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PERFORMANCE EVALUATION TEST RESULTS

SPACECRAFT CABIN MOISTURE-REMOVAL SYSTEM 630275-1

NASA CONTRACT NAS9-4238

SS-3929

October 20, 1965

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GARRETT AIRESEARCH MANUFACTURING DIVISION
Los Angeles, California

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Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

Prepared by V. Vidugiris

Approved by W. J. O'Reilly
W. J. O'Reilly

ABSTRACT

The performance evaluation test was conducted as Phase II, Task 2 of Contract NAS9-4238 as defined in AiResearch Progress Report SS-3826-2.

The purpose of the subject test was to determine the performance of the spacecraft regenerable moisture-removal system under 14-day spacecraft mission simulation, varying the moisture injection rates. The test objectives were to determine (1) the amount of moisture that the system adsorbs, (2) dew points in and out of the system and the cabin dew-point profile, (3) bed temperatures as a function of time, (4) cycle-time effects, and (5) effects of extended cycling.

All of the test objectives listed above were met in this test, and the results are presented in this report.

ADMINISTRATIVE DATA

Purpose of test:	To determine the performance of the spacecraft regenerable moisture-removal system under 14-day spacecraft mission simulation conditions.
Manufacturer's part no.:	Cabin Water Removal System 630275-1
Quantity of items tested:	One system
Date test started:	August 16, 1965
Date test completed:	August 31, 1965
Test conducted by:	AiResearch Manufacturing Company, a division of The Garrett Corporation, Torrance, California

SECTION I

GENERAL INFORMATION

1.1 SYSTEM DESCRIPTION

The spacecraft regenerable moisture-removal system is designed to adsorb water from the spacecraft cabin gas and reject this water to space vacuum on a cyclic basis, using automatic equipment.

The system (Figure 1-1) consists of a single sorbent bed and heat exchanger unit, a motorized butterfly valve to control cabin air flow through the unit, another motorized valve to provide rejection of the water to vacuum, a check valve to isolate the system from the cabin during vacuum desorption, and a fan that provides flow through the system and additional flow about the Gemini cabin for ventilation. The coolant flows continuously through the plate-fin heat exchanger at constant temperature.

The system removes water by adsorbing moisture from the cabin gas as it passes through the sorbent bed/heat exchanger. As the moisture is adsorbed in the silica gel, a quantity of heat is liberated and transferred to the coolant in the heat exchanger passages. At a preselected time-cycle interval, the motorized valve that controls the cabin gas flow is automatically closed, allowing the check valve to close. The motorized valve controlling the vacuum duct is then opened and remains open for a designated length of time for desorption. At the end of this time period, the vacuum valve is closed, the cabin gas flow valve is opened, causing the check valve to open, and the adsorption cycle starts again.

The fan operates continuously at a gas flow rate of from 50 to 70 cfm. Most of the flow through the fan is provided by the ports located upstream of the fan. The ports are sized to allow a preselected flow rate through the sorbent bed/heat exchanger plus additional gas flow to maintain cabin gas circulation so that moisture from remote parts of the cabin may be adsorbed.

The estimated system performance is given in Table 1-1, which lists analytically derived values of temperature, flow rates, and cycle-time intervals.

1.2 COMPONENT DESCRIPTION

1.2.1 Motorized Valves

Two motorized valves are installed on one of the heat exchanger inlet plenums. One valve closes off the gas flow through the sorbent bed; the other valve opens the sorbent bed to vacuum.

The valves are 2.0-in. diameter Gemini cabin-outflow butterfly spoon valves (Part 122634-1-1), modified to accept a motor for automatic sequencing instead of the manual device. The motors are standard aircraft production-qualified actuators, modified at the mounting base to attach to the Gemini valve. The actuators have back-limit switches to facilitate automatic sequencing.

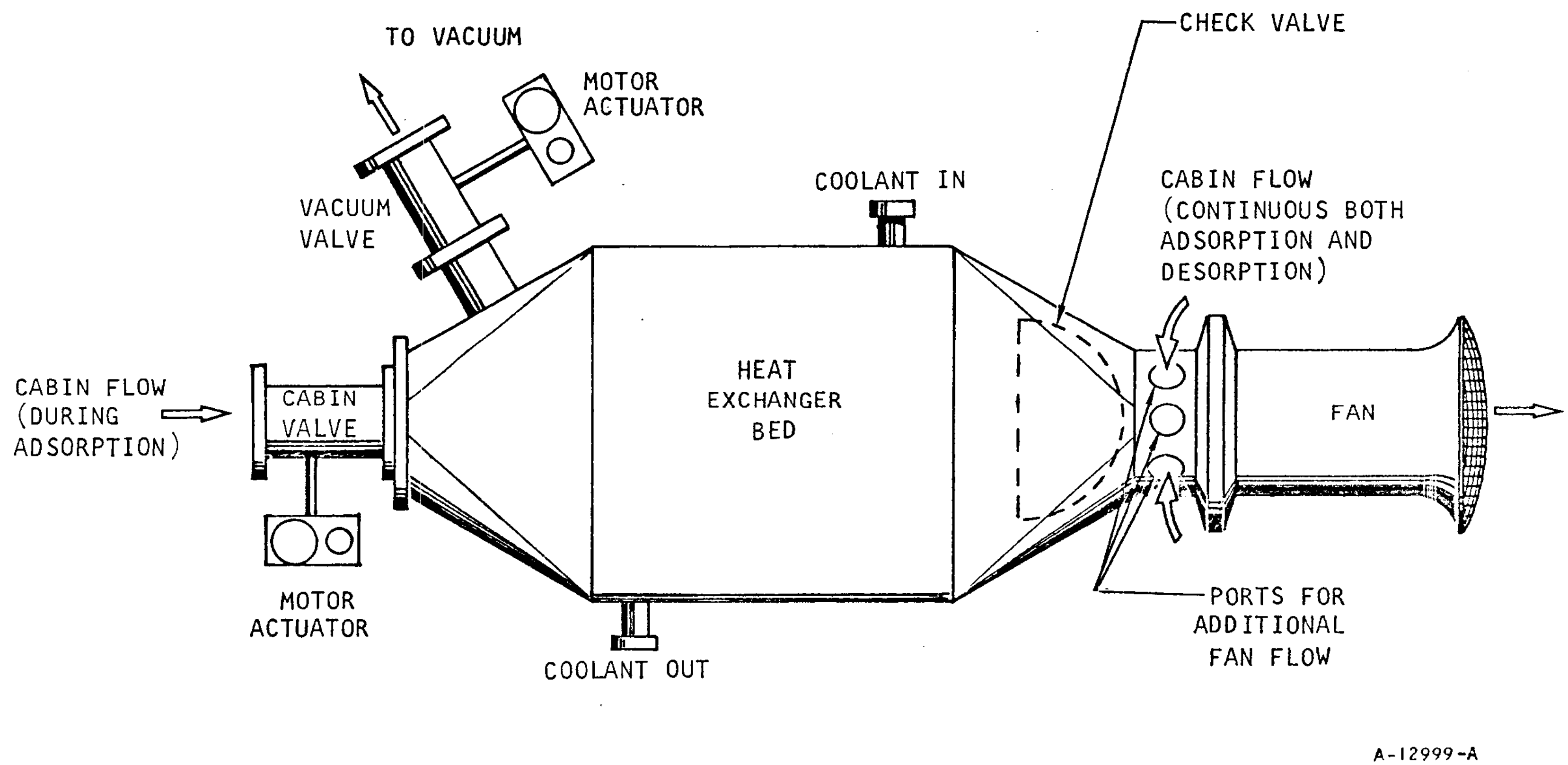

Figure 1-1. Moisture-Removal System Schematic

TABLE I-I

SYSTEM DESCRIPTION

Sorbent time cycle		
Adsorption, min	30	
Desorption, min	15	
Gas flow rate		
Sorbent bed, lb/hr	15	
Fan, cfm	50	
Coolant		
Flow, lb/hr	80	
Inlet temperature, ^{o}F	60	
Valves		
Cycle time, sec	20	
Energy		
Voltage (flight unit), v ac	115	
Voltage (R&D unit), v dc	28	
Current (both units), amp	0.5	
Valve actuation sequence		
1	Close Cabin	To desorb
2	Open Vacuum	
3	Close Vacuum	To adsorb
4	Open Cabin	

1.2.2 Check Valve

The check valve that seals the end of the sorbent bed opposite the motorized spoon valve is a production item qualified in the Gemini program and used in the suit-loop recirculating line ducts. The valve (Part 123374) is 3.0 in. in diameter and has molded O-ring seals. The check valve, which is placed in the fan plenum downstream from the heat exchanger, is designed to withstand vacuum on one side, and to seal against leakage to the point of a flow rate to vacuum of less than 0.0005 lb per min. The check valve has a cracking pressure of less than 0.5 in. H_2O.

1.2.3 Sorbent Bed/Heat Exchanger

The sorbent bed/heat exchanger used in this system closely matches the envelope of the existing Gemini cabin heat exchanger, in that it has the same external dimensions with regard to mounting provisions, length, height, and width. The gas flow openings, however, are flanged so that the fan and valve plenums can be attached to the core and the sorbent can be installed. Also, one set of fluid coolant passages, with their external connecting bosses, has been removed.

The internal configuration of the heat exchanger core is modified to allow for an increase in the number of gas passages and in the gas-passage void volume; straight fins are used in place of the offset fins to enable filling the void space with the silica gel sorbent. Pertinent heat exchanger data are given in Table 1-2.

1.2.4 Fan

The fan is a reworked production Gemini cabin fan. The power, the fan speed, and the cabin circulation condition conditions remained practically unchanged. Rework was necessary because the present configuration of the fan is required to draw gas through the sorbent bed/heat exchanger, in contrast to the previous flow-through configuration.

The fan provides 50 to 70 cfm of gas circulation in the cabin, while maintaining the design gas flow rate through the sorbent bed/heat exchanger.

1.3 TEST PROCEDURE

The test was conducted in accordance with the procedure stipulated in AiResearch Progress Report SS-3826-2, Pages 3-6, 3-7, and 3-8. Detailed procedures are described in Section 2.

TABLE 1-2

HEAT EXCHANGER DESCRIPTION

Size, external	
Height, in.	4.5
Length, in.	5.5
Width, in.	6.5
Size, internal	
Number of gas passages	12
Fin height, in.	0.25
Fin width, in.	0.25
Fin-plate width, in.	6.45
Fin-plate length, in.	5.25
Total sorbent volume, cu in.	100
Face area, sq in.	19.4
Area to length ratio, in.	3.68
Material	
Stainless steel	
Coolant loop	
Number of loops	1
Sorbent	
Weight, lb	2.65
Moisture content, lb	0.265
Residence time, sec	0.4

SECTION 2

TEST SETUP AND INSTRUMENTATION

2.1 GENERAL

The test specimen installation inside the vacuum chamber is shown schematically in Figure 2-1 and pictorially in Figure 2-2. Figure 2-3 shows the overall test setup including dew-point analyzers, coolant cart, control console, and vacuum chamber. The condenser that was built for this test to freeze the water during desorption cycles is shown in Figure 2-4. Twenty-seven parameters were recorded during the test, utilizing a Digital Data Acquisition System. In the following paragraphs the special equipment and instrumentation used during the test are briefly described.

2.2 SYSTEM TEST CONTROL CONSOLE

The system test control console was used to initiate commands to the fan, the systems shutoff valves, and the remotely actuated test valves and also to control water injection rates into the chamber and heat inputs. Instrumentation for visual monitoring was provided for certain parameters--e.g., fan voltage and amperage, chamber pressure, valve voltage and amperage, heater wattage, etc. The electrical schematic of the control console and the test setup is shown in Figure 2-5.

2.3 DEW-POINT ANALYZER

Dew points were obtained by utilizing AiResearch dew-point analyzers. Through the network of toggle valves located in the control console, it was possible to select various samples. To eliminate the possibility of water vapor condensing in the sampling lines, line heating elements and insulators were used in addition to thermal insulators on all bulkhead fittings. Dew points were recorded on a Brown Multipen recorder. Figure 2-6 presents a schematic of the pressure and dew-point sampling points.

2.4 COOLANT CART

A coolant cart was used to provide the necessary cooling for system operation. By means of an automatic control system, any preselected coolant temperature between -70°F and 200°F can be achieved. For this test the coolant temperature at the heat exchanger inlet was maintained at a nominal 60°F and the flow at 80 lb per hr. Monsanto MCS-198 fluid was used as the coolant medium.

2.5 VALVE ACTUATION

Remote actuation was incorporated on all valves to control the system and to achieve different modes of operation (adsorb-desorb). All signals for these actuations were originated at the control console.

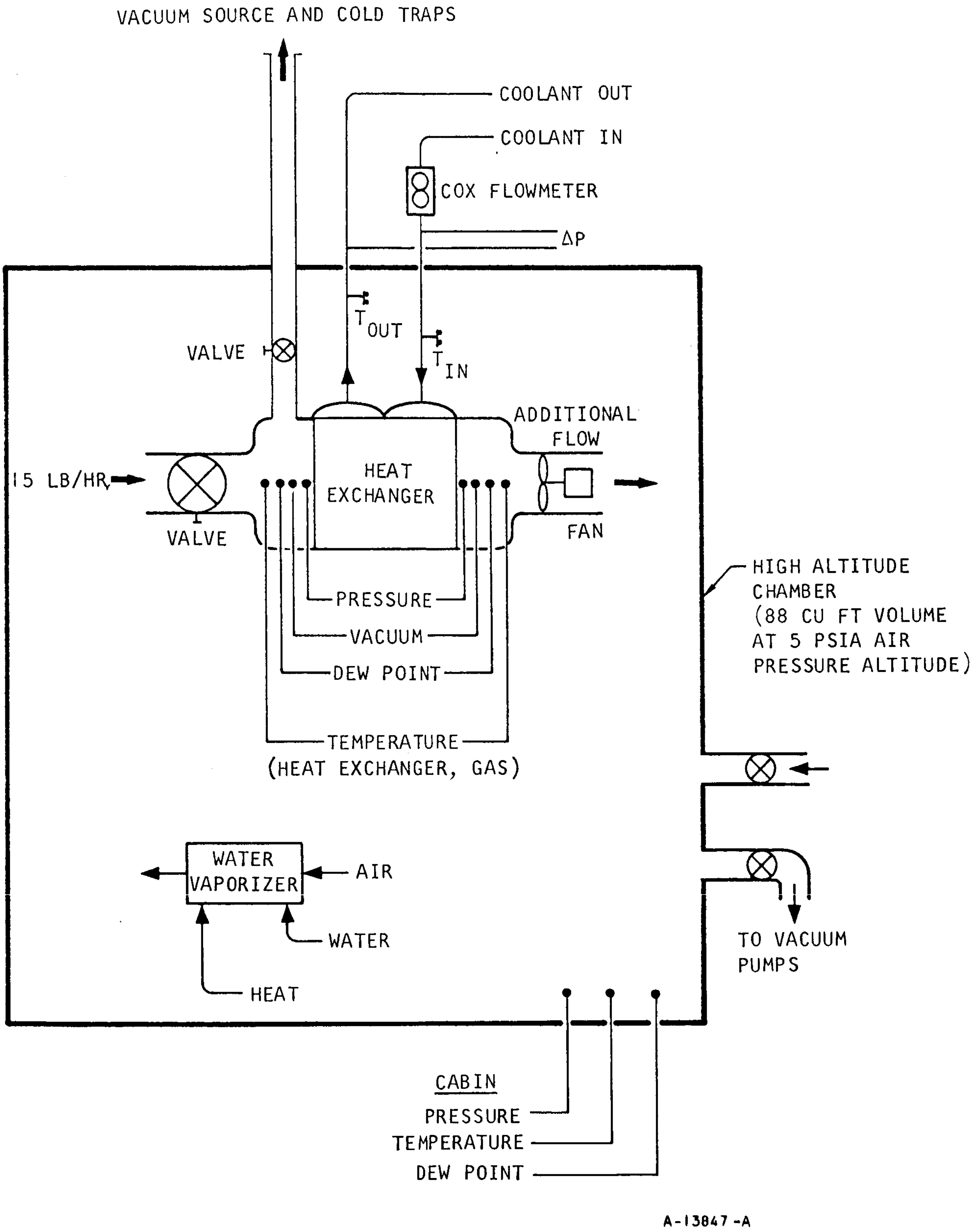

Figure 2-1. Development Test Setup Schematic

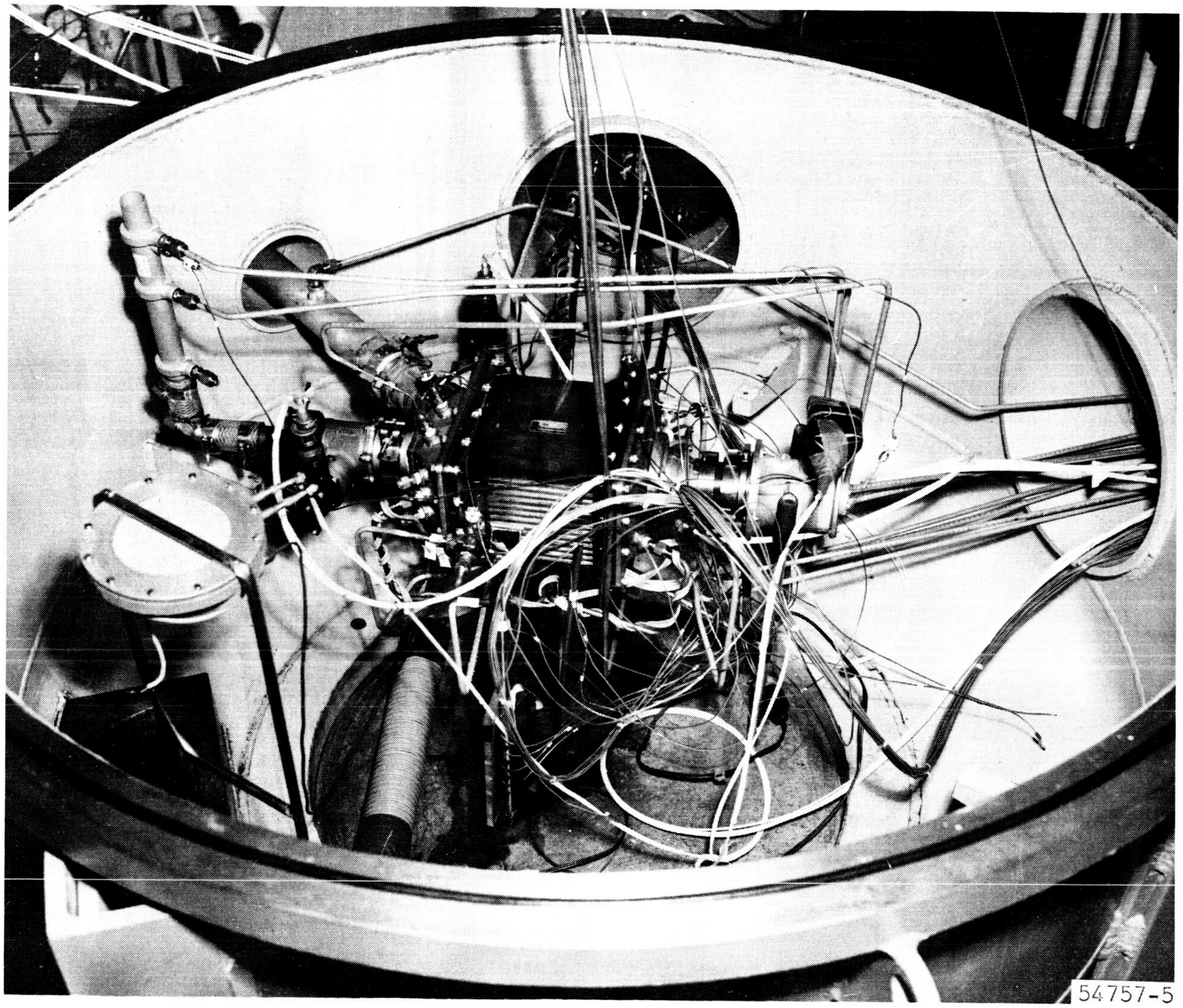

Figure 2-2. Installation of the Test Specimen Inside the Vacuum Chamber (P/N 630275-1)

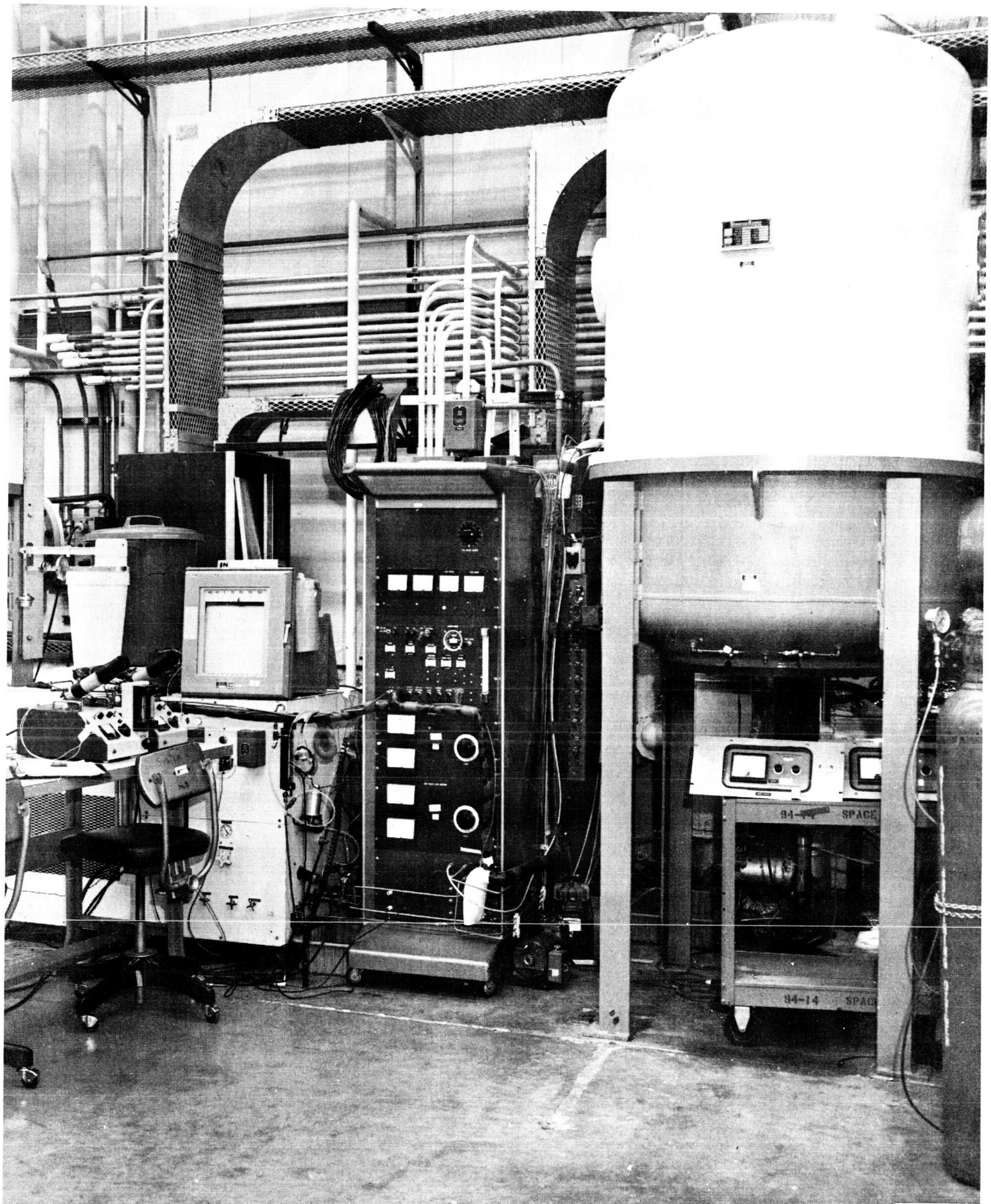

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Figure 2-3. Overall Test Setup, Cabin Moisture Adsorption System (P/N 630275-1)

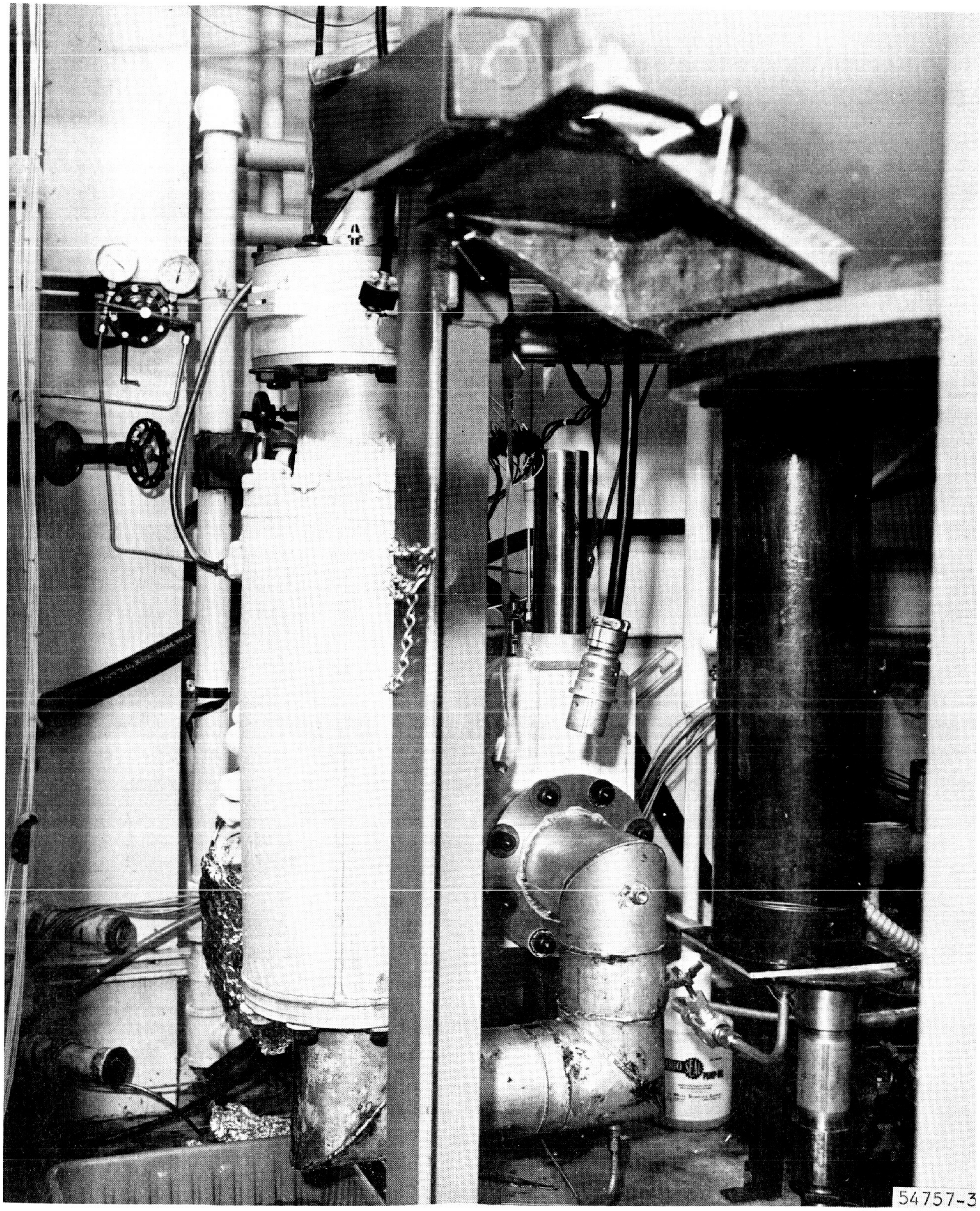

Figure 2-4. Condenser Installation

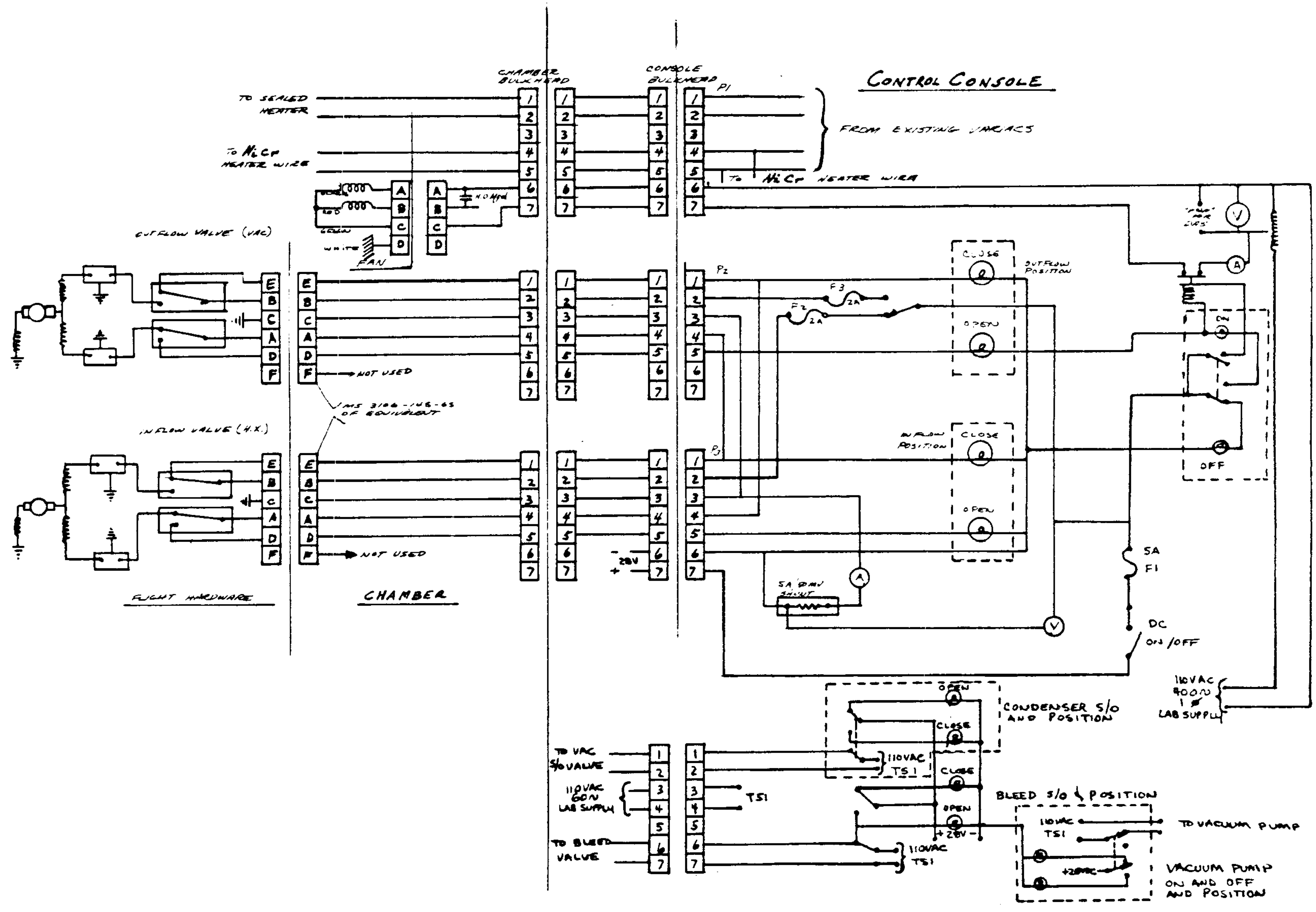

Figure 2-5. Electrical Schematic for Cabin Moisture-Removal System

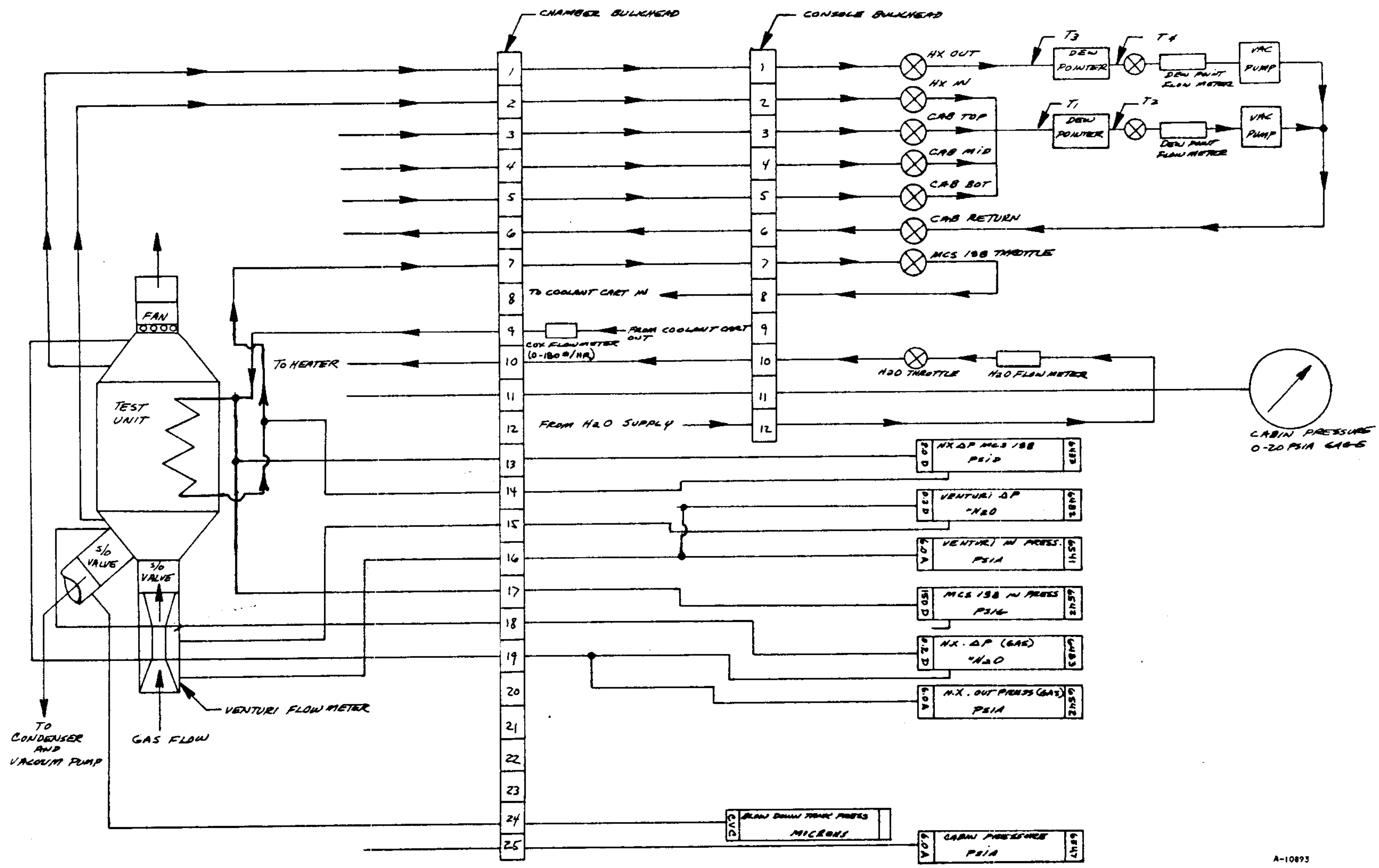

Figure 2-6. Schematic for Pressure Transducer and Dew-Point Analyzer Installation

2.6 WATER EVAPORATOR

The water was injected into the chamber in the vapor form by utilizing a porous vessel with an integral heater element. Heat load into the heater was controlled by a Variac and monitored with panel meters located on the console. A flowmeter was used to monitor water injection rates with backup readings of weight reduction of the water source.

2.7 INSTRUMENTATION

Provision was made to automatically record the data listed in Table 2-1 from instrumentation located as shown in Figures 2-6 and 2-7, by means of a Digital Data Acquisition System. In addition, the visual readout instrumentation shown on the system control panel was used for setting conditions and was also manually recorded as a backup for the DDAS.

The Digital Data Acquisition System (DDAS) gathers, conditions, digitizes, and records the necessary test information. The system gathers information through variable-reluctance pressure transducers, premium grade temperature thermocouples, and a Cox turbine flowmeter. The signals are transmitted through high-grade, low-capacity, double-shielded cables to a multiplexer which commutates the information into a time-sharing schedule. From there, the signal-conditioning units reduce all parameters to a uniform voltage input to the analog-to-digital converter, which converts the information in a binary coded decimal form. The information is then routed through various logic circuits to the tape-write amplifier and is recorded in a format compatible with the IBM 7074 and 7094 computers. The computer uses this information in conjunction with previously recorded calibration data to reduce the DDAS format to engineering units and to a form that is presentable to the California Computer Products X-Y Plotter.

The DDAS incorporates 230 recording channels, of which 27 were used for this test. The sampling rate was 80 samples per min for four min during the transitional phases from adsorb to desorb and reverse, and 8 samples per min for the remainder of each cycle.

TABLE 2-1

TEST PARAMETERS RECORDED BY
THE DIGITAL DATA ACQUISITION SYSTEM

Item No.	Parameter	Range	Transducer
1	Heat exchanger gas inlet temperature	-60^0 to 160^0F	CuC thermocouple
2	Heat exchanger gas outlet temperature	-60^0 to 160^0F	CuC thermocouple
3	Pitot tube No. 1 in temperature	-60^0 to 160^0F	CuC thermocouple
4	Coolant in temperature	-60^0 to 160^0F	CuC thermocouple
5	Coolant out temperature	-60^0 to 160^0F	CuC thermocouple
6	Silica gel bed No. 1 temperature	-60^0 to 160^0F	CuC thermocouple
7	Silica gel bed No. 3 temperature	-60^0 to 160^0F	CuC thermocouple
8	Silica gel bed No. 4 temperature	-60^0 to 160^0F	CuC thermocouple
9	Chamber No. 1 temperature	-60^0 to 160^0F	CuC thermocouple
10	Chamber No. 2 temperature	-60^0 to 160^0F	CuC thermocouple
11	Chamber No. 3 temperature	-60^0 to 160^0F	CuC thermocouple
12	Coolant heat exchanger ΔP	0 to 2 psi	2.0 D
13	Coolant inlet pressure	0 to 120 psig	150.0 D
14	Heat exchanger pitot tube inlet pressure	0 to 6 psia	6.0 A
15	Heat exchanger pitot tube ΔP	0 to 4 in. H_2O	0.2 D
16	Heat exchanger gas out pressure	0 to 6 psia	6.0 A
17	Heat exchanger gas ΔP	0 to 4 in. H_2O	0.2 D
18	Chamber pressure	0 to 6 psia	6.0 A
19	Blowdown tank pressure	30 to 200	CVC
20	Coolant flow	20 to 2000 cps	Cox 100 lb/hr
21	Cabin fan frequency	200 to 600 cps	VD No. 1
22	Fan inlet voltage	0 to 400 30 vrms	Microtran MT 5, HP 400 H - VD No. 4
23	Fan input current	0 to 5 amps ac	Microtran MT 1, 5A No. 1 shunt - 50
24	Valve input voltage	0 to 30 v dc	VD No. 3
25	Valve input current	0 to 5 amps dc	5 A No. 2 shunt - 50
26	Heater wattage	0 to 400 w	Hall S/N 11 device

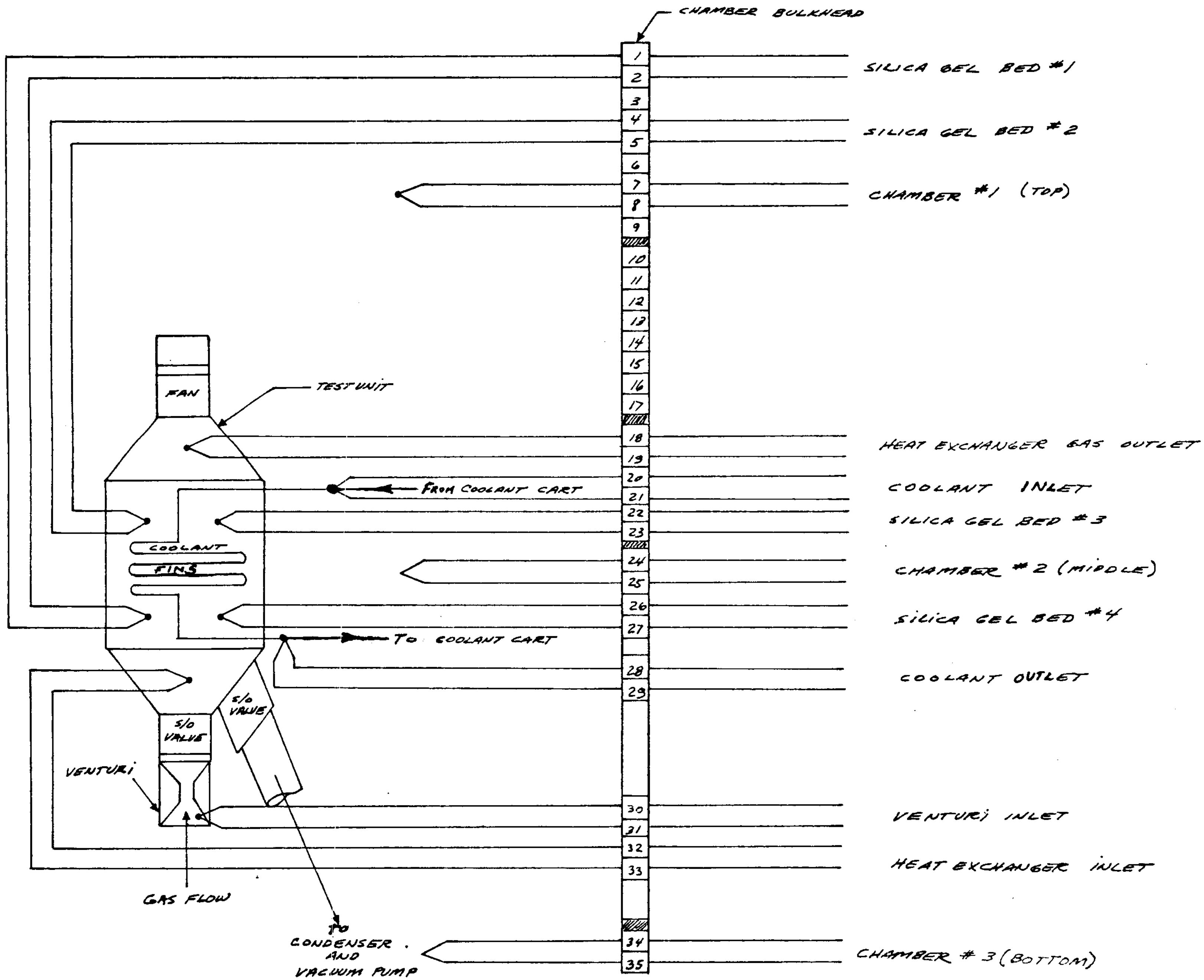

Figure 2-7. Schematic for Thermocouple Installation

SECTION 3

14-DAY SPACECRAFT CABIN MISSION SIMULATION TEST

3.1 TEST PROCEDURE

3.1.1 Evacuated the vacuum chamber to 5 psia and maintained this pressure for the duration of the test.

3.1.2 Maintained chamber temperature at 75 ±5°F by regulating power to the heater.

3.1.3 The environment inside the chamber was air.

3.1.4 Started the fan and established the gas mass flow through the sorbent bed at 15 lb per hr by adjusting fan cover ring. This flow rate was maintained for the duration of the test.

3.1.5 Started the coolant cart and adjusted coolant flow to 80 lb per hr with a temperature at the heat exchanger inlet of 60 ±1°F.

3.1.6 Started recording all the parameters listed in Table 2-1, utilizing Data Acquisition System.

3.1.7 Initiated required water injection into the chamber to provide 0.2 lb per hr water vapor flow rate through the bed. This was accomplished by monitoring dew-point temperature at the heat exchanger gas inlet.

3.1.8 During the 14-day mission simulation, the following cycling was maintained:

a. Water adsorption for 30 min

b. Water desorption for 15 min

3.1.9 Water vapor injection into the heat exchanger was varied in the sequence shown below every 60 hr:

TABLE 3-1

Dew Point Temperature (°F) at Heat Exchanger Inlet	Water Vapor Flow Rate lb/hr	Minimum Power Input Into the Heater, Watts*
37	0.2	62
47	0.3	92
53	0.38	117
57	0.45	138
64	0.54	167

*Varied power input to maintain cabin temperature at 75 ±5°F

3.1.10 The sequential events required to accomplish the cycle listed in Paragraph 3.1.8 were:

3.1.10.1 To close the vacuum valve and open the cabin valve. (This was accomplished automatically from the control console.)

3.1.10.2 To close condenser test valves.

3.1.10.3 Circulate chamber gas through the sorbent bed at 15 lb per hr rate for 30 min.

3.1.10.4 Twenty minutes after opening the cabin valve, start precooling condenser (used to minimize moisture entering vacuum system) by flowing liquid N_2 through the coils.

3.1.10.5 Open condenser test valves.

3.1.10.6 Evacuate the line to 30 microns or lower.

3.1.10.7 After 30 min of water adsorption period, close cabin valve and open the vacuum valve.

3.1.10.8 Desorb for 15 min.

3.1.10.9 Close the vacuum valve and open cabin valve.

3.1.10.10 Close condenser test valves.

3.1.10.11 Start condenser deicing and water recovery process. (This was accomplished within 20 min.)

3.1.10.12 Open condenser test valves.

3.1.10.13 Start precooling of the condenser for 10 min.

3.1.10.14 After 30 min of water adsorption, close the cabin valve and open the vacuum valve.

3.1.10.15 Desorb for 15 min.

3.1.10.16 Repeat steps 3.1.10.9 through 3.1.10.15.

3.1.11 The cycling-sequence timing period remained the same for 344 hr of the mission. During the last 11 hr of the mission, cycling of 30 min adsorb, 30 min desorb, and 15 min adsorb, and 30 min adsorb was also performed.

3.1.12 During the entire 14-day mission, test parameters listed in Table 2-1 were recorded by an IBM data acquisition system.

3.1.13 The following test parameters were recorded manually:

3.1.13.1 Heat exchanger inlet dew-point temperature--every 5 min during the adsorption cycle.

3.1.13.2 Heat exchanger outlet dew-point temperature--every 5 min during the adsorption cycle.

3.1.13.3 Cabin top, middle, and bottom dew points--every 5 min during the desorption cycle.

3.1.13.4 Chamber pressure--every hour.

3.1.13.5 Vacuum line pressure--before every desorption cycle.

3.1.13.6 Weight of the water--every hour.

3.1.13.7 Heater power--every hour.

3.1.14 A Brown recorder was used to record the following temperature parameters:

3.1.14.1 Heat exchanger inlet

3.1.14.2 Heat exchanger outlet

3.1.14.3 Coolant in

3.1.14.4 Chamber No. 1

3.1.14.5 Chamber No. 2

3.1.14.6 Chamber No. 3

3.1.14.7 Dew point analyzer No. 1 line temperature

3.1.14.8 Dew point analyzer No. 2 line temperature

3.1.15 The amount of the water recovered was measured and recorded.

3.1.16 Test completion:

3.1.16.1 Finished the mission with the desorption cycle.

3.1.16.2 Stabilized the system and depressurized the chamber.

3.1.16.3 Turned the fan off.

3.1.16.4 Removed the system from the test setup

3.2 DISCUSSION OF TEST RESULTS

During the 14-day Gemini mission simulation test, the following six water vapor flow rates were initiated through the sorbent bed in a cyclic manner and maintained for approximately 60 hr each:

Water Vapor Flow Rate	Chamber Dew Point	
0.2 lb/hr	(37°F)	
0.3 lb/hr (min)	(47°F)	Required Performance Range
0.38 lb/hr (nominal)	(53°F)	
0.45 lb/hr (max)	(57°F)	
0.50 lb/hr	(61°F)	
0.54 lb/hr	(64°F)	

The air flow through the silica gel bed was set and maintained at 15 ±0.5 lb per hr. The chamber pressure was maintained at 5 psia and the chamber dry-bulb temperature at 80°F. The coolant flow through the heat exchanger was established at 80 lb per hr with the coolant inlet temperature to the heat exchanger at 60°F. To assure the required water flow rate through the bed, the dew-point temperature was measured and maintained at the heat exchanger inlet.

During the mission, the system operated as required and met all design requirements (0.3 lb per hr, 0.38 lb per hr, and 0.45 lb per hr water vapor flow rates) using a cycling of 30 min adsorb and 15 min desorb time. However, when 0.5 lb per hr water vapor flow rate was initiated, which is in excess of the design requirements of the system, the heat exchanger's outlet dew-point temperature increased to 30°F. The cycling was then changed to 30 min adsorb and 30 min desorb, which resulted in only a slight drop in outlet dew point; but when cycling was changed to 15 min adsorb and 30 min desorb, heat exchanger outlet dew-point temperature decreased from 27°F to 10°F in 4 hr.

Only typical heat exchanger inlet and outlet dew-point temperatures and chamber dry-bulb temperature at the beginning and the ending of each water injection rate and the more significant parameters of 0.45 lb per hr water injection rate are chosen for presentation in this report because of the voluminous amount of data produced by the DDAS. The remaining plots of the test data and 200 sheets of manual data are on file. Table 3-2 summarizes the most significant test parameters of the mission.

The heat exchanger inlet and outlet dew-point and chamber dry-bulb temperatures between 10.5 and 22.25 mission hours and between 54.5 and 66.5 mission hours are presented in Figures 3-1 and 3-2. The required water vapor flow rate into the silica gel bed was 0.2 lb per hr. The required dew-point

TABLE 3-2

SUMMARY OF TEST RESULTS

Mission Time hr	H_2O Rate lb/hr	Chamber Dry-bulb Temperature °F	HX In Dew-point Temperature °F	HX Out Dew-point Temperature °F	Coolant In Temp (°F)	Coolant Out Temp (°F)		Silica Gel Bed No. 1 Temp (°F)		Silica Gel Bed No. 3 Temp (°F)		Silica Gel Bed No. 4 Temp (°F)		Blowdown Tank Press.
					Adsorb - Desorb	Adsorb	Desorb	Adsorb	Desorb	Adsorb	Desorb	Adsorb	Desorb	Microns
9-24	0.2	80-84	37-45(40)	3-12	52-62	62-70	52-46	62-70	39-46	62-66	42-49	60-64	40-48	30-240 +
55-67	0.2	79-81	32-41(37)	2-8	60	68-70	50-54	70-74	42-52	70-66	46-52	66-72	42-54	30-240 +
70-82	0.3	78-82	42-51(47)	9.5-14.5	60	68-70	48-52	70-74	40-48	66-70	42-46	66-72	40-50	30-240 +
126-138	0.3	79-82	42-48(47)	10-14	60	68-70	48-52	70-74	40-48	68-72	44-50	66-70	44-50	30-240 +
141-156	0.38	79-81	48-56(53)	11.5-21	60	68-70	42-46	70-72	40-42	68-72	42-48	70-76	40-48	30-240 +
196-209	0.38	79-82	50-56(53)	16-23	60	68-70	42-46	72-76	38-42	68-72	42-48	66-70	42-46	20-240 +
287-310	0.45	80-83	55-58(57)	22-28	60	70-72	46-48	72-76	40-44	68-72	45-50	68-73	44-48	30-240 +
314-325	0.54	79-82	61-66(64)	24-32	64-60	70-74	46-48	76-80	38-42	70-74	44-48	68-70	40-42	30-240 +
325-344	0.5	80-83	60-63(61)	26-32										
344-350 [x]	0.5	80	60-61(61)	23-27										
350-355 [xx]	0.5	80	61-64(61)	10.5-18.0										

[x] 30 min adsorb, 30 min desorb

[xx] 15 min adsorb, 30 min desorb

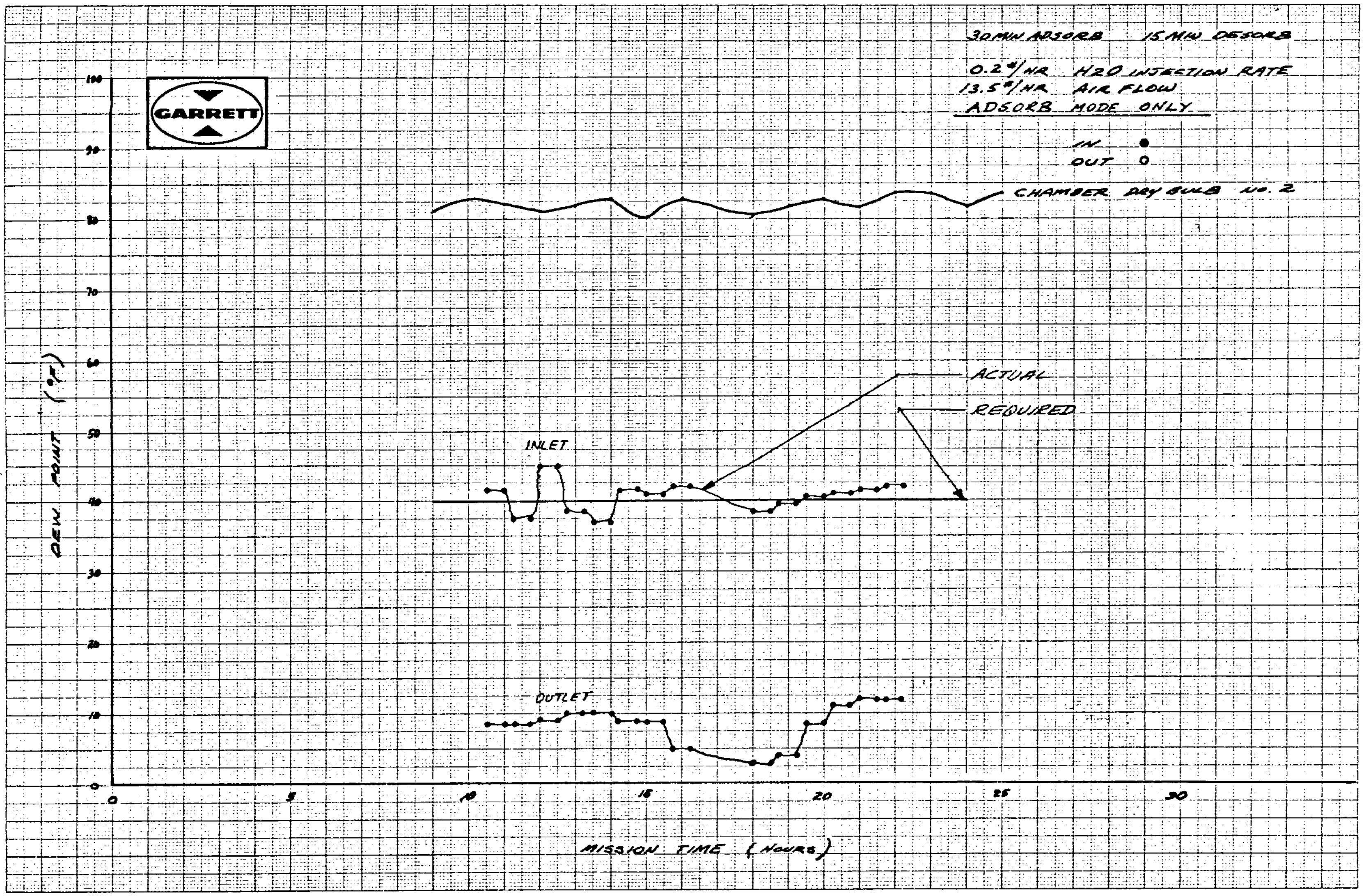

Figure 3-1. Dew Point vs Mission Time

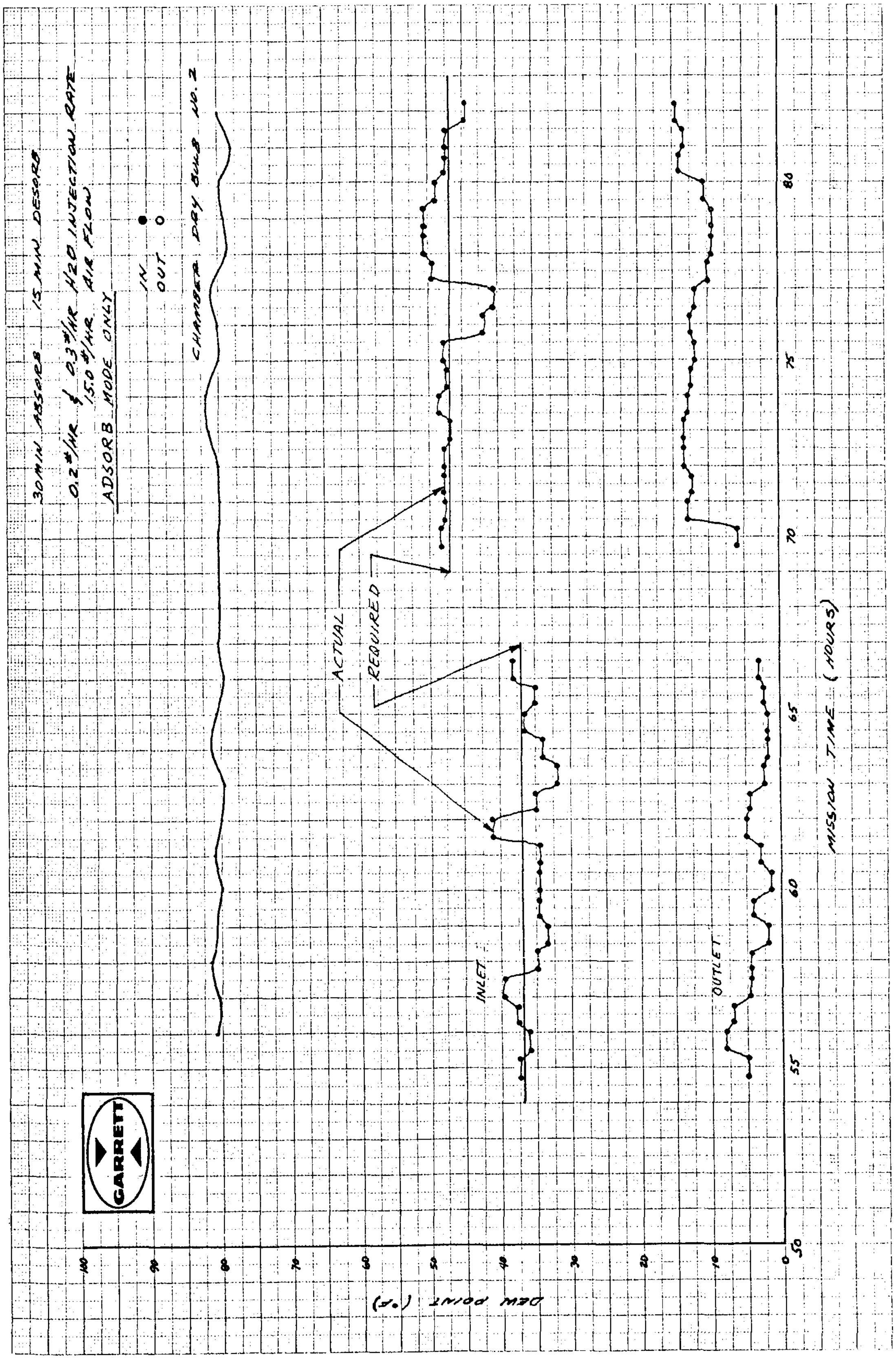

Figure 3-2. Dew Point vs Mission Time

temperature at the heat exchanger inlet, based on 15 lb per hr air flow, was 37°F. Figure 3-2 also presents the first 12 hr of 0.3 lb per hr water vapor flow rate through the unit. The required heat exchanger inlet dew point was 47°F, and the heat exchanger outlet dew-point temperature stayed between 12.5°F and 15°F most of the time, showing a slight decrease between 130 and 135 hr. The actual inlet dew points during the adsorb cycle showed some degree of variation, because the water injection rate into the chamber remained constant during the adsorb and desorb cycles, while no moisture was removed from the chamber during the desorb cycle; this caused the dew point to go up. Figure 3-3 presents four typical continuous cycles showing the heat exchanger inlet dew-point temperature changing from 46°F to 32°F during adsorption period and from 32°F to 46°F during desorption cycle. The heat exchanger outlet dew-point temperature varied from 5°F to 10°F. After 16 hr of operation, improved vacuum dropped the heat exchanger's outlet dew point from 9°F to 2.5°F. Four typical continuous cycles at 0.3 lb per hr water vapor flow rate are presented in Figure 3-4. The heat exchanger outlet temperature during adsorb mode increased from 10°F to 15°F.

Figures 3-5 and 3-6 show required and actual inlet dew-point temperatures at 0.38 lb per hr (nominal) water vapor flow rate. Required dew point at the inlet was 53°F; the actual inlet dew point at the beginning of this run was slightly low (50°F - 47.5°F) outlet dew point varied between 15°F and 20°F. At 202.5 hr, heat exchanger outlet dew point increased to 27°F, because the inlet dew-point temperature was too high. Figure 3-7 presents four continuous cycles at 0.38 lb per hr water vapor flow rate. The inlet dew point varied between 60°F and 48°F during adsorption and between 48°F and 60°F during desorption. The outlet dew point was between 15°F and 20°F.

Figure 3-8 covers the time between 287 and 310 hr of the mission. During this time, the water vapor flow rate was at design maximum, 0.45 lb per hr. The required and actual heat exchanger inlet dew-point temperatures were at 57°F. The outlet dew point varied between 22.5 and 30.0°F. Chamber temperature (dry-bulb) was 80.5°F. Four typical continuous cycles are presented in Figure 3-9. Inlet dew point during the adsorb cycle varied from 65°F to 50°F and during the desorb cycle from 50°F to 65°F. The outlet dew point-temperature varied between 20°F and 30°F.

During the later part of the simulated mission, water vapor flow rates in excess of the required maximum were used in order to determine the operating limits of the moisture-removal system. A water vapor flow rate of 0.54 lb per hr was run, and the results are presented in Figure 3-10. To achieve this vapor flow rate at the gas flow rate of 15 lb per hr, it was necessary to maintain a simulated cabin dew point of approximately 64°F, which is higher than desirable. In addition, system outlet dew points in excess of 30°F were experienced, indicating a decreased dynamic removal efficiency.

The water vapor flow rate was then reduced to 0.50 lb per hr and the system outlet dew point still remained rather high and showed a tendency to increase with time, as indicated in Figure 3-11. In order to prevent an increase in the outlet dew point, the desorption time was increased from 15 min to 30 min. This improved the performance somewhat, but the tendency for the outlet dew point to increase persisted. Next the adsorption time was

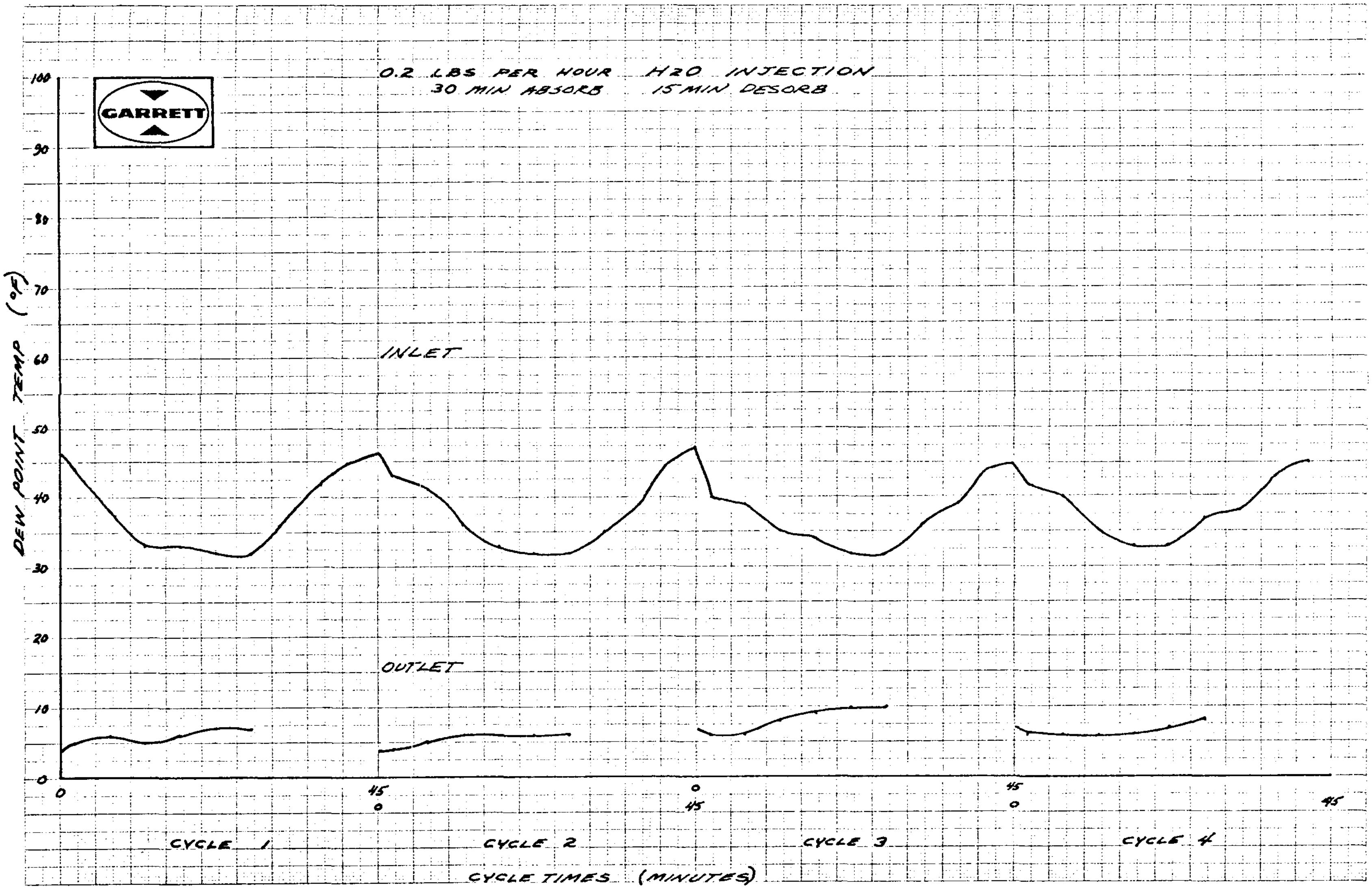

Figure 3-3. Dew Point vs Cycle Time

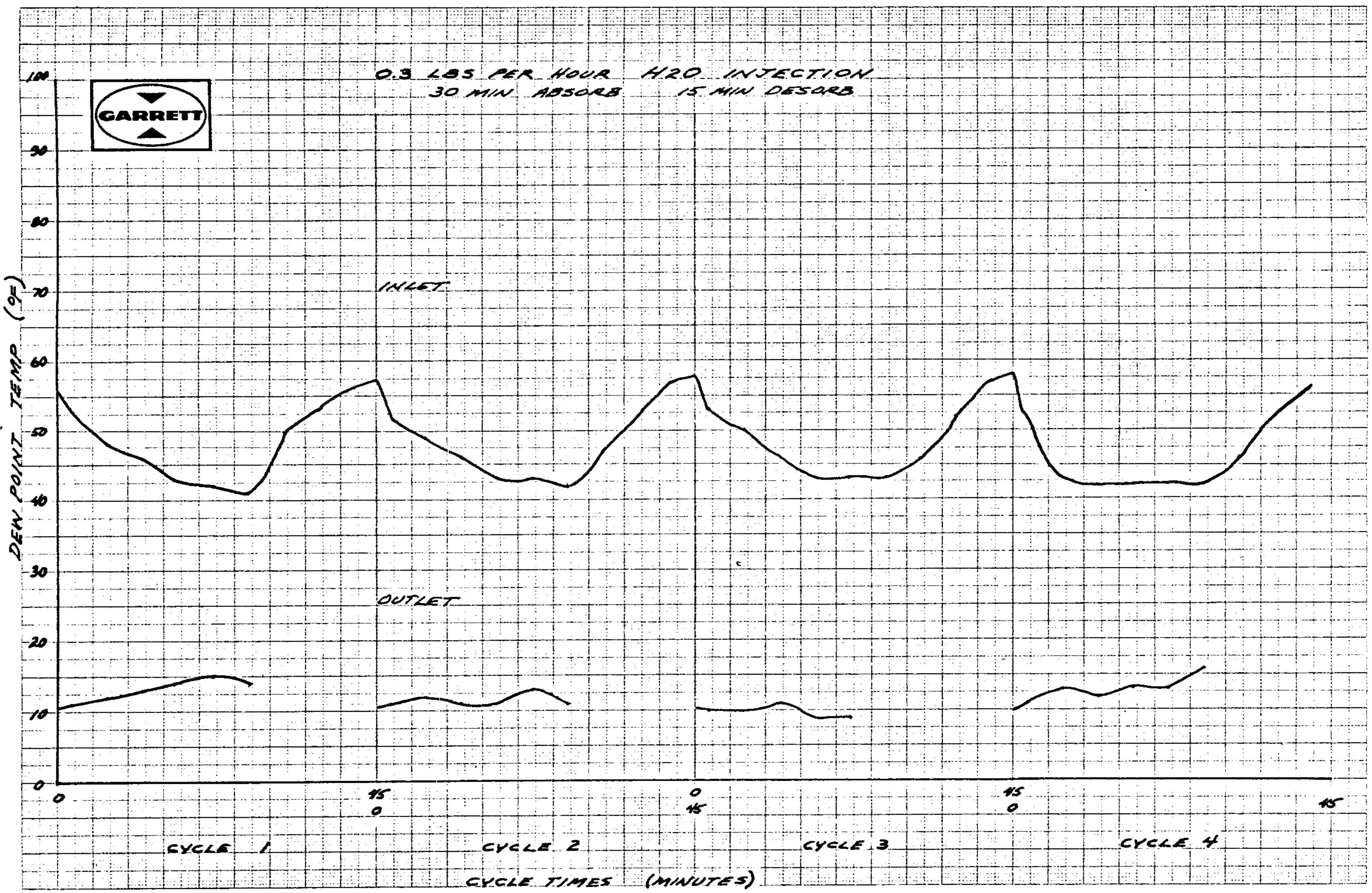

Figure 3-4. Dew Point vs Cycle Time

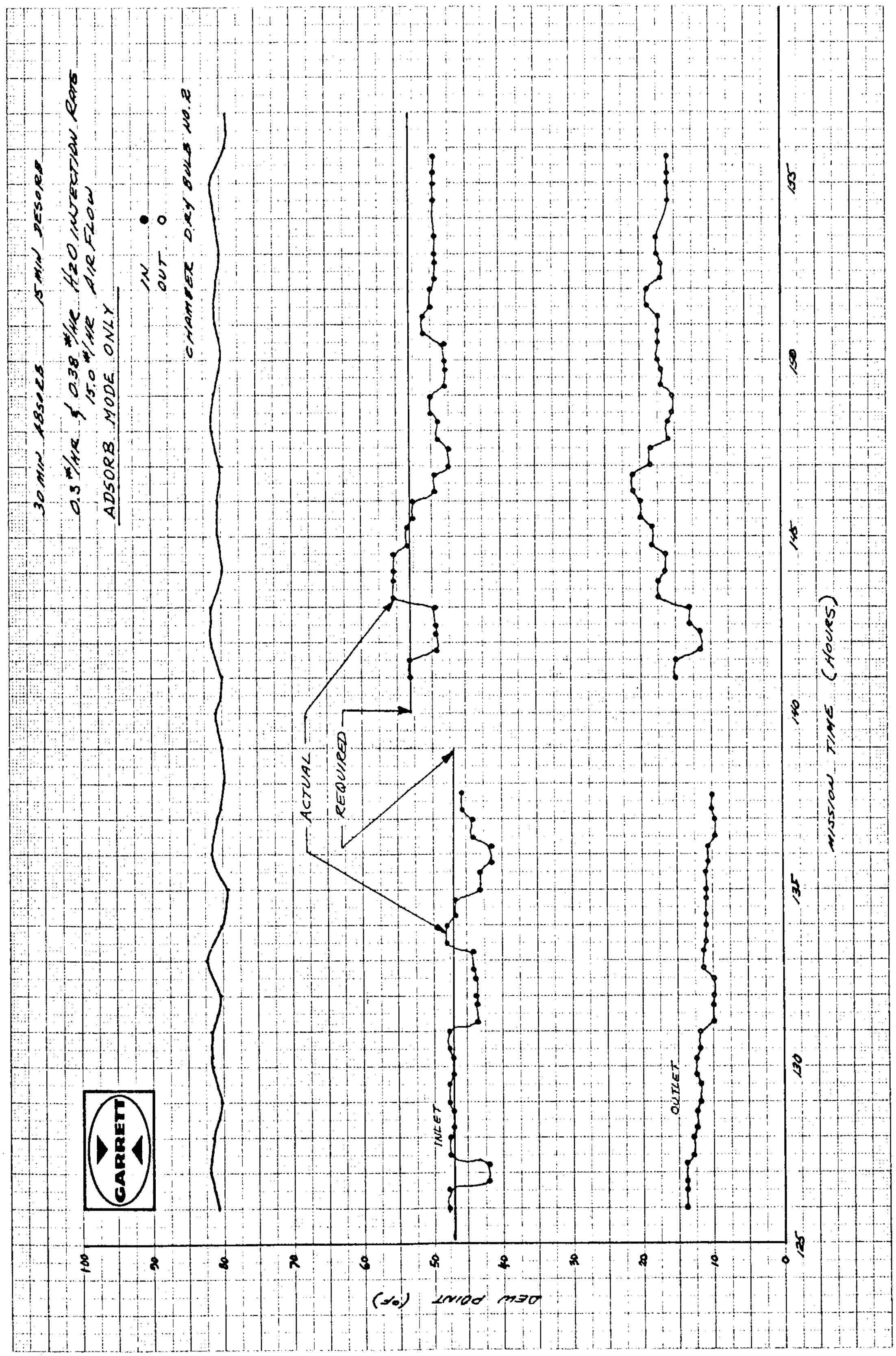

Figure 3-5. Dew Point vs Mission Time

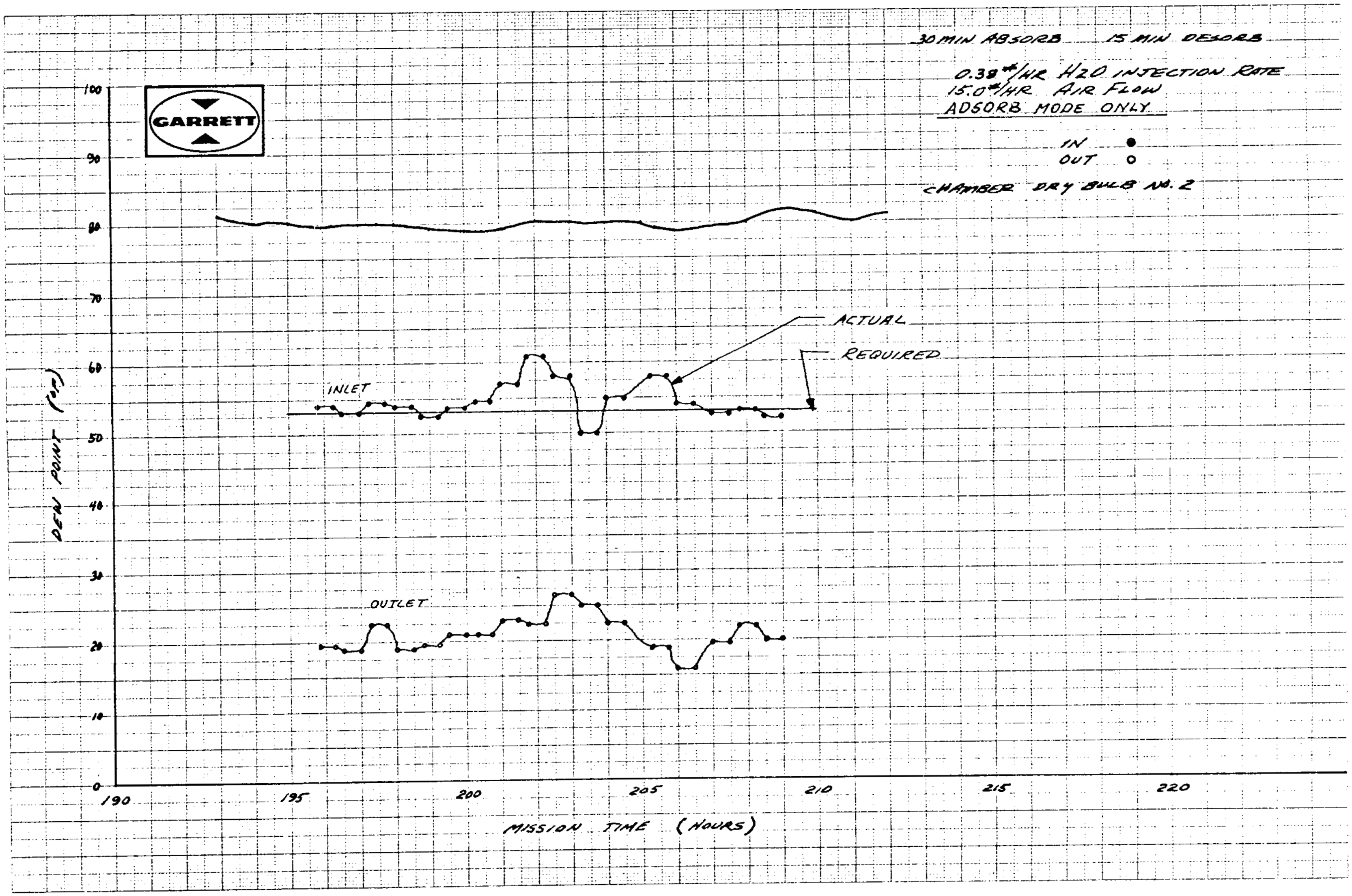

Figure 3-6. Dew Point vs Mission Time

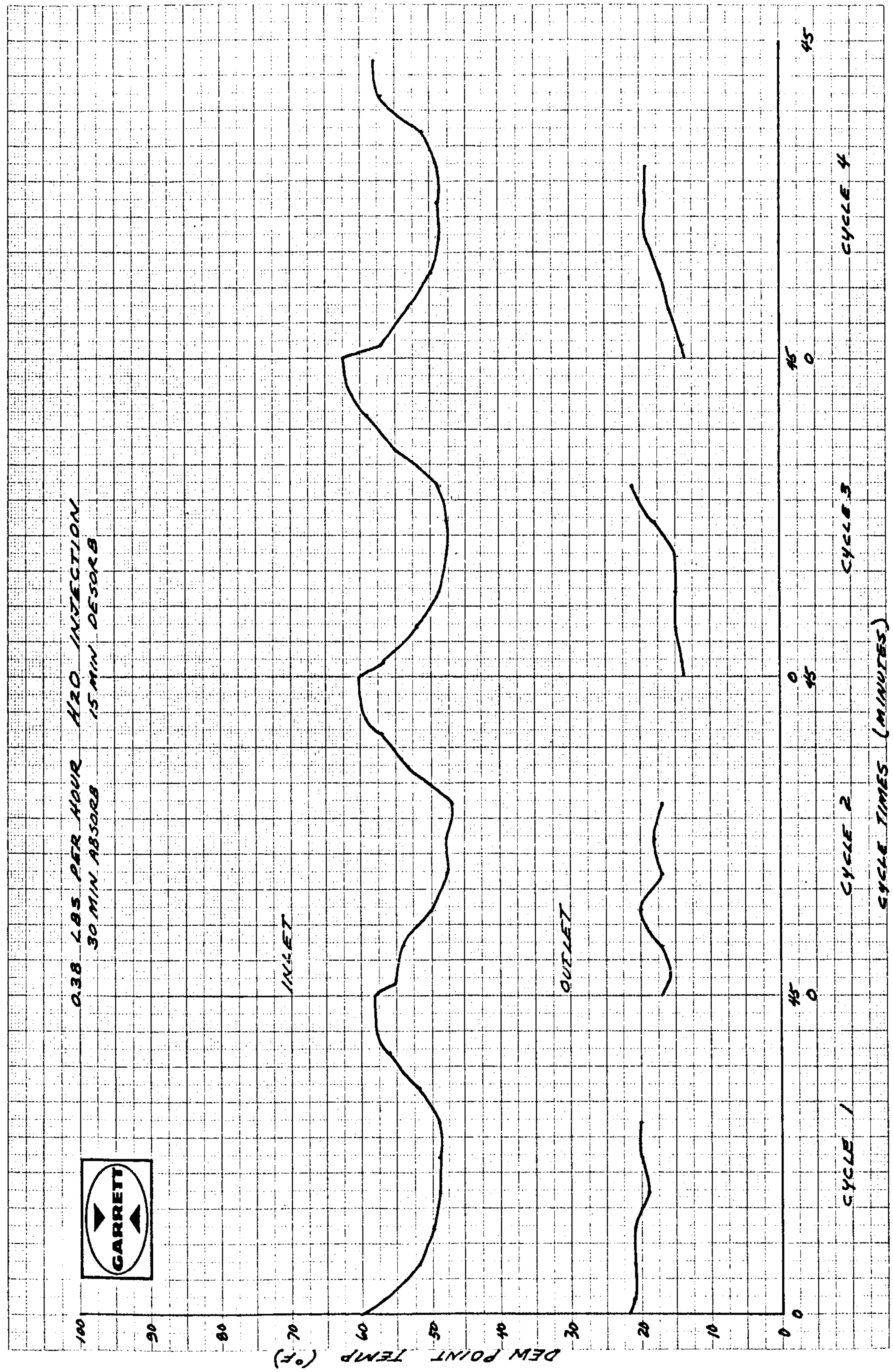

Figure 3-7. Dew Point vs Cycle Time

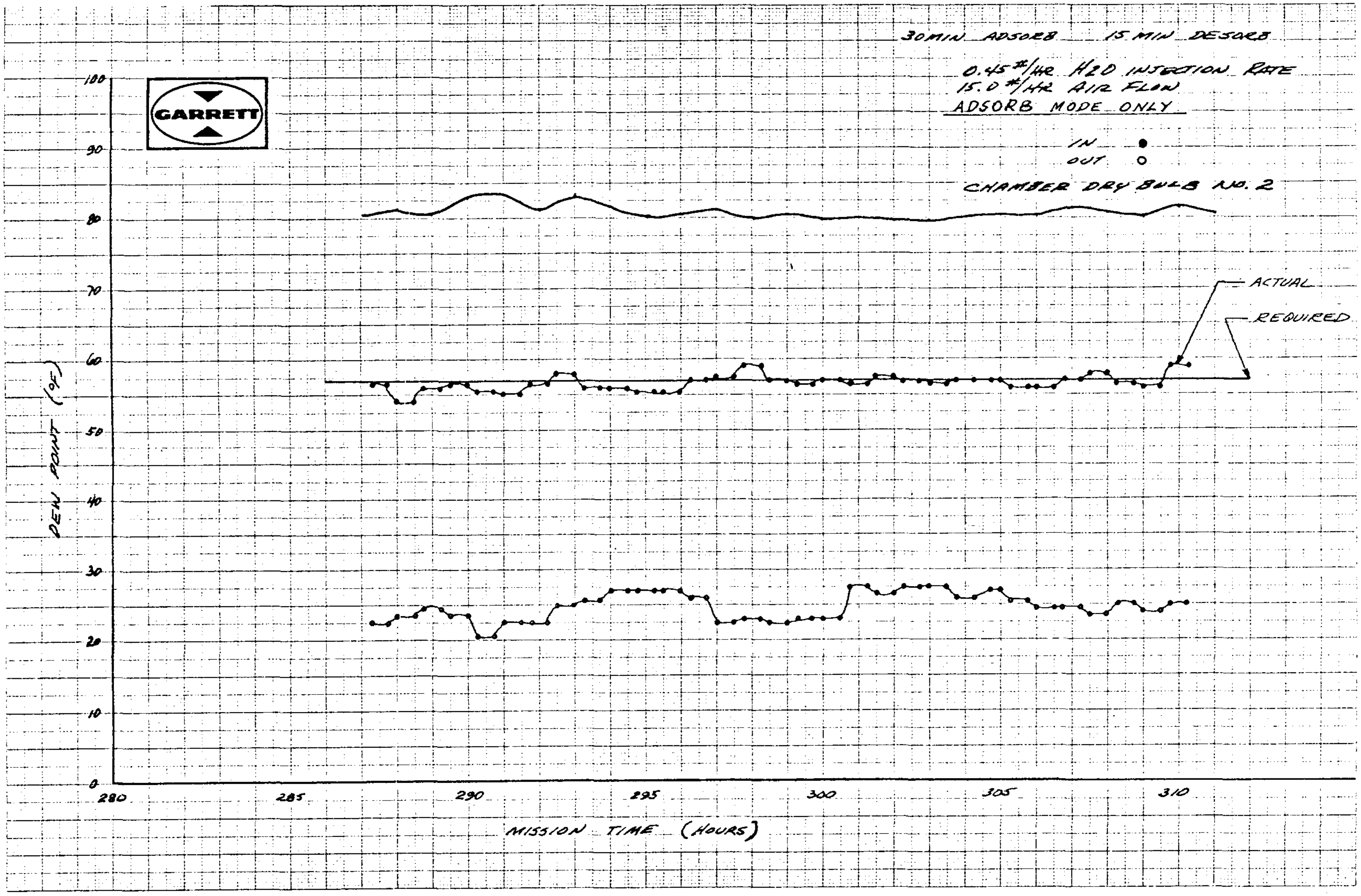

Figure 3-8. Dew Point vs Mission Time

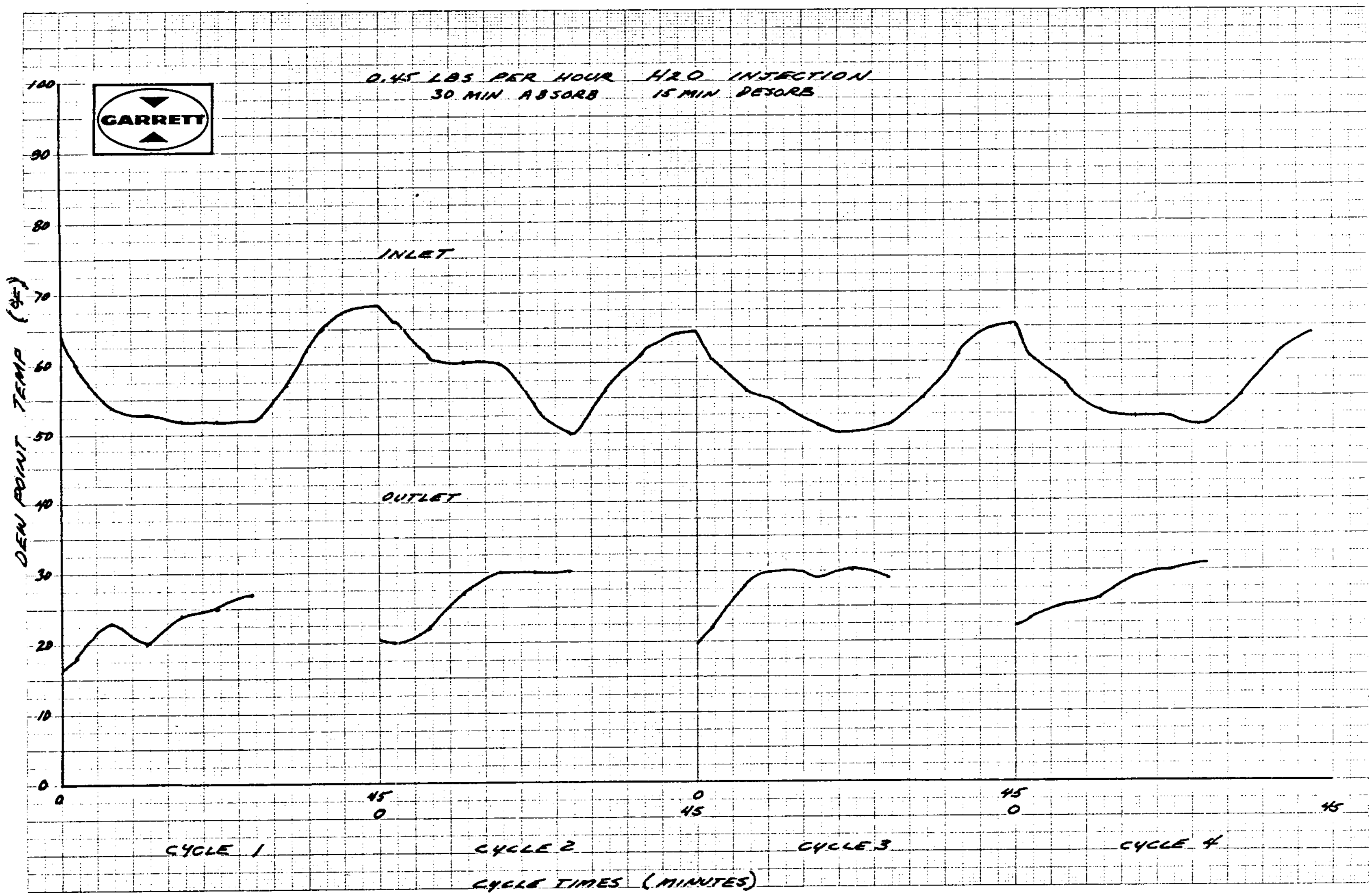

Figure 3-9. Dew Point vs Cycle Time

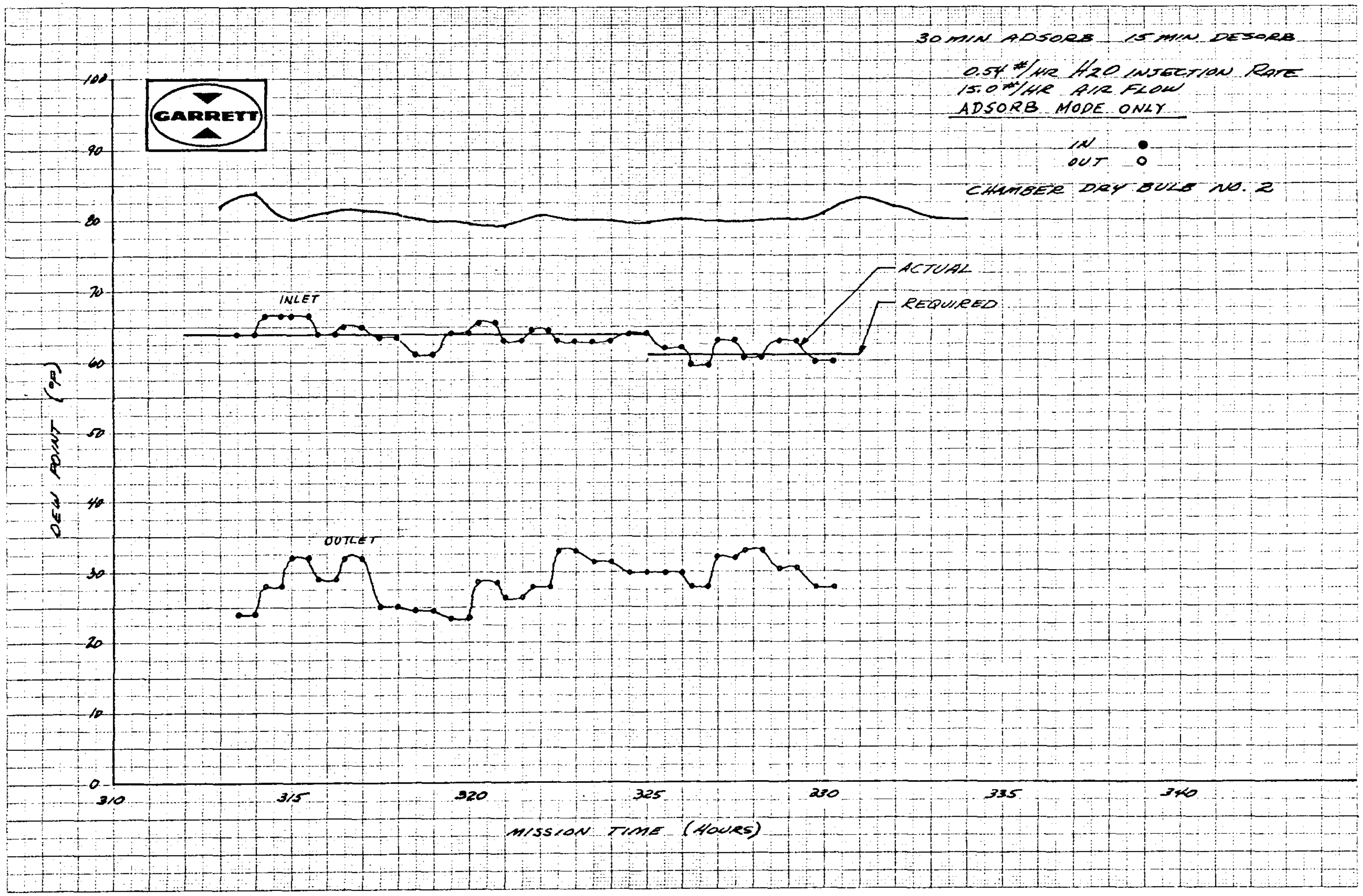

Figure 3-10. Dew Point vs Mission Time

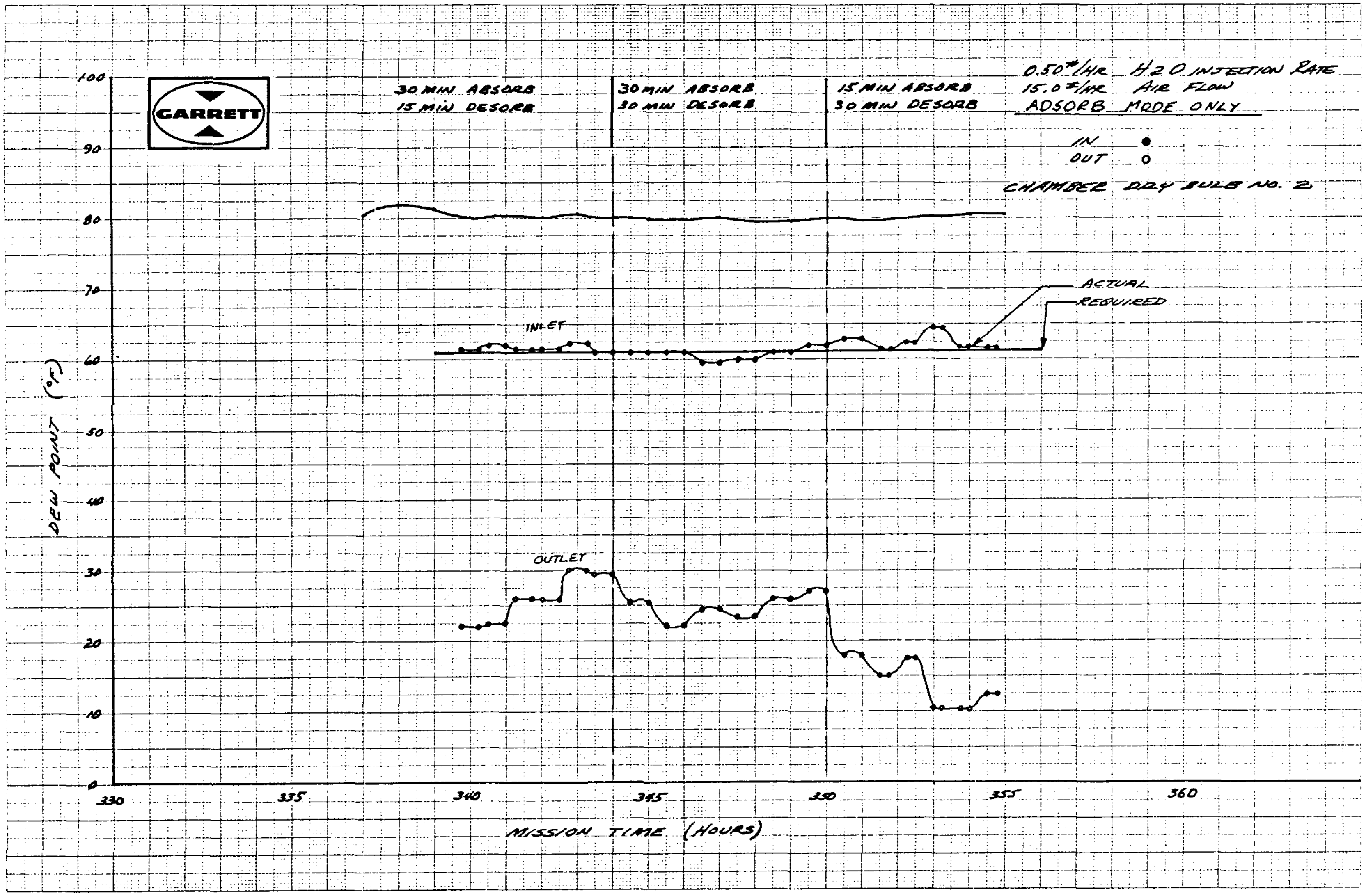

Figure 3-11. Dew Point vs Mission Time

reduced from 30 min to 15 min, which resulted in a marked improvement in performance. Figures 3-12, 3-13, and 3-14 show typical outlet and inlet dew point profiles for the various combinations of cycle time described above.

It is important to note that in the above discussion the water vapor flow rate referred to defines the amount of moisture flowing through the adsorption bed. The total amount of water rejected to the simulated vacuum is the product of the water vapor flow rate, the dynamic removal efficiency, and the ratio of adsorption time to total elapsed time.

Several significant parameters monitored by the DDAS and plotted by the X-Y plotter were selected for this report as typical. These plots, Figures 3-15 through 3-28, cover approximately the same period in the mission as is covered in Figure 3-8. The total data output of the DDAS (900 separate plots) was too voluminous to be presented in this report; it is on file, however, at AiResearch.

In conclusion, it can be stated that the system operated satisfactorily and met all design requirements even though desorption was performed at a much higher vacuum than was desired. (Desirable vacuum pressure = 30 microns; actual = 300 microns). The system also showed a potential ability to handle a higher water adsorption rate than required, if the cycling of 15 min adsorption and 30 min desorption were employed.

Figure 3-12. Dew Point vs Cycle Time

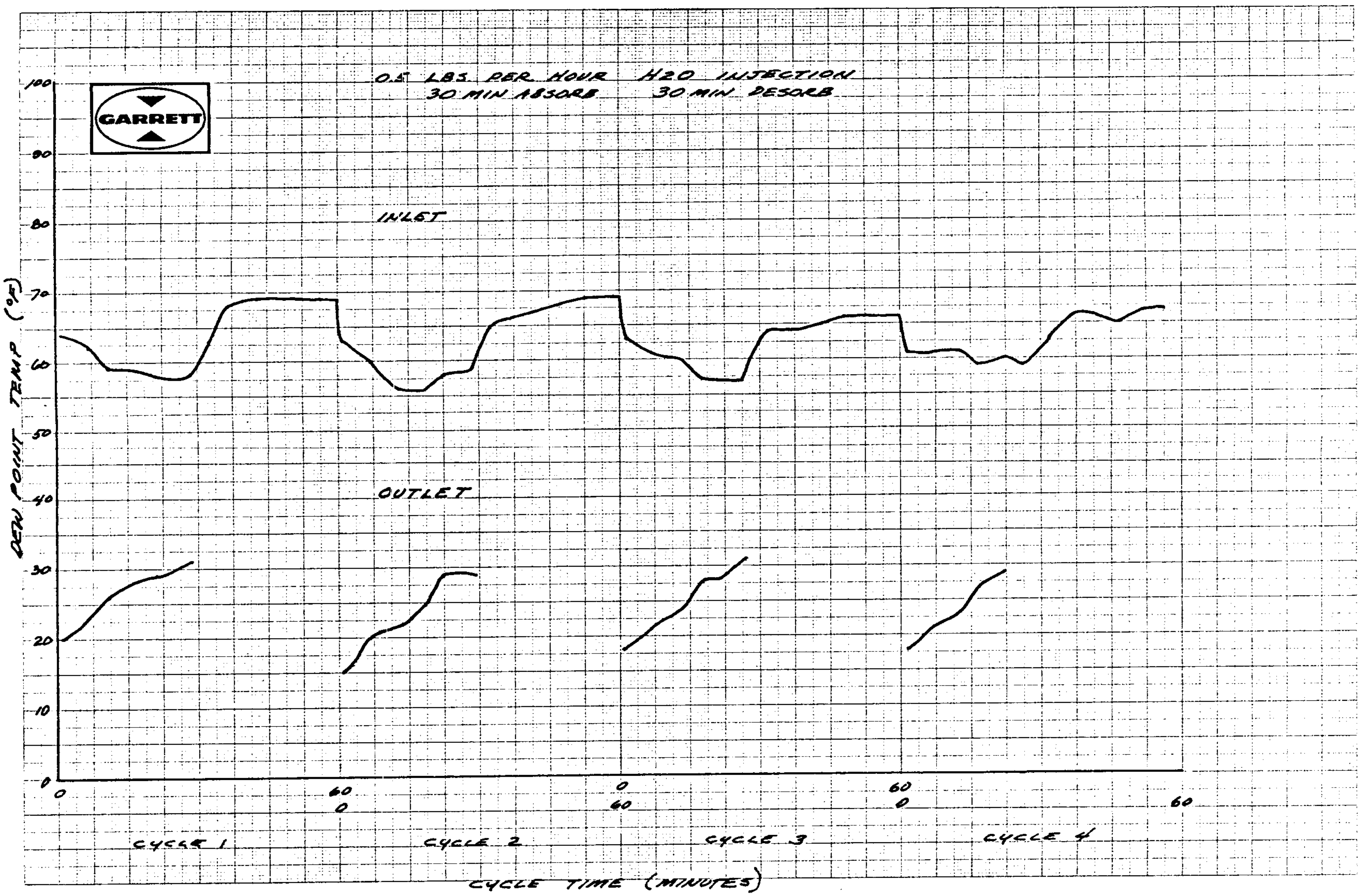

Figure 3-13. Dew Point vs Cycle Time

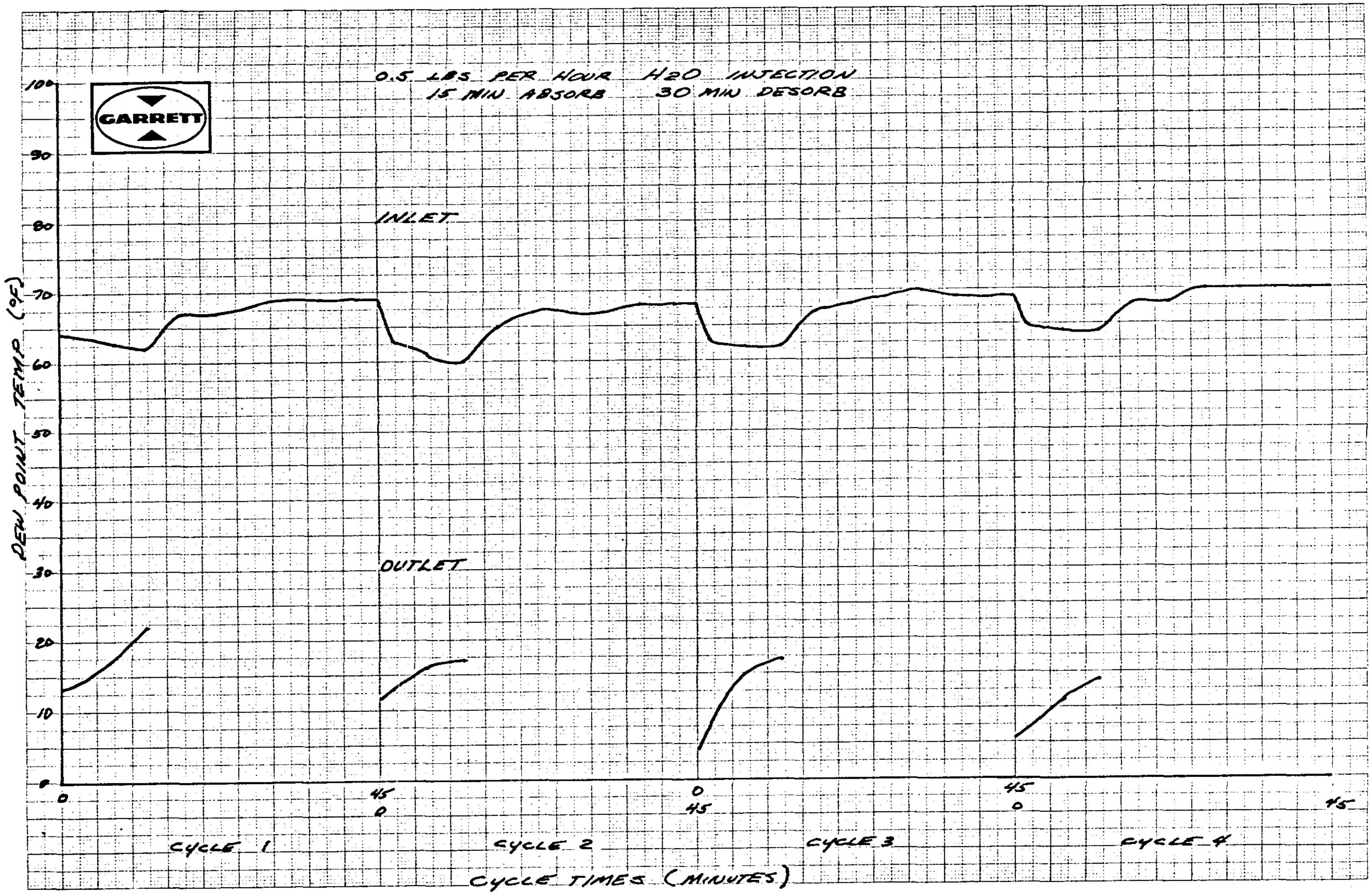

Figure 3-14. Dew Point vs Cycle Time

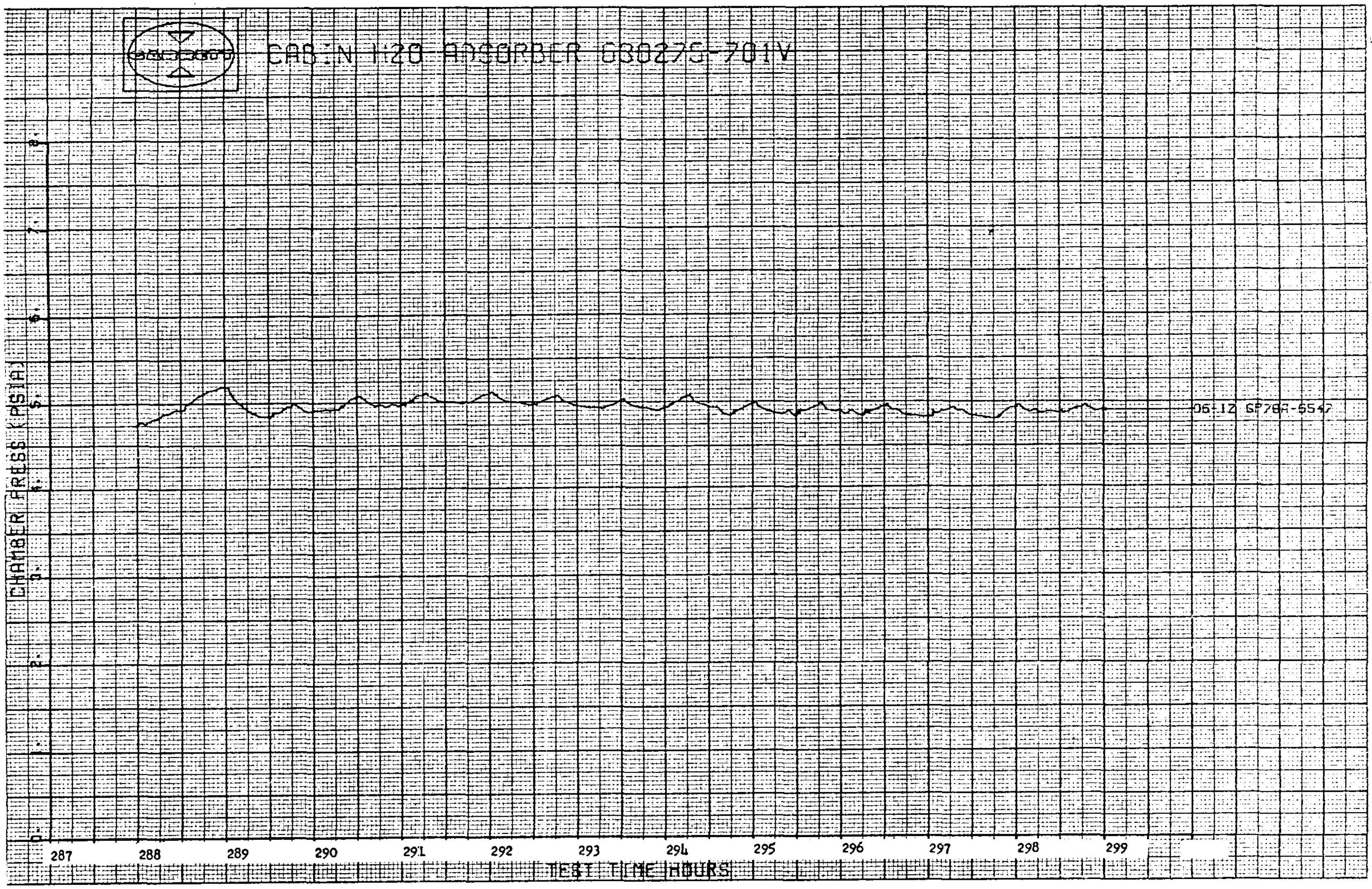

Figure 3-15. Chamber Pressure vs Test Time

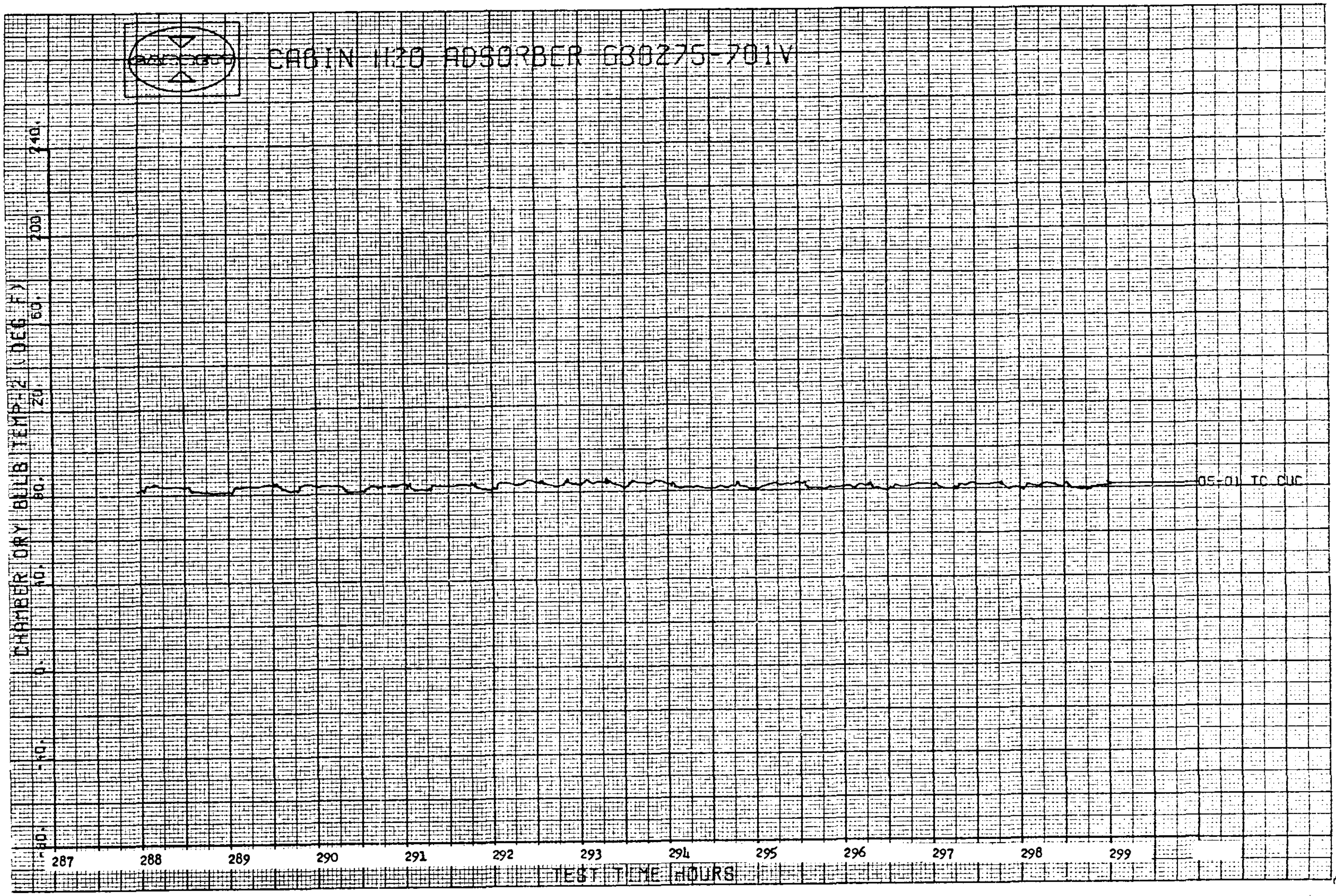

Figure 3-16. Chamber Dry-Bulb Temperature vs Test Time

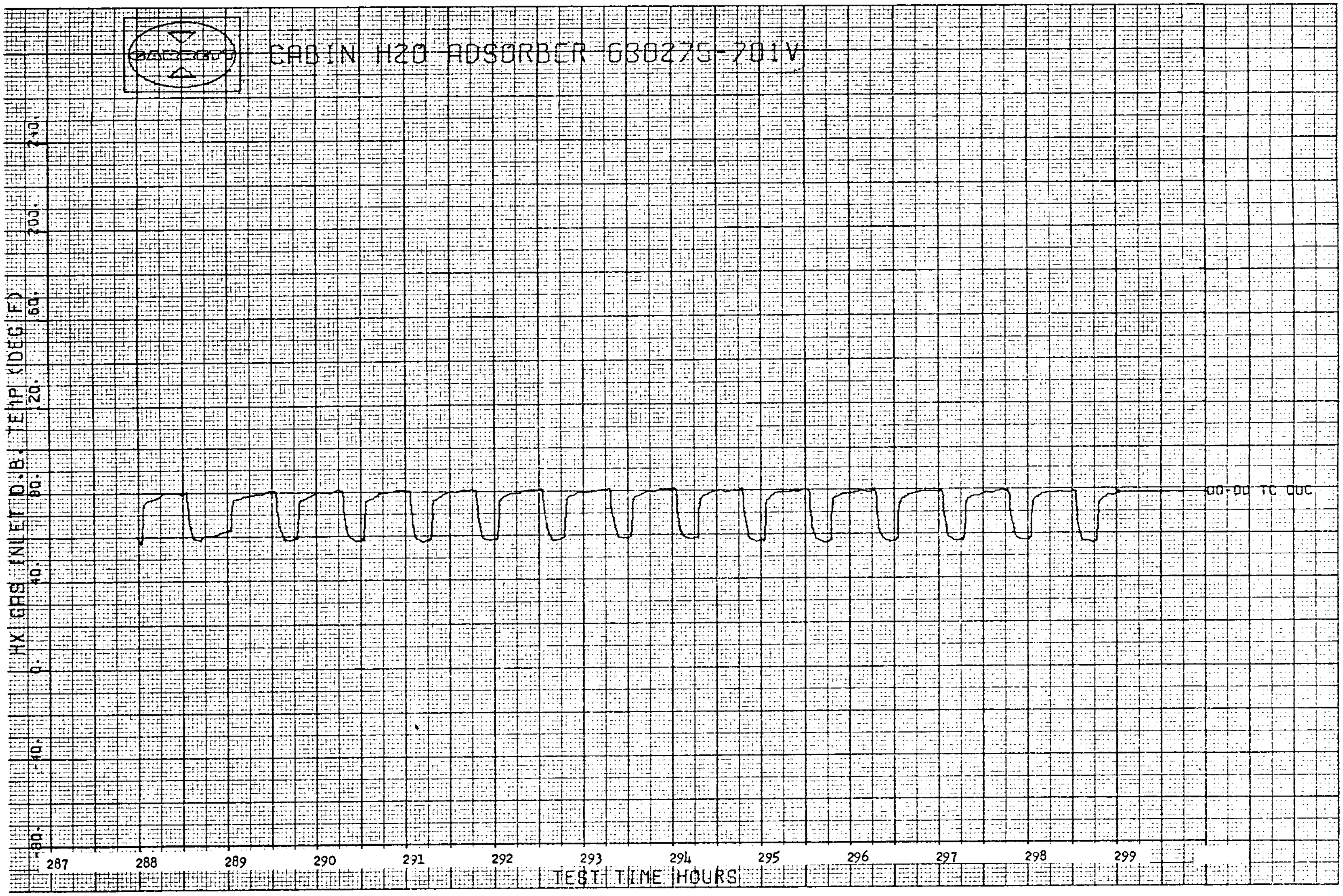

Figure 3-17. Heat Exchanger Gas Inlet Dry-Bulb Temperature vs Test Time

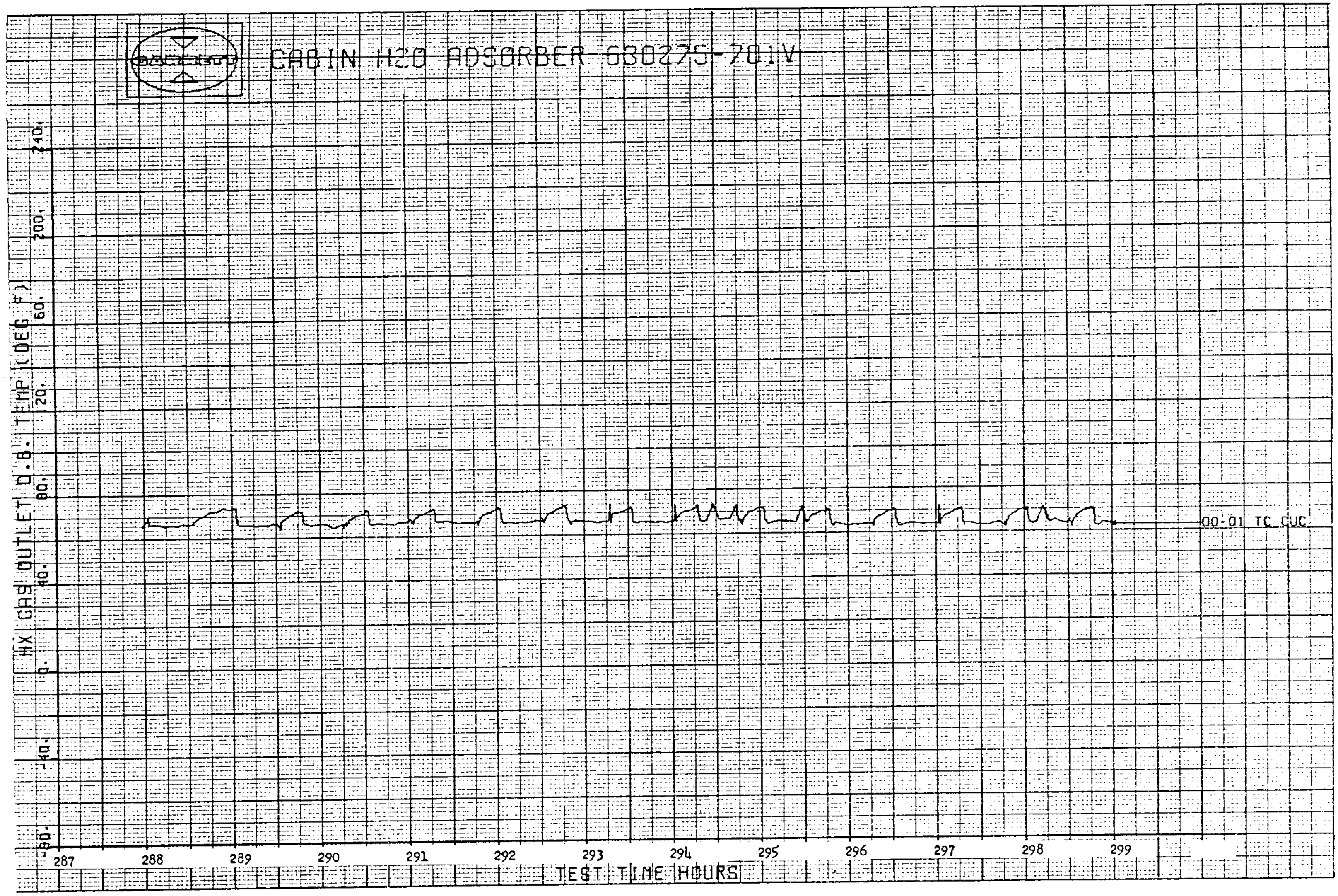

Figure 3-18. Heat Exchanger Gas Outlet Dry-Bulb Temperature vs Test Time

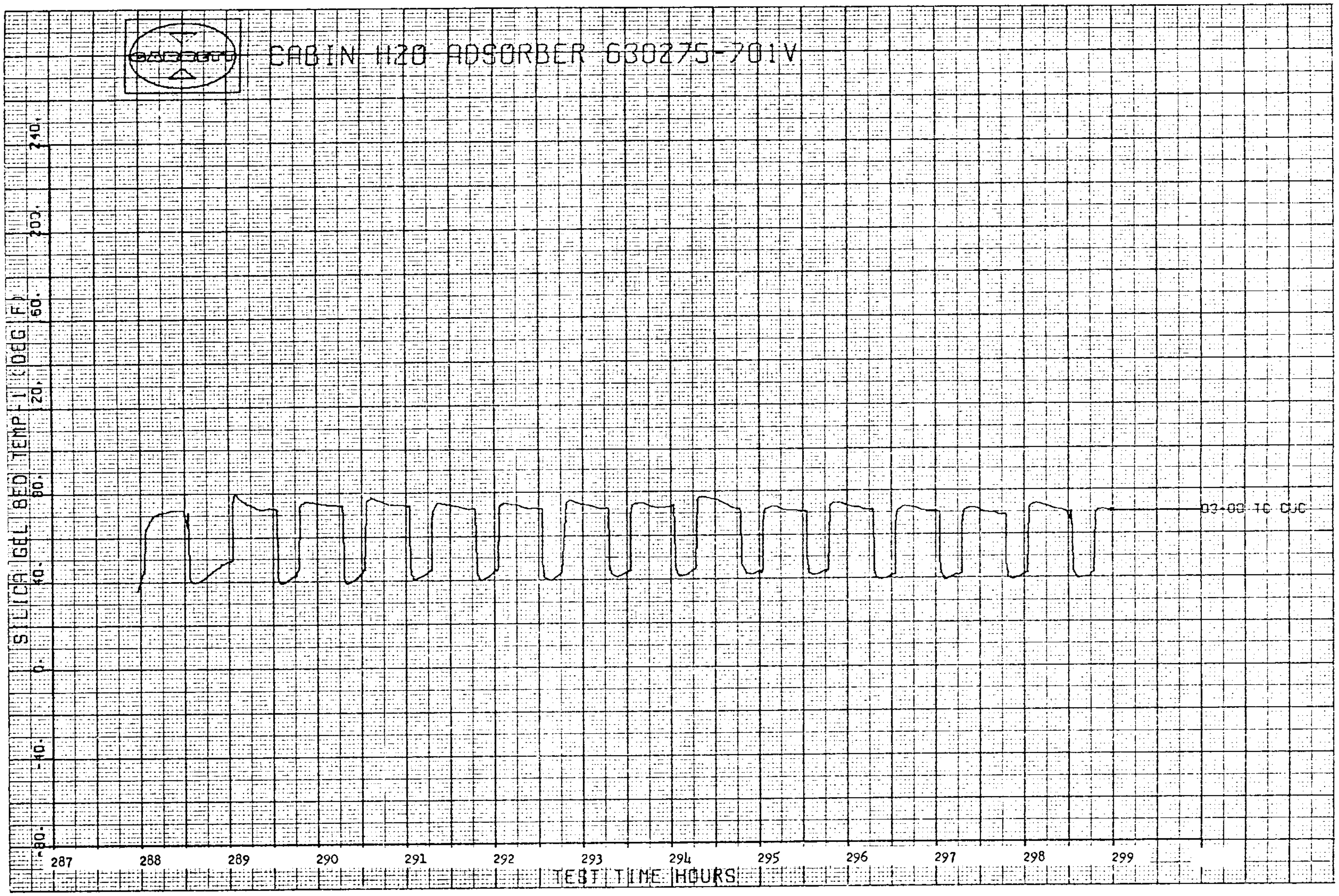

Figure 3-19. Silica Gel Bed Temperature vs Test Time

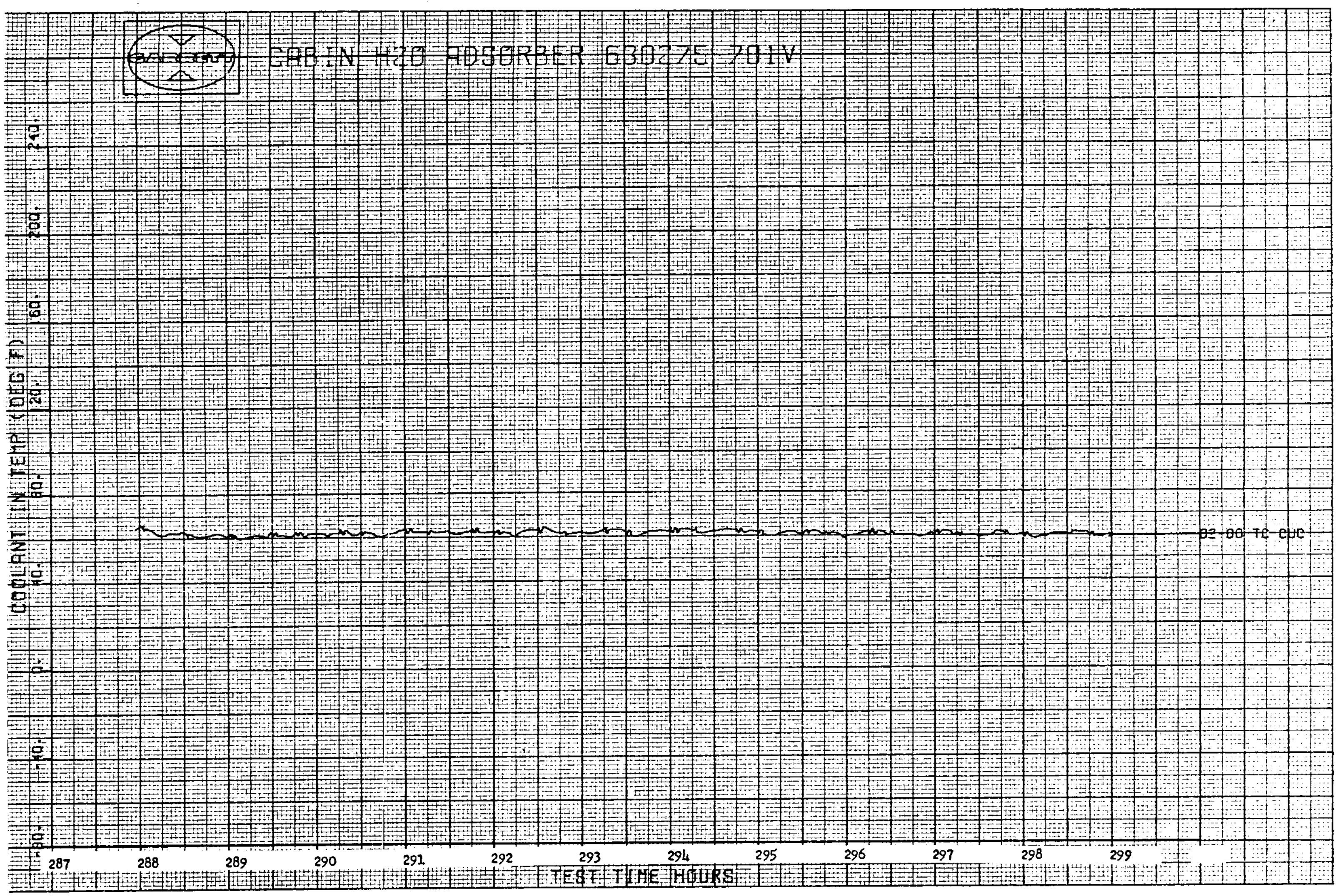

Figure 3-20. Coolant In Temperature vs Test Time

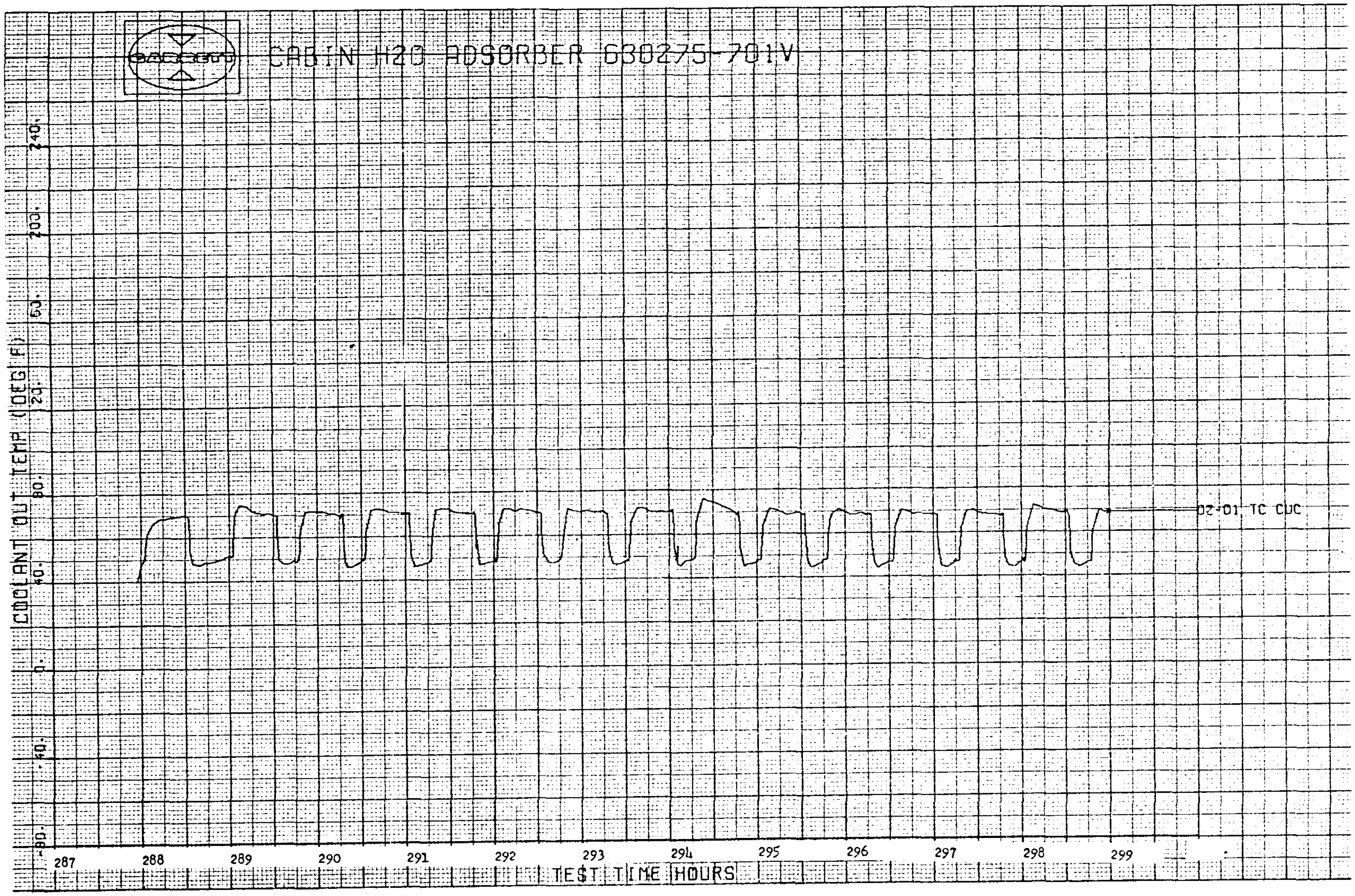

Figure 3-21. Coolant Out Temperature vs Test Time

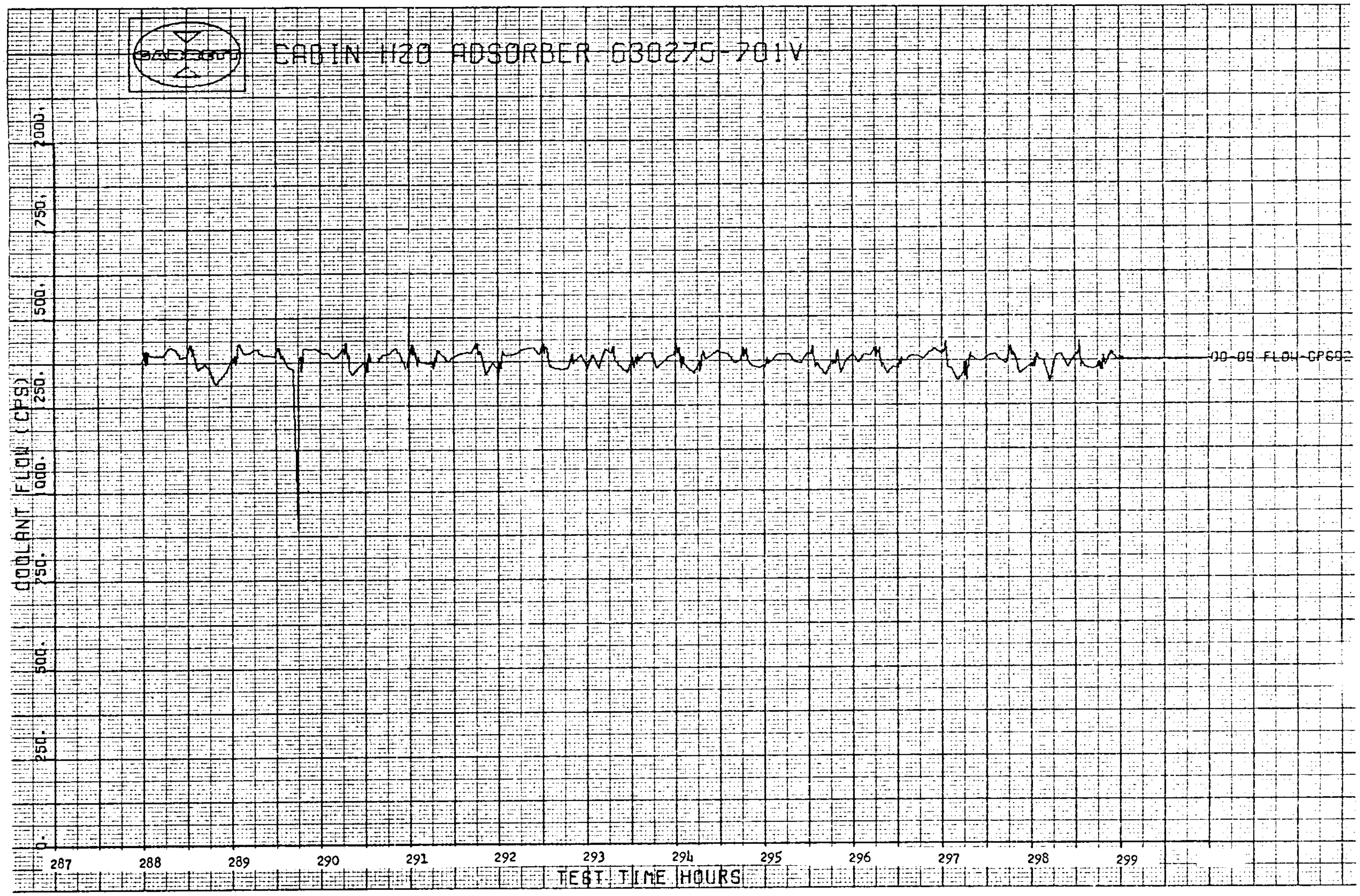

Figure 3-22. Coolant Flow vs Test Time

Figure 3-23. Heat Exchanger Gas Out Pressure vs Test Time

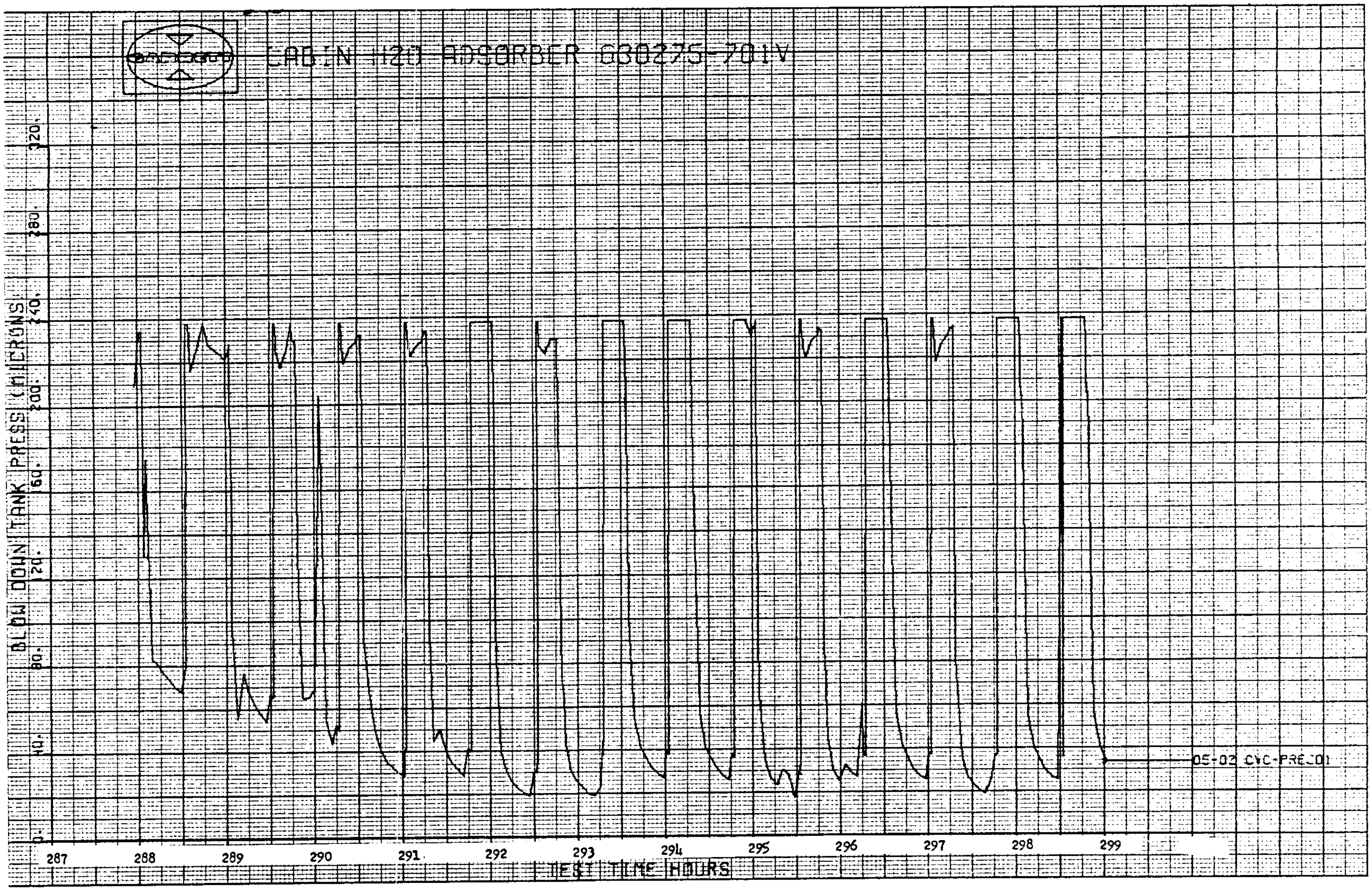

Figure 3-24. Blowdown Tank Pressure vs Test Time

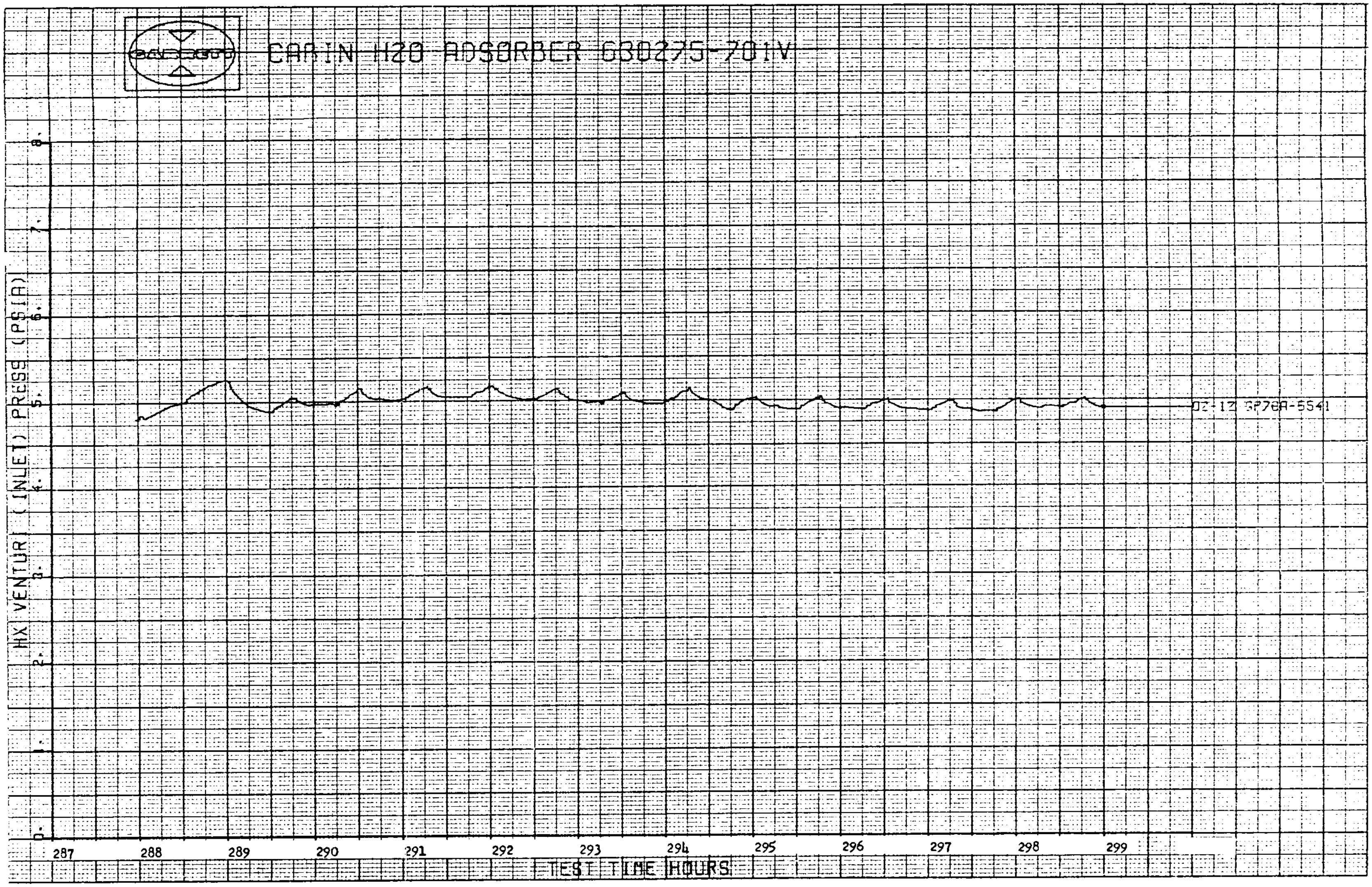

Figure 3-25. Heat Exchanger Venturi Pressure vs Test Time

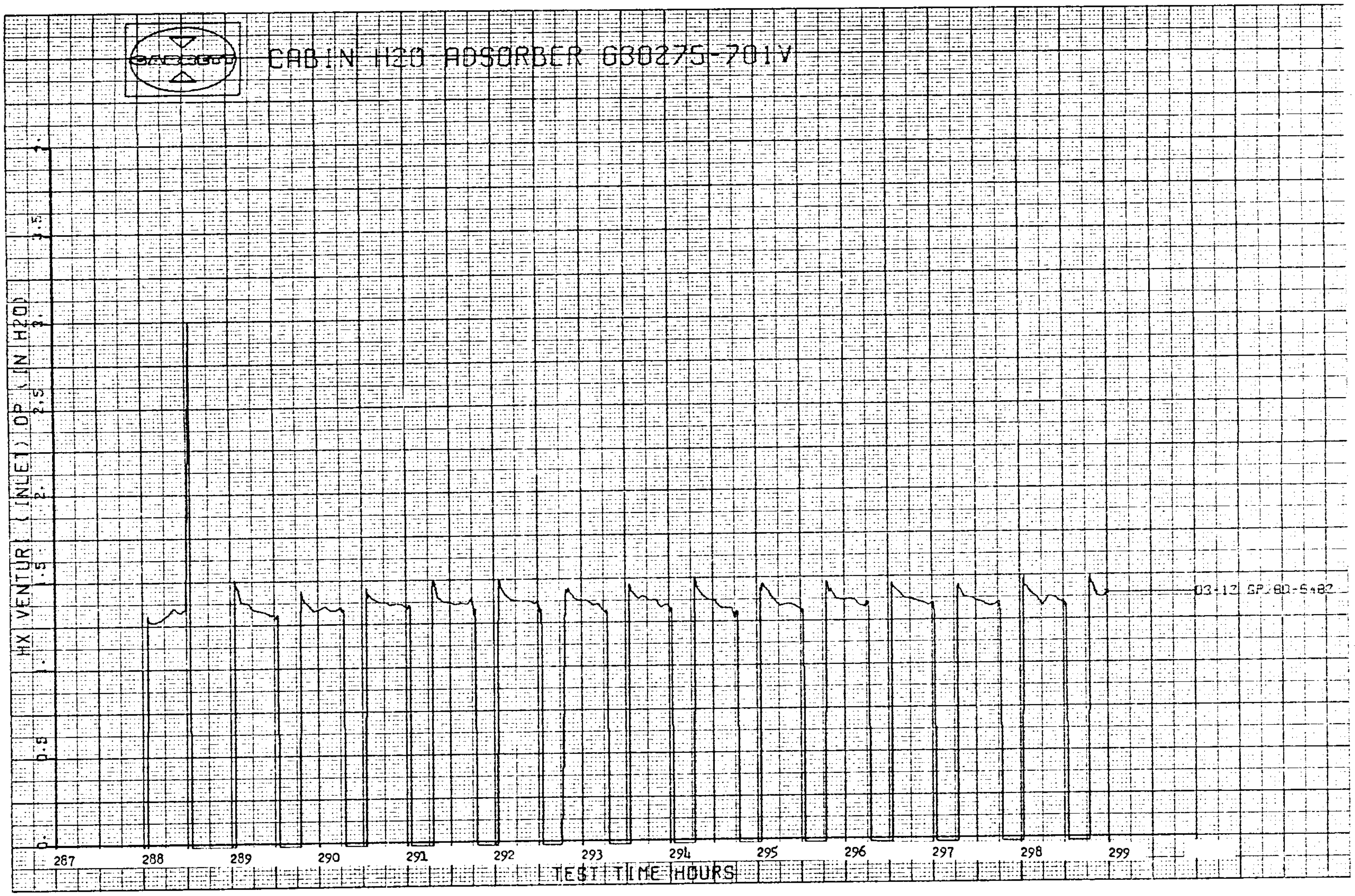

Figure 3-26. Heat Exchanger Venturi ΔP vs Test Time

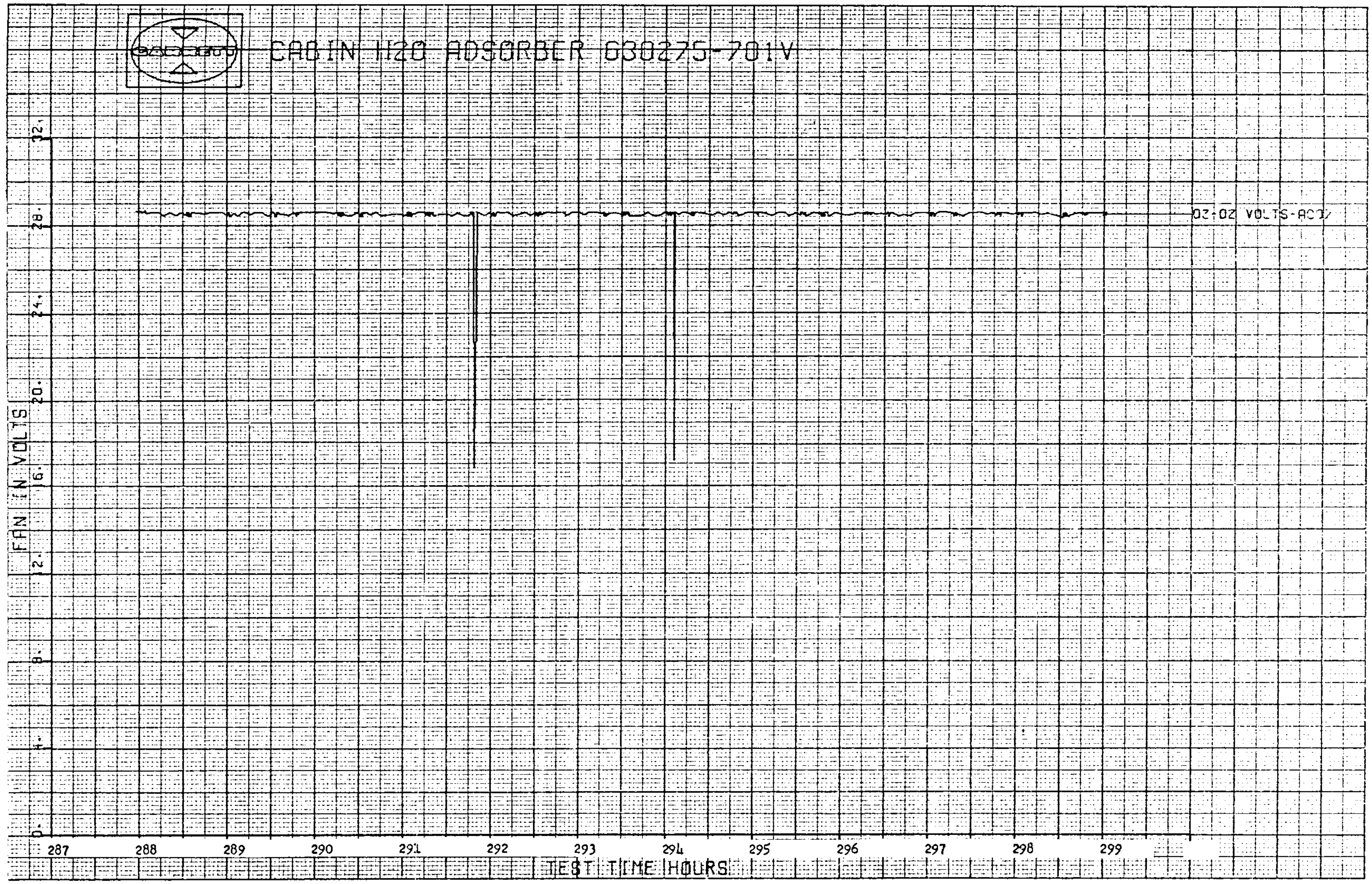

Figure 3-27. Fan Voltage vs Test Time

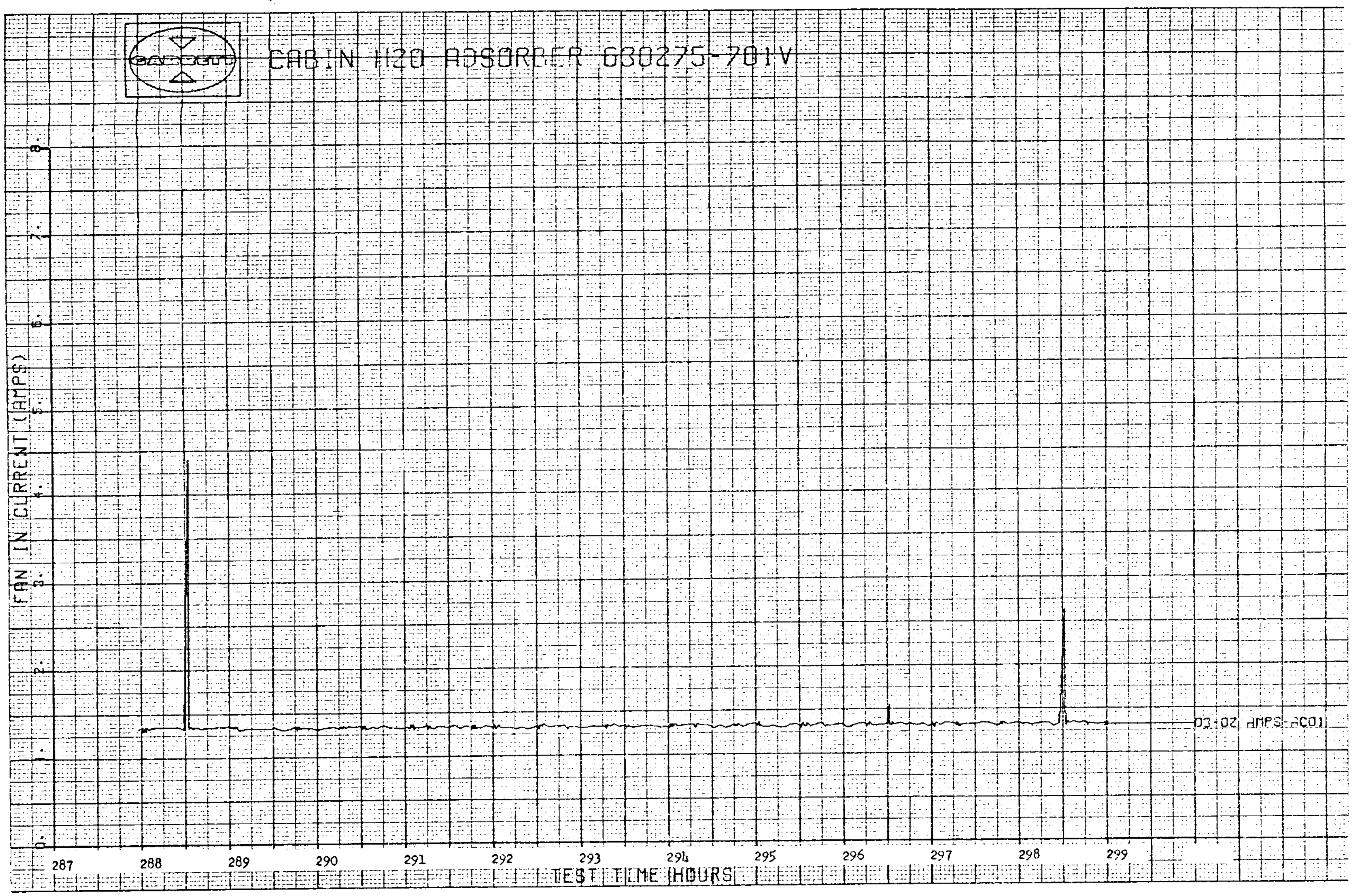

Figure 3-28. Fan Amperage vs Test Time