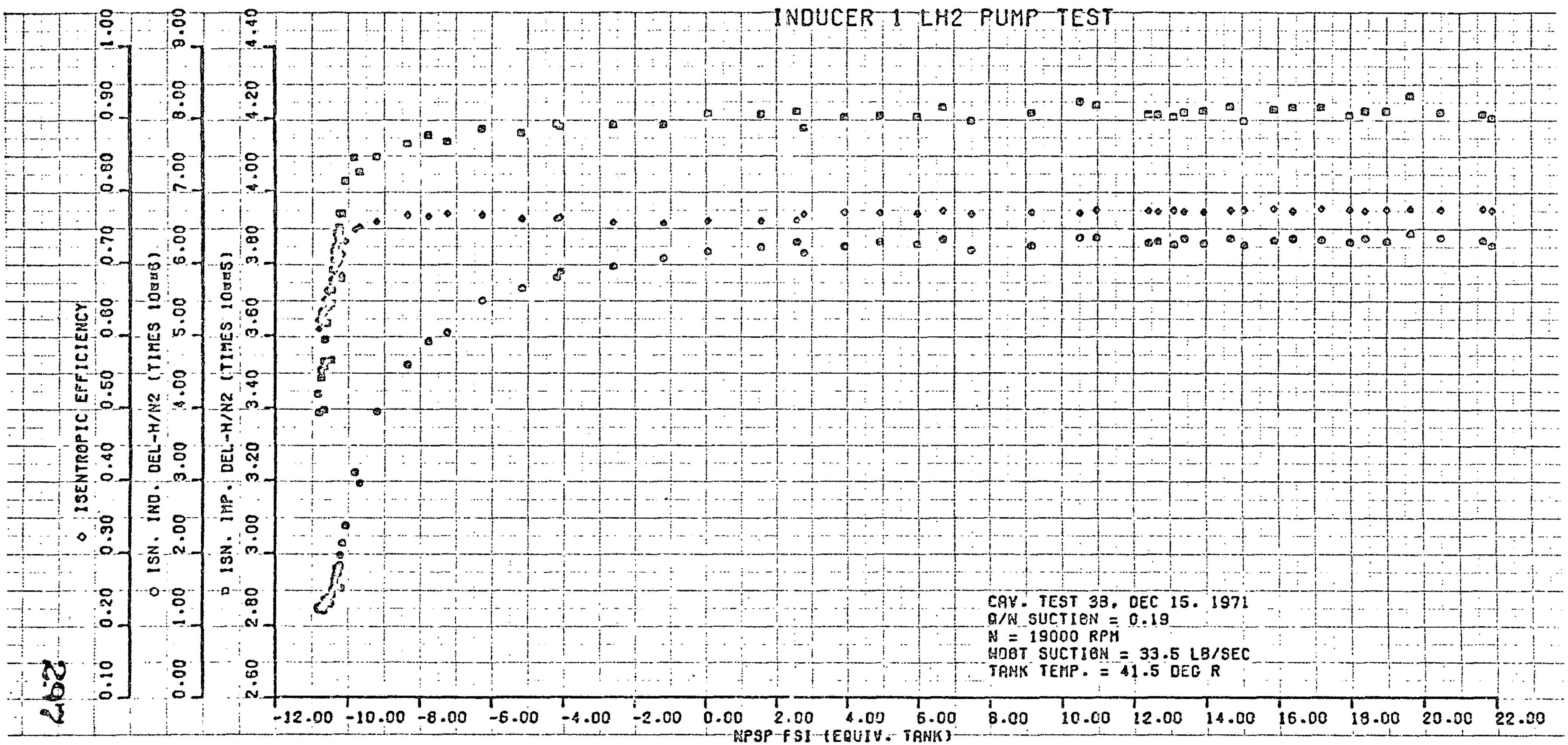
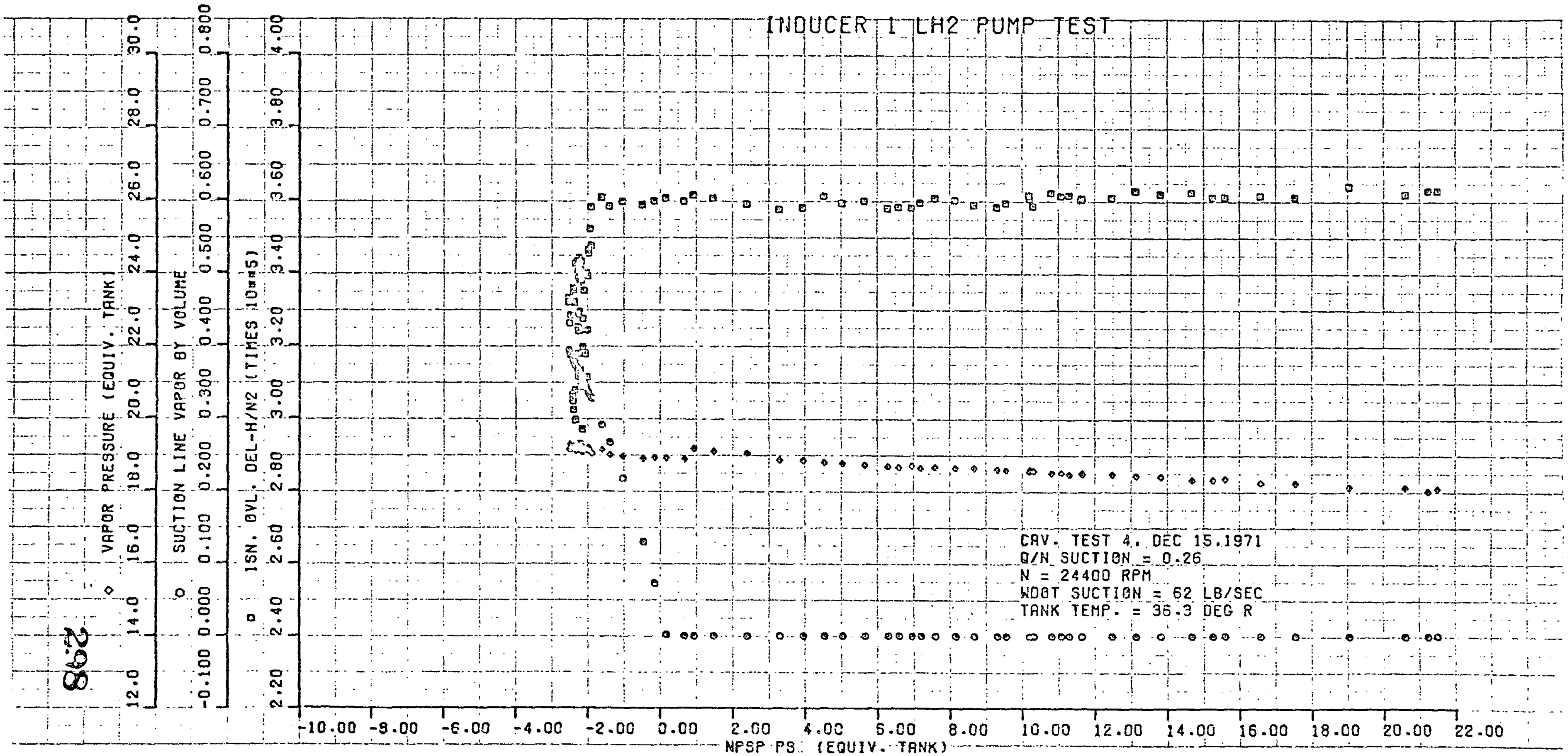
CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-12.00 -10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 38. DEC 15. 1971
Q/N SUCTION = 0.19
N = 19000 RPM
WDOT SUCTION = 33.5 LB/SEC
TANK TEMP. = 41.5 DEG R

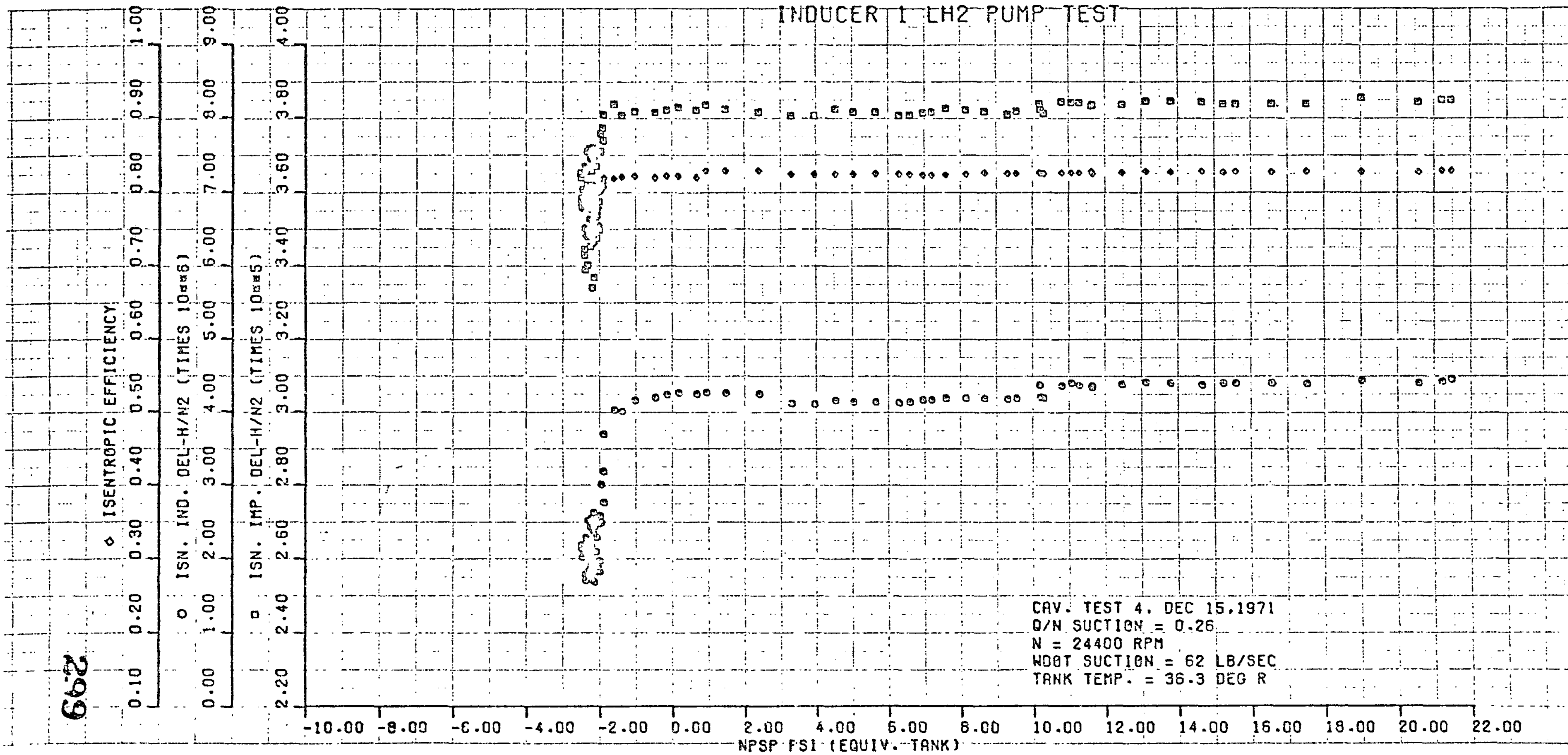


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP FSI (EQUIV. TANK)
CAV. TEST 38, DEC 15, 1971
Q/N SUCTION = 0.19
N = 19000 RPM
WDOT SUCTION = 33.5 LB/SEC
TANK TEMP. = 41.5 DEG R

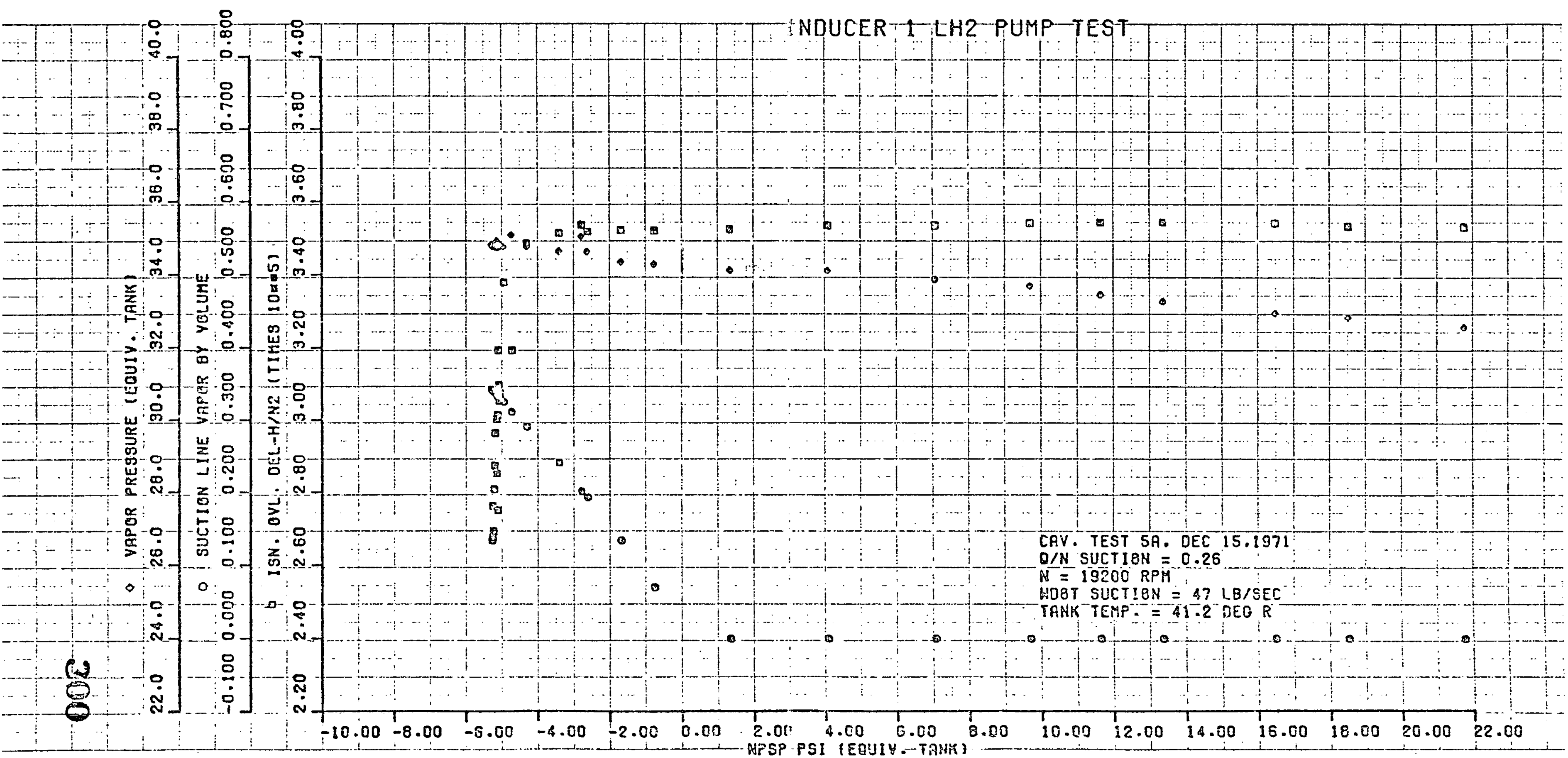
297


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 4, DEC 15,1971
Q/N SUCTION = 0.26
N = 24400 RPM
WDOT SUCTION = 62 LB/SEC
TANK TEMP. = 36.3 DEG R

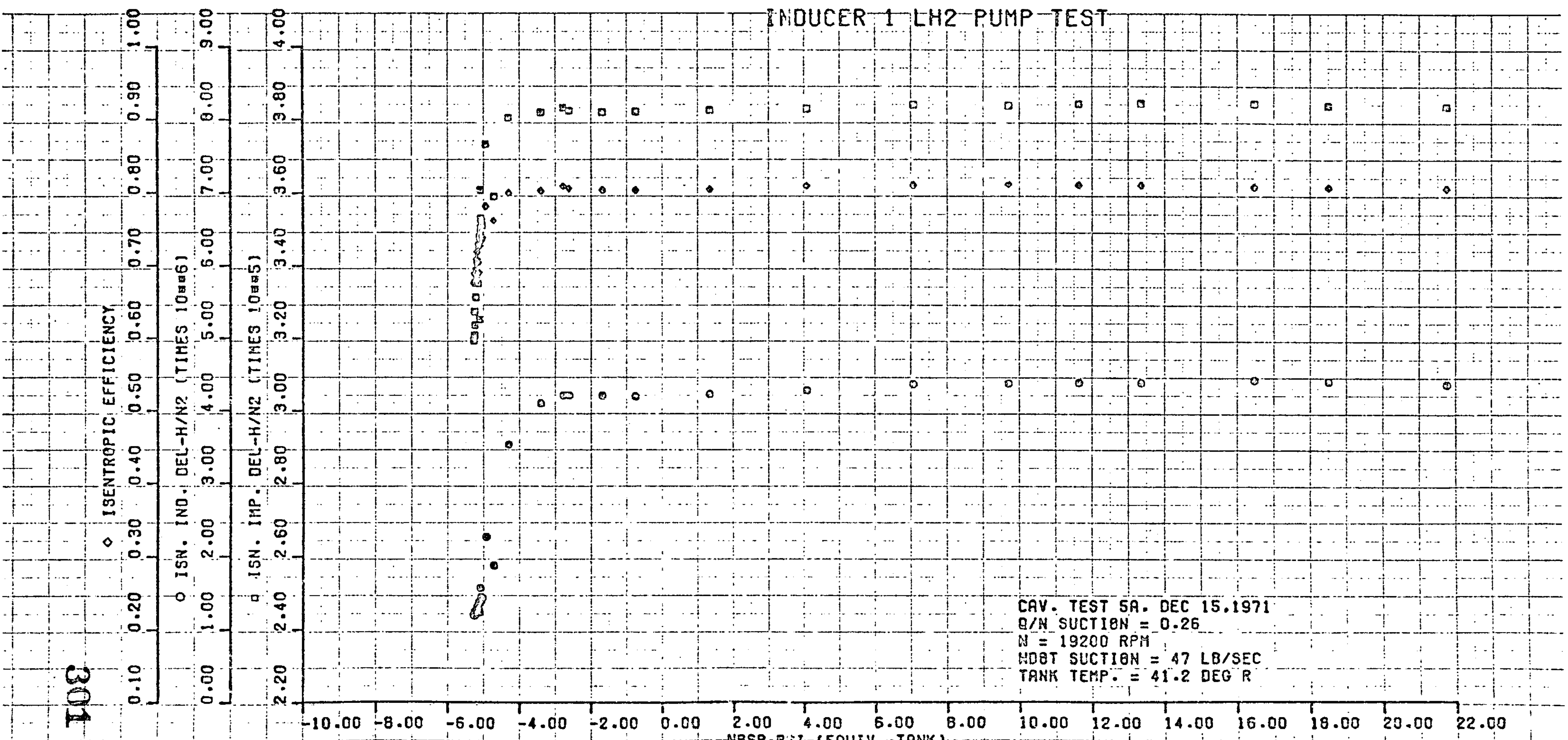
298


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 4, DEC 15,1971
Q/N SUCTION = 0.26
N = 24400 RPM
WDOT SUCTION = 62 LB/SEC
TANK TEMP. = 36.3 DEG R

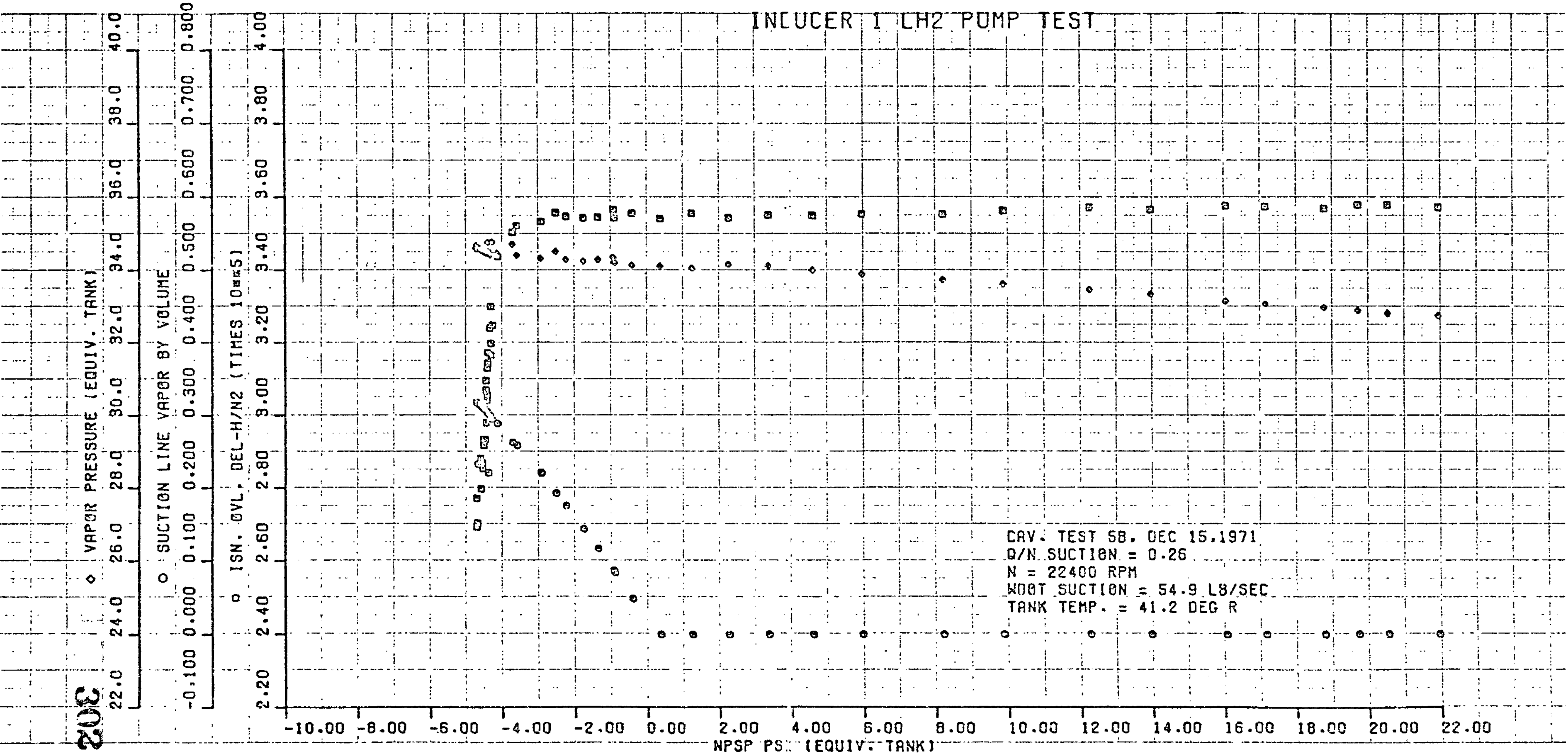
299


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
40.0 38.0 36.0 34.0 32.0 30.0 28.0 26.0 24.0 22.0
0.800 0.700 0.600 0.500 0.400 0.300 0.200 0.100 0.000 -0.100
4.00 3.80 3.60 3.40 3.20 3.00 2.80 2.60 2.40 2.20
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV.-TANK)
CAV. TEST 5A, DEC 15,1971
Q/N SUCTION = 0.26
N = 19200 RPM
WDOT SUCTION = 47 LB/SEC
TANK TEMP. = 41.2 DEG R

300


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP-PSI-(EQUIV. TANK)
CAV. TEST 5A. DEC 15.1971
Q/N SUCTION = 0.26
N = 19200 RPM
WDOT SUCTION = 47 LB/SEC
TANK TEMP. = 41.2 DEG R

301



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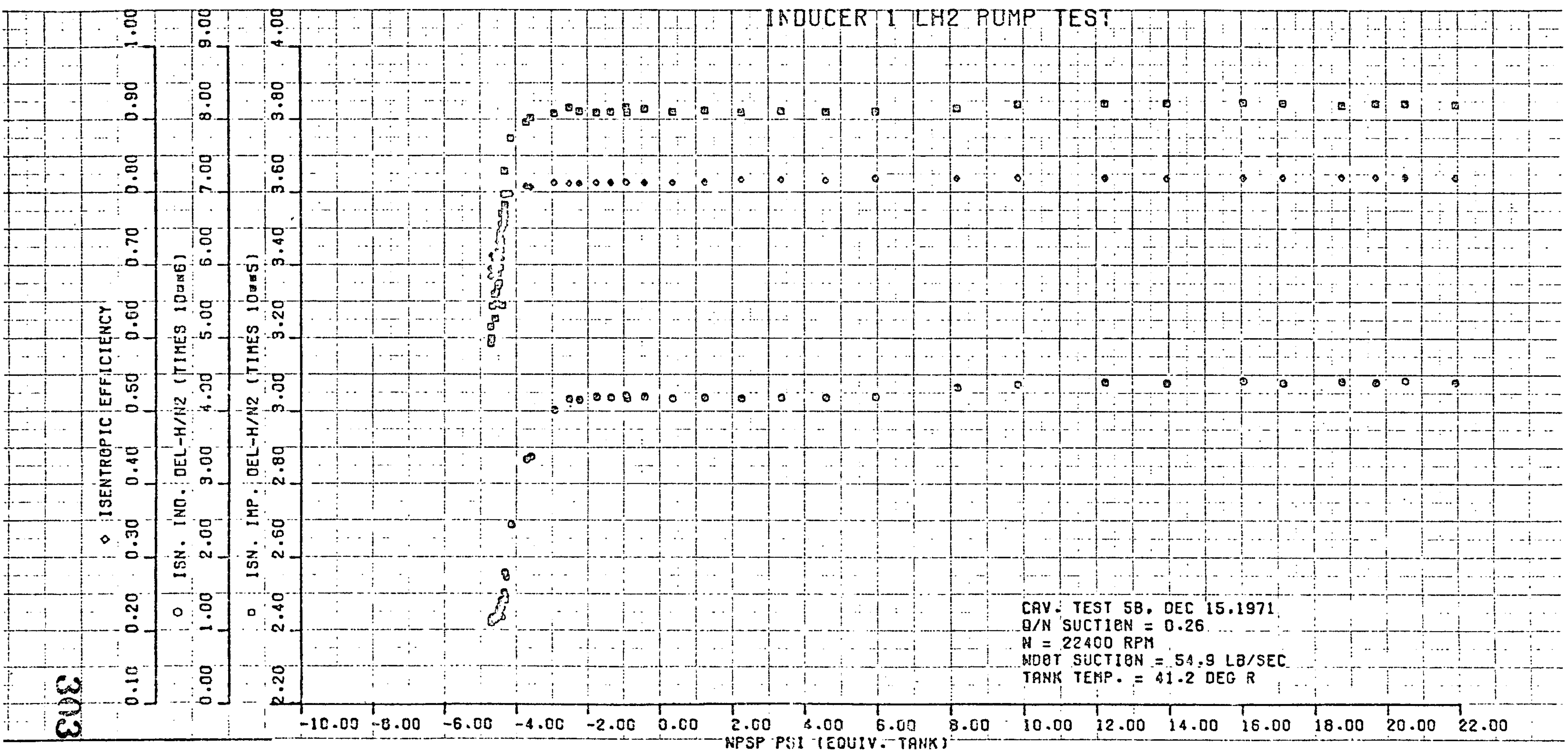
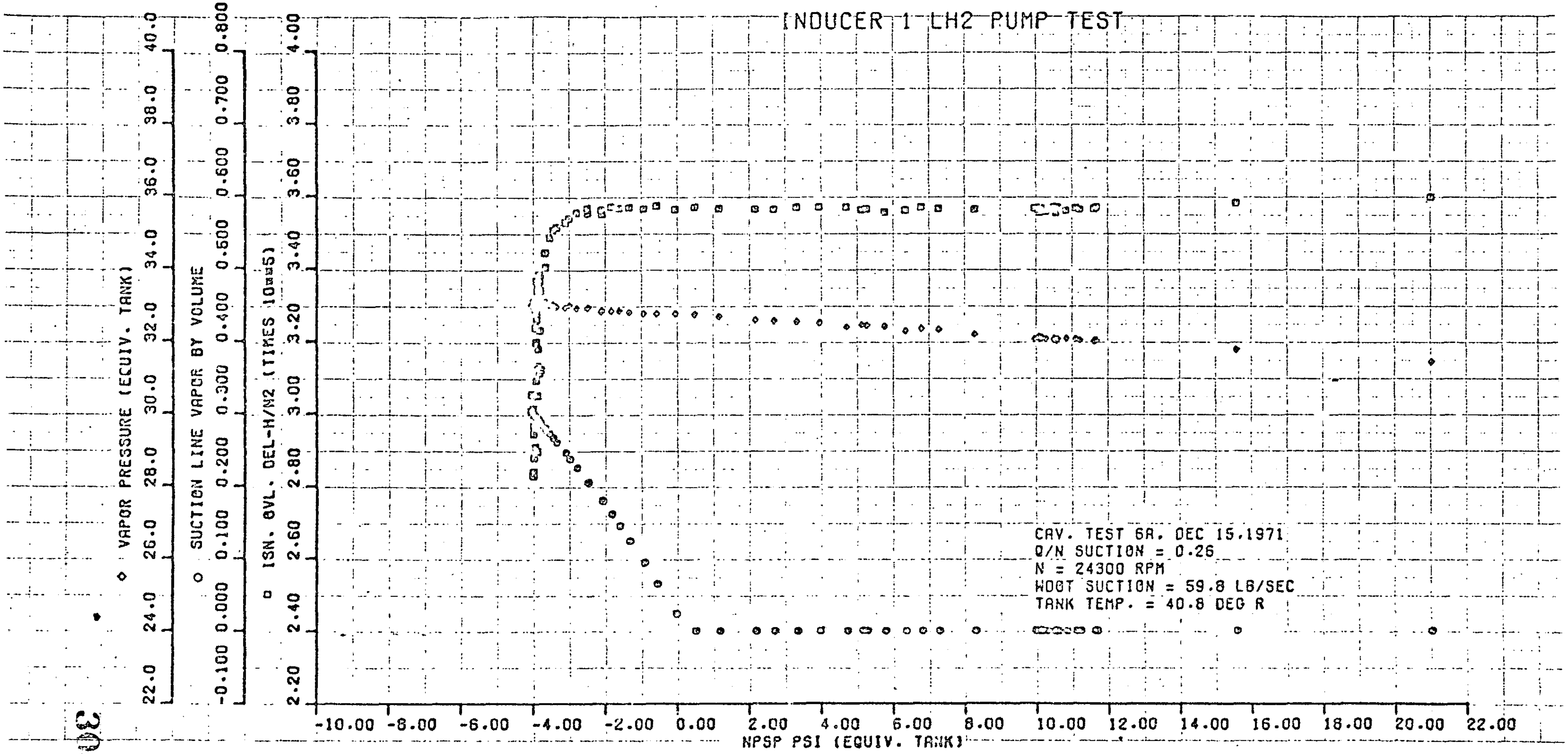
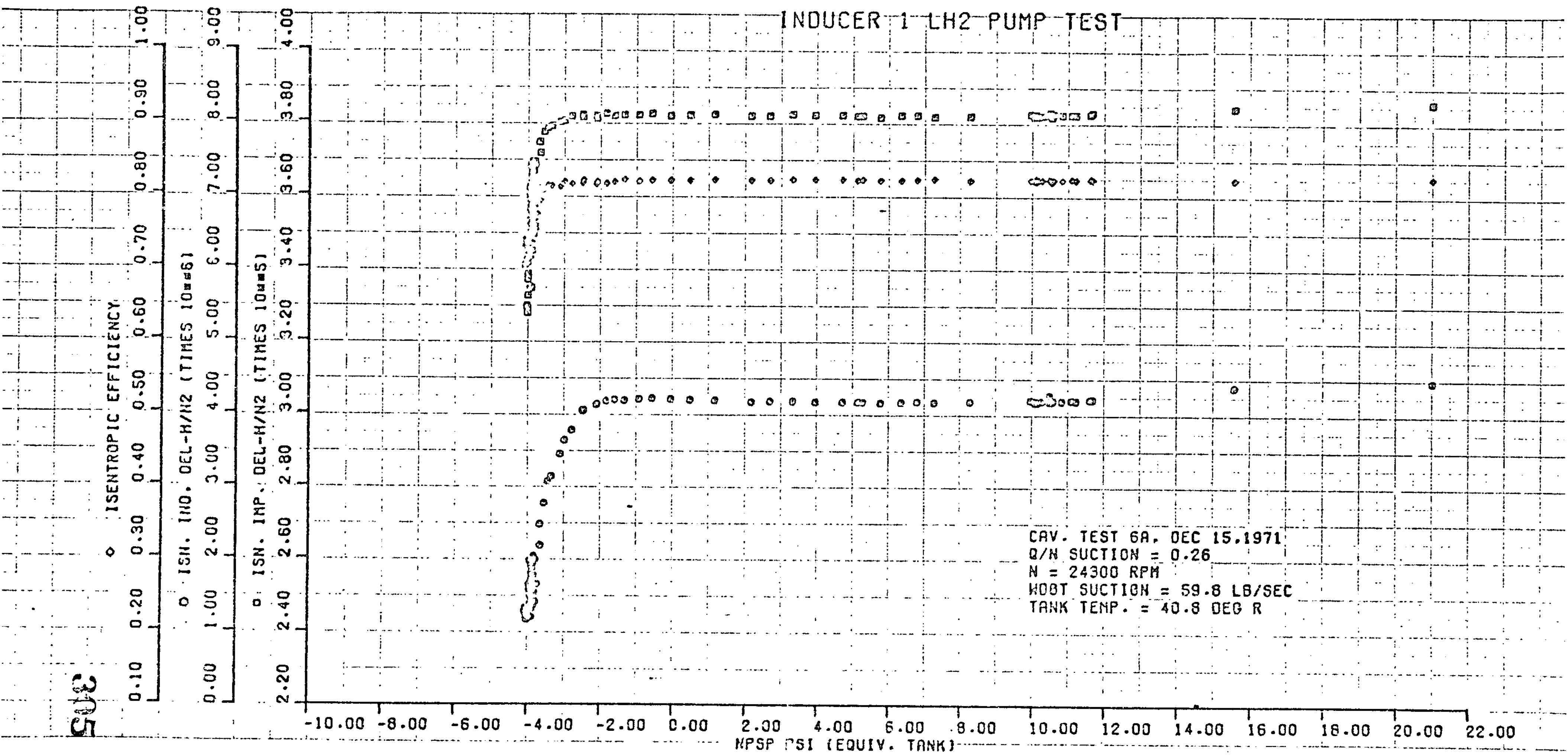
CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02



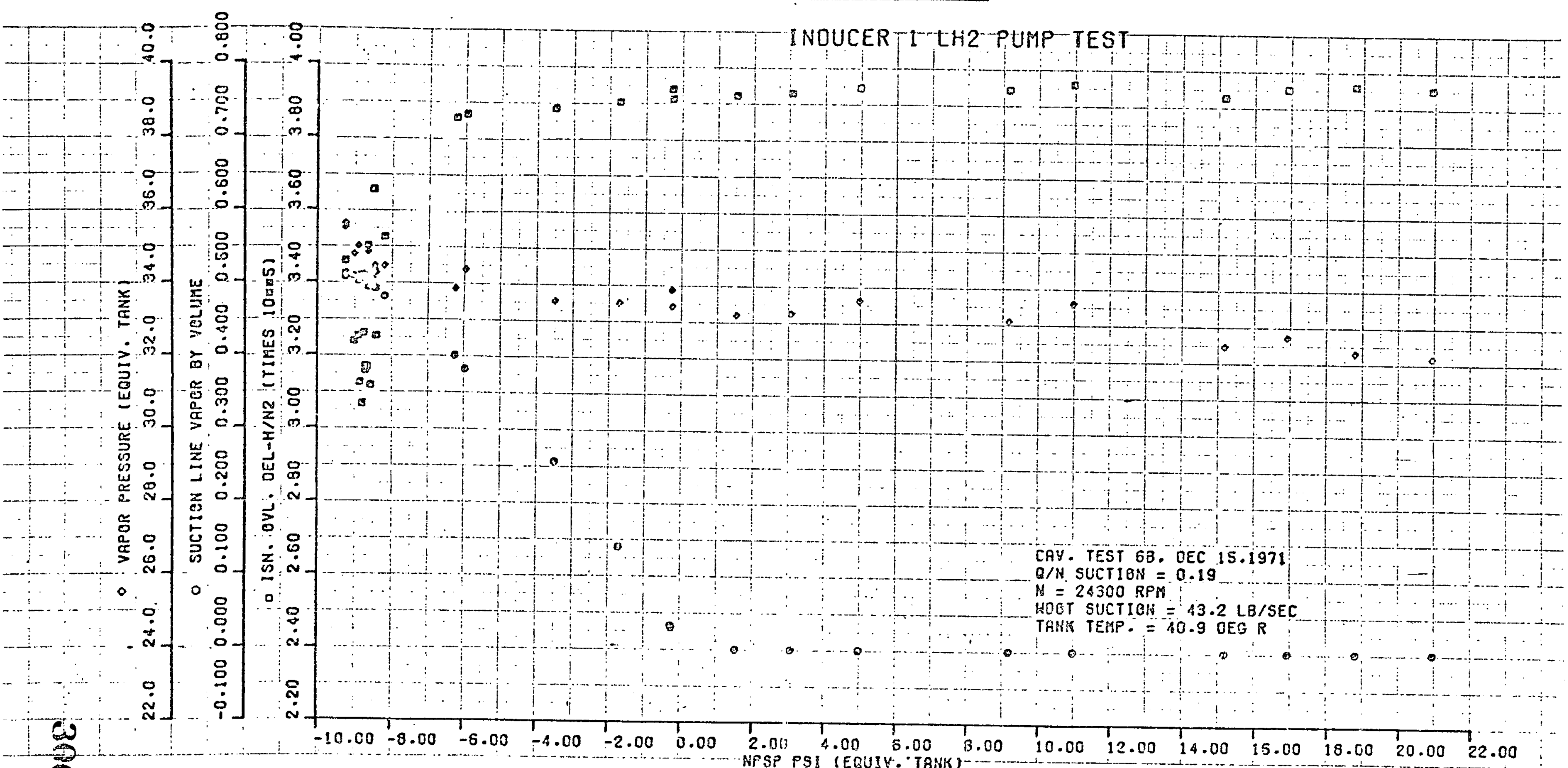
GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

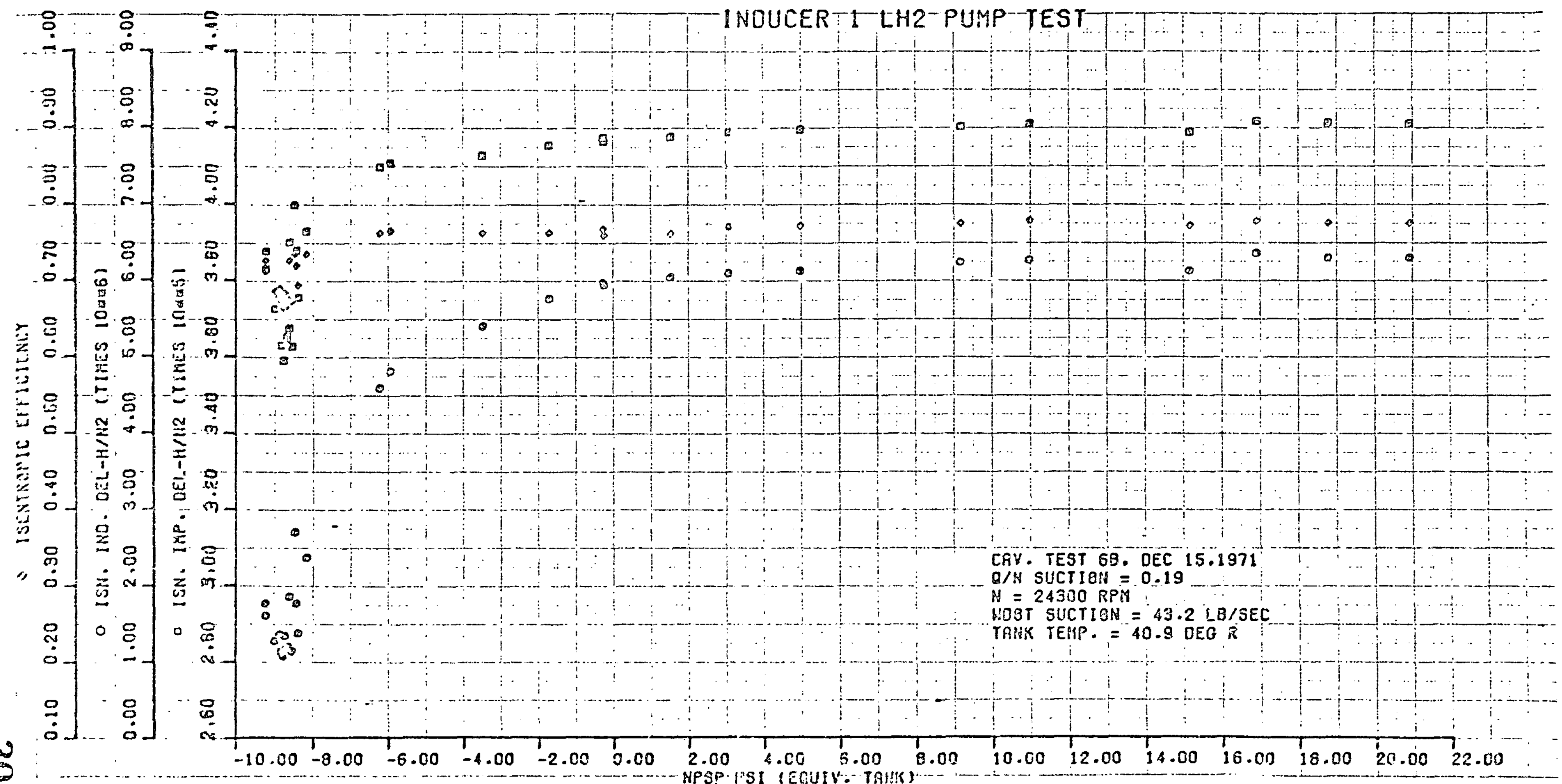
GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 6A, DEC 15,1971
Q/N SUCTION = 0.26
N = 24300 RPM
WDOT SUCTION = 59.8 LB/SEC
TANK TEMP. = 40.8 DEG R

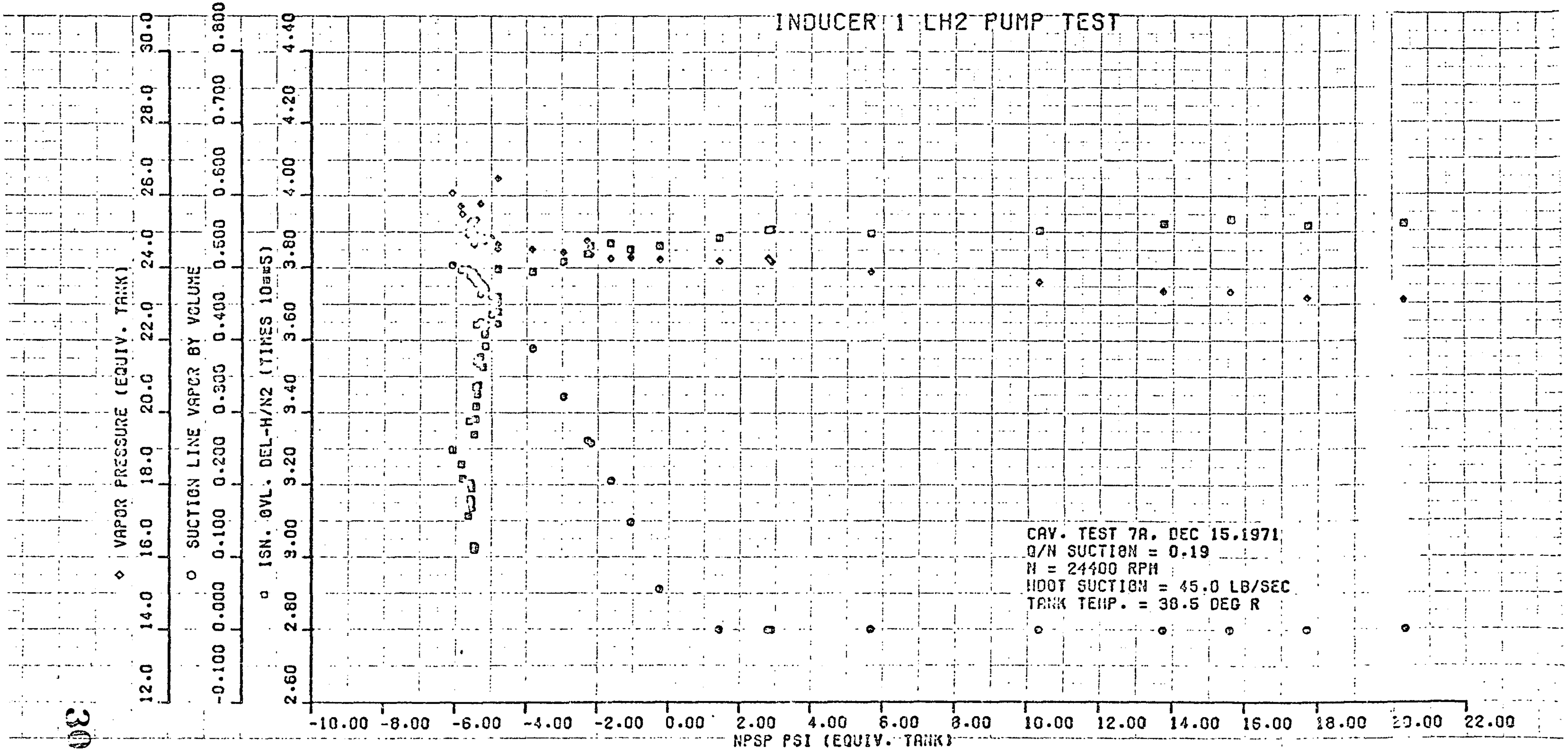

INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 6A. DEC 15,1971
Q/N SUCTION = 0.26
N = 24300 RPM
WDOT SUCTION = 59.8 LB/SEC
TANK TEMP. = 40.8 DEG R

305

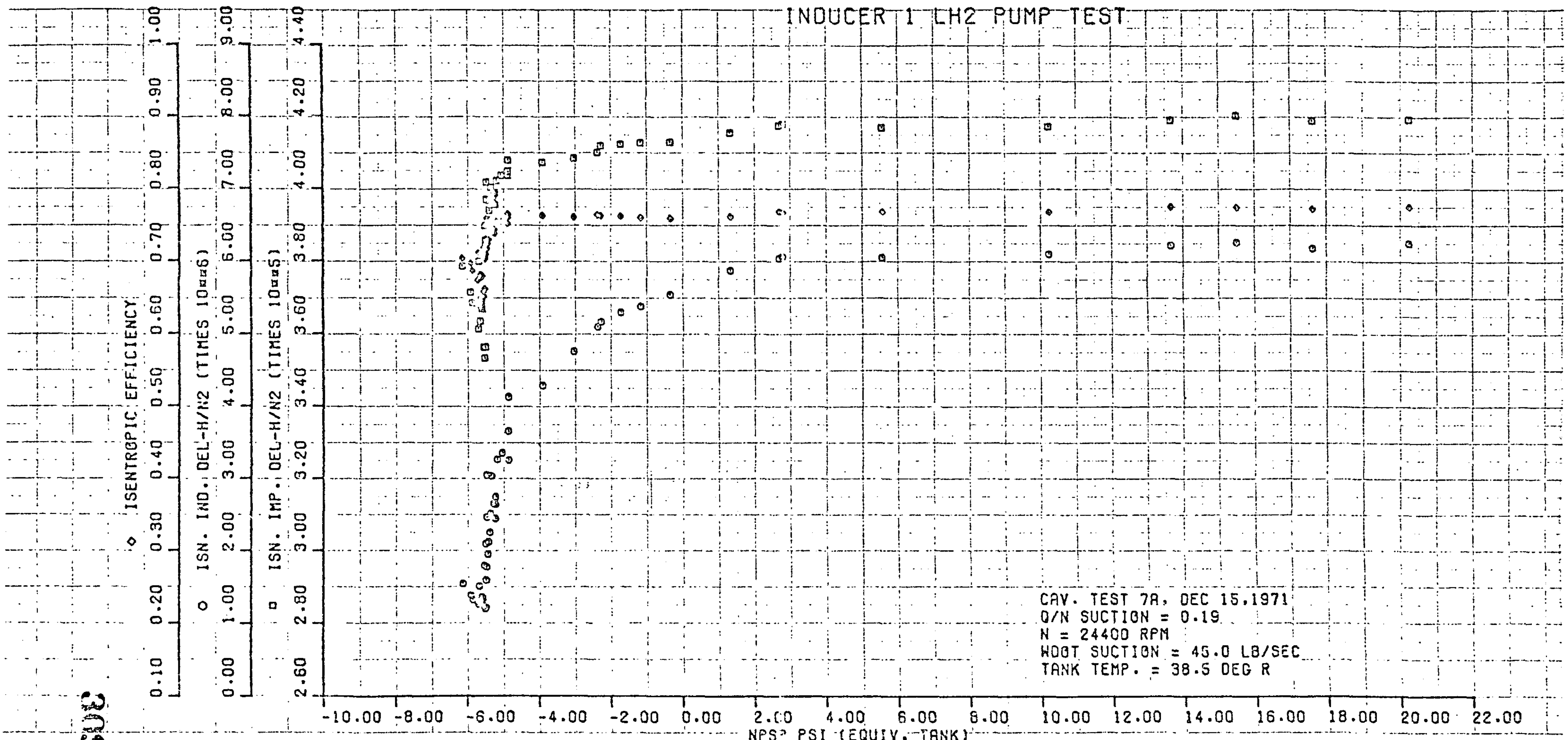

INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
CAV. TEST 6B, DEC 15,1971
Q/N SUCTION = 0.19
N = 24300 RPM
WDOT SUCTION = 43.2 LB/SEC
TANK TEMP. = 40.9 DEG R



INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/H2 (TIMES 10**6)
ISN. IMP. DEL-H/H2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 68. DEC 15.1971
Q/N SUCTION = 0.19
N = 24300 RPM
WDOT SUCTION = 43.2 LB/SEC
TANK TEMP. = 40.9 DEG R

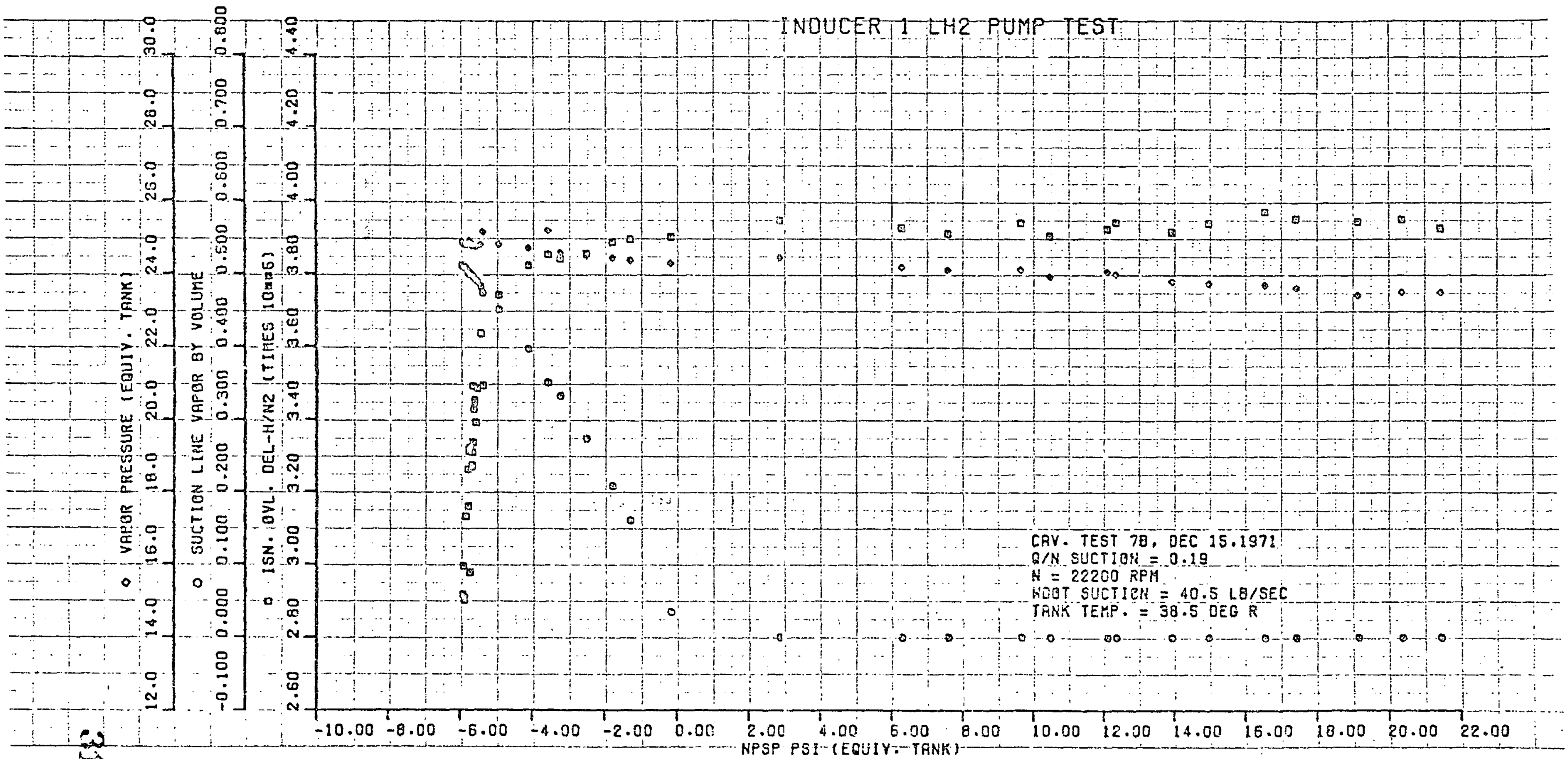


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 7A, DEC 15,1971
Q/N SUCTION = 0.19
N = 24400 RPM
WDOT SUCTION = 45.0 LB/SEC
TANK TEMP. = 38.5 DEG R

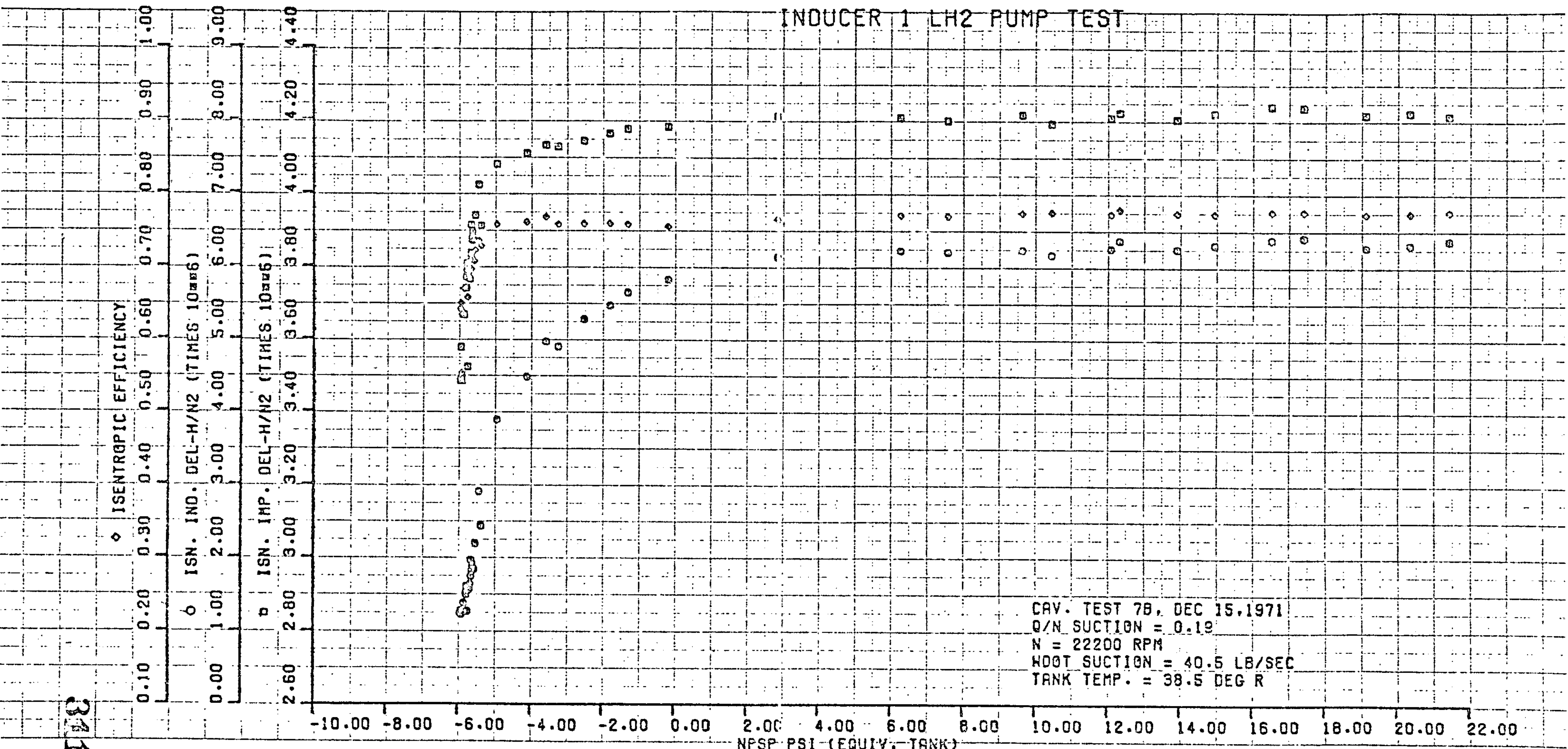


INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 7A, DEC 15,1971
Q/N SUCTION = 0.19
N = 24400 RPM
WDOT SUCTION = 45.0 LB/SEC
TANK TEMP. = 38.5 DEG R

309



SALMA CO. SANTA CLARA, CALIF. CHART No. 12-02



INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**6)
CAV. TEST 78, DEC 15,1971
Q/N SUCTION = 0.19
N = 22200 RPM
WDOT SUCTION = 40.5 LB/SEC
TANK TEMP. = 38.5 DEG R
NPSP PSI (EQUIV. TANK)

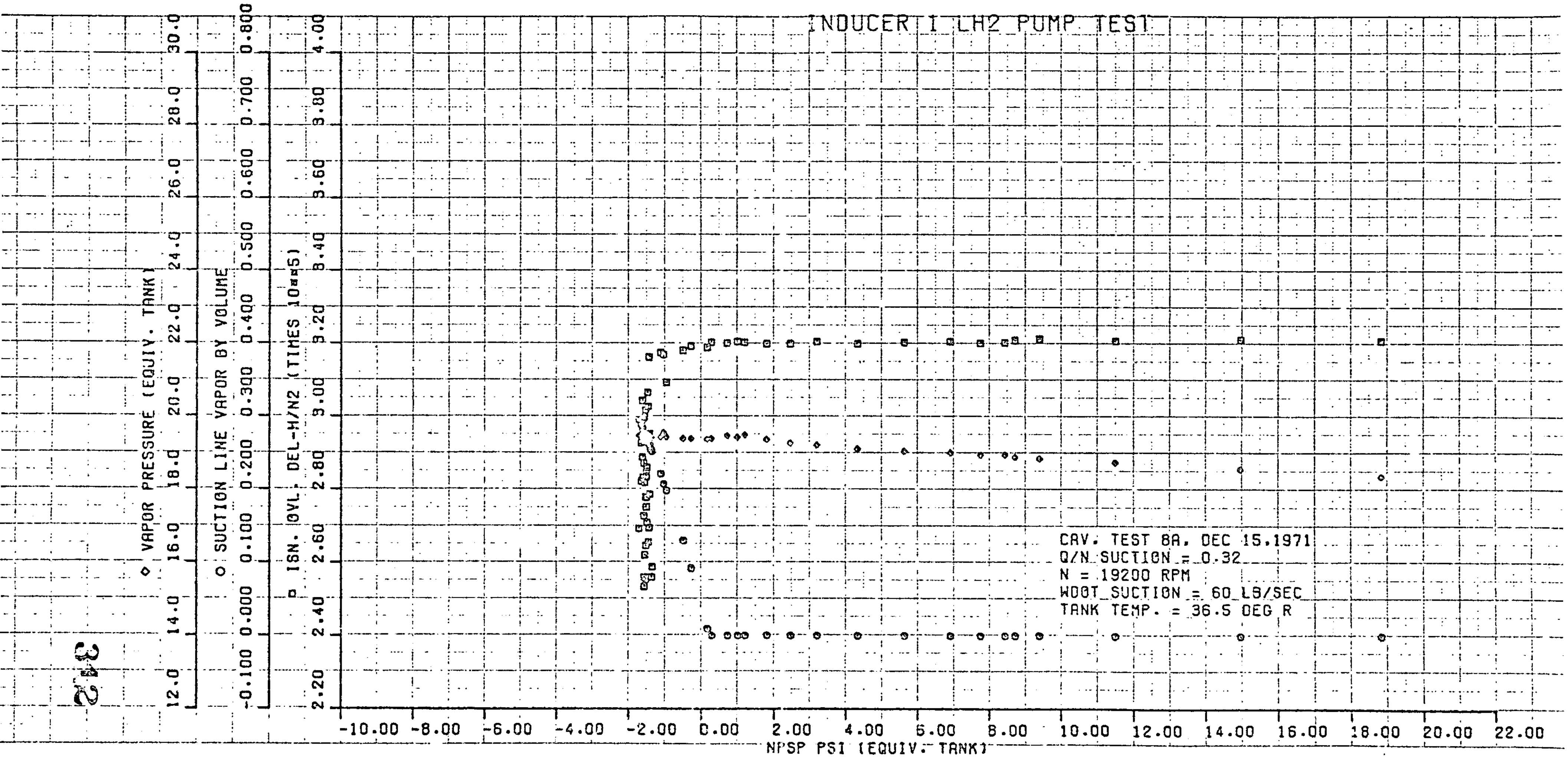


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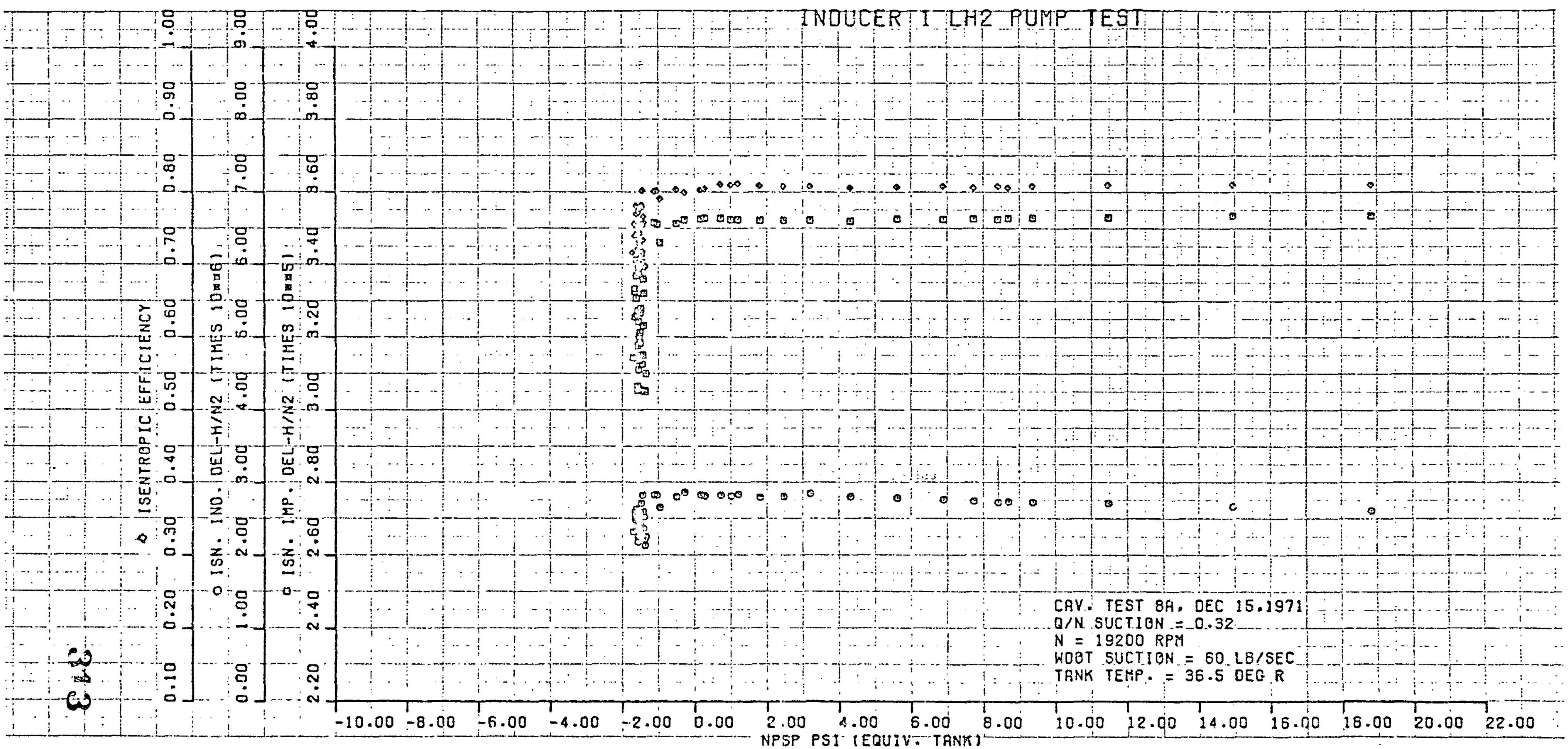
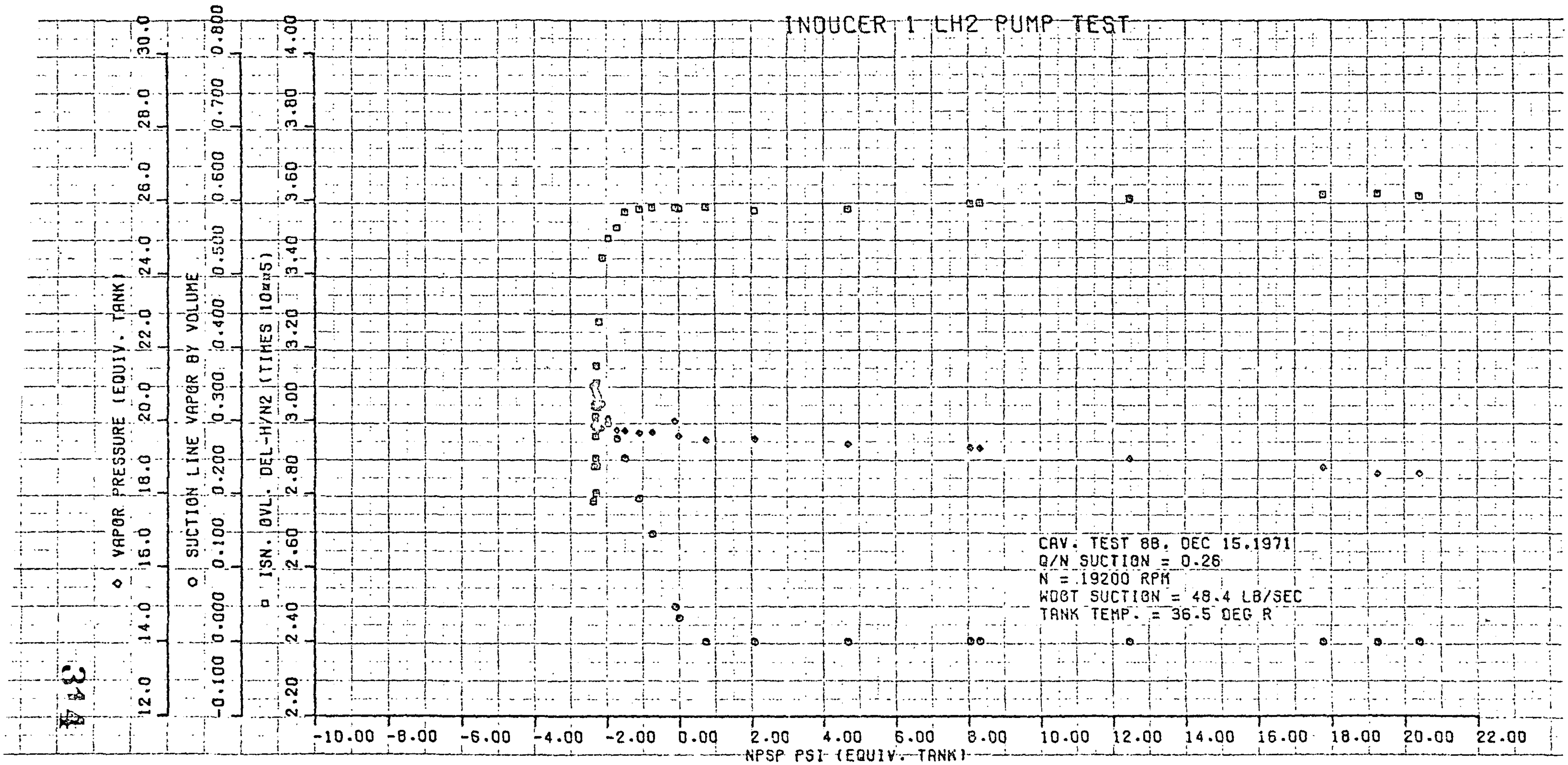
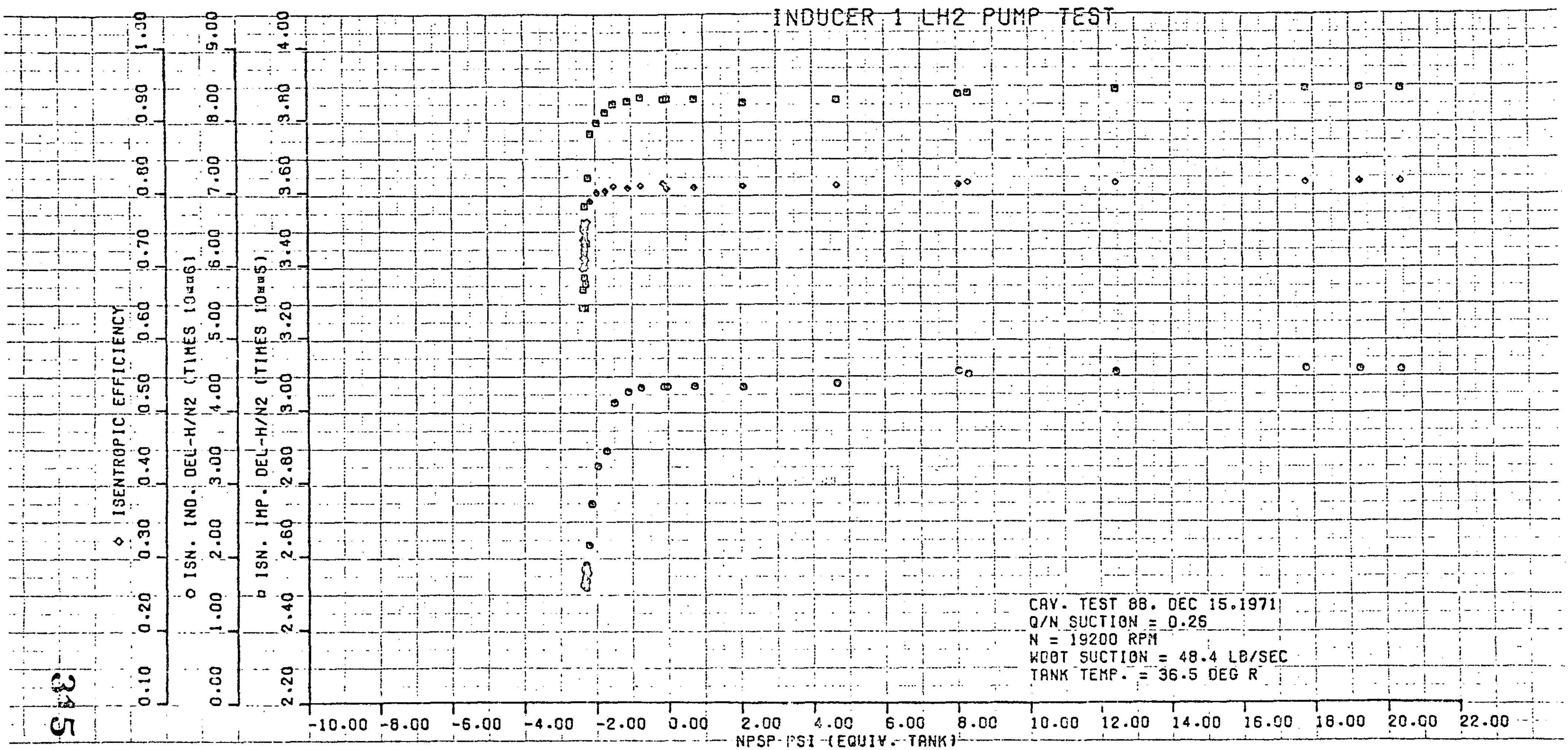
CHART No. 12-02

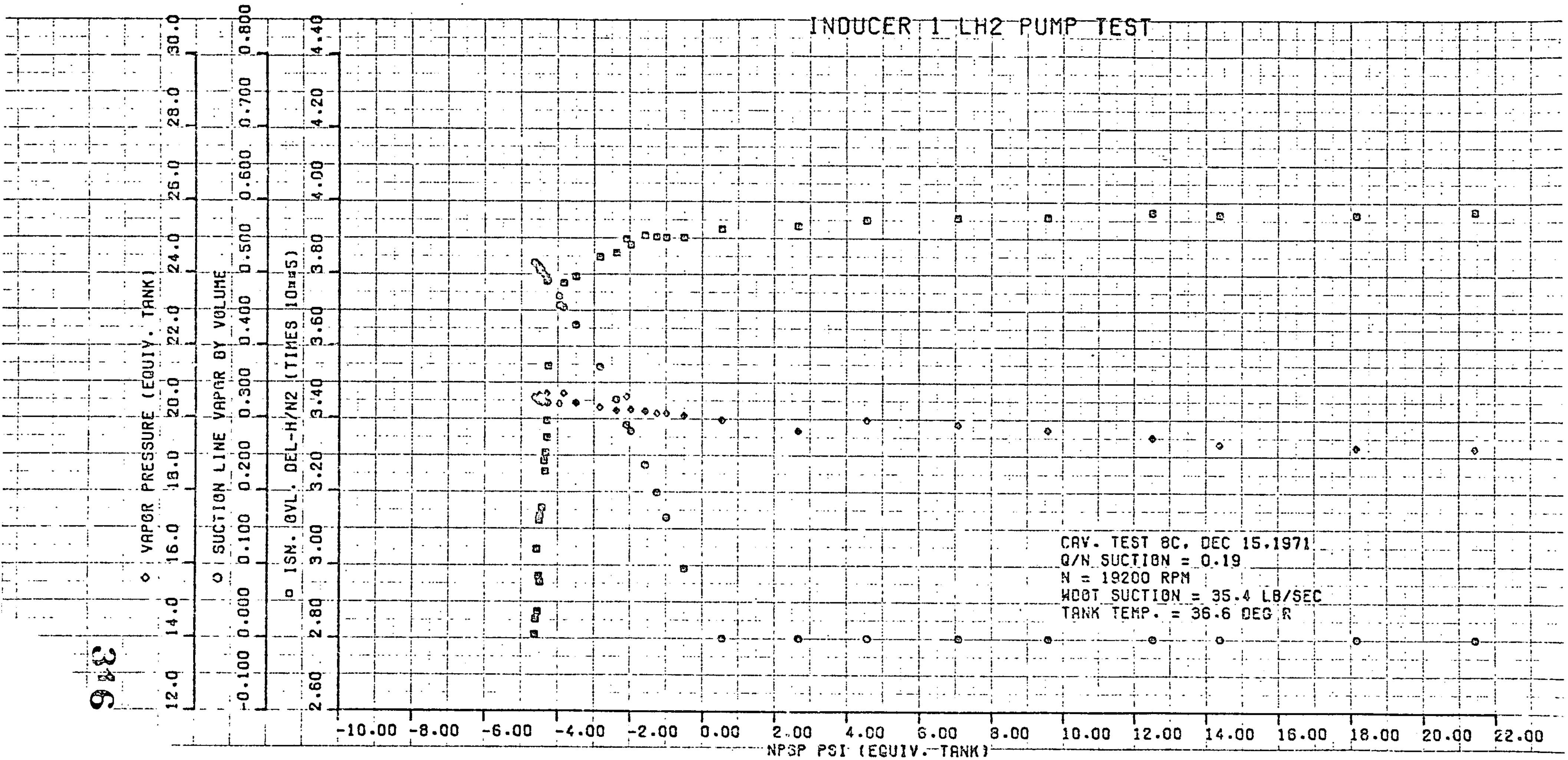
CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER I LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 8A, DEC 15,1971
Q/N SUCTION = 0.32
N = 19200 RPM
WDOT SUCTION = 60 LB/SEC
TANK TEMP. = 36.5 DEG R

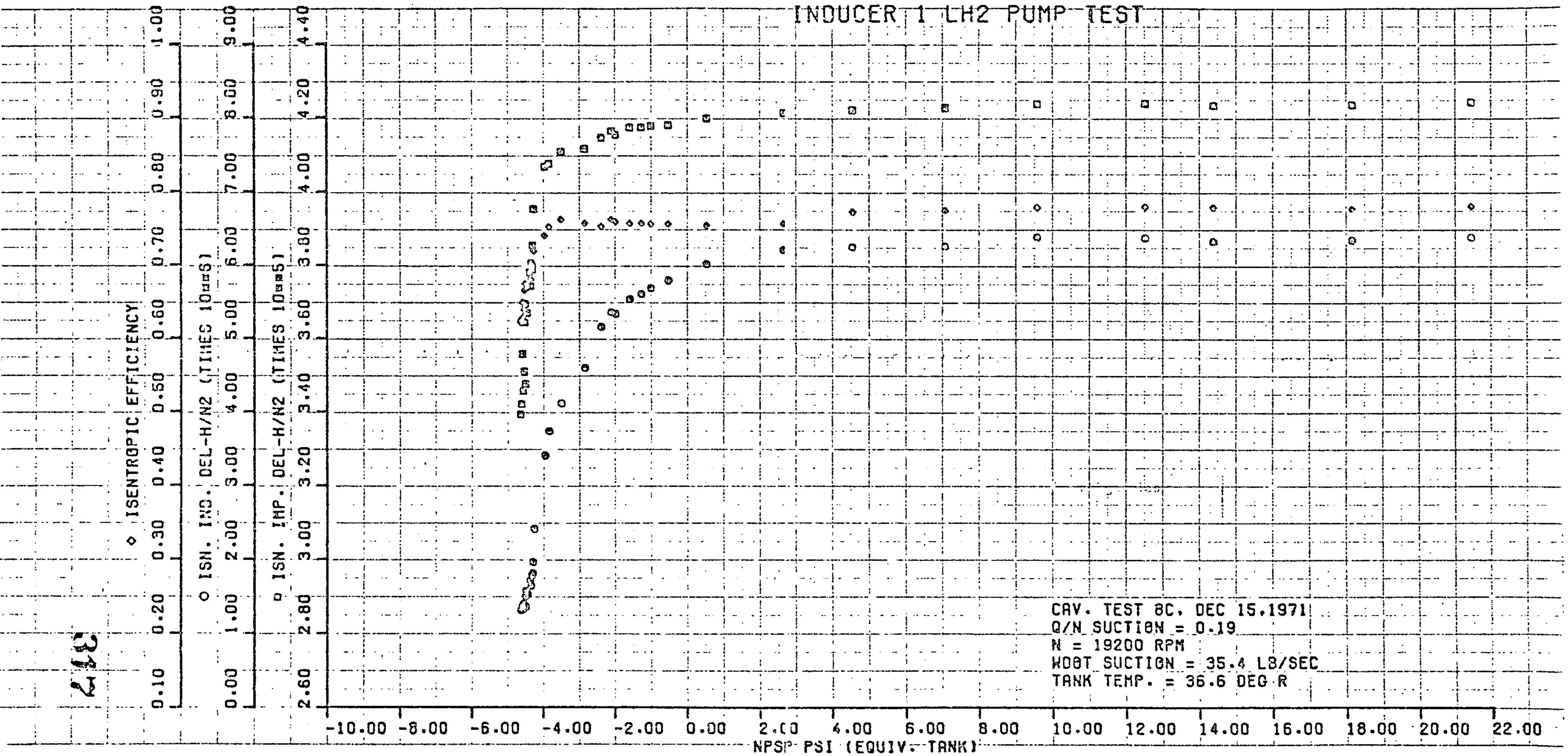
313


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 88, DEC 15,1971
Q/N SUCTION = 0.26
N = 19200 RPM
WDOT SUCTION = 48.4 LB/SEC
TANK TEMP. = 36.5 DEG R


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 88. DEC 15.1971
Q/N SUCTION = 0.26
N = 19200 RPM
WDOT SUCTION = 48.4 LB/SEC
TANK TEMP. = 36.5 DEG R



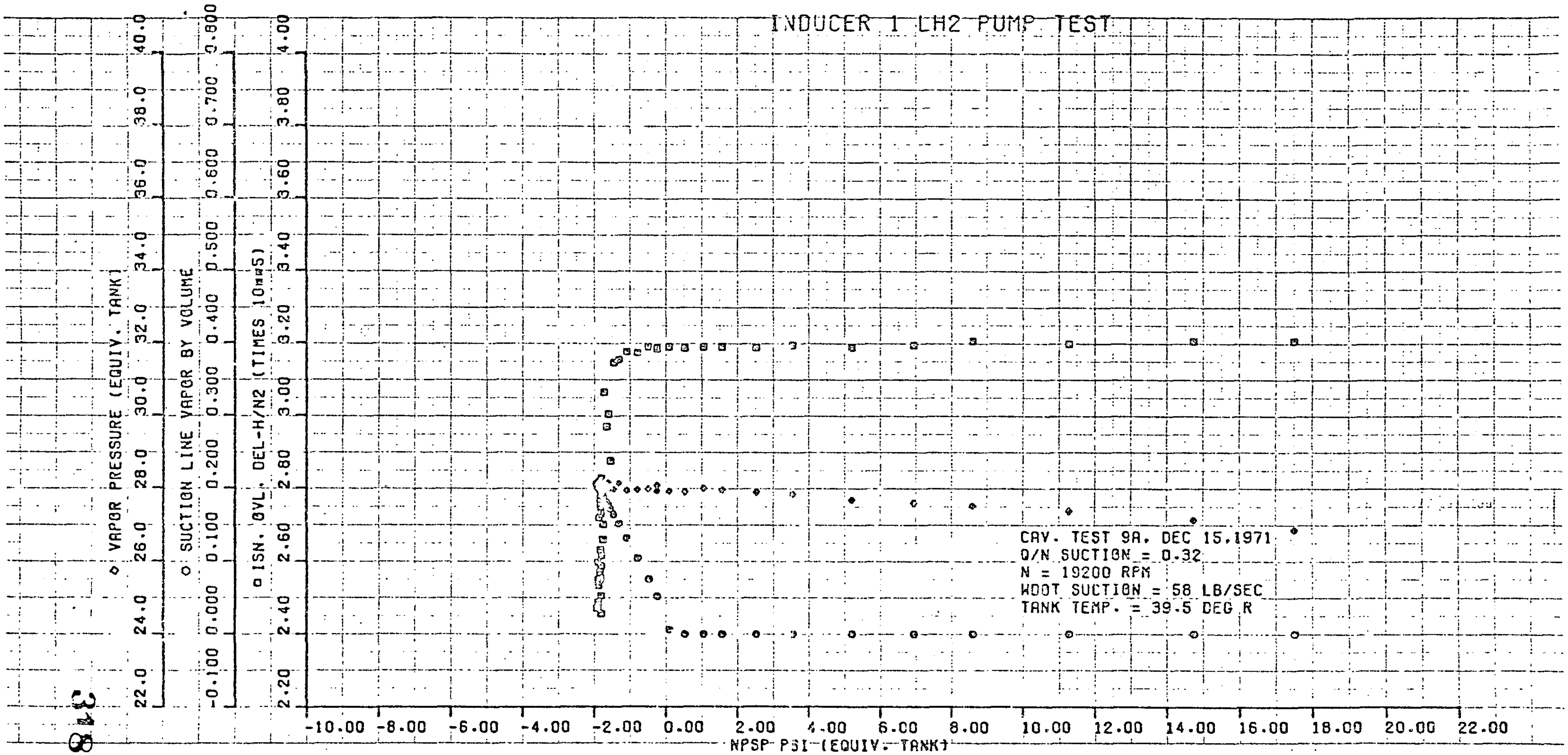
INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
CAV. TEST 8C, DEC 15,1971
Q/N SUCTION = 0.19
N = 19200 RPM
WDOT SUCTION = 35.4 LB/SEC
TANK TEMP. = 36.6 DEG R
NPSP PSI (EQUIV. TANK)
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
-0.100
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00



317

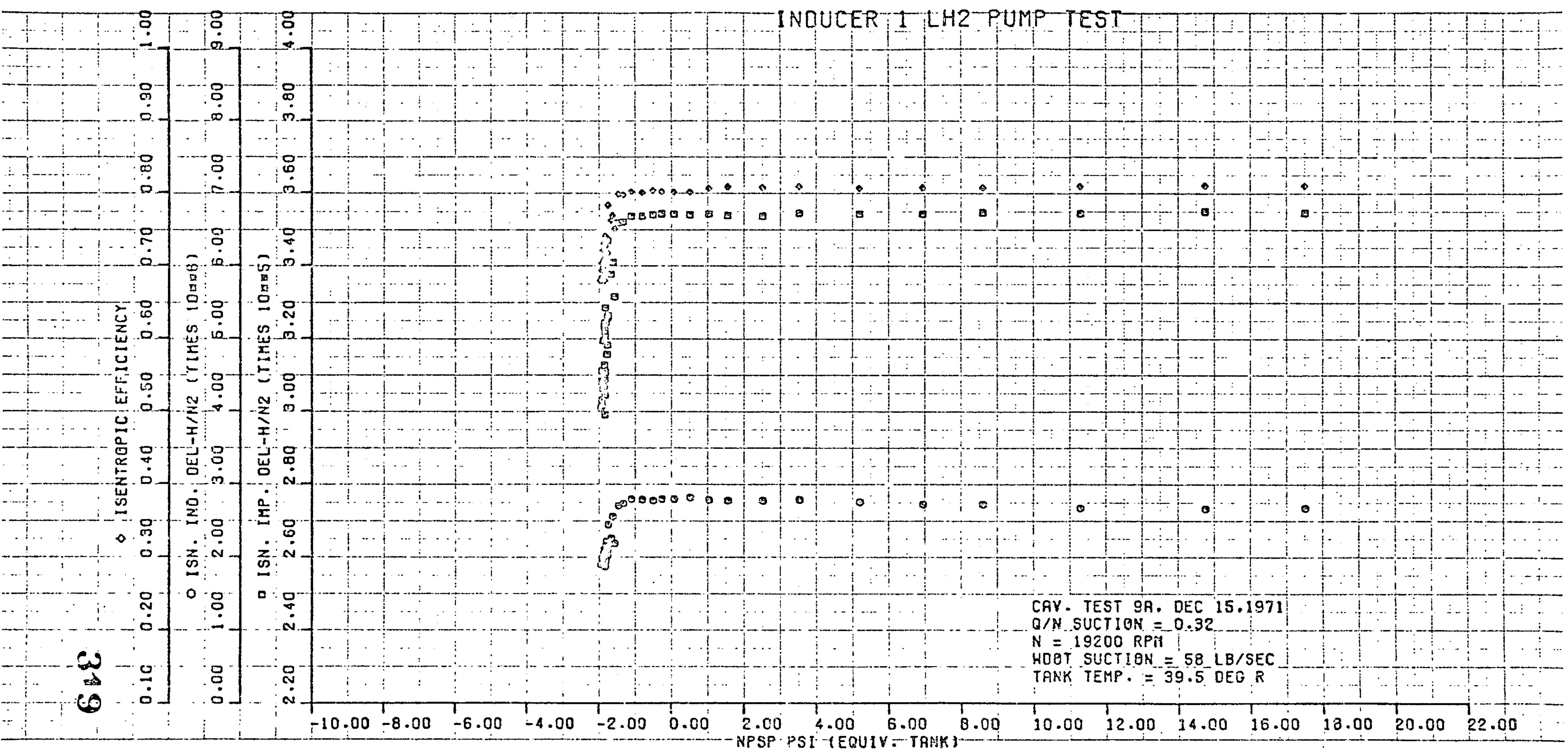
CHART No. 12-02

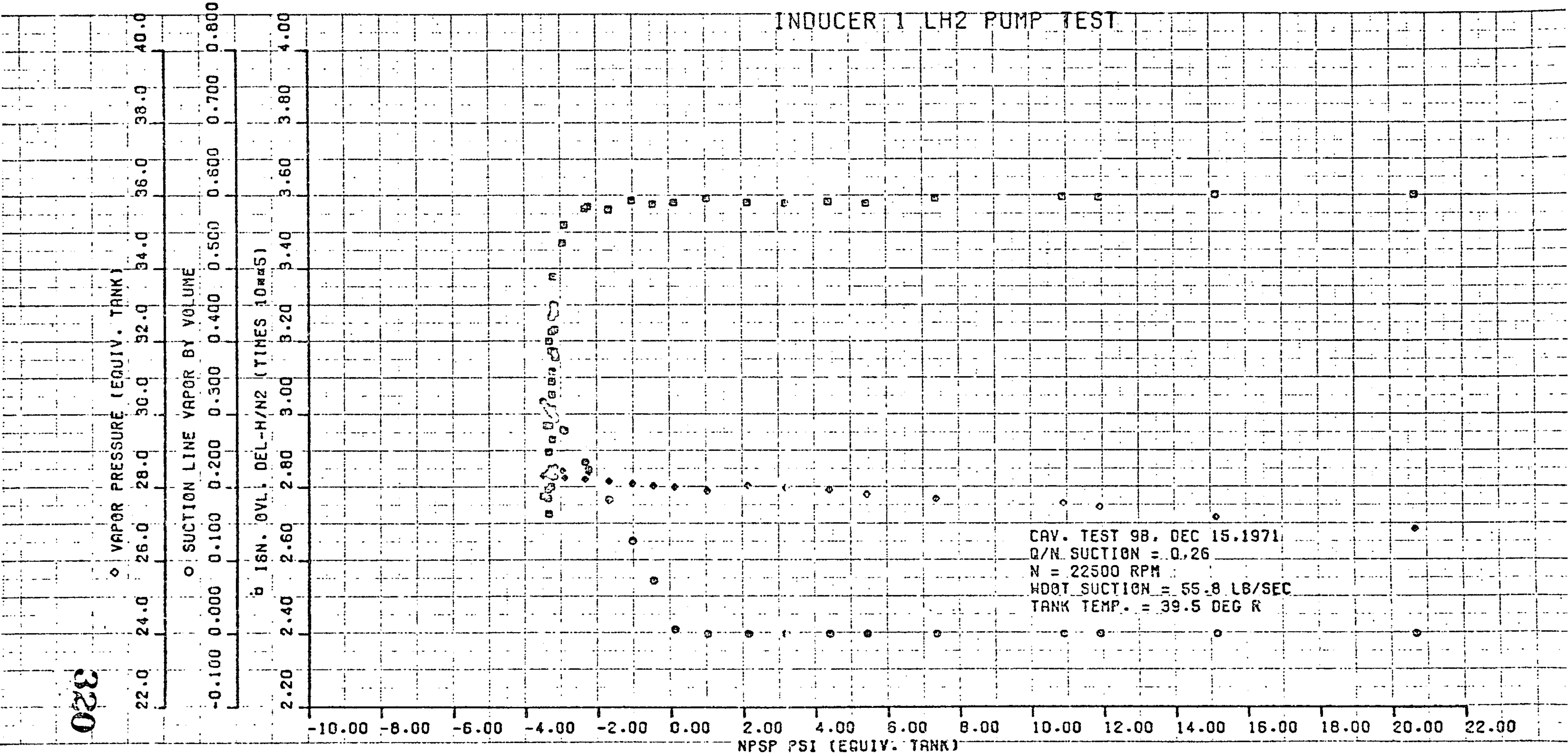
CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02



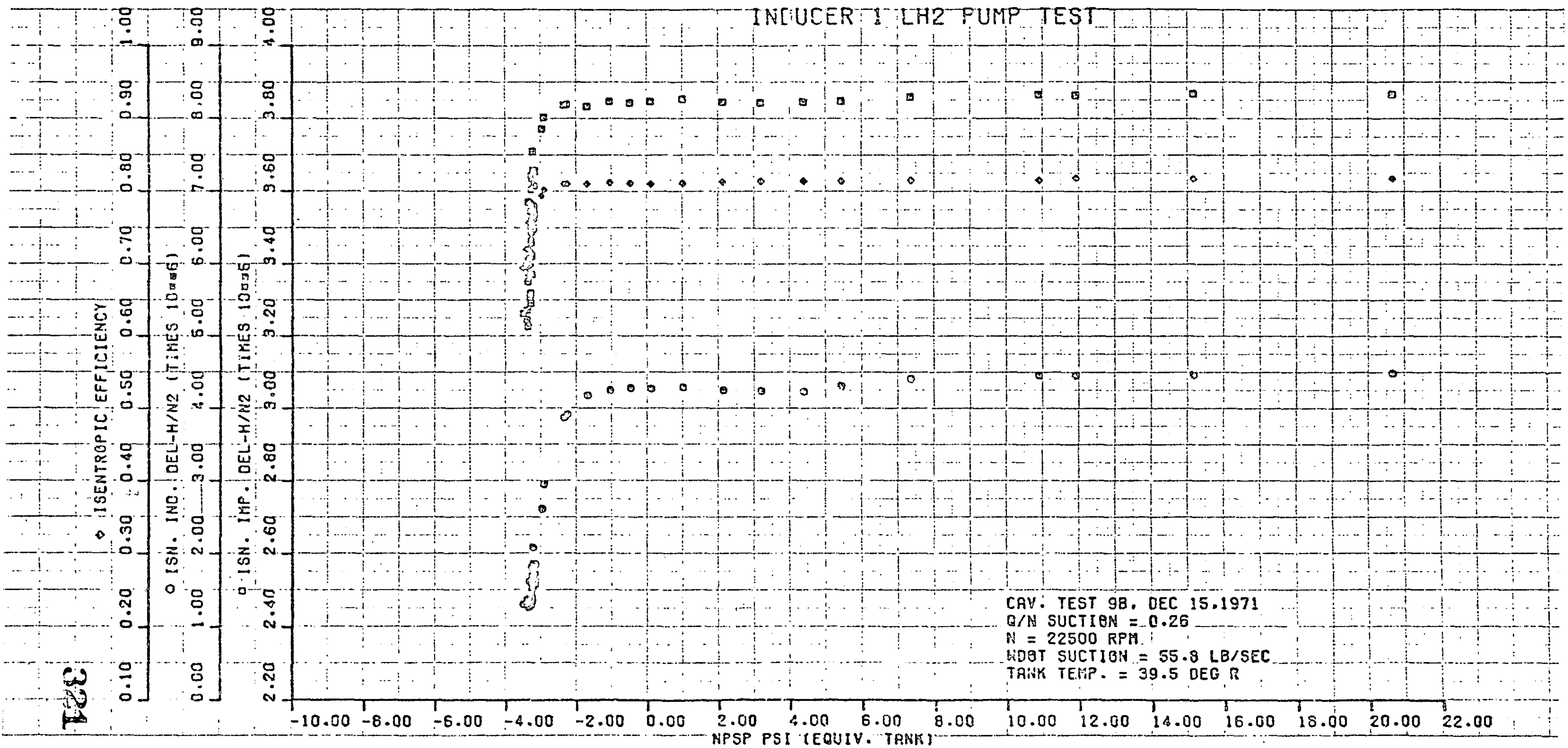
318

GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**8)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 9A. DEC 15.1971
Q/N SUCTION = 0.32
N = 19200 RPM
WDOT SUCTION = 58 LB/SEC
TANK TEMP. = 39.5 DEG R

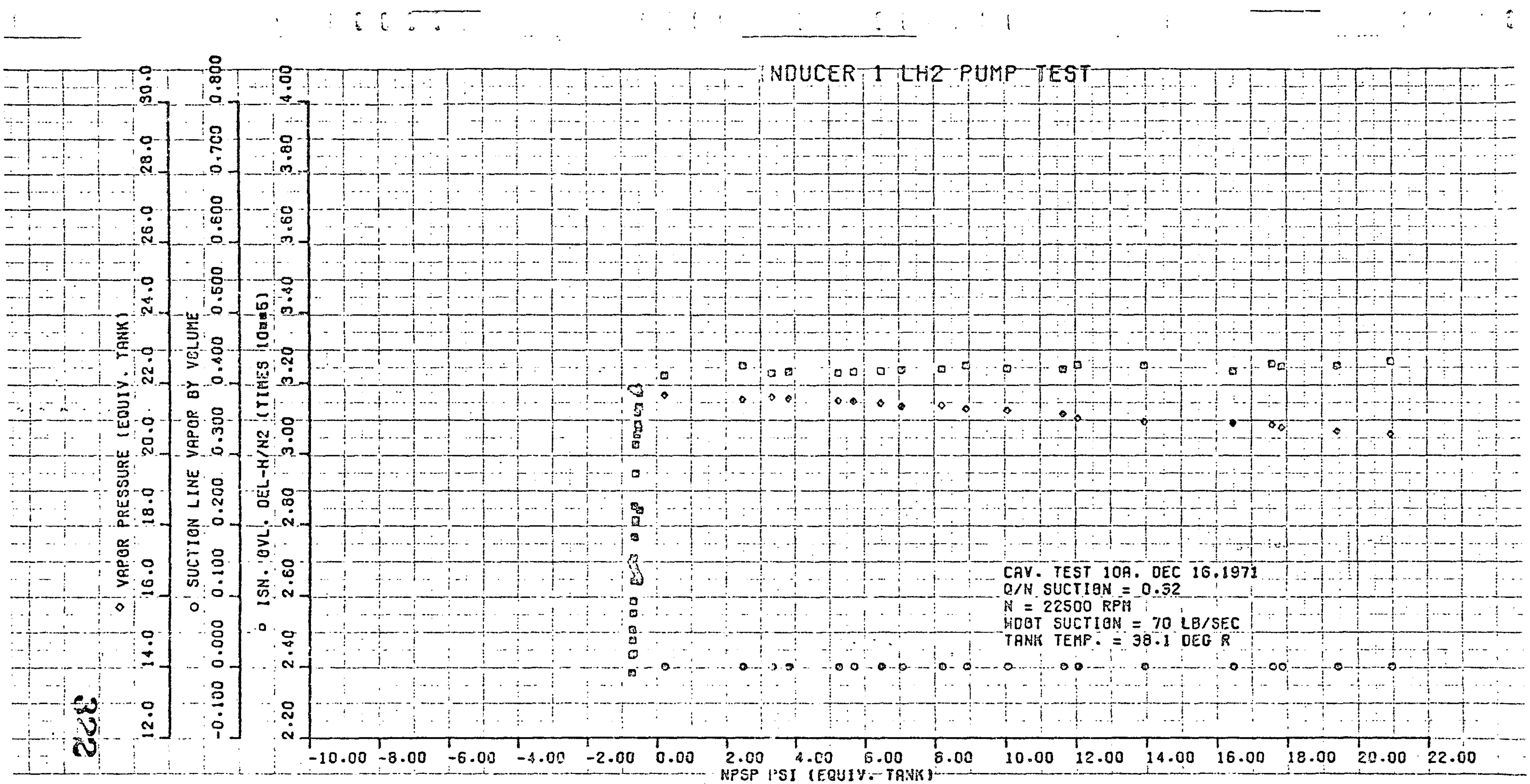


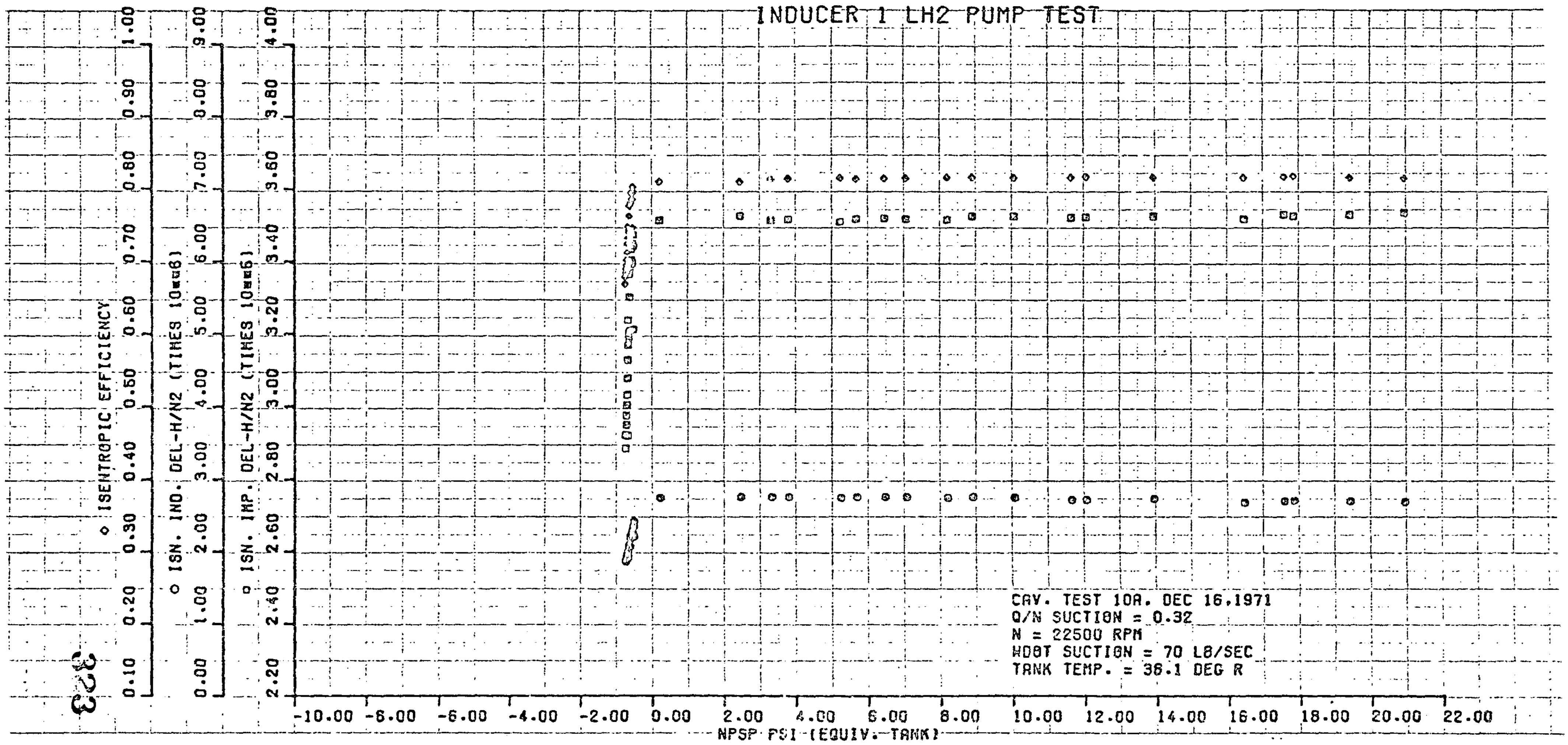
320
CHART No. 12-02



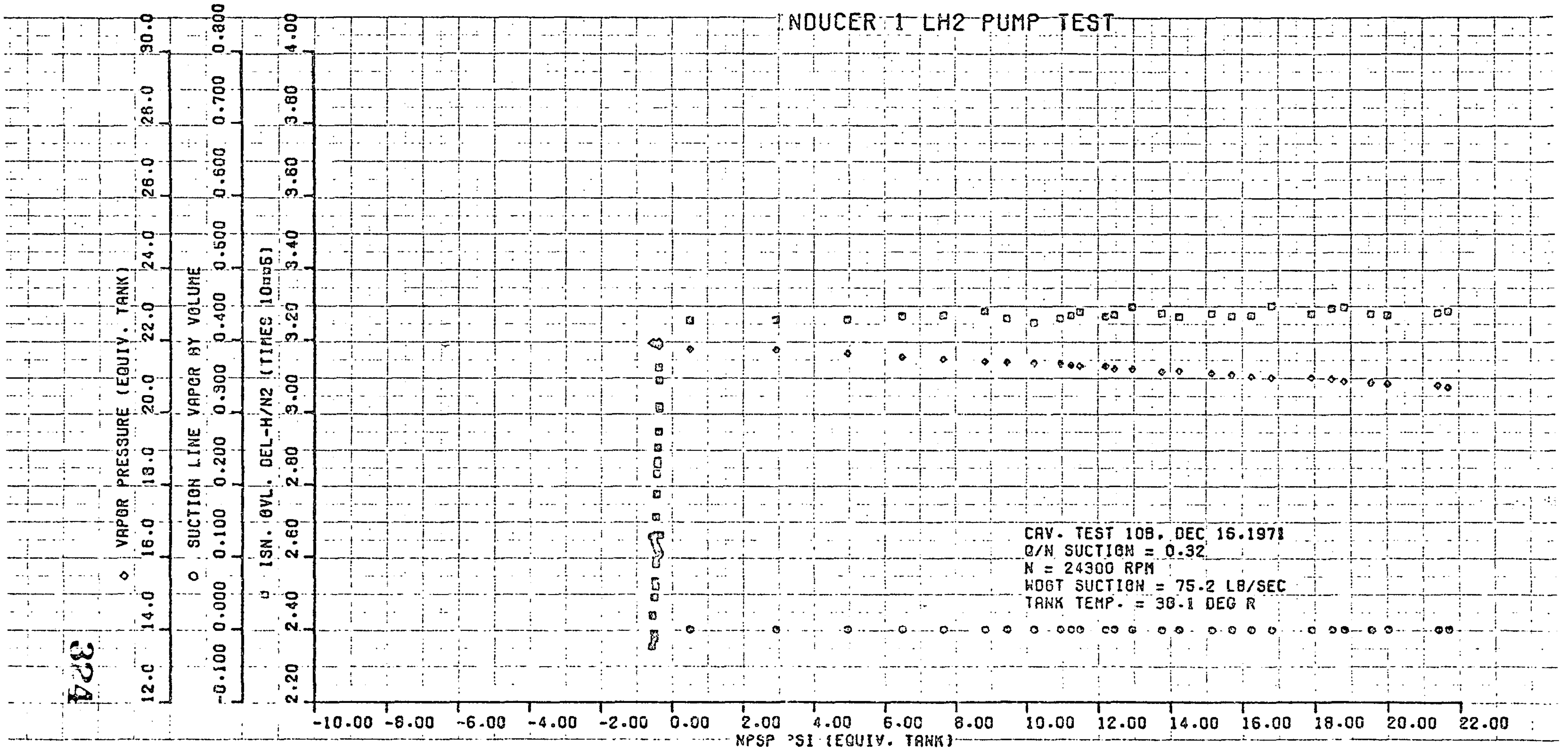
321

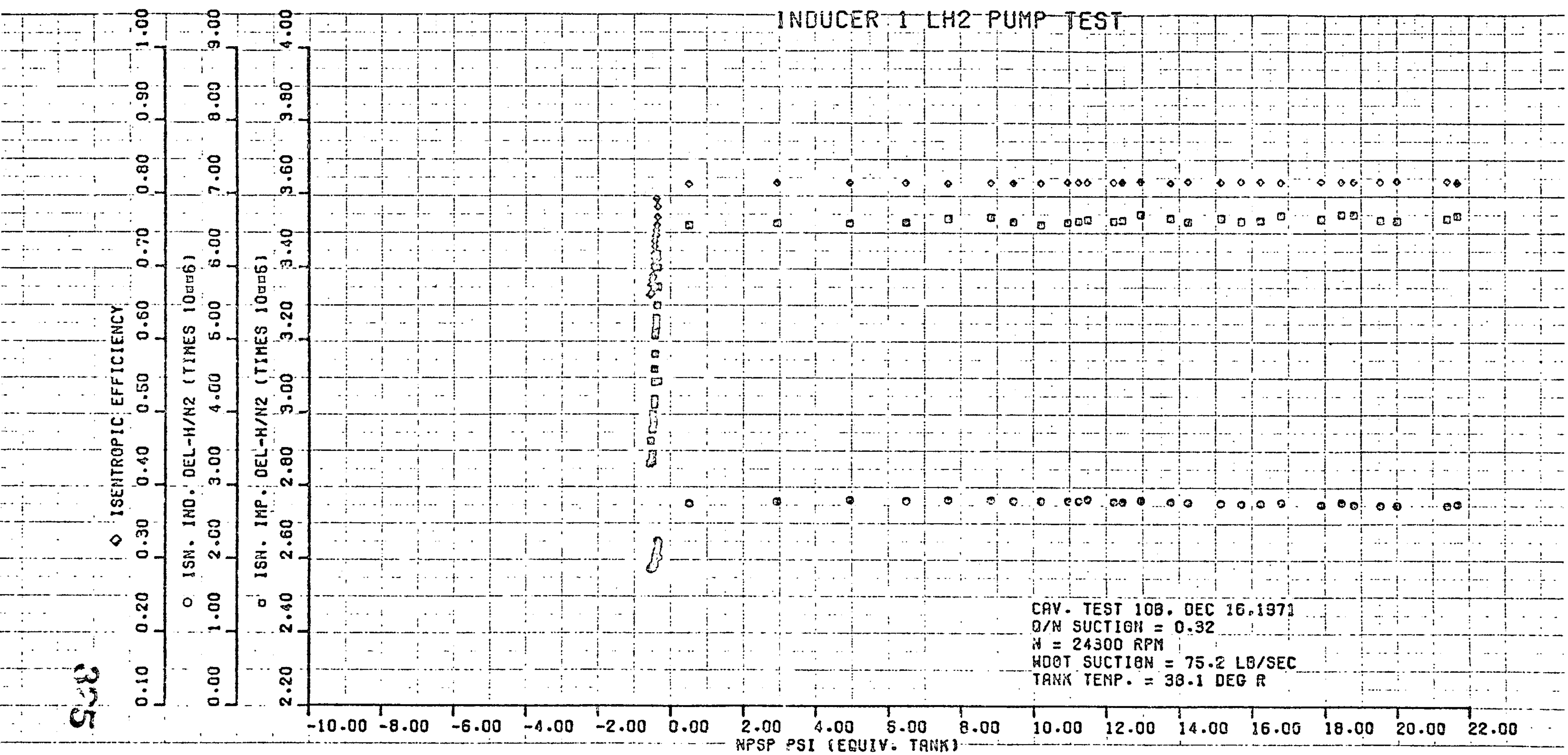
CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
CAV. TEST 10A. DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 70 LB/SEC
TANK TEMP. = 38.1 DEG R
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**6)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 10A. DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 70 LB/SEC
TANK TEMP. = 38.1 DEG R

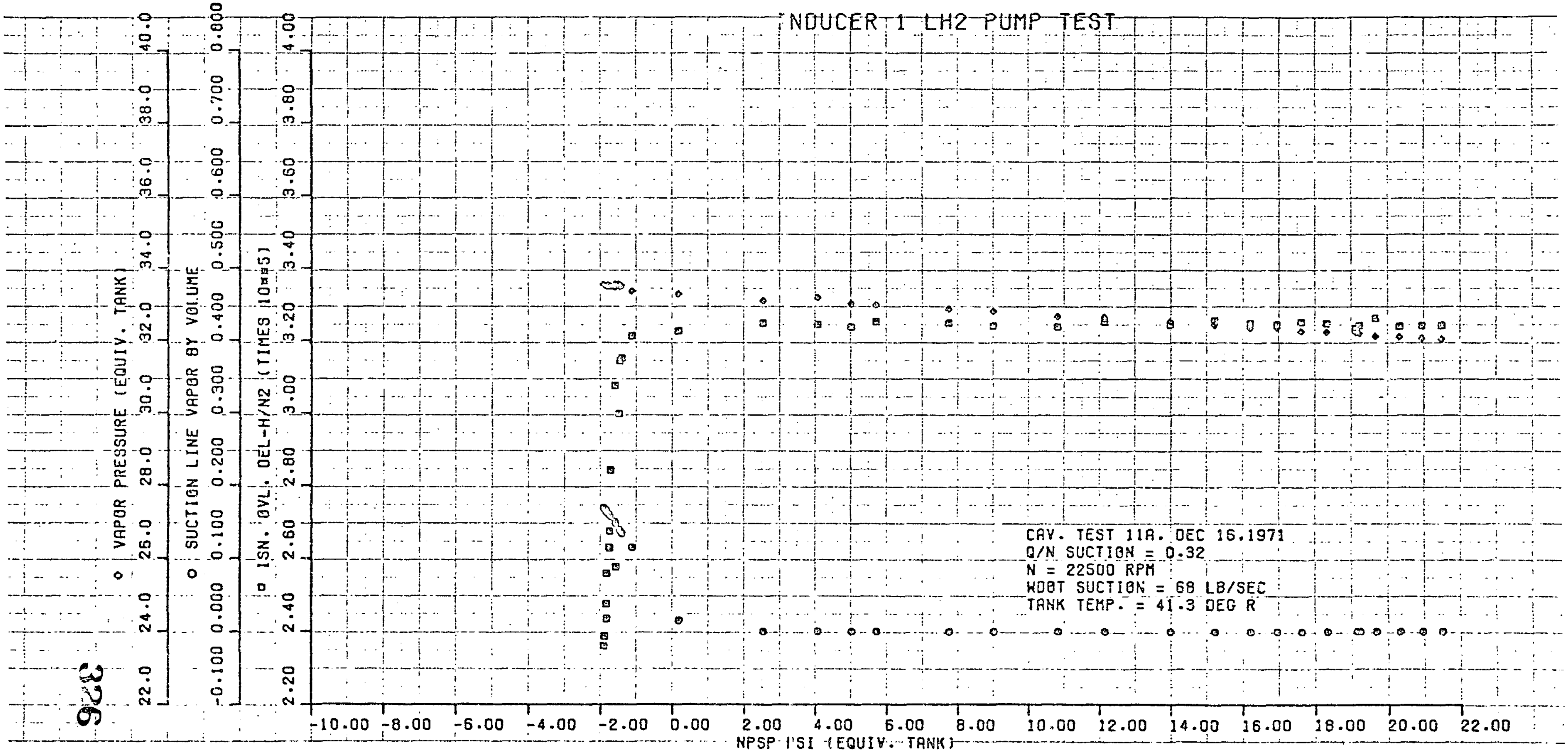
328


INDUCER 1 LH2 PUMP TEST
CAV. TEST 108, DEC 16,1971
Q/N SUCTION = 0.32
N = 24300 RPM
WDOT SUCTION = 75.2 LB/SEC
TANK TEMP. = 38.1 DEG R
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**6)
NPSP PSI (EQUIV. TANK)
324



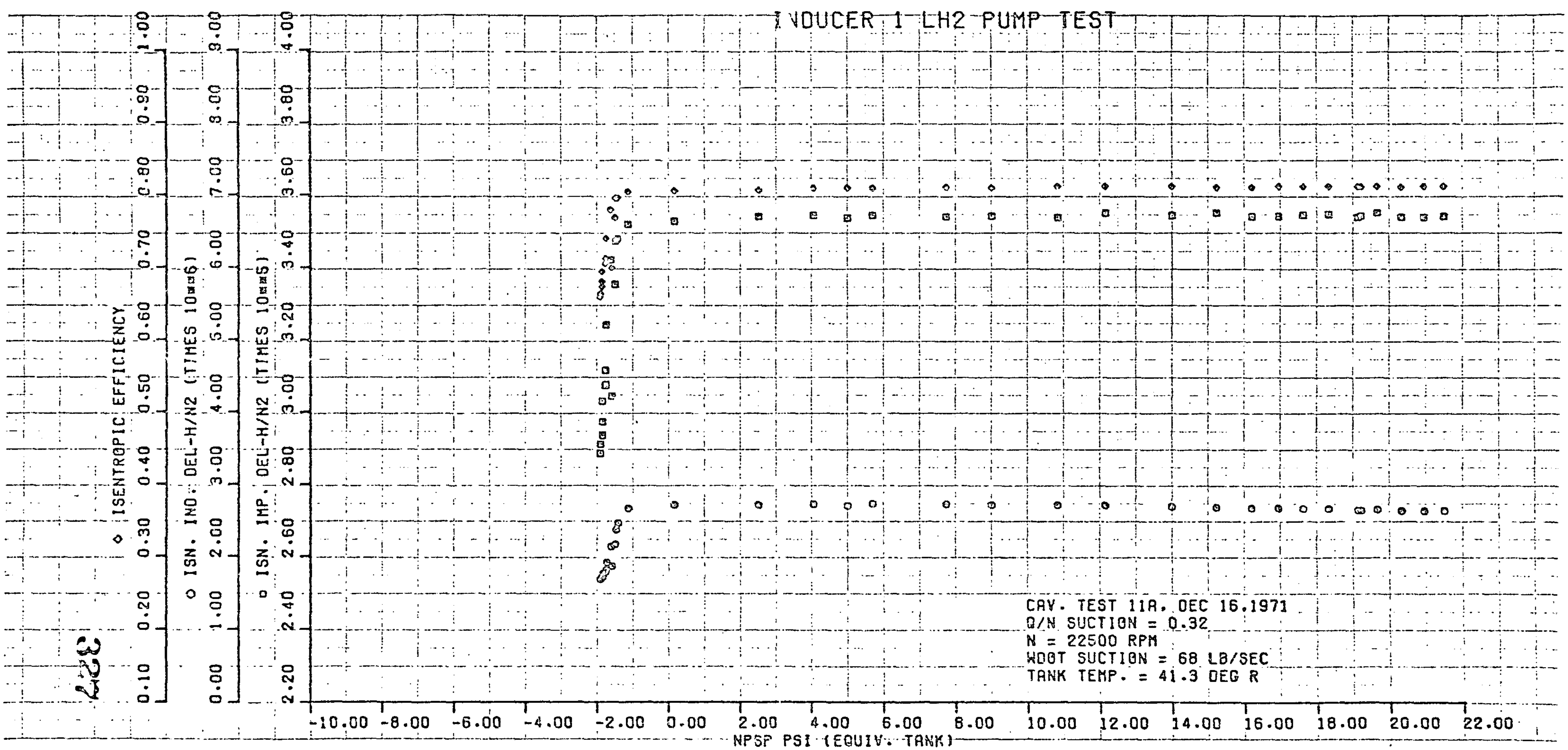
INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**6)
NPSP PSI (EQUIV. TANK)
CAV. TEST 108. DEC 16,1971
Q/N SUCTION = 0.32
N = 24300 RPM
WDOT SUCTION = 75.2 LB/SEC
TANK TEMP. = 38.1 DEG R

325

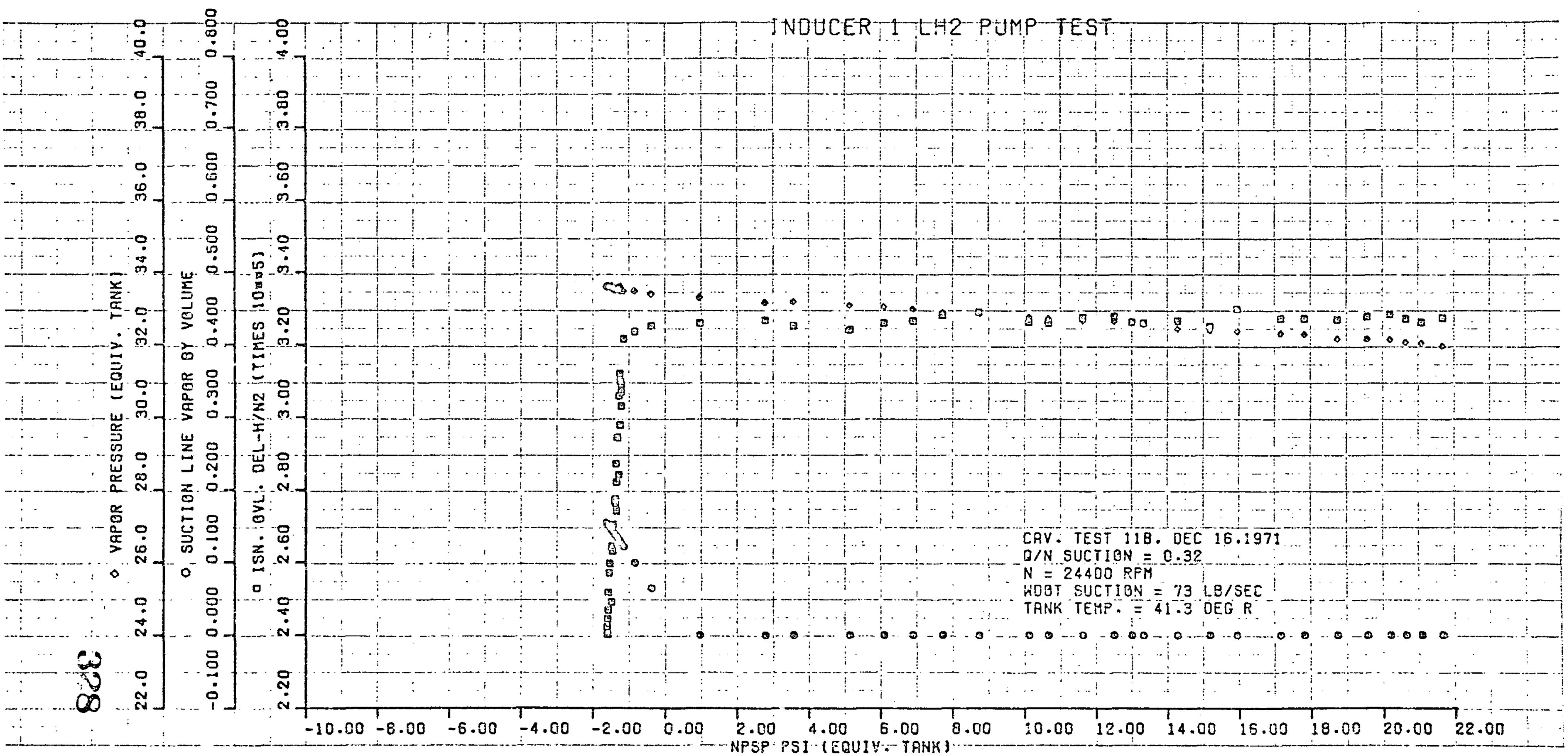


NDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 11A. DEC 16.1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 68 LB/SEC
TANK TEMP. = 41.3 DEG R

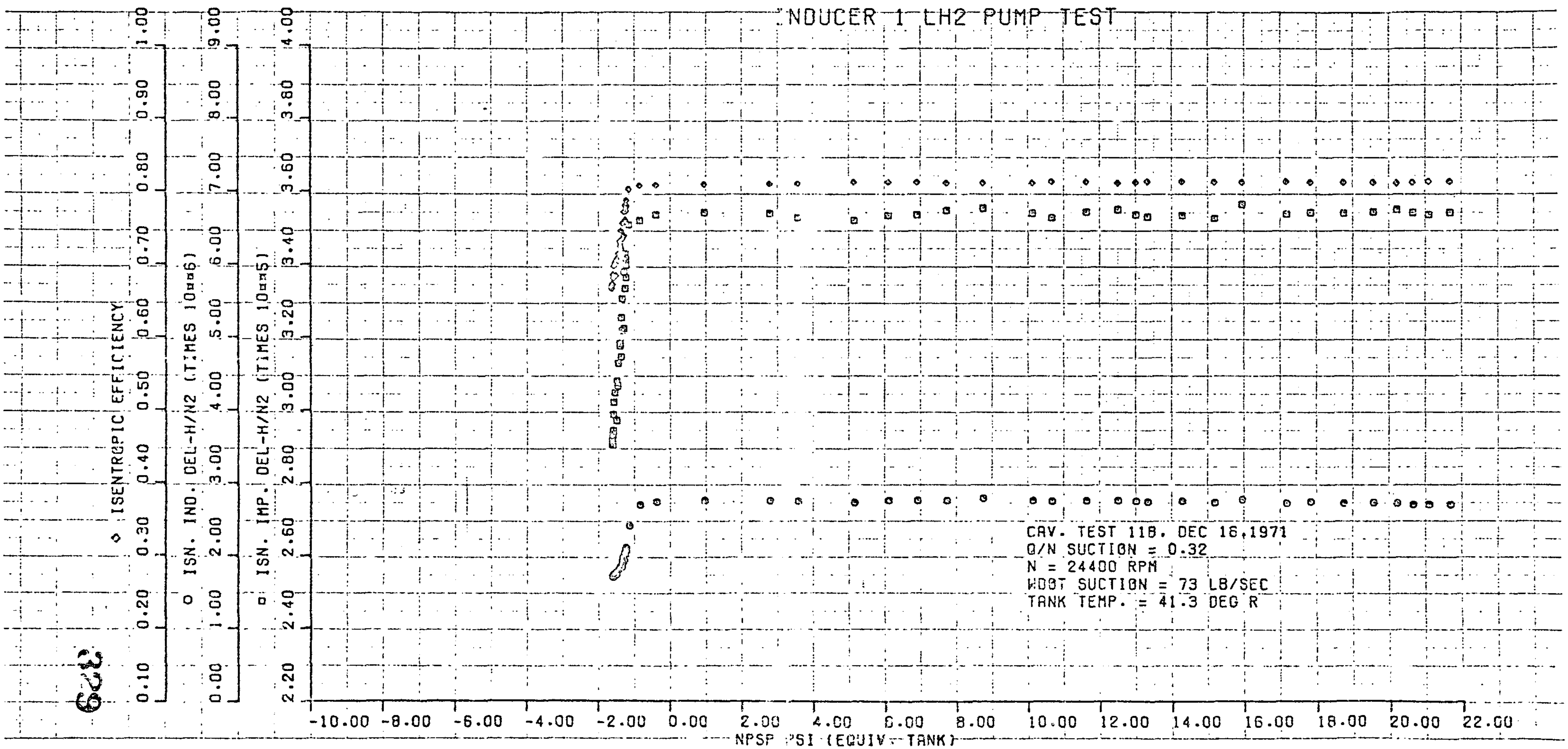
326

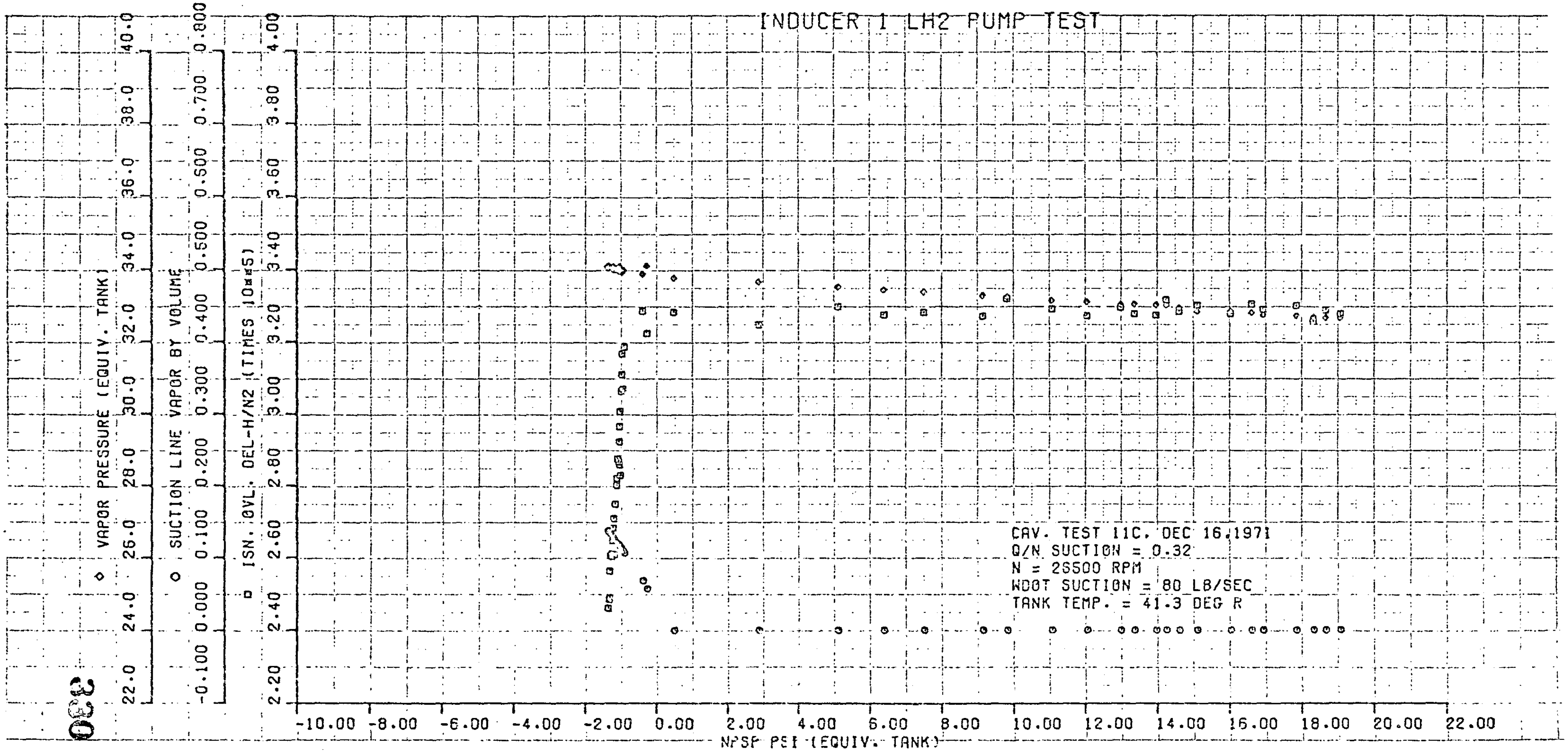

INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 11A, DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 68 LB/SEC
TANK TEMP. = 41.3 DEG R

327

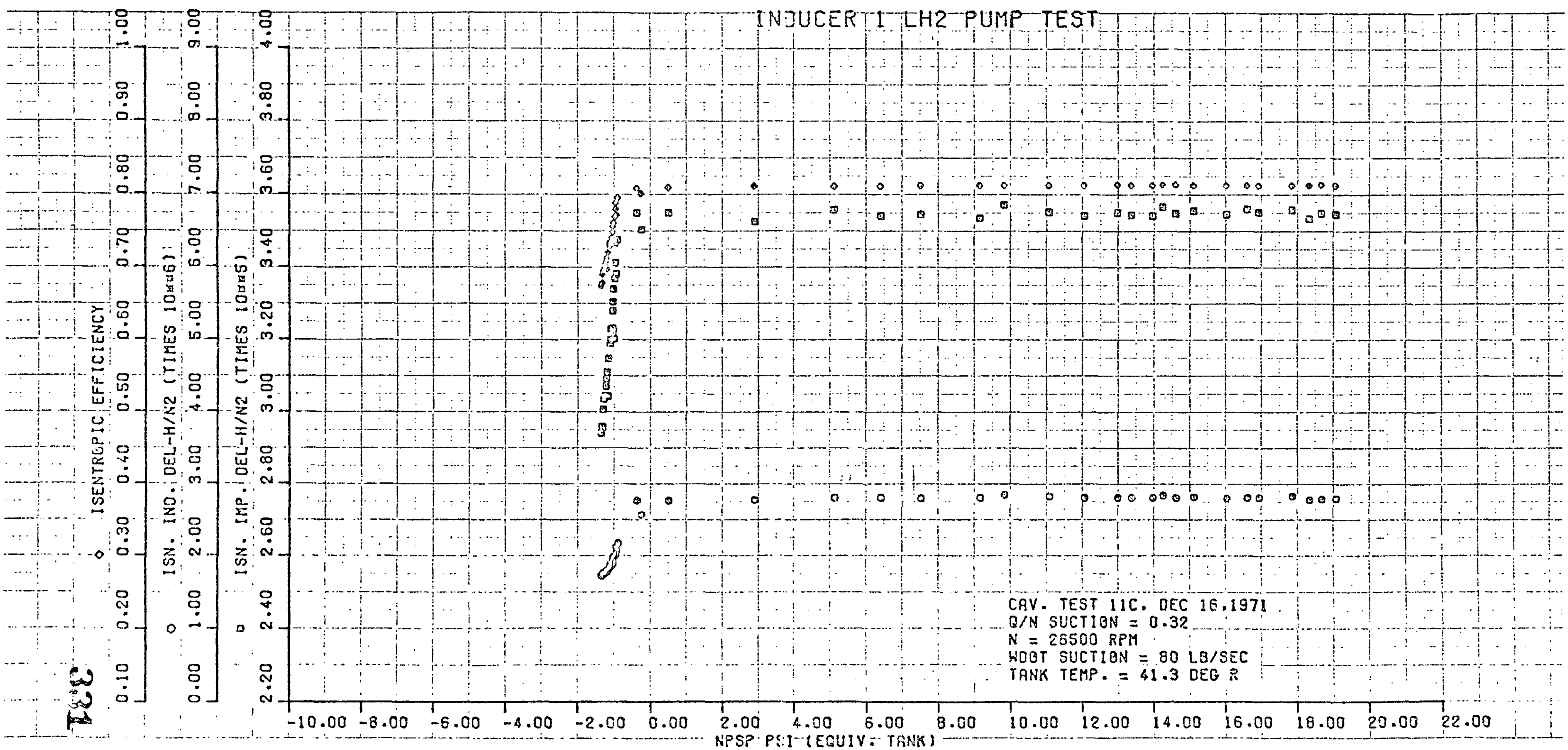

INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 118, DEC 16,1971
Q/N SUCTION = 0.32
N = 24400 RPM
WDOT SUCTION = 73 LB/SEC
TANK TEMP. = 41.3 DEG R

328


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV - TANK)
CAV. TEST 118, DEC 16,1971
Q/N SUCTION = 0.32
N = 24400 RPM
WDOT SUCTION = 73 LB/SEC
TANK TEMP. = 41.3 DEG R

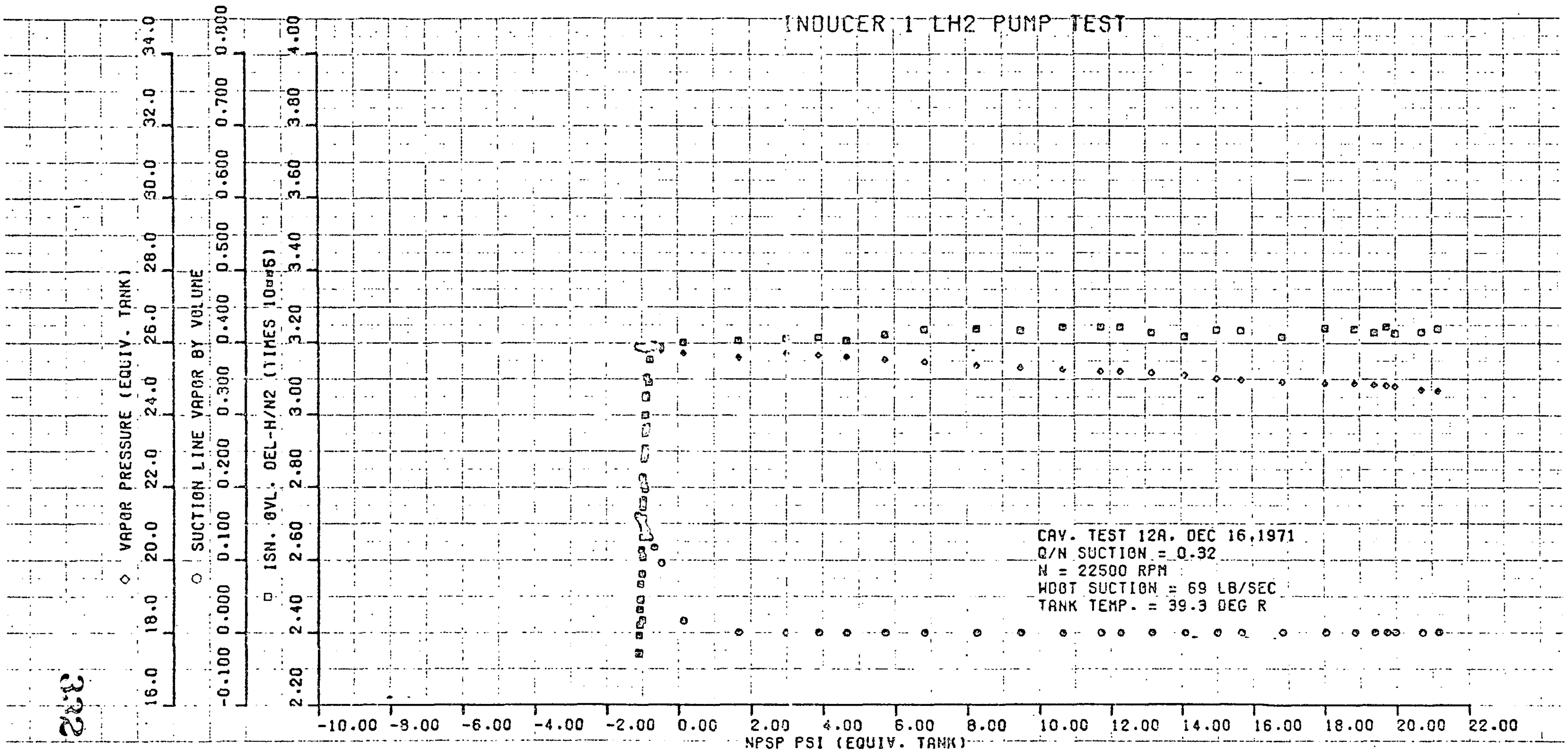

INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 11C. DEC 16,1971
Q/N SUCTION = 0.32
N = 26500 RPM
WDOT SUCTION = 80 LB/SEC
TANK TEMP. = 41.3 DEG R

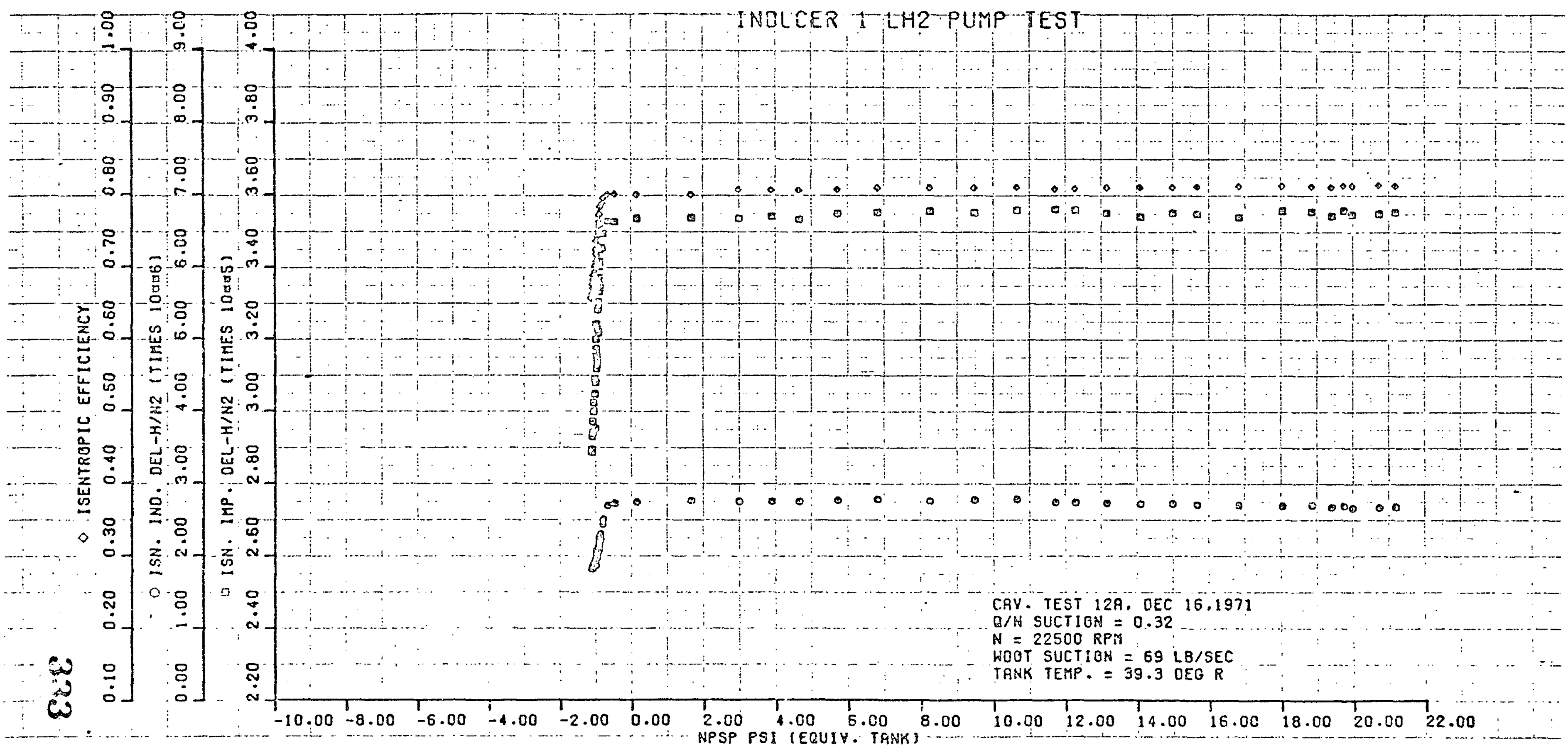
330



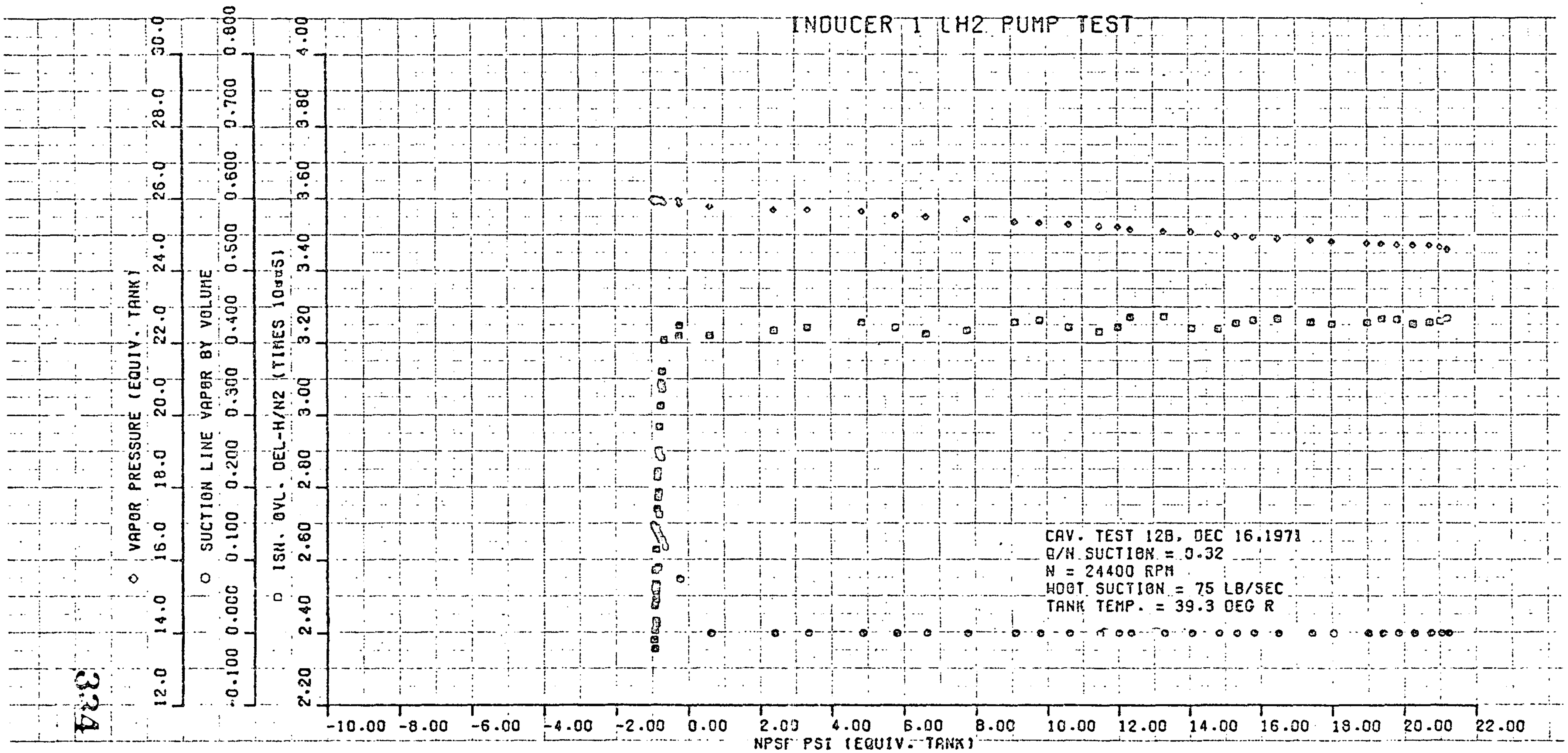
INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 11C. DEC 16,1971
Q/N SUCTION = 0.32
N = 26500 RPM
WDOT SUCTION = 80 LB/SEC
TANK TEMP. = 41.3 DEG R

331


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**6)
16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0 32.0 34.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 12A. DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 69 LB/SEC
TANK TEMP. = 39.3 DEG R

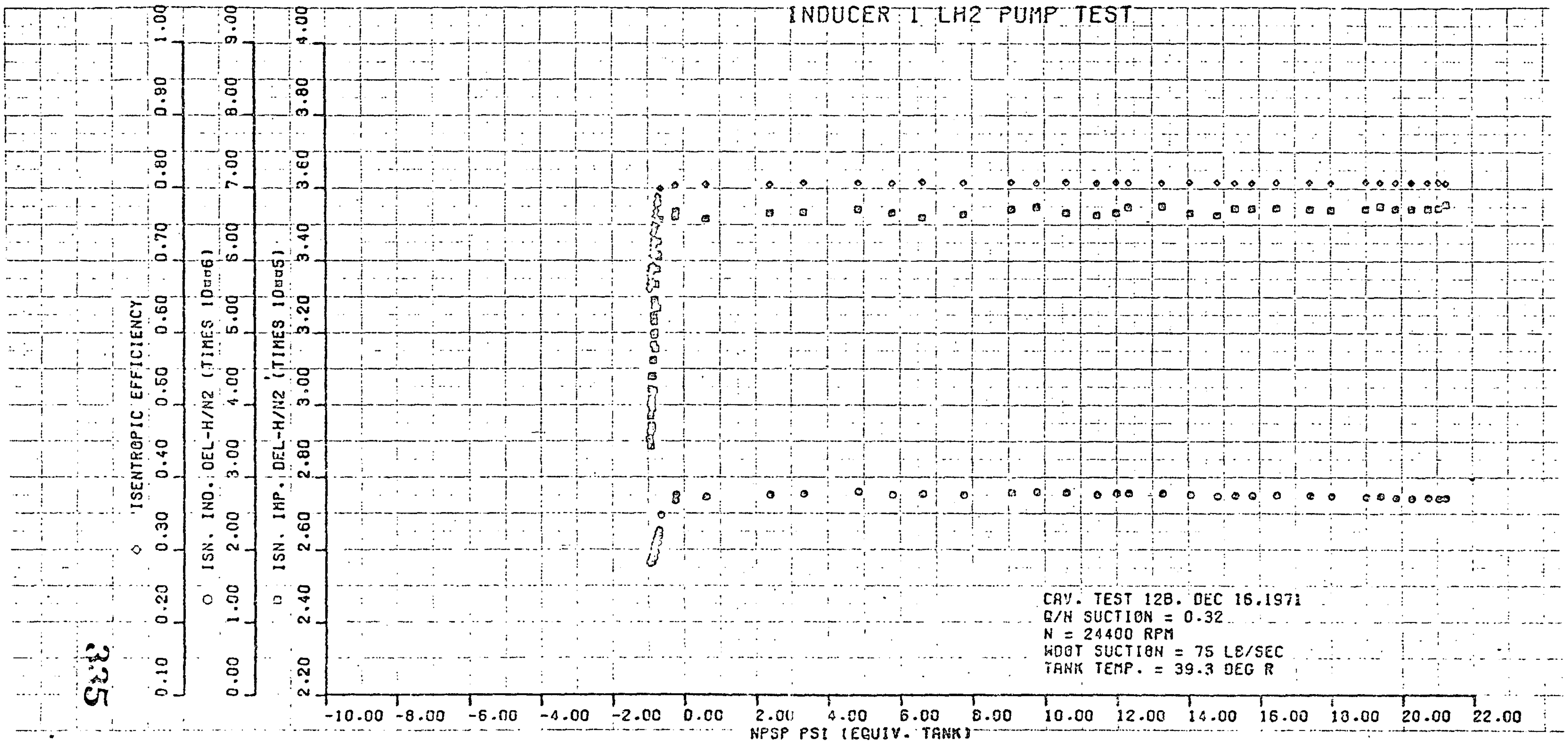

INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 12A, DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 69 LB/SEC
TANK TEMP. = 39.3 DEG R

323

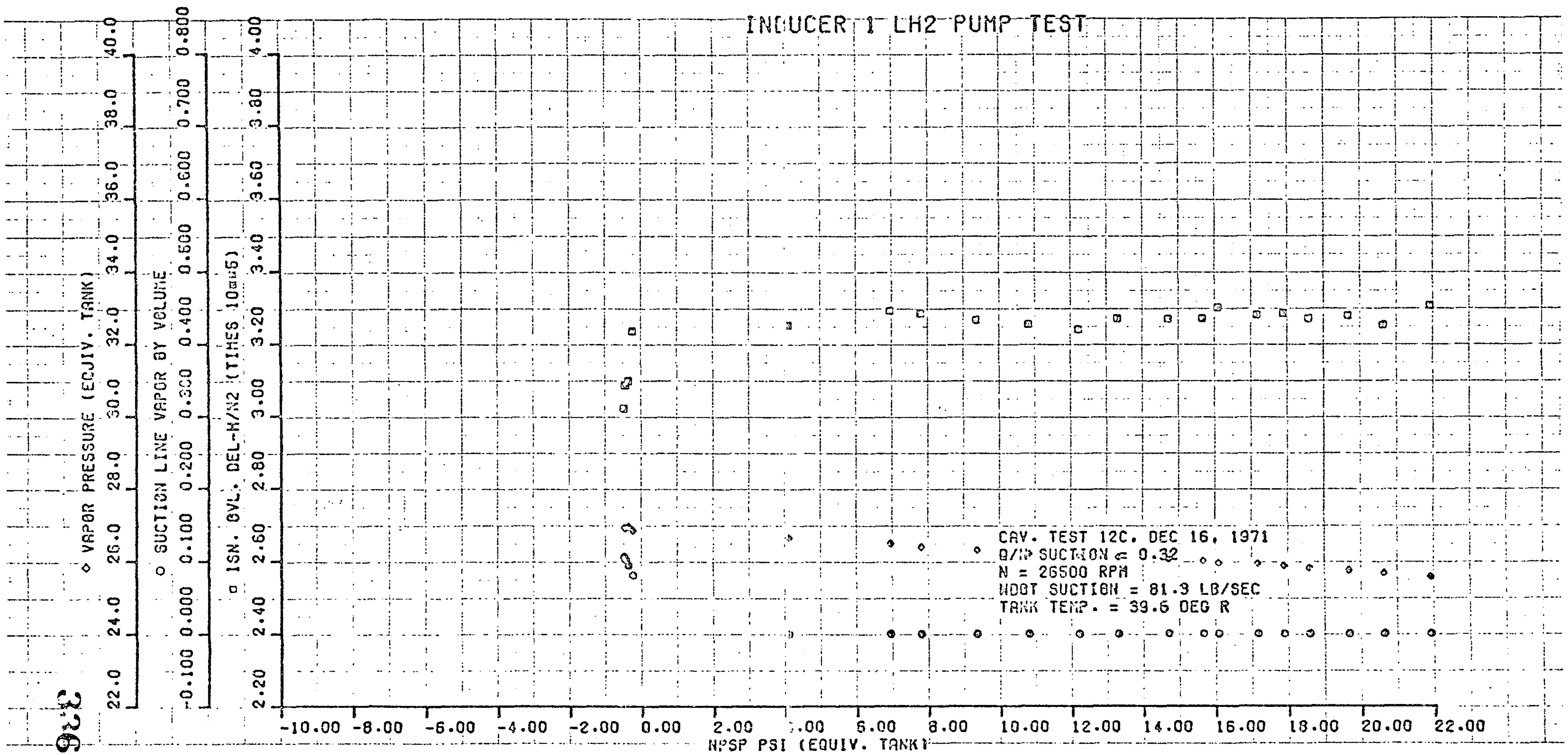


324

CHART No. 12-02



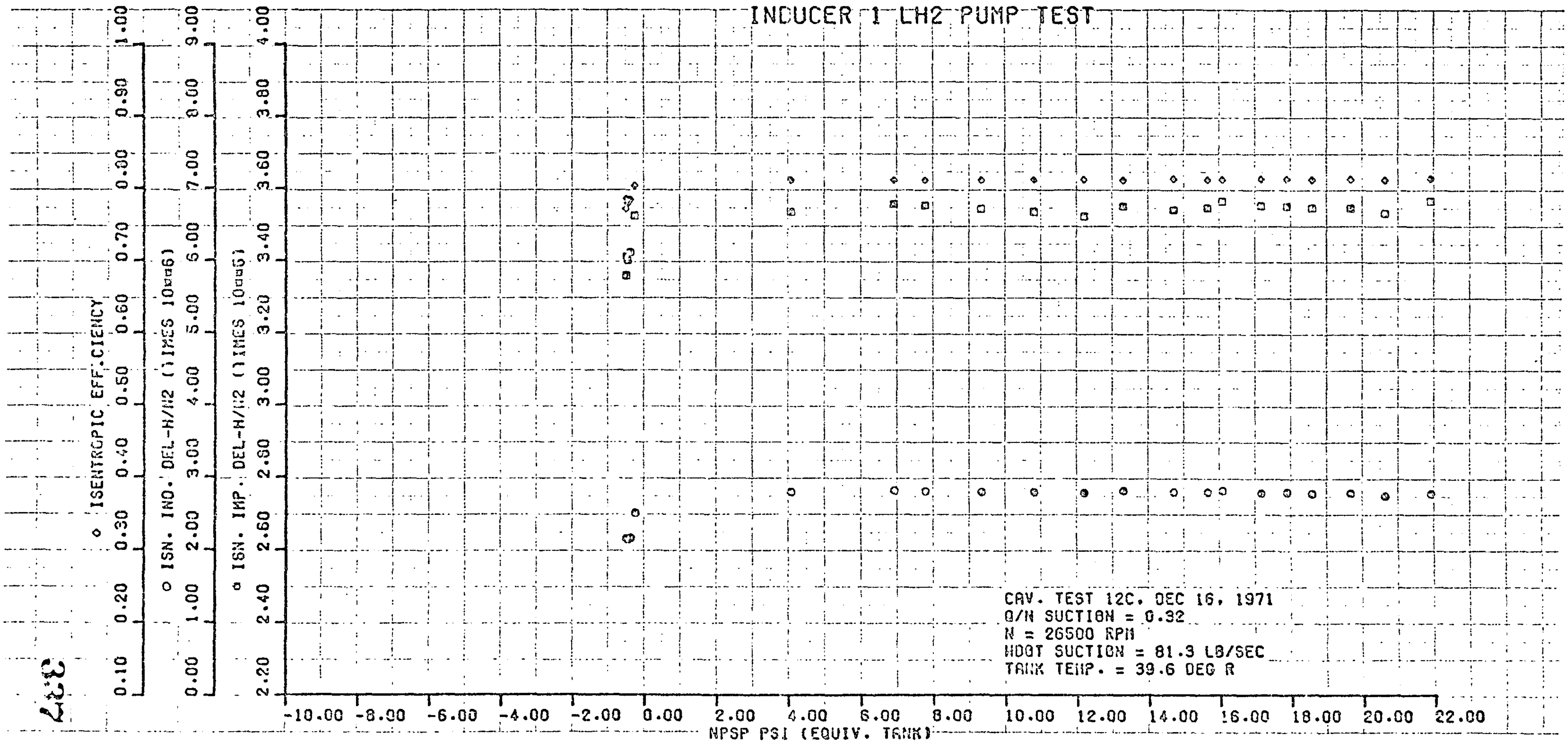
INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 128. DEC 16,1971
Q/N SUCTION = 0.32
N = 24400 RPM
WDOT SUCTION = 75 LB/SEC
TANK TEMP. = 39.3 DEG R
335



326

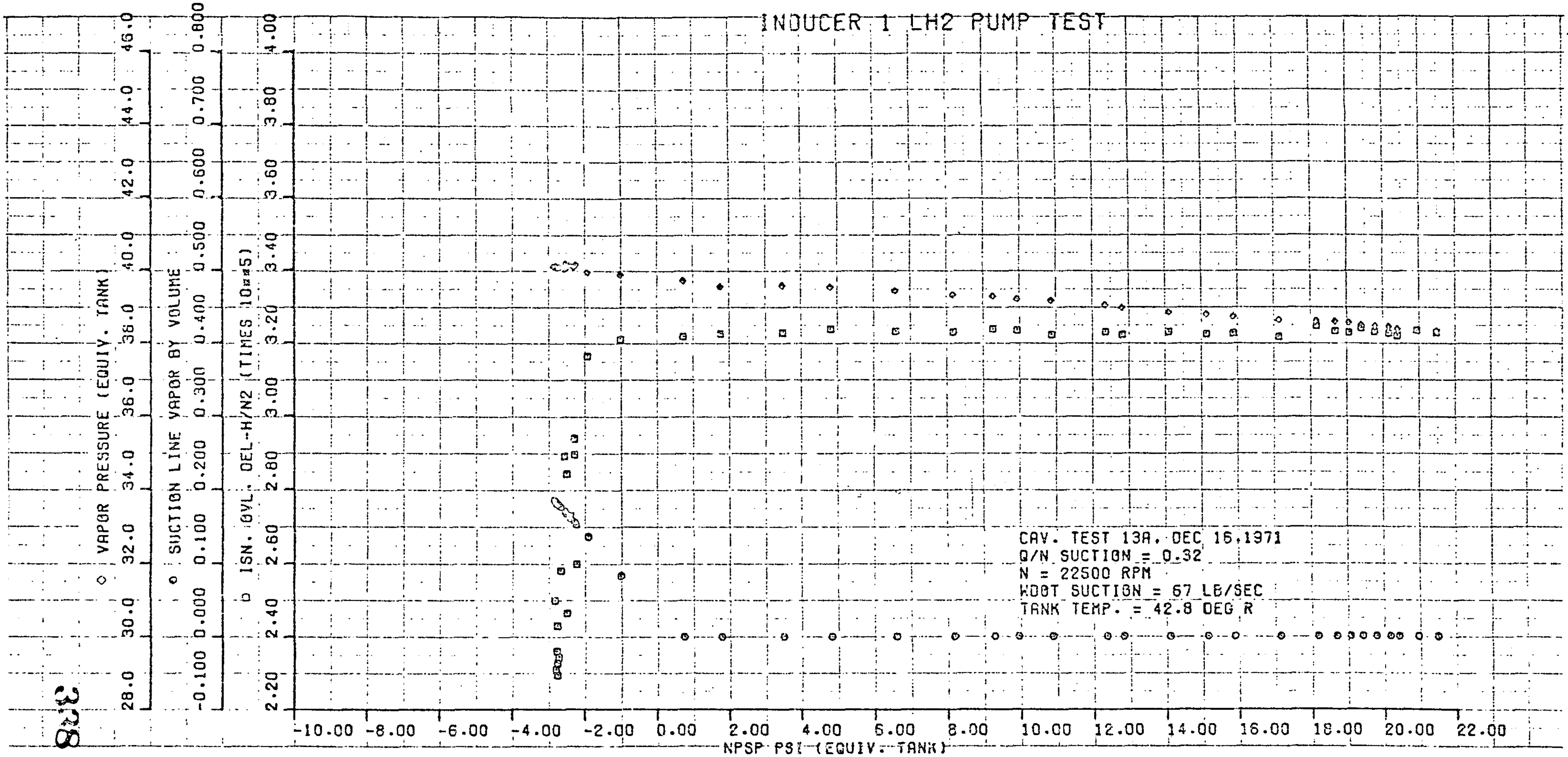
CHART No. 12-02

CO. SANTA CLARA, CALIF. CHART No. 12-02



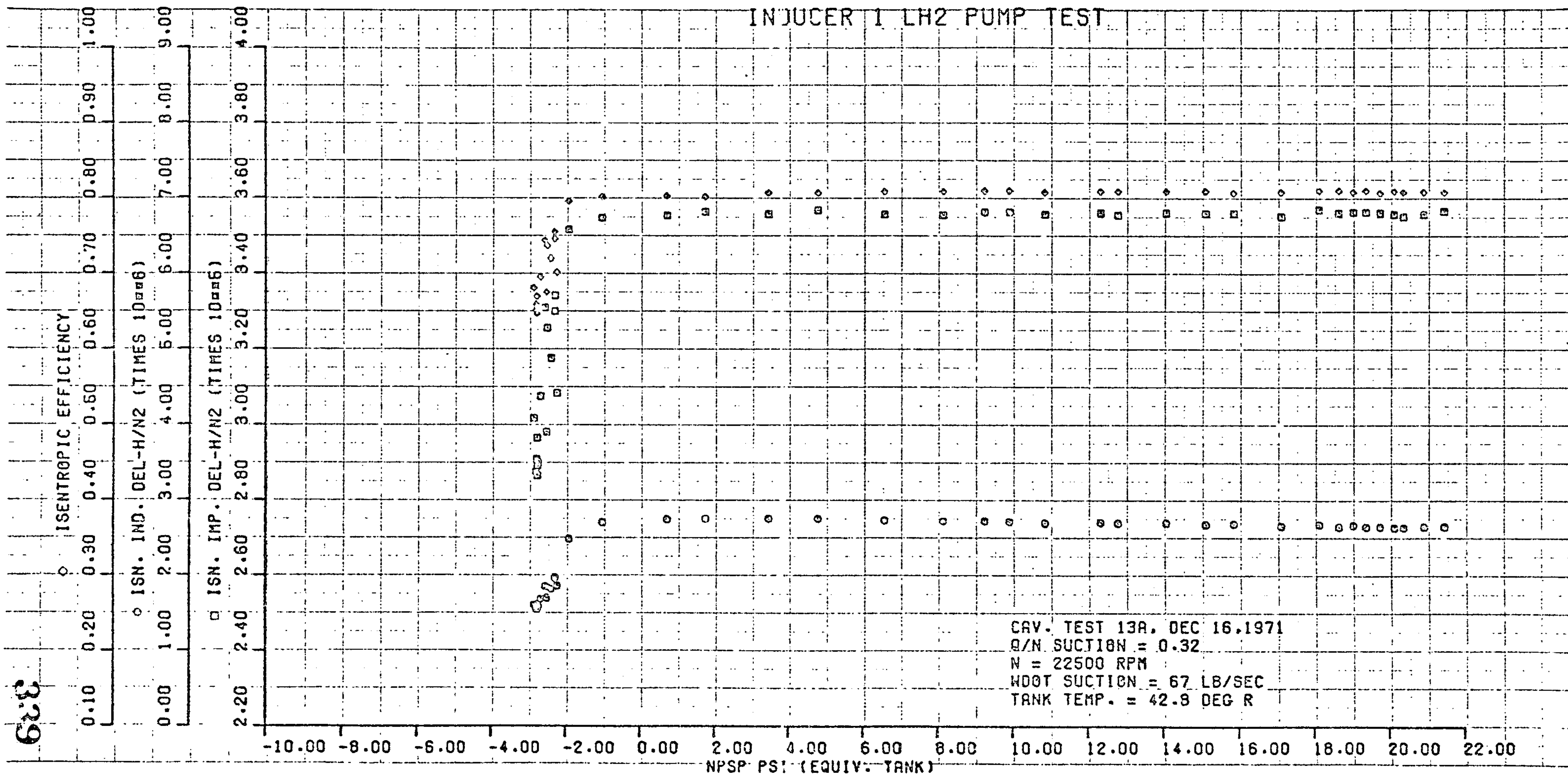
INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFF.CIENCY
ISN. IND. DEL-H/H2 (TIMES 10**6)
ISN. IMP. DEL-H/H2 (TIMES 10**6)
NPSP PSI (EQUIV. TANK)
CAV. TEST 12C, DEC 16, 1971
Q/N SUCTION = 0.32
N = 26500 RPM
WDOT SUCTION = 81.3 LB/SEC
TANK TEMP. = 39.6 DEG R

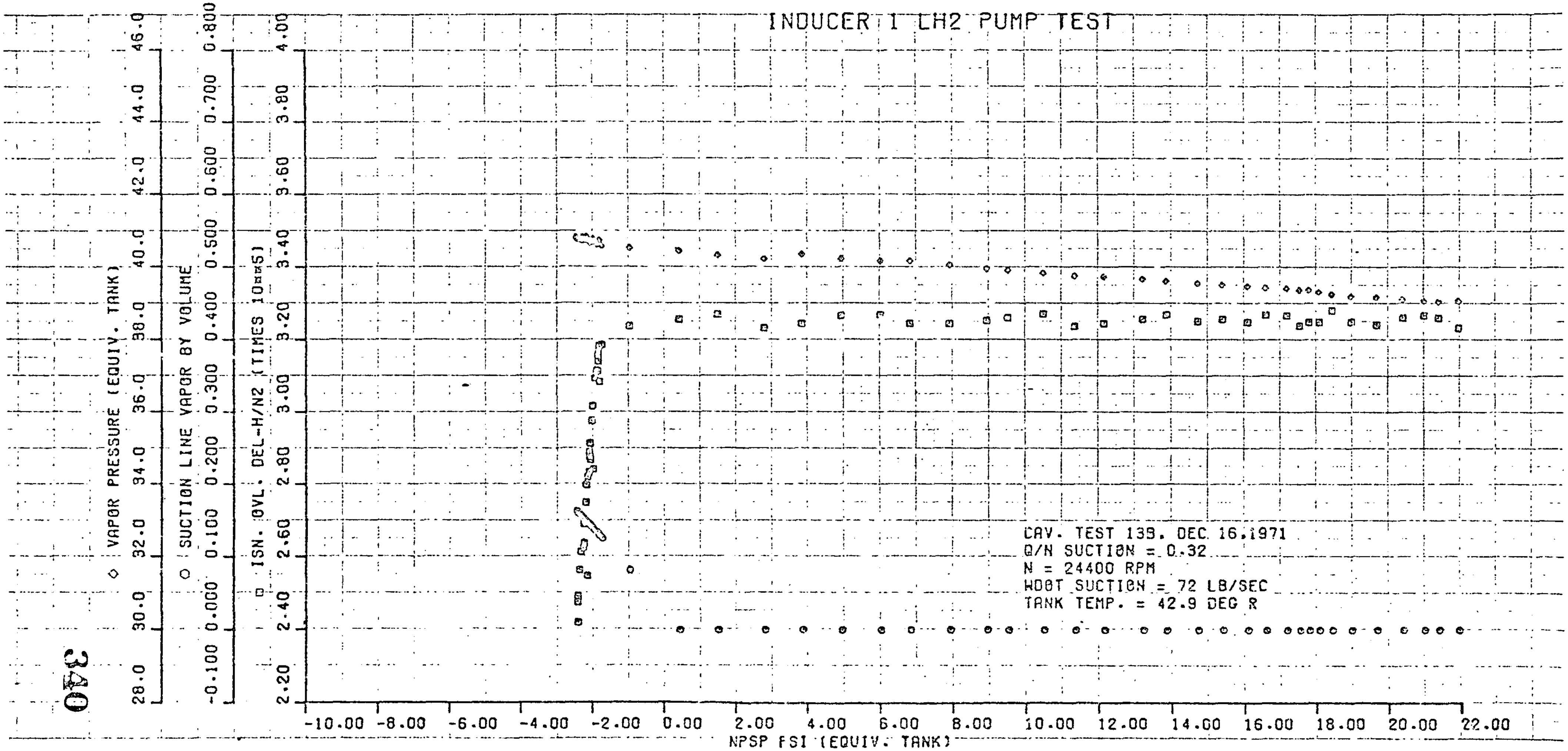
337



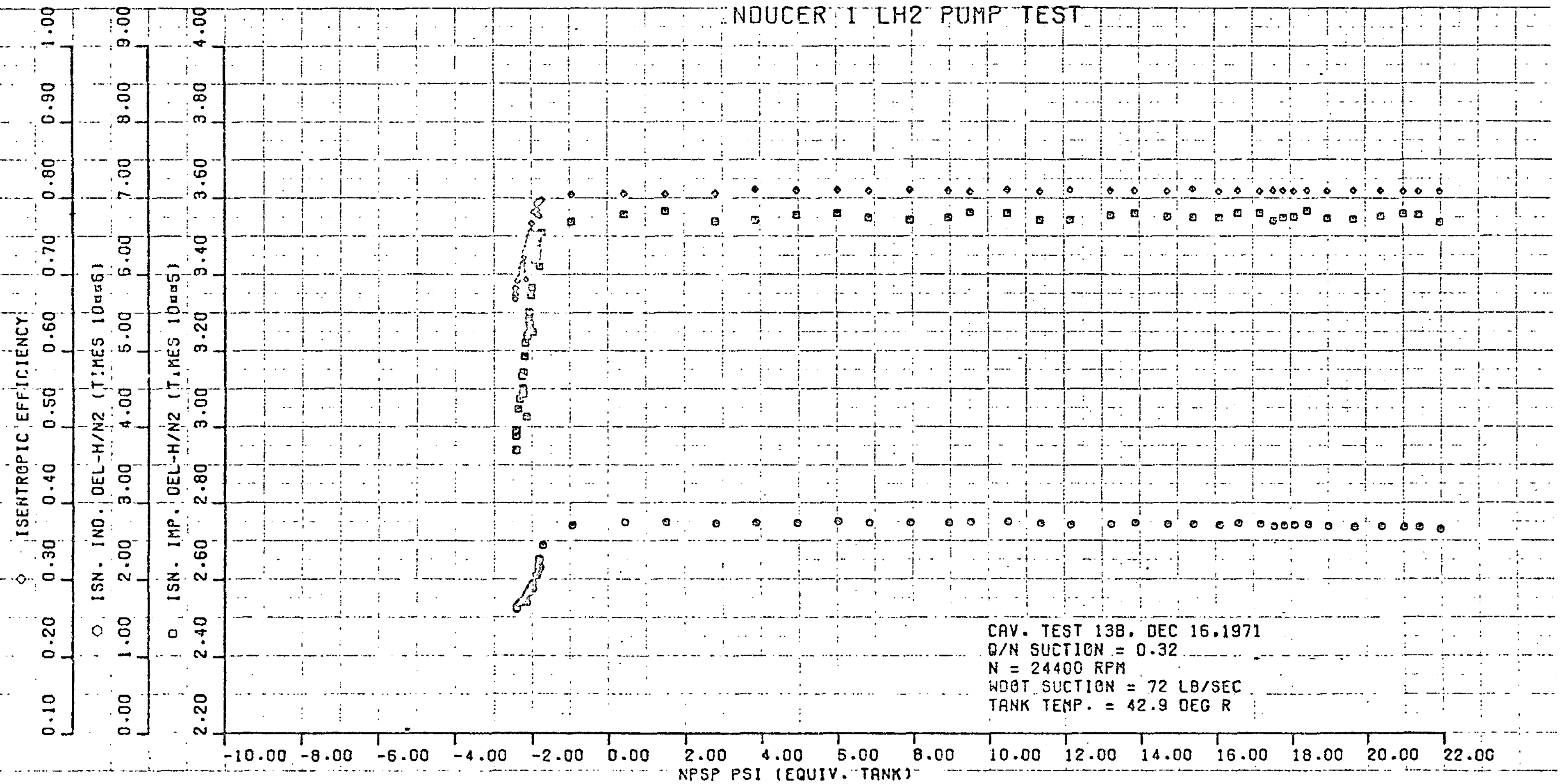
INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 13A, DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 67 LB/SEC
TANK TEMP. = 42.8 DEG R

328


INDUCER I LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**6)
CAV. TEST 13A, DEC 16,1971
Q/N SUCTION = 0.32
N = 22500 RPM
WDOT SUCTION = 67 LB/SEC
TANK TEMP. = 42.8 DEG R
NPSP PSI (EQUIV. TANK)
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00

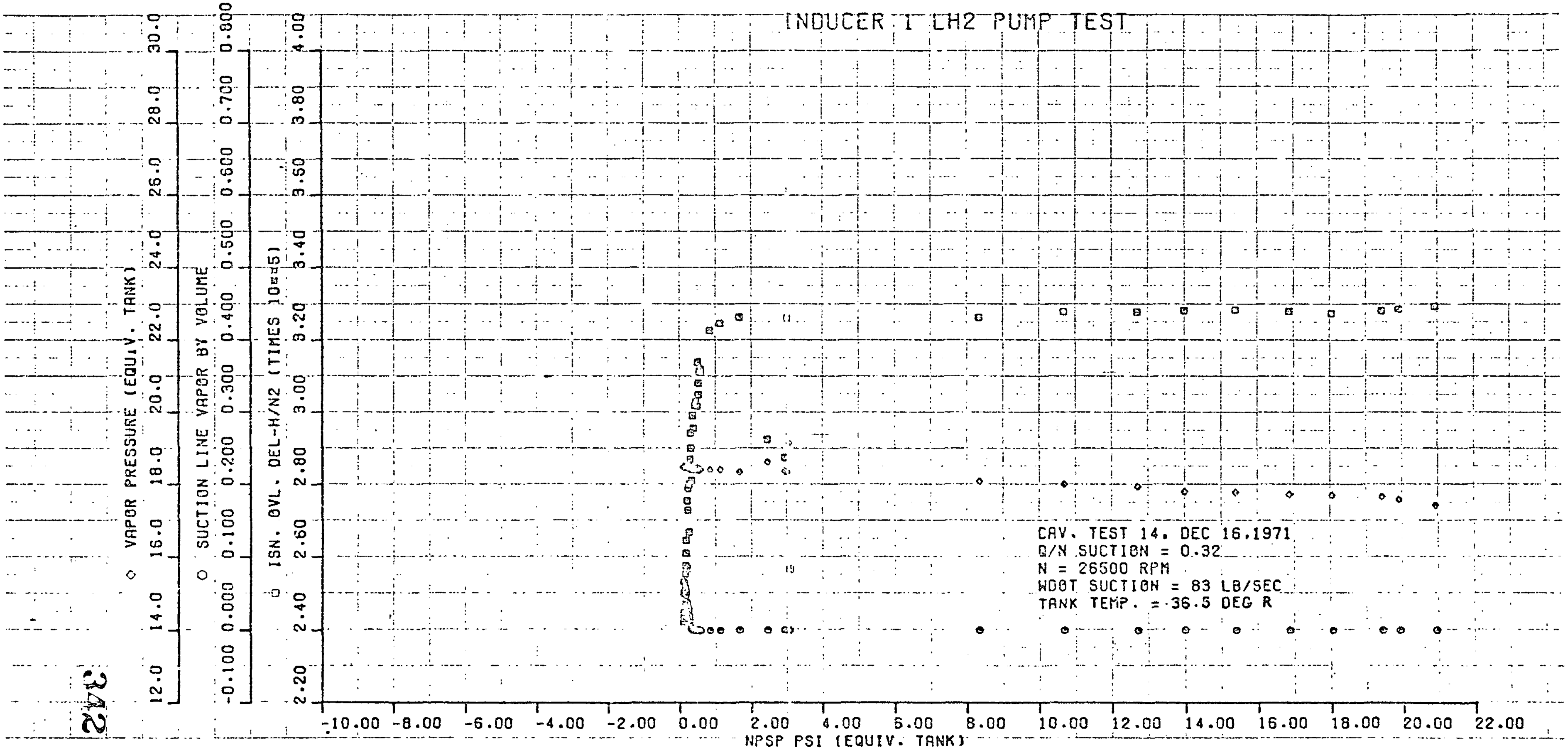


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
28.0
30.0
32.0
34.0
36.0
38.0
40.0
42.0
44.0
46.0
-0.100
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 139. DEC 16,1971
Q/N SUCTIØN = 0.32
N = 24400 RPM
WDØT SUCTIØN = 72 LB/SEC
TANK TEMP. = 42.9 DEG R

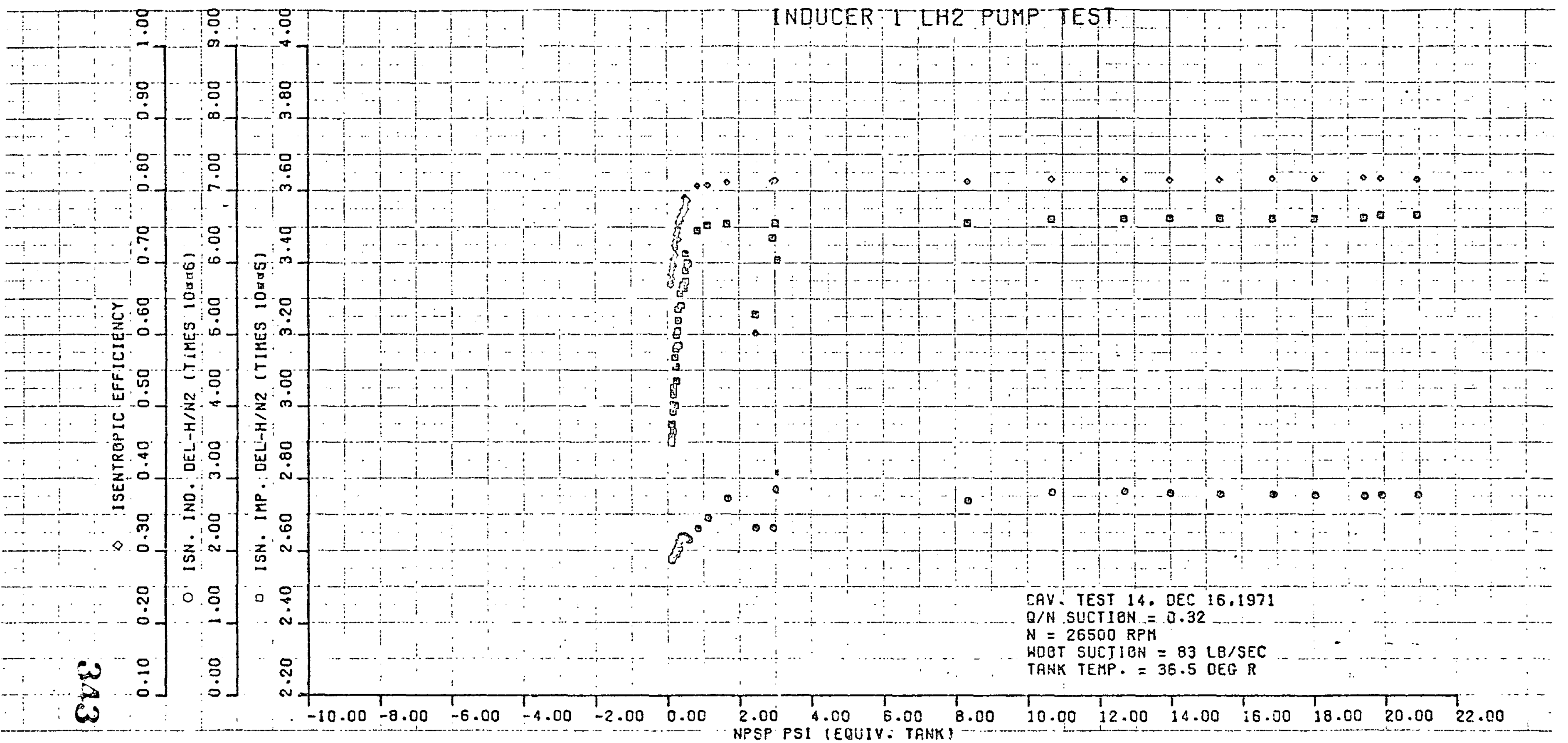


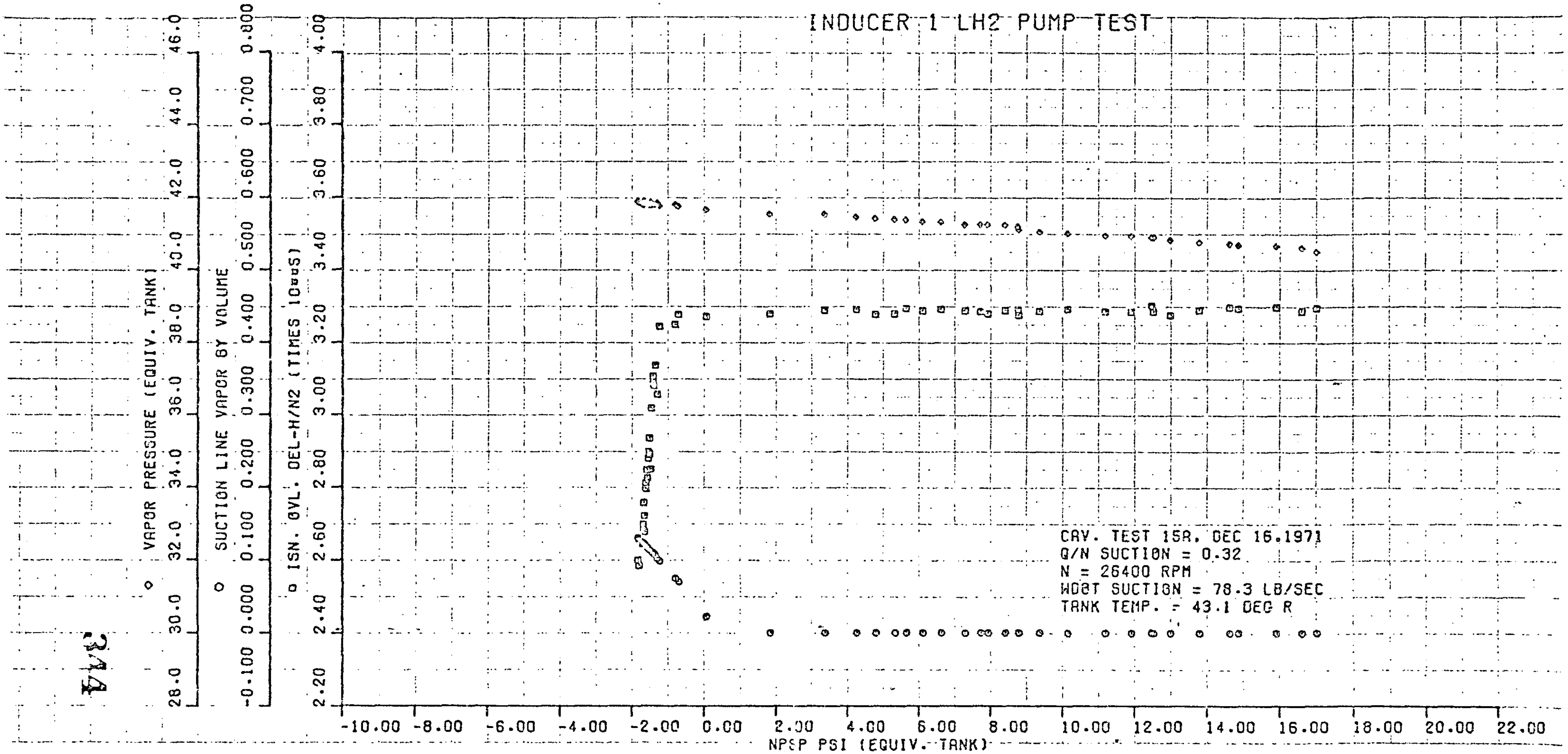
NDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 13B, DEC 16,1971
Q/N SUCTION = 0.32
N = 24400 RPM
WDOT SUCTION = 72 LB/SEC
TANK TEMP. = 42.9 DEG R

m

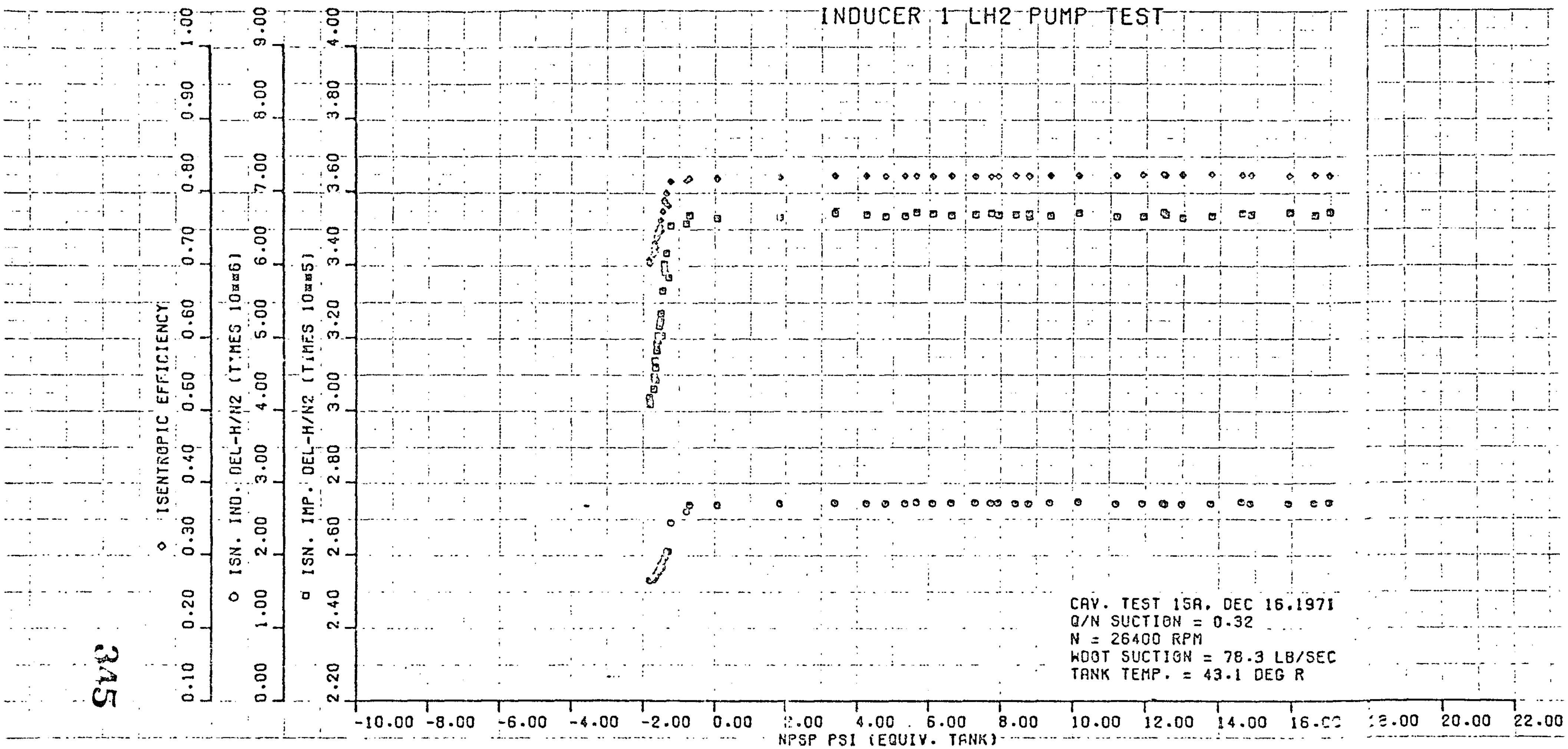

INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 14. DEC 16.1971
Q/N SUCTION = 0.32
N = 26500 RPM
WDOT SUCTION = 83 LB/SEC
TANK TEMP. = 36.5 DEG R

342


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 14. DEC 16,1971
Q/N SUCTION = 0.32
N = 26500 RPM
WDOT SUCTION = 83 LB/SEC
TANK TEMP. = 36.5 DEG R

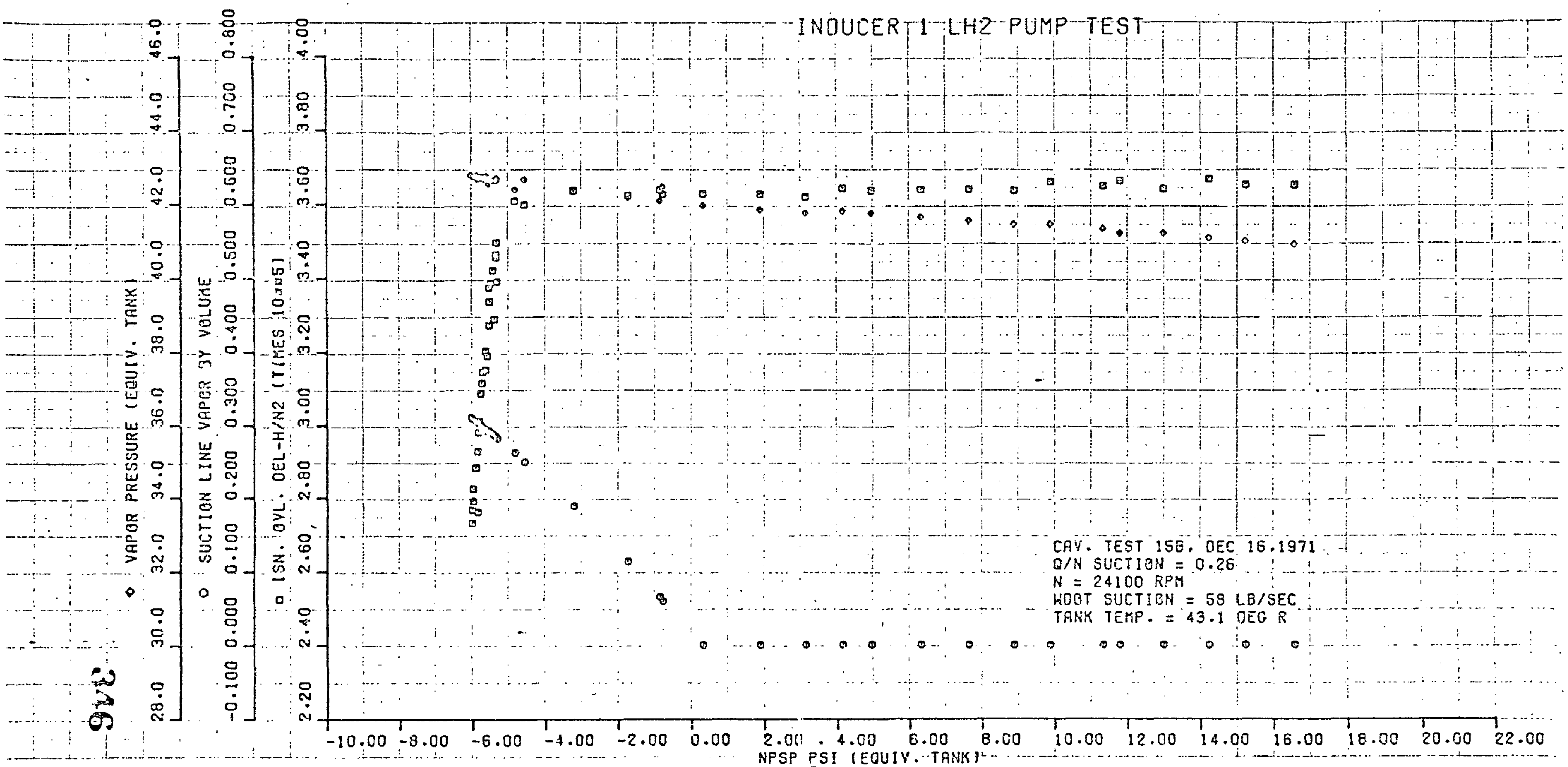


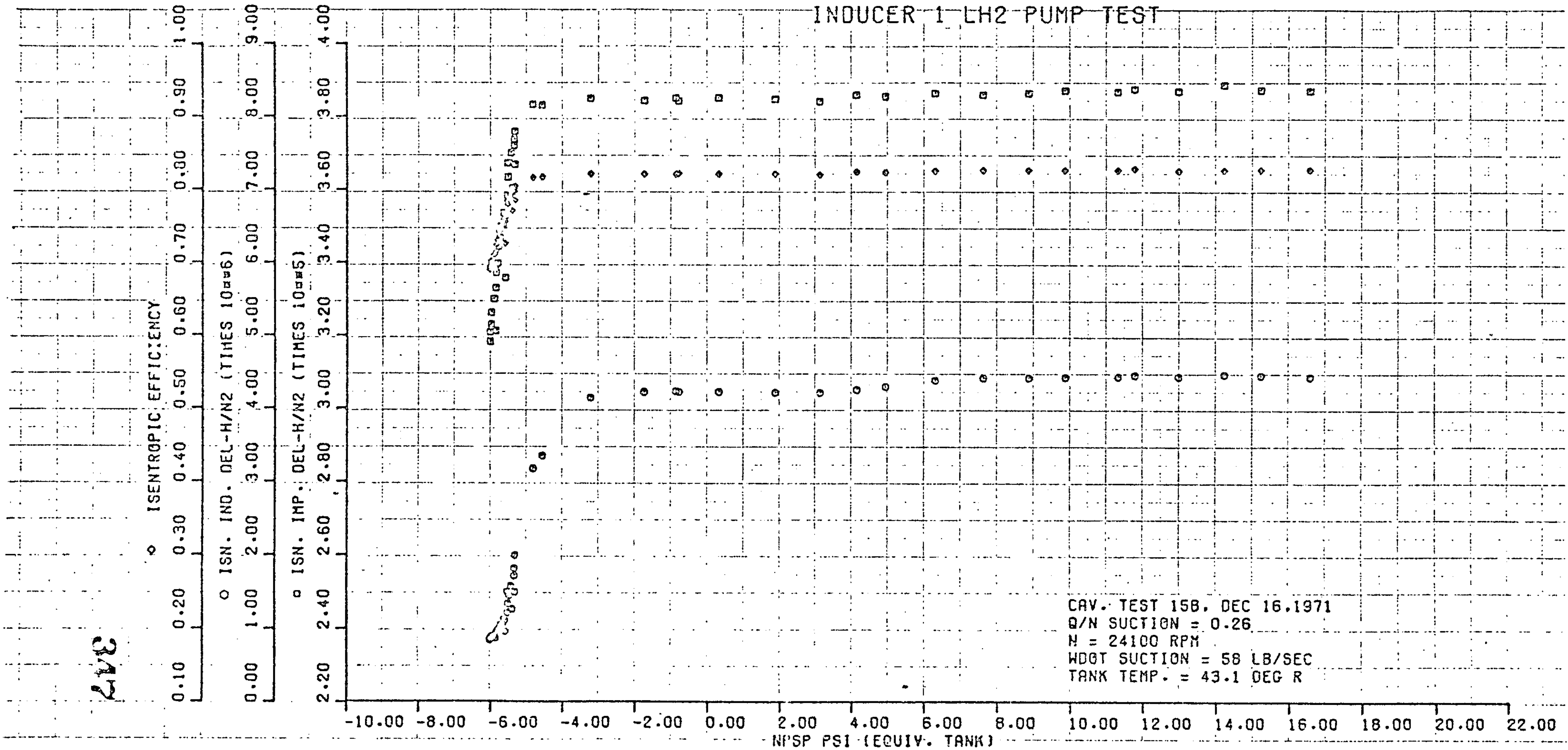
INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**S)
NPSP PSI (EQUIV. TANK)
CAV. TEST 15A, DEC 16,1971
Q/N SUCTION = 0.32
N = 26400 RPM
WDOT SUCTION = 78.3 LB/SEC
TANK TEMP. = 43.1 DEG R
374



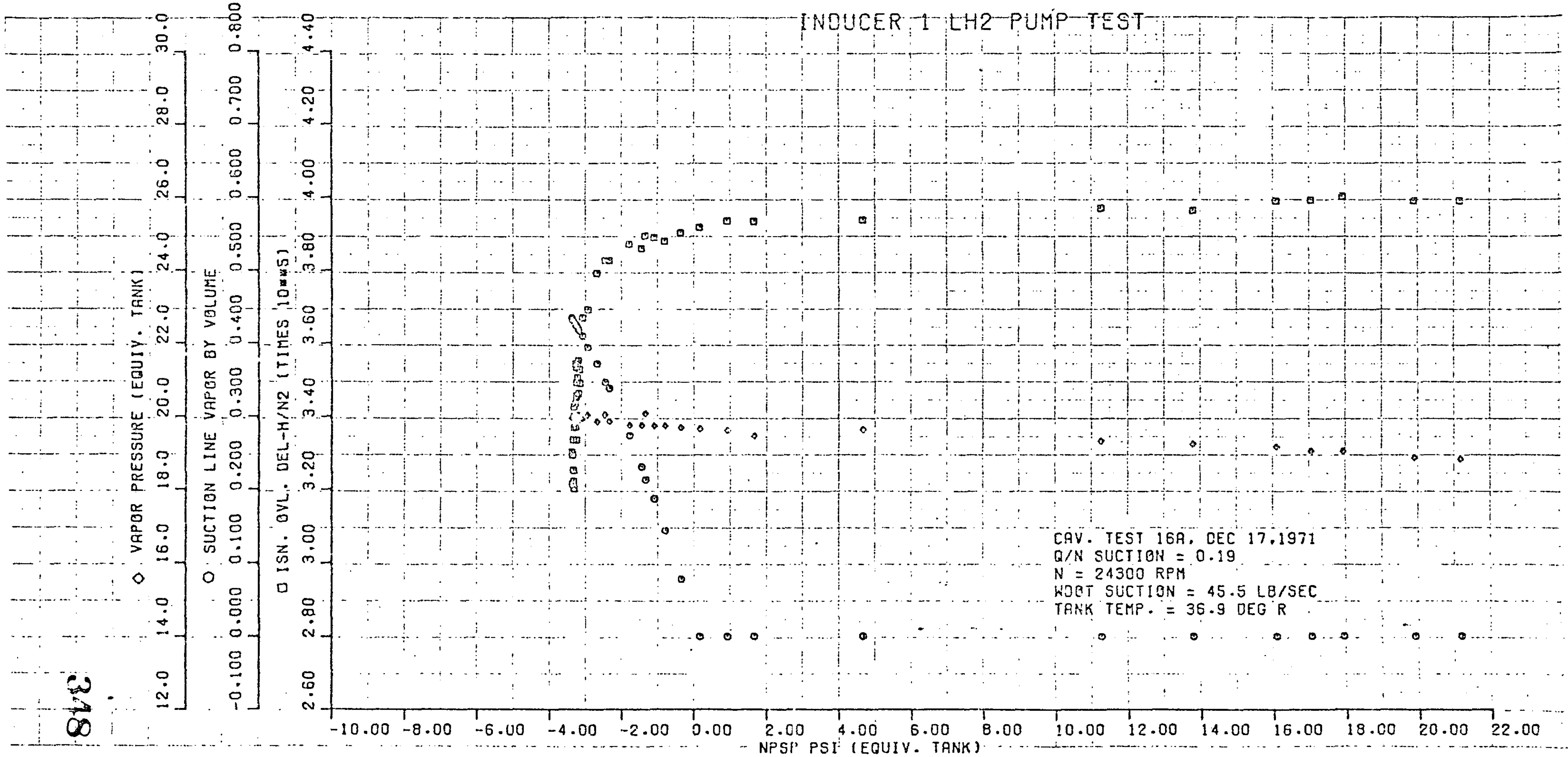
INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 15A, DEC 16,1971
Q/N SUCTION = 0.32
N = 26400 RPM
WDOT SUCTION = 78.3 LB/SEC
TANK TEMP. = 43.1 DEG R

345

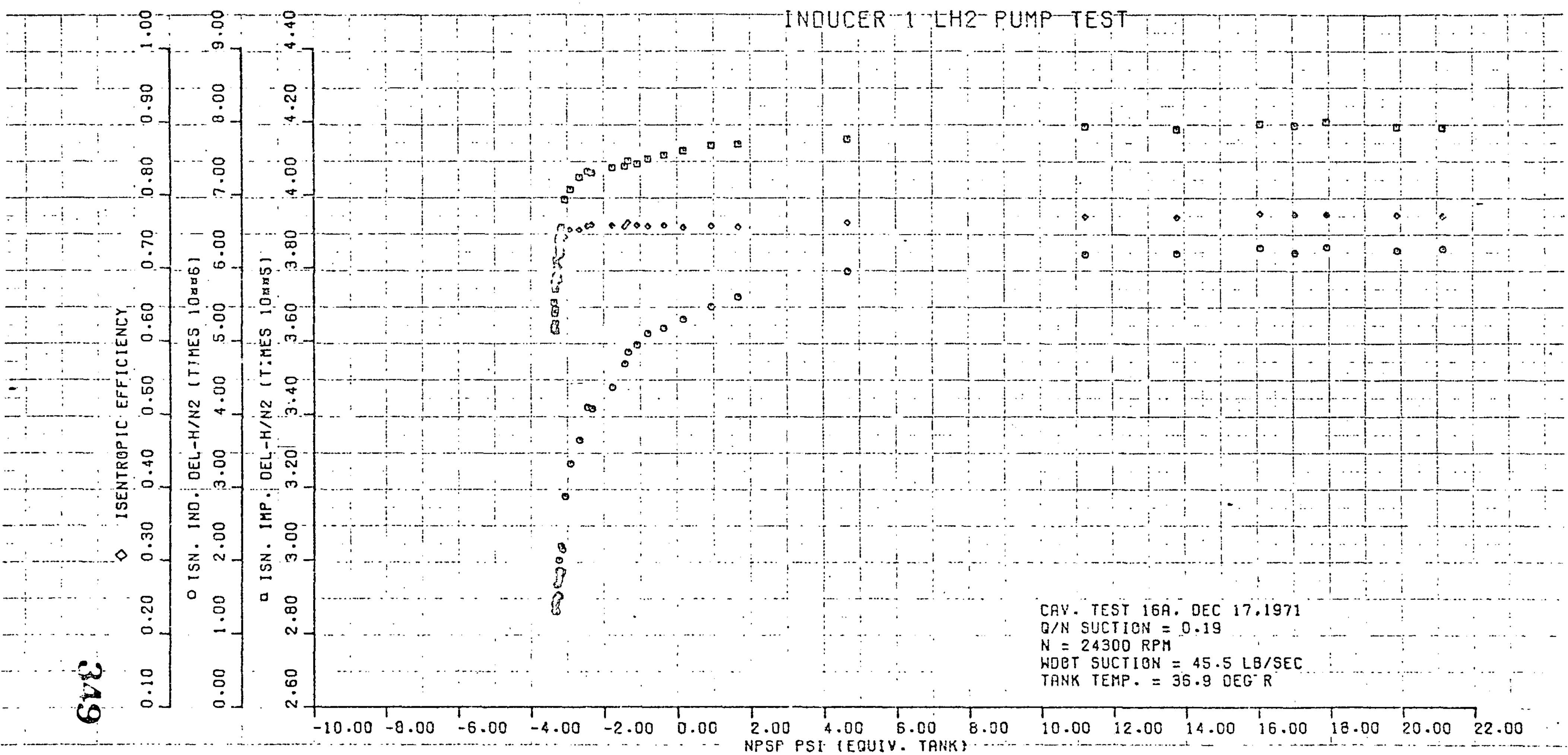

INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
28.0 30.0 32.0 34.0 36.0 38.0 40.0 42.0 44.0 46.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 158, DEC 16,1971
Q/N SUCTION = 0.26
N = 24100 RPM
WDOT SUCTION = 58 LB/SEC
TANK TEMP. = 43.1 DEG R

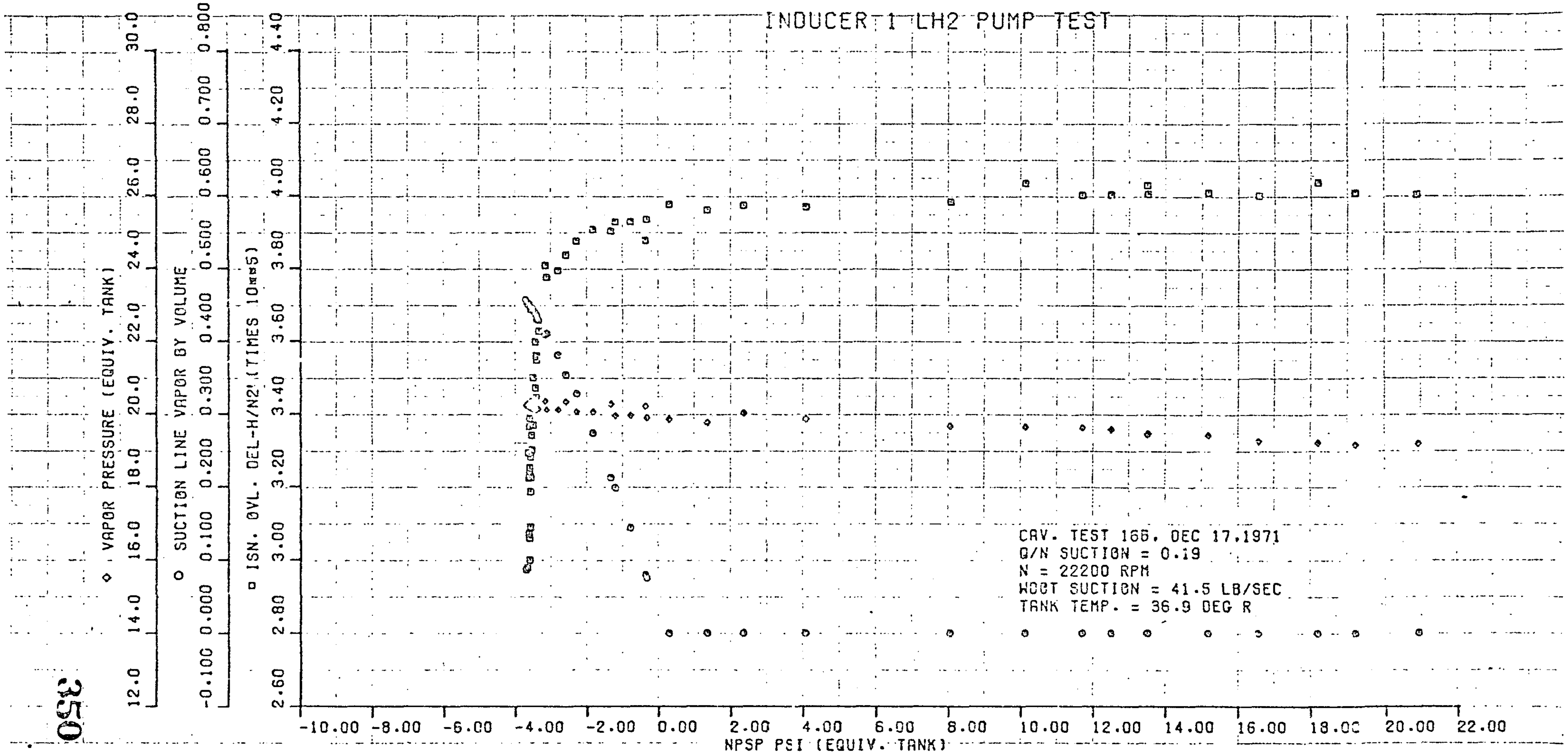

INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 158, DEC 16,1971
Q/N SUCTION = 0.26
N = 24100 RPM
WDOT SUCTION = 58 LB/SEC
TANK TEMP. = 43.1 DEG R

347


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
CAV. TEST 16A, DEC 17,1971
Q/N SUCTION = 0.19
N = 24300 RPM
WDOT SUCTION = 45.5 LB/SEC
TANK TEMP. = 36.9 DEG R
NPSP PSI (EQUIV. TANK)
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40

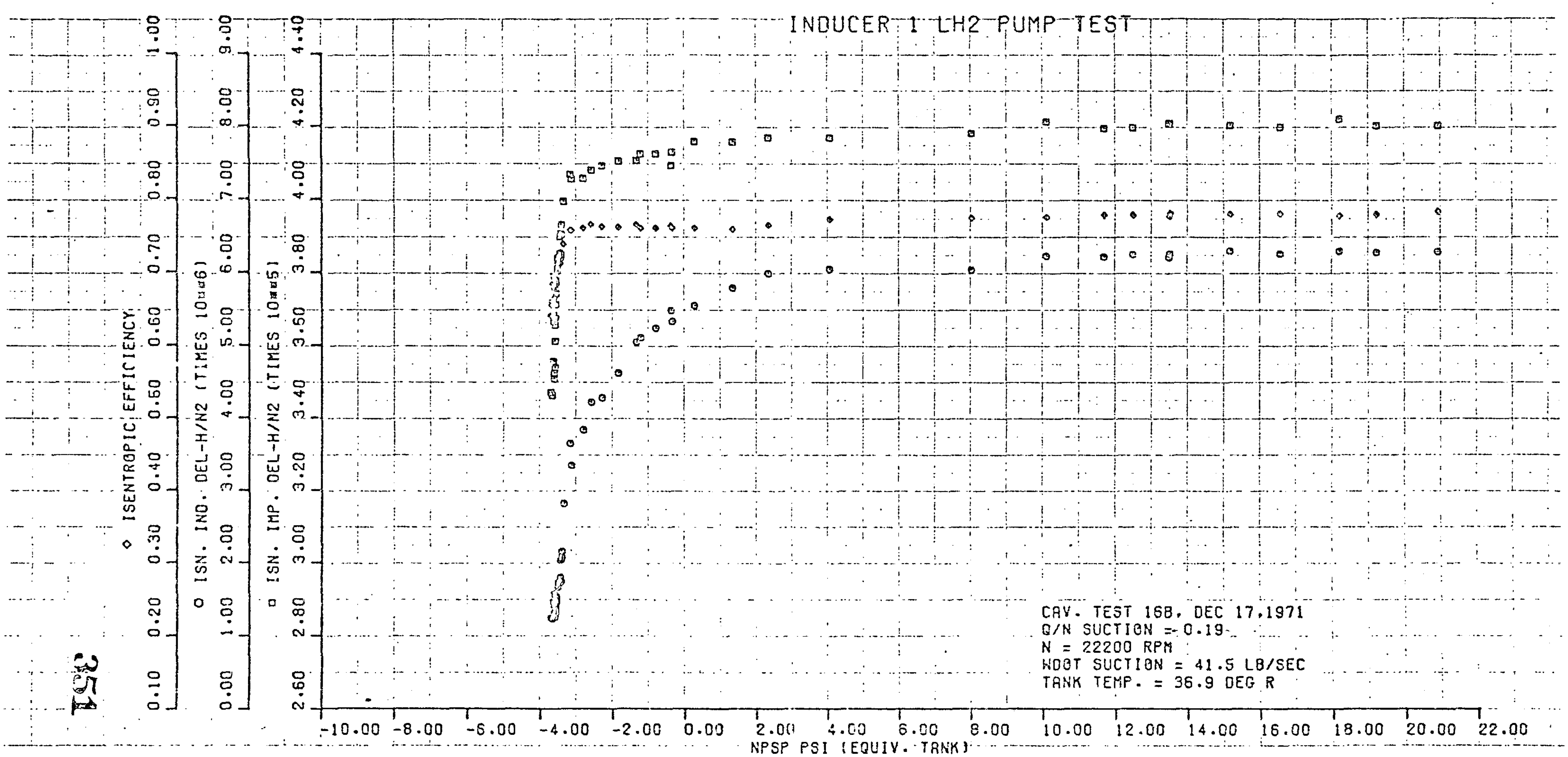
348


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 16A. DEC 17,1971
Q/N SUCTION = 0.19
N = 24300 RPM
WDOT SUCTION = 45.5 LB/SEC
TANK TEMP. = 36.9 DEG R

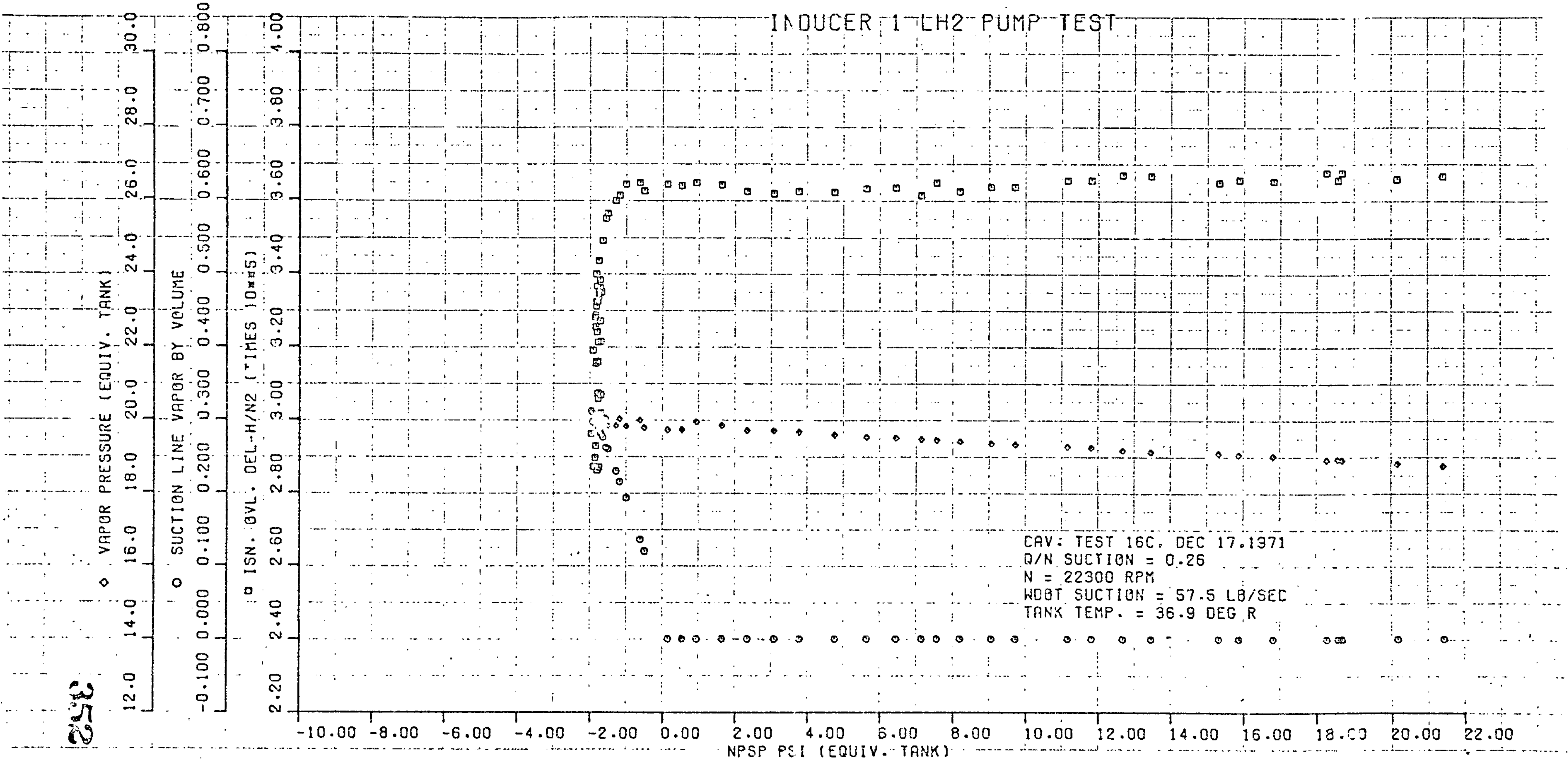


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
4.40
4.20
4.00
3.80
3.60
3.40
3.20
3.00
2.80
2.60
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 166, DEC 17,1971
Q/N SUCTION = 0.19
N = 22200 RPM
WOOT SUCTION = 41.5 LB/SEC
TANK TEMP. = 36.9 DEG R

350

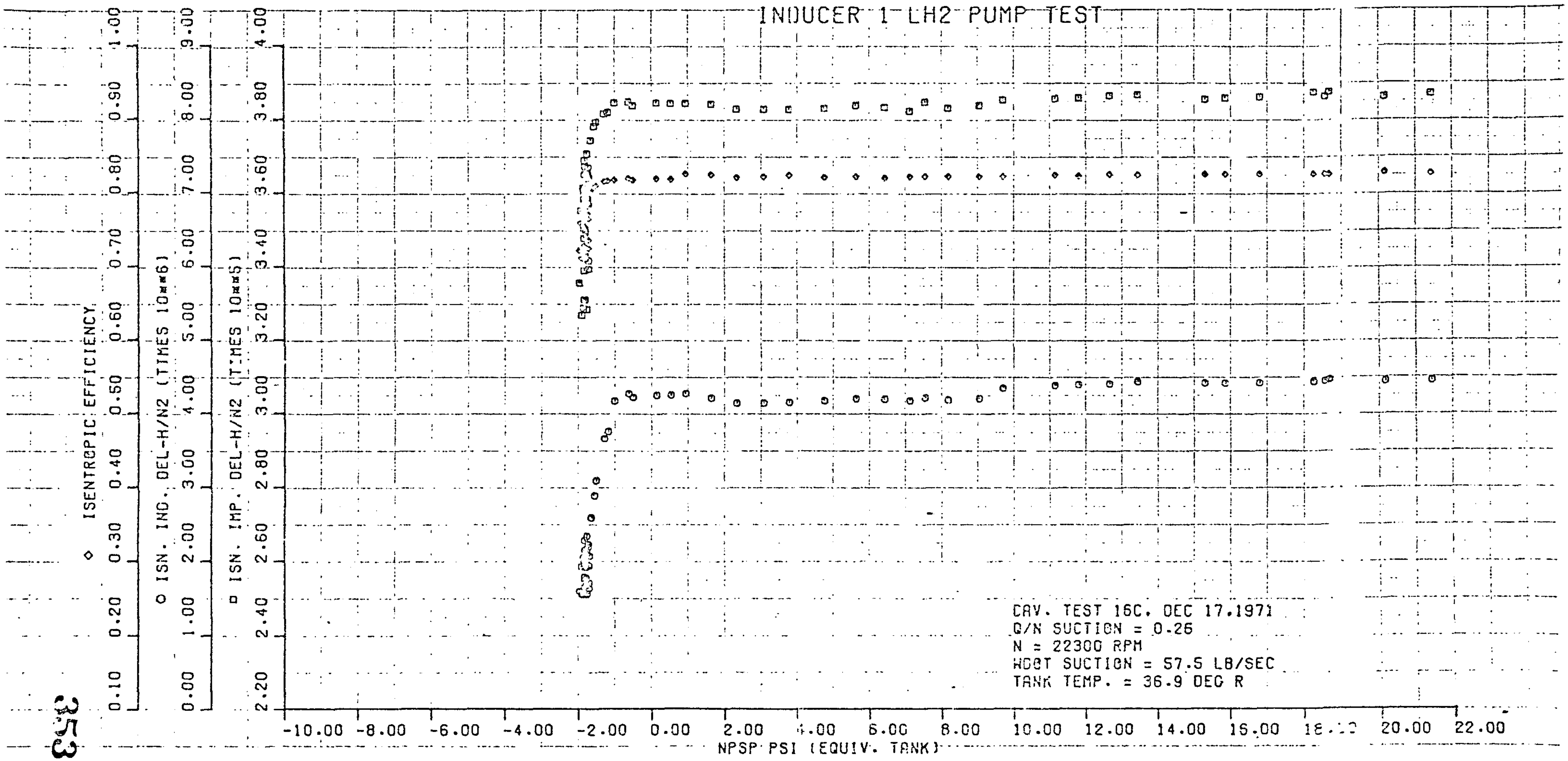

INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 168, DEC 17,1971
Q/N SUCTION = 0.19
N = 22200 RPM
WDOT SUCTION = 41.5 LB/SEC
TANK TEMP. = 36.9 DEG R
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00

351

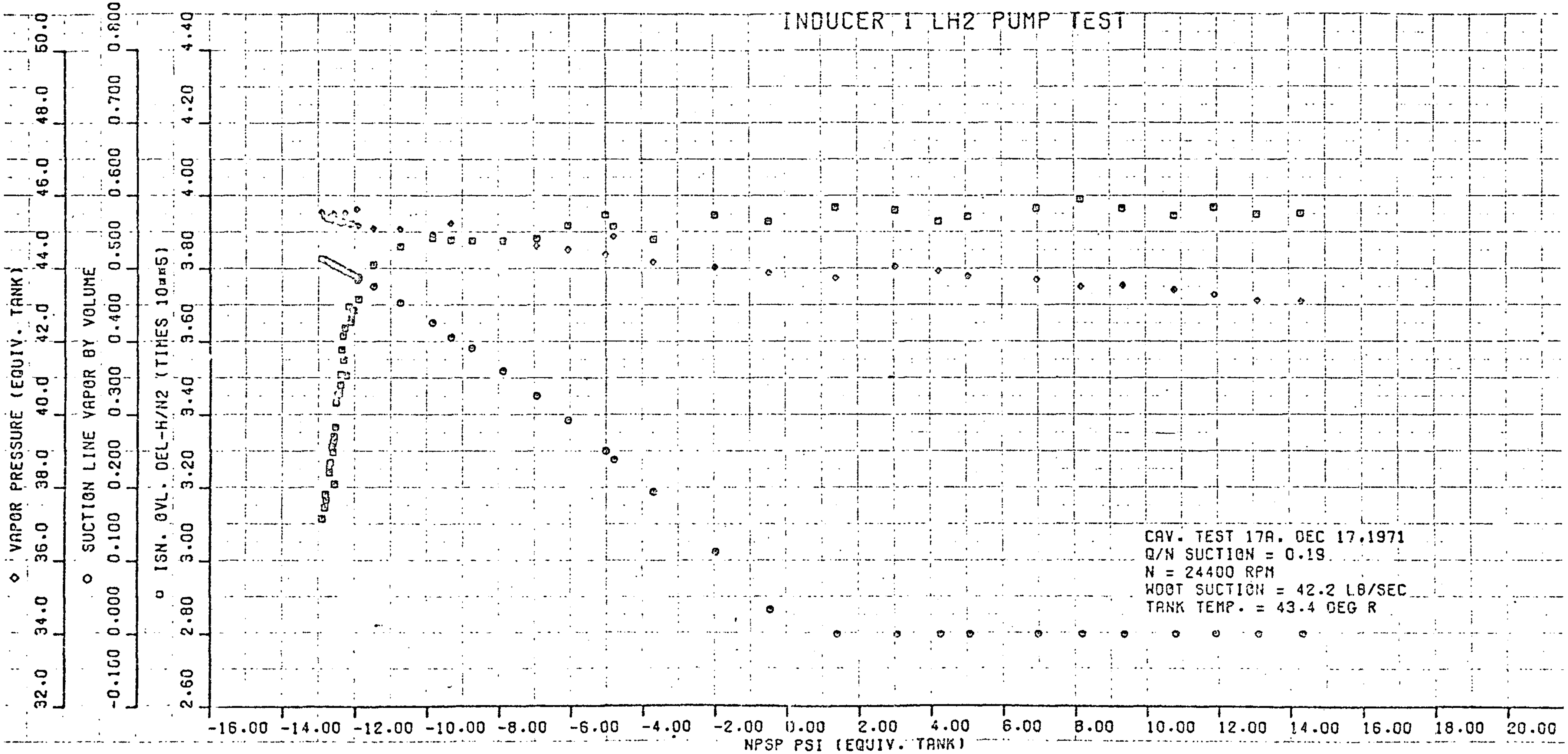


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 16C, DEC 17,1971
Q/N SUCTION = 0.26
N = 22300 RPM
WDOT SUCTION = 57.5 LB/SEC
TANK TEMP. = 36.9 DEG R

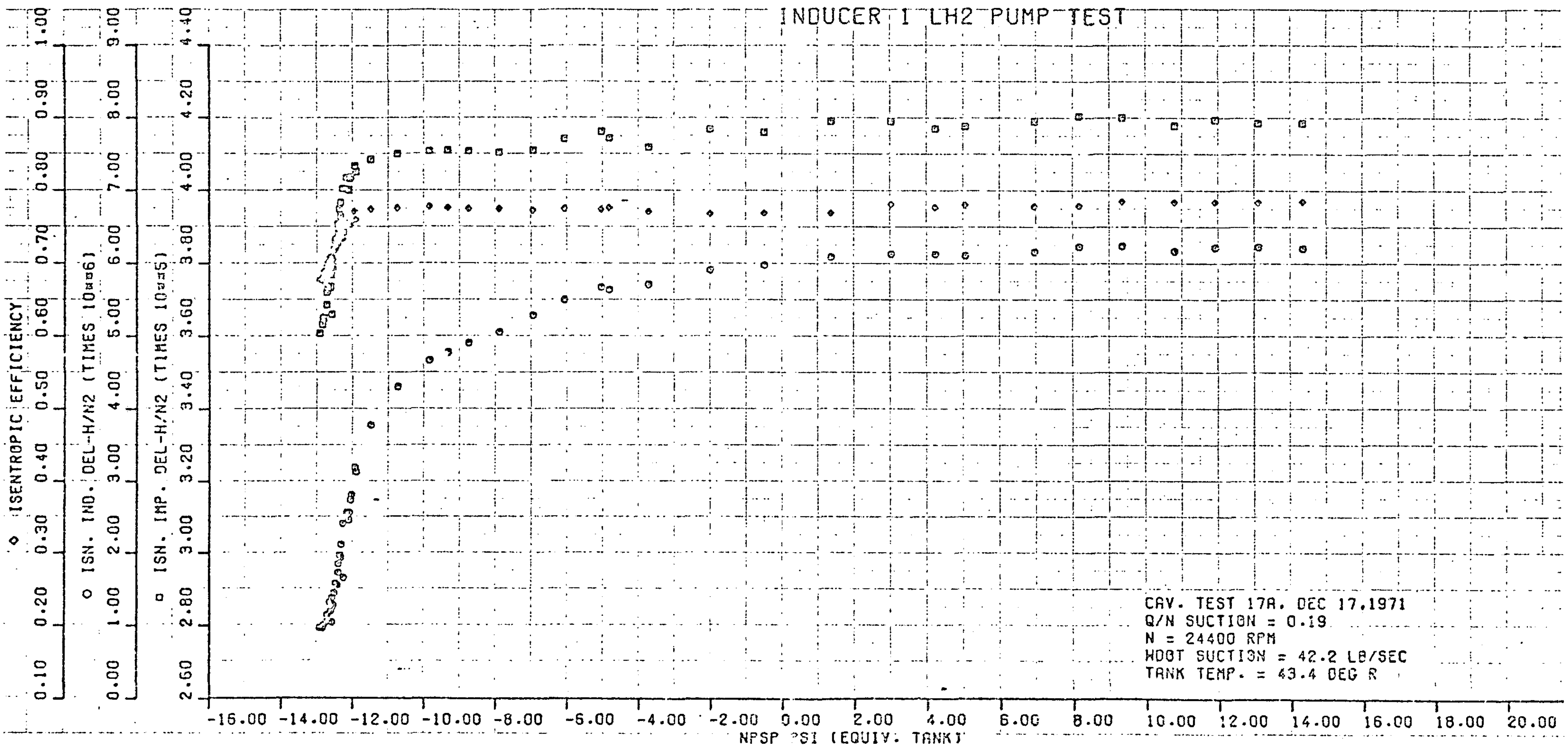
352


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 16C, DEC 17,1971
Q/N SUCTION = 0.26
N = 22300 RPM
WDOT SUCTION = 57.5 LB/SEC
TANK TEMP. = 36.9 DEG R

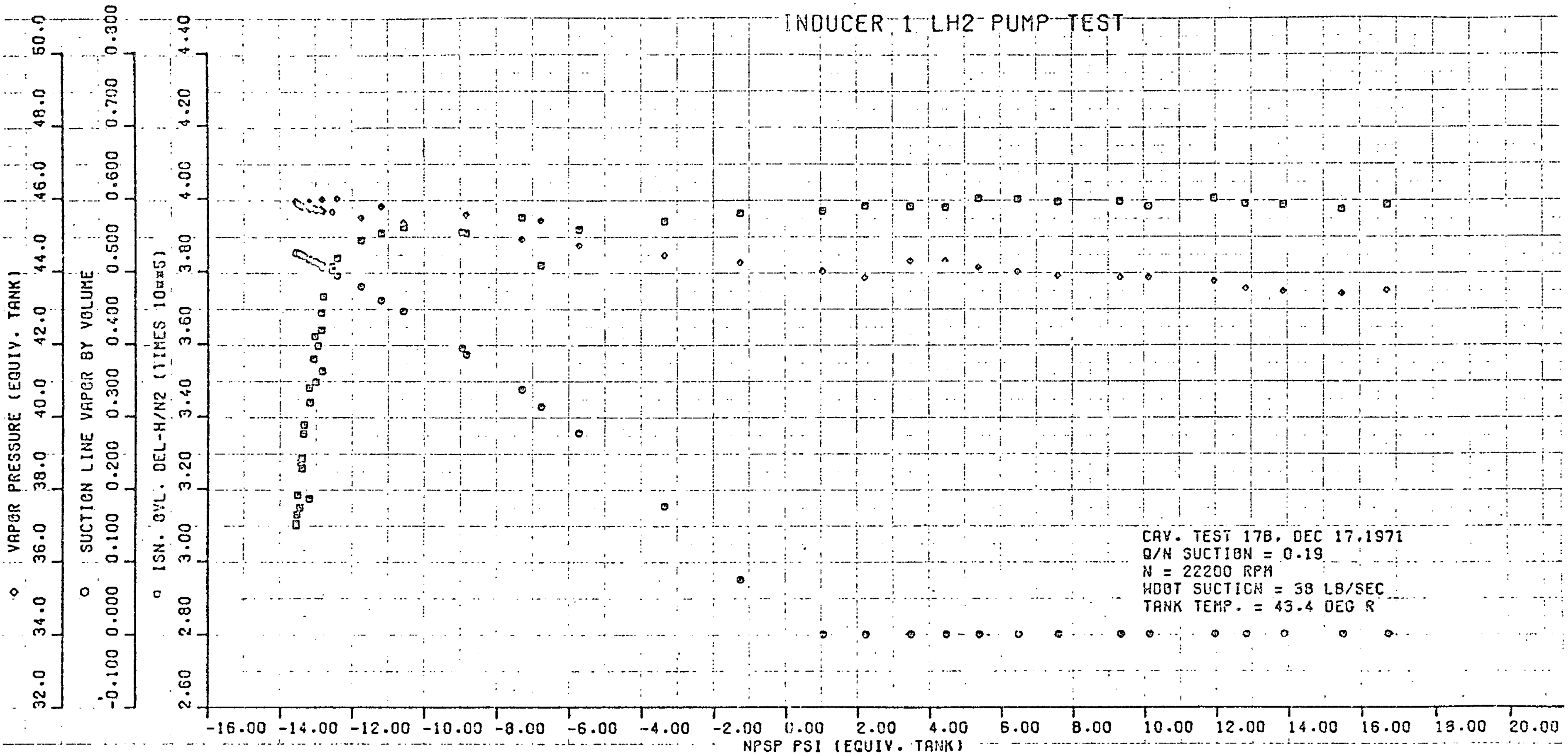
353


INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
50.0 48.0 46.0 44.0 42.0 40.0 38.0 36.0 34.0 32.0
0.800 0.700 0.600 0.500 0.400 0.300 0.200 0.100 0.000 -0.100
4.40 4.20 4.00 3.80 3.60 3.40 3.20 3.00 2.80 2.60
-16.00 -14.00 -12.00 -10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 17A. DEC 17,1971
Q/N SUCTION = 0.19
N = 24400 RPM
WDOT SUCTION = 42.2 LB/SEC
TANK TEMP. = 43.4 DEG R

354

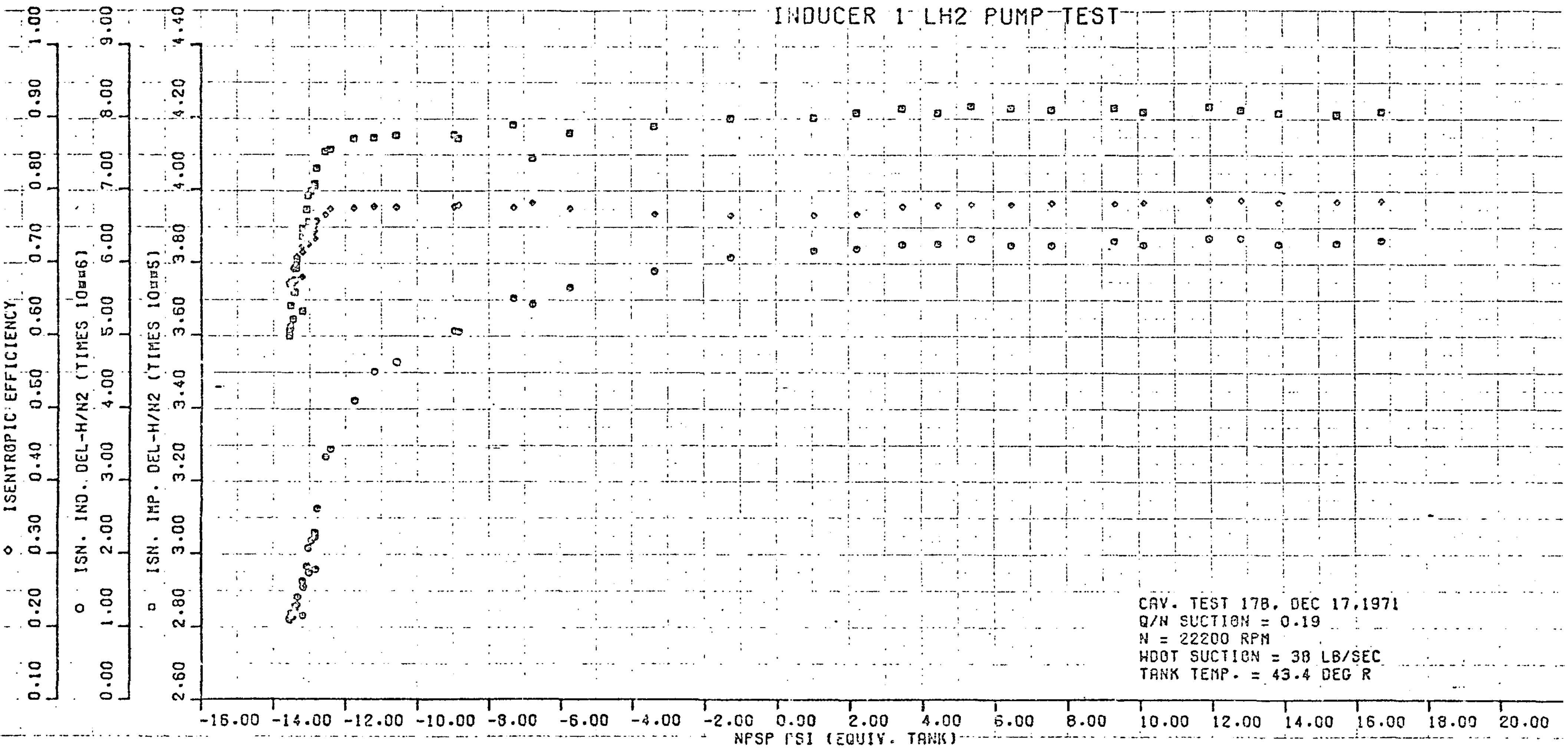

INDUCER I LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 17A. DEC 17,1971
Q/N SUCTION = 0.19
N = 24400 RPM
WDOT SUCTION = 42.2 LB/SEC
TANK TEMP. = 43.4 DEG R

355
F

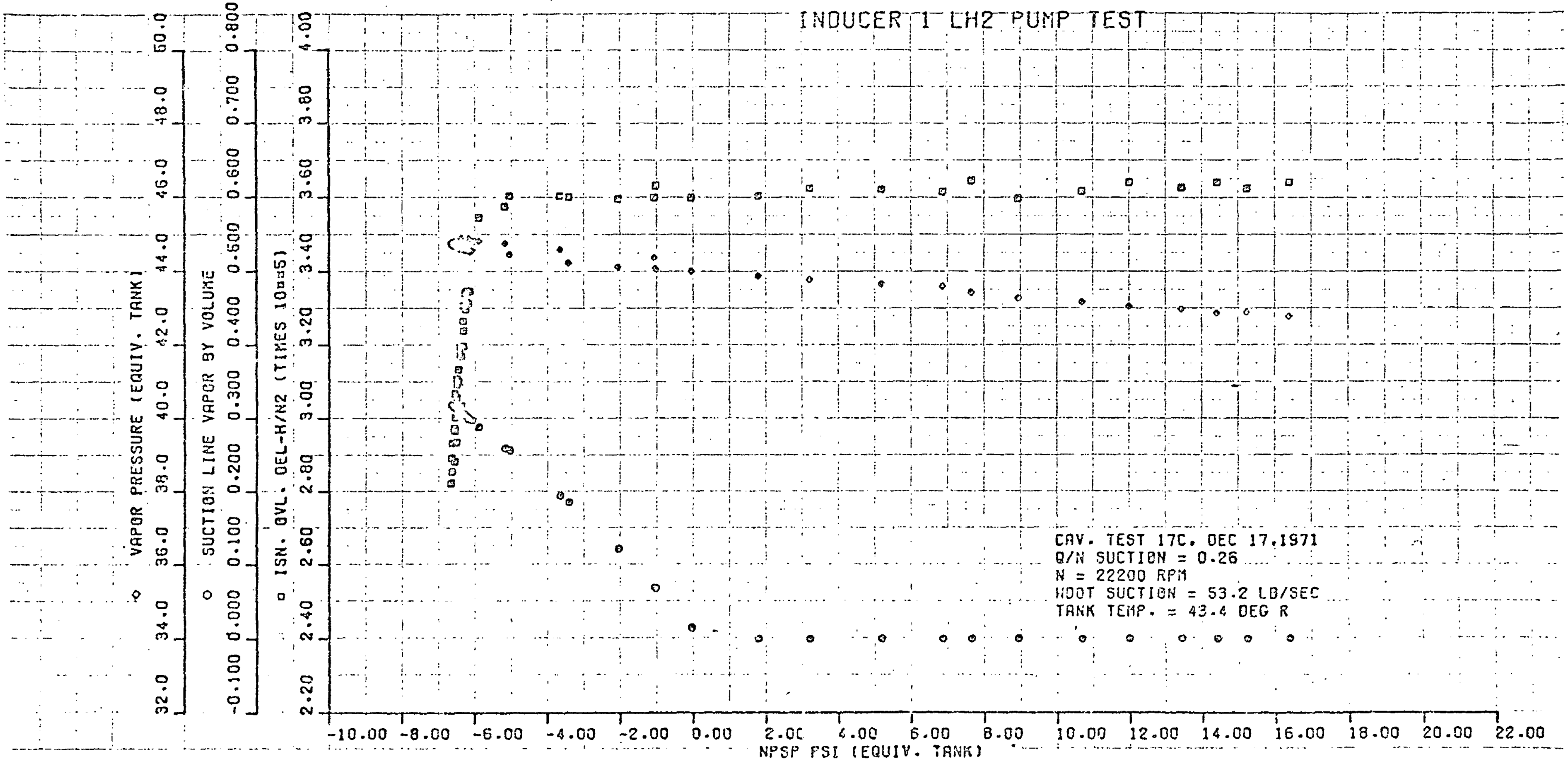


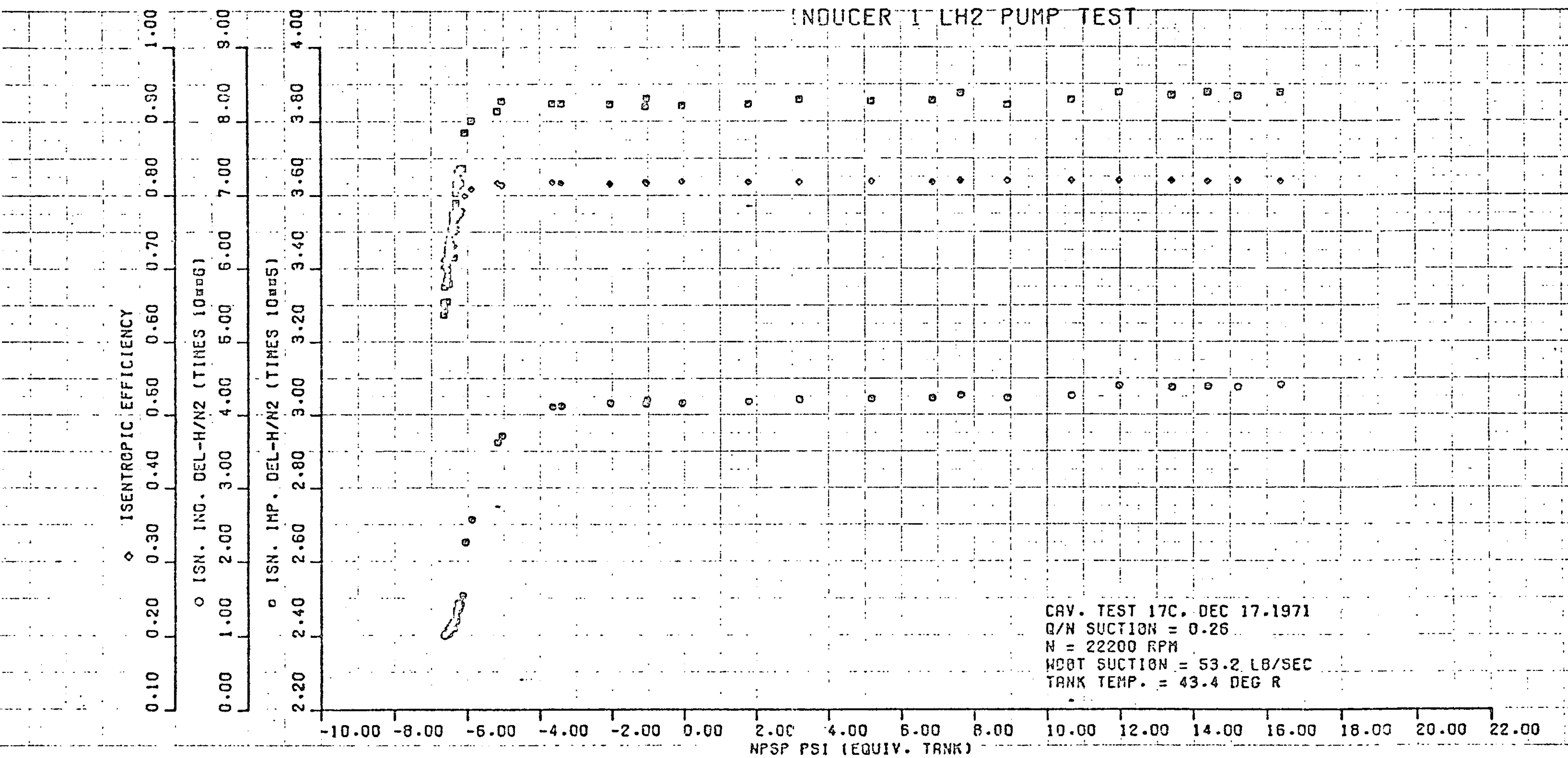
INDUCER 1 LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 17B, DEC 17,1971
Q/N SUCTION = 0.19
N = 22200 RPM
WDOT SUCTION = 38 LB/SEC
TANK TEMP. = 43.4 DEG R

356

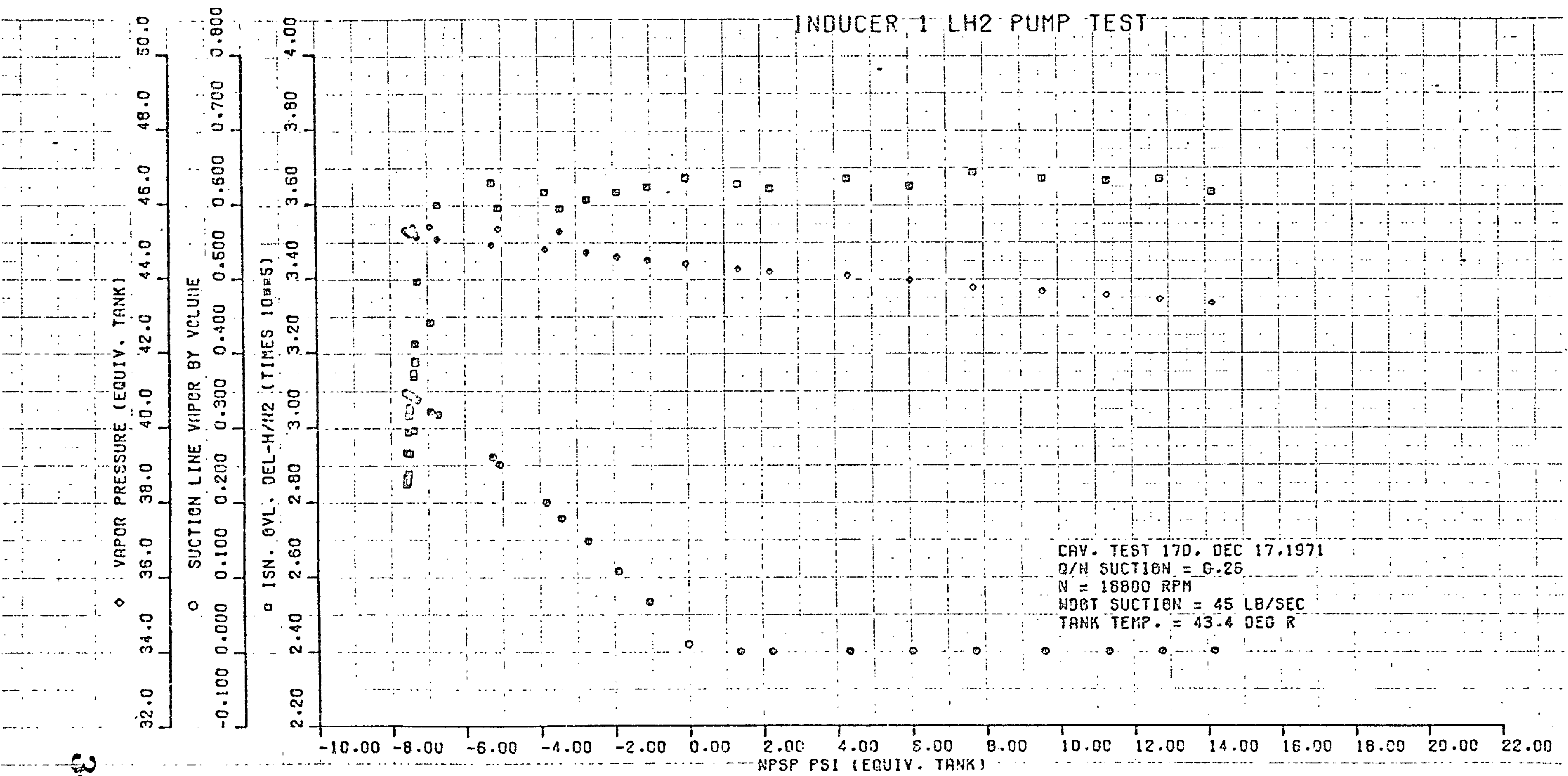

INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 17B, DEC 17,1971
Q/N SUCTION = 0.19
N = 22200 RPM
WDOT SUCTION = 38 LB/SEC
TANK TEMP. = 43.4 DEG R

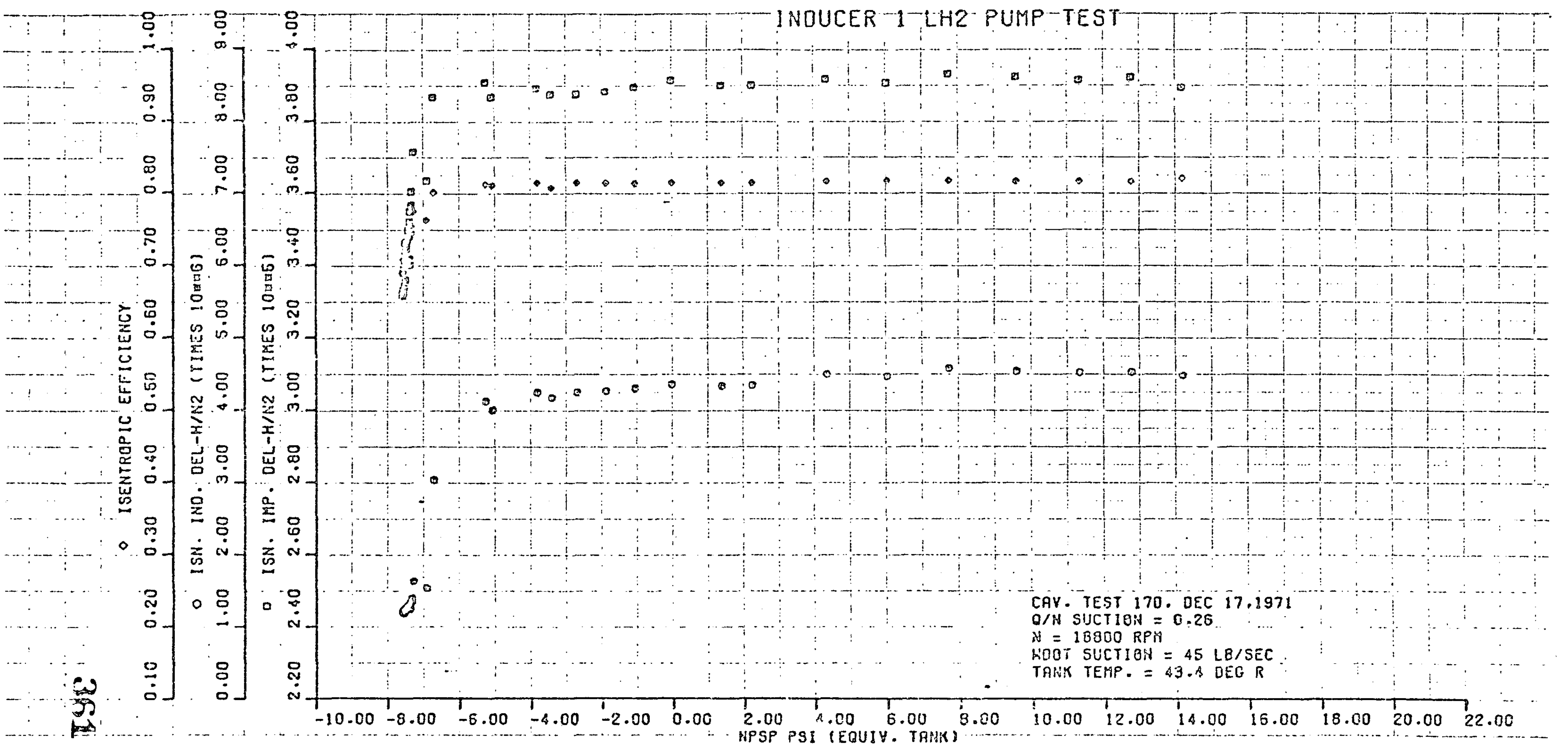
357

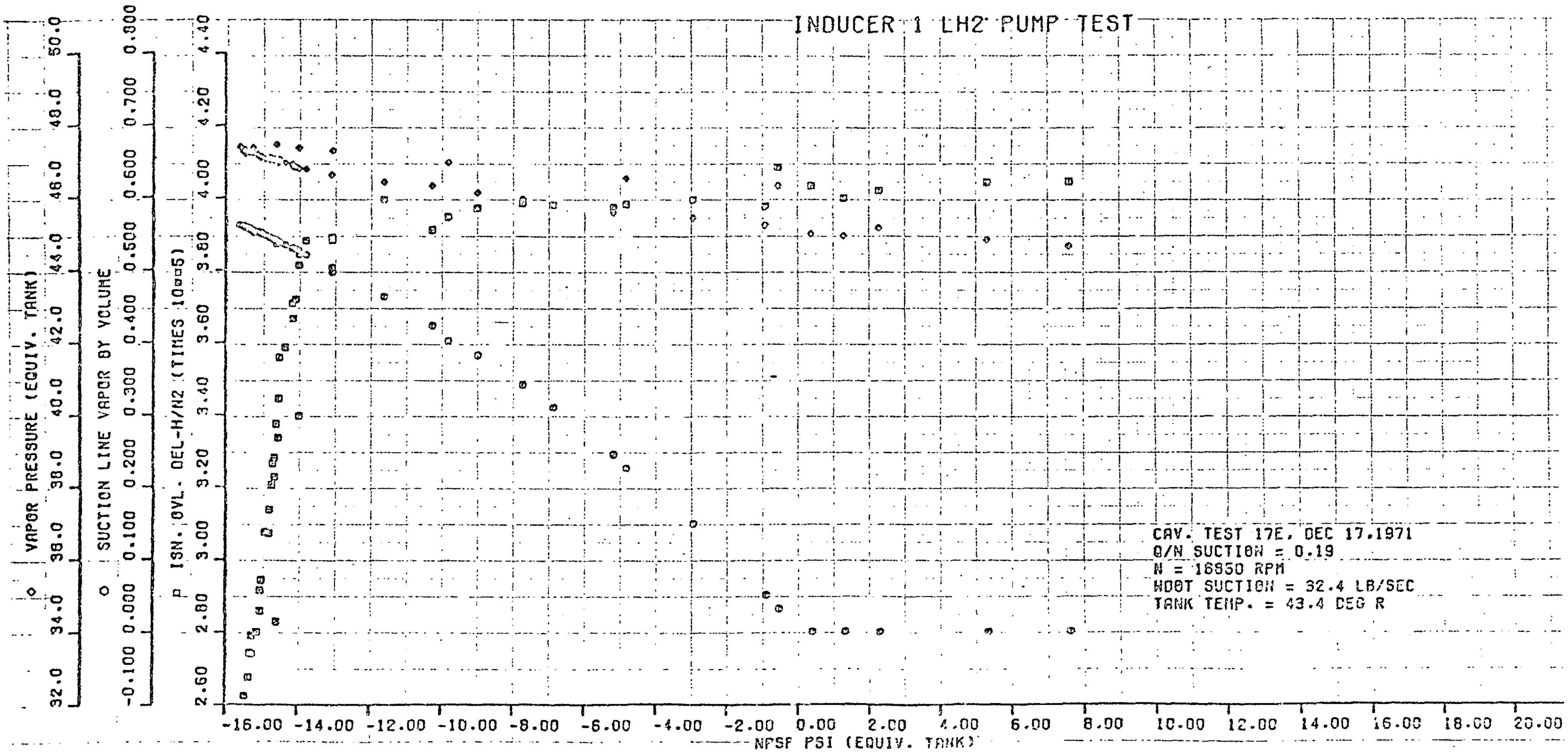

INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. BVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 17C. DEC 17,1971
Q/N SUCTION = 0.26
N = 22200 RPM
WDOT SUCTION = 53.2 LB/SEC
TANK TEMP. = 43.4 DEG R

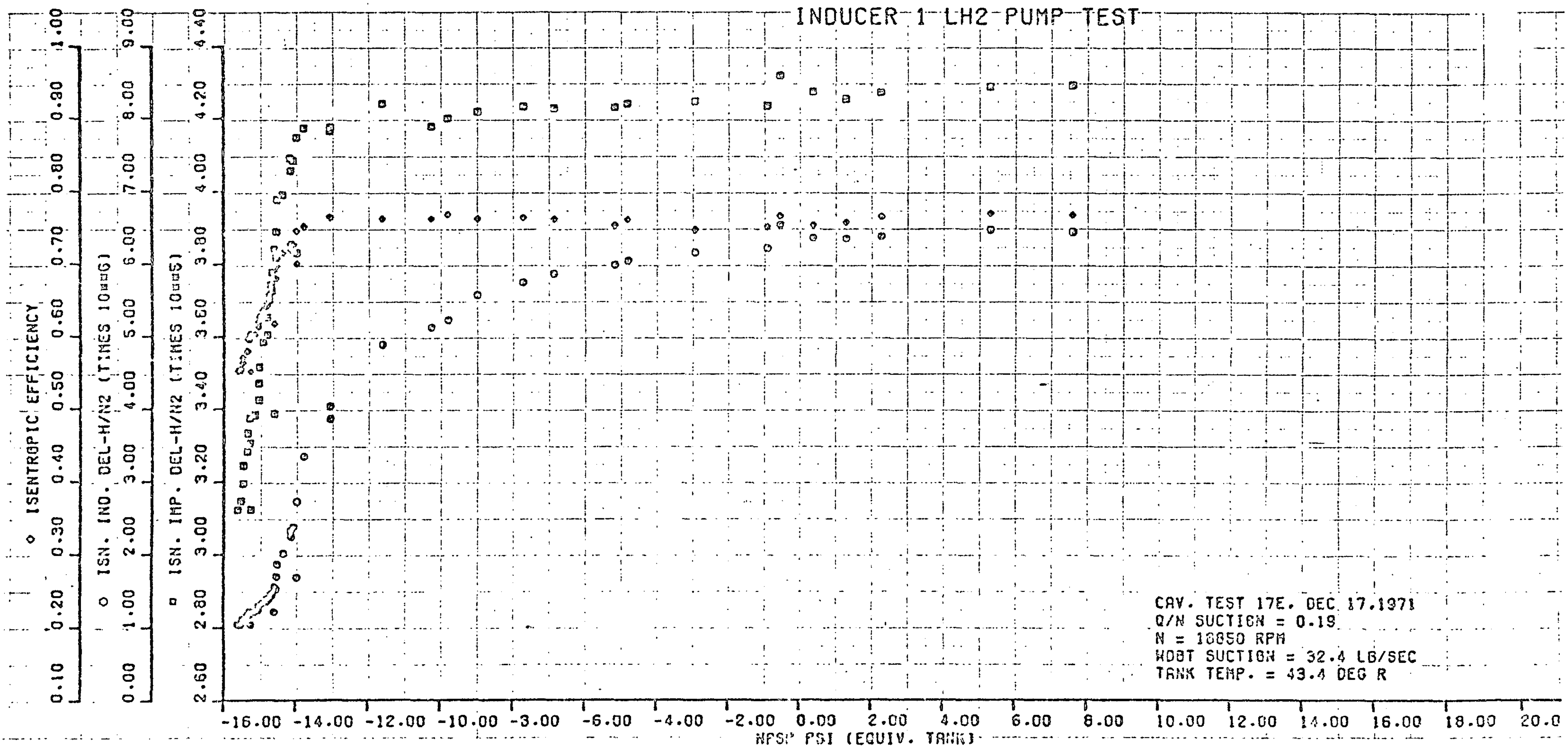


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
CAV. TEST 17C, DEC 17,1971
Q/N SUCTION = 0.26
N = 22200 RPM
WDOT SUCTION = 53.2 LB/SEC
TANK TEMP. = 43.4 DEG R
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 170, DEC 17,1971
Q/N SUCTION = 0.26
N = 16800 RPM
WDOT SUCTION = 45 LB/SEC
TANK TEMP. = 43.4 DEG R


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 170, DEC 17,1971
Q/N SUCTION = 0.26
N = 16800 RPM
WDOT SUCTION = 45 LB/SEC
TANK TEMP. = 43.4 DEG R


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSF PSI (EQUIV. TANK)
CAV. TEST 17E, DEC 17,1971
Q/N SUCTION = 0.19
N = 16950 RPM
WDOT SUCTION = 32.4 LB/SEC
TANK TEMP. = 43.4 DEG R


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-16.00 -14.00 -12.00 -10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.0
NPSH PSI (EQUIV. TANK)
CAV. TEST 17E. DEC 17.1971
Q/N SUCTION = 0.19
N = 10850 RPM
WDOT SUCTION = 32.4 LB/SEC
TANK TEMP. = 43.4 DEG R

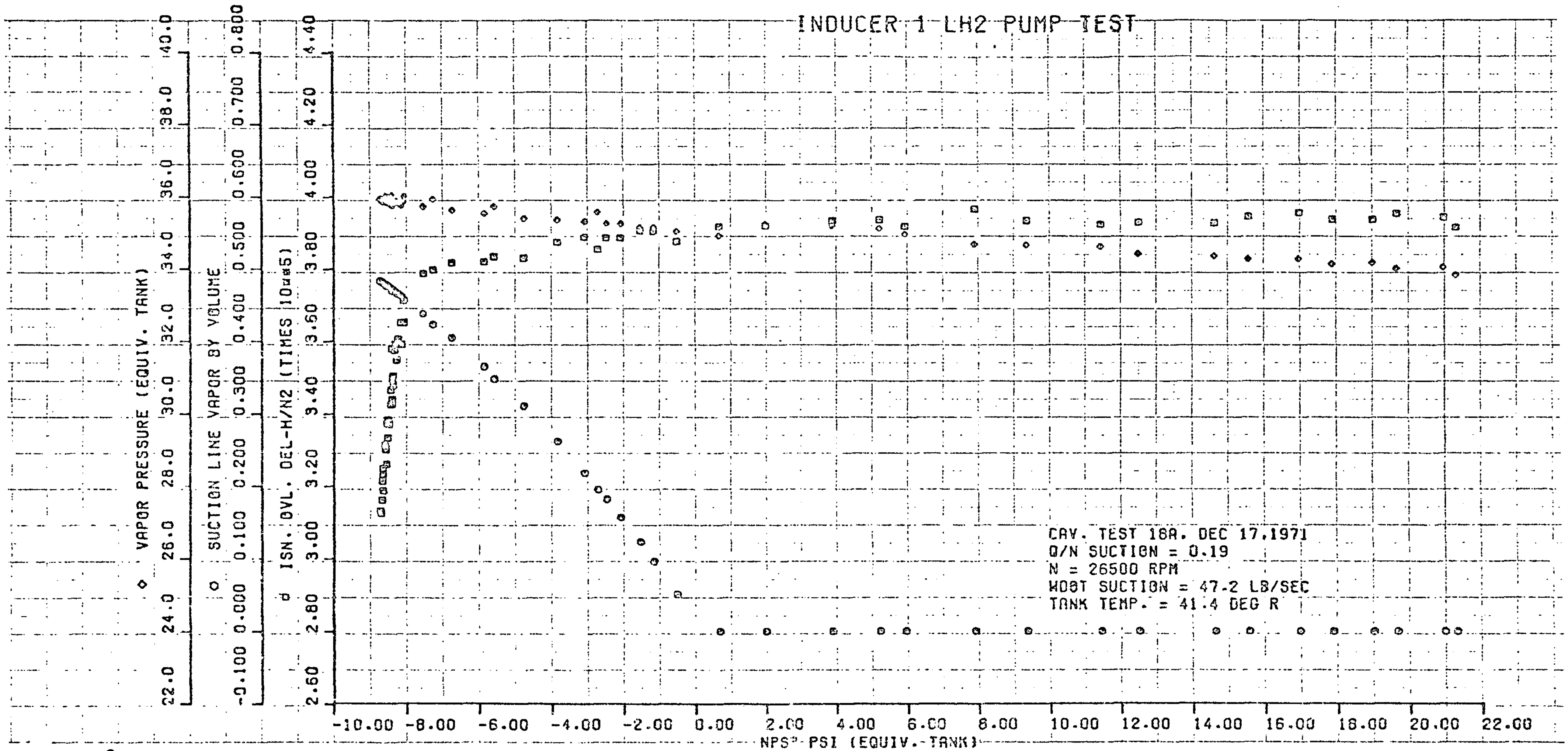


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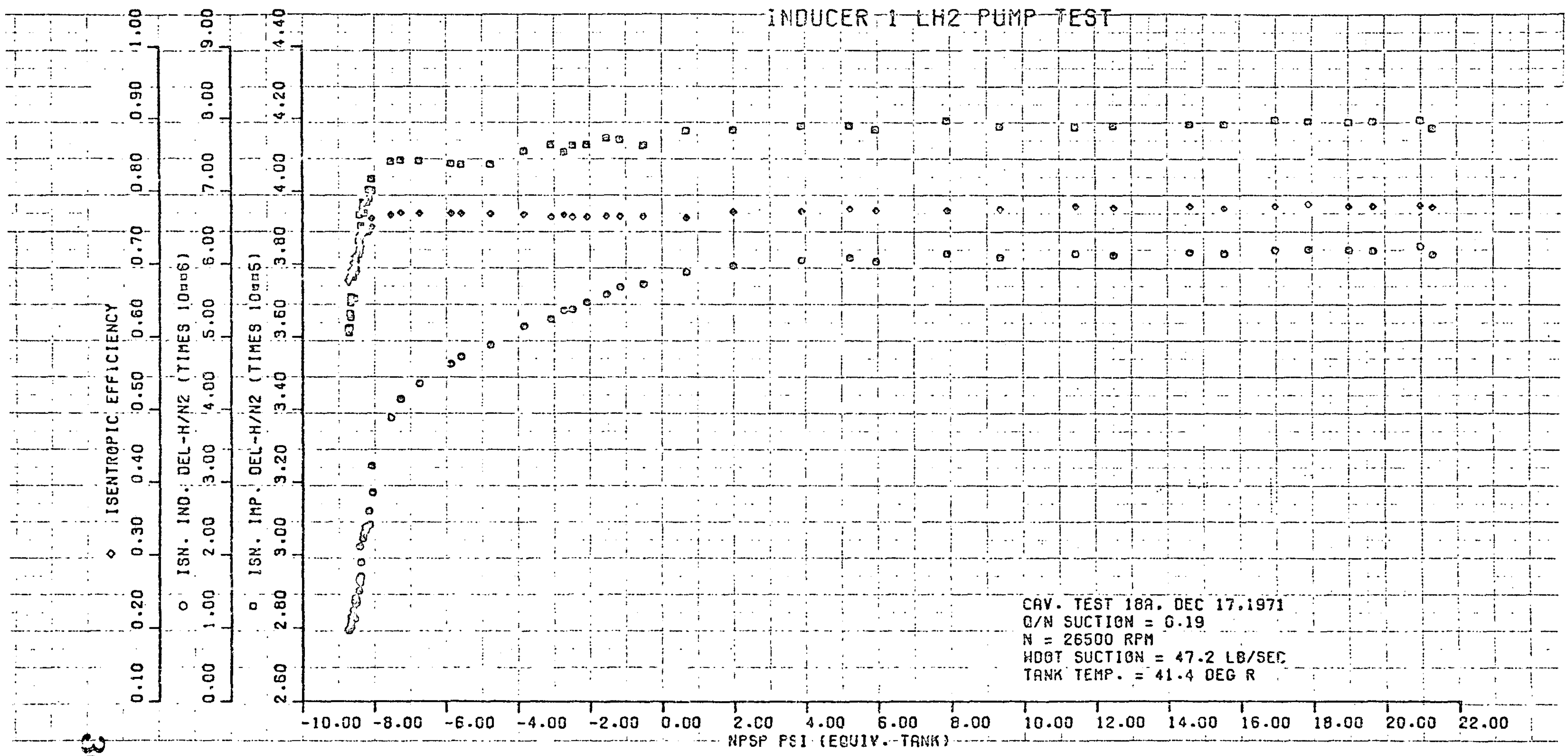
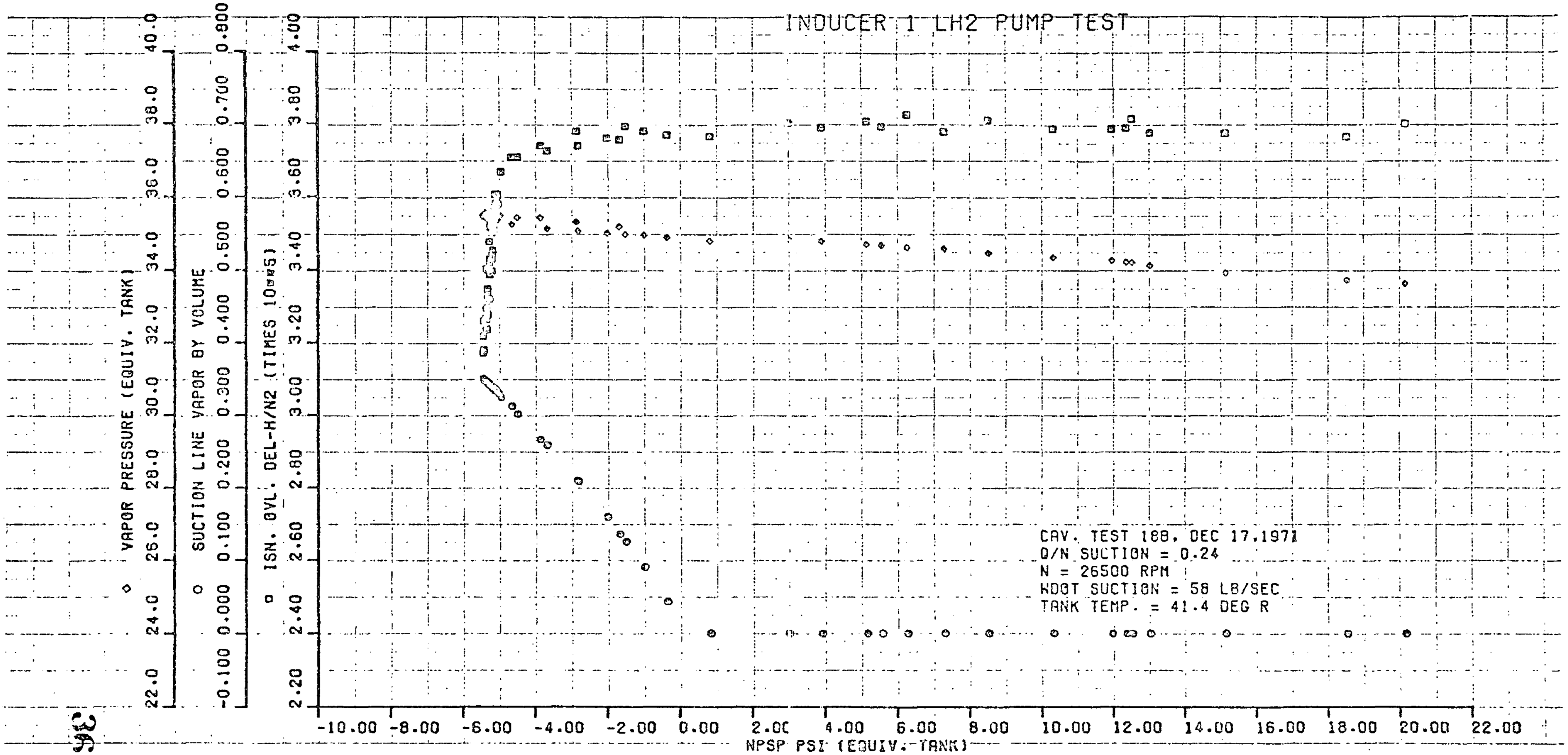
CHART No. 12-02



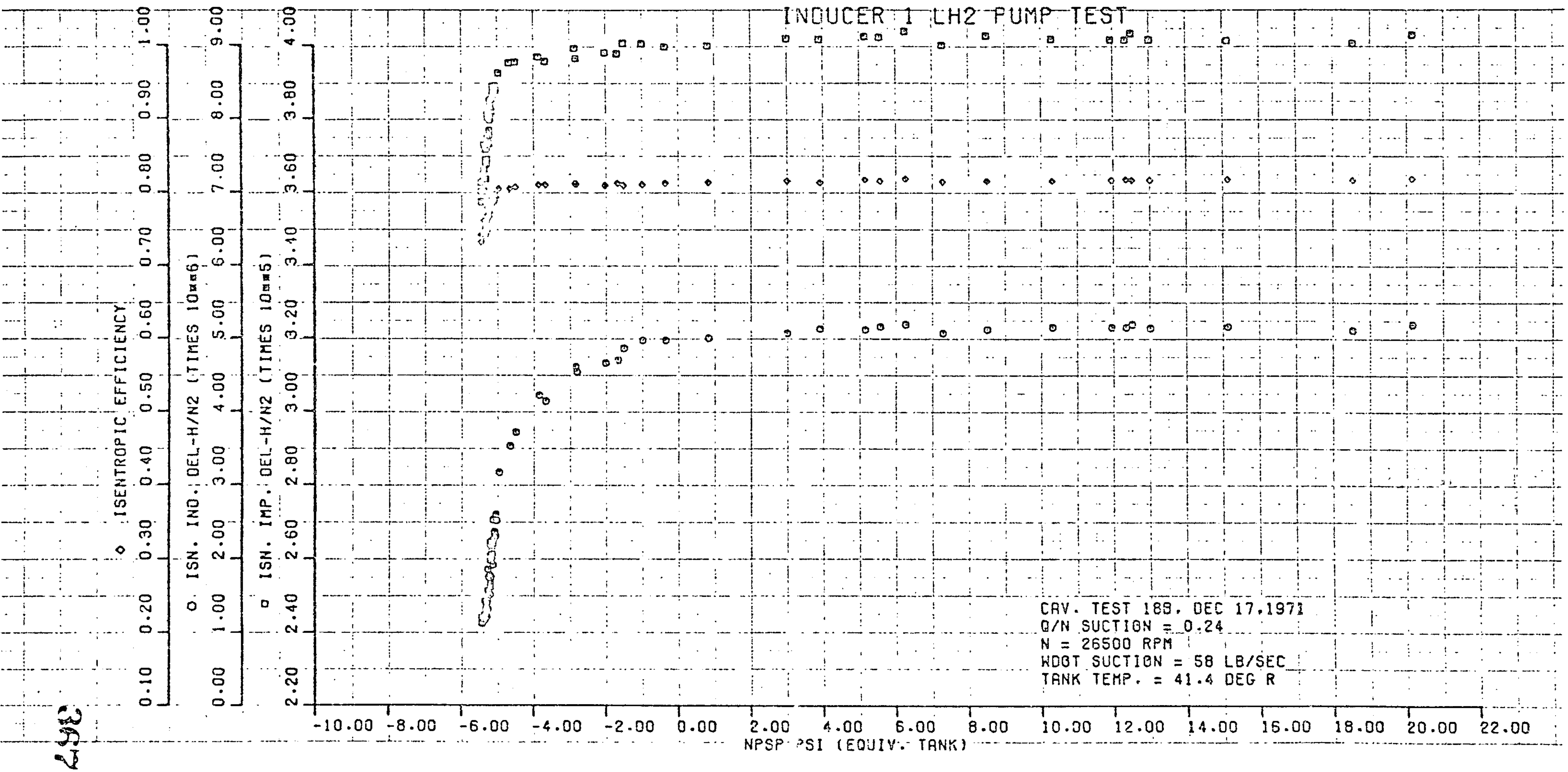
365

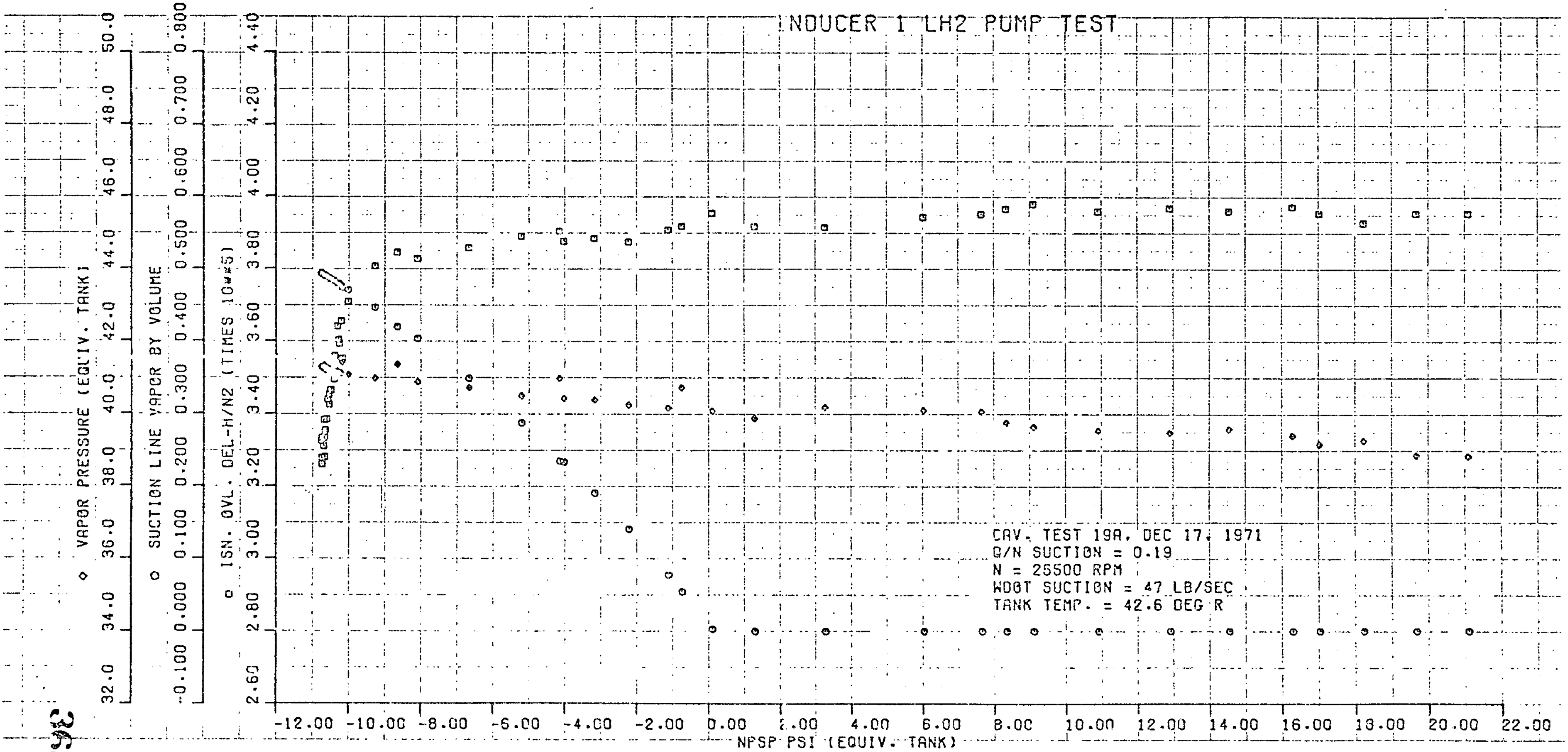
CHART No. 12-02



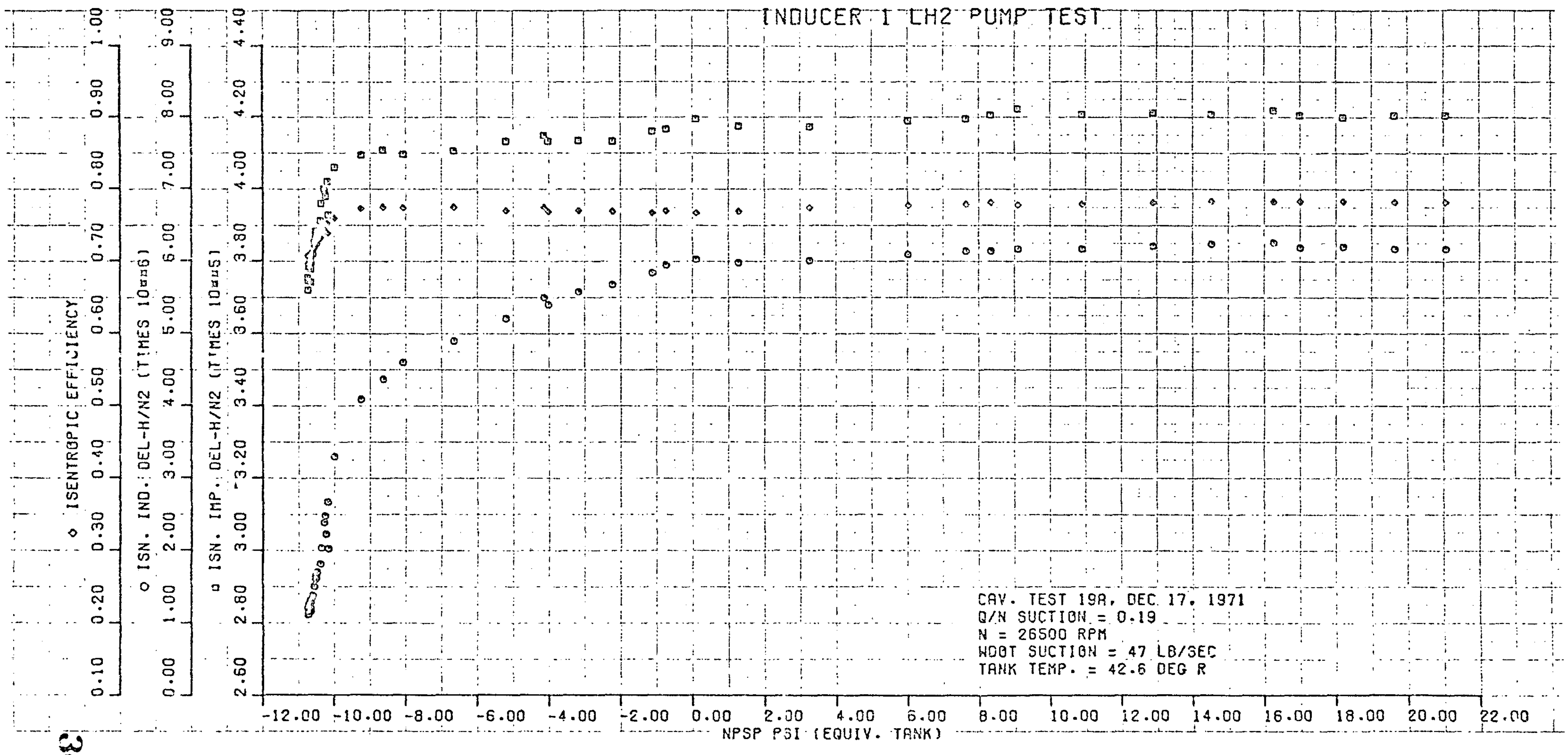
INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 188, DEC 17,1971
Q/N SUCTION = 0.24
N = 26500 RPM
WDOT SUCTION = 58 LB/SEC
TANK TEMP. = 41.4 DEG R

366

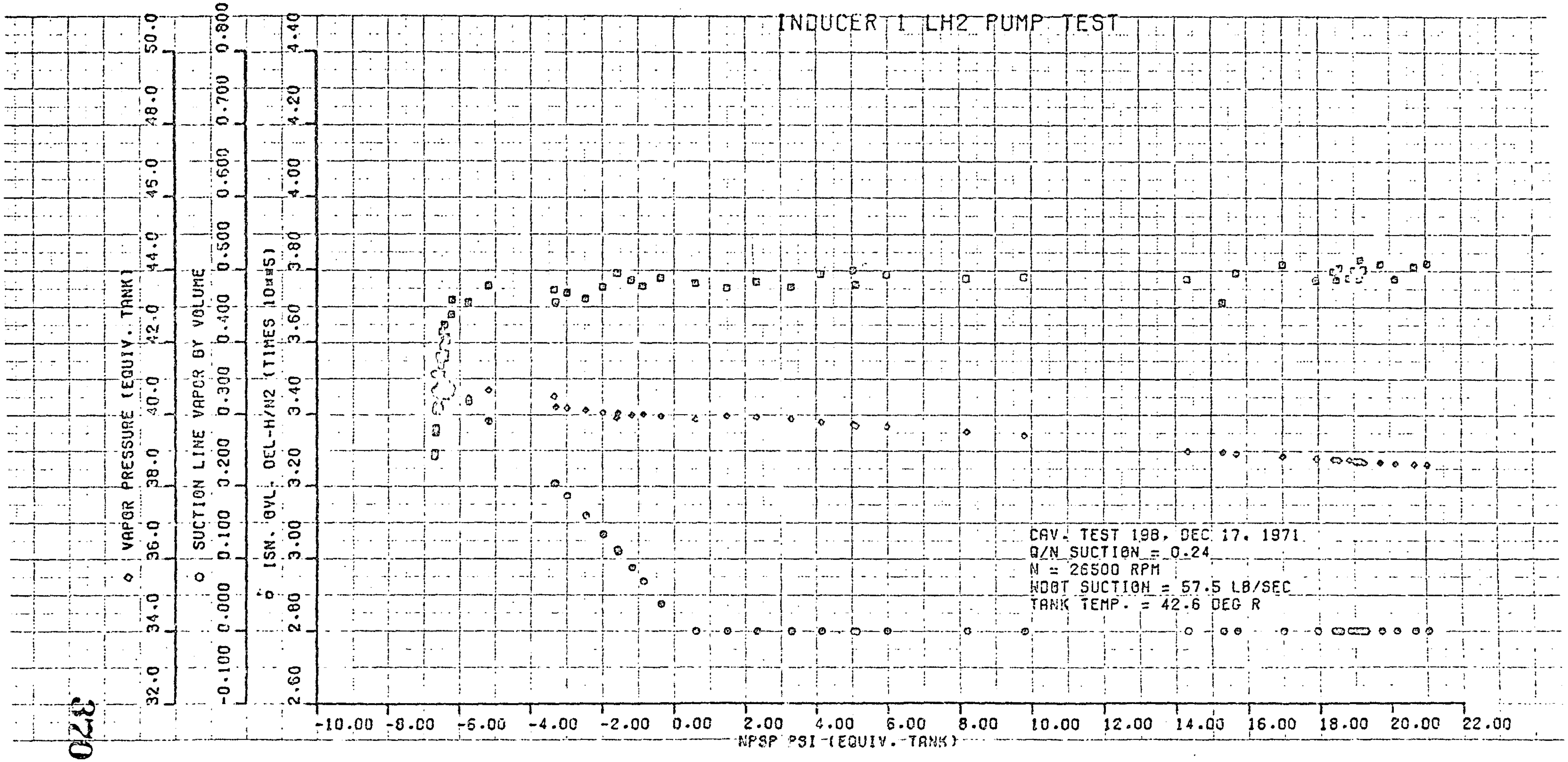

INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CRV. TEST 189, DEC 17,1971
Q/N SUCTION = 0.24
N = 26500 RPM
WDOT SUCTION = 58 LB/SEC
TANK TEMP. = 41.4 DEG R



368
CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

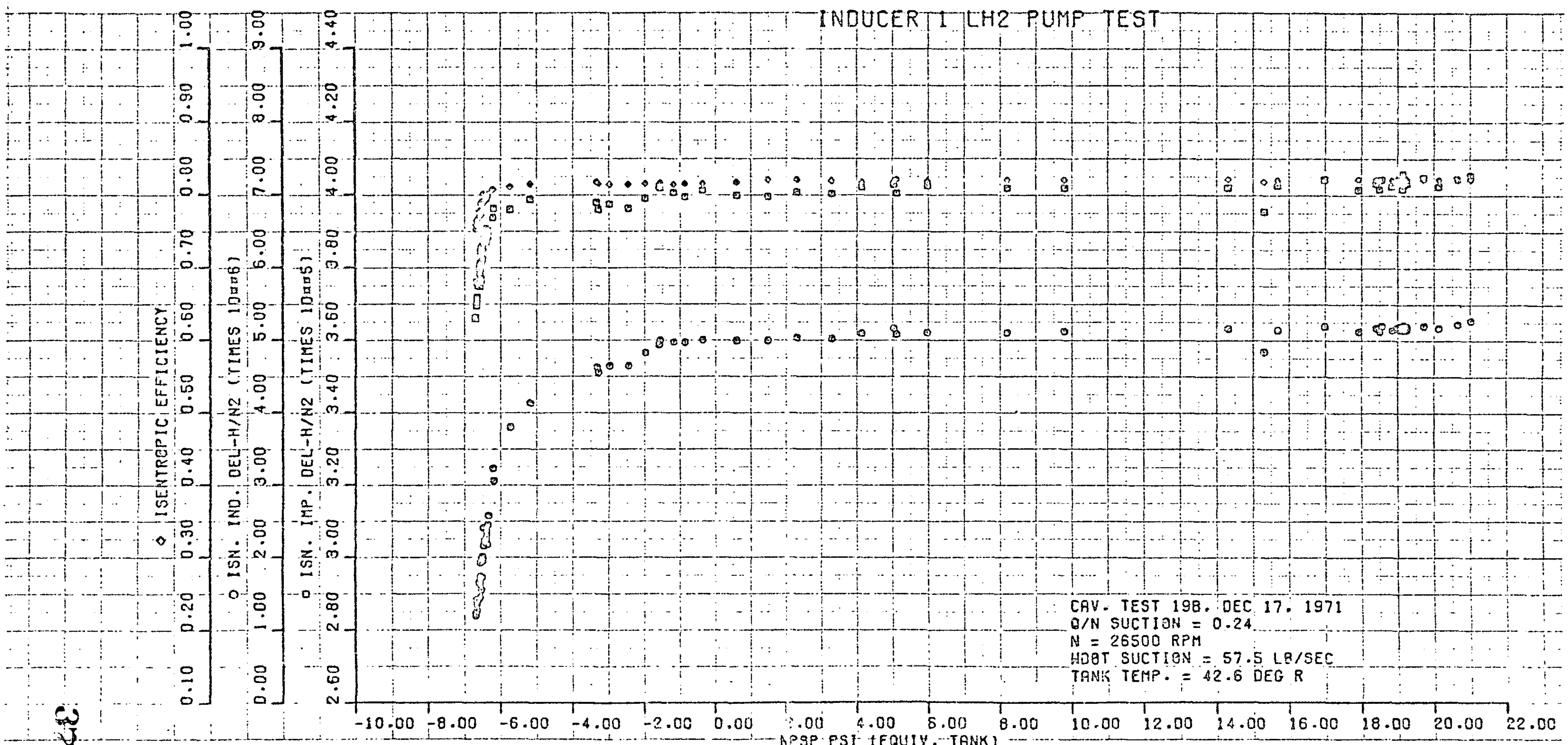

INDUCER I LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 19A, DEC. 17, 1971
Q/N SUCTION = 0.19
N = 26500 RPM
WDOT SUCTION = 47 LB/SEC
TANK TEMP. = 42.6 DEG R

369



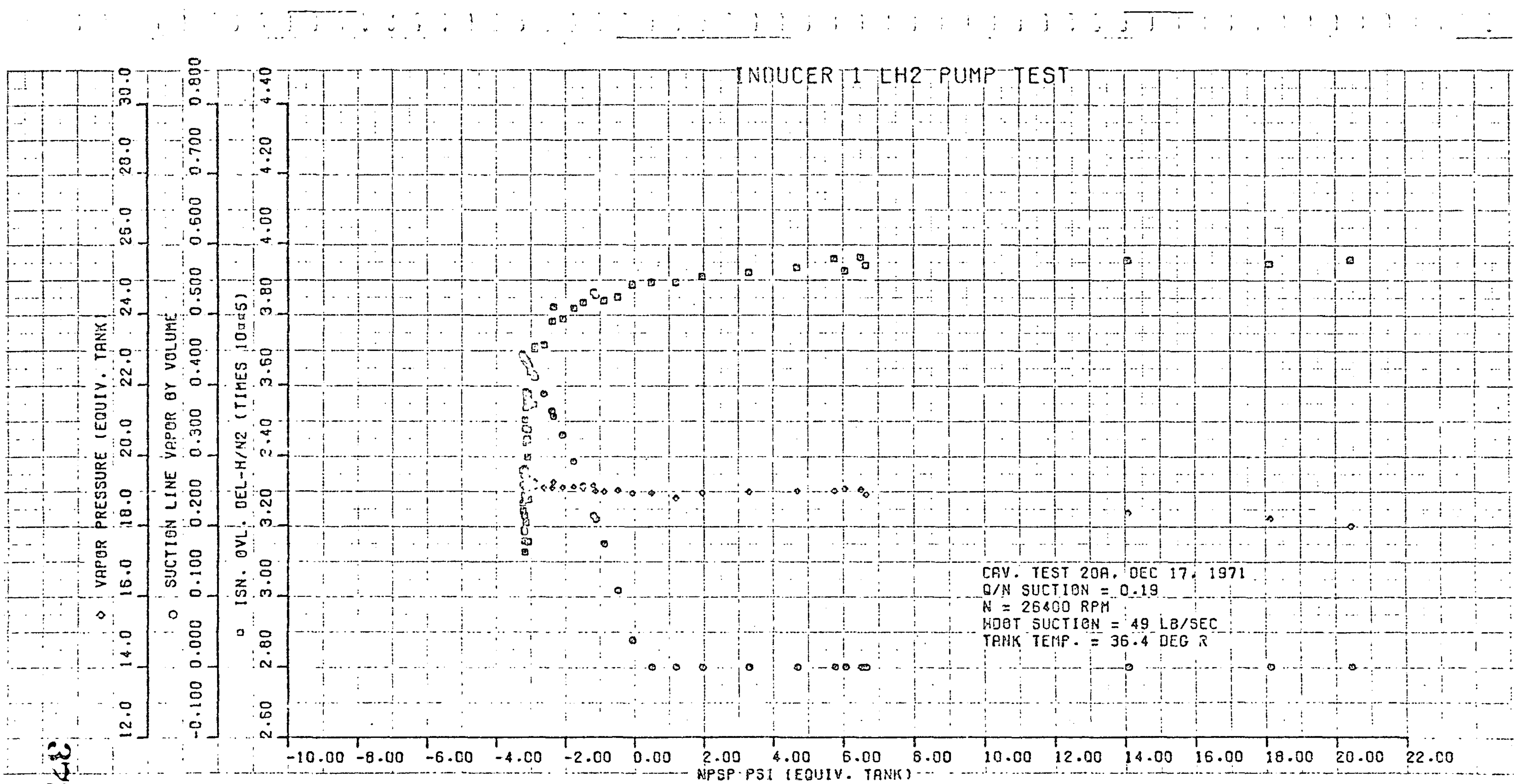
370

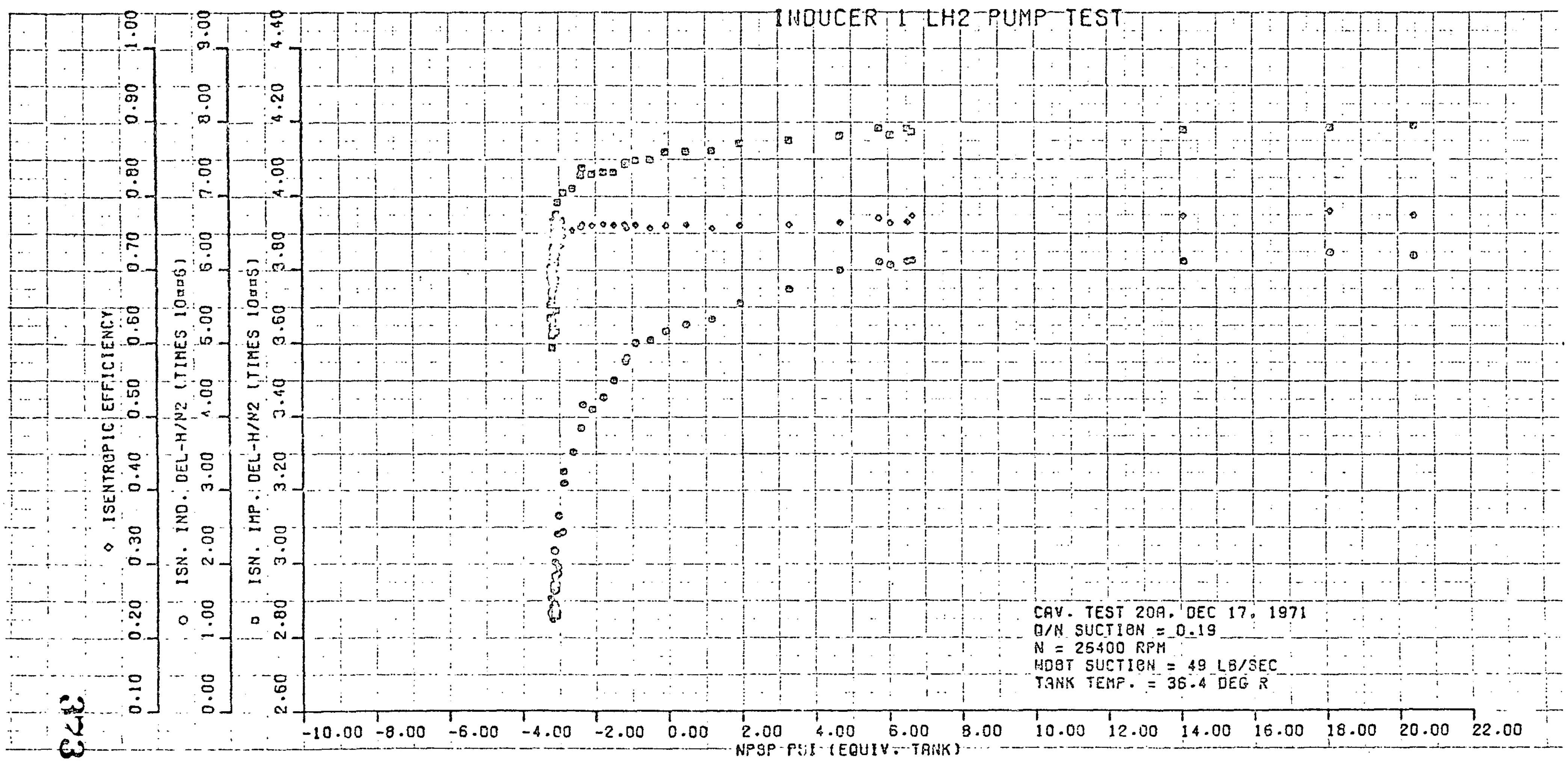
SALMA CO. SANTA CLARA, CALIF. CHART No. 12-02 cut

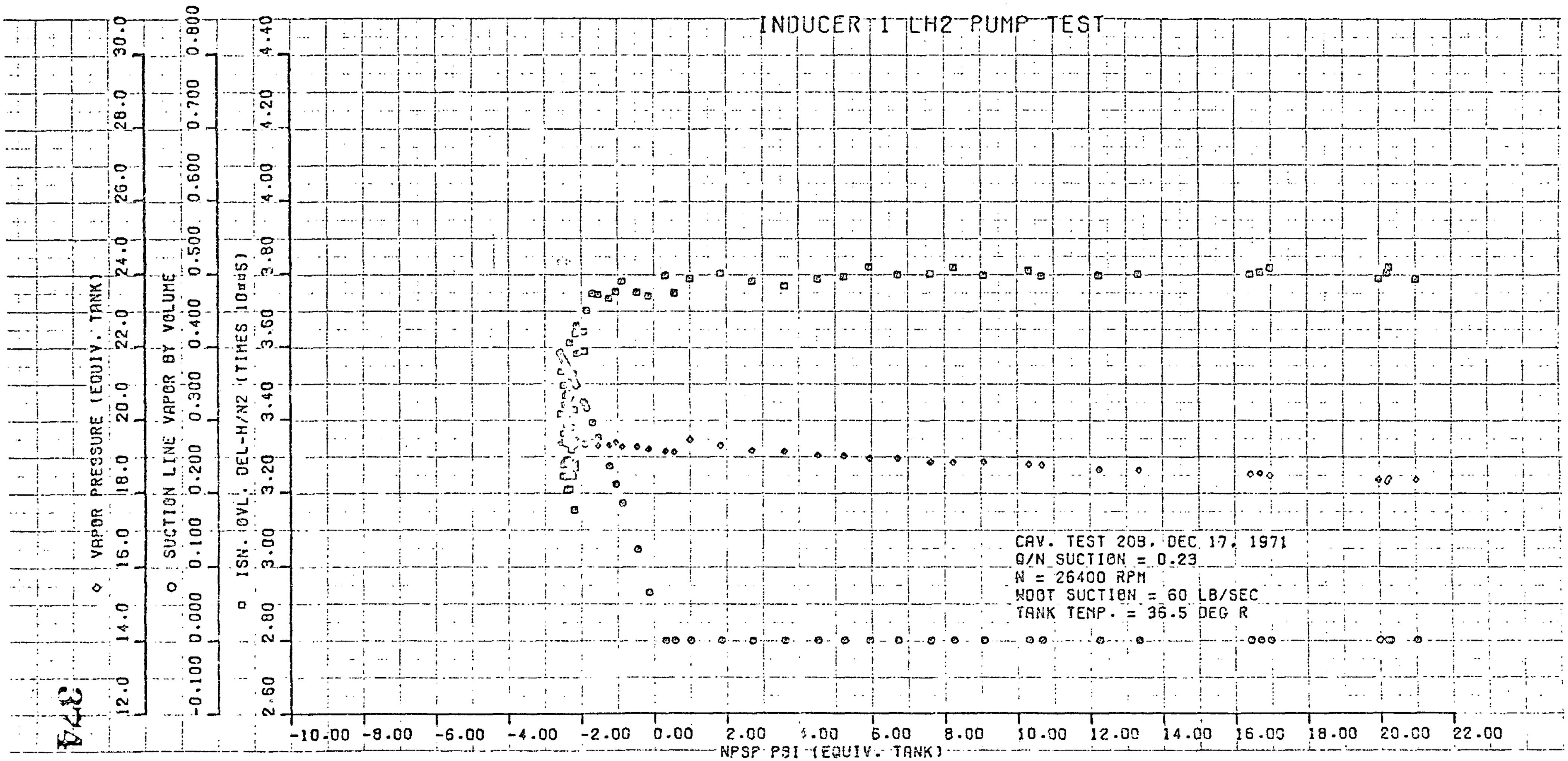


377

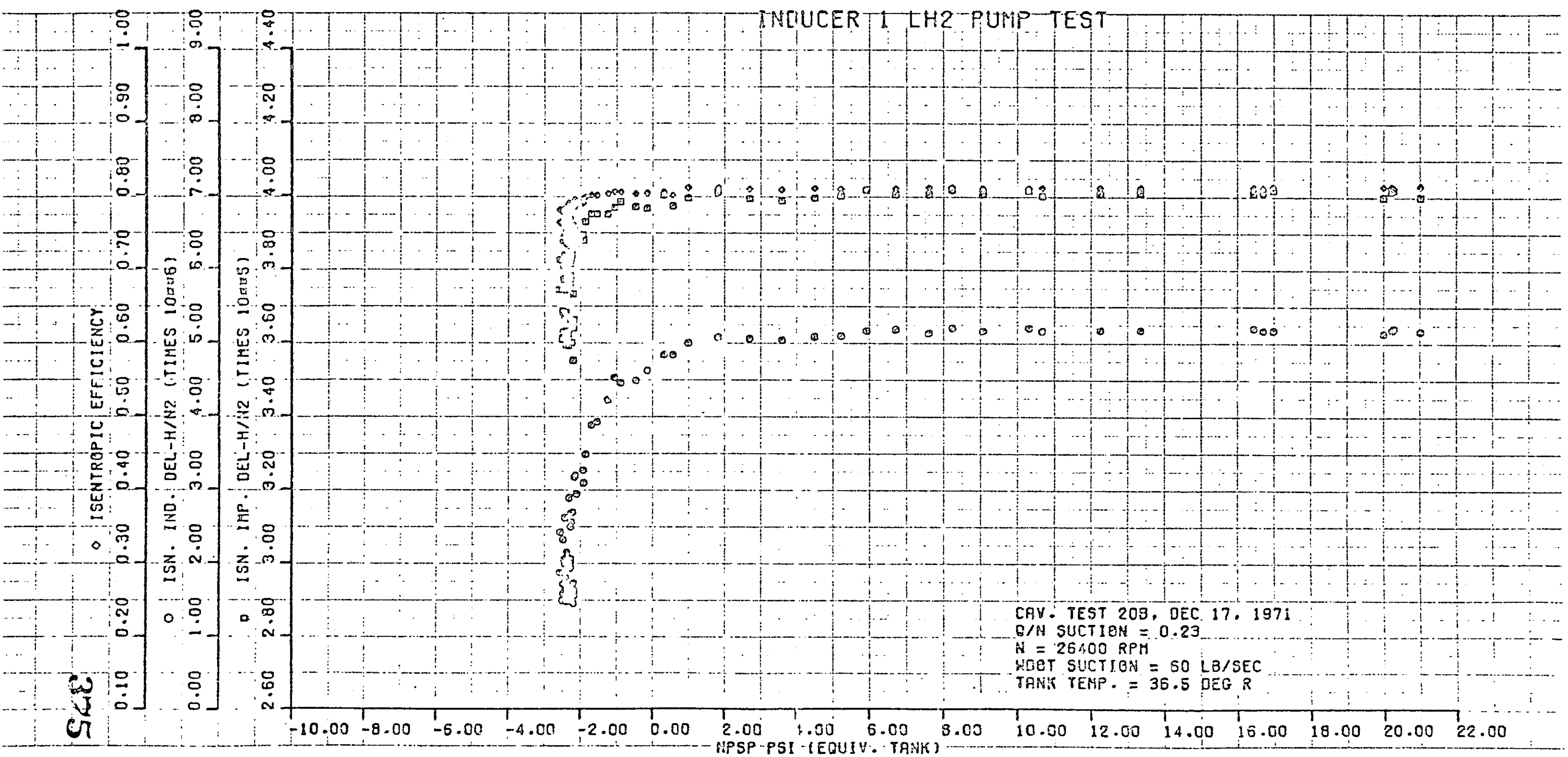
GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
CAV. TEST 20A, DEC 17, 1971
Q/N SUCTION = 0.19
N = 26400 RPM
WDOT SUCTION = 49 LB/SEC
TANK TEMP. = 36.4 DEG R
NPSP PSI (EQUIV. TANK)
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 20A, DEC 17, 1971
Q/N SUCTION = 0.19
N = 26400 RPM
WDOT SUCTION = 49 LB/SEC
TANK TEMP. = 36.4 DEG R

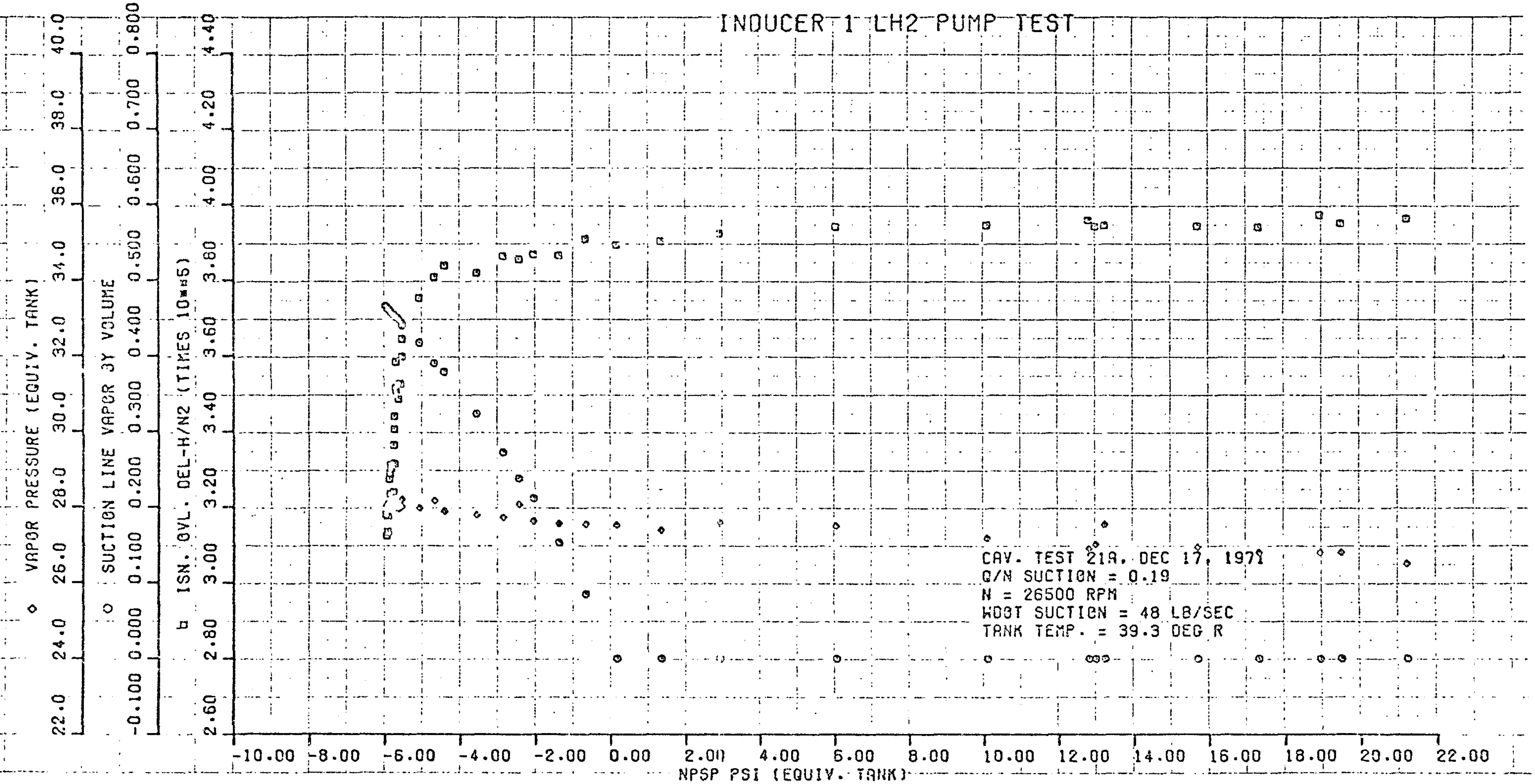


CO. SANTA CLARA, CALIF. CHART No. 12-02

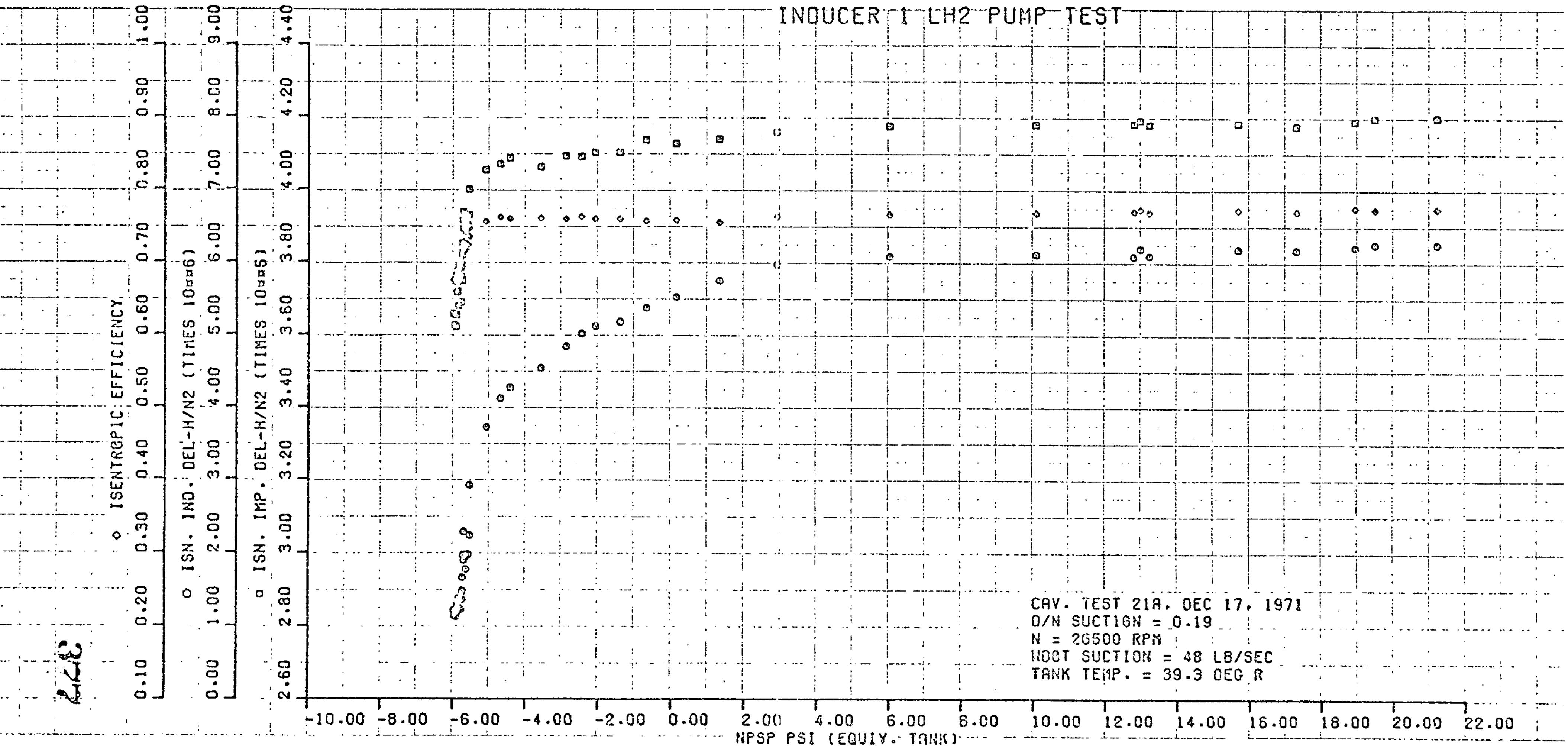


375

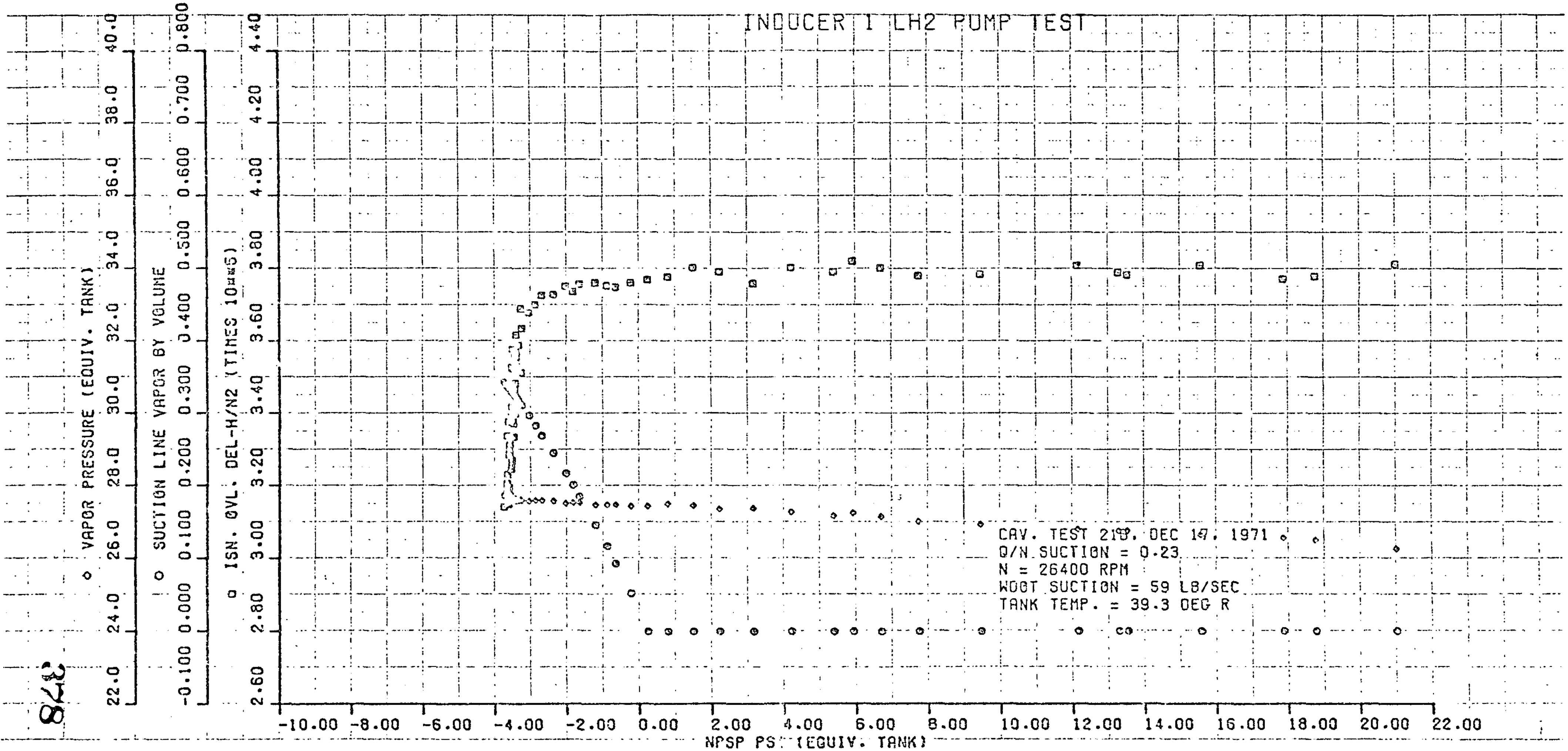
SANBORN CO. SANTA CLARA, CALIF. CHART No. 12-02

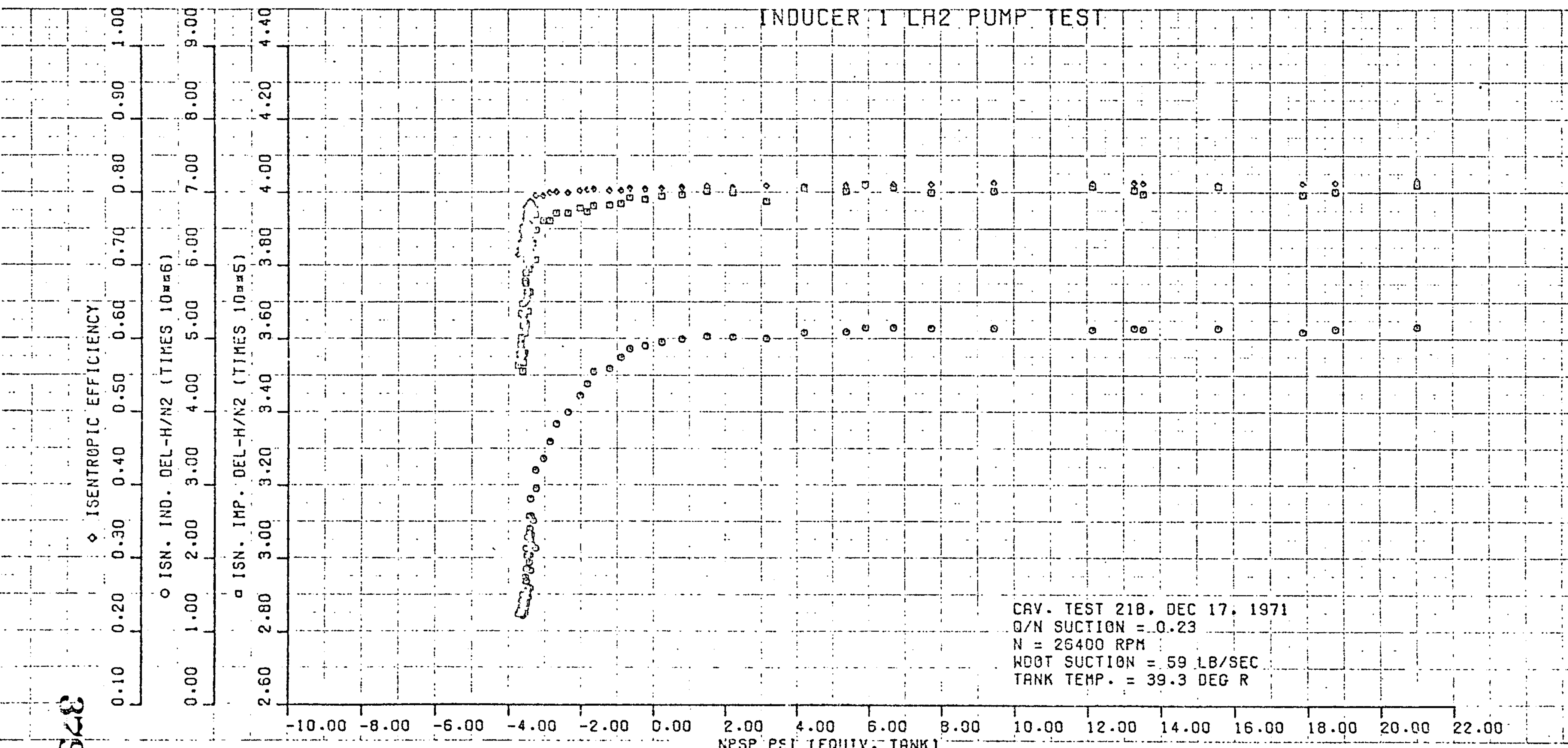


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
40.0 38.0 36.0 34.0 32.0 30.0 28.0 26.0 24.0 22.0
0.800 0.700 0.600 0.500 0.400 0.300 0.200 0.100 0.000 -0.100
4.40 4.20 4.00 3.80 3.60 3.40 3.20 3.00 2.80 2.60
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 21A, DEC 17, 1971
Q/N SUCTION = 0.19
N = 26500 RPM
WDOT SUCTION = 48 LB/SEC
TANK TEMP. = 39.3 DEG R


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 21A, DEC 17, 1971
O/N SUCTION = 0.19
N = 26500 RPM
WDOT SUCTION = 48 LB/SEC
TANK TEMP. = 39.3 DEG R
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00

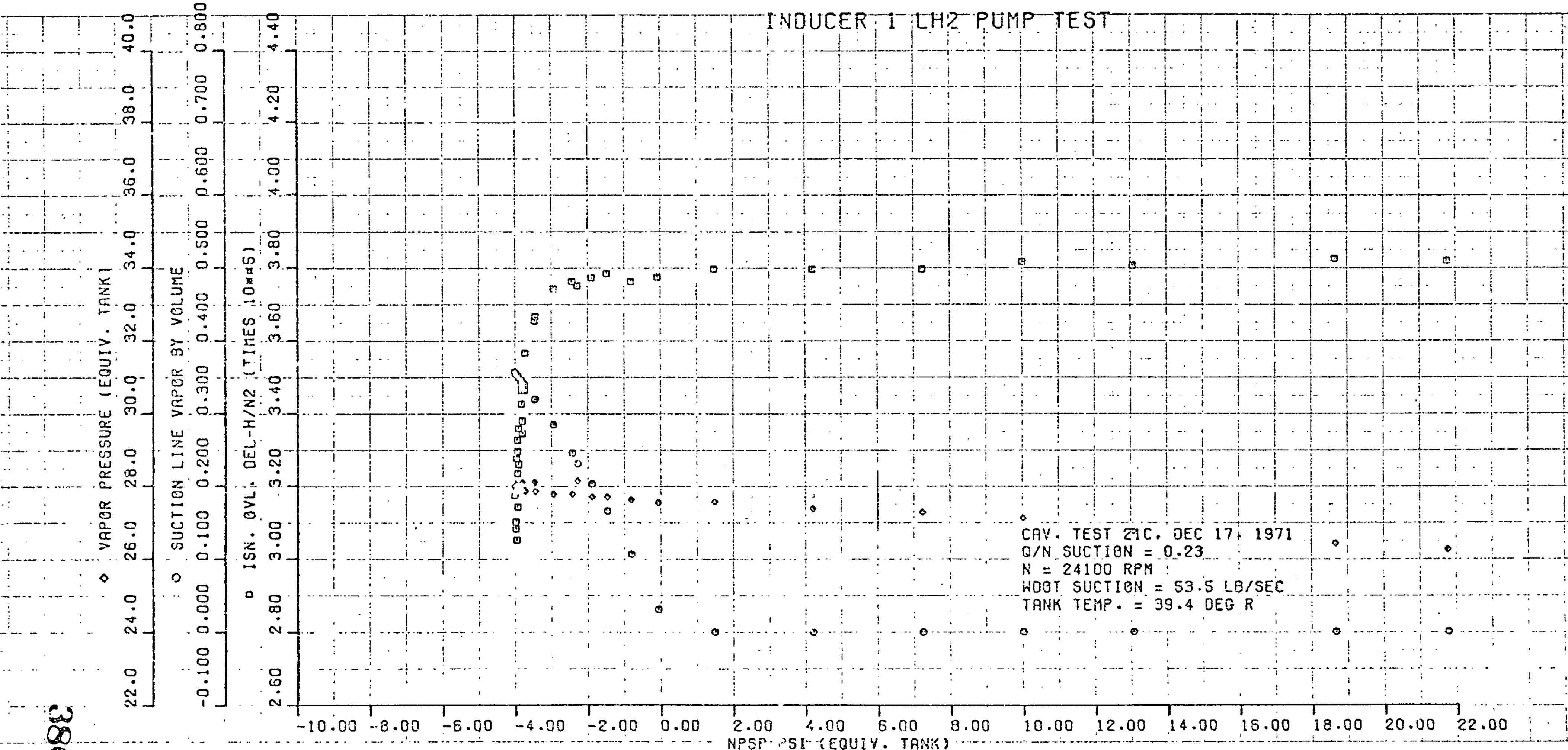
372

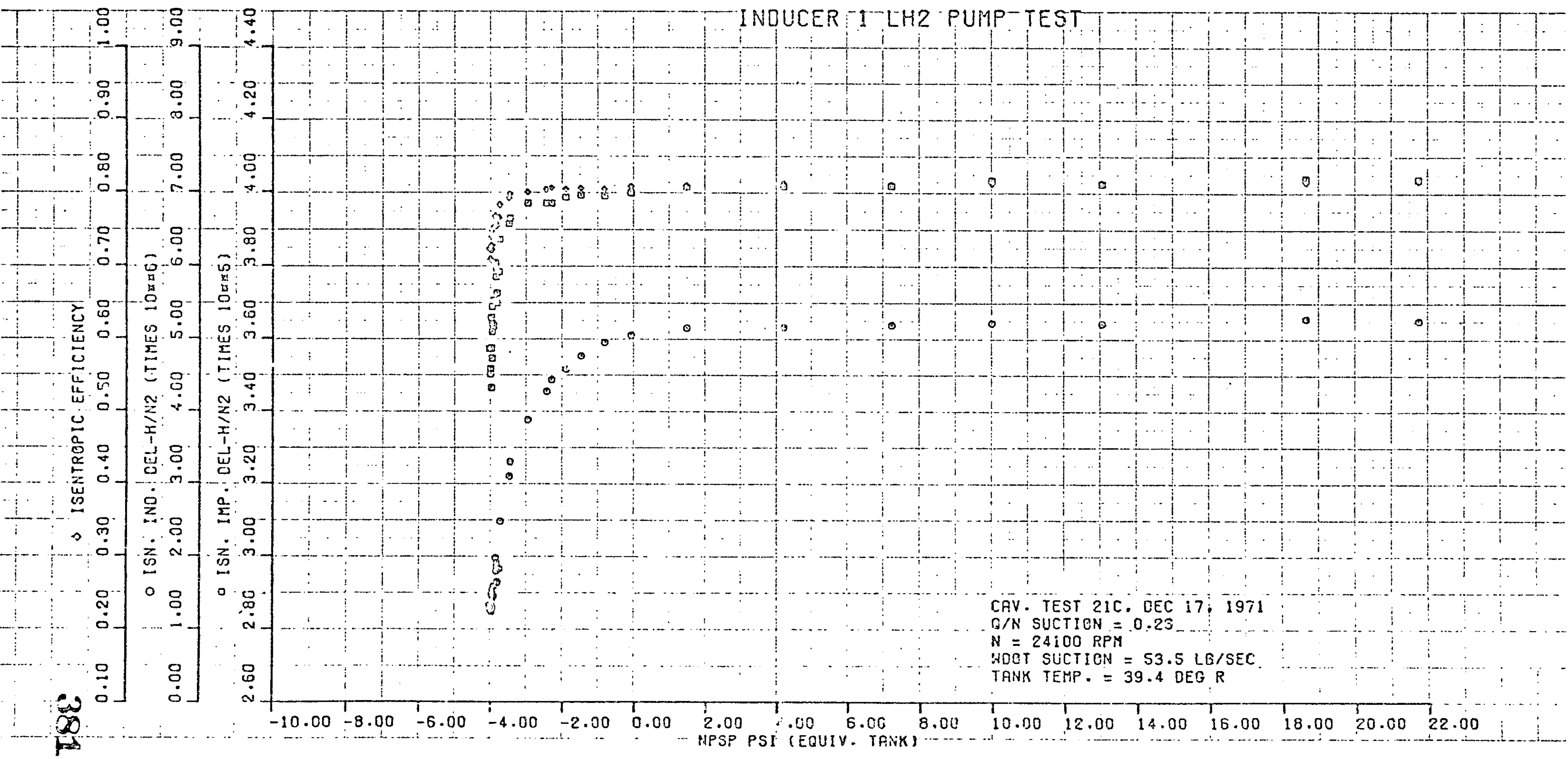

INDUCER I LH2 PUMP TEST
CAV. TEST 21B, DEC 17, 1971
Q/N SUCTION = 0.23
N = 26400 RPM
WDOT SUCTION = 59 LB/SEC
TANK TEMP. = 39.3 DEG R
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)



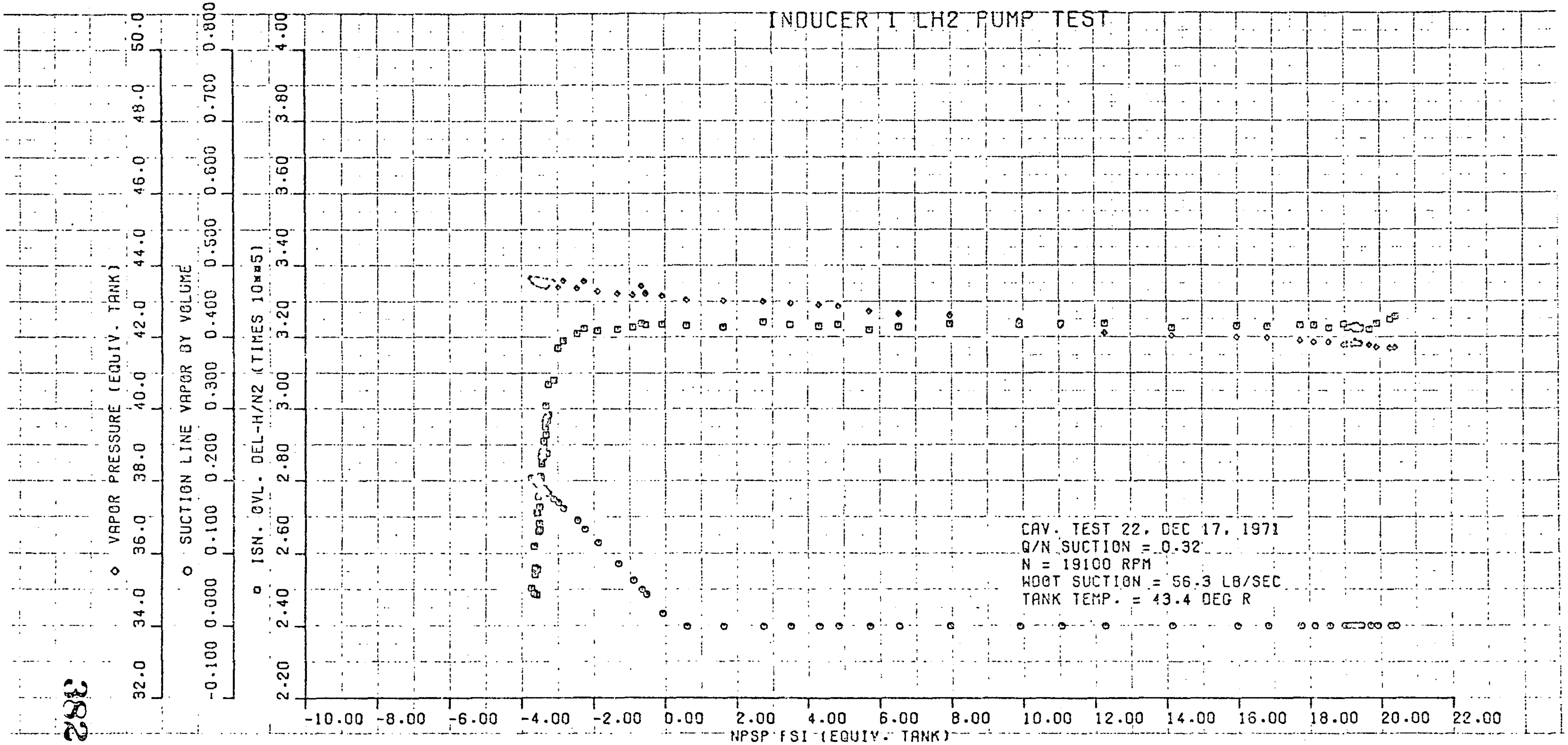
379

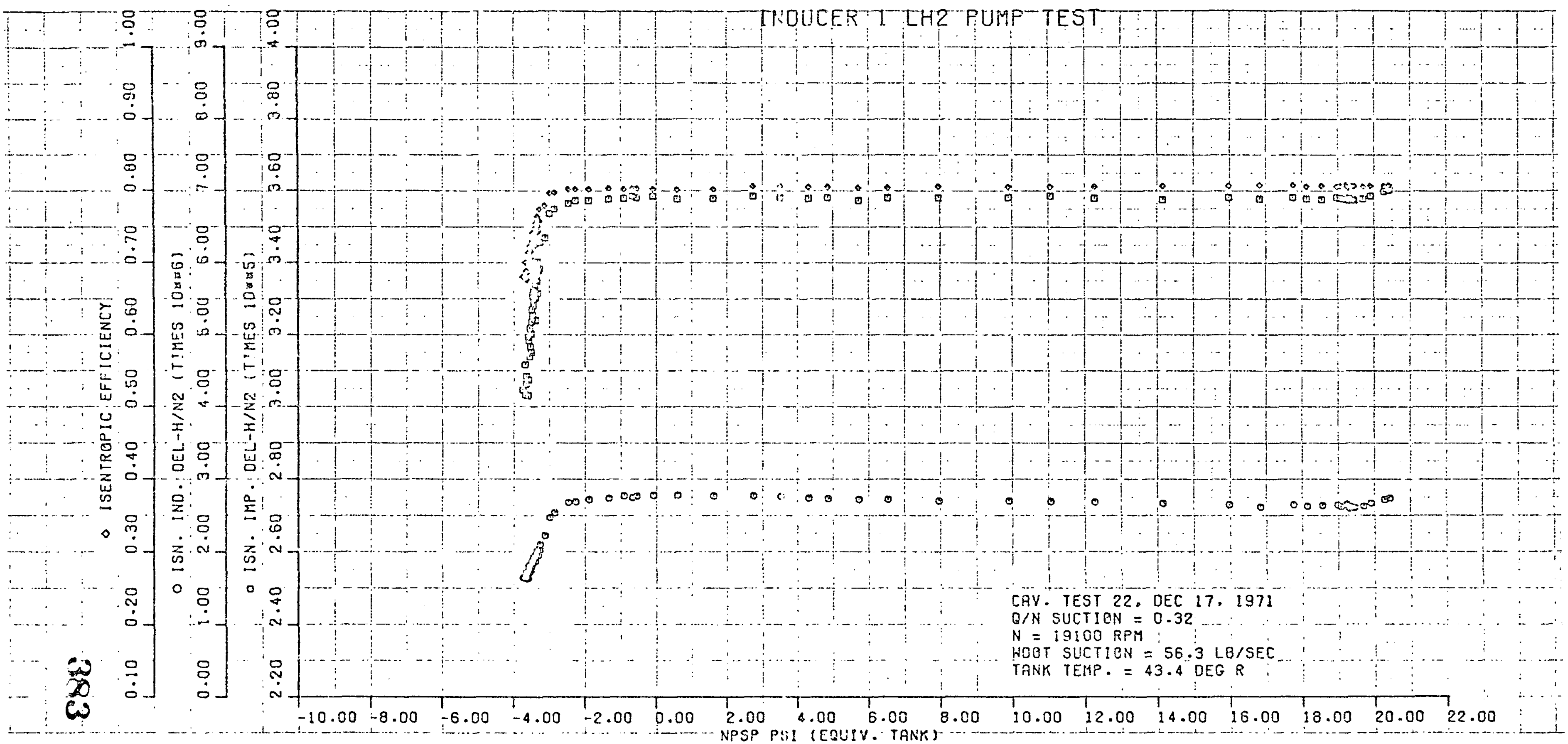
G A N M A CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
22.0 24.0 26.0 28.0 30.0 32.0 34.0 36.0 38.0 40.0
-0.100 0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40
CAV. TEST 21C, DEC 17, 1971
Q/N SUCTION = 0.23
N = 24100 RPM
WDOT SUCTION = 53.5 LB/SEC
TANK TEMP. = 39.4 DEG R


INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 21C, DEC 17, 1971
Q/N SUCTION = 0.23
N = 24100 RPM
WDOT SUCTION = 53.5 LB/SEC
TANK TEMP. = 39.4 DEG R

381

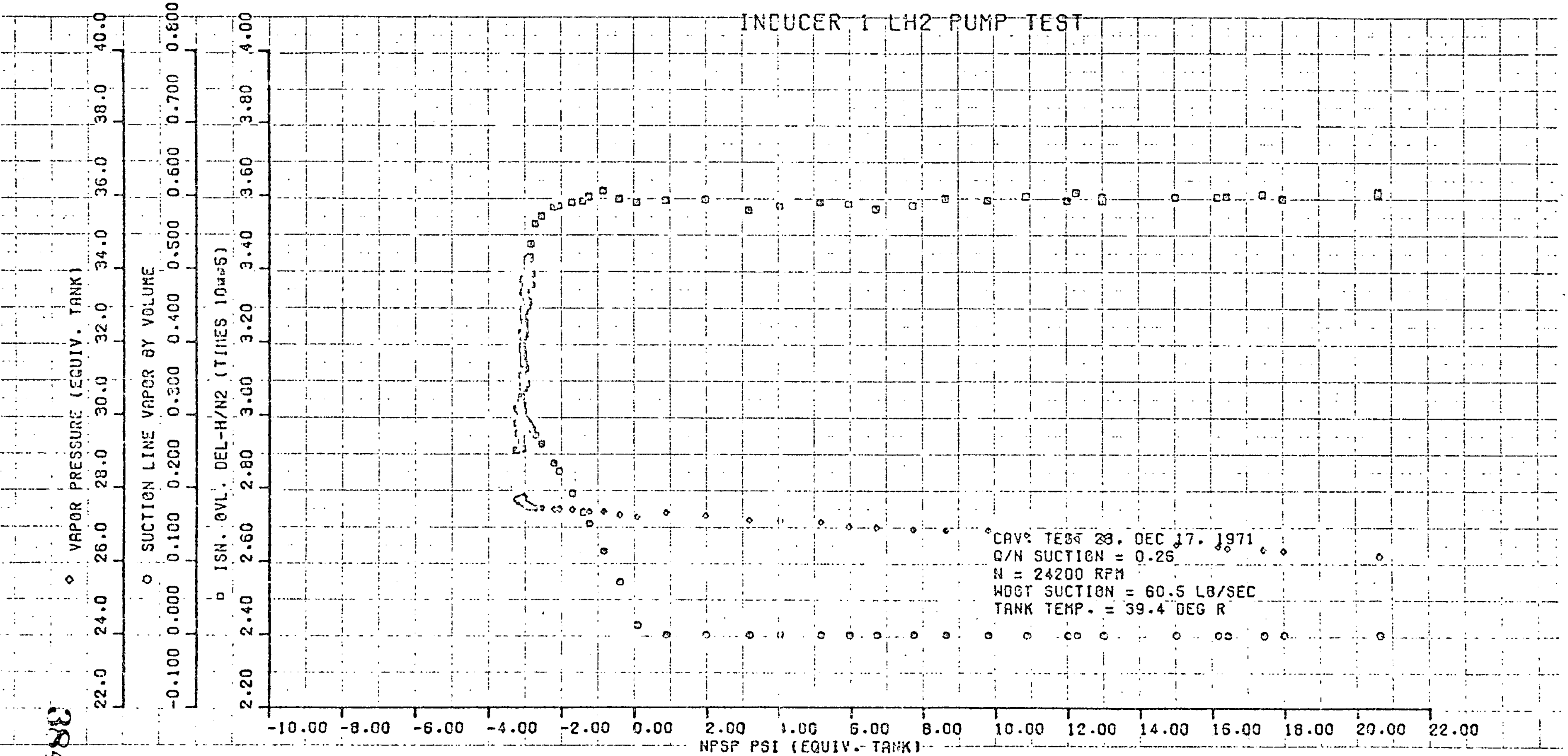

INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP FSI (EQUIV. TANK)
CAV. TEST 22, DEC 17, 1971
Q/N SUCTION = 0.32
N = 19100 RPM
WDOT SUCTION = 56.3 LB/SEC
TANK TEMP. = 43.4 DEG R



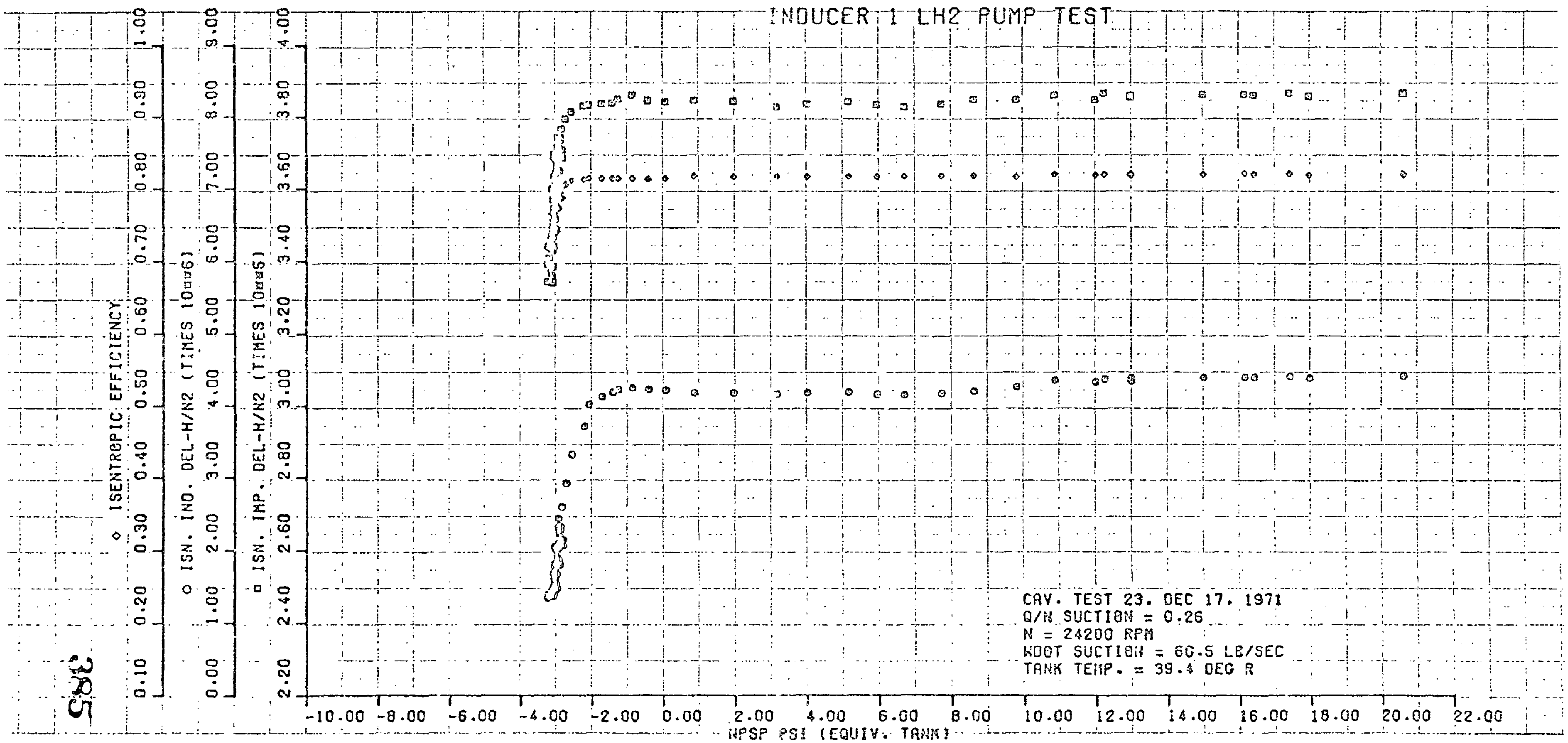
383

GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02

G1

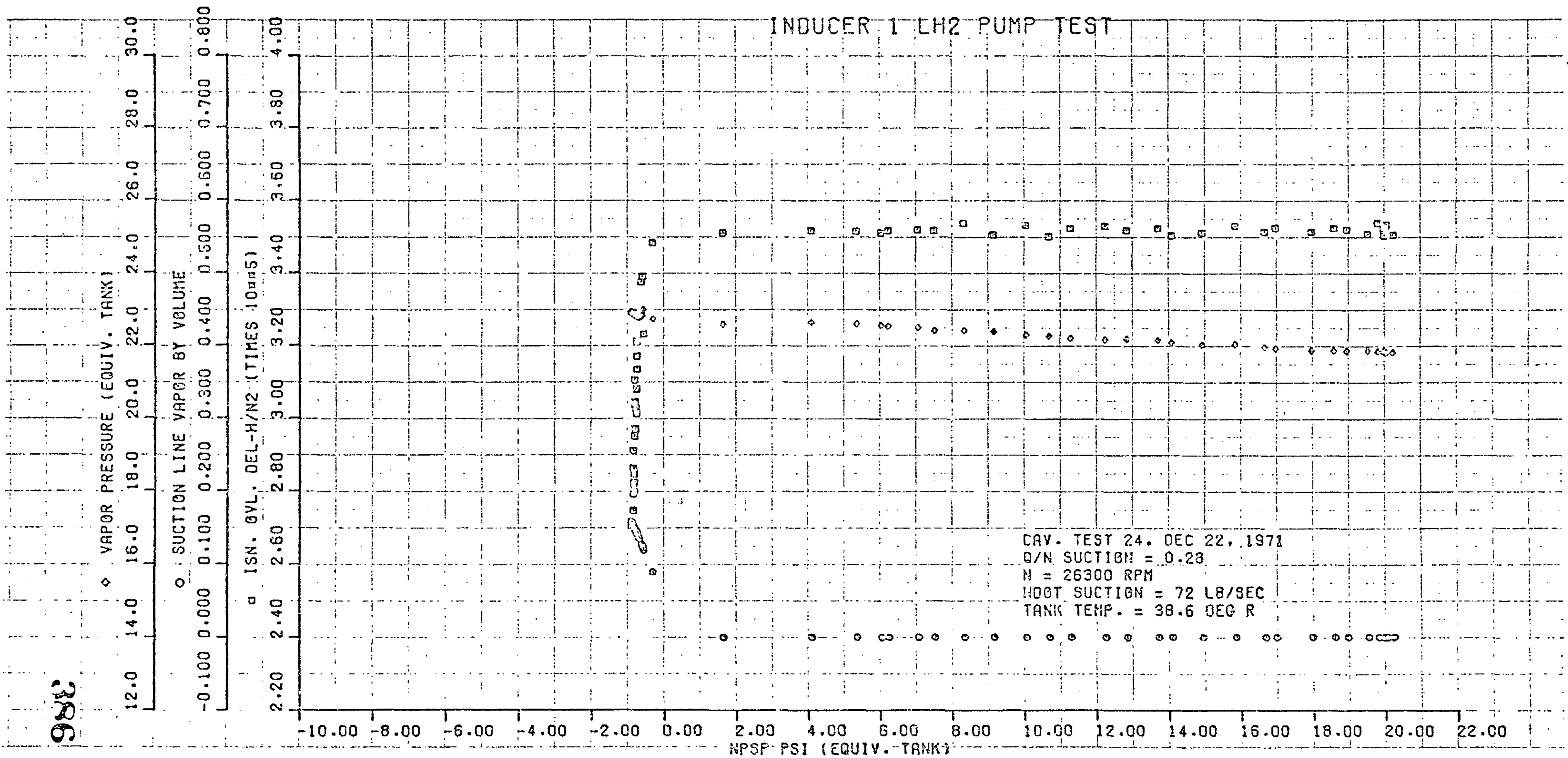


GALMA CO. SANTA CLARA, CALIF. CHART No. 12-02



385

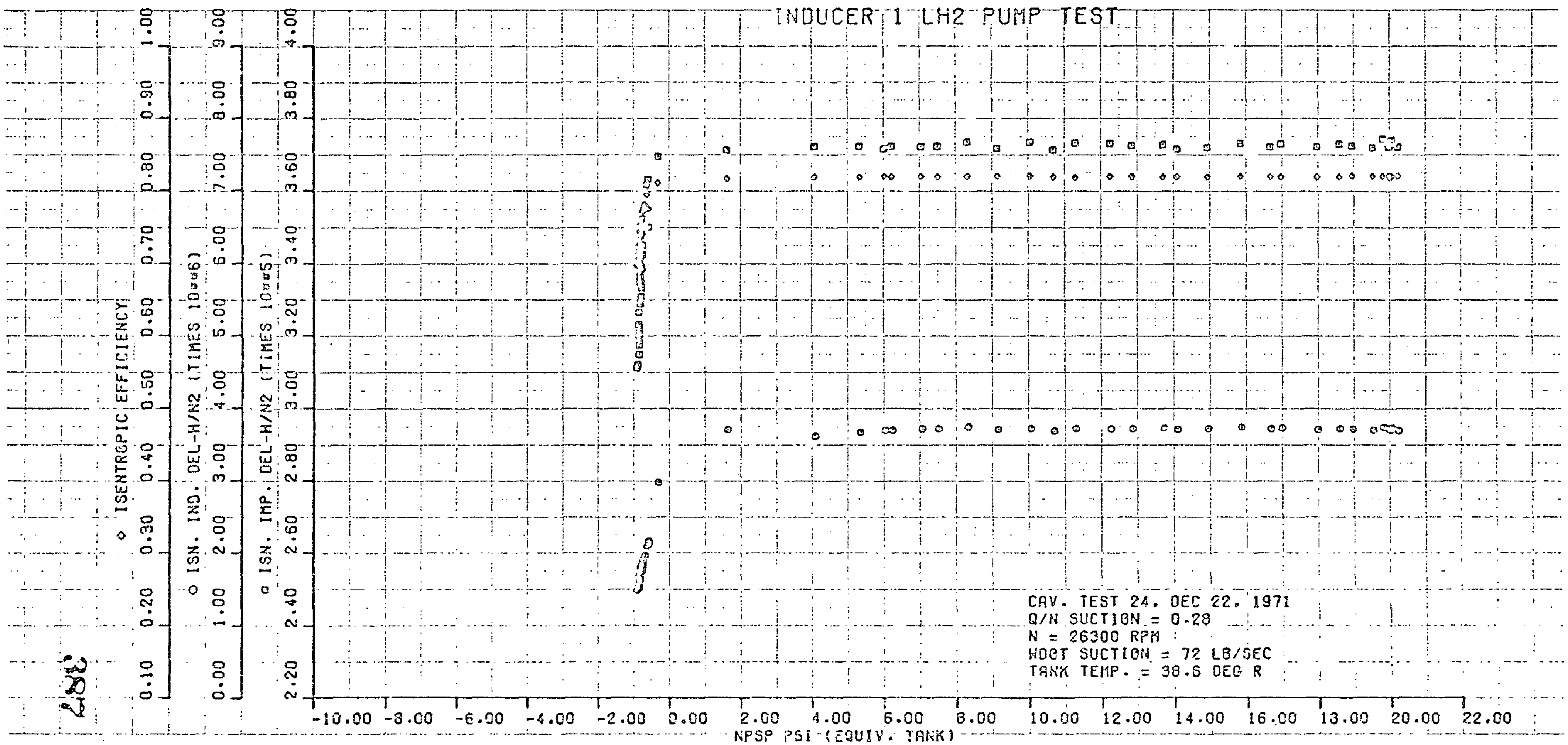
CHART No. 12-02

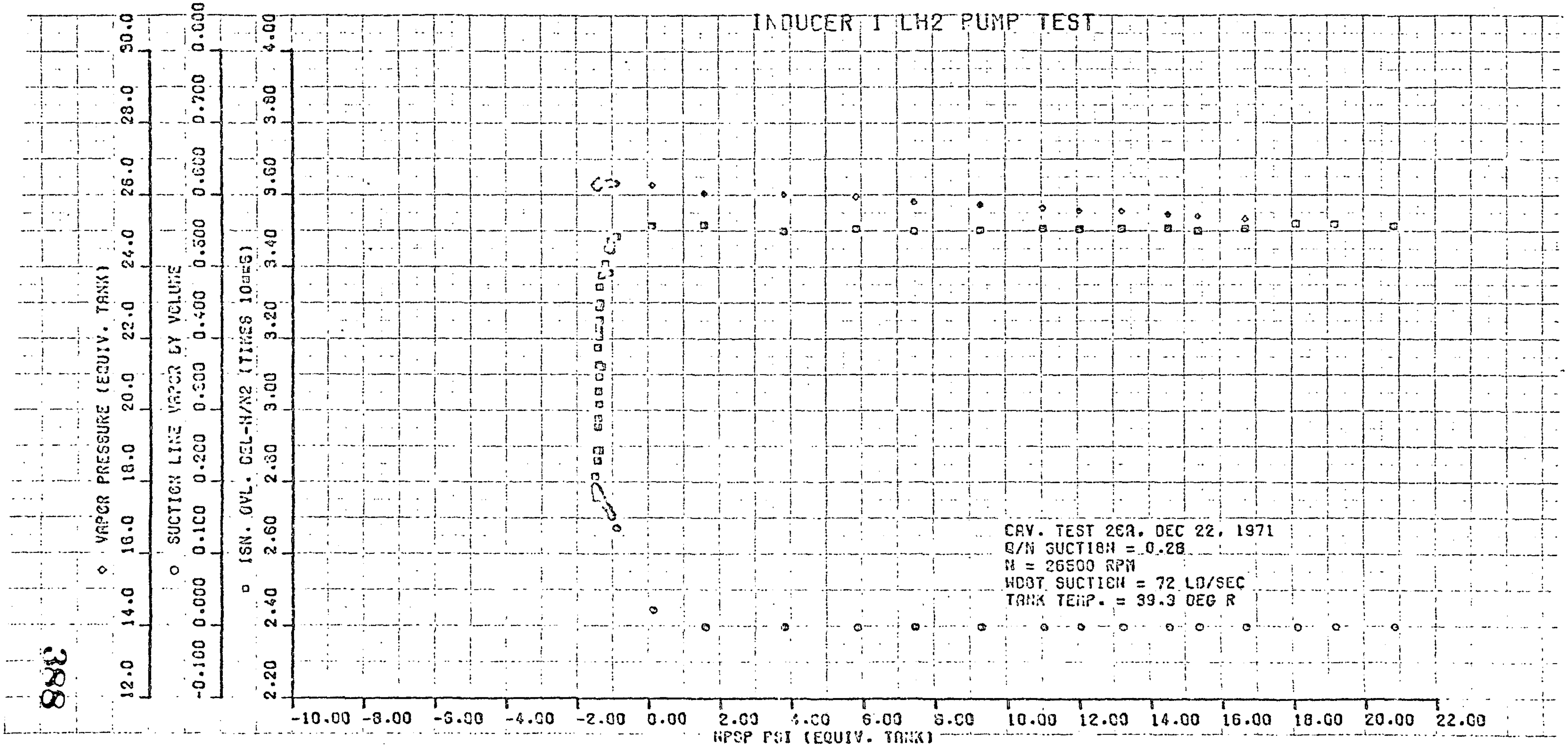


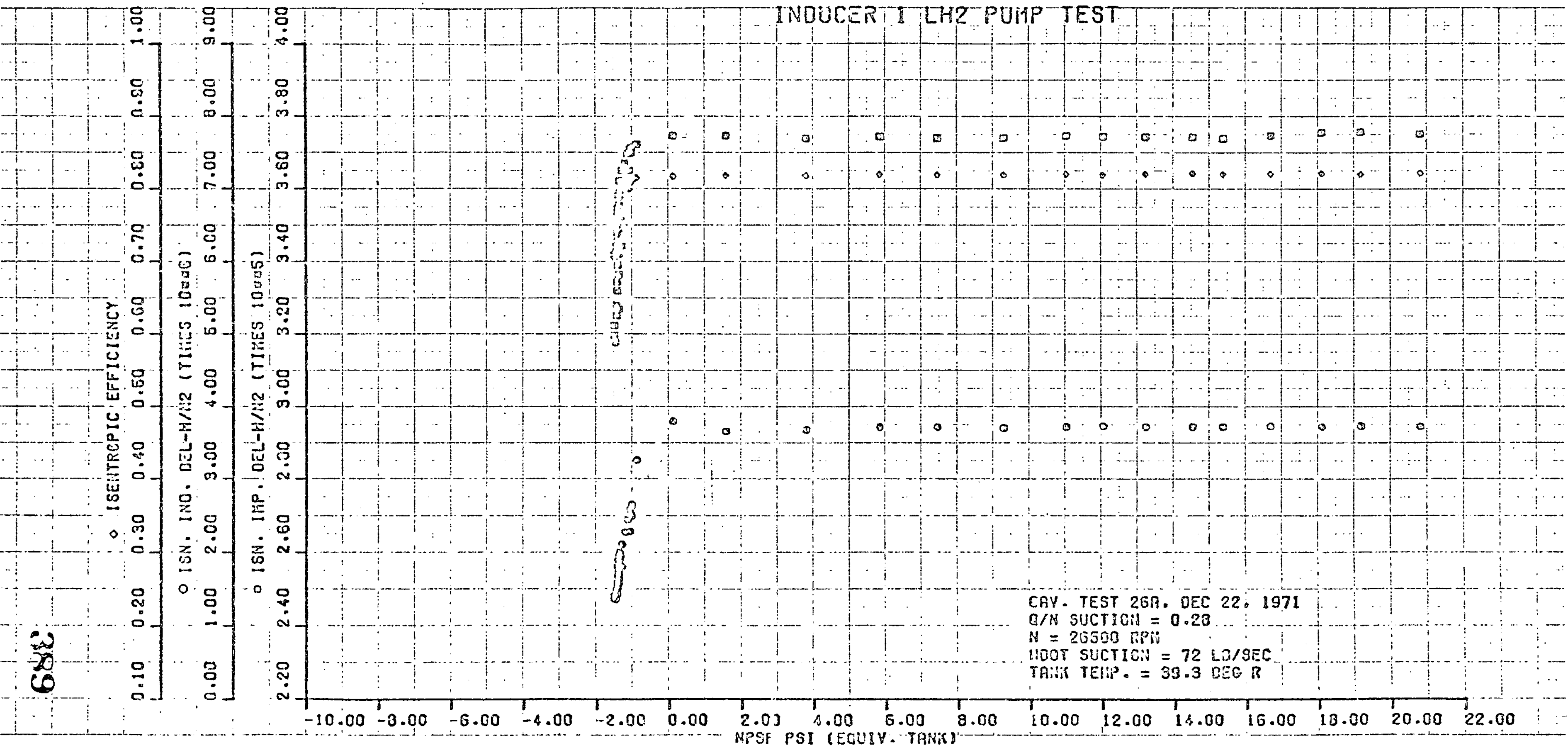
386

CHART No. 12-02

CHART No. 12-02

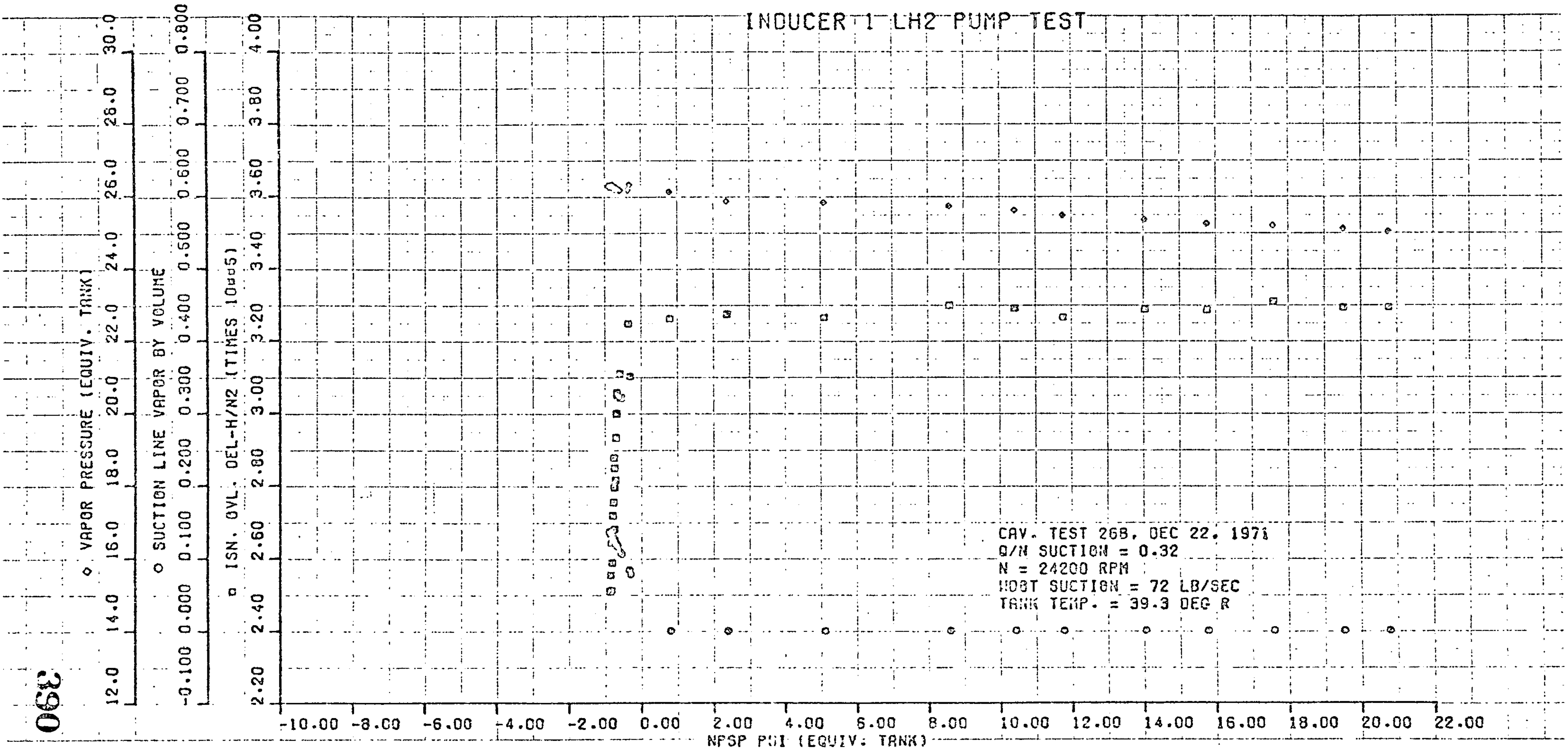

INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 24, DEC 22, 1971
Q/N SUCTION = 0.28
N = 26300 RPM
WDOT SUCTION = 72 LB/SEC
TANK TEMP. = 38.6 DEG R
387


INDUCER I LH2 PUMP TEST
◇ VAPOR PRESSURE (EQUIV. TANK)
○ SUCTION LINE VAPOR BY VOLUME
□ ISN. OVL. CEL-H/N2 (TIMES 10**6)
CAV. TEST 26A, DEC 22, 1971
Q/N SUCTION = 0.28
N = 26500 RPM
WDOT SUCTION = 72 LB/SEC
TANK TEMP. = 39.3 DEG R
NPSP PSI (EQUIV. TANK)
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
388

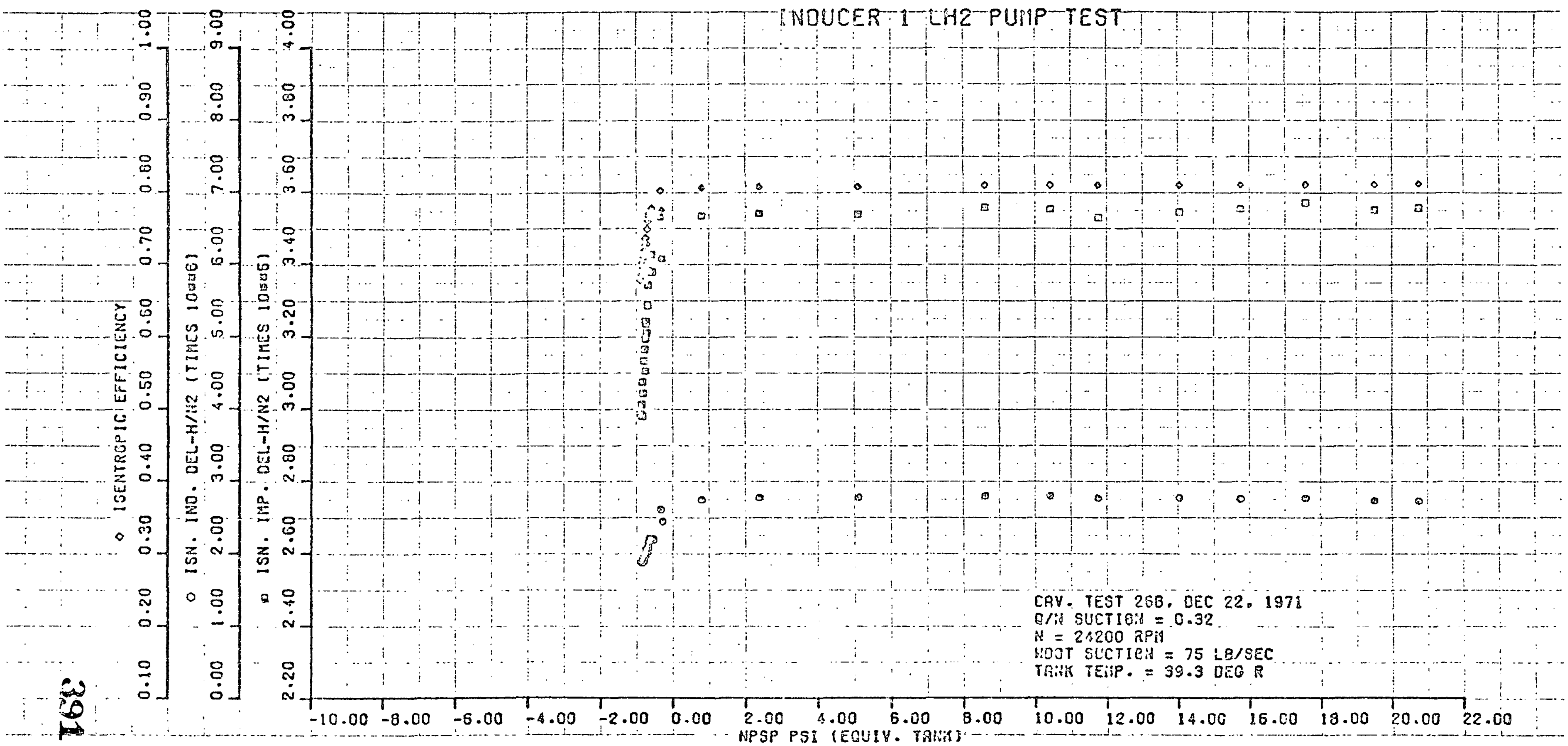


INDUCER I LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSF PSI (EQUIV. TANK)
CAV. TEST 26A. DEC 22, 1971
Q/N SUCTION = 0.28
N = 26500 RPM
WDOT SUCTION = 72 LB/SEC
TANK TEMP. = 39.3 DEG R

389

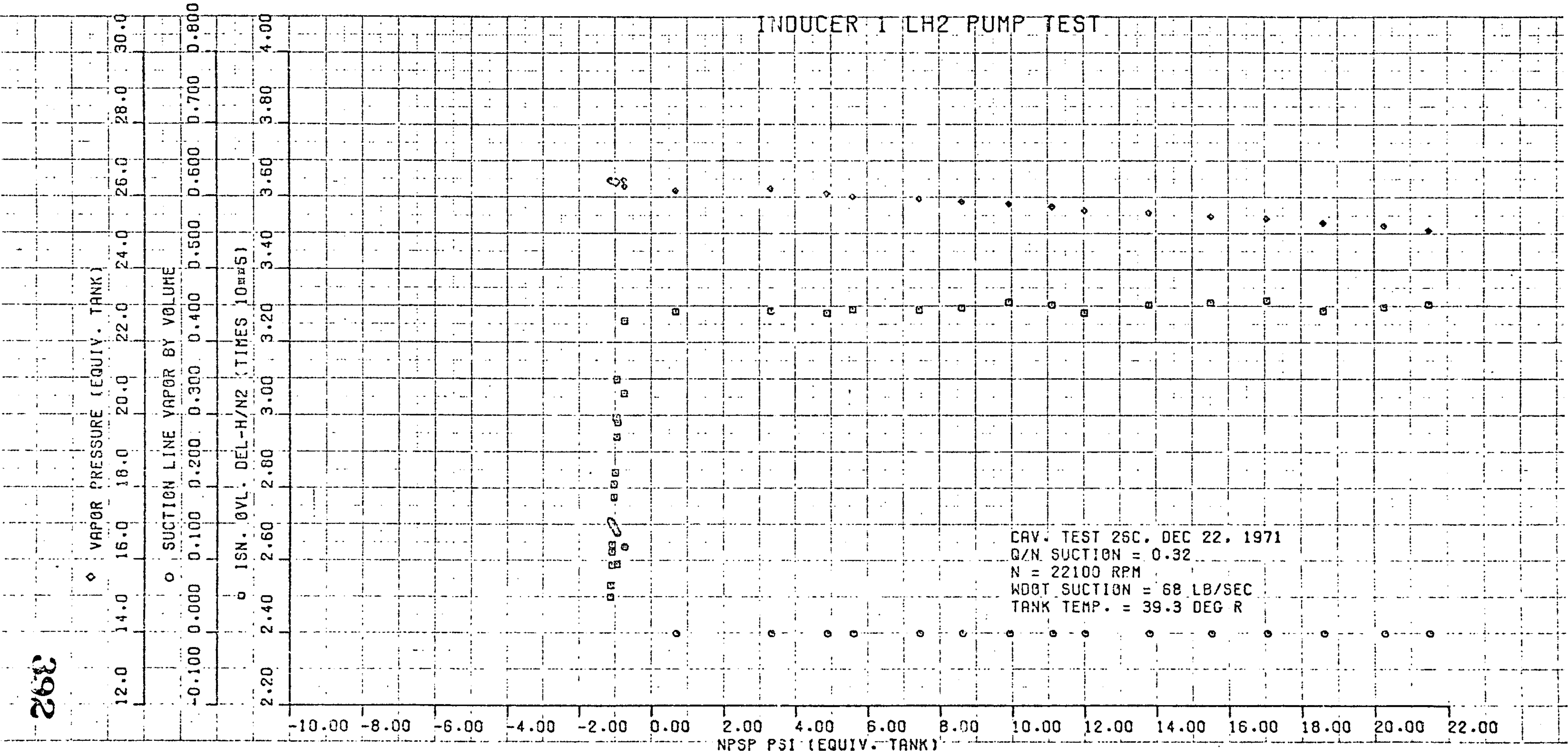

INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
CAV. TEST 26B, DEC 22, 1971
Q/N SUCTION = 0.32
N = 24200 RPM
WDOT SUCTION = 72 LB/SEC
TANK TEMP. = 39.3 DEG R
NPSP PSI (EQUIV. TANK)

390



INDUCER 1 LH2 PUMP TEST
◇ ISENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/H2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 26B, DEC 22, 1971
Q/N SUCTION = 0.32
N = 24200 RPM
WDOT SUCTION = 75 LB/SEC
TANK TEMP. = 39.3 DEG R

391


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 26C, DEC 22, 1971
Q/N SUCTION = 0.32
N = 22100 RPM
WDOT SUCTION = 68 LB/SEC
TANK TEMP. = 39.3 DEG R
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
-0.100
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
2.20
2.40
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00

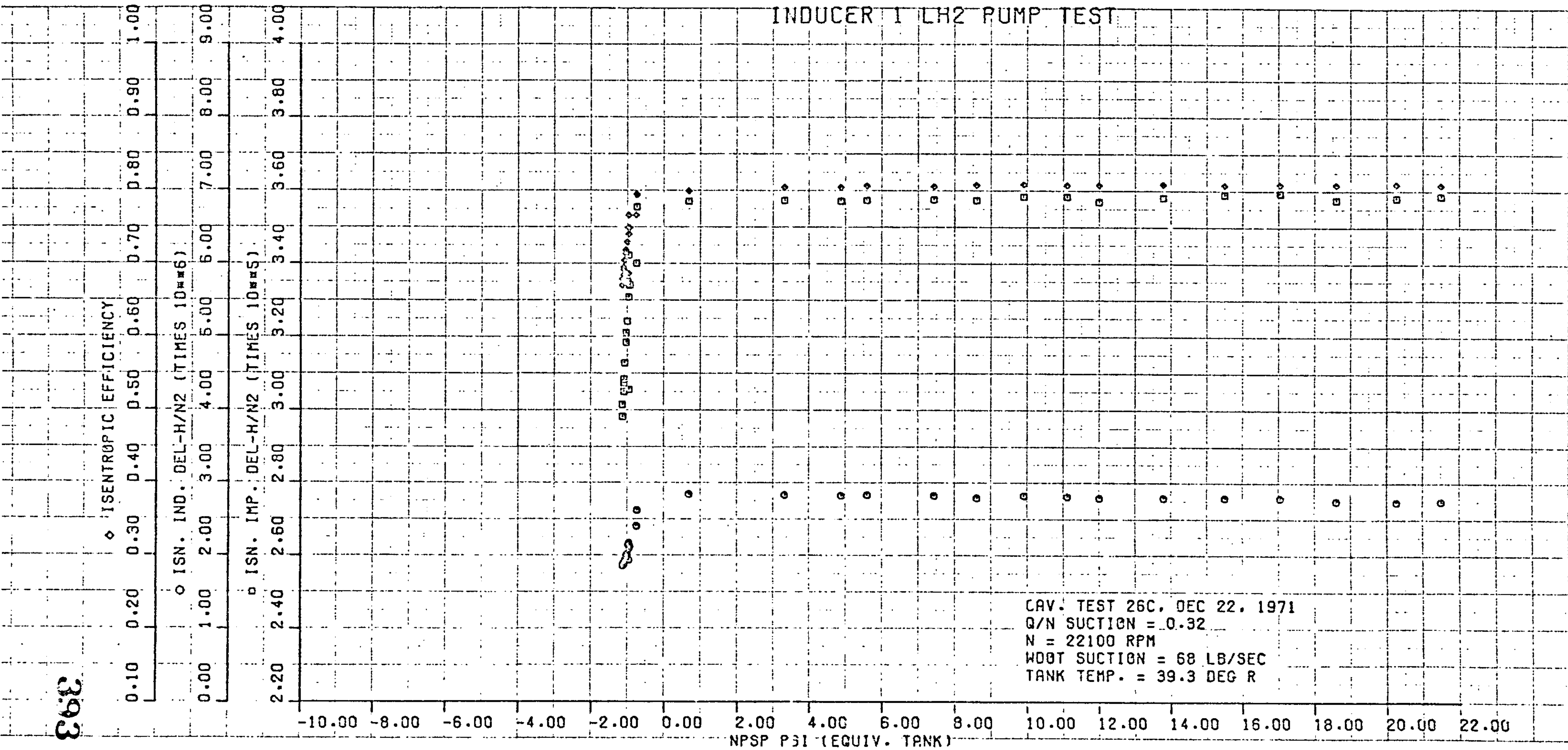


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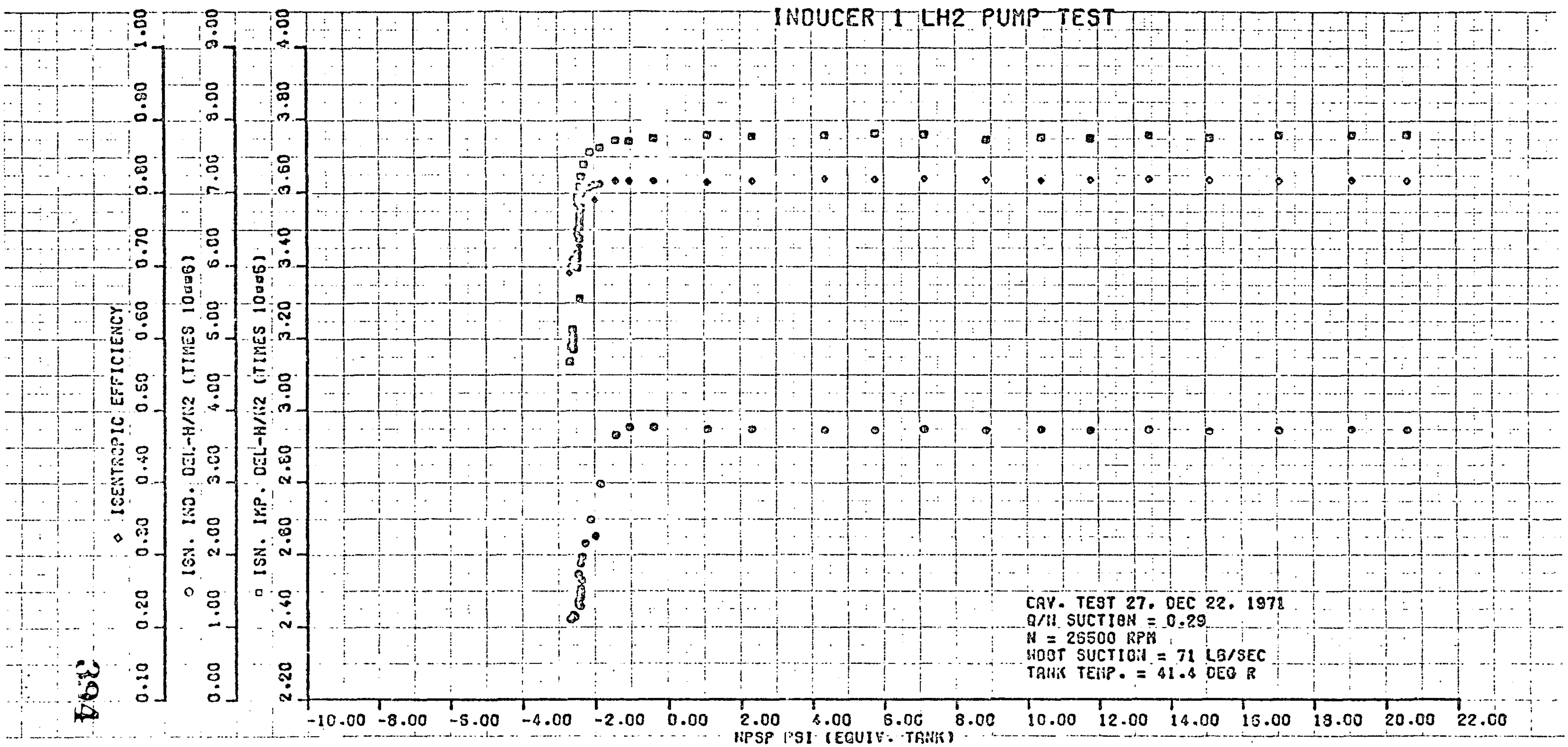
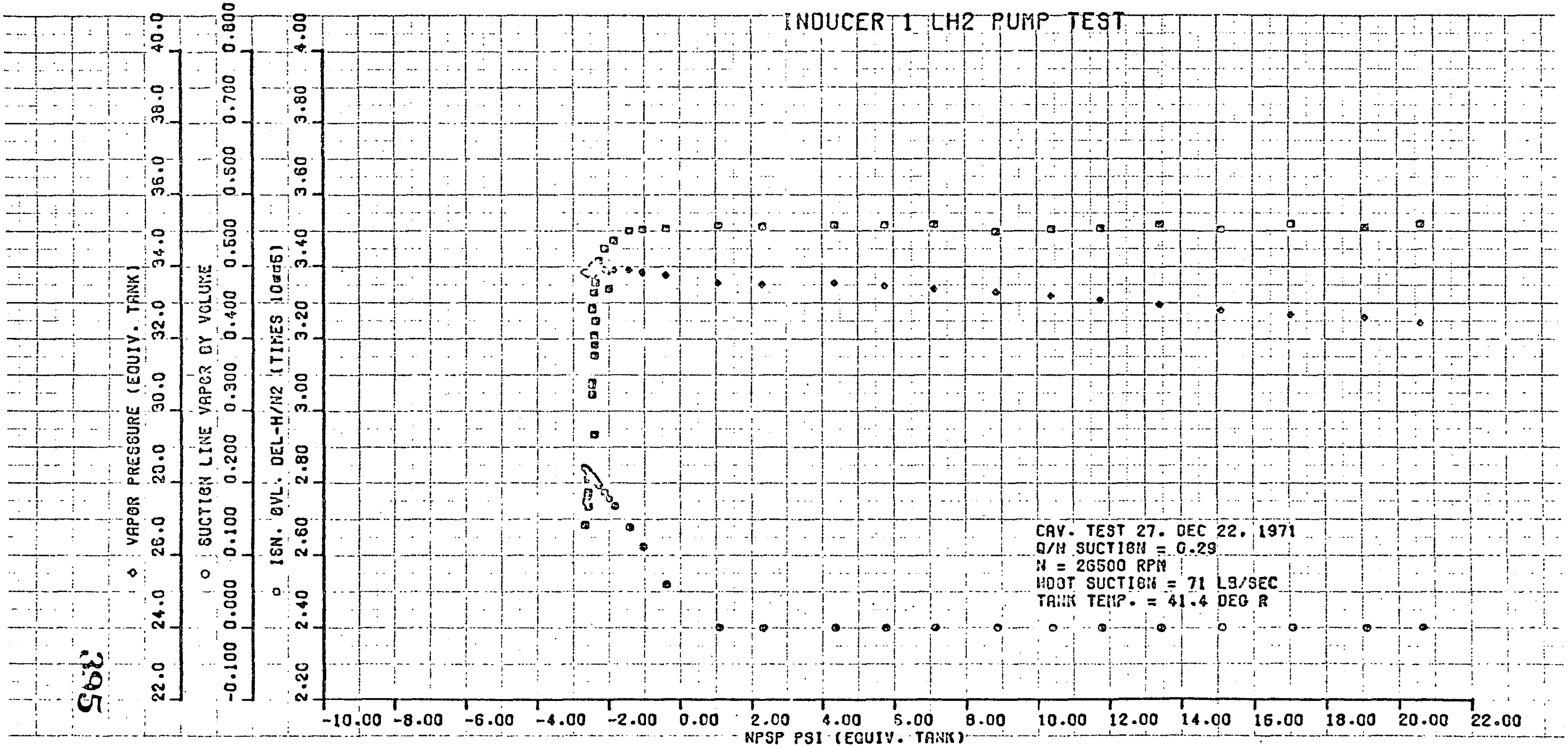
CHART No. 12-02

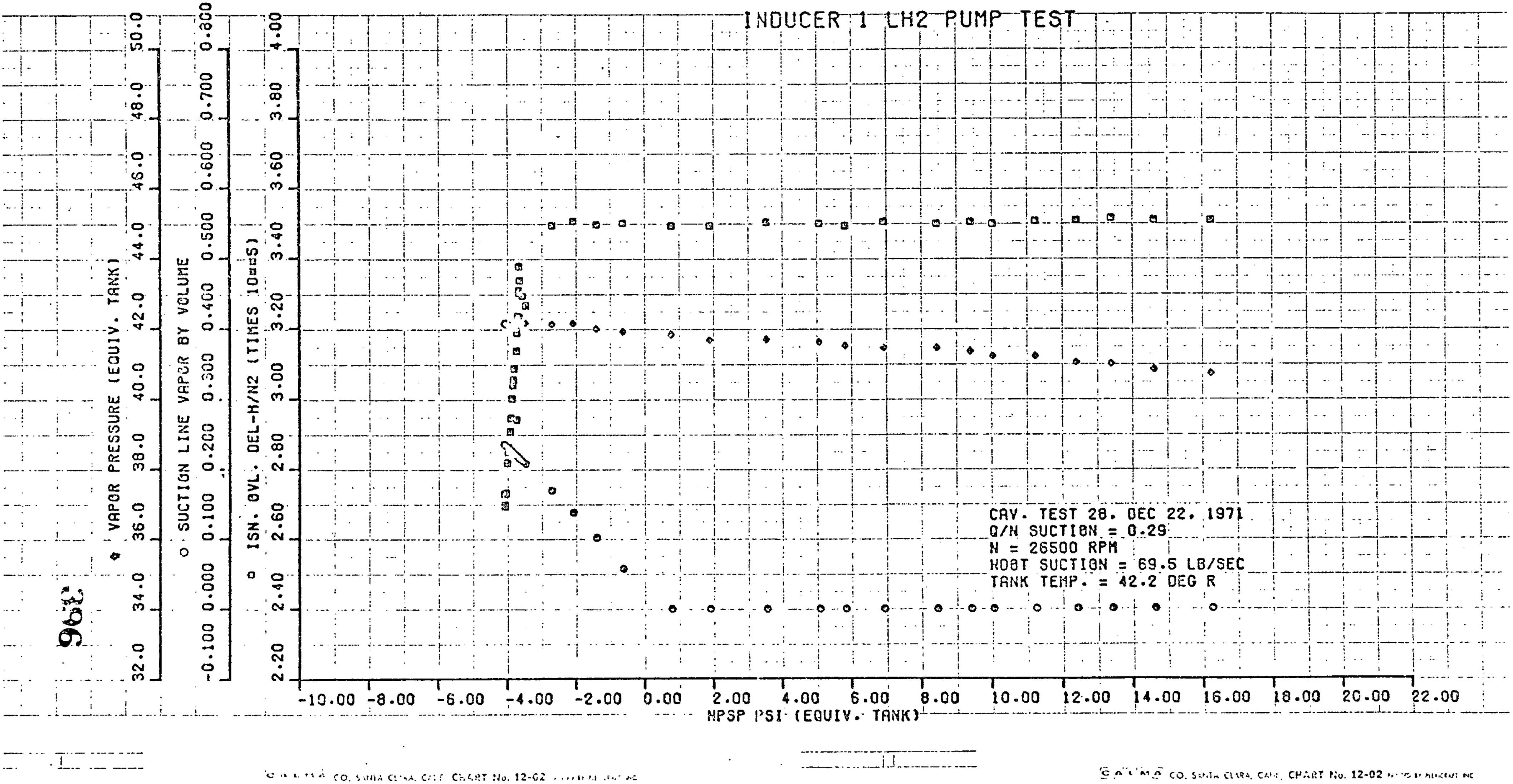

INDUCER 1 LH2 PUMP TEST
◇ ICENTROPIC EFFICIENCY
○ ISN. IND. DEL-H/N2 (TIMES 10**6)
□ ISN. IMP. DEL-H/N2 (TIMES 10**6)
0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00
2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00
-10.00 -8.00 -6.00 -4.00 -2.00 0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00
NPSP PSI (EQUIV. TANK)
CAV. TEST 27. DEC 22. 1971
Q/N SUCTION = 0.29
N = 26500 RPM
WDOT SUCTION = 71 LB/SEC
TANK TEMP. = 41.4 DEG R

394



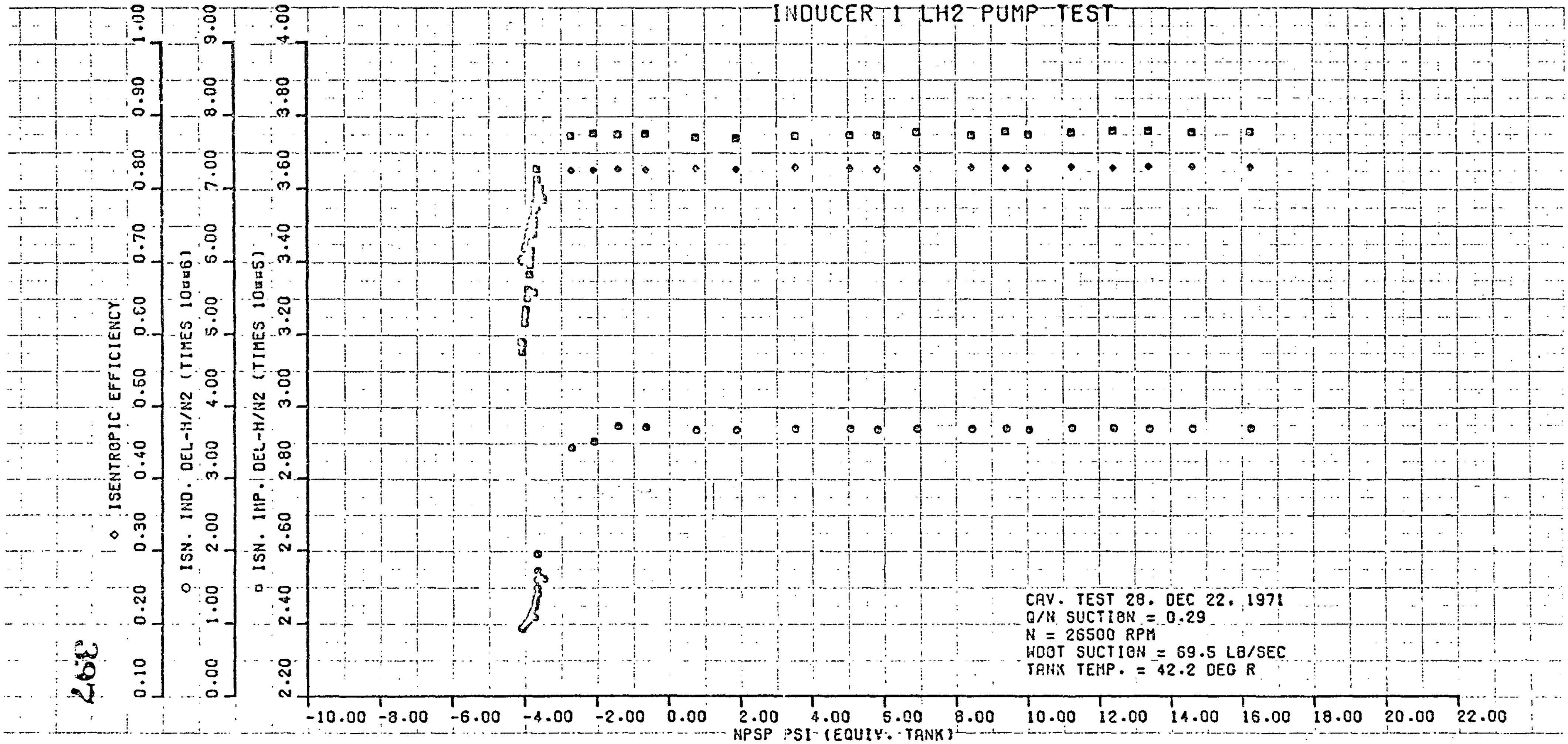
INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 27. DEC 22. 1971
Q/N SUCTION = 0.29
N = 26500 RPM
WDOT SUCTION = 71 LB/SEC
TANK TEMP. = 41.4 DEG R

395



INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 28. DEC 22. 1971
Q/N SUCTION = 0.29
N = 26500 RPM
WDOT SUCTION = 69.5 LB/SEC
TANK TEMP. = 42.2 DEG R

396



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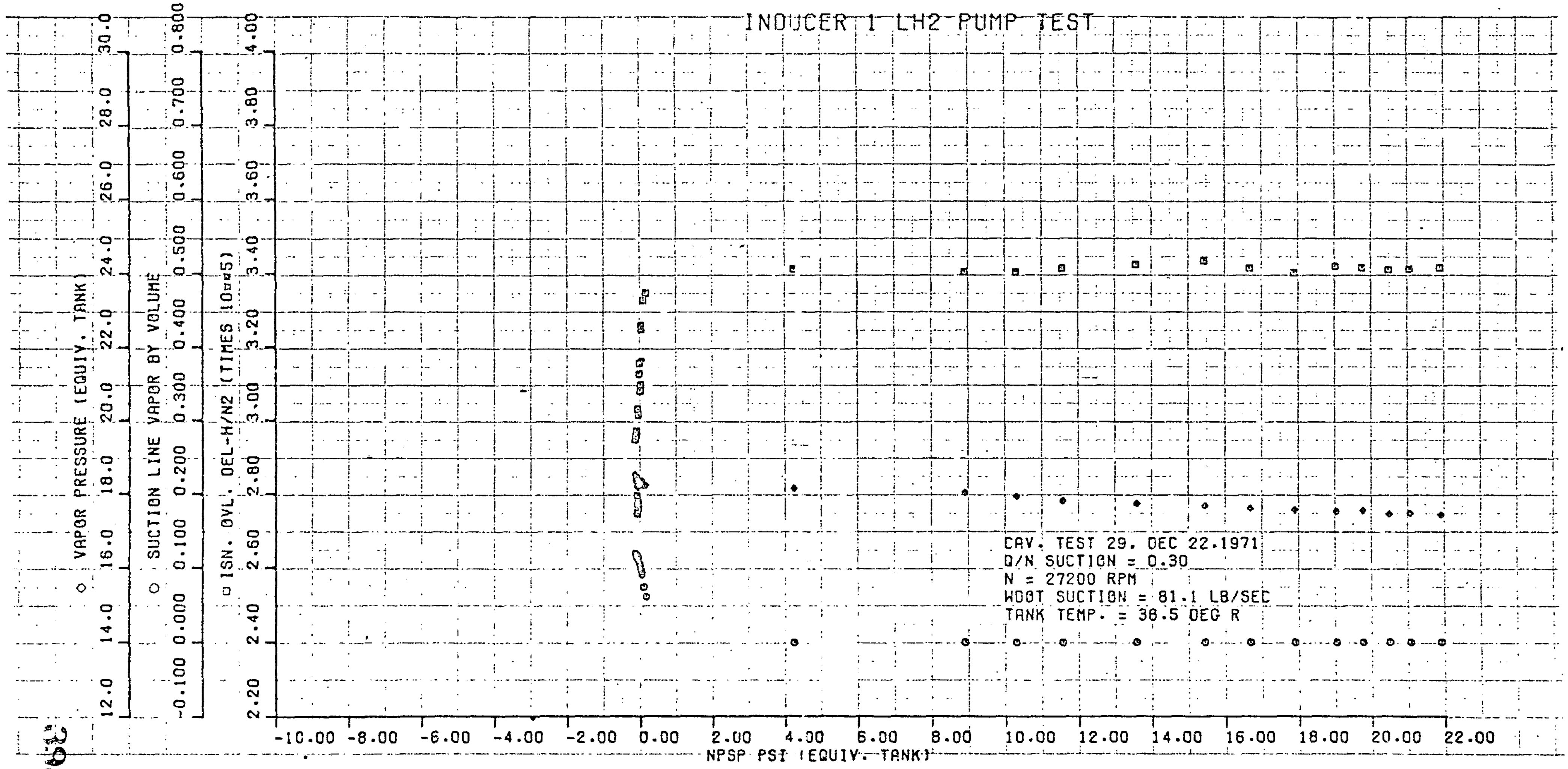
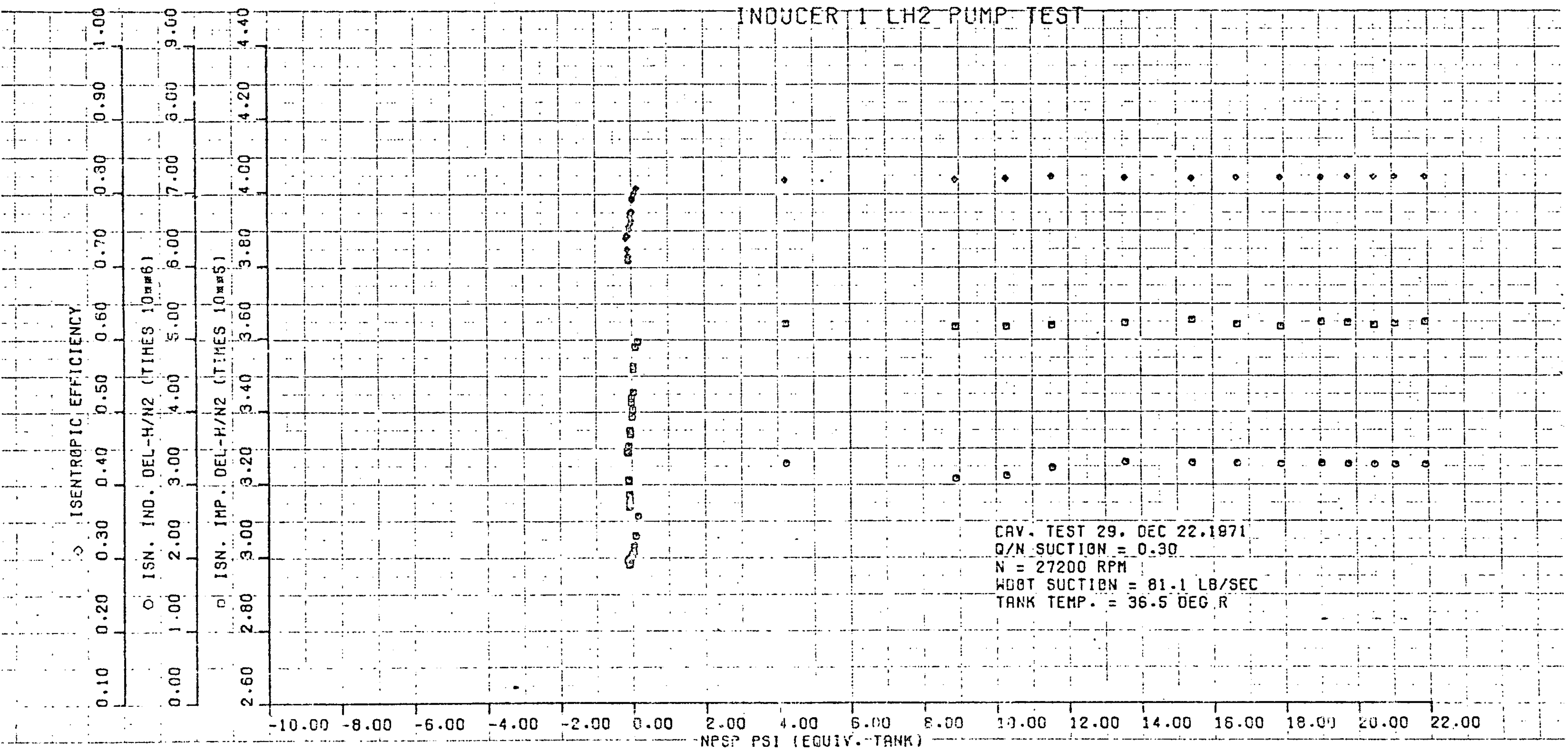
CALMA CO. SANTA CLARA, CALIF. CHART No. 12-02


INDUCER 1 LH2 PUMP TEST
VAPOR PRESSURE (EQUIV. TANK)
SUCTION LINE VAPOR BY VOLUME
ISN. OVL. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 29. DEC 22.1971
Q/N SUCTION = 0.30
N = 27200 RPM
WDOT SUCTION = 81.1 LB/SEC
TANK TEMP. = 38.5 DEG R

398


INDUCER 1 LH2 PUMP TEST
ISENTROPIC EFFICIENCY
ISN. IND. DEL-H/N2 (TIMES 10**6)
ISN. IMP. DEL-H/N2 (TIMES 10**5)
NPSP PSI (EQUIV. TANK)
CAV. TEST 29. DEC 22,1971
Q/N SUCTION = 0.30
N = 27200 RPM
WDOT SUCTION = 81.1 LB/SEC
TANK TEMP. = 36.5 DEG R