Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION

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SVHSER 5966

INVESTIGATIONS TO IMPROVE CARBON DIOXIDE CONTROL WITH AMINE AND MOLECULAR SIEVE TYPE SORBERS

by

John F. Bertrand, Harlan F. Brose,
Frank L. Kester and Dr. Peter J. Lunde

March 1972

Prepared Under Contract NAS 1-8944 By

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Division of United Aircraft Corp.
Windsor Locks, Conn.

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FOREWORD

This report was prepared by Hamilton Standard, Division of United Aircraft Corporation, for the National Aeronautics and Space Administration's Langley Research Center in accordance with Contract NAS 1-8944.

The authors wish to express their appreciation to Mr. Rex B. Martin, NASA Langley Research Center Technical Monitor, for his technical advice and support throughout this program.

ABSTRACT

INVESTIGATIONS TO IMPROVE CARBON DIOXIDE CONTROL

WITH

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The optimization trends and operating parameters of an integral molecular sieve bed heat exchanger were investigated. The optimum combination of substrate and coating for the HS-B porous polymer was determined based on the CO_2 dynamic capacity in the presence of water vapor. Full size HS-B canister performance was evaluated. An Amine CO_2 Concentrator utilizing IR-45 sorber material and available Manned Orbiting Laboratory hardware was designed, fabricated and tested by Hamilton Standard for use as an experiment in the NASA 90-day space simulator test of 1970. It supported four men in the simulator for 71 days out of the 90-day test duration.

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SUMMARY

This report describes the analyses and laboratory investigations performed, the results and the conclusions reached from the tasks authorized under the NASA/LRC CO_2 Control Improvement Program, Contract NAS 1-8944.

The CO_2 Concentrator Heat Exchanger Design Study utilized a Hamilton Standard Molecular Sieve CO_2 concentrator computer model to investigate the optimization and trends of operating parameters involved in the design of an integral Molecular Sieve bed heat exchanger.

A range of heat exchanger conductance, and transport fluid flow was determined for maximum performance. The canister heat leak was found negligible with the proper use of canister wall insulation thus making the position of the outer coil in relation to the canister wall non-critical. It was also determined that a decrease in vacuum pump capacity produces a relatively small increase in half cycle time with a significant decrease in the system total equivalent weight.

The Polymer Sorbent Investigation evaluated the performance of coated porous polymer materials by comparative flow through performance derived from laboratory test tube size canister testing. These tests were instrumental in selecting an indicated optimum combination of substrate and sorbent coating based on the CO_2 dynamic capacity in the presence of water vapor. It also determined for the selected sorbent that an increase in the influent gas stream dew point up to 70°F results in a corresponding increase in the dynamic CO_2 capacity, and that the selected sorbent combination has no appreciable dynamic capacity for O_2 and N_2.

Full size canister testing showed that the selected HS-B sorbent is capable of a 3% dynamic bed loading when operating under typical spacecraft conditions, that the inlet P_{CO_2} has minimal effect on the CO_2 bed loading capacity. The current mesh size (25-45) produces a relatively high canister pressure drop, which would impose excessively high circulating fan power penalties in a spacecraft environmental control system design. It was recommended that further polymerization studies should be performed to improve this type sorbent material to provide greater thermal stability, less water solubility and greater CO_2 capacity.

A major effort of the contract was to utilize IR-45 sorber, an aminated polymer, as described: 1) by Mine Safety Appliance Research Corporation (MSA) under a NASA/LRC contract, and 2) by laboratory investigation undertaken in this contract, NAS 1-8944, with MOL hardware (Manned Orbiting Laboratory) where suitable to provide a system for the 90-day manned space simulator test. The unit was built by Hamilton Standard and shipped to test site where it successfully supported four men in the space simulator test

for 71 days out of the 90 day duration. A post test evaluation revealed that system performance deteriorated during the testing at Hamilton Standard and in the 90-day test and that the performance drop was due to a degradation of the IR-45 material with use.

INTRODUCTION

The consideration of extended mission times for manned space flights established the need for some type of oxygen reclamation. The current system concepts reclaim oxygen from carbon dioxide and require a constant supply of the gas in pure form. A great deal of development effort has been expended on CO_2 concentrator systems that continually remove and concentrate carbon dioxide from the cabin atmosphere with subsequent delivery upon demand.

One concept uses Molecular Sieves in a thermal pressure swing (75-300°F, 0.3 to 1.0 psia) system which requires an integral canister heat exchanger to cyclically heat and cool the bed. A computer model for this type of system, with substantiating empirical data, had been previously developed at Hamilton Standard. Since only a limited amount of Molecular Sieve, heat exchanger design data was available, an optimization study was undertaken using the computer model, to study the trends of pertinent operational parameters such as heat exchanger UA_S, transport fluid flow etc. and their effects on the system total equivalent weight.

An inherent deficiency associated with the use of Molecular Sieves as a CO_2 sorber is its preferential affinity for H_2O which necessitates the use of a desiccant to pre-dry the influent gas stream. Consequently, research continues for other sorbent materials having more desirable characteristics. A material previously identified by the contractor as a candidate sorber for CO_2 concentration was investigated to determine optimum loading on inert substrate candidate materials. Two tasks involving this sorber material were provided in this contract, 1) a laboratory program to select the optimum substrate, percentage coating combination based on comparative breakthrough curves (Polymer Sorbent Investigation) and 2) a test program in a full size canister based on the above investigation and aimed at determining the CO_2 dynamic removal capacity on a continuous cyclic basis.

A previous laboratory investigation conducted by Mine Safety Appliance Research Corporation (MSA) under a NASA/LRC contract selected a commercial resin, IR-45 (a styrene divinyl benzene copolymer aminated with diethylene-triamine), with steam desorption as a potential CO_2 sorber. The NASA/LRC after considering the state of amine technology at the time and the availability of certain flight prototype hardware from the cancelled MOL program negotiated with Hamilton Standard to design (using MOL hardware whenever possible and with MSA assistance), fabricate and test an experimental Amine CO_2 Concentrator system for the 90-day manned test conducted in 1970.

OBJECTIVES

The program objectives were to: 1) investigate certain new concepts for CO_2 concentration, and 2) develop information pertaining to several problem areas that had existed in laboratory units of earlier design. The general purpose of these analytical and laboratory investigations was to increase CO_2 concentration system performance and efficiency and provide greater flexibility in future system designs.

CONCLUSIONS AND RECOMMENDATIONS

CO_2 CONCENTRATOR HEAT EXCHANGER DESIGN STUDY

For the conditions of this study, an integral heat exchanger having a UA_S of 2 to 4.5 BTU/Hr.-°F per lb. of Molecular Sieve and a transport fluid flow (water) of 5.5 to 7.0 lbs./hr. per lb. of Molecular Sieve results in maximum performance, i.e., pounds of CO_2 concentrated per hour per lb. $\left(\frac{\text{lbs. } CO_2}{\text{TEW-hr.}}\right)$. A UA_S of up to 2.5 BTU/hr.-°F-lb. can be achieved with either finned or plain serpentine tube. Above this point, a plate-fin heat exchanger becomes more practical.

The canister heat leak can be reduced with the proper utilization of wall insulation so that the position of the outer coil in relation to the canister wall is not critical.

The smaller of the two vacuum pumps compared in this analysis affected a relatively small increase in half cycle time, an increase in the $\frac{\text{lbs. } CO_2}{\text{TEW - hr.}}$, and a significant decrease in the system total equivalent weight (T.E.W.).

POLYMER SORBENT INVESTIGATION

The combination of Porapak S and polyethylenimine with a 44.3% coating by weight is considered the best of the sorbers investigated for absorption of CO_2 under the test conditions described.

An increase in the inlet gas stream dew point up to at least 70°F is associated with a corresponding increase in the CO_2 dynamic capacity.

The selected HS-B combination displays no appreciable dynamic sorption capacity for oxygen or nitrogen.

FEASIBILITY TESTING OF HS-B SORBENT IN A FULL SIZE CANISTER

The HS-B material utilized in a full size canister is capable of producing a 3% CO_2 dynamic bed loading when operating under typical spacecraft conditions. System flow, absorption cool down time and desorption fluid temperature all have an effect on the CO_2 capacity.

Changes in the inlet P_{CO_2} do not seem to affect the sorbent CO_2 capacity but do affect the rate of absorption which necessitates adjustments in the absorb cycle time to realize a constant 3% CO_2 dynamic bed loading.

No HS-B material degradation was experienced while operating under a typical spacecraft condition; however, material degradation can occur if HS-B is exposed to oxygen at elevated temperatures (above 150°F) or subjected to liquid water which will remove the coating material.

The current available mesh size (25 to 45) of HS-B material produces a relatively high canister pressure drop which would impose excessive circulating fan power penalties in a spacecraft environmental control system design.

Further polymerization studies should be performed on this type sorbent to provide greater thermal stability in the presence of oxygen, reduce water solubility and pressure drop characteristics. Improved CO_2 cyclic capacity certainly seems feasible and should be investigated further.

AMINE SORBER CO_2 CONCENTRATOR

The Amine CO_2 Concentrator unit designed and fabricated by Hamilton Standard with IR-45 sorber material processed and furnished by MSA Research Co. under a separate NASA/LRC contract was capable of removing CO_2 to support a four man crew in a spacecraft simulation test. The feasibility of this system concept was demonstrated. Quantitative information derived on the system performance during the test was minimal; however, the system supported four men in the space simulator for 71 days of the 90 day duration.

The CO_2 dynamic capacity of IR-45 material decreased with time as evidenced by the drop in performance determined during the post 90-day test performance task.

The functional capacity of the sorber was evidently reduced by the cyclic steaming and drying as shown by the decrease in the anion exchange capacity of IR-45 material subsequent to the 90-day test, and by the analysis of the residues collected from the feed water pumps and filter.

DISCUSSION

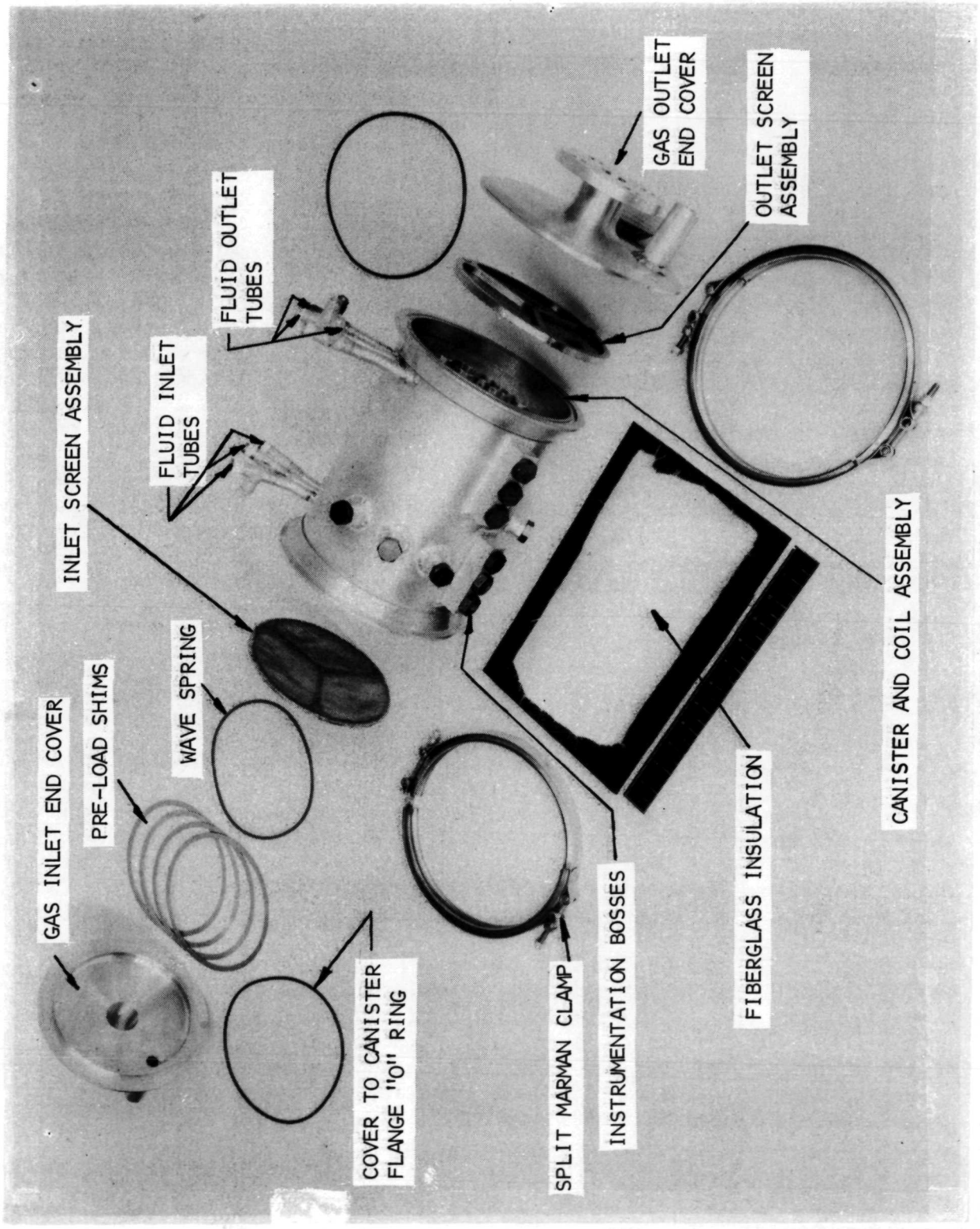
CO_2 CONCENTRATOR HEAT EXCHANGER DESIGN STUDY

Laboratory systems developed at Hamilton Standard using Molecular Sieve sorber for CO_2 concentration have utilized a canister design with heating and cooling coils as shown in figure 1 and 2. The tube assembly, consisting of concentric helically-wound aluminum tubes attached to aluminum fins, was found to be adequate in providing heat transfer within the canister to cyclically heat and cool the Molecular Sieve material. A computer program and analytical model was set up and compared with empirical data to determine the model's capability to predict the performance of such a Molecular Sieve CO_2 concentrator design.

The purpose of this task was to utilize and refine these analytical techniques to provide general design and operation information for packed beds of Molecular Sieve with internal heat exchanger provisions. Design parameters, such as heat exchanger UA_s, transport fluid flow rate, vacuum pump characteristics, cycle time, and heat exchanger geometry as it affects the heat leak from the canister, were to be investigated.

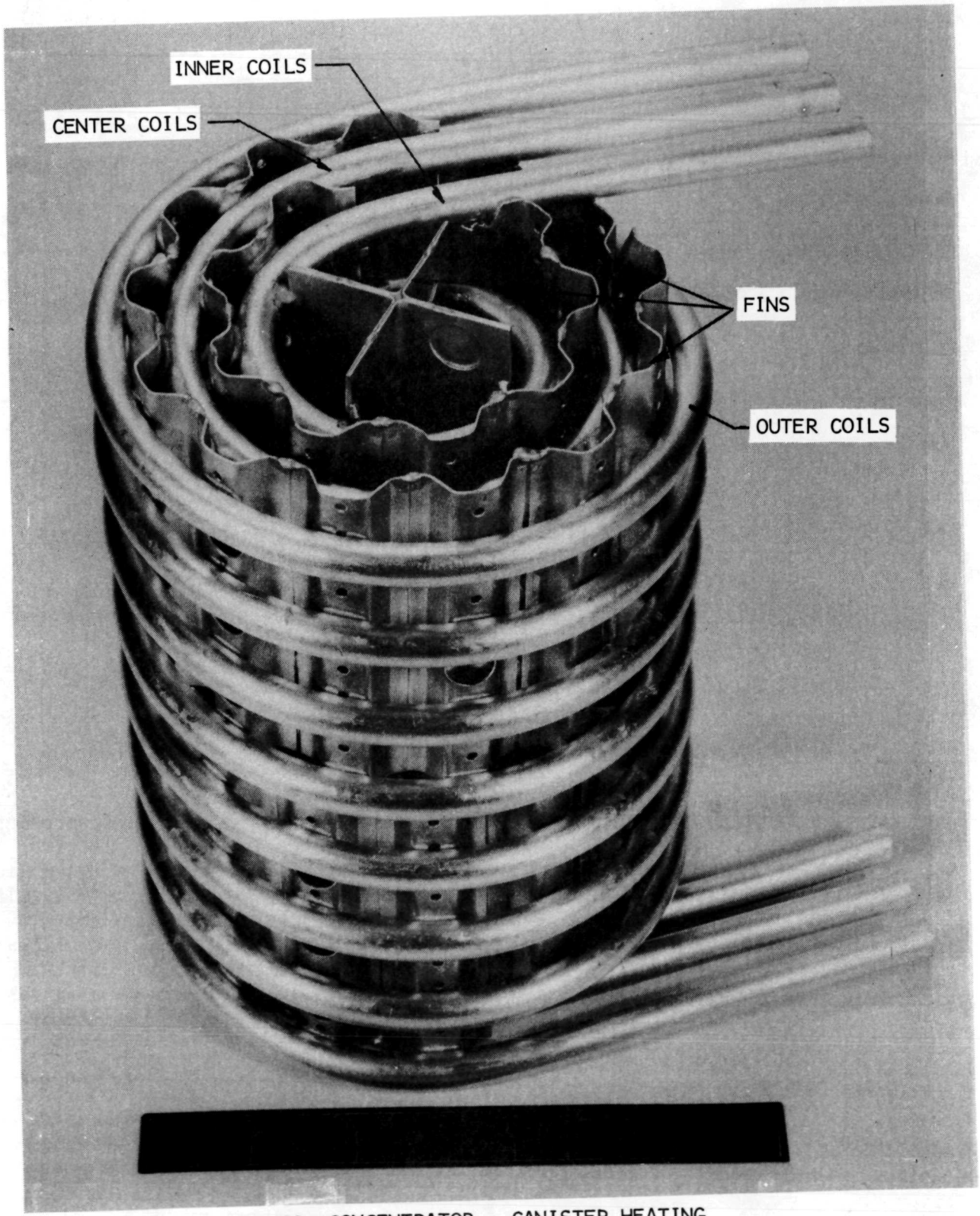
System Description

A CO_2 concentrator design appropriate for use on 1970-1980 missions was chosen as the basis for study. A simplified system schematic is shown in figure 3, which defines the flow paths between components. Process gas enters the regenerable CO_2 removal system and is directed to a desiccant bed for water removal, and is then passed through the Molecular Sieve material for CO_2 adsorption. Two Molecular Sieve canisters are utilized in this system; one is adsorbing while the other is desorbing. A vacuum pump is required to evacuate the canister and to reduce the P_{CO_2} over the sorber to effect the desorption of CO_2 and to transfer the desorbed CO_2 to an accumulator. A fin and coil heat exchanger embedded in the Molecular Sieve cools the bed during adsorption and heats it during desorption to increase the process efficiency. Each of the two adsorbent beds contains 22 pounds of Linde 5$\mathring{A}$ Molecular Sieve material, a commonly used sorber for which experimental performance data is readily available. The canister configuration has a wall thickness of 0.07 inches, a length of 8.60 inches, and utilizes a 0.50 inch thick fiberglass insulating blanket against the inside surface of the outer wall. Fluid at 42°F is used for cooling the bed during adsorption and is cyclically changed to 190°F for heating the Molecular Sieve material during desorption.



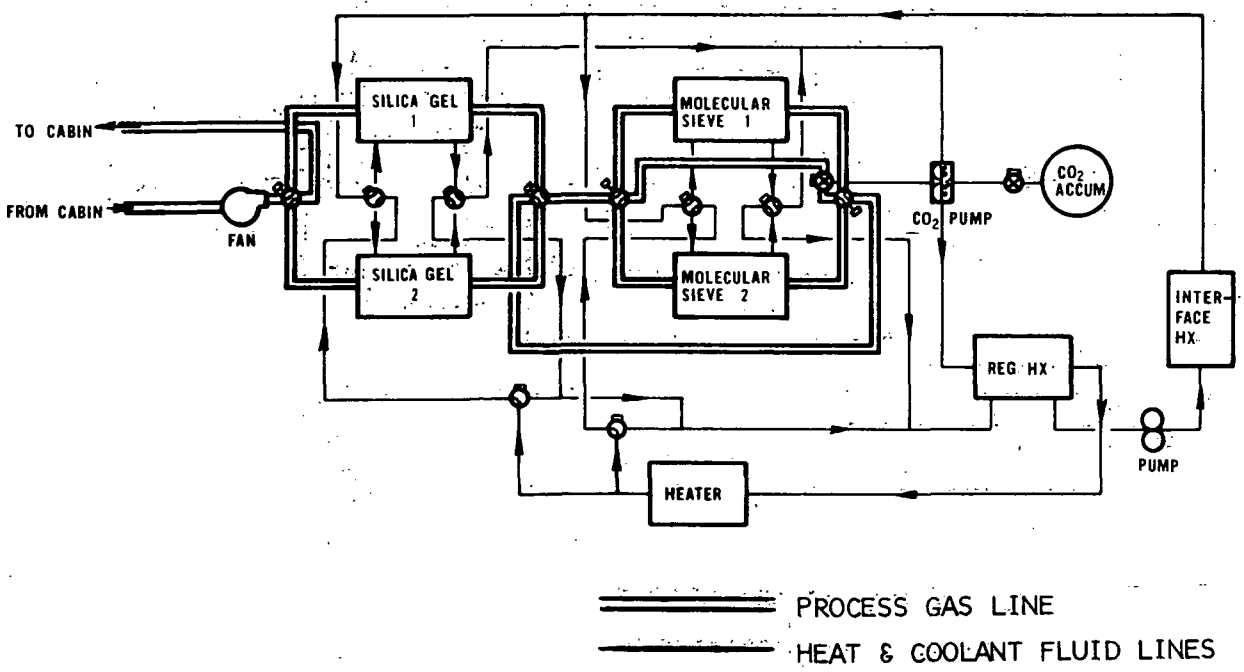
CO_2 CONCENTRATOR - CANISTER

FIGURE 1



CO_2 CONCENTRATOR - CANISTER HEATING AND COOLING COIL ASSEMBLY

FIGURE 2



BASELINE CO_2 CONCENTRATOR SCHEMATIC (SIMPLIFIED)

FIGURE 3

Computer Program Description

The H-327 Computer Program predicts CO_2 Concentrator performance by combining math models of the major component processes employed in the concentrator. The transient processes occurring during adsorption and desorption within the beds are described using a finite difference technique employing multiple modes or canister sections. Four modes are used for adsorption while only one mode is utilized for the desorbing Molecular Sieve bed. The Molecular Sieve desorption mode includes the bed together with the vacuum pump and accumulator. The details of the mathematical models are described as follows:

Molecular Sieve Bed Adsorption.- This process occurs in the presence of a gas flow. The basic equations are presented as follows:

Mass Balance: $$\frac{\partial m_o}{\partial t} = \frac{\partial m_{in}}{\partial t} - \frac{\partial m_a}{\partial t}$$

Adsorption Rate: $$\frac{\partial m_{ab}}{\partial t} = K_a (P-P^*)$$

where $\frac{\partial m_o}{\partial t}$ = Adsorbate mass flow out of mode, lbs/hr.

$\frac{\partial m_{in}}{\partial t}$ = Adsorbate mass flow into a mode, lbs/hr.

$\frac{\partial m_a}{\partial t}$ = Rate of adsorbate adsorbed in a mode, lbs/hr.

K_a = A x SKA x V x M lbs/hr. - mm Hg

Adsorption Thermal Balance:

Bed Surface Temperature

$$T_{surf} = \frac{K_S \times T_{amb.} + K_T \times T_B}{K_T + K_S}$$

Heat Loss to Ambient

$$Q_{Loss} = K_T (T_{Surf} - T_B)$$

Heat Generated in Bed

$$Q_{Gen.} = K_H \times \frac{\partial m_a}{\partial t}$$

Heat Conducted to Gas

$$Q_g = (mCp)_g (T_B - T_g)$$

Heat Conducted to Liquid

$$Q_L = (HA)_L (T_L - T_B)$$

Axial Heat Conduction

$$Q_A = K_A (T_{B2} - T_{B1})$$

A lumping process was used as an approximation to integration with respect to distance in the adsorbing bed. Thus, in each lump or section no variation with distance occurs in pressure, concentration or bed loading.

The characteristics of the physical process and the limitations implied by the above equations are discussed below:

1) The gas phase at a given distance, Z, from the bed inlet has an adsorbate partial pressure P, which depends only on Z, time, and inlet concentration.

2) The driving potential between the gas and the solid surface is the difference between the partial pressure of the adsorbate in the gas and the equilibrium (isotherm) pressure of the adsorbate.

3) At the surface the solid is in contact with the gas and mass transfer occurs through a film with a conductance proportional to a coefficient, K_a, derived from experimental evidence.

4) The analysis is carried out at the macroscopic level.

5) The bed and gas flow are homogeneous throughout every bed section.

6) Mixing or dispersion in the direction of flow is negligible.

7) The adsorption process generates heat proportional to the rate of mass adsorption with the proportionality factor being a function of bed loading.

8) Cooling and heating liquid transfer heat to the bed-wall but not to the carrier gas. Gas temperature is assumed equal to bed temperature.

9) Axial heat conduction in the liquid and gas is neglected but is considered within the bed.

10) The temperature in either the fluid or the wall is a function only of bed axial distance, Z, and time.

Molecular Sieve Bed Desorption.- The basic equations employed in modeling vacuum desorption are listed as follows:

Mass Flow of CO_2 Out of Bed:

$$\frac{\partial m_o}{\partial t} = (P \stackrel{*}{-} Pe) \frac{K_R}{1 + \frac{K_R}{A_L}}$$

Heat Transfer to Bed:

$$\frac{\partial T_B}{\partial t} = \frac{HA_L}{M_Z \times Cp_b} (T_L - T_B) - \frac{Q_{Sorb} + Q_{Loss}}{M_Z \times Cp_b}$$

Heat Transfer to Fluid:

$$\frac{\partial T_L}{\partial t} = \frac{HA_L}{M_L \times Cp_L} (T_B - T_L) - \frac{(W)\ Cp_L}{M_L \times Cp_L} (T_L - T_{LI})$$

Desorption Thermal Balance:

Heat Lost to Ambient

$$Q_{Loss} = K_T (T_{Surf} - T_B)$$

Where $T_{Surf} = \dfrac{K_S \times T_{amb.} + K_T \times T_B}{K_T + K_S}$

Heat of Desorption

$$Q_{Sorb} = K_H \times \frac{\partial m_o}{\partial t}$$

Axial Heat Conduction

$$Q_A = K_A (T_{B2} - T_{B1})$$

The major assumptions and approximations employed in solving these equations are discussed below:

1) The desorption model assumes the entire bed as a single section.

2) The driving temperature difference between the liquid and the bed at the inlet to the bed is used to calculate the heat transfer between the bed and the fluid. It is assumed that there is no axial conduction. Consequently, an overall heat transfer coefficient is employed.

3) The free CO_2 gas is assumed to be at the bed temperature, (i.e., HA between the gas and the bed is assumed large compared to HA between the liquid and the bed). The desorbing CO_2 is assumed to remove negligible energy from the canister because of the small quantity of CO_2 involved.

4) Equilibrium relations between T, m_{ab}/M_Z and P* are assumed to hold during transients. A constant value for K_R was assumed.

5) The pressure drop is assumed to be directly proportional to the flow rate (as in the Blake-Kozany equation).

6) It was assumed that no desorption of non-CO_2 gas (which may be present at the beginning of a desorption cycle) occurs.

Vacuum Pump, Line, and Accumulator

The computer program is designed to accept, in the form of a table, the performance of the vacuum pump in the following form:

$$\dot{m}_{CO_2} = f (P_i, P_o, T_i)$$

$$PW = f (P_i, P_o, T_i)$$

The $\dot{m}_{CO_2}$ values are calculated by utilizing the small and large vacuum pump performance maps shown in figure 4.

The compressor power is calculated as follows:

$$(P_W)_{Comp.} = \frac{M_{CO_2\ i}\ H_{AD}}{\eta\ COMP} \times .0226 \times n$$

Where $$H_{Ad} = \frac{k}{k-1} \times \left[\frac{1545}{M_{CO_2}}\right] T_i \left[\left(P_o/P_i\right)^{\frac{k-1}{k}} - 1\right]$$

$$\eta\ Comp = \left[1 + \text{clearance} - \text{clearance} \times \text{leakage} \left(\frac{P_o}{P_i}\right)^{\frac{1}{k}}\right] \times F_C$$

$$= \left[1 + .2 - (.2)\ (1.1)\left(\frac{P_o}{P_i}\right)^{1/k}\right] \times F_C$$

$F_C = .50$ for large pump
$F_C = .40$ for small pump

$$(P_W)\ Motor = \frac{(P_W)\ comp.}{\eta\ Motor} \qquad \eta\ Motor = .60$$

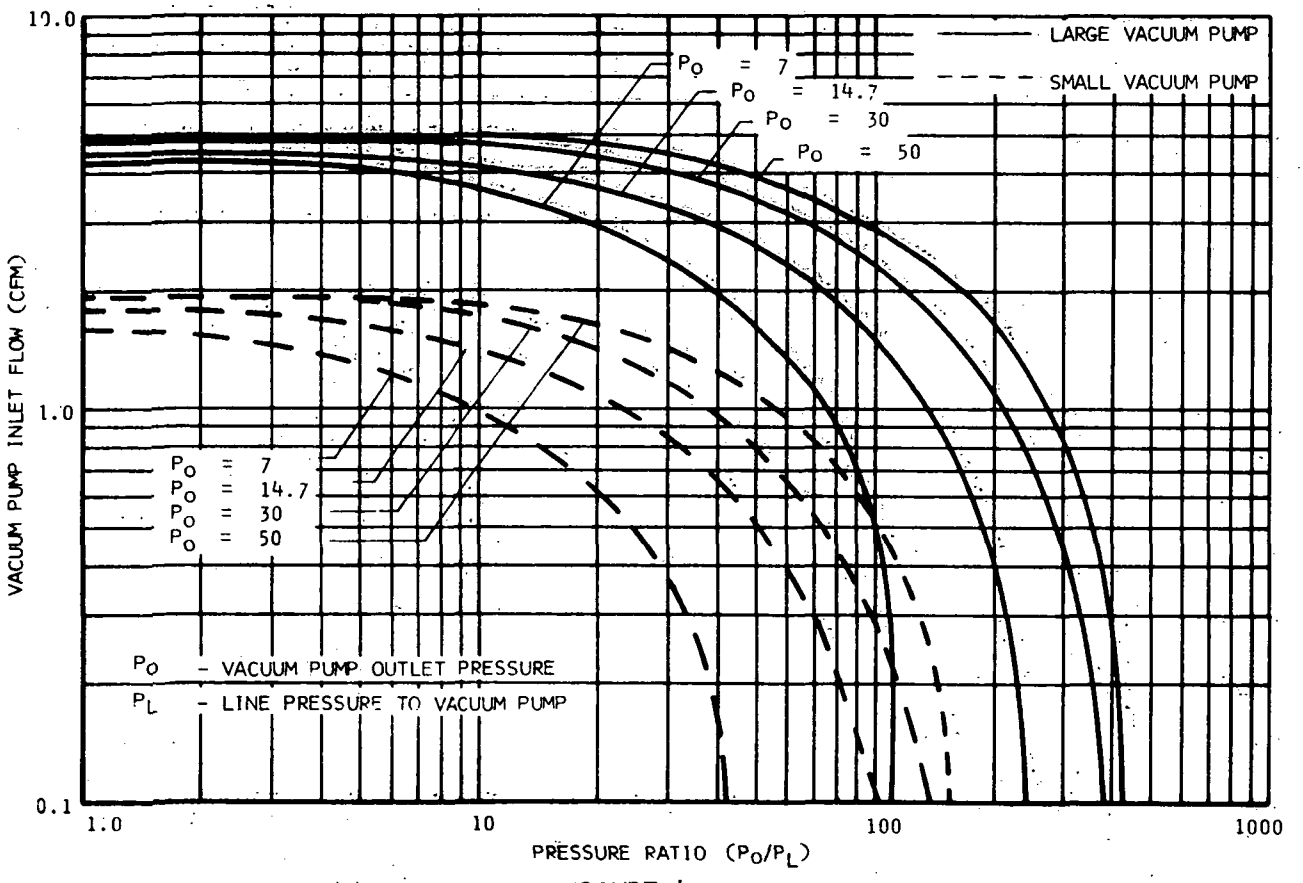


FIGURE 4

The following equations are used to describe the line and accumulater performance:

$$\frac{d\,P_L}{d\,t} = \frac{(\dot{m}_{CO_2} - \dot{m}_{G_i})\ R\ T_i}{(144)\ V_L\ M_g}$$

$$\frac{d\,P_{CO_{2_L}}}{dt} = \frac{(\dot{m}_{CO_{2_o}} - \dot{m}_{CO_{2_i}})\ R\ (51.714)\ T_i}{(144)\ V_L\ M_{CO_2}}$$

$$\frac{d\,P_A}{dt} = \frac{K\,P_A\ (\dot{V}_{CO_{2_i}} - \dot{V}_{CO_{2_o}})}{V_{ACC}}$$

Calculation of P*:

The program calculates P* from the weight loading of adsorbate on adsorbent and temperature using the Polyani Potential Theory.[1] This procedure, together with the equations used, is described as follows:

CO_2 Adsorption on Molecular Sieve

1) Given weight loading of CO_2 on molecular sieve, $W = \frac{ma}{Mz} = \frac{\text{lbs } CO_2}{\text{lbs M.S.}}$ and T_B in °F and °K.

2) Calculate ϕ

$$\phi = W\left(\frac{Vm}{M}\right)$$

Vm = 21 cc/gm-mole
M = 44 gm/mole
ϕ is loading in cc/gm

3) Calculate A_R

$$A_R = -1.124\ (\ln\phi)^2 - 33.74\ \ln\phi + 15.4$$

4) Calculate P°/P*

$$P°/P* = \ln^{-1}\left(\frac{A\ Vm}{T_B}\right)$$

T_B in °K

Numbers in ( ) correspond to numbered references in the bibliography.

5 Calculate P°

$$P° = e^{0.0152T + 5.719} \quad T_B \leq 180°F$$

$$= e^{-0.00348T + 9.053} \quad T_B > 180°F$$

where P° is in psia

6 Calculate P*

$$P^* = \left(\frac{P°}{P°/P^*}\right) \quad (51.7 \text{ mmHg/psia})$$

A summary of the Computer Parametric Symbols used in the program is presented in table 1.

TABLE 1

SUMMARY OF COMPUTER PARAMETRIC SYMBOLS

Symbol	Symbol Definition	Symbol Value
A	Surface area per volume Molecular Sieve	= 427 ft^2/ft^3
A_L	Empirical variable	= .516 $P_B^{.2}$ + 1.3 $(\frac{537}{T_B})^{1.7}$
A_{Surf}	Canister surface area	= πD_{o1} x L ft^2
A_R	Retentivity factor	= $\frac{°K - mole}{cc}$
CEMAO	Volume flow rate out of accumulator	= .0945 ft^3/min.
C_{P_b}	Specific heat of bed	= .253 BTU/lb -°R
C_{P_g}	Specific heat of process gas	= .2 BTU/lb -°R
C_{P_L}	Specific heat of liquid	= 1.0 BTU/lb. - °R
C_{P_w}	Specific heat of canister wall	= .22 BTU/lb -°R
D_C	Heating coil diameter	= .915 ft
D_I	Insulation inner diameter	= .977 ft
D_o	Canister inner diameter	= 1.06 ft.

TABLE 1 (continued)
SUMMARY OF COMPUTER PARAMETRIC SYMBOLS

Symbol	Symbol Definition	Symbol Value
D_{o1}	Canister outer diameter	= 1.08 ft
E	Canister surface emissivity	= .9
HA_L	Liquid to bed conduction coefficient	= BTU/hr - °R
H_{AD}	Vacuum pump head	= ft
H_C	Conduction coefficient, canister to ambient	= .2 BTU/hr - ft^2 - °R
k	Specific heat ratio of CO_2	= 1.3
K_A	Bed axial conduction coefficient	= .0031 BTU/hr -°R
K_a	Adsorption rate	= lbs/hr - mm Hg.
K_B	Thermal conductance of bed	= .10 BTU/hr - ft - °R
K_C	Thermal conductance of canister	= 100 BTU/hr - ft - °R
K_H	Heat of adsorption coefficient	= $f\left(\frac{ma}{Mz}\right)$
	Heat of Adsorption Coefficient as a Function of Bed Loading	
	$\frac{ma}{Mz}$ $\frac{lbs\ CO_2}{lbs\ M.S.}$ / K_H BTU/lb CO_2 adsorbed	
	0 / 525.00	
	0.010 / 493.75	
	0.015 / 440.00	
	0.05 / 425.00	
	1.00 / 425.00	
K_I	Thermal conductance, insulation	= .2 BTU/hr - ft - °R
K_R	Overall bed desorption rate constant	= .127 lb/hr - mm Hg.
K_S	Radiation and convection coefficient	= A_{Surf} (E + H_C)
K_T	Conduction coefficient from bed to wall	= $\frac{K_1 + K_2 + K_3}{K_2 K_3 + K_1 K_3 + K_1 K_2}$
K_1		= $\frac{2\pi K_B L}{\ln (DI/Dc)}$

TABLE 1 (continued)
SUMMARY OF COMPUTER PARAMETRIC SYMBOLS

Symbol	Symbol Definition	Symbol Value
K_2		$= \frac{2\pi K_I L}{\ln (D_o/D_I)}$
K_3		$= \frac{2\pi K_C L}{\ln (D_o^1/D_o)}$
L	Length of canister	= .717 ft
M	Adsorbate molecular wt., M.S.	= 44.0 lb/lb - mole
M_{CO_2}	Molecular weight of CO_2	= 44 lbs/mole
M_g	Molecular weight of gas at inlet to vacuum pump	= lbs/mole
M_L	Mass of liquid in bed	= 6.75 lbs
MS	Molecular Sieve	
M_W	Mass of canister wall	= 30.8 lbs
M_Z	Mass of Molecular Sieve in bed	= 22 lbs
m_a	Mass of CO_2 adsorbed	= lbs
m_{ab}	Mass of CO_2 desorbed	= lbs
$\dot{m}_{CO_2}$	Mass flow rate of desorbed from bed	= lbs/hr
$\dot{m}_{CO_{2i}}$	Mass flow rate of CO_2 into vacuum pump	= lbs/hr
$\dot{m}_{CO_{2o}}$	Mass flow rate of CO_2 out of vacuum pump	= lbs/hr
$\dot{m}_{g_i}$	Mass flow rate of gas into vacuum pump	= lbs/hr
m_{in}	Mass of CO_2 at canister inlet	= lbs
m_o	Mass of CO_2 at canister outlet	= lbs
n	Number of stages	= large pump - 3 small pump - 2
P°	Saturation pressure at operating temp.	= psia
P	Partial pressure in gas phase	= psia

TABLE 1 (continued)
SUMMARY OF COMPUTER PARAMETRIC SYMBOLS

Symbol	Symbol Definition	Symbol Value
P^*	Adsorbate equilibrium partial pressure in Molecular Sieve	= mm Hg.
P_A	Accumulator pressure	= psia
PACC	Initial accumulator pressure	= 30.0 psia
P_B	Pressure in bed	= psia
P_e	Pressure at canister exit	= psia
P_i	Pressure at vacuum pump inlet	= psia
P_L	Pressure in line	= psia
P_o	Pressure at vacuum pump outlet	= psia
P_W	Vacuum pump power	= watts
R	Adsorbate gas constant (MS)	$= 12.6 \frac{\text{mm Hg.} - \text{ft}^3}{\text{lb} - {}^\circ\text{R}}$
SKA	Adsorption gas phase mass transfer	$= 7.39 \times 10^{-4} \frac{\text{lb-mole}}{\text{hr-ft}^2\text{-mm Hg.}}$
Q	Heat	= BTU/hr
t	Time	= hr
$T_{amb.}$	Ambient temperature	= 530°R
T_B	Bed temperature	= °R
T_g	Process gas inlet temperature	= °R
T_i	Temperature at vacuum pump inlet	= 544°R
T_L	Liquid temperature in tubes, static	= °R
T_{LI}	Liquid flow temperature in	= °R
T_{Surf}	Canister sruface temperature	= °R
V	Bed volume	= .0542 ft^3
V_{ACC}	Volume of accumulator	= 1000 ft^3
$V_{CO_2 i}$	Volume flow rate of CO_2 into accumulator	= ft^3/hr

TABLE 1 (continued)
SUMMARY OF COMPUTER PARAMETRIC SYMBOLS

Symbol	Symbol Definition	Symbol Value
$V_{CO_{2_o}}$	Volume flow rate of CO_2 out of accumulator	= ft^3/hr
V_D	Vacuum pump volumetric displacement	= ft^3/hr
V_g	Process gas volumetric flow rate	= 2086 ft^3/hr
V_L	Volume of line (pumping system)	= .1375 ft^3
V_m	Molar volume	= cc/gm - mole
W	Mass flow rate	= lbs/hr
η	Efficiency	= %

The CO_2 concentrator equivalent weight was obtained by the addition of component fixed weights and equivalent weight penalties for power consumption and heat rejection. The equivalent weight penalties imposed are detailed in table 2.

TABLE 2

IMPOSED EQUIVALENT WEIGHT PENALTIES

Regulated 115 VAC 400 cycle 3 phase electric power	0.710 lbs/watt
Heat Rejected to Cabin	0.05 lbs/BTU/hr
Heat from Bed to Transport Fluid	0.03 lbs/BTU/hr
Heat from Transport Fluid to Bed (unregulated D.C.)	0.45 lbs/watt

In calculating the power consumption penalty for the vacuum pump, the time-averaged power value was employed.

All variable parameters were investigated utilizing two different size vacuum pumps (see Performance Map, figure 4) so that the effects of operating at two desorb pressure ranges 0.3 to 2.5 psia (small pump) and 0.1 to 1 psia (large pump) could be explored.

The Heat Exchanger weight to UA ratio arrived at from empirical data and used in the computer program is:

$$0.208 \frac{\text{lb. Hx Core}}{\text{BTU/hr} - {}^{\circ}\text{F}}$$

Computer Program and Results

The computer program described was then used to examine the effect on heat exchanger performance in a packed bed by varying selected system parameters.

The transport fluid flow and the heat exchanger UA_s parameters were initially investigated using the two different size vacuum pumps (see figure 4) and a fixed cycle time of 120 minutes (60 minutes adsorb - 60 minutes desorb).

The transport fluid (water) flow was varied over a range of 15.5 to 232.5 lbs/hr. A value of UA_s = 48.3 BTU/hr. scaled-up from the 5 lb. (UA_s = 11 BTU/hr.) experimental canister to the 22 lb. computer model was used. The results of the analysis were examined on the basis of lbs. CO_2/TEW*-hr. and are plotted in figure 5 as a function of transport fluid flow-rate. As the flow increases within practical limits, the effect on the lbs. CO_2/TEW-hr. diminishes to the point where further increases in flow have no appreciable effect on system performance. This effect is caused by an increasing tube internal film conductance with increasing flow until the $1/h_iA_i$ term in the UA calculation (figure 6) becomes insignificant.

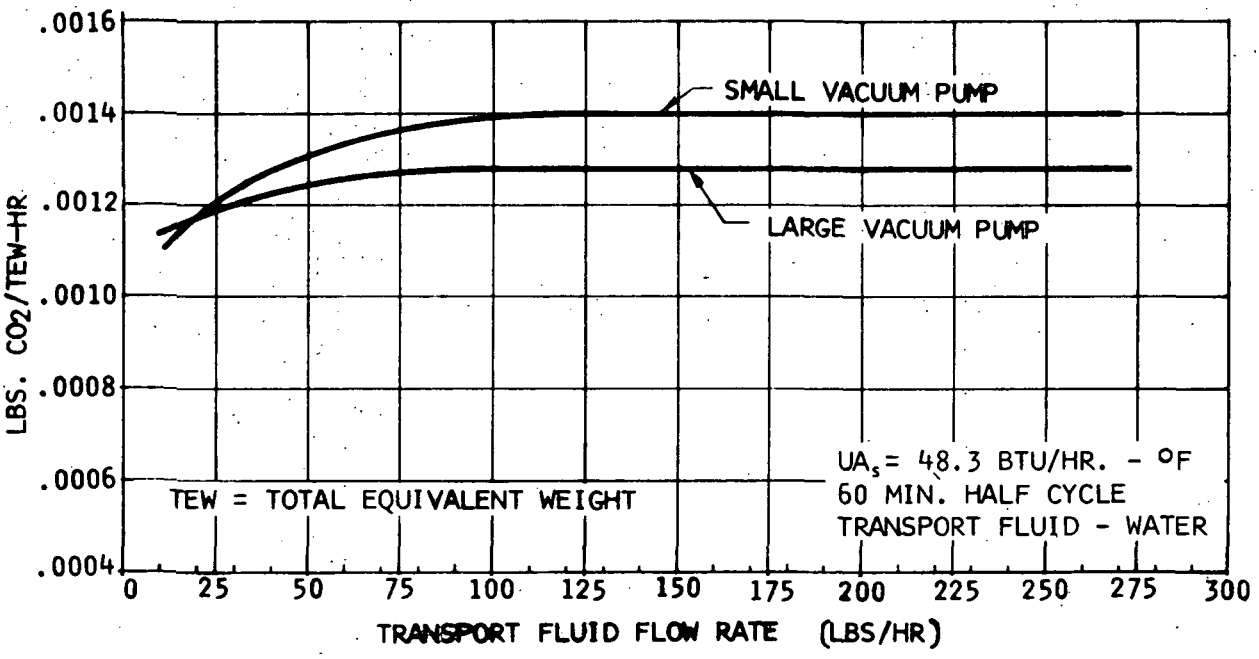
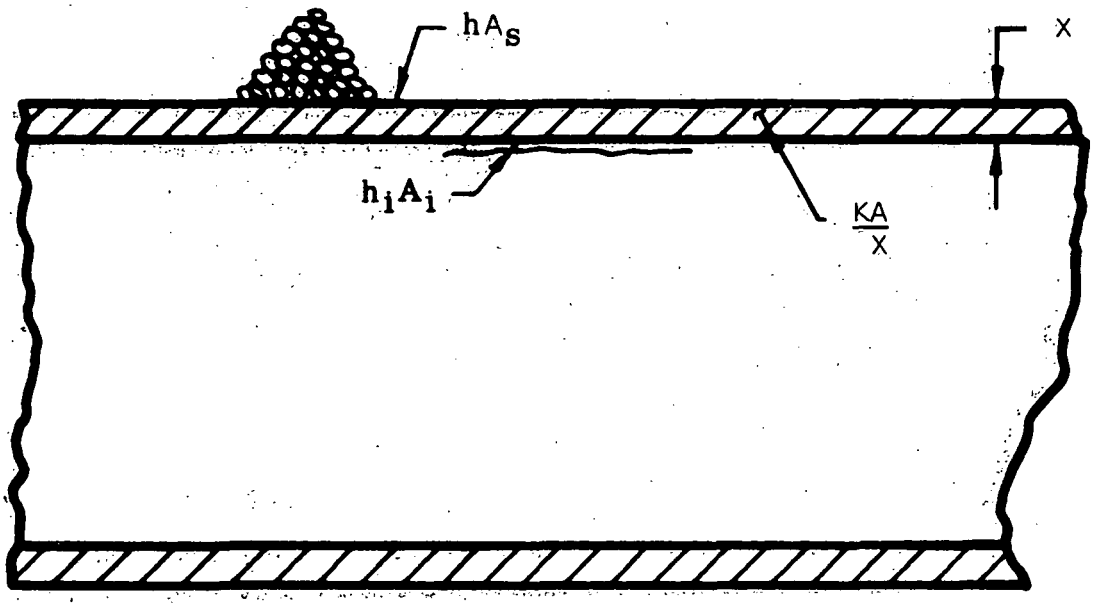


FIGURE 5

*TEW - Total Equivalent Weight, lbs



$$UA_s = \frac{1}{\frac{1}{h_iA_i} + \frac{1}{\frac{KA}{X}} + \frac{1}{hA_s}} \approx hA_s$$

LIQUID FLOW VALUE SELECTED INSURES VERY LARGE VALUE OF h_iA_i

ALUMINUM OFFERS LITTLE RESISTANCE

CONTROLLING TERM

A = MEAN TUBE SURFACE AREA, SQ. FT.
A_i = TUBE INTERNAL SURFACE AREA, SQ. FT.
A_s = TOTAL TUBE (OUTSIDE) AND FIN SURFACE AREA, SQ. FT.
h = OUTSIDE SURFACE COEFFICIENT, BTU/(HR) (SQ. FT.) ($^\circ$F)
h_i = INSIDE FILM COEFFICIENT, BTU/(HR) (SQ. FT.) ($^\circ$F)
K = THERMAL CONDUCTIVITY, BTU/(HR) (SQ. FT.) ($^\circ$F/FT.)
U = OVERALL COEFFICIENT, BTU/(HR) (SQ. FT.) ($^\circ$F)
X = TUBING WALL THICKNESS, FT.

UA_S DEFINITION

FIGURE 6

A similar investigation was carried out for the overall heat exchanger conductance UA_S, which is defined as the product of the overall heat transfer coefficient U and the heat exchanger tube and fin external surface area A_S (see figure 6). A single transport fluid flow rate of 155 lb/hr. was selected from figure 5 to eliminate this parameter as a variable in this analysis of system performance. Values of UA_S used ranged from 14.7 to 120.7 BTU/hr.-°F. The heat exchanger weight is a direct function of UA_S which is varied by increasing or decreasing the surface area. The results are plotted in figure 7 again on the basis of effect on the lbs. CO_2/TEW-hr. As expected, the variation of heat exchanger (UA_S) within a practical range exhibits the same trend as the transport fluid flow rate variations; however, it has a more pronounced effect on the system performance. A point is indicated in each case above which no significant increase in performance can be obtained.

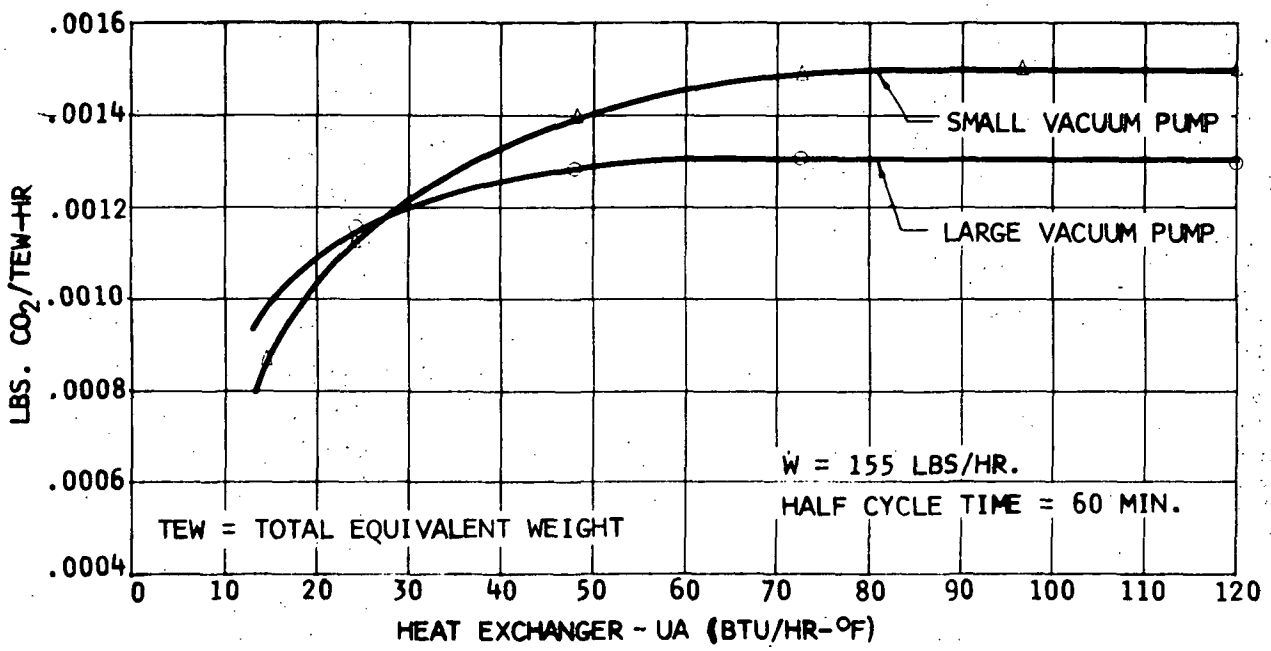
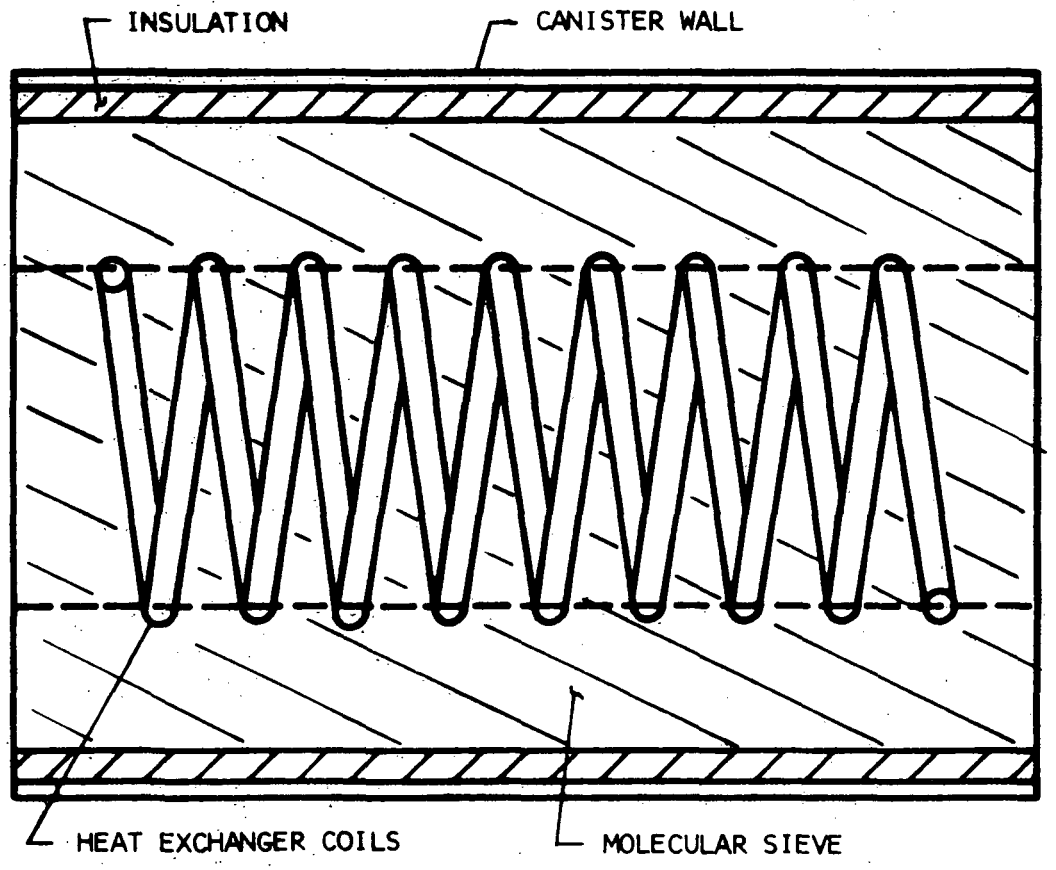


FIGURE 7

The effect of the canister heat leak on performance was also investigated. Initially, the computer model for these radial heat loss calculations, indicated that the heat exchanger outer coil should be located so that equal masses of Linde 5Å material were located within the coils and outside the coils. (See figure 8). This study was conducted by running nominal operating conditions with the heat exchanger outer coil moved in steps toward the canister insulated wall to gradually increase the amount of heat leak. The

results showed that the heat leak from the canister under the worst conditions represents less than 10% of the total available heat and has a minor effect on performance.



SIMPLIFIED MOLECULAR SIEVE CANISTER

FIGURE 8

Based on the results of the transport fluid flow rate and heat exchanger UA_S studies, values considered optimum for both pumps with a reasonable margin of safety (flow rate 155 lbs/hr., heat exchanger UA_S 96.6 BTU/hr.-°F) were chosen to investigate the effects of cycle time on system performance. Half cycle times selected for this investigation were 30, 40, 50, 60, 80, 120 and

240 minutes. Again, the analysis included the effects of using both a large and small vacuum pump. The results are shown in figure 9 and 10. When considering yield (lbs CO_2/hr.) by itself, figure 9 indicates that the large vacuum pump at the optimum point provides the best performance (support 14 men based on 2.2 lbs. CO_2/man day; the small vacuum pump would support 11 men). However, when the effects of system total equivalent weight are introduced (figure 10), the curves show that the small vacuum pump has a much lower system weight and its performance based on lbs. CO_2/TEW-hr. is approximately 16% greater than that of the larger vacuum pump. Although the large vacuum pump removes CO_2 at a higher rate, the power penalty associated with the larger capacity unit lowers performance on a per pound basis. The optimum half cycle time for the small vacuum pump is 67 minutes.

A complete listing of the computer cases run for both the small and large vacuum pump is presented in tables 3 and 4.

A summary of the fixed system parameters, the scaled items and the indicated optimum results for the design point investigated is shown in table 5.

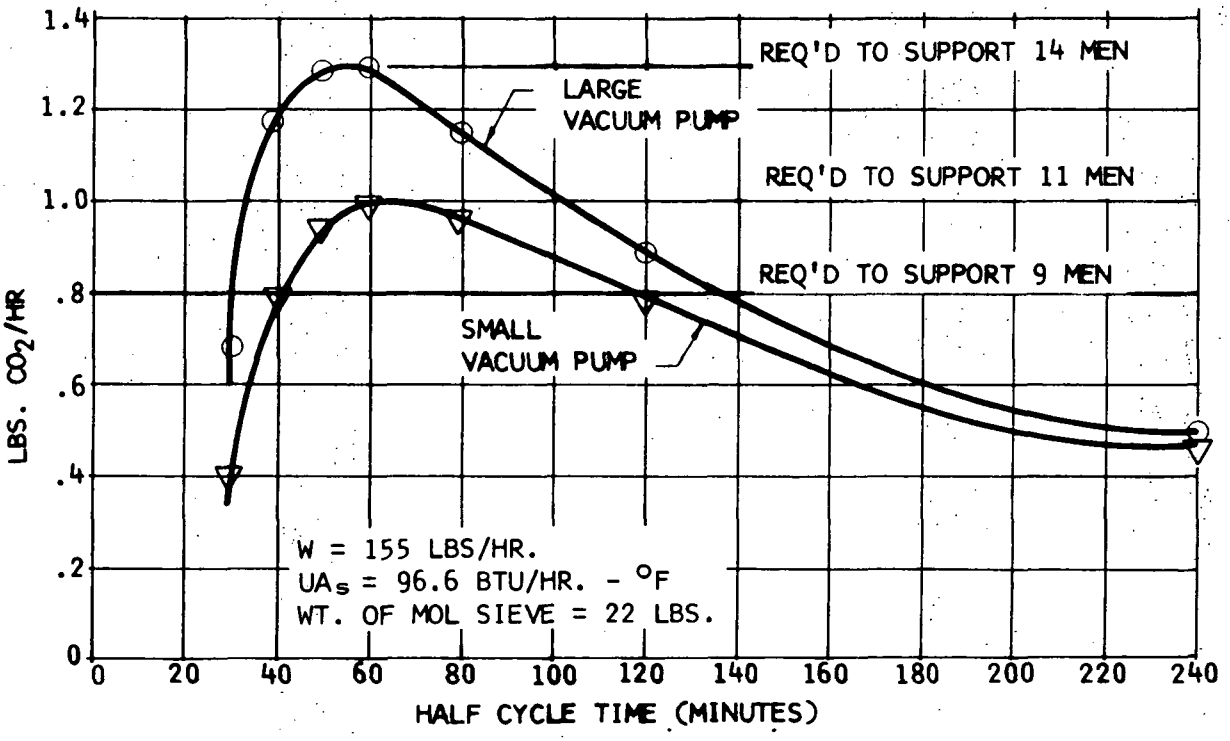


FIGURE 9

TABLE 3

CASES RUN - SMALL PUMP

Case No.	Fluid Flow (Lbs./Hr.)	UA (BTU/Hr-°F)	Half Cycle Time (Minutes)	(Lbs. CO_2/Hr.)	Total Equivalent Weight (TEW)	(Lbs. CO_2/ TEW-Hr.)
1	15.5	48.3	60	0.5951	520	0.001144
2	77.5	↓	↓	0.7667	559	0.001371
3	155.0	↓	↓	0.7955	568	0.001401
4	232.5	↓	↓	0.8052	574	0.001403
5	155.0	14.7	↓	0.3737	433	0.000862
6	↓	24.1	↓	0.5528	491	0.001126
7	↓	72.5	↓	0.9301	625	0.001488
8	↓	96.6	↓	0.9983	665	0.001501
9	↓	120.7	→	1.0382	696	0.001490
10	↓	96.6	30	0.3845	603	0.000637
11	↓	↓	40	0.7860	638	0.001232
12	↓	↓	50	0.9340	660	0.001414
13	↓	↓	80	0.9627	645	0.001493
14	↓	↓	120	0.7878	583	0.001351
15	→	→	240	0.4604	485	0.000950

TABLE 4

CASES RUN - LARGE PUMP

Case Letter	Fluid Flow (Lbs./Hr.)	UA (BTU/HR-°F)	Half Cycle Time (Minutes)	(Lbs. CO_2/Hr.)	Total Equivalent Weight (TEW)	(Lbs. CO_2/ TEW-Hr.)
A	15.5	48.3	60	0.8192	709	0.001154
B	77.5	↓	↓	1.0568	831	0.001271
C	155.0	↓	↓	1.0969	896	0.001281
D	232.5	↓	↓	1.1096	867	0.001280
E	155.0	14.7	↓	0.5453	558	0.000977
F	↓	24.1	↓	0.7814	676	0.001156
G	↓	72.5	↓	1.2256	938	0.001305
H	↓	96.6	↓	1.2867	989	0.001301
I	↓	120.7	↓	1.3215	1027	0.001287
J	↓	96.6	30	0.5956	710	0.000839
K	↓	↓	40	1.1847	940	0.001260
L	↓	↓	50	1.2830	989	0.001297
M	↓	↓	80	1.1537	927	0.001243
N	↓	↓	120	0.8855	788	0.001123
O	↓	↓	240	0.4881	595	0.000819

TABLE 5

SYSTEM PERFORMANCE SUMMARY

Fixed Parameters	
System Total Pressure, psia	7
System Inlet CO_2 Concentration (P_{CO_2}), mm Hg.	7
Adsorb Fluid Temperature, °F	42
Desorb Fluid Temperature, °F	190
Molecular Sieve Canister Inlet Dew Point, °F	- 90 min.
Molecular Sieve Canister Gas Inlet Temp., °F	50
Wt. of Molecular Sieve, lbs.	22
Scaled Items	
* System Flow, cfm	34.8
Indicated Optimum Results	
Desorb Pressure, psia (Small Pump)	0.3 to 2.5
Half Cycle Time, minutes	67
Transport Fluid Flow, lbs./hr.	155
Heat Exchanger UA_s, BTU/Hr-°F	96.5
CO_2 Yield, Lbs. CO_2/Hr.	1.0
Total System Equivalent Wt., Lbs.	660
CO_2 Yield Based on System Total Equiv. Wt., Lbs. CO_2/TEW-Hr.	0.00152

* Flow scaled-up from 5 lbs. of molecular sieves used in test canister (7.90 cfm).

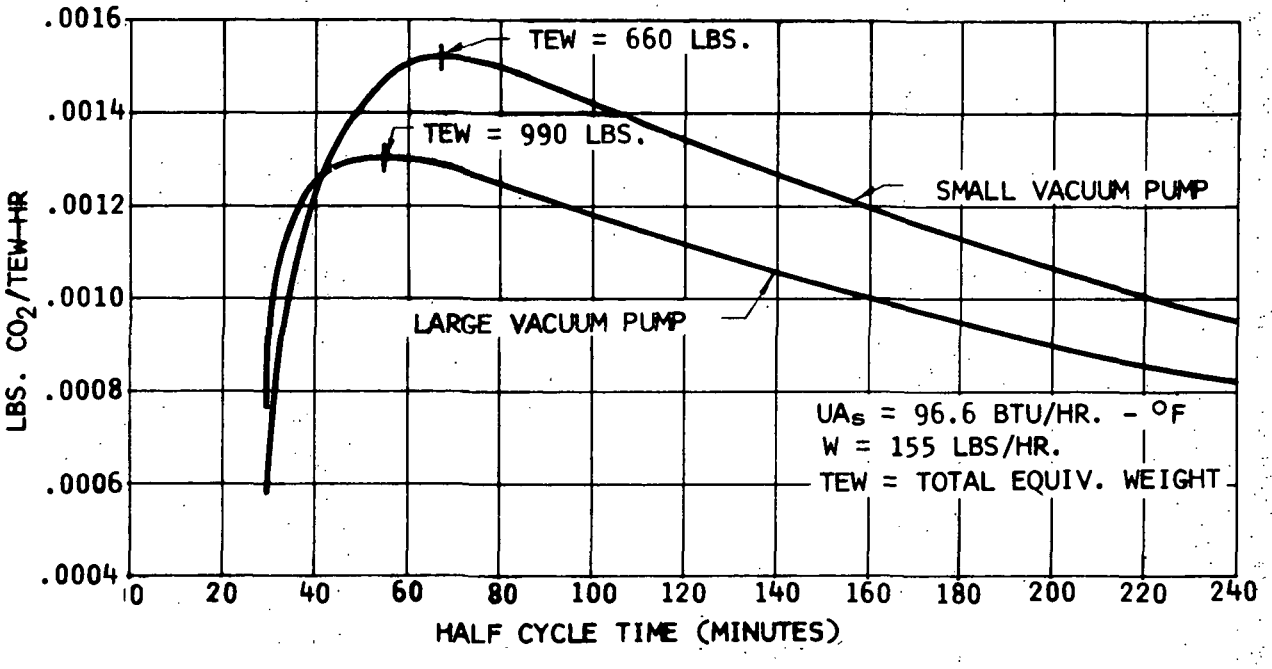


FIGURE 10

Concentrator Scaling

The program was directed toward the optimization of system parameters associated with the sizing of Molecular Sieve bed internal heat exchangers with consideration for system performance and total equivalent weight. The study was centered around one specific CO_2 concentrator design point with certain assumed "fixed" operating conditions. Scaling of certain system parameters at other CO_2 removal requirements is possible to give a good approximation for sizing Molecular Sieve CO_2 concentrator systems. It should be understood, however, that changes in the "fixed" parameters could have a significant effect on system performance requiring further analysis for optimization.

Initially, the number of men that the system will be required to support and the CO_2 removal rate based on 2.2 lbs. CO_2/man-day must be established. The lbs. CO_2/TEW-hr. =0.00152 and the half cycle time = 67 minutes would remain the same since the same sorber material will be used, the "fixed" parameters will be the same, and the ratio of heat exchanger surface area per cubic inch of Molecular Sieve will be the same. The pounds of Molecular Sieve for each of the two canisters will be proportional to the system yields. The inlet gas flow, the heat exchanger UA_S, the total system equivalent weight

and the transport flow (water), will be proportional to the weight of Molecular Sieve used in each of the two canisters. The system equivalent weight for the larger units would be slightly in excess of the true value, consequently, the weight for the smaller units would be lighter. However, the values arrived at would be good approximations. The scaled transport fluid flows are again good approximations but would require further heat transfer analyses to arrive at the optimum values.

Conclusions

For the conditions of this study, an integral heat exchanger having a UA_S of 2 to 4.5 BTU/Hr.-°F per lb. of Molecular Sieve and a transport fluid flow (water) of 5.5 to 7.0 lbs./hr. per lb. of Molecular Sieve results in maximum performance, i.e., pounds of CO_2 concentrated per hour per lb. $\left(\frac{\text{lbs. } CO_2}{\text{TEW-hr}}\right)$. A UA_S of up to 2.5 BTU/hr.-°F-lb. can be achieved with either finned or plain serpentine tube. Above this point, a plate-fin heat exchanger becomes more practical.

The canister heat leak can be reduced with the proper utilization of wall insulation so that the position of the outer coil in relation to the canister wall is not critical.

The smaller of the two vacuum pumps compared in this analysis affected a relatively small increase in half cycle time, an increase in the $\frac{\text{lbs. } CO_2}{\text{TEW - hr}}$, and a significant decrease in the system total equivalent weight (T.E.W.).

POLYMER SORBENT INVESTIGATION

The preferential affinity of Molecular Sieve for H_2O over CO_2 necessitates the use of desiccant beds prior to the CO_2 sorber to insure a moisture free influent gas. The drying beds plus the power required to regenerate the desiccant material impose an additional weight penalty on the system which potentially, if eliminated, would reduce the equipment weight and complexity and increase the system reliability.

Active sorbent materials held on an inert porous polymer substrate such as partition columns in chromotography have shown promise as CO_2 sorbents in that they do not require water removal prior to processing the carbon dioxide. HS-B, a new regenerable CO_2 concentrator sorber conceived by Hamilton Standard*, has been shown in previous IR&D laboratory tests to possess dynamic CO_2 sorption and desorption capabilities potentially more suitable for future spacecraft requirements.

A polymer sorbent investigation was conducted on polymer type sorbers for application to CO_2 absorption.

The initial task objective was to determine the optimum HS-B combination from a number of substrates and percent coatings which would possess the capability of operating in the presence of water vapor while still retaining a high dynamic capacity for CO_2 removal and needing only moderate regeneration requirements. The program consisted of two phases: substrate variation tests and coating concentration tests.

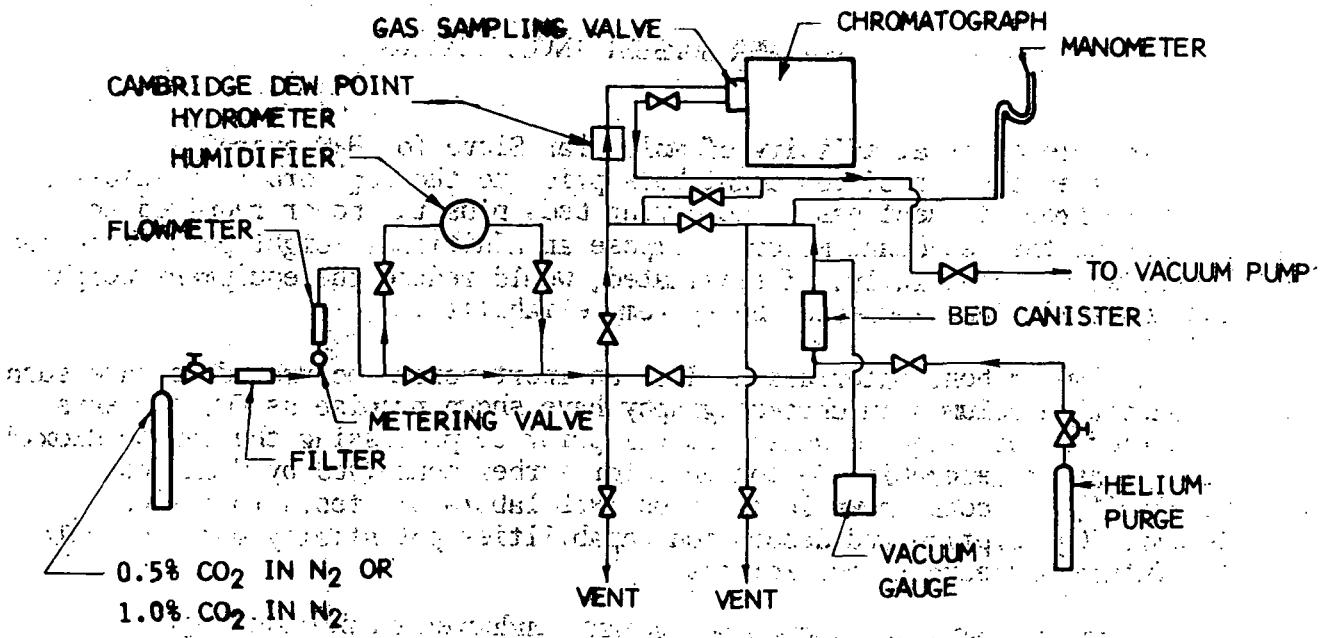
Test Program

Five different polymer substrate materials were each coated with polyethylenimine. These sorber samples were then subjected to gas flow/breakthrough tests to evaluate the CO_2 and H_2O dynamic capacities. The substrate material demonstrating the greatest CO_2 capacity was then utilized for additional tests in which a range of concentration of polyethylenimine coating agent was subjected to the same gas flow/breakthrough tests for a performance evaluation.

Test Apparatus and Procedure

The laboratory CO_2 Concentration Vacuum-Desorption Test Apparatus is shown in figure 11. The experimental procedure employed for the HS-B testing was to place a freshly prepared sorbent sample (five grams) into the test

* A PATENT APPLICATION HAS BEEN SUBMITTED TO THE UNITED STATES PATENT OFFICE DESCRIBING A CO_2 CONCENTRATOR SYSTEM AND SORBER MATERIAL COMPOSITION.



VACUUM-DESORPTION TEST APPARATUS-SCHEMATIC

FIGURE 11

tube size canister and precondition the material prior to initiation of the cyclic sorption-desorption testing. A 50°F dew point nitrogen gas stream (100 cc/min.) containing a 1% by volume concentration of CO_2 (7.6 mm Hg) was passed through the test canister until the outlet CO_2 concentration was 0.8% by volume. The bed was then vacuum desorbed at 1 PSIA and 180°F for a period of 30 minutes. The material was now ready for breakthrough testing.

The following sorption and desorption conditions were employed during the tests:

Sorption	
Carrier Gas	N_2
Flow Rate, cc/min.	100
Inlet Gas Temperature, °F	73 to 76 (ambient)
Total Pressure, psia	14.7 (760 mm Hg)
CO_2 Partial Pressure, mm Hg	7.6 (1% by volume)
Initial Bed Temperature, °F	130
Termination	When the outlet CO_2 concentration is 0.8% by volume

NOTES.-
Gas inlet dew point was set with a Cambridge Dew Point Hydrometer. Chromatographic sampling was used to monitor the inlet and outlet concentrations of CO_2 and H_2O vapor.

Desorption	
Bed Temperature, °F	150 and 180
Pressure, psia	1 and 0.5
Half Cycle Time, Min.	30

Following the 30 minute pre-condition and each succeeding desorption period, the heat source was de-energized thus cooling the bed to establish a temperature of 130°F. At this point the preset sorption gas stream was directed through the canister until the outlet CO_2 concentration was 0.8% by volume as indicated on the chromatograph trace. The desorption-sorption conditions for each test point were repeated until consistent breakthrough curves were attained.

Test Results

Substrate variation tests.- A summary of all substrate variation tests is shown in table 6. The actual breakthrough curves for the poorest and the best performing substrate material are presented in figures 12 and 13. The dynamic capacity values are determined by an area analysis of the respective breakthrough curve, the CO_2 mass flow rate, and the weight of the bed sample.

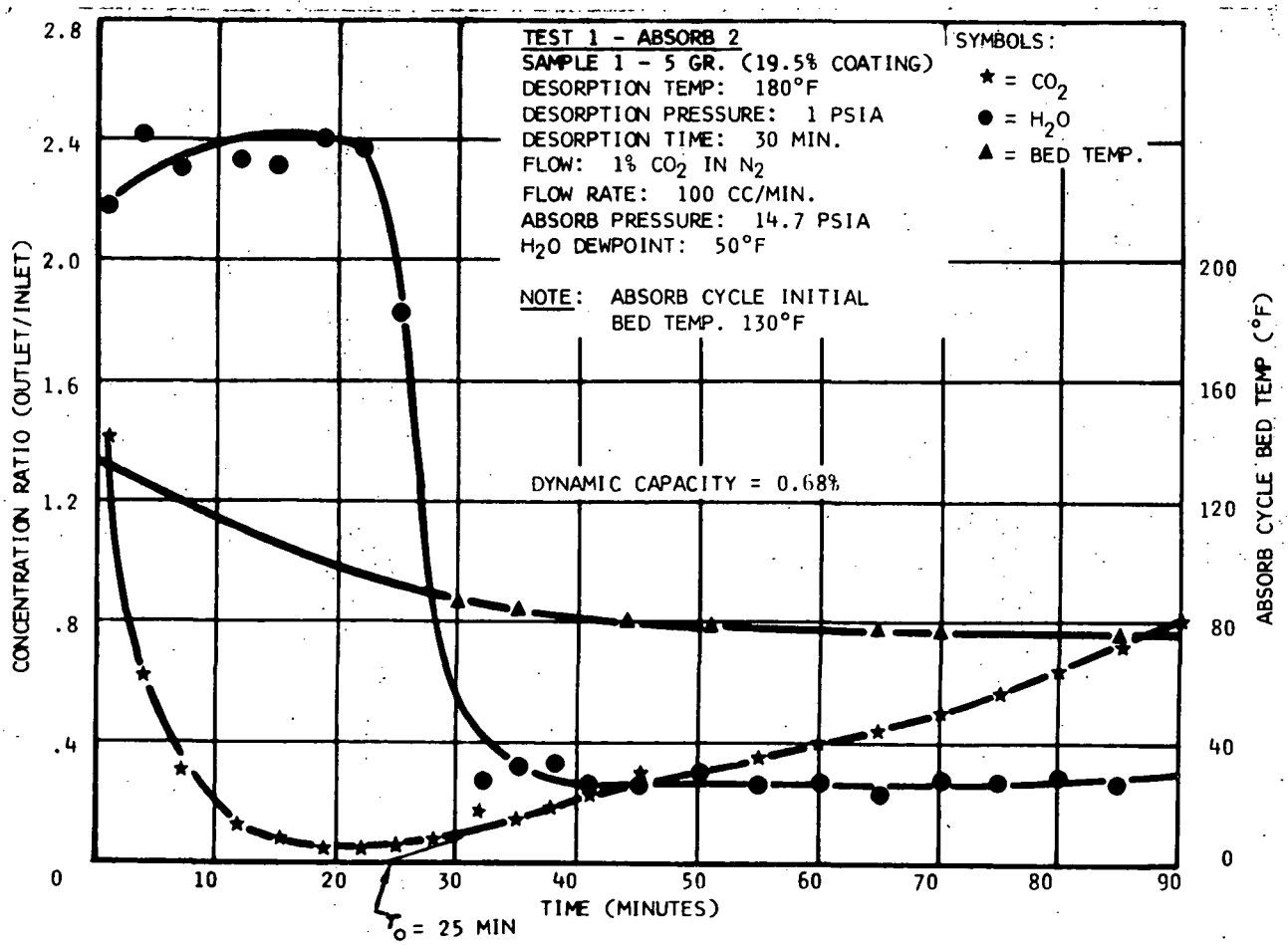


FIGURE 12

TABLE 6

SUBSTRATE VARIATION TEST RESULTS

Sample No.	Commercial Designation	Polyethylenimine Coating Concentration (% by Weight)	Desorption Temperature (°F)	Desorption Pressure (psia)	Initial Breakthrough Time (τ_o) (minutes)	CO_2 Dynamic Capacity (% by Weight)
1	Porapak R	19.5	180	1.0	25.0	.68
			180	0.5	51.5	1.82
			150	1.0	27.0	.78
			150	0.5	29.0	.86
2*	Porapak S	23.0	180	1.0	61.5	2.14
			180	0.5	71.0	2.55
			150	1.0	40.0	1.28
			150	0.5	56.0	1.47
3	Porapak N	23.0	180	1.0	50.0	1.77
4	Porapak P	34.2	180	1.0	31.5	1.03
5	Porapak Q-S	26.4	180	1.0	49.5	1.57

*Sample 2 was selected as the substrate for the coating variation tests.

NOTE: Porapak is a styrene polymer marketed by Waters Associates, Framingham, Mass.

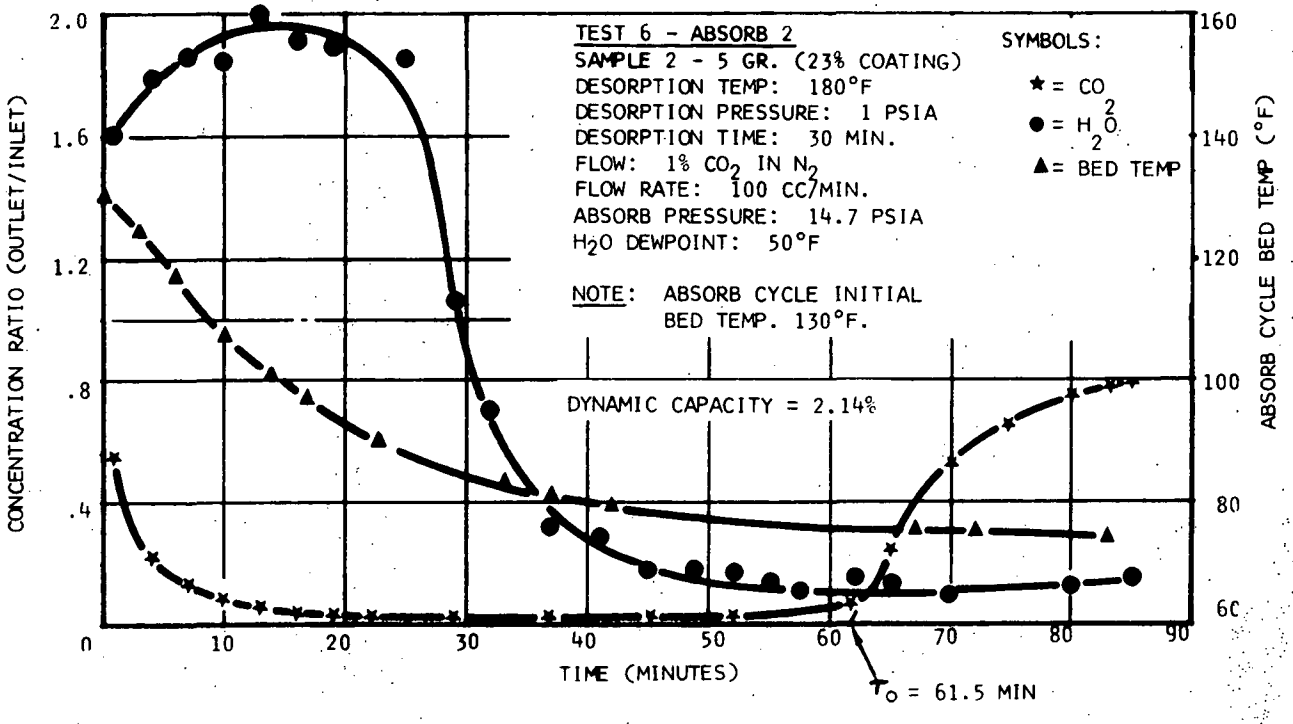


FIGURE 13

It is expressed as a weight percent (weight of CO_2 sorbed/weight of bed material x 100). The initial breakthrough time τ_o is defined as the point on the time axis where the extended slope of the breakthrough curve intersects the zero CO_2 concentration line.

Since samples 3, 4 and 5 did not perform as well as sample 2 at the 180°F, 1 psia test point (table 6), the map was not completed at the remaining conditions.

All the breakthrough curves exhibit a similar type of water desorb-absorb profile. The water accumulation on the bed during each CO_2 sorption is not completely removed during desorption at the temperature (180°F and 150°F) and pressure (1 psia and 1/2 psia) levels utilized for these tests. Due to a weak chemical bond, the heated influent gas purges water off the sorber during the initial portion of the CO_2 sorption phase until a bed temperature is reached where absorption of water is resumed for the remainder of the test.

Sample 2 was selected as the best substrate material for the follow-on testing phase based on its higher dynamic capacity for CO_2.

Polyethylenimine coating variation tests.- The objective of these tests was to determine the percent concentration of polyethylenimine on the substrate that would give the maximum CO_2 dynamic capacity. Comparative breakthrough curves were run on the prepared samples at the 180°F, one psia test point; the sorption-desorption conditions and procedures employed were the same as described under substrate testing.

The test results are summarized in table 7, the actual breakthrough curves for the best material combination are shown in figure 14 and a summary plot is shown in figure 15 of CO_2 dynamic capacity versus percent coating concentration by weight.

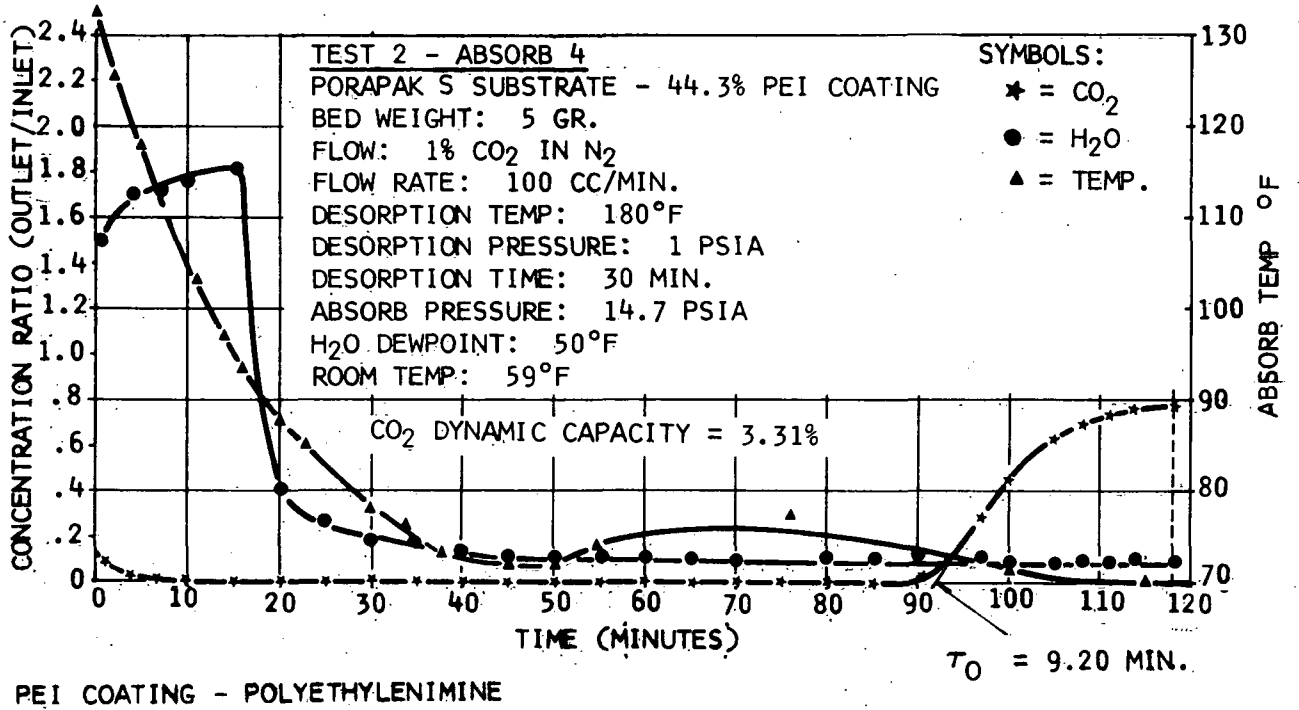


FIGURE 14

It is seen from table 7 that 44.3% concentration of polyethylenimine on Porapak S (44 PEI/PS) displayed the greatest CO_2 dynamic capacity (3.31% by weight) at the desorption conditions of 180°F and 1 psia.

This sample combination was subjected to additional performance optimization tests at lower desorption pressures and temperatures; the respective breakthrough curves are shown in figures 16 to 18. Note that the dynamic capacity (table 7) is increased from 3.31% to 3.60% when the desorption pressure is reduced from 1 psia to 1/2 psia at 180°F; and that lowering the bed desorption temperature from 180°F to 150°F at 1 psia reduced the dynamic capacity from 3.31% to 1.94%.

TABLE 7

COATING VARIATION TEST RESULTS

Sorber* Coating Concentration PEI/PS (% by Weight)	Desorption Temperature (°F)	Desorption Pressure (psia)	Initial Breakthrough Time (τ_o) (minutes)	CO_2 Dynamic Capacity (% by Weight)
23.0	180	1	61.5	2.14
34.4	180	1	73.5	2.58
44.3**	180	1	92.0	3.31
59.0	180	1	54.0	2.02
49.0	180	1	74.5	2.76
		Performance Optimization Tests		
44.3**	180	0.5	98	3.60
44.3**	150	1	56.5	1.94
44.3**	150	0.5	66	2.26

*All tests are with Porapak S substrate

**Combination Selected

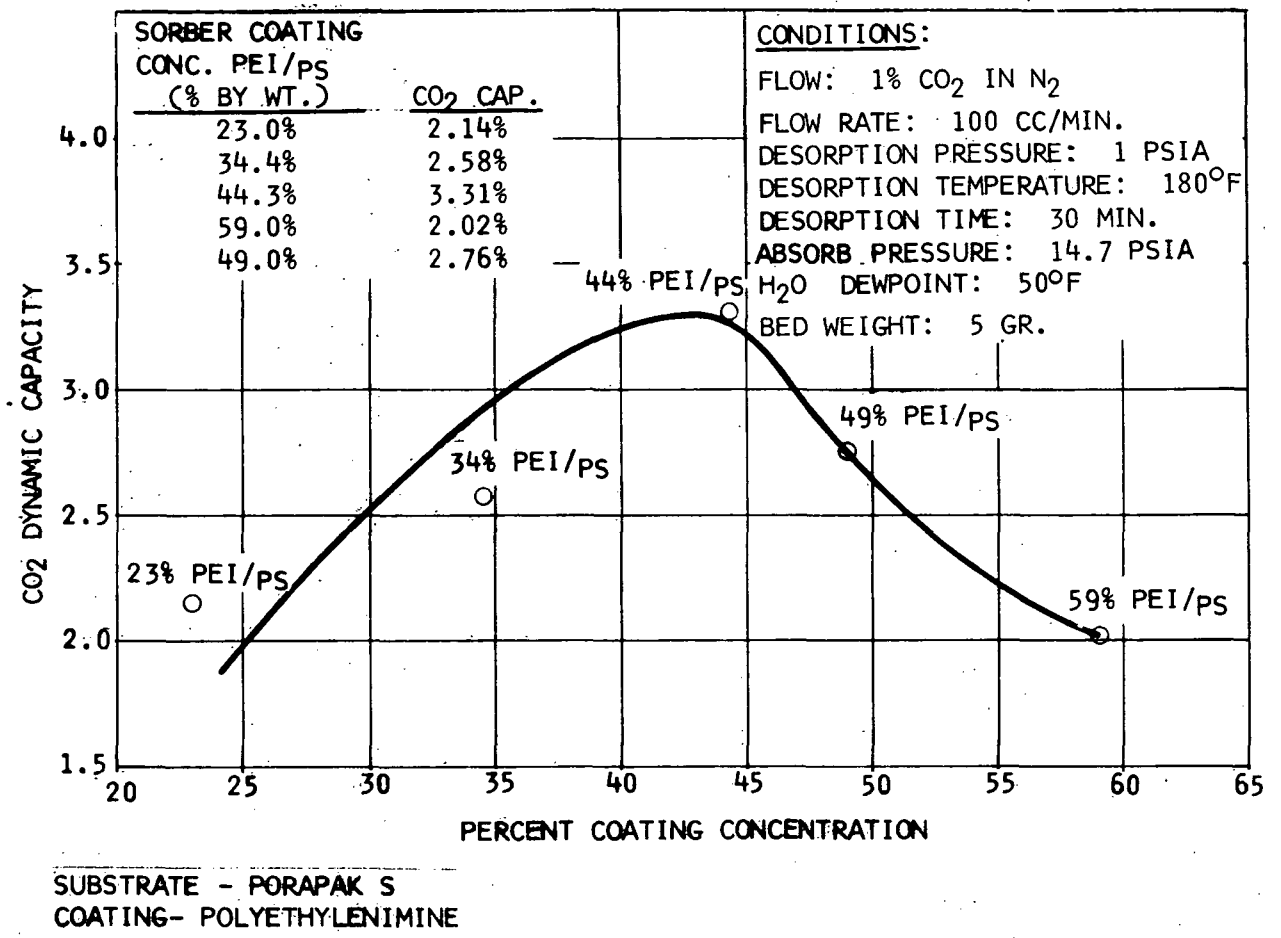
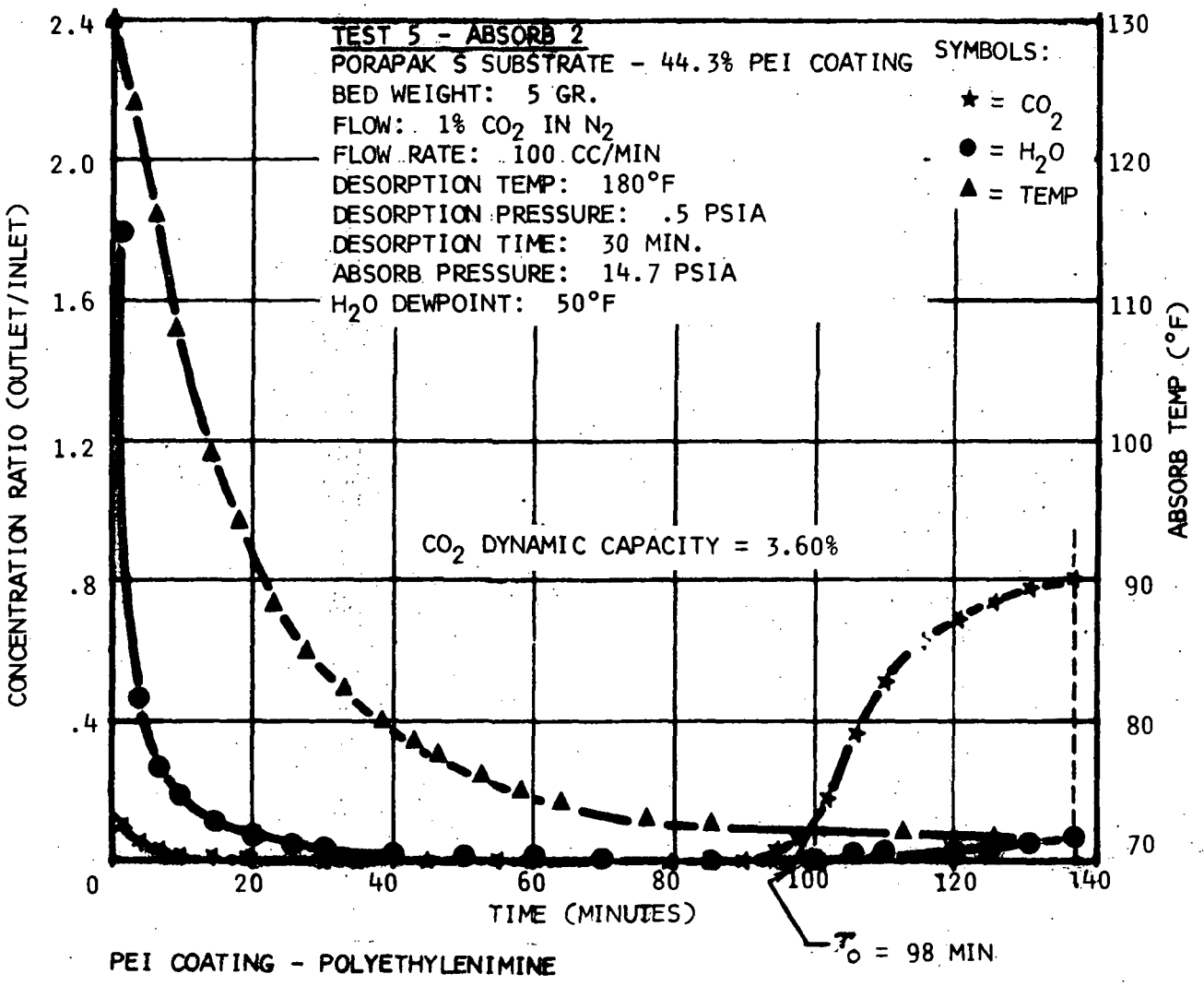


FIGURE 15

Performance Optimization Tests

Dew point variations tests.- Two tests were run on the 44 PEI/PS material combination at the test conditions of 180°F, 1 psia and an inlet dew point of 70°F in the first test and -20°F for the second test. These variations in dew point were made to investigate the corresponding changes in bed CO_2 dynamic capacity. The respective breakthrough curves are shown in figures 19 and 20; a plot of CO_2 dynamic capacity versus inlet H_2O partial pressure is presented in figure 21. The results indicate that a 39% increase in CO_2 dynamic capacity is realized by increasing the dew point from 50°F to 70°F, and conversely, a decrease in dew point from 50°F to -20°F results in a 53% reduction in CO_2 dynamic capacity.

O_2, N_2 dynamic capacity tests.- Tests were run to determine if the 44 PEI/PS sorbent had any appreciable capacity for O_2 and N_2. The empty canister system was initially filled with helium. Air was then injected into the inlet port and the time increment was recorded when the air reached



PEI COATING - POLYETHYLENIMINE

FIGURE 16

the chromatograph, as indicated by a rapid rise in the O_2 and N_2 concentrations. This was approximately 3 minutes. The canister was then filled with 44 PEI/PS and the same test procedure was repeated. A comparison of the respective times to reach the chromatograph together with the observed O_2 and N_2 traces indicated that the sorbent had no appreciable dynamic capacity for O_2 and N_2.

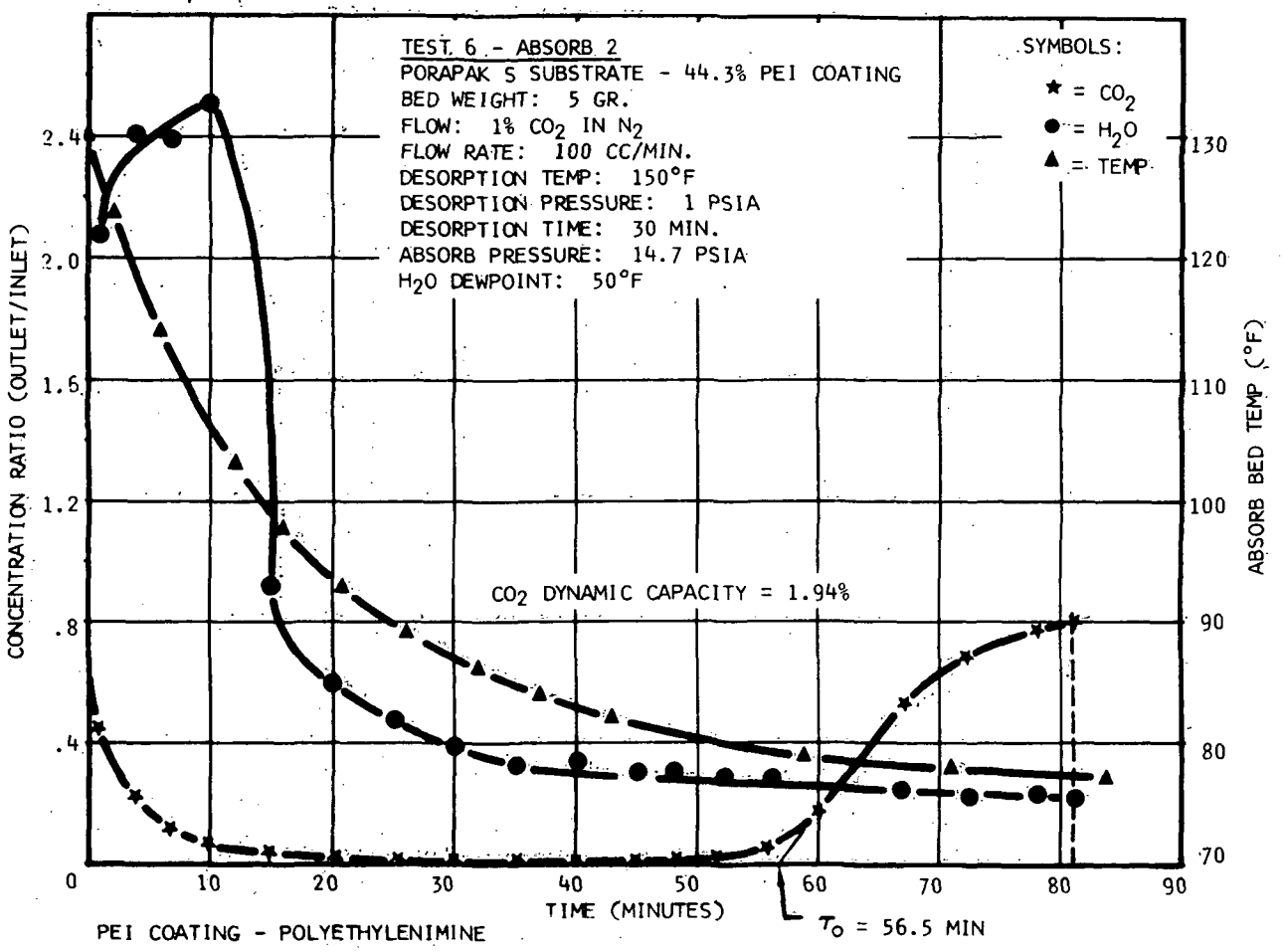
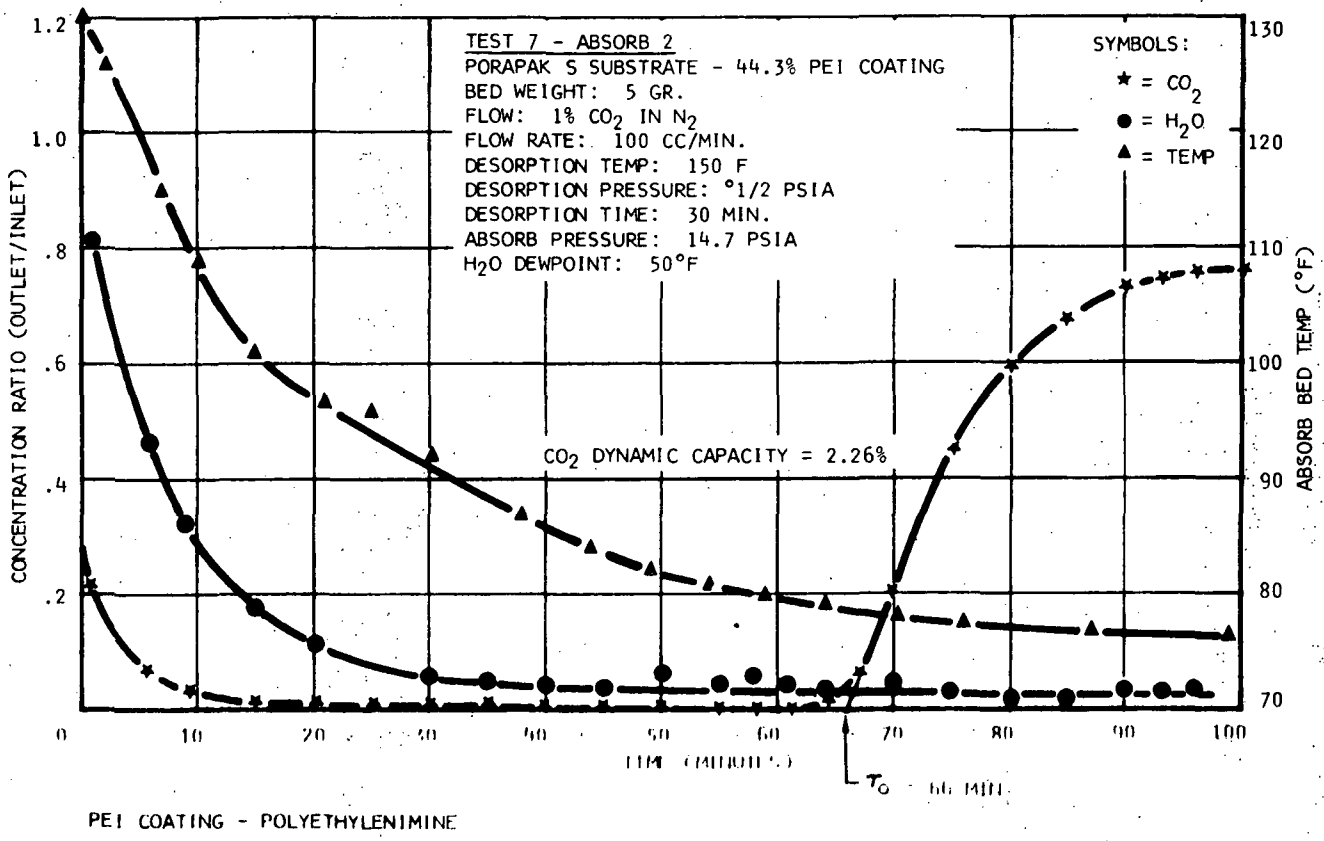
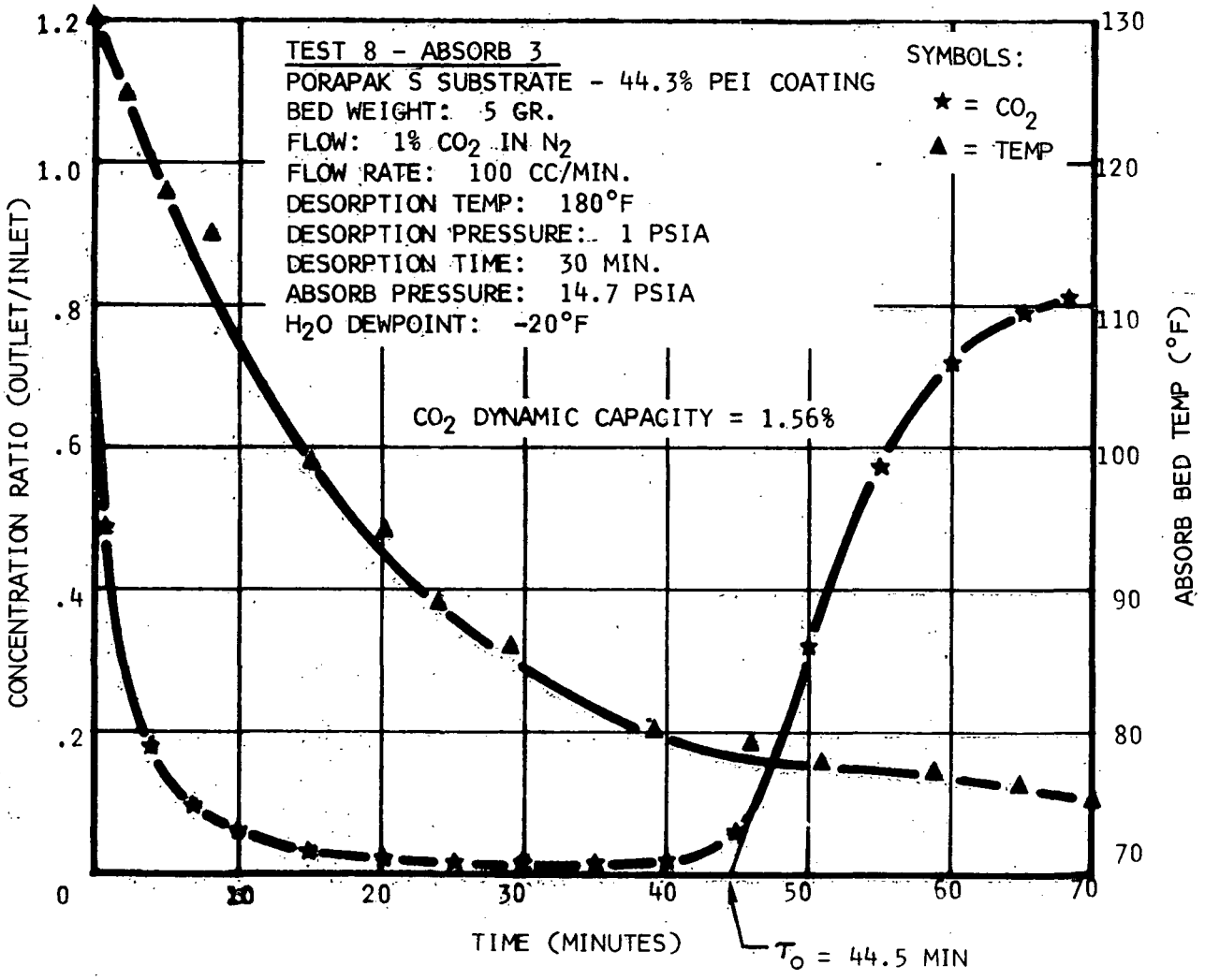

TEST 6 - ABSORB 2
PORAPAK S SUBSTRATE - 44.3% PEI COATING
BED WEIGHT: 5 GR.
FLOW: 1% CO_2 IN N_2
FLOW RATE: 100 CC/MIN.
DESORPTION TEMP: 150°F
DESORPTION PRESSURE: 1 PSIA
DESORPTION TIME: 30 MIN.
ABSORB PRESSURE: 14.7 PSIA
H_2O DEWPOINT: 50°F
SYMBOLS:
★ = CO_2
● = H_2O
▲ = TEMP
CO_2 DYNAMIC CAPACITY = 1.94%
CONCENTRATION RATIO (OUTLET/INLET)
ABSORB BED TEMP (°F)
TIME (MINUTES)
T_o = 56.5 MIN
PEI COATING - POLYETHYLENIMINE

FIGURE 17



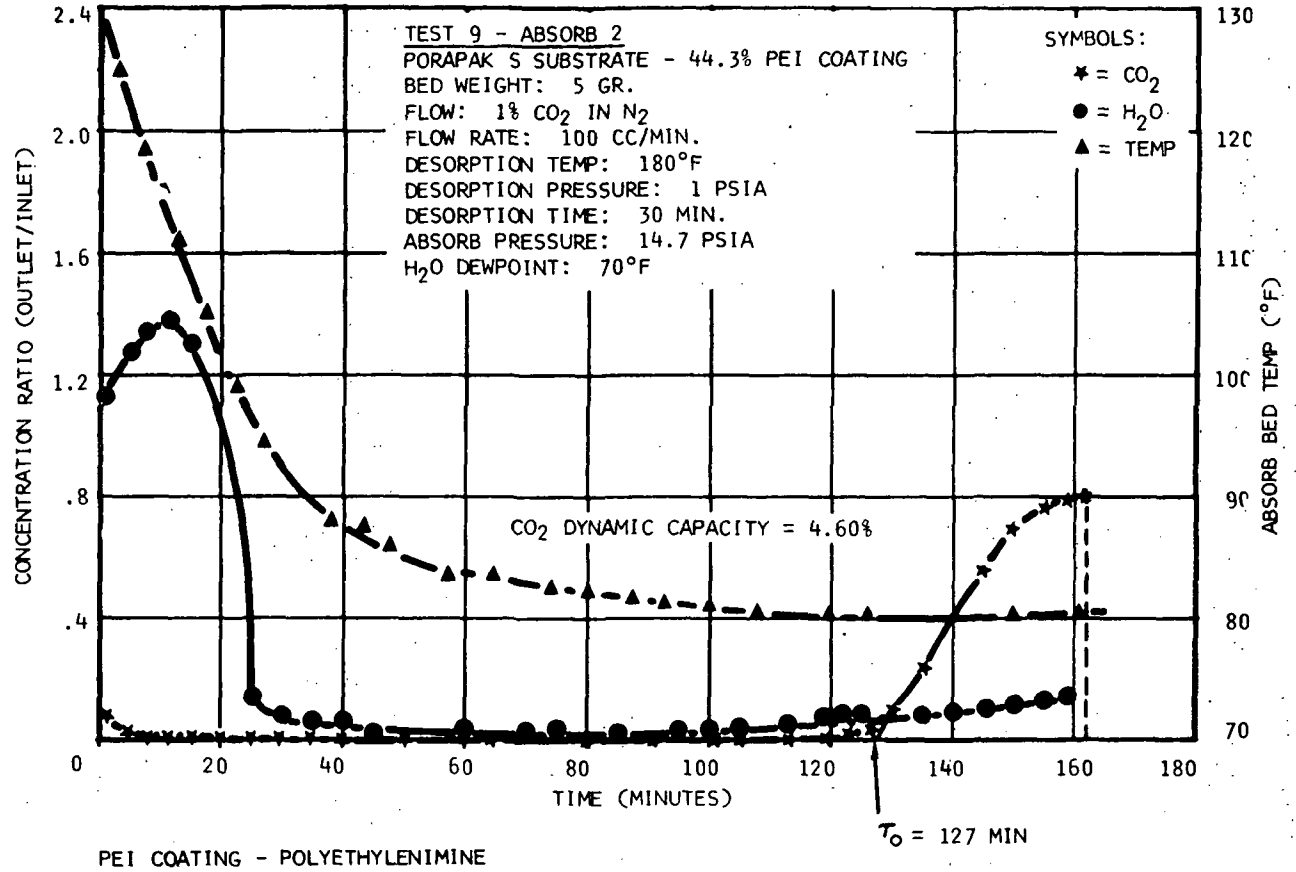
PEI COATING - POLYETHYLENIMINE

FIGURE 18



PEI COATING - POLYETHYLENIMINE

FIGURE 19



PEI COATING - POLYETHYLENIMINE

FIGURE 20

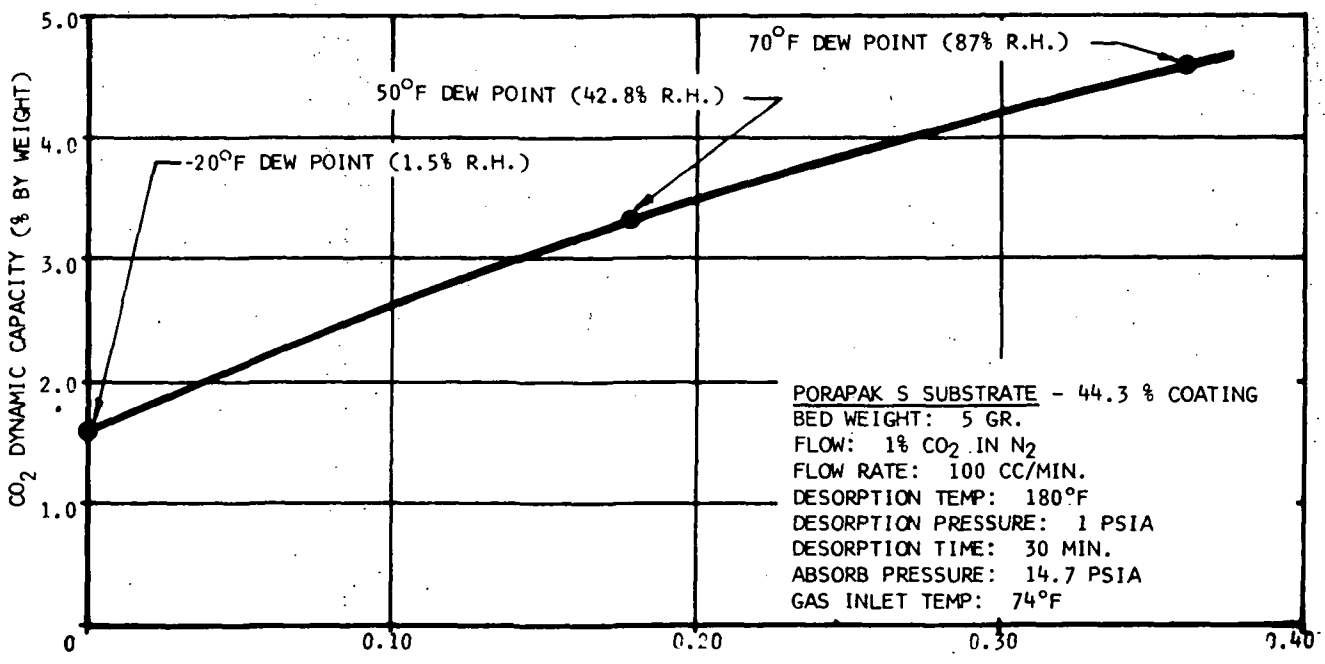


FIGURE 21

Conclusions

The combination of Porapak S and polyethylenimine with a 44.3% coating by weight is considered the best of the sorbers investigated for absorption of CO_2 under the test conditions described.

An increase in the inlet gas stream dew point up to at least 70°F is associated with a corresponding increase in the CO_2 dynamic capacity.

The selected HS-B combination displays no appreciable dynamic sorption capacity for oxygen or nitrogen.

FEASIBILITY TESTING OF HS-B SORBENT IN A FULL SIZE CANISTER

Preliminary small scale testing conducted in the Polymer Sorbent Investigation authorized by this contract and previously reported upon in this report, had indicated that HS-B material possesses an adequate dynamic CO_2 capacity in the presence of water vapor and will desorb collected water and CO_2 under mild heat (190°F) and vacuum (0.5 psia). Performance on small samples (5 grams) looked promising, and indicated the need to test this sorbent in a large canister.

Further efforts were authorized under contract modification No. 6 to make a preliminary determination of the feasibility of HS-B as a CO_2 sorbent in a full size canister and to ascertain what development risks might be involved in the preliminary design of a CO_2 collection system using this type sorber for space station-type missions and for the SSP ETC/LSS.

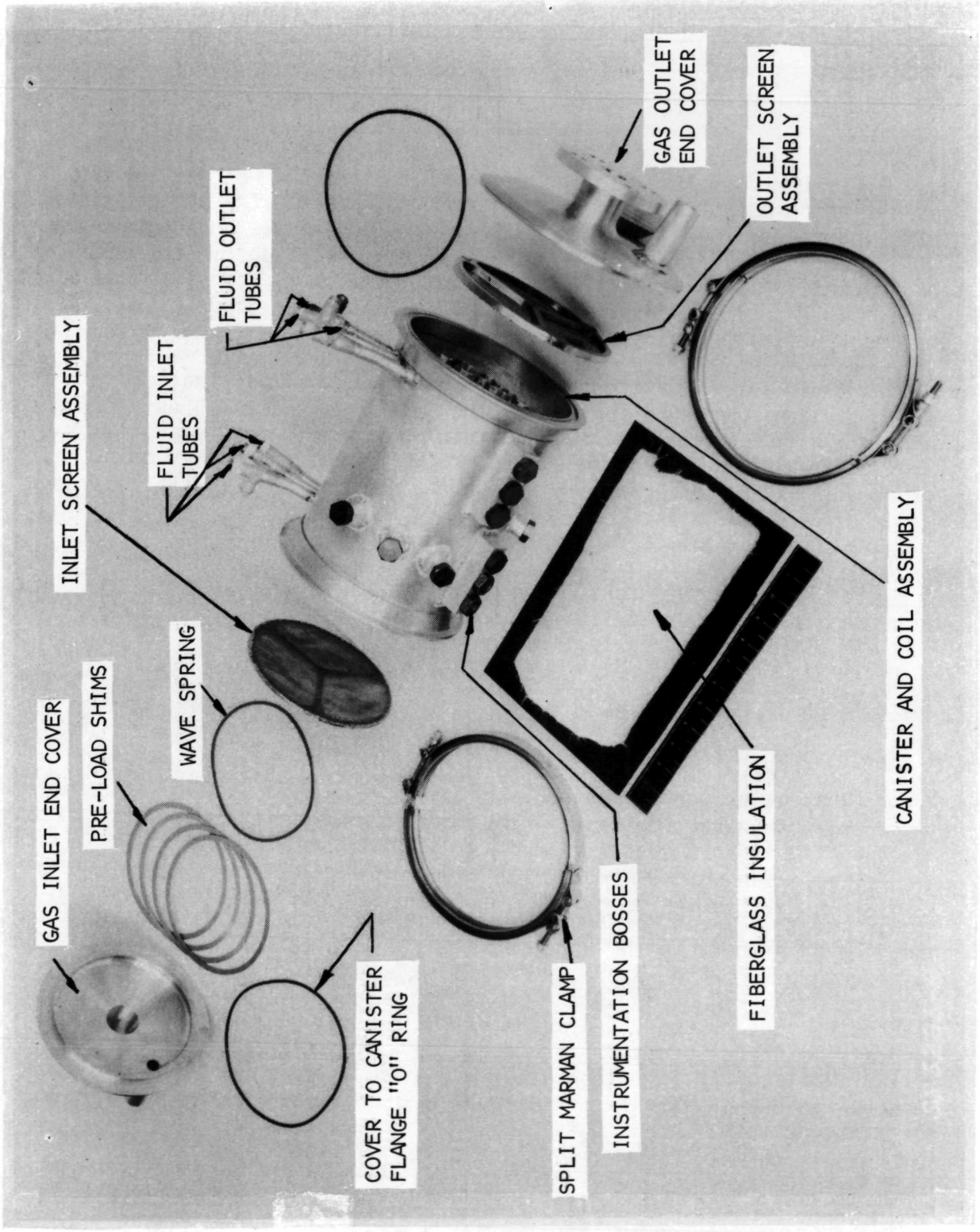
The program consisted of the following areas:

1) Canister preparation;
2) Rig modification and preparation;
3) Performance testing and results.

Canister Preparation

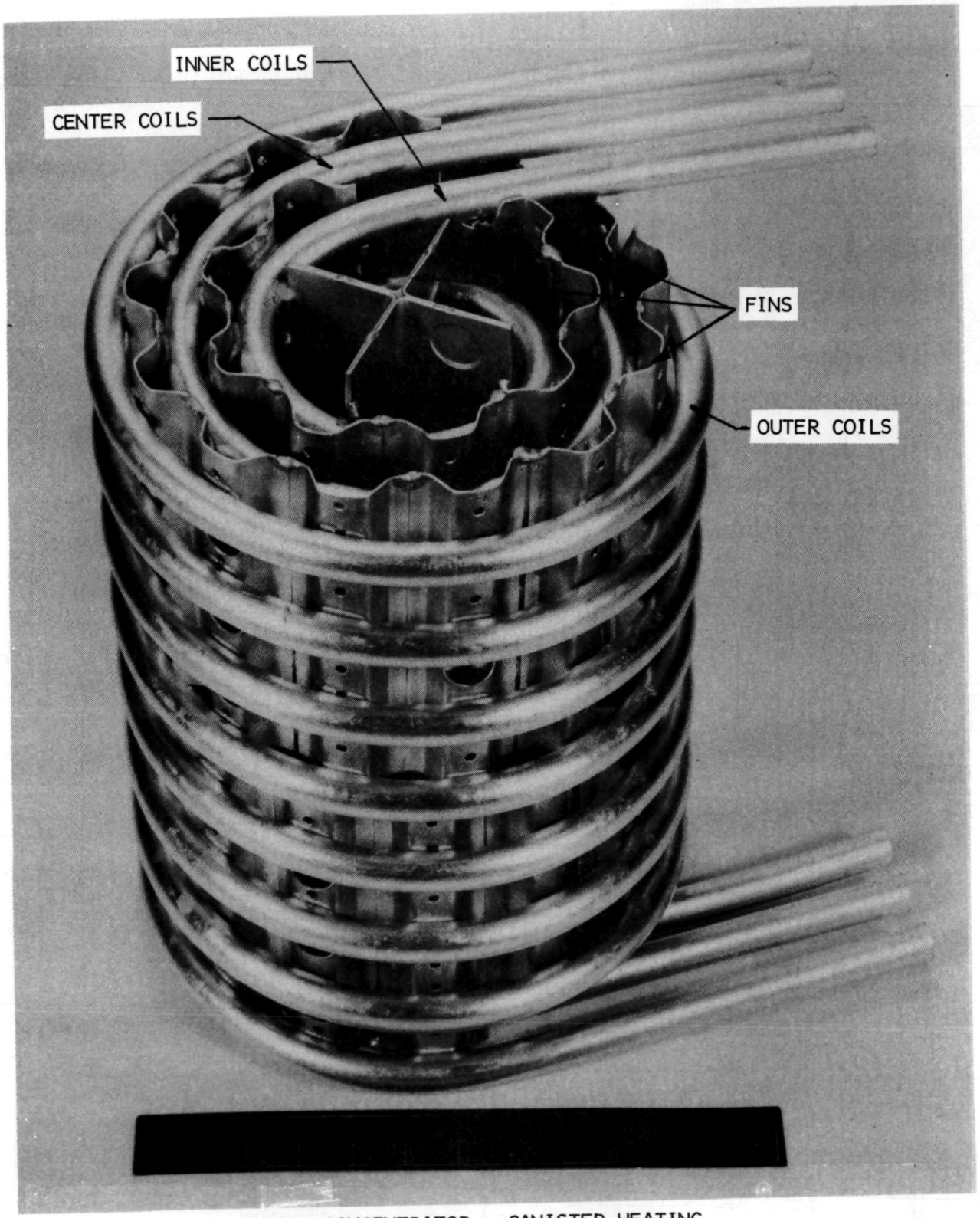
HS-B material consists of a polyethylenimine coating on a substrate of divinylbenzene or acrylic ester. The coating is deposited to a loading of 40% by weight on the substrate. The sorbent physically is a white to cream colored free flowing powder with particle size ranging from 25 to 45 mesh. The material can be exposed to water vapor up to atmospheric pressure and up to a temperature of 212°F without affecting the water soluble coating. Liquid water, however, must be avoided since it leaches the coating from the bed. HS-B is inert to the usual atmospheric constituents at room temperature but exposure to oxygen above 150°F should be avoided since a darkening of the material and a reduction in the CO_2 sorption capacity has been observed while attempting to accelerate the aging of the material by heating. (No loss of capacity has been observed when operating within the CO_2 concentrator parametric limits). At temperatures of 200 - 250°F in oxygen, the material darkens rapidly (apparently oxidizing) without flame, with a loss in CO_2 sorption capacity.

An existing CO_2 concentrator canister assembly (figure 22) containing an integral heating and cooling tube and fin heat exchanger (figure 23) was utilized for these feasibility tests. Since the HS-B material particle size was between 25 to 45 mesh, it was decided not to use the 0.50 inch thick fiberglass insulation mat against the canister outer wall as had been used



CO_2 CONCENTRATOR - CANISTER

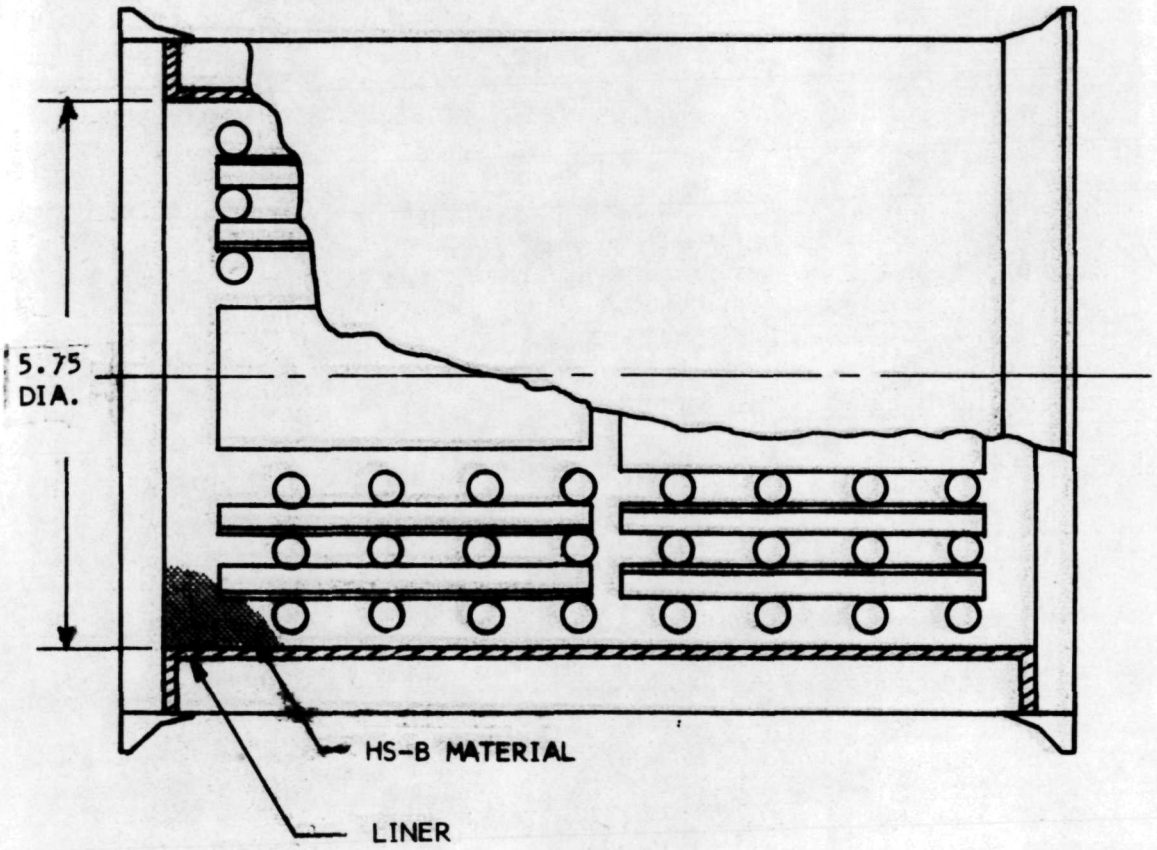
FIGURE 22



CO_2 CONCENTRATOR - CANISTER HEATING AND COOLING COIL ASSEMBLY

FIGURE 23

previously for the larger mesh Molecular Sieve to prevent gas flow channeling. The canister was modified as shown in figure 24 to incorporate an inner liner which reduced the effective canister inside diameter, thereby, providing for a more uniform distribution of the heat exchanger surface throughout the sorbent material. The HS-B material previously used was modified to provide a larger mesh (25 to 45) substrate material to reduce the packed canister gas flow pressure drop. After positioning the bed thermocouples and attaching the outlet screen and cover, the canister cavity was filled with three pounds of the prepared material in consecutive one inch layers that were vibrated lightly after each additional layer to form the desired packing density. Shims without the usual wave spring were used to provide a preload that would hold the material firmly between the two retaining screens without crushing.



CANISTER MODIFICATION

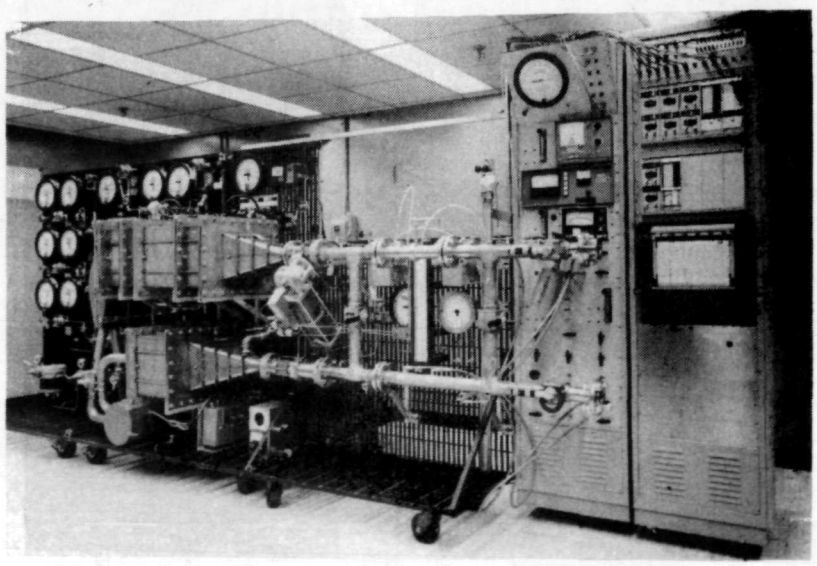
FIGURE 24

Rig Modification and Preparation

The Hamilton Standard Multi-purpose Rig (figure 25) was designed to provide a gas flow (in this case atmospheric air) in a closed loop and automatically control the pressure, inlet temperature, flow rate, dew point and CO_2 concentration to selected values. The unit also provides both hot and cold fluids with automatic temperature control which were used to heat and cool the canister.

The rig modification also provides a CO_2 collection system, figure 26. This system consists of a double end vacuum line, a condenser, an automatically controlled back pressure regulating valve to set and control the canister evacuation pressure during desorb, a vacuum/compressor system consisting of one double head diaphragm pump plumbed in parallel and two single head diaphragm pumps mounted in series, an ullage dump port, a CO_2 collection tank with a pressure relief valve and an automatic bleed system to set and regulate the cyclic gas dump reference pressure and associated valving.

The test instrumentation is listed in table 8. Conventional instrument methods were used for measuring pressure, temperature and flow. Specialized instrumentation was used for measuring humidity (dew point hygrometer), and CO_2 concentration (infrared gas analyzer). Thermocouples, located in a pattern to give both axial and radial profiles (see figure 27), are positioned in the canister prior to packing in order to obtain useful temperature information during heating and cooling.



RIG 88 MULTI-PURPOSE TEST RIG FACILITY

FIGURE 25

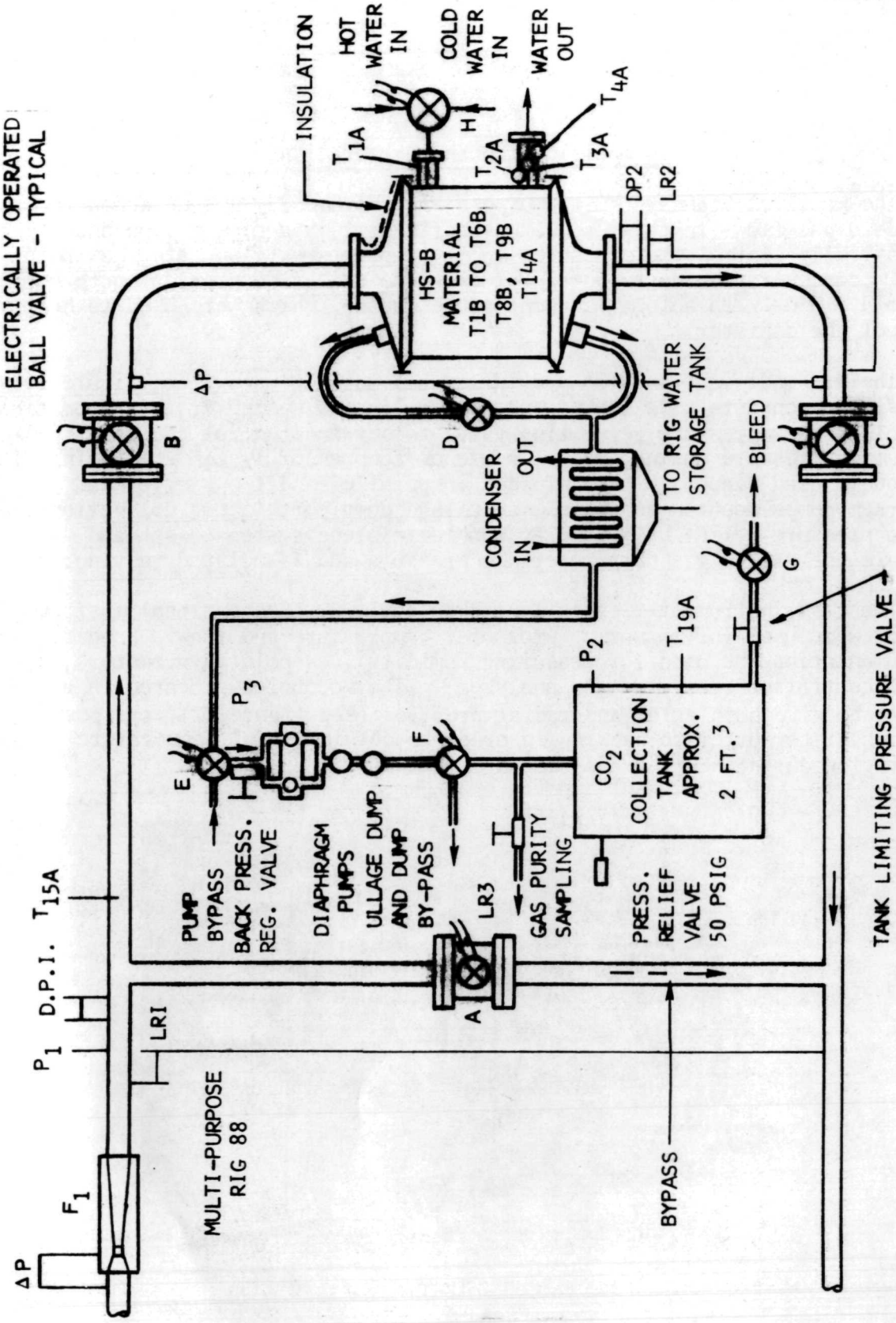


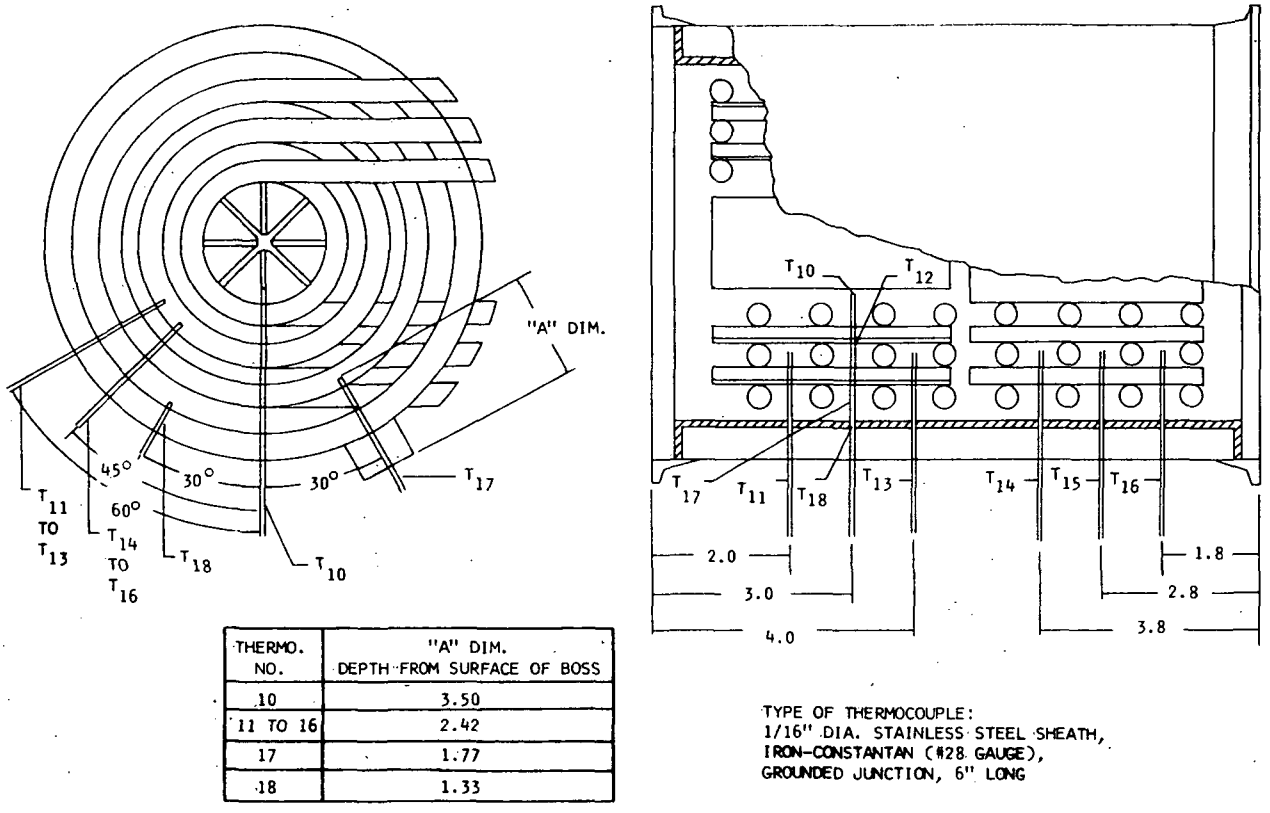
FIGURE 26

HS-B FEASIBILITY TEST SETUP

TABLE 8

HS-B FEASIBILITY TEST INSTRUMENTATION CHART

Ident.	Item Measured	Range	Method	Visual Readout	Accuracy
T 1A	Water/Glycol-Canister Inlet	50°F to 180°F	Copper-Constantan Thermocouple	Recorder	± 5°F
T 2A	Water/Glycol-Canister Outlet (Inner Coil)	50°F to 180°F	Copper-Constantan Thermocouple	Recorder	± 5°F
T 3A	Water/Glycol-Canister Outlet (Middle Coil)	50°F to 180°F	Copper-Constantan Thermocouple	Recorder	± 5°F
T 4A	Water/Glycol-Canister Outlet (Outer Coil)	50°F to 180°F	Copper-Constantan Thermocouple	Recorder	± 5°F
T 14A	Bed Temperature-Station T14	50°F to 180°F	Copper-Constantan Thermocouple	Recorder	± 15°F
T 15A	Canister Gas Inlet Temp.	30° to 70°F	Copper-Constantan Thermocouple	Recorder	± 3°F
T 19A	CO_2 Collection Tank Gas Temp.	30° to 100°F	Copper-Constantan Thermocouple	Recorder	± 3°F
T 1B	Bed Temperature-Station T11	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 2B	Bed Temperature-Station T12	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 3B	Bed Temperature-Station T13	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 4B	Bed Temperature-Station T18	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 5B	Bed Temperature-Station T10	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 6B	Bed Temperature-Station T17	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 8B	Bed Temperature-Station T15	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
T 9B	Bed Temperature-Station T16	50° to 180°F	Iron-Constantan Thermocouple	Recorder	± 15°F
P_1	Canister Gas Inlet Press.	0-30 psia	Ashcroft Gauge	Gauge Dial	± 0.1 psia
P_2	CO_2 Collection Tank Gas Press.	0-50 psig	Heise Gauge	Gauge Dial	± 0.1 psig
P_3	Canister Evacuation Press.	0-12 12-24 psia	Wallace & Tiernan	Gauge Dial	± 0.05 psia
ΔP	Canister Differential Press.	0-40" H_2O	Wallace & Tiernan	Gauge Dial	± 0.1" H_2O
LR_1	CO_2 Concentration-Inlet	100%=	Lira-Infrared Analyzer	Lira Meter Recorder Trace	± 3% F.S.
LR_2	CO_2 Concentration-Outlet	100%=	Lira-Infrared Analyzer	Lira Meter Recorder Trace	± 3% F.S.
LR_3	CO_2 Collection Gas Purity	100%=100% CO_2	Lira-Infrared Analyzer	Lira Meter Recorder Trace	± 3% F.S.
DP_1	Canister Dew Point-Inlet	-40° -120°F	Cambridge Dew Point Hygrometer	Meter Recorder Trace	± 0.1°F
DP_2	Canister Dew Point-Outlet	-40° -120°F	Cambridge Dew Point Hygrometer	Meter Recorder Trace	± 0.1°F
F_1	Canister Inlet Flow		Venturi Type Flowmeter	ΔP (in. of H_2O) and calib. charts	
S	Weight of CO_2 Adsorbed	0-300 lbs.	Beam Scale	Scale	± 0.2 lbs.



THERMO. NO.	"A" DIM. DEPTH FROM SURFACE OF BOSS
10	3.50
11 TO 16	2.42
17	1.77
18	1.33

HS-B FEASIBILITY TEST BED THERMOCOUPLE LOCATIONS

FIGURE 27

The test set-up (figure 26) was operated in the following manner. Prior to initiating the first sorption cycle, valves B and C are closed and A is opened so that the gas flow conditions can be preset in the bypass loop. Valves E and F are positioned for bypass flow through the vacuum/compressors and the three units are energized. Valves D and G are in the closed position, the cold fluid pump is de-energized, and the liquid rotary valve H is set to supply cold fluid to the canister coils. When the gas flow conditions have stabilized in the bypass loop, the first sorption cycle is started by opening valves B and C and closing valve A thus directing the gas stream through the canister. These conditions prevail throughout the specified sorption cycle time while the CO_2 is being absorbed on the sorber. At a specified time, the cold fluid pump is energized thus cooling the bed material for the remainder of the sorption period.

When sorption is completed, the canister is isolated by opening valve A and closing valves B and C. Valve D is then opened, valve E is positioned for evacuating the canister, and valve F is positioned to pump the canister ullage gas to atmosphere for a specified length of time. The pumping system back pressure regulating valve is set to provide the desired canister evacuating pressure. At the termination of the canister ullage dump, the fluid rotary valve is repositioned to supply hot fluid to the canister coils and valve F is repositioned to direct the desorbed CO_2 into the collection tank. The inline condenser unit removes most of the desorbed water vapor prior to entering the pumping system. At a predetermined time before termination of the desorb half cycle, the rotary fluid valve H is changed to direct cold fluid to the canister coils thus cooling the bed material in preparation for the following sorption cycle. With the prescribed desorb cycle time period completed, valve D is closed and valves E and F are changed to provide bypass flow through the pumps.

The sorption mode is again initiated by opening valves B and C and closing valve A. At an assigned period of time into the sorption half cycle, valve G is opened to reduce the tank pressure to the lower limiting pressure value set by the back pressure regulating valve and then closed. The valve sequencing as described is completely automatic and is repeated on a cyclic basis for each test point until conditions have stabilized.

Performance Testing and Results

The major test program objectives were: 1) to determine the dynamic cyclic capacity of the HS-B material for CO_2 under typical spacecraft operating conditions; 2) to obtain limited parametric data for the major variables such as influent gas flow rate and temperature, partial pressure of carbon dioxide and the desorption fluid temperature; and 3) to determine whether the organic sorbent degrades during the test program.

Initially, the sorbent material was saturated with water at 50°F thus producing the greatest restriction to flow at the selected gas inlet dew point due to water loading and expansion of the sorbent material when wet; fluid at 50°F was simultaneously passed through the canister coils. Two tests were conducted, one at 14.7 and the other at 10 psia, to determine the canister pressure drop. The gas flow was increased in steps until the ΔP values approached the limiting head capacity of the rig circulating pump system. The results are shown in figure 28.

The canister pressure drop vs flow between 0.5 to 2 minutes into each sorption half cycle were recorded in the parametric tests that followed and are presented in figure 29. Comparison of the two 14.7 psia curves (figures 28 and 29) show that the ΔP values with the sorbent saturated are approxi-

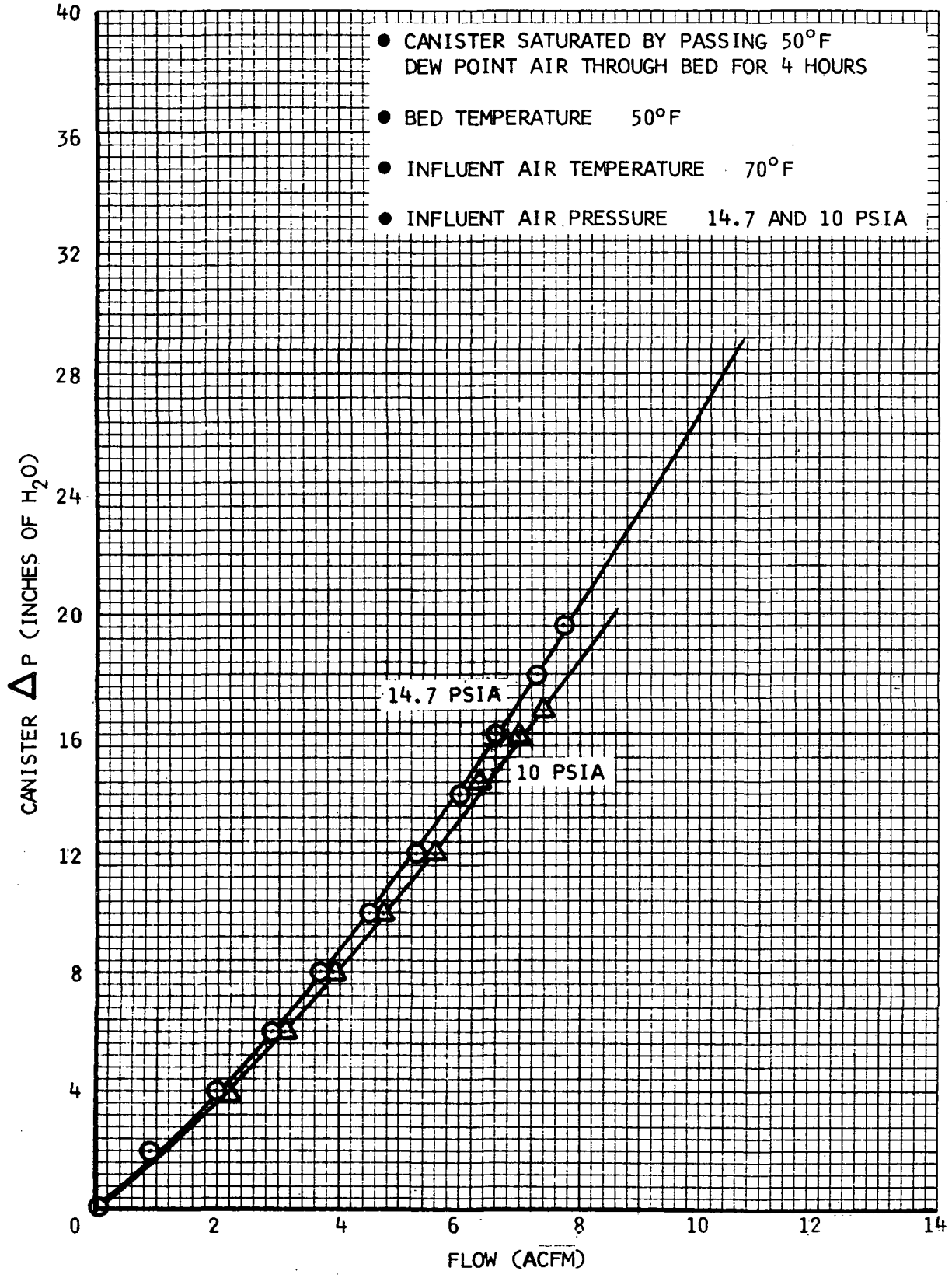

● CANISTER SATURATED BY PASSING 50°F DEW POINT AIR THROUGH BED FOR 4 HOURS
● BED TEMPERATURE 50°F
● INFLUENT AIR TEMPERATURE 70°F
● INFLUENT AIR PRESSURE 14.7 AND 10 PSIA
14.7 PSIA
10 PSIA
CANISTER ΔP (INCHES OF H2O)
FLOW (ACFM)
0
4
8
12
16
20
24
28
32
36
40
2
6
10
14

FIGURE 28

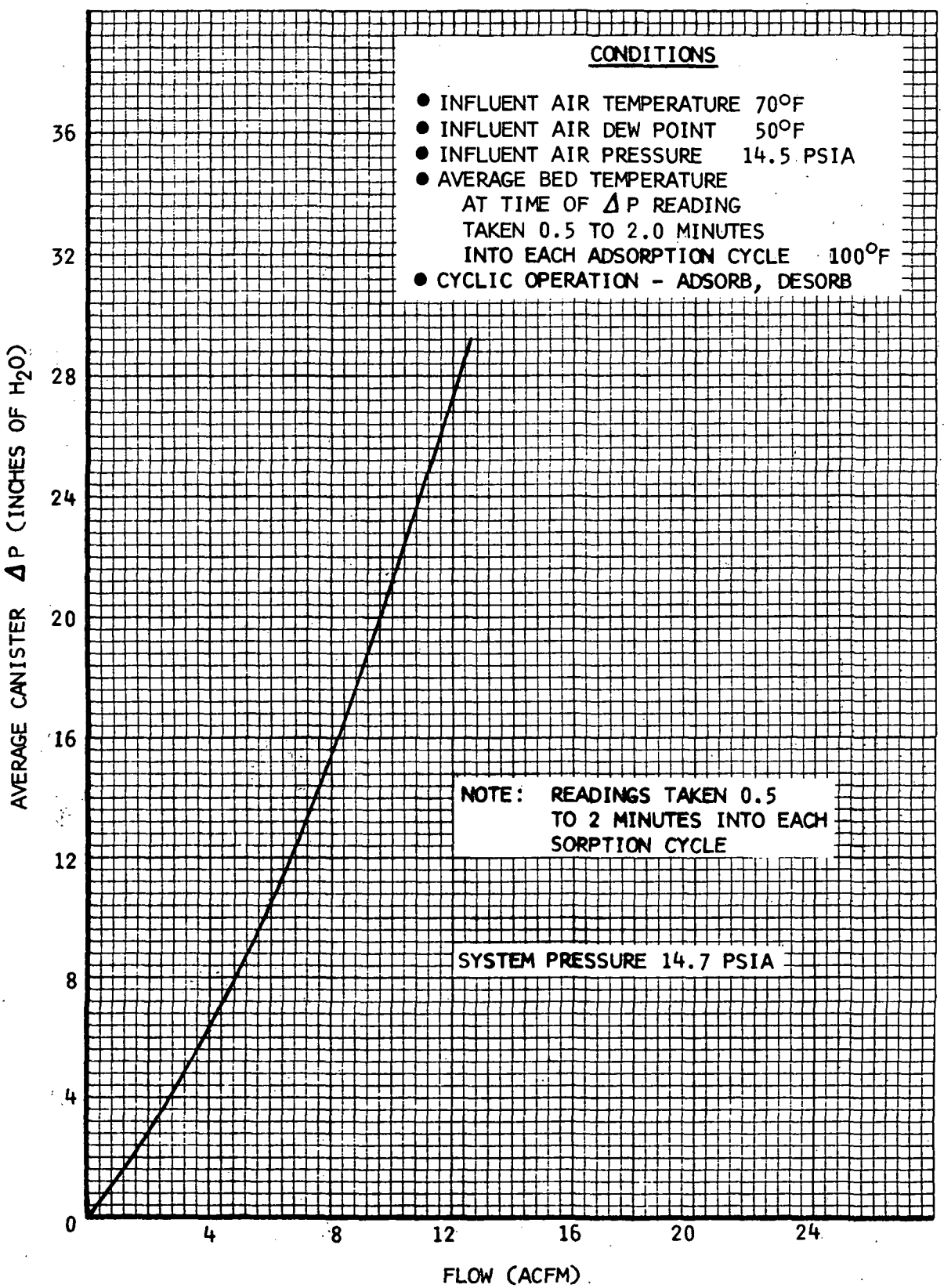
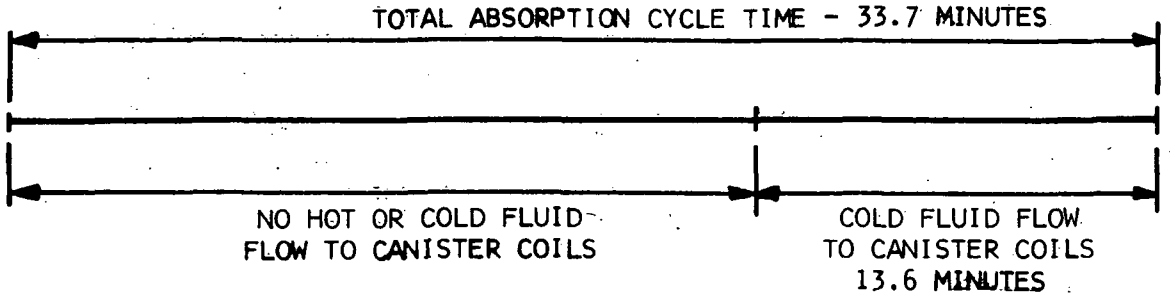

CONDITIONS
● INFLUENT AIR TEMPERATURE 70°F
● INFLUENT AIR DEW POINT 50°F
● INFLUENT AIR PRESSURE 14.5 PSIA
● AVERAGE BED TEMPERATURE AT TIME OF Δ P READING TAKEN 0.5 TO 2.0 MINUTES INTO EACH ADSORPTION CYCLE 100°F
● CYCLIC OPERATION - ADSORB, DESORB
NOTE: READINGS TAKEN 0.5 TO 2 MINUTES INTO EACH SORPTION CYCLE
SYSTEM PRESSURE 14.7 PSIA
AVERAGE CANISTER Δ P (INCHES OF H2O)
0
4
8
12
16
20
24
28
32
36
4
8
12
16
20
24
FLOW (ACFM)

FIGURE 29

mately 28% higher than those recorded with a relatively dry bed. In addition, some of the sorption time periods during cyclic operation were extended to study the flow restriction characteristics with time. The ΔP values at a set inlet gas flow remained fairly constant for 60 to 70 minutes and then gradually increased. The increase was probably due to free water accumulation in the bed with an accompanying expansion of sorbent particles.

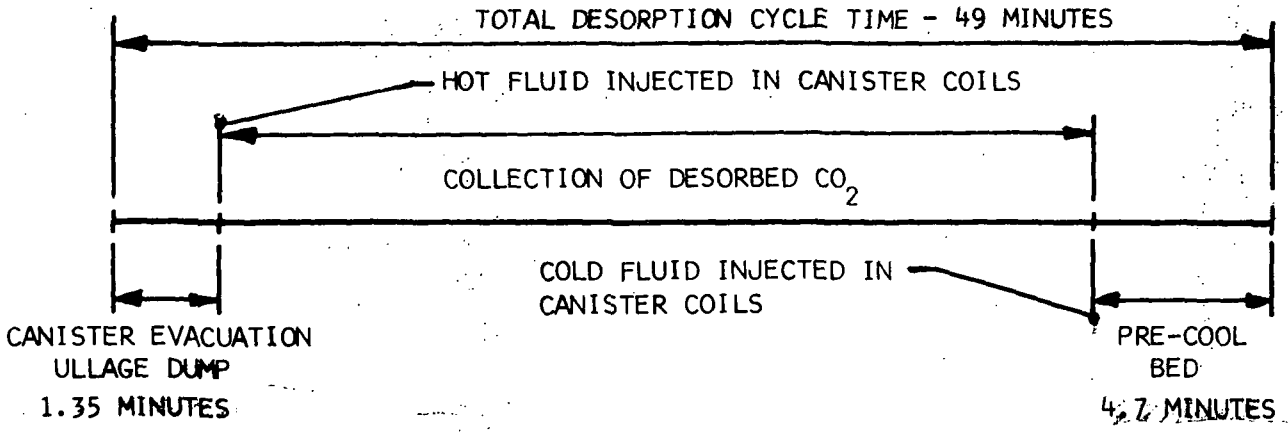
The pressure drop with an inlet gas flow of 7.90 CFM for 5 pounds of Molecular Sieve packed in the same canister (without the liner modification) was 2 to 5 inches of water. Therefore, it would be advantageous to develop larger size HS-B pellets to decrease the associated pressure drop and reduce the resultant circulating fan power penalty.

Trial and error adjustments established that an absorb cycle time of 33.7 minutes was necessary to produce a 3% by weight bed loading of CO_2 at a pressure of 14.7 psia, an inlet air flow of 7.8 CFM, gas temperature of 57°F, dew point of 50°F and CO_2 partial pressure of 5 mmHg. It was determined that the sorption capacity was increased 10 to 15% by precooling the bed to 100 to 130°F during the latter portion of the desorption cycle and running the first 20 minutes of the sorption cycle without cooling the bed. Cooling of the bed was again resumed during the remaining minutes of the sorption process (see figure 30). Also, a desorption cycle time of 49 minutes was established when using a canister evacuation pressure of 0.5 psia and a hot fluid (70% glycol and 30% water) temperature of 200°F. The process consists of evacuating the canister to dump the ullage, flowing hot fluid through canister coils to desorb CO_2, transferring the desorbed CO_2 from the canister to the CO_2 collection tank with the vacuum/compressor system and flowing cold fluid in the canister coils during the latter portion of the cycle to precool the bed prior to the next sorption cycle (see figure 31).



HS-B ABSORPTION CYCLE BASELINE CONDITIONS

FIGURE 30



HS-B DESORPTION CYCLE
BASELINE CONDITIONS

FIGURE 31

The accumulated test time on full scale canister HS-B operation (absorption and desorption) amounted to 160 hours with the last 60 hours being devoted to the parametric testing specified in the contract work statement. A summary of the test conditions is shown in table 9 and the test log sheets are presented in Appendix A. The first (3) and last (10) series of tests were run at the baseline condition to check for any degradation of the sorber with time. One parameter at a time was changed in each series (4 through 9) of tests. A primary goal of the tests was to determine the absorb cycle time needed to maintain a 3% CO_2 cyclic bed loading.

Testing was conducted at atmospheric pressure and the cold transport fluid temperature was set at 50°F. Deviations from the planned test schedule were: 1) a hot fluid temperature of 200°F instead of 180°F in order to establish an average bed temperature of 185°F for adequate desorption at a canister evacuation pressure of 0.5 psia; 2) the test set-up limited the gas inlet temperature to 57°F instead of 50°F when operating with an inlet dew point of 50°F; and 3) in the series 4 runs no change in the absorb time was needed to produce a 3% CO_2 bed loading even though the flow was increased by 1.5. The understanding of the sorption mechanisms at present is inadequate to explain this phenomenon. In each series of runs, a cyclic steady state was attained within 2 to 3 cycles as confirmed by a comparison of P_{CO_2} and dew point traces. Inlet and outlet P_{CO_2} values from cycle to cycle were repeated within ±0.1 mmHg while the outlet dew point (inlet and outlet) repeated within ±2°F.

TABLE 9

HS-B FEASIBILITY TEST CONDITIONS

Run Series	Flow (CFM)	Gas Inlet Temp. (°F)	Inlet Dew Point (°F)	CO_2 Part. Press. (mm Hg)	DESORPTION					ADSORBTION	
					Fluid Temp. (°F)	Evac. Press. (psia)	Desorb Cycle Time (Min)	Ullage Dump Time (Min.)	Pre-Cool Time (Min)	Adsorb Cycle Time (Min.)	Cool Time (Min)
3*	7.8	57	50	5	200	0.50	49	1.35	4.7	33.7	13.6
4	11.8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
5	5.3	↓	↓	↓	↓	↓	↓	↓	↓	50.1	30
6	11.8	↓	↓	1.0	↓	↓	↓	↓	↓	112	92
7	7.8	77	↓	5	↓	↓	↓	↓	↓	33.7	13.6
8	↓	57	↓	↓	150	↓	↓	↓	↓	↓	↓
9	↓	↓	↓	↓	200	↓	↓	↓	↓	↓	0
10	↓	↓	↓	Repeat Baseline Conditions				↓	↓	↓	13.6

NOTES: * Baseline Conditions
System Pressure 14.7 psia
Cooling Fluid Temp. - 50°F

The feasibility test results tabulated in table 10 include the CO_2 purity in percent and the yield per cycle. Yield was derived from the weight of CO_2 absorbed and also was calculated from the CO_2 collection tank pressure, temperature and volume (gas law). The calculated yields are considered to be more accurate than the scale readings of (ΔW); therefore, the calculated values were used for purposes of comparison.

TABLE 10

HS-B FEASIBILITY TEST RESULTS

Run No.	Wt. Of CO_2 Added Lbs. Beg. Of Sorption	Wt. Of CO_2 Added Lbs. End Of Sorption	CO_2 Collection Tank Press. psia Beg. Of Collection	CO_2 Collection Tank Press. psia End Of Collection	ΔP CO_2 Collection Tank psi	CO_2 Collection Tank Temp. °F	CO_2 Purity % By Volume	Calc. Yield Lbs. CO_2/ Cycle	ΔW Of CO_2 Sorbed Per Cycle Lbs.	Integ. Values Lbs. CO_2/ Cycle	Integ. Values Lbs. H_2O/ Cycle
3A	150.19	150.08	-	-	-	-	94.5		0.11		
3B	150.08	149.99	-	-	-	-	94.5		0.09		
3C	149.99	149.90	-	-	-	-	91.0		0.09		
3D	149.90	149.81	-	-	-	-	96.0		0.09		
3E	149.80	149.71	25.1	31.0	5.9	-	97.0		0.09		
3F	149.65	149.56	25.0	31.0	6.0	-	98.0		0.09		
3G	149.48	149.40	-	-	-	-	-		0.08		
3H	-	-	25.8	32.2	6.4	-	94.5	0.094	-		
3I	149.45	149.36	25.0	30.9	5.9	-	94.5	0.087	0.09		
3J	149.36	149.27	25.0	30.8	5.8	-	94.5	0.086	0.09	0.09	0.076
4A	149.05	148.96	25.1	31.4	6.3	82	98.0	0.093	0.09		
4B	148.96	148.87	25.0	31.3	6.3	83	98.0	0.093	0.09		
5A	148.60	148.51	25.4	31.7	6.3	80	96.0	-	0.09		
5B	148.51	148.42	25.3	31.3	6.0	80	96.0	-	0.09		
5C	148.42	148.33	25.2	31.4	6.2	80	96.0	0.091	0.09		
5D	148.33	148.24	25.3	31.4	6.1	82	96.0	0.090	0.09		
5E	148.24	148.15	25.6	32.1	6.5	78	94.5	0.090	0.09		
6A	148.87	148.79	25.0	30.8	5.8	80	94.5	0.086	0.08		
6B	148.79	148.69	25.6	31.7	6.1	78	97.0	0.090	0.10		
6C	148.69	148.60	25.4	31.5	6.1	78	98.0	0.090	0.09		
7A	148.14	148.06	25.2	30.8	5.6	76	93.0	0.083	0.08		
7B	148.06	147.97	-	30.8	5.6	85	94.0	-	0.09		
7C	147.97	147.88	25.2	30.8	5.6	86	93.0	0.083	0.09		
7D	147.88	147.79	25.2	31.0	6.6	87	92.0	0.086	0.09		
7E	147.79	147.71	24.0	30.5	6.5	80	94.0	0.082	0.08		
9A	149.27	149.20	25.0	30.0	5.0	-	95.5	0.074	0.07		
9B	149.20	149.13	25.0	30.5	5.5	-	94.5	-	0.07		
9C	149.13	149.05	25.2	30.5	5.3	82	97.0	0.079	0.08		
10A	147.71	147.63	25.5	31.3	5.8	85	96.0	0.086	0.08		
10B	147.63	147.55	25.4	31.3	5.9	82	96.0	0.087	0.08		
10C	147.55	147.46	25.2	31.2	6.0	86	94.5	0.089	0.09		

Series 3 runs conducted at the baseline condition produced good agreement in the amount of CO_2 removed per cycle as determined by the weight method, the CO_2 collection pressure calculations and a sample graphical integration (figure 32). Actual traces of the CO_2 infrared analyzer (Lira) and the dew point hygrometer records for some of the series 3 run are shown in figures 33 and 34. It will be noticed that both CO_2 and water are absorbed at a gradually decreasing rate during the first 20 minutes when all fluid flow is terminated in the canister coils and that an immediate increase in both absorption rates occures when cold fluid is directed through the coils for the remainder of the absorb cycle. The sorption mechanisms for the HS-B material are not yet clearly understood; however, it is evident that the increased absorption during the latter portion of the cycle is due to the

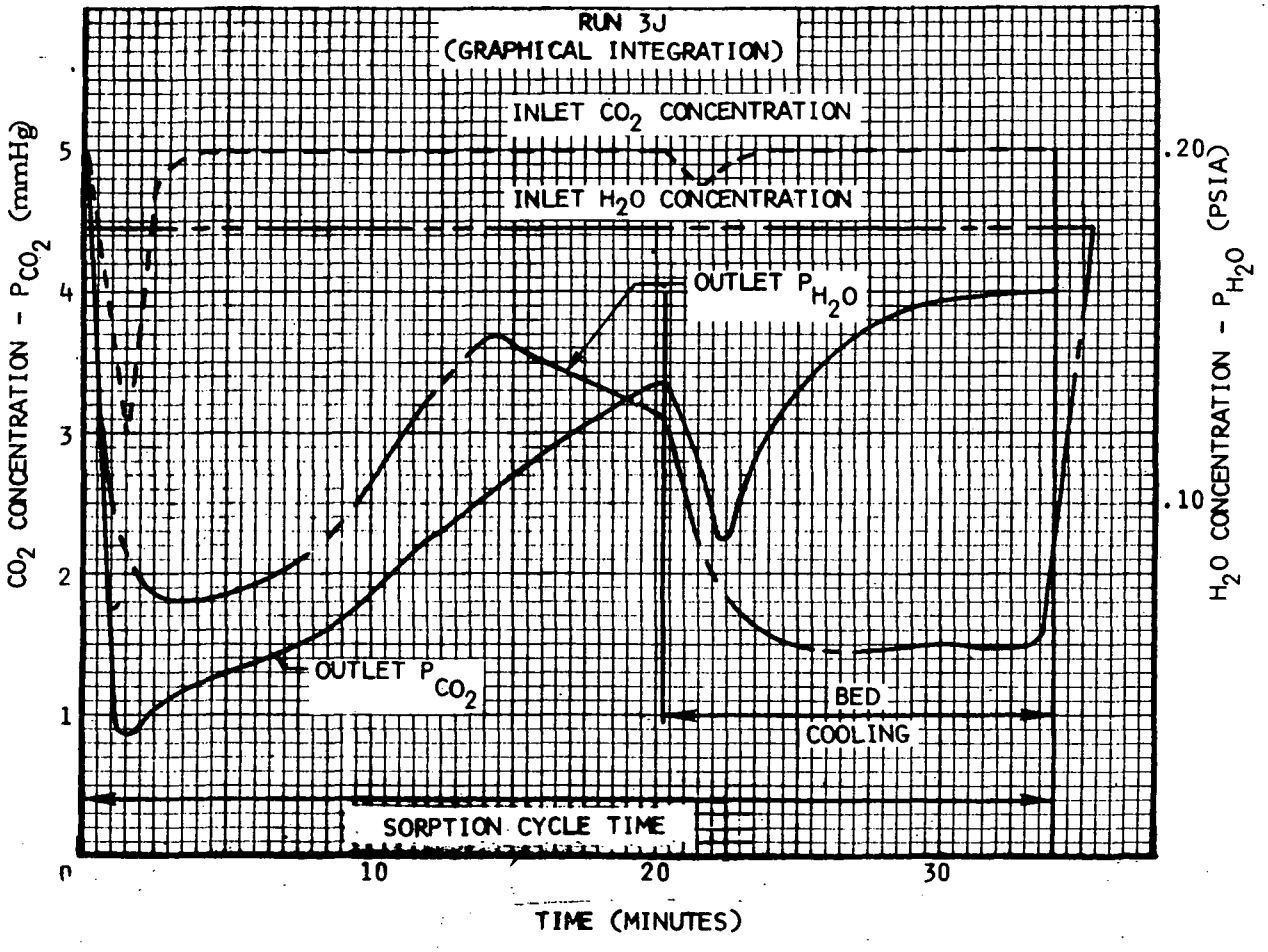


FIGURE 32

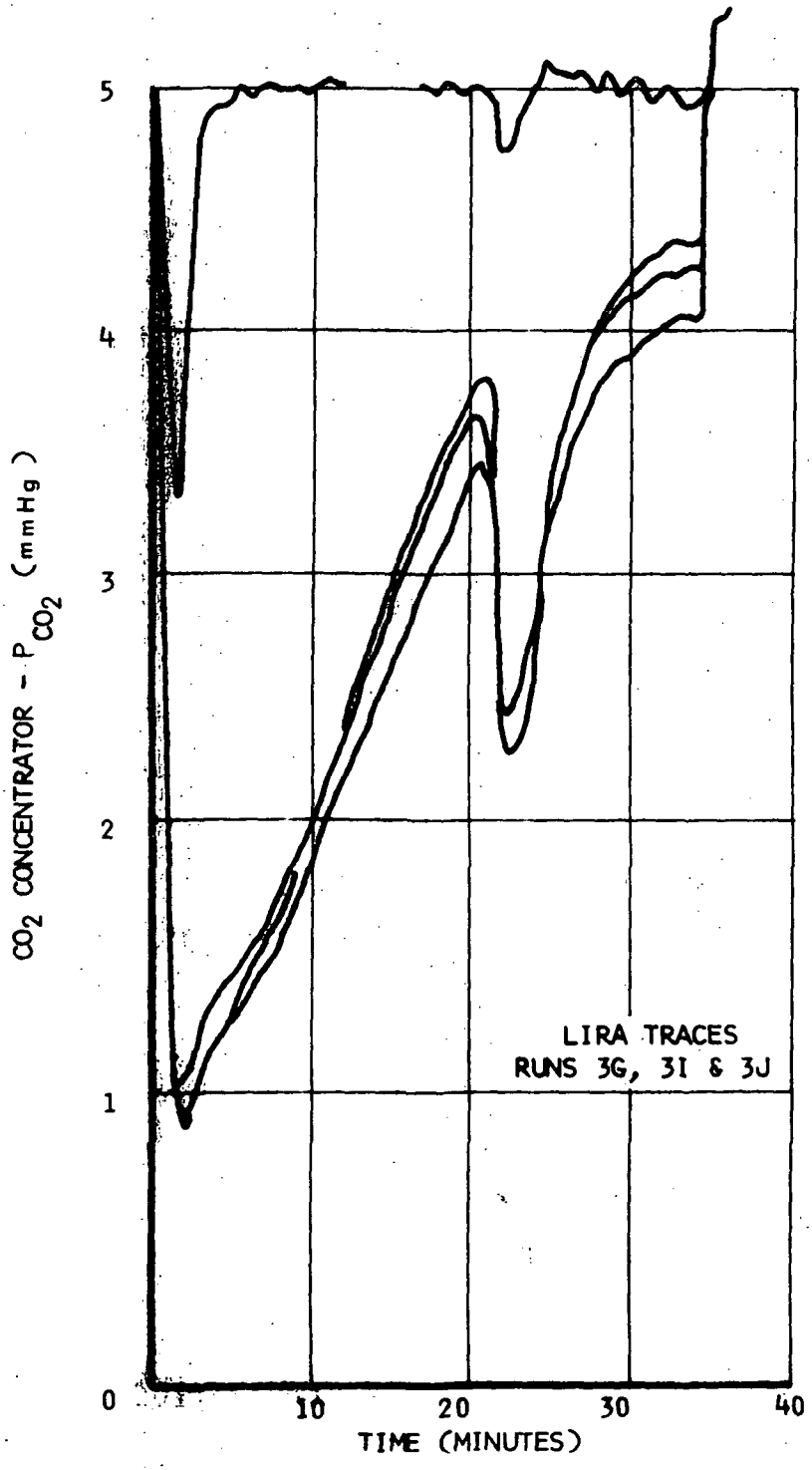

CO_2 CONCENTRATOR - P_{CO_2} (mmHg)
0
1
2
3
4
5
10
20
30
40
TIME (MINUTES)
LIRA TRACES
RUNS 3G, 3I & 3J

FIGURE 33

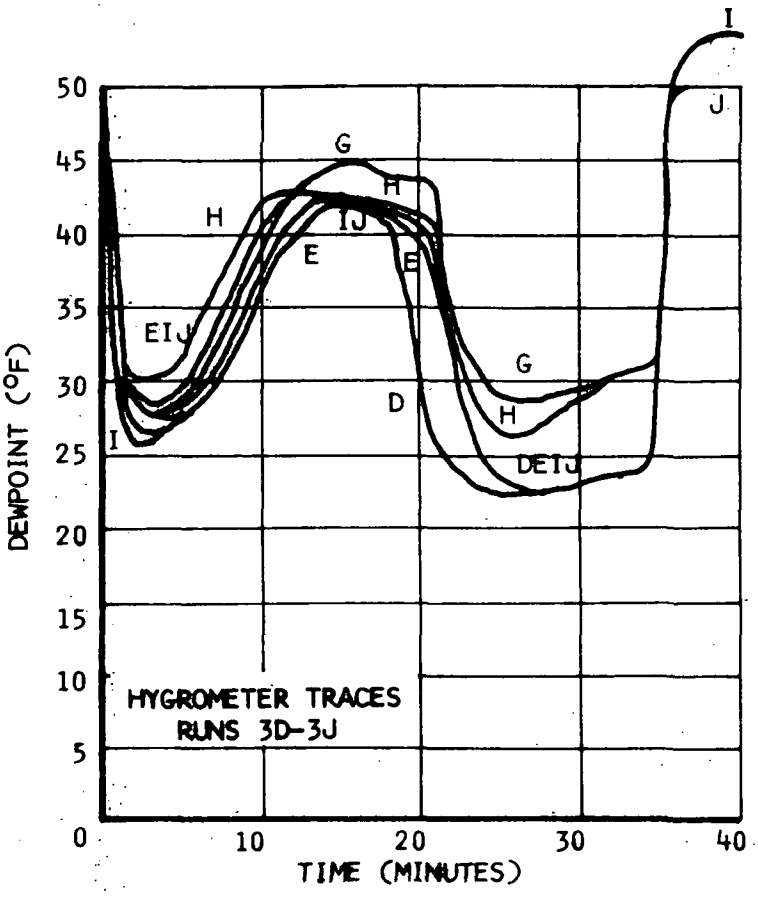
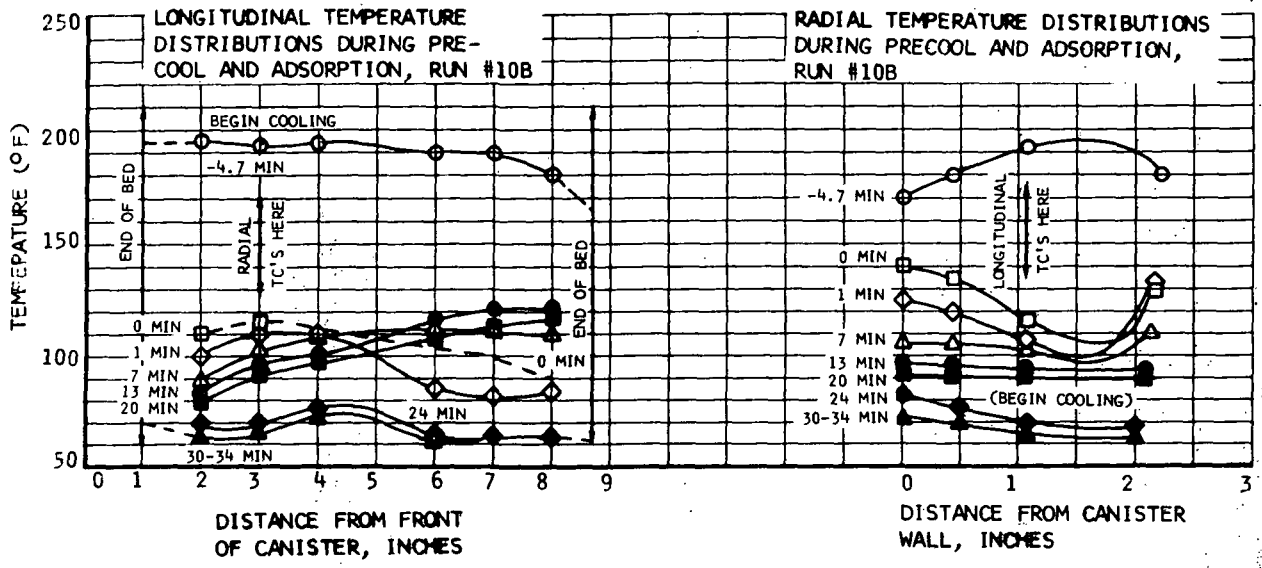


FIGURE 34

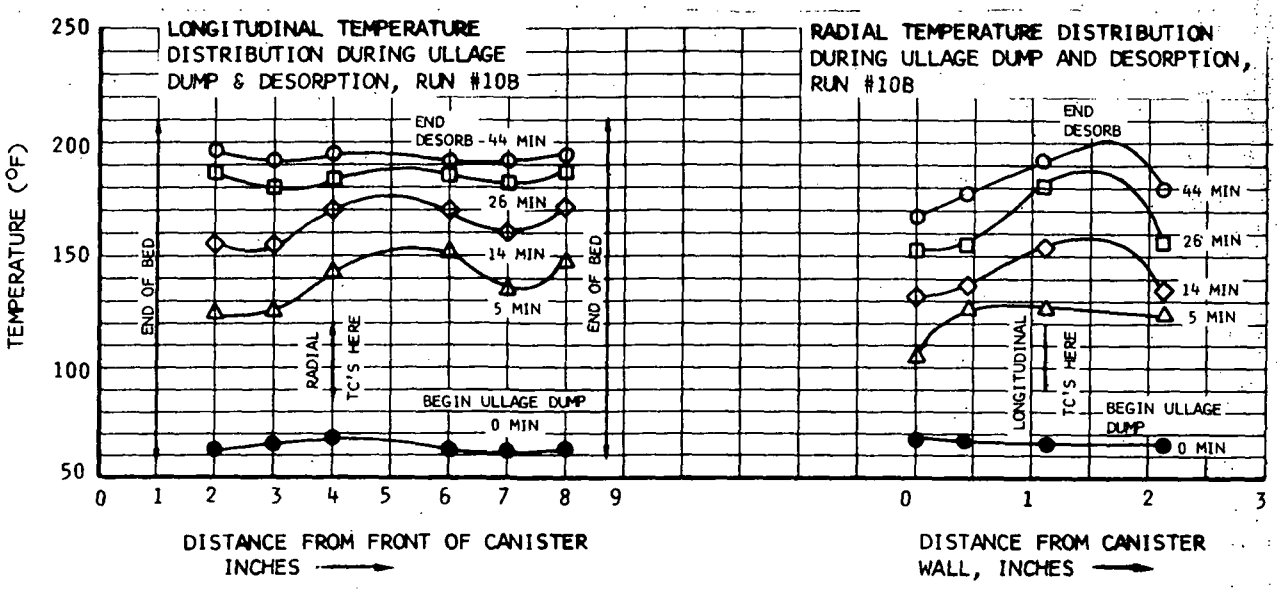
lowering of the bed temperature. Axial and radial bed temperature profiles at the baseline condition (run 10B) are shown in figures 35 and 36. Typical canister evacuation pressure versus time and CO_2 collection tank pressure versus time curves for run 3I are presented in figures 37 and 38. Both curves show that a majority of the CO_2 desorption takes place during the first 22 minutes of the desorb cycle. The wide range in CO_2 purity probably resulted from collection system leakage; however, CO_2 purity as high as 98% was attained during some runs.

Changes in gas stream flow were explored in the series 4 and 5 runs. Initially, when the nominal flow was increased by a factor of 1.5 to 11.8 CFM, the absorption time remained the same to acquire a slightly higher than 3% CO_2 bed loading. With the flow decreased to $\frac{\text{NOMINAL}}{1.5}$ (5.3 CFM), the absorb time had to be extended to 50.1 minutes to realize a 3% CO_2 bed loading.



BED TEMPERATURE PROFILES DURING COOL-DOWN & ADSORPTION

FIGURE 35



BED TEMPERATURE PROFILES DURING ULLAGE DUMP & DESORPTION

FIGURE 36

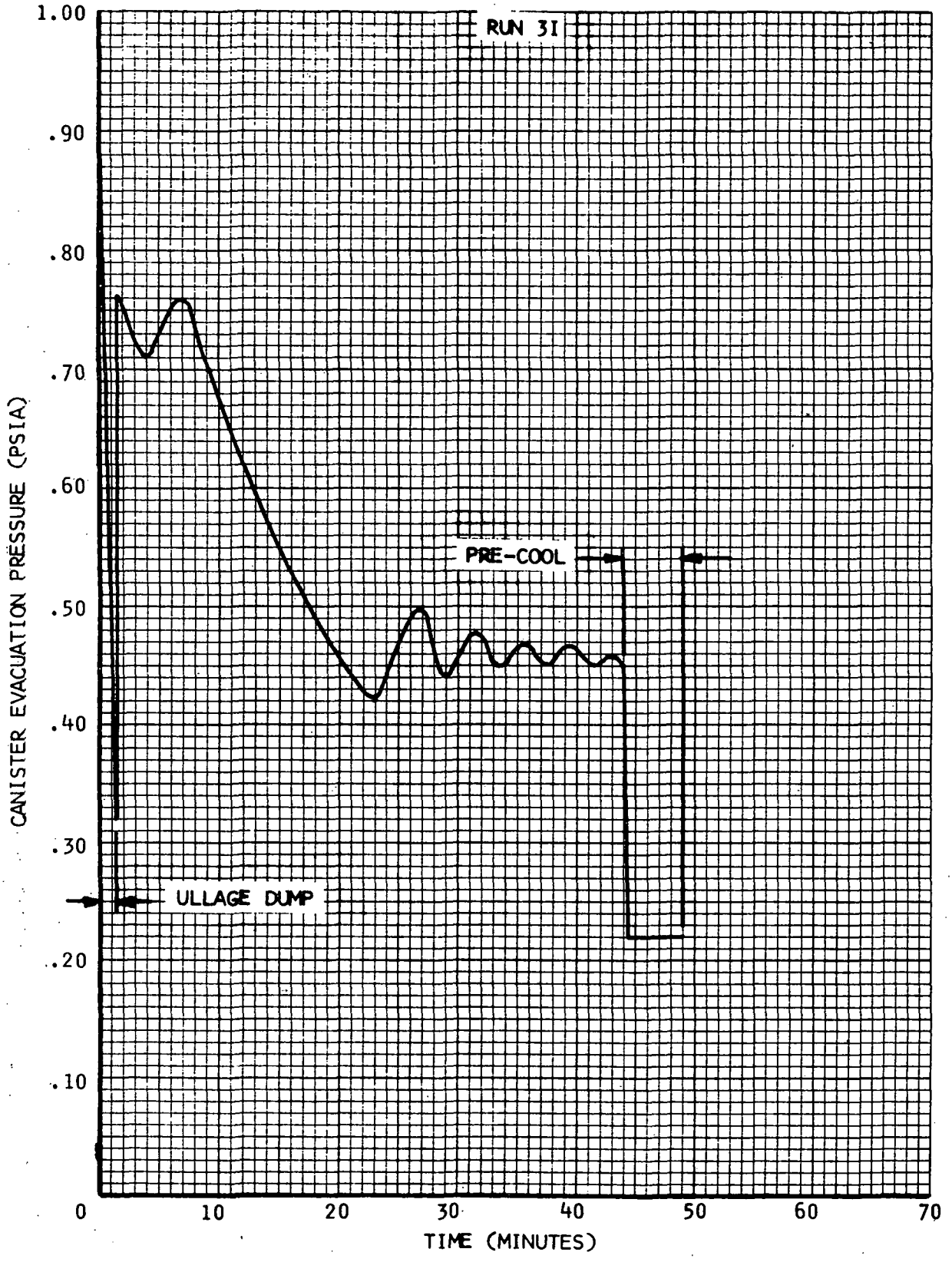

RUN 31
PRE-COOL
ULLAGE DUMP
CANISTER EVACUATION PRESSURE (PSIA)
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
10
20
30
40
50
60
70
TIME (MINUTES)

FIGURE 37

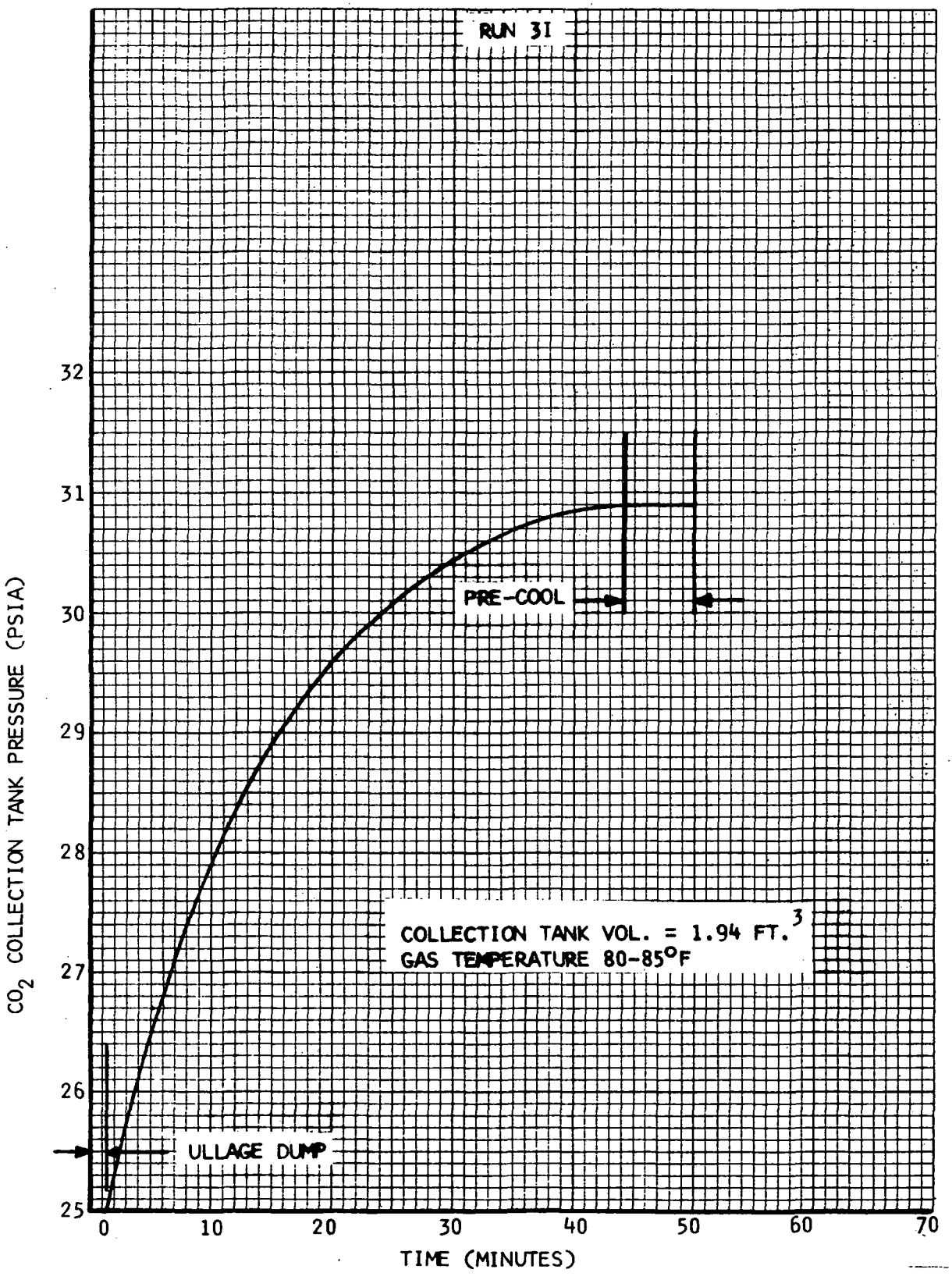

RUN 31
PRE-COOL
ULLAGE DUMP
COLLECTION TANK VOL. = 1.94 FT.3
GAS TEMPERATURE 80-85°F
CO_2 COLLECTION TANK PRESSURE (PSIA)
32
31
30
29
28
27
26
25
0
10
20
30
40
50
60
70
TIME (MINUTES)

FIGURE 38

In the series 6 runs, the P_{CO_2} was reduced from 5 mmHg to 1 mmHg. Extensions in the absorb time from 33.7 to 112 minutes and the cool time from 13.6 to 92 minutes was necessary to attain the nominal case 3% CO_2 bed loading.

Series 7 runs explored the effect of raising the gas inlet temperature from 57° to 77°F with otherwise nominal operating conditions. No appreciable change in the bed loading was observed.

A reduction in the desorb fluid temperature to 150°F during the series 8 runs produced no significant CO_2 capacity.

Series 9 runs eliminated the bed cooling time during absorb at the baseline condition. A reduction in the CO_2 bed loading from 3% to 2.5% was recorded.

The baseline condition was repeated in the series 10 runs with no appreciable change in bed capacity indicating that no material degradation had taken place.

Before and after the parametric testing, a breakthrough test was conducted as a further search for any possible material degradation. In both cases, the bed was initially desorbed with a hard vacuum at an average bed temperature of 200°F for 5 to 7 hours. The canister was then cooled to 55°F prior to the start of the absorption process. Air (5 CFM) at a pressure of 14.4 psia, and an inlet dew point of 50°F, a sensible inlet temperature of 57°F and an inlet P_{CO_2} of 9 mmHg was passed through the bed until the outlet P_{CO_2} equaled the inlet P_{CO_2}. A plot of the inlet and outlet Lira traces with time presented in figure 39 shows no appreciable change in the CO_2 capacity.

Summary of Results

An increase in the nominal flow by a factor of 1.5 slightly increased the CO_2 bed loading from 3.0% to 3.1% at the same absorb time of 33.7 minutes. A decrease from nominal flow to $\frac{\text{NOMINAL}}{1.5}$ produced a 3% bed loading with an extended absorb time of 50.1 minutes.

Lowering the P_{CO_2} from 5 mmHg to 1 mmHg had no significant effect on bed capacity; however, the absorb cycle time had to be extended to 112 minutes with a corresponding increase in the cooling period to 92 minutes. Since a set amount of chemi-sorption capacity is always available, the reduced driving force associated with the drop in P_{CO_2} is compensated for by an increase in the absorb and bed cooling times.

An increase in the gas inlet temperature from 57°F to 77°F with

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SVHSER 5966

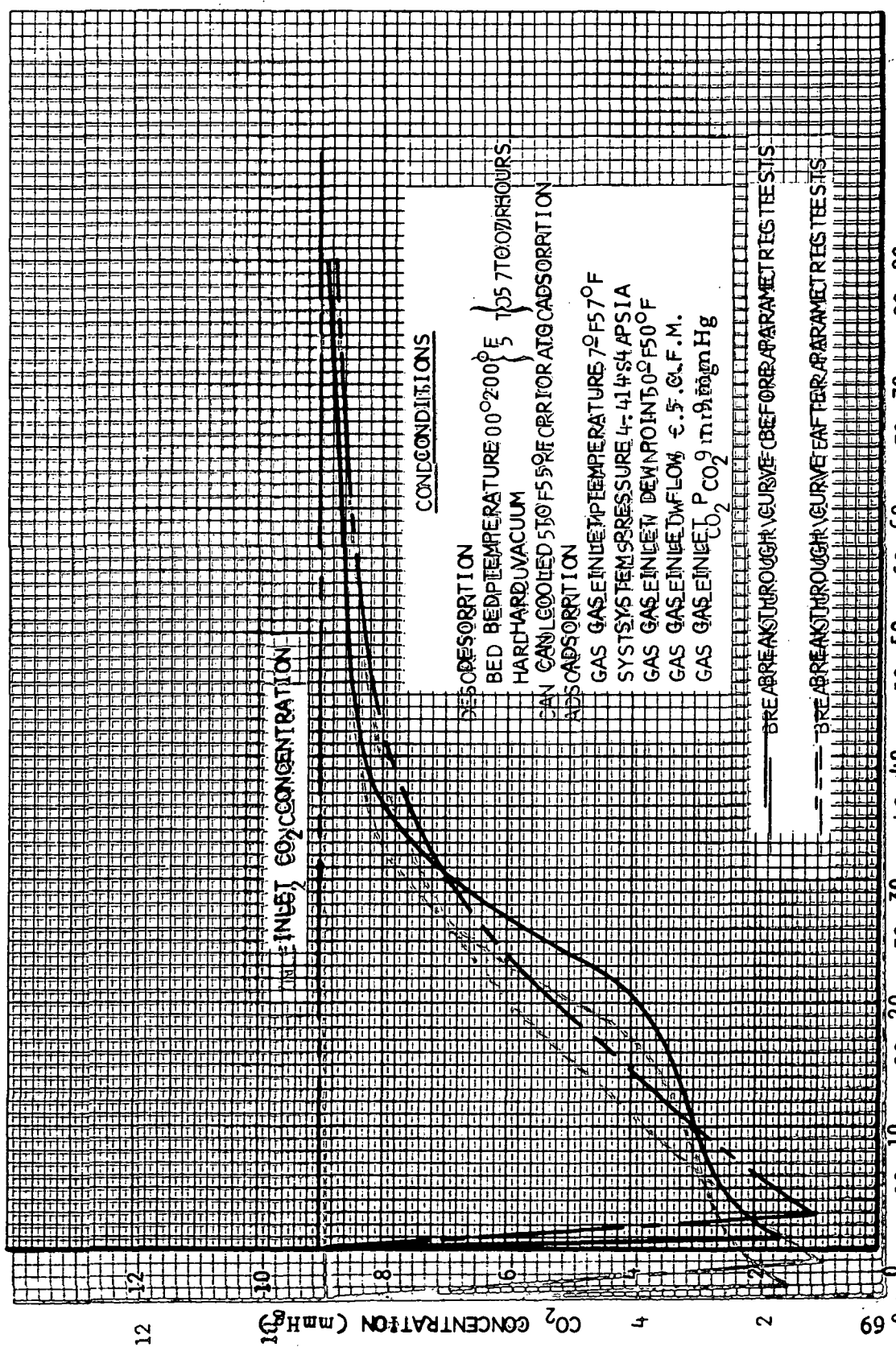


FIGURE 39

otherwise nominal operating conditions showed no appreciable difference in bed loading.

No significant CO_2 bed loading was realized when the desorb fluid temperature was lowered from 200°F to 150°F.

The elimination of bed cooling during the latter portions of absorb reduced the CO_2 bed loading from 3.0% to 2.5%.

The baseline condition and breakthrough curve tests conducted at the beginning and end of the program showed no degradation in performance.

Conclusions

The HS-B material utilized in a full size canister is capable of producing a 3% CO_2 dynamic bed loading when operating under typical spacecraft conditions. System flow, absorption cool down time and desorption fluid temperature all have an effect on the CO_2 capacity.

Changes in the inlet P_{CO_2} do not seem to affect the sorbent CO_2 capacity but does affect the rate of absorption which necessitates adjustments in the absorb cycle time to realize a constant 3% CO_2 dynamic bed loading.

No HS-B material degradation was experienced while operating under a typical spacefraft condition; however, material degradation can occur if HS-B is exposed to oxygen at elevated temperatures (above 150°F) or subjected to liquid water which will remove the coating material.

The current available mesh size (25 to 45) of HS-B material produces a relatively high canister pressure drop which would impose excessive circulating fan power penalties in a spacecraft environmental control system design.

Recommendations

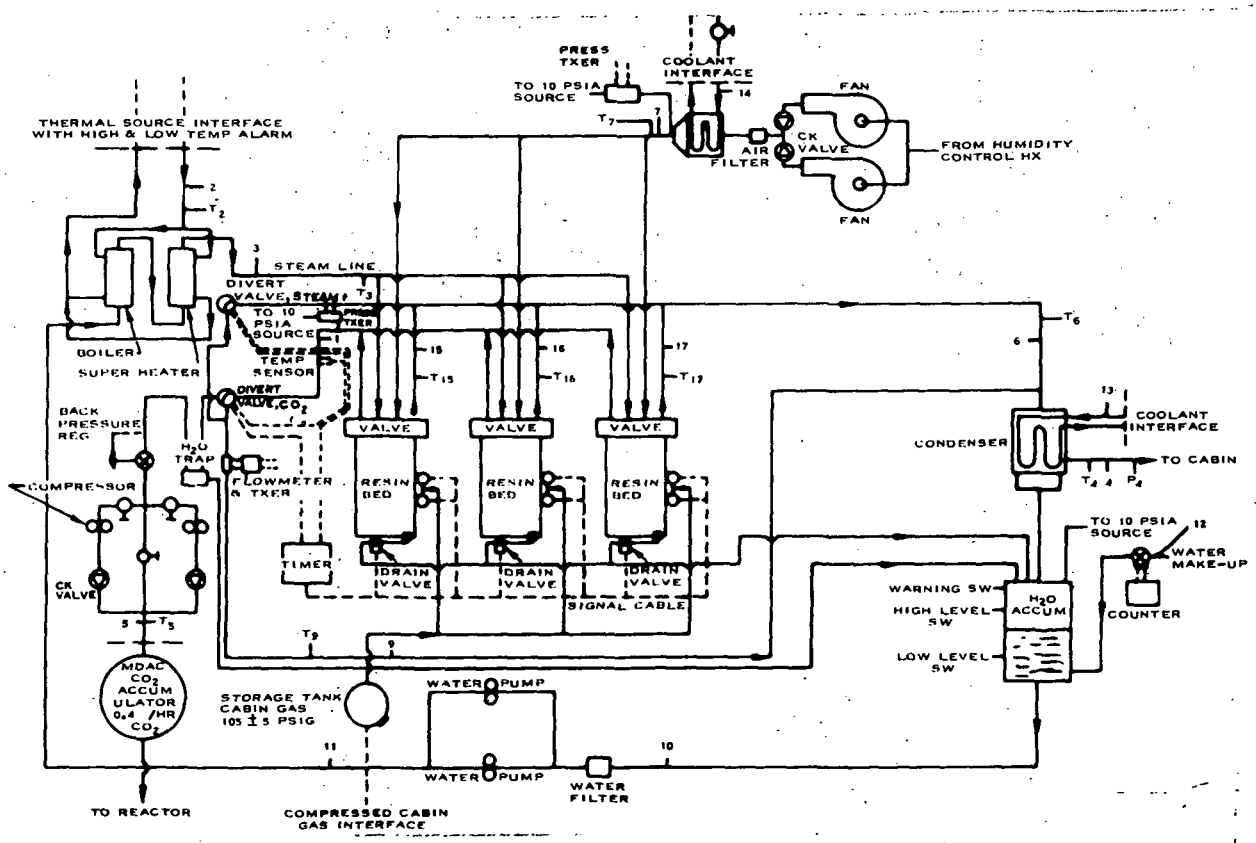
Further polymerization studies should be performed on this type sorbent to provide greater thermal stability in the presence of oxygen, reduce water solubility and pressure drop characteristics. Improved CO_2 cyclic capacity certainly seems feasible and should be investigated further.

AMINE SORBER CO_2 CONCENTRATOR

Hamilton Standard designed and fabricated a CO_2 Concentrator as a system experiment for the 90-day manned space simulator test conducted in mid-1970 as a research project of the NASA Biotechnology advance research program. The unit utilized hardware available from the Manned Orbiting Laboratory program (MOL) wherever possible and IR-45 as the CO_2 sorber (Rohm and Haas commercial ion exchange resin). This Amine sorber was identified by Mine Safety Appliance Research Corporation (MSA) as a potential CO_2 removal agent under contract with Langley Research Center, NAS 1-7263, R&D of Polymer Sorber for CO_2 Control [2]. The three phase program consisted of 1) a Design, Analysis and Feasibility Study 2) the Fabrication Development and Acceptance Test of the unit and 3) the Post 90-Day Test Analysis.

Design, Analysis and Feasibility Study

The Amine CO_2 Concentration system that resulted from the design and analysis phase is shown in the schematic figure 40. The range of flow



AMINE CO_2 CONCENTRATOR SCHEMATIC
FIGURE 40

conditions for the system are given in table 11. The system consists of three MOL canister assemblies packed with IR-45, a circulation fan with in line spacer, an air filter, an inlet air heat exchanger, an air outlet heat exchanger, a two stage boiler, a water trap, a compressor with in line spacer, a water reservoir and flow and temperature sensors and controls.

System Design

The system is designed to utilize either two or three beds and include sensors and controls which allow a wide choice in operating conditions including different absorption and desorption times when using three beds. During the absorb phase, the influent cabin air with CO_2 is circulated by the fan through the air filter and the heat exchanger to control the inlet gas temperature and humidity as desired and through the canister on absorb, and through the outlet heat exchanger or condenser to cabin. The CO_2 is removed from the gas stream by the IR-45 material.

Simultaneously, superheated steam from the steam generator is directed through the bed on desorb and initially the ullage gas is dumped through the condenser to cabin. A flowmeter is located in the canister desorption outlet to sense a flow rate change. When the flow of desorbed CO_2 increases sharply, a valve is positioned to redirect the flow of CO_2 to the compressor and collection system. A back pressure regulator is located upstream of the compressor to maintain the proper pressure within the canister and generation system. This maintains the steam temperature. Also, the sorber will degrade if exposed to high temperature and low pressure simultaneously. A water trap removes any free water in the desorption gas stream. As desorption is completed, the temperature of the bed effluent gas rises. At a preselected temperature, depending on the thermocouple location, a controller mechanism repositions the CO_2 diverter valve and opens a second diverter valve so that steam is directed to the outlet of the system. The steam flow by-passes the flowmeter to the outlet due to the relatively less restrictive flow path opened by the second diverter valve. This mode of operation is continued until the preselected cycle time is concluded.

The cooling and heating fluids for the boiler and inlet and outlet heat exchangers are supplied externally by the test facility.

Component and Material Selection

During the design and analytical phase, the component functions were defined and selected and manufacturing and procurement drawings were prepared. A description of the selected hardware is given as follows:

Circulating fan.- The fan was to be capable of circulating 30 CFM at 10 psia against a head pressure of 30 inches of water. A duplex spiral fan

TABLE 11

FLOW CHART

Location	Pressure (psia)	Temperature (°F)	Flow (lbs/hr)	Relative Humidity (%)
1	15 max. CO_2 10 min. CO_2	220 CO_2 70 CO_2	*2.5 max. CO_2 0.4 Ave. CO_2	100%
2	60 psig	235 max. 225 min.	50 lbs./min. max. 30 lbs./min. min.	
3	15 max. 10 min.	220 max. 200 min.	7.0 max. Steam 5.0 min. Steam	
4	10.10 max. 9.90 min.	85 max. 45 min.	90 max 80 nom. 60 min.	100%
5	35 psig max.	100 max.	*2.5 max. CO_2 0.4 Ave. CO_2	
6	10.10 max. 9.90 min.	180 max. 60 min.	90 max. 80 nom. 60 min.	100%
7	11.0 max. 10.0 min.	130 max. 50 min.	90 max. 80 nom. 60 min.	
9	10.1 max. 9.9 min.	220 max. 60 min.		
10	10.1 max. 9.9 min.	100 max. 50 min.	7.0 max. 5.0 min.	
11	15.0 max. 10.0 min.	100 max. 50 min.	7.0 max. 5.0 min.	
12	60 max. psig	100 max. 50 min.	10 lbs./day max. 6 lbs./day min.	
13	60 max. psig	40 max. 36 min.	19 lbs./min. max. 10 lbs./min. min.	
14	60 max.	60 max. 50 min.	**10 lbs./min. 0 lbs./min	
15	10.1 max. 9.90 min.	200 max. 60 min.	90 max. 80 nom. 60 min.	100%
16	10.1 max. 9.90 min.	200 max. 60 min.	90 max. 80 nom. 60 min.	100%
17	10.1 max.	200 max. 60 min.	90 max. 80 nom. 60 min.	100%
Hum. Cont. HX	10.1 max. 9.90 min.	60 max. 45 min.	90 max. 80 nom. 60 min.	45°F D.P. max.

*Peak flow during desorb.
**Adjusted to control #7 temp. as required.

was selected for this application. The unit selected is suitable for operation in an ambient temperature up to 55°C (131°F) providing the flow is not reduced below 20 CFM for more than 5 minutes per hour. The temperature rise across the fan is from 40°F to 150°F (STP). Two impellers are internally ducted in series and driven by an integrally mounted induction motor. The design tends to give longer life with trouble free operation. The motor is a permanent, split phase, capacitor-run induction motor for a single phase power supply designed for continuous duty. There are no centrifugal switches, starting relays or brushes thus eliminating the possibility of arcing.

Circulating fan check valves.- A MOL circular double check valve was selected to allow two circulating fans to be assembled together for redundancy. This application consists of two inlet ports separated by a partition on the upstream side and covered on the downstream side by two semicircular spring loaded flaps. The unit is mounted in a housing which provides two inlet tubes, a gasket to form a seal around each inlet port, and a single outlet tube. The head developed by either circulating fan overcomes the spring load and opens the flap on its respective inlet port. The fan head pressure is applied to the back surface area of the closed flap to further assist the spring load in sealing off the inlet port not in use.

Air filter.- A particulate filter was selected with a 25 μ absolute max., AISI 300 series stainless steel element. The element fits in an aluminum alloy housing with AND 10050-16 ports. The pressure drop across the unit is 5" H_2O max. with a flow of 20 CFM at an inlet pressure of 10 psia and a temperature of 160°F.

Heat exchanger (inlet temperature control).- A plate and fin heat exchanger was selected to control the process gas inlet temperature and humidity. The unit is a crossflow design of fluxless brazed aluminum construction. The temperature rise across the fan was 40 to 150°F (STP). To achieve an operating gas temperature within the range of 50° to 120°F as indicated by the tests at MSA, the process gas is divided, a portion is by-passed around the heat exchanger, and part passes through the heat exchanger.

A design condition at a system pressure of 10 psia was assumed in which the gas temperature leaving the fan was 150°F. The gas temperature leaving the heat exchanger was 55°F and 35% of the air flow was through the heat exchanger. The heat exchanger must remove:

$$Q = \dot{W}_{air}\, C_p\, \Delta T = (.35 \times 1.5)\ .24(150-55) = 12 \text{ BTU/min.}$$

where $\dot{W}_{air} = 30 \text{ ft}^3/\text{min.} \times .05 \text{ lbs/ft}^3 = 1.5 \text{ lbs/min.}$

Allowing a 5°F rise in the coolant temperature, the coolant flow required would be:

$$\dot{W}_{coolant} = \frac{Q}{C_p \Delta T} = \frac{12 \text{ BTU/min.}}{.45 \text{ BTU/lb °F} \times 5°F} = 5.3 \text{ lbs/min.}$$

A computer program was utilized to determine the adequacy of a unit available from the LEM program for this application.

For example,

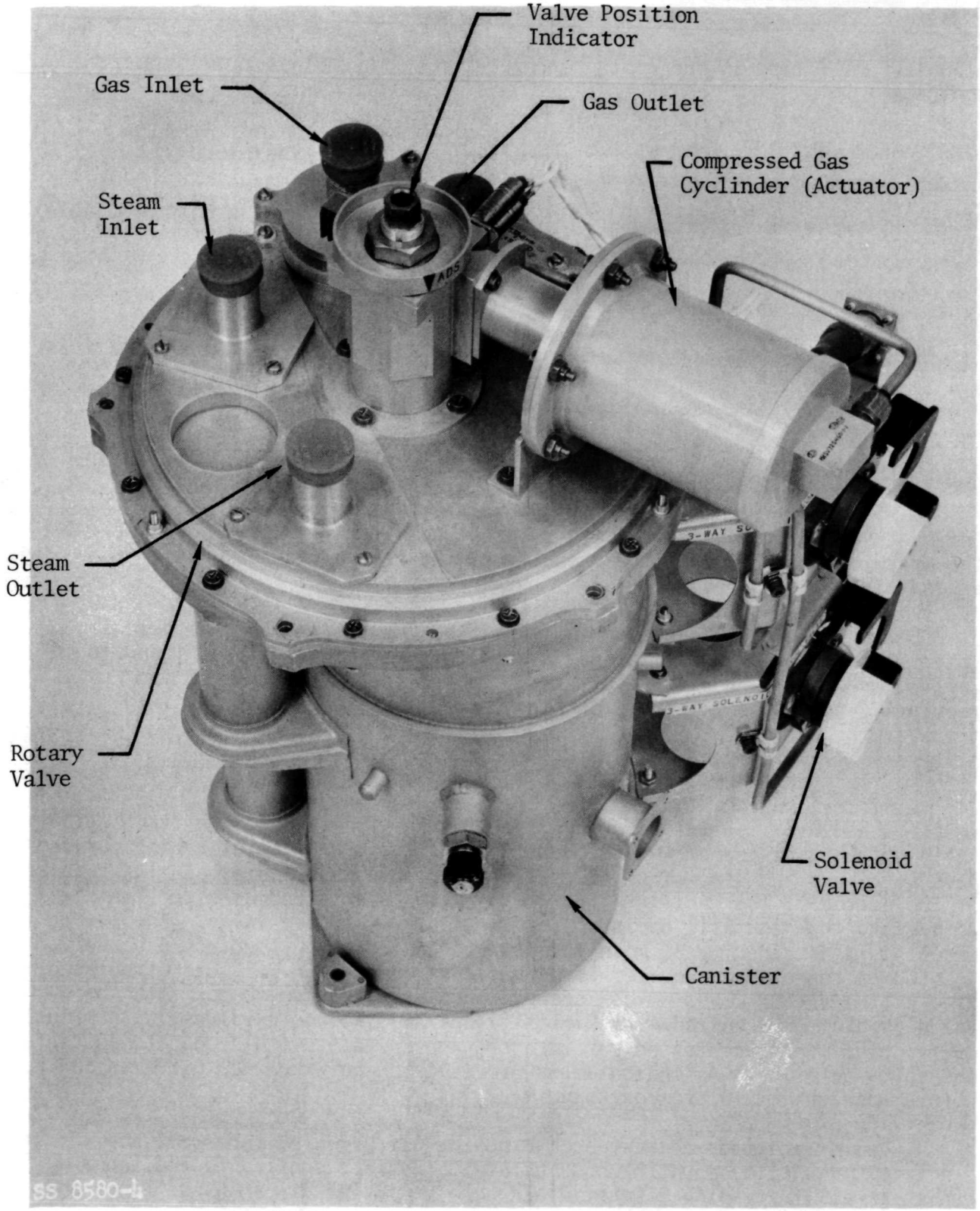
Input	$\dot{W}_{air} = 0.5$ lbs/min.	$\dot{W}_{coolant} = 5$ lbs/min.
	$T_{air} = 150°F$	$T_{coolant} = 40°F$
Output		
	$T_{air} = 40.7°F$	$T_{coolant} = 46.8°F$

The 0.7°F difference between the air outlet temperature and the coolant inlet temperature indicated that the capacity of the heat exchanger was far in excess of that required.

During the development test program, the control of the canister air inlet temperature by bypassing gas around the heat exchanger was found to be ineffective. Passing all the air flow through the heat exchanger and regulating the coolant inlet flow with a needle valve gave the desired temperature control.

Canister and valve assembly.- Three canister and valve assemblies were modified and utilized in the system (see figure 41) to hold the IR-45 sorber. The aluminum canister of welded construction provides integral tubing for the passage of gas and steam from the valve on top of the canister and its release at the bottom of the canister. Solenoid valves are included on the canister to actuate the pneumatic operation of the four-way rotary valve. The sorbent material is retained by 80 mesh screens top and bottom. A rotary disc valve located on top of the canister is actuated by compressed gas into either end of a cylinder that moves a rack and pinion gear mechanism to position the valve porting as required. Electrically operated solenoid valves, with manual override, release compressed gas into the appropriate cylinder end to initiate the valve rotation. An indicator is provided to show when the valve is in the absorb, desorb or isolate position.

The modifications consisted of blocking off a center tube port and an electrical connector mounting boss hole with patches epoxied to the inner canister wall, providing a water drain hole, epoxying discs in the inner and outer valve housings to block off the center tube valve ports, and the



FEASIBILITY TEST CANISTER
MODIFIED MOL ITEM #506

FIGURE 41

fabrication of new inlet and outlet manifold adapters. A closed pore foam insulation jacket was formed around each canister. An adhesive was applied to the outside surface and the foam was covered with aluminum foil.

Each of the three canisters was initially filled with 7.65 lbs. of IR-45 material as received from Mine Safety Appliance Research Corporation with a water loading of 15% by weight. MSA under contract with NASA/LRC had previously conducted a survey and laboratory investigations to identify and characterize a sorber that might be utilized to advantage over Molecular Sieve for CO_2 concentration. Ion exchange resins were ultimately selected for extensive investigation with an electro-balance and in small scale dynamic tests. A commercially produced weak base amine resin (IR-45) as processed by MSA showed the greatest overall potential for removing CO_2 in a gas stream and was selected for use in the full-scale breadboard unit. The resin, a styrene divinyl benzene copolymer aminated with diethylenetriamine, is durable and absorbs CO_2 in the presence of water vapor thus eliminating the need of predrying the inlet gas stream. Desorption can be accomplished at cabin pressure rather than in a partial vacuum as in the case of Molecular Sieve. The unit structure of the resin is shown in figure 42 and the manufacturer's data on the IR-45 material is presented in table 12. The results of an evaluation of IR-45 amine material by NASA/MSC for flammability, odor and off gassing are shown in table 13.

Outlet or Condenser Heat Exchanger.- The temperature and humidity of the gas leaving the sorbent beds during absorption may vary to approximately 200°F, and 100% R.H. To minimize loading the cabin air conditioning and the loss of water from the CO_2 concentration system, a heat exchanger was employed to cool the system effluent air and trap out the condensed moisture. The condensate is returned to the system water accumulator, from which it is drawn for steam generation as required.

The most demanding condition occurs when a canister begins the absorption phase. The effluent gas temperature is high (>170°F) and the rate of evaporation from the sorber is at a maximum thus producing the highest sensible and latent heat loads on the outlet heat exchanger. The estimated condenser peak heat loads for a three bed system are shown in table 14.

A MOL stainless steel plate and fin cross-flow heat exchanger with integral wicking was considered for this application, since it was designed for a similar application in the original MOL system. The capacity of the unit was checked to insure an adequate capability for handling peak loads. Assuming a maximum rise of 25°F across the coolant section of the heat exchanger, which is supplied with Coolanol 35 (approx. C_p = 0.45 BTU/lb-°F) at 38°±2°F, the coolant flow required to reject the total heat load of 116.8 BTU/min. is:

$$\dot{W} = \frac{Q}{C_p \Delta T} = \frac{116.8}{.45 \times 25} = 10.3 \text{ lbs/min.}$$

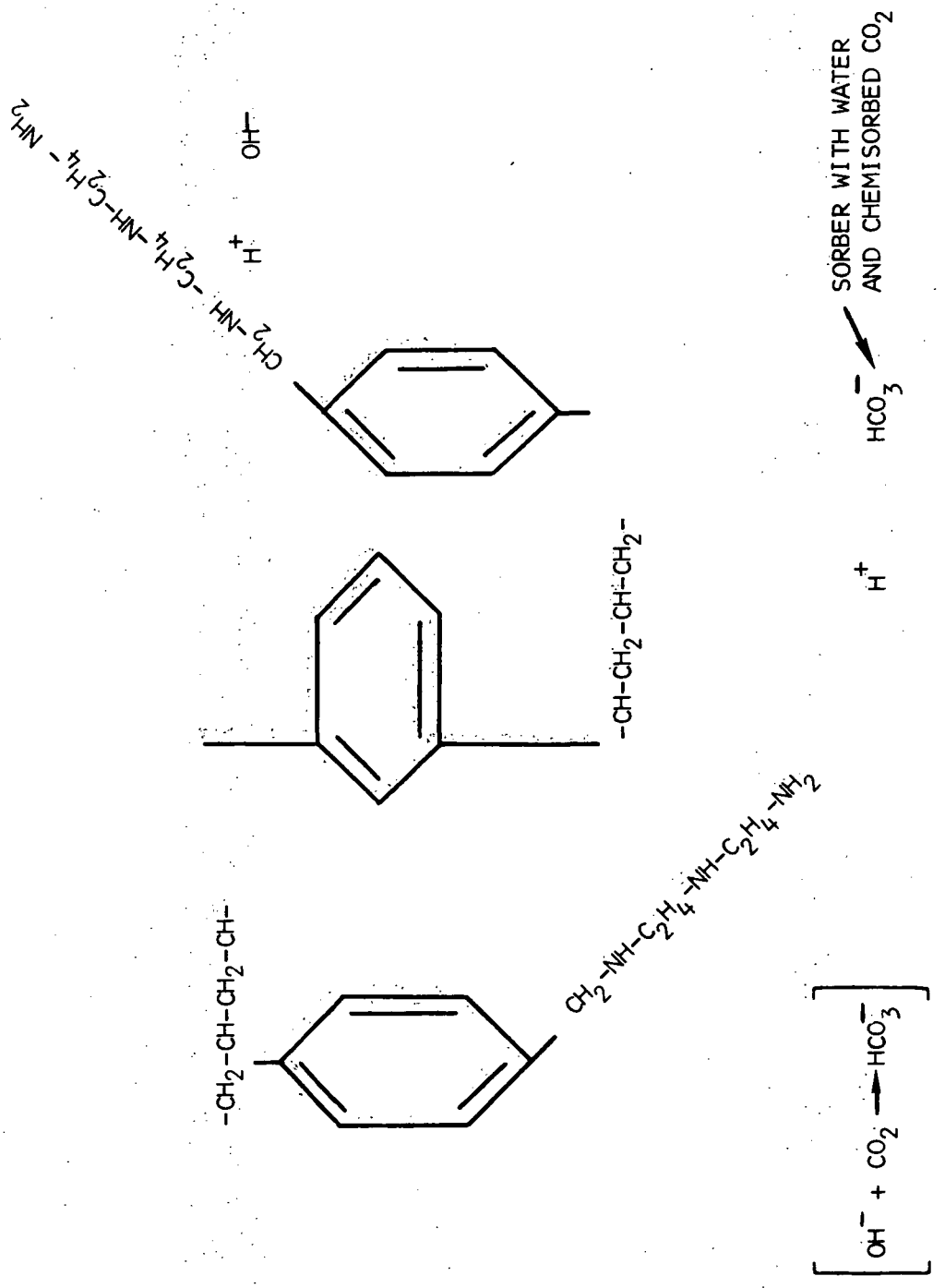

SORBER WITH WATER AND CHEMISORBED CO_2
HCO_3^-
H^+
$OH^- + CO_2 \rightarrow HCO_3^-$
$-CH_2-CH-CH_2-CH-$
$CH_2-NH-C_2H_4-NH-C_2H_4-NH_2$
$-CH-CH_2-CH-CH_2-$
$CH_2-NH-C_2H_4-NH-C_2H_4-NH_2$
H^+
OH
AMINE MOLECULAR STRUCTURE

FIGURE 42

TABLE 12

MANUFACTURER'S DATA ON IR-45

Physical Characteristics	
Physical Form:	Uniform, bead-like particles
Density:	39 to 43 lbs. per cu. ft.
Moisture Content:	37 to 45 percent
Screen Grading:	20 to 50 mesh
Effective Size:	0.35 to 0.50 millimeters
Uniformity Coefficient:	1.6 max.
Voids:	35 to 45 percent
Chemical Characteristics	
Exchange Capacity:	43 kilograms per cu. ft. maximum as calcium carbonate (27 kilograms dynamic capacity)
pH Range:	0 to 7
Chemical Stability:	Excellent. Completely insoluble and inert in strong acids (except nitric), concentrated alkalies, aliphatic and aromatic hydrocarbons, alcohols, ethers and all other common solvents. Prolonged exposure to strong oxidizing agents should be avoided.
Stability at Elevated Temperatures:	Outstanding. The exchange capacity was found unchanged after prolonged exposure to boiling water (212°F).

TABLE 13

MSC EVALUATION OF IR-45

Test Results Of Off-Gasing Evaluation		
Sample	Total Organics	Carbon Monoxide
As Received	1.43 Millimole/25M^3	1.64 Millimole/25M^3
Methanol Wash	0.068	7.45
Steam Cycled	0.136	0.98
Methanol Extracted Plus Steam Exposure	0.27	2.75

General Comments On MSC Evaluation Of IR-45

1) IR-45 passes flammability criteria.

2) IR-45 passes odor criteria.

3) IR-45 passes total organics criteria.

4) IR-45 is borderline on CO off-gasing but steam exposure reduces concentrations sufficiently for pass rating.

TABLE 14

ESTIMATED CONDENSER
SENSIBLE AND LATENT HEAT LOADS
(THREE BED OPERATION)

	Bed Half Way Through Absorption		
1)	Latent load	8.6 BTU/min	
2)	Sensible load	4.5 BTU/min	
3)	Total load		13.1 BTU/min
	Bed Just Starting to Absorb		
4)	Latent load	83.3 BTU/min	
5)	Sensible load	20.3 BTU/min	
6)	Total peak load		103.6 BTU/min
7)	Total latent load	91.9 BTU/min	
8)	Total sensible load	24.8 BTU/min	
9)	Total load		116.8 BTU/min

Effluent gas temperature = 193°F

H_2O evaporation rate = .093 lbs/min

The capacity of the heat exchanger was estimated as follows:

Cold Side

Hot flow path length (L_{hot}) = 6.5 in.
Cold flow path length (L_{cold}) = 4.2 in.

Fin height = 0.075 inches
18 fins per inch
Thickness = 0.002 in. stainless steel serrated, 11 layers

Primary plate area = 4.70 ft^2
Secondary fin area = 6.28 ft^2

$$D_{HYD} = \frac{4 \cdot A \text{ (flow area)}}{W.P. \text{ (wetted perimeter)}} \quad \frac{4 \cdot 5.4 \text{ in.}^2}{351 \text{ in.}} = 0.0615 \text{ in.} = 0.00511 \text{ ft.}$$

The hA_C is calculated as follows:

$$\dot{W}_{coolanol\ 35} = 10\ lbs/_{min} \times 60\ min/_{hr} = 600\ lbs/_{hr}.$$

$$A_{flow\ area} = \text{No of layers} \times \text{Fin height} \times L_{hot}$$
$$= 11 \times 0.075 \times 6.5$$
$$= 5.4\ in.^2 \text{ or } 0.0375\ ft^2$$

$$G = \frac{\dot{W}}{A} \quad \frac{600}{0.0375} = 16000\ lbs/_{hr\text{-}ft^2}$$

$$\text{Reynolds number} = R_e = \frac{G\ D_{HYD}}{\mu_{coolanol\ 35}}$$

$$= \frac{16000\ \frac{lbs}{hr\text{-}ft^2} \times 0.0051\ ft}{40\ \frac{lbs}{ft\text{-}hr}}$$

$$= 2.0$$

$$\text{Prandle number} = P_r = \frac{C_p\ \mu}{K}$$

$$= \frac{.45 \times 40}{.07}$$

$$= 257$$

$$\frac{R_e\ P_r\ D_{HYD} \times 10^{-2}}{\frac{L_{cold}}{12}} = \frac{2.0 \times 257 \times 0.0051 \times 10^{-2}}{\frac{4.22}{12}} = 0.073$$

From figure 8-12 in "Principles of Heat Transfer" [3]

$$\text{the } N_u \text{ (Nusselt's number)} = \frac{h\, D_{HYD}}{K} = 5$$

$$\therefore\ h = \frac{N_u\, K}{D_{HYD}}$$

$$= \frac{5 \times 0.07}{.0051}$$

$$= 68.5$$

$$A_{cold} = A_{prim.} + A_{sec.} = 4.7 + 6.3 = 11.0\ ft^2$$

$$\therefore\ hA_C = 68.5 \times 11$$

$$= 750\ BTU/_{hr\text{-}^\circ F} \text{ or } 12.5\ BTU/_{min.\text{-}^\circ F}$$

Hot Side
Fin height = 0.25 in.
12 fins per in.
Thickness = 0.002 in., N_i
10 layers

Primary area = 4.15 ft^2
Secondary area = 26.75 ft^2

$$D_{HYD} = \frac{4 \times A \text{ (flow area)}}{W.P. \text{ (wetted perimeter)}} = \frac{4 \times 10.5\ in.^2}{336\ in.} = 0.125 \text{ in., } 0.01 \text{ ft}$$

The hA_H is calculated as follows:

$$\dot{W}_{air} = 90\ lbs/hr.$$

$$A_{flow\ area} = \text{No. of layers} \times \text{Fin height} \times L_{cold}$$

$$= 10 \times 0.25 \times 4.2$$

$$= 10.5\ in.^2 = 0.073\ ft^2$$

$$G = \frac{\dot{W}}{A} = \frac{90}{0.073} = 1230 \frac{lbs}{hr\text{-}ft^2}$$

$$R_e = \frac{G\, D_{HYD}}{\mu}$$

$$= \frac{1230 \times 0.01}{1.2 \times 10^{-5} \times 3.6 \times 10^3}$$

$$= \frac{12.3 \times 10^2}{4.3}$$

$$= 286$$

from figure 8-2 in "Principles of Heat Transfer " [3]

$N_u = 3$

$$h = N_u \frac{K}{D_{HYD}}$$

$$= \frac{3 \times 0.016}{.01}$$

$$= 4.8 \text{ BTU/}_{hr\text{-}ft^2\text{-}°F}$$

$A_{hot} = A_{prim.} + A_{sec.} = 4.1 + 26.7 = 30.8 \text{ ft}^2$

$hA_{hot} = 4.8 \times 30.8$

$= 148 \text{ BTU/}_{hr\text{-}°F} = 2.46 \text{ BTU/}_{min.\text{-}°F}$

The overall $UA = \frac{hA_H \times hA_C}{hA_H + hA_C} = \frac{2.5 \times 12.5}{2.5 + 12.5} = 2.1 \text{ BTU/}_{min.\text{-}°F}$

$$\Delta T_{ave} = \frac{TH_{in}^{air} + TH_{out}}{2} - \frac{Tc_{in}^{coolant} - Tc_{out}}{2}$$

$$= \frac{193 + 70}{2} - \frac{38 + 63}{2}$$

$= 131 - 50$

$= 81°F$

The heat exchanger effectiveness ϵ is determined as follows:

The thermal mass of the gas $C_{min} = \dot{W} C_p = 1.5 \text{ lb/}_{min} \times 0.24 \text{ BTU/}_{lb\text{-}°F} = 0.36 \text{ BTU/}_{min.\text{-}°F}$

The thermal mass of the Coolanol $C_{max} = \dot{W} C_p = 10 \text{ lb/}_{min} \times 0.45 \text{ BTU/}_{lb.\text{-}°f} = 4.5 \text{ BTU/}_{min.\text{-}°F}$

$$\frac{C_{min}}{C_{max}} = \frac{0.36}{4.5} = 0.08$$

$$\frac{UA}{C_{min}} = \frac{2.1}{0.36} = 5.8$$

Using the $\frac{C_{min}}{C_{max}}$ and $\frac{UA}{C_{min}}$ values in figures 11-19 in "Principles of Heat Transfer" [3], the Effectiveness is = 0.96.

The heat exchanger capacity = $Q = UA\ \Delta T_{ave}$
$= 2.1 \times 81 \times 0.96$
$= 163\ BTU/_{min.}$

A comparison of the heat exchanger capacity Q = 163 BTU/min. and the condenser heat load for the worst case Q = 116.8 BTU/min. indicated that the MOL unit was adequate for the Amine CO_2 Concentrator three bed operation.

Water accumulator.- The water accumulator is an aluminum cylindrical tank of welded construction. The water make-up inlet and feed water outlet ports are located in an integral bottom mounting flange. The top cover is sealed by a flat rubber gasket and provides connections for the installation of the low, high and limit level switches and fittings for the condenser drain, the water trap drain, the canister drain system, and the reference pressure. When the low level switch is actuated, an inlet water supply solenoid valve is automatically opened and the water level is raised until the high level switch is actuated (1.9 lbs of water) which then automatically closes the inlet water supply valve. A counter mounted on the display and control panel registers the number of accumulator fillings. If the high level switch should become inoperative, the water level would continue to rise until the limit-level switch was actuated. At this time, a warning light or buzzer would be actuated to reveal the problem to the system monitor at which point the water level would have to be manually controlled.

It was assumed that the loss of water through the condenser and in the collected CO_2 (est. 0.01 lbs/hr) would be from 0.2 to 0.47 lbs of water/hr. Based on this assumption, the amount of water between the low and high level switches was set at 1.9 lbs so that a reservoir fill would occur at each 4 to 10 hour period.

Water filter.- An automotive gas line filter consisting of a housing, a glass bowl and filter element was inserted upstream of the water pump to remove any particulate material that might be entrained in the water.

Water pump.- An all polypropylene bellows type metering pump was selected to supply water to the boilers. The bellows (one inch in diameter) with hypalon poppet valves functions as a positive displacement pump. Since there are no running contact surfaces, the pump can run dry and handle any contaminants that might be present in the water supply. The pump is self-priming except at very low pumping rates. The pump is driven by a 115 Vac fan cooled motor with a gear box and needle bearing output shaft that turns at 7-1/2 RPM. The maximum discharge pressure is 10 PSIG and the maximum flow capacity is 10.0 lbs/hr. The pumping rate is selected by changing the crank throw.

Boilers.- The boilers were sized by determining the steam and fluid flow rates. It was assumed that only the bed material and canister would be heated and that the solenoid valves and insulation would remain at ambient. The total thermal mass is:

Three resin beds (5.45 lbs of dry IR-45 each) in one hour - 20 min.
3 cycles/hr x 5.45 lbs x 0.26 BTU/lb-°F (spec. heat)= 4.25.BTU/hr-°F

The water remaining in the beds after absorption (residual water)
3 cycles/hr x 5.45 lbs x 0.12 $\frac{\text{lbs } H_2O}{\text{lbs of bed}}$ x
1 BTU/lb-°F = 1.96 BTU/hr-°F

Three canisters at 23.2 lbs each
3 cycles/hr x 23.2 x 0.21 BTU/lb-°F (spec. heat) = 14.60 BTU/hr-°F

Total Thermal Mass = 20.81 BTU/hr-°F

It was assumed that the desorption begins at 96°F and ends at 200°F for a ΔT of 104°F, therefore, the heat required in one hour is:

$$Q_{req'd} = 20.81 \text{ BTU/hr-°F} \times 104°F = 2160 \text{ BTU/hr (36 BTU/min)}$$

Additional heat is needed to reheat the steam condensate which results throughout the desorption cycle until steam temperature is reached throughout the bed. This is compensated for by using a $\frac{\Delta T}{2}$ when determining the steam available sensible heat.

The heat capacity of the steam ($Q_{avail.}$) is equal to the latent heat of condensation (q_l) plus the sensible heat of the condensed water (q_s) at a ΔT_{AVE} which is equal to 1/2 the temperature drop from 200°F to 96°F.

therefore: $Q_l = \dot{W}_{steam} \times h_{fg}$
where $\dot{W}_{steam}$ = steam flow in lbs/hr.
h_{fg} = 978 BTU/lb at 200°F and saturated (Keenan and Keyes steam tables) [4]

and $\dot{Q}_s = \dot{W}_{steam} \times C_{pH2O} \times \Delta T_{ave}$
where $\dot{W}_{steam}$ = steam flow in lbs/hr.
$C_{pH_2O} = 1$ = specific of water
$\Delta T_{ave} = \frac{200-96}{2} = 52°F$

For cyclic equilibrium Qavail = Qreq'd; using this relationship the steam flow was determined as follows:

$$Q_{req'd} = Q_{avail} = q_l + q_s = \dot{W}_{steam} \times h_{fg} + \dot{W}_{steam} \times C_{pH2O} \times \Delta T_{ave}$$
$$= \dot{W}_{steam} (h_{fg} + C_{pH2O} \times T_{ave})$$
$$\therefore \dot{W}_{steam} = \frac{Q_{req'd}}{(h_{fg} + C_{pH2O} \times \Delta T}$$
$$= \frac{2160}{(978 + 1 \times 52}$$
$$= \frac{2160}{1030}$$
$$= 2.1 \text{ lbs/hr}$$

For this approximation the requirements for absorbing the CO_2 and the heat lost to ambient were ignored.

The boiler feedwater temperature was assumed to be 70°F. The quantity of heat needed to raise 2.1 lbs/hr of water from 70°F to 200°F and then boil it is:

$Q_B = \dot{w}$ (h_g at 200°F - h_f at 70°F)
= 2.1 (1146 - 38)
= 2.1 (1108)
= 2330 BTU/hr

Assuming a 2°F drop in heating fluid temperature, the fluid flow requirement to heat the boiler feed water as above is:

$$\dot{W}_{hot\ fluid} = \frac{Q_B}{C_p\ \Delta T\ Coolanol}$$
$$= \frac{2330 \text{ BTU/hr}}{0.45 \text{ BTU/lb °F} \times 2°F}$$
$$= 2580 \text{ lbs/hr (43 lbs/min)}$$

Using the above requirements, two straight line inner fin liquid to liquid heat exchangers (1.125" in dia. - 30" long) were selected. The two

units were mounted side by side in a vertical position and connected in series to insure the production of superheated steam. The boilers are of copper construction, nickel plated and silver brazed for improved heat transfer.

Flow sensing mechanism. - Previous development tests at MSA showed that the effluent flow rate increased sharply as the CO_2 began to be expelled from the canister during desorption. A flowmeter was utilized to indicate this transition point. The flowmeter consisted of a laminar flow restriction utilized to produce a differential pressure that is proportional to the gas flow. A variable reluctance differential pressure transducer, (0 to 10 inches of H_2O) was used to sense the delta pressure and a transistorized carrier-demodulator to produce a proportional DC voltage (0 to 5 volts). A controller was provided to reposition the CO_2 diverter solenoid valve (flow to CO_2 collection tank) depending upon the generated voltage. The actuation voltage value is pre-selected with the panel voltmeter set pointers based on trial and error results. A time delay was incorporated in the electrical control circuitry to make this sensing mechanism inoperative during the initial five minutes of each desorb cycle to prevent switching from occurring due to the cycling of canister valves.

Steam temperature sensing mechanism. - An unshielded copper constantan thermocouple (reference junction 250°F) was inserted in the canister steam outlet line to sense the effluent temperature. The amplified thermocouple milli-volt signal is sensed by a temperature controller utilized in the electrical control circuitry. A decrease in the milli-volt signal to a pre-selected value repositions the CO_2 diverter valve and opens a second solenoid valve to provide a steam flow path to the outlet condensor.

Diverter valves. - Three-way continuous duty solenoid valves were selected to divert the flow of gas and steam on a cyclic basis. The stainless steel body contains metal seats, a 0.375 inch diameter orifice and ports with 0.5 inch pipe threads. The solenoid enclosure is explosion proof and water tight. The C_v flow factor, as defined in the vendor's catalog, of 1 was found to be compatible with the system gas and steam flows. The valve operates on 115V, 60 CPS power; the inrush current is 1.8 amps and the holding current is 0.38 amps.

Water trap. - A water trap was needed in the CO_2 collection system between the CO_2 diverter solenoid valve and the back pressure regulating valve to remove any free water prior to entering the diaphragm pumps and the CO_2 collection tank. In the unit selected, the phase separation and liquid ejection are accomplished by means of two controlled-porosity ceramic elements, one liquid repellant (hydrophobic) and the other liquid permeable and gas-impervious when wet (hydrophilic) located in a cast bronze housing. The saturated gas entering the unit, passes over the upper element which allows the gas to pass through. Droplets coalesce on the surface of the element due to the non-wetting action of the liquid on this

particular material. The liquid drops fall to the bottom and pass through the liquid permeable (wettable) element without entrapped gas. The liquid permeable element, being constructed of micro-porous porcelain, with pores less than 1 micron in diameter, and constantly wet by wick action (initially primed with water) constitutes an air seal up to the rated limit of wicking pressure (gas inlet pressure 14.5 + .5 psia, water outlet pressure 7 psia min.). Ports with 0.25 inch pipe threads are provided for a water drain to the accumulator. The inlet line from the CO_2 diverter valve to the trap was formed in 1 foot long flat coils and wrapped around the condenser inlet coolant line (insulated) to promote condensation of any water vapor in the CO_2 and its subsequent removal in the trap.

Back pressure regulating valve. - A back pressure regulator valve was utilized in the CO_2 collection line upstream of the compressor to control the steam pressure to between 10 to 15 psia as desired to prevent reduction of pressure in the desorbing canister during the CO_2 collection process. The valve selected is a spring opposed diaphragm operated pneumatic back pressure regulator. All components with the exception of the diaphragm and pintle seat are made of Type 316 molybdenum stabilized stainless steel; the diaphragm and pintle seat are teflon impregnated fiberglass. This combination of materials offers the required resistance to corrosion. An adjusting screw and lock nut are provided for setting the desired desorb system operating pressure. The valve is capable of handling the flow (0.17 CFM of CO_2), pressure (inlet 10 to 15 psia, outlet 1 to 2 psia) and temperature (220°F max.) requirements.

Diaphragm compressor. - The compressor selected was a twin-head vacuum/pressure diaphragm compressor, parallel connected with V-belt coupled to a 1/6 horsepower explosion-proof motor and switch and with the compressor and motor mounted on a common base. The compressor housing construction is cast aluminum and the diaphragm material is a nylon reinforced neoprene. The motor is designed for 115V/60 CPS power and rotates at 1725 RPM; the compressor speed is 2280 RPM. The unit is capable of pumping 0.7 lbs/hr of the desorbed gas (98% CO_2, 2% H_2O) at 20 psid min. above an inlet pressure of 7-12 psia. Check valves with a cracking pressure of 1 psi are provided in the pump outlet line to prevent backflow of the collected CO_2. Manual operated needle valves are placed in the bypass and inlet lines to equalize the inlet and outlet pressure when starting and for isolation purposes.

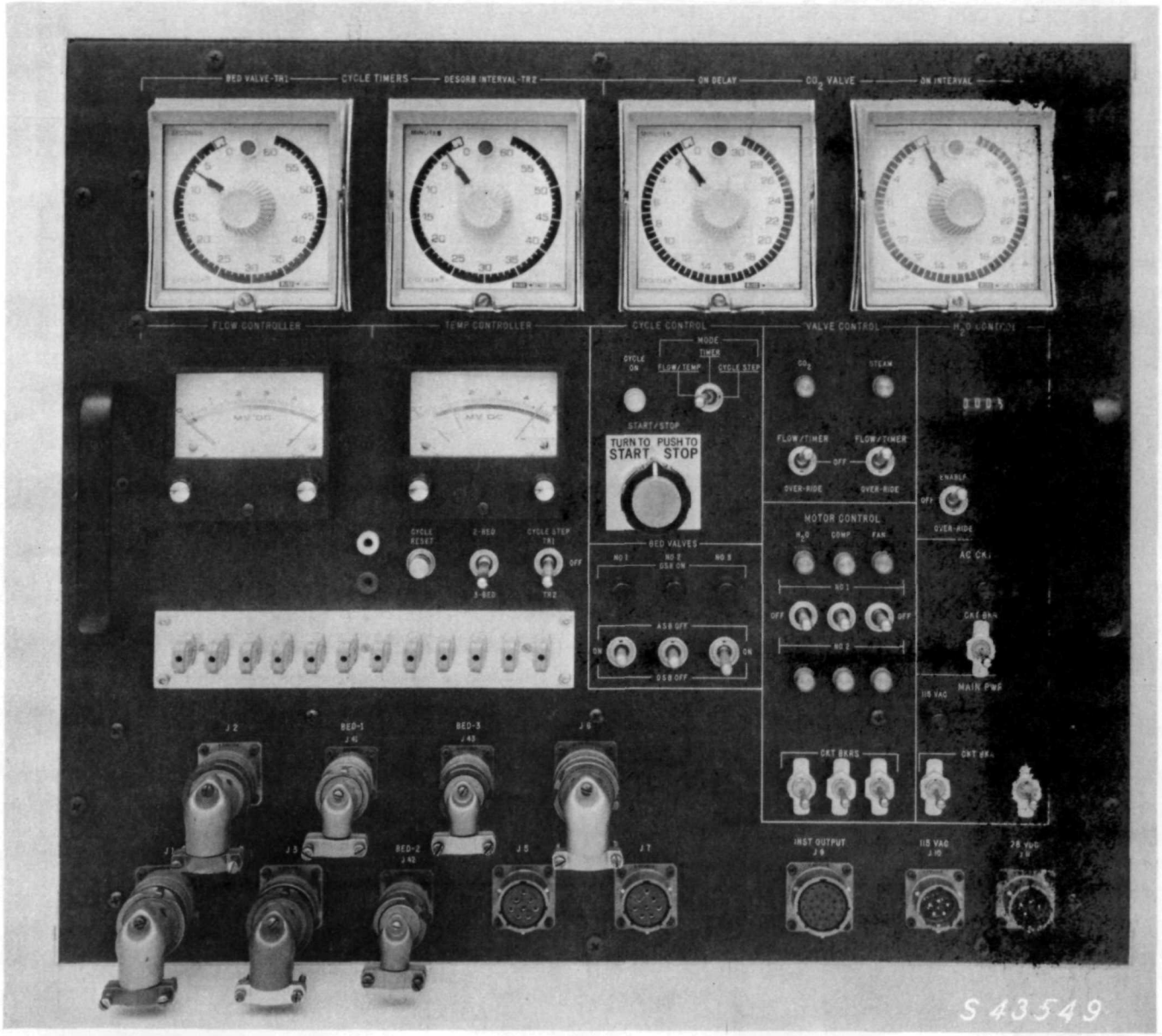
Storage tank (compressed gas). - A storage tank was needed to store cabin simulator gas at 105 + 5 psig for actuation of the canister valves. A carbon steel bottle previously utilized for storing Freon 22 was used for this application. The tank contains a blowout pressure disc that is designed to rupture at 300 psig; the burst pressure is 450 psig. Calculations showed the tank volume to be more than adequate since the amount of gas needed for one rotary valve actuation (once every 15 or 20 minutes) lowered the tank pressure by approximately 10 psi. The compressed gas supply equipment with

the necessary pressure limiting controls was provided by the test facility.

Component redundancy. - Since the life expectancy of the commercially manufactured components was either marginal, or not specified, two circulating fans, water pumps and diaphragm compressors were incorporated in the package to ensure continued operation of these functionally important items.

Frame. - The frame design utilized aluminum floor grating to provide structural support and mounting facilities for the component parts. The frame with all hardware installed forms a package that is 48" long x 48" high x 27" wide as dictated by the available installation envelope in the manned test space simulator. Shelves, a canister lower support bar and a vertical center section are provided for assembly of the component items with bracket, bolt and nut combinations that utilize the grating construction for clamping. An interface panel with identified port openings is supplied to consolidate all external gas and fluid connections.

Electrical display and controls. - The electrical controls were designed to provide automatic or manual operation of the unit and to incorporate adequate flexibility to ensure acceptable performance during the 90 day test period. The circuit breakers, relays, controllers, etc. together with the electrical circuitry are housed in a metal enclosure measuring 20 5/8" long x 17 3/4" high x 12" wide. The panel display is shown in figure 43. Controls on the panel include timers, Flow and Temperature Control Meters, Start-Stop Switch, the power, bed and instrumentation connectors thermocouple jack, accumulator water fill counter, and the toggle switch and indication light groupings labeled to describe each function. A "motor start" push button switch was added to the panel (not shown in figure 43) to bypass the fan, water pump and compressor overload circuit breakers when depressed to facilitate energizing the units under initial peak starting loads. The controls provide for either 2 or 3 bed operation with three control modes. The flow/temperature mode, most often used, automatically sequences the canister rotary valves on a time basis and utilizes the flow and temperature control mechanisms to position the CO_2 and steam diverter valves. A five minute delay at the beginning of each desorb cycle was added to prevent premature opening of the CO_2 valve due to transient flow fluctuations. The timer mode of operation was provided as back-up for use in case of a flow and/or temperature control malfunction. The preset CO_2 valve "on delay" and "on interval" timers then automatically control the CO_2 and steam diverter valve sequential timing. If the two control modes just described are inoperative the unit can still be operated manually by operating the "cycle step" switch (between TR_1 & TR_2) to time the cycles and by sequencing the CO_2 and steam diverter valves at the proper time by manually moving the valve control CO_2 and steam valve switches between the "off" and "override" positions. An additional safety feature provides an interlock between the water pump and the compressor that will shut down the pump if a malfunction occurred to make the compressor inoperative to prevent over-wetting of the beds.



ELECTRICAL CONTROL BOX PANEL DISPLAY

FIGURE 43

Instrumentation. - Copper-constantan thermocouples were located in the system for continuous monitoring of critical temperatures (T_1 to T_7, T_9, T_{15}, T_{16} and T_{17}). Variable reluctance differential pressure transducers were used to measure the ΔP across the circulating fan (P_7 = 0 to 2 psi), and the canister desorb outlet pressures (P_1 = 0 to 10 psi).

Materials selection. - Although few guidelines were specified regarding the quality and safety requirements of the system, an effort was made to select component materials that would be acceptable to the NASA COMAT and the manned test contractor document "Test Plan and Procedures, Operation 90 Day Test of a Regenerative Life Support System, Section 6.3.1, Selection of Materials and Supplies." [5] However, the short schedule, together with limited funding dictated the purchase of commercial hardware which often time contained materials that were not compatible with the above referenced documents. A materials list (see Appendix B) was prepared to comply with the manned test contractor request to give each material identity, the weight and the justification for use.

The following hardware fire safety criteria and materials compatibility rules were utilized in the selection of materials:

1) The solenoid valves, compressors and fans are explosion proof.

2) All electrically operated hardware is provided with circuit breaker overload protection.

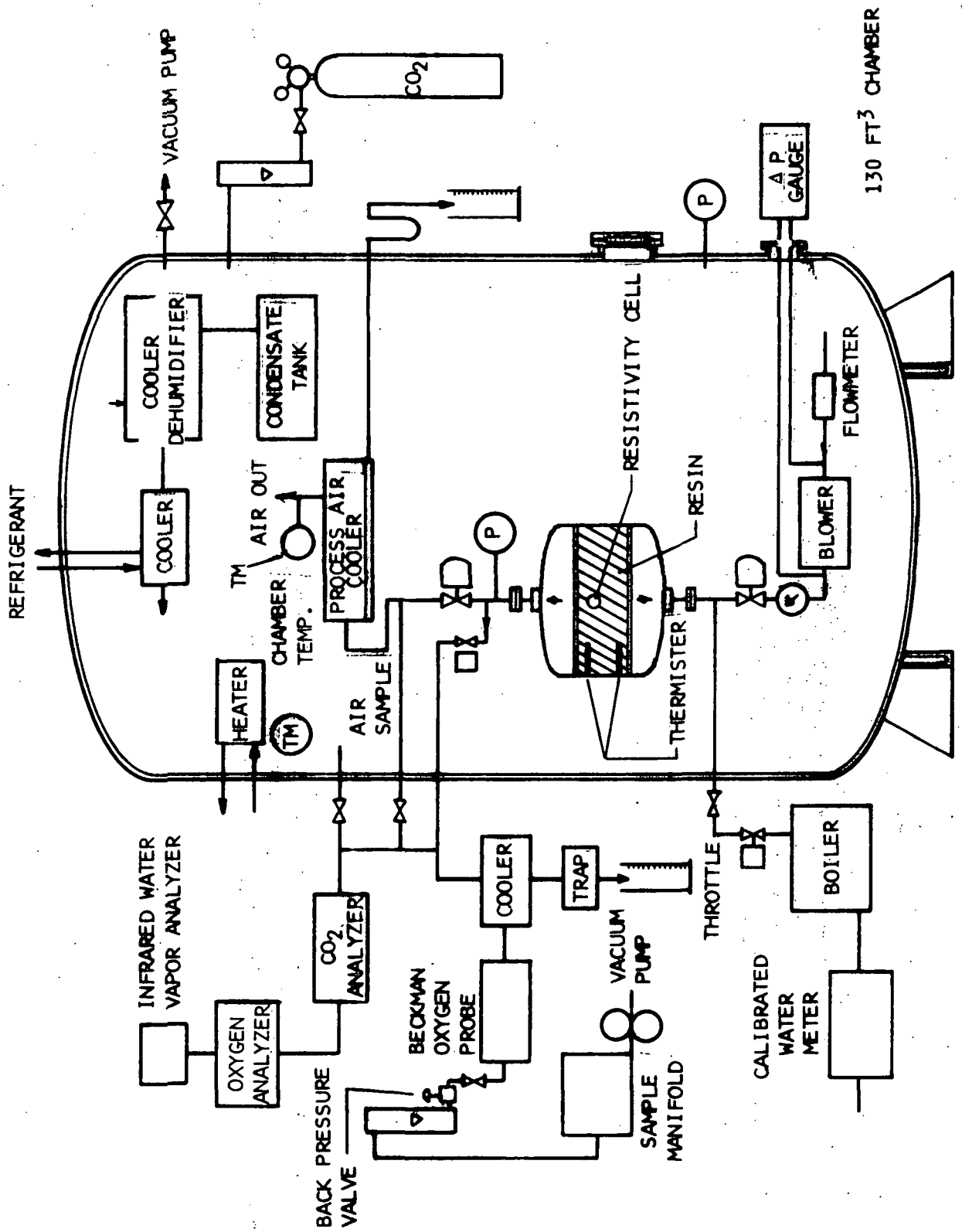
3) Hardware containing painted exterior surfaces are spaced in the package such that flame propagation between components is prevented.

4) The electrical components (switches, relays, timers, etc.) constructed of many different types of non-metallic materials are contained in a vented metal box. The electrical control box assembly together with all electrically operated hardware were subjected to an outgassing test in a 130°F oven for three days.

Acceptability of the Amine CO_2 Concentrator system was based on the contaminant removal capability of the test cabin atmosphere control system; the outgassing rates and test procedure of NASA Document D-NA-0002 were used as a guide.

Feasibility Tests

Design data testing at MSA.- A modified MOL canister (see figure 41) was delivered to MSC Research Corporation for testing to determine the amount of IR-45 material to pack in the canister, the gas flow, the steam flow (boiler feed water flow), the cycle time, the need for a 2 or 3 bed operation and other operational parameters needed to collect an adequate amount of CO_2 for the support of a four man system.



MINE SAFETY APPLIANCE RESEARCH CORP. (MSA) TEST FACILITY SCHEMATIC

FIGURE 44

The canister was packed with 5.45 lbs of dry IR-45 material leaving the necessary void volume for swelling when wet (approximately 1% increase in volume for every 1% of water loading. The material volume after desorption (wet) was calculated to approximate the canister free volume so that material particles would be packed very lightly against the canister walls and the retaining screens. This wet condition increases the canister pressure drop with a resulting drop in gas flow (CFM) during the initial few minutes of the subsequent absorb cycle.

The packed canister was installed in the MSA space chamber facility as shown in figure 44. This facility is capable of supplying a gas stream at the desired P_{CO_2}, dewpoint and inlet temperature for absorption and the required steam flow for desorption. Instrumentation is provided to measure actual temperatures and pressures, inlet and outlet P_{CO_2}, gas and liquid flows, and inlet and outlet dewpoint.

The initial series of tests simulating a two bed operation with an absorption gas flow of 20 CFM, a P_{CO_2} of 4 mmHg and a system pressure of 7 psia achieved at CO_2 removal rate up to 0.408 lbs/hr but cyclic equilibrium could not be sustained. The 30 minute absorption time was not sufficient to dry the bed to its original water loading level, therefore, the bed would flood after the completion of 3 or 4 cycles. An increase in the absorption time with the same flow rate provided additional evaporative drying of the bed but the CO_2 absorption rate was so low at the 30 minute time period that the CO_2 yield decreased below the required 0.375 lbs/hr. Increasing the flow rate was unacceptable because the increased velocity would interfere with the absorption reaction and the canister pressure drop would have exceeded the circulating fan capability. Lowering the flow rate with a corresponding increase in cycle time lowered the CO_2 yield below the required amount.

A second series of tests simulating a three bed operation achieved an equivalent CO_2 removal rate of 0.405 lbs/hr along with a cycle equilibrium in the bed water loading. Typical absorption and desorption curves are shown in figures 45 and 46. The desorption curves show the sharp flowrate increase that occurs when the ullage flow ends and the CO_2 emission begins.

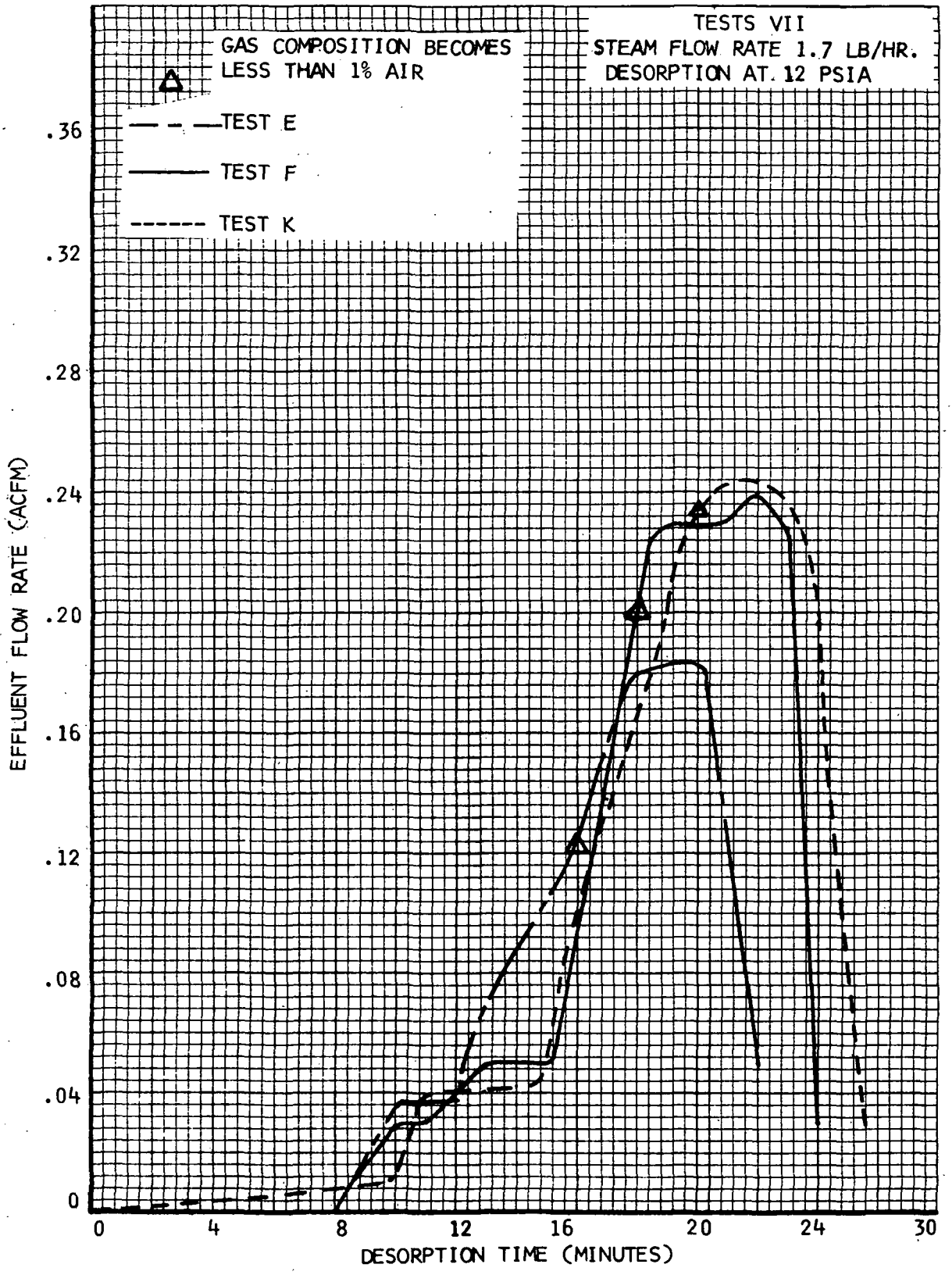
An analytical study of test data accumulated during these feasibility tests at MSA produced the following conclusions:

1) A two MOL canister cyclic operation did initially remove the CO_2 production of four men; however, the water balance was such that flooding of the beds occurred after 3 or 4 cycles.

2) A steady state operation with three MOL canisters is feasible but marginal in capacity primarily due to inherent control limitations of the system. The cyclic bed water loading control for 3 bed operation is extremely critical. Balanced flow between 2 absorping beds is

TYPICAL ABSORPTION CURVES AT 7 PSIA
TEST VII K
IN
OUT
CO_2 PARTIAL PRESSURE (mmHg)
4.0
3.0
2.0
1.0
0
5
10
15
20
25
30
35
40
45
ABSORPTION TIME (MINUTES)
0
10
20
30
FLOW RATE @ 85°F (ACFM)

FIGURE 45



TYPICAL DESORPTION CURVES

FIGURE 46

essential but is not practical without positive flow control during the phase in which one bed is very moist and the other bed is considerably drier. In any case, 3 bed operation is not a very practical system concept.

Fabrication, Development and Acceptance

Unit Fabrication

Government Furnished Equipment (GFE) from the cancelled MOL ECS Program and a LM heat exchanger were utilized in the system design upon being transferred to this program. Selected parts were procured and hardware such as the frame, heat exchanger headers, water accumulator, tube adapters, mounting brackets, etc. were designed and fabricated. The modified MOL canisters and the system heat exchangers were encased with a closed pore foam insualtion and then covered with an adhesive and aluminum foil to protect the insulation against possible external fire.

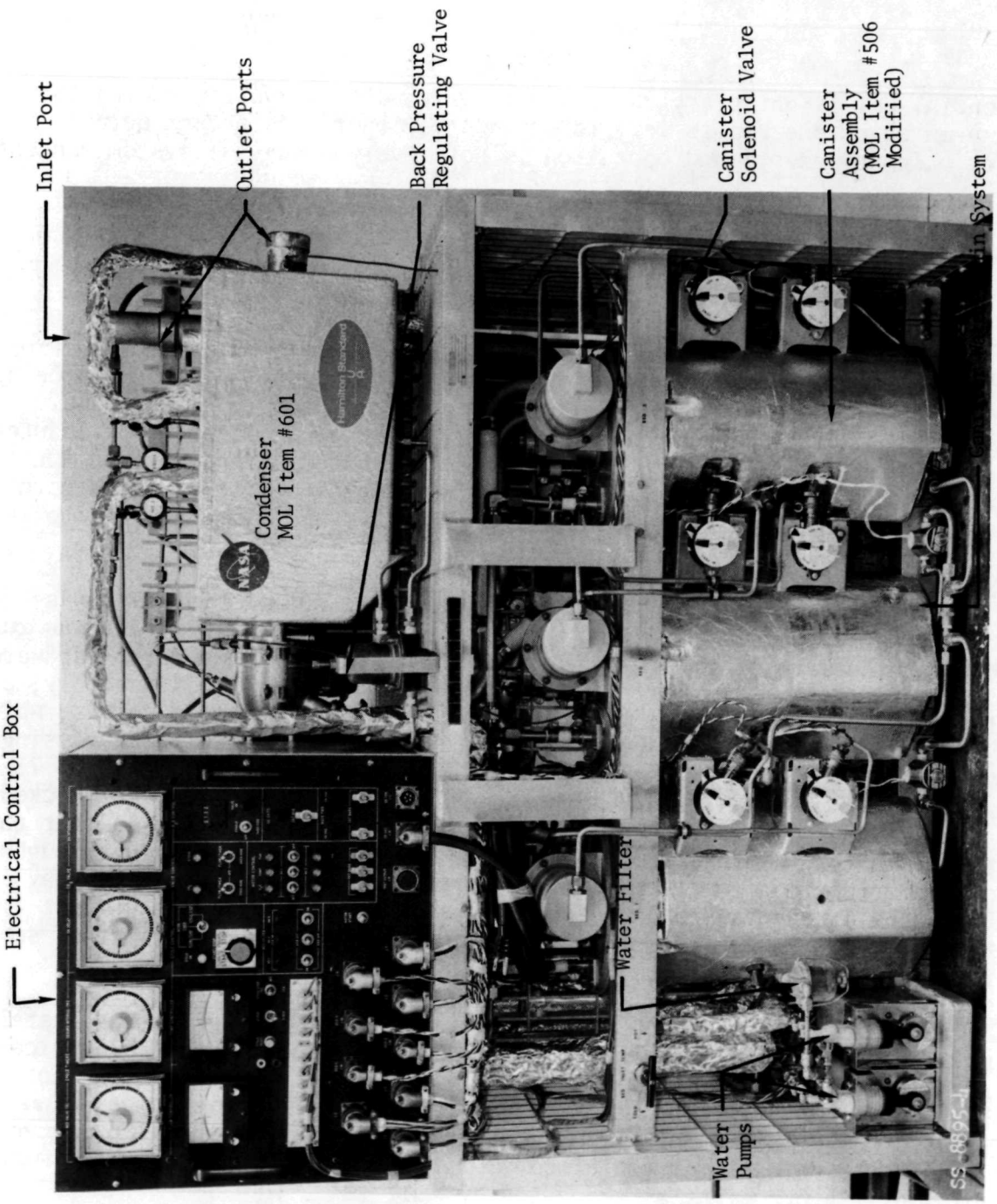
Prior to assembling the unit, a non-metallic out-gassing test was mutually agreed upon by Hamilton Standard and NASA/LRC. This test was run to determine the rate of offgassing of organics and CO. Commercial hardware including the entire display panel and electrical control box assembly, circulating fans, compressors, water pumps and diverter solenoid valves, which contained non-metallic materials that did not meet spacecraft out-gassing criteria, were placed in a chamber and baked at 130°F for a period of 72 hours at atmospheric pressure. The atmosphere had initially been checked as a baseline. Gas samples were taken daily. The test disclosed that the total organics (reference to Pentane) off-gassing rate decreased throughout the 72 hour period from 18 ppm/day average the first day to 7.5 ppm/day average the second day to 5 ppm/day average the third day. CO was not detectable with the instrument available, although the lower limit of sensitivity was higher than the accepted threshold limit value for CO.

The components were mounted, the hard and soft tubing fit and installed with the selected fittings and clamps, the instrumentation and electrical wiring was run to the electrical control box connectors and certain hot and cold tubes were insulated with silicon fibrous material with an aluminum foil covering. This Amine CO_2 Concentration assembly is shown in figures 47 and 48. Each canister contained 7.65 lbs. of IR-45 material at a water loading of 15% by weight as processed by MSA.

Development Testing

The Amine CO_2 Concentrator unit was connected to the test facility (see figure 49) forming recirculating process air loop. This rig contained an automatic control system that is capable of supplying a gas stream to the unit at a constant P_{CO_2}, dew point, pressure and temperature. A bypass loop is provided to preset operating conditions prior to directing the gas flow to the unit. An adjoining fluid temperature control

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

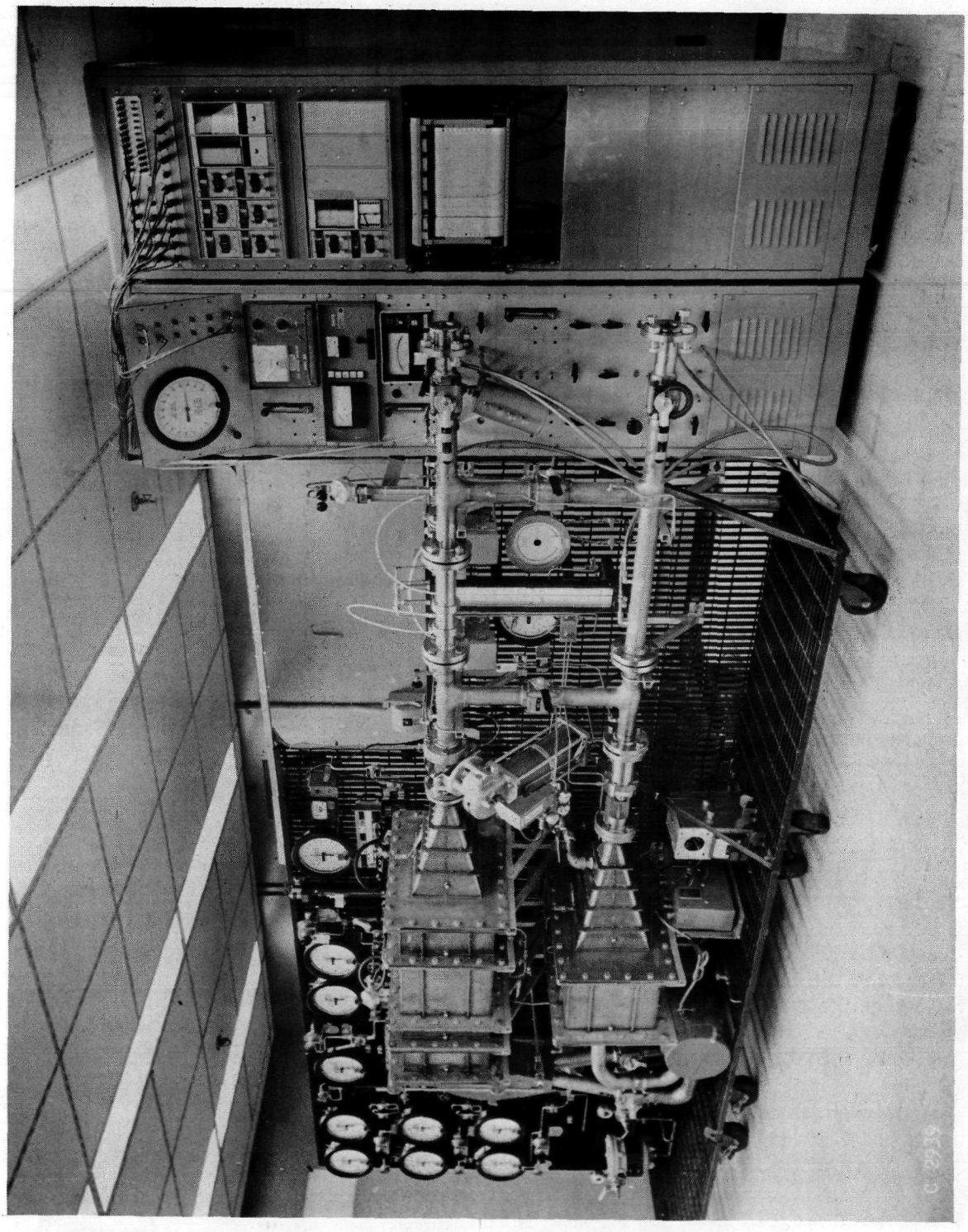


AMINE CO_2 CONCENTRATOR
(FRONT VIEW)

FIGURE 47

AMINE CO_2 CONCENTRATOR (REAR VIEW)

FIGURE 48



RIG 88 MULTI-PURPOSE TEST RIG FACILITY

FIGURE 49

cart supplies fluid (70% glycol and 30% water) to the condenser, heat exchanger and boiler at specified temperatures and calculated equivalent flows that were compatible with the Coolanol 35 fluid to be used in the manned test. An Instrumentation Chart (table 15) summarizes the parameters to be measured, the range, method and the visual readout and accuracy. Calibration curves for the Lira CO_2 analyzers and flowmeters, together with the thermocouple recorder positions and a plot of recorder scale readings versus temperature (^oF) appear in Appendices C to F.

The testing was conducted in accordance with a test plan as presented in Appendix G. The initial checkout tests were run to ensure proper operation of the component parts, the sensing mechanisms and the electrical control system, and also to establish operational procedures and conditions for the acceptance test phase to follow. The three canister operating conditions initially set were essentially the same as those previously stated in the MSA feasibility test conclusions; however, until the unit operating characteristics became more familiar, it was decided to follow a conservative approach and extend the cycle time from 40 minutes absorb - 20 minutes desorb to 60 minutes absorb - 30 minutes desorb to prevent excessive wetting of the beds. The boiler feed water rate was also gradually increased from 2.2 lbs/hr to 4.0 lbs/hr in order to set the opening of the steam valve prior to the termination of each desorb cycle to prevent dumping excessive amounts of desorbed CO_2 back to the system outlet port. The CO_2 yield when utilizing the 60 minute absorb - 30 minute desorb, a CO_2 inlet partial pressure to 4 mm Hg, a system operating pressure of 10 psia, a canister gas inlet temperature of 83^oF, an inlet dew point of 38 - 44^oF, and a boiler feed water rate of 3.5 lbs/hr was 0.40 lbs of CO_2/hr (9.6 lbs/day) which is adequate to support a 4 man system.

A periodic monitoring of the CO_2 outlet concentration showed that breakthrough was occurring well before the termination of each desorb period, therefore, indicating that the absorption time could be shortened. A revised cycle time that decreased the absorption time to 50 minutes with a corresponding desorption time of 25 minutes and an increased boiler feed water rate of 4 lbs/hr produced a CO_2 yield of 0.48 lbs/hr (11.5 lbs/day). The temperature profiles are shown in figure 50. The test log sheets together with a log sheet symbol sheet are included in Appendix H; data were recorded 5 to 10 minutes after the start of each desorb cycle.

The checkout tests were instrumental in proving out the capabilities of the unit on a short duration basis and also indicated that the following system modifications had to be incorporated for more efficient operation:

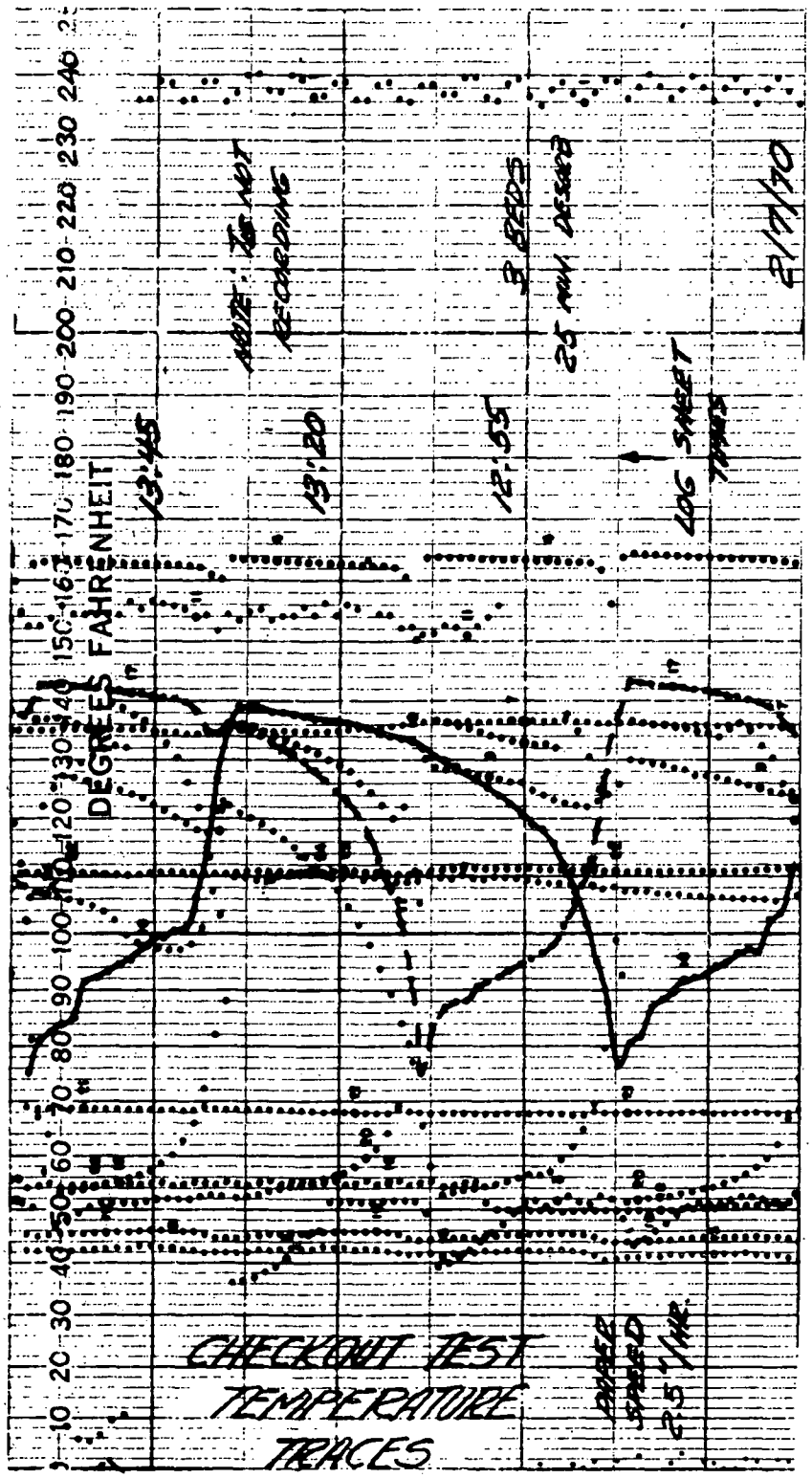
1) The replumbing of the flowmeter in a vertical position instead of horizontal to eliminate pressure transducer fluctuations due to entrapped condensed water.

TABLE 15

AMINE CO_2 CONCENTRATOR TESTS INSTRUMENTATION CHART

Ident.	Item Measured	Range	Method	Visual Readout	Accuracy
T_1	Boiler Hot Fluid-Outlet	200 to 235°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
*T_2	Boiler Hot Fluid-Inlet	200 to 235°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_3	Boiler Steam-Outlet	190 to 220°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_4	Condenser Gas-Outlet	45 to 85°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_5	Compressor Gas-Outlet	50 to 100°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_6	Condenser Adsorb Gas-Inlet	60 to 180°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_7	Heat Exchanger Gas-Outlet	50 to 130°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_9	Condenser Desorb Gas-Inlet	60 to 220°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
T_{14}	CO_2 Collection Tank	50 to 100°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
*T_{15}	Canister #1 Adsorb Gas-Outlet	60 to 200°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_{16}	Canister #2 Adsorb Gas-Outlet	60 to 200°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
*T_{17}	Canister #3 Adsorb Gas-Outlet	60 to 200°F	Copper-Constantan Thermocouple	Recorder Milli-Volt Scale	± 3°F
T_{18}	System Gas Inlet	45 to 60°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
T_{19}	Condenser Coolant-Inlet	36 to 40°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
T_{20}	Condenser Coolant-Outlet	40 to 60°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
T_{21}	Heat Exchanger Coolant-Inlet	50 to 60°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
T_{22}	Heat Exchanger Coolant-Outlet	50 to 70°F	Copper-Constantan Thermocouple	Recorder Temp. Scale	± 3°F
SPI	System Pressure-Inlet	0 - 30 psia	Ashcroft Gauge	Gauge Dial	± 0.1 psi
SPO	System Pressure-Outlet	0 - 30 psia	Ashcroft Gauge	Gauge Dial	± 0.1 psi
AP	CO_2 Accumulator Pressure	-30 to 150 psia	Ashcroft Gauge	Gauge Dial	± 0.5 psi
SIPP	System Inlet CO_2 Partial Press.	100%-2% CO_2	Lira Infrared Analyzer	Lira Meter	±3% F.S.
SOPP	System Outlet CO_2 Partial Press.	100%-2% CO_2	Lira Infrared Analyzer	Lira Meter.	±3% F.S.
APP	CO_2 Accumulator Partial Press.	100%-100% CO_2	Lira Infrared Analyzer	Lira Meter	±3% F.S.
SIDP	System Inlet Dew Point	38 to 43°F	Cambridge Dew Point Hygrometer	Meter	± 0.1°F
SODP	System Outlet Dew Point	40 to 85°F	Cambridge Dew Point Hygrometer	Meter	± 0.1°F
SIF	System Inlet Flow	26 to 30 CFM	Venturi Type Flowmeter	ΔP inches of H_2O and calib. charts	± 2% of F.S.
CCF	Condenser Coolant Flow	5 to 10 CFM	Flowrator Meter	Meter Scale	± 2% of F.S.
ACF	Air HX Coolant Flow	2 to 6 CFM	Flowrator Meter	Meter Scale	± 2% of F.S.
BCF	Boiler Coolant Flow	15 to 20 CFM	Flowrator Meter	Meter Scale	± 2% of F.S.
CO_2 Wt	Wt. of CO_2 Adsorbed	0 to 300 lbs.	Beam Scale	Scale	± 0.1 lbs.

* Unit Thermocouple



CHECKOUT TEST TEMPERATURE TRACES

FIGURE 50

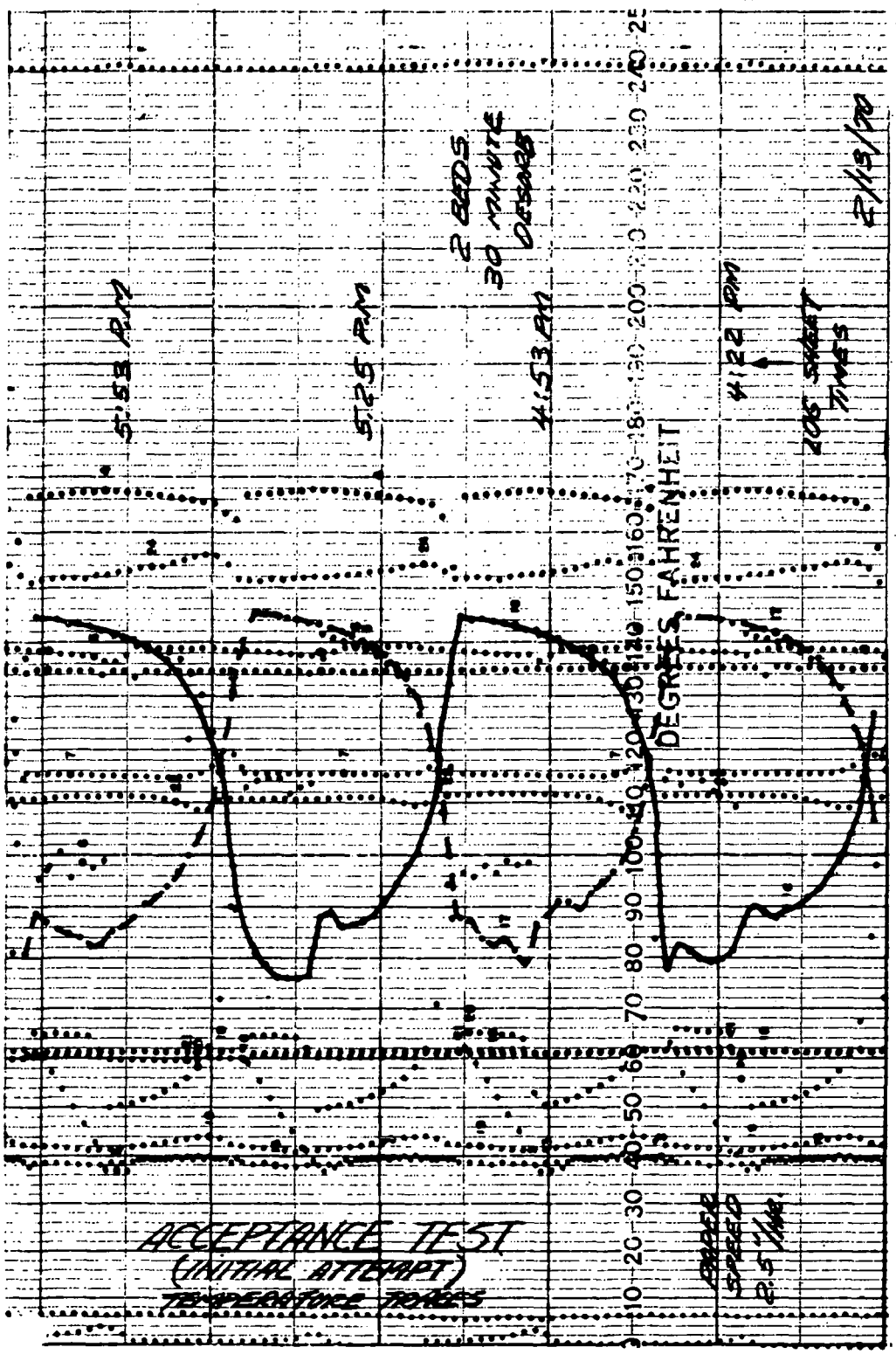
2) The lengthening of the CO_2 pumping line to form longitudinal coils that are wrapped around the condenser coolant line to trap an increased amount of condensed water thus reducing the amount of water vapor being pumped to the CO_2 accumulator.

3) The addition of a lower pressure ratio hydrophilic element in the water trap to increase the capability for the passage of condensed water to the water accumulator.

4) The addition of a five minute time delay in the electrical control system to cut out the flowmeter transducer element at the beginning of each desorb period to prevent the premature actuation of the CO_2 diverter valve.

Acceptance Test

Initial attempt. - The acceptance test phase was initiated utilizing the 50 minute absorb - 25 minute desorb operating conditions that produced acceptable performance during the checkout tests. During 20 desorb cycles (8.3 hours) the CO_2 yield averaged out at 0.40 lbs/hr; however, the purity had settled out to 85% due to excessive system leakage caused by the existing ΔP between the ambient and the system operating pressure (10 psia). Since this condition would not exist in the space simulator operation, it was decided to operate the unit at 14.7 psia to investigate the CO_2 purity capabilities. During the following 6 hours, the CO_2 purity increased to 95% but the CO_2 yield dropped from 0.40 lbs/hr to 0.24 lbs/hr. The deterioration in bed #1 become so extensive that the flow controller with a scale pointer setting of 1.0 would not actuate the CO_2 valve. The unit was then run for the next 12 hours utilizing the built-in timers to 1) actuate the CO_2 valve 15 minutes into each desorb cycle to direct the desorbed CO_2 flow to the collection system, 2) hold the valve in this position for 7 minutes, and 3) at that point simultaneously reposition the CO_2 valve and open the steam valve to direct the steam flow to the condenser. Although the unit operated satisfactorily on the timer mode, it did nothing to improve the CO_2 yield. However, the CO_2 purity was raised from 95 to 98% by proper sequencing of the CO_2 valve thus eliminating the flow of canister ullage to the CO_2 accumulator. The unit was then returned to the Flow/Temp. mode of operation and the drain plug on each canister was loosened one at a time while on absorb to check for condensed water accumulation. The amounts of water collected were: canister #1 - 1000 ML, canister #2 - 275 ml and canister #3 - 275 ml. During the next 29 hour period, carrier gas was passed periodically through canisters #1 and #2 to try and regenerate the beds, accumulated condensed water was drained periodically from each canister, and the effects of changes in the canister gas inlet temperature (95 to 117°F) on performance were investigated. None of these attempts were successful in returning the CO_2 yield to the original 0.40 lbs/hr; however, the purity in the majority of cycles ranged from 98 to 100%. Since beds #1 and #2 could not be regenerated and bed #1 was producing the lowest yield/cycle, it was decided to run a two canister operation (#2 and #3) utilizing 30 minute desorb. Ten hours of



ACCEPTANCE TEST (INITIAL ATTEMPT) TEMPERATURE TRACES

FIGURE 51

running under these conditions revealed that the automatic two canister operation performed as designed, that the CO_2 yield was 0.20 lbs/hr, and that the CO_2 purity was 99% (temperature traces - figure 51). The desorb cycle time was then reduced to 21 minutes and the flow controller meter pointer setting was reduced from 1.5 MV to 1.0 MV. These conditions produced a CO_2 yield of 0.14 lbs/hr at a pruity of 99%. Changing the canister gas inlet temperature in steps within the range of 80°F to 110°F made no appreciable difference in the CO_2 yield/hr.

During the acceptance testing, some difficulties were encountered with some of the commerical hardware. The back pressure regulating valve that was inoperative periodically was found to be improperly assembled and had to be repaired. One of the circulating fans that was noisy (fan hitting end cover) and would not reach operating speed was found to be improperly shimmed and had to be repaired by the vendor. Interference between the compressor head and the eccentric rocker arm due to improper clearances was found to be responsible for the heavy knocking noise in one of the diaphragm compressor units. The head was properly relieved to eliminate this condition.

Hamilton Standard personnel and representatives from MSA, MDAC and NASA/LRC who monitored the checkout and acceptance tests jointly concluded: 1) that the continuous testing operation should be terminated since the desired CO_2 yield could not be sustained over an extended period of time; 2) that the unit in general performed satisfactorily from a mechanical and electrical standpoint, except for the minor difficulties experienced with commercial hardware, that inadequate knowledge on the very critical water balance control of the IR-45 material prevented the attainment of the desired performance objectives; 3) that the unit at this time due to performance difficulties was not acceptable for the 90 day simulator experiment; and 4) that a short development program should be immediately initiated to investigate the bed water balance control problem.

Bed water balance investigation. - The development program was initiated by investigating the rate of CO_2 removal with time during the absorption phase for each canister. The curve profiles resembled one another with the highest rate of removal occurring after 10 minutes into the absorption process. An examination of the areas under the curves showed that bed #3 absorbed the greatest amount of CO_2, that bed #2 absorbed a slightly less amount and that bed #1 absorption capacity was very poor as was experienced during the previous tests.

The next item to be investigated was to determine the amount of condensed water that is collected in the bottom of each canister during its particular desorption cycle. On a two canister (#1 and #2) operation basis (25 min. desorb), the average amount of water collected each time in bed #1 was 338 ml, and in bed #2 was 229 ml. When operating with three beds (25 min. desorb), the average amount of water collected was: bed #1 - 340 ml, bed #2 - 308 ml, and bed #3 - 292 ml.

A review of the CO_2 absorption rate data previously taken indicated that breakthrough might still be occurring during the 50-minute absorption cycle; therefore, it was thought worthwhile to operate the unit with a 40-minute absorption time and a corresponding 20-minute desorb cycle. It was also thought at this time that the mass of the bed was large enough to supply enough heat after desorption to adequately evaporate water from the bed during the absorption cycle and that a high canister gas inlet temperature (105-117°F) was unnecessary. It was decided to investigate system performance utilizing the 20-minute desorption cycle through a range of canister inlet gas temperatures (45°F to 60°F). A tabulation of the results follows:

No. of Canisters	Desorb Cycle Time (min.)	Length of Operation (Hours)	Canister Gas Inlet Temp. (°F)	CO_2 Yield (lbs/hr)	CO_2 Yield (lbs/day)	Purity (%)
3	20	13	50	0.45	10.8	97
3	20	8	45	0.45	10.8	97
3	20	8	60	0.45-0.40	10.8-9.8	97
2	20	4	50	0.45-0.33	10.4-7.9	95

Since it is difficult to evaluate the merits of a particular set of operating conditions with just a few cycles, it was decided to try the second attempt at running an acceptance test utilizing the 20-minute desorb cycle (40 min. absorption) and a 50°F canister gas inlet temperature.

Second attempt. - Prior to the initiation of the second acceptance test cycling, an automatic canister drain system was installed to transfer the collected condensed water back to the water accumulator. Each canister was provided with the same type of hydrophilic element that is used in the water trap. The positive ΔP (1 psi) during the absorption process forces the collected water through the elements of the canisters on absorb and back to the water accumulator.

In 22 hours of operation, the CO_2 yield gradually decreased from 9.5 lbs/day to 8.3 lbs/day. The purity ranged from 97 to 99%. The remaining ten hours of the already aborted acceptance attempt was run using a 16-minute desorb cycle (32 minute absorption time). The CO_2 yield dropped to 6.5 lbs/day with a decrease to 6.0 lbs/hr during the final 10 hours of testing.

The development test program was continued to further investigate the cyclic wetting and drying characteristics of the IR-45 material. During the next 111 hours of testing, beds were dried out when an examination of operational data showed them to be wet, two and three bed operation was repeated, and the canister gas inlet temperature T_7 was varied from 50° to

120°F to try and establish a cyclic bed water loading equilibrium condition. Stable operation of the unit was never sustained for more than 10 to 15 hours before a gradual deterioration of one or two beds would decrease the CO_2 yield. An oxygen analyzer added to the test set-up to determine the level of O_2 in the CO_2 accumulator was in agreement with the gas sampling Lira CO_2 purity readings. During this test period, steam was observed to be escaping from the canister #1 side bleed hole located over an electrical connector that had been previously sealed off with a patch. This problem necessitated the removal of the canister from the unit and the dumping of the IR-45 material to repair the patch located on the inner canister wall.

The IR-45 material removed from canister #1 was extremely wet as predicted by the very poor bed performance and was found pressed against the top fine mesh retaining screen; the inner patch was found to be loosened. The patch had been previously formed to fit over a bulge on the canister inner surface, caused by the installation of the electrical connector at assembly, and the remaining patch surface area was inadequate to properly bond the patch to the canister wall. The repair was completed utilizing a larger patch and the canister was filled with only 6.5 lbs of new IR-45 material as received from MSA (15% water loading by weight) to provide a greater void volume for material expansion when wet. The hydrophilic elements in the drain system were examined and found to be coated with a white film which was later identified by laboratory tests as aluminum oxide; some condensed water was found in the canisters indicating that the drain system was not 100% effective. The elements were cleaned and reinstalled. Prior to reassembly of the canister #1 on the frame, a test was set-up to determine the approximate water loading with time when passing steam through the bed. The canister assembly was mounted on a scale and provisions were made to direct steam flow from the concentrator generating system to the canister. Valving provided in the steam outlet line allowed the canister to be pressurized to 3.5 ± 3/4 psi above the ambient pressure. Prior to starting the test, 500 ml of water was added to the bottom of the canister to prime the hydrophilic element; however, it still took approximately 15 minutes before water drainage occurred. The boiler water feed rate was 6.74 lbs/hr. The rate of water absorption during the steam purge vs. time is shown in figure 52.

Canister #1 was positioned in place on the frame and the wet bed material (after desorb test) was dried by utilizing a drying process which consisted of purging the bed with system gas at 120°F until the particular canister gas outlet temperature trace (in this case T_{15}) was within 15°F of the gas inlet temperature trace (T_7). At this time, it was believed that the bed water loading could not be controlled to produce a state of operational equilibrium for an extended period to time and that periodic changes to the gas inlet temperature must be made to produce cyclic wetting and drying of the beds. Since the last operational data indicated that the beds were wet, it was decided to run with a gas inlet temperature of 95°F to dry out the beds and at some convenient time, as indicated by the canister outlet gas temperature traces, lower the gas inlet temperature to initiate the wetting and drying cyclic mode of operation. After 15 hours of operation, the restricted flow condition through canister #1 while on absorb that had previously been

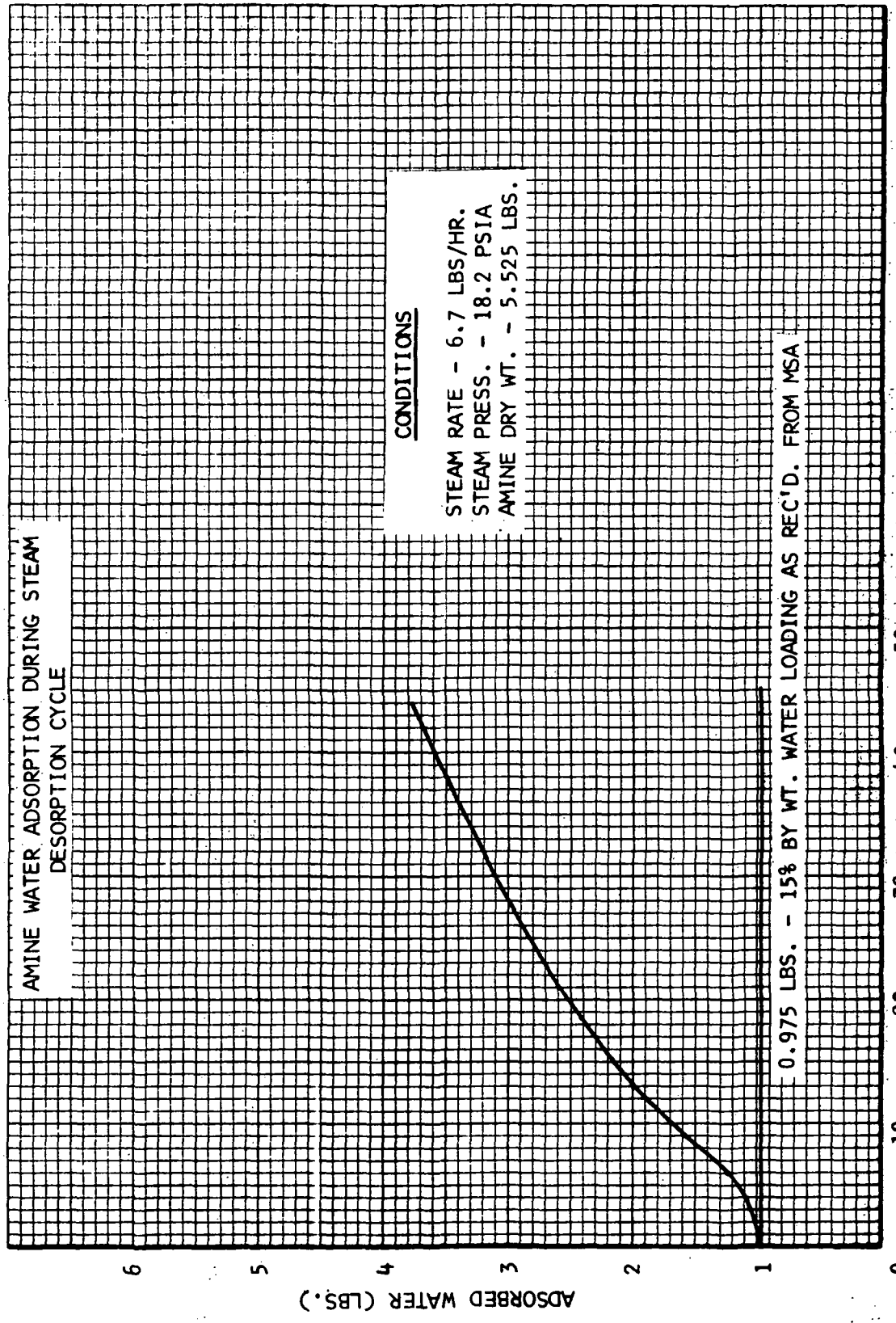

AMINE WATER ADSORPTION DURING STEAM DESORPTION CYCLE
CONDITIONS
STEAM RATE - 6.7 LBS/HR.
STEAM PRESS. - 18.2 PSIA
AMINE DRY WT. - 5.525 LBS.
0.975 LBS. - 15% BY WT. WATER LOADING AS REC'D. FROM MSA
ADSORBED WATER (LBS.)
0
1
2
3
4
5
6
TIME (MINUTES)
10
20
30
40
50

FIGURE 52

observed in each of the three beds recurred. Changes made to the gas inlet temperature setting and the boiler water feed rate had very little effect on the situation. It was thought that possibly the wet material in bed #1 had again expanded up against the fine retaining screen thus providing a flow restriction, so another 0.577 lbs of IR-45 material was removed through a canister side bleed hole during the absorb cycle. No improvement in the periodic flow restriction problem was observed. A further study of the fan inlet pressure trace (P_7) showed that the elimination of the flow restriction was a step change like the opening of a valve rather than the gradual change that would be expected when a wet bed was being regenerated by evaporative drying. Throughout this development test period, there were two main items of concern:

1) The condensed water accumulation in the canisters and its effect on the control of the bed water loading; and

2) The possibility of the fine mesh retaining screens providing some type of flow restriction.

A review of previously run heat exchanger screen test data showed that a 400 x 400 mesh screen loaded with water could produce a pressure drop of 30 inches of H_2O which, of course, is approximately equal to the maximum pumping head of the system circulating fan. These facts were instrumental in rendering a decision to remove all 3 canisters from the unit to replace the 400 x 400 mesh retaining screens with 80 x 80 mesh screening and to replace the hydrophilic element drain system with a positive separate solenoid valve type. The valve on the canister just beginning absorb would be actuated and timed for one minute (valve opened) by the TR1 Bed Valve Timer. The incoming gas flow would force the collected water out of the canister and back to the water accumulator.

Third attempt. - With the rework complete, a third acceptance test attempt was initiated. The set-up conditions are shown in table 16.

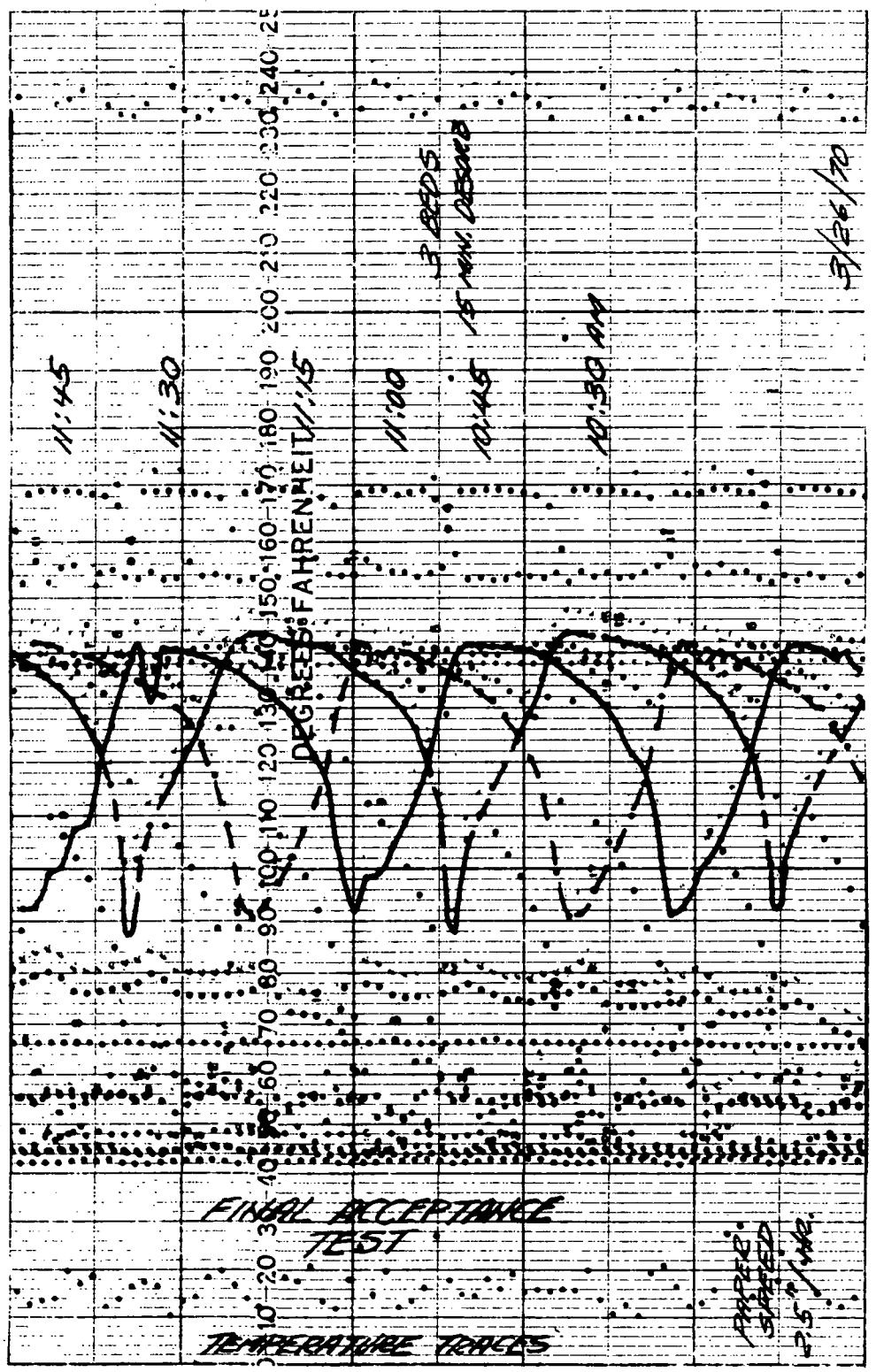
The unit continued to operate without further adjustments for 3 days (72 hours) and for the first time a continuous cyclic bed water loading equilibrium was realized. The average yield of CO_2 per day by the CO_2 bottle scale readings was 9.72 lbs/day and by the CO_2 accumulator ΔP readings was 9.42 lbs/day. The CO_2 purity was 94 to 95%; however, previous tests at 14.7 psia, where the positive ΔP across the unit is eliminated, showed that the unit was capable of supplying 98% pure CO_2. The temperature traces for this operation are shown in figure 53. The absorption and desorption profiles are presented in figure 54 and 55. It will be noticed that during absorption the significant CO_2 sorption for each bed occurs during the first 10 minutes; also, that during desorb most of the CO_2 is purged off the bed between the ninth and the twelfth minute time period.

The effectiveness of the new solenoid valve drain system was evaluated by placing a hand on the canister drain tube that was just ready to start the absorb cycle. When the Bed Valve TR1 Timer was acutated, the solenoid

TABLE 16

FINAL ACCEPTANCE TEST SETUP CONDITIONS

Canister inlet dew point, °F	38 - 42
Canister gas inlet P_{CO_2}, mmHg	4
Canister gas inlet flow, CFM	26
Canister gas inlet temperature, °F (T_7)	80
Compressed N_2 pressure (for valve actuation), psig	100
Absorb cycle time, minutes	30
Desorb cycle time, minutes (TR1 + TR 2 timers)	15
System pressure, psia	10
Condenser water/glycol flow, lbs./min.	7.35
Condenser water/glycol temperature, °F	37
Condenser water/glycol pressure, psig	60
Heat exchanger water/glycol flow, lbs./min.	4.17
Heat exchanger water/glycol temperature, °F	56
Heat exchanger water/glycol pressure, psig	60
Boiler water/glycol flow, lbs./min.	18.2
Boiler water/glycol temperature, °F	235
Boiler water/glycol pressure, psig	60
Boiler feed water rate, lbs./hr.	6.7



ACCEPTANCE TEST (FINAL) TEMPERATURE TRACES

FIGURE 53

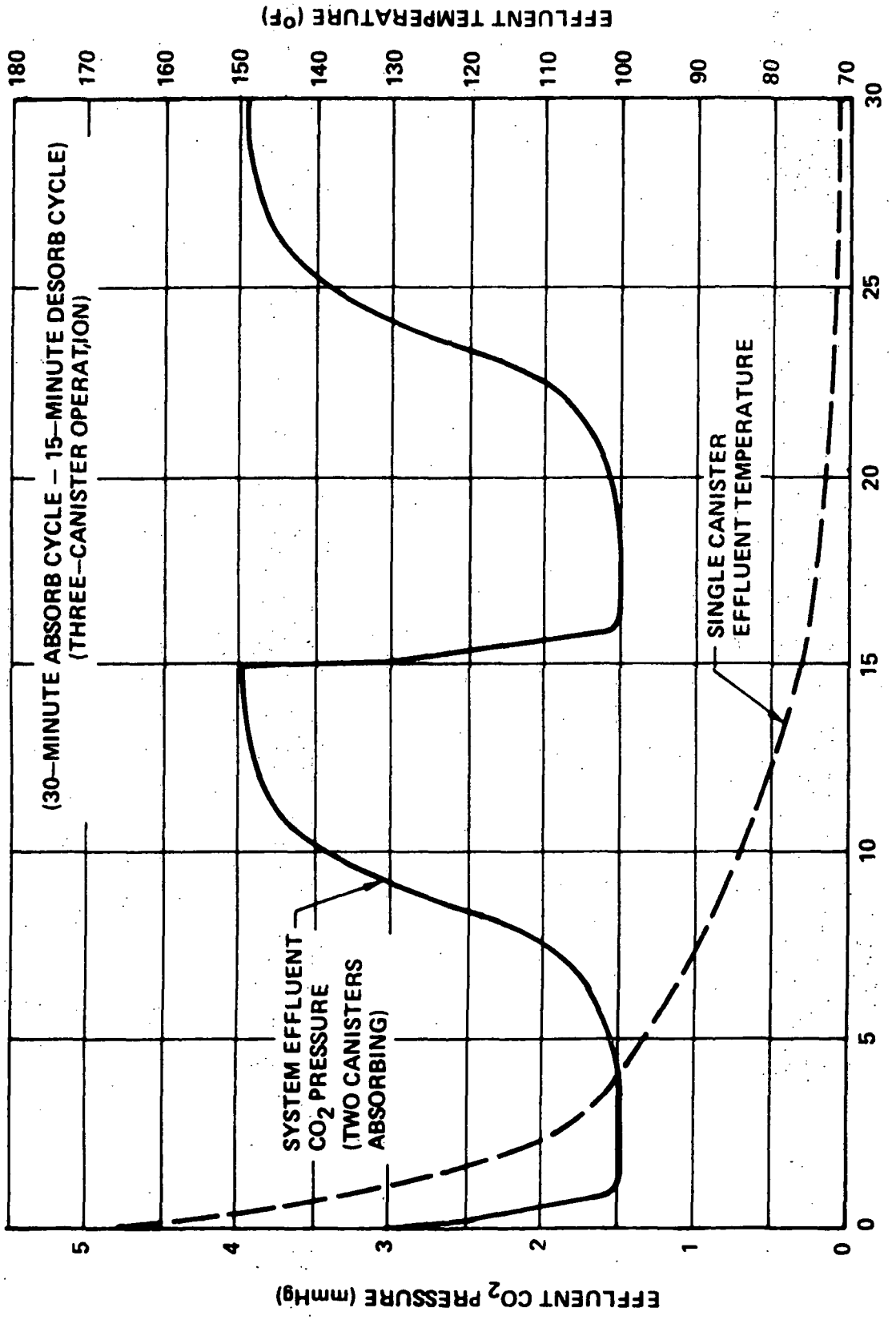

EFFLUENT TEMPERATURE (°F)
180
170
160
150
140
130
120
110
100
90
80
70
(30–MINUTE ABSORB CYCLE – 15–MINUTE DESORB CYCLE)
(THREE–CANISTER OPERATION)
SINGLE CANISTER
EFFLUENT TEMPERATURE
SYSTEM EFFLUENT
CO_2 PRESSURE
(TWO CANISTERS
ABSORBING)
30
25
20
15
10
5
0
TIME (MINUTES)
EFFLUENT CO_2 PRESSURE (mmHg)
5
4
3
2
1
0

FIGURE 54

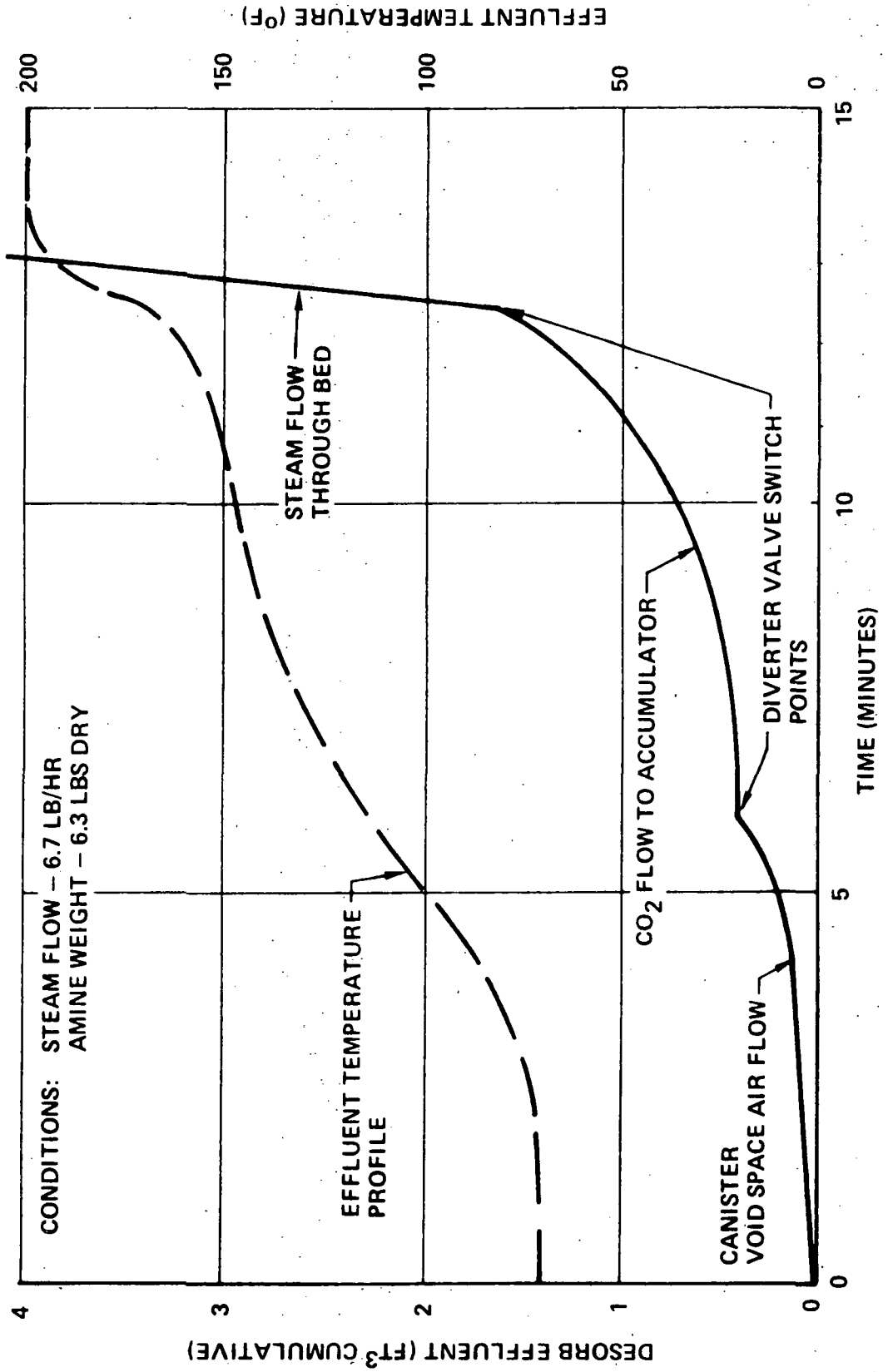

EFFLUENT TEMPERATURE (°F)
200
150
100
50
0
15
10
5
0
TIME (MINUTES)
DESORB EFFLUENT (FT³ CUMULATIVE)
4
3
2
1
0
CONDITIONS: STEAM FLOW – 6.7 LB/HR
AMINE WEIGHT – 6.3 LBS DRY
STEAM FLOW THROUGH BED
EFFLUENT TEMPERATURE PROFILE
CO_2 FLOW TO ACCUMULATOR
DIVERTER VALVE SWITCH POINTS
CANISTER VOID SPACE AIR FLOW

FIGURE 55

valve opened and the tube became very hot as the incoming gas pushed the collected water back to the water accumulator. Approximately 5 to 10 seconds before the end of the 1 minute valve open period, the drain pipe turned cool indicating that all the hot water had been purged from the canister and that absorb gas was now passing through the tube.

The unit was next run at a system pressure of 14.7 psia. For the first four hours, all other operating conditions were identical to the acceptance test; for the following eight hours, the P_{CO2} was reduced from 4 mmHg to 1 mmHg.

Results Duration (Hours)	P_{CO2} (mm of Hg)	CO_2 Yield Bottle Weights (lbs/day)	Accum. ΔP (psi)	CO_2 Purity (%)
4	4	9.84	9.42	97 - 99
8	1	5.04	4.84	99

It will be noticed that an approximate 50% reduction in the CO_2 yield (lbs/day) was associated with a 75% reduction in the P_{CO2}.

The last test conducted on the unit was a seven hour test at a system pressure of 14.7 psia with the canister gas inlet temperature set at 50°F. This change would reduce the amount of evaporative cooling during absorb with a corresponding increase in the bed water loading that would produce an increase in the CO_2 yield. A comparison of the results with previous data accumulated at an 80°F gas inlet temperature follows:

Results Duration (Hours)	P_{CO2} (mm of Hg)	Gas Inlet Temperature (°F)	CO_2 Yield Bottle Wt. (lbs/day)	Accum. ΔP (psi)	Purity (%)
7	4	50	10.46	10.15	99
4	4	80	9.84	9.42	99

Lowering the canister gas inlet temperature to 50°F increased the CO_2 collection by approximately 8%.

It should be understood that all the testing conducted on the Amine CO_2 Concentrator unit was oriented toward the attainment of acceptable performance to support a four man crew during the 90-day test experiment. Schedule and funding constraints did not permit any optimization of system performance.

The system Installation Procedures, Start-up and Shutdown Procedures, Scheduled Maintenance and Failure Mode Analysis (Trouble Shooting) documents appear in Appendices J to M.

The NASA/LRC accepted the Amine CO_2 Concentrator unit for inclusion in the 90-day space simulator tests. The unit was shipped to the McDonnell Douglas Astronautics Company (MDAC) on April 14, 1970.

Post 90-Day Test Analysis

Modification number 11 to the CO_2 Control Improvement Contract No. NAS 1-8944 authorized a Post 90-Day Test Analysis which consisted of the following parts:

1. Evaluation of the 90-day test performance.
2. Amine CO_2 Concentrator performance check-out test.
3. Unit disassembly and inspection of hardware.
4. Laboratory chemical analyses and material comparative studies.

The objective was to check for any degradation of IR-45 material and/or system performance that might have occurred during the 90-day test, the reasons for such degradations, if found, and recommendations to improve future Amine CO_2 Concentrator systems' design for manned tests.

Evaluation of 90-Day Test Performance

The Amine CO_2 Concentrator Unit was installed in place in the Space Simulator utilizing the "Installation Procedure" (Appendix J). Services such as hot and cold Coolanol 35, compressed air, water and electrical power (115 VAC and 28 VDC) were connected to the specified ports and receptacles on the interface and electrical control box panel. Thermocouple and other instrumentation extension leads were run from the control box panel connectors (J9, P9) to alrams and recorders. Also, a line was run from the "CO_2 OUT" port (interface panel) to the test facility CO_2 accumulator.

The unit was started using the 3 bed operation mode in accordance with the "start-up procedures" (see Appendix K) and was run the equivalent of one day prior to initiating the 90 day test while the space simulator operating conditions were being set.

The 90 day test started on June 13, 1970 and was terminated on September 10, 1970. The unit operated 71 days out of the 90 day duration. The average P_{CO_2} level over each 12 hour period is plotted in figure 56. During the first 11 days, the unit operated on three beds and held the P_{CO_2} level between 4 to 5 mmHg. Then, it gradually increased to an unacceptable level which necessitated a shut-down of the unit on the 14th day. Whenever the Amine system was inoperative, the backup Molecular Sieve unit was put into service. This initial shut-down was caused by a sticking problem with the bed #1 rotary valve when positioning the porting from desorb to absorb. Applying the maximum actuation gas pressure (120 psig) and lubricating the rotary valve plate did not remedy the situation, therefore, the valve had to be manually actuated every 45 minutes. The abnormal rise in cabin P_{CO_2} was caused by a disrupted bed water balance due to a lag in port sequencing when

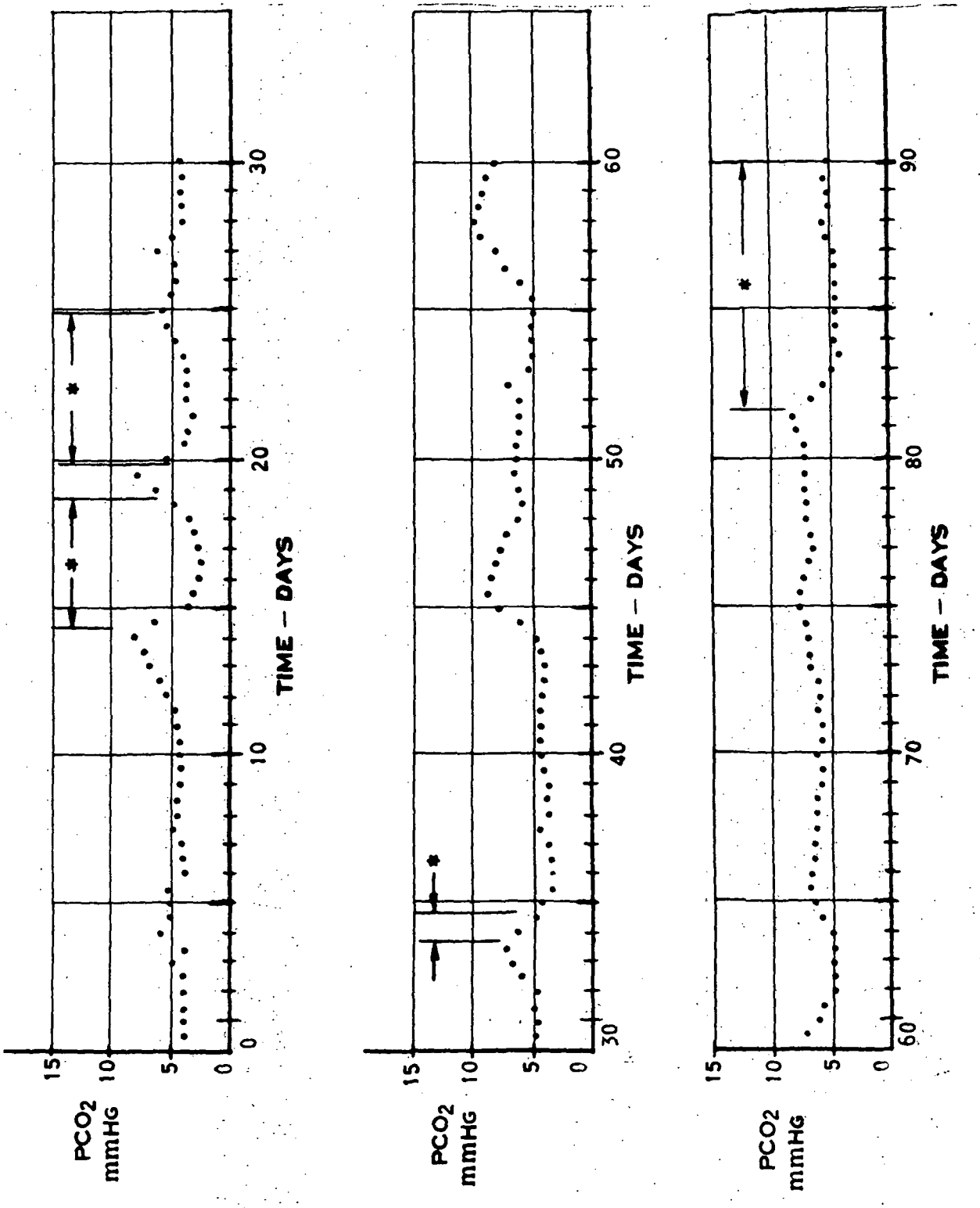

PCO2 mmHg
15
10
5
0
0
10
20
30
TIME – DAYS
*
*
PCO2 mmHg
15
10
5
0
30
40
50
60
TIME – DAYS
*
PCO2 mmHg
15
10
5
0
60
70
80
90
TIME – DAYS
*
* MOLECULAR SIEVE BACKUP USED
AMINE CO2 CONCENTRATOR 90-DAY TEST PERFORMANCE

FIGURE 56

manually actuating the bed #1 rotary valve and an excessively high inlet gas temperature that was found to be 15°F hotter than indicated.

On the 19th day, the unit was started again on a two bed operation (beds #2 and #3) using a 15 minute cycle time with a resulting rise in the P_{CO_2} after a few hours of operation which again necessitated a shut-down of Amine concentrator. At this point, it was determined that the unit thermocouple junction set point of 250°F had changed and that the recorded temperature readings were approximately 15°F lower than the actual temperatures. It was decided to run the unit at a 70°F indicated temperature (actual 85°F) to improve the cyclic bed water loading.

On the 25th day, operation of the Amine unit was resumed on a two bed operation (bed #2 and #3) utilizing a 13 minute cycle. A P_{CO_2} of between 4 to 5 mmHg was held until the 33rd day when an excessive rise occurred due to the malfunction of a hot Coolanol 35 system pump. The Amine unit was shut-down for a few hours to replace the transport fluid pump and also to install a N_2 line (109 psig) for the rotary valve actuation in place of the cabin gas compressor system that became inoperative. When restarting the unit on the 34th day, the #1 circulating fan could not be energized and a shift to the #2 fan was made. The fan malfunction was attributed to its being dead-headed when the high pressure gas supply was too low in pressure to properly reposition the rotary valves.

For the following 9 days the P_{CO_2} held between 4 and 5 mmHg. During this period, the gas inlet temperature was gradually decreased in order to increase the unit CO_2 removal rate. On the 46th day, the water loading in the beds became excessively high due to reduced evaporation during absorb at the lower gas inlet temperatures causing an unacceptable rise in the P_{CO_2} level. The water pump was de-energized and 3 cycles were run without steam desorb to dry out the beds.

For the remaining days (46 to 80), the P_{CO_2} was controlled between 5 to 8 mmHg with three peaks that approached 9 to 10 mmHg. The main problem during this time, was a plugged condenser drain line that had to be periodically purged out with pressurized N_2. This condition disrupted the bed water balance and necessitated frequent adjustments to the gas inlet temperature and steam rate to hold the P_{CO_2} at an acceptable level. Other troubles encountered were a sticking water feed solenoid valve that had to be replaced on the 73rd day and the loss of IR-45 material through a relief hole in canister #3 on the 74th day; the hole was plugged to remedy this condition.

On the 80th day, the two bed operation was changed from #2 and #3 to #1 and #2 due to a gradually increasing P_{CO_2} level thought to be caused by the loss of material (1.53 lbs) in canister #3. The unit ran for approximately 1-1/2 days and was then shut down for good due to the increasing difficulty of manually actuating the bed #1 rotary valve. The concentrated CO_2 purity throughout the test ranged between 96 to 98 percent.

A summary of the troubles encountered with the Amine CO_2 Concentrator unit during the 90-day test is tabulated in table 17. It includes the type of malfunction, the cause, and the corrective action taken. In all cases, the crew was able to take corrective action without requiring materials from outside the chamber, which stresses the importance of the attention given in the system design to redundancy and alternate modes of operation. The number of malfunctions is minimal when considering that this experimental unit was the first spacecraft type Amine CO_2 Concentrator system built, that the unit utilized modified MOL hardware that was not designed for this application and that the design, fabrication, assembly, development and acceptance testing were completed in the extremely short schedule period of eight months. This effort was instrumental in bringing a laboratory concept to the prototype manned test hardware stage.

The performance record during the 90-day test demonstrated that the Amine CO_2 Concentrator system was capable of removing adequate amounts of CO_2 to support 4 men in a closed ecological system.

Crew comments.- Comments from the inside crew were as follows:

1) Too much attention was required to operate the unit.
2) More direct readout instrumentation should have been provided to eliminate frequent referrals to the channel selector.
3) An odor from the amine material persisted throughout the test period whenever the Amine CO_2 Concentrator was in operation. Although the crew became acclimated to it, they could always notice an increase in the odor when going from the living quarters to the equipment area.

The outside crew made these additional observations:

1) The unit transferred too much heat and moisture to the cabin atmosphere.
2) The uninsulated steam lines (outlet manifold) presented a hazard as well as a heat leak.
3) The water consumption for the Amine CO_2 Concentrator was higher than expected thus overworking the water reclamation system and the humidity control system.

Effects on other subsystems.-

Sabatier Reactor/Toxin Burner Unit: The purity of the CO_2 delivered by the Amine CO_2 Concentrator was adequate and posed no detrimental effects on the Sabatier reactor or toxin burner catalyst. However, the unit did concentrate trace amounts of Freon 113 (TF) which poisoned the Sabatier reactor and toxin burner catalyst materials. The source of the Freon 113 is attributed to the cleanup following spillage of Coolanol 35 from a ruptured line during the unmanned Space System Simulator baseline test. Although the cabin was ventilated for several days prior to a repeat of the unmanned baseline

TABLE 17

AMINE CO_2 CONCENTRATOR
90-DAY TEST COMPONENT MALFUNCTIONS

Test Days	Malfunction	Cause	Corrective Action
3 to 10 & 81	Bed #1 rotary valve sticking when re-positioning porting for adsorb	Excessive friction between rotary valve plate and seals	Lubricating plate and manual operation not successful - went to two bed operation
24 & 81	Unit operating temperatures 15°F higher than the indicated readings	Unit thermocouple reference junction set point had changed	Compensated for discrepancies between actual and indicated temperatures
29,62,64, 66,67,71, 72 & 73	Water accumulator dry or overflowing	Water supply solenoid valve sticking in both the open & close positions	Cycled with panel override switch - finally replaced solenoid valve
48,58,60, 63,75,77 & 79	Condenser drain line plugged	Deposits of material in line	Periodically purging the line with pressurized N_2
60	Noise in compressor #1	Unknown	Switched to compressor #2
71	28 volts "power on" light not energized (unit running)	Burned out bulb	Replaced bulb
74 & 80	Amine material & steam leaking from hole in Bed #3	Epoxied patch loosened	Plugged hole (Amine material not replaced)
34	Fan #1 would not start	Fan-Deadheaded-due to loss of high press. air supply for repositioning rotary valves.	Switched to fan #2

test, it is believed that trace quantities remained absorbed on the simulator surfaces.

Water management: Water make-up to the Amine CO_2 Concentrator (approximately 1/4 of the water used) was much higher than expected due to the periodic plugging of the condenser drain line. This condition produced a high humidity in the inlet air to the wick evaporator (when operating) which caused periodic premature flooding of the first wicks. The high cabin humidity also imposed an extra load on the zero-g condenser/separator unit. A chemical analysis of the condenser drain water showed that trace amounts of acetone, ethyl alcohol and isopropyl alcohol were present. It is assumed that the acetone was a trace contaminant in the gas stream while the ethyl and isopropyl alcohols could have come off the beds since they are utilized in the manufacture and processing of the IR-45 material.

Thermal Conditioning Unit: The Amine CO_2 Concentrator unit dissipated excessive amounts of heat in the equipment area thus raising the temperature above the upper design level. However, the Thermal Conditioning Unit was capable of maintaining comfortable temperature levels in the living quarters throughout the test.

Amine CO_2 Concentrator Performance Check-Out Tests

The Amine CO_2 Concentrator was received at Hamilton Standard on 17 December 1970. A post 90-day test inspection was conducted to insure that all components and systems were operating as designed prior to initiating the concentrator performance check-out tests; replacement hardware was added and repairs were made where required. The results of this inspection were as follows:

1) The water supply solenoid valve was found missing. It had been removed at MDAC due to faulty operation and could not be located. The simulator crew had reported that the inside of the valve was quite corroded. A replacement valve was installed.
2) Examination of the feed water pumps showed the inside of the plastic bellows and valves to be coated with a light tan sticky material that was collected for residue sample #1. The pumps were calibrated; #1 pump produced 8.06 lbs/hr of water and #2 pump produced 6.88 lbs/hr. No leakage was found in the #1 unit as had been reported by the simulator crew. More of the residue sample #1 was also found and collected in the water filter element and bowl. A new filter element was installed.
3) The circuitry and switching operations in the electrical control box all worked as designed except for the actuation of bed #3 gas solenoid valve, used to position the rotary valve porting from absorb to desorb, that was traced to a bad relay (#23) and an inoperative temperature controller caused by corrosion of the

unshielded thermocouple junction (T_1); the sensor was replaced. The simulator crew had reported this malfunction during the last days of Amine CO_2 Concentrator operation.

4) The water accumulator limit and overfill alarm switches worked as designed.
5) The temperature reference junction set point was checked and found to be 264.2°F or 14.2°F higher than the design setting of 250°F. This condition had been previously reported by Hamilton Standard support personnel and the simulator crew.
6) The bottom drain lines for canister #1 and #3 were found plugged and were reopened by purging with high pressure N_2.
7) All unshielded canister outlet gas thermocouples (T_{15}, T_{16} and T_{17}) were inoperative and had to be replaced. The open junctions had been attacked by corrosion.
8) The loosened patch in canister #3 was repaired. This patch covered an opening originally intended for an electrical connector. Its loosening had allowed steam and IR-45 material to leak from the canister during the 90-day test.
9) Excessively high torque was required to rotate the valve on canister #1. All valves were made operative with 140 psig N_2 by coating the valve plates with silicon grease.
10) Circulating fan #1 and compressor #1 were inoperative as had been reported by the simulator crew.

The three beds were dried in accordance with the long duration storage instructions specified in the Amine CO_2 Concentrator Start-up and Shut-down Procedure (see Appendix K) to prepare the unit for the performance checkout test.

The Amine CO_2 Concentrator setup on the Multi-purpose Rig 88 for the performance checkout tests is shown in figure 57. It was identical to the acceptance test setup at Hamilton Standard prior to shipment of the unit except for a vacuum collection system attached to the condenser drain port to eliminate water carry-over due to clogging of the drain line.

A three bed operation to compare present and Hamilton Standard acceptance test performance was considered. It was turned down due to the loss of 1.53 lbs. of IR-45 material in bed #3 during the 90-day test, which would produce unequal flows during the two bed absorptions involving bed #3.

Test #1.- A two canister operation using beds #1 and #2 dried out but otherwise as received from the MDAC 90-day test was run under the following conditions:

Canister Gas Flow, CFM	20
Canister Gas Inlet Temp., °F	80 ± 3
System Total Pressure, Psia	$14.7\pm.1$
System Inlet P_{CO_2}, mmHg	$4\pm.2$

AMINE CO_2 CONCENTRATOR SETUP ON MULTI-PURPOSE RIG 88

FIGURE 57

System Inlet Dew Point, °F	38-42
System Air Mixture	Air
Feed Water Pump Flow, lbs/hr (Pump) #2	6.6
Absorb Cycle Time, min.	15
Desorb Cycle Time, min.	15
Transport Fluid (By Weight)	70% Glycol, 30% H_2O
Condenser Coolant Flow, lbs/min	8
Condenser Coolant Temp., °F	37 to 40
Condenser Coolant Press., Psig	60±1
Heat Exchanger Coolant Flow, lbs/min.	2
Heat Exchanger Coolant Temp., °F	37 to 40
Heat Exchanger Coolant Press., Psig	60±1
Boiler Fluid Flow, lbs/min	20
Boiler Fluid Temp., °F	245
Boiler Fluid Pressure, PSIG	60±1

The log sheets for test #1 and #2 together with the inlet and outlet infrared analyzer (Lira) calibrations are presented in Appendix N and P.

Results.- The two canister operation yielded the following:

Bed #1 (26 days of operation during the 90-day test):
Collected 0.07 lbs of CO_2/15 min. desorb, or an equivalent of 3.36 lbs of CO_2/day. CO_2 purity - 94%.

Bed #2 (71 days of operation during the 90-day test):
Collected 0.05 lbs of CO_2/15 min. desorb, or an equivalent of 2.40 lbs of CO_2/day. CO_2 purity - 94%.

Bed #1 had approximately 40% greater capacity for CO_2 removal than bed #2. The Performance Check-Out Test Absorption Profiles in figure 58 show that the ability of bed #2 to absorb CO_2 was for some reason greatly decreased.

Test #2.- A majority of the IR-45 material, 4.87 lbs. (dry wt.), was removed from canister #1. Difficulty was experienced in removing the last remaining material through the only available small size bleed hole in the side of the canister. An equivalent amount of new IR-45 material, as received from MSA was added. The same test procedure was repeated.

Results.- Testing with the new IR-45 yielded:

Bed #1 (80% new IR-45 material as received from MSA):
Collected 0.08 lbs of CO_2/15 min. desorb, or an equivalent of 3.84 lbs/day. CO_2 purity - 94.5%.

Bed #2 (71 days of operation during the 90-day test):
Collected 0.05 lbs of CO_2/15 min. desorb, or an equivalent of 2.40 lbs of CO_2/day. CO_2 purity - 94.5%.

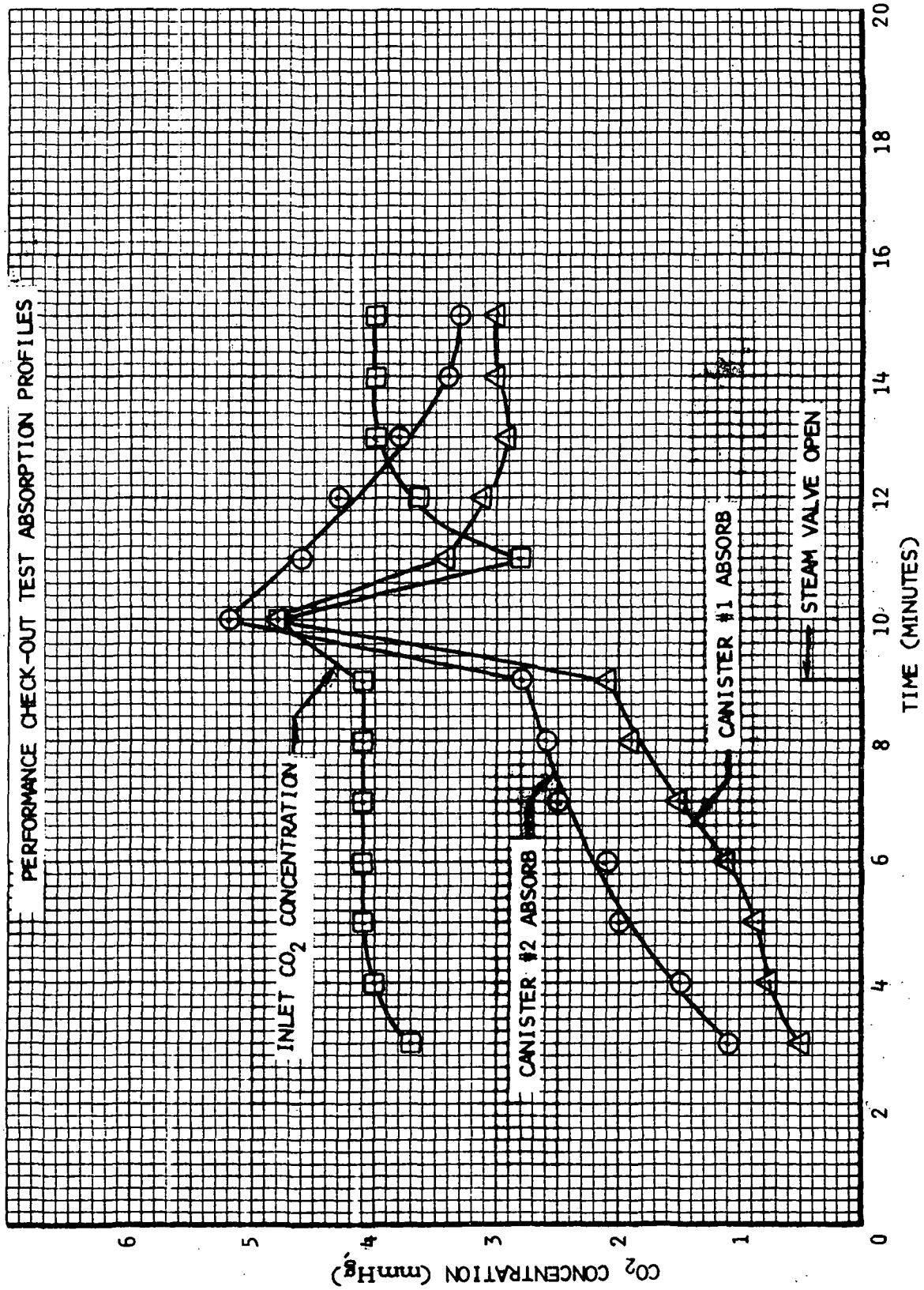

PERFORMANCE CHECK-OUT TEST ABSORPTION PROFILES
INLET CO_2 CONCENTRATION
CANISTER #2 ABSORB
CANISTER #1 ABSORB
STEAM VALVE OPEN
CO_2 CONCENTRATION (mmH_g)
TIME (MINUTES)
0
1
2
3
4
5
6
2
4
6
8
10
12
14
16
18
20

FIGURE 58

The CO_2 cclllected on bed #1 was approximately 14% greater than the collection rate of bed #1 (material as received from the 90-day test) in test #1.

Notes:

1) The CO_2 Δwts. and CO_2 collection tank ΔP's were averaged over the last eight cycles of each test. (See Log Sheets in Appendix N).
2) The CO_2 removed by actual CO_2 bottle weights and calculated by using the CO_2 collection tank volume (1.94 ft^3), Δpressure and temperature (gas law) agreed within 2% to 8%.
3) The two canister operating conditions were not optimum but adequate for the comparative performance evaluation.

Three canister operation with 6.5 lbs of new IR-45 material in each bed at Hamilton Standard prior to shipment removed 9.6 lbs of CO_2 per day. It will be noticed on log sheet #1 (Test #2), see Appendix N, that the CO_2 removal rates for bed #1 during the initial running were higher due to 15% by weight water loading of the new IR-45 material added. Rough calculations show that two cans each packed with 6.5 lbs of IR-45 material, as received from MSA, operating at a lower gas inlet temperature and a 13 minute adsorb/desorb cycle time could collect 9.6 lbs of CO_2 per day. It is believed that the reduction observed in the CO_2 removal capacity is due to material degradation with time and not with system operation.

Summary of results (performance check-out tests).-

Test #1	Bed #1	Bed #2
Quantity of dry IR-45 mat'1., lbs.	6.1	6.4
Operation during 90-day test, days	26	71
CO_2 collected during each 15 min desorb, lbs.	0.07	0.05
CO_2 bed loading $\left(\frac{\text{lbs. } CO_2/15 \text{ min. desorb}}{\text{lb. of dry IR-45}}\right)$, %	1.15	0.78
Equiv. CO_2 collected per day, lbs.	3.36	2.40
System (Beds #1 & #2) CO_2 collected per day, lbs.	5.76	
CO_2 purity, %	94	94
Comparative bed capacity	Approx. 40% greater than Bed #2	
No. of desorb cycles at HS or MDAC	882	3,962

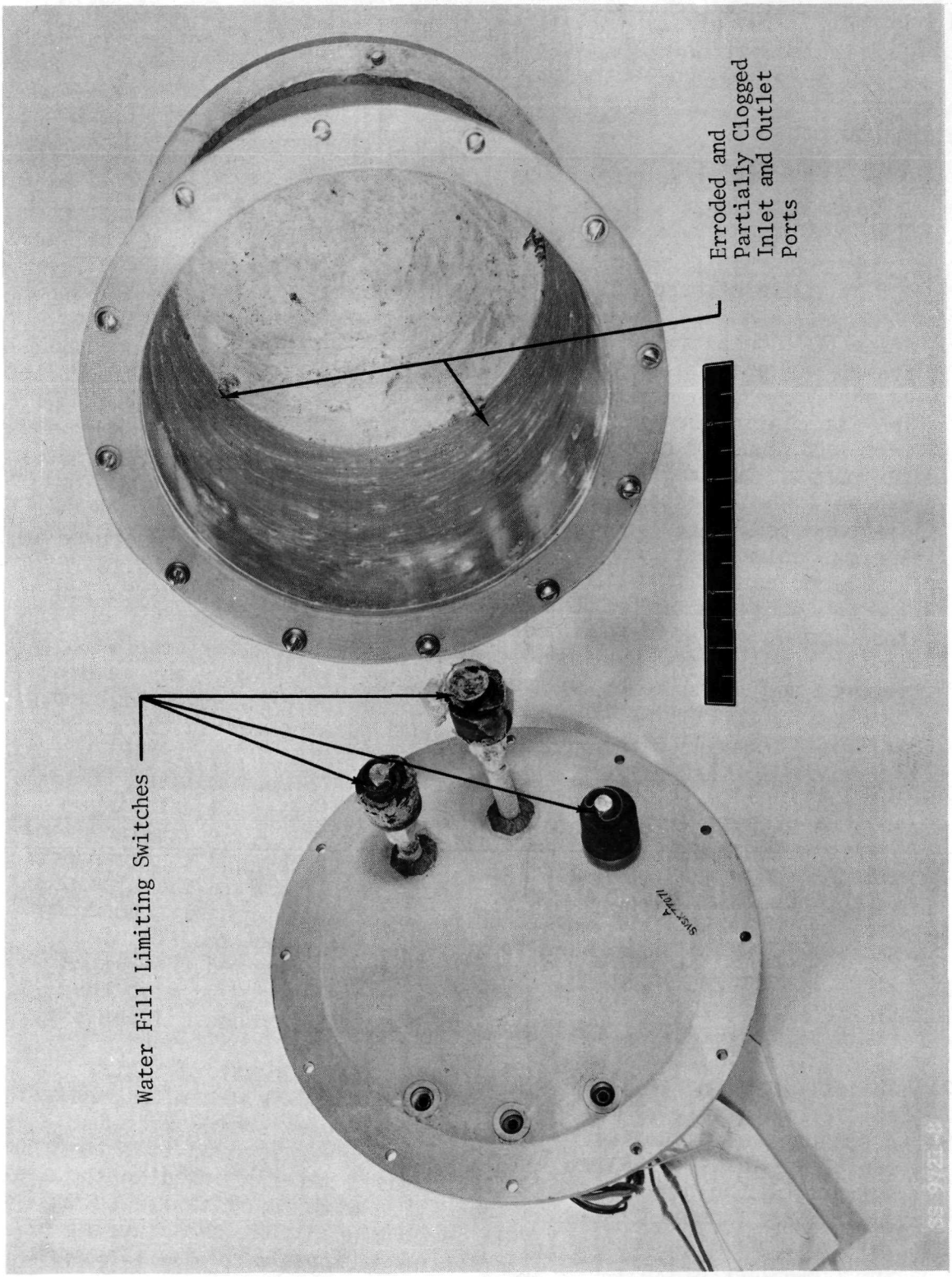
Test #2	Bed #1	Bed #2
Quantity of dry IR-45 mat'1., lbs.	6.1 80% new IR-45 mat'1.	6.4
Operation during 90-day test, days	20% mat'1.-26 80% mat'1.-0	71
CO_2 collected during each 15 min. desorb, lbs.	0.08	0.05

CO_2 bed loading $\frac{\text{lbs. } CO_2/15 \text{ min. desorb}}{\text{lb. of dry IR-45}}$	1.31		0.78
Equiv. CO_2 collected per day, lbs.	3.84		2.40
System (Beds #1 & #2) CO_2 collected per day, lbs.		6.24	
CO_2 Purity, %	94.5		94.5
Comparative bed capacity	Approx. 14% greater than Bed #1 in Test #1		Same as Test #1
No. of desorb cycles at HS & MDAC	20% mat'l.-882 80% mat'l.-0	3,962	

Unit Disassembly and Inspection of Hardware

The Amine CO_2 Concentrator components and connecting tubing were removed from the frame. Inspection of the hardware revealed the following:

1) The Circulating Fan #1 that had been dead-headed during the 90-day test was found to have an open winding in the motor.
2) The pumping mechanism in Compressor #1 was found seized. The motor ran well when the belt drive to the diaphragm pump heads was disconnected.
3) The gas inlet heat exchanger and the air filter were found to be in excellent condition with no visible residue material deposits.
4) The canister gas outlet aluminum tube ends underneath the teflon tube connectors were found corroded.
5) The hydrophilic and hydrophobic elements in the water trap were removed and found to be in good condition with hardly any accumulation of foreign particles. Green corrosion consisting of copper salts covered the brass parts, as would be expected in the presence of water and oxygen.
6) Two fittings on the bottom flange of the water accumulator (fill and outlet ports) and a top fitting for the system equalizing pressure lines were found partially clogged. The drain line from the condenser was found partially clogged at the end that connects to the accumulator. Two erroded spots were found in the aluminum base near the fill and outlet ports. This was probably caused by a galvanic reaction between the aluminum base and the stainless steel fittings. A sticky, grayish substance covered the bottom (approx. 1/8" deep), and sides of the accumulator and also the limit switches. This residue was collected for chemical analysis (see figure 59).
7) The straight tube boilers contained a heavy deposit of a rust colored material. This substance was removed for chemical analysis.
8) A substantial amount of dirty amine fines was removed from the condenser inlet. A gray, sticky material was removed from the inner surface of the drain plate. The Refrasil material used in the drain cavity was found in excellent condition with no excessive accumulation of foreign material. It is concluded that the plugging of the condenser drain line, experienced during the 90-day test must



WATER ACCUMULATOR AT DISASSEMBLY

FIGURE 59

have been caused by the clogging of the small size drain hole and tubing.

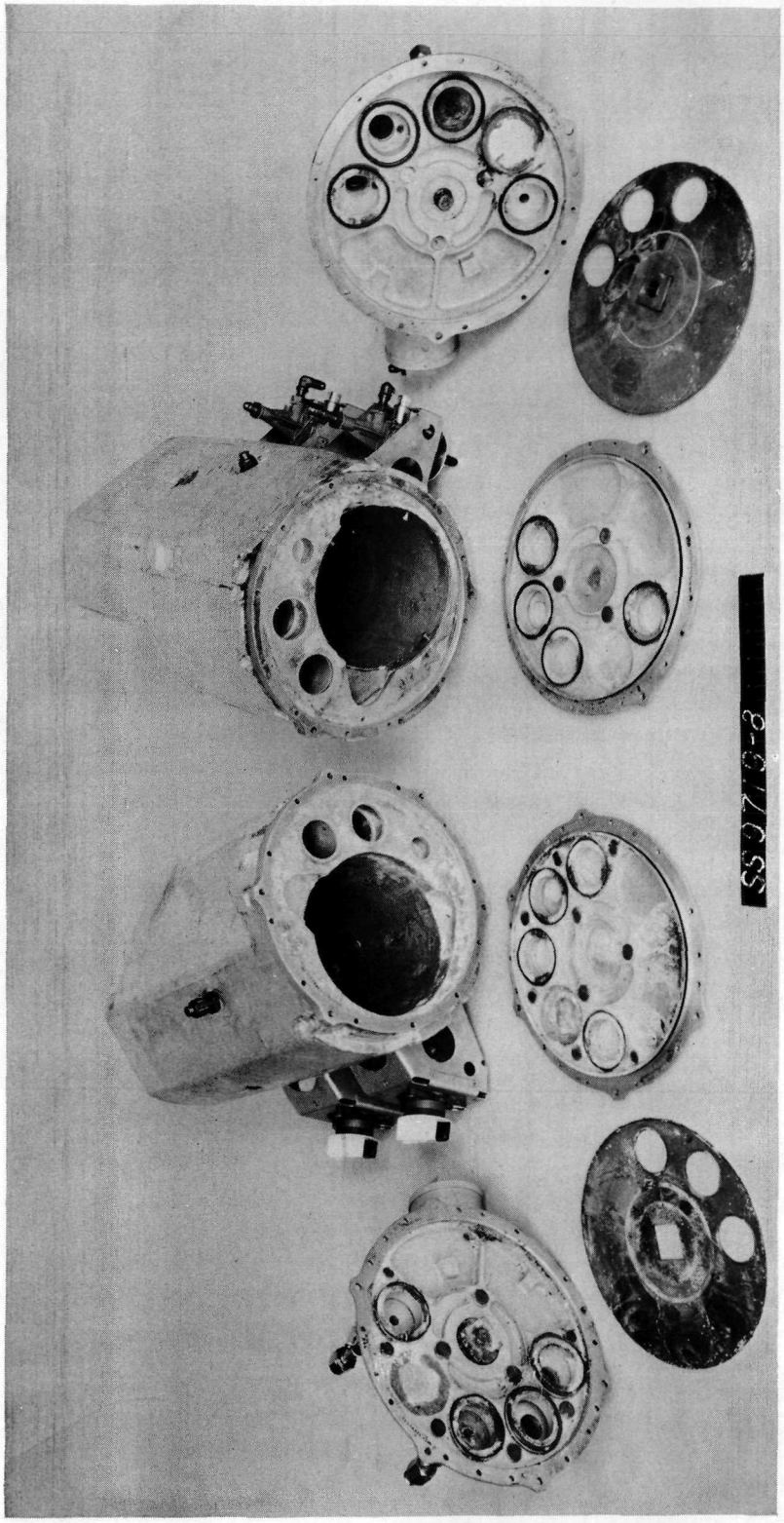
9) The rotary valves and canister were then disassembled. The dry weight of IR-45 material in each canister was determined to be 6.1 lbs. in canister #1, 6.4 lbs. in canister #2 and 4.97 lbs. in canister #3, with 1.53 lbs. lost during the 90-day test through a leak in the side wall of canister #3. Originally, each canister had been filled with 6.5 lbs. (dry weight) of IR-45 material. The loss in canister #1 (0.4 lbs.) and canister #2 (0.1 lbs.) had been attributed to leakage in the silastic rubber seal between the upper retaining screen holder and the canister wall and the passage of fines through the retaining screen. White deposits (removed for chemical analysis) were found on the upper canister flange faces and on the mating rotary valve bottom plates. A dirty sandlike material was found in the canister and rotary valve flange cavities (also removed). Photographs of the disassembled canisters and valves are shown in figures 60 and 61. The #3 canister and valve assembly in general was much cleaner with less corrosion deposits than the other two canisters. The excessive corrosion was believed to be caused by leaving the beds wet when operations were terminated. The stainless steel polished rotary valve plates contained deposits of IR-45 and foreign particles but the finish was very good with very few indications of surface deterioration.

10) The temperature reference junction whose set point had changed from 250 to 264.2°F, was removed from the electrical control box for examination. A change in the ohm value of a resistor in the oven temperature control circuit was responsible for the change in set p int. After changing the bad resistor, the readjusted set point of 250°F held constant for 4 days.

Laboratory Chemical Analysis and IR-45 Material Comparative Studies

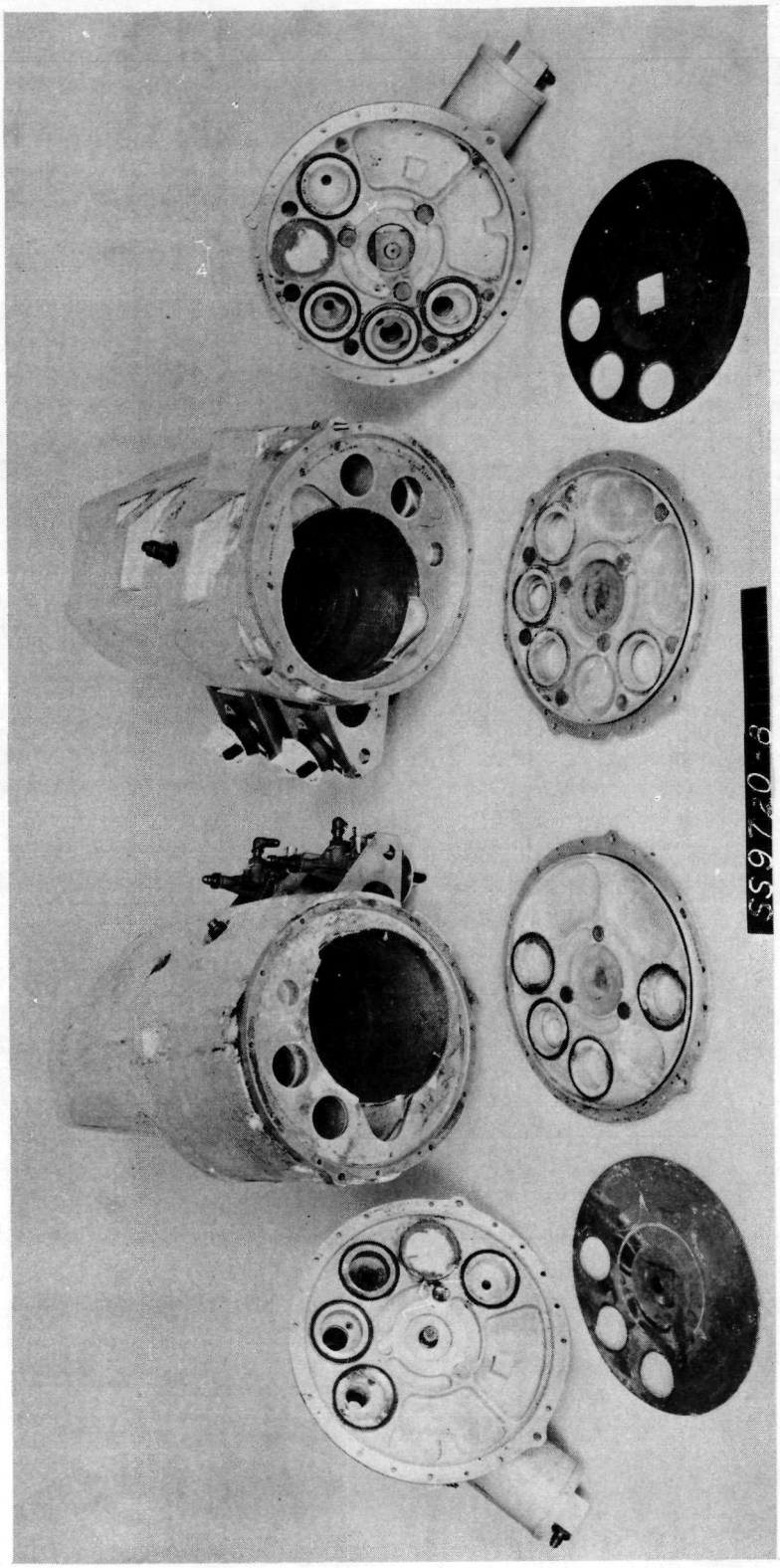
Residue and IR-45 material chemical analysis.- Residue materials collected during the assembly of the Amine CO_2 Concentrator unit were chemically analyzed on a Grating Infrared Spectrophotometer (Perkins-Elmer 621). A listing of the residue numbers, where they were found and the resulting chemical analysis (C.A.) follows:

Residue #1 - removed from the feed water filter and pumps.
C.A. - an organic fragment from the degradation of the IR-45 material that shows the presence of the amine leakage.
Residue #2 - removed from the aluminum water accumulator.
C.A. - a mixture of silicon dioxide, aluminum hydroxide and aluminum oxide.



DISASSEMBLED BEDS #1 AND #2

FIGURE 60



DISASSEMBLED BEDS #2 AND #3

FIGURE 61

Residue #3 - removed from the walls of the boiler, also includes particles received from MDAC which were found when removing the bottom boiler feed water inlet fitting.
C.A. - silicon dioxide.
Residue #4 - removed from the condenser inlet.
C.A - a mixture of IR-45 material and silicon dioxide.
Residue #5 - removed from the cover and plate in the condenser condensate drain port.
Residue #6 - removed from the canister top flange and the mating bottom plates of the rotary valves.
Residue #7 - removed from the inside rotary valve cavities.
Residue #8 - removed from the canister top flange cavities.
Residue #9 - removed from the steam inlet tube on canister #1.
C.A. - samples 5 through 9 are essentially the same and consisted of mixtures of hydrated aluminum hydroxide and aluminum oxide. Sample #8 was selected as representative of the group and was further tested on the differential scanning calorimeter which confirmed the identification of aluminum hydroxide based on the phase transition involving the loss of water.

In addition to these residue samples, new IR-45 material, as received from MSA, and material from bed #3 were compared on the Infrared Spectrophotometer. Chemical changes between the two samples were observed and attributed to cleavage of the side chains (the amine segments) from the aromatic polymeric matrix. The evidence, however, does not indicate aromatic ring cleavage of the polymer. A more detailed chemical analysis would be required for a more definite explanation of the degradation mechanism.

A portion of each residue together with 283 grams of IR-45 material from Bed #3 was forwarded to the NASA/LRC as directed in the contract Statement of Work.

Laboratory IR-45 material comparative studies.-

Anion Exchange Capacity: Samples of new IR-45 material as received from MSA, and material from beds #2 and #3 were each subjected to the titration procedure as shown in Appendix Q to determine the relative anion exchange capacity. The following results were obtained:

Material Sample		Milliequivalent Anion Exchange Capacity Gram of Dry Free Base Form Resin
New		5.35
Bed #2	Same operating	4.65
Bed #3	time at HS and MDAC	4.34

The anion exchange capacity which is involved in the chemi-sorption-desorption process was reduced by 13 to 19 percent during the unit operating time at Hamilton Standard and the 90-day simulator test. A reduction in the anion exchange capacity relates in trend with the drop in system performance experienced during the Amine CO_2 Concentrator post 90-day performance check-out tests.

Mechanical and Physical Properties: To determine mesh size, each sample was sifted through progressively courser size screens with the following results:

INCREASING PARTICLE SIZE ↑	SCREEN MESH SIZE NO.	NEW IR-45 (%)	BED #3 IR-45 (%)
	20	1.9	7.4
	30	58.0	73.8
	40	38.0	18.4
	50	1.9	0.4
	Dust	0	0

The new material contained a greater percentage of fines which passed through leakage paths around the retaining screens during unit operation.

The approximate crush strength of the two IR-45 materials was determined by placing a 5 gram sample in a 1/2" dia. metal cavity. A close fitting plunger was inserted and pressure was gradually applied until the first indications of particle damage were observed.

Results

	Pressure Applied psig	Force lbs.
New IR-45	250	49
Bed #3 IR-45	500	98

The bed #3 material with its greater percentage of larger particle sizes was capable of withstanding higher stress loadings before particle damage occurred thus displaying a higher crush strength.

The bulk density of the same two IR-45 materials was determined:

Results	g/cc	$lbs./ft^3$
New IR-45	0.578	36.0
Bed #3 IR-45	0.564	35.2

The new IR-45 material with its greater percentage of fines would produce the higher bulk density.

Water absorptive capacity was determined. Dry nitrogen gas was initially passed through a bubbler at 70°F. Then, the saturated gas was directed through each of the two samples for a period of 142 hours. This yielded the following:

	Initial Water Loading (% By Wt)	Water Loading After 142 Hr Test (% By Wt)	ΔWater Absorbed (% By Wt.)
New IR-45	20.3	27.6	7.3
Bed #3 IR-45	22.8	34.3	11.5

Although the IR-45 material from bed #3 contained slightly higher water loading initially, it still had a greater absorption capacity for water over the 142 hour period. It is assumed that the greater capacity displayed is due to the collection of water in the voids left by the amine material that is steamed off the styrene base.

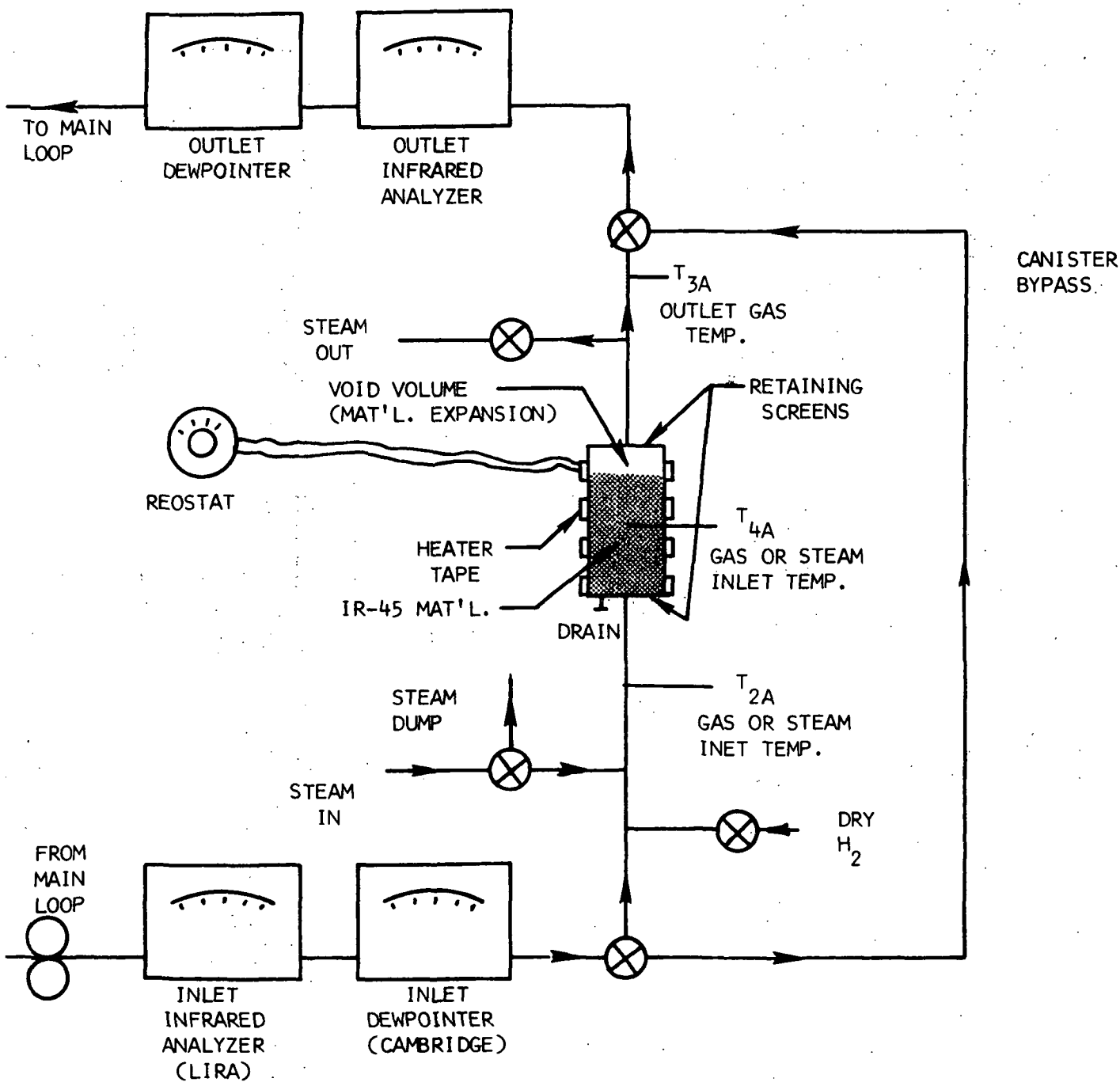
Summary of results (mechanical & physical properties).-

	New IR-45	Bed #2 IR-45	Bed #3 IR-45
Anion Exchange Capacity, Milleq. Anion Exchange Capacity / Grams of Dry Free Base Form Resin	5.35	4.65	4.34

Mesh Size	New IR-45	Bed #2 IR-45	Bed #3 IR-45
Mesh Size, % — 20	1.9		7.4
30	58.0		73.8
40	38.0		18.4
50	1.9		0.4
Dust	0		0
Crush Strength, lbs.	49		98
Bulk Density, lbs/ft^3	36		35.2
Water Absorbed (142 hrs., 70°F sat. N_2), % by Wt.	7.3		11.5

Comparative Breakthrough Curve Tests

The breakthrough curve laboratory test setup is shown schematically in figure 62. A test tube size canister was mounted vertically and installed into the Multi-purpose Rig 88 instrumentation sampling lines between the inlet and outlet infrared analyzers and dewpointers. The rig main loop was used to preset and maintain the inlet gas stream operating conditions; the sampling gas stream bypassed the canister while test conditions were being



BREAKTHROUGH CURVE TEST SETUP SCHEMATIC

FIGURE 62

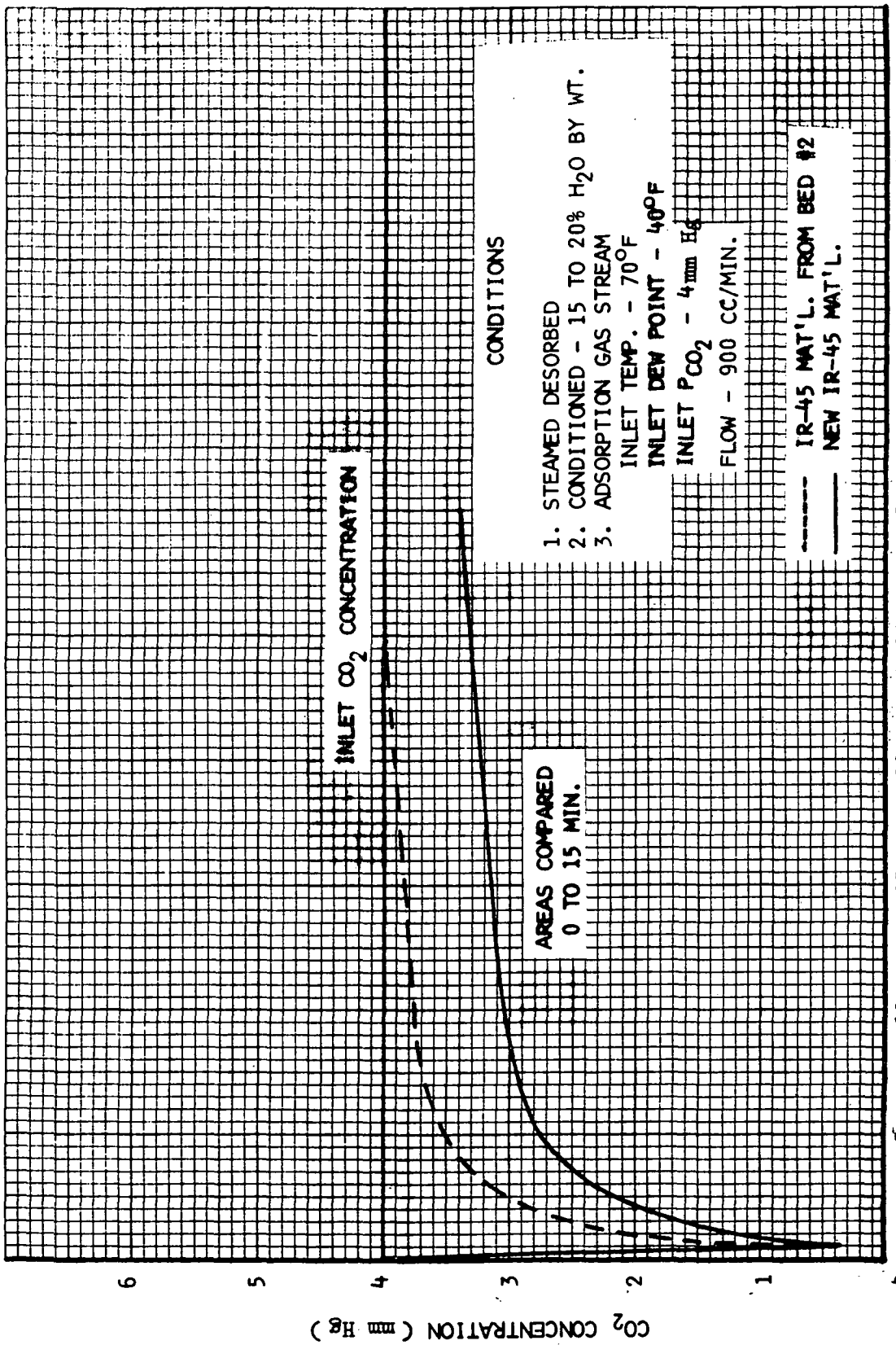
set. A steam generator was provided to supply the necessary steam flow for desorption. An electric heater tape, with a reostat control, was wrapped around the canister to heat the walls thus preventing any premature condensation of the steam when desorption was initiated. The absorb gas flow was set a 900 cc/min. to coincide with the sampling flow requirement for the infrared analyzers (Lira). The IR-45 sample weight and the steam flow values were ratioed down from the material weights and flows used for the larger Amine CO_2 Concentrator canisters. Thermocouples were provided to measure inlet and outlet gas and steam temperatures and bed temperature. Infrared analyzers (Lira) were utilized to monitor inlet and outlet CO_2 concentrations; the inlet and outlet moisture content was measured by Cambridge Dewpointers.

For Test #1 a 3.54 gram (dry weight) sample of new IR-45 material, as received from MSA, was placed in the canister leaving the necessary void volume for material expansion when wet. Retaining screens (80 x 80 mesh) are provided to contain the material within the cavity. First, a flow of steam (0.0087 lbs/hr) at a temperature of 212-215°F was injected into the canister to desorb all accumulated CO_2 from the bed. The steam flow was continued for 15 minutes beyond the point where the breakthrough of steam was observed at the canister outlet. Then, a 900 cc/min. flow of dry nitrogen (9 to 16 PPM H_2O) was directed through the bed until the outlet dew point was 10°F which indicated that the IR-45 material was fairly dry. The material was then conditioned by passing a 900 cc/min. flow of nitrogen at an inlet temperature of 70°F and an inlet dew point of 65°F (85% relative humidity) for 15 minutes beyond the point where the inlet and outlet dew points were equal to establish a bed water loading of between 15 to 20 percent by weight. The breakthrough curve test was initiated by presetting a nitrogen flow (900 cc/min.) with an inlet temperature of 70°F, an inlet dew point of 40°F and an inlet CO_2 concentration of 4 mmHg in the canister bypass loop until conditions had stabilized. The flow was then directed through the canister, thus initiating absorption, and was continued until the outlet P_{CO_2} was 90% of the inlet P_{CO_2}. This test procedure was repeated until two similar curves within the accuracy of the instrumentation were obtained.

For Test #2 a 3.54 gram (dry weight) sample of IR-45 material from the Amine CO_2 Concentrator #2 bed was placed in the test canister and subjected to the same test procedures as described for test #1.

The log sheets and the infrared analyzer (Lira) calibration curves are presented in Appendices R and S.

Results.- The breakthrough curves for the new IR-45 material and material removed from the Amine CO_2 Concentrator bed #2 are shown in figure 63. Both curves display the early characteristic breakthrough time and also show that the CO_2 dynamic capacity of the IR-45 material used



COMPARATIVE BREAKTHROUGH CURVES

FIGURE 63

during the 90-day test is approximately 50% less than the new IR-45 material received from MSA, by comparison of areas under the curves for an equivalent 15 minute absorb time period.

Recommended Design Changes

The recommended changes that should be incorporated in future Amine CO_2 Concentrator designs for manned tests are:

1) Conductivity sensors, with readout instrumentation, should be inserted in all canisters to indicate the wetness or dryness of the IR-45 material in each bed.
2) An automatic temperature controller, with a manual selector, should be provided to set and control the gas inlet temperature to the beds.
3) A filter should be added in the condenser drain line to remove foreign particles from the condensate prior to its entering the water accumulator
4) Adequate sealing between the retaining screens and the canister walls and the proper mesh size screening should be provided to prevent IR-45 material carryover.
5) The canisters should be sized to hold an extra amount of IR-45 material to allow for performance degradation with mission time.
6) The canister design should contain mechanisms for containment of IR-45 material in a zero "g" environment with allowances for material expansion when wet.
7) The system design should provide for the most efficient use of available heat by first, utilizing the initial hot, wet effluent absorption gas to supply heat to the desorbing bed during the initial portion of the half cycle and second, to automatically shut-off the feed water pump after steam breakthrough in the desorbing bed to terminate steam production for the remainder of the desorb half cycle.
8) Filters should be sized to provide the longest practical times between scheduled element changes or cleaning.
9) The packaging should provide adequate accessibility to all components for maintenance and repairs.
10) The steam pressure level should be adequate to drive the desorbed CO_2 from the bed to the accumulator thus eliminating the need for pumps.

CONCLUSIONS

The Amine CO_2 Concentrator unit designed and fabricated by Hamilton Standard with IR-45 sorber material processed and furnished by MSA Research Corporation under a separate NASA/LRC contract was capable of removing CO_2 to support a four-man crew in a spacecraft simulation test. The feasibility of this system concept was demonstrated. Quantitative information derived on the system performance during the test was minimal; however, the system supported four men in the space simulator for 71 days of the 90-day duration.

The CO_2 dynamic capacity of IR-45 material decreased with time as evidenced by the drop in performance determined during the post 90-day test performance task.

The functional capacity of the sorber was evidently reduced by the cyclic steaming and drying as shown by the decrease in the anion exchange capacity of IR-45 material subsequent to the 90-day test, and by the analysis of the residues collected from the feed water pumps and filter.

BIBLIOGRAPHY

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APPENDIX A

HS-B CO_2 Removal Feasibility Testing In Full Size Canister Log Sheets

HSP-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: t. B SUMMARY
TEST ENGINEER:
NAME OF RIG: PJ Sunde
PROJECT & ENG. ORDER NO.

SHEET 1 OF 2 DATE 7-28-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

RUN NO	Flow	Press.	Temp.	Dew Pt.	Part. Press CO_2	WT H2O	Desorb Fluid Temp	Desorb Press	Can ΔP initial	CO_2 ΔP	Accum. Tank VOL	Accum. Tank TEMP	Accum. Tank WT CO_2 Calc.	WT CO_2 MCAS.	WT CO_2 INT.*	WT H_2O INT.*	CO_2 Purity	Time no cool	Adsorb cool	Ullage Dump	Desorb	Pre-cool
	cfm	PSIA	°F	°F	mm Hg	lbs	°F	PSIA	in H_2O	PSIA	FT^3	°F	lbs	lbs	lbs	lbs.	%	min	min	min	min	min
3A	7.8	—	59	50	5.	3.0	200	.50	16.8	—	1.94	—	—	.13?			94.5	20.1	13.6	1.35	43.0	4.7
3B	(7.8)	—	59	50	5.	3.0	200	.50	—	—	1.94	—	—	.09			94.5	20.1	13.6	1.35	43.0	4.7
3C	(7.8)	—	58	50	5.	3.0	200	.50	—	—	1.94	—	—	.09			91.	20.1	13.6	1.35	43.0	4.7
3D	(7.8)	—	58	50	5.	3.0	200	.48	—	—	1.94	—	—	.09			96	20.1	13.6	1.35	43.0	4.7
3E	7.8	14.5	58	50	5.	3.0	200	.50	15.8	—	1.94	—	—	.09			97	20.1	13.6	1.35	43.0	4.7
3F	7.8	14.6	57	50	5.	3.0	200	.50	15.5	—	1.94	—	—	.09			98	20.1	13.6	1.35	43.0	4.7
3G	7.8	—	57	49	5.	3.0	200	.50	15.5	—	1.94	—	—	.08			100+	20.1	13.6	1.35	43.0	4.7
3H	(7.8)	—	59	48	5.	3.0	200	.50	—	6.4	1.94	—	.094	LATE .05			94.5	20.1	13.6	1.35	43.0	4.7
3I	7.8	14.5	57	49	5.	3.0	200	.50	15.6	5.9	1.94	—	.087	.09			94.5	20.1	13.6	1.35	43.0	4.7
3J	7.8	14.4	57	50	5.	3.0	200	.50	15.4	5.85	1.94	—	.086	.09			94.5	20.1	13.6	1.35	43.0	4.7
9A	7.9	14.44	58	50	5.	3.0	200	.50	15.8	5.0	1.94	—	.074	.07			95.5	33.7	0	1.35	43.0	4.7
9B	7.9	14.20	58	50	5.	3.0	200	.50	15.8	—	1.94	—	—	.07			94.5	33.7	0	1.35	43.0	4.7
9C	7.9	14.5	58	50	5.	3.0	200	.50	15.9	5.35	1.94	82	.079	.08			97	33.7	0	1.35	43.0	4.7
4A	11.8	14.3	58	50	5.	3.0	200	.50	27.2	6.3	1.94	82	.093	.09			98	20.1	13.6	1.35	43.0	4.7
4B	11.8	14.3	57	50	5.	3.0	200	.50	25.7	6.3	1.94	83	.093	.09			95	20.1	13.6	1.35	43.0	4.7
6A	11.8	14.4	58[1]	50	.9	3.0	200	.50	25.7	5.8	1.94	80	.086	.08			94.5	20.1	92	1.35	43.0	4.7
6B	11.8	14.5	56	48	.9	3.0	200	.48	24.8	6.1	1.94	78	.090	.10			97	20.1	92	1.35	43.0	4.7
6C	11.8	14.6	56	49	.9	3.0	200	.48	27.2	6.1	1.94	78	.090	.09			98	20.1	92	1.35	43.0	4.7

REMARKS:

*INTEGRATED VALUES FROM RECORDER CHARTS
1 Started at 75°F. 60°in 1/2 hr.

79279

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSP-175.1A 1/69

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: H 3 SUMMARY

TEST ENGINEER

NAME OF RIG: P J Fink

PROJECT & ENG. ORDER NO.

SHEET 2 OF 2 | DATE 7-28-70

TEST PLAN NO.

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS

RUN NO	FLOW	PRESS	TEMP	DEW PT	ADRT PRESS CO_2	WT HSB	DESORB FLUID TEMP	DESORB PRESS	CAN ΔP	CO_2 ΔP	ACCUM VOL	TANK TEMP	TANK WT CO_2 CALC	WT CO_2 MEAS	WT CO_2 INT	WT H_2O INT	CO_2 PURITY	ADSORB TIME no cool	ADSORB TIME cool	ULLAGE DUMP	DESORB	PRE-COOL
									init Δ													
	CFM	PSIA	°F	°F	mmHg	lbs	°F	PSIA	$in H_2O$	PSIA	FT^3	°F	lbs	lbs	lbs	lbs	%	min	min	min	min	min
5A	(5.3)	—	57	49	4.9	3.0	200	.48	—	—	1.94	80	—	.09			96	20.1	30	1.35	43.0	4.7
5B	(5.3)	14.6	57	48	4.9	3.0	200	.50	—	—	1.94	80	—	.09			96	20.1	30	1.35	43.0	4.7
5C	5.3	14.6	57	49	4.9	3.0	200	.50	8.5	6.2	1.94	80	.091	.09			96	20.1	30	1.35	43.0	4.7
5D	5.3	15.0	57	49	4.9	3.0	200	.50	8.6	6.1	1.94	82	.090	.09			96	20.1	30	1.35	43.0	4.7
5E	5.3	15.0	57	48	4.9	3.0	200	.50	8.6	6.1	1.94	78	.090	.09			94.5	20.1	30	1.35	43.0	4.7
7A	7.8	—	76	49	4.9	3.0	200	.40	17.0	5.6	1.94	76	.083	.08			93	20.1	13.6	1.35	43.0	4.7
7B	7.8	—	76	50	4.9	3.0	200	.50	15.3	—	1.94	85	—	.09			94	20.1	13.6	1.35	43.0	4.7
7C	7.9	14.34	77	50	4.9	3.0	200	.50	15.9	5.6	1.94	86	.083	.09			93	20.1	13.6	1.35	43.0	4.7
7D	7.9	14.41	77	49	4.9	3.0	200	.50	16.6	5.8	1.94	87	.086	.09			92	20.1	13.6	1.35	43.0	4.7
7E	7.9	14.39	75	49	4.9	3.0	200	.50	15.8	5.5	1.94	80	.086	.08			94.5	20.1	13.6	1.35	43.0	4.7
10A	7.7	—	60	48	4.9	3.0	200	.50	16.0	5.8	1.94	85	.086	.08			96	20.1	13.6	1.35	43.0	4.7
10B	7.8	—	60	50	4.9	3.0	200	.50	16.4	5.9	1.94	82	.087	.08			96	20.1	13.6	1.35	43.0	4.7
10C	7.9	14.2	60	50	4.9	3.0	200	—	16.6	6.0	1.94	86	.089	.09			94.5	20.1	13.6	1.35	43.0	4.7

REMARKS:

79280

A-2

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: H5T
TEST ENGINEER: P Lunde - 7-24-70
NAME OF RIG: BASIC DATA
PROJECT & ENG. ORDER NO.: Crew controlled.

SHEET OF | DATE
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

RUN	BOTTLE W_{O_2} BEGIN	BOTTLE W_{O_2} END	TANK P_{O_2} BEGIN	TANK P_{O_2} END	ΔW bottle	ΔP tank	Temp tank	Flow	ΔP begin	Desorb P	ris P
	lbs		psia		lbs	psi	°F	volts	in H_2O	psia	psia
3A	150.19	150.08	—	—	?.13	—	—	2.42	16.8	.5	—
3B	150.08	149.99	—	—	.09	—	—	—	—	.5	—
3C	149.99	149.90	—	—	.09	—	—	—	—	.5	—
3D	149.90	149.81	—	—	.09	—	—	—	—	.48	—
3E	149.80	149.71	25.1	31.0	.09	5.9	—	2.44	15.8	.5	14.5
3F	149.65	149.56	25.0	31.0	.09	6.0	—	2.42	—	.5	14.6
3G	149.48	149.40	—	—	.08	—	—	2.43	15.8	.5	—
3H	LATE 149.56	149.45	25.8	32.2	LATE .05		—	—	—	.5	—
3I	149.45	149.36	25.0	30.9	.09		—	2.42	15.6	.5	14.5
3J	149.36	149.27	25.0	30.85	.09		—	2.44	15.4	.5	14.4
9A	149.27	149.20	25.0	30.0	.07		—	2.46	15.8	.5	14.44
9B	149.20	149.13	25.0	30.5	.07		—	2.45	15.8	.5	14.20
9C	149.13	149.05	25.2	30.55	.08		82	2.46	15.9	.5	14.5
4A	149.05	148.965	25.1	31.4	.09		82	4.22	27.2	.5	14.3
4B	148.965	148.87	25.0*	31.3	.09		83	4.21	25.7	.5	14.3
6A	148.87	148.79	24.0*	30.8	.08		80	4.22	8.7	.5	14.4
6B	148.79	148.69	25.6	31.7	.10		78	4.24	8.4	.48	14.5
6C	148.69	148.60	25.4	31.5	.09		78	4.24	9.2	.48	14.6

RUN	BOTTLE W_{O_2} BEGIN	BOTTLE W_{O_2} END	TANK P_{O_2} BEGIN	TANK P_{O_2} END	ΔW bottle	ΔP tank	Temp tank	Flow	ΔP begin	Desorb P	ris P
	lbs		psia		lbs	psi	°F	volts	in H_2O	psia	psia
5A	148.60	148.51	25.4	31.7	.09		80	—	—	.48	—
5B	148.51	148.42	25.3	31.3	.09		80	1.62	9.7	.5	14.6
5C	148.42	148.33	25.2	31.4	.09		80	1.62	8.5	.5	14.6
5D	148.33	148.24	25.3	31.4	.09		82	1.62	8.6	.5	15.0
5E[1]	148.24	148.15	24.6**	32.1	.09		78	1.62	8.6	.5	15.0
7A	148.14	148.06	25.2	30.8	.08	5.6	76	—	17.0	.4	—
7B	148.06	147.97	—	30.8	.09		85	2.40	15.3	.5	—
7C	147.97	147.88	25.2	30.8	.09		86	2.44	15.9	.5	14.39
7D	147.88	147.79	25.2	31.0	.09		87	2.44	16.6	.5	14.41
7E	147.79	147.71	24.0	30.5	.08		80	2.44	15.8	.5	14.39
10A	147.71	147.63	25.5	31.3	.08		85	2.38	16.0	.5	—
10B	147.63	147.55	25.4	31.3	.08		82	2.43	16.4	.5	—
10C	147.55	147.46	25.2	31.2	.09		86	2.44	16.6	—	14.2

CO_2 TANK PURITY %

3A	3B	3C	3D	3E	3F	3G	3H	3I	3J	RUN
94.5	94.5	91	96	97	98	100+	94.5	94.5	94.5	CO_2%
9A	9B	9C	4A	4B	6A	6B	6C	5A	5B	RUN
95	94.5	97	98	97	94.5	97	98	96	96	CO_2%
5C	5D	5E	7A	7B	7C	7D	7E	10A	10B	RUN
96	96	94.5	93	94	93	92	94.5	96	96	CO_2%
10C										RUN
94.5										CO_2%

REMARKS:
*MUST BE 25.0
** " " 25.6?
1 DESORB TEMP OUT OF CONTROL - 240°F FLUID 225° BED.

NOTE: ALL DESORB FLUID AT 200F EXCEPT RUN 5E.

81550

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3B DATA
TEST ENGINEER: P Hunde
NAME OF RIG: 7-2470
PROJECT & ENG. ORDER NO.

SHEET 2 OF 2 | DATE
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3A

RUN #	T_{air} inlet	T_{DEW} PT COND.	RUN #	T_{air} inlet	T_{DEW} DT COND.
3A	59	50	5A	57	49
3B	59	50	5B	57	48
3C	58	50	5C	57	49
3D	58	50	5D	57	49
3E	58	50	5E	57	48
3F	57	50	7A	76	49
3G	57	49	7B	76	50
3H	59	48	7C	77	50
3I	57	49	7D	77	49
3J	57	50	7E	75	49
9A	58	50	10A	60	48
9B	58	50	10B	60	50
9C	58	50	10C	60	50
4A	58	50			
4B	57	50			
6A	58	50			
6B	56	48			
6C	56	49			

REMARKS: 1 Started at 75°F. 60° in ½ hr

79290

APPENDIX B

CO_2 Concentration (Amine) System

Materials List

MATERIALS LIST - CO_2 CONCENTRATOR (AMINE) SYSTEM

	Material Ident	Remarks
Fan:		Based on 5 psia O_2 environment
	1. Enamel Paint K1393 Randolf Products-Carlstad, N.J. Used with 4511 thinner 446 in^2 each fan 892 in^2 total Weight - 0.224# total	Flammability, flash, fire, odor - No data Passes CO Fails TO All materials adjacent pass COMAT. To be tested for outgassing
	2. DC 33 Silicone Grease Dow Corning	Passes COMAT
	3. Teflon Insulated Wiring	Passes COMAT
Pump:	1. Poly Propylene (Bellows) 3.14 in^2 0.016 lbs.	Not COMAT tested. Odor, CO, TO should not be a problem. Material contains water
	2. Phenolic (Grommet & sleeving on Gear Drive Shaft) Gromet - 2.302 in^2, 0.0133 lbs. Sleeving - 0.942 in^2, 0.00236 lbs.	Small volume used (not COMAT tested). All other surrounding material pass COMAT To be tested for outgassing
Electrical Control Box:	Plastics: Lexan, Phenolic, Cycolac, Bakolite, Silicone Rubber, Diallyl-Pthalate, Furane 17B Potting, Chloroprene, Polystyrene, Buterate See Sheet 2 & 3	Total assembly will be tested for outgassing with acceptability based on removal capability of the DAC system. Fire proof by metal vented case.
3 Way Solenoid Valve:	1. Epoxy painted solenoid valve case 35.8 in^2 ea; 71.6 in^2 total Wt. 0.018# total	Same as Fan Enamel above
	2. Silicone insulated wire	Passes COMAT To be tested for outgassing
Compressor:	1. Epoxy Paint (motor) 494 in^2 ea; 988 in^2 total Wt. 0.247# total	See above
	2. Vinyl insulated power Leads to be Teflon tape wrapped	PVC passes Fire propagation rate CO, TO Fails Odor Teflon-passes COMAT To be tested for outgassing
2 Way Solenoid Valve:	1. Teflon insulated wire	
Flex Line:	TFE (Teflon)	Passes COMAT
Insulation:	1. Isofoam PE 10 Rigid Closed Cell Polyurethane - Obtain from Isocyanate Products Foil Adhesive - SR 585 Pressure sensitive Silicone Adhesive G.E., Waterford, N. Y. Aluminum Tape No 7402 obtain from Mystic Tape Co.	Passes COMAT with foil

	Material Ident	Remarks
Insulation: (Continued)	2. J. M. Microfoil insulating tape (type 475) Johns-Manville (Fibrous silica and aluminum) 100 ft x 1" width x 1/2" thickness Wt. 0.014#	All similar materials pass COMAT
Accumulator:	1. Teflon Insulated Wire (switches)	
	2. AMS 3302 Silicone Rubber (gasket)	Passes COMAT
General:	1. DAC system has odor outgassing removal capability. Crew is protected from fire with automatic sprinkler system fire extinguishers, telephone, rapid escape	
	2. COMAT acceptability criteria for coatings per NASA document: D-NA-0002 5 psia O_2 @ 160°F @ 72 hrs. exposure 150 TO - 100 Micro Grams per Gram of sample CO - 25 ODOR - Based on subjective opinion of 5 man panel 2 objections cause rejection SAMPLE SIZE - 46.5 + 2.5 in^2 of Material Surface Per Liter of Chamber Volume	
Timers (TR 1, 2, 3, 4):	Case: Cycolac (plastic), Marbon Chemical, Wash., W. Va. Window: Lexan (G.E.) Knobs: Cycolac Ring (rear): Phenolic	
Circuit Breakers:	Inside Shell: Bakelite Toggle Seal: Silicone Rubber Form Bar Wire: Insulating Coat (unknown)	
Capacitors:	Case: Molded Plastic (G. E. General Phenolic) Paint: (White) Markum 71335P black ink	
Panel Jacks & Plugs:	Jacks & Plugs: Diallyl-Pthalate Name Tag: Can be removed, has paint	
Pressure Xducers:	(2) Gaskets: 25% Glass filled teflon Circuit Board: Glass Epoxy Capacitor Cover: Mylar Xformer Case: Plastic (type unknown) Potting: Furane 17B Connector: Molded Melamine	
Mtr-Run Capacitors Oil Type:	Araclor oil, Mfg. by Monsanto-Chemical	
Switches:	Base: General purpose Phenolic (Bakelite Plastic)	
Socket & Plugs:	TBD	
Lights:	Caps: Buterate Plastic	

	Material Ident
Flow & Temp. Controllers:	Nylon, Molded Zytel #101, black Lexan, Molded G.E. #141-701 Phenolic, Molded, Union Carbide Plastics #BMG-7500-blk-24 Sealing Compound - Chem-Masters, Inc. #L401-1 Anti-static agent, Catanac SN American Cynamid Co. Epoxy Eccocoat #EC-210 Grey, Silicone Fluid Dimethyl Polysiloxane, Dow Corning Lacquer, Lacquer Products #3-512 Paint, black aladin #12412 Paint, white enamel, Jamestown Paint and Varnish #83331 Ink, black ISCC-NBS #267 (Fed. Std. 595-17038) Varnish, Durant #Y-107A, CN-632 A3066 Type I
Counter:	Not available (Proprietary)
Pushbutton:	Handle - nylon (glass filled) Cams - nylon (2) seals - Butyl rubber Plunger and Contact Block - Alkyd Legen Plate - Epoxy paint fill
Connectors:	Insert: Chloroprene Polymer Ink Stamp: Fed Spec TT-I-558 with Sterling Varnish V-87 Coating Rivet Paint: TT-E-489 Class A
Timer:	Cover - Polystyrene Timer Base: - Bakelite Printed Ckt Board - G-10 Knob - Phenolic Plastic (injection molded)

NOTE: The total estimated weights of the non-metallic materials contained in the electrical control box equipment shown on Sheets 2 and 3 are summarized on the following Pages 4 and 5.

ELECTRICAL CONTROL BOX

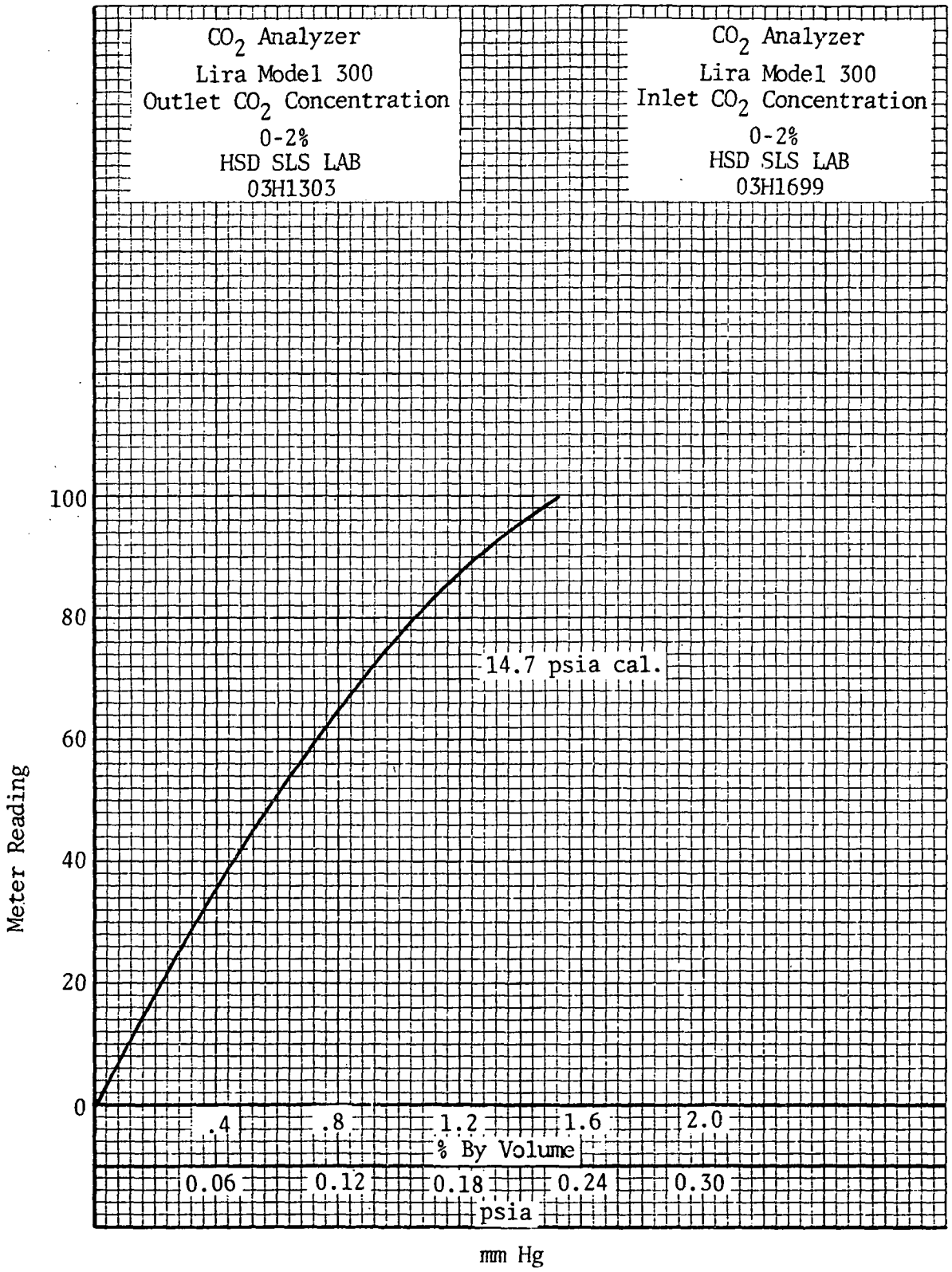
Summary of Non-Metallic Weight Estimates
Exclusive of Non-Metallics Inside Heremetically Sealed Cases

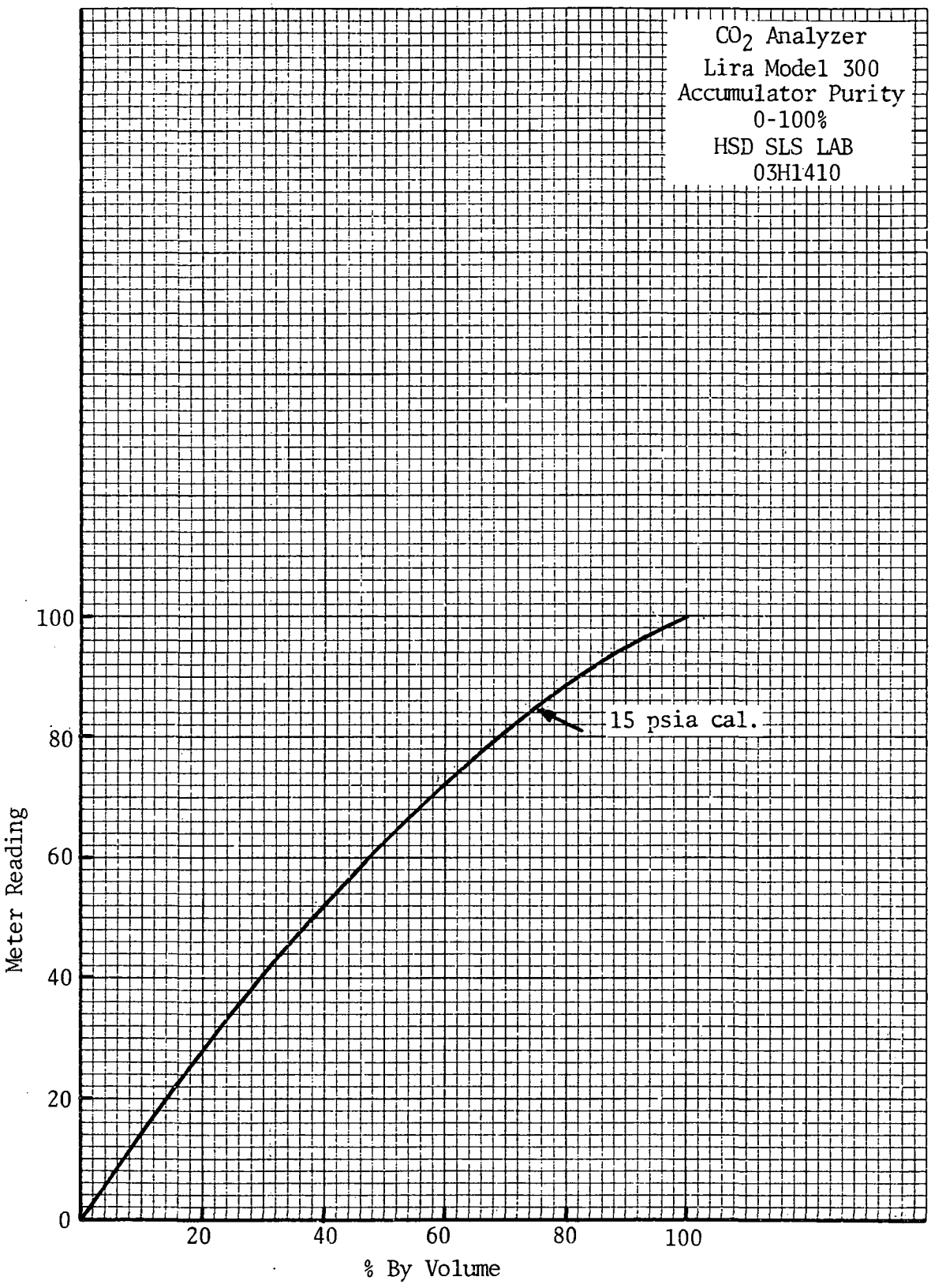
Material Identification	Estimated Weight (oz)
Cycolac (Plastic), Marbon Chemical, Washington, W. Va.	16.2
Lexan (G.E.) (Type Unknown)	4.0
Lexan, molded, G.E. #141-701	6.0
Phenolic (Type Unknown)	6.0
Phenolic, molded, Union Carbide Plastics #BGM-7500-blk-24	22.0
Bakelite (Type Unknown)	4.0
Silicone Rubber	1.0
Diallyl-Pthalate	1.5
Paint (White) Markum 71335P black ink	1.0
Paint, black aladin #12412	0.2
Paint, white enamel, Jamestown Paint and Varnish #83331	0.02
Lacquer, Lacquer Products #3-512	0.1
Varnish, Durant #Y-107A, CN-632 A3066 Type 1	0.22
Ink, black ISCC-NBS #267 (Fed. Std. 595-17038)	0.1
Epoxy filled paint, (Type Unknown)	0.1
Ink, Fed. Spec. TT-I-558	0.1
Sterling Varnish V-87 Coaling	0.33
Paint TT-E-489 Class A	3.3
25% Glass Filled Teflon	1.0
Glass Epoxy Circuit Board	1.5
Mylar Capacitor Cover	0.5
Furane 17B Potting	2.0
Molded Melamine	2.0
Buterate Plastic	3.2
Nylon, Molded Zytel #101, black	6.0
Nylon, Glass Filled	2.0
Nylon	1.0
Chem-Masters, Inc. #L401-1 Sealing Compound	1.0
Catanac SN, Anti Static Agent, American Cynamid Co.	0.2

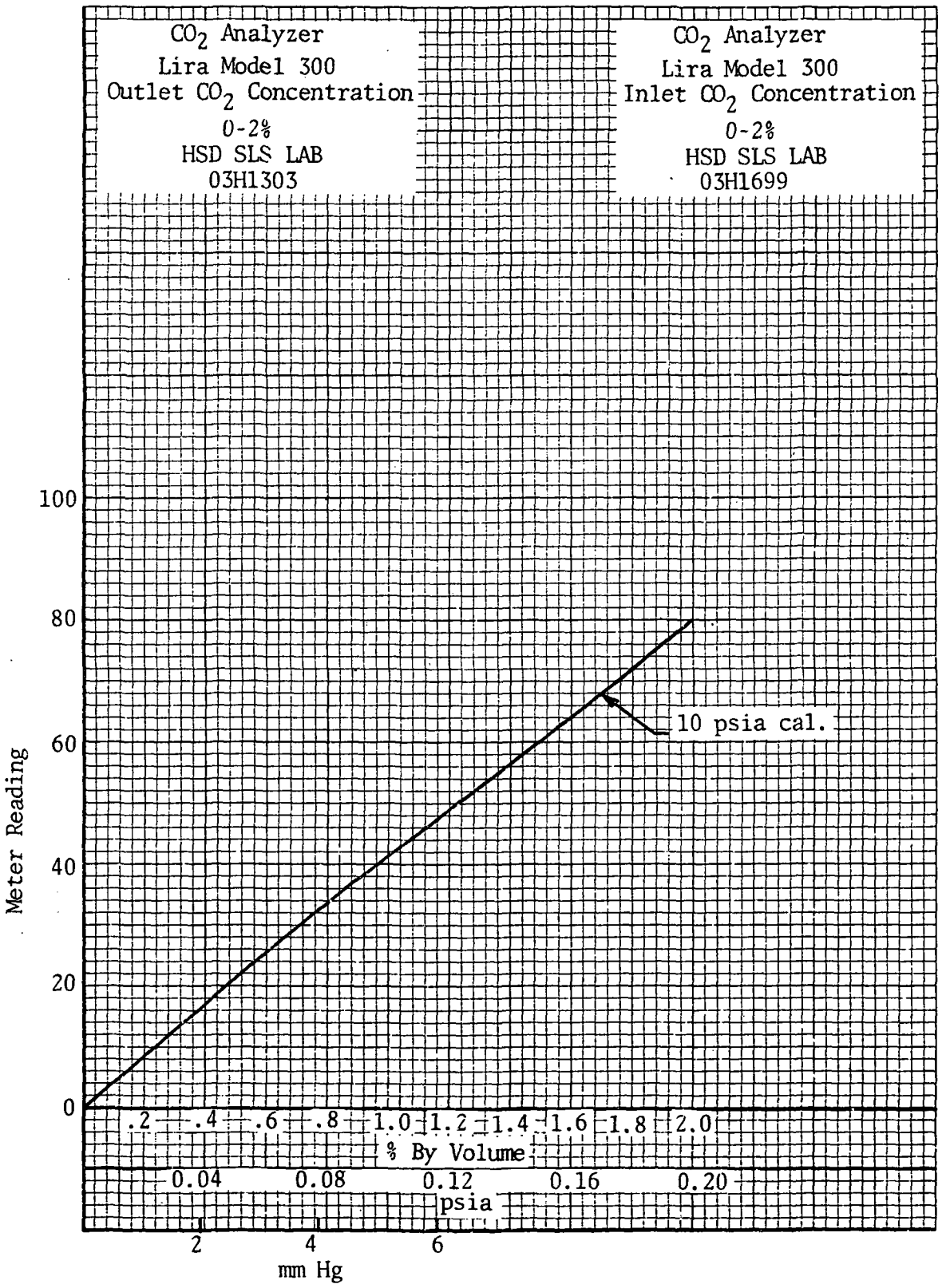
Material Identification	Estimated Weight (oz)
Epoxy Eccocoat #EC-210 Gray, Silicone Fluid Dimethyl Polysiloxane, Dow Corning	2.0
Butyl Rubber	2.0
Alkyd	1.0
Chloroprene Polymer	33
Polystyrene	4.0
G-10, Printed Circuit Board Material	3.0
Teflon Wire Insulation	15.3
UL Type "S" Rubber	5.2
Rubber (Type Unknown)	2.0
Phenolic Plastic (injection molded)	1.0

APPENDIX C

Infrared Analyzer (Lira) Calibration Curves


CO_2 Analyzer
Lira Model 300
Outlet CO_2 Concentration
0-2%
HSD SLS LAB
03H1303
CO_2 Analyzer
Lira Model 300
Inlet CO_2 Concentration
0-2%
HSD SLS LAB
03H1699
14.7 psia cal.
Meter Reading
100
80
60
40
20
0
.4
.8
1.2
1.6
2.0
% By Volume
0.06
0.12
0.18
0.24
0.30
psia
mm Hg


CO_2 Analyzer
Lira Model 300
Accumulator Purity
0-100%
HSD SLS LAB
03H1410
15 psia cal.
Meter Reading
0
20
40
60
80
100
% By Volume
20
40
60
80
100


CO_2 Analyzer
Lira Model 300
Outlet CO_2 Concentration
0-2%
HSD SLS LAB
03H1303
CO_2 Analyzer
Lira Model 300
Inlet CO_2 Concentration
0-2%
HSD SLS LAB
03H1699
Meter Reading
100
80
60
40
20
0
10 psia cal.
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
% By Volume
0.04
0.08
0.12
0.16
0.20
psia
2
4
6
mm Hg

APPENDIX D

Fluid Flow Meter Calibration Curves

Flow Meter (Fluid) Used For Amine CO_2 Concentrator Development & Acceptance Tests

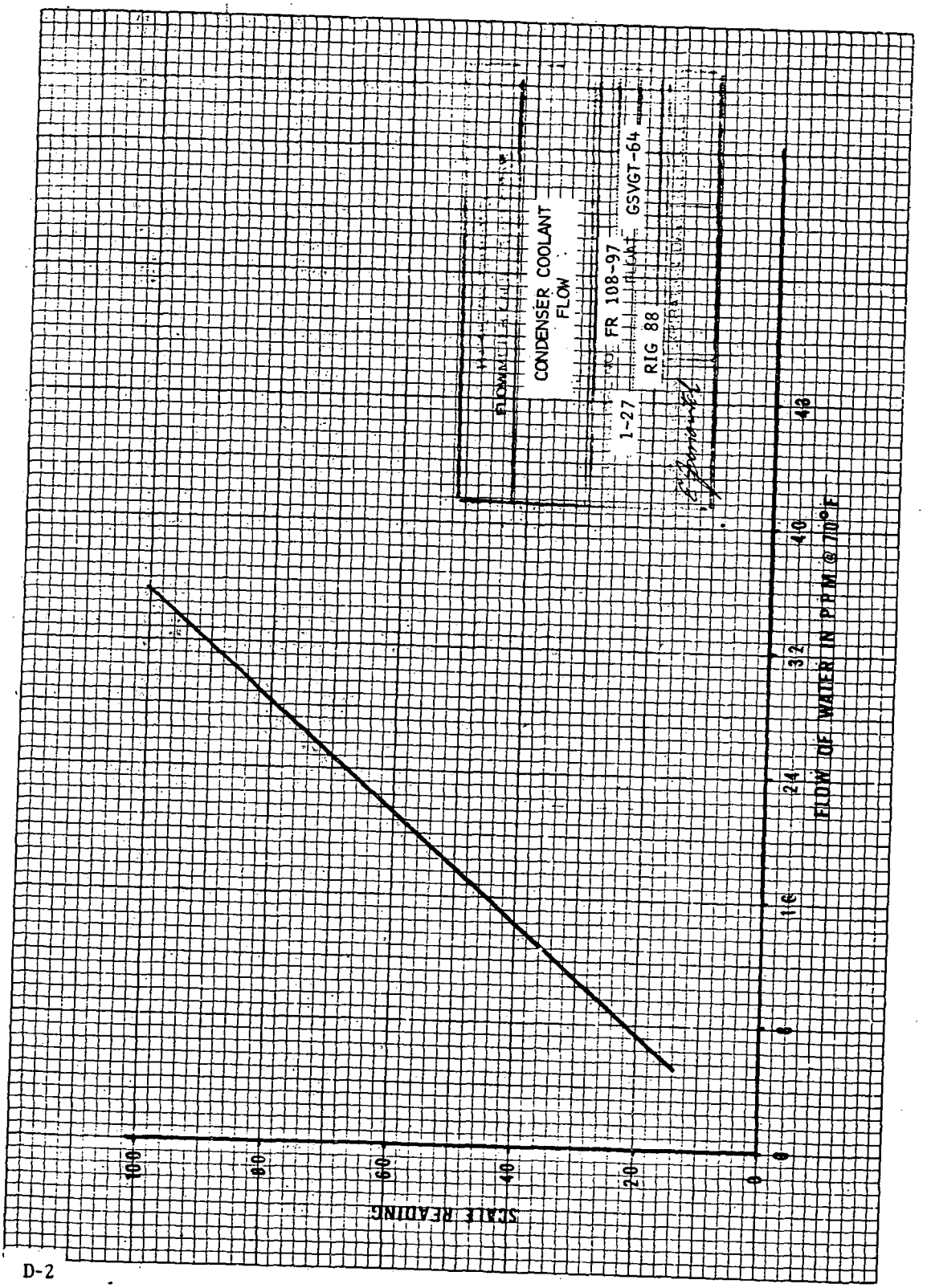
	Flow Meter Serial #
1. Condenser Coolant Flow	FR 108-97 (CCF)
2. Heat Exchanger Coolant Flow	FR 112-29 (ACF)
3. Boiler Hot Fluid Flow	FR 116-30 (BCF)

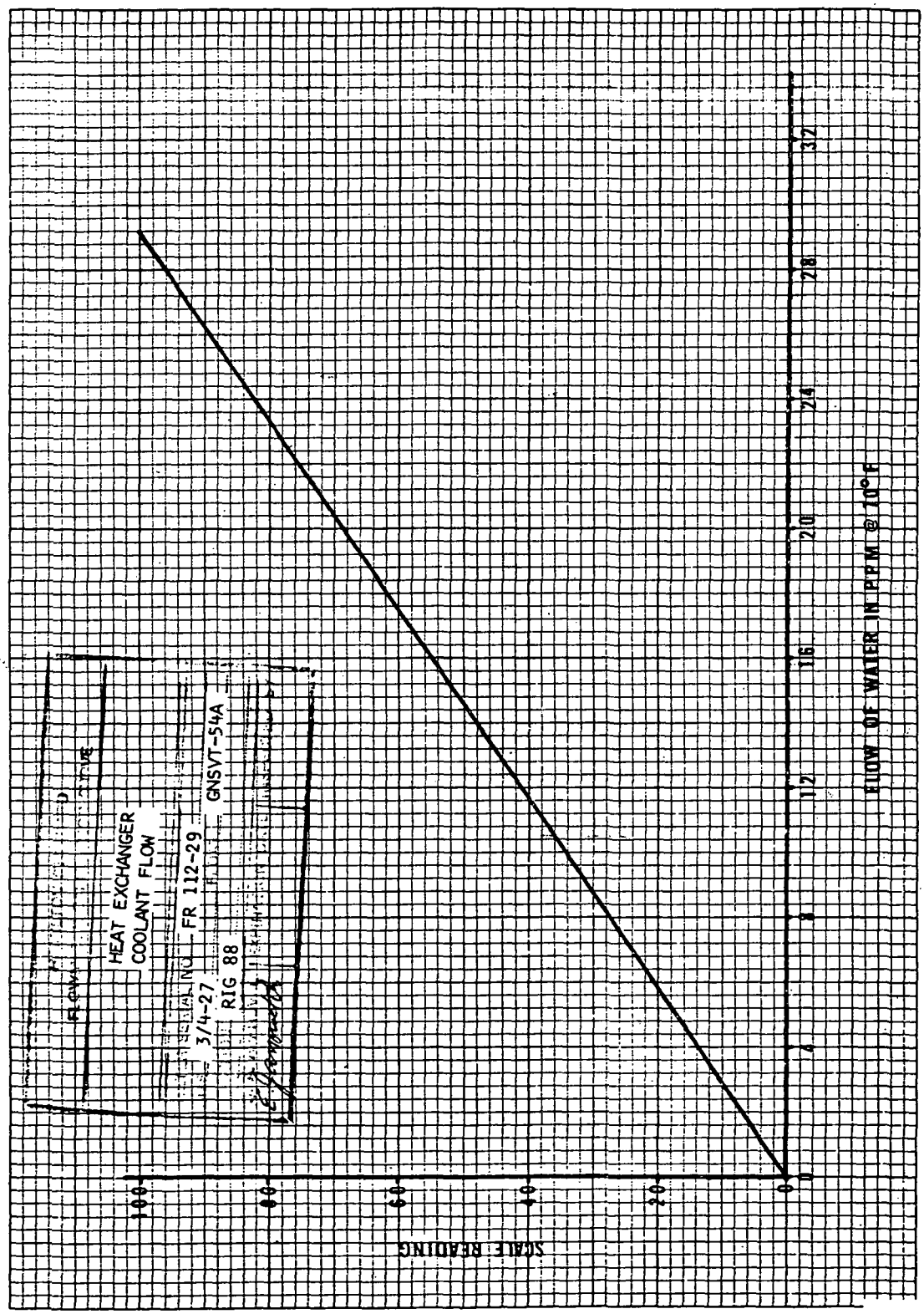
Meters calibrated with water at 70°F

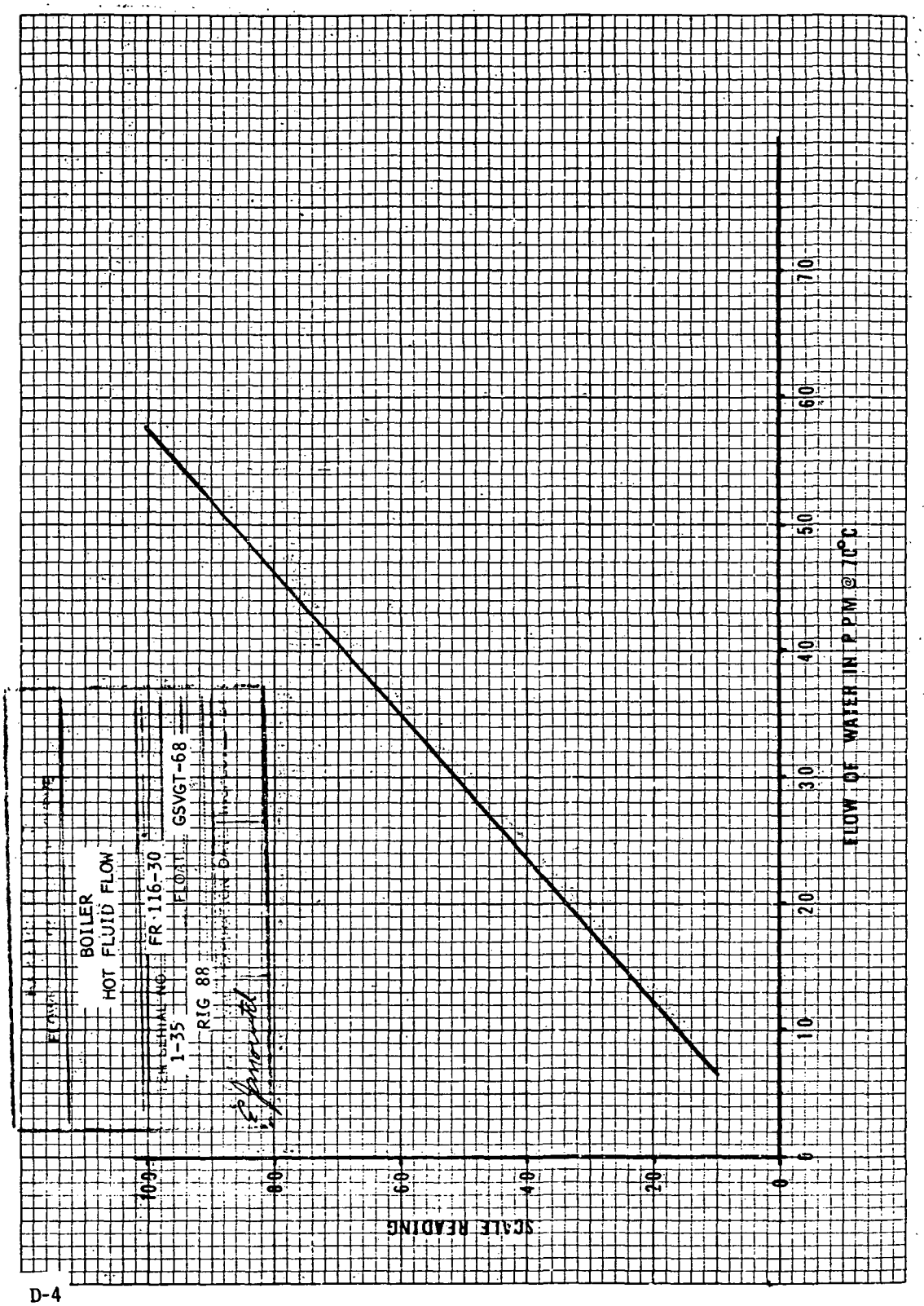
Fluid used in Rig 88 - 70% glycol and water

Approx. equiv. Coolanol 35 flow =

1.53 x 70% glycol and water flow







APPENDIX E

Gas Flow Meter Calibration Curves

System Inlet Flow (SIF)

Venturi Flow Meter Serial #5654

1. Find the $\frac{\Delta P}{P}$ value on Figure 1 corresponding to the system inlet flow ΔP (inches of H_2O) reading on the log sheet (SIF) and the system inlet flow temperature (T_{18}).

2. Determine the system inlet flow (CFM) on Figure 2 corresponding to the $\frac{\Delta P}{P}$ value and the system inlet flow temperature (T_{18}).

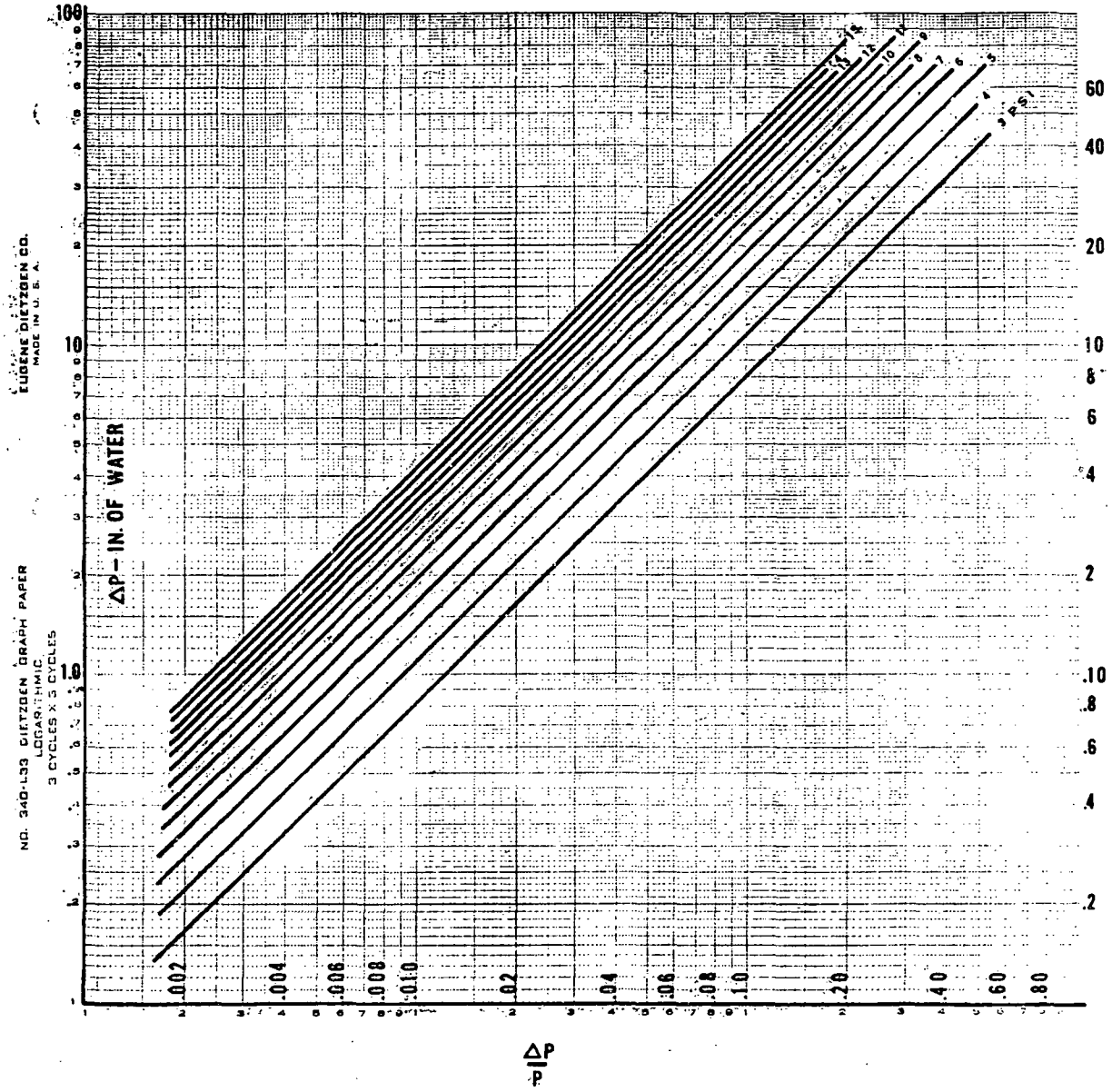

ΔP – IN. OF WATER
ΔP/P
EUGENE DIETZGEN CO. MADE IN U. S. A.
NO. 340-L33 DIETZGEN GRAPH PAPER
LOGARITHMIC
3 CYCLES X 5 CYCLES
PSI

FIGURE E-1

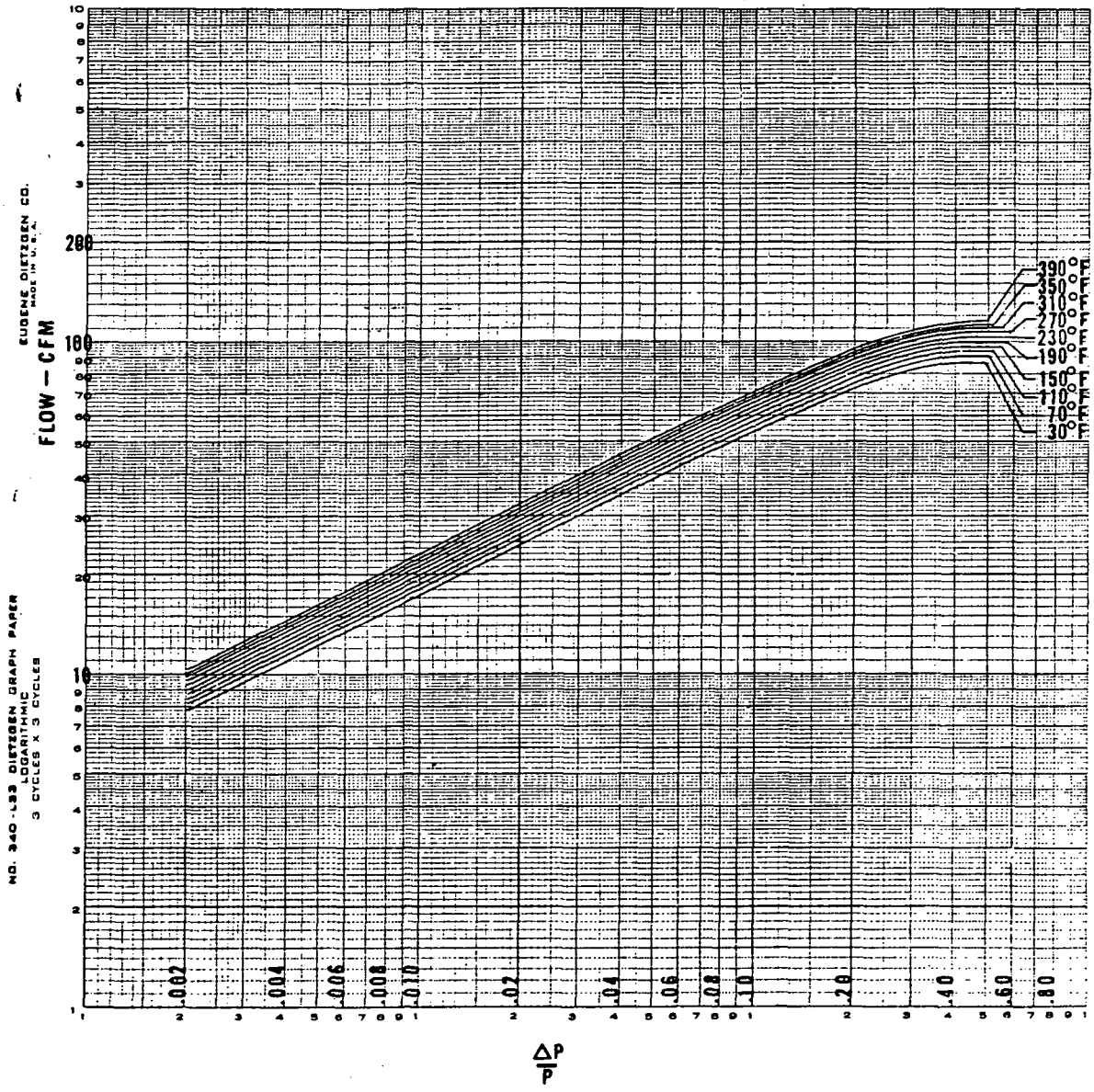

FLOW – CFM
EUGENE DIETZGEN CO.
MADE IN U.S.A.
NO. 340-133 DIETZGEN GRAPH PAPER
LOGARITHMIC
3 CYCLES X 3 CYCLES
390°F
350°F
310°F
270°F
230°F
190°F
150°F
110°F
70°F
30°F
ΔP/P

FIGURE E-2

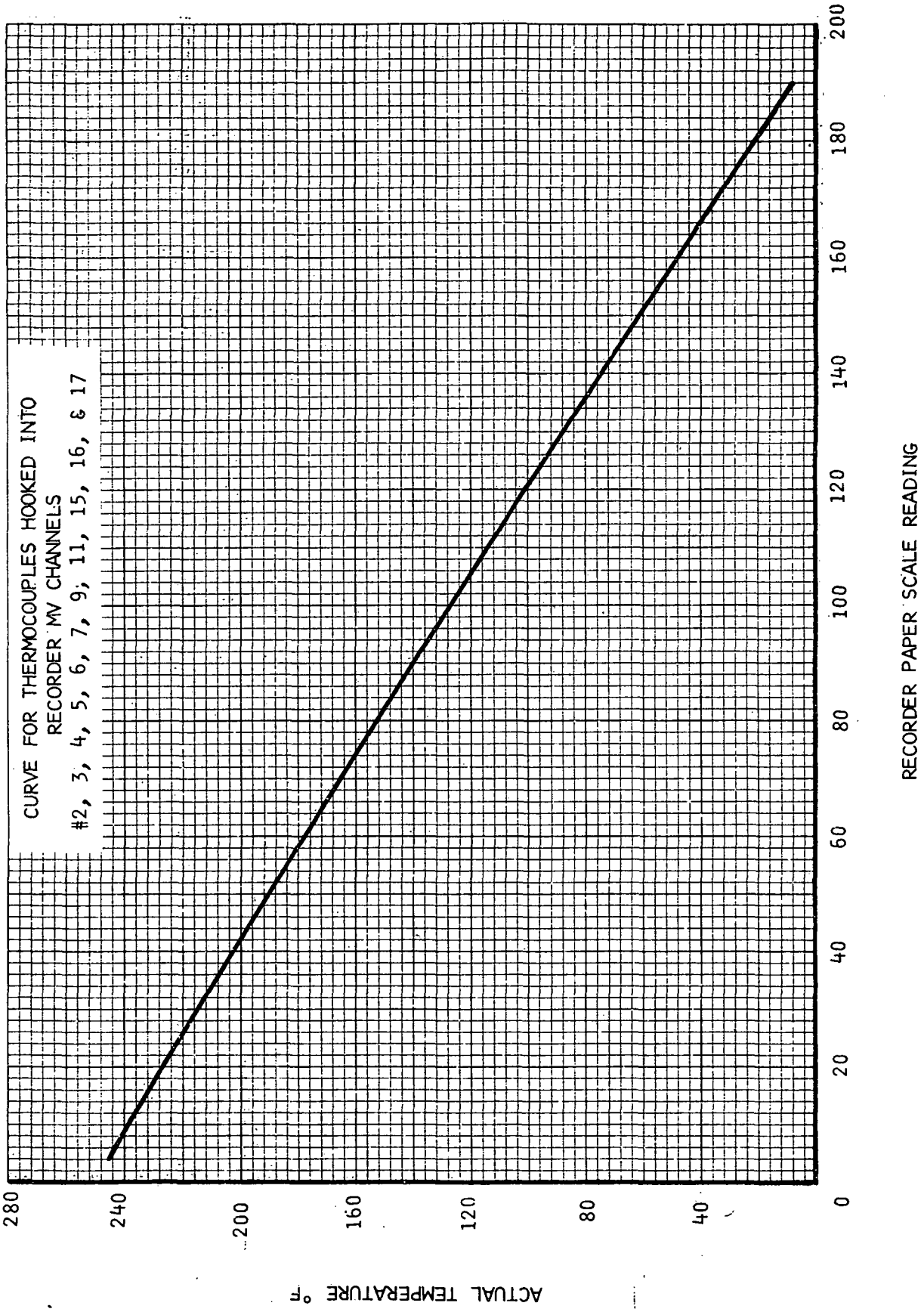
APPENDIX F

Thermocouple Locations

Thermocouple Positions

Recorder Position	Unit Thermocouple	Item Measured	Milli-Volt Channel
1		Boiler Coolant Outlet	
2	T_2	Boiler Coolant Inlet	X
3	T_3	Boiler Steam Outlet	X
4	T_4	Condenser Air Outlet	X
5	T_5	Compressor Air Outlet	X
6	T_6	Condenser Adsorb Air Inlet	X
7	T_7	Air Heat Exchanger Outlet	X
8		Rig Preheater Air Outlet	
9	T_9	Condenser Desorb Air Inlet	X
10		Rig Dew Point Condenser Air Outlet	
11		Rig Dew Point Analyzer Output	X
14		CO_2 Accumulator Tank	
15	T_{15}	Canister #1 Adsorb Outlet	X
16	T_{16}	Canister #2 Adsorb Outlet	X
17	T_{17}	Canister #3 Adsorb Outlet	X
18		System Air Inlet	
19		Condenser Coolant Inlet	
20		Condenser Coolant Outlet	
21		Air Heat Exchanger Coolant Inlet	
22		Air Heat Exchanger Coolant Outlet	
23		Rig Glycol Tank	
24		Room Temperature	

NOTE: Use following curve for #2, 3, 4, 5, 6, 7, 9, 11, 15, 16, 17; remainder of the thermocouple traces are direct reading.


CURVE FOR THERMOCOUPLES HOOKED INTO RECORDER MV CHANNELS
#2, 3, 4, 5, 6, 7, 9, 11, 15, 16, & 17
ACTUAL TEMPERATURE °F
280
240
200
160
120
80
40
0
RECORDER PAPER SCALE READING
200
180
160
140
120
100
80
60
40
20

APPENDIX G

Development Test Plan For Ion Exchange Resin CO_2 Concentrator

HSF-755J 4/67

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION UA®
WINDSOR LOCKS, CONNECTICUT 06096

CODE IDENT NO.	SPECIFICATION NO.	REV
73030	HS	

SPECIFICATION TITLE Ion Exchange Resin CO_2 Concentrator, Acceptance Test Plan for

PREPARED BY Thomas Park DATE 11/25/70 APPROVED BY _____ QUALITY & RELIABILITY DATE

APPROVED BY _____ PROJECT DATE APPROVED BY _____ PURCHASING DATE

APPROVED BY _____ TECH STANDARDS DATE APPROVED BY _____ MANUFACTURING DATE

APPROVED BY _____ MATERIALS DATE APPROVED BY _____ DESIGN DATE

APPROVED BY _____ SPEC CONTROL DATE APPROVED BY _____ DATE

GOVERNMENT APPROVAL _____ WHEN REQUIRED DATE

CUSTODIAN _____

EXP RELEASE _____ DATE PROD. RELEASE _____ DATE

HSF-755.1D 4/67

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

CODE IDENT NO.	SPECIFICATION NO.	REV
73030	HS	

1.0 SCOPE

This test plan details the acceptance tests to be conducted on the Ion Exchange Resin CO_2 Concentrator System designed and fabricated under NASA Contract NAS 1-8944.

2.0 OBJECTIVES

It is the objective of the Amine CO_2 Concentrator to remove the CO_2 production of a 4-man crew and supply the CO_2 to an accumulator at a purity of 98% minimum. These performance goals are defined in more detail in Section 4.1. The performance goals are not contractual obligations. HS will, however, attempt to obtain maximum CO_2 removal performance desirably above the 4-man load to allow maximum degradation margin for the intended 90-day test at MDAC.

3.0 REFERENCES

3.1 HSD drawing SVSK 77060; System, CO_2 Ion Exchange Resin.

3.2 HSD drawing SVSKHS 77068; Concentrator Interface Drawing.

4.0 REQUIREMENTS

4.1 The following are the major performance goals of the Ion Exchange Resin CO_2 Concentrator System:

4.1.1 CO_2 Removal - 9.0 lbs CO_2/day average minimum.

4.1.2 CO_2 Purity - 98% pure minimum.

4.2 The following are minor performance goals of the system:

4.2.1 Water Make-up - 2.5 lbs/day maximum.

4.2.2 Effluent Air Temp - 85°F maximum.

4.3 Interface conditions:

4.3.1 As listed on SVSK 77060.

4.4 Interface configuration:

4.4.1 As defined by SVSKHS 77068.

HSF-755, ID 4/67

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

CODE IDENT NO.	SPECIFICATION NO.	REV
73030	HS	

5.0 TEST DEFINITION

5.1 Nominal Preset Conditions

5.1.1 Pressures

System Inlet and Outlet Pressure	10 psia (±0.1 psia difference inlet to outlet and ±0.3 psia total pressure)
Desorb Pressure	12 psia
Supply to 364 valve	55 psig ±5 psi
Partial Pressure of CO_2	4.0 mmHg at System Inlet ±0.5 mmHg

5.1.2 Temperatures

System Inlet	45-55°F Dry Bulb 35-40°F Dew Point
Canister Inlet	110 ±5°F
Condenser Coolant	40 ±5°F Inlet
Fan HX Coolant	55 ±5°F Inlet
Boiler Coolant	245 ±5°F Inlet

5.1.3 Flows

Fan HX Coolant	Adjusted as required, not to exceed #/min
Condenser Coolant	5.5-7.5 lbs/min
Boiler Coolant	15-20 lbs/min

5.1.4 Timing

Absorb	50 minutes
Desorb	25 minutes

System will be run in 3 can mode with 25 minute separation between initiation of absorb cycle for each canister.

5.2 Data

5.2.1 Temperatures will be plotted on a 24 channel multi-point recorder whose 24 channels will be assigned as follows:

5.2.1 (Continued)

1. Boiler Coolant Outlet
2. T_2 Boiler Coolant Inlet
3. T_3 Boiler Steam Outlet
4. T_4 Condenser Air Outlet
5. T_5 Compressor Air Outlet
6. T_6 Condenser Absorb Air Outlet
7. T_7 Air HX Outlet
8. Preheater Air Outlet
9. T_9 Condenser Desorb Air Inlet
10. D.P. Cond Air Outlet
11. D.P. Anal. Output
12. Inlet LIRA CO_2 Anal. Output
13. Glycol Tank
14. CO_2 Accumulator Tank
15. T_{15} Can #1 Adsorb Outlet
16. T_{16} Can #2 Adsorb Outlet
17. T_{17} Can #3 Adsorb Outlet
18. System Air Inlet
19. Condenser Coolant Inlet
20. Condenser Coolant Outlet
21. Air HX Coolant Inlet
22. Air HX Coolant Outlet
23. Spare
24. Room Temp.

The recorder will be operated continuously throughout the test and each data point will be sampled and recorded every two (2) minutes (approximately).

5.2.2 Flows

The following flow rates will be recorded on the test log sheets at the intervals specified:

System Inlet	3 minute intervals
Boiler Makeup Water	30 minute intervals
Condenser Coolant	30 minute intervals
Air HX Coolant	30 minute intervals
Boiler Coolant	30 minute intervals
CO_2 Usage (Bottle Weight)	30 minute intervals

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5.2.3 Pressures

The following pressures will be recorded on the test log sheets at the intervals specified:

Barometric Pressure	4 hour intervals
System Pressure	30 minute intervals
Desorb Pressure	Strip Chart - continuous
Accumulator Pressure	30 minute intervals
Accumulator CO_2 and O_2 Concentration	30 minute intervals
Hot and Cold Pressure Drop	30 minute intervals
System Inlet CO_2 Concentration	30 minute intervals

5.3 Test Duration

It is intended that the unit shall be operated continuously for a 5 day period. Variations in nominal setup conditions, in addition to those indicated in 5.4, may be made during the test as instructed by the NASA. These variations will be added below during the test and noted on the test log sheets.

HSF-755.1D 4/67

5.4 Alternate Modes

The following attenate modes will be checked during the 5-day test for a 12 hour period.

A. Two bed operation on a 50 minute adsorb and a 25 minute desorb.

B. Timing mode for CO_2 dump to accumulator on normal 3 bed operation.

In addition, each redundant component listed below shall be operated for a 12 hour period minimum.

A. Fan

B. Compressor

C. Pump

APPENDIX H

Test Data Log Sheets

Log Sheet Symbols

	Symbol	Reading
# Bed on Desorb	DB	Number
CO_2 Bottle Weight	CO_2 wt.	Lbs.
Difference Between CO_2 Bottle Weight For Each Desorb	Δ wt.	Lbs.
System Inlet CO_2 Partial Pressure	SIPP	Lira Scale Reading
System Outlet CO_2 Partial Pressure	SOPP	Lira Scale Reading
System Inlet Flow	SIF	Inches of H_2O Across Venturi Flow Meter
System Pressure, Inlet	SPI	Gauge psia Reading
System Pressure, Open	SPO	Gauge psia Reading
Condenser Coolant Flow	CCF	Flow Meter Scale
Air Hx Coolant Flow	ACF	Flow Meter Scale
Boiler Coolant Flow	BCF	Flow Meter Scale
System Inlet Dew Point	SIDP	Cambridge Dew Pointer °F
System Outlet Dew Point	SIDP	Cambridge Dew Pointer °F
H_2O Counter Reading	H_2O C	Number
CO_2 Valve Indicator Light "On"	CO_2 On	Minutes
CO_2 Valve Indicator Light "Off" (Steam Valve Indicator Light "On")	CO_2 Off	Minutes
Accumulator Pressure (Beginning and End of CO_2 Collection)	AP	psia

Log Sheet Symbols (Continued)

	Symbol	Reading
Difference in Accumulator Pressure (For Each Desorb)	Δ AP	psi
Accumulator Partial Pressure	APP	Lira Scale Reading

Checkout Tests

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: CO_2 Atmosphere System
TEST ENGINEER: T Peck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.:

SHEET 1 OF 1 | DATE 2/19/70
TEST PLAN NO.:
MODEL NO.:
PART NO.:
SERIAL NO.:
OPERATORS:

		SIF H_2O	CCF %	ACF %	BCF %	SP	AP	APP	SAP	CO_2	H_2OF	H_2OC									
*	10:50	6.9	20	9	30	10.2	3.5	96	?	161.73	1.8	5									
	11:20	5.9	20	5	30	10.2	1.5	94		161.69	2.2	6		AT START OF BES CAN 2							
	12:05	5.5	21	5	30	10.2	0	92		161.65	3.2	6									
	12:50	5.9	20.5	4	29.9	10	16	95		161.49	3.5	7		STEAM VALVE SWITCHED AT 28 MIN INTO CYCLE							
	1:50	5.9	21	4	30	10	30	95		161.17	3.5	8/8									
	2:25	5.9	21	4	30	10.5	32	95.5		161.02	3.5	9									
	2:50	5.9	21	4	30	10.5	20	95.5		160.99	3.5	9		VENT ACCUMULATOR @ 2:36 38 PSIA							
	3:30	6.1	20	~0	30	10.3	25	96		160.80	3.5	9									
	3:50	5.8	20	~0	29.3	10.1	28.5	94.5		160.65	3.5	9									
	4:25	5.5	20	~0	30	10.1	31	94		160.53	3.5	10									
										160.47				AT SHUT DOWN							

REMARKS: CO_2 Accumulator filled with CO_2 @ 65 psig @ 98% purity. * All readings are taken at 15 min. into the time interval.
Start test 10:30
12:12 H_2O VALVE CYCLED TO #7

79252

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER-5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: CO_2 MINE SYSTEM

TEST ENGINEER: T. PECK

NAME OF RIG:

PROJECT & ENG. ORDER NO.:

SHEET 1 OF | DATE 2/5/70

TEST PLAN NO.:

MODEL NO.:

PART NO.:

SERIAL NO.:

OPERATORS:

	TIME	SIF "H_2O	CCF %	ACF %	BCF %	SP PSIA	AP PSI	APP % S.R.	SAP "H_2O	CO_2 M LBS.	N_2 OP LBS/HR	H_2O C NUM.									
	13:40									160.40											
	14:18	5.6	17.2	~0	29.5	10.3	9.0	92		160.13	?	11						# 3 BED	DESORB		
	14:48	5.6	17.2	~0	30.0	10.25	0*	87		160.01	"	11						# 1 "		"	
	15:20	5.7	17.2	20	29.5	10.3	0*	89		159.80	"	11	ΔP	9 PSI	FOR	ACCUM.	P.	# 2 "		"	
	15:50	5.6	17.2	~0	29.5	10.2	11.5	92		159.60	"	11	ΔP	WPSI	FOR	ACCUM		# 3 BED	DESORB		
+	16:20	5.5	17.2	~0	29.5	10.2	19.5	93		159.40	"	11	ΔP	8 PSI	FOR	ACCUM		# 1 BED	DESORB		
	16:50	4.2	17.2	~0	29.5	10.3	10.05	93		159.30	"	12	ΔP	10 PSI	FOR	ACCUM.		# 2 BED	DESORB		
	17:21	4.3	17.2	~0	29.5	10.3	20.05	95		159.10	"	12	ΔP	9 PSI	FOR	ACCUM.		# 3 BED	DESORB		
		60	MIN.	ADSORB																	
		30	MIN	DESORB																	

REMARKS:

? 2.8 TO 3.5 LBS/HR. + BLED DOWN ACCUM. TO 10 PSIG.

* WORKING ON LIRA - DUMPED ACCUM. FOUND & REPAIRED A LEAK.
15:45 RECALIBRATED 100% LIRA.

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CR-112021
SVHSER 5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: CO_2 AM. & SYSTEM
TEST ENGINEER: T. PECK
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET 1 OF
DATE 2/7/70
TEST PLAN NO.:
MODEL NO.:
PART NO.:
SERIAL NO.:
OPERATORS:

	TIME	SIF "H_2O	CCF %	BCF %	ACF %	SPI PSIA	AP PSI	APP % S.P.	SPI PSIA	CO_2 W LBS.	H_2O F LBS/HR	H_2O C NUM.	B.P. "HG.	SPO PSIA							BED ON DESIRED
	10:10	6.0	17.2	31	35	10.2				157.70				10.3			50	MIN.	ADJUSTED		
	10:20	6.0	17.2	31	35	10.2	22	73		158.70		12	34.3	10.3			25	MIN	DESIRED		2
	10:47	5.6	18.0	31	0	10.1	22	66		158.60		12	34.3	9.9	BLED	ACCUM.	TO	5	PSIG.		3
	11:12	5.2	17.2	31	2	10.1	11	60		158.51		13	34.3	10.2	BLED	ACCUM	TO	5	PSIG		1
	11:40	5.5	17.2	31	2	10.25	6	20		158.41		13	34.3	10.22	BLED	ACCUM.	TO	0	PSIG		2
	12:00	5.2	17.2	30.5	8	10.25	17.8	69		158.31		13		10.26							3
									NO	READINGS											1
	12:55	4.7	17.2	30	8	10.40	12.0	40		158.00		14	34.3	10.1	BLED	ACCUM	TO	5	PSIG		2
	13:20	5.0	17.2	30	8	10.40	16.0	80		157.92	4.0	14	33.8	10.35							3
	13:45	5.5	17.2	30	5	10.40	30.0	78		157.61	4.0	14	33.8	10.35	BLED	ACCUM.	TO	5	PSIG		1
	14:11	4.8	17.2	30	5	10.35	5.0	10		157.41	4.0	14	33.8	10.30		ΔP	13	PSI	ACCUM		2
6	14:31	3.8	17.2	30	5	10.50	16	80		157.28	4.0	14	33.5	10.45	BLED	ACCUM	TO	10	PSIG		3
	15:02	5.3	17.2	30	5	10.51	10	82		157.02	4.0	15	33.5	10.50		ΔP	13	PSI	ACCUM.		1
	15:28	5.2	17.2	30	5	10.35	21.5	84		156.82	4.0	15	33.5	10.32		ΔP	8	PSI	ACCUM		2
	15:50	4.9	17.2	30	5	10.40	28.0	84		156.62	4.0	15	33.5	10.35							3

6 SET FLOW CONTROLLER METER TO 4.
5 READJUSTED WATER PUMP FLOW TO EST 4.0 LBS. OF H_2O/HR.

REMARKS:
1. CONTAMINATED CO_2 BY PURGING SYSTEM GAS THROUGH DRY WATER TRAP.
2. READJUSTED WATER PUMP FLOW TO AN EST. 3.5 LBS. OF H_2O/HR.
3. 11:30 ADDED WATER TO WATER LOOP TO ELIMINATE LEAKAGE.
4. AGAIN READJUSTED WATER PUMP FLOW TO EST 3.8 LBS OF H_2O/HR.

79255

Acceptance Test

1st Attempt

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Acceptance Test
TEST ENGINEER: TPeck, HBrose et al
NAME OF RIG: Multi Purpose #88
PROJECT & ENG. ORDER NO: Amine CO_2 Concentrator

SHEET / OF | DATE 2/10/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP CO_2	SIF	SPI	SPO	AP	APP O_2	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2 W	H_2O	OB	BP	MIN. CO_2 ON	MIN STEAM ON	SIDP	OUT O.P		ACCUM BOTTLE ΔWEIGHT
0818	32	6,0	9.9	9.9	0		[redacted]	17.5	30 ~~17.5~~	0			156.57	1	1	29.87	16	23				0
0845	32	5.0	9.85	9.9	10.2	[redacted]	89	17.5	30	0	22	20	156.42	1	2		14	23	38			.15
0912	32	4.8	9.9	9.9	2 7/41		88	17.5	30	0	22	20	156.28	1	3		12	23	39			.29
0937	32	4.9	9.9	9.9	10		96	18	30	0	22	20	156.12	1	1		13	19	40			.45
1002	32	4.8	9.95	9.95	21		91	18	30	0	22	20	155.91	1	2		14	21	41			.66
1030	32	3.4	9.9	9.9	32.5/30		90	18	30	0			155.29	1	3		12	22½	[redacted]			.80
1053	31.5	4.8	10.0	10.0	42.5/[redacted]		91	17.5	30	*5	22	19	155.62	1	1		14.5	19	43			.95
1123	32	3.9	10.0	10.0	17/16		90	17.5	30	6			155.43	1	2		15	20	42			1.14
1148	33	3.7	10.0	10.05	**2/45		88	17.5	30	6	22	19	155.27	1	3		12	22	41			1.30
1211	31	4.8	10.0	10.0	4/[redacted]		89	17.5	30	6	22	19	155.01	@12:00 2	1	29.78	-		43			1.56
1235	31	4.4	10.0	10.0	4 1/40		85	17.5	30	6			154.81	2	2		16	[redacted]	44			1.76
PM 1:03	35	3.2	10.0	10.0	2		85	17.5	30	6			154.80	2	3		13	19	[redacted]			1.77
1:27	31	4.0	10.0	10.05	16		[redacted]	17.5	30	6			154.61	2	1		14	24	44			1.96 †
1:52	30	3.7	10.05	10.05	19.5		82	17.5	30	6			154.60	2	2		15	-	43			1.97
2:19	32	4.0	10.07	10.10	0		79	17.5	30	6			154.41	2	3		12	22	44			2.16
2:45	34	4.65	10.08	10.10	11.5/40		85	17.5	30	6			154.22	3	1		16	19	45			2.35
3:11	30	3.62	10.05	10.10	17.5/[redacted]		85	17.5	30	6			154.03	3	2		16	20	45			2.54
3:38	27	~~3.09~~	10.10	10.10	24.5/41		~~78~~	17.5	30	6			153.83	3	3		16		46			2.74
4:03	32	4.45	10.10	10.10	39.5/[redacted]		85	17.5	30	6			153.81	3	1	29.43	17	20	46	50		2.95
4:29	31	3.60	10.10	10.10	11.5/100		85	17.5	30	6			153.53	3	2		16	19	46	52		3.04
⊛ 4:50	25	4.90	14.3	14.3	**/15.5		84	17.5	30	6			153.35	4	3		16	21	46	44		3.22
5:20	60	7.3	14.4	14.4	26.5/[redacted]		88	17.5	30	6			153.15	4	1		19	21	46	44		3.42

REMARKS:
Started Test with water manually set to high limit overlaid with a light indication.
Started Test at 8:10 AM * Read a bottom flow meter ** Bled through line for this reading
*Shut down cooling H2O for 1/4 Hr Had to adjust flow ACF at 11:15 ⊛ CHANGED TO RUN INLET PRESS. AT 14.7 PSIA.
† Regul. out ‡‡ Reg. in

76778

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CR-112021
SWISER 5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE TEST
TEST ENGINEER: J. BERTRAND
T. PECK, H. EROSE & CO.
NAME OF RIG: MULTI-PURPOSE #XX
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATION

SHEET 2 OF | DATE 2/10/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP CO_2	SIF	SPI	SPO	AP	APP O_2	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2 IN	H_2O C	DB	BP	MIN CO_2 ON	MIN. STEAM ON	SIDP	OUT DP		ACCUM BOTTLE A WT
5:45	32	5.2	14.8	14.8	29.5		88	18	30	6			152.96	4	2	29.43	18.5	21	46	47		3.58
6:10	26	4.2	14.8	14.8	32.5/32		88	18	30	6			152.78	4	3	29.48	15	20	46	50		3.76
* 6:37	22	7.5	14.8	14.9	42/5		90	18	30	6			152.59	4	1	"	20	22	50	48		3.95
7:02	30	5,5	14.8	14.8	8/8		90	18	30	6			152.58	4	2	"	18	21	46	42		3.96
7:30	24	4.5	14.8	14.8	12/11.8		91	18	30	6			152.58	4	3	"	14	19	46	44		3.96
7:54	24	7.7	14.8	14.8	20.5/20		92.5	18	30	6			152.48	4	1	"	21	21	50	50		4.06
8:29	30	5.3	14.8	14.8	20		—	18	30	6	SEE		152.38	4	2	"	16	20	48	44		4.16
8:46	24	5.8	14.8	14.8	25/24.5		92.5	18	30	6	NOTE		152.37	5	3	29.27	14	20	48	46		4.17
9:12	32	7.8	14.8	14.8	34/34		93	18	30	6			152.19	5	1	"	15	21	52	48		4.35
9:37	32	5.3	14.8	14.8	32/26	*	89	18	30	6			152.09	5	2	"	5	20	50	47		4.45
10:03	31	5.7	14.8	14.85	45/5.5		88	18	30	6			152.08	5	3	"	14	18	50	46		4.46
10:30	30	7.8	14.8	14.8	15/15		92.5	18	30	6			151.98	5	1	"	—	22	50	46		4.58
** 10:50	24	4.8	14.8	14.8	15		93	18	30	6			151.97	5	2	"	15	21	50	48		4.57
I 11:20	24	5.6	14.8	14.9	20.5/20.5		94	18	30	6			151.97	5	3	29.23	15	21	50	48		4.57
11:45	26	7.7	14.8	14.9	28.2		95	18	30	6			151.96	5	1	"	15	22	50	48		4.58
12:14	22	4.6	14.8	14.8	30		90	18	30	6			152.45	5	2	"	15	22	50	48		4.12
12:37	26	5.6	14.8	14.9	35/0		92	18	30	6			152.40	5	3	"	15	22	50	48		4.17
1:04	23	7.7	14.7	14.75	9/8.5		95	18	30	6			152.32	5	1	"	15	22	50	48		4.25
1:29	26	4.7	14.9	14.95	9.0		92	18	30	6			152.20	5	2	"	15	22	50	48		4.37
1:55	26	5.6	14.9	15.0	15.0		94	18	30	6			152.16	5	3	"	15	22	49	55		4.41
2:14	26	7.7	14.9	15.0	20.0		95	18	30	6			152.04	5	1	29.11	15	22	50	Δ_1		4.48
2:45	26	5.9	14.9	15.0	20.0		94	18	30	6			151.99	5	2	"	"	"	Δ	Δ_1		4.58

2/11/70 3/10/70

REMARKS:
* LOWERED FLOWS TO ACCUM. - DRUM FOUND FILLED WITH WATER VAPOR.
1, 9:54 COUNTER CHANGED TO 5. * OPENED CO_2 VALVE TOO FAR, SOME ULLAGE RUNNED INTO THMC.
** RUNNING ON TIMERS, CO_2 VALVE ON IN 15 MIN., ON INTERVAL 6 MIN. THEN STEAM VALVE OPENS.
I CHANGED TO 7 MIN. INTERVAL.
NOTE: MY WTS. IN BRACKETS ARE IN QUESTION — WTS FROM 12:14 ON ARE OK!!
Δ_1 - SENSOR TOO ERRATIC TO READ

79254

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HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE TEST
TEST ENGINEER: R. PETILLO, T. PECK, J. BEATTAND
NAME OF RIG: MULTI-PURPOSE PK 05
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 3 OF
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS
DATE 7/11/70

	TIME	SIPP CO_2	SIF	SPI	SPO	AP	APP O_2	MAP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2W	H_2OC	DB	BP	CO_2 ON MIN.	STEAM ON MIN.	SIDP	OUT DP	FDP	ACCUM BOTTLE ΔWT
AM	3:05	26	5.6	14.9	14.95	24	-	96	18	30	6			151.95	6	3	29.11	15	22	*	*		4.62
↓	3:35	26	8.0	14.9	14.95	31	-	96.5	18	30	6			151.85	6	1	"	"	"	*	*		4.72
	4:05	26	5.9	14.9	15.0	31	-	96.5	18	30	6			151.22	6	2	"	"	"	*	*		4.85
	4:27	25	5.8	14.9	15.0	35	-	96.5	18	30	6			151.64	6	3	29.08	"	"	*	*		4.93
	4:53	23	7.9	14.9	15.0	33	-	97	18	30	6			151.57	6	1	"	"	"	*	*		5.00
	5:18	26	5.9	14.9	15.0	33	-	97	18	30	6			151.48	6	2		"	"	*	*		5.09
	5:44	25	5.9	14.9	15.0	37	-	97.5	18	30	6			151.41	6	3	29.05	"	"	*	*		5.16
	6:11	25	7.8	14.9	15.0	38.5/6	-	97.5	18	30	6			151.35	6	1	"	"	"	*	*		5.22
	6:35	29	5.8	14.9	15.0	6	-	97.0	18	30	6			151.23	6	2	"	"	"	*	*		5.35
	7:02	31	5.9	14.9	14.9	11.5		97.5	18	30	6			151.17	6	3		"	"	*	*	3	5.41
**	7:32	48	8.0	14.9	15.0	16.5		97.5	18	30	6			151.13	6	1		"	"	*	*		5.45
	7:53	31	5.6	14.9	15.0	17.2		96.5	18	30	6			151.08	6	2	29.08	"	"	50	55	3	5.50
	8:26	99	6.1	14.9	15.0	22.5		98	18	30	6			150.00	6	3	"	"	"	51	58		5.58
	8:47	30	8.1	14.9	15.0	30		98	18	30	6			149.09	6	1	"	"	"	54	60	3.8	5.76
	9:12	30	5.9	14.9	15.0	30		98	18	30	6			148.95	6	2	"	"	"	52	60	2.5	5.83
	9:35	30	5.7	14.9	15.0	36		98	18	30	6			148.84	7	3		"	"	51	70		5.94
	9:50		8.0	15.1	15.0	48.5/6		98	18	30				148.78	7	1		**	**	54	57	1.8	6.00
	10:18	30	6.5	15.1	15.0	5		99	18	30				148.63	7	2		14	20	54	59		6.05
	10:33		6.0			13.5		99		22				148.53	7	3		10	17	50	69		6.25
TT	[redacted]	24	7.9	14.9	150	26		99		26				148.41	7	1	29.19			53	62		6.37
	11:55		6.0			26		~~98~~						148.21		2		125					
↓	12:19		6.0	14.9	16.0	33.5		98	18	30	6			148.14		3		10	17	52	58		6.64
PM																							

REMARKS:
* SENSOR TOO ERRATIC TO READ ** changed 364 valve press to 100 psi
*9:46 Flow sensor went erratic when steam bypassed — SHUT H_2O PUMP FOR #1 DESICCANT
9:52 Noted line downstream of cond tripped when #3 went to absorb - Cond coolant outlet was hot for 1 min. During that 1000 ml water from cond 1, 275 from cond 2 & 3. (TT)

79257

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CR-112021
SVHSER 5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE TEST
TEST ENGINEER: J. BERTRAND, T. PECK
NAME OF RIG: RIG 85
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 5 OF | DATE 2/11/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	SIPP CO_2	SIF	SPI	SPO	AP	APP O_2	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2 W	H_2O C	DB	BP	CO_2 ON MIN.	STEAM ON MIN.	SIDP	OUT DP	FDP	ALUM BITTLE ΔP
Φ	8:51	27	7.4	14.9	15.1	25.0	29.5	38	17	30	6			148.10	7	1	29.12		NO STEAM	40	42		0.91
	9:16	30	8.1	14.9	15.1	9/9.0		82	17	30	6			148.01	7	2	"	"	15	38	40		1.00
	9:43	26	7.8	14.9	15.1	9.0/17.0		86.5	17	30	6			147.90	7	3	29.12	9.4	13.6	42	42		1.11
	10:09	31	8.8	14.95	15.1	17.5/[illegible]		90.0	17	30	6			147.80	7	1	"	9.0	19.0	38	42		1.21
*	10:34	24	8.0	14.9	15.1	25/34.5			17	30	6			147.70	7	2	"	8.5	13.5	3*	42		1.31
	10:52	26	7.8	14.9	15.1	34.5/42.0		96 94	17	30	6			147.46	7	3	"	8.0	13.0	42	42		1.55
	11:26	30	8.2	14.9	15.1	5.0/15		97	17	30	6			147.33	7	1	"	9.5	17.5	42	38		1.68
	11:51	26	8.2	14.9	15.1	14.2/23		97.5	17	30	6			147.23	8	2	"	8.0	12.5	42	38		1.78
	12:16	26	7.8	14.9	15.1	22.2/31		98	17	30	6			147.09	8	3	29.25	8.5	13.5	42	42		1.92
↓	12:44	30	8.4	14.9	15.1	30/38.5		99	17	30	6			146.94	8	1	"	10.5	18.0	42	40		2.07
Am	1:07	27	8.1	14.9	15.1	5/15		99	17	30	6			146.83	8	2	"	9.0	13.0	42	40		2.18
	1:33	27	7.7	14.9	15.1	14/22		99	17	30	6			146.66	8	3	"	9.0	12.0	42	40		2.35
	1:58	27	8.4	14.9	15.0	29/31		100	17	30	6			146.54	8	1	"	11.0	19.0	42	40		
	2:25	26	8.0	14.9	15.0	30.5/37		100	17	30	6			146.45	8	2	"	8.5	12.0	41	44		
	2:50	26	7.8	14.9	15.0	37/44		100	17	30	6			146.27	8	5	29.28	7.5	12.0	41	43		
	3:15	26	8.2	14.9	15.0	5/15		100	17	30	6			146.17	8	1	"	11.0	18.0	41	42		
*	3:40	26	8.0	14.9	15.0	15/20		99	17	30	6			146.05	9	2	"	8.0	12.0	41	42		
	4:05	26	7.7	14.9	15.0	20/27		99	17	30	6			145.9	9	3	"	8.0	11.5	41	42		
	4:30	29	8.4	14.9	15.0	24/32		99.5	17	30	6			145.79	9	1	"	10.5	[illegible]	41	42		
	4:53	29	8.2	14.9	15.0	36.5/43		99	17	30	6			145.66	9	2	"	8.5	12.5	40	42		
	5:15	32	7.9	14.9	15.0	0/7.5		98.5	17	30	6			145.45	9	3	"	8.0	13	41	42		3.56
⊙	5:49	31	8.5	14.9	15.0	7/18.5		98	17	30	6			145.34	9	1		11.0	19.0	41	47		

REMARKS:
Φ CLOSED OFF WATER PUMP FOR SECOND TIME FOR BED #1 DESORB.
9:15 CHANGED FROM #1 TO NO 2 PUMP.
* CALIBRATED 100% CO2.
⊙ Held cycle 9 min longer due to having steam on override (set previous cycle 4 hours at 70 return dew point)

79259

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST — AP RISE

TYPE OF TEST: ACCEPT. VCE TEST
TEST ENGINEER: J. BERTRAND, T. PECK
NAME OF RIG: R16 & 8
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 6 OF | DATE 2/11/70
TEST PLAN NO.:
MODEL NO.:
PART NO.:
SERIAL NO.:
OPERATORS:

TIME	SIPP CO_2	SIF	SPI	SPO	AP	APP	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2W	H_2OC	DB	APP [redacted]	CO_2 ON MIN.	STEAM ON MIN.	SIDP °F	OUT DP	FDP V.	ACCUM BOTTLE ΔP
6:24	26	8.0	14.9	15.0	7/15	–	98	17	30	6			145.22	10	2	O_2	8	~14	40	43		
6:52	31	8.1	14.9	15.0	5.5/13.5		83/95 **	17.5	30	6			145.08	10	3		8	12.5	41	42		
7:15	30	8.2	14.9	15.0	13/23		94	17.5	30	6			144.96	10	1		13	19	40	41	1.2	
7:39	27	7.8	14.9	15.0	23/29		94.5	18	30	6			144.88	10	2		8	12	40	42		
8:07	31	7.7	14.9	15.0	28.5/34.5		94.5	18	30	6			144.73	10	3	29.56	8½	13	41	42		
8:31	31	8.4	14.9	15.0	0/6 ***		96	18	30	6			144.60	10	1		14	20	41	42		
9:02	27	8.0	14.9	15.0	5.5/12		96.2	18	30	6			144.51	10	2		9	13	40	42		
† 9:23	29.5	7.5	14.9	15.0	10/17		96	18	30	9			144.39	11	3	29.38	9	13	41	41	1.7	1
9:48	31	8.4	14.9	15.0	17/24		97	18	30	9			144.23	11	1		16.	21	41	42	1.6	
– 10:15	25	7.9	14.9	15.0	23.5/31	7.5	97	18	30	9			144.13	11	2		10	14	41	42	1.6	
10:47	31	8.0	14.9	15.0	30/37	7.8	96.5	17.5	30	9			143.97	11	3		10	14	41	43	1.6	
11:10	31	8.5	14.9	15	0/8	8	96	17.5	30	9			143.82	11	1		16.5	15.5	41	43	1.2	
11:34	25	7.7	14.9	15	7.5/16.5	9	⊙98	17.5	30	9			143.75	11	2		11	15.2	41	42	1.6	
11:59	28	7.7	14.9	15	15.5/24	8.5	97.5	17.5	30	9			143.60	11	3		10	15	41	42	1.7	
12:24	28	7.9			23/29	6	98.5						143.45	12	1		18	22		40	1.4	
12:50	25	7.4			28.5/38	9.5	99.0						143.32		2		11	~15		42	1.8	
PM 1:15	27.5	7.4			5/15	10	99.5						143.19		3		10	15.5		43	1.8	
1:39	27	7.9			12.5/16.5	4	100						143.01		1		19.2	22.5	40	42	1.6	
2:06	26	7.4			16/22.5	11.5	100						142.91		2		11	16.5	41	43	1.8	
†† 2:30	28	7.4			26.5/37	10.5	100			9.5			142.78		3		10.5	16	40	42	1.8	
2:56	27	8.1			15.5/19.2	3.7	100	18	30	9			142.62		1		17	20.2	36	42	1.4	
– 3:30	29	7.2			19/30.5	11.4	99.5	14	30	9			142.46	13	2		11	17	39			

REMARKS:
* STARTED COMPR. #1 ** changed back to #2 comp. #1 comp has small vacuum leak. It dilutes CO_2
*** VENT VALVE ON TANK LEFT OPEN 1-2 MIN. ESTIM. 5 LBS SAY ON PRESS
+ TEMP. T7 CHANGED FROM 117°F TO 105°F ⊙ Calibration checked & found 100% at 98
†† 500 ml. taken out of Bed #1

BP = 29.36
79260 29.51 (3R)

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE TEST
TEST ENGINEER: H. BROSE / R. PETILLO & CO.
NAME OF RIG:
PROJECT & ENG. ORDER NO.:

SHEET 7 OF
DATE 2/12/70
TEST PLAN NO.:
MODEL NO.:
PART NO.:
SERIAL NO.:
OPERATORS:

	TIME	GIPP CO_2	SIF	SPI	SPO	AP	ΔAP RISE	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_2W	H_2O_c	DB	APP	CO_2 ON mm	Steam on min	SDP	OUT DP	FDP	Accum
	3:48	25	6.6	14.9	15	29/40	11	100	18	30				142.37	13	3		10.5	16.5	40	42		0
	4:10	28	7.3	14.9	15	39/41	2	100	18	30	9			142.22	13	1		17	21	42	44		
* ⊙	4:40	28	6.5	14.8	15	5/17	12	99	18	30	9			142.03	13	2		11	18	41	44		
	5:05	26	4.9	14.9	15	17/29	12	99	18	30	9			141.86	13	3		11	17.5	39	40		
	5:35	27	5.3	14.9	15	29/38	9	100	18	30	9			141.75	13	2		11.5	17.5	39	40		
	6:10	27	4.7	14.9	15	4/16	12	100	18	30	9			141.56	13	3		11.5	18.0	40	44		
	6:40	29	5.4	14.9	15	15.5/26	10.5	100	18	30	9			141.31	13	2		12	18.0	40	41		1.06
	7:10	29	4.8	14.9	15	25/36	11	100	18	30	9			141.20	14	3		11.5	18.0	41	43		1.17
*	7:39	24	5.1	14.9	15	35/43	8	98	18	30	9			141.03	14	2		13	20.0	41	42		1.34
*	8:09	22	4.6	14.9	15	5/17	12	98.5	18	30	9			140.86	14	3		11.8	18.0	43	43		1.51
	8:40	27	5.1	14.9	15	16/25.6	9.6	98.5	18	30	9			140.65	14	2		13.5	19.0	40	38		1.72
	9:10	23	4.7	14.9	15	[illegible]/15	10.3	99	18	30	9			140.52	14	3		12	18.5	42	41		1.85
	9:40	25	4.9	14.9	15	5.0/15.5	10.5	98.5	18	30	9			140.34	14	2		14	20	41	41		2.03
Φ	10:17	29	4.7	14.9	15	6/16	10.0	98	18	30	9			140.23	14	3		13	19	42	42		2.14
	10:42	24	4.9	14.9	15	5/12	7.0	98	18	30	9			140.04	14	2		15.5	20	42	42		2.31
**	11:14	22	4.9	14.9	15	11.5/22	10.5	98	18	30	9			139.88	14	3		13	19	41	42		2.47
↓	11:43	15	4.9	14.9	15	9/7	7	97	18	30	9			139.77	14	2		16	20.5	42	42		2.58
	12:14	18	4.7	14.9	15	6.0/14	8	97	18	30	9			139.66	15	3		14	18.5	42	42		2.69
□	12:45	16	4.9	14.9	15	13/17	4	97	18	30	9			139.55	15	2		17	20	41	42		2.80
	1:14	18	4.9	14.9	15	16/23	7	98	18	30	9			139.44	15	3		14	19	44	42		2.91
	1:45	17	4.9	14.9	15	21.5/27	4.5	98	18	30	9			139.34	15	2		16.5	20	42	42		3.01
	2:15	22	4.7	14.9	15	3/10	7	98	18	30	9			139.25	15	3		15	19	42	42		3.10

REMARKS:
* RECAL 100% LIRA
** INLET LIRA SET TOO HIGH - SHOULD HAVE BEEN SCALE READING OF [illegible] BAR 29.56
⊙ CHANGE TO 2 BED OPERATION (30 MIN DESORB)
□ TIGHTENED HEAD BOLTS (8) ON COMPRESSOR #2
Φ ROTORARY VALVE 165 ON B CAN #2 DID NOT FULLY ACTUATE (LOW PRESS. 65 PSI) SEE LOG.

79261

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT. CE TEST
TEST ENGINEER: T. PECK / J. BERTRAND
NAME OF RIG: RIG 88
PROJECT & ENG. ORDER NO.: AMINES CO2 CONC.

SHEET 8 OF
DATE 2/13/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP CO_2	S/F	SPI	SPO	AP	ΔAP RISE	APP. CO_2	CCF	BCF	ACE	HDP	CDP	$CO_{2_{IN}}$	H_2O_C	DB	APP O_2	CO_2 ON MIN.	STEAM ON MIN.	S/DP °F.	OUT DP °F.	FDP V.	ACCUM BOTTLE WT.
2:45	20	4.8	14.9	15	9/12.5	3.5	98	18	30	9			139.16	15	2		17	20	41	41		3.19
3:15	20	4.8	14.9	15	12/18.5	6.5	98.5	18	30	9			139.05	15	3		15	19	41	43		3.30
3:45	17	4.8	14.9	15	17.5/21	3.5	99	18	30	9			138.97		2		17	20	41	43		3.38
4:22	16	5.0			20.5/26.5	6.0	98.5						138.87		3		15.5	19	40	40		3.48
4:53	20	4.9			5/9.5	4.5	99						138.77		2		17	20	40	41		3.58
5:25	20	5.0			9/15	6.0	99						138.68		3		15	19	40	40		3.67
* 5:53	17	4.95			14/17.5	3.5	99						138.60		2		22	20		41		3.75
6:25	32	4.95			17/22	5.0	99						138.49		3		15	20		41		3.86
6:54	28	4.9			21/26	5.0	98.5						138.36		2		16	21		41		3.99
7:25	32	4.95			24.5/32	7.5	99						138.25		3		14.5	21	41			4.10
** 7:44	29	4.95			6.5/9	3.5	99						138.17		2		16.5	No Switch	40			4.18
@ 8:04		4.85	14.9	15	8.5/14	5.5	99	18	30	9			138.11	15	3		14.5	18.5	40	42		4.24
*** 8:26	27	4.9			13.5/17.5	4.0	99			9			138.01	15	2		15.5	19	41	41		4.34
@@ 8:50	17	4.95			10.2/16	6.0	99			9.2			137.91	16	3		15	19	40	40		4.44
9:10	19	4.9		15	10.5/14	3.5	99	17.5	30	12.5			137.83	16	2		16	20	41	43		4.52
9:30	19	4.95	14.9	15	10.4/14	3.0	99	17.5	30	12			137.76	16	3		15	19	41	42		4.59
9:50	19	4.5			10.5/14.5	—	—	17.5	30	12.5			137.71	16	2		18	19	41	44		4.64
10:20	22	5.0	14.9	15	13.3/17	3.7	99	17.5	30	11.5			137.66	16	3		15	18	40	41		4.69
10:40	13	5.0	14.9	15	10/12.2	2.2		17.5	30	11.5			137.61	16	2		17	20		42		4.74
X 11:12	24	4.9	14.9	15	12/14	2		17.5	30	15			137.56	16	3		16	20				4.79
11:25	15	5.0	14.9	15	13.0/15	2	99	17.5	30	15			137.50	16	2		17.5	20	41	43		4.85
XX 11:47	20	4.9	14.9	15	13.5/17.2	3.2	99	17.5	30	15			137.50				17	20	40	43		

REMARKS:

* LIRA TO 28 maintain percentage of CO_2/min
** CHANGED TO 20 min. cycle
@ set Flow control at 1 MV, bad inlet valve.
@@ changed to 100 °F bad inlet valve.
X to ADP Inlet Duct Temp.
■ set 364 valve press at 100 # used needle valve to control flow rate.
*** changed Lira back to 17
XX started recording out in error

BP 5AM 29.51 "Hg

79262 auto stds

NSP-178.1A 1/67

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE TEST
TEST ENGINEER: H. BROSE / R. PETILLO & CO.
NAME OF RIG: RIG 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC

SHEET 9 OF
DATE 2/13/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	Time	SIPP CO_2	SIF	SPI	SPO	AP	ΔAP	APP CO_2	CCF	RCF	ACF	HOP	COP	COW	H_2O	DB		CO_2 ON	STEAM ON	SIDA	SODP	H_2O ml	Accum Bottle wt
PM	12:19	10	5.0	14.9	15.0	8.0/10.5	2.5	98.5	17.5	30	15			137.36	16	2		17	20.5	40	41		1
	12:28	*	4.6			10/11.5	1.5	99	18	30	15			137.36		3		17	20	39	43		4.99
	12:48	21	4.0			11.8/13.8	1.8	99						137.31		2		17	20.5	52	53		5.04
	1:10	16	4.5	14.85	14.95	12/14.5	2.5	99.5			9**			137.24		3		17	20.5	41	50		5.11
	1:30	40+	4.2		15.0	13.2/15.5	2.3	100						137.19		2		17	20	41	42		5.16
	1:53	29†	4.7			15/16.5	1.5	99.8			9.5			137.15		3		17	20	41	42		5.20
	2:19	17	4.9			16/17.2	1.2	99.8						137.10		2		17	19.8	1	1		5.25
	2:35	17	4.5			15.5/— ††	—	100						137.07		3		16.7	19.2	45	44		5.28
	2:59	17	4.0			14.5/								137.02	16	2		17		41	45		5.33
	3:36	20	5.0			11.5/13	1.5				9.5				16	3		17	20	41			
	3:55	21	5.0			12/14	2	99						136.94	16	2		17	20			190	
X	4:10	19	5.2			14/16	2	100			17			136.94	17	3		16	18	40	42	175	5.41
	4:31	13	5.2			15/17	2	100			17			136.88	17	2		16	19	41	41	265	5.47
	4:52	15	5.2			13.9/15	2	100	18	30	17			136.82	17	3		16	19	40	42	220	5.53
	5:13	15	5.2	14.9	14.95	14.5/17	2.5	100	18	30	17			136.78	17	2		16	19	40	41	280	5.57
	5:34	16	5.3			15.5/18	2.5	100	18	30	17			136.74	17	3		16	18.5	40	41	225	5.62
	5:56	22	5.4	14.9	14.95	14/17	3	100	18	30	17			136.69	18	2		15	18.5	1	1	215	5.69
	6:19	14	5.3	14.9	15.0	16/18.5	3.5	99	18	30	17			136.62	18	3		15	18.5	40	41	225	5.76
	6:41	14	5.3	14.9	15.0	17.5/21	3.5	99	18	30	17			136.56	18	2		15	18	1	1	260	5.82
	7:02	14	5.4	14.9	14.95	19.5/23	3.5	99	18	30	17			136.49	18	3		15	18	42	44	205	5.89
	7:23	13	5.3	14.9	15.0	21/24	3.0	99	18	30	17			136.43	18	2		15	18	42	42	255	5.95
	7:46	12	5.4	14.95	15.0	23/26	3.0	97	18	30	17			136.36	19	3		14.5	18	42	42	215	6.02

REMARKS:
* RESET ADJUST. ON CONTROLLER (VALVE) CO_2 INLET
** INCR. CANIST. TEMP (INLET) TO 110°F
† INLET CO_2 STILL VARIABLE
†† NO REHPING - VALVE LEFT OPEN
X changed temp canister inlet to 80°F
DRAINED [illegible] FROM BED 1 @ 5:30 PM

76785

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACL. TANCE TEST
TEST ENGINEER: J. BERTRAND, T. PECK
NAME OF RIG: RIG 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 10 OF
DATE 7/13/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP CO_2	S/F	SPI	SPO	AP	ΔAP	APP CO_2	CCF	BCF	ACF	HDP	CDP	CO_{2W}	H_2O_C	DB		CO_2 ON	STEAM ON	S/DP	SODP	H_2O mb	ACCUM BOTTLE WT.
8:02	16	5.5	14.9	14.85	25/26	3	99	18	30	17			136.30	19	2		14.5	18	41	42	270	6.08
8:30	17	5.3	14.9	15.0	9/13	4	99	18	30	17			136.26	19	3		14.5	18	41	42	220	6.12
8:45	13	5.3	14.9	15.0	12/16	4	99	18	30	17			136.19	19	2		14.0	17.5	42	42	250	6.19
9:06													136.11									6.27

SHUT OFF WATER PUMP & COMPRESSOR.*

SHUTDOWN PROCEDURE

1.) #2 ON ADSORB FOR 30 MIN.
#1 & #3 ARE ON ISOLATE
BRING CANISTER INLET TEMP. UP TO 100 °F.

2.) #3 ON ADSORB (30 MIN.)
#1 & #2 ARE ON ISOLATE

3.) #1 ON ADSORB FOR 30 MIN.
#2 & #3 ARE ON ISOLATE

NOTE: BED #1 STARTED WITH A HIGH ΔP
PUT BED #2 ON ADSORB ALSO TO PREVENT OVERHEATING FAN.
INCREASED GAS INLET TEMP TO 110°F AND STILL
FLOW WOULD NOT PASS THROUGH BED (3 ΔP ACROSS RIG FLOWMASTER)

4.) CHECK CANS #1, 2 & 3 FOR FREE ACCUMULATED WATER - NONE

5.) PUT BEDS #1, 2 & 3 ON ADSORB. 11:00 TO 12:30

REMARKS:
* TESTED OUT NEW INTERLOCK - WHEN COMPRESSOR CIRCUIT BREAKER WAS SHUT DOWN WATER PUMP WAS AUTOMATICALLY SHUT OFF.

NOTE: CALIBRATED NO 3 WATER PUMP - FOUND LOTS OF PARTICLES IN THE WATER BEING PUMPED IN CANISTER. 400 GRAMS IN 10 MIN. (5.3 LBS/HR)

79263

Development Tests

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Bed Adsorption Profile
TEST ENGINEER: T Peck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 11 OF | DATE 2/17/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP	SIF	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF			CO_2	H_2O	DB	SOPP	CO_2 ON	STEAM ON	SIDP	SODP	H_2O D
2:30	16	5.5	14.9	15	5/21	16	7.3	17.5	295	37				24	3 Zeolite Abs.			22	60		215
2:35	20	5.5	14.9	15	20.5/~~27~~	~~10.5~~	7.9	17.5	295	39				25	3 only adv 2		14	22	63		155
4:30	—	5.3	14.9	15	2/13.5	11.5		17.5	29.5	10				25	3		11	19	60	60	315
2:25													132.87								
2:30													.85								
2:35					#2 adsorbing								.80								
2:40													.78								
2:45													.76								
2:50													.76								
2:55													.75								
~~3:00~~													.74								
3:05													.73								
3:10													.73								
3:15													.72								
3:20													.72								
3:26													.72								
3:30													132.72								
3:35	5												.50			0					
3:40	10				#3 adsorbing								.66			1					
3:45	20												.63			1					
3:50	19												.60			3					
3:55	22												.58			5					
4:00	22												.57			6					
4:05	19												.55			9					
4:10	19												.54								
4:15													.54								

REMARKS: Started Test with a desorb of bed #2 @ 1:55 PM * Started with N2 in accumulator

79264

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: RED ABSORPTION PROFILE
TEST ENGINEER: T. PECK
NAME OF RIG: 58
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 12 OF
DATE 7/18/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SIF	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF			CO_2 W	H_2O C	DB A/B	SOPP	CO_2 ON	STEAM ON	SIDP	SODP	H_2O D ML
10:30	16	5.3	14.9	15	17		~~15~~	18	29	38			132.52		1	7			60	62	
10:35	17	5.2	14.9	15				18	28	38			132.52		1	7			60	62	
10:40	17	5.2	14.9	15				18	28	38			132.50		1	6			59	58	
10:45	16	5.0	14.9	15									132.50		1	—			60	59	
10:50	17	5.1	14.9	15									132.50		1	—			60	61	
10:55	18	5.1	14.9	15									132.49		1				59	58	
10:58	START DESORB														1						
11:00A					12		88								DB		18				
1:40P	14	5.0	14.9	15	5/13	8	88			26			132.23	28	2		13	20	40	47	185
2:07	20	5.6	14.9	15	13/17	4	89			26		.03	132.20	28	1		19	24	38	46	330
2:35	17	5.0			17/23.5	6.5	89					.11	132.09	29	2		12	17	39	~~49~~	190
3:05	17	5.7			21/25	4	90					.12	131.97	29	1		19	23	48	48	310
3:35	17	5.0			25/33	8	90					.08	131.89	29	2		12	17	48	48	200
4:05	17	5.5			28/32.5	4.5	91					.08	131.81	29	1		19	23	44	44	335
4:35												.11	131.70	30	2						

REMARKS:

79265

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: BED A4 ORPTION PROFILE
TEST ENGINEER: H. BROSE / R. PETILLO / TI PEG
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONC.

SHEET 12 OF | DATE 9/19/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SIF	SPI	SPD	AP	ΔAP	CO_2 APP	CCF	BCF	ACF	ΔW	#1 CO_2 WC	#2 CO_2 WC	HDC	DB	SOPP	CO_2 ON	STEAM ON	SLOP	SODP	H2OD mL
9:09	17	~~5.5~~	14.7	14.7	0/8	8	94	17	29	78		←	131.70	30	2		16~~7~~	20.5	~~37~~	—	265
9:38	17	5.7	|	|	8/15	7	93	|	27	70		←	131.59	|	1		2~~4~~.5	N.T.	39	41	325
10:10	17	5.3	|	|	14.5/21.5	7	94	|	|	68		←	131.49	|	2		14	18.5	|	41	230
10:38	22	5.7	|	|	21.5/29	7.5	94	|	|	|		* 131.39	131.30	31	1		18.5	24	|	|	335
11:09	18	5.3	|	|	~~29.5~~/36.5	8	93.5	|	|	|		131.28	131.21	|	2		14.5	20	|	|	220
11:48	19	5.6	|	|	36.5/8	6.5	~~88~~ 94	|	30	|		131.18	131.10	32	1		20	—	|	|	270
12:08	17	5.2	|	|	7.5/15.5	8	96	|	29	|		131.06	130.99	|	2		15	20	|	|	230
10:39	21	5.6	|	|	15.5/21.5	6	96	1	1	67.5		130.94	130.86	|	1		21	26	|	|	370
1:08	17	5.3	|	|	21.5/30	8.5	96.2	17	30	68		130.82	130.76	|	2		15.5	81	|	|	250
1:38	21	6.1	|	|	30/36.8	6.8	96.5	|	29.5	67.5		130.71	—	33	1		21.5	27.5	|	40	360
2:08	13	5.3	|	|	5/14.5	9.5	96	|	|	|		130.62	130.57	|	2		16	22	|	41	260
2:37	19	5.5	|	|	14/20.5	7.5	97	|	|	|		130.49	130.44	34	1		20.5	26	|	|	~~343~~
3:07	18	5.2	|	|	21.5/31	9.5	97	|	|	|		130.41	130.34	34	2		16	22	|	|	265
3:37	19	8.7	|	14.8	31/34	3	96	17	29.5	68.5	.14		130.27	130.21	34	3		17	20	|	|	300
4:00	17	9.0	|	14.7	6.5/13	6.5	95	|	|	68	.12		130.15	130.08	34	~~2~~ 1		19	NO TRIP	|	|	290
4:25	17	8.7	14.7	14.7	13/23.5	10.5	96	|	|	|	.16		129.99	129.95	35	2		16	22.5	|	39	300
4:50	17	8.7	14.7	14.7	22/28	6	96	|	|	|	.10		129.89	129.79	35	3		15	22	|	41	265
5:15	17	9.1	|	|	28/34	7	96	|	|	|	.15		129.74	129.65	36	1		19	NO TRIP	|	|	375
5:40	17	8.6	|	|	1/12	11	96	|	|	|	.19		129.55	129.50	|	2		15	23	|	|	295
6:05	17	8.7	|	|	12/24.5	12.5	97	|	|	|	.13		129.42	129.37	|	3		15	22	|	|	305
6:30	17	9.1	|	|	24/32	8	97.5	|	|	|	.16		129.26	129.18	37	1		18	NO TRIP	|	|	350
6:55	18	8.8	|	|	10/21	11	97	|	|	|	.19		129.07	129.04	37	2		15.5	23	|	|	310

REMARKS:
* CO_2 WC @ START OF CYCLE / 15 min. into cycle
⊡ SWITCH TO [illegible] OF INTAKE (25 MIN DSB)

79266

HSP-178.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: BED ADSORPTION PROFILE
TEST ENGINEER: J. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONC

SHEET 14 OF
DATE 2/19/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SIF	SP1	SPO	AP	ΔAP	CO_2 APP	CCF	BCF	ACF	ΔW	#1 CO_2 W	#2 CO_2 W	H_2O C	DB	SOPP	CO_2 ON	STEAM ON	SIDP	SODP	H_2O D ML
7:20	12	8.8	14.7	14.7	21/34	13	97	17.5	29.5	67.5	.10	128.97	128.87	37/38	3		15	22	41	41	300
7:45	16	9.0			5/14	9	97.5				.19	128.78	128.70	38	1		17.5	NO TRIP			340
8:10	18	8.7			14/25.5	11.5	98				.17	128.61	128.54	38/39	2		15.5	23			315
8:35	18	8.7			25.8/37.5	12	98				.15	128.46	128.40	39	3		15	23			285
9:00	17	9.0		14.8	10/12.5	2.5	98				.17	128.29	128.20	39	1		17.5	NO TRIP			345
9:25	17	8.8			17.5/29.5	12	98				.17	128.12	128.05	39/40	2		15	23			320
9:50	17	8.7			29.5/41.5	12	98				.12	128.00	127.91	40	3		15	22.5			300
10:15	17	9.0			5/14	8	98				.17	127.83	127.74	40	1		17.5	NO TRIP			345
10:40	17	~~8.6~~ 7.60			14	—	98				.18	127.65	127.60	40	—		—	—			—
11:05	17	5.2			14	—	98				.12	127.53	127.50	40	—		—	—			—
11:30	—	—	—	—	14	—	98	—	—	—	.09	127.44	—	40	—		—	—	—	—	—

REMARKS:
* SHUT DOWN H_2O PUMP & COMPRESSOR

79267

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3 Bed 2, 10 Cycle 50% Adsorb
TEST ENGINEER: H Brose / R. Petillo
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 15 OF. DATE 2/20/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP	SIP	SPI	SPO	AP	ΔAP	APP	CCP	BLF	ACF	#1 CO_2 W	#1 CO_2 ΔW	H2O	DB	SOPP	CO_2 ON	Steam ON	SIDP	SOOP	H_2O ON
9:45	17	9.3	14.7	14.7	22/6.5	14.5	9.3	17.5	30	6.6	127.75	ΔW	41	3	10	8	15	3.9	41	≈230
10:10	17	9.3	14.7	14.7	6/21.5	15.5	9.8				127.26	.14	42	1	7	7	16	3.9	42	250
10:30	17	9.1			21.5/32.5	11	9.5				127.11	.15		2	7	8	14			235
10:55	17	9.0			0/11	11	9.6				126.95	.16	43	3	7	9	?			230
11:15	17	9.2			10.5/19.5	9	9.5				126.80	.15		1	6	9	15		43	280
11:35	17	9.1			19.5/30	11.5	9.5				126.64	.16		2	6	8	13	3.9	42	240
11:49	15	8.9			5/16.5	11.5	9.7			6.5	126.50	.14	43/44	3	7	9.5	14		50	205
12:10	15	9.0			4.5/25.5	9	9.5				126.33	.17	44	1	6.5	10	15		48	280
12:29	13	8.7			4/15	11.0	9.7				126.19	.14		2	6.5	9	14			200
12:50	13.5	8.8			15/26.5	11.5	9.7				126.02	.17		3	5.5	9.5	14.5			225
1:10	16	8.7			4/13.5	6.5	9.7				125.89	.13	45	1	6	10	15.5		56	270
1:30	17	7.5			13.5/24.5	11	9.7				125.73	.16		2	10	9.5	14		41	200
1:51	16	8.4			2/14.5	12.5	9.7	18			125.61	.12		3	4	9.5	14.5		42	220
2:13	14	8.4			14/22	8	9.7				125.44	.17	45/46	1	5	9.5	15		41	265
2:35	16	8.9			22/32	10	9.7				125.28	.16	46	2	6	9.5	14		44	200
2:57	16	9			0/11.5	11.5	9.7				125.14	.14		3	6	10	14.5		41	220
3:17	16	9.1			11/21	10	9.7	17.5			124.99	.15		1	6	9	15		44	275
3:38	17	9.0			19/30	11	9.7				124.84	.15	47	2	7	9	14.5		42	215
3:59	17	8.9			30/40	10	9.7				124.68	.16		3	5	9.5	16		45	220
4:20	17	9.1			35/45	10	9.7				124.54	.14	48	1	5	9.5	17			290
4:40	17	9.0			2/12	10	9.7				124.39	.15	48	2	6	10	14.5			200
5:00	17	9.0			12/23.5	11.5	9.7				124.25	.14	48	3	6	8	15			220

REMARKS: started test at 9:30 AM with both H_2O pump running. started with #2 bed desorb. started to take data on #3 bed desorb

79268

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3 BED 1/40 CYCLE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO. CONCENTRATOR

SHEET 16 OF
DATE 2/20/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SIF	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF		#1 CO_2N	ΔW	H_2OC	DB	SOPP	CO_2 ON	STEAM ON	SIDP	SODP	H_2O ML
5:20	17	9.2	14.7	14.7	22/32	10	96.5	17.5	30	66		124.10	.15	48/49	1	6	9	15	39	43	280
5:40	17	9.1			29/38.5	10.5	96.5					123.94	.16	49	2	6	9.5	16			230
6:00	17	9.0			5.5/17	11.5	96.5					123.79	.15	49	3	6	10	15			225
6:20	16	9.0			12/21.5	9.5	96					123.64	.15	49/50	1	6	9.5	16			270
6:40	17	8.9			21.5/31.5	10	96.5					123.49	.15	50	2	6	10	15			240
7:00	17	8.9			22.5/38	10.5	96.5					123.34	.15	50	3	6	10	16			230
7:20	17	9.1			6/15.5	9.5	97					123.20	.14	50/51	1	6	9	16			285
7:40	17	9.0			15.5/25.5	10	97					123.04	.16	51	2	6	10	15			235
8:00	17	8.9			25.5/36.5	11	97			68		122.89	.15	51	3	6	10	16			225
8:20	17	9.0			36.5/45	8.5	98			69		122.75	.14	51/52	1	6	9	17			280
8:40	16	8.8			5/15.5	10.5	98			67		122.60	.15	52	2	5	10	15			230
9:00	16	8.8			15.5/26.5	11	97.5					122.45	.15	52	3	6	10	15			235
9:20	17	8.9			5/14	9	97					122.31	.14	52/53	1	6	9.5	16.5			280
9:40	17	8.4			4/24.5	10.5	98					122.16	.15	53	2	5	10	15			225
10:00	17	8.8			24.5/35.5	11	98*					122.02	.14	53	3	6	10	15.5			235
10:20	16	9.0			5/14	9	97					121.86	.16	53	1	3**	10	16.5			290
10:40	17	8.9			14	—	97					121.71	.15	53	~~2~~	3	—	—			—
11:00	18	5.7			14	—	97					121.56	.15	53	—	10	←	—			—
11:15	—	—	—	—	—	—	—	—	—	—	—	121.47	.09	—	—	—	—	—	—	—	—

REMARKS:
* RE CAL
** H_2O PUMP, COMPRESSOR OFF

79269

HSP-175.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3 bed 4. Candidate 20/90 cycle
TEST ENGINEER: H Brose / T. Fink
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO2 Concentrator

SHEET 17 OF | DATE 2/21/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	S:PP	SOPP	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF	SIF	CO2M	ΔW	OB	CO2 ON	Steam ON	SIDP	SODP	H2O °C	H2O ML
9:25	F		14.7	14.7	~~19.5~~ 19.5	11	95.5	17.5	30	100	10	~~0.00~~		2	19	15	33		53/54	275
9:45	17	8			22.5 / 32.0	14.5	97			100+	9.2	121.38		3	10	17	35	41	54	250
10:05	17	4			5.5 / 19.0	14.5	94				9.2	121.27	.11	1	10	18	37	44	54	280
10:25	18	4			19.0 / 30	11	97				8.9	121.10	.17	2	10.5	18.5	45	47	55	270
10:45	17	4			29.3 / 40	10.7	97				9.0	120.95	.15	3	10.5	16	45	47	55	265
11:05	17	5			5.0 / 14.2	9.2	97				9.2	120.80	.15	1	10	18.5	45	45	55	275
11:25	17	3			14.0 / 25.0	11	97.5				9.0	120.64	.16	2	10.5	15	42	45	56	250
11:45	17	4			25.0 / 36.0	11	98				9.0	120.49	.15	3	10	16	41	43	56	245
12:05	17 17 17 / 18 18 18	3 3 5.6 / 5.5 7			0.5 / 9.5	9	97				9.3	120.33	.16	1	10	16.5	41	44	56	265
12:25	18	4			9.5 / 21.0	11.5	97.5				9.0	120.18	.15	2	10.5	15.5	42	44	57	250
12:45	18	3			21.0 / 32.0	11	97				8.9	120.03	.15	3	10	16	40	44	57	225
1:05	17	3			31.5 / 40	8.5	97				9.1	119.85	.18	1	10	17	40	44	57/58	310
1:25	17	3			6 / 17	11	96.5				8.9	119.70	.15	2	10.5	15	40	1	58	250
1:45	17	3			16.5 / 28	11.5	97				8.9	119.56	.14	3	10.5	15.5	1	1	58	240
2:05	17	3			28 / 36	8	97				9.0	119.41	.15	1	10.5	16.5	1	1	58/59	290
2:25	17	9			5 / 15.5	10.5	97				8.9	119.26	.15	2	10	15	42	45	59	240
2:46	17	3			15.5 / 27	11.5	97.5				8.9	119.09	.15	3	10.5	15.5	42	44	59	215
3:10	17	5			27 / 35	8	97				8.98	118.95	.14	1	10.5	17	42	43	59/60	290
3:25	17	3			5 / 16.5	11.5	96.5				8.9	118.80	.15	2	10.5	15.5	41		60	265
3:45	17	3			2.5 / 14	11.5	96.5				8.9	118.65	.15	3	10	15.5			60	230
4:05	17	3			12 / 20	8	97				9.0	118.50	.15	1	10.5	17			60/61	295
4:25	17	3			20 / 31	11	97				8.8	118.36	.14	1	10.5	16			61	260

REMARKS:

Flow trip set on 2. Steam trips set on 2 & 3.

After canister switch dew point & outlet holds at about 60 °F for 3 minutes.

79270

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3 Bed 4 - Can Adst 20/40 Cycle
TEST ENGINEER: T. Peck / R. Petillo
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentration

SHEET 1 OF
DATE 7/21/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

* TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF	SIF	CO_2 W	ΔW	DB	CO_2 ON	STEAM ON	SIDP	SODP	H_2O C	H_2O ML		
4:45	17	3	14.7	14.7	30	—	97	12.5	30	100+	8.9	118.21	.15	3	—	—	41	41	61	—		
5:05	18	9	1	1	30	—	97	1	1	1	6.0	118.06	.15	1	—	—	1	1	61	—		
5:25												117.97	.09									

REMARKS:
* SHUT DOWN WATER PUMP & COMPRESSOR

79271

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 3 BED 60°, BULB 40° DEW POINT
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 19 OF | DATE 2/23/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	CCF	BCF	ACF	SIF	CO_2 W	ΔW	DB	CO_2 ON	STEAM ON	SIDP	SODP	H_2O C	H_2O ML		
9:48	32	16	14.7	14.7	29/32	12	97	17.5	30	26	9.7	117.97		2	14	20	~~39~~ 43	~~39~~ 43	61	285		
10:~~28~~	16	6	14.7	14.7	32/46	14	97			24.5	8.9	117.86	.11	3	10	18	41	40	61	240		
10:30	17	2	14.7	14.7	0/NG	—	97			25	9.0	117.75	.11	1	10	18	42	~~42~~	61/62	255		
10:47	17	1			7/17	10	98				8.8	117.60	.15	2	10	14.5	42	44	62	210		
11:08	17	3			17/28	11	99.5				8.8	117.45	.15	3	10	15	41	42	62	215		
11:2~~8~~	16	2			~~28~~ 36	8	100			26.5	9.0	117.31	.14	1	9.5	16	41	43	62/63	300		
11:48	17	2			5/15	10	*98				8.8	117.16	.15	2	9	14	42		63	225		
12:08	17	3			15/26	11	97				8.9	117.01	.15	3	10	15	44		63	150		
12:~~28~~	16.5	2.5			~~26~~ 14.5	8.5	97				9.0	116.87	.14	1	10	16	44	45	63	265		
12:~~48~~	17	2			14.5/24	9.5	97				8.9	116.71	.16	2	9.5	14	44	48	64	205		
1:08	17	3			24/34.5	10.5	97			28	8.8	116.59	.12	3	9.5	15	46	46	64	25	290	
1:28	17	2			34.5/40	5.5	98			29	9.1	116.46	.13	1	9.5	16	46		64	270		
1:48	17	3			0/10	10	95.5			30.5	8.8	116.32	.14	2	9.5	14.5	46		64	210		
2:08	17	3			10/20	10	97				8.9	116.17	.15	3	9.5	14.5	43	44	64/65	165		
2:28	17	4			20/28	8	96				9.0	116.02	.15	1	10	15.5	41		65	280		
2:48	17	3			25/34	9	96.5				8.8	115.90	.12	2	9.5	14.5	39	46	66	215		
3:09	17	4			4.5/16	11.5	96				8.9	115.76	.14	3	10	15	39	46	65/66	340		
3:29	17	4			15/23	8	96				8.9	115.63	.13	1	10	16	39	43	66	270		
3:50	18	4			23/32	9	96				8.9	115.50	.13	2	9.5	14.5			66	215		
⊙4:10	16	4			32	—	—				8.8	115.36	.14	3	—	—	36	40	66	100		
4:30	18	13			32	—	—				6.3	115.16	.20	1	—	—			66	—		
4:50												115.13	.03									

REMARKS: READINGS TAKEN AT 5 MIN INTO DESORB CYCLE
Read @ 4:33. Barom. @ 12:45 29.88 "Hg
* CAL
⊙ SHUT DOWN H_2O & COMPRESSOR

79272

HSF-178.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 2 BED 5C DRY BULB 40° DEW PT
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 20 OF
DATE 2/26/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	APP	CCF	BCF	ACF	SIF	CO_2 W	ΔW	DB	CO_2 ON	STEAM ON	SIDP	SODP	H_2O C	H_2O	APP		
2:12 PM	20	18	14.6	14.5	0 / 10.5	10.5	16.5	29.5	38	7.2	182.67		2	11	17	32	33	66		96		
2:25	18	0	14.7	14.7	10.5 / 24.5	14	16.5	29.5	31	5.7	187.63	.04	3	10	16.5	37	39	67		96		
2:45	18	0	14.7	14.7	21 / 28.5	7.5			35	5.5	187.56	.07	2	10	14	36	40	67		96		
3:05	18	0	14.7	14.7	28 / 35.5	7.5			37	5.5	187.38	.18	3	10	14	42	40	67		96		
3:25	17	0	14.7		0 / 2.5	2.5*			32	5.5	187.27	.11	2	10	14	42	44	67		95		
3:45	17	0			2.5 / 10	7.5			44	5.5	187.15	.12	3	10	14	41	46	67		95		
4:05	17	2			10 / 16.5	6.5			44	5.6	187.05	.10	2	9	13	41	42	67		95		
4:25	17	0			16.5 / 24	7.5				5.6	186.92	.13	3	10	13.5	41		67		95		
4:45	17	—			20.5 / 27.5	7.0				5.6	186.80	.12	2	9.5	13	42		67		94		
5:05	17	—			27.5 / 35	7.5				5.6	186.68	.12	3	10	14	41		67		94		
5:25	17	—			3.5 / 11.5	8.0				6.2	186.56	.12	2	10	14	42		67		92		
5:45	17	0			11.3 / 19	7.7	17.5		53	6.0	186.45	.11	3	10	14	40	40	67		93		
⊙ 6:05	19	3			19 / 26	7.5				5.8	186.33	.12	2	10	13.5	41	42	67		94		
6:25	19									5.8	186.22	.11	3	—	—	40	41	67				

REMARKS:
* ACCUM TANK LEFT OPEN - READING N.G.
⊙ Turned off H_2O

79292

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

Acceptance Test

2nd Attempt

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Acceptance
TEST ENGINEER: H. Brose / T. Peck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 21 OF
DATE 2/20/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2W	ΔW	CO_2 ON	Steam ON	SIDP	SODP	H2OC	DB			
2:25	16	16	14.7	14.7	0/5	7.5	95	8.5	17.5	30	65	186.13	0	14*	40	40	42	69	3			
2:45	18	15			5/19	13.5	96	8.4	17.5	30	56	186.13	.11	7.5	15	41	48	69	#1			
3:05	17	8			6/17	10.5	95	6.8		30	58**	186.02	.07	—	16	35	45		2			
3:25	16	2			17/25.5	8.5	98	8.3			68**	185.95	.14	12	16.5	38	43		3			
3:45	16	5			25/32	7	98	7.9			70	185.81	.16	9	14.5	36	45	69	1			
4:05	16	10			32.5/40.5	9	98	7.0	17.5	30	70	185.65	.16	11	16.5	36	44	69	2			
4:25	16	2			4.5/13	8.5	98	8.3				185.55	.15	12	15.5	41	46	69	3			
4:45	15	4			2/8.5	6.5	98	8.4				185.40	.15	8.5	14	44		69	1			
5:05	17	8			8.5/18	9.5	98	6.8				185.25	.08	10.5	14.5	44		69	2			
5:25	16	3			14/22.5	8.5	98	8.2			72	185.17	.15	12	16	46	52	69	3			
5:45	16	4			22/29	7.0	98	8.3				185.02	.15	8	14	43	52	69	1			
6:05	17	9			28.5/38	9.5	98	6.7				184.87	.09	10	16	41	48	69	2			
6:25	17	2			5/14	9	98	8.2				184.76	.15	12	15.5	41	47	69	3			
6:45	16	4			13.5/20	6.5	98	8.3				184.61	.15	8.5	14	42	48	69	1			
7:05	17	5			20/30	10	98	8.3				184.46	.14	10	15	41	54	69	2			
7:25	16	6			29.5/37.5	8	97.5	8.3			73	184.32	.13	12	17	41	47	69	3			
7:45	16	4			15/24	9	98	8.3			75	184.19	.14	8	15	41	47	69	1	20 MIN DESIRED		
8:05	17	5			5/15	10	98	8.3			76	184.05	.13	10	14.5	41	47	69	2			
8:25	16	7			14.5/23	8.5	98	8.3			77	183.92	.11	11.5	15	41	47	69	3			
8:45	15	4			22.5/30	7.5	99	8.3			77	183.81	.13	8	14.5	41	47	69	1			
9:05	16	4			29.5/39	9.5	99	8.3				183.68	.13	10.5	16.5	41	47	70	2			
9:25	16	6			4.5/14	9.5	99	8.4				183.55	.14	10	16	41	47	70	3			

REMARKS: Start of Test 2:20 PM 2/19/70. Data taken 5 min. into the desorb cycle.
* Increased water flow by one turn on pump #1.
** Adjusted to obtain 50°F cabinet temp.
" " " " " " " "
Started test with at 0 psi. & filled with unpure CO_2.
CO_2 Purity taken at end of desorb

9293

HSP-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: T. PECK / R. Petillo
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 22 OF
DATE 2/27/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2W	ΔW	CO_2 ON	STEAM ON	SIDP	SODP	H_2OC	DB	PP_{CO_2}	
9:45	14 18.5 17	8	14.7	14.7	13.5 21	7.5	99	8.4	18	30	79.5	183.41	.13	8	15	41	47	70	1	1	
10:05	17	5			20 29	9	99	8.3			83	183.28	.13	10	14.5			70	2	1	
10:25	16	6			28 36	8	99	8.4				183.15	.12	10.5	15.5			70	3	1	
10:45	16	5			10 17	7	99	8.4				183.03	.13	5.5	13.5			70	1	1.2	
11:05	17	5			16 25.5	9.5	99	8.3				182.90	.14	9.5	14			70	2	1.2	
11:25	16	6			24 32.5	8.5	99	8.3				182.76	.12	10.5	15.5			70	3	1.1	
11:45	16	5			30.5 37	6.5	98	8.4				182.64	.14	6.5	15			70	1	1.1	
3/28 12:05	17	5			36.5 43	6.5	97.5	8.4				182.50	.12	9	16			70	2	1.2	3/28/70
12:25	17	6.5			5 14	9	97	8.5				182.38	.12	10	14			70	3	1.3	
12:47	16	5			2 8.5	6.5	97.5	8.5				182.26	.13	6.5	13		50	70	1	1.1	
1:08	17	5			7.5 16.5	9	98	8.4				182.13	.13	9	13.5			70	2	1.1	
1:28	17	6.5			15.5 23.5	8	98	8.5				182.00	.14	10	14.5			70	3	1.1	
1:48	16	5.5			22 29.5	6.5	98	8.5				181.86	.12	6.5	13.5		53	71	1	1.4	
2:08	17	5.5			27 36.5	8.5	98	8.4				181.74	.13	6	15			71	2	1.6	
2:28	16	6.5			8 18.5	10.5	96	8.5				181.61	.13	5.5	14		51	71	3	1.8	
2:48	17	5.5			17 24	7	96	8.5				181.48	.12	5	13		54	71	1	2.0	
3:08	16	5			22.5 32	9.5	96	8.3				181.36	.11	5	14		57	71	2	2.1	
3:27	17	6			5 14.5	9.5	96	8.5				181.25	.13	5	14		59	71	3	2.2	
3:48	16	5.5			14 20.5	6.5	96	8.2				181.12	.14	6	13.5		50	71	1	1.9	
4:08	16	5			19.5 29	9.5	96	8.4				180.98	.12	5	14		48	71	2	1.9	
4:29	17	6			28 36.5	8.5	95.5	8.5				180.86	.11	5.5	15.5		49	71	3	2	
4:49	16	6			9 41	7	96	8.7				180.75	.13	6	14		47	71	1	1.7	

REMARKS:

(180.62)

2:35 BP 29.96 "Hg

79294

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY
LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: R. PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO2 CONCENTRATOR

SHEET 23 OF
DATE 9/28/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CCW	ΔW	CO_2 ON	STEAM ON	SIDP	SODP	H_2OC	DB	PPO_2
5:08	16	5.5	14.7	14.7	9/12.5	8.5	97	8.4	18	30	83	180.62	.13	9	13.5	41	48	71	2	1.4
5:28	16	6			16/24	8.0	97	8.5				180.49	.11	10	14		53	71 1/2	3	1.3
5:49	16	6			23/29.5	6.5	97	8.6				180.38	.13	5	14		50	72	1	1.3
6:10	17	6			28.5/35.5	7.0	96.5	8.4				180.25	.12	7	14		47	72	2	1.5
6:29	16	6.5			5.5/14	8.5	97	8.4			82.5	180.13	.11	10	14		50	72	3	1.8
6:49	16	6			12.5/18	5.5	97	8.6				180.02	.12	5.5	14		56	72	1	2.0
7:09	16	6			12.5/21.5	9	97	8.4				179.90	.12	5	13.5		50	72	2	0.8 *
7:30	17	7			20.5/29.5	8.0	97	8.5			90**	179.78	.11	5	15		47	72	3	1.0
7:50	17	6			27.5/32.5	5.0	97	8.6				179.67	.11	9	14	41	52	72	1	0.9
8:10	18	7			31/39	8.0	98	8.4				179.56	.11	8	15		-	72	2	0.7
8:30	17 18 17 18	6 8 15 11			4/13.5	9.5	-	8.3				179.45	.12	5	14		53	72	3	-
8:50	18	6			13/18.5	5.5	97	8.6				179.33	.13	6	15		48		1	1.0
9:10	17	7			17.5/26	8.5	96.5	8.3				179.20	.11	5.5	13.5		51		2	1.1
9:30	16	7			25.5/33	8.5	97	8.4				179.09	.10	9	15		50		3	1.0
9:50	18	7			28.5/36	8.5	97	8.6				178.97	.13	8	15		52	73	1	0.9
10:10	19	9			10.5/20	9.5	97	8.4				178.86	.11	8	13	41	52	73	2	0.8
10:30	17	7			19/28	9.0	97	8.4				178.75	.11	5.5	15	41	49		3	0.9
⊕ 10:50	17	7			26/31.5	5.5	97	8.6				178.64	.13	6	15		54		1	0.9
11:10	14 17 19 20 21 17	9 8 9 17 12			29.5/38.5	7.0	98	8.4				178.51	.11	5	14		48		2	1.0 *
11:30	19	7			36.5/42.5	8.0	97	8.5				178.40	.10	9	16		49		3	0.8
11:50	15 18 17 18 18 19	7 7 7 8 9 11			.5/5.5	5.0	97.5	8.7				178.30	.11	9	15		51		1	0.9
12:10	21	9			4.5/12.9	8.0	97.5	8.4				178.19	.11	8	13.5		51		2	0.6

REMARKS:
* zero drift in O_2 analyzer corrected.
ΔP on Boiler flow is 22 psi
ΔP on Condensor flow is 19 psi
** Adjusted inlet flow to Fan H/X to bring temp of Cond inlet from 52°F to 50°F
BP @ 6:50 30.02 "Hg
⊕ Took Lira readings every 2.5 min.
✓ set flow control to 1.5 from 1.8.

79295

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Acceptance
TEST ENGINEER: Hibrose / T. Beck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 24 OF | DATE 3/28/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SF	CCF	BCP	ACP	CO_2 W	ΔW	CO_2 ON	Steam ON	SIDP	SODP	MIDC	DB	PPO_2		
12:30	13.5	9	14.7	14.7	11.5 / 19.5	8	97	8.4	17.5	30	90	178.08	.12	9	14	41	48	73	3	—		
12:50	17	9			4 / 15	—	98	8.7				177.96	.12	10	14	41	47		1	0.4		
1:10	17	—			3 / 11.5	8.5	98	8.4				177.84	.11	8	13		—		2	0.2		
1:30	18	—			10.5 / 18.5	8.0	99	—				177.73	.12	9	14		—		3	0.2		
1:50	17	7			17.5 / 21.5	4.0	99	8.4				177.61	.12	10	14		58		1	0.2		
2:10	20	11			21 / 29.5	8.0	99	8.4				177.49	.11	8	14		48	74	2	0.2		
2:35	18	9			29.5 / 38	8.5	99	8.5				177.38	.10	9	15		49		3	0.2		
2:55	18 16 17 19 18	9 5 8 13 12 14 16			34.5 / 38.5	4.0	99	8.6				177.28	.12	11	15		54		1	0.2		
3:15	19 18 19 16	14 16			32 / 44	7.0	99	8.3				177.16	.10	8	—	41	52		2	0.2		
3:35	17	9			11 / 20	9.0	99	8.4				177.06	.12	9	13.5		49		3	0.2		
3:55	17	8			19 / 22.5	3.5	99	8.2				176.94	.11	10	—		55		1	0.2		
4:15	17	10			9 / 16	7	98	8.3				176.83	.11	7	12.5		50		2	0		
4:35	17	8			15 / 22.5	7.5	98	8.3				176.72	.11	9	14	38	49		3	0		
4:55	18	8			22 / 25	3	99	8.8				176.61	.11	11	14	40			1	0		
5:10	17	10			23 / 31	8	99	8.3				176.50	.10	25	13	43			2	0		
5:28	15	7			31 / 37.5	6.5	99	8.3				176.40	.08	8	14	42			3	0.1		
5:43	17	5			36 / 39	3	99	8.7				176.32	.11	10.5	15.9	41	52	75	1	0.1	STEAM AT MID BED VENT	
5:58	17	10			15 / 23	8	99	8.3				176.21	.07	7.5	12	41			2	0.4		
6:13	17	8			21 / 28	7	99	8.6				176.14	.09	9	14	41			3	0.4		
6:28	17	6			19 / 22	3	99	8.8				176.05	.10	11	14	41	48		1	0.4		
6:48	18	11			14 / 23	9	99	8.4				175.95	.08	6	12.5	41	56		2	0.5		
7:05	17	8			20 / 27.5	7.5	99	8.4				175.87 175.80	.07	9	13.5	41	47		3	0.4		

REMARKS: * Accumulator Dump Valve left on.
~~4:06 PM SWITCHED TO FAN #1~~ 4:50 PM - SWITCHED TO 16 MIN CYCLE

79296

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: T. BECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 25 OF | DATE 7/28/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2W	ΔW	CO_3 ON	STEAM ON	SIDP	SODA	H_2OC	PPO_2	DB		
7:22 PM	17	6	14.2	14.7	23.5/26.5	3	99	8.8	18	30	90	175.80	.11	10	14	41	47	75	~~0.5~~	1	STEAM AT MID BED VENT	
7:37	17	12			29.5/33	8.5	99	8.3				175.69	~~.08~~	6.5	13	41	50	75	~~0.6~~	2		
7:54	17	8			23.5/31	7.5	99	8.5				175.61	.08	9	14		50		—	3		
8:10	17	6			22/31	3	99	8.7				175.53	—	11	14		54		—	1		
8:26	17	12			24/32	8	99	8.3				—	.17	7.5	12.5		57		⊙ *	2		
8:42	17	7			28.5/36	7.5	99	8.4				175.36	.09	6	14		47		Δ0.4	3		
8:58	17	6			26/28.5	2.5	99	8.9				175.27	.11	11	14		49		0.6	1	WATER AT MID VENT	
9:15	17	12			25/33	8	99	6.9				175.16	.06	7	13		47	~~75~~ 76	0.6	2		
9:21	17	7			26/33	7	100	6.9				175.10	.09	9	14			76	0.6	3		
9:42	17	7			26.5/38	1.5	Δ98	8.8				175.01	.11	11	14.5			76	0.6	1	WATER AT VENT & HOLE	
10:04	17	12			17/26	9	98	6.8				174.90	.05	7	12.5			76	0.6	2		
10:19	17	7			20/27.5	7.5	98	8.1				174.85	.09	9	13			76	0.6	3		
10:35	16	6			23.5/25	1.5	98	8.8				174.76	.09	12	14				0.7	1		
10:52	18	12			21.5/30	8.5	97.5	7.1				174.67	.06	8	13				0.8	2	WATER AT VENT & HOLE	
11:08	16	4			26.5/34	7.5	97	7.0				174.61	.10	9	13.5				Δ0.1	3		
11:24	17	6			⊙/1	1	97	8.8				174.51	.09	12	14				0.1	1		
11:40	17	10			1/9.5	8.5	97	6.8				174.42	.06	6.5	12				0.1	2		
11:56	17	4			9.5/16	7.5	97	6.6				174.36	.10	9	12.5				0	3		
12:12	17	7			14/15	1	97	8.9				174.26	.10	13	14				0.1	1	WATER AT VENT & HOLE	
12:27	16.5	10			14/23	9	97	6.7				174.15	.06	7	12		48		0	2		
12:44	16	3			21.5/29.5	8	97.5	6.6				174.09	.10	8.5	13				0	3		
1:01	16	7			28/29	1	97.5	8.8				173.99	.11	12	13.5				0.1	1	WATER AT	

3/11

REMARKS:
* FOUND INLET LINE PLUMBED TO OUTLET PORT - REVERSED LINE
⊙ OFF SCALE NEGATIVE - WILL RECAL
Δ RECAL
THROTTLED WATER VALVE @ 10:30 SHOWN PUT LEE JET IN INTAKE
DROP IN FLOW AT 9:15 READING MAY BE DUE TO WETTING OF BED 1 CAUSED BY BACKFLOW THRU WATER SEPARATOR ELEMENT WHEN ACCUMULATOR WAS FILLING FROM WATER LINE - BED 1 HAD JUST FINISHED DESORB & WAS ALREADY WET. TH
ADDITIONAL H2O LOW RATED FLOW

79297

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSP-178.1A 1/86

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTA :E
TEST ENGINEER: R. Petillo
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 26 OF
DATE 2/11/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2W	ΔW	CO_2 ON	STEAM ON	SIDP	SODP	H_2O_c	PPO_2	DB	
1:16	17	18	14.7	14.7	0/9	9.0	97.5	6.4	18	30	90	173.89	.06	7	12	41	48	76	0.1	2	
1:32	15	2.5			8.5/16.5	7.0	98	6.7				173.83	.10	8	12.5		49		0	3	
1:49	16	7			14/14.5	0.5	98	8.8				173.73	.08	12.5	13.5				0	1	*
2:07	18	12			14/22.5	8.5	98	6.8				173.65	.08	7.5	12		48		0	2	
2:21	15	2.5			21.5/29	8.5	98	6.7				173.57	.10	8	13				0	3	
2:38	16	7			28.5/29.5	1.0	98	8.9				173.47	.10	12	14				0	1	*
2:53	17	11			28.5/36.5	8.0	98	6.8				173.37	.05	7	13			77	0.1	2	
3:10	15	2			5.5/14	8.5	97.5	6.6				173.32	.10	8	12.5	40			0.1	3	
3:26	15	6			12.5/14	1.5	94	8.8				173.22	.10	6	13.5				1.6	1	
3:42	17	12			13/22	9.0	96.5	6.6				173.15	.07	5	11.5				0.7	2	
3:58	15	2			20.5/29	8.5	97	6.7				173.05	.09	8	13				0.5	3	
4:15	16	6			27.5/28	0.5	97	8.9				172.96	.09	12	13	41			0.5	1	*
4:31	17	12			27/35.5	8.5	97	6.8				172.87	.07	6	12.5				0.6	2	
4:47	15	2			6/14	8.0	97.5	6.7				172.80	.10	8	12.5	40			0.4	3	
5:04	16	6			12.5/13	0.6	97.5	8.9				172.70	.10	12.5	13.6				0.4	1	
5:19	17	12			12/20.5	8.5	97.5	6.8				172.60	.08	7	11.5				0.4	2	
5:35	16	7			19/27.5	8.5	98	8.5				172.52	.09	16.5	12.5				1.1	3	*
5:52	16	5			25/26	1.0	98	8.9				172.43	.10	13.5	14.5				0	1	
6:09	18	12			25/34	9.0	97	6.9				172.32	.06	5	12.5				0.1	2	
6:20	17	2			6/15	9.0	97.5	6.7				172.27	.10	8	12				0	3	
6:40	16	6			14/14.5	0.5	97	8.8				172.17	.09	12.5	13.5				0.5	1	
6:59	18	12			14/22	8.0	97.5	6.5				172.08 (172.00)	.08	7.5	12				0.6	2	

REMARKS:
* DB #1 Leaks water at vent during cycle
* Zeroed O_2 analyzer (OFF by 0.4 %)

79299

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: R. Perillo / H. Bruse
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 3 OF
DATE 1/11/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2 WT.	ΔWt.	CO_2 ON	STEAM ON	SIDP	SODP	H_2O_C	PPO_2	DB		
7:14	16	2	14.7	14.7	22/30	8.0	98	6.7	18	30	90	172.00	0.10	7.5	13	40	49	77	0.3	3		
7:29	15	5			9/9.5	0.5	97.5	8.9				171.90	0.09	12	12.5	41		77	0.4	1	*	
7:45	17	10			8.5/12.5	9.0	97.5	6.8				171.81	.07	7.5	11	39			0.3	2		
8:01	16	2			16.5/25.5	8.0	98	6.7				171.74	.09	7	-	41	53		0.2	3		
8:18	18	7			23.5/24	0.5	98	9.0				171.65	.11	12	12.5	41	48	78	0.3	1		
8:34	18	18			29.5/36	9.0	97.5	4.9				171.54	.03	8	13	39	48	78	0.3	2		
8:51	17	7			31.5/36	4.5	97.5	8.4				171.51	.09	8.5	13	44	49		0.4	3		
9:07	17	5			5.5/8	3.5	98	8.9				171.42	.12	13.5	16	45	49		0.3	1		
9:22	18	11			20/28.5	8.5	98	7.0				171.30	.07	-	12	39	46		0.3	2		
9:39	17	3			12.5/21	9.0	98.5	7.0				171.23	.11	8	12	40	47		0.2	3		
9:55	16	5			19.5/20.5	1.0	98	8.9				171.12	.10	12.5	14	42	47		0.2	1		
T 10:11	18	12			17.5/27	9.5	98	6.9				171.02	.10	8	12	37	44		0.2	2		
10:28	19	1			25.5/26	0.5	98	5.5				170.92	.11	10	11	37	45		0.2	1		
10:43	14	13			26.5/32	6.5	98	4.8				170.81	.02	8	12	36	45		0.3	2		
‡ 10:55	17	1			1/—	—	—	5.6				170.79	.11	-	-	36	49		-	1		
11:11	17	17			1.5/8.5	7.0	98	5.0				170.68	.02	9.5	12.5	36	48		0.3	2		
11:26	17	1			2/9.5	2.5	98	5.8			92	170.66	.11	12	14.5	47	56		0.3	1		
11:42	16	14			9/16.5	7.5	97	5.0				170.55	.03	6	11	41	46		0.5	2		
12:09	16	1			13/14.5	1.5	97	5.8			90	170.52	.11	12	13	41	44		0.5	1		
12:20	15	14			12.5/20	7.5	97	5.1	17.5			170.41	.02	8	11	40	46		0.4	2		
12:37	13 17 19 20 20 20	1 1 5 3 7 8 11			18.5/21	2.5	94	5.8				170.39	.11	5	13	40	44		1.4	1		
12:53	17	16			16.5/24	7.5	95.5	5.0				170.28	.02	5	11.5	39	45		1.0	2		

REMARKS:

* WATER LEAKS OUT OF VENT ON CAN #1

‡ Skipped one desorb on bed #1

T ** Shut off bed #3 to recondition bed #1, switched to two bed operation bed 1 & 2 gave bed 3 a complete 32 min adsorb.

79300

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: Acceptance
TEST ENGINEER: H. Brose / T. Peck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 28 OF | DATE 9/11/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	SIPP	SOPP	SPI	SPO	AP	ΔAP	APP	SIF	CCF	BCF	ACF	CO_2W	AW	CO_2 ON	Steam ON Heat OFF	SIDP	SODP	H_2OC	PPO_2	DB
1:10	18	1	14.7	14.7	22.5/26	3.5	94	5.6	17.5	30	90	170.26	.12	5	Heat	40	44	78	1.5	1
1:26	17	15			25.5/32.5	7.0	94	5.0				170.14	.02	7	12	40	45		1.5	2
1:40	15	10			32/—	—	—	5.8				170.12	.12	—	—	40	44		—	1*
1:52								5.0				170.00								
7:35	36	40			31			5.1				169.80				38	39	78		
7:40	START SYSTEM — DESORB BED #2 — 2 BED CYCLE																	BED	1 & 2	
7:45	18	2.1	14.7	14.7	31/34	3	95	5.4	17.5	30	29	169.80	.02	12.5	NO TRIP	39	40	78	0.8	2
8:01	22	9			9.5/17	7.5	96	5.4				169.78	.08	5.5	8	40	43		0.4	1
8:18	17	11			15/23	8	95.5	5.3				169.70	.07	5.5	12.5	40	43		0.6	2
8:34	16	2			20.5/25	4.5	95	5.4				169.63	.08	5.5	8	40	44		0.8	1
8:50	18	9			8.5/14.5	6	94	5.4				169.55	.07	5.5	12	40	43		0.9	2
9:07	17	3			13/17.5	4.5	94	5.4				169.48	.08	5	8	40	44		1.0	1
9:23	17	6			16/22	6	93	5.4				169.40	.07	5.5	12	40	44		1.2	2
9:39	15	3			20.5/25.5	5	93	5.5				169.33	.10	5.5	9	40	44		1.3	1
9:55	18	9			23.5/29	5.5	93.5	5.4				169.23	.08	9.5	12.5	40			1.2	2
10:12	17	3			27/31.5	4.5	94	5.5				169.15	.08	6.0	9.5				1.2	1
10:28	17	4			24.5/30.5	6	94.5	5.4				169.01	.10	7.5	12.5				1.0	2
10:44	16	3			24.5/30	5.5	95	5.5				169.97	.10	5.5	10				1.0	1
11:01	17	3			17/22.5	5.5	95.5	5.4				168.87	.09	9	12.5				0.9	2
11:17	16	4			19/25	6	95	5.4				168.78	.09	5	9.5				1.0	1
11:33	17	4			17.5/23.5	6	95	5.4				168.64	.09	8.5	12.5				1.0	2
11:49	16	4			22/28	6	95	5.4				168.60	.09	7	10.5			79		1

REMARKS: * Shut off water pumps - No desorb on bed #1 168.51

** Hold adsorb cycle on bed 1 & shut off cooling to Fan H/x to rapidly dry bed #1.

79301

HSF-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT VCE
TEST ENGINEER: T. PECK / R. PERILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 29 OF
DATE ~~1/20~~ 2/20
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	AP	ΔAP	APP	SIDP	SODP	H_2O C	CO_2 ON	STEAM ON	PPO_2	CO_2 W	ΔW	DB
AM 12:05	17	2	5.3	14.7	14.7	17.5	79.5	30	14.5/90	5.5	96	40	44	79	9.5	12.5	0.6	168.51	0.10	2
12:23	17	5	5.6						18.5/94.5	6.0	96		43		7	10	0.5	168.41	0.10	1
12:37	17	3	5.4						23/99	6.0	96.5		44		9.5	13	0.6	168.31	0.10	2
12:54	17	5	5.6						28/103.5	5.5	97				7	11	0.3	168.21	0.09	1
1:11	17	3	5.4						5/12	7.0	95				5	12	0.8	168.12	0.10	2
1:26	17	5	5.5						11/17	6.0	95				5	10	0.9	168.02	0.09	1
1:43	17	3	5.3						15.5/22	6.5	95		43		5	12.5	1.2	167.93	0.10	2
1:59	17	5	5.6						20.5/27	6.5	96				8	11	0.9	167.83	0.08	1
2:15	16	2	5.6						25/31.5	6.5	95		44		5	13	1.1	167.75	0.10	2
2:31	17	6	5.6						7/13.5	6.5	94.5		45		5	11	1.2	167.65	0.09	1
2:47	16	2	5.5						12/17	5.0	95		43		10	12.5	1.0	167.56	0.10	2
3:04	17	7	5.6						15/21.5	6.5	96		44	80	8	11	0.9	167.46	0.10	1
3:19	16	2	5.4						20/25	5.0	96				10	12.5	0.7	167.36	0.09	2
3:35	17	6	5.6						24/30.5	6.5	96		43		8.5	12	0.5	167.27	0.07	1
3:52	16	2	5.3						28/33.5	5.5	96		44		5	13.5	0.7	167.20	0.10	2
4:08	16	6	5.7						4/10.5	6.5	96		46		8.5	11.5	0.5	167.10	0.08	1
4:24	16	2	5.3						7/11.5	4.5	96.5		44		10	12	0.4	167.02	0.11	2
4:40	17	7	5.6						10/16	6.0	97		45		8	11.5	0.4	166.91	0.08	1
4:56	16	2	5.3						15/20	5.0	97				10	13	0.3	166.83	0.10	2
5:14	18	8	5.6						19/24.5	5.5	97.5				8.5	12	0.2	166.73	0.07	1
5:29	17	3	5.2						23/28.5	5.5	97				10	13	0.2	166.66	0.10	2
5:45	17	7	5.6	14.7	14.7	17.5	79	30	27/32.5	5.5	97	40	44	80	9	13	0.1	166.56	0.08	1

REMARKS:

B.P. 30.18" Hg @ 4 AM

79303

HSP-175.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP. NCE
TEST ENGINEER: R. Petrillo - C. DeSimone
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: Amine CO_2 Concentrator

SHEET 30 OF
DATE 3/2/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	AP	ΔAP	APP	SIDP	SODP	H_2O_C	CO_2 ON	STEAM ON	PPO_2	CO_2 WE.	ΔWE	DB
6:02	17	3	5.2	14.7	14.7	17.5	79	30	5/11	6	95.5	40	43	80	5	12	0.6	166.98	0.10	2
6:18	18	8	5.6						9/15	6	95				5	11.5	0.7	166.38	0.07	1
6:33	16	2	5.2						13/18.5	5.5	94.5			80 81	5.5	12.5	1.0	166.31	0.10	2
6:50	17	8	5.6						17/23	6	94.5			81	5	12	1.0	166.21	0.08	1
7:06	16	3	5.2						20/26	6	95				5.5	12.5	1.2	166.13	0.10	2
7:23	17	8	5.6						24/30.5	6.5	94.5				5	13	1.2	166.03	0.06	1
7:38	16	3	5.2						3/8	5	94				5.5	12	1.4	165.97	0.10	2
7:55	17	8	5.6						6/12	6	94				5	12	1.4	165.87	0.07	1
8:05	17	3	5.1						10/15.5	5.5	94	40			6	12	1.6	165.80	.09	2
8:30	18	10	5.6						13/19.5	6.5	94				6	12	1.5	165.71	.07	1
8:50	18	6	5.0						18/25	6.5	93.5				6	13	1.6	165.64	.07	2
9:00	18	9	5.6						21.5/26	4.5	93.0				6	13	1.4	165.57	.08	1
9:18	17	5	—						26/30	4.0	94.5				9.5	13	0.6	165.49	.08	2
9:33	19	9	5.6						29.5/34	4.5	95.0				10	14.5	1.2	165.41	.09	1
9:50	16	4	4.6						6/11	5.0	94.0				5	12	1.8	165.32	.09	2
10:06	18	9	5.6						11/15.5	4.5	93.5				5.5	13	1.6	165.23	.08	1
10:22	16	5	4.5						15/20	5.0	93.5				5.0	12	1.6	165.15	.08	2
10:38	18	9	5.5						19/24.5	5.5	93.0				5.0	13.5	1.7	165.07	.08	1
10:54	17	6	4.4						23/29	6.0	93.0				5.0	13	1.8	164.99	.07	2
11:10	17	8	5.5						28/33	5.0	92.0			82	5.0	15.5	2.1	164.92	.07	1
11:27	17	9	4.3						5.5/10.5	5.0	92.0				5.0	12.0	1.6	164.85	.07	2
11:43	18	9	5.6						9.5/13.5	4.0	91.0				5.5	14.0	2.0	164.78	.06	1

REMARKS: changed flow trip back to 2.0V from 1.0V.

79305

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: C. DeSimone
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 31 OF
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS
DATE 3-2-70 (3/20)

	TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	AP	ΔAP	APP	SIDP	SODP	H_2OC	CO_2 on	Steam on	PPO_2	CO_2 wt	ΔWt.	DB		
*	12:00	17	12	4.6	14.7	14.7	18	32	30	12.5 / 17.5	5.0	91.5	38	45	82	5.0	12.0	1.9	164.72	.06	2		
	12:16	17	9	5.5				1		16.5 / 20	3.5	90.5	39		1	5.5	14.0	2.1	164.66	.07	1		
	12:32	17	13	4.6				30		19 / 23.5	4.5	91	40		83	5.0	12.0	2.1	164.59	.05	2		
**	12:49	16	7	5.4						22 / 25.5	3.5	91	40	—		5.0	15.0	2.4	164.54	.07	1		
	1:03	17	14	4.6						24.5 / 29	4.5	91.5	39	45		9.5	13.0	2.1	164.47	.05	2		
o	1:20	18	11	5.5						28.5 / 30	1.5	92				11.5	14.5	2.0	164.42	.06	1		
	1:36	18	15	4.5						29.5 / 33	3.5	92				5.0	13.0	1.9	164.36	.04	2		
Δ	1:52	16	8	5.5						32.5 / 34	1.5	91				8.0	15.0	2.2	164.32	.06	1		
x	2:08	17	16	4.6				40		5 / 10.5	5.5	92.5						1.8	164.26	.04	2		
	2:24	17	9	5.6				20		10 / 12.5	2.5	92						1.8	164.22	.07	1		
	2:40	15	14	4.4						11.5 / 16	4.5	92.5						1.7	164.15	.04	2		
	2:57																		164.11		1		
	2:58	shut down, dry both beds								#2 first									164.09		2		
	6:15	DRY OUT OF CAN #2 COMPLETE SWITCH TO DRY OUT CAN #1																			1		
	11:20	PM	NOTICED HIGH H_2O LEVEL LIGHT ON - INLET DP HIGH - 680 COOLANT 41-50°F																		2		
			H_2O COUNT STILL AT 83 - CAUSED BY H_2O CONDENSED FROM BED 1 EFFLUENT																		1		
	11:30	START CYCLING																	163.65		~~2~~		
	11:35	50	52	5.8	14.7	14.7	17.5	47.5	30	14.5 / 19	4.5	93 / 93	35	41	83	10.5	12.5	1.4	~~163.65~~ 163.64	.01	2	FLOW TRIP 2.5	
	11:59	30	17	5.0			17			16 / 22	6	94	53	46	83	5.5	7.5	0.9	163.64	.03	1	2.5	
3/3	12:07	19	11	5.6			18	20		19.5 / 23	3.5	94	49	46		8.5	10.5	0.8	163.61	.09	2	RESET TO 2.0	
	12:25	18	8	5.6				20.5		21 / 25	4.5	95	43	47		5 ⊙	7	0.7	163.52	.08	1	⊙ reset to 3.5	
	12:43	17	13	5.7						23 / 28	5	95	43	47		8.5	10.5	0.5	163.44	.07	2		

REMARKS:
* Increased inlet temp to canisters from 50 to 60°F
** Increase flow trip to 2.5 V from 2.0
Δ switch to timer motor, removed diaphragm
o found fitting loose on transducer, reset trips to 2.0 from 2.5
x increased inlet temp to cans from 60°F to 70°F

76804

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: AC ENDURANCE
TEST ENGINEER: T. PECK / R. PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 32 OF | DATE 3/3/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	AP	ΔAP	APP	CO_2 ON	Steam ON	PPO_2	CO_2 Wt	ΔW	D B		
AM 12:58	22	11	5.7	14.7	14.7	18.5	20.5	30	45	51	.83	25/28.5	3.5	95.5	8	10	0.4	163.37	0.08	1		
1:14	21	9.5	5.4						42	48		25/30.5	6.5	95	8	11	0.3	163.29	0.07	2		
1:30	17	4	5.7									11/16	6.5	95.5	6	8	0.3	163.22	0.10	1		
1:47	20	9.5	5.4							47		14/20	6	96	8	10.5	0.2	163.12	0.09	2		
2:04	17	3	5.7									18/22.5	4.5	96	6.5	9	0	163.03	0.11	1		
2:18	21	7	5.4							48		21/27.5	6.5	96.5	8.5	11.5	0	162.92	0.09	2		
2:34	19	3	5.6									26/30.5	4.5	96.5	7	10	0	162.83	0.10	1		
2:51	20	9	5.9									28/34	6	97	8.5	11.5	0	162.73	0.08	2		
3:07	17	2	5.7									5/9.5	4.5	97.5	8	10	0	162.65	0.10	1		
3:24	19	8	5.4									8/14	6	97.5	8.5	10.5	0	162.55	0.08	2		
3:39	19	3	5.6									12/17	5	98	8.5	11	0	162.47	0.10	1		
3:57	21	7	5.2									19/21	7	98.5	8.5	11	0	162.37	0.08	2		
4:12	20	3	5.5							47	84	19/23.5	4.5	98.5	9	11.5	0	162.29	0.10	1		
4:28	15	5	4.3						41	46		23/28.5	6.5	98	8	11	0	162.19	0.09	2		
4:45	19	5	5.5						42	47		26/30.5	4.5	98	9.5	12.5	0	162.10	0.10	1		
5:01	16	6	4.5						41	48		29/35	6	98	8	12	0	162.00	0.08	2		
5:17	21	4	5.5						42	46		5/10	5	99	10.5	12.5	0	161.92	0.09	1		
5:33	15	7	4.2									8/13.5	5.5	98.5	8	10	0	161.83	0.09	2		
5:49	16	5	5.5							47		12/16	4	98.5	10.5	12.5	0	161.74	0.08	1		
6:05	20	11	4.9						41			14/20	6	98	8.5	11	0	161.66	0.08	2		
6:21	17	5	5.5						42	46		19/22	3	99	11	12.5	0	161.58	0.08	1		
6:37	17	9	4.7	14.7	14.7	18.5	20.5	30	41	47	84	21/27	6	99	8	11	0	161.50	0.06	2		

REMARKS:

B.P. 30.27" Hg @ 5:22 AM

79306

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: R. PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET OF 33 DATE 3/3/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	AP	ΔAP	APP	CO_2 ON	STEAM ON	PPO_2	CO_2 wt.	Δwt	DB		
AM	6:54	21	6	5.5	14.7	14.7	18.5	20.5	30	42	46	84	25/28	3	99	11.5	13.5	0	161.44	0.09	1		
	7:10	16	14	4.7						41	47	85	27/32.5	5.5	99	8	11	0	161.35	0.04	2		
	7:27	21	7	5.5						42	48		30/30.5	0.5	—	12.5	14.5	—	161.31	0.09	1		
	7:43	15	13	4.7						41	47		5/11.5	6.5	100	8	10.5	0	161.23	0.06	2		
	7:59	20	7	5.5						42	48		11/12	—	—	12.5	13	—	161.17	0.08	1		
													12/						161.09		2		
	8:13		dry	out	can	#	1						1								1		
	11:50	—	—	5.0	14.7	14.7	17.5	20.5	30	39	41	85	12/19.5	7.5	99	8	16	0.2	160.86	0	2		
	12:10	-	—	5.3			17.5	18	30	41	45	85	17.5/19	1.5	99			0.2	160.86	0.04	1		
	12:25	21	13	5.3						41	46		18.5/27.5	9.0	99			0.2	160.82	.05	2		PPO_2
	12:41	21	13	5.4			18.0			41	46		24.0/24.5	—	99			—	160.77	.07	1		4.6
	12:57	20	10	5.2			18.0	19.0		41	46		24.0/—	—	95			—	160.70	.07	2		4.0
PM	1:16	12	12	5.5			18.0	19.0		41	46		26/26	—	94			0.	160.63	.06	1		3.2
	1:31	19	10	5.6			18.0	19.0		41	46		23/31	8.0	94				160.57	0.10	2		1.2
	1:48	16	13	5.7			18.0	19.0	30	41	46		28/29.5	1.5	98				160.47	0.09	1		4.0
	2:03	21	8	5.2			18.0	19.0	30	41	46		27/34.5	7.5	93				160.40	0.08	2		2.4
	2:19	20	5	5.6			18.0	19.0	30	41	46		29/36	2.0	93				160.32	0.08	1		1.6
	2:35	19	9	5.7						41	46		27/39	7.0	93				160.24	0.08	2		1.4
	2:51	20	8	5.7						41	46		29/53	4.0	93			—	160.16	0.10	1		—
	3:08	13	7	4.8						40.5	46		32/38	6.0	92	6.5	15.0		160.06	0.11	2		1.2
	3:24	20	8	5.6						41	46		35/41	6.0	92				159.95	0.11	1		1.2
	3:39	20	4	4.8						40.5	46	86	39/44	5.0	92				159.86	0.09	2		1.2
																			159.77				

REMARKS:

79307

HSP-178.1A 1/66

Hamilto.. Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP NCG
TEST ENGINEER: JGWFINCK / T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 34 OF | DATE 3/3/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3/3	TIME	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	AP	ΔAP	APP	CO_2 ON	STEAM ON	PPO_2	CO_2 WT	ΔWT	DB
PM	3:56	20	6	5.6	14.7	14.7	18.0	19.0	30.0	41	46	86	40 / 45	5.0	92	6.5	13.0	1.2	159.77	0.09	1
	4:14	20.5	5	4.1						40			40.5 / 45	4.5	92			1.2	159.68	0.08	2
	4:28	19	5	5.6						41			— / 32	—	92			1.2	159.60	.08	1
	4:44	17	4	4.4						40			31 / 36	5	92			1.3	159.52	.08	2
	5:00	20	9	5.5						42			0 / 5.5	6.5	90			1.8	159.44	.09	1
	5:16	16	6	4.8						42	48		2.5 / 7	4.5	93.5	7.0	13.5	1.4	159.35	.09	2
	5:32	17	7	5.7									5.0 / 10.5	5.5	93			1.5	159.26	.09	1
	5:48	20	7	4.9						41	45		7 / 12	5	94			1.4	159.17	.08	2
	6:04	17	7	5.8						42		86	10.5 / 15.5	5	94			1.6	159.09	.07	1
	6:20	17	9	4.7						41		87	13.5 / 18.5	5	94	7	13	1.6	157.02	.08	2
	6:37	18	8	5.8						42			17 / 22	5	94			1.6	158.89	.08	1
	6:52	18	12	4.8						41			20.5 / 25	4.5	94			1.6	158.86	.07	2
	7:09	17	8	5.8						42			23.5 / 27	3.5	94			1.8	158.79	.07	1
	7:25	18	10	4.8						41			21 / 24	3*	94			1.6	158.72	.06	2
	7:42	17	9	5.8						42			22 / 25.5	3.5	94			1.8	158.66	.08	1
	7:57	17	11	4.6						41	47		23.5 / 28.5	5.0	94	7	13.5	1.8	158.58	.06	2
	8:14	17	12	5.8						42			27.5 / 30.5	3.0	94			1.6	158.52	.07	1
	8:30	15	13	4.7						41			19.5 / 24.5	5.0	94			1.6	158.45	.05	2
	8:46	17	13	5.7						42			22 / 25.5	3.5	94	7		1.8	158.40	.05	1
	9:02	18	18	4.6						44			24 / 29	5	94	6	13	2.0	158.32	.04	2
	9:18	17	12	5.8						44			18 / 19.5	1.5	92			2.4	158.28	.08	1
	9:34	20	20	4.8						43		87/88	14 / 16.5	2.5*	95			1.8	158.20	.03	2

REMARKS:
* N.6. APP VALVE LEFT ON

76810

HSP-175.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 35 OF
DATE 2/3/70
TEST PLAN NO. 3, 1/70
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 W	ΔW	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SOOP	H_2O C	CO_2 ON	Steam ON	AP	ΔAP	APP	PPO_2		
9:50	1	158.17	.08	17	10	5.9	14.7	14.7	18	14	30	43	45	88	6	13	13.5/16	2.5	94	2.0	RAISED TO 80°F	T7
10:05	2	158.09	.03	18	18	4.4						42				11	14/19	5	94	2.0		
10:21	1	158.06	.08	17	9	5.9						42					13.5/19	1.5	92	2.0		
10:37	2	157.98	.03	20	20	4.7						42					7/12	5	94	1.8		
10:53	1	157.95	.07	17	9	5.9										12	10.5/11	0.5	89	3.0		
11:09	2	157.88	.01	22	22	4.6										13	8/13	5	94	2.0		
11:25	1	157.87	.09	17	11	5.9				11							11/12	1.0	92	2.6	RAISE TO 100°F	T7
11:41	2	157.78	.02	20	20	4.6							48				11/16	5	94	2.0		
11:57	1	157.76	.08	17	9	5.9											14.5/16.5	2	90	3.2		
7/4 12:13	2	157.68	.02	20	20	4.6									5.5	13.5/13.0	15/20	5	93	4.0		
12:29	1	157.66	.09	17	9	6.0											17.5/22	4.5	84	5.4		
12:47 AM	2	157.57	.03	16	16	4.8											14/19	5	90	3.9		
1:02	1	157.59	.07	23	13	6.0											14/17	3.5	82	5.8		
1:18	2	157.47	.04	18	18	4.5											15/20	5	86	5.6		
1:32	1	157.43	.01	23	10	5.7											19/23	4	87	6.9		
1:48	2	157.36	.04	19	19	4.7											21/26.5	5.5	85	5.0		
2:05	1	157.32	.08	23	9	5.8			18	10						13	5/10.5	5.5	76.5	8.0	WATER IN WET HOLE	
2:21	2	157.24	.04	19	19	4.7				11							9/14	5	80	7.4		
2:37	1	157.20	.08	20	11	6											13/17.5	4.5	74	—		
2:53	2	157.12	.04	20	20	4.7											12/17.5	5.5	80	4.2		
3:09	1	157.08	.07	23	9	6								89			17/21	4	73	5.4		
3:25	2	157.01	.04	20	20	4.7	14.7	14.7	18	14	30	42	48	89	5.5	13	21/26	5	79.5	5.6	DROPPED T7 TO 80°F	

REMARKS:

76811

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ALLEPTAL E
TEST ENGINEER: R. Pusillo
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 36 OF | DATE 4/4/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3/4	TIME	DB	CO_2 wt.	Δ wt.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	DCF	BIDP	SODP	H_2Oc	CO_2 ON	STEAM ON	AP	ΔAP	APP	PPO_2
AM	3:41	1	156.97	0.07	22	8	6.7	14.7	14.7	18	14	30	42	48	89	5.5	13	20/24	4	72	8.2
	3:57	2	156.90	0.04	19	19	4.7											23/28.5	5.5	79	8.0
	4:13	1	156.86	0.09	22	7	5.7											5/10.5	5.5	69	9.7
	4:29	2	156.77	0.04	19	19	4.7											9/15	6	76.5	9.2
	4:45	1	156.73	0.08	21	8	5.8											13/12.5	4.5	68	9.7
	5:01	2	156.65	0.03	22	22	4.7				17							15/21	6	76.5	9.2
	5:17	1	156.62	0.09	22	7	5.7											20/23.5	3.5	70	9.0
	5:33	2	156.53	0.03	22	22	4.7											23/28.5	5.5	77	8.4
	5:49	1	156.50	0.09	22	7	5.6											26/30	4.0	68.5	9.6
	6:05	2	156.41	0.03	22	22	4.7											21/26.5	5.5	78	6.8
	6:21	1	156.38	0.09	22	7	5.6				11							5/10	5	70	9.0
	6:37	2	156.29	0.04	21	21	4.7											8/14	6	76	8.4
	6:53	1	156.25	0.08	22	6	5.7											13/17	4	70	9.0
	7:09	2	156.17	0.03	21	21	4.6											16/21.5	5.5	77	8.4
	7:25	1	156.14	0.08	22	5	5.6											21/25	4	70	9.2
	7:41	2	156.06	0.03	22	22	4.3											24/27.5	5.5	77	8.4
	7:57	1	156.03	0.07	22	7	5.6								90			28/31.5	3.5	72	9.0
	8:13	2	155.96	0.05	22	22	4.6											30/35.5	5.5	77.5	7.8
	8:29	1	156.91	0.08	22	7	5.6											5/11	6.0	72	9.6
	8:45	2	155.83	0.03	20	20	3.0											5/11	6.0	77	10.6
	9:00	1	155.80	0.08	23	6	5.5											5/9	4.0	70	9.8
	9:16	2	155.72 (155.69)	0.03	26	25	4.0											5/—	—	—	—

REMARKS:
— BACKPRESSURE REGULATOR REMOVED FOR INSPECTION DURING THIS CYCLE.

79308

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP NCE
TEST ENGINEER: JGW FINCK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 37 OF
DATE 3-4-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 WT.	ΔWT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	STEAM ON	AP	ΔAP	APP	PPO_2		
3/4 AM																							
*	932	1	155.69	.09	22	7	5.6	14.7	14.7	18	11	30	42	48	90	5.5	13	5/—	—	—	—		
	948	2	155.60	.03	25	25	4.1						42				14.5	6/12	6.0	79	6.8		
	1005	1	155.57	.09	22	6	5.5											9/10	1.0	78	7.4		
	1021	2	155.48	.03	23	23	4.2											5/11	6.0	82	5.6		
	1037	1	155.45	.10	23	6	5.5											10/12	2.0	81	6.4		
	1053	2	155.35	.04	22	22	4.1											7/13	6.0	84	6.4		
	1110	1	155.31	.09	22	6	5.9											10/13	3.0	81	6.2		
	1126	2	155.22	.03	22	22	3.8											7/13	6.0	84	6.6		
**	1145	1	155.19	.09	21	7	5.5						42	46				5/—	—	—	—		
	12:58	2	155.10	.02	20	20	4.3						41	48				3.5/8.5	5.0	87	3.3		
@	12:15	3	155.08	.10	20	5	5.9						42	45		6.5	13.5	8.0/11.5	3.5	84	4.0		
	1231	2	154.98	.03	70	70	5.0						42	48		6.5	14.5	6.5/11.5	5.0	87	4.4		
	1299	3	154.95	.08	20	5	5.9						42	46				9/15.5	6.5	87	2.8		
PM	1:03	2	154.87	.04	20	20	5.2						42	46				11.5/16.5	5.0	88	4.4		
	1:19	3	154.83	.08	21	6	5.6						42	46				12.5/16.0	4.5	86	2.8		
	1:35	2	154.75	.05	14	14	5.3						42	46				13/17	5.0	88	4.2		
	1:51	3	154.70	.08	22	6	6.0						42	46				13/16	3.0	86	2.8		
	2:12	2	154.62	.05	15	14	5.3						42	46				12/16.5	4.5	88	***		
	2:24	3	154.57	.08	21	7	5.6						42	44				12.5/15.5	3.0	87	—		
	2:39	2	154.49	.05	16	13	5.4						42	45				14/18.5	4.5	82	—		
	2:56	3	154.44	.08	21	6	5.7						42	45				17/20.5	3.5	87	—		
	3:12	2	154.34	.05	16	13	5.4	14.7	14.7	18	11	30	42	45	90	6.5	14.5	19/23.5	4.5	86	—		

154.31

REMARKS:
* BACKPRESS REGULATOR RE-INSTALLED NEAR END OF THIS CYCLE. ** Left O_2 Analyzer on.
@ switched to beds 2 & 3 from 1 & 2.
*** Beckman O_2 ANALYZER INDICATES OFF SCALE (NEGATIVELY)

76812

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP TEE
TEST ENGINEER: JGWFINCK / T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 38 OF | DATE 7-4-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3/4 PM TIME	DB	CO_2 WE	ΔWt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	STEAM ON	AP	ΔAP	APP	PPO_2
3:28	3	154.31	.10	21	6	5.9	14.7	14.7	18	11	30	42	45	90	6.5	14.5	22/25	3.0	88	*
3:44	2	154.21	.04	18	14	5.4	〃	〃	〃	〃	〃	42	—	〃	〃	〃	24/28	4.0	89	*
4:01	3	154.17	.08	20	6	5.6	〃	〃	〃	**〃	〃	42	48	〃	〃	〃	27/30	3.0	88	*
4:17	2	154.09	.04	21	18	5.4	〃	〃	〃	9	〃	42	48	91	〃	〃	29/32.5	3.5	90	—
4:33	3	154.05	.08	18	8	5.6	〃	〃	〃	〃	〃	〃	44	〃	〃	〃	30/—	—	—	—
4:48	2	153.97	.05	21	16	5.5	〃	〃	〃	8.5	〃	〃	59	〃	〃	〃	—/—	—	—	—
5:05	3	153.92		18	7	5.5	〃	〃	〃	〃	〃	42	46		6.0	13.0				
			.26																	
6:10	3	153.66	.06	18	11	5.9	14.7	14.7	18	8.5	30	42	48	91	6	13	8/16.5	7.5	90	
6:26	2	153.60	.03	17	10	5.7	〃	〃	〃	〃	〃	〃	〃	〃	5	12	8/16.5	5.5	90	
6:42	3	153.57	.07	17	7	5.5	〃	〃	〃	〃	〃	〃	〃	〃	1	1	8/15.5	7.5	93	
6:58	2	153.50	.05	20	17	5.7	〃	〃	〃	〃	〃	〃	〃	〃	5	13	15.5/21	5.5	93.5	
7:14	3	153.45	.08	17	7	5.6	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	21/24	3.0	93.5	
7:30	2	153.37	.05	17	15	5.8	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	24/29.5	5.5	94	
7:46	3	153.32	.08	17	7	6.0	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	29.5/32.5	3.0	94	
8:02	2	153.24	.05	17	15	5.8	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	5/11	6.0	95	
8:18	3	153.19	.09	17	8	6.0	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	11/14.5	3.5	94	
8:34	2	153.10	.06	17	15	5.9	〃	〃	〃	〃	〃	〃	52	92	4.5	13	14/19.5	5.5	94	
8:50	3	153.04	.09	17	7	6.1	〃	〃	〃	〃	〃	〃	54	〃	〃	〃	19.5/22.5	3.0	94	
9:06	2	152.95	.05	17	14	5.9	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	22.5/28	5.5	94	
9:22	3	152.90	.08	17	8	6.1	〃	〃	〃	8	〃	〃	〃	〃	4.5	12	28/31	3.0	94	
9:38	2	152.82 (152.77)	.05	17	14	6.0	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	31/35	4.0	94	

REMARKS:
*BECKMAN OXYGEN ANALYZER PEGGED (POSITIVE)
**ACF FLOW CHANGED TO 9 DURING THE MIDDLE OF THIS CYCLE.

76805

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP. .NCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 39 OF | DATE 12/4/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 wt	ΔWt	SIPP	SOPP	SIF	SPI	BPO	CCF	ACF	BCF	SIDP	SODP	H_2O c	CO_2 ON	Steam ON	AP	ΔAP	APP
PM	9:54	3	152.77	.07	17	8	5.9	14.7	14.7	18	8	30	42	58	92	4.5	12	35/38	3.0	94
	10:10	2	152.70	.07	17	12	6.0											38/42.5	4.5	94
	10:26	3	152.63	.06	17	8	5.6										11	0/4	4.0	94
	10:43	2	152.57	.07	17	12	6.0											3.5/8.5	5.0	94
	10:59	3	152.50	.07	17	8	5.4											8.5/12	3.5	94
	11:16	2	152.43	.07	17	12	6.0											12/16.5	4.5	94
	11:32	3	152.36	.07	17	8	5.4											16.5/20.5	4.0	94
	11:48	2	152.29	.07	17	11	6.0											20.5/25	4.5	94
	12:04	3	152.22	.08	17	7	5.5											25/29	4.0	94
	12:20	2	152.14	.07	17	9	6.0							48	93			29/33.5	4.5	94
	12:36	3	152.07	.07	17	6	6.0											5/10	5.0	94
	12:52	2	152.00	.08	17	6	6.0											9/14	5.0	94
AM	1:08	3	151.92	.08	17	5	5.5											14/18	4.0	94
	1:24	2	151.84	.07	17	10	6.2											18/23.5	5.5	94
	1:40	3	151.77	.07	17	6	6.1											23/27	4.0	94
	1:56	2	151.70	.07	17	11	6.0											27/32	6.0	93.5
	2:12	3	151.63	.08	17	5	5.5											32/35.5	3.0	94
	2:28	2	151.55	.07	17	10	5.7											0/6	6.0	94
	2:44	3	151.48	.08	17	8	5.5			18.5								6/9.5	3.5	94.5
	3:00 AM	2	151.40	.07	17	12	5.7						42	45				9/14.5	5.5	94.5
	3:16	3	151.33	.08	17	6	6.0			18				48	94			14/18	4.0	95
	3:32	2	151.25	.07	17	12	5.7	14.7	14.7	18	0	30	42	48	94	4.5	12	18/23	5.0	95

REMARKS:

76806

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT. NCE
TEST ENGINEER: R. Pesto
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 10 OF 10 | DATE 7/5/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 Wt	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	STEAM ON	AP	ΔAP	APP
AM 3:48	3	151.18	0.08	17	6	5.9	14.7	14.7	18	0	30	42	45	95	4.5	12	28/26.5	3.5	95
4:05	2	151.10	0.08	17	12	5.7										12	26.5/32	5.5	95
4:21	3	151.02	0.09	17	6	5.9										12	5/9	4.0	95
4:38	2	150.93	0.06	17	12	5.8									4	11.5	9/14	5.0	95
4:59	3	150.87	0.09	17	8	5.8			18.5							1	14/18	4.0	96
5:11	2	150.78	0.06	17	12	5.8										12	18/23	5.0	95
5:27	3	150.72	0.09	17	8	5.7						41				1	23/26.5	3.5	96
5:43	2	150.63	0.06	17	12	5.8										11.5	26/31.5	5.5	96
5:59	3	150.57	0.09	17	8	5.8									4.5	12	5/9	4.0	95.5
6:15	2	150.48	0.05	17	10	5.8						42			4	11.5	9/14	5.0	96
6:31	3	150.43	0.09	17	6	5.8									4.5	12	14/16.5	2.5	96
6:47	2	150.34		17	12	5.9									4.5	12	16.5/22	5.5	95
	3	POWER	OFF	5	min.	WHEN	28	VDC	PWR	SUPP	WAS	INADVERT.	DISCONN.						
7:30	2	150.27	0.04	35	35	5.9								95	4	11.5	5/12	7	96
PM 2:48	3	150.20	.03	35	35	5.9									4	12	5/—		
8:00	2	150.20	.00	17	experiencing difficulty in switching beds - OK no problem														
8:14	3	150.20	0.08	17	17	4.9											5/10	5.0	96
8:30	2	150.12	0.05	17	14	5.7											10/15	5.0	95
8:46	3	150.07	0.07	17	9	5.5											15/17.5	2.5	95
9:02	2	150.01	0.06	16	17	5.8						41	47				17/22.5	5.5	95
9:17	3	149.99	.07	18	5	4.7						41	46	96		2	23/24.5	2.5	95
9:33	2	149.92	.04	21	16	5.7						42	46	96	4.5	12	24.5/29.5	5.0	95

REMARKS: 149.89

79309

HSP-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: JGW Finck
NAME OF RIG: 89
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 41 OF
DATE 3-5-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3/5 AM

TIME	DB	CO_2 wt	Δwc	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 DN	STEAM ON	AP	ΔAP	APP
949	3	149.88	.07	20	6	4.5	14.7	14.7	18.5	0	30	41	46	96	4.5	12	29/31	2.0	96
1006	2	149.81	.05	24	16	5.8	〃	〃	〃	〃	〃	41	48	〃	〃	〃	25.5/30.5	5.0	96
1022	3	149.76	.06	18	6	5.4	〃	〃	〃	〃	〃	42	46	〃	〃	〃	30/32	2.0	96
—	2	149.70	.06	12 16 18 / 19 20 20	7 17 18 / 21 20 19	5.9	〃	〃	〃	〃	〃	42	46	〃	〃	〃	31.5/36	5.5	96
1054	3	149.64	.06	11 32 12 / 21 16 18	9 23 13 / 16 18 18	4.3	〃	〃	〃	〃	〃	42	46	〃	〃	〃	35.5/37.5	2.0	95
** 1110	2	149.58	.05	21	15	5.7	〃	〃	〃	8	〃	42	46	〃	〃	〃	21/25.5	4.5	95
1126	3	149.53	.08	23	10	5.3	〃	〃	〃	9	〃	42	46	〃	〃	〃	35.5/38.5	3.0	95
1142	2	149.45	.05	21	14	5.8	〃	〃	〃	9.5	〃	42	46	〃	〃	〃	28/32	4.0	95
1158	3	149.40	.07	17	8	5.3	〃	〃	〃	〃	〃	42	47	97	〃	〃	21/26	4.0	95
PM 1212	2	144.33	—	—	—	*LUNCH	BREAK		*	—	—	—	—	—	—	—	—	—	—
1304	3	149.13	.06	12	8	4.1	14.7	14.7	18.5	9.5	30	41	46	97	4.5	12	35/38.5	4.5	95
1320	2	149.07	.06	22	11	5.8	〃	〃	18.5	9	30	42	46	〃	〃	〃	21/25	4.0	93
1336	3	149.01	.06	14	8	4.4	〃	〃	〃	〃	〃	42	47	〃	〃	〃	23.5/28.5	5.0	93
1352	2	146.95	.07	20	11	5.8	〃	〃	〃	〃	〃	42	47	〃	〃	〃	28/31.5	3.5	92
1408	3	149.88	.06	12	9	4.9	〃	〃	〃	〃	〃	42	46	98	5.5	13.0	30/34.5	4.5	92
1424	2	149.82	.07	22	11	5.9	〃	〃	〃	〃	〃	42	48	〃	4.5	13.0	6.5/10	3.5	91
1440	3	149.75	.05	16	13	4.8	〃	〃	〃	〃	〃	42	48	〃	〃	〃	9.5/14	4.5	91
1456	2	149.70	.07	19	10	5.9	〃	〃	〃	〃	〃	42	48	〃	〃	〃	12.5/15.5	3.0	90
1512	3	149.63	.06	12	11	5.1	〃	〃	〃	〃	〃	42	46	〃	〃	〃	14/19.5	5.5	91
1528	2	149.57	.07	19	9	5.9	〃	〃	〃	〃	〃	42	47	〃	〃	〃	18.5/21.5	3.0	90
1544	3	149.51	.06	12	10	5.0	〃	〃	〃	〃	〃	41	46	〃	〃	〃	20/25.5	5.5	91
1600	2	149.44	.08	18	8	6.0	14.7	14.7	18.5	9	30	42	48	98	4.5	13.0	25/29.5	4.5	90

REMARKS: 148.3%

* LUNCH BREAK - MISSED DESORB 2-3-2 CYCLES.

** Changed inlet temp. to canisters from 120°F to 105°F.

76807

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: JGW FINCK / T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATION

SHEET 42 OF
DATE 3-5-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

3:15 PM TIME	DB	CO_2 wt	ΔWt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	STEAM ON	AP	ΔAP	APP
1616	3	148.36	.05	13	11	4.8	14.7	14.7	18.5	9	30	42	46	98	4.5	13.0	3.7 / 3.2	5	90
1632	2	148.31	.07	17	12	6.0								1	5	13.5	31.5 / 34	2.5	90
1648	3	148.24	.05	17	13	5.1								99	5	14.5	33.5 / 38	4.5	90
1704	2	148.19	.09	17	5	6.0									5	14	19.5 / 24	4.5	90
1723	3	148.10	.05	17	15	5.1									5	14.5	0 / 5.5	5.5	91
1739	2	148.05	.08	17	12	6									1	1	5.0 / 8.5	3.5	91
1755	3	147.97	—	17	15	5.1									6	14.5	8.0 / —	—	—
1811	2	~~147.85~~	.15	17	12	6											— / 11	3	94
1827	3	147.78	.04	17	15	5.1											8 / 13.5	4.5	93
1843	2	147.74	.11	17	12	6											13.5 / 17	3.5	93
1859	3	147.63	.05	17	15	5.1											16.5 / 23	6.5	94
1915	2	147.58	.09	17	7	6											21 / 24	3	93
1931	3	147.49	.03	17	15	5.1											23.5 / 29	5.5	94
1947	2	147.46	.10	17	5	6								100			29 / 31.5	2.5	92
2003	3	147.36	.04	17	16	5.2											31 / 36.5	5.5	93
2019	2	147.32	.09	17	8	6											4.5 / 25	3	92
2035	3	147.23	.03	17	17	5.2										14	25 / 13	5.5	92
* 2051	2	147.20	.10	17	6	6											13 / 15.5	2.5	92
* 2107	3	147.10	.03	17	17	5.2											15.5 / 21	5.5	93
2123	2	147.07	.08	17	7	6											21 / 23	2	92
2139	3	146.99	.06	17	16	5.1											23 / 29	6	92
2155	2	146.[illegible]	.08	17	6	5.4											29 / 31	2	92

REMARKS:
* CO_2 VALVE [redacted] PROBLEM (LOUD BUZZING WHEN ENERGIZED) - RAPPED WITH RUBBER HAMMER - BUZZING STOPPED - MANUALLY RECYCLED TO VERIFY OPERATION - MAYBE VALVE WAS STUCK

76808

HSF-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT NCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 43 OF
DATE 3/5/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	DB	CO_2 wt	ΔWt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	Steam ON	AP	ΔAP	APP
2211	3	146.85	.04	17	16	5.1	14.7	14.7	18	9	30	42	46	100	6	14	30.5/36	5.5	94
2227	2	146.81	.09	17	6	5.6	"	"	"	"	"	"	"	"	"	"	36/37.5	1.5	92
2243	3	146.72	.04	17	15	5.1	"	"	"	"	"	"	58	101	"	"	4/10.5	6.5	95
2259	2	146.68	.09	17	5	5.9	"	"	"	"	"	"	55	"	"	"	10.5/12.5	2	94
2316	3	146.59	.04	17	17	5.1	"	"	"	"	"	"	*59	"	"	"	12/18	6	95
2332	2	146.55	.10	17	5	5.8	"	"	"	"	"	"	58-45	"	"	"	18/20	2	93
2348	3	146.45	.03	17	17	5.2	"	"	"	"	"	"	58-45	"	"	"	20/25.5	5.5	95
3/6 0004	2	146.42	.09	17	5	5.9	"	"	"	"	"	"	55	"	"	"	25.5/27.5	2	92
0021	3	146.33	.04	17	17	5.2	"	"	"	"	"	"	56	"	"	"	27.5/33	5.5	95
0037	2	146.19	.09	17	5	6.0	"	"	"	"	"	"	54	"	"	"	5/7.5	2.5	94
0053	3	146.20	.03	17	17	5.2	"	"	"	"	"	"	56	"	"	"	7/13	6.0	96
0110	2	146.17	.09	17	6	5.8	"	"	"	"	"	"	56	"	"	"	12.5/14.5	2.0	94
0126	3	146.08	.04	17	17	5.2	"	"	"	"	"	"	52	"	"	"	14/20	6.0	96
0142	2	146.04	.08	17	6	5.4	"	"	"	"	"	"	54	"	"	"	20/22	2.0	94
0158	3	145.96	.03	17	17	5.2	"	"	"	"	"	"	52	102	"	"	21.5/27.5	6.0	96
0215	2	145.93	.09	17	4	4.8	"	"	"	"	"	41	50	"	"	"	27/29	2.0	94
0231	3	145.84	.04	17	17	5.1	"	"	"	"	"	42	56	"	"	"	29/34	5.0	95.5
0247	2	145.80	.08	17	4	4.2	"	"	"	"	"	41	48	"	"	"	10/12.5	2.5	92.5
0303	3	145.72	.03	17	17	5.0	"	"	"	"	"	42	56	"	"	"	12/17.5	5.5	94
0319	2	145.69	.08	17	5	4.8	"	"	"	"	"	41	50	"	"	"	17.5/19.5	2.0	92
0335	3	145.61	.04	17	17	5.2	"	"	"	"	"	42	56	"	"	"	19/24.5	5.5	93
0351	2	145.57	.08	17	5	4.6	14.7	14.7	18	9	30	42	45	102	6	14	24.5/26.5	2.0	90

REMARKS:
*45 at end of cycle

76809

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT VCE
TEST ENGINEER: R. Petillo - C. DeSimone
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 44 OF | DATE 3-6-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	ΔWT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	STEAM ON	AP	ΔAP	APP
0408	3	145.49	0.03	17	17	5.1	14.7	14.7	18	9	30	42	56	102	6	14	26/31	5.0	92
0424	2	145.46	0.07	17	5	4.8							47				31/33	2.0	90
0440	3	145.39	0.04	17	17	5.2							49				3/8.5	5.5	93
0456	2	145.35	0.07	17	5	5.0						41					8.5/10.5	2.0	92
0512	3	145.28	0.04	17	17	5.1							56				10/15	5.0	92
0529	2	145.24	0.08	17	5	5.0						42					16/17	2.0	89
0545	3	145.16	0.03	17	17	5.1											16.5/22	5.5	92
0601	2	145.13	0.08	17	6	5.2						41	54				21.5/23.5	2.0	89
0617	3	145.05	0.04	17	16	5.2						42					22/27	5.0	92
0633	2	145.01	0.07	17	6	5.3											27/29	2.0	90
0649	3	144.94	0.03	17	16	5.1							52				29/33.5	4.5	91
0705	2	144.91	0.06	17	6	5.2											5/7.5	2.5	90
0721	3	144.85	0.04	17	16	5.1							56				7.5/12	4.5	90
0737	2	144.81	0.08	17	7	5.2								103			10.5/12.5	1.5	90
0753	3	144.73	0.02	17	16	5.0											12/17	5.0	90
0809	2	144.71	0.07	17	6	5.1											16/18	2.0	88
*0825	3	144.64	0.02	17	16	5.0				0							18/	--	88
0841	2	144.62	.07	-	-	-				>0							/24	—	88
0858	3	144.55	.03	17	16	5.0				>0		41	57				21.5/25.5	4.0	89.5
0915	2	144.52	.07	15	8	5.0				>0 <10		41	56				25.5/27.5	2.0	87.5
0931	3	144.45	.03	17	16	5.0						41	58				27.5/31	3.5	89.5
0946	2	144.42	.01	15	8	5.1						41	60				31/33	2.0	88

REMARKS:
* Changed canister inlet temp from 105°F To 120°F.

79310

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: A EPTANCE
TEST ENGINEER: C. DeSimone
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINE CO_2 CONCENTRATOR

SHEET 45 OF | DATE 8-6-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 wt	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 on	Steam on	ΔP	ΔAP	APP
1002	3	144.35	.03	17	16	4.9	14.7	14.7	18	>10	30	41	61	103	6	-14	5.5/9.5	4.0	88.5
1018	2	144.32	.06	15	9	5.1						41	60				9.5/11.5	2.0	88
1034	3	144.26	.03	17	16	5.0						41	60				11.5/15.5	4.0	89.5
1050	2	144.23	.06	15	9	5.1						41	61				15.5/17	1.5	88.5
1106	3	144.17	.03	17	16	5.0						41	61				17/21	4.0	89
1123	2	144.14	.06	15	9	5.2						41	61				21/22.5	1.5	88
1139	3	144.08	.04	17	16	5.0						41	61				22.5/26.5	4.0	89
1155	2	144.04	.06	16	10	5.1						41	60				26.5/28.5	2.0	87.5
1211	3	143.98		17	16	5.0						41	61				28.5		
1227	2						LUNCH												
1243	3						LUNCH										3.7		89.5
1259	2	143.86	.06	15	9	5.2	14.7	14.7	18	<10	30	41	61	104	6	14	6/8	2.0	87.5
1315	3	143.80	.04	17	15	5.0						41	61				5*/4.5	*	88
1331	2	143.76	.05	16	9	5.3						41	61				4.5/6.5	2.0	87
1347	3	143.71	.04	17	15	5.0						41	61				6/10	4.0	88
1403	2	143.67	.05	15	9	5.3						41	61				10/11.5	1.5	87
1419	3	143.62	.04	16	15	5.0						41	61				11.5/15	3.5	87.5
1435	2	143.58	.05	15	10	5.3						41	61				15/17	2.0	86.5
1451	3	143.53	.04	17	16	5.0						41	62				17/20.5	3.5	87.5
1507	2	143.49	.05	16	11	5.4						41	61				20.5/22.5	2.0	86
1523	3	143.44	.04	16 17 17 / 17 17 21	15 15 17 / 18 18 26	5.0						41	56				22/26	4.0	87.5
1539	2	143.40	.05	15 15 17 / 17 17 20	9 10 13 / 15 16 24	5.4						41	51				25.5/27.5	2.0	86
1555	3	143.35 / 143.31	.04	16	16	5.0						41	61				27.5/29.5	—	87

REMARKS:

* left APP sample valve on during cycle

RAN OUT OF 2% CAL GAS - NOW USING 1½% CAL GAS EQUAL TO 61% ON HSA SCALE

STOP RUN AT 1610

76802

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096
20 MIN. DESORB
40 MIN. ADSORB
SPACE & LIFE SYSTEMS LABORATORY
3 CANISTER LOG OF TEST
DRAINED OUT 320 ML OF WATER FROM #1

TYPE OF TEST: SETTLING CONDITIONS
TEST ENGINEER: BERTRAND - BROSE
NAME OF RIG:
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATION

SHEET 46 OF | DATE 2/16/70
TEST PLAN NO.
MODEL NO. # TURNED ON HX FLOW
PART NO. TO COIL TEMP. #7 TO
SERIAL NO. 95°F.
OPERATORS

	TIME	DB	CO_2 WT.	ΔWT	S/PP	SOPP	S/F	SPI	SPO	CCF	ACF	BCF	S/DP	SODP	H_2O_C	CO_2 ON.	CO_2 OFF	ΔP	ΔAP	APP			
	9:10	2	143.12	.06	27	26	7.0	10	10	16	0	30	40	—	108	—	—	20/19.5	.5	87			
AM	9:25	3	143.06	.03	42	44	4.2	10	10	17	0	30	40	—	108	6.0	6.5	20					
	9:40	1	143.03	.05	29	29	6.6	10	9.5	17	0	30	40	—	109	—	9.0	23	3				
XX	10:00	2	142.97	.06	24	22	5.8	10	9.5	17	0	30	40	33	109	5.0	9.0	25/24.5	2	87			
*	10:40	3	142.91	.06	25	19	5.8	10	9.5	17	0	30	40	33	109	7.0	13.0	24/28	4	87			
⊗	10.44	1	142.85	.08	27	21	6.0	10.2	10.15	17	0	30	39	34	109	8.0	15.5	28/30.5	2.5	88			
+	11:03	2	142.77	.08	27	21	6.0	10,1	10.15	17	0	30	39	34	109	10.5	20.0	30.5/32.5	2.0	87			
	11:28	3	142.68	.06	33	29	6.0	10.15	10.15	17.5	0	30	40	34	109	8.0	17.0	32.5/34	2.5	87			
Φ	11:47	1	142.62	—	33	27	5.9	10.15	10.15	17.5	0	30	40	34	109	8.5	18.0	34/35.5	1.5	88			
	12:08	2	—	.17	32	27	6.1	1	1	1	1	1	39	34	1	—	—	—	—	—			
	12:25	3	142.45	.04	31	32	6.0	1	1	1	1	1	39	34	1	—	—	—	—	—			
	12:45	1	142.44	.01	32	33	6.1	10.15	10.15	17.5	0	30	39	34	109	10.5		4/9	8.0	85			
⊕		2	142.40	.06	30	24	6.0	1	1	1	1	1	39	34	1	—	—	8/—	—	—			
	1:38	3	142,34	.05	20	24	—	1	1	1	1	1	40	—	1	—	—	—	—	—			
	1:45	1	142.29	.03	34	37	6.5	10.3	10.3	17.5	0	30	40	34	109	10.5	16.5	8/13	5.0	87			
PM	2:05	2	142.26	.10	30	26	6.1	10.15	10,10	17.5	0	30	39	32	110	8.0	17.0	13/18	5.0	88			
	2:25	3	142.16	.06	32	28	6.0	10.15	10.10	17.5	0	30	39	32	110	8.0	18.0	18/23.2	5.2	89			
	2:45	1	142.10	.06	32	25	6.1	10,20	10.10	17.5	0	30	39	33	110	9.0	19.0	23/27.5	4.5	90			
	3:06	2	142.04	.08	32	25	6.1	10.15	10.10	17.5	0	30	39	33	110	8.0	17.5	27/30.5	3.5	90			
#	3:36	3	141.96	.08	33	25	6.0	10.15	10.10	17.5	10	30	39	34	110	8.0	17.0	11.5/16	5.5	90			
	3:56	1	141.88	.08	34	24	6.1	10.20	10.10	17.5	8	30	39	34	110	10.0	14.5	16/21.2	4.2	91			
	4:08	2	141.79	.10	31	25	6.1	10.20	10.10	17.5	9	30	40	31	110	9.0	18	22/26.5	4.5	91			

REMARKS:
9:35 TURN BACK EACH WATER PUMP 1 TURN CCW.
XX BACKED OFF ONE MORE TURN ON WATER PUMPS.
* " " 1/2 " " " " "
Φ SHUT OFF WATER PUMPS DURING SEC. #2 & #3 TO DRY OUT TUBES
• BACK OFF 1 TURN ON WATER PUMPS - PUMPS IN ALL CASES OF ADJ. TURNED ARE DURING LAST MINS WHEN STEAM IS ON.
+ PUMP #1 - ADVANCED SCREEN (UNIT) 1/2 TURN
• No Desorb. 78307 *

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: SETTLE CONDITIONS
TEST ENGINEER: BERTRAND - BRUSE - PETILLO
NAME OF RIG:
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATION

SHEET 47 OF
DATE 3/16/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 WT.	ΔWT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
PM	4:26	3	141.69	.08	32	24	6.0	10.15	10.10	17.5	9	30	40	34	110	9.0	18	26/30	4	91			
	4:46	1	141.61	.09	28	25	6.1	10.15	10.10	17.5	9	30	39	34	111	10.0	20	11/12.8	6.8	91			
	5:07	2	141.52	.09	29	23	6.0									9.0	18	17.5/22.5	5.0	93			
	5:23	3	141.43	.10	31	31	6.0		10.10	17.5	8	30		33		9.0	18	22.5/27	4.5	92			
	5:57	1	141.83	—	33	35	6.2				8.5					—*	—**	27/30	3.0	92			
	6:10	2	172.92	.05‡	34	27	5.9				8.5					9.0	18.5	30/33	3.0	93			
	6:27	3	172.87	.09	29	24	5.9							35		9.0	19.5	5/12	7.0	92.5			
	6:47	1	172.78	.09	29	24	6.1							33		10.0	20	11.5/19	8.5	92.0			
	7:07	2	172.69	.11	31	24	6.0									9.0	17.5	19/24.5	5.5	92.5			
	7:28	3	172.58	.11	31	25	6.0									9.0	19.0	5/12	7.0	91.0			
	7:49	1	172.47	.10	31	28	6.1									10.0	**	12/18.5	6.5	91.0			
	8:09	2	172.37	.11	31	24	5.9									9.0	18	18/24	6.0	90.5			
	8:29	3	172.26	.12	31	25	5.9	10.10			8.5					9.0	19	5/12.5	7.0	90.0			
	8:49	1	172.14	.10	31	26	6.0									11.0	**	12.5/19	6.5	90.0	Baro.	30.01	"Hg
	9:09	2	172.04	.12	31	26	6.0							32	112	9.0	18	18/24	6.0	90.0			
	9:29	3	171.92	.09	31	23	5.9									9.5	**	23.5/29	5.5	89.5			
⊙	9:49	1	171.83	.09	30	24	6.1	10.10	10.00					33		10.0	19.5	5/13.5	8.5	90.0			
	10:09	2	171.74	.11	30	21	5.9									9.0	17.0	13/19.5	6.5	94.0	☆		
	10:24	3	171.63	.10	31	23	5.9									9.0	18.5	19/25.5	6.5	93.5			
	10:49	1	171.53	.10	31	25	6.1									9.5	30	25/30	5.0	94.0			
	11:09	2	171.43	.10	30	22	6.0									8.5	19.5	25/32.5	4.0	94.0			
	11:29	3	171.33	.09	31	24	5.9	10.10	10.00	17.5	8.5	30	39	33	112	8.0	20.0	0/7	7	93			

REMARKS:
* DID NOT TAKE IT
** DID NOT OCCUR
† NEW BOTTLE
‡ NOT FULL CYCLE INTAKE DUE TO CHANGE OF CO_2 BOTTLE
⊙ [redacted] WATER PUMP #2 (½ TURN CW)
☆ CAL. LIRA OFF (LOW) BY 4%

78308

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: SETTING CONDITIONS
TEST ENGINEER: R. PETILLO / T. PECK
NAME OF BIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET: 48 OF
DATE: 7/17/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 WT	ΔWt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O	CO_2 ON	CO_2 OFF	AP	ΔAP	APP
	11:53	1	171.24	.09	27	24	6.2	10.1	10.05	18	8	29.5	40	33	112	8	17	15/65	8.5	93.5
AM	12:17	2	171.15	.09	30	1	4.1									8.5	17	15/21	6	94
	12:37	3	171.09	.06	40	29	3.7									8.5	18	21/27	6	93
	12:53	1	170.97	.12	33	25	5.6									10	16.5	27/33	2	93
	1:13	2	170.89	.08	32	30	4.1									8.5	18	0/6.5	6.5	93
	0133	3	170.83	.09	32	21	3.7						38			8.5	18	6/13.5	7.5	93
	0153	1	170.74	.11	32	24	5.8						40			10	16.5	13.5/16.5	3	93
	0213	2	170.63	.06	32	30	4.1						39			8.5	17	16.5/22.5	6	93
	0233	3	170.57	.10	32	20	3.8									8.5	18	22/28	6	91
	0253	1	170.47	.08	32	28	5.9						40			10.5	16.5	27.5/29.5	2	92
	0313	2	170.39	.05	32	30	4.1						39			8.5	18.5	29/32.5	3.5	92
	0333	3	170.34	.09	32	20	3.7				11*		39			8.0	19	32.5/35.5	3.0	93
	0353	1	170.25	.07	32	28	6.1									11	18	35/36.5	1.5	93
**	0413	2	170.18	.04	32	31	4.2									8	18	0/4	4	93
	0433	3	170.14	.10	32	20	3.8									8	18	4/11.5	7.5	92
	0454	1	170.04	.11	31	27	5.9						40			11	17	11.5/14.5	3	92
	0514	2	169.93	.65	31	31	4.2						39			8.5	16.5	14/20.5	6.5	92
	0534	3	169.88	.11	31	22	3.8									8.5	18	20/26.5	6.5	92
	0554	1	169.77	.10	31	27	6.0						40			12	18.5	26/28.5	2.5	92
	0614	2	169.67	.04	31	31	4.2						39			8.5	19	28.5/32	3.5	92
	0634	3	169.63	.10	32	21	3.8									8	NO TRIP	32/35	3	92
⊙	0654	1	169.53	.06	31	27	5.9						40		1/2 1/3	9	15	5.5/9	3.5	93

REMARKS:
*15, 16, 17 INDICATE BEDS DRYING GRADUALLY - INCREASE ACF TO DECREASE DRYING ABILITY OF T,
** REDUCED FLOW CONTROLLER TRIP PT TO 1.75 FROM 2.0 BECAUSE OF CO_2 SHOWING UP IN OUTLET LIRA
⊙ INCREASED STEAM RATE BY TURNING ADJ SCREW ON PUMP #1 1TURN CLOCKWISE

78309

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

O END OF CYCLE N2 STEAM VALVE ACTUATION

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

● - DENOTES NO DESIRED

TYPE OF TEST: ACCEPT. NCG
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 49 OF | DATE 12/30
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

Time	DB	CO_2 wt.	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
0714	2	169.47	.07	31	30	4.2	10.05	10.05	18	11	30	39	34	113	7	14.5	9/15.5	6.5	94			
0735	3	169.40	.10	31	20	3.9	"	"	"	"	"	"	"	"	6.5	15	15/22.5	7.5	93			
0756	1	169.30	.11	32	25	6.0	"	"	"	"	"	40	"	"	10	15	22/24.5	2.5	93			
08:16	2	169.19	.06	32	29	4.3	10.00	9.95	18	10.5	30	39	34	113	8	16	24/28.5	4.5	93			
08:37	3	169.13	.13	32	25	3.8	10.0	9.95	18	11	30	39	34	113	7	16.5	28.5/32	4.5	93			
08:56	1	169.03	.06	32	27	6.2	10.0	10.0	18	11	30	40	34	113	10	17	32/34	2.0	93	→	5.77 LBS CO_2 IN 24 HRS	
09:16	2	168.97	.08	32	30	4.3	10.05	10.0	18	11	30	39	34	113	7	15	11/18	7.0	94			
09:36	3	168.89	.09	32	22	4.0	10.05	10.0	18	11	30	39	34	113	7	15.5	18/25	7.0	93			
10:00	● 1	168.80	.10	32	26	6.0	"	"	"	0	"	"	"	113	—	—	—	—	—			
10:15	2	168.70	.08	32	29	4.0	10.0	10.0	18	0	30	38	34	113	9.5	17.5	24.2/28.5	4.3	92			
	3	168.62	.13	RAISED	PRESS.	TO 14.7	REMOVED		WT.	6 GRAMS		OR 18-45			MAT.	FROM	BED #1		MAT. DRY	#3	
10:56	1	168.49	.10	32	28	6.0	10.0	10.0	18	12.5	30	40	34	113	9.0	19.0	31.5/33.5	2.0	92			
11:22	2	168.39	.01	31	36	4.2	10.05	9.95	18	11.5	30	39	34	113	6.0	18.0	11/18	7.0	92			
11:37	3	168.38	.10	32	21	4.1	10.0	9.95	18	10.0	30	39	34	113	8.0	16	17.5/25	7.5	92	MOVED CO_2 SEN. ASSEMBLY TO 2		
11:54	1	169.28	.11	32	27	6.0	10.05	10.0	18	10.5	30	40	34	113	10.0	16.0	28.5/31	2.5	92			
12:10	2	169.17	.10	31	33	4.2	10.05	10.0	18	11.0	30	39	34	113	6.5	14.5	27/30.5	3.5	91			
12:25	3	169.16	.10	32	22	3.8	10.05	10.0	18	10.0	30	39	34	113	7.0	—	11/19	8.0	94	checked CO_2 on APP & found low by 3		
12:45	1	169.06	.10	32	30	5.9	10.05	10.05	18	10.5	30	40	35	113	10	15.6	19.5/21	2.5	93.5			
13:00	2	169.06	.09	32	—	4.0	10.05	10.05	18	10.5	30	40	35	113	7	13	21/26	5.0	93.5			
13:15	3	167.87	.11	—	—	3.8	10.0	10.0	18	10.5	30	39	34	113	7	16°	26.5/30.5	5.0	—			
13:35	1	167.77	.03	—	—	5.7	10.0	10.0	18	11.0	30	39	34	113	10	16°	30/32	2.0	—			
13:47	2	167.74	.02	31	30	4.0		10.0	18	10.5	30	39	34	113	6.5	12.5	11.5/17.5	6.0	94			

REMARKS:

[redacted] CCW UP

+ BACK OFF CCW 1 TURN ON WATER PUMP #1, TURNED Hx CONTROL VALVE TO MAX HEATING POSITION. CHECK FLOW THRU CCW #1 = 1.5" WATER (VERY LOW FLOW)

● RETURNED WATER PUMP #1 TO + COND. (1 TURN CLOCKWISE)

XX CHANGED TO 16 MIN. CYCLE,

1. CAL. INLET LINE A - 1.5% GAS THAT SHOULD BE 61 WAS 45 WHEN 1.2 (CAL.) READ 45, OL READ 52

78310

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

H-58

HSF-175.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

16 MIN. DESAT CYCLE

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

O STEM VALVE DID NOT TRIP

TYPE OF TEST	ACCEPT. ICE
TEST ENGINEER	BERTRAND - BROWSE
NAME OF RIG	88
PROJECT & ENG. ORDER NO.	AMINES CO_2 CONCENTRATOR
SHEET	50 OF
DATE	3/17/70
TEST PLAN NO.	
MODEL NO.	
PART NO.	
SERIAL NO.	
OPERATORS	

	TIME	DB	CO_2 WT.	Δ WT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
	14:04	3	167.72	.09	32	20	4.0	10.0	9.95	18	10.5	30	39	34	113	7.0	13.5	11.5/19	7.5	93			
	14:20	1	167.63	.10	31	23	6.0	10.0	10.0	18	11.0	30	40	35	113	11.0	15.5	12/14.5	2.5	92			
	14:36	2	167.53	.01	32	27	4.2	10.0	10.0	18	10.5	30	39	34	113	7.0	13.0	13.5/19	5.5	93			
	14:53	3	167.52	.10	32	19	3.8	10.0	9.95	18	10.5	30	39	34	113	7.0	14.0	11.5/18	6.5	92			
	15:08	1	167.42	.10	32	22	5.9	10.0	9.95	18	10.5	30	40	34	113	11.0	16°	18/19.5	1.5	92			
	15:25	2	167.32	.00	32	28	4.2	10.0	9.95	18	10.5	30	39	34	114	6.5	13.0	19.5/24	4.5	92			
	15:43	3	167.32	.10	32	22	4.0	10.2	10.15	18	10	30	39	34	114	7.0	14.5	23.5/28.5	5.0	92			
	15:57	1	167.22	.10	32	22	5.8	10.2	10.15	18	11	30	40	34	114	11.5	16°	11/12	1.0	92			
*	16:12	2	167.12	.00	32	28	3.9	10.2	10.15	18	10.5	30	40	34	114	6.0	12.0	12/18	6.0	92			
**	16:26	3	167.12	.11	32	22	3.5	10.3	10.3	18	10.5	30	40	34	114	7.0	14.0	11/18	7.0	92			
	16:45	1	167.01	.07	34	31	5.7	10.3	10.3	18	10.5	30	40	34	114	[illegible]	5.5	17.5/18.5	1.0	91.5			
	17:02	2	[illegible]	.04	34	28	5.5	10.3	10.3	18	10.5	30	40	34	114	7.0	13.0	17.5/23.5	6.0	92			
	17:17	3	166.90	.10	33	19	4.2	10.3	10.3	18	10.5	30	40	34	114	7.0	14.5	23/28	5.0	93			
	17:32	1	166.80	.08	34	26	6.0	10.3	10.3	18	10.5	30	40	34	114	12.5	16.5	5/6	1.0				
		2	166.72																				
		3				Removed .527# Amine from bed #1 and returned flow to 3.5																	
3/18/70 →		1				by keeping the ccu ondsor 6.																	
	9:39	2	166.42	.10	34	21	6.3	10.05	10.0	18	11.0	30	39	34	114	6.5	13	9/16	7.0	93.5			
XXX	9:05	3	166.32	.10	34	22	6.3	10.0	10.05	18	11	30	39	34	114	8.0	16°	16/22	6.0	94			
	10:09	2	166.22	.07	32	22	6.0	10.0	9.95	18	11	30	40	34	114	7.0	12.5	11/16.5	5.5	94			
	10:26	3	166.15	.09	33	20	6.0	10.0	9.95	18	10	30	40	34	114	6.0	12.5	16/22.5	6.5	94			
XXXX	10:40	1	166.06	.04	33	26	4.3	10.0	9.95	18	10	30	40	34	114	7.5	16	11/20	9.0	94			

REMARKS

* PUT BED #1 ON ISOLATE FOR ONE CYCLE.
** CO_2 CONTROLLER MALFUNCTIVE FOR ONE CYCLE.
XXX PUMP 1/2 TURN MORE FLUID.
XXXX PUMP 1/2 " " " .

78311

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: RICHARD - ROSE
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 57 OF | DATE 2/18/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DS	CO_2 WT.	ΔWT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_c	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
10:54	2	166.02	.08	33	16	6.0	10.0	9.95	18	10	30	40	34	114	6.0	12.0	19/24	5.0	94			
11:09	3	165.94	.12	34	18	6.0	10.0	9.95	18	11	30	40	34	114	6.0	11.0	11/17	6.0	94			
11:35	1	165.82	.10	34	21	6.1	10.0	9.95	18	10	30	40	34	114	6.5	16	16.5/26	9.5	94.5			
11:45	2	165.72	.11	34	16	6.1	10.0	9.95	18	10	30	40	34	114	5.5	10.0	11/17	6.0	95			
12:03	3	165.61	.11	33	17	6.1	10.0	9.95	18	10	30	40	34	114	5.5	11	11.5/22.5	6.0	95			
* 12:15	1	165.50	.06	33	26	4.3	10.0	9.95	18	10	30	40	34	114	6.5	15	11/21	10.0	95			
12:34	2	165.44	.10	33	20	4.8	10.0	9.95	18	10	30	40	34	114	5.5	12	21/26	5.0	95			
12:52	3	165.34	.11	33	15	5.9	10.0	10.0	18	10	30	40	34	114	5.0	13	25.5/29	4.5	95			
13:07	1	165.23	.09	33	21	6.0	10.0	10.0	18	10	30	40	34	114	7.0	16	28.5/32.5	4.0	95			
13:24	2	165.14	.05	32	18	6.0	10.0	9.95	18	10	30	40	34	114	5.0	12.5	32/34.5	2.5	95			
13:39	3	165.09	.10	33	19	6.1	10.0	9.95	18	10	30	40	34	114	5.5	11.5	11/18	7.0	94			
13:56	1	164.99	.09	32	25	4.4	10.0	9.95	18	10	30	40	34	114	7.0	16	17/26	9.0	94			
14:14	2	164.90	.10	32	15	6.1	10.0	9.95	18	10	30	40	34	114	5.5	11.0	11/17	6.0	94.5			
14:27	3	164.80	.12	32	16	6.1	10.0	9.95	18	10	30	40	34	114	6.0	11.5	17/22	5.0	94			
Φ 14:44	1	164.68	.08	32	25	4.5	10.0	9.95	18	10	30	40	34	114	7.0	15.5	22/28.5	6.5	95			
15:02	2	164.60	.11	32	16	6.1	10.0	9.95	18	10	30	40	37	114	6.0	12.5	11/18	7.0	94.5			
15:17	3	164.49	.10	33	18	6.1	10.0	9.95	18	10.5	30	40	37	114	6.0	12.0	17.5/23	5.5	95			
15:33	1	164.39	.08	32	20	6.2	10.0	9.95	18	10.5	30	40	37	114	7.0	15	22.5/29	6.5	94.5			
15:49	2	164.31	.03	32	24	4.8	10.0	9.95	18	10.0	30	40	37	114	6.0	14	28/32	4.0	94			
16:06	3	164.28	.11	32	10	5.6	10.0	9.95	18	10	30	40	37	114	6.0	12.5	11/18	7.0	94			
16:21	1	164.17	.10	33	22	6.3	10.0	9.95	18	10	30	40	37	114	6.5	13	17.5/24	6.5	95			
16:38	2	164.07	.06	32	26	3.9	10.0	9.95	18	10	30	40	37	114	6.0	14	23/28.5	5.0	94.5			

REMARKS:
* SIF - DROPPED FROM 6.1 TO 4.3 !!!! - RECOVERED ABOUT 12 MIN. INTO THE CYCLE.
Φ STARTED AT SIF 4.5 - 7.0 MIN. INTO CYCLE JUMPED TO 6.0 - STARTED TO ADSORB (LIRAS)

78312

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: BERTRAND - ELOSE
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATION

SHEET 52 OF | DATE 7/18/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 INT.	ΔNT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP
*	16:55	3	16401	.09	33	17	6.0	10.0	9.95	18	16	30	40	38	114	5	12	28/31	3	95
**	17:10	1	163.92	.09	32	21	6.2		10							5.5	**	5/13	7	95.5
	17:25	2	163.83	.04	32	27	4.1								115	5.5	10.5	12.5/18.5	6	95
+	17:40	3	163.79	.07	32	21	3.9				14					5.5	11.0	18/23.5	5.5	95
	17:55	1	163.72	.07	32	25	4.6									6.0	**	23/28.5	1.5	94
	18:10	2	163.65	.05	32	24	4.1									5.5	11.5	24/28.5	4.5	94
	18:25	3	163.60	.14	33	21	6.0									5.5	10.5	5/12	7	95
①	18:40	1	163.46	.08	32	26	4.3				13.5					6.0	11.5	11.5/18	7.5	95
	18:55	2	163.38	.04	32	24	4.0									5.0	11.0	18/23	5	95
	19:13	3	163.34	.12	32	20	4.3									5.0	10.0	22.2/26.5	4	95.5
	19:28	1	163.22	.04	32	26	4.3									6.0	11.0	26/29	3	95
	19:43	2	163.18	.09	32	25	4.1									5.0	10.0	5/12	7	95
	19:58	3	163.09	.05	32	18	3.8									5.0	10.0	11.5/17	5.5	95
	20:15	1	163.04	.08	32	19	5.7									7.0	9.0	17/18.5	1.5	94.5
‡	20:30	2	162.96	.04	32	26	4.3									5.5	12.0	18/23.5	5.5	95
	20:45	3	162.92	.10	32	17	3.8									5.0	11.5	23.5/28	4.5	95
	21:00	1	162.82	.07	32	21	6.0									7.0	11.0	5/8	3.0	95
	21:15	2	162.75	.04	32	26	4.2									5.0	11.5	7.5/13.5	5.0	95
	21:30	3	162.71	.09	32	18	3.8									5.5	11.0	13/19.5	6.5	96
	21:45	1	162.62	.08	31	22	5.5									7.5	11.0	19/21	2.0	94
	22:00	2	162.54	[illegible]	32	26	4.2									5.5	11.5	20.5/26	5.5	94
	23:35	2	162.19		33	28	4.2	10	10	18	13.5	30	40	38	115	5.0		10/17	7.0	94.5

REMARKS:
* DECR. CY. TIME TO 15 MIN — INCR PUMP #2 ½ TURN CW - INCR ACE (T) DOWN TO 80°F)
** STEAM CY. NEVER OBTAINED
\+ TEMP CORR - HAD DROPPED 10°F
① INCR H_2O PUMP ½ TURN CW
‡ DECR. H_2O PUMP ½ TURN CCW

78313

Acceptance Test

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: BROSE / PETILLO / PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 5-3 OF
DATE 2/23/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_2	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
22 28	1	162.03	.18	31	20	5.8	10	10	18	15	30	42	44	120	—	—	0 / —	—	—			
—	2	—	↓	—	—	—	↓	↓	↓	↓	↓	↓	↓	↓	—	—	—	—	—			
22 58	3	161.85	.04	32	22	8.9	10	10	18	15	30	42	44	120	7	14	3 / 5.5	05	94	ATMOS. PRESS		
23 14	1	161.81	.02	59	63	5.6	↓	↓	18	14	↓	41	37	121	5	11	3.5 / 4.5	1.0	94	10 PSIA		
23 29	2	161.79	.08	32	17	5.8	↓	↓	18	13	30	41	38	↓	5	11.5	4.5 / 15	11.5	96	↓		
23 44	3	161.71	.11	33	13	5.8	↓	↓	↓	↓	↓	41	38	↓	5	12	15 / 20.5	9.5	96.5			
2359	1	161.60	.10	33	16	5.9	↓	↓	↓	↓	↓	↓	↓	↓	6	13	24 / 31	7	96			
3/24 0014	2	161.50	.08	32	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	12	31 / 35.5	4.5	95			
0029	3	161.42	.11	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	10	0 / 9	9	95			
0044	1	161.31	.14	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	11	9 / 18.5	9.5	95			
0059	2	161.17	.12	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	11	18 / 26	8	95			
0115	3	161.05	.12	32	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	12.5	25.5 / 32.5	7	94			
0130	1	160.93	.11	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	13	32 / 37.5	5.5	95			
* 0145	2	160.82	.10	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.0	10	5 / 14.5	9.5	95			
0201	3	160.72	.10	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	12	14 / 23	9	95			
0218	1	160.62	.12	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	13	23 / 30.5	7.5	95			
** 0233	2	160.50	.11	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	5.5	12	30 / 35.5	5.5	95			
0248	3	160.39	.11	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	11	5 / 14	9	95			
0303	1	160.28	.12	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	12	14 / 22.5	8.5	95.5			
0318	2	160.16	.12	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	12	22 / 29	7	95.5			
0333	3	160.04	.14	33	16	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	10	0 / 8.5	8.5	95			
0348	1	159.90	.12	33	18	5.8	↓	↓	↓	↓	↓	↓	↓	↓	6	11.5	8.5 / 17.5	8.5	94			

REMARKS:
* TIMED ABSORB CYCLE WITH STOPWATCH - INDICATED 14 MIN CYCLE ACTUALLY TOOK 14 MIN 45 SEC TO COMPLETE - ADJUSTED
** " " " " " " " " " " " " 14 MIN 7 SEC " " "

78315

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCE -ANCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 54 OF
DATE 3/24/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δ WT	SIPP	SOPP	SIF	SP∅	SPO	CCF	ACF	BCF	S∅P	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP
0403	2	159.78	.12	33	16	5.8	10	10	18	13	30	40	37	121	6	11	14 / 21.5	7.5	95
0418	3	159.66	.12	33	17	5.8	"	10.1	"	"	"	"	"	"	6	12	21 / 28.5	7.5	95
0433	1	159.54	.10	33	17	5.8	10.1	"	"	"	"	"	"	"	6	13	28.5 / 34	5.5	95
0448	2	159.44	.10	33	17	5.8	10.05	"	"	"	"	"	"	"	6	10	4.5 / 13.5	9	93
0503	3	159.34	.11	33	17	5.7	10	10.05	"	"	"	"	"	"	6.5	12	13.5 / 21.5	8	94
0518	1	159.23	.11	33	17	5.8	"	"	"	"	"	"	"	"	6	12	21 / 28.5	7.5	94
0533	2	159.12	.12	33	17	5.7	"	"	"	"	"	"	"	"	5.5	9.5	4 / 12	8	94
0548	3	159.00	.10	33	17	5.7	"	"	"	"	"	"	"	"	6	11	12 / 20	8	94
0603	1	158.90	.11	33	17	5.8	"	"	"	"	"	"	"	"	6	12	19.5 / 27	7.5	95
0618	2	158.79	.10	33	17	5.7	"	"	"	"	"	"	"	"	5.5	11.5	27 / 32.5	5.5	95
0633	3	158.69	.11	33	18	5.8	"	"	"	"	"	"	"	"	6	10	2 / 11.5	9.5	92
0648	1	158.58	.11	33	17	5.8	"	"	"	"	"	"	"	"	6	11	11 / 18.5	8.5	*92
0703	2	158.47	.11	33	17	5.7	"	"	"	"	"	"	"	"	6	11.5	19 / 26	7	92
0718	3	158.36	.10	33	17	5.7	"	"	"	"	"	"	"	"	6	12	26 / 32	6	92
0734	1	158.26	.10	33	18	5.7	"	"	"	"	"	"	"	"	6	10.5	5 / 14.5	9.5	90
0749	2	158.16	.10	33	18	5.7	"	"	"	"	"	"	"	[redacted]	5.5	10.5	14 / 21.5	7.5	91
0804	3	158.06	.12	33	18	5.7	10.0	10.05	18	13	30	40	37	122	6.0	12	21 / 28	7.0	91
0820	1	157.94	.09	33	18	5.7	10.0	10.05	18	13	30	40	37	122	6.0	12.5	28 / 33	5.0	91
0836	2	157.85	.09	32	20	5.7	10.0	10.6	18	13	30	40	37	122	6.0	11.0	13.5 / 22	8.5	91
0852	3	157.74	.11	32	18	5.7	10.0	10.5	18	13	30	40	37	122	6.0	12	21.5 / 28.5	7.0	93
0906	1	157.63	.08	33	19	5.7	10.0	10.5	18	13	30	40	37	122	6.0	12.5	28.0 / 33.5	5.5	92
0920	2	157.55 / 157.44	.11	33	19	5.7	10.0	10.5	18	13	30	40	37	122	6.0	10.5	12.5 / 20	7.5	91

REMARKS:
* RECAL APP LIRA

78314

HSF-178.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT. ICE
TEST ENGINEER: FINCK / BERTRAND
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 55 OF
DATE 7/24/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 wt	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
AM	0935	3	157.44	.12	33	19	5.7	10.0	10.5	18.0	13.0	30.0	40.0	38.0	122	6.0	11.5	19.5/27	7.5	91.0			
	0950	1	157.32	.08	33	19	5.7	10.	10.5	18	13	30	40	38	122	6.0	12.5	26.5/32.5	6.0	91.0			
	1005	2	157.24	.10	33	19	5.7	10	10.5	18	13	30	40	38	122	5.5	10.0	12.0/19	7.0	90.0			
	1021	3	157.14	.11	33	18	5.7	10	10.5	18	13	30	40	38	122	5.0	11.5	19/26	7.0	91			
	1036	1	157.03	.08	33	19	5.7	10	10.5	18	13	30	40	38	122	6.0	12.0	25.5/31.5	6.0	92			
	1051	2	156.95	.11	33	18	5.7	10	10.05	18	13	30	40	38	122	5.5	10.0	12/19.5	7.5	91			
	11:06	3	156.84	.12	33	17	5.7	10	10.05	18	13	30	40	38	122	6.0	11.5	19/26	7.0	91			
+	11:21	1	156.72	.09	33	19	5.7	10	10.05	18	13	30	40	38	122	6.0	11.5	23/27.5	* 4.5	96	BAD CAL.		
	11:36	2	156.63	.09	33	20	5.8	10	10	18	13	30	40	38	122	5.5	11.5	27/32.5	5.5	96	BAD CAL.		
	11:51	3	156.54	.12	33	18	5.8	10	10	18	13	30	40	38	122	6.0	10.5	12/19.5	7.5	94	BAD CAL.		
++	12:06	1	156.42	.10	33	18	5.8	10	10	18	13	30	40	38	122	6.0	11.5	19/26.5	7.5	98			
PM	12:21	2	156.32	.08	33	18	5.8	10	10	18	13	31	40	37	122	6.0	11.0	21.5/27.5	6.0	93			
	12:36	3	156.24	.10	32	17	5.8	10	10	18	13	31	40	38	122	5.5	12.0	27.5/32.5	5.0	93			
	12:52	1	156.14	.08	32	18	5.8	10.1	10.1	18	13	31	39	36	122	6.0	12.0	32/36	4.0	—			
	13:08	2	156.06	.09	33	17	5.9	10.1	10.1	18	13	31	40	37	122	5.5	9.5	5.5/14.5	9.0	92			
	1321	3	155.97	.11	33	17	5.8	10.1	10.1	18	13	31	40	37	122	6.0	10.5	14/21	7.0	92			
	1336	1	155.86	.10	33	18	5.8	10.1	10.1	18	13	31	40	37	122	5.5	10.0	6.0/13.5	7.5	93			
	1351	2	155.76	.09	33	17	5.8	10.1	10.1	18	13	31	40	37	122	5.5	10.0	13/20	7.0	93			
	1406	3	155.67	.12	33	17	5.8	10.1	10.1	18	13	31	40	37	122	5.5	9.5	6.0/13	7.0	93			
	1422	1	155.55	.11	33	18	5.9	10.1	10.1	18	13	31	40	37	122	5.5	10.5	12.5/20	7.5	93			
	1436	2	155.44	.10	33	17	5.8	10.1	10.1	18	13	31	40	37	122	6.5	9.0	5.5/12.5	7.0	95			
	1452	3	155.34	.12	33	17	5.8	10.1	10.1	18	13	31	40	37	122	5.5	10.0	12/19	7.0	95			

REMARKS: 155.22

* LEFT 100% LIRA ON - LOST CO_2
\+ SET 100% POINT ON LIRA. (ACCUM. PURITY).
++ RECALIBRATED 100% LIRA. (ACCUM. PURITY) and inlet & outlet LIRA.

78316

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: FINCK / BERTRAND
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 56 OF
DATE 9/24/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	ΔWT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
1507	1	155.22	.10	33	18	5.8	10.1	10.1	18	13	31	40	37	122	5.5	9.5	5.5/12.5	7.0	95			
15:21	2	155.12	.10	33	17	5.8	10.05	10.1	18	13	31	40	38	123	5.5	10.0	12/19	7.0	95			
15:32	3	155.02	.10	33	18	5.8	10.1	10.1	18	13	31	40	38	123	6.0	11	19/25.5	6.5	95			
15:52	1	154.92	.10	33	17	5.9	10.1	10.1	18	13	31	40	39	123	6.0	10	6/13	7.0	94			
16:07	2	154.82	.10	33	18	5.9	10.1	10.1	18	13	31	40	39	123	5.5	10	13/20	7.0	94			
16:22	3	154.72	.11	33	17	5.8	10.1	10.1	18	13	31	40	39	123	6.0	11	20/27	7.0	94			
16:37	1	154.61	.11	33	19	5.9	10.1	10.1	18	13	31	40	39	123	6.0	10	6/13.5	7.5	93.5			
16:52	2	154.50	.10	33	17	5.7	10.1	10.1	18	13	31	40	39	123	6.0	10.5	19.5/26.5	7.0	94			
17:07	3	154.40	.10	33	19	5.8	10.1	10.1	18	13	31	40	39	123	5.5	11	20/27	7.0	93.5	*		
17:22	1	154.30	.10	33	19	5.8	10.1	10.1	18	13	31	40	39	123	6.0	10	6/14	8.0	93.5			
17:37	2	154.20	.11	33	18	5.8	10.1	10.1	18	13	31	40	39	123	5.5	10	13/21	7.0	93.5			
17:52	3	154.09	.10	33	19	5.8	10	10	18	13	30	40	38	123	6.0	11.5	20/27	7.0	93.5	cal		
18:07	1	153.99	.11	33	18	5.8	10	10	18	13	30	40	38	123	6.0	12	26.5/33.5	6.0	94			
18:22	2	153.88	.08	33	19	5.8	10	10	18	13	30	40	38	123	6.0	8.5	0/5	5.0	88	—	—	— ?
18:37	3	153.80	.11	33	17	5.7	10	10	18	13	30	40	38	123	6.0	9.5	3/10.5	7.5	94	*		
18:52	1	153.69	.11	33	17	5.8	10	10	18	13	30	40	38	123	6.0	11.0	10/17.8	7.8	94			
19:07	2	153.58	.10	33	17	5.8	10	10	18	13	30	40	38	123	6.0	11.5	12.5/19.5	7.0	94			
19:22	3	153.48	.10	33	17	5.8	10	10	18	13	30	40	38	123	6.0	12.0	29/36.5	6.5	94			
19:37	1	153.38	.12	33	17	5.8	10	10	18	13	30	40	38	123	6.0	11.0	5/12.5	8.5	93			
19:52	2	153.26	.10	33	18	5.8	10	10	18	13	30	40	38	123	6.0	11.0	13/20.5	7.5	94			
20:07	3	153.16	.10	33	18	5.8	10	10	18	13	30	40	38	123	6.0	12.0	20/27.5	7.5	94			
20:22	1	153.06	.08	33	18	5.8	10	10	18	13	30	40	38	123	6.0	13.0	27/33	6.0	93.5			

REMARKS:
* COLLECT H_2O ACC. TK
** MEASURE " " "
‡ WATER PUMP ½ TCCW (DECR)

78317

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT. CE
TEST ENGINEER: PETILLO / PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 57 OF
DATE 2/24/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	ΔWT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
2037	2	152.98	.10	33	18	5.8	10	10	18	13	30	40	38	123	6.0	9.5	2/10	8	92			
2052	3	152.88	.10	33	17	5.7									6.0	10.5	10/17	7	93			
2107	1	152.78	.12	33	17	5.8									6.0	11.5	17/24	7	93			
2122	2	152.66	.09	33	18	5.8									6.0	12.0	23/30	7	92.5	CO_2 Station		
2137	3	152.57	.11	33	17	5.7									6.0	10.0	5/12.5	7.5	93			
2152	1	152.46	.10	33	17	5.8									6.0	11.0	12/19	7.0	92.5			
2207	2	152.36	.10	33	17	5.8									6.0	11.0	16/23	7.0	93			
2222	3	152.26	.10	33	17	5.8									6.0	12.0	22.5/29	6.5	94			
2237	1	152.16	.07	33	17	5.9									6.0	13.0	28.5/34	6.5	93.5			
2252	2	152.09	.12	33	17	5.8									6.0	9.5	2/10	8	90	CO_2 Cal check		
2307	3	151.97	.10	33	16	5.8									6.0	10.5	10/17	7	93			
2322	1	151.87	.09	33	17	5.8									6.0	11.5	16.5/23.5	7	94			
2337	2	151.78	.09	33	17	5.8									6.0	11.5	23/29.5	6.5	94			
2353	3	151.69	.09	33	17	5.8									6.0	12	29/34	5	94			
0008	1	151.60	.09	33	17	5.8									6.5	11	13/21	8	95			
0023	2	151.51	.09	33	17	5.8									6	11.5	20.5/27	6.5	95			
0038	3	151.42	.09	33	17	5.8									6	12	26.5/32.5	6	95			
0053	1	151.33	.08	33	17	5.8									6	13	31.5/36	4.5	95			
0108	2	151.25	.09	33	18	5.8									6	10	5/14.5	9	92			
0123	3	151.16	.09	33	17	5.8								124	6	11	14.5/21.5	7	93			
0138	1	151.07	.11	33	17	5.8									6	12	21.5/28	6.5	93			
0153	2	150.96	.10	33	17	5.8									6	12.5	28/33	5	93			

REMARKS:

78340

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 58 OF
DATE 7/25/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 wt	ΔWt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
0208	3	150.86	.10	33	17	5.8	10	10	18	13	30	40	38	124	6	9	0/5.5	5.5	92			
0223	1	150.76	.10	33	18	5.8									6	10	5.5/12.5	7	93			
0238	2	150.66	.10	33	17	5.8									6	11	12.5/19.5	7	93			
0253	3	150.56	.10												6	12	19/26	7	93			
0308	1	150.46	.10												6.5	13	26/32	6	94			
0323	2	150.36	.10												6	9	0/7	7	94			
0338	3	150.26	.10												6.5	10.5	7/14	7	94			
0353	1	150.16	.10												6.5	11.5	14/21	7	96	RE CAL APP		
0408	2	150.06	.09												6	9.5	0/7	7	96			
0423	3	149.97	.09												6.5	9.5	0/7	7	96			
0438	1	149.88	.09												6.5	9.5	0/7	7	97			
0453	2	149.79	.10												6	10	7/14	7	97			
0508	3	149.69	.10												6.5	11.5	13.5/20.5	7	97			
0523	1	149.59	.11												6.5	12.5	20.5/27.5	7	97			
0538	2	149.48	.11	33	~~12~~	5.8									6	12	20/27.5	7.5	98			
0553	3	149.37	.11		17										6	12	20.5/27.5	7	98			
0608	1	149.26	.10												6	12	20/27	7	98			
0623	2	149.16	.10												6	12	20/27	7	98			
0638	3	149.06	.10												6	12	20/27	7	98			
0653	1	148.96	.10												6	12	20/27	7	98			
0708	2	148.86	.10		16										6	12	20/27.5	7.5	98			
0723	3	148.76	.09		17										6	13	27/33	6	98			

REMARKS:

78341

HSP-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET: 59 OF
DATE: 3/25/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δwt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2OC	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
0738	1	148.67	.08	33	17	5.8	10	10	18	13	30	40	38	124	6	13	26.5/32.5	6	98			
0753	2	148.59	.10	"	16	"	"	"	"	"	"	"	"	"	6	12	20/27.5	7.5	98			
08:10	3	148.49	.10	33	16	5.9	9.9	9.9	18	13	30	40	36	124	6	12	21/27.5	6.5	97.5			
08:25	1	148.39	.10	33	16	6.0	10.1	10.1	18	13	30	40	36	124	6	12.5	20/27.5	7.5	98	→	94.5*	
08:40	2	148.29	.09	33	17	6.0	10.15	10.1	18	13	30	40	36	124	6	11.5	21/27.5	6.5	94			
08:55	3	148.20	.09	32	16	6.0	10.1	10.1	18	13	30	40	36	124	6.5	13	25/31	6.0	94			
09:10	1	148.11	.09	32	16	6.1	10.1	10.1	18	13	30	40	36	124	6.5	13	26/31.5	5.5	94.5			
09:25	2	148.02	.10	32	16	6.0	10.15	10.1	18	13	30	40	36	124	6	12	25/31	6.0	95			
09:40	3	147.92	.08	32	15	6.0	10.05	10	18	13	30	40	37	125	6.5	13	25/31	6.0	94.5			
09:55	1	147.84	.10	32	15	6.0	10.1	10.05	18	13	30	40	37	125	6	11.5	5/12	7.0	95			
10:10	2	147.74	.09	32	15	6.0	10.05	10	18	13	30	40	37	125	6	11.2	5/12	7.0	95			
10:25	3	147.65	.10	32	16	6.0	10.05	10	18	13	30	40	37	125	6	11.5	5/12	7.0	95			
10:40	1	147.55	.10	32	16	6.0	10.05	10	18	13	30	40	37	125	6.5	12	10/17	7.0	95			
10:55	2	147.45	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6	11.25	10/17	7.0	95			
11:11	3	147.35	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6.5	12	10/17	7.0	95.5			
11:25	1	147.25	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6.5	12	10/17	7.0	95.5			
11:40	2	147.15	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6	11.5	15/22	7.0	95.5			
11:55	3	147.05	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6.5	12	15/22	7.0	95.5			
12:12	1	146.95	.10	32	15	6.0	10.05	10	18	13	30	40	37	125	6.0	12	15/22	7.0	95			
12:26	2	146.85	.09	32	15	5.9	10.05	10	18	13	30	40	37	125	6	12	20/26.7	6.7	95			
12:42	3	146.76	.11	32	17	5.9	10.05	10	18	13	30	40	37	125	6	12	21/27.5	6.5	95.5			
12:56	1	146.65	.10	32	16	6.0	10.05	10.05	18	13	30	40	38	125	6.5	12.5	21/27.5	6.5	95.5			

REMARKS:
* RECALIBRATED 100% LINE - CORRECT READING 94.5

78342

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: BERTRAND
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 60 OF
DATE 2/25/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	ΔWT.	SIAP	SOAP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
13:13	2	146.55	.10	32	17	5.9	10.0	10.0	18	13	30	40	37	125	6.0	12	20/27	7.0	94			
13:26	3	146.45	.09	32	17	6.0	10	10	18	13	30	40	37	125	6	12.5	25/31	6.0	94			
13:40	1	146.36	.09	32	14	6.0	10.1	10.05	18	13	30	40	37	125	6	13	25/31.2	6.2	94			
13.55	2	146.27	.09	32	14	5.9	10.05	10.05	18	13	30	40	38	125	6	12.5	25/31	6.0	93.5			
14.12	3	146.18	.09	32	16	5.9	10.05	10.05	18	13	30	40	38	125	6	12	25/31	6.0	93.5			
14:28	1	146.09	.09	32	15	6.0	10.05	10.05	18	13	30	40	38	125	6	12	5/12	7.0	93.5			
14:41	2	146.00	.10	32	15	5.9	10.05	10.05	18	13	30	40	38	125	6	11.25	11.5/18.5	7.0	93			
14:56	3	145.90	.10	32	15	6.0	10.05	10.05	18	13	30	40	38	125	6	11.25	5/12	7.0	93			
15:12	1	145.80	.10	32	14	5.9	10.05	10.05	18	13	30	40	38	125	6.5	12	11.5/18.5	7.0	93			
15:27	2	145.70	.10	32	15	6.0	10.05	10.05	18	13	30	40	38	125	6	11.25	5.0/12.0	7.0	93			
15:41	3	145.60	.10	33	14	5.9	10.05	10.05	18	13	30	40	38	125	6	11.5	12.0/18.5	7.5	93			
15:56	1	145.50	.10	32	14	6.0	10.05	10.05	16	13	30	40	38	125	6	11.5	5/11.5	6.5	93			
16:11	2	145.40	.10	32	15	5.9	10.05	10.05	18	13	30	40	38	125	6	12	11.5/18.5	7.0	92.5			
16:27	3	145.30	.10	32	14	5.9	10.05	10.05	18	13	30	40	38	125	6	12	18/25	7.0	92			
16:42	1	145.20	.08	32	14	5.9	10.05	10.05	18	13	30	40	38	125	6	13	25/32	7.0	89	Cal. LIRA		
16:57	2	145.12	.10	32	17*	5.9	10.05	10.05	18	13	30	40	38	125	6	11.5	6/14	8	90			
17:12	3	145.01	.09	32	17	5.9	10.05	10.05	18	13	30	40	38	125	6	12.5	14/23.5	9.5	88			
17:27	1	144.93	.09	32	17	5.9	10.05	10.05	18	13	30	40	38	125	5.5	13.5	23.5/33.5	10	84			
17:42	2	144.84	.10	32	17	5.9	10.05	10.05	18	13	30	40	38	125	6	11	0/8	8	85	Cal	LIRA	
17:57	3	144.74	.10	32	17	5.9	10.05	10.05	18	13	30	40	38	125	6	11.5	8/16	8	86			
18:13	1	144.64	.10	32	17	5.9	10.05	10.05	18	13	30	40	38	125	6	12	15.5/23	7.5	87			
18:28	2	144.54	.09	32	17	5.9	10.05	10.05	18	13	30	40	38	125	6	11.6	5/13	8	86			

REMARKS: * CORR. PRESS. (WAS 10 PSIA NOW 11 PSIA)

78343

HSP-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT ICE
TEST ENGINEER: BERTRAND / PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 6 OF
DATE 5/25/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	ΔWT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 OIN	CO_2 OFF	AP	Δ AP	APP	
1843	3	144.45	.11	32	17	5.9	10	10	18	13	30	40	38	125	6	11.5	13/21	8	87	* LIRA CHECKS OK
1858	1	144.34	.10	32	17	5.9									6	12.5	20.5/28	7.5	90	
1913	2	144.24	.09	32	17	5.9									6	11.5	5/13	8	88	
1928	3	144.15	.11	32	17	5.9									6	11.5	13/20.5	7.5	89	
1943	1	144.04	.10	32	17	5.9									6	12.5	20/28	8	89	
1958	2	143.94	.10	32	17	5.9									6	11.0	5/13	8	88.5	* CHECKED LIRA, OK
2013	3	143.84	.10	32	17	5.9									6	11.5	13/20.5	7.5	90	
2028	1	143.74	.10	32	17	5.9									6	12.5	20/32.5	7.5	89	
2043	2	143.64	.10	32	17	5.9									6	11.5	5/18.5	8.5	89	
2058	3	143.54	.11	32	17	5.9									6	11.5	13/21	8	90	* LIRA CHECKED OK
2113	1	143.43	.10	32	17	5.9								126	6	12.5	20/32.5	7.5	90	
2128	2	143.33	.09	32	17	5.9									6	11.5	5/13	8	90	
2143	3	143.24	.10	32	17	5.9									6	11.5	12/19.5	7.5	90	
2158	1	143.14	.10	32	17	5.9									6	12.0	19/26.5	7.5	90	
2213	2	143.04	.09	32	17	5.9							36		6	12.5	26/32.5	6.5	90	
2228	3	142.95	.08	32	17	5.9							38		6	11.0	5/13	8	91	
2243	1	142.87	.10	32	17	6.0									6	12.0	5/13	8	91	
2258	2	142.77	.10	32	17	6.0									6	11.5	5/13	8	91	
++ 2313	3	142.67	.10	32	17	5.9									6	12.0	13/20.5	7.5	92	
2328	1	142.57	.11	32	17	5.9									6	12.0	13/20.5	7.5	91.5	
2343	2	142.46	.09	32	17	5.9									6	12.0	13/20.5	7.5	92	
2358	3	142.37	.09	32	17	5.9									6	12.0	20.5/27.5	7	92	

REMARKS:
++ BUZZING SOLENOID - STOPPED WHEN TAPPED

78344

NSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPT. ICE
TEST ENGINEER: PETILLO / PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 62 OF
DATE 2/26/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 wt	Δwt	SIPP	SOPP	SIF	SPI	SPO	OCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
0013	1	142.28	.09	32	17	5.9	10	10	18	13	30	40	38	126	6	13	21/28.5	7.5	92			
0028	2	142.19	.09												6	12	20.5/28.5	8	92			
0043	3	142.10	.09												6	13	28/34	6	92			
0058	1	142.01	.09												6	13	20/28.5	8.5	91			
0113	2	141.92	.09												6	12	20/28	8	88	*RECAL LIRA		
0128	3	141.83	.09												6	12	20/28	8	88			
0143	1	141.74	.10												6	12.5	18/25.5	7.5	88			
0158	2	141.64	.10												6	11.5	0/8	8	88			
0213	3	141.54	.10												6	11.5	8/16	8	88			
0228	1	141.44	.10												6	12.5	16/23.5	7.5	87	CHECK LIRA O.K.		
0243	2	141.34	.10												6	13	23/30.5	7.5	87			
0258	3	141.24	.09												6	13	30/35.5	5.5	87			
0313	1	141.15	.09												6	12	0/8	8	87			
0328	2	141.06	.10												6	12	8/16	8	87			
0343	3	140.96	.10												6	12	15.5/23	7.5	87			
0358	1	140.86	.10												6	13	23/30	7	87			
0413	2	140.76	.09												6	13	30/35.5	5.5	90	CO_2 VALVE BUZZING		
0428	3	140.67	.09												6	11.5	0/8.5	8.5	87			
0443	1	140.58	.10												6	12	8.5/16	7.5	87			
0458	2	140.48	.10												6	12.5	16/24	8	87			
0513	3	140.38	.10												6	12.5	23.5/30	6.5	87			
0528	1	140.28	.09												6.5	12	0/4.5	4.5	90	*FAN MID PORT CONN		

N.G.

REMARKS:

78345

MBF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 63 OF 1 DATE 12/6/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 wt	Δ wt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP
0543	2	140.19	.10	32	17	5.9	10	10	18	13	30	40	38	127	6	11	4.0/11	7	91
0558	3	140.09	.10												6	12	10.5/17	6.5	93
0613	1	139.99	.10												6.5	12.5	17/23	6	93
0628	2	139.89	.10												6	12	23/29	6	95
0643	3	139.79	.10												6.5	12	4/11	7	94
0658	1	139.69	.10												7	12.5	11/17.5	6.5	94
0713	2	139.59	.09										36		6	12	17/23.5	6.5	94
0728	3	139.50	.10												7	13	23/29.5	6.5	94
0743	1	139.40	.10		16										6.5	12	2/9	7	94
0758	2	139.30	.10	32	16	5.9	10	9.95	18	13	30	40	36	127	6	11.5	9/15	6	94
0814	3	139.20	.10	32	16	6.0	10	9.95	18	13	30	40	38	127	6.5	12	15/21.5	6.5	94
0828	1	139.10	.10	32	16	6.0	10	9.95	18	13	30	40	38	127	6.5	13	21/27.5	6.5	94
0845	2	139.00	.09	32	16	6.0	10	9.95	18	13	30	40	38	127	6.0	12	27.2/32.5	5.0	94
+ 0900	3	138.91	.10	32	16	5.9	10	9.95	18	13	30	40	38	127	6.5	12	5.2/12.0	6.8	96
0915	1	138.81	.10	32	16	6.0	10	9.95	18	13	30	40	36	127	6.5	12	11.5/18	6.5	96
0930	2	138.71	.10	32	16	6.0	10	9.95	18	13	30	39	35	127	6.5	12	18/24	6.0	96
0945	3	138.61	.10	32	16	6.0	10	9.95	18	13	30	39	36	127	6.5	13	24/30	6.0	96
1000	1	138.51	.08	32	16	6.0	10	9.95	18	13	30	40	36	127	6.5	12	2/8	6.0	96.5
1015	2	138.43	.10	32	16	6.0	10	9.95	18	13	30	40	36	127	6	11.5	8/14.5	6.5	96.5
1030	3	138.33	.10	32	16	5.9	10	9.95	18	13	30	39	36	127	6.5	12	14/21	7.0	97
1045	1	138.23	.09	32	16	5.9	10	9.95	18	13	30	40	37	127	6.5	13	20.5/27.2	6.7	97
1100	2	138.14	.10	32	16	5.9	10	9.95	18	13	30	40	37	127	6	12.5	27/32.5	5.5	97

REMARKS:
+ CAL. 100 Tg LINE.

78346

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCLIMATANCE
TEST ENGINEER: BERTRAND
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 64 OF
DATE 2/26/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 WT.	Δ WT.	S/AP	SOPP	S/F	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	Δ AP	AAP			
+	11:15	3	138.04	.09	32	16	6.0	10.0	9.95	18	13	30	40	36	127	6.5	12	4.5 / 8.5	* 4.0	96.5			
	11:30	1	137.95	.10	32	17	6.0	10.0	9.95	18	13	30	39	36	127	6.5	12	8.2 / 15	6.8	97			
	11:45	2	137.85	.10	32	17	5.9	10.0	10	18	13	30	39	36	127	6.25	11.5	14.5 / 21	6.5	97			
	12:00	3	137.75	.10	32	17	5.9	10	10	18	13	30	40	36	127	6.5	12.5	21 / 27.5	6.5	96.5			
	12:15	1	137.65	.09	32	16	6.0	10	10	18	13	30	39	36	127	6.5	13	27.2 / 33	5.8	96.5			
	12:30	2	137.56	.10	32	18	5.9	10	10	18	13	30	39	36	127	6.5	11.5	5 / 11.8	6.8	96			
	12:48	3	137.46	.09	32	20	6.0	10	10	18	13	30	40	36	127	6.5	12.0	11.5 / 18.5	6.8	96			
	13:00	1	137.37	.10	32	17	6.0	10	10	18	13	30	39	37	127	6.5	12.5	18 / 24.5	6.5	96			
**	13:18	2	137.27	.09	32	20	5.9	10	10	18	13	30	40	38	127	6.5	12	24 / 30	6.0	95.5			
	13:30	3	137.18	.10	32	16	5.9	10	10	18	13	30	40	38	128	6.5	11.5	5 / 11.8	6.8	95			
	13:45	1	137.08	.10	32	17	6.0	10.1	10.05	18	13	30	39	39	128	6.5	12	11.5 / 18	6.5	94			
	14:00	2	136.98	.11	32	17	5.9	10.1	10.05	18	13	30	39	39	128	6.0	11.5	18 / 24	6.0	94			
	14:16	3	136.87	.10	32	18	5.9	10.1	10.05	18	13	30	40	40	128	6.0	12.5	24 / 30.2	6.2	94.5			
	14:31	1	136.77	.09	32	16	5.9	10.1	10.05	18	13	30	40	40	128	6.0	12	5 / 11.8	6.8	94.5			
	14:46	2	136.68	.10	32	17	5.9	10.1	10.05	18	13	30	39	40	128	6.0	11.5	11.5 / 18	6.5	94			
	15:01	3	136.58	.10	32	17	5.9	10.1	10.05	18	13	30	40	40	128	6.5	12	18 / 24.2	6.2	94			
#	15:16	1	136.48	.10	32	17	5.9	10.1	10.05	18	13	30	40	41	128	6.5	13	24 / 30	6.0	96			
	15:31	2	136.38	.09	32	17	5.9	10.1	10.05	18	13	30	38	40	128	6.0	11	3 / 9.8	6.8	95.5			
	15:46	3	136.29	.10	32	17	5.9	10.1	10.05	18	13	30	39	40	128	6.0	12	9.5 / 16	6.5	95.5			
	16:02	1	136.19	.10	32	16	5.9	10.1	10.05	18	13	30	40	41	128	6.5	12	16 / 22.2	6.2	95			
	16:16	2	136.09	.09	32	17	5.9	10.1	10.05	18	13	30	40	41	128	6.0	12	21.8 / 28.2	6.4	95			
	16:31	3	135.00	.09	32	17	5.9	10.1	10.05	18	13	30	39	40	128	6.0	13	28 / 33	5.0	95			

REMARKS:
* LEFT 100% LIQN SAMPLING VALVE AFTER CALIBRATING 100% LIQA.
+ CALIBRATED 100% LIQA
** CALIBRATED INLET & OUTLET LIQAS.
# CAL. 100% LIQA.
!!! HUMID ATMOS - COND. COOLANT LINES DRIPPING.

78347

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEPTANCE
TEST ENGINEER: BERTRAND - PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 65 OF
DATE 2/26/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT.	Δ WT.	SIAP	SOAP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
16:45	1	135.91	.08	32	18	5.9	10.1	10.05	18	13	30	40	39	128	6.5	11.5	12/19	7	95			
1700	2	135.83	.09												6	12	19/25	6	94.5			
1715	3	135.74	.10												6	12.5	25/31	6	94.5			
1730	1	135.64	.10	32	18	5.9									6	12	5/12	7	94			
1745	2	135.54	.10	32	18	5.9									6	11	11.5/19	7.5	94			
1800	3	135.44	.09	32	18	5.9									6	12	18/24.5	6.5	94			
1815	1	135.35	.10	32	18	5.9									6	13	24/30	6	94			
1830	2	135.25	.10	32	18	5.95									6	11.5	5/12	7	94			
1845	3	135.16	.09	32	18	5.9									6	12	11.5/18.5	7	94			
1903	1	135.06	.10	32	18	5.9									6	12	18/24.5	6.5	94			
1918	2	134.96	.08	32	18	5.9									6	12	24/30.5	6.5	94			
1933	3	134.88	.09	32	18	5.9									6	12	5/12	7	94			
1947	1	134.79	.10	32	18	5.9									7	12	12/18	6	94.5			
2002	2	134.69	.10	32	18	5.9									7	11.5	18/24	6	94.5			
2017	3	134.59	.09	32	17	5.9									6.5	13	24/30.5	6.5	94.5			
2033	1	134.50	.10	32	18	6									6.5	12	5/12	7	94.5			
2048	2	134.40	.10	32	18	5.9									6	12	11.5/18.5	7	94			
2103	3	134.30	.10	32	18	5.9									6	12	18/24.5	6.5	94.5			
2118	1	134.20	.06	32	18	5.9									6.5	13	24/30.5	6.5	95			
2133	2	134.12	.10	32	18	5.9	10.15	10.20						129	6	11	5/12	7	94.5			
2148	3	134.02	.10	32	18	5.9	10.15	10.20							6	11.5	12/18.5	6.5	94			
2203	1	133.92	.10	32	18	5.9	10.15	10.20	18	13	30	40	39	129	6	12	18/24.5	6.5	94			

REMARKS:

78348

HSP-179.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: ACCEP 'NCE
TEST ENGINEER: PETILLO / PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 66 OF
DATE 8/26/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δ Wt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O_C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
2218	2	133.82	.09	32	18	5.9	10.2	10.2	18	13	30	40	39	129	6	11.5	24/30	6	94			
2233	3	133.73	.10	32	18	5.9									6.5	11.5	5/12	7	93.5			
2248	1	133.63	.09	32	18	5.9									6	11.5	12/18	6	93			
2303	2	133.54	.09	32	18	5.9									6	11.5	18/24	6.5	~~95~~	cal.	LiRA	WAS 2%LOW
2318	3	133.45	.10	32	18	5.9									6.2	12.5	23.5/30	6.5	95			
2333	1	133.35	.09	32	18	5.9							44		6	11.5	5/6.5	6.5	94.5			
2348	2	133.26	.09	32	18	5.9	10.1	10.1	18	13	30	40			6	11	4/10.5	6.5	95			
3/27 0003	3	133.17	.09	|	|	|	|	|	|	|	|	|	|	|	6	12	10/16.5	6.5	95			
0018	1	133.08	.09	|	|	|	|	|	|	|	|	|	|	|	6	12	16/22.5	6.5	95			
* 0033	"2"	132.99	.09	32	17	5.9	|	|	|	|	|	|	|	|	|	—	—	—	—	—			
** 0048	"3"	132.90	.03	32	25	3.7	|	|	|	|	|	|	|	|	|	—	—	—	—	—			
		132.87		SHUT DOWN — ISOLATE CAN #1																		

REMARKS:
* START SHUTDOWN - TURN OFF WATER PUMPS - ISOLATE CAN #2 - CAN 1 & 3 IN ABSORB
** ISOLATE CAN 3 - CAN 1 IN ABSORB

78349

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

1 mm of Hg P_{CO_2} Evaluation

HSF-178.1A 1/86

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 1MM CO_2 EVALUATION
TEST ENGINEER: PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 67 OF
DATE 4-1-86
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 WT	Δ WT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SDP	SODT	H_2O C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
*	10:15	2	132.84	.03	~~XX~~	~~XX~~	10.1	14.7	~~14.7~~	18	13.5	30	40	40	130	10.5	NO TRIP	0/5	5	95			
	10:30	3	132.81	.03	X	X	9.4	14.7	14.7	18	13.5	30	40	43	131	8.5	15	5/11	6	—			
	10:50	1	132.78	.12	40	31	9.4	14.7	14.7	18	13.5	30	40	44	131	8.5		11/18	7	96			
	11:00	2	132.66	.11	40	25	9.3	14.7	14.7	18	13.5	30	40	45	131	8.5	13	18/24	6	96.5			
	11:15	3	132.55	.11	40	27	9.3	14.7	14.7	18	13	30	40	47	131	8.5	13.5	23.5/30	6.5	96.5			
	11:30	1	132.44	.11	40	29	9.3	14.7	14.7	18	13.5	30	40	44	131	8	13	5/11.5	6.5	97			
	11:45	2	132.33	—	40	28	9.3	14.7	14.7	18	13.5	30	40	44	131	8.5	13	11/17	6	97			
	12:05	3	—	.20	43	32	9.2	14.7	14.7	18	13.5	30	40	44	131	8	13	17/23	6	97			
	12:19	1	132.18	.12	43	29	9.3	14.7	14.7	18	13.5	30	40.5	45	131	8	13	23.5/29.5	6	97			
	12:34	2	132.01	.10	42	34	9.3	14.7	14.7	18	14	30	41	44	131	8	13	4/11	7	97			
	12:49	3	131.91	—	43	30	9.2	14.7	14.7	18	14	30	41	44	131	8	13	10.5/17	6.5	99	CAL ART LIRA 236 LOW		
	13:00	1	—	.22	43	32	9.3	14.7	14.7	18	14	30	41	44	131	8	13	16.5/22.5	6	99			
	13:20	2	131.69	.12	43	32	9.3	14.7	14.7	18	14	30	41	44	131	8	13	22/28.5	6.5	99			
	13:35	3	131.57	.11	43	38	9.3	14.7	14.7	18	14	30	41	44	131	8	13	28.5/34.5	6	99			
	13:53	1	131.46	.10	44	85	9.3	14.7	14.7	18	14.5	30	41.5	46	131	7.5	13	5/11.5	6.5	99			
	14:08	2	131.36	.13	44	35	9.2	14.7	14.7	18	14.5	30	42	47	131	7	13	11/17.5	6.5	99			
	14:23	3	131.23	.10	44	35	9.2	14.7	14.7	18	14.5	30	42	46	131	7	13	17.5/24.5	7	98.5			
	14:38	1	131.13	.10	44	33	9.2	14.7	14.7	18	14.5	30	42	48	131	7.5	13	24.5/30	5.5	99			
	14:54	2	131.03	.13	44	32	9.2	14.7	14.7	18	14.5	30	42	48	131	8	13	4.5/11	6.5	98.5			
	15:10	3	130.90	.10	44	33	9.2	14.7	14.7	18	14.5	30	42	46	131	8	12.5	11/17.5	6.5	99			
	15:25	1	130.80	.09	43	34	9.2	14.7	14.7	18	14.5	30	42	46	131	7.5	NO TRIP	17/23.5	6.5	99			
	15:40	2	130.71	.04	43	11	9.2	14.7	14.7	18	14.5	30	41	47	131	7.5	12.5	23/29.3	6.3	98.5			

REMARKS:
* #2 FAN & COMPR USED / SIPP SOPP LIRA CALIBR. @ 100% = .22 psia

79312

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 1 MM CL EVALUATION
TEST ENGINEER: PETILLO / PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 68 OF
DATE 4-1-70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δ WT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
1557	3	130.67	.05	13	7	9.1	14.7	14.7	18	14.5	30	42	47	131	8	12	29.5/33	4.5	99			
1612	1	130.62	.06	12	7	9.2	14.7	14.7	18	14.5	30	42	45	132	8.5	12	0/3.5	3.5	99			
1627	2	130.56	.05	12	8	9.2	14.7	14.7	18	14.5	30	42	45	132	8.5	12	2.5/5.5	3.0	99			
1642	3	130.51	.05	12	8	9.2									8	12	5.5/9	3.5	99			
1659	1	130.46	.05	12	8	9.3									8	11.5	9/12	3.0	99			
1714	2	130.41	.06	13	8	9.2									8	12	12/15	3	99			
1729	3	130.35	.06	13	8	9.2							49		8	12	14.5/18	3.5	99			
1744	1	130.29	.06	13	8	9.3							45		8.5	12	18/20.5	2.5	99			
1759	2	130.23	.06	13	8	9.2							45		8	11.5	20/23	3	99			
1814	3	130.17	.05	13	8	9.2							46		8.5	12	23/25.5	2.5	99			
1832	1	130.12	.06										45		8.5	16	25.5/28	2.5	99			
1847	2	130.06	.05										49		9	13	28/31	3	99			
1902	3	130.01	.06										46		9	12	30/33	3	99			
1917	1	129.95	.06			9.3							48		8.5	12	5/8	3	99			
1932	2	129.89	.05			9.2							45		8.5	12	8/10.5	2.5	99			
1947	3	129.84	.05										48		8	12	10.5/14	3.5	99			
2002	1	129.79	.05	13	8	13		13.8				37	47		8	11	14/16.5	2.5	99	INCR	FLOW	
2017	2	129.79	.06	13	8	12.9		13.8				40			8	11.5	16.5/20	3.5	99	RECAL-OK.		
2032	3	129.68	.06	13	8	12.6		13.8				41	50		8.5	11.5	19.5/22.5	3	99			
2047	1	129.62	.06	13	8	12.7						41	46		8	11.5	22/25	3	99			
2102	2	129.56	.05	13	8	12.1						41	51		8	11.5	25/28	3	99			
2117	3	129.51	.05	13	8	13						42	50	133	8.5	12	4.5/8	3.5	99			

REMARKS:

79313

HSF-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 2 MM CO_2 VALUATION
TEST ENGINEER: PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTRATOR

SHEET 69 OF
DATE 4/1/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δ WT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
2134	1	129.46	.05	13	8	13	14.7	13.8	18	14	30	41	51	133	8	11.5	7.5/11	3.5	99			
2149	2	129.41	.05	1	1	12.9	|	|	1	1	1	42	51	|	8.5	12	10.5/14	3.5	99			
2204	3	129.36	.05	13	8	13	|	|	|	|	|	42	53	|	8	11.5	14/17	3	99			
2219	1	129.31	.05	13	8	13.1	|	|	|	|	|	41	47	|	8.5	11.5	17/20	3	99			
2234	2	129.26	.05	13	8	12.9	|	|	|	|	|	40	52	|	9	12	19.5/22.5	3	99			
2249	3	129.21	.05	13	8	9.4	|	14.7	|	|	|	48	49	|	9	12.5	22.5/25	2.5	99	DECR. FLOW		
2304	1	129.16	.05	13	8	9.4	|	|	|	|	|	46	47	|	9	12	25/27.5	2.5	99			
2319	2	129.11	.05	13	8	9.0	|	|	|	|	|	44	49	|	9	12	27.5/30	2.5	99			
* 2334	3	129.06	.05	13	8	9.1	|	|	|	|	|	43	47	|	—	—	—	—	—			
⊡ 2349	1	129.01	.02	13	8	6.5	|	|	|	|	|	42	43	|	—	—	—	—	—			
⊙ 2400	—	128.99		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			

REMARKS:
* ISOLATE CAN 3 – ABSORB CANS 1 & 2
⊡ ISOLATE CANS 1 & 3 – ABSORB CAN 2
⊙ ISOLATE CANS 1, 2, & 3

79314

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

50°F Canister Gas Inlet Temperature

P_{CO_2} = 4 mm Hg

HSP-178.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 4 mm CO_2 ~~SOLGAH~~. 15 min HALF CY. (SOLF GAS INLET VENT)
TEST ENGINEER: PETILLO
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONCENTR.

SHEET 70 OF
DATE 2/2/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 Wt	Δ Wt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
0953	3	128.96	.09	44	31	9.4	14.7	14.7	17	36	30	~~41~~	42	133	9	NO TRIP	~~85~~ 11.5	6.5	99			
1015	1	128.87	.11	44	32	9.3	14.7	14.7	17	36	30	41	47	|	9	14.5	11.5 ~~18~~	6.5	99			
1030	2	128.76	.09	44	28	9.2	14.7	14.7	17	37	30	41	47	|	8.5	13.5	17.5 ~~43.5~~	6	98.5			
1045	3	128.67	.11	44	29	9.2	14.7	14.7	17	37	30	41	45	134	8	13	21 ~~27.5~~	6.5	98.5			
1100	1	128.56	.10	44	26	9.1	14.7	14.7	17	39	30	41	45	134	9	13.5	27 ~~31.5~~	4.5	98.5			
1115	2	128.46	.09	44	29	9.1	14.7	14.7	17	40	30	41	45	134	9	14	31.5 ~~37~~	5.5	98.5			
1130	3	128.37	.10	44	26	9.1	14.7	14.7	17.5	40	30	41	47	134	8	13	5 ~~12.5~~	7.5	99			
1145	1	128.27	.11	44	26	9.1	14.7	14.7	17	40	30	41	45	134	9	13	12 ~~17.5~~	5.5	98.5			
1200	2	128.16	.10	44	27	9.1	14.7	14.7	17	40	30	41	46	134	9	13.5	17.5 ~~23.5~~	6	98.5			
1215	3	128.06	.10	44	25	9.1	14.7	14.7	17	58	30	41	46	134	8	13	23 ~~29.5~~	6.5	98.5			
1230	1	127.96	.11	44	26	9.2	14.7	14.7	17	50	30	41	46	134	8.5	13.5	5 ~~11~~	6	99			
1245	2	127.85	.10	44	26	9.1	14.7	14.7	17	50	30	41	45	134	9	14	10.5 ~~17~~	6.5	99.5			
1300	3	127.75	.12	44	26	9.1	14.7	14.7	17	50	30	41	46	134	8.5	14	16.5 ~~23.5~~	7	99.5	LIRA SAT OK		
1215	1	127.63	.10	44	24	9.1	14.7	14.7	17	50	30	41	46	139	8.5	13.5	23.5 ~~29.5~~	6	99.5			
1290	2	127.53	.11	44	26	9.0	14.7	14.7	17	50	30	41	46	134	9	14	0 ~~6.5~~	6.5	99			
1245	3	127.42	.11	44	26	9.0	14.7	14.7	17	50	30	41	46	134	9	14	6 ~~13~~	7	99			
1300	1	127.31	.12	44	25	9.0	14.7	14.7	17	50	30	41	45	134	8.5	14	13 ~~19~~	6	98.5			
1315	2	127.19	.11	44	24	9.0	14.7	14.7	17	50	30	41	46	134	9	14	19 ~~26~~	7	99			
1330	3	127.08	.14	44	25	9.0	14.7	14.7	17	50	30	41	46	135	8.5	14	25.5 ~~33~~	7.5	99			
1345	1	127.94	.10	44	23	8.9	14.7	14.7	17	50	30	41	46	135	8.5	14	0 ~~6~~	6	98.5			
1400	2	127.84	.11	44	24	8.9	14.7	14.7	17	50	30	41	45	135	9	14	5.5 ~~12.5~~	7	99			
1415	3	127.73	.12	44	23	8.9	14.7	14.7	17	50	30	41	45	135	8.5	14	12 ~~20~~	8	99			

REMARKS:

79315

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

CR-112021
SVHSER 5966

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

~~50~~ 30°F GAS INLET TEMP.

TYPE OF TEST: 4MM CO_2 ~~50% R.H.~~, 15 min HALF 24.
TEST ENGINEER: PETILLO - PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 71 OF
DATE 4/2/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 Wt	Δ Wt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	ΔAP	APP			
1430	1	127.61	.11	44	24	9.0	14.7	14.7	17	50	30	41	45	135	8.5	14	18.5/25	5.5	99			
1445	2	127.50	.11	44	24	8.9	14.7	14.7	17	50	30	41	45	135	9	14.5	25/32	7	99			
1500	3	127.39	.12	44	23	8.9	14.7	14.7	17	50	30	41	44	135	8	14	0/5.5	7.5	98.5			
1515	1	127.27	.11	44	22	8.85	14.7	14.7	17	50	30	41	44	135	8.5	14.5	7/12.5	5.5	98.5			
1530	2	127.16	.11	44	24	8.8	14.7	14.7	17	50	30	41	44	135	8.5	14	12/19.5	7.5	98			
1545	3	127.05	.12	44	26	8.8	14.7	14.7	17	50	30	41	44	135	8.5	14	19/27.5	8.5	98			
1600	1	126.93	.10	44	26	8.9	14.7	14.7	17	50	30	41	45	135	8.5	14	27/32.5	5.5	98	LIRA OFF 1%		
1615	2	126.83	.11	44	26	8.8	14.7	14.7	17	50	30	41	46	135	9	14.5	5/11.5	6.5	99			
1630	3	126.72	.10												8.5	14.5	18	7	99	*		
1645	1	167.52	.12	43	21	8.8						41			8.5	13.5	18/23.5	5.5	99			
no.3	2	167.40	.12	44	24	8.8						40	46		8.5	14.5	23/30	7	99			
1718	3	167.28	.12	44	21	8.8						41	46		8.5	15	5/12.5	7.5	99			
1733	1	167.16	.11	43	19	8.8						41	51		8.5	14	12.5/18.5	6	99			
1748	2	167.05	.11	43	21	8.8						41	47	136	9	14.5	18/25	7	99			
1803	3	166.94	.12	44	20	8.8						41	52		8.5	14.5	25/32	7	99			
1818	1	166.82	.12	44	18	8.8						41	46		8.5	14.5	5/11	6	99			
1833	2	166.70	.12	43	20	8.8						41	49		8.5	14.9	11/18	7	99			
1848	3	166.58	.12	44	20	8.8						41	50		8.5	14	16/23.5	7.5	99			
1903	1	166.46	.12	44	20	8.8						41	46		8.5	14	23/28	5	99			
1918	2	166.34	.10	44	20	8.8						41	46		9	NO TRIP	5/11	6	99			
1933	3	166.24	.10	44	21	8.8						41	46		8.5	14.5	11/17.5	6.5	99			
1948	1	166.14	.10	44	20	8.8						41	46		8.5	14	17/22	5	99			

REMARKS:
* CHG CO_2 BOTTLES - ENDING WT. 125.62 LB

79316

NSF-178.1A 1/68

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 4MM CO_2 5a ~~4H~~, 15 MIN ½ CYCLE / 50°F GAS INLET TEMP.
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC.

SHEET 72 OF | DATE 4/2/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME	DB	CO_2 WT	Δ WT	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	SODP	H_2O C	CO_2 ON	CO_2 OFF	AP	Δ AP	APP			
2003	2	166.04	.10	44	20	8.8	14.7	14.7	18	50	30	41	46	136	9	14.5	23/28	6	99			
2018	3	165.94	.10	43	20	8.8						41	46	136	8.5	NO TRIP	5/11.5	6.5	99			
2033	1	165.84	.10	44	20	8.8						41	50		8.5	14.5	11/16.5	5.5	99			
2048	2	165.74	.11	43	20	8.8						41	47		9	14.9	16/23.5	7.5	99			
2103	3	165.63	.11	44	20	8.8						41	48		8.5	14	21/29	8	100	LIRA O.K.		
2118	1	165.52	.11	44	19	8.8						41	47		8.5	15	5/10	5	99			
2133	2	165.41	.11	44	20	8.8						41	46		8.5	14.5	10/17	7	99			
2148	3	165.30	.11	44	20	8.8						41	46		8.5	NO TRIP	16/23.5	7.5	99			
2203	1	165.19	.12	43	19	8.8						41	51		8.5	14.9	23/28	5	99			
2218	2	165.07	.11	44	20	8.8						41	46		8.5	NO TRIP	5/12.5	7.5	99			
2233	3	164.96	.11	43	20	8.8						41	48		8.5	NO TRIP	12/19	7	99			
2248	1	164.85	.11	43	19	7.5		15.2				41	45		9	NO TRIP	19/21	3	99	(FLOW CAL)		
2303	2	164.74	.09	44	20	8.6		14.7				41	46		8.5	NO TRIP	5/12	7	99			
2318	3	164.65	.10	43	19	8.7						41	52	137	8.5	NO TRIP	11/17.5	6.5	99			
2333	1	164.55	.14	43	19	8.8						41	46		—	—	—	—	—	CAN #1 ISOLATED		
2348	2	164.41	.06	43	36	6.0						41	42		—	—	—	—	—	CAN #2 ISOLATED		
2358		164.35		SHUT		DOWN	- ALL		CANS			ISOLATED										

REMARKS:

79318

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: 50°F CAN INLET GAS, 4mm CO_2 5% RH, 15 MIN HALF CYCLE
TEST ENGINEER: T. PECK
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: AMINES CO_2 CONC

SHEET 1 OF 1 | DATE 4/2/70
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

	TIME	DB	CO_2 wt	SIPP	SOPP		TIME	DB	CO_2 wt	SIPP	SOPP		TIME	DB	CO_2 wt	SIPP	SOPP
0	1728	1	167.16	41	38		1743	2	167.05	40	40		1758	3	166.94	44	45
1	1729	1		30	16		1744	2		33	18		1759	3		28	25
2	1730	1		46	16		1745	2		46	17		1800	3		46	17
3	1731	1	167.14	44	17		1746	2	167.03	43	18		1801	3	166.92	43	18
4	1732	1		43	18		1747	2		44	19		1802	3		43	19
5	1733	1		43	19		1748	2		43	21		1803	3		44	20
6	1734	1	167.11	44	21		1749	2	167.00	[illegible]	23		1804	3	166.88	44	22
7	1735	1		44	23		1750	2		44	25		1805	3		44	24
8	1736	1		44	25		1751	2		44	27		1806	3		44	25
9	1737	1	167.08	44	28		1752	2	166.97	44	28		1807	3	166.85	44	28
10	1738	1		48	39		1753	2		44	30		1808	3		46	32
11	1739	1		46	46		1754	2		46	39		1809	3		44	40
12	1740	1	167.06	44	47		1755	2	166.95	43	43		1810	3	166.83	43	41
13	1741	1		45	49		1756	2		43	43		1811	3		43	43
14	1742	1		44	47		1757	2		44	45		1812	3		43	44
15	1743	1	167.05	40	40		1758	2	166.94	44	45		1813	3	166.82	46	44

REMARKS:

79317

APPENDIX J

Amine CO_2 Concentrator Installation Procedure

AMINES CO_2 CONCENTRATOR

INSTALLATION PROCEDURES

Use Interface Drawing SVSKHS 77068 and System Schematic SVSK 77060.

1. Check the unit for any damage that occurred during shipment and repair.

2. Remove the shipping skids from the frame end pieces.

3. Place the unit in the simulator area reserved for this experiment.

4. Connect all the fluid and gas lines to the interface panel. This will include:

   A. Attach the Coolanol 35 lines to the heat exchanger, the condensor and the water boilers "in" and "out" ports. Provisions should be made to measure the inlet flows, temperatures and pressures within the ranges specified on the interface and system schematic drawings.

   B. The water supply line should be connected to the "H_2O in" port.

   C. The compressed gas supply line should be connected to the port marked "oxygen supply." The MDAC gas supply compressor should provide an automatic pressure limiting switch to limit the unit tank pressure to the specified 105 ±5 psig and a relief valve set at 130 ±10 psig. The compressor must be capable of supplying 320 cu. inches/hr minimum of cabin gas at 100 psig.

   D. The simulator CO_2 accumulator inlet line should be connected to the "CO_2 out" port.

   E. The "Vacuum" Port Must Be Left Open!! Do Not Connect It To Vacuum!!

5. Connect an inlet gas hose to the 1.745 / 1.755 diameter unit inlet tube. The unobstructed length of this hose with the same inlet diameter or larger shall not exceed 20 feet.

6. Electrical Connections

   A. Connect the 25-31 VDC power supply to the P11 Bendix Connector PT08E-14-5S 300 (previously supplied by HS) as shown on the interface drawing and mate with the J11 connector on the unit panel.

   B. A 115 VAC cord with a P10 Bendix Connector PT08E-14-5S 300 (another one previously supplied by HS) has been supplied with the unit. Mate the P10 connector with the J10 connector on the unit panel.

6. (Continued)

NOTE: The cord insulation is not compatible with the materials requirements and should be replaced to teflon covered wires or wrapped with teflon tape.

7. Instrumentation

A. Make instrumentation external wire connections to the P9 Bendix Connector PT08E-18-32P 300 (previously supplied by HS) as shown on the interface drawing and mate with the J9 connector on the unit panel.

CAUTION:

Load Impedence - Loads placed across instrumentation outputs shall be 100K Ω (minimum).

Thermocouple Outputs - DC MV signals from copper constantan thermocouples are referenced to + 250°F in the unit control box. Use copper lines to instrumentation readouts. Polarity indicated on the interface drawing is for temperatures below 250°F.

8. Alarm Systems Required (Buzzer or Flashing Light)

A. H_2O high limit warning signal (contacts "S" and "T").

B. High and low limit warning signal to keep the boiler Coolanol 35 flow within 25 to 50 lbs/min.

C. High and low limit warning signal to keep the boiler Coolanol 35 temperature within 225 to 235°F.

D. A warning signal to prevent the P_7 transducer from exceeding 25 inches of H_2O pressure. This device should incorporate a 1 minute time delay to avoid giving a signal during possible instantaneous pressure peaks while the canister valves are changing port positions.

E. A low pressure warning signal for the gas pressure tank inlet supply line that will be energized when the tank pressure drops below 85 psig.

APPENDIX K

Amine CO_2 Concentrator Startup

& Shutdown Procedures

AMINES CO_2 CONCENTRATOR

START-UP AND SHUT-DOWN PROCEDURE

START-UP PROCEDURES

Automatic Operation (Three Beds)

1. Set the Coolanol 35 flows, temperatures and pressures for the condensor, and the boilers as specified in the setup conditions (Figure 1).

2. Place all switches (including circuit breakers) in the "off" position.

3. Place the 115 VAC Main Power Circuit Breaker Switch and the AC Circuits Circuit Breaker Switch in the "on" position. The respective indicator lights should be energized.

4. A 2 hour warm-up period (for ref. junction stabilization) should precede placing the Main Power 28 VDC Circuit Breaker Switch in the "on" position. The 28 VDC indicator light should be energized.

5. Place the H_2O Control Switch in the "Enable" position. Check to make sure that the water supply is turned on and that the MDAC supplied warning light or buzzer is not energized. When starting for the first time with an empty water accumulator, make sure that the panel fill indicator light is energized. Also make sure that this light is de-energized when the accumulator is filled with water. Again the MDAC warning light or buzzer should not be energized.

6. Reset the H_2O Counter to Zero.

7. Place the two Valve Control Switches (CO_2 and Steam) in the Flow/Timer position.

8. Place the Cycle Control Switch in the Flow/Temperature position

9. Place the three Bed Valve Switches in the "on" position.

10. Place the Operation Mode Switch in "3 Bed" operation.

11. Set the TR1 Timer for 60 seconds.

12. Set TR2 Timer for 1 minute less than the Desorb Time specified in Figure 1. (TR1 + TR2 = total desorb cycle time).

13. Set the Flow Controller left hand trip pointer (red) at "0" and the right hand trip pointer (red) to "2".

Automatic Operation (Three Beds) - Continued

14. Set Temperature Controller left hand trip pointer (red) at "2" and the right hand trip pointer (red) to "2.5".

15. Place the Motor Control Circuit Breaker Switches in the "on" position.

16. Turn the Bottom Canister Valve Manual Handle on bed #3 to the "Adsorb" position. When the canister valve top indicator shows it to be in the "Adsorb" position, return the Solenoid Valve Manual Handle to the "Auto" position.

17. Place all Canister Solenoid Valve Handles in the "Auto" position.

18. Twist the Start Button counter-clockwise to start unit. Check the canister valve indicators to make sure that bed #1 and bed #3 are in the "Adsorb" position and that bed #2 is in the "Desorb" position. The "Cycle On" and bed #2 "Desorb On" Indicator Lights should be energized.

19. Select a circulating fan (#1 or #2), depress the "Motor Start" Push Button, and simultaneously place the Fan Switch in the selected fan position. Release the "Motor Start" Push Button when fan has reached operating speed. Immediately, check the discharge port for a flow indication!! If the fan is dead-headed, place the "Motor Control" Fan Switch in the "off" position and determine the trouble (see failure mode analysis) prior to re-starting the unit.

20. Select a compressor. Open the selected Compressor Hand Valve and the Equilization Hand Valve. Close the remaining Compressor Hand Valve. Depress the "Motor Start" Push Button and place the selected compressor "Motor Control" Switch in the "on" position. When the compressor has reached operating speed, release the "Motor Start" Button and close the Equalization Hand Valve.

21. Select a water pump and place the corresponding "Motor Control" Switch in the "on" position. Check visually for water pump operation.

22. Use the "Bed Inlet Temperature Hand Valve" to adjust the Coolanol 35 flow to the heat exchanger (at the specified pressure and temperature, see Figure 1) in order to establish the desired canister gas inlet temperature (T_7) as specified in Figure 1. Frequent checks of the T_7 trace with corresponding "Bed Inlet Temperature" Valve adjustments, if necessary, must be made until conditions have stabilized.

23. Check to see that the Steam Valve is continually energized (indicator light) between 11 to 13 minutes into each 15 minute desorb cycle. If the actuation time is below 11 minutes, this means that the steam production rate is excessive and that the feed pump water rate should be decreased. This is accomplished by turning the pump flow adjusting screw counter-clockwise, ½ turn at a time (follow instruction on pump connecting rod) until the steam valve actuation is properly timed. Watch a complete desorb cycle prior to making further adjustments. If the steam valve opening is greater than

Automatic Operation (Three Beds) - Continued

23. (Continued)

13 minutes, this indicates that the steam production rate is too low and that the feed water pumping rate must be increased. The pump adjustment procedures are the same except that the flow adjustment screw is turned in the clockwise direction.

24. If at anytime the system operation is in question, shut off the water pump by placing the Motor Control H_2O Switch in the "off" position. This action will terminate steam generation which will in turn stop any further desorption of the beds to prevent excessive wetting of the Amines material. When the operational problem has been solved, re-start the water pump by placing the Motor Control H_2O Switch in the Selected Pump Energized Position.

Automatic Operation (Two Beds)

Same procedure as specified for 3 bed operation except for:

1. Place "Operation Mode" Switch in "2 Bed" operation position.

2. Connectors J41 (bed #1) and J42 (bed #2) are energized during the 2 bed operation. If it is desired to use bed #3, remove the connector of the bed not to be run, and replace it with the bed #3 connector.

3. The canister not being used should be placed in the "Isolate" position.

   If bed is on adsorb:
   Position the Top Canister Solenoid Valve to "Desorb". Watch the top valve indicator and when the "Isolate" position is opposite the black line, turn the Solenoid Valve Handle to "Vent".

   If bed is on desorb:
   Position the Bottom Canister Solenoid Valve to "Adsorb". Watch the top valve indicator and when the "Isolate" position is opposite the black line, turn the Solenoid Valve Handle to "Vent".

   Both solenoid valve handles of the canister not being used should be in the "Vent" position prior to proceeding.

   NOTE: If trouble is encountered in stopping the valve in the "Isolate" position with the solenoid valves, place the Valve Handles in the "Vent" position and use a wrench on the top nut (above the valve position indicator) to trim the valve position. When manual valve positioning is utilized, the valve must be turned slowly to allow gas to escape from the drive piston chamber.

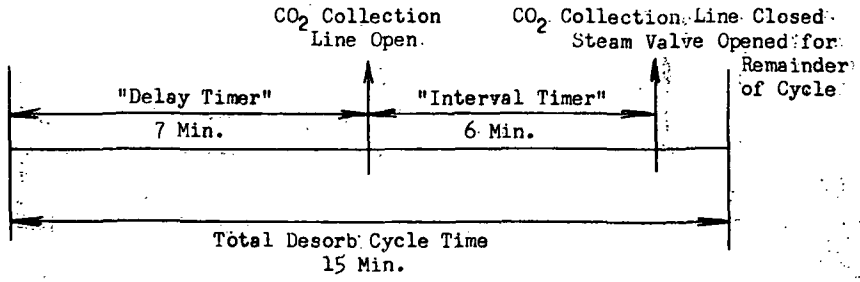
Automatic Timer Operation (Two or Three Beds)

NOTE: To be used only if automatic mode of operation fails (see Failure Mode Analysis).

1. Position "Mode Switch" in "Timer" position.

2. Set the "On Delay" timer for 7 minutes (see Failure Mode Analysis for the operational criteria for final timer setting).

3. Set the "On Interval" for 6 minutes (see Failure Mode Analysis for the operational criteria for final timer setting).



4. Place the CO_2 and the Steam Valve Control Switches in the "Flow/Timer" position.

Manual Operation (Two or Three Beds)

NOTES: A. See Failure Mode Analysis for operational criteria for using this method of operation.
B. The Manual Operating Procedures follow the system switching logic.
C. The flow and temperature sensor meters indicate but do not automatically operate the CO_2 or Steam valves.
D. A second and minute counter must be used.

1. Place the "Cycle Control" Mode Switch in the "Cycle Step" position.

2. Place the Two "Valve Control" Switches in the "off" position.

3. Place the Three "Bed Valve" Switches in the "on" position.

4. At the beginning of each desorb cycle, place the "Cycle Step" Switch in the "TR1" position.

5. After 60 seconds, place the "Cycle Step" Switch in the "TR2" position.

Manual Operation (Two or Three Beds) - Continued

6. After 7 minutes into the desorb cycle or as indicated by the flow controller readout, place the CO_2 Valve Control Switch in the "Over-Ride" position.

7. After 13 minutes into the desorb cycle or as indicated by the temperature controller readout, place the CO_2 Valve Control Switch in the "off" position and place the Steam Valve Control Switch in the "Over-Ride" position. Keep the switch in this position for the remainder of the desorb cycle and then return it to the "off" position.

8. Repeat items 4 through 7 for each desorb cycle.

Figure 1

AMINES CO_2 CONCENTRATOR

SETUP CONDITIONS

Canister Gas Inlet Temperature, °F (T_7)	$80^{\pm 3}$
Compressed Gas Tank Pressure (for valve actuation), psig	$105^{\pm 5}$
Compressed Gas Flow, cu. inches	320 cu. in/hr min at 100 psi
Adsorb Cycle Time, minutes	30
Desorb Cycle Time, minutes (TR_1 + TR_2 Timers)	15
Automatic Bed Cycle Sequence	2, 3 and 1
Condensor Coolanol 35 Fluid Flow, lbs/min	$15^{\pm 5}$
Condensor Coolanol 35 Fluid Temperature, °F	$37^{\pm 5}$
Condensor Coolanol 35 Fluid Pressure, psig	60 max.
Heat Exchanger Coolanol 35 Fluid Flow, lbs/min	as req'd. to set T_7
Heat Exchanger Coolanol 35 Fluid Temperature, °F	$55^{\pm 5}$
Heat Exchanger Coolanol 35 Fluid Pressure, psig	60 max.
Boiler Coolanol 35 Fluid Flow, lbs/min	30-50
Boiler Coolanol 35 Fluid Temperature, °F	$230^{\pm 5}$
Boiler Coolanol 35 Fluid Pressure, psig	60 max.

NOTES:

1. The MDAC gas inlet hose must be attached to the unit $1.745^{1.755}$ O.D. inlet tube and the unobstructed length of this hose with the same inlet diameter or larger must not exceed 20 ft.
2. The inlet gas coming from the MDAC humidity control unit shall have a dew point within the range of 38 to 44°F and a dry bulb temperature within 45 to 60°F.

AMINES CO_2 CONCENTRATOR

START-UP AND SHUT-DOWN PROCEDURE

SHUT-DOWN PROCEDURES

Short Duration (1-2 Days)

Objective - To dry out each bed by subjecting each one to a 30 minute adsorb with no further desorb cycling.

NOTE: This procedure can be initiated on any bed that is ready for a desorb cycle; however, for consistency, the automatic sequence of bed #2, #3 and #1 will be used.

1. At approximately one (1) minute prior to the start of a desorb cycle on bed #2, shut off the water pump by placing the Motor Control H_2O Switch in the "off" position. Also, place the three Bed Valves in the "Desorb Off" position.

2. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #2 as indicated by the light (bed #2 valve will stay in the "Adsorb" position), move the Top Canister Solenoid Valve Handle to the "Desorb" position. When the valve indicator shows that the canister is in "Isolate" move the top solenoid valve handle to the "Vent" position (use wrench on valve nut to trim if necessary).

3. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #3 as indicated by the light, place the valve in "Isolate" as explained in item 2.

4. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #1 as indicated by the light, push the stop button to terminate unit operation. Place bed #1 valve in the "Isolate" position as explained in item 2.

5. Make sure all 6 Solenoid Valve Handles are in the "Vent" position.

6. Place all Valve Control, H_2O Control, and Motor Control Switches in the "off" position.

7. Place the Main Power 28 VDC Circuit Breaker Switch in the "off" position.

8. The A.C. Circuits, Circuit Breaker Switch and the Main Power 115 VAC Circuit Breaker Switch can be left in the "on" position or may be shut off. It must be remembered, however, that a 2 hour warm-up period is required prior to start-up to properly heat the reference junction to insure stable instrumentation readouts. The reference junction is powered by the 115 VAC circuit.

9. Terminate flow of fluids to the boiler, heat exchanger, and condensor.

Long Duration Storage

Objective - To throughly dry out each bed by initially cooling down the last bed on desorb and by subjecting each bed to a long duration adsorb with no further desorb cycling.

1. At approximately one (1) minute prior to the start of a desorb cycle on bed #2, shut off the water pump by placing the Motor Control H_2O Switch in the "off" position. Also place the Three Bed Valves in the "Desorb Off" position.

2. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #2 as indicated by the light (bed #2 valve will stay in the "Adsorb" position), move the Top Canister Solenoid Valve Handle to the "Desorb" position. When the valve indicator shows that the canister is in "Isolate", move the Top Solenoid Valve Handle to the "Vent" position. (Use wrench on valve nut to trim if necessary.)

   Solenoid Valve Handles Should Always Be In "Vent" Position Prior To Any Manual Adjustment Of The Valve!!

3. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #3 as indicated by the light, place the valve in "Isolate" as explained in item 2.

4. When the TR1 and TR2 timers indicate the start of a desorb time period for bed #1 as indicated by the light, push the stop button to terminate the unit operation.

5. Place all Motor Control Switches and Valve Control Switches in the "off" position.

6. Turn off all the Coolanol 35 flow to the boilers, heat exchanger and condenser.

7. The bed #1 valve should be in the "Adsorb" position.

8. Place the Cycle Step Switch in the "TR2" position.

9. Place the Cycle Control Switch in the "Cycle Step" position and restart the unit by twisting the start button in the counter-clockwise direction.

10. Depress the Motor Start Push Button and position the Fan Motor Control Switch to energize either fan. Keep the Motor Start Push Button depressed until the circulating fan unit reaches operating speed, then release the push button.

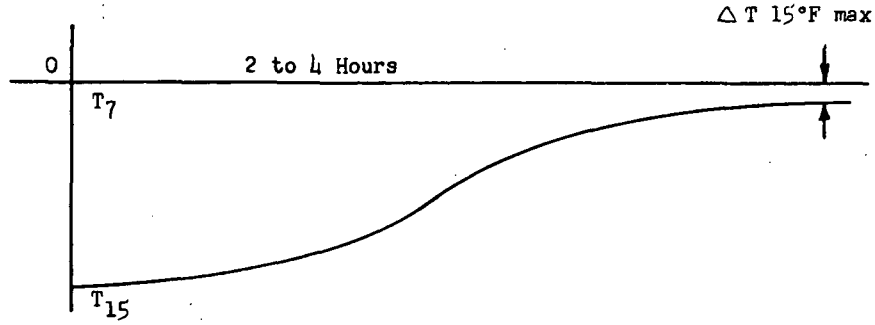
11. Check the bed #1 Canister Solenoid Valve Handles, make sure they are in the "Vent" position and manually adjust the valve with a wrench to back-off approximately 6° from the true "Adsorb" position. This built-in leakage is provided to dry out the void volume of the valve.

12. Check the outlet ports and/or the circulating fan transducer pressure trace (P_7) to make sure that the flow through the bed has not been significantly reduced. If it has, decrease the valve displacement from the true "Adsorb" position.

Long Duration Storage - Continued

13. Check to make sure that coolant is not being circulated through the condensor!! This condition could flood the system with condensed water.

14. Monitor T_7 and T_{15} and continue the adsorption process until the two temperature traces are within a temperature spread of no more than 15°F.



15. When bed #1 is dry, use bed #2 Canister Solenoid Valve (lower) to position the valve in "Adsorb" and leave the two handles in the "Vent" position. Use bed #1 Upper Canister Solenoid Valve to position the valve in "Isolate" again leaving the two handles in the "Vent" position. Manually adjust (wrench) bed #2 valve to establish the approximate 6° displacement from the "Adsorb" true position and check the flow as explained in item 12.

16. Monitor T_7 and T_{16} temperature traces as explained in item 14.

17. When bed #2 is dry, use bed #3 Canister Solenoid Valve (lower) to position the valve in "Adsorb" and leave the two handles in the "Vent" position. Use bed #2 Upper Canister Solenoid Valve to position the valve in "Isolate" again leaving the two handles in the "Vent" position. Manually adjust (wrench) bed #3 valve to establish the approximate 6° displacement from the "Adsorb" true position and check the flow as described in item 12.

18. Monitor T_7 and T_{17} temperature traces as described in item 14.

19. When bed #3 is dry, push the red button to stop the unit operation. Make sure all the canister solenoid valve handles are in the "Vent" position and manually adjust (wrench) each canister valve to establish the approximate 6° displacement from the "Adsorb" true position.

20. Turn off all switches.

21. Cover the inlet and the two outlet ports.

APPENDIX L

Amine CO_2 Concentrator Scheduled Maintenance

AMINES CO_2 CONCENTRATOR

SCHEDULED MAINTENANCE

1. At least once during each 24 hour period, check the set-up conditions as shown in Figure 1 and adjust if necessary to be within the specified ranges. If the canister gas inlet temperature (T_7) is too high, gradually turn the Bed Inlet Temperature Valve to the Left to increase the heat exchanger coolant flow thus lowering the gas inlet temperature. Conversely, turn the valve to the Right to increase the gas inlet temperature. Frequent checks should be made after a valve adjustment to insure that the gas inlet temperature has stabilized within the specified limits.

2. At least once during each 24 hour period, check to make sure that the P_{CO_2} has not exceeded 4 mmHg and that the CO_2 purity is at an acceptable level. If they are not within the acceptable limits, consult the failure mode analysis to determine the problem together with an associated course of action to rectify the condition.

3. After every 7 days of unit operation, change the water filter element in accordance with the following instructions:

   A. Shut off the water pump by placing the H_2O Motor Control Switch in the "off" position. Further shut-down of the system is not necessary while changing the filter element!!

   B. Loosen the screw at the bottom of the filter unit and remove the glass bowl.

   C. Throw away the element, the small gasket and the large gasket.

   D. Clean out the bowl.

   E. Place the new large gasket, coated with Krytox, on the element flange that fits against the glass bowl.

   F. Install the element and gasket in the bowl and fill with water.

   G. Place the new small gasket, coated with Krytox, on the underside of the filter metal cap.

   H. Insert the element and bowl sub-assembly up against the filter cap. Place the mounting prongs around the bowl, hook onto the cap, and tighten the lower screw.

   I. Start the water pump by placing the same pump H_2O Motor Control Switch in the energized position and observe the next desorb cycle. If the Steam Control Valve fails to trip, shut down the water pump (H_2O Motor Control Switch "off") and check the filter gaskets to make sure they are fitted properly and not allowing cabin gas to leak into the feed water system. Repeat this procedure, if necessary, until the Steam Control Valve is actuating properly.

APPENDIX M

Amine CO_2 Concentrator Failure Mode Analysis

FAILURE-MODE ANALYSIS

I. Continuous rise in the simulator cabin P_{CO_2}.

A. Premature Unit Shut-Down ("Cycle on" light de-energized)

1. Power Failure (115 VAC and/or 28 VDC indicator lights de-energized) - Return power and restart unit in accordance with the start-up procedure, automatic operation (three beds); except, do not start the water pump until each bed has had one adsorb cycle.

2. Shut Down by Fan or Compressor Overload Condition (Interlock) The "Cycle on" light should be de-energized and the Circuit Breaker Switch of the malfunctioning fan or compressor should be in an intermediate position. Restart the unit in accordance with the "start-up procedure", automatic operation (three beds) utilizing the redundant fan or compressor; except, do not start the water pump until each bed has had one adsorb cycle.

Immediately Check The Main Outlet Port For Flow!! If the fan is dead-headed or the flow is drastically reduced (P_7 trace), immediately push Red Stop Button.

a. Check for faulty operation of the canister valves in the "Adsorb" cycle in accordance with Section IC. of this document.

b. Check for clogged drain lines or an inoperative drain solenoid valve. This situation would cause excessive bed wetting and a restriction to the circulating fan flow. Start the unit in accordance with Items 1 through 18 of the "Start-Up Procedures" automatic operation (three beds). Do not start the water pump fans or compressors. Just prior to the beginning of each desorb period, place your hand on the canister drain valve going on desorb to feel the movement of the plunger when actuated. If not, it means that the particular valve is inoperative and must be replaced with a spare. If all the valves actuate, shut down the system by pushing the Stop Button. Loosen the drain line fitting at each canister drain port to see if any of the canisters are filled with condensed water. Completely drain out any can that contains water and check the drain hole (use mirror), the short drain line, and the solenoid valve port for any blockage. Reassemble the drain system after cleaning, and start the unit using the "Start-Up Procedures", automatic operation (three beds) up to and including Item 19 (do not energize the water pump). Run under these conditions until each canister has been subjected to 60 minutes of drying with the canister gas inlet temperature control valve in the full hot condition (closed). Complete canister #2, 3, and 1 sequence twice. Then, complete Items 20 to 24 in the "Start-Up Procedures", automatic operation (three beds).

I. (Continued)

B. Premature Shut-Down of Water Pump (Visual check) The unit will not shut-down but the Motor Control H_2O Lights will be de-energized and the water pump Circuit Breaker Switch should be in some intermediate position if the malfunction was caused by an overload condition. Reposition the H_2O Circuit Breaker Switch in the "on" position if necessary. Place the Motor Control H_2O Switch in position for the same water pump unit that was running. If it starts, watch the pump through a few bed cycles. If it will not start or the circuit breaker is again tripped, energize the redundant water pump and check the Steam Valve actuation time (adjust the feed water flow rate if necessary) in accordance with item 23 in the start-up procedures, automatic operation (three beds).

C. Faulty Operation of the Canister Valves Check the bed valve indicator lights to determine which canister is on "desorb". Check all the top valve indicators to see if they are in their respective "adsorb" and "desorb" positions.

If not:

1. Check the compressed cabin gas bottle pressure; make sure it is within the specified range of 105 ±5 psig.

2. Make sure all the solenoid valve handles are in the "auto" position.

3. If items 1 or 2 are at fault, correct the condition and if a valve has stuck in adsorb, drain canister and dry the canister using the procedures of I.A.b. If valve has stuck in adsorb, restart unit in accordance with the "Start-Up Procedures", automatic operation (three beds).

4. If items 1 and 2 check out favorably and only one canister valve is not positioning properly, change to a two canister mode of operation in accordance with the "Start-Up Procedures", automatic operation (two beds). The MDAC back-up CO_2 concentrator may be needed periodically to limit the P_{CO_2} to 4 mmHg. If two canister valves are malfunctioning, push the stop button to terminate unit operation and utilize the MDAC CO_2 concentrator for cabin CO_2 control.

D. Late Actuation of the CO_2 Valve Gradually decrease the setting of the flow controller meter right hand pointer (red) in 0.3 meter reading increments until the ΔP on the accumulator for each cycle is adequate to bring the P_{CO_2} to 4 mmHg or below. Be sure the CO_2 purity is at an acceptable level.

E. Early or Late Actuation of the Steam Control Valve

1. If the steam control valve fails to trip during the "desorb" period, shut down the water pump (H_2O motor control switch "off") and check the filter gaskets to make sure they are fitted properly and not broken, thus allowing the leakage.

I. (Continued)

E. (Continued)

1. (Continued)

of cabin air in the feed water system. Refit the gaskets if necessary, and restart the water pump to see if this action has remedied the situation.

2. If there is still insufficient flow to trip the steam valve, turn on the redundant water pump.

3. If the steam control valve trip is early or late, adjust the feed water flow rate in accordance with item 23 in the "Start-Up Procedures", automatic operation (three beds). Make Sure That Operating Conditions Have Stabilized prior to leaving the unit unattended!!!

F. Canister Gas Inlet Temperature (T_7) Not Within Specified Limits Figure 1 Gradually turn the canister inlet temperature valve in the "cold" direction if the temperature is too high and in the "hot" direction if it is too "low". Make Sure That The Final Valve Setting Operating Conditions Have Stabilized Prior to Leaving The Unit Unattended!!!

G. Erratic Operation of the Flow and/or the Temperature Controller Erratic and unstable actuation of the CO_2 and/or the steam control valve will necessitate switching to the Automatic Timer Operation as described in the "Start-Up Procedures".

H. Improper Setting of "On Delay" or "On Interval" When on Automatic Timer Operation Increase the 6 minute "Interval Timer" setting 1 minute. Check a few cycles for accumulator increased ΔP each cycle. If an improvement is noticed, try adding 1 minute more; however, the steam break-through on the canisters should not occur more than 2 minutes before the steam valve is actuated. A possible reduction in the 7 minute "Delay Timer" setting may also help. Try a 1 minute change and watch the accumulator ΔP for improvement. Too low a setting will result in poor CO_2 purity.

I. Back Pressure Regulating Valve Pressure is Above 15 psia (See P_1 pressure trace) A considerable quantity of CO_2 will be dumped to cabin when the CO_2 valve is repositioned for flow to the condenser. Loosen the adjustment screw to bring the pressure regulation within the required 12 to 15 psia range.

J. Empty Water Accumulator Water pump running but not pumping water to boilers. Check the operation of the water supply solenoid valve by placing the H_2O Control Switch in the "over-ride" position and listen for the click of the solenoid actuation or the sound of running water. If neither one occurs, leave the H_2O Control Switch in the "over-ride" position for a period of time to see if the MDAC high level warning light or buzzer is energized. If not, the solenoid valve is clogged or is stuck in the closed position (tap valve lightly). If the valve cannot be made to function properly, shut down the unit by

I. (Continued)

J. (Continued)

pushing the stop button and use the MDAC backup unit for the removal of CO_2.

K. Low Flow of CO_2 to MDAC Accumulator During the "Desorb" Cycling

1. Check the back pressure regulator pressure (P_1 trace, 12 to 14 psia) to see if the valve is blocked or closed "off". If so, shut down the compressor and place the steam valve switch in over-ride. Remove the valve, remove the bonnet, clean the seat, reassemble, and reinstall. Reset the steam valve switch in the "flow/timer" position, start the compressor and readjust the Back Pressure Relief Valve (12-14 psia).

2. Try both compressor systems.

3. If the trouble cannot be found in items 1 and 2, it is probably a malfunctioning diverter valve or a clogged hydrophorbic element in the water trap. In either case, due to the inaccessability of the hardware, the unit operation should be terminated by pushing the Stop Button and using the MDAC backup unit for the removal of CO_2.

L. Timer Malfunction If the "Bed Valve" or "Desorb Interval" timer fails, push the system red stop button and remove the timer by taking out the remaining screw at the base of the timer, lifting the handle and pulling the timer out of the panel. Remove either the "On Delay" or the "On Interval" and install it to replace the failed timer. Restart the unit according to the start up procedure; however, do not turn on the water pump until each bed has gone through two adsorb cycles. Also keep the canister gas inlet temperature control valve in the full hot position (closed) until the water pump is turned on.

II. Low CO_2 Purity.

A. Early Actuation of the CO_2 Valve Canister ullage gas is pumped to the MDAC accumulator. If on "Automatic Flow Control Operation", gradually increase the flow controller right hand pointer setting. If on "Automatic Timer Operation", gradually decrease the "Delay Timer" setting. In either case, Always Let The Operating Conditions For One Setting Stabilize Before Making Further Adjustments!!!

B. Compressor Excess Leakage Compressor pumping cabin air into the MDAC accumulator. Shut off the compressor system being used by placing the compressor "Motor Control" Switch in the "off" position. Close the Compressor Hand Valve for the compressor that had been used. Start the redundant compressor as described in the start up procedures. Check the water pump to make sure it was not de-energized by the control box interlock.

C. Malfunctioning Flow Controller Causing erratic and early actuation of the CO_2 valve allowing canister ullage to be pumped to the

II. (Continued)

C. (Continued)

MDAC accumulator. Go to the Automatic Timer Operation as described in the "Start-Up Procedures".

D. Malfunctioning Back Pressure Relief Valve Allowing the compressor to pump a partial vacuum in the canister on "Desorb" (see P_1 pressure trace). Shut down the compressor and place steam valve switch in over-ride. Remove the valve from the unit, disassemble (remove bonnet) and clean parts. Re-assemble and re-install in the CO_2 concentrator system. Start the unit again in accordance with the "Start-Up Procedures", automatic operation (three beds). Adjustment of the regulator to give a P_1 pressure of 12-14 psia value may be required. Turn the stem in to increase pressure. If the valve continues to be inoperative and cannot be repaired and the CO_2 purity becomes intolerable, use the MDAC backup unit for CO_2 removal.

III. High effluent gas temperature and/or visible water mist from the two outlet ports.

A. Low Flow and/or High Temperature Coolanol 35 to Condenser Not properly condensing the water vapor in the condenser unit. Adjust or repair the MDAC provided Coolanol 35 flow and temperature control devices to deliver the specified Coolanol 35 flow and temperature to the condenser unit.

IV. Excess water in the MDAC CO_2 Accumulator.

A. Clogged Water Trap Hydrophylic Element Due to the inaccessability of the water trap, the element cannot be removed and cleaned. If possible, install a second water trap or dryer in the line between the Amines CO_2 Concentrator and the MDAC Accumulator.

V. Warning buzzer or light actuation (MDAC supplied).

A. H_2O High Limit Warning Indicates no shut off of the water supply or excessive leakage through the water make up solenoid valve. Shut down the unit. Break the line down-stream of the solenoid valve and connect it to a water supply line that contains a manually operated valve. The warning buzzer or light will stay actuated until the water level in the water accumulator drops. Re-start the unit ("Start-Up Procedures") and manually fill the water accumulator every 8 to 12 hours. Each time fill the accumulator until the warning buzzer or light is energized.

B. High or Low Boiler Coolanol 35 Flow Warning Shut off the water pump. Adjust or repair the MDAC flow control device to provide a boiler Coolanol 35 flow that is within the specified limits (see Figure 1). Restart the water pump.

V. (Continued)

C. High or Low Boiler Coolanol 35 Temperature Warning Shut off the water pump. Adjust or repair the MDAC temperature control device to provide a boiler Coolanol 35 temperature that is within the specified limits (see Figure 1). Restart the water pump.

D. Gas Inlet Pressure Warning (exceeding 25" of H_2O) Follow the fan overload (dead-headed) trouble-shooting procedure in Section I.A.2.a. and c.

E. Low Compressed Gas Bottle Pressure Warning (85 psig or Below) Shut off the water. Adjust or repair the MDAC compressor and pressure control system so that the tank pressure is within the specified limits (105 ±5 psig). Restart the water pump.

APPENDIX N

Amine CO_2 Concentrator Performance Checkout Test Log Sheets

(Tests #1 & #2)

HSF-175.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

38 9.2 14.7

TYPE OF TEST: Ammine CO_2 Concentrator Performance Checkout Test #1
TEST ENGINEER: J Bertrand / T. Peck
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: 18 20 40

SHEET 1 OF 2 DATE 3/17/71
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS Kibbe "ABR"

Time	DB	CO_2 wt	Δ wt	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	H_2O C	CO_2 ON	CO_2 OFF STEAM ON	AP PSIA	Δ AP PSI	APP	FAN HEAD
0857	2	210.19	.06	40.0	30.	4.4	14.5	14.5	19.5	–	34.0	40.0	0	11.5	14.0	14.5/17.8	3.3	94	13.4
0912	1	210.13	.05	39.0	21.	4.3	14.5	14.5	19.5	–	34.0	38.0	1	7.	11.5	15/20.2	5.2	94	12.0
0926	2	210.08	.06	39.0	12.0	3.8	14.5	14.5	20.0	–	34.0	37.5	2	7	9.0	14.7/18	4.1	93	13.3
0941	1	210.02	.04	38.0	22.0	3.9	14.5	14.5	19.5	–	34.0	39.0	2	6	9.0	14/19.8	5.1	94	12.0
0956	2	209.98	.11	39.0	16.	3.75	14.5	14.5	19.5	–	34.0	38.0	3	6.5	9.0	14.6/17.4	3.8	94	13.0
1011	1	209.87	.06	40.	22.0	3.7	14.5	14.5	19.5	–	34.0	38.0	4	6.0	9.0	14.6/20.0	5.4	94	12.6
1027	2	209.81	.12	40.	12.0	3.65	14.5	14.5	19.5		34.0	38.0	4	6.5	9.0	14.7/18.8	4.1	94	13.4
1042	1	209.69	.05	39.	18.0	3.65	14.5	14.5	19.5		34.0	38.0	5	6.0	9.0	14.6/20.	5.4	94	12.5
1057	2	209.64	.08	39.	11.0	3.65	14.6	14.5	19.5		34.0	38.0	5	6.5	9.0	14.7/18.6	3.9	94	13.3
1112	1	209.56	.06	40.0	18.0	3.6	14.5	14.5	19.5		34.0	38.0	6	6.5	9.0	14.8/22.2	5.4	94.5	12.8
1128	2	209.50	.06	40.0	10.0	3.8	14.5	14.5	19.5	–	34.0	38.0	7	6.5	9.0	14.7/18.4	3.7	94	13.1
1143	1	209.44	.06	40.0	19.0	3.9	14.5	14.5	19.5	–	34.0	38.0	8	6.0	9.0	14.7/20.3	5.6	94	12.0
1158	2	209.38	.08	39.0	9.0	3.9	14.5	14.5	19.5	–	34.0	38.0	8	7.0	9.0	14.7/18.9	3.7	94	13.1
1213	1	209.30	.06	39.0	20.0	3.7	14.5	14.5	19.5		34.0	38.0	9	6.5	9.0	14.7/20.3	5.6	94	12.5
1228	2	209.24	.09	39.	11.0	3.7	14.5	14.5	19.5		34.0	38	9	7.0	9.0	14.7/18.3	3.6	94	12.95
1243	1	209.15	.05	39.	21.	3.85	14.5	14.5	19.5		34.0	38.	10.	6.5	9.0	14.6/20.1	5.5	94.5	11.8
1259	2	209.10	.08	39.	16.0	3.8	14.5	14.5	19.5	–	34.0	38.	11	7.0	9.0	14.7/18.0	3.3	94	12.85
*1313	1	209.02	.05	39.0	20.0	4.0	14.45	14.45	19.5	–	34.0	38.0	12	6.5	9.0	14.7/20.2	5.5	94.5	11.7
1327	2	208.97	.08	39.0	16.0	3.8	14.5	14.5	19.5	–	33.5	38.0	12	7.0	9.0	14.6/18.0	3.4	94.0	12.9
1343	1	208.89	.05	39.0	22.0	4.0	14.45	14.45	19.5		34.0	38.0	13	7.0	10.0	14.6/20.0	5.4	94.0	11.5
1358	2	208.84	.09	40.0	15.0	3.9	14.5	14.5	19.5		34.0	38.0	13	7.5	10.0	14.6/18.3	3.2	94.0	13.0
1414	1	208.75	.05	40.0	19.0	3.9	14.5	14.5	19.5		34.0	38.0	14	7.0	10.0	14.6/20.0	5.4	94.	11.35

REMARKS: 3.4.70 Post test wt 210.19   C.B = 29.67 @ 72°   * Back off 1/4 turn on H_2O Pump #2
13:25 Noticed H_2O leaking (drops) from side of can #2

Beds #1 & #2, dried out but otherwise as received from MDAC.

712

HSF-178.1A 1/6(

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

14.7

TYPE OF TEST: 4 Bed CO_2 Concentrator Performance Checkout Test #1
TEST ENGINEER: J. Bertrand & T. Peck
NAME OF RIG: Rig #88
PROJECT & ENG. ORDER NO.: 18

SHEET 2 OF 2 DATE 2/12/71
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS Kibbe

Time	Bed	CO_2 WT	Δ WT	SIFP	SOFP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	H_2O C	CO_2 ON	CO_2 OFF STEAM ON	ΔP PSIA	ΔP PSIA	APP	FAN H_2O
1428	2	208.70	.07	40.0	10.0	39.5	14.5	14.5	20.0	—	34.0	38.0	15	7	10	14.6/18.1	3.5	94.0	13.2
1443	1	208.13	.05	39.0	24.0	3.8	14.4	14.4	19.5	—	33.0	38.0	15	7	10	14.6/20	5.4	94.5	11.35
1459	2	208.58	.08	39.0	14.0	3.9	14.5	14.5	20.0	—	34.0	38.0	16	8	10	14.6/18	3.2	94.0	12.85
1514	1	208.50	.06	39.0	23.0	4.0	14.4	14.4	20.0	—	34.0	38.0	17	7	10	14.5/18	5.3	94.5	11.0
1530	2	208.44	.07	39.0	14.0	4.0	14.5	14.5	20.0		34.0	38.0	17	8	10	14.6/17.6	3.0	94.0	12.6
1543	1	208.37	.04	39.0	24.0	4.0	14.4	14.4	20.0		34.0	38.0	18	7	10	14.6/20.	5.4	94	10.65
		208.33																	

REMARKS:
14:45 STEAM LEAKING FROM PLUG IN BED #2

BEDS #1 & #2, DRIED OUT, BUT OTHERWISE AS RECEIVED FROM MDAC

710

HSF-178.1A 1/67

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST 38

14.7 14.7

TYPE OF TEST: [illegible] CO_2 CONCENTRATING [illegible] CHECK OUT TEST #2

TEST ENGINEER: J. BERTOLINO / R. DETILLO

NAME OF RIG: RIG 88

PROJECT & ENG. ORDER NO.: 38-42

SHEET 1 OF 2 DATE 8/11/71

TEST PLAN NO.

MODEL NO.

PART NO.

SERIAL NO.

OPERATORS [illegible]

TIME	DB	CO_2 WT.	Δ WT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	H_2O C	CO_2 ON	CO_2 OFF STREAM	AP PSIA	Δ AP PSI	APP	[illegible]	
0927	2	208.32	.08	40.0	28.0	5.7	14.65	14.65	19.0	—	34.0	38.0	0	9.0	—	14.7/11.6	2.9	93.	11.85	
0945	1	208.27	.08	40.0	29.0	5.6	14.65	14.65	21.	—	34.0	39.0	1	6.0	11.5	15.2/23.2	8.0	93	9.8	
1000	2	208.19	.10	40.0	9.0	4.5	14.7	14.7	20.	—	34.0	40.0	1	7.0	10	11.8/18.8	3.7	94	12.2	
1015	1	208.09	.07	40.0	29.0	5.3	14.65	14.65	20.0	—	34.0	38.0	2	7.0	10.5	14.8/22.0	7.2	94	9.7	
1030	2	208.0[illegible]	.09	41.0	16.0	4.65	14.65	14.65	20.0	—	34.0	40.0	3	7.0	10.0	14.8/19.1	3.6	95	12.0	
1045	1	207.93	.08	39.0	29.0	5.4	14.65	14.60	20.0	—	34.0	38.0	3	7.0	11.	14.8/22.0	7.2	95	9.65	
1100	2	207.85	.09	40.0	14.0	4.6	14.7	14.7	20.0	-	34.0	39.0	4	7.0	10.0	11.8/18.5	3.7	94.5	11.8	
1115	1	207.76	.06	39.0	30.0	4.8	14.65	14.65	20.0	—	34.0	41	5	7.0	11.	14.7/21.6	6.9	95	10.7	
1130	2	207.70	.11	40.0	10.0	4.5	14.65	14.7	20.0	-	34.0	38.0	5	6.5	10.0	14.8/18.8	4.0	95	11.8	
11:45	1	207.59	.05	40.0	30.0	5.4	14.6	14.65	20.0	-	34.0	40.0	6	7.0	10.5	14.8/21.6	6.8	95	9.65	
12:02	2	207.54	.10	40.0	13.5	4.4	14.65	14.7	20.0		34.0	38.0	6	7.0	10.0	14.8/18.7	3.9	95.5	11.75	
1217	1	207.44	.07	40.	30.0	4.9	14.65	14.65	20.0		34.0	40.	7	7.0	11.0	14.8/21.6	10.8	95.5	10.5	
1231	2	207.37	.10	40.	12.0	4.4	14.7	14.7	20.0		34.0	40	7	7.5	10.0	11.8/18.3	3.5	95.0	12.2	
1246	1	207.27	.05	39.0	30.	4.8	14.65	14.65	20.0		34.0	38.0	8	7.0	11.0	11.8/21.2	6.4	96.0	10.7	
1300	2	207.22	.08	40.	10.0	4.4	14.7	14.7	20.0		34.0	41.0	9	7.0	10.	14.8/18.4	3.6	95.5	12.2	
1315	1	207.14	.05	40.0	28	4.67	14.7	14.7	20.0		34.0	38.0	9	7.0	11.0	14.8/21.2	6.4	95.5	11.15	
1330	2	207.09	.09	40.0	17.0	4.55	14.7	14.7	20.0		34.0	37.0	10	7.0	10.0	11.8/14.1	2.3	94.5	11.9	*
1345	1	207.00	.08	40.0	28.0	4.4	14.65	14.65	20.0		34.0	42.0	11.0	7.0	10.5	14.8/21.0	6.2	95.5	11.1	
1400	2	206.92	.08	40.0	17.0	4.3	14.7	14.7	20.0		34.0	38.0	11.0	7.0	10.0	14.8/18.2	3.4	95.0	12.2	
1415	1	206.84	.06	39.0	30.0	4.7	14.65	14.65	20.0		34.0	34.0	12.0	7.0	10.5	14.8/21.0	6.2	95.0	10.7	
1431	2	206.78	.08	40.0	18.0	4.1	14.7	14.7	20.0		34.0	40.0	12.0	7.0	9.5	14.8/18.2	3.4	95.0	12.7	
1446	1	206.70	.05	40.0	30.0	4.8	14.65	14.65	20.0		34.0	38.0	13.0	7.5	11.0	14.8/20.8	6.0	95.0	10.8	

REMARKS: BAR. PRESS. 14.7 PSIA (29.94" HG @ 72°F)

CO_2 BOTTLE WT START 208.37

* TANK VALVE LEFT OPEN

BED #2 - SAME AS TEST #1

BED #1 - 4.57 LBS (DRY WT.) OF IR-45 MAT'L. REMOVED AND REPLENISHED WITH NEW IR-45 MAT'L. AS RECEIVED FROM NASA.

711

HSP-178.1A 1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

38 14.7 14.7

TYPE OF TEST: 4 ZONE CO_2 CONCENTRATOR
PERFORMANCE / CHECK OUT TEST #2
TEST ENGINEER: J. ENG. TOMAND / R. PETILLO
NAME OF RIG: C/G 88
PROJECT & ENG. ORDER NO.: SP-42

SHEET 2 OF 2 DATE 3/19/71
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS: ABF4

TIME	O.B	CO_2 WT.	Δ WT.	SIPP	SOPP	SIF	SPI	SPO	CCF	ACF	BCF	SIDP	H_2O C	CO_2 ON	CO_2 OFF GT.3%	AP PSIA	Δ AP PSI	APP	FAN HEAD			
~~15:00~~	2	~~206.65~~	.06	40.0	18.0	4.3	14.7	14.7	20.0	—	34.0	40.0	14.0	7.0	10.0	14.8 / 14.82	3.4	94.5	12.2			
15:15	1	206.59	.07	39.	30.	4.6	14.65	14.65	20.0	—	34.0	40.0	14.0	7.0	11.0	14.8 / 14.86	5.8	94.5	11.1			
~~15:30~~	2	206.52	.09	40.0	12.0	3.95	14.7	14.7	20.0	—	34.0	38.0	15.0	7.0	10.0	14.8 / 14.83	3.5	94.5	12.5			
15:45	1	206.42	.07	39.0	30.5	4.4	14.65	14.65	20.0	—	34.0	40.	16.	7.0	11.0	14.8 / 14.88	6.0	94.5	11.0			
16:00	2	206.36	.08	40.0	13.0	3.95	14.7	14.7	20.0	-	34.0	38.0	16	7.0	9.5	14.8 / 14.82	3.4	94.0	12.95			
16:16	1	206.28 / 206.23	.05	40.0	27.0	4.4	14.65	14.65	20.0	-	34.0	38.0	17	7.5	11.0	14.8 / 14.87	5.8	94.5	11.10			

REMARKS:

RED #2 SAME AS TEST #1
RED #1 - 4.87 LBS. (DRY WT.) OF 1R-45 MATL. REMOVED AND REPLENISHED WITH NEW 1R-45 MATL. AS RECEIVED FROM NSH.

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CR-112021
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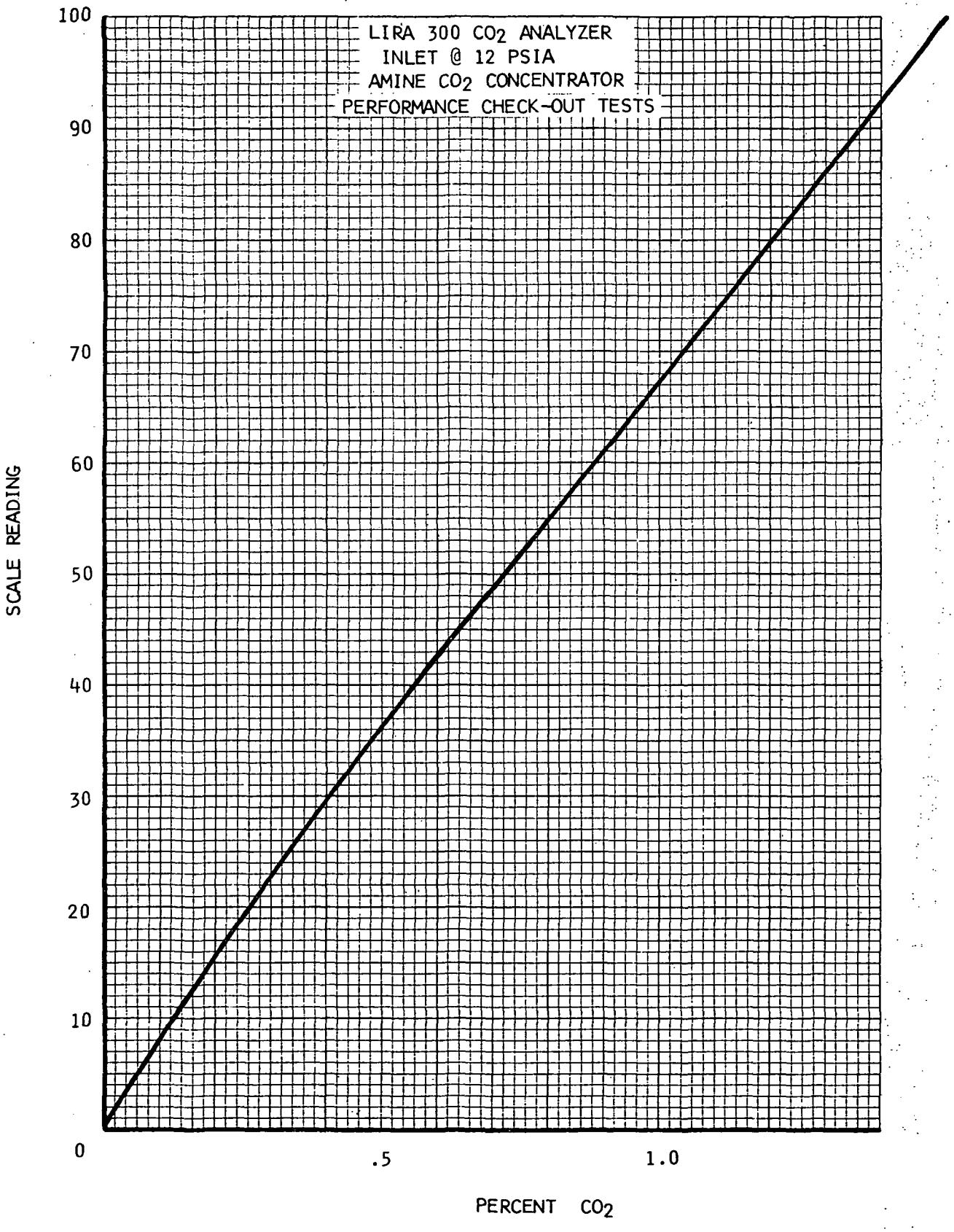
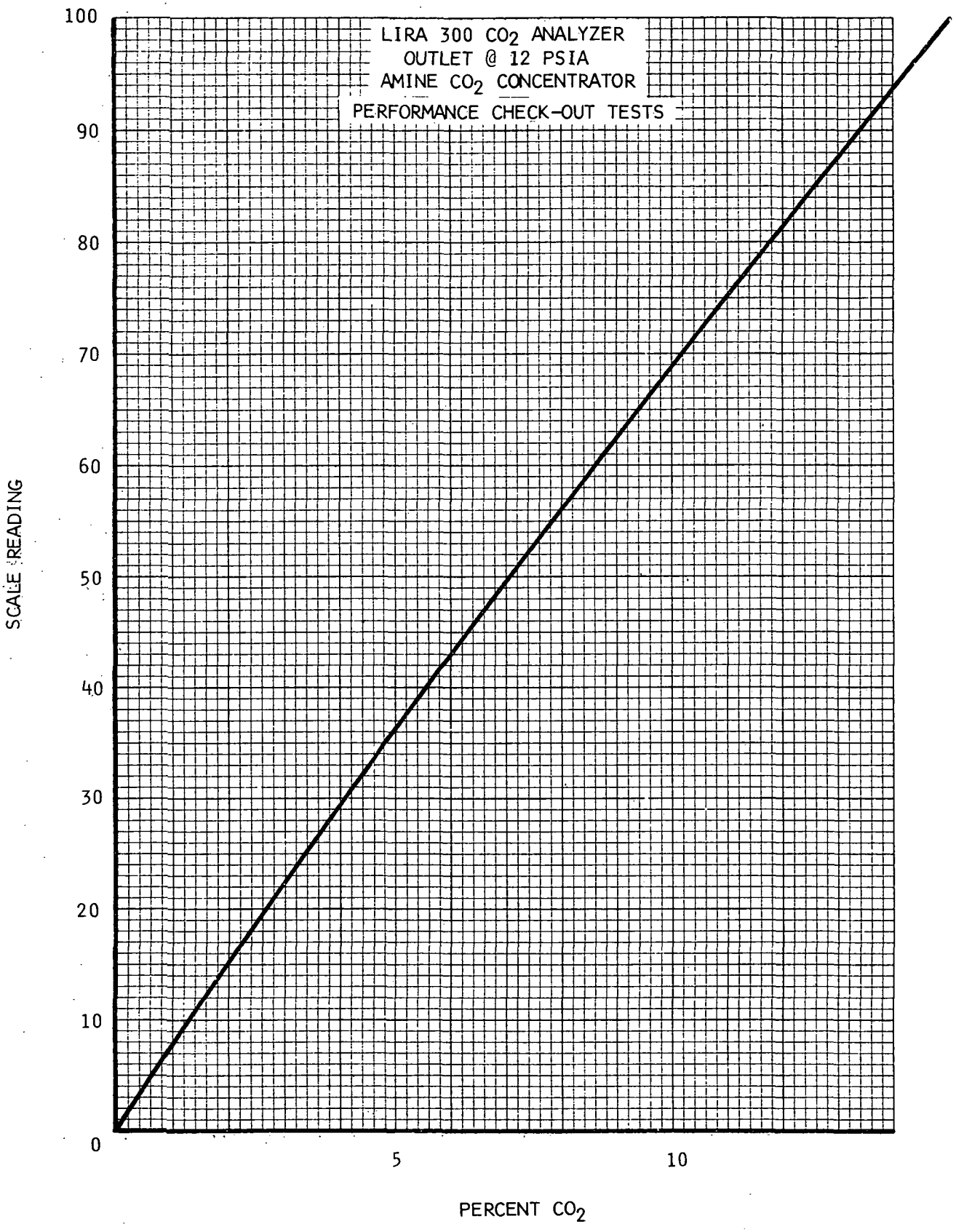
APPENDIX P

Amine CO_2 Concentrator Performance

Checkout Test Inlet & Outlet

Infrared Analyzer (Lira) Calibration


LIRA 300 CO_2 ANALYZER
INLET @ 12 PSIA
AMINE CO_2 CONCENTRATOR
PERFORMANCE CHECK-OUT TESTS
SCALE READING
100
90
80
70
60
50
40
30
20
10
0
.5
1.0
PERCENT CO_2


LIRA 300 CO_2 ANALYZER
OUTLET @ 12 PSIA
AMINE CO_2 CONCENTRATOR
PERFORMANCE CHECK-OUT TESTS
SCALE READING
100
90
80
70
60
50
40
30
20
10
0
5
10
PERCENT CO_2

APPENDIX Q

Anion Exchange Capacity Procedure

Type of Exchanger: Weak-base anion exchange resins only, like Amberlite IR-45.

Principle: Anion exchange capacity is determined by first converting the anion exchange resin to the chloride form and then eluting it with sodium sulfate.

Reagents: 4 percent HCl
Alcohol
4 percent Na_2SO_4
Methyl orange indicator
0.1 N NaOH
5 percent K_2CrO_4
0.05 N $AgNO_3$

Procedure:

1. Weigh out accurately 5 grams of the conditioned sample along with another sample for solids determination.

2. Quantitatively transfer the capacity sample to an ion exchange column.

3. Pass through the column 1-liter of 4 percent HCl. Rinse with about 1 liter of alcohol, checking completion of the rinse by adding water and methyl orange to some of the collected effluent. Flow rate should be 5 bed volumes per minute.

4. Pass through the column exactly 1 liter of 4 percent Na_2SO_4, collecting the effluent in a 1-liter volumetric flask. Use the same flow rate.

5. Shake the flask well and transfer 100-ml. aliquots to an Erlenmeyer flask.

6. Add 2 drops of methyl orange and, if pink, just enough 0.1 N NaOH to change the color back to yellow.

7. Add 1 ml. of 5 percent K_2CrO_4 and titrate with 0.05 N $AgNO_3$ until color changes from yellow to yellow-orange.

8. Calculate the anion exchange capacity using the following equation:

$$\frac{\text{ml.}_{AgNO_3} \times N_{AgNO_3} \times 10}{\text{Sample wt.} \times \frac{\% \text{ Solids}}{100}} = \frac{\text{Meq. anion exchange capacity}}{\text{Gram of dry free-base form resin}}$$

APPENDIX R

Comparative (IR-45) Breakthrough Curve Test

Log Sheets (Tests #1 & #2)

MSF-175.1A:1/66

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT 06096

SPACE & LIFE SYSTEMS LABORATORY

LOG OF TEST

TYPE OF TEST: BREAKTH ROUGH CURVE #2
TEST ENGINEER: T. PECK / NEW 1R-45
NAME OF RIG: 88
PROJECT & ENG. ORDER NO.: TEST #1

SHEET OF DATE 4/23/71
TEST PLAN NO.
MODEL NO.
PART NO.
SERIAL NO.
OPERATORS

TIME		INLET D.P.	OUTLET D.P.		INLET TEMP	OUTLET TEMP	BED TEMP		INLET LIRA	OUTLET LIRA		OUT %CO_2	OUT mm Hg		FLOW CC/MIN
MIN		°F	°F		°F	°F	°F		%	%					
0		40	–		70	–	70		52.5	–					
.5										8		.035	.57		900
1										16		.15	1.14		
1.5										25		.24	1.82		
2.0										28		.27	2.05		
2.5										30		.285	2.17		
3.0										33		.315	2.4		
3.5										34		.325	2.47		
4.0										35		.335	2.55		
4.5										36		.345	2.63		
5.0		40	60		70	70	69		53	37		.355	2.7		900
10		39	58		70	70	67		53	42		.405	3.08		900
15		42	56		70	70	67		53	43		.415	3.16		900
20		41	56		70	70	67		53	44		.425	3.23		900
25		39	55		70	70	67		52.5	45		.435	3.31		900
30		39	54		70	70	67		53	46		.445	3.39		900
35		40	53		70	70	67		53	47		.455	3.46		900
40		41	53		70	70	67		53	48		.465	3.54		900
45		39	52		70	70	67		53	49		.475	3.62		900

REMARKS:
LIRA CHECK CAL AFTER TEST
INLET – OK
OUTLET – OK

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R-2

JS 4/67 **Hamilton Standard** DIVISION OF UNITED AIRCRAFT CORPORATION
INDSOR LOCKS, CONNECTICUT • U.S.A.

LOG OF TEST
ENGINEERING LABORATORIES

SET 1 OF

RIG NO. 88
TYPE OF TEST BREAKTHROUGH #5 - BED #2 MAT'L — TEST #
PLAN OF TEST NO.
W.P.I. NO.
SERIAL NO.
PART NO.
DATE 4/28/71
ENGINEER T. Peck
OPERATORS

UNITS →	% SCALE	% SCALE	°F	°F	°F	°F	°F	CC/MIN		% CO_2	mmHg					
TIME MINUTES	INLET LIRA	OUTLET LIRA	INLET D.P.	OUTLET D.P.	INLET TEMP	OUTLET TEMP	BED TEMP	FLOW		OUTLET	OUTLET					
.5	54	9	40	60	69	69	67	900								
1	54	26	40	61												
1.5	54	34	40	62												
2	54	39	40	62												
2.5	54	41.5	39.5	60.5												
3	54	44	39.5	59.5												
3.5	54	45	39.5	59												
4	54	46	39.4	58												
4.5	54	47	39.4	58												
5	54	48	39.2	57.5	69	69	68	900								
10	54	52	43	56	69	69	68	900								
15	54	53	40	55	69	69	67	900								

REMARKS: LIRA CAL. CHECKED OUT AFTER TEST OK

PAGE NO.

REPORT NO.

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION U A®

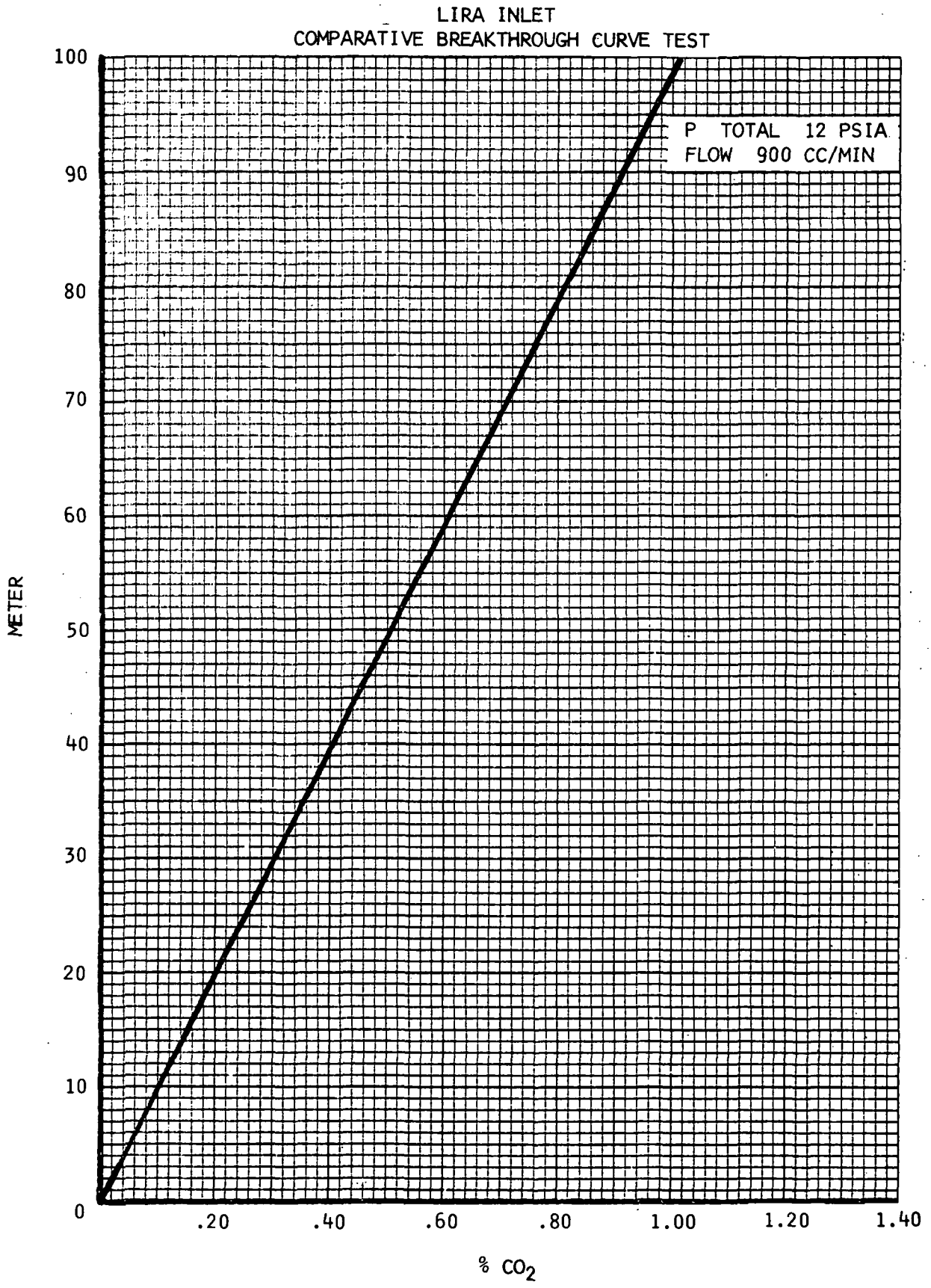
CR-112021
SVHSER-5966

APPENDIX S

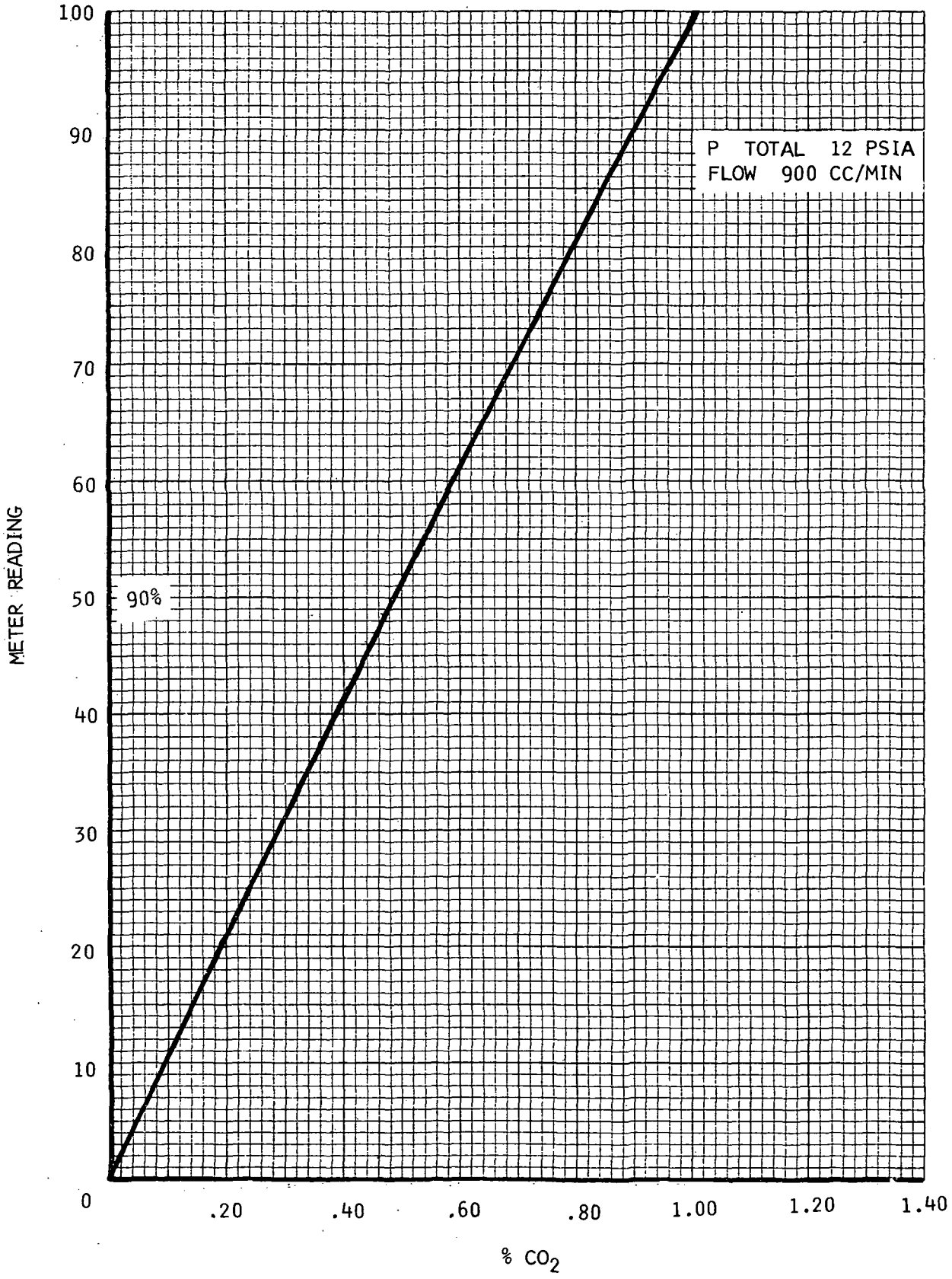
Comparative (IR-45) Breakthrough Curve Test

Inlet & Outlet Infrared Analyzer (Lira) Calibrations

Hamilton Standard
DIVISION OF UNITED AIRCRAFT CORPORATION



LIRA OUTLET
COMPARATIVE BREAKTHROUGH CURVE TEST



APPENDIX T

Symbols and Abbreviations

Symbols and Abbreviations

A	Mean tube surface area, square feet
A_i	Tube internal surface area, square feet
A_s	Total tube (outside) and fin surface area, square feet
Accum.	Accumulator
ACFM	Actual cubic feet per minute
AISI	American Iron and Steel Institute
AND	Air Force, Navy Design
$\mathring{A}$	Angstrom
BTU	British Thermal Unit
BTU/Hr.	British Thermal Units per hour
BTU/HR.-°F	British Thermal Units per hour per degree Fahrenheit
C	Carbon
Cp	Specific heat, BTU/Lb./°F
C_v	Flow factor as defined in ASCO Catalog No. 27
cc/Min.	Cubic centimeters per min.
CFM	Cubic feet per minute
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$C\bar{O}_3$	Carbonic Ion
D.C.	Direct Current
°C	Degree Centigrade
°F	Degree Fahrenheit
ΔP	Differential Pressure
ΔT	Differential Temperature
Dia.	Diameter

DP	Dew Point
E	Effectiveness
ECS	Environmental Control System
F	Flowmeter
Ft.	Feet
Ft^3	Cubic Feet
Ft^3/Min.	Cubic feet per minute
GFE	Government Furnished Equipment
g/cc	Grams per cubic centimeter
Gr.	Grams
h	Surface film coefficient, BTU/(Hr) (Sq Ft) (°F)
h_{fg}	Enthalpy, BTU/Lb.-Evaporation
h_i	Inside film coefficient, BTU/(Hr) (Sq Ft) (°F)
hA	Heat transfer film coefficient times the heat exchanger fin geometry area
H^+	Hydrogen Ion
H_2	Hydrogen
Hg	Mecury
H_2O	Water
Hr.	Hour
HS-B	Designation for Hamilton Standard proprietary CO_2 sorber material
Hx	Heat Exchanger
"	Inches
IR-45	Styrene divinyl benzene copolymer aminated with diethylenetriamine, manufactured by Rohm & Haas Company
K	Thermal conductivity, BTU/(Hr) (Sq Ft) (°F/Ft)
Lbs.	Pounds

$\frac{\text{Lbs. } CO_2}{\text{Hr.}}$	Pounds of carbon dioxide collected per hour
$\frac{\text{Lbs. } CO_2}{\text{TEW-Hr.}}$	Lbs. of CO_2 collected per total equivalent weight per hour
Lbs./Ft^3	Pounds per cubic foot
Lbs./Hr.	Lbs. per hour
Lbs./Min.	Lbs. per minute
LM	Lunar Module
LR	Lira Reading
Max.	Maximum
MDAC	McDonnell Douglas Astronautics Company
Min.	Minute
Min./Hr.	Minutes per hour
ml	Milliliters
mm	Millimeters
MOL	Manned Orbiting Laboratory
MSA	Mine Safety Appliance Research Corporation
μ	Micron
MV	Millivolt
N_2	Nitrogen
NASA COMAT	National Aeronautics and Space Administration Characteristic of Materials
NASA LaRC	National Aeronautics and Space Administration Langley Research Center
NASA MSC	National Aeronautics and Space Administration Manned Spacecraft Center
#	Number
O_2	Oxygen

O.D.	Outside Diameter
$\overline{OH}$	Hydroxide Ion
P	Pressure
P_{CO_2}	System carbon dioxide partial pressure
P_{H_2O}	Partial pressure of water
%	Percent
pH	Degree of acidity or alkalinity
PL	Line pressure to vacuum pump
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
PVPO	Vacuum Pump Outlet Pressure
PVPO/PL	Pressure Ratio
Q	Quantity of heat in British Thermal Units per hour
Q_{AVAIL}	Available heat
Q_B	Boiler heat needed
Q_L	Latent heat of condensation
$Q_{REQ'D}$	Heat required
Q_S	Sensible heat
Reg. Hx	Regenerable heat exchanger
R.H.	Relative Humidity
RPM	Revolutions per minute
S	Scale Weight
Sq. Ft.	Square Feet
STP	Standard, Temperature and Pressure
T	Temperature

T_{LMTD}	Log mean temperature difference
τ_o	Initial breakthrough time - point on the time axis where the extended slope of the breakthrough curve intersects the zero CO_2 concentration line.
TEW	Total Equivalent Weight
U	Overall coefficient BTU/(Hr) (Sq Ft) (°F)
UA_s	Overall heat transfer coefficient times the heat exchanger surface area
VAC	Volts Alternating Current
VDC	Volts direct current
v/60 CPS	Volts/cycles per second
$\dot{W}_{AIR}$	Flow
X	Tubing wall thickness, feet