UNITED TECHNOLOGIES
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PREPROTOTYPE SAWD SUBSYSTEM

FINAL REPORT

PREPARED UNDER CONTRACT NAS 9-13624

BY

HAMILTON STANDARD

DIVISION OF UNITED TECHNOLOGIES CORPORATION

WINDSOR LOCKS, CT

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

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Foreword

This Final Report has been prepared by Hamilton Standard Division of United Technologies Corporation for the National Aeronautics and Space Administration's Lyndon B. Johnson Space Center in accordance with the requirements of Contract NAS 9-13624, "Regenerable CO_2 and Humidity Control Systems".

The guidance and advice provided by the NASA Technical Monitor, Mr. Robert J. Cusick of the Lyndon B. Johnson Space Center's Crew Systems Division is greatly appreciated.

Hamilton Standard personnel responsible for the conduct and completion of this program were Messrs. Harlan F. Brose, Program Manager; Kenneth J. Dresser, Project Engineering Manager; Albert M. Boehm, Senior Experimental Engineer; Timothy A. Nalette, Analytical Engineer; and Terry M. Grayson, Electrical Engineer.

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SUMMARY

A regenerable, three-man preprototype solid amine, water desorbed (SAWD) CO_2 removal and concentration subsystem has been designed, fabricated, and successfully acceptance tested by Hamilton Standard. The preprototype SAWD incorporates a single solid amine canister to perform the CO_2 removal function, an accumulator to provide the CO_2 storage and delivery function, and a microprocessor which automatically controls the subsystem sequential operation and performance.

The SAWD subsystem was configured to have a CO_2 removal and CO_2 delivery capability at the rate of 0.12 kg/hr (0.264 lb/hr) over the relative humidity range of 35 to 70%. The controller was developed to provide fully automatic control over the relative humidity range via custom software that was generated specifically for the SAWD subsystem.

The preprototype SAWD subsystem demonstrated a total of 281 hours (208) cycles of operation during ten acceptance tests that were conducted over the 35 to 70% relative humidity range. This operation was comprised of 178 hours (128 cycles) in the CO_2 overboard mode and 103 hours (80 cycles) in the CO_2 reduction mode. The average CO_2 removal/delivery rate met or exceeded the design specification rate of 0.12 kg/hr (0.264 lb/hr) for all ten of the acceptance tests.

INTRODUCTION

The Regenerable CO_2 and Humidity Control System program began in 1973 with the development of a breadboard, and later a flight prototype solid amine system which was regenerated by vacuum desorption. The effort for that phase of this program was reported in the Flight Prototype CO_2 and Humidity Control System Final Report, SVHSER 7182. This system, Solid Amine/Vacuum Desorbed (SAVD), was most desirable on fuel cell-powered vehicles, like Shuttle, due to the abundance of water. More recently, SAWD (Solid Amine/Water Desorbed) development was added as a more desirable approach for CO_2 control on solar cell-powered vehicles (Extended Duration Orbiter and/or Space Station). This effort, preceding the current program phase, was reported in the Lightside Atmospheric Revitalization System Study Report, SVHSER 7224.

Program Description

The current program phase, reported herein, began in 1981 and incorporates the effort directed by Contract Modifications 32S, 33S, 34S, and 35C. The specific tasks associated with these modifications are fully defined by the Statement of Work that is tabulated for each in the Appendices.

The initial Statement of Work (Modification 32S) directed that a preprototype SAWD system be designed and built using an existing preprototype SAWD canister/steam generator assembly and commercially-available hardware for other components wherever possible. A minimum of 120 hours of acceptance testing was specified to verify system operation prior to SAWD delivery to the NASA. Documentation, in the form of drawings, user manual, test plan, Failure Modes and Effects Anaysis, nonmetallic materials list, and a final report were also specified.

Later modifications (Modifications 33S and 34S) directed the addition of canister instrumentation and a microprocessor to control the system, to monitor operation and performance, to detect malfunctions, and to shut down the SAWD to a safe hold condition, in the event of a malfunction. The modified SAWD was also required to be compatible with the interface of the NASA's Regenerative Life Support Equipment (RLSE) laboratory.

The final modification (Modification 35C) directed that a support package be designed and built to permit endurance evaluation in the Crew System Division's (CSD) life test facility. Additional provisions, both hardware and controller software, were specified to provide more exact operational monitoring and more extensive automatic tabulation of the performance records.

Program Objective

The basic objective of this phase of the program is the design, fabrication, and acceptance testing of a three-man preprototype SAWD CO_2 removal and concentration subsystem. This preprototype SAWD is to be capable of interfacing with both the RLSE laboratory and the CSD Life Test Laboratory for further test evaluation.

SAWD Specifications

The basic design goals are specified in the following tabulation.

PARAMETER	SPECIFICATION
Crew Size	3
CO_2 Removal/Delivery Rate	0.120 kg/hr (0.264 lb/hr)
Cabin PCO_2	3.8 mmHg
Cabin Temperature	292 to 300°K (65 to 80°F)
Cabin Relative Humidity	35 to 70%
Cabin Dew Point*	277 to 289°K (39 to 61°F)
Cabin Pressure	101 kPa (14.7 psia)
CO_2 Delivery Pressure	126 kPa (18.3 psia)
CO_2 Removal Package Size	0.56mW X 0.62mW X 0.79mD (22" W X 24.5" H X 31" D)

* within the relative humidity limits

Basic SAWD Description

The SAWD subsystem, illustrated pictorially in Figure 1, is comprised of four basic assembly packages, namely:

1. CO_2 Removal Package
2. CO_2 Storage/Delivery Package
3. Controller Package
4. Life Test Laboratory Support Package

The CO_2 removal package performs the regenerable CO_2 removal function via alternate absorption and desorption of the CO_2 removal canister. During absorption, CO_2-laden air flows through the canister (wherein the CO_2 is removed), then returns to the cabin. Regeneration of the CO_2 canister is accomplished during operation in the desorption mode (wherein the CO_2 is released from the canister), by heating the canister contents with steam produced in the steam generator. The evolved CO_2 is routed to the CO_2 storage/delivery package or is dumped overboard, if no use of the CO_2 is desired. The CO_2 storage/delivery package supplies CO_2 to an atmosphere revitalization system at a constant delivery rate from the CO_2 that is accumulated during desorption. The sequencing operation of both the CO_2 removal package and the CO_2 storage/delivery package is directed by controller software as a function of time and/or instrument (eg - thermocouples, pressure sensors, and flow meters) signals that are logged by the data acquisition unit.

The life test laboratory support package, intended solely for use during subsystem evaluation in the CSD Life Test Laboratory, consists of a stand, inlet filter, and exhaust muffler. This equipment permits testing of the SAWD in this relatively uncontrolled environment.

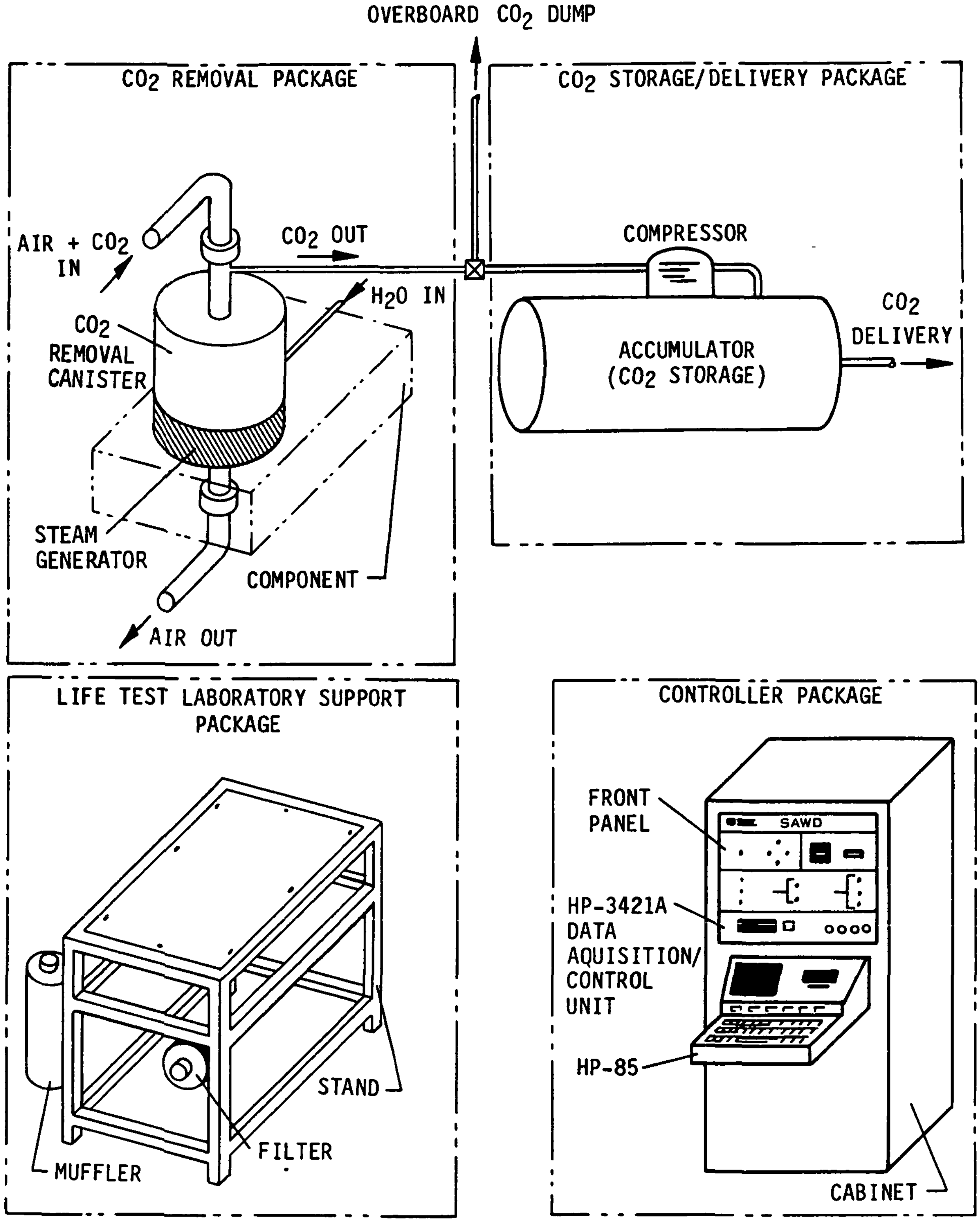

FIGURE 1

BASIC SAWD SUBSYSTEM ASSEMBLY

CONCLUSIONS

The preprototype SAWD subsystem has been demonstrated to meet or exceed the performance requirements for the removal/delivery of CO_2 specified in the Statements of Work for the development of a Preprototype SAWD Subsystem per NASA Contract NAS9-13624 in Modifications 32S, 33S, 34S, and 35C.

From a hardware standpoint, the SAWD integrates proven components to form a simple subsystem configuration that has been demonstrated to be amenable to fully automatic control of both component operation and subsystem performance. Further, the subsystem has demonstrated the capability to automatically shut-down to a safe-hold condition in the event of an operational anomaly.

The solid amine, with over 3,500 hours of cyclic operational usage and no observed performance degradation, has demonstrated the potential for long life with high reliability and efficiency.

RECOMMENDATIONS

The test results and the analyses conducted during this program have demonstrated that a SAWD CO_2 control subsystem can be designed to meet the regenerable CO_2 removal/concentration requirements for long term space missions or for extended duration Orbiter missions and thereby avoid significant launch and resupply penalties.

To optimize the SAWD subsystem design, it is recommended that:

- The preprototype SAWD be endurance tested to quantify the useful amine life.
- Long term operational performance data be generated to permit further refinement of the automatic control algorithms.
- Performance tests at CO_2 levels between 3.8 and 15 mmHg be conducted to define the subsystem capabilities.

The present preprototype SAWD should be used to evaluate the preceding recommendations. It is further recommended that a multiple canister preprototype SAWD subsystem be designed, fabricated, and tested to evaluate techniques for minimizing weight, volume, or power.

SUBSYSTEM DESCRIPTION

This section of the final report describes the SAWD physically to identify the configuration and arrangement of the component parts of the subsystem. The operating components of the preprototype SAWD are shown schematically in Figure 2.

The preprototype SAWD is comprised of four physically separate packages containing the components principally concerned with CO_2 removal, CO_2 storage/delivery, control of the operating cycle, and the subsystem support required for open loop operation in the Crew Systems Division Life Test Laboratory. The components in each package are listed in Table 1. The four individual assembly packages are:

a) CO_2 Removal Package
b) CO_2 Storage/Delivery Package
c) Controller Package
d) Life Test Laboratory Support Package

The CO_2 Removal Package components are mounted on a frame 77.5 cm (30.5 inches) long by 54.6 cm (21.5 inches) wide by 19.1 cm (7.5 inches) high. The overall package dimensions are 83.8 x 54.6 x 59.7 cm (33 x 21.5 x 23.5 inches). The package is illustrated in Figures 3 through 8. Interface connections to the package are located on its front face (Figure 3) and described in Table 2. The package (including dry amine) weighs 52.0 kilograms (114.5 pounds). It can be installed for operation on a bench or table-top, although more ready access to its internal components is obtained utilizing a stand that supports the frame to leave the lower surface of the package exposed.

The CO_2 Storage/Delivery Package components are mounted on a horizontal platform 45.7 cm (18 inches) long by 33 cm (13 inches) wide welded to the top of the 91.4 cm (36 inches) by 43.2 cm (17 inches) diameter horizontal cylindrical accumulator. The overall dimensions of the package, shown in Figures 9 through 11 are 100.3 x 43.2 x 73.6 cm (39.5 x 17 x 29 inches). Its interface connections, all on the top surface (Figure 11), are described in Table 3. The package weighs 37.9 kilograms (83.6 pounds) as shipped.

The Controller Package components are housed in a cabinet 141 cm (55.5 inches) high by 54.6 cm (21.5 inches) wide by 66 cm (26 inches) deep, mounted on casters. Its overall depth with the computer keyboard in its withdrawn operating position is increased to 99 cm (39 inches). The package weighs 118.2 kilograms (260.3 pounds). Its front surface, shown in Figure 12, includes the SAWD operating status display panel, the data acquisition/control unit status panel, and the computer input keyboard/display. Its back surface, Figure 13, includes an interior access panel and all interface connections as described in Table 4.

1 - CO_2 Removal Package
2 - CO_2 Storage/Delivery Package
3 - Controller Package
4 - Life Test Lab Support Package

A1 CO_2 Accumulator
B1 Sorbent Bed
C1 Operating Sequence Controller
C2 Steam Generator Controller
E1 Open Loop Air Outlet Silencer
F1 Air Fan
F2 Water Pump
F3 CO_2 Compressor
G1 Steam Generator
I1 Open Loop Inlet Air Filter
P1 Sorbent Bed Pressure Transducer
P2 High Pressure Switch - Desorb Air Vent
P3 Low Pressure Switch - Accumulator
P4 High Pressure Switch - Accumulator
P5 High Pressure Switch - Water Pump
R1 Desorb CO_2 Back Pressure Regulator
R2 Delivery CO_2 Pressure Regulator
R3 Accumulator Pressure Relief Valve
T0 Steam Generator Control Temperature Setting
T1 Inlet Air Temperature Sensor
T2 Header Temperature Sensor
T3 Outlet Air Temperature Sensor
T4-T8 Sorbent Bed Temperature Sensors
V1 Pneumatic Pressure Control Solenoid Valve
V2 CO_2 Compressor Bypass Solenoid Valve
V3 Desorb Air Vent Solenoid Valve
V4 Desorb CO_2 Dump Solenoid Valve
V5 Delivery CO_2 Solenoid Valve
V6 Sorbent Bed Inlet Pneumatic Valve
V7 Sorbent Bed Outlet Pneumatic Valve
V8 Water Flow Diverter Manual Valve
V9 Desorb CO_2 Check Valve
Ø1 Delivery CO_2 Flow Control Orifice
TP1-TP5 Test Ports

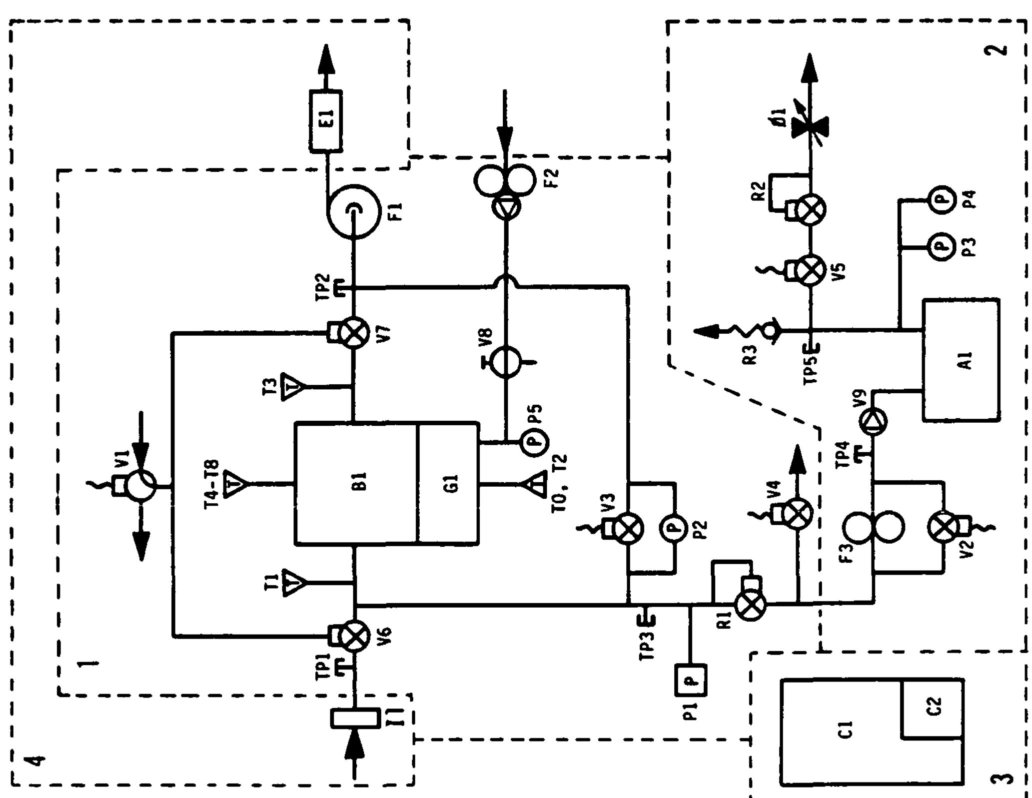

FIGURE 2

PREPROTOTYPE SAWD NOMENCLATURE SCHEMATIC

TABLE 1

SUBSYSTEM PACKAGE COMPOSITION

Package		Component
CO_2 Removal	B1	Sorbent Bed
	G1	Steam Generator
	V1	N_2 Pressure/Vent Solenoid Valve
	V3	Desorb Air Vent Solenoid Valve
	V4	Desorb CO_2 Dump Solenoid Valve
	V6	Sorbent Bed Inlet Pneumatic Valve
	V7	Sorbent Bed Outlet Pneumatic Valve
	V8	Water Flow Diverter Valve
	F1	Air Fan
	F2	Water Pump
	R1	Desorb CO_2 Back Pressure Regulator
	P1	Sorbent Bed Pressure Transducer
	P2	Pressure Switch - Desorb Air Vent
	P5	Pressure Switch - Water Pump
CO_2 Storage/Delivery	A1	CO_2 Accumulator
	V2	CO_2 Compressor Bypass Solenoid Valve
	V5	CO_2 Delivery Solenoid Valve
	V9	Desorb CO_2 Check Valve
	F3	CO_2 Compressor
	R2	Delivery CO_2 Pressure Regulator
	R3	Accumulator Pressure Relief Valve
	Ø1	Delivery CO_2 Flow Control Orifice
	P3	Low Pressure Switch - Accumulator
	P4	High Pressure Switch - Accumulator
Controller	C1	Operating Sequence Controller
	C2	Steam Generator Controller
Life Test laboratory Support Package	E1	Open Loop Air Outlet Silencer
	I1	Open Loop Inlet Air Filter

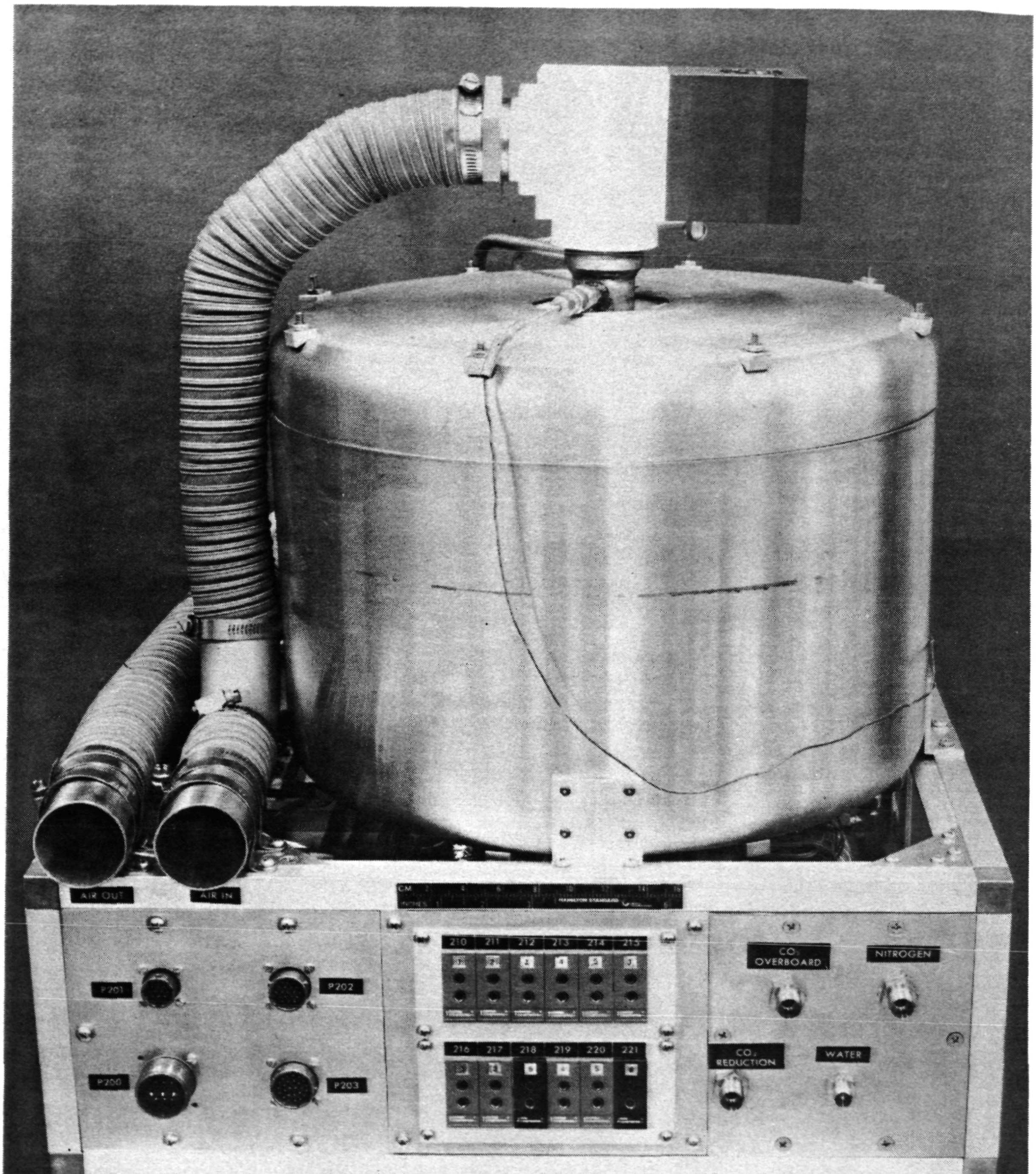

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FIGURE 3

CO_2 REMOVAL PACKAGE
FRONT VIEW

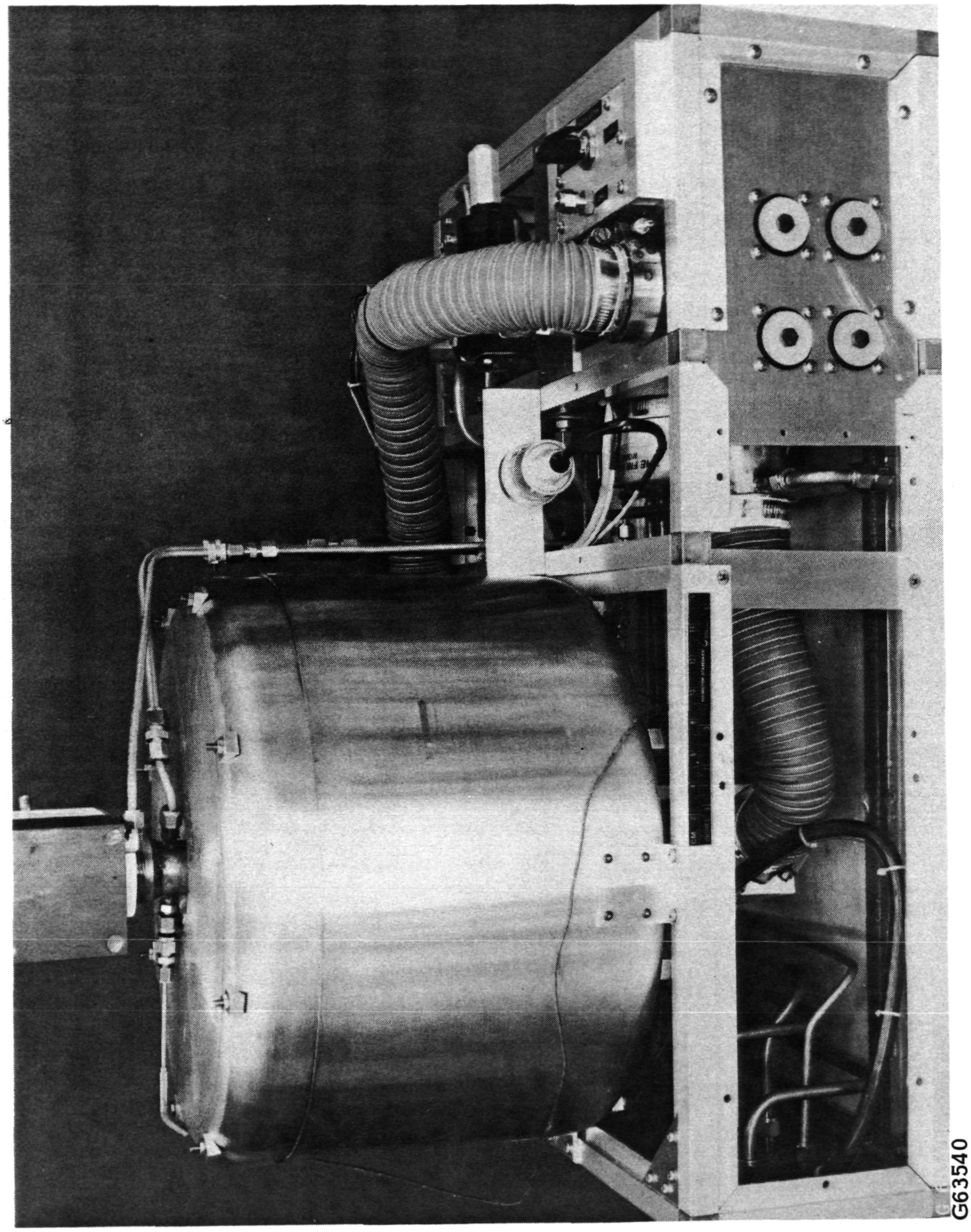

FIGURE 4

CO_2 REMOVAL PACKAGE
RIGHT SIDE VIEW

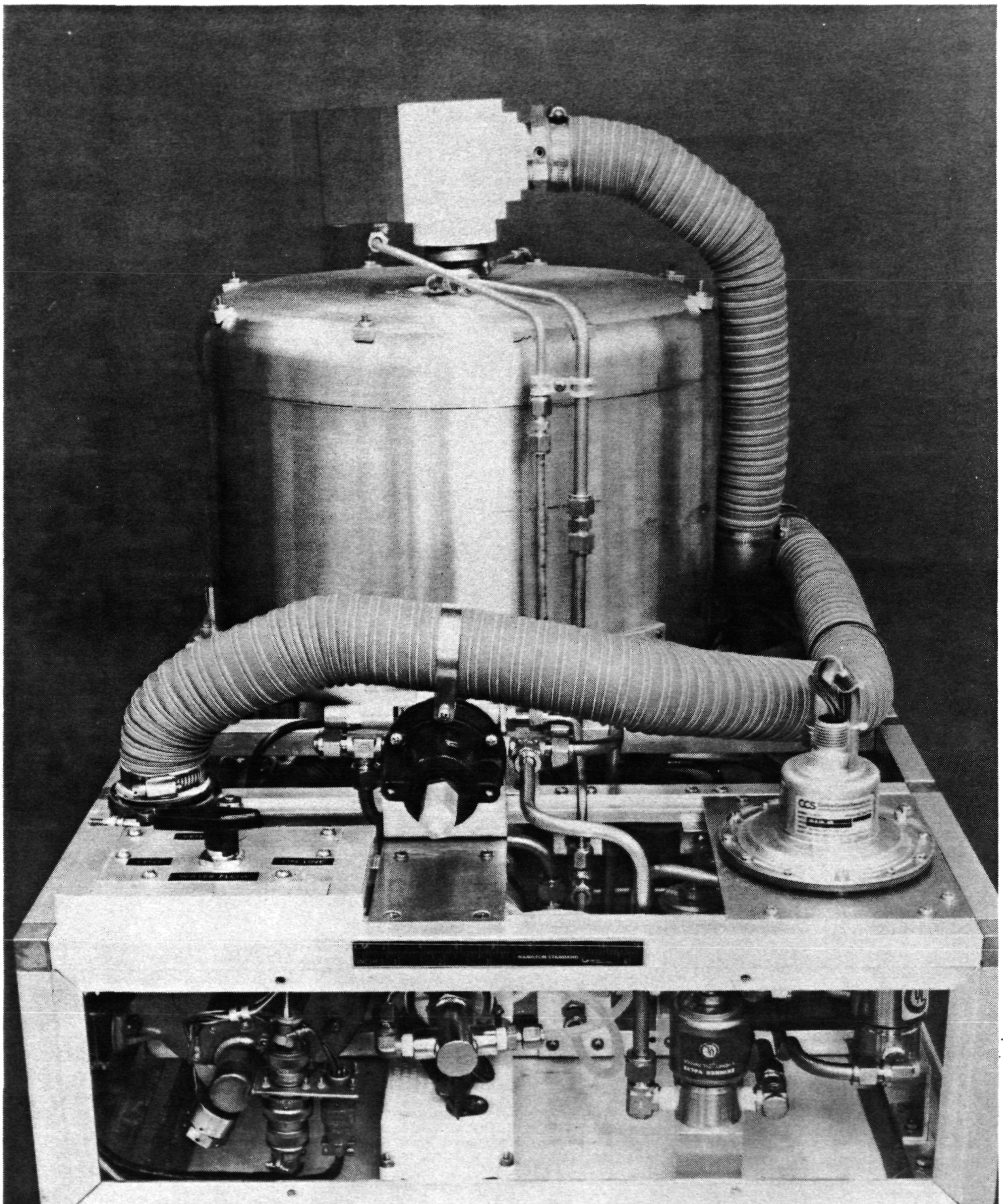

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FIGURE 5

CO_2 REMOVAL PACKAGE
REAR VIEW

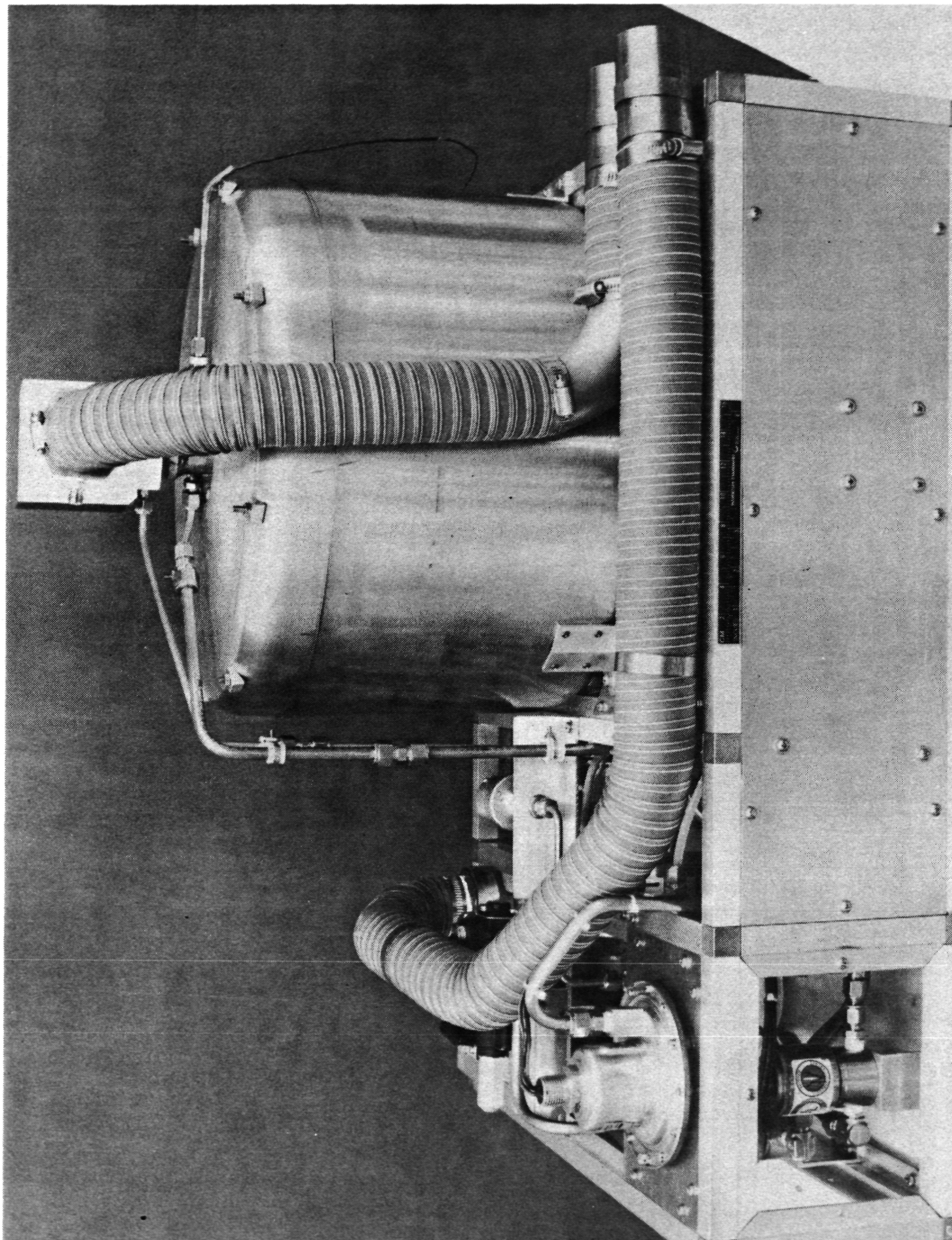

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FIGURE 6

CO_2 REMOVAL PACKAGE
LEFT SIDE VIEW

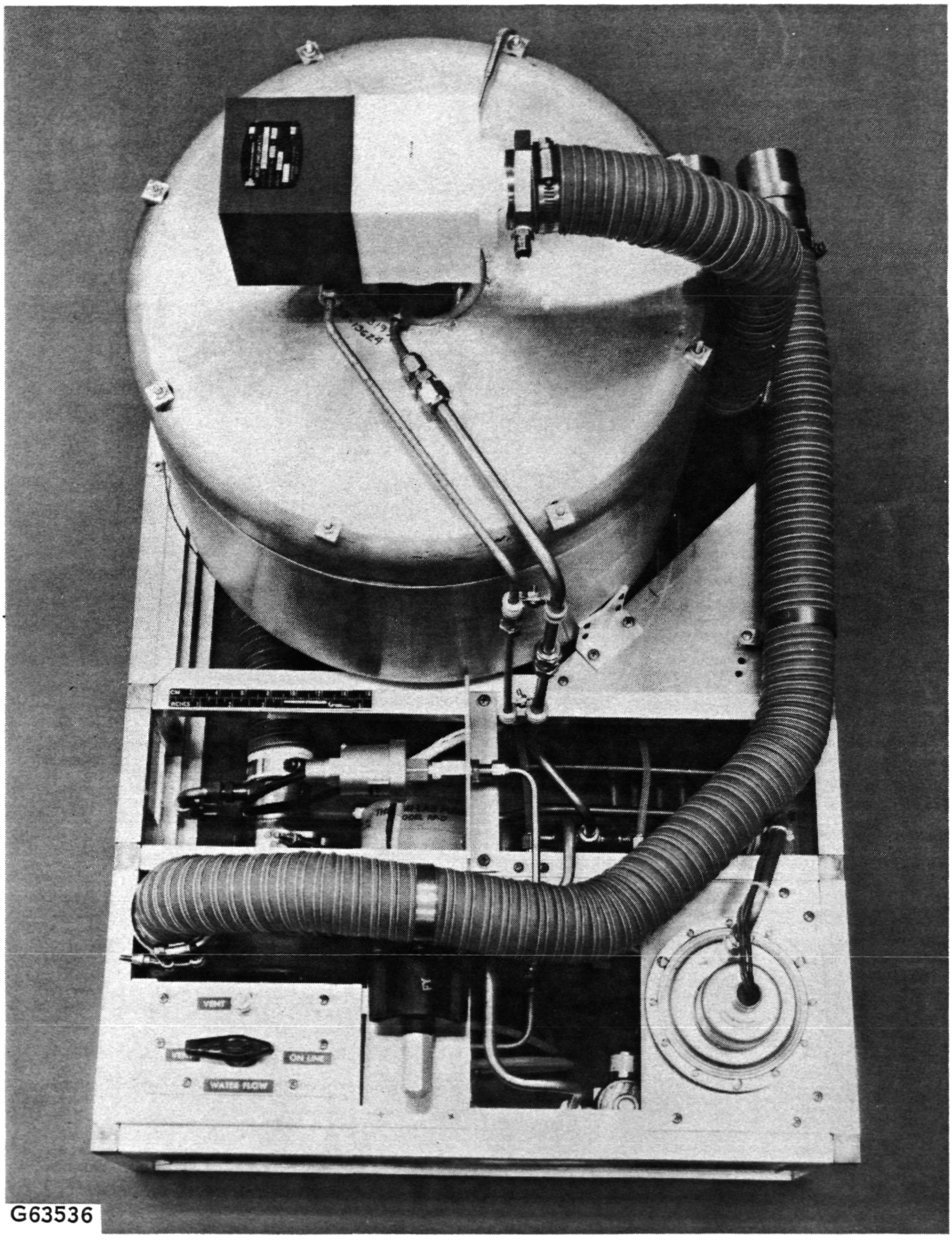


FIGURE 7

CO_2 REMOVAL PACKAGE
TOP VIEW

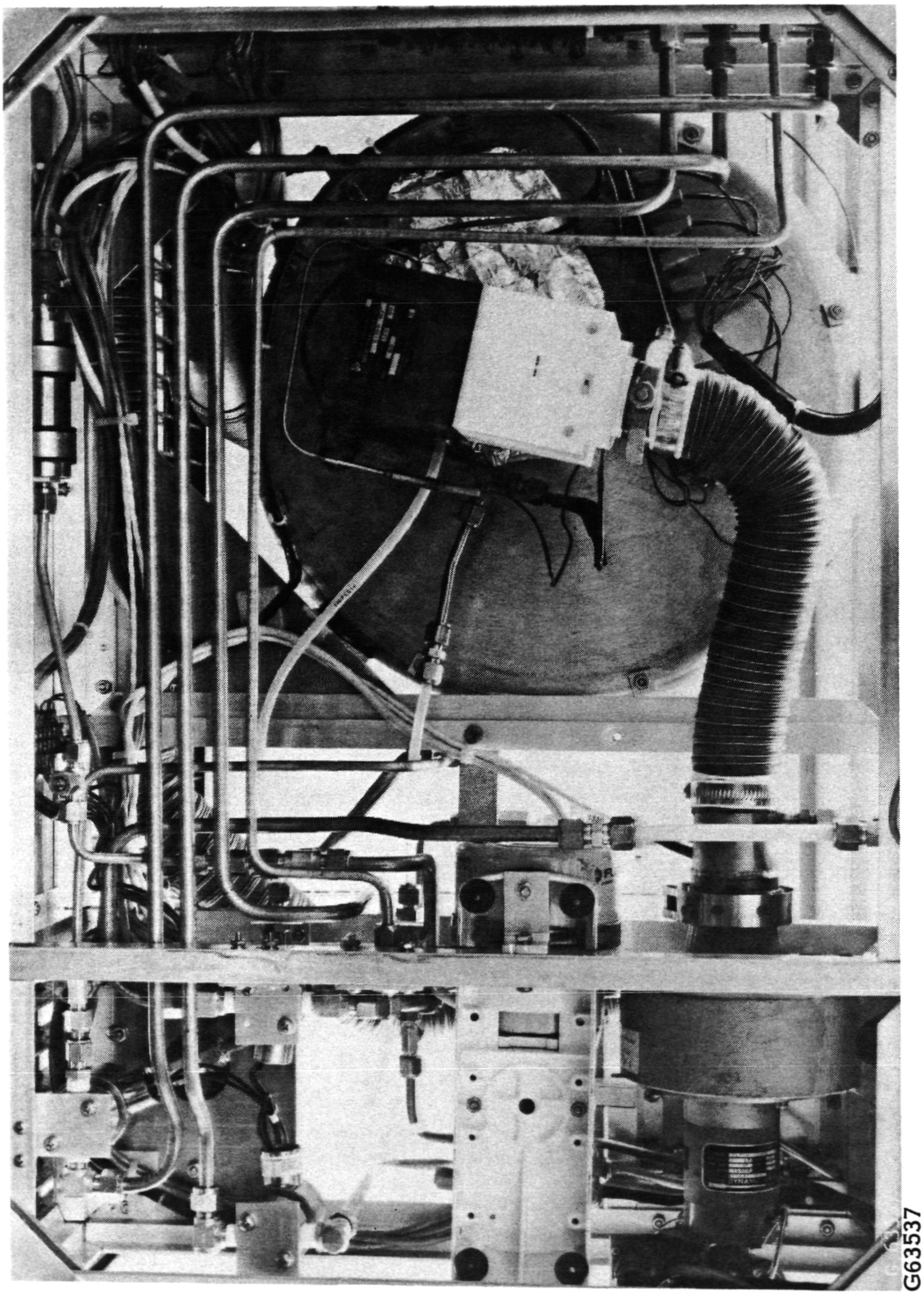
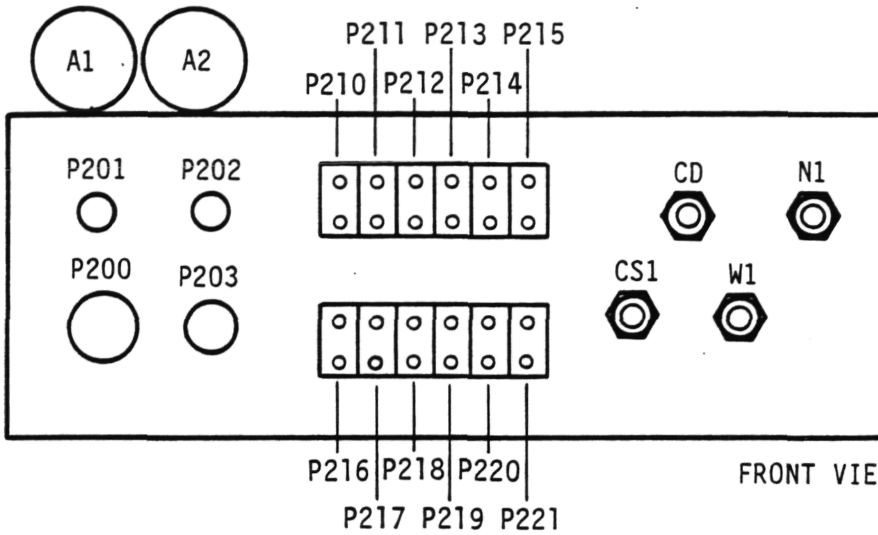


FIGURE 8

CO_2 REMOVAL PACKAGE
BOTTOM VIEW

TABLE 2

CO_2 REMOVAL PACKAGE INTERFACE CONNECTIONS



FRONT VIEW

ID No.	Connector Size/Type	Medium	Connected To
A1	2" OD Tube/Clamp	Outlet Air	Cabin/Test Rig
A2	for Flex Hose	Inlet Air	Source
P200	3102A-20-9P	115V, 1Ø, 60 Hz (G1,F2)	Controller 100
P201	PT02A-12-10P	24V DC (V1,V3,V4)	Controller 101
P202	PT02A-14-19P	115V, 3Ø, 400 Hz (F1)	Controller 102
P203	PT02A-16-26P	24V DC, 5V Signal	Controller 103
P210 - P218	2 Pin Female Thermocouple Connector	TC Signal (T0 - T8)	Sequence Controller
CS1	3/8" Male Swagelok	CO_2 - Storage	CS2-CO_2 Storage Package
CD	"	CO_2 - Dump	Overboard
N1	3/8" Male Swagelok	Nitrogen (V6,V7 Pressure)	N_2 Supply
W1	1/4" Male Swagelok	Water (G1)	H_2O Supply

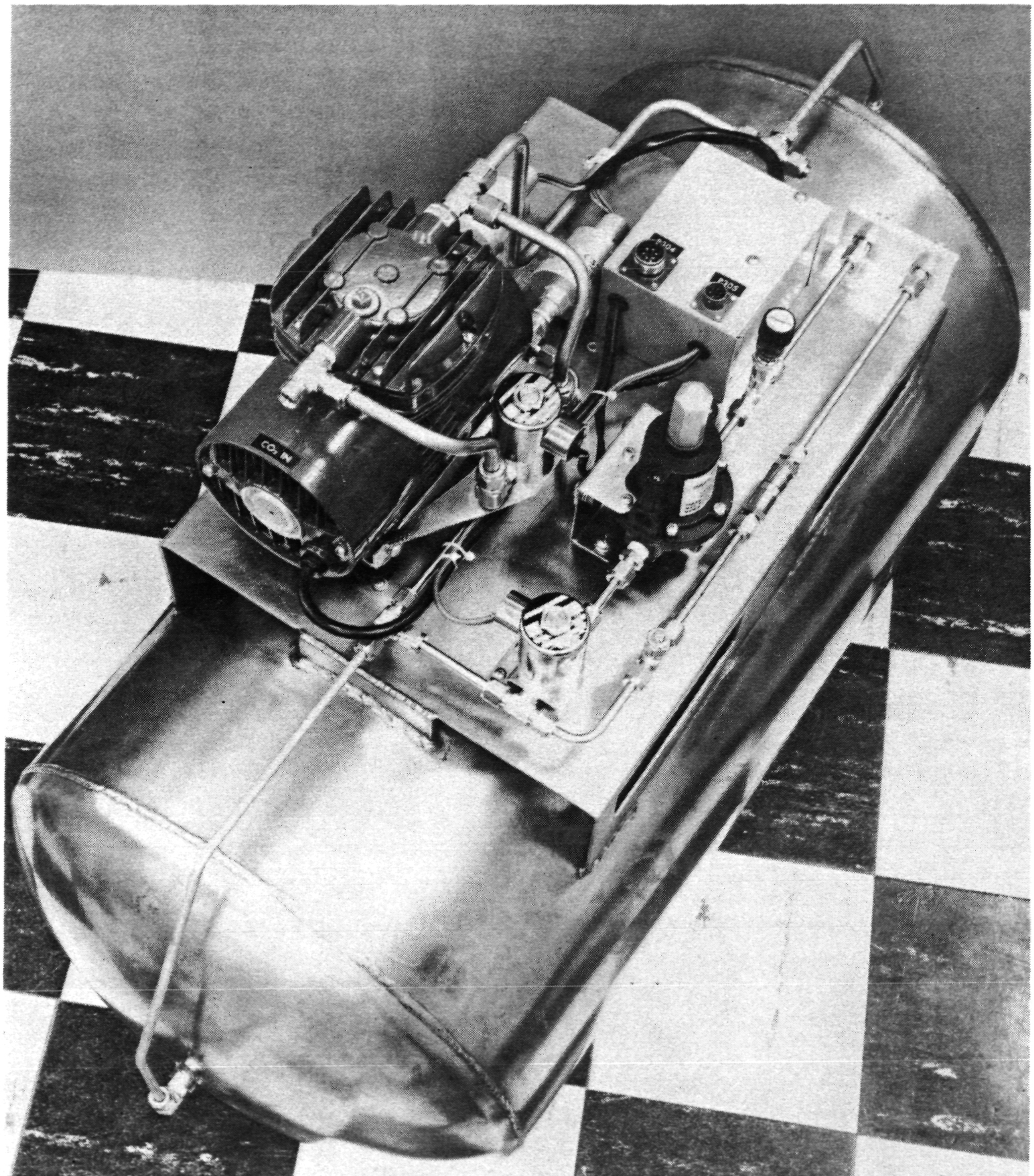


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FIGURE 9

CO_2 STORAGE/DELIVERY PACKAGE
TOP LEFT VIEW

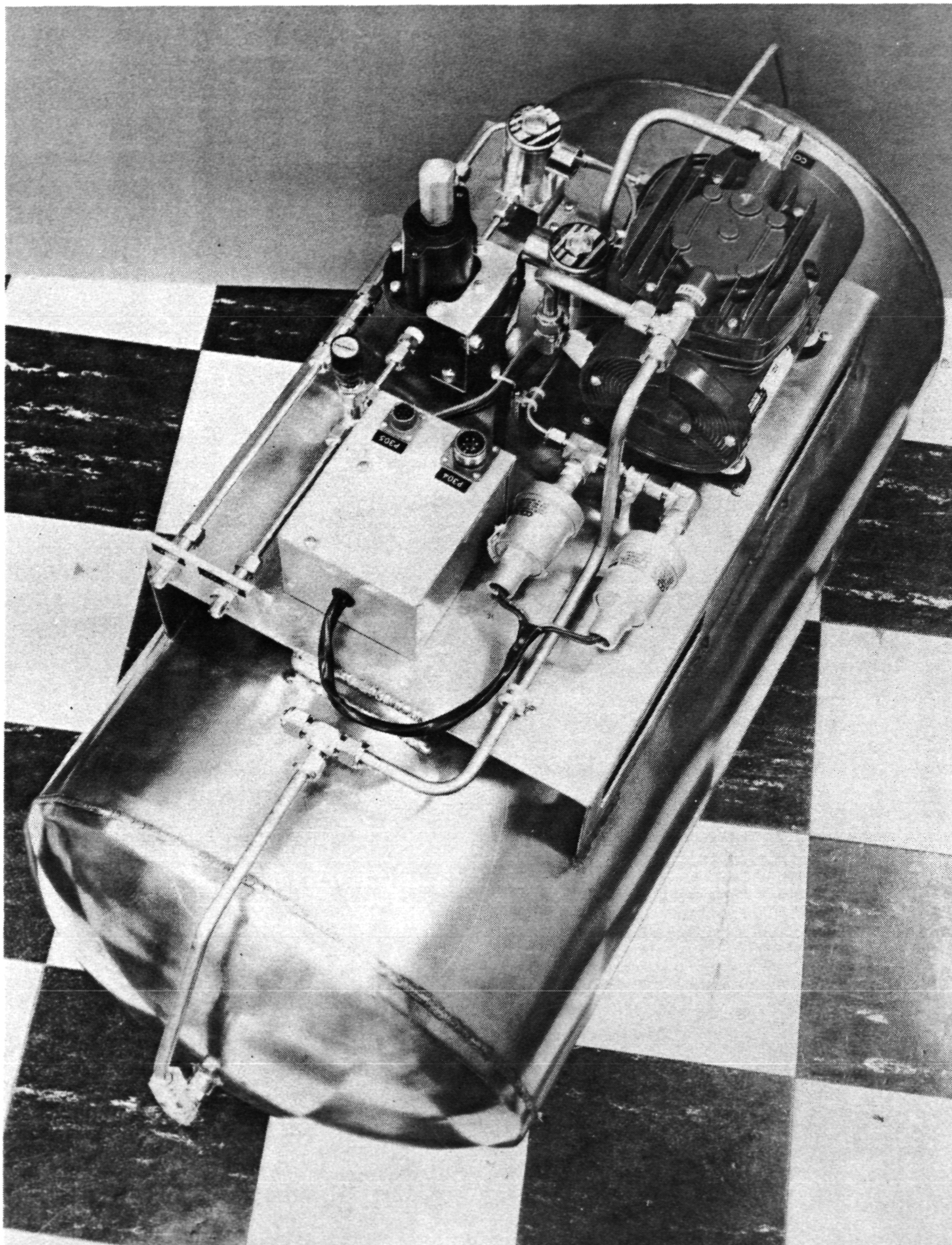

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FIGURE 10

CO_2 STORAGE/DELIVERY PACKAGE
TOP RIGHT VIEW

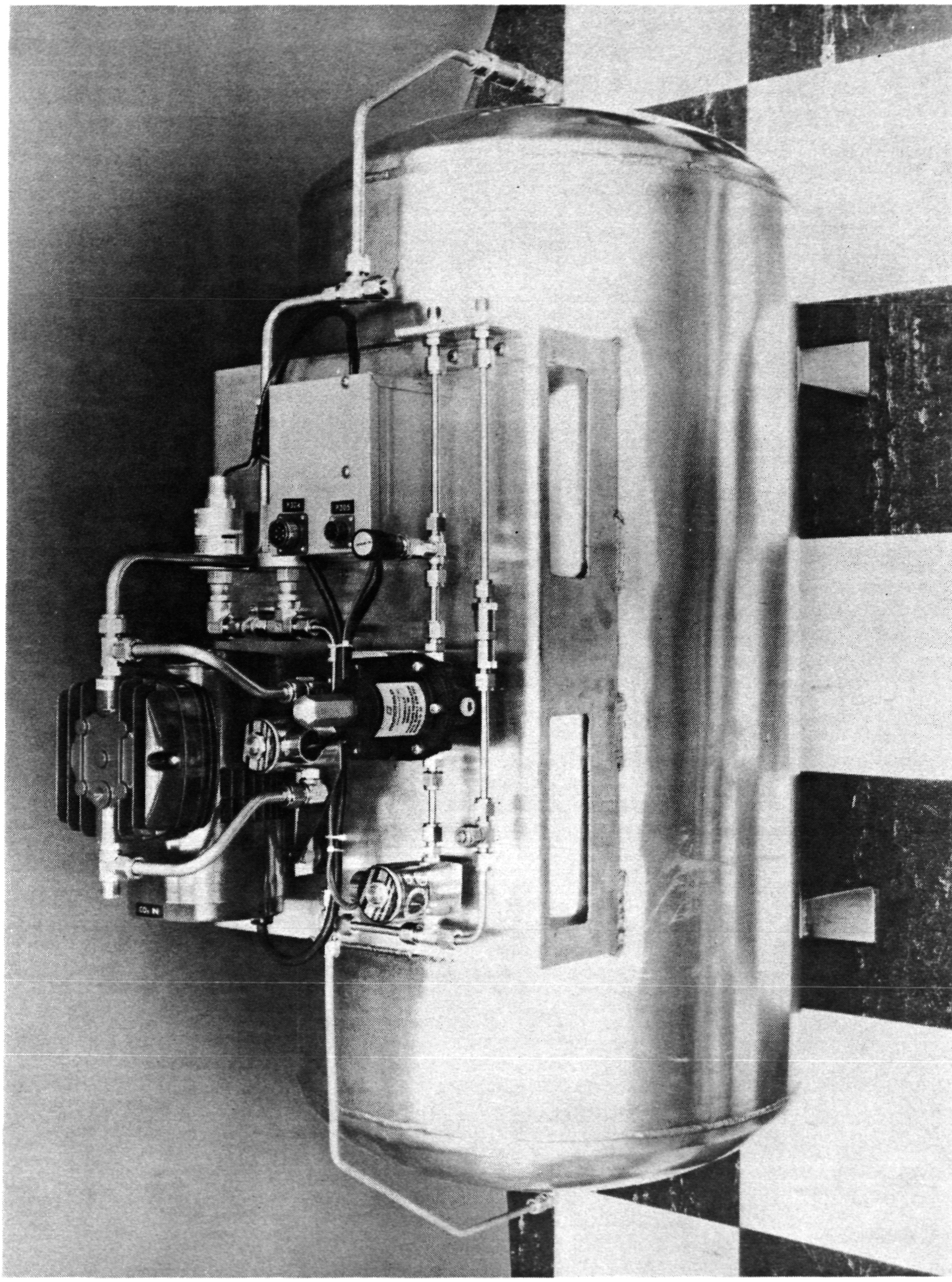
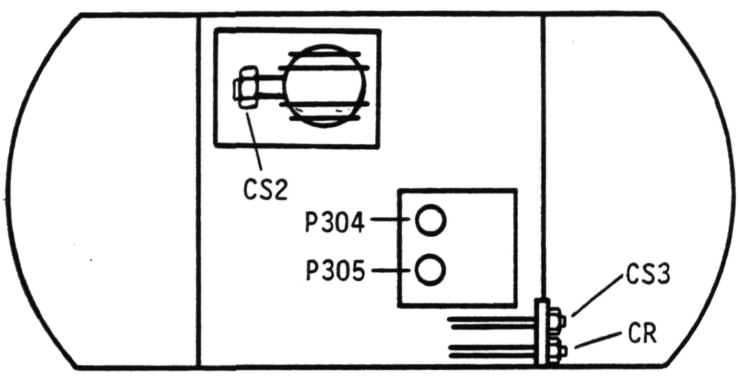


FIGURE 11

CO_2 STORAGE/DELIVERY PACKAGE
FRONT VIEW

TABLE 3

CO_2 STORAGE PACKAGE INTERFACE CONNECTIONS



TOP VIEW

ID No.	Connector Size/Type	Medium	Connected To
CS2	3/8" Male Swagelok	CO_2 - Storage	CS1 - CO_2 Removal Package
CS3	1/4" Male Swagelok	CO_2 - Reduction	Reduction Subsystem
CR	1/4" Male Swagelok	CO_2 - Vent	Overboard
P304	MS3102A-145-6P	115V, 1Ø, 60 Hz (F3,V2)	Controller 104
P305	PT02A-10-6P	24V DC (V5) 5V Signal (P3,4)	Controller 105

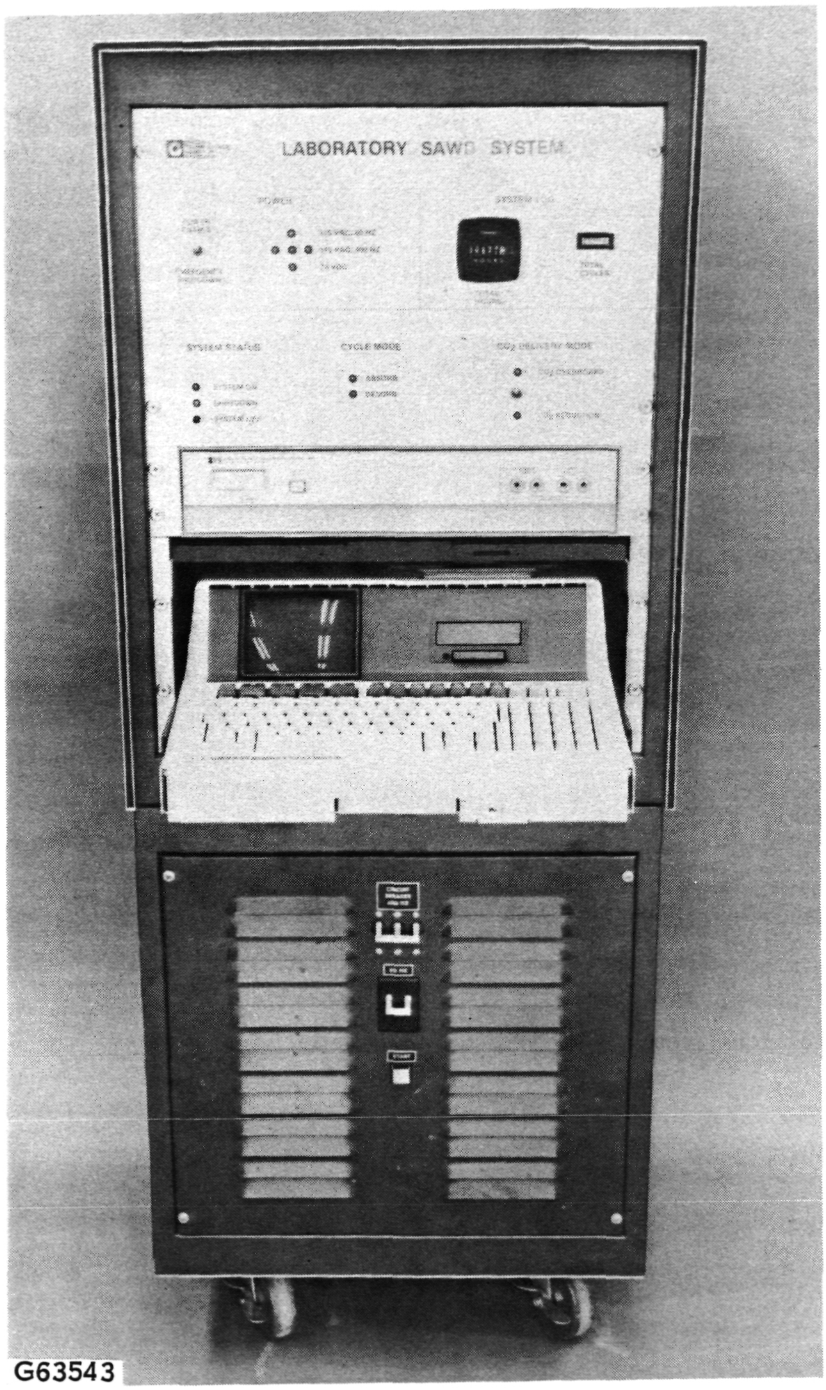


FIGURE 12

CONTROLLER PACKAGE
FRONT VIEW

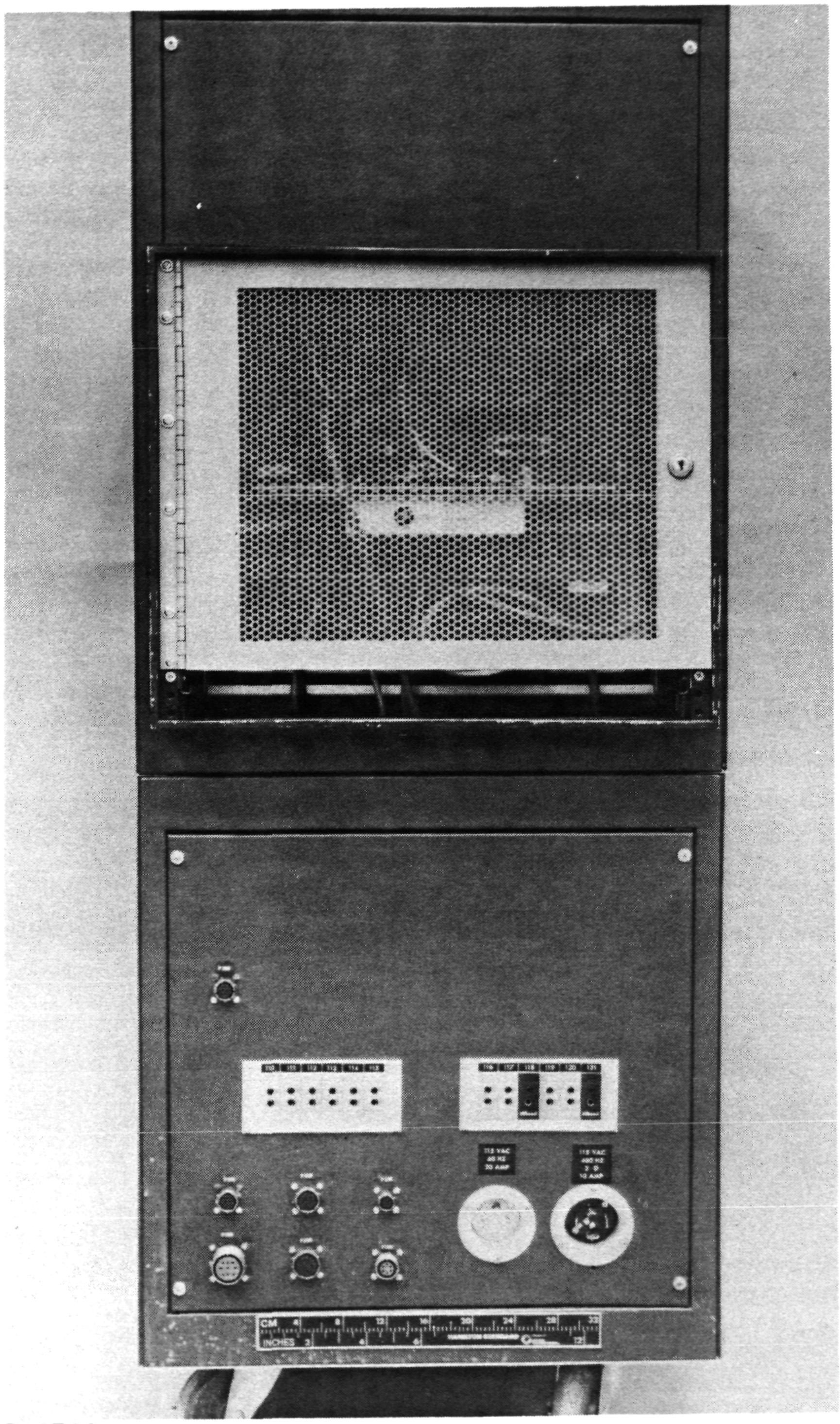


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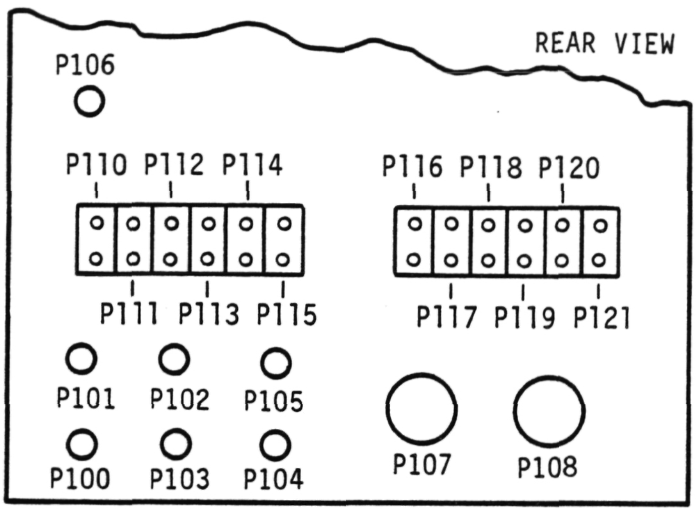
FIGURE 13

CONTROLLER PACKAGE
REAR VIEW

TABLE 4

CONTROLLER PACKAGE INTERFACE CONNECTIONS



ID No.	Connector Size/Type	Medium	Connected To
P107	3-Prong Twist Lock	115V, 1Ø, 60 Hz	Power Source
P108	5-Prong Twist Lock	115V, 3Ø, 400 Hz	Power Source
P100	3106A-20-95	115V, 1Ø, 60 Hz	CO_2 Removal Pkg. 200
P101	PT02A-12-105	24V DC	CO_2 Removal Pkg. 201
P102	PT02A-14-195	115V, 3Ø, 400 Hz	CO_2 Removal Pkg. 202
P103	PT02A-16-265	24V DC, 5V Signal	CO_2 Removal Pkg. 203
P104	MS3102A-145-65	115V, 1Ø, 60 Hz	CO_2 Storage Pkg. 304
P105	PT02A-10-65	24 VDC, 5V Signal	CO_2 Storage Pkg. 305
P106	PT02A-12-105	Signal	External Equipment
P110 P118 -	2 Pin Female Thermocouple Connector	TC Signal	CO_2 Removal Package 210 - 218

For operation in the CSD Life Test Laboratory, a support package for the CO_2 Removal Package is provided. Shown in Figure 14, the package provides a stand to hold the removal package on top of an electronic scale at a height convenient for observation and maintenance. The scale electronic components are housed in an enclosure mounted on a shelf of the support package located under the removal package. The stand also supports the inlet air filter I1, and the air exhaust silencer E1, which interface with the removal package connections A1 and A2 (Table 2) when operating in an open loop configuration. The support package measures 77.5 cm (30.5 inches) by 54.6 cm (21.5 inches) by 78.8 cm (31 inches), and weighs 18.2 kilograms (40.0 pounds).

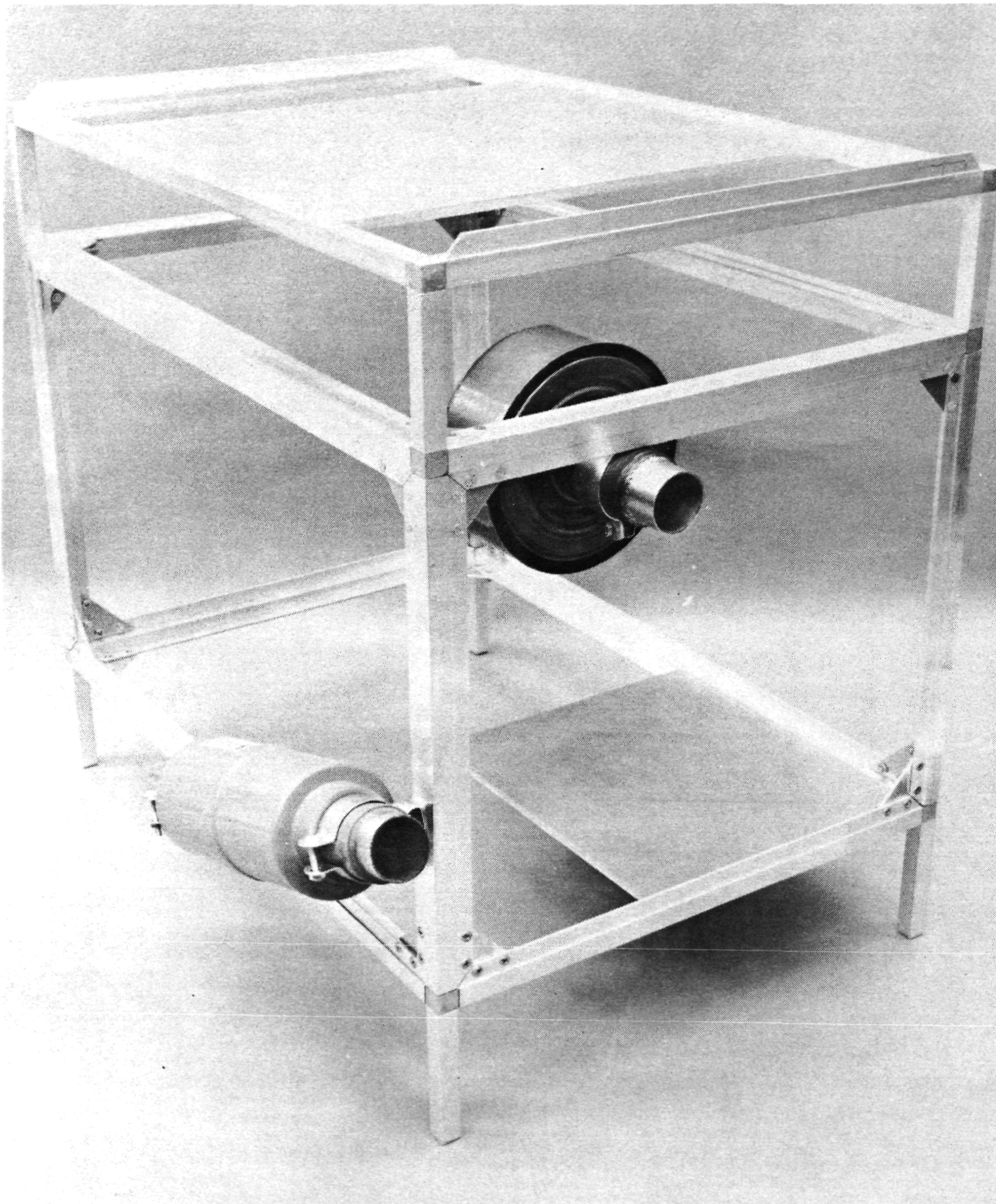


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FIGURE 14

LIFE TEST LABORATORY SUPPORT PACKAGE

SUBSYSTEM DESIGN

The preprototype SAWD subsystem is designed to conform with all requirements of the NASA Statement of Work, contained as Exhibit "A" in Contract Modification 32S, 33S, 34S, and 35C of NASA Contract NAS 9-13624 as shown in the Appendix of this report.

Design Philosophy

An overall design philosophy at the subsystem level was directed for the preprototype SAWD by the program modifications. An existing preprototype SAWD canister/steam generator assembly, in conjunction with commercially available components that were chosen to functionally satisfy the subsystem performance requirements, was specified to form the basic SAWD subsystem hardware.

In addition, a commercially available microprocessor was specified to provide subsystem control via use of custom software to accomplish the cyclic sequencing necessary to meet the SAWD subsystem performance specifications.

SAWD Performance Goals

The preprototype SAWD CO_2 removal subsystem is designed on the basis of a 3-man nominal metabolic load at the 3.8 mmHg ambient CO_2 level. The system is capable of operating in either a CO_2 overboard dump mode or a continuous CO_2 delivery mode to a CO_2 reduction subsystem. The SAWD is designed to fit within a 56 cm (22 inch) wide by 62 cm (24.5 inch) high by 79 cm (31 inch) deep envelope, exclusive of the controller, CO_2 storage/delivery, and life test laboratory support packages. The subsystem is designed to be capable of integrating with (and operation in) either the CSD RLSE laboratory or life test laboratory.

The performance goals specified for the SAWD subsystem are summarized in the following tabulation.

Preprototype SAWD
Design Specifications

Parameter	Specification
Crew Size	3
CO_2 Removal/Delivery Rate	0.120 kg/hr (0.264 lb/hr)
Cabin PCO_2	3.8 mmHg
Cabin Temperature	292 to 300°K (65 to 80°F)
Cabin Relative Humidity	35 to 70%
Cabin Dew Point*	277 to 289°K (39 to 61°F)
Cabin Pressure	101 kPa (14.7 psia)
CO_2 Delivery Pressure	126 kPa (18.3 psia)
CO_2 Removal Package Size	0.56mW X 0.62mW X 0.79mD (22" W X 24.5" H X 31"D)

* within the relative humidity limits

SAWD Design Details

This section describes the significant design considerations related to finalizing the SAWD subsystem, identifies the specific major components that comprise each SAWD package and discusses the operational characteristics of each package. The complete SAWD subsystem schematic (SVSK 105648) is reproduced in Figure 15 for reference. The nomenclature schematic was presented previously in Figure 2, and the subsystem package composition was previously tabulated in Table 1.

The sequencing operation of the preprototype SAWD subsystem is fully automatic and is controlled by microprocessor software that was custom developed for this subsystem. The microprocessor continuously monitors the operating parameters, activates the required event changes, calculates the subsystem performance, provides a display and printout of performance results and will automatically shut the SAWD down to a safe hold condition in the event of an operational anomaly. Table 5 presents a tabulation of the sequenced component conditions that are automatically directed during SAWD subsystem operation.

The following paragraphs describe the design details for the four packages that comprise the SAWD subsystem.

CO_2 Removal Package - The major components of this assembly are the CO_2 removal canister/steam generator assembly (SVSK 103199), fan, water pump, sequencing valves, and the pressure switch. This assembly is specified by connotations on SVSK 105825-100, and was illustrated pictorially in Figures 3 through 8. The components reside within the box (designated SVSK 105825-100) on the Figure 15 schematic (SVSK 105648) and within the CO_2 Removal Package box on Figure 2.

The heart of this package is the CO_2 removal canister/steam generator assembly that is illustrated in Figure 16. This assembly (fabricated during an earlier phase of this program) houses the amine (IRA-45) bed that physically removes CO_2 from the air stream and has an internal steam generator to produce the desorption steam. The hardware was modified during this program by the addition of temperature sensors (7 sensors total) and a pressure sensor for control purposes. (The use of these sensors is discussed in subsequent sections.)

The cyclic SAWD performance maps for operation at an ambient CO_2 level of 3.8 mmHg with the IRA-45 amine are presented in Figures 17, 18, and 19. Figure 17 shows the relationship of CO_2 loading and amine moisture content with total absorption mass flow (m_a/W_B). Total absorption mass flow is defined as:

$$m_a/W_B = \frac{\text{Airflow rate (Kg/min) X Absorption Time (min)}}{\text{Dry Amine Weight (Kg)}} = \frac{\text{Kg Air}}{\text{Kg Amine}}$$

Figure 18 illustrates the CO_2 removal rate characteristic as a function of total absorption mass flow. Figure 19 presents the relationship between desorption cycle duration and total absorption mass flow for a constant heating rate of approximately 900 watts (3070 Btu/hr). These performance characteristics were developed from test data with this canister assembly.

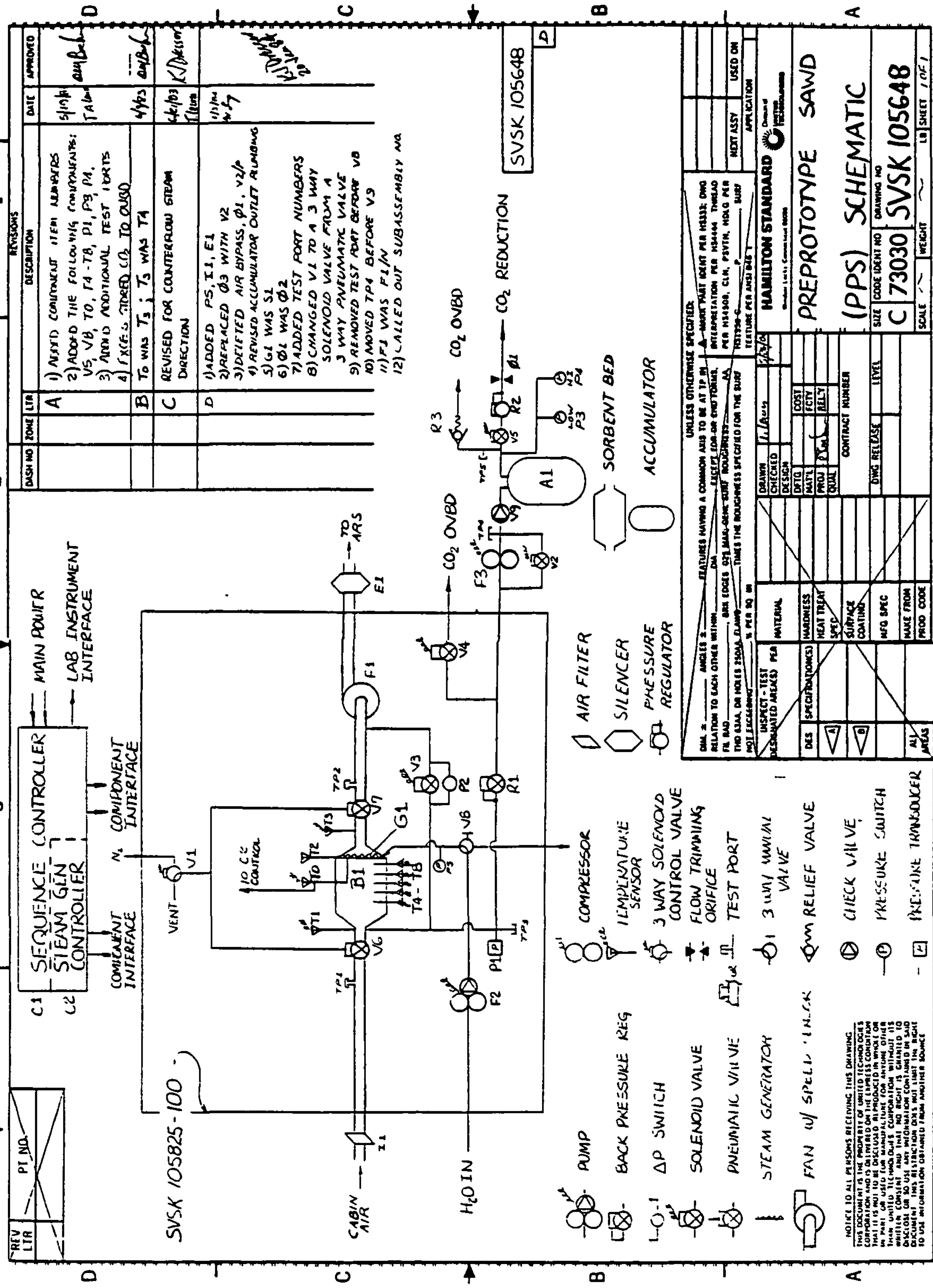


FIGURE 15

PREPROTOTYPE SAWD SCHEMATIC

PREPROTOTYPE SAWD OPERATING SEQUENCE CONDITIONS

	Component/Parameter		Operating Cycle Phase				CO_2 Delivery Mode	
			ABS	DES1	DES2	DES3	DUMP	RED
B1-	Sorbent Bed	Air Flow	On	Off	Off	Off	-	-
G1-	Steam Generator	Water Flow/ Heater Power	Off/Off	Off/On	On/On	On/On	-	-
A1-	CO_2 Accumulator	CO_2 Flow In	Off	Off	O/R[1]	O/R[1]	Off	-
V1-	N_2 Pressure/Vent Solenoid Valve	Position	Vent	P	P	P	-	-
V2-	CO_2 Compressor Bypass Solenoid Valve		Shut	Shut	Shut	Open[3]	-	-
V3-	Desorb Air Vent Solenoid Valve		Shut	Open	Open	Shut	-	-
V4-	Desorb CO_2 Dump Solenoid Valve		Shut	Shut	Shut	O/R[1]	Open	-
V5-	CO_2 Delivery Solenoid Valve		-	-	-	-	-	Open
V6-	Sorbent Bed Inlet Pneumatic Valve		Open	Shut	Shut	Shut	-	-
V7-	Sorbent Bed Outlet Pneumatic Valve		Open	Shut	Shut	Shut	-	-
V8-	Water Flow Diverter Valve	Position[2]	-	-	To G1	To G1	-	-
V9-	Desorb CO_2 Check Valve		Shut	Shut	Shut	O/R[1]	Shut	-
F1-	Air Fan		On	Off	Off	Off	-	-
F2-	Water Pump		Off	Off	On	On	-	-
F3-	CO_2 Compressor		Off	Off	Off	On[8]	-	-
R1-	Desorb CO_2 Back Pressure Regulator		Off	Off	Off	On	On	-
R2-	Delivery CO_2 Pressure Regulator		-	-	-	-	-	On
R3-	Accumulator Pressure Relief Valve	Position[4]	-	-	-	-	-	-
Ø1-	Delivery CO_2 Flow Control Orifice CO_2 Flow		-	-	-	-	-	On
P1-	Sorbent Bed Pressure Transducer	Signal	On	On	On	On	On	-
P2-	Pressure Switch-Desorb Air Vent		Off	Off	Off	On[5]	-	-
P3-	Low Pressure Switch-Accumulator		-	-	-	-	-	6
P4-	High Pressure Switch-Accumulator		-	-	-	-	-	7
P5-	High Pressure Switch-Water Pump	Water Flow	-	-	9	9	-	-

1- O/R - Overboard/Reduction as determined by selection of CO_2 delivery mode.
2- Water flow diverted manually for test or sampling as required, except during DES2 and DES3.
3- Momentary open at start of DES3.
4- Open only if accumulator CO_2 pressure > 45 psig.
5- Signal at start of DES3 to close V3.
6- Closes V5 when accumulator CO_2 pressure decreases to 20 psig.
7- Opens V5 when accumulator CO_2 pressure increases to 38 psig.
8- Compressor on if reduction CO_2 delivery mode selected.
9- Turns off water pump if G1 pressure exceeds 90 psig.

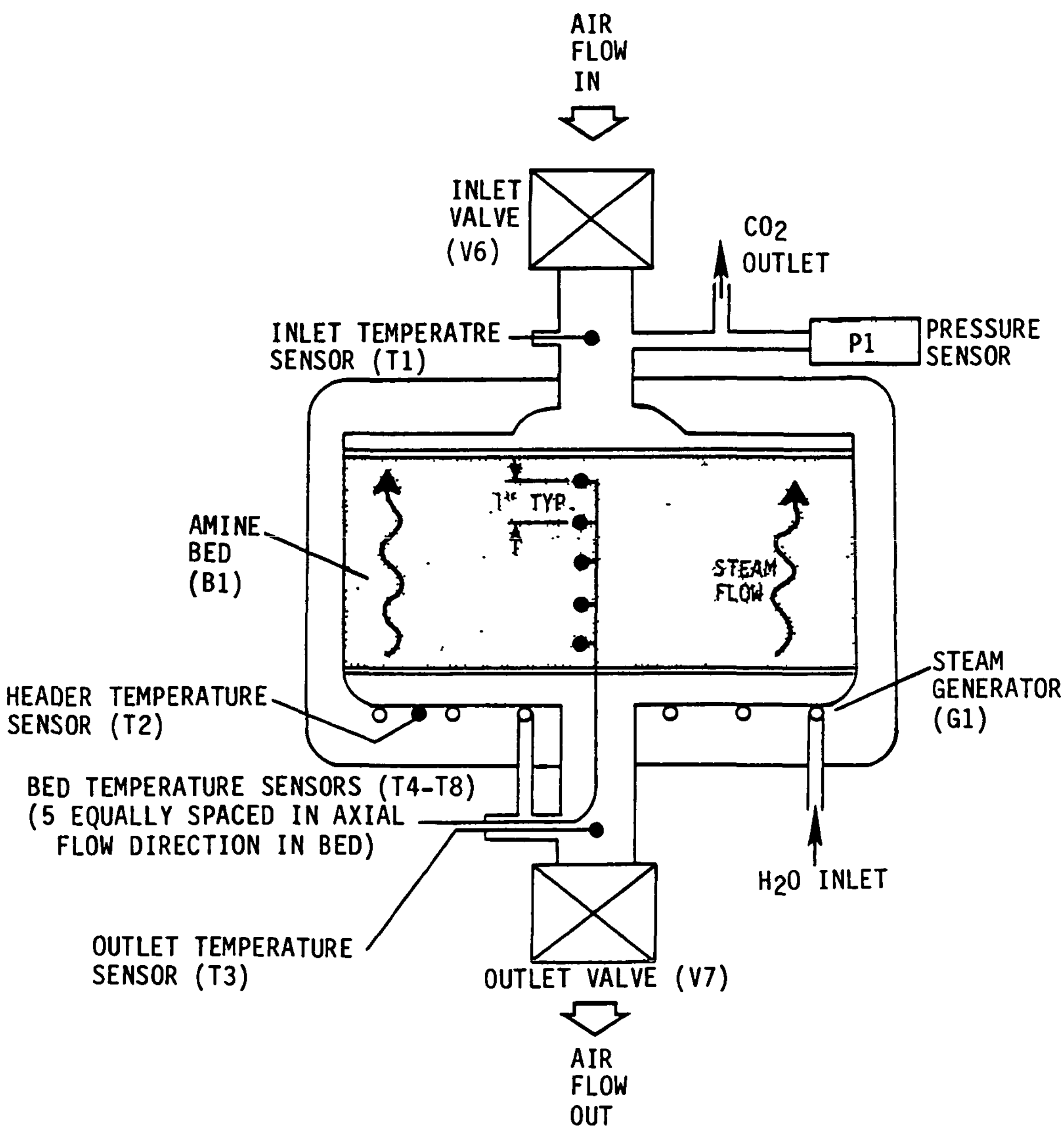


FIGURE 16

SAWD CANISTER/STEAM GENERATOR ASSEMBLY

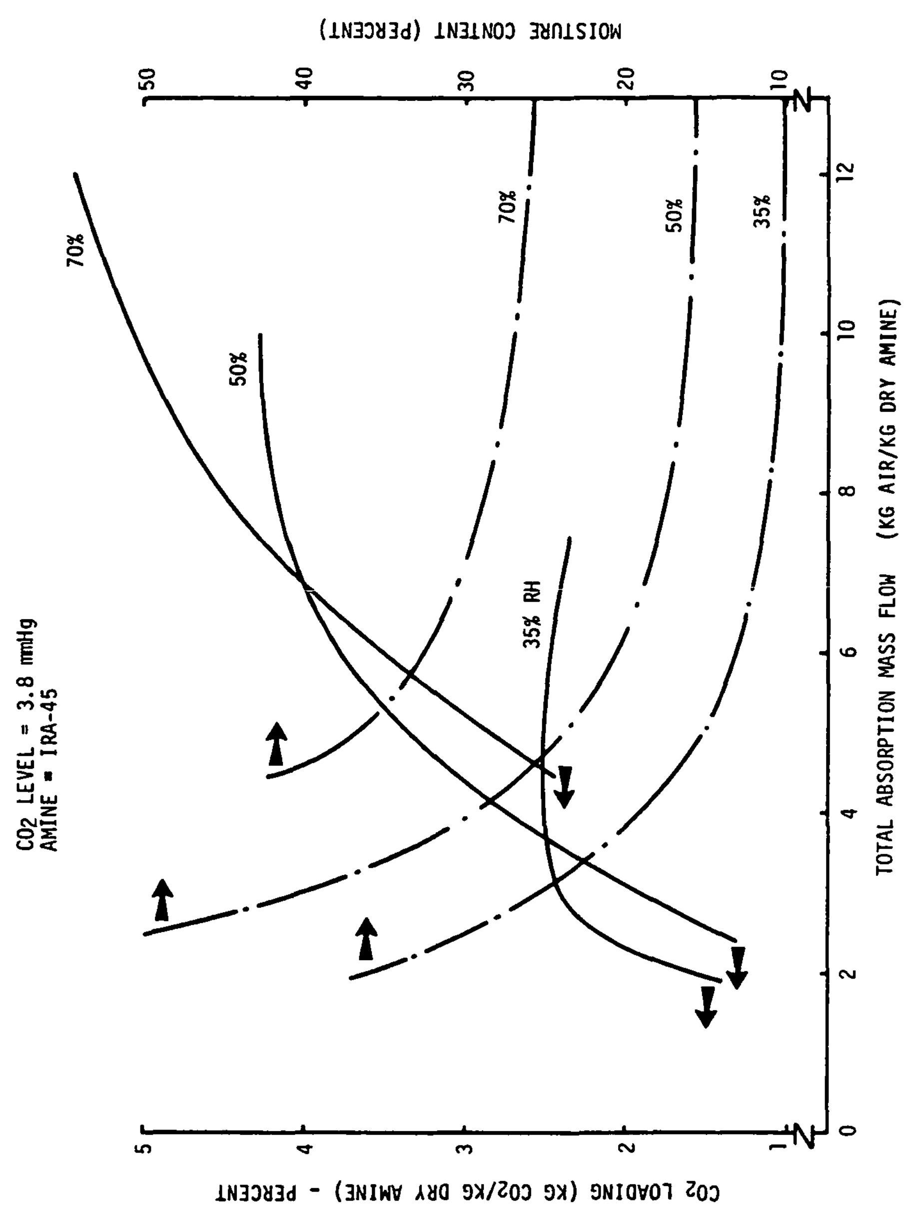


FIGURE 17

CYCLIC SAWD PERFORMANCE

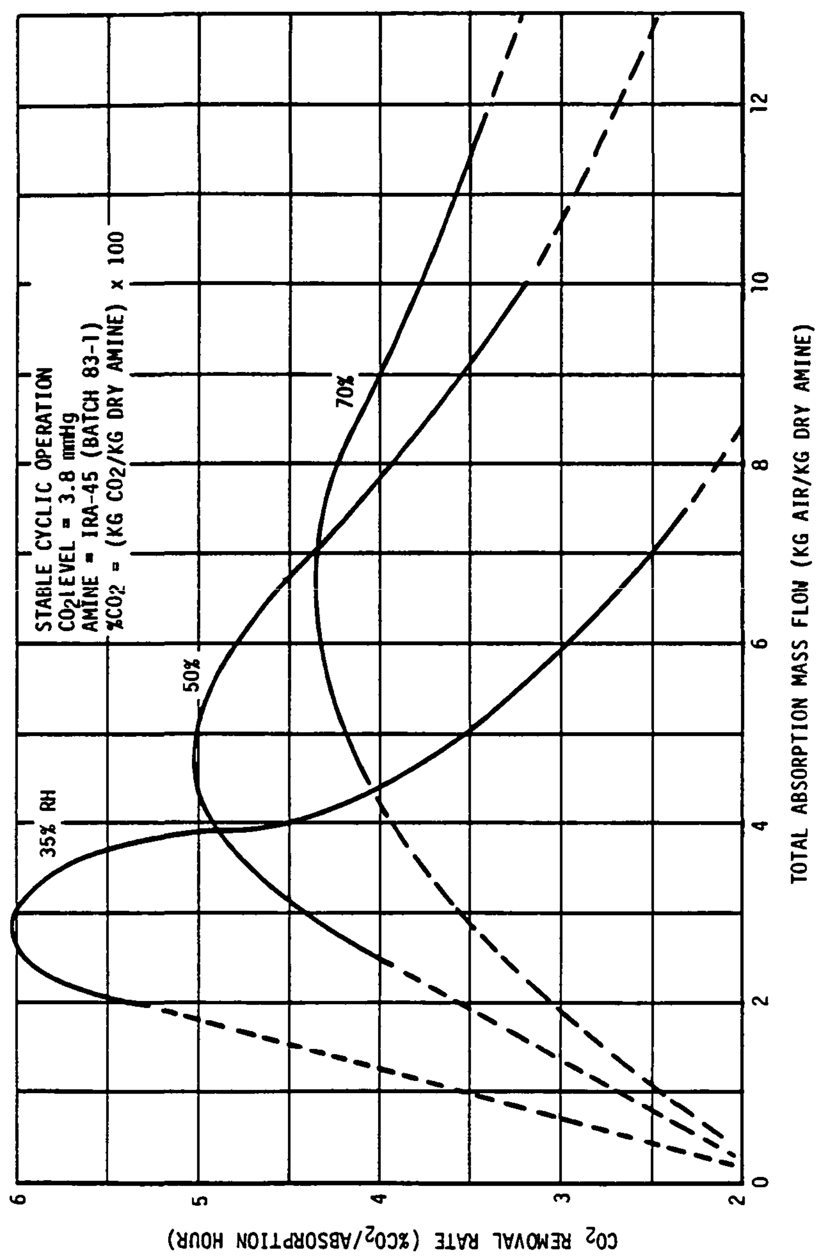


FIGURE 18

SAWD CO_2 PERFORMANCE CHARACTERISTIC

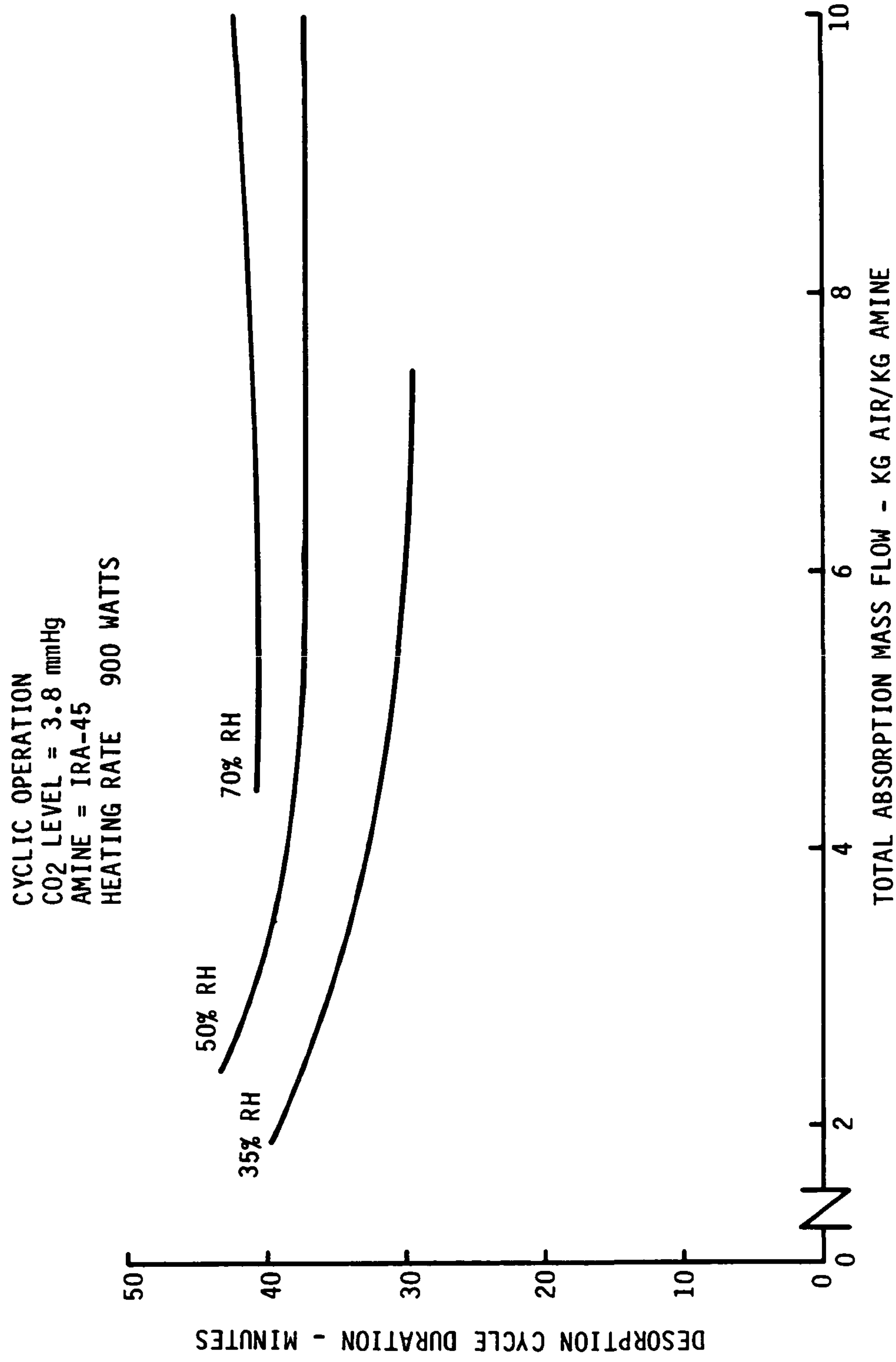


FIGURE 19

SAWD DESORPTION CYCLIC CHARACTERISTIC

These performance characteristics were used, with airflow at 600 lpm (21 cfm), to establish the cyclic SAWD operating characteristic defined in Figure 20. The design CO_2 removal rate is specified as 0.120 kg/hr (0.264 lb/hr). Figure 20 shows that CO_2 removal performance is met (or exceeded) for the following range of absorption durations, as a function of relative humidity.

Acceptable Absorption Duration (Minutes)	Relative Humidity (Percent)
20 to 36	35
29 to 83	50
42 to 130	70

However, to maintain steady state operating conditions over the 35 to 70 percent relative humidity range, it is desirable to maintain the amine as near a stable and constant moisture content as possible. Further, to minimize desorption energy, it is desirable to operate the amine in the driest condition that will achieve the specified CO_2 removal rate of 0.120 kg/hr (0.264 lb/hr). Figure 21 shows the desorption energy characteristic as a function of absorption cycle duration and Figure 22 presents the moisture content relationship with absorption cycle duration. It can be observed from Figure 21 that the desorption energy levels off at about 30 to 35 minutes for the 35 percent RH conditions, at about 40 to 50 minutes for 50 percent RH, and above 80 minutes for operation under 70 percent RH conditions. Figure 22 shows that relatively stable moisture content conditions also occur at or above these same absorption cycle durations.

Then to ensure SAWD subsystem performance at (or above) the specified CO_2 removal rate, to minimize desorption power requirements, and to achieve stable moisture content conditions; the SAWD subsystem is designed to operate along the operation relationship line illustrated in Figure 23. (This figure is an overlay of Figure 22 upon Figure 20.) Figure 24 presents the SAWD subsystem design relationship for absorption cycle duration as a function of the ambient relative humidity. This design relationship is fundamentally a control relationship for the SAWD subsystem and its use is discussed further in subsequent sections of this report.

The CO_2 removal package design specifications are defined in the following tabulation.

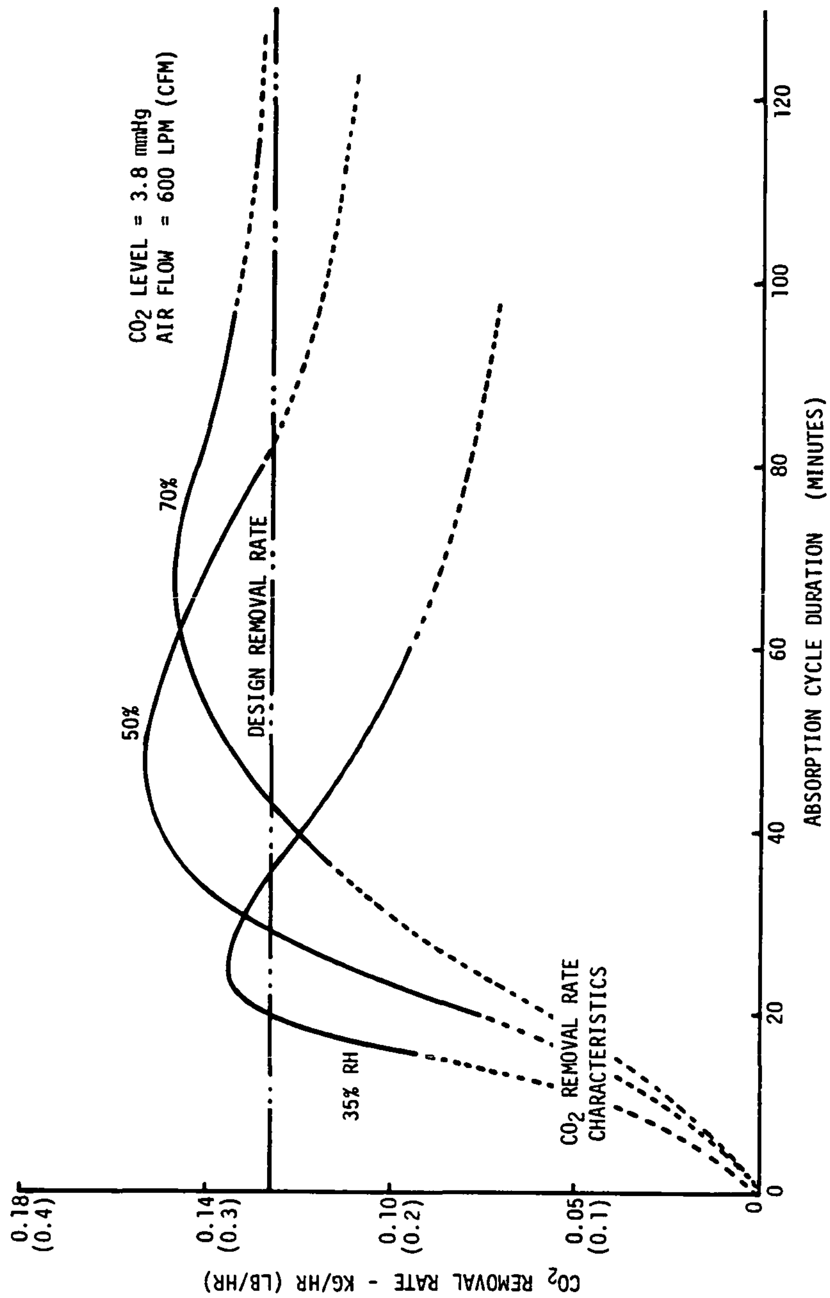


FIGURE 20

CYCLIC SAWD PERFORMANCE

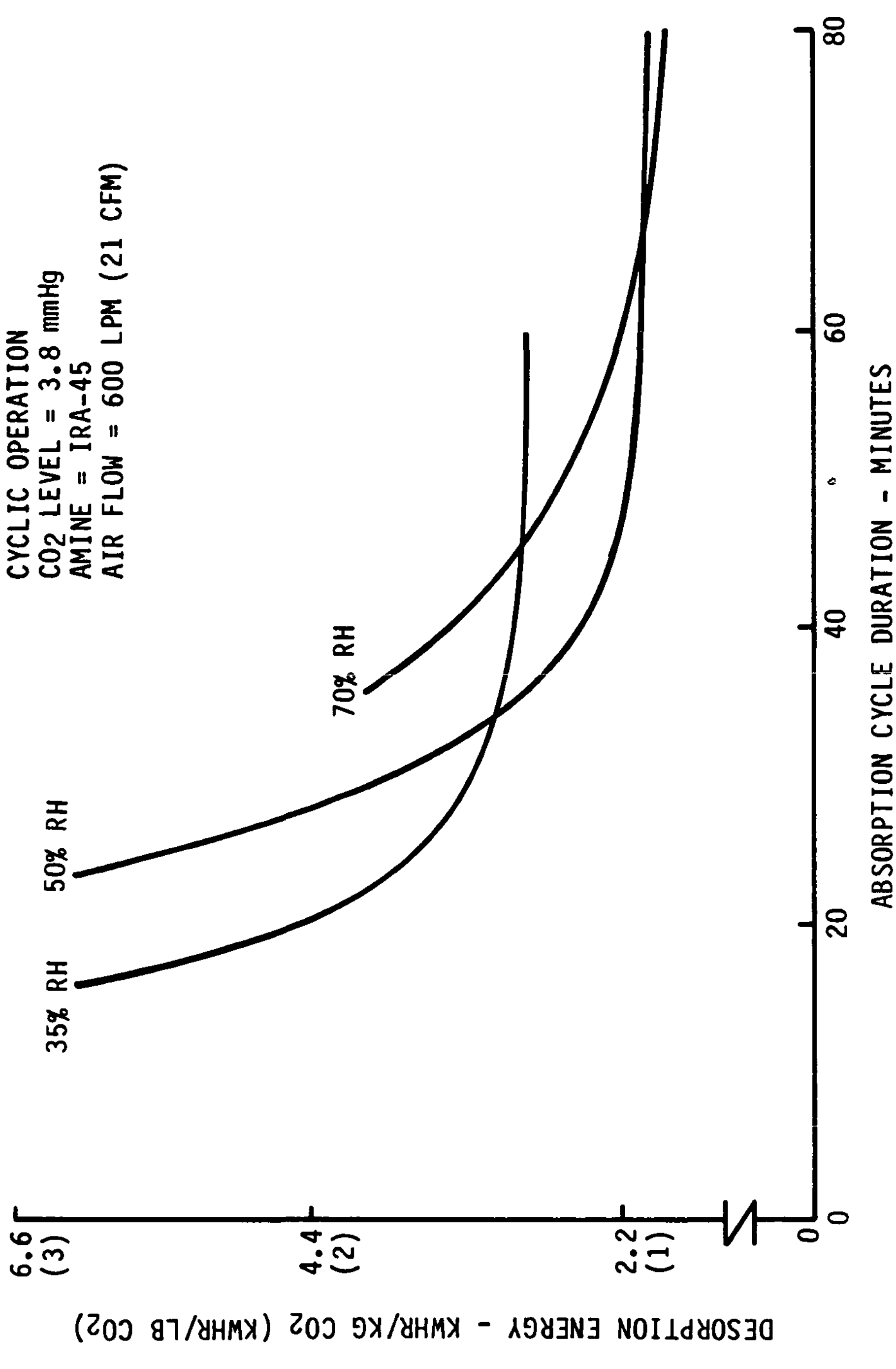


FIGURE 21

SAWD DESORPTION ENERGY CHARACTERISTIC

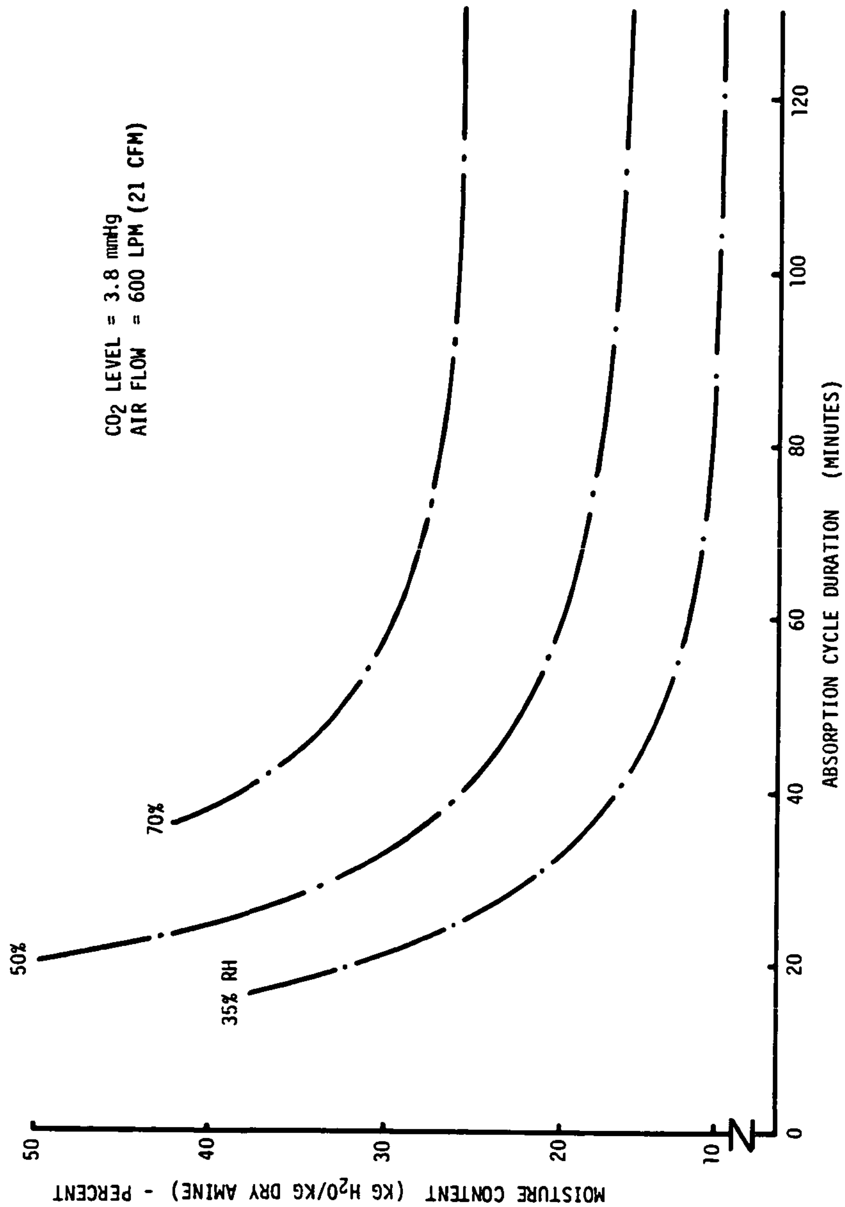


FIGURE 22

CYCLIC SAWD PERFORMANCE

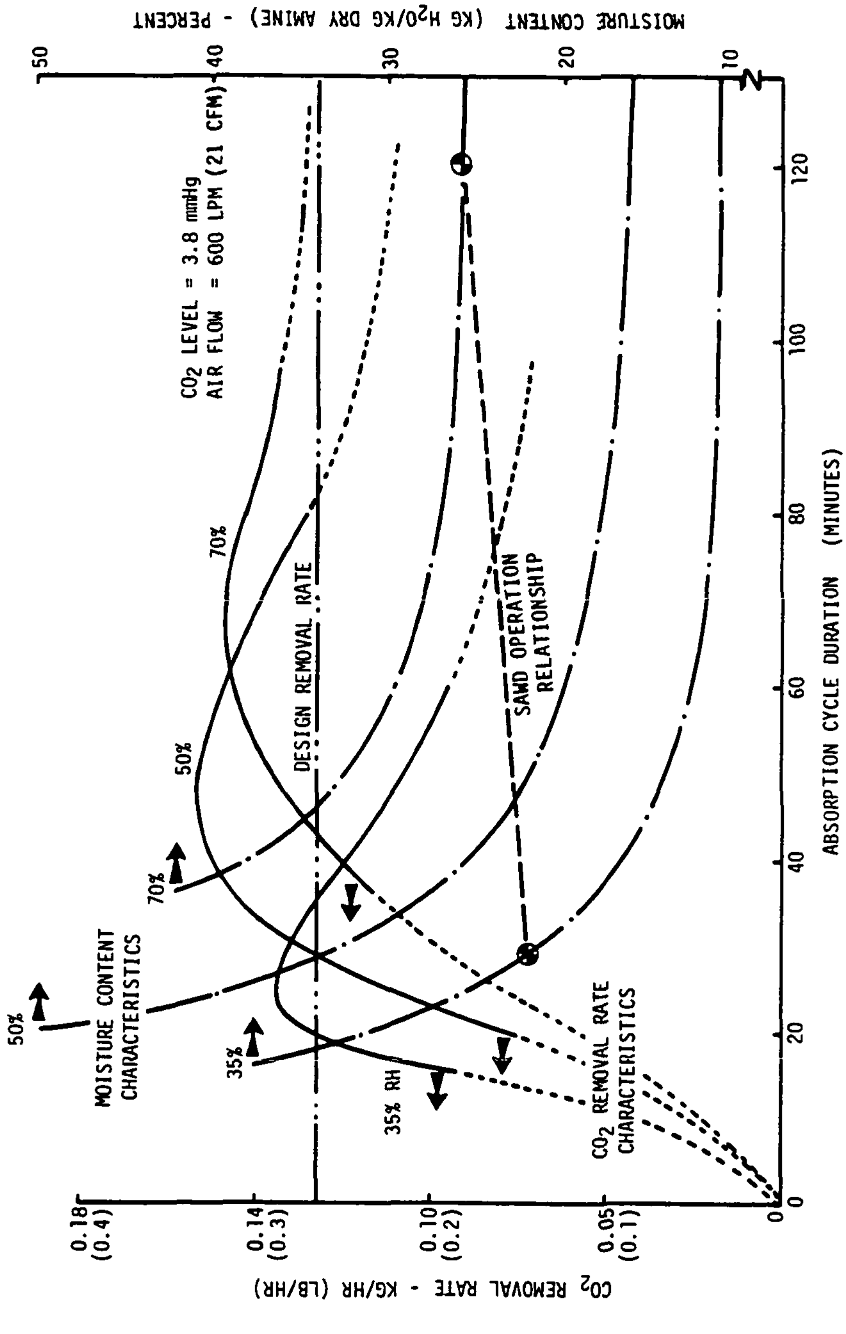


FIGURE 23

CYCLIC SAWD PERFORMANCE

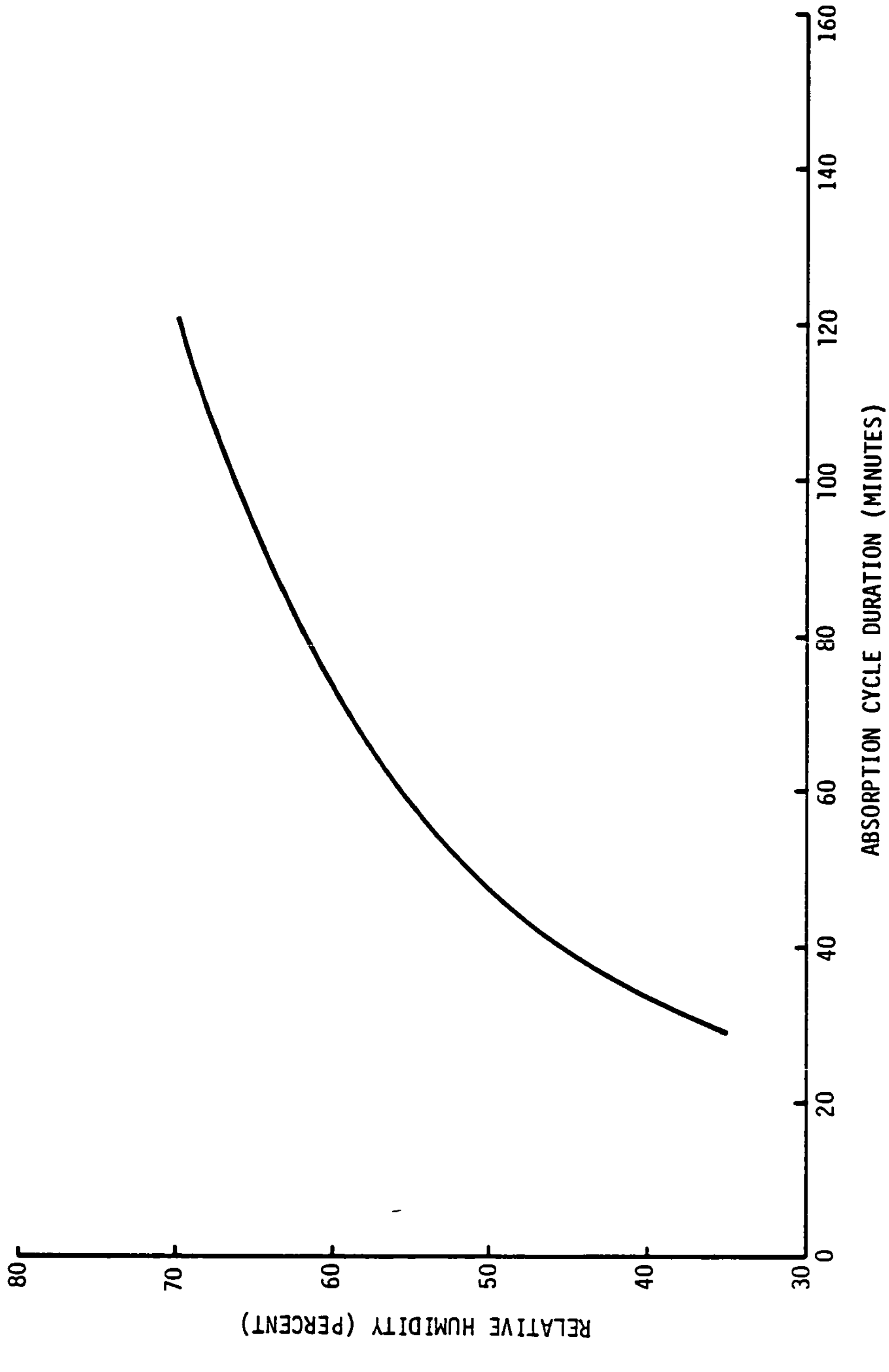


FIGURE 24

SAWD SUBSYSTEM DESIGN RELATIONSHIP

CO_2 Removal Package Specifications

Parameter	Specification
Canister Pressure	101 kPa (14.7 psia)
Airflow Rate	600 lpm (21.0 cfm)
Amine Weight (Dry)	7.0 kg (15.5 lb)
Steam Flow Rate	(3-4 lb/hr)
Absorption Cycle Duration	
35% Relative Humidity	33 minutes
50% Relative Humidity	51 minutes
70% Relative Humidity	124 minutes
Desorption Power	900 watts
Pump Power	100 watts
Fan Power	200 watts
Valve Actuation Power	10 watts/valve

CO_2 Storage/Delivery Package - The major components of this assembly are the accumulator, compressor, and pressure switches. This assembly is specified by drawing on SVSK 105692, and is illustrated pictorially in Figures 9 through 11. The package components are shown on the Figure 15 schematic (SVSK 105648), and within the CO_2 Storage/Delivery Package box on Figure 2.

This package provides the function of collecting, storing, and/or delivering the CO_2 to the atmosphere revitalization system when the SAWD is operating in the CO_2 reduction mode. This assembly is not used if the SAWD subsystem is operating in the "CO_2 Overboard" delivery mode. (In the "CO_2 Overboard" delivery mode, CO_2 flows directly from the CO_2 removal package to ambient through valve V4.) During desorption of the amine (which is physically located in the CO_2 removal package), CO_2 is evolved from the bed in advance of the steam wave as it progresses through the bed. Figure 25 illustrates a typical desorption CO_2 flow profile. During the first 5 to 7 minutes of desorption, slave air (which is trapped in the canister at the end of absorption) is vented to ambient through valve V4. Shortly thereafter, CO_2 begins to evolve from the canister. When the CO_2 flow rate through orifice Ø1 reaches 1.4 lpm (0.05 cfm), pressure switch P2 generates a signal that activates the compressor. The compressor then pumps the CO_2 into the accumulator for storage. A constant CO_2 delivery flow at a rate of 0.120 kg/hr (0.264 lb/hr) and a pressure of 126 kPa (18.3 psia) is provided from the accumulator when the SAWD is operating in the CO_2 reduction mode. Storage of the CO_2 in the accumulator occurs at pressures between 138 kPa (20 psia) which is the low pressure switch P3 setting and 309 kPa (45 psia) which is the full open relief valve R3 setting. During operation at the design CO_2 delivery rate, CO_2 may be delivered from the accumulator to a CO_2 reduction system at any time during the SAWD operating cycle when there is sufficient CO_2 in the accumulator to maintain a pressure greater than 138 kPa (20 psi). The delivery is controlled by valve V5, which is opened to permit flow when pressure switch P4 indicates an accumulator pressure of at least 262 kPa (38 psi). The valve remains open until pressure switch P3 indicates a decrease in the accumulator pressure to 138 kPa (20 psia). Continuous flow at the design delivery rate is maintained by the pressure regulator R2 and the variable orifice flow control valve Ø1.

TEST CONDITIONS:

Dry Amine Weight.........12.55lbs
Inlet Air Flow...........21.00cfm
Inlet Air Pressure.......14.70psia
Inlet Dew Point..........62.00Deg F
Inlet pCO2............... 3.80mmHG
Inlet Air Temperature....72.00Deg F

Test No 114-Cycle 29   Max CO2 Flow= .26cfm   Des Time=42.4min

CO Loading...............5.04%

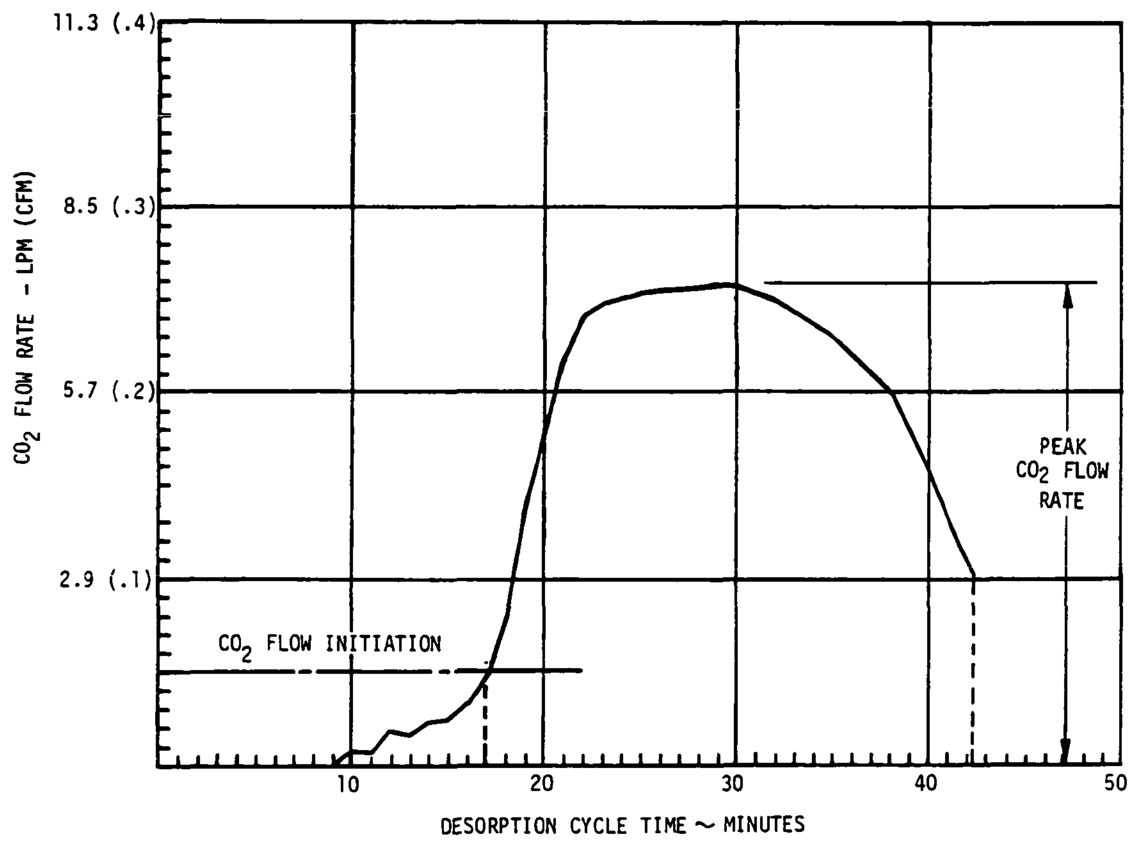


FIGURE 25

DESORPTION FLOW PROFILE

If the desorption CO_2 flow rate (CO_2 evolved from the CO_2 removal package) exceeds the design delivery rate, with the accumulator full, the excess CO_2 is vented overboard through relief valve R3. Under steady flow conditions at the design CO_2 delivery rate, the accumulator is partially filled during each desorption cycle; CO_2 is delivered constantly to CO_2 reduction; and no overboard venting occurs.

The CO_2 Storage/Delivery Package specification are defined in the following tabulation.

CO_2 Storage/Delivery Package Specifications

Parameter	Specification
Accumulator Pressure (Maximum)	309 kPa (45 psia)
CO_2 Delivery Pressure	126 kPa (18.3 psia)
CO_2 Delivery Rate	0.120 kg/hr (0.264 lb/hr)
Low Pressure Switch P3 Setting	138 kPa (20 psia)
High Pressure Switch P4 Setting	262 kPa (38 psia)
Maximum Compression Rate	11 lpm (0.40 cfm)
Accumulator Volume	113 l (4 ft3)
Relief Valve R3 Setting	296 kPa (43 psia)

Controller Package - The major components of this assembly, illustrated in Figures 12 and 13, are the Hewlett Packard equipment, the status display panel, the cabinet housing, and the required electrical apparatus which supplies power and provides signal communication between the CO_2 removal package, CO_2 storage/delivery package, and the microprocessor. The Hewlett Packard equipment consists of a 3056 DL Data Logger which integrates a 3421A Data Acquisition/Control Unit with an HP-85 computer to perform the microprocessor function.

The automatic operation of the preprototype SAWD is controlled by programmed software through the Hewlett Packard model HP-85 computer. Initial information required by the program is manually input by the operator via the computer keyboard. Manual override of the program can be accomplished through keyboard inputs.

The Hewlett Packard model 3421A Data Acquisition/Control Unit monitors the subsystem operating parameters and controls the operation of all components except the steam generation heater, which is controlled by a separate Partlow Type J temperature control. Both of these control devices are located within the controller package.

The controller package provides automatic sequencing and control of the cyclic absorb/desorb and CO_2 delivery processes. It continuously monitors the operating parameters, actuates component operation, calculates performance, and automatically shuts the system down in the event of an operational anomaly. The Cathode Ray Tube (CRT) provides a display, updated once a minute, of the status of the subsystem, the time since initiation of the current absorption (ABSORB) or desorption (DESORB) phase of the cycle, and the operating temperatures. A typical display is shown in Figure 26.

```
ABSORPTION CYCLE NO.             109
ABSORPTION CYCLE TIME, MIN.       26

              T1 = 72
              T2 =121
              T3 = 66
              T4 = 82
              T5 = 76
              T6 = 70
              T7 = 68
              T8 = 65
-------------------------------------

                           PRINTOFF
SAWDOFF                    PRINTON
```

FIGURE 26

TYPICAL CONTROLLER CATHODE RAY TUBE DISPLAY

The CRT also displays a message describing any anomaly that results in an automatic shutdown of the SAWD and the message is also printed on the HP 85 internal printer. Separate data performance printouts are provided at the operator's keyboard input request.

Automatic shutdown of the subsystem is initiated by the controller when specified ranges of critical operating conditions are exceeded. A historical data record (which is a printout of the sensor readings for the 15 minute period preceding the shutdown), including an identification of the reason for the shutdown, will be provided if an external printer is in use. Any of the twenty programmed shutdowns, triggered by an anomaly detected by a process stream sensing or control device, can initiate an automatic shutdown of the SAWD subsystem to a safe hold condition.

A system log of total hours and cycles run is maintained by digital counters on the control display panel. Colored lights on the operating status display panel indicate elecrical power availability and the system operational status: green while ON, yellow during SHUTDOWN (automatic), and red while OFF. The ABSORB or DESORB phase of the operating cycle is indicated by a green light during the ON status, and the selected CO_2 DELIVERY MODE during desorb is indicated by a green light at the CO_2 OVERBOARD or CO_2 REDUCTION position of the control switch.

The functional interconnections of the controller package with the CO_2 removal package and the CO_2 storage/delivery package are represented by schematic in Figure 27. This schematic shows that the controller processes both discrete and analog signals, operates either or both packages, and displays or prints output on the HP 85 devices and an external printer, if incorporated.

Complete details of the sequential operation/control of the SAWD subsystem, the controller logic, and the controller software are presented in the section entitled "SUBSYSTEM OPERATION/CONTROL".

Life Test Laboratory Support Package - This assembly, is supplied for use during test evaluation in the CSD Life Test Laboratory. The package, illustrated in Figure 14, provides a stand to hold the CO_2 removal package on top of an electronic scale at a height convenient for observation and maintenance. The scale electronic components are housed in an enclosure mounted on a shelf of the support package located under the removal package. The stand also supports the inlet air filter I1, and the air exhaust silencer E1, which interface with the removal package connections A1 and A2 when operating in an open loop configuration. The support package measures 77.5 cm (30.5 inches) by 54.6 cm (21.5 inches) by 78.8 cm (31 inches), and weighs 18.2 kilograms (40.0 pounds).

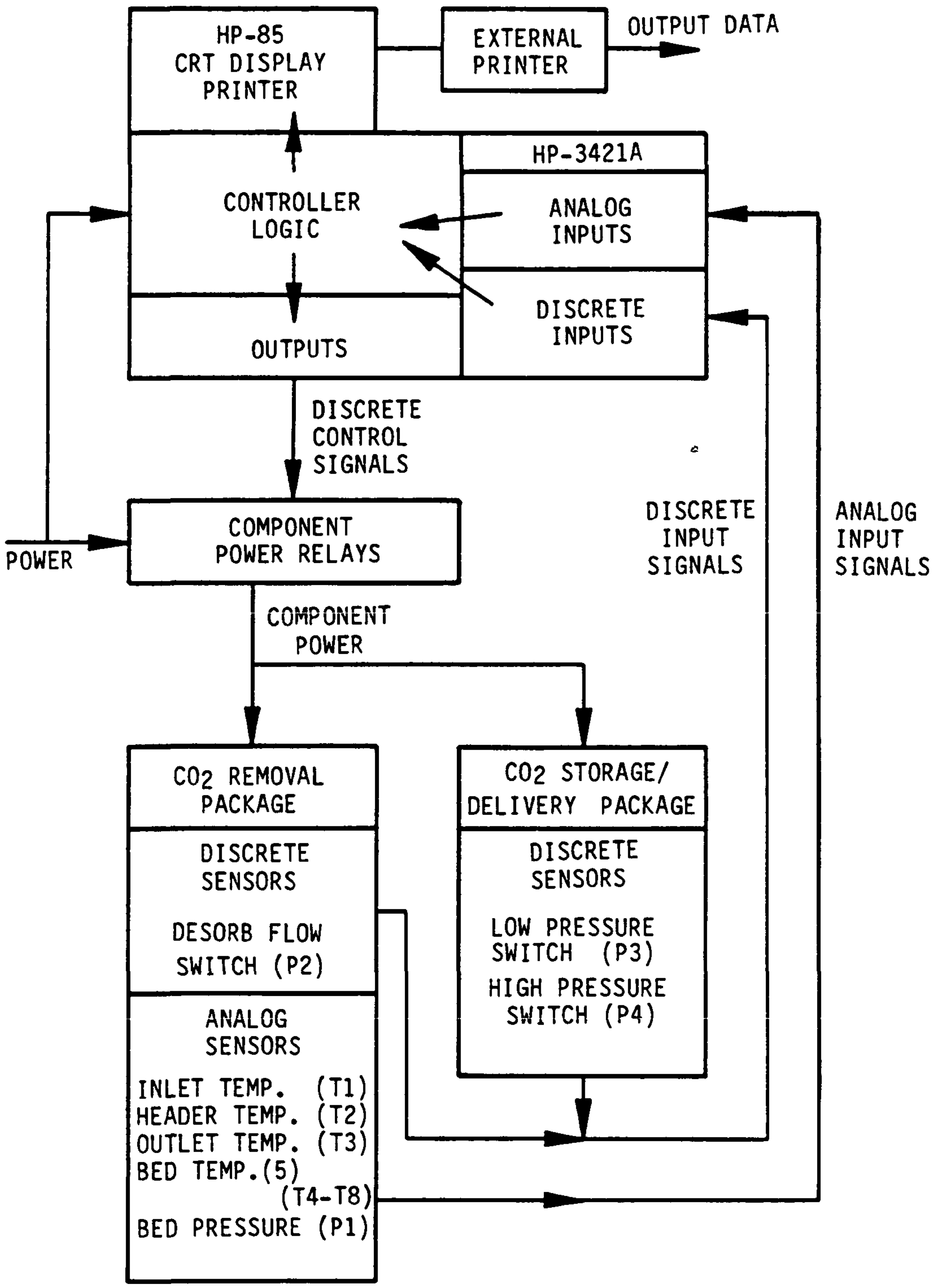


FIGURE 27

SAWD CONTROL SCHEMATIC

SUBSYSTEM FABRICATION

The overall philosphy employed for the preprototype SAWD was to use as many standard "off-the-shelf" items as possible, in conjunction with the existing canister/steam generator assembly to construct the subsystem assembly. The components were assembled by engineering personnel to construct each subsystem package.

The preprototype SAWD subsystem consists of four (4) individual assembly packages. These packages are:

a) CO_2 Removal Package
b) CO_2 Storage/Delivery Package
c) Controller Package
d) Life Test Laboratory Support Package

CO_2 Removal Package

The major component of the CO_2 removal package is the canister/steam generator assembly (SVSK 103199). The canister assembly was fabricated earlier and modified during this program phase to conform to the preprototype SAWD subsystem requirements. The major modification to the canister assembly consisted of the incorporation of temperature and pressure sensors for subsystem control purposes. The components of the SAWD canister assembly, details associated with each component, and the component manufacturer (as available) are as shown in Table 6.

CO_2 Storage/Delivery Package

The major components in the CO_2 storage/delivery package are the accumulator, the compressor, and pressure switches. The compressor is a diaphragm type unit purchased from Thomas Industries (P/N 917 CA20 - TFE). The accumulator (SVSK 105692) is a standard thirty (30) gallon unit manufactured by Stainless Steel Metals, Inc. (P/N 8530). The stainless steel accumulator has been modified to include stainless steel feet and a stainless steel platform on which the other components are located. A parts list for the CO_2 storage/delivery package is shown in Table 7.

Controller Package

The main components of the preprototype SAWD controller package consist of a Hewlett Packard HP-85 computer with 16K memory, a GFE cabinet which houses the computer, and a Hewlett Packard 3056DL data logger. The cabinet has been modified to incorporate a sliding tray on which the computer has been mounted. The sliding tray allows storage of the computer within the cabinet when the system is not in use, and pull out for easy access.

Table 8 presents a list of the SAWD controller package parts, together with a description of the part and its manufacturer. The data logger option board configurations for the Hewlett Packard data logger are presented in Table 9. This table presents the components within the SAWD subsystem which can be monitored and for which data can be printed.

Table 6

SAWD CANISTER PARTS LIST

1. Bed Retention Assembly (2)	Harrison & King Perforating Company; Stainless Steel Perforated Plate-AMS5513, 16 gauge Brunswick Corp. Technetics Div.; Stainless Steel Felt Metal Part Number FM1302 430 Stainless Steel 0.062" Thick 10% Density 46 Micron Filter
2. Outer Shell	Cole-Parmer Inst. Corp.; Part Number 7233-00
3. Inner Shell	Cole-Parmer Inst. Corp.; Part Number 7232-00
4. Inner Cover	Cole-Parmer Inst. Corp.; Part Number 7232-00
5. Outer Cover	Cole-Parmer Inst. Corp.; Part Number 7233-00
6. Cover Retaining Rods (8)	Stainless Steel Threaded Rods #10-32
7. Inner Cover Gasket	Silicone Rubber
8. Water Evaporator Assembly - Element	1570 Watt Heating Chromalox; Part Number TRI-7612 120 V
- Sheath	3/8" OD, .049" Wall Type 304 SS Tube
9. Header Tubes	1.5" O.D. X .065" wall type 304 SS Tube
10. Valve Adapters	1.5" NPT to 1.5" Tube 304 SS
11. Rigid Polyurethane Foam	Stephan Chemical Co.; G-300 Series Rigid Foam
12. Sealant	General Electric Corp. RTV Type 108
13. Thermocouple, Type T	Omega Engineering Corp.; Part Number SCPSS-020G-12
14. Thermocouple, Type T	Hamilton Standard, Part Number N/A
15. Thermocouple, Type T	Omega Engineering Corp.; Part Number SCPSS-020G-18
16. Amine	Rohm & Haas Co.; Amberlite IRA-45

Table 7

CO_2 STORAGE/DELIVERY PACKAGE PARTS LIST

Quantity	Item	Part No.	Manufacturer/Description
1	Accumulator	SVSK 105692-1	Stainless Steel Metals, Inc., 30 Gallon
1	Compressor	917CA20	Thomas Industries
1	Pressure Regulator	10122T/N	Fairchild Industrial Products
1	Relief Valve	SS-4CA-3	Nupro Company
1	Pressure Switches	611G8001	Custom Control Sensors, Inc.
1	Pressure Switches	611G8003	Custom Control Sensors, Inc.
1	Solenoid Valve	B52DB2125	Skinner Electric Valve
1	2 Way N.C. Valve	V52DB1100	Skinner Electric Valve
1	Check Valve	SS-6C-1	Nupro Company
1	Metering Valve	SS-4MG	Nupro Company

TABLE 8

SAWD CONTROLLER PARTS LIST

SAWD CONTROLLER PARTS LIST
SVSK107467, SHEET 1

QUANTITY	ITEM #	PART #	MANUFACTURER/DESCRIPTION
1	CB108	JB3-C3-A-5-3	HEINEMANN/CIRCUIT BREAKER, 400HZ, 5A
1	CB107	JB2-A3-A-20-3	HEINEMANN/CIRCUIT BREAKER, 60HZ, 20A
3	K1-K3	7D2410	IR/SOLID STATE RELAY, 280V, 60HZ, 10A
5	K4-K8	602-1	TELEDYNE/SSR, 280V, 400HZ, 10A
1	K107	W199AX-9	MAGNECRAFT/RELAY, 120V, 60HZ, 30A
2	K108-9	KUP14A55-120	POTTER&BRUMFIELD/RELAY,120V, 60HZ, 10A
3	TB1-3	355-31-25-001	CINCH/JONES STRIP, 25 POSITIONS
1	TB4	8-540	CINCH/ JONES STRIP
1	---	5256	HUBBELL/OUTLET CONNECTOR, 125V, 15A
1	PS1	83-24-225-2	SOLA/ POWER SUPPLY, 24V, 2.5A
1	PS2	905	ANALOG DEVICES/ POWER SUPPLY, 5V, 1A
1	SGC1	76BC3304102000	PARTLOW/ TEMPERATURE CONTROLLER
1	---	CB1372	BUD/ VERTICAL PANEL CHASSIS

SAWD CONTROLLER PARTS LIST
SVSK107467, SHEET 2

1	---	3056DL	HEWLETT PACKARD/ DATA LOGGER, WITH: 2 EA OPTION 020 BOARDS, MULTIPLEXER 1 EA OPTION 050 BOARD, DIGITAL I/O 1 EA OPTION 201, HP-IB INTERFACE
1	---	HP-85F	HEWLETT PACKARD/ COMPUTER, WITH: 1 EA 82903A, 16 K MEMORY 1 EA 00085-15005, ADVANCED PRG. ROM 1 EA 82939A, RS-232 INTERFACE 1 EA OPTION 326, 120VAC, 60HZ POWER

SAWD CONTROLLER PARTS LIST
SVSK107467, SHEET 3

5	BD1,R1-5	RESISTOR, 7.5 K OHMS, 2 WATTS, 10%
5	BD1,CR1-5	DIODE, 1N4148
5	BD2,R1,2,4,7,8	RESISTOR, 220 OHMS, 1/4 WATT, 10%
1	BD2,R3	RESISTOR, 10K OHMS, 1/4 WATT, 10%
2	BD2,R5,6	RESISTOR, 1.5 K OHMS, 1/4 WATT, 10%
1	BD2,Q1	TRANSISTOR, 2N2904
2	BD3,R1,7	RESISTOR, 1.5 M OHMS, 1/4 WATT, 5%
5	BD3,R2,3,5,6,11	RESISTOR, 0.1 M OHMS, 1/4 WATT, 5%
1	BD3,R4	RESISTOR, 33 K OHMS, 1/4 WATT, 5%
1	BD3,R8	RESISTOR, 120 K OHMS, 1/4 WATT, 5%
2	BD3,R9,10	RESISTOR, 1.0 M OHMS, 1/4 WATT, 5%
1	BD3,R12	RESISTOR, 4.7 K OHMS, 1/4 WATT, 5%
1	BD3,C1	CAPACITOR, CERAMIC, 0.1 uF, 50 V
1	BD3,C2	CAPACITOR, TANTALUM, 1.0 uF, 35 V
1	BD3,C3	CAPACITOR, MYLAR, 0.1 uF, 600 V
1	BD3,C4	CAPACITOR, MYLAR, 0.22 uF, 600 V
1	BD3,Q1	TRANSISTOR, 2N2222
1	BD3,VR1	ZENER DIODE, 1N751
1	BD3,U1	IC, QUAD OP-AMP, LM324

TABLE 8 (CONTINUED)
SAWD CONTROLLER PARTS LIST

SAWD CONTROLLER PARTS LIST
SVSK107467, SHEET 3 (CONTINUED)

QUANTITY	ITEM #	PART #	MANUFACTURER/DESCRIPTION
2	BD3,U2,3		IC, QUAD NAND GATE, CD4011
1	BD3,U4		IC, 2^12 COUNTER, CD4020
1	K10	643-1	TELEDYNE/SSR, 120V, 5A
1	PS3	905	ANALOG DEVICES/ POWER SUPPLY, 5V, 1A
9	LED1-9	HLMP-3507	HEWLETT PACKARD/ GREEN LED
1	LED10	HLMP-3401	HEWLETT PACKARD/ YELLOW LED
1	LED11	HLMP-3301	HEWLETT PACKARD/ RED LED
1	SW1	7501K12	CUTLER HAMMER/ SPST SWITCH
1	SW2	8820K16	CUTLER HAMMER/ DPDT SWITCH
1	M1	10186	CRAMER/ ELAPSED TIME INDICATOR
1	CTR1	6NR-115AN	NUMERON/ EVENT COUNTER
1	---	CU-108A	BUD/ 7X5X3 MINIBOX

MISCELLANEOUS ITEMS

1000 FT	---	20 GA	WIRE FOR HARNESSES AND CONTROLLER
300 FT	---	16 GA	WIRE FOR HARNESSES AND CONTROLLER
100 FT	---	12 GA	WIRE FOR HARNESSES AND CONTROLLER
35 FT	---	20 GA/TC	8 PAIR CABLE FOR THERMOCOUPLES
35 FT	---	20 GA/TC	1 PAIR CABLE FOR STEAM GENERATOR TC
100	---	4 INCH	NYLON CABLE TIES

TABLE 9

PREPROTOTYPE SAWD DATA LOGGER
OPTION BOARD CONFIGURATIONS

SLOT	CARD	TERM	CHANNEL	TRANSDUCER	FUNCTION	MIN	TYP	MAX	COMMENTS
0	020	0	0	VALVE	ACTUATOR	CLS		OPN	VALVE V1
0	020	1	1	VALVE	ACTUATOR	CLS		OPN	VALVE V3
0	020	2	2	THRMCOUPLE	TEMP	30		350	T1, CAN INLET TEMP
0	020	3	3	THRMCOUPLE	TEMP	30		350	T2, CAN HEADER TEMP
0	020	4	4	THRMCOUPLE	TEMP	30		250	T3, CAN OUTLET TEMP
0	020	5	5	THRMCOUPLE	TEMP	30		250	T4, BED TEMP
0	020	6	6	THRMCOUPLE	TEMP	30		250	T5, BED TEMP
0	020	7	7	THRMCOUPLE	TEMP	30		250	T6, BED TEMP
0	020	8	8	THRMCOUPLE	TEMP	30		250	T7, BED TEMP
0	020	9	9	THRMCOUPLE	TEMP	30		250	T8, BED TEMP
1	020	0	10	VALVE	ACTUATOR	CLS		OPN	VALVE V4
1	020	1	11	VALVE	ACTUATOR	CLS		OPN	VALVE V5
1	020	2	12	PRESSURE	VOLTAGE	0V		5V	PR, BED PRESSURE
1	020	3	13						
1	020	4	14	SPEED	FREQ	0		1500	N, FAN SPEED
1	020	5	15	DEW POINT	----	0		10V	NASA SUPPLIED
1	020	6	16	SCALE	----	0		10V	NASA SUPPLIED
1	020	7	17	FLOW METER	----	0		10V	NASA SUPPLIED
1	020	8	18						
1	020	9	19						
2	050	0	20	SSR	DIG OUT				WATER PUMP POWER
2	050	1	21	SSR	DIG OUT				COMPRESSOR POWER
2	050	2	22	SSR	DIG OUT				STEAM GEN POWER
2	050	3	23	SSR					SPARE 400 HZ RELAY
2	050	4	24	SSR					SPARE 400 HZ RELAY
2	050	5	25	SSR	DIG OUT				FAN POWER
2	050	6	26	LED	DIG OUT				SYSTEM ON/OFF IND.
2	050	7	27	LED	DIG OUT				SHUTDOWN INDICATOR
2	050	0	20	SWITCH	DIG IN				P2 DELTA PRESSURE SW
2	050	1	21	SWITCH	DIG IN				S1 CO2 MODE SWITCH
2	050	2	22	SWITCH	DIG IN				P3 CO2 STORAGE LO
2	050	3	23	SWITCH	DIG IN				P4 CO2 STORAGE HI
2	050	4	24	+5 VDC	DIG IN				SYSTEM ON
2	050	5	25	SWITCH	DIG IN				P5 STEAM GEN BACK PRES
2	050	6	26						
2	050	7	27						

Life Test Lab Support Package

The life test lab support package consists of an air inlet filter, an air exhaust silencer, and a test stand to support the CO_2 removal package. The test stand has been custom fabricated at Hamilton Standard specifically for supporting the CO_2 removal package during usage in the CSD Life Test Laboratory. The air inlet filter, which was incorporated to reduce the intake particulate levels, is a standard model purchased from Consolar. The air exhaust silencer has been added to reduce noise levels associated with the 21 cfm (600 lpm), 11,000 rpm fan motor. The silencer is a standard model manufactured by Rotron.

SAWD Electrical System Details

Table 10 presents a listing of the preprototype SAWD electrical system input/output components. This parts list details the location (subsystem package) on which the component is found, specifies the sensing element and operating range of the component (as applicable), the load requirements of items (as applicable), and the indication provided by each of the indicator lights in the SAWD controller package.

Table 11 presents a listing of the connectors used in the SAWD subsystem. The table defines the component within the SAWD subsystem on which the connector is located. Table 12 is a second list of the connectors used in the preprototype SAWD as grouped by equipment manufacturer.

SAWD Subsystem Assembly

The SAWD subsystem is defined by the electrical and mechanical drawings which are listed in Table 13. Electrical power, signal and fluid interfaces must be connected between the four (4) subsystem packages and the external supply sources in order to complete assembly of the SAWD.

Electrical power and signal sources connecting the four (4) subsystem packages are wired in accordance with the electrical schematic, SVSK 107469. Electrical cables for power and signal transmission between the controller, CO_2 removal, and CO_2 storage/delivery packages are provided as part of the SAWD subsystem. The cables are of sufficient length so as to permit the remote locations of each package. Mating connectors for electrical power and external signals to the controller package are provided with the unit.

Polyflo tubing (1/4 and 3/8 inch OD) is used for fluid lines throughout the SAWD subsystem. These fluid lines provide water and pressurizing gas to the CO_2 removal package, and transmit CO_2 to the storage/delivery package, overboard dump or CO_2 reduction subsystem. The polyflo tubing is cut to fit as required in accordance with the preprototype SAWD (PPS) schematic (SVSK 105648).

TABLE 10
PREPROTOTYPE SAWD SYSTEM I/O

INPUTS

ITEM NO.	DESCRIPTION	SENSING ELEMENT	RANGE	LOCATION
T1	TEMP	THERMOCOUPLE, TYPE T	30-350 F	CAN IN
T2	TEMP	THERMOCOUPLE, TYPE T	30-350 F	CAN HEADER
T3	TEMP	THERMOCOUPLE, TYPE T	30-250 F	CAN OUTLET
T4	TEMP	THERMOCOUPLE, TYPE T	30-250 F	BED
T5	TEMP	THERMOCOUPLE, TYPE T	30-250 F	BED
T6	TEMP	THERMOCOUPLE, TYPE T	30-250 F	BED
T7	TEMP	THERMOCOUPLE, TYPE T	30-250 F	BED
T8	TEMP	THERMOCOUPLE, TYPE T	30-250 F	BED
P1	PRESSURE	CAPACITIVE	0-5 VDC	BED
P2	PRESSURE	SWITCH	DISCRETE	ULLAGE BYPASS DELTA P
P3	PRESSURE	SWITCH	DISCRETE	CO2 STORAGE TANK
P4	PRESSURE	SWITCH	DISCRETE	CO2 STORAGE TANK
P5	PRESSURE	SWITCH	DISCRETE	STEAM GENERATOR
N	SPEED	MAGNETIC COIL	1 Vp-p	FAN
S1	SWITCH	TOGGLE SWITCH	OPN/CLS	CONTROL PANEL
DP	DEW POINT	——	0-10 VDC	NASA SUPPLIED
SC	SCALE	——	0-10 VDC	NASA SUPPLIED
FM	FLOW METER	——	0-10 VDC	NASA SUPPLIED

OUTPUTS

TABLE 10 (CONTINUED)
PREPROTOTYPE SAWD SYSTEM I/O

ITEM NO.	DESCRIPTION	LOAD REQUIREMENTS	LOCATION
V1	VALVE	24VDC @ 0.4A	PNEUMATIC CONTROL VALVE
V3	VALVE	24VDC @ 0.4A	ULLAGE BYPASS VALVE
V4	VALVE	24VDC @ 0.4A	CO2 OVERBOARD VENT VALVE
V5	VALVE	24VDC @ 0.4A	CO2 ACCUMULATOR OUTLET VALVE
F1	FAN	115VAC 3P @ 1A 400 HZ	
F2	PUMP	115VAC @ 1A	WATER FEED LINE
F3	PUMP	115VAC @ 3.3A	CO2 COMPRESSOR
SG	STEAM GEN	115VAC @ 1A	CONTROLLER POWER

INDICATOR LIGHTS

ITEM NO.	COLOR	DESCRIPTION	INDICATION
I1	GREEN	LED	115V 60 HZ POWER
I2	GREEN	LED	115V 400 HZ A POWER
I3	GREEN	LED	115V 400 HZ B POWER
I4	GREEN	LED	115V 400 HZ C POWER
I5	GREEN	LED	24V DC POWER
I6	GREEN	LED	SYSTEM ON
I7	YELLOW	LED	SHUTDOWN
I8	RED	LED	SYSTEM OFF
I9	GREEN	LED	ABSORB
I10	GREEN	LED	DESORB
I11	GREEN	LED	CO2 OVERBOARD
I12	GREEN	LED	CO2 REDUCTION

TABLE 11

CONNECTOR LIST

LOCATION CODE: CON....CONTROLLER HRN....HARNESS
CMP....COMPRESSOR PPS....SAWD PLANT

CONNECTOR #	MANUFACTURER	PART #	LOC	DESCRIPTION
J100	AMPHENOL	3106A-20-18P	HRN	SAWD 115V 60 HZ LOAD POWER
J101	BENDIX	PT06A-12-10P	HRN	SAWD 24V LOAD POWER
J102	BENDIX	PT06A-14-19P	HRN	SAWD 115V 400 HZ LOAD POWER
J103	BENDIX	PT06A-16-26P	HRN	SAWD INSTRUMENTATION
J104	CANNON	MS3106A-14S-6P	HRN	COMPRESSOR 115V 60 HZ POWER
J105	BENDIX	PT06A-10-6P	HRN	COMPRESSOR 24V POWER, INST
J106	BENDIX	PT06A-12-10P	HRN	NASA SUPPLIED HARNESS
J110			HRN	THERMOCOUPLE
J111			HRN	THERMOCOUPLE
J112			HRN	THERMOCOUPLE
J113			HRN	THERMOCOUPLE
J114			HRN	THERMOCOUPLE
J115			HRN	THERMOCOUPLE
J116			HRN	THERMOCOUPLE
J117			HRN	THERMOCOUPLE
J150	CANNON	MS3106A-18-1S	CON	FRONT PANEL POWER SIGNALS
J151	BENDIX	PT06A-12-10S	CON	FRONT PANEL STATUS SIGNALS
J200	AMPHENOL	3106A-20-18S	HRN	115V 60 HZ LOAD POWER INPUT
J201	BENDIX	PT06A-12-10S	HRN	24V LOAD POWER INPUT
J202	BENDIX	PT06A-14-19S	HRN	115V 400 HZ LOAD POWER INPUT
J203	BENDIX	PT06A-16-26S	HRN	INSTRUMENTATION OUTPUT
J210			HRN	THERMOCOUPLE
J211			HRN	THERMOCOUPLE
J212			HRN	THERMOCOUPLE
J213			HRN	THERMOCOUPLE
J214			HRN	THERMOCOUPLE
J215			HRN	THERMOCOUPLE
J216			HRN	THERMOCOUPLE
J217			HRN	THERMOCOUPLE
J250	BENDIX	PT06A-10-6S	HRN	SPEED SENSOR
J251	DEUTSCH	AFD56-14-5SN	HRN	FAN POWER
J252				

TABLE 11 (CONTINUED)

CONNECTOR LIST

J253	BENDIX	PT06A-10-6S	HRN	PRESSURE SENSOR POWER & OUTPUT
J304	CANNON	MS3106A-14S-6S	HRN	COMPRESSOR 115V 60 HZ POWER
J305	BENDIX	PT06A-10-6S	HRN	COMPRESSOR 24V POWER, INST
P100	AMPHENOL	3102A-20-18S	CON	SAWD 115V 60 HZ LOAD POWER
P101	BENDIX	PT02A-12-10S	CON	SAWD 24V LOAD POWER
P102	BENDIX	PT02A-14-19S	CON	SAWD 115V 400 HZ LOAD POWER
P103	BENDIX	PT02A-16-26S	CON	SAWD INSTRUMENTATION
P104	CANNON	MS3102A-14S-6S	CON	COMPRESSOR 115V 60 HZ POWER
P105	BENDIX	PT02A-10-6S	CON	COMPRESSOR 24V POWER, INST
P106	BENDIX	PT02A-12-10S	CON	NASA SUPPLIED INSTRUMENTATION
P110			CON	THERMOCOUPLE
P111			CON	THERMOCOUPLE
P112			CON	THERMOCOUPLE
P113			CON	THERMOCOUPLE
P114			CON	THERMOCOUPLE
P115			CON	THERMOCOUPLE
P116			CON	THERMOCOUPLE
P117			CON	THERMOCOUPLE
P150	CANNON	MS3102A-18-1P	CON	FRONT PANEL POWER SIGNALS
P151	BENDIX	PT02A-12-10P	CON	FRONT PANEL STATUS SIGNALS
P200	AMPHENOL	3102A-20-18P	PPS	115V 60 HZ LOAD POWER INPUT
P201	BENDIX	PT02A-12-10P	PPS	24V LOAD POWER INPUT
P202	BENDIX	PT02A-14-19P	PPS	115V 400 HZ LOAD POWER INPUT
P203	BENDIX	PT02A-16-26P	PPS	INSTRUMENTATION OUTPUT
P210			PPS	THERMOCOUPLE
P211			PPS	THERMOCOUPLE
P212			PPS	THERMOCOUPLE
P213			PPS	THERMOCOUPLE
P214			PPS	THERMOCOUPLE
P215			PPS	THERMOCOUPLE
P216			PPS	THERMOCOUPLE
P217			PPS	THERMOCOUPLE
P250	BENDIX	PT02A-10-6P	PPS	SPEED SENSOR
P304	CANNON	MS3102A-14S-6P	CMP	COMPRESSOR 115V 60 HZ POWER
P305	BENDIX	PT02A-10-6P	CMP	COMPRESSOR 24V POWER, INST

TABLE 12

PREPROTOTYPE SAWD CONECTOR LIST

(_) INDICATES LOWER CASE LETTERS

ITEM NO.	PART NO.	WIRE SIZE	LOCATION	DESCRIPTION
	AMPHENOL #	16	A	
J100	3106A-20-18P	12	B	STEAM GENERATOR-RETURN
J200	3106A-20-18S	16	C	WATER PUMP-RETURN
P100	3102A-20-18S	16	D	WATER PUMP-HOT
P200	3102A-20-18P	16	E	WATER PUMP-SAFETY GROUND
	CABLE CLAMP: 97-3057-1012-1	12	F	STEAM GENERATOR-SAFETY GROUND
		16	G	
		16	H	
		12	I	STEAM GENERATOR-HOT
	BENDIX#	20	A	V4-HOT
J101	PT06A-12-10P		B	V3-HOT
J201	PT06A-12-10S		C	V3-RETURN
P101	PT02A-12-10S		D	
P201	PT02A-12-10P		E	
			F	
			G	SHIELD GROUND
			H	V1-HOT
			J	V4-RETURN
			K	V1-RETURN
	BENDIX #	20	A	
J102	PT06A-14-19P		B	
J202	PT06A-14-19S		C	
P102	PT02A-14-19S		D	
P202	PT02A-14-19P		E	
			F	

TABLE 12 (CONTINUED)
PREPROTOTYPE SAWD CONECTOR LIST

			G	
			H	
			J	
			K	SPARE
			L	SPARE
			M	SPARE
			N	
			P	FAN-PHASE A
			R	FAN-PHASE B
			S	FAN-PHASE C
			T	SHIELD GROUND
			U	
			V	FAN-RETURN
J103	BENDIX # PT06A-16-26P	20	A	
J203	PT06A-16-26S		B	
P103	PT02A-16-26S		C	
P203	PT02A-16-26P		D	
			E	
			F	
			G	
			H	
			J	
			K	PRESSURE SENSOR +24V
			L	PRESSURE SENSOR +24V RETURN
			M	SHIELD GROUND
			N	PRESSURE SENSOR-OUTPUT
			P	PRESSURE SENSOR-RETURN
			R	

TABLE 12 (CONTINUED)
PREPROTOTYPE SAWD CONECTOR LIST

			S	SPEED SENSOR-HI
			T	SPEED SENSOR-LO
			U	SPEED SENCOR-SAFETY GROUND
			V	
			W	PRESSURE SWITCH (P2)-NO
			X	PRESSURE SWITCH (P2)-COMMON
			Y	PRESSURE SWITCH (P2)-NC
			Z	
			(A)	PRESSURE SWITCH (P5)-NC
			(B)	PRESSURE SWITCH (P5)-COMMON
			(C)	PRESSURE SWITCH (P5)-NO
	CANNON #	16	A	COMPRESSOR POWER
J104	MS3106A-14S-6P		B	RETURN
J304	MS3106A-14S-6S		C	GROUND
P104	MS3102A-14S-6S		D	
P304	MS3102A-14S-6P		E	
			F	
	BENDIX #	20	A	P3-HI
J105	PT06A-10-6P		B	P3/P4-COMMON
J305	PT06A-10-6S		C	P4-LO
P105	PT02A-10-6S		D	SHIELD GROUND
P305	PT02A-10-6P		E	V5-HOT
			F	V5-RETURN
	BENDIX #		A	DEWPOINT RETURN
J106	PT06A-12-10P	20	B	SHIELD GROUND
P106	PT02A-12-10S		C	
			D	SHIELD GROUND
			E	FLOW METER RETURN
			F	FLOW METER +

TABLE 12 (CONTINUED)
PREPROTOTYPE SAWD CONECTOR LIST

			G	SCALE +
			H	DEWPOINT +
			J	SHIELD GROUND
			K	SCALE -
J107 P107	HUBBELL # 7327 7555	12		115VAC 60 HZ HOT
				RETURN
				SAFETY GROUND
J108 P108	HUBBELL #	18		115VAC 400 HZ HOT, PHASE A
				115VAC 400 HZ HOT, PHASE B
				115VAC 400 HZ HOT, PHASE C
				RETURN
				SAFETY GROUND
J110 J210			+	CAN INLET-THERMOCOUPLE
			-	CAN INLET-THERMOCOUPLE
J111 J211			+	CAN HEADER-THERMOCOUPLE
			-	CAN HEADER-THERMOCOUPLE
J112 J212			+	CAN OUTLET-THERMOCOUPLE
			-	CAN OUTLET-THERMOCOUPLE
J113 J213			+	BED-THERMOCOUPLE
			-	BED-THERMOCOUPLE
J114 J214			+	BED-THERMOCOUPLE
			-	BED-THERMOCOUPLE
J115 J215			+	BED-THERMOCOUPLE
			-	BED-THERMOCOUPLE
J116 J216			+	BED-THERMOCOUPLE
			-	BED-THERMOCOUPLE
J117 J217			+	BED-THERMOCOUPLE
			-	BED-THERMOCOUPLE

TABLE 12 (CONTINUED)

PREPROTOTYPE SAWD CONECTOR LIST

J150 P150	CANNON# MS3106A-18-1S MS3102A-18-1P		A	
			B	115VAC 60 HZ RETURN
			C	115VAC 400 HZ PHASE A POWER SIG
			D	115VAC 400 HZ PHASE B POWER SIG
			E	115VAC 400 HZ PHASE C POWER SIG
			F	115VAC 400 HZ RETURN
			G	
			H	
			I	115V 60 HZ
			J	RELAY POWER
J151 P151	BENDIX# PT06A-12-10S PT06A-12-10P	20	A	24 VDC
			B	SHUTDOWN INDICATOR SIGNAL
			C	5 VDC
			D	SYSTEM ON INDICATOR SIGNAL
			E	V1 ACTUATED SIGNAL
			F	SG ON SIGNAL
			G	
			H	S1 SIGNAL INPUT TO DATA LOGGER
			J	5V RETURN
			K	V1-RETURN
J250 P250	BENDIX # PT06A-10-6P PT02A-10-6S		A	SPEED SENSOR-HI
			B	SPEED SENSOR-LO
			C	SPEED SENSOR-SAFETY GROUND
			D	
			E	
			F	
J251	DEUTSCH # AFD56-14-5SN		A	FAN-PHASE A
			B	FAN-PHASE B
			C	FAN-PHASE C

TABLE 12 (CONTINUED)
PREPROTOTYPE SAWD CONECTOR LIST

			D	FAN-RETURN
			E	FAN-SAFETY GROUND
J252	MS24266-R14B-15SN		1	V2-OPEN
			2	V2-CLOSE
			3	V2-RETURN
			4	
			5	
			6	
			7	
			8	
			9	
			10	
			11	
J253	BENDIX # PT06A-10-6S		A	PRESSURE SENSOR +24V
			B	PRESSURE SENSOR +24V RETURN
			C	PRESSURE SENSOR-OUTPUT
			D	PRESSURE SENSOR-RETURN
			E	PRESSURE SENSOR-SAFETY GROUND
			F	

Table 13

SAWD SUBSYSTEM DRAWINGS

Drawing No.	No. Sheets	Title	Latest Revision
Electrical			
SVSK 107467	3	Schematic, SAWD Controller	12/06/83
SVSK 107468	1	PPS Package, Inter. Harness Dwg.	12/06/83
SVSK 107469	1	PPS System Block Diagram	1/12/84
Mechanical			
SVSK 86322	1	Fan, Centrifugal	1/24/84
SVSK 103199	8	Preprototype SAWD Canister Assy.	1/24/84
SVSK 105648	1	Preprototype SAWD (PPS) Schematic	1/24/84
SVSK 105692	1	SAWD Accumulator	1/24/84
SVSK 105825	2	Preprototype SAWD (PPS) System	1/24/84
SVSK 108048	1	Test Stand, SAWD I	1/24/84

SUBSYSTEM OPERATION AND CONTROL

This section describes the preprototype SAWD operational sequence and presents the logic used by the controller to affect proper sequencing. The function of each control related sensor is identified during explanation of the software logic.

Subsystem Operation

The operating components of the preprototype SAWD were shown previously in Figure 2. The subsystem's normal sequential operating cycle consists of an absorption cycle followed by desorption. However, subsystem start-up begins with a desorption cycle to ensure that the amine moisture content is controlled. A test series is normally terminated with an absorption cycle to prevent the subsystem from being shut down with a hot sorbent bed. Operation during absorption, desorption, and with CO_2 delivery are described in the following paragraphs.

Absorption Operation - During absorption (ABS) cabin air is drawn by fan F1 through the solid amine absorbent bed B1. Valve V1 is positioned to supply pressurized nitrogen which opens pneumatically controlled valves V6 and V7 to permit air flow at a rate determined by the fan operating characteristics. The steady state air flow rate is about 600 liters (21 ft^3) per minute. All other valves, the compressor, and the pump are maintained in the closed or off position by the controller. No other flow occurs during absorption except the flow of carbon dioxide from the accumulator A1 to the reduction unit if the CO_2 reduction mode is operational. Absorption continues for the period determined by the controller as a function of the average measured relative humidity of the inlet air during the cycle. The controller then initiates desorption.

Desorption Operation - Desorption (DES) proceeds through three distinct stages, namely:

(1) Preheat stage during which the steam generator is heated prior to initiating water flow (DES1).

(2) Bleed stage when trapped air is bled from the system (DES2).

(3) CO_2 delivery stage during which CO_2 is released from the amine bed (DES3).

At the onset of DES1, valve V1 is positioned to vent pressurized nitrogen and close valves V6 and V7, isolating the amine bed from the atmosphere. Power to fan F1 is off. Power to the steam generator G1 heater is turned on to preheat the steam generator coils and the canister header. Valve V3 is opened to permit the venting to the atmosphere of air trapped in the amine bed canister at the completion of absorption. After about two minutes of DES1 preheat, DES2 begins when power is supplied to the water pump F2 to provide water flow (3-4 lb/hr) to the steam generator. The air displaced by the steam introduced into the bed is vented at a low flow rate until CO_2 desorption from the amine begins, increasing the air flow rate through V3. The flow rate increase causes an increase in the pressure drop across V3 and the activation of pressure switch P2. This generates a signal that closes valve V3 and, depending on the preselected CO_2 delivery mode, either opens valve V4 to dump CO_2 overboard or powers compressor F3 to deliver CO_2 to accumulator A1. This sequence begins DES3. If CO_2 delivery is in the reduction mode, valve V2 is opened momentarily to relieve the downstream pressure and prevent activation of the compressor's overpressure shutdown. DES3 is continued until the bed outlet temperature T1 increases to 65.5°C(150°F) indicating that the desorption is complete. The controller then initiates the next absorption cycle.

The cyclic operation, absorption followed by desorption, continues until an end of test command is initiated by the controller. The end of test command initiates an absorption followed by a normal shutdown sequence.

<u>CO_2 Delivery Operation</u> - During DES3, the desorbed CO_2 can be delivered to the CO_2 reduction subsystem of the Atmosphere Revitalization System through the SAWD accumulator, or dumped overboard. The delivery mode is selected by manually positioning switch S1 on the controller panel.

If the CO_2 reduction mode is selected, the signal from pressure switch P2 will close valve V3 and start the CO_2 compressor F3 to pump the desorbed CO_2 into the accumulator. If the CO_2 overboard mode is selected, the P2 signal will close V3 and open valve V4 to vent the desorbed CO_2.

The delivery of CO_2 is initiated by opening valve V5 to permit flow when pressure switch P4 indicates an accumulator pressure of at least 262 kPa (38 psia). The CO_2 can then be delivered from the accumulator to a CO_2 reduction system at any time during the SAWD operating cycle when there is sufficient CO_2 in the accumulator to maintain a pressure greater than 138 kPa (20 psia). Valve 5 remains open until pressure switch P3 indicates a decrease in the accumulator pressure to 138 kPa (20 psia). Continuous flow at a preselected rate is maintained by the pressure regulator R2 and the variable orifice flow control valve Ø1.

Subsystem Control

The controller package provides automatic sequencing and control of the cyclic absorb/desorb process. The controller monitors all operating parameters, actuates the components, calculates subsystem performance data, and provides automatic shutdown in the event of an operational anomaly, or the completion of the test series. The sensed operating parameters are identified in Table 14. The parameters designated by an asterisk control the cyclic operation of the SAWD. The other parameters monitor performance, generate a signal to cause component actuation, and/or initiate automatic shutdown.

Table 14

SAWD SUBSYSTEM OPERATING PARAMETERS

Parameter Sensed	Sensor Identification	
Dew Point Temperature	DP*	Ambient Air Dewpointer
F1 Air Fan Speed	N	Fan Rotational Speed Sensor
Bed Air/Steam Pressure	P1	Sorbent Bed Pressure Transducer
CO_2 Flow-Induced Pressure	P2*	High Pressure Switch Desorb Air Vent
Flow Restriction-Induced Pressure	P5	High Pressure Switch Water Pump
ABS - Inlet Air Temperature DES - Outlet Steam Temperature	T1*	Inlet Air Temperature Sensor
Header Temperature	T2*	Header Temperature Sensor
ABS - Outlet Air Temperature DES - Steam Temperature	T3	Outlet Air Temperature Sensor
Sorbent Bed Temperatures	T4-T8	Bed Temperature Sensors
Reduction - CO_2 Desorption Flow Rate Overboard - Accumulator CO_2 Delivery Flow Rate	M1	CO_2 Flow Rate
CO_2 Delivery Start Pressure (Accumulator)		High Pressure Switch Accumulator
CO_2 Delivery Stop Pressure (Accumulator)		Low Pressure Switch Accumulator

* These parameters are used to control cyclic operation, i.e., Absorption time and the starting and stopping of Desorption.

Logic diagrams for the SAWD controller software are presented in Figures 28 through 35. Figure 28 presents the main controller software logic. This program provides overall management of the subsystem operation via utilization of the subroutines identified in Figures 29 through 35.

The microprocessor operations that are available, in the order of their programmed occurrence, are as follows:

1. A functional checkout of the SAWD operating components. (This is activated via use of the subroutine "CHECKOUT".)

2. The instrument calibration curves are loaded into memory (eg - the electronic scale uses the subroutine "SCALE", the CO_2 flowmeter uses "FLOW").

3. The initializing parameters are input (eg - date, time of day).

4. An option is available to recondition the amine to a 20% moisture content condition.

5. Input the total number of cycles desired to be run.

6. Enter the initial test conditions (eg - inlet temperature, dew point, etc.).

7. Print the output heading.

8. Press the start button on the controller front panel.

9. Set the time interval for the "WATCHDOG" reset. This "WATCHDOG" fundamentally is electronic circuitry that will affect an automatic shutdown if any electronic device is nonresponsive when scanned.

10. Read and display the time and temperatures.

11. Check for out of limits conditions. If any parameter is out of limits, then initiate an automatic shutdown.

12. If all parameters are within limits, then continue SAWD operation.

During subsystem start-up, the controller scans the operating parameters of the subsystem and activates a shutdown sequence if an anomaly exists. The conditions considered to be abnormal during start-up are listed in Table 15.

In the normal operating mode, the subsystem starts operation by activating a desorption. The controller automatically initiates each of the three phases of desorption - DES1, DES2, and DES3. Figure 29 presents the logic diagram for SAWD operation during desorption.

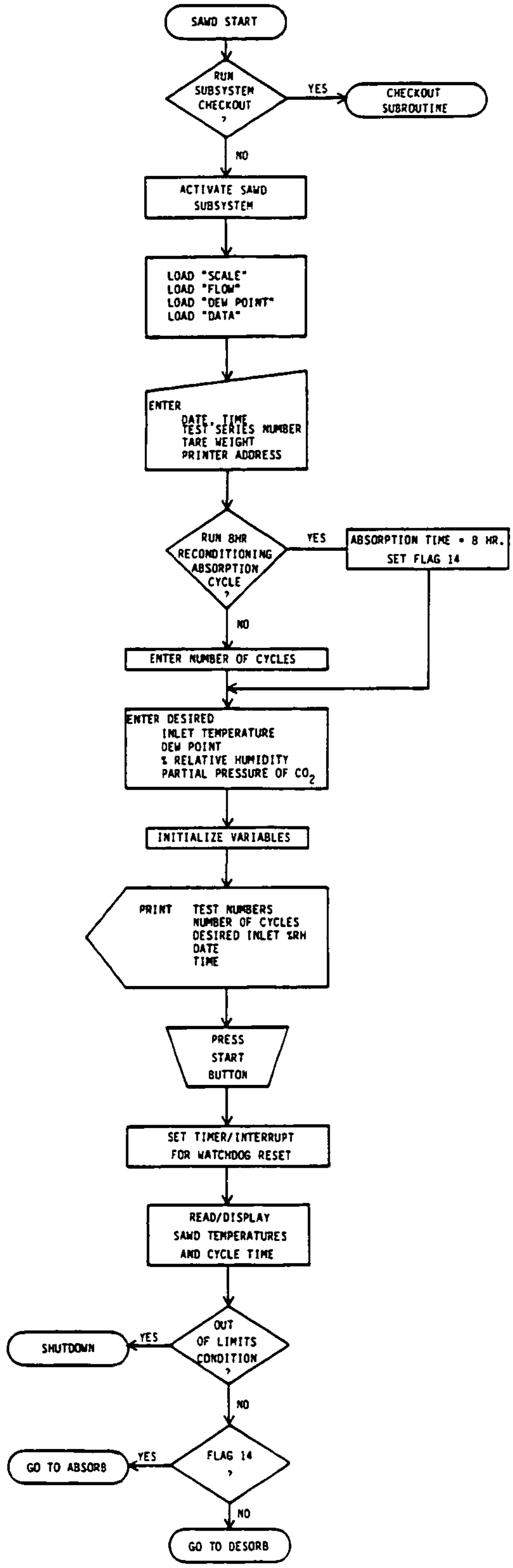


FIGURE 28

SAWD CONTROLLER LOGIC

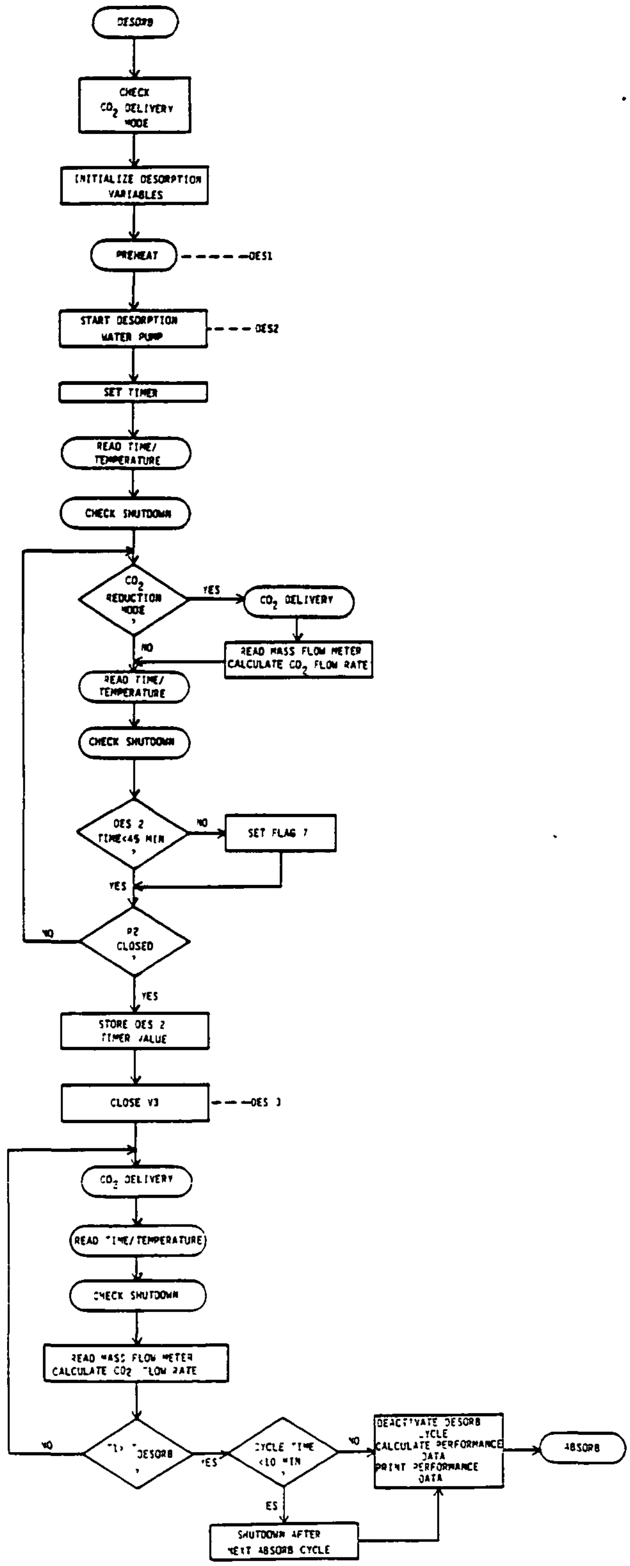


FIGURE 29

DESORB SUBROUTINE

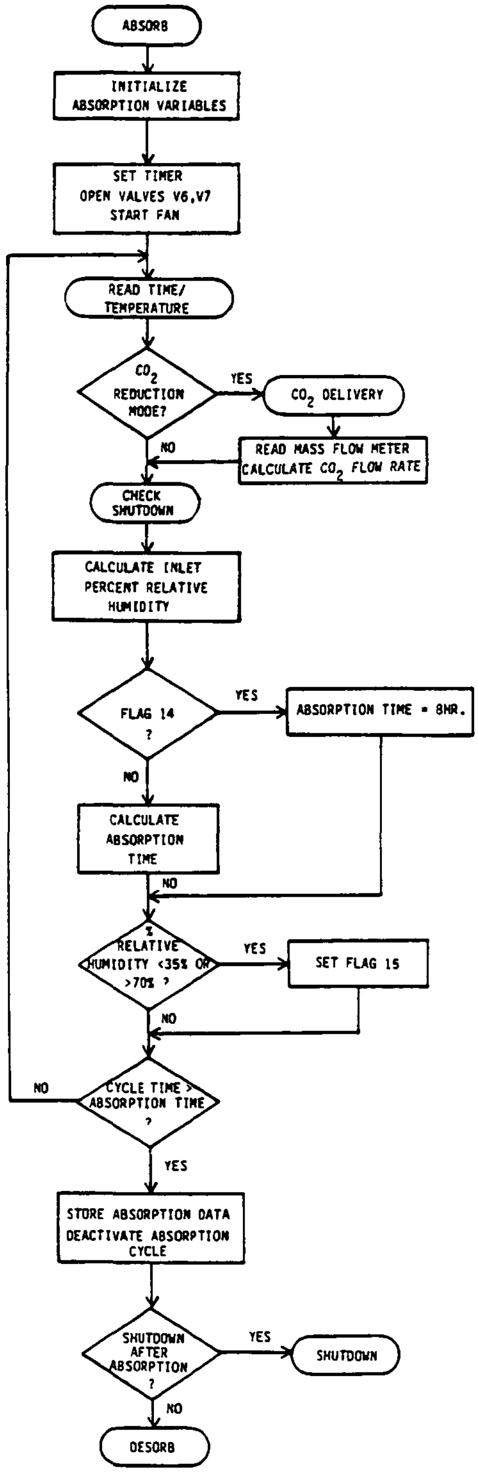


FIGURE 30

ABSORB SUBROUTINE

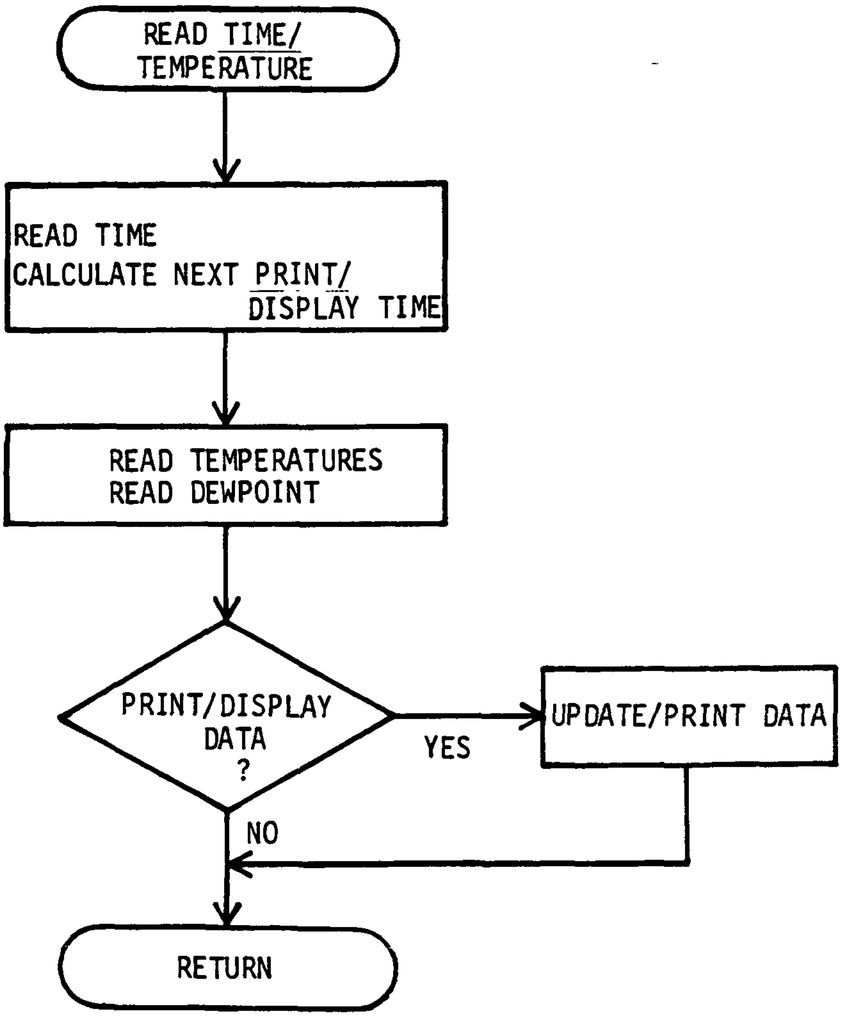


FIGURE 31

TIME/TEMPERATURE SUBROUTINE

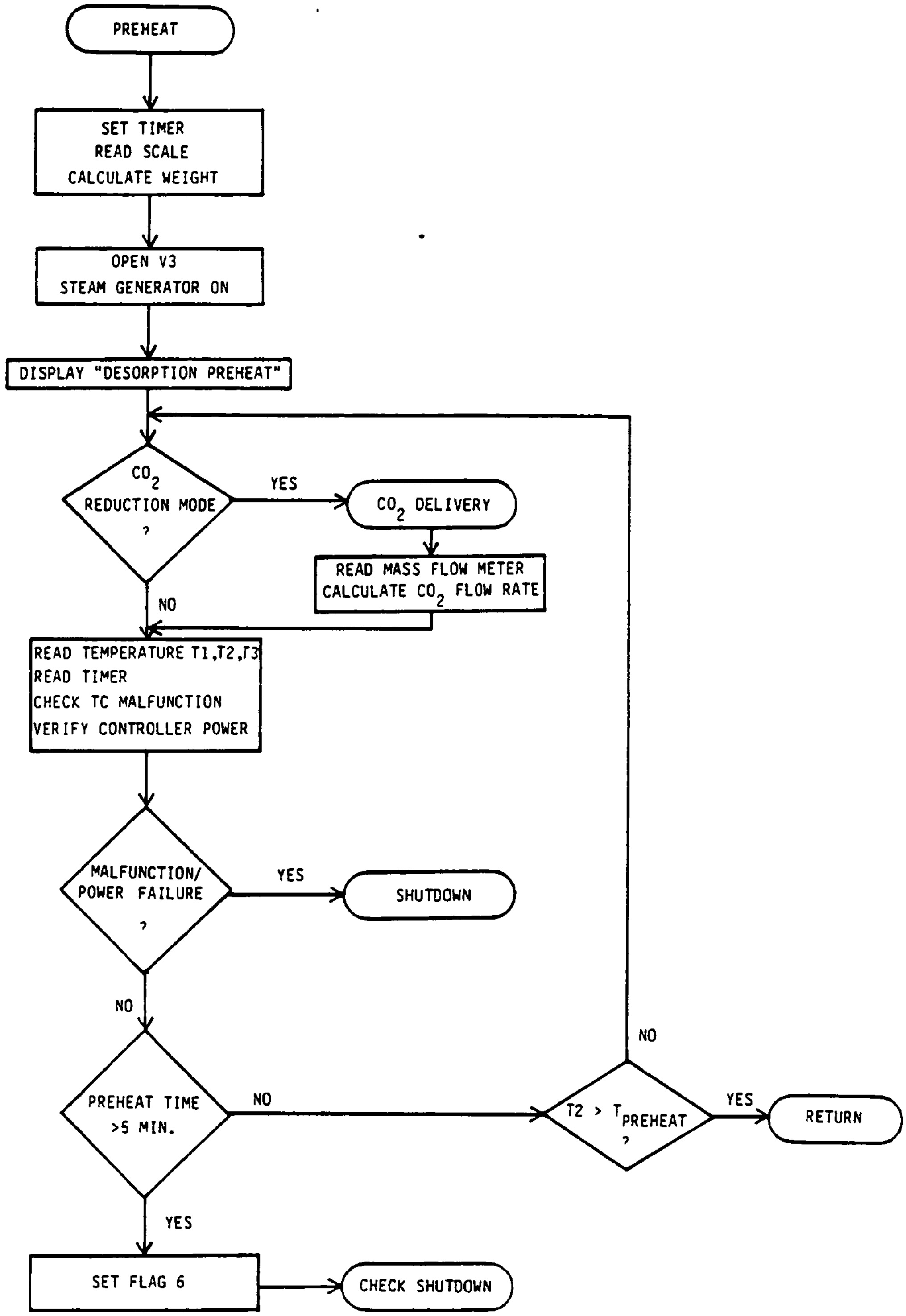


FIGURE 32

PREHEAT SUBROUTINE

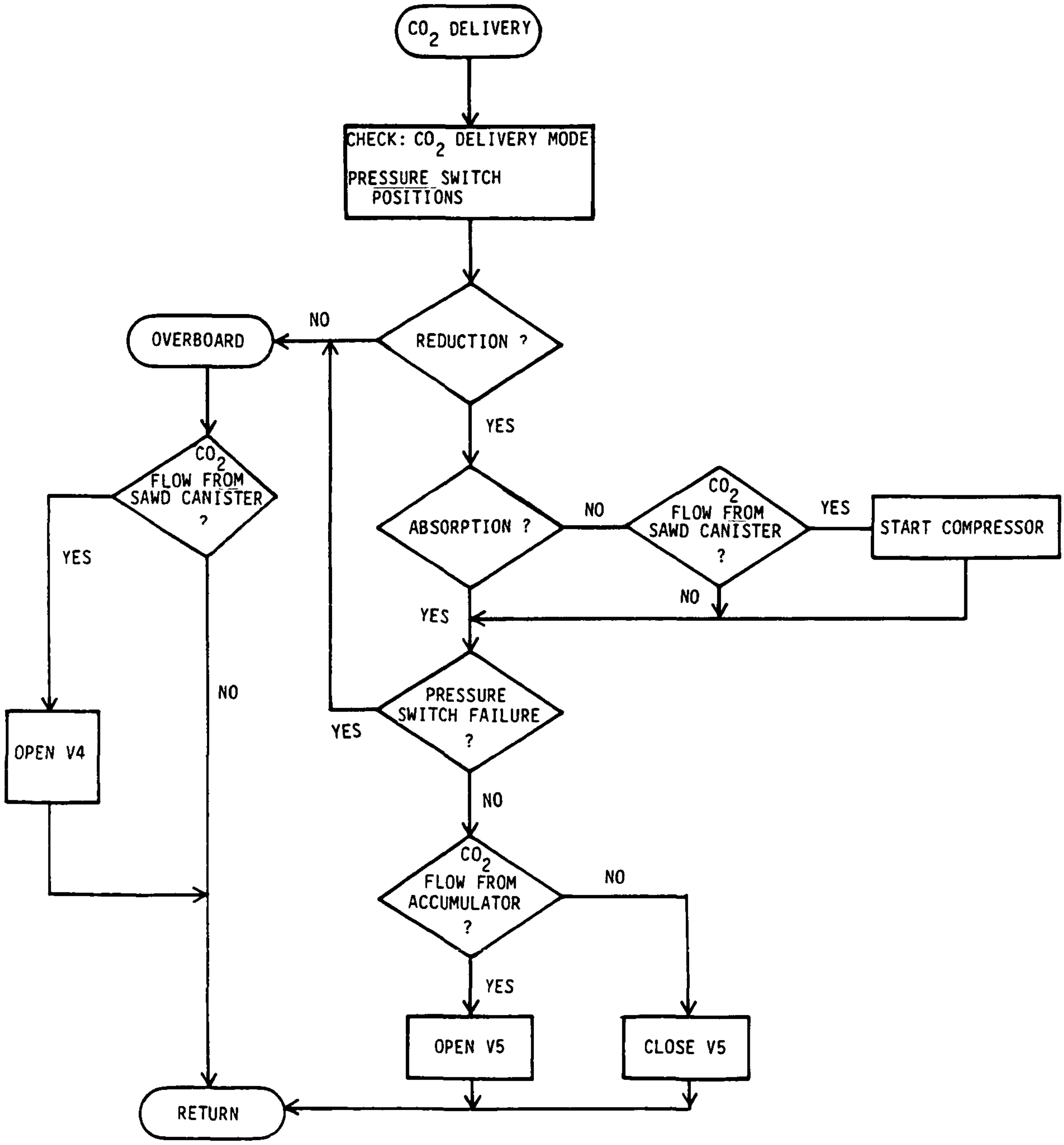
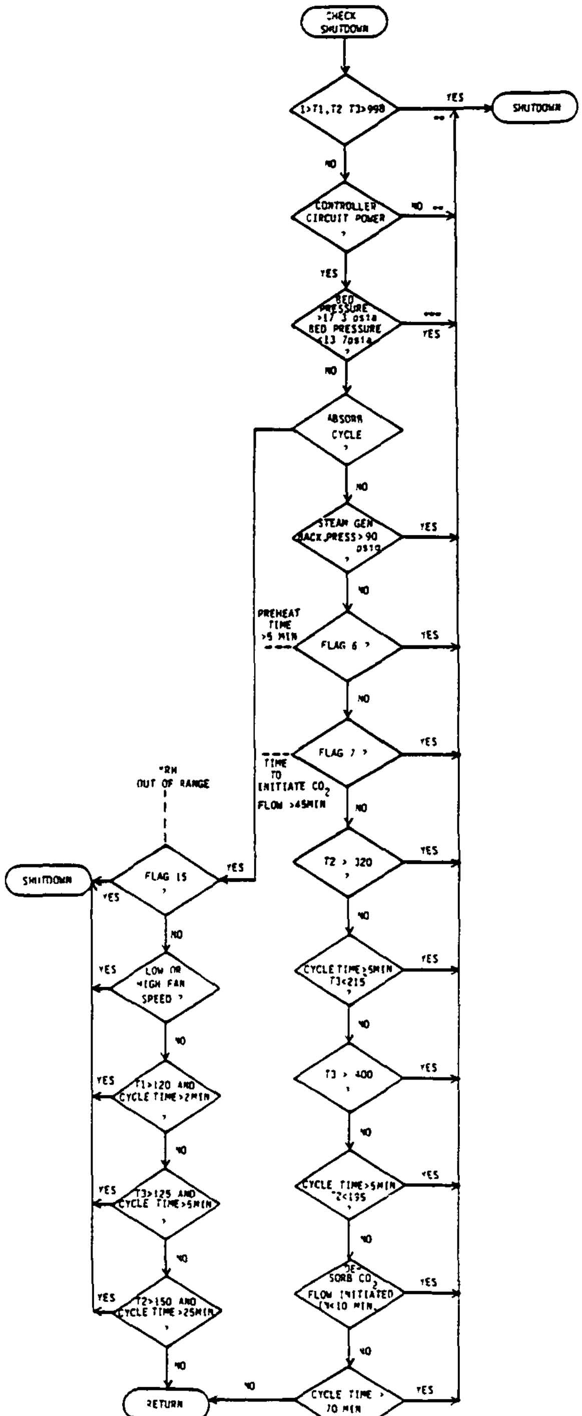


FIGURE 33

CO_2 DELIVERY SUBROUTINE



* ALL SHUTDOWNS RESULT IN AN APPROPRIATE SHUTDOWN MESSAGE BEING PRINTED ON HP-85 INTERNAL PRINTER
ALL SHUTDOWNS OCCURRING DURING AN ABSORPTION CYCLE RESULT IN IMMEDIATE SHUTDOWN
** IMMEDIATE SHUTDOWN
*** IMMEDIATE SHUTDOWN IF DURING AN ABSORPTION CYCLE

FIGURE 34

SHUTDOWN DETECTION SUBROUTINE*

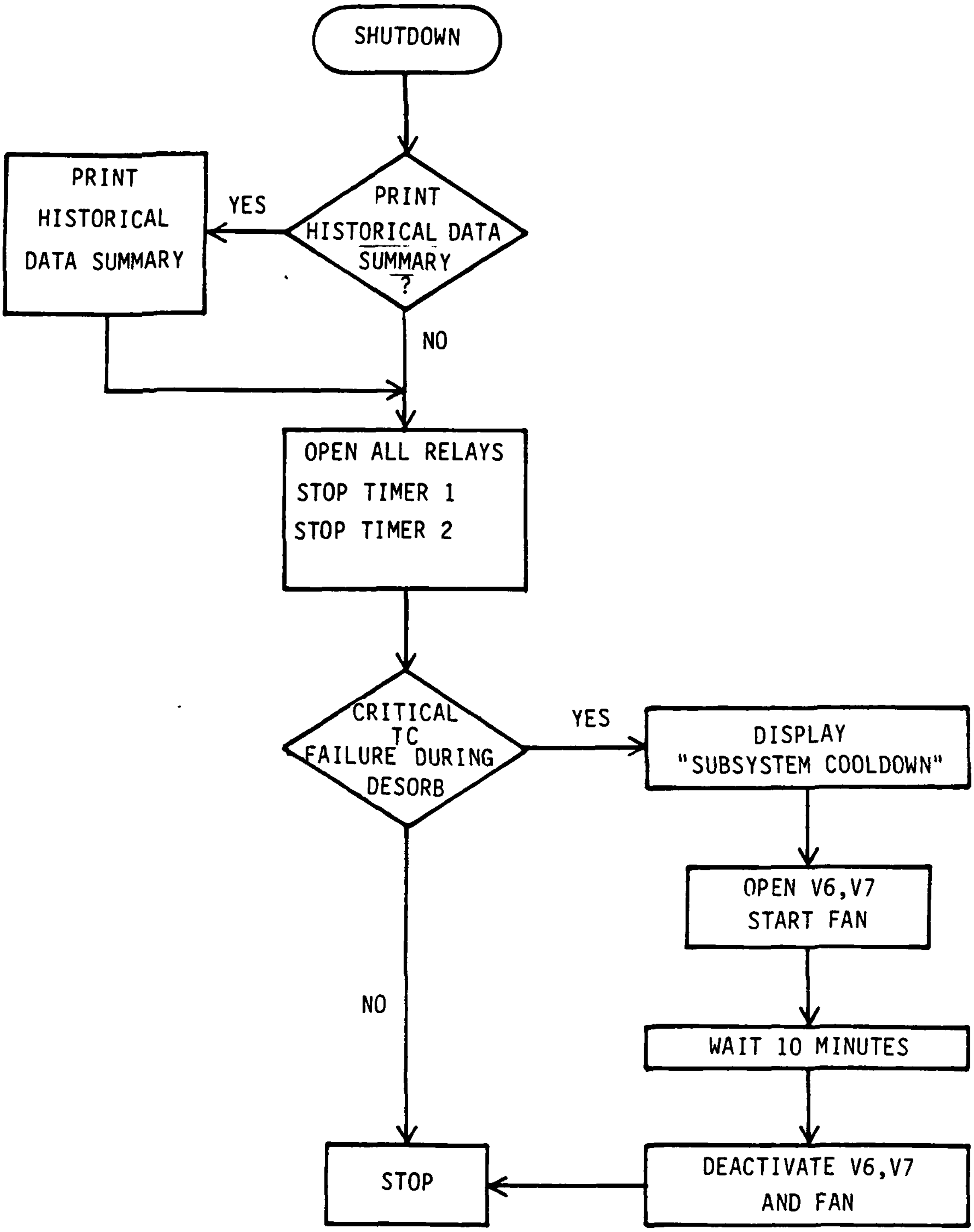


FIGURE 35
SHUTDOWN SUBROUTINE

Table 15

SUBSYSTEM START-UP ANOMOLIES

Inlet Air Temperature	T1 > 150°F
Header Temperature	T2 > 300°F
Outlet Temperature	T3 > 350°F
Pressure Switch P2 Is Closed	

Desorption phase DES1 is initiated when the controller signals the application of power to the steam generator. The primary control parameter during DES1 is the header temperature T2. A header temperature greater than 54.4°C (130°F) is sufficient to generate steam of 100% quality at 100°C (212°F). When the header temperature exceeds 54.4°C (130°F), the controller terminates DES1 and initiates DES2.

Desorption phase DES2 begins upon the completion of DES1. The primary control parameter during DES2 is the CO_2 flow-induced pressure difference across the desorb air vent solenoid valve, V3. The pressure switch, P2, is activated when the pressure difference across V3 exceeds 2.49 kPa (10 inches of H_2O). This increase in pressure is due to a flow through V3 exceeding approximately 1.42 l/min (0.05 cfm) and is indicative of CO_2 flow initiation from the sorbent bed. When this occurs, all trapped air has been purged from the canister header and the sorbent bed, and pure CO_2 is being evolved from the amine. The activation of P2 signals the end of DES2.

Desorption phase DES3 is activated by the controller at the completion of DES2. The primary control parameter during DES3 is the outlet steam temperature, T1. Toward the end of DES3, the steam wave approaches the outlet surface of the sorbent bed resulting in a rapid increase in temperature at T1. When T1 reaches 65.5°C (150°F), an end of desorb command is activated by the controller which signals the end of DES3. A typical desorption flow profile showing DES2 and DES3 is shown in Figure 36. Performance data, in the format illustrated by Figure 36, are printed at the end of desorption, if the required instrumentation (electronic scale and CO_2 mass flow meter) and an external printer are incorporated in the test setup. At this point, desorption is terminated and the controller activates an absorption.

Absorption is activated upon completion of desorption. The logic diagram for SAWD operation during absorption was presented in Figure 30. The primary control parameter during absorption is the inlet air relative humidity. The absorption time varies as a function of the inlet air relative humidity. The specific design relationship between absorption duration and inlet relative humidity was presented in Figure 24. However, during the early stages of operational development, the air flow transient presented in Figure 37 was established. This fan flow rate characteristic results when the amine bed moisture content decreases from the wet condition that exists immediately after desorption to a moisture level near the design operating condition. The reduced flow characteristic predicates a longer adsorption duration to expose the amine to the proper amount of air. Accordingly, the relative humidity related control parameter during absorption shifts slightly, as is shown in Figure 38.

The SAWD airflow rate, as a function of pressure drop, is presented in Figure 39. This characteristic is shown for two fans and three levels of moisture content. The first fan experienced bearing failure after about 50 hours of operation and was replaced by the second fan. The second fan experienced bearing failure after between 100-200 hours of operation. These fan bearings are believed to have contained Beacon 325 as a lubricant and to have been aged by about 10 years of shelf life. The fan manufacturer now incorporates Mobil 28 as the standard bearing lubricant, and recommends (and supplies the bearings with) Syncolon lubricant for moist air applications with that fan. Bearings, lubricated with Mobil 28, were procured and used in the second fan for the acceptance tests.

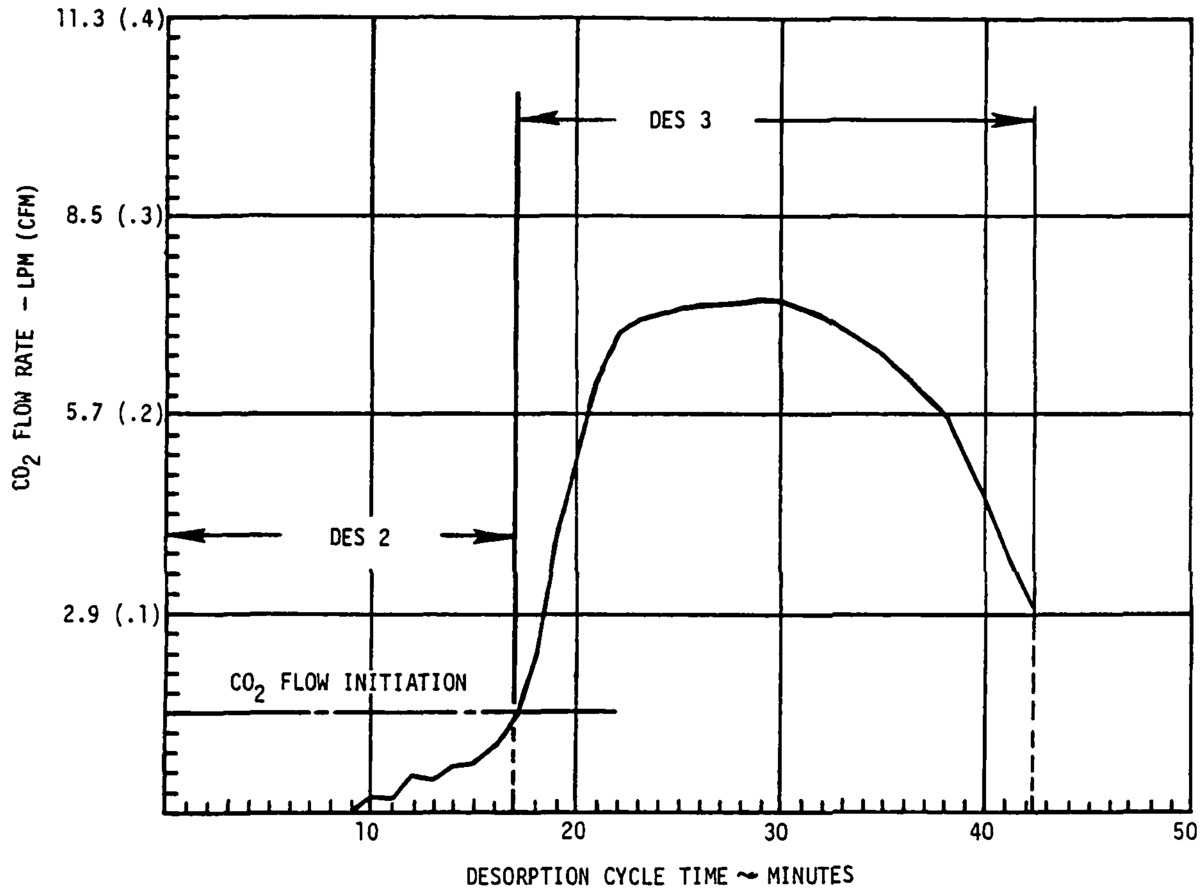


FIGURE 36

TYPICAL DESORPTION FLOW PROFILE

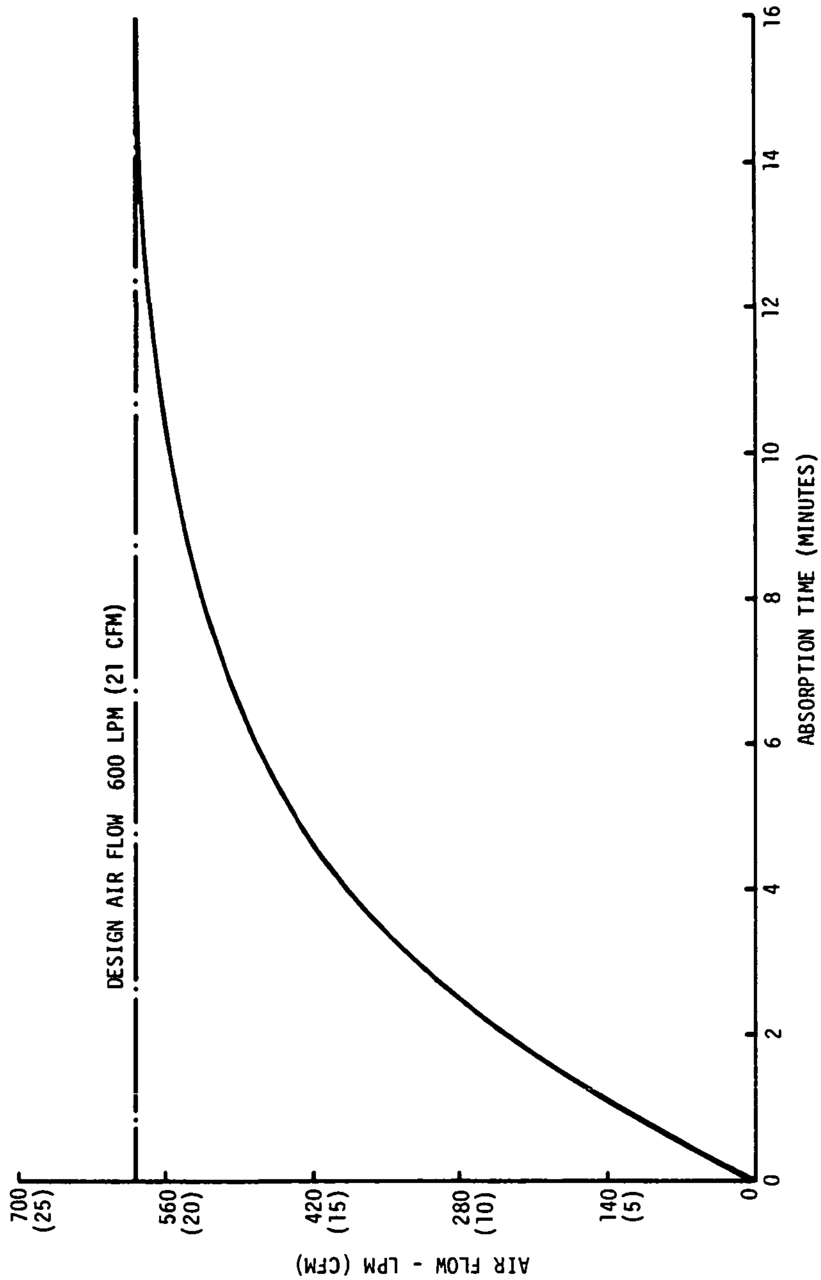


FIGURE 37

ABSORPTION CYCLE FLOW TRANSIENT

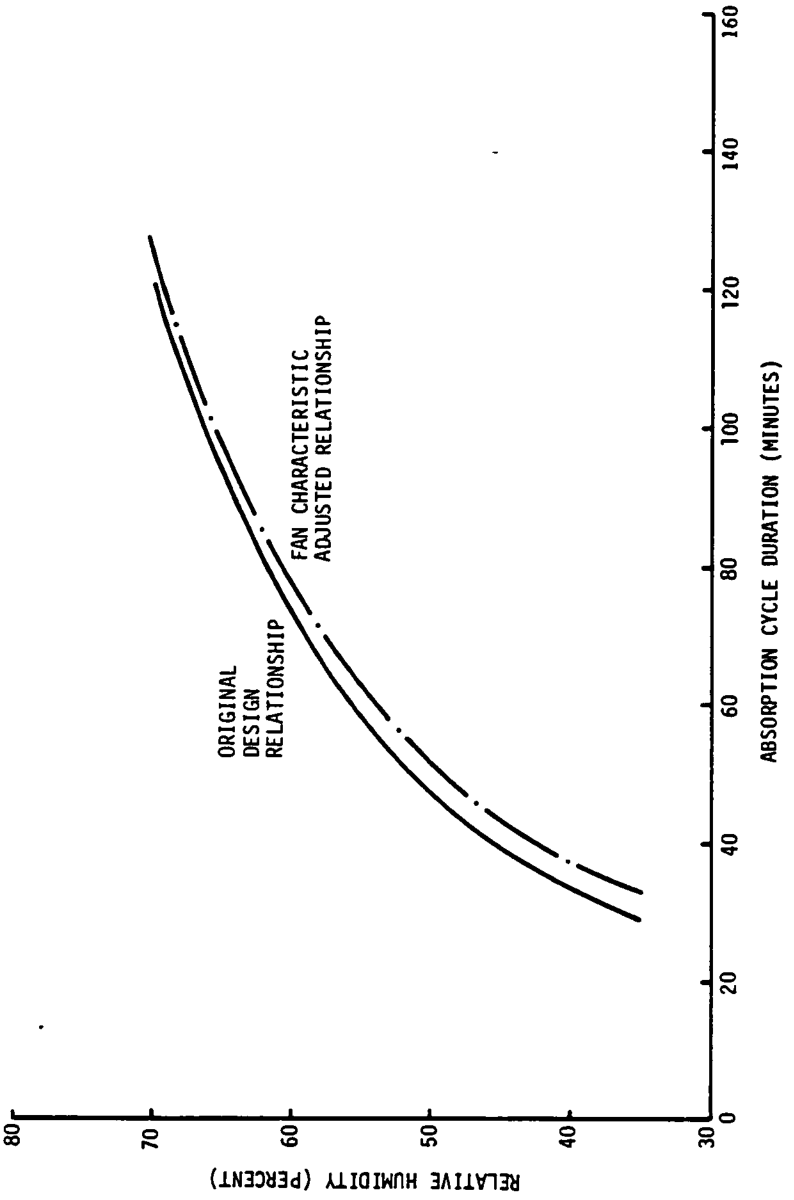


FIGURE 38

ABSORPTION CYCLE CONTROL RELATIONSHIP

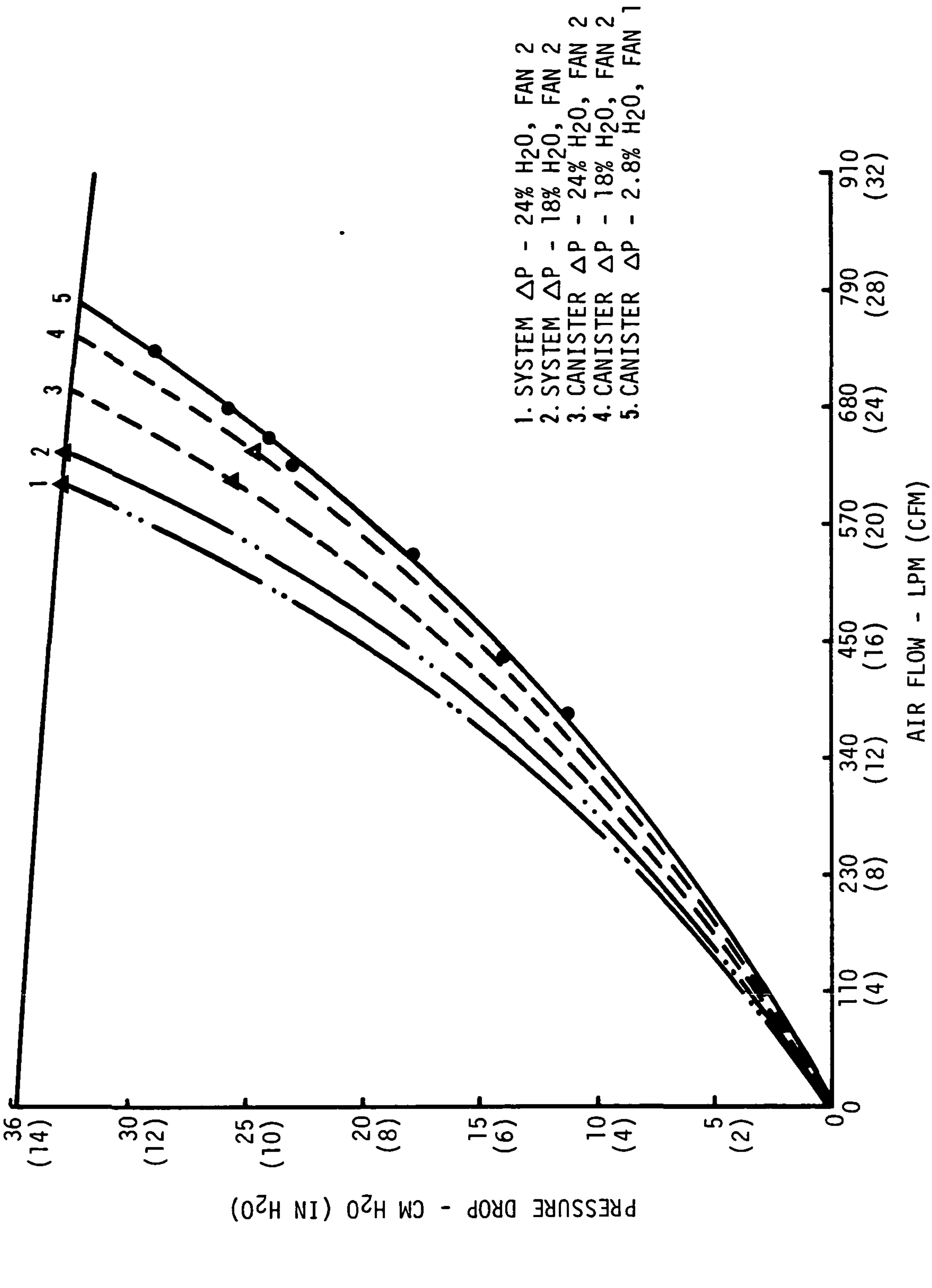


FIGURE 39

SAWD AIR FLOW vs PRESSURE DROP CHARACTERISTIC

The absorb subroutine (Reference Figure 30) continually recalculates the absorption duration as a function of the average relative humidity experienced during the current absorption and compares the calculated time to the measured operating time. When the calculated absorption time equals or exceeds the actual time of operation in absorb, the controller concludes absorption. This controller relationship maintains the sorbent bed moisture content level between 22-26 percent. The controller directs SAWD operation into the desorption phase again upon completion of absorption.

Automatic Shutdown Control - The logic diagrams for the shutdown detection and shutdown subroutines are presented in Figures 34 and 35, respectively. These subroutines cause the SAWD subsystem to shutdown to a safe hold condition when one of the sensors incurs an out-of-limits reading. The occurrence of an automatic shutdown causes the output (to the external printer) of a record of all sensor readings for the 15 minute period preceding the shutdown. Tables 16 and 17 illustrate typical automatic shutdown records for absorption and desorption, respectively. This data record also identifies the instant of occurrence and the shutdown number. The shutdown number identifies the sensing element that triggered the shutdown and the possible component malfunction that caused the out-of-limits sensor reading. There are twenty programmed automatic shutdowns which are defined in Table 18. Table 19 presents a complete description of the triggering sensors, the type of sensor, location, and the parameter sensed.

CO_2 Storage/Delivery Control - The control of CO_2 storage and delivery is governed by the high and low pressure switches, P4 and P3 respectively. This operational mode must initially be manually selected by placing the CO_2 Delivery Mode switch (located on the controller display panel) in the CO_2 reduction position.

The CO_2 accumulator is sized to accommodate the CO_2 that is evolved during desorption at a rate greater than 0.12 kg/hr (0.264 lb/hr). Storage, therefore, only occurs during that period of the desorption phase when the CO_2 evolution rate exceeds 0.12 kg/hr. Delivery of the CO_2 to the CO_2 reduction system can be initiated at any time that the accumulator pressure is at or above 262 kPa (38 psia) and is activated by the high pressure switch, P4. The delivery of CO_2 continues until the low pressure switch, P3, is activated at 138 kPa (20 psia). Under normal operating conditions, with delivery initiated at an accumulator pressure above 262 kPa (38 psia), the low pressure switch is never activated. The logic diagram for the CO_2 delivery subroutine is presented on Figure 33.

TABLE 16

SAWD HISTORICAL DATA SUMMARY

TEST NUMBER 102

SAWD AUTO SHUTDOWN-ABSORPTION CYCLE- 10
TIME INTO CYCLE,min: 5.5
SHUTDOWN NUMBER- 4
DATE 01/10/1983
TIME 11:10:40

MINUTES BEFORE SHUTDOWN	SAWD TEMPERATURES,DEGF T1	T2	T3	T4	T5	T6	T7	T8	INLET AIR DEW POINT DEGF	FAN SPEED SENSOR READING	SAWD BED PRESSURE PSIA
1	68.3	202.4	138.4	71.9	78.7	86.0	94.1	103.0	60.4	793	14.8
2	68.3	212.8	155.4	74.7	85.7	95.3	105.4	115.3	60.4	794	14.8
3	68.3	223.1	172.7	80.9	95.6	106.6	110.1	120.5	60.7	796	14.8
4	68.9	238.1	198.7	97.8	115.6	120.1	140.5	149.5	60.8	797	15.6
5	75.2	254.9	229.5	131.1	150.5	161.3	170.1	175.5	60.7	800	15.6
6	193.5	267.7	267.5	208.9	209.8	209.8	209.3	209.5	60.8	0	15.6
7	91.1	267.8	330.2	215.1	215.2	215.1	214.7	214.6	60.8	0	15.8
8	89.2	267.7	331.9	215.5	215.7	215.6	215.2	215.1	61.0	0	15.9
9	88.6	267.6	334.4	215.5	215.9	215.9	215.5	215.4	60.9	0	16.0
10	88.0	267.5	337.3	215.1	215.8	215.9	215.5	215.4	60.7	0	16.0
11	87.6	267.6	337.3	213.9	215.8	215.9	215.5	215.4	60.3	0	16.0
12	87.0	267.4	335.7	205.6	215.7	215.9	215.5	215.4	60.2	0	16.0
13	86.2	267.2	336.0	171.3	215.5	215.8	215.5	215.4	60.3	0	16.0
14	85.5	267.0	338.4	137.8	215.3	215.8	215.5	215.3	60.4	0	16.0
15	84.9	267.1	336.1	123.6	215.1	215.8	215.5	215.4	60.5	0	16.0

TABLE 17

SAWD HISTORICAL DATA SUMMARY
TEST NUMBER 103

SAWD AUTO SHUTDOWN-DESORPTION CYCLE- 11
TIME INTO CYCLE,min: 5.1
SHUTDOWN NUMBER- 9
DATE 01/12/1984
TIME 07:57:07

MINUTES BEFORE SHUTDOWN	SAWD TEMPERATURES,DEGF								INLET AIR DEW POINT DEGF	FAN SPEED SENSOR READING	SAWD BED PRESSURE PSIA
	T1	T2	T3	T4	T5	T6	T7	T8			
1	71.6	231.4	214.1	72.4	70.2	65.5	61.5	100.2	52.8	0	15.1
2	71.6	226.2	214.1	72.4	70.3	65.5	61.2	80.4	52.8	0	15.1
3	71.7	221.5	214.1	72.3	70.2	65.5	61.0	72.9	52.8	0	15.2
4	71.8	213.7	214.3	72.2	70.3	65.6	60.8	67.4	52.8	0	15.0
5	71.9	181.4	297.6	72.5	70.4	66.0	60.9	64.4	52.8	0	15.0
6	72.1	134.8	163.1	72.1	70.2	65.8	60.6	62.3	52.9	0	15.0
7	72.8	83.7	64.6	72.0	70.2	66.4	60.1	61.1	52.8	790	15.0
8	72.7	84.3	64.7	72.0	70.2	66.3	60.2	61.2	52.8	790	15.0
9	72.7	84.9	64.8	71.9	70.1	66.3	60.3	61.3	52.8	730	15.0
10	72.8	85.8	65.0	71.9	70.0	66.3	60.3	61.4	52.8	789	15.0
11	72.8	86.6	65.1	71.8	70.0	66.3	60.4	61.5	52.8	789	15.0
12	72.8	87.3	65.1	71.8	70.0	66.2	60.5	61.6	52.8	789	15.0
13	72.8	88.3	65.3	71.7	69.9	66.2	60.6	61.7	52.8	790	15.0
14	72.8	89.1	65.4	71.7	69.9	66.2	60.7	61.8	52.8	789	15.0
15	72.8	89.9	65.5	71.7	69.9	66.1	60.8	61.9	52.8	789	15.0

Table 18

AUTOMATIC SHUTDOWN DEFINITION

SD NO.	SHUTDOWN MESSAGE -CRT DISPLAY	CYCLE PHASE	SENSING ELEMENT	POSSIBLE COMPONENT MALFUNCTION
1	Desorb Time < 10 Min.	DES3	T1	T1 Reading Low
2	Critical TC Failure	ALL	T1,2,3	TC Open Circuit
3	Water Pressure > 90 psi	DES2,3	P5	G1 Blockage
4	Inlet Air RH Range	ABS	DP,T1	--
5	Controller Circuit	ALL	-	Bite Circuitry Peripheral Not Responsive
6	Preheat Time > 5 Min.	DES1	T2	G1 Heat Low F2 On Early C2 Circuit
7	CO_2 Flow Start > 45 Min.	DES2	P2	G1 Heat Low F2 On Early V6 Open V7 Open V4 Open V1 Failed Closed
8	Header Temp. > 320°F	DES2 DES3	T2	F2 Flow Low C2 Circuit
9	Steam Temp. < 215°F	DES2 DES3	T3	G1 Heat Low F2 Flow High V6 Open V7 Open V1 Failed Closed C2 Circuit
10	Steam Temp. > 400°F	DES2 DES3	T3	F2 Flow Low C2 Circuit
11	Header Temp. < 195°F	DES2 DES3	T2	G1 Heat Low F2 Flow High V6 Open V7 Open V1 Failed Closed C2 Circuit

Table 18 (Continued)

AUTOMATIC SHUTDOWN DEFINITION

SD NO.	SHUTDOWN MESSAGE -CRT DISPLAY	CYCLE PHASE	SENSING ELEMENT	POSSIBLE COMPONENT MALFUNCTION
12	Bed Pressure > 17.3 psi	DES1,2	P1	P2 Failed Open V3 Failed Closed R1 Set High
		DES3 O'B'D	P1	V4 Failed Closed R1 Set High
		DES3 RED	P1	F3 Failed Off V2 Failed Closed V9 Failed Closed R1 Set High
13	Bed Pressure < 13.7 psi	ALL	P1	F3 Failed On R1 Set Low
14	CO_2 Flow Start < 10 Min.	DES2	P2	G1 Heat High F2 Flow Low V3 Failed Closed
15	Desorb Time > 70 Min.	DES3	T1	G1 Heat Low F2 Flow High
16	Low Fan Speed	ABS	N	F1 Motor, Bearings
17	High Fan Speed	ABS	N	F1 Motor, Power
18	Inlet Air Temp. > 120°F After 2 Min.	ABS	T1	G1 On F1 Failed Off V6 Closed V7 Closed V1 Failed Open C2 Circuit
19	Outlet Air Temp. > 125°F After 5 Min.	ABS	T3	G1 On F1 Failed Off V6 Closed V7 Closed V1 Failed Open C2 Circuit
20	Header Temp. > 150°F After 25 Min.	ABS	T2	G1 On F1 Failed Off V6 Closed V7 Closed V1 Failed Open C2 Circuit

TABLE 19

SENSORS TRIGGERING AUTOMATIC SHUTDOWNS

Sensor Identification		Type	Location	Parameter Sensed
DP	Ambient Air Dewpointer	---	External	Dew Point Temperature
N	Fan Rotational Speed Sensor	Magnetic Coil	Fan Motor Housing	F1 Air Fan Speed
P1	Sorbent Bed Pressure Transducer	Capacitive, 0-5VDC	CO_2 Desorb Line	Bed Air/Steam Pressure
P2	High Pressure Switch Desorb Air Vent	Mechanical Switch	Desorb Air Vent Line	CO_2 Flow-Induced Pressure
P5	High Pressure Switch Water Pump	Mechanical Switch	Water Feed Line	Flow Restriction-Induced Pressure
T1	Inlet Air Temperature Sensor	Thermocouple Type T	Bed Air Inlet	ABS - Inlet Air Temp. DES - Outlet Steam Temp.
T2	Header Temperature Sensor	Thermocouple Type T	Canister Inlet Header	Header Temperature
T3	Outlet Air Temperature Sensor	Thermocouple Type T	Bed Air Outlet	ABS - Outlet Air Temp. DES - Steam Temp.

SUBSYSTEM ACCEPTANCE TESTS

Objective

The purpose of the preprototype SAWD subsystem acceptance tests is to verify the following specific operational requirements:

1. The ability of the SAWD to provide a CO_2 removal capability at the rate of 0.12 kg/hr (0.264 lb/hr) over the 35 to 70% relative humidity range.

2. The abililty of the SAWD to provide CO_2 delivery in the CO_2 reduction mode at the rate of 0.12 kg/hr (0.264 lb/hr) over the 35 to 70% relative humidity range.

3. The ability of the controller software to automatically control the SAWD subsystem operation over the 35 to 70% relative humidity range.

The cumulative acceptance test duration is to be a minimum of 120 hours, with the CO_2 storage/delivery package operated for a minimum of ten cycles in the CO_2 reduction mode to verify the compatibility of the integrated subsystem. The testing is to be in accordance with the following tabulated test conditions.

Test Conditions

Inlet CO_2 Level (mmHg)	Inlet Relative Humidity (%)	Inlet Temperature (°F)	Minimum Test Duration (hr)
3.8	35	72	24
3.8	50	72	72
3.8	70	72	24

Summary

The preprototype SAWD subsystem demonstrated a total of 281 hours (208 cycles) of operation during ten acceptance tests that were conducted over the 35 to 70% relative humidity range. This operation was comprised of 178 hours (128 cycles) in the CO_2 overboard mode and 103 hours (80 cycles) in the CO_2 reduction mode. The average CO_2 removal/delivery rate met or exceeded the design specification rate of 0.12 kg/hr (0.264 lb/hr) for all ten of the acceptance tests. The data from these tests are summarized on Table 20 and the individual data sheets for each acceptance test are presented in Tables 21 through 28.

The controller demonstrated the ability to automatically control operation of the SAWD subsystem over the 35 to 70% relative humidity range. The amine moisture content was maintained within the design range of 22-26% moisture for all tests, except nine cycles of Test 105, where the moisture content dropped to slightly below 21%.

Table 20

SAWD ACCEPTANCE TESTS

ACCEPTANCE TEST SUMMARY

Test	Inlet CO_2 Level (mmHg)	Relative Humidity (%)	Average CO_2 Process Rate [kg/hr(lb/hr)]	Total Cycles	Total Hours	CO_2 Delivery Mode
101	3.8	51.8	0.143(0.315)	24	38.4	Overboard
102-A	3.8	61.2	0.139(0.305)	3	6.2	Overboard
102-B	3.8	64.6	0.132(0.290)	10	18.8	Overboard
102-C	3.8	67.9	0.122(0.269)	10	25.3	Overboard
104	3.8	37.1	0.122(0.268)	15	18.1	Overboard
105	3.8	36.8	0.121(0.266)	22	24.5	Overboard
106	3.8	35.3	0.125(0.276)	44	47.0	Overboard
			Subtotal	128	178.0	Overboard
103	3.8	50.0	0.127(0.279)	27	39.2	Reduction
107	3.8	34.8	0.121(0.266)	35	37.7	Reduction
108	3.8	51.4	0.123(0.270)	18	26.5	Reduction
			Subtotal	80	103.0	Reduction
			Total	208 Cycles	281 Hours	

TABLE 21

ACCEPTANCE TEST NO. 101
12/19/1983

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 52degF
RELATIVE HUMIDITY 50%
FLOW RATE 21cfm
pCO_2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	51.1	53.3	39.9	23.0	3.18	0.309	1.6
2	51.5	54.2	40.2	23.0	3.28	0.315	3.2
3	52.0	55.1	40.2	23.1	3.30	0.313	4.8
4	51.7	54.5	40.3	23.2	3.29	0.314	6.4
5	51.8	54.7	40.3	23.3	3.26	0.311	8.1
6	52.0	55.1	40.5	23.2	3.32	0.314	9.7
7	51.5	54.0	40.2	23.4	3.25	0.312	11.3
8	52.2	55.4	40.5	23.2	3.34	0.315	12.9
9	52.3	55.8	40.4	23.4	3.34	0.314	14.6
10	51.8	54.7	39.9	23.3	3.28	0.314	16.2
11	51.6	54.4	38.4	24.0	3.23	0.314	17.8
12	53.0	57.2	38.9	23.7	3.37	0.318	19.4
13	51.3	53.6	38.6	24.1	3.24	0.318	21.0
14	52.3	55.6	38.1	23.9	3.28	0.317	22.6
15	51.7	54.5	38.1	23.7	3.24	0.317	24.2
16	51.8	54.7	38.3	23.6	3.26	0.317	25.8
17	51.3	53.6	38.3	23.5	3.20	0.315	27.3
18	51.5	54.0	37.8	23.5	3.22	0.318	28.9
19	51.4	53.7	37.8	23.3	3.22	0.319	30.5
20	51.7	54.4	37.8	23.2	3.23	0.317	32.0
21	51.3	53.5	38.1	23.2	3.21	0.318	33.6
22	51.8	54.7	37.9	23.2	3.22	0.315	35.2
23	52.0	55.1	37.9	23.0	3.26	0.317	36.8
24	52.3	55.6	38.1	22.9	3.26	0.315	38.4

TABLE 22

ACCEPTANCE TEST NO. 102
12/21/1983

DESIRED TEST CONDITIONS:

TEMPERATURE	72degF
DEW POINT	60degF
RELATIVE HUMIDITY	70%
FLOW RATE	21cfm
pCO2 LEVEL	3.8mmHg

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	59.2	74.0	40.6	25.6	3.99	0.316	2.0
2	61.4	81.6	39.9	25.0	4.04	0.303	4.0
3	63.0	88.2	40.3	24.4	4.18	0.296	6.2

ACCEPTANCE TEST NO. 102
01/08/1984

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	59.9	76.5	36.9	24.5	3.90	0.313	1.9
2	62.8	87.3	36.8	24.3	4.10	0.300	4.0
3	66.2	102.8	37.1	23.9	4.32	0.281	6.4
4	67.0	107.1	37.4	23.6	4.38	0.276	8.9
5	66.9	106.5	37.4	23.7	4.39	0.278	11.3
6	43.6	42.0	30.2	26.4	.31	0.039	12.5
7	62.0	84.4	29.6	25.7	.44	0.035	14.5
8	62.5	86.0	29.6	24.8	.47	0.037	16.4
9	44.4	43.1	29.7	24.4	.27	0.033	17.7
10	34.7	33.2	28.3	24.6	.18	0.026	18.8

ACCEPTANCE TEST NO. 102
01/09/1983

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	70.4	126.5	36.7	22.5	4.21	0.235	2.8
2	67.0	107.2	36.6	22.7	4.23	0.268	5.2
3	68.2	113.8	36.9	22.9	4.37	0.264	7.8
4	67.7	110.8	37.2	23.2	4.38	0.270	10.3
5	67.5	109.6	37.7	23.8	4.43	0.274	12.8
6	66.8	105.8	37.7	24.3	4.38	0.278	15.2
7	67.2	108.3	37.9	24.6	4.43	0.277	17.7
8	67.9	111.9	38.1	24.6	4.48	0.272	20.2
9	68.7	116.7	38.0	24.6	4.48	0.264	22.8
10	67.8	105.7	37.9	24.6	4.46	0.283	25.3

TABLE 23

ACCEPTANCE TEST NO. 103
01/12/1984

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 52degF
RELATIVE HUMIDITY 50%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	49.9	51.1	33.7	N/A	N/A	0.280	1.5
2	50.8	52.8	33.9	N/A	N/A	0.259	2.9
3	51.2	53.7	34.2	N/A	N/A	0.258	4.4
4	50.6	52.5	33.8	N/A	N/A	0.268	5.9
5	49.8	51.0	33.9	N/A	N/A	0.269	7.4
6	49.6	50.7	33.9	N/A	N/A	0.263	8.8
7	49.5	50.4	34.0	N/A	N/A	0.262	10.3
8	49.1	49.7	34.0	N/A	N/A	0.265	11.7
9	48.9	49.5	33.8	N/A	N/A	0.275	13.1
10	49.0	49.7	33.8	N/A	N/A	0.285	14.5
11	49.3	50.0	34.0	N/A	N/A	0.291	16.0
12	49.0	49.8	34.1	N/A	N/A	0.295	17.4
13	49.0	49.7	33.8	N/A	N/A	0.296	18.8
14	48.8	49.5	33.8	N/A	N/A	0.298	20.3
15	50.8	52.7	33.7	N/A	N/A	0.268	21.8
16	51.3	53.7	33.6	N/A	N/A	0.268	23.3
17	50.8	52.8	33.3	N/A	N/A	0.272	24.7
18	50.3	51.9	33.4	N/A	N/A	0.269	26.2
19	50.4	52.1	33.1	N/A	N/A	0.287	27.7
20	50.5	52.2	33.3	N/A	N/A	0.285	29.1
21	49.6	50.6	32.9	N/A	N/A	0.290	30.6
22	49.7	50.9	32.8	N/A	N/A	0.288	32.0
23	50.1	51.6	32.8	N/A	N/A	0.288	33.4
24	49.8	50.9	32.6	N/A	N/A	0.289	34.9
25	50.3	51.9	32.6	N/A	N/A	0.288	36.3
26	50.6	52.5	32.5	N/A	N/A	0.287	37.8
27	50.4	51.9	32.6	N/A	N/A	0.286	39.2

TABLE 24

ACCEPTANCE TEST NO. 104
01/03/1984

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 45degF
RELATIVE HUMIDITY 37%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	36.1	34.4	36.5	26.1	2.23	0.285	1.2
2	36.1	34.4	36.3	26.2	2.15	0.269	2.4
3	36.3	34.6	36.1	26.2	2.16	0.278	3.6
4	37.2	35.5	35.8	25.9	2.18	0.277	4.8
5	37.6	35.7	35.6	26.0	2.17	0.275	6.0
6	37.5	35.7	35.5	26.0	2.16	0.274	7.3
7	37.3	35.5	35.5	26.2	2.11	0.269	8.5
8	37.4	35.7	35.3	26.4	2.10	0.268	9.7
9	37.3	35.5	35.3	26.0	2.08	0.266	10.9
10	37.2	35.5	36.1	25.8	2.07	0.262	12.1
11	37.2	35.5	35.5	25.6	2.06	0.262	13.3
12	37.2	35.5	35.0	25.3	2.03	0.259	14.5
13	37.5	35.7	34.9	25.2	2.05	0.262	15.7
14	36.9	35.3	34.7	24.9	1.99	0.257	16.9
15	36.9	35.3	34.9	24.5	2.02	0.260	18.1

TABLE 25

ACCEPTANCE TEST NO. 105
01/04/1984

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 44degF
RELATIVE HUMIDITY 37%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	36.6	34.8	33.1	23.3	1.99	0.262	1.2
2	37.8	35.9	33.1	23.2	2.08	0.271	2.4
3	37.3	33.5	31.8	23.3	1.94	0.268	3.5
4	36.3	32.6	31.6	23.1	1.93	0.272	4.6
5	36.3	32.6	31.4	23.0	1.86	0.262	5.7
6	36.6	33.0	31.6	22.8	1.94	0.270	6.8
7	36.7	33.0	31.4	22.8	1.87	0.262	7.9
8	36.7	33.0	31.7	22.6	1.92	0.268	9.0
9	37.0	33.2	31.7	22.6	1.90	0.264	10.1
10	36.7	33.0	32.4	22.4	1.92	0.264	11.2
11	36.5	32.8	31.4	22.3	1.91	0.268	12.3
12	36.4	32.8	32.4	22.1	1.89	0.261	13.4
13	36.5	32.7	31.4	21.8	1.86	0.261	14.5
14	36.7	33.0	31.4	21.7	1.94	0.272	15.6
15	36.9	33.2	31.4	21.5	1.94	0.270	16.8
16	36.8	33.0	31.1	21.4	1.90	0.267	17.9
17	36.6	32.7	32.4	21.2	1.92	0.266	19.0
18	36.9	33.2	31.4	21.1	1.92	0.268	20.1
19	36.8	33.0	31.4	21.0	1.94	0.272	21.2
20	36.6	32.8	31.4	21.1	1.79	0.251	22.3
21	37.1	33.4	31.4	20.9	1.88	0.261	23.4
22	36.7	33.0	31.3	20.8	1.87	0.262	24.5

TABLE 26

ACCEPTANCE TEST NO. 106
01/14/1984

DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 44degF
RELATIVE HUMIDITY 36%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	37.0	35.4	31.8	25.3	2.26	0.303	1.2
2	35.5	33.8	31.7	25.8	2.18	0.300	2.3
3	35.6	33.8	31.7	26.1	2.15	0.296	3.4
4	35.2	33.5	31.6	25.9	2.12	0.293	4.5
5	35.5	33.8	31.7	26.3	2.05	0.282	5.6
6	35.5	33.8	31.7	26.2	2.09	0.288	6.8
7	35.4	33.8	31.8	26.2	2.13	0.293	7.9
8	35.3	33.8	31.7	26.2	2.08	0.287	9.0
9	35.2	33.5	31.7	26.2	2.09	0.289	10.1
10	35.3	33.8	31.7	26.1	2.08	0.287	11.2
11	35.0	33.2	31.4	26.2	2.00	0.279	12.4
12	35.0	33.2	31.4	26.2	2.00	0.278	13.5
13	34.9	33.3	31.5	26.0	2.05	0.285	14.6
14	35.1	33.5	31.4	26.1	2.00	0.278	15.7
15	34.9	33.3	31.2	26.0	1.96	0.274	16.8
16	35.0	33.2	31.1	25.9	1.96	0.274	17.9
17	35.1	33.5	31.2	25.9	1.97	0.274	19.0
18	35.0	33.5	31.1	25.8	1.96	0.273	20.1
19	34.9	33.3	30.9	25.6	1.94	0.272	21.2
20	34.7	33.0	30.9	25.6	1.94	0.273	22.3
21	34.8	33.2	30.9	25.5	1.96	0.275	23.4
22	34.5	32.9	30.7	25.4	1.92	0.272	24.5
23	35.2	33.5	30.8	25.1	1.98	0.278	25.6
24	36.0	28.4	30.1	25.4	1.73	0.266	26.6
25	35.5	27.8	30.4	25.3	1.75	0.271	27.6
26	36.2	28.6	30.1	25.5	1.68	0.258	28.6
27	35.5	27.8	30.1	25.5	1.73	0.269	29.6
28	36.0	28.4	30.4	25.5	1.79	0.275	30.6
29	35.5	27.8	30.4	25.5	1.73	0.268	31.6
30	35.5	27.8	30.4	25.5	1.72	0.267	32.6
31	35.3	27.6	30.4	25.8	1.72	0.268	33.6
32	34.9	27.3	30 4	26.0	1.67	0.262	34.6
33	34.9	27.4	30.4	26.1	1.71	0.267	35.6
34	35.0	29.4	30.8	26.0	1.81	0.271	36.6
35	35.0	29.4	30.8	26.1	1.81	0.270	37.6
36	35.2	29.4	30.8	26.2	1.79	0.268	38.7
37	35.2	29.7	30.8	26.3	1.81	0.269	39.7
38	35.3	29.7	30.8	26.3	1.81	0.269	40.7
39	35.0	29.4	31.0	26.3	1.82	0.272	41.8
40	35.1	29.4	30.8	26.5	1.78	0.267	42.8
41	35.3	29.7	30.8	26.5	1.80	0.268	43.8
42	35.3	29.7	30.8	26.5	1.80	0.267	44.9
43	35.3	29.7	30.8	26.5	1.81	0.269	45.9
44	35.3	30.5	30.9	26.2	1.82	0.267	47.0

TABLE 27

ACCEPTANCE TEST NO. 107
01/16/1984

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 44degF
RELATIVE HUMIDITY 36%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	36.4	34.9	30.6	N/A	N/A	0.252	1.1
2	36.0	34.6	30.3	N/A	N/A	0.250	2.2
3	35.9	34.3	30.0	N/A	N/A	0.250	3.3
4	35.8	34.3	30.3	N/A	N/A	0.250	4.5
5	35.5	33.9	30.1	N/A	N/A	0.250	5.6
6	35.2	33.6	29.8	N/A	N/A	0.250	6.6
7	35.2	33.7	29.6	N/A	N/A	0.250	7.7
8	35.3	33.7	29.6	N/A	N/A	0.250	8.8
9	35.2	33.6	29.5	N/A	N/A	0.251	9.9
10	34.9	33.4	29.6	N/A	N/A	0.251	11.0
11	35.4	33.7	29.6	N/A	N/A	0.251	12.1
12	35.1	33.7	29.6	N/A	N/A	0.251	13.2
13	34.8	33.0	29.4	N/A	N/A	0.253	14.2
14	34.9	33.4	29.6	N/A	N/A	0.268	15.3
15	34.6	33.0	29.3	N/A	N/A	0.265	16.4
16	35.1	33.4	29.4	N/A	N/A	0.265	17.5
17	34.7	33.0	29.5	N/A	N/A	0.265	18.5
18	34.6	33.0	29.6	N/A	N/A	0.265	19.6
19	35.0	33.4	29.5	N/A	N/A	0.266	20.7
20	34.9	33.3	29.3	N/A	N/A	0.265	21.8
21	34.4	32.9	29.5	N/A	N/A	0.265	22.8
22	34.3	32.9	29.6	N/A	N/A	0.266	23.9
23	34.1	32.6	29.2	N/A	N/A	0.266	25.0
24	34.3	32.8	29.1	N/A	N/A	0.266	26.0
25	34.3	32.8	29.2	N/A	N/A	0.266	27.1
26	34.4	32.7	29.2	N/A	N/A	0.267	28.2
27	34.2	32.7	29.2	N/A	N/A	0.267	29.2
28	34.0	32.4	28.9	N/A	N/A	0.268	30.3
29	33.9	32.4	28.9	N/A	N/A	0.266	31.3
30	34.1	32.4	28.7	N/A	N/A	0.266	32.4
31	34.2	32.7	28.9	N/A	N/A	0.266	33.4
32	34.1	32.7	28.7	N/A	N/A	0.266	34.5
33	34.1	32.7	28.9	N/A	N/A	0.266	35.6
34	34.0	32.4	28.7	N/A	N/A	0.267	36.6
35	33.9	32.4	28.9	N/A	N/A	0.267	37.7

TABLE 28

ACCEPTANCE TEST NO. 108
01/19/1984

****
DESIRED TEST CONDITIONS:
TEMPERATURE 72degF
DEW POINT 44degF
RELATIVE HUMIDITY 35%
FLOW RATE 21cfm
pCO2 LEVEL 3.8mmHg
****

CYCLE NO.	AVG. %RH	CYCLE TIME (min) AB	DE	BED LOADING (lb/lb dry amine) %H2O	%CO2	CO2 REMOVAL RATE (lb/hr)	ACCUMULATED TIME (hrs)
1	44.1	42.8	30.2	N/A	N/A	0.000	1.3
2	45.0	44.0	29.7	N/A	N/A	0.007	2.5
3	46.8	46.2	29.6	N/A	N/A	0.269	3.8
4	47.4	47.1	30.0	N/A	N/A	0.269	5.1
5	46.3	45.6	30.5	N/A	N/A	0.270	6.4
6	45.5	44.6	30.5	N/A	N/A	0.274	7.7
7	55.1	62.3	31.6	N/A	N/A	0.270	9.3
8	56.7	66.4	32.1	N/A	N/A	0.262	11.0
9	56.1	64.6	31.8	N/A	N/A	0.261	12.6
10	55.3	62.8	31.9	N/A	N/A	0.261	14.3
11	55.0	62.0	31.9	N/A	N/A	0.261	15.9
12	54.1	59.8	31.9	N/A	N/A	0.263	17.4
13	53.9	59.2	31.7	N/A	N/A	0.266	19.0
14	52.4	55.9	31.5	N/A	N/A	0.271	20.5
15	51.7	54.7	31.5	N/A	N/A	0.276	21.9
16	52.4	56.0	31.6	N/A	N/A	0.284	23.4
17	53.7	58.6	32.1	N/A	N/A	0.290	25.0
18	52.9	57.1	31.6	N/A	N/A	0.277	26.5

The controller demonstrated the ability to monitor subsystem operation, detect malfunctions, and shutdown the SAWD to a safe hold condition. This capability was verified for all twenty of the programmed shutdowns that were defined in the Operation/Control section.

Test Description

The SAWD subsystem testing was accomplished in conjunction with the Multipurpose Air Rig (Rig 88), which is shown by schematic in Figure 40. The Multipurpose Air Rig was used to supply air at the desired conditions of temperature, relative humidity, and CO_2 concentration. This test rig is independently controlled to maintain the desired SAWD inlet conditions at a nearly constant level and can operate unattended for up to four days continuously.

All acceptance testing was accomplished with the CO_2 removal package seated upon an electronic scale, which allowed measurement of the amine bed weight change, and with the desorbed CO_2 flow routed through a CO_2 mass flow meter. The CO_2 flow meter was used to measure the CO_2 loading on the amine bed. This measurement of CO_2 loading, in conjunction with the weight reading from the electronic scale, permitted calculation of the moisture content of the amine bed. Therefore the incorporation of these two instruments provided the data required to continuously establish the operating performance level of the SAWD subsystem. Table 21 illustrates the operating performance results that are computed by the controller software and output at the end of each cycle via an external printer that was employed during the acceptance tests.

All acceptance tests were conducted with the air inlet filter, I1, and the exhaust silencer, E1, installed to demonstrate the design performance specifications are met with the preprototype SAWD subsystem configuration that is to be evaluated in the CSD Life Test Laboratory.

Each acceptance test was initiated with the normal start-up procedure and terminated with the normal shutdown sequence. Therefore all acceptance tests were conducted with fully automatic control directed by the controller, until an end of test sequence command was input from the computer keyboard. The cyclic performance data was printed at the end of each full SAWD cycle (absorption plus desorption) and these performance data are presented in Tables 21 through 28.

Discussion of Results

The preprototype SAWD subsystem demonstrated CO_2 removal/delivery performance at or above the design specification performance level for a total of 281 hours (208 cycles) of operation, in both the CO_2 overboard and CO_2 reduction modes, over the 35 to 70% relative humidity range. Table 20 presents a summary of these acceptance test results. The data for each individual acceptance test are presented in Tables 21 through 28.

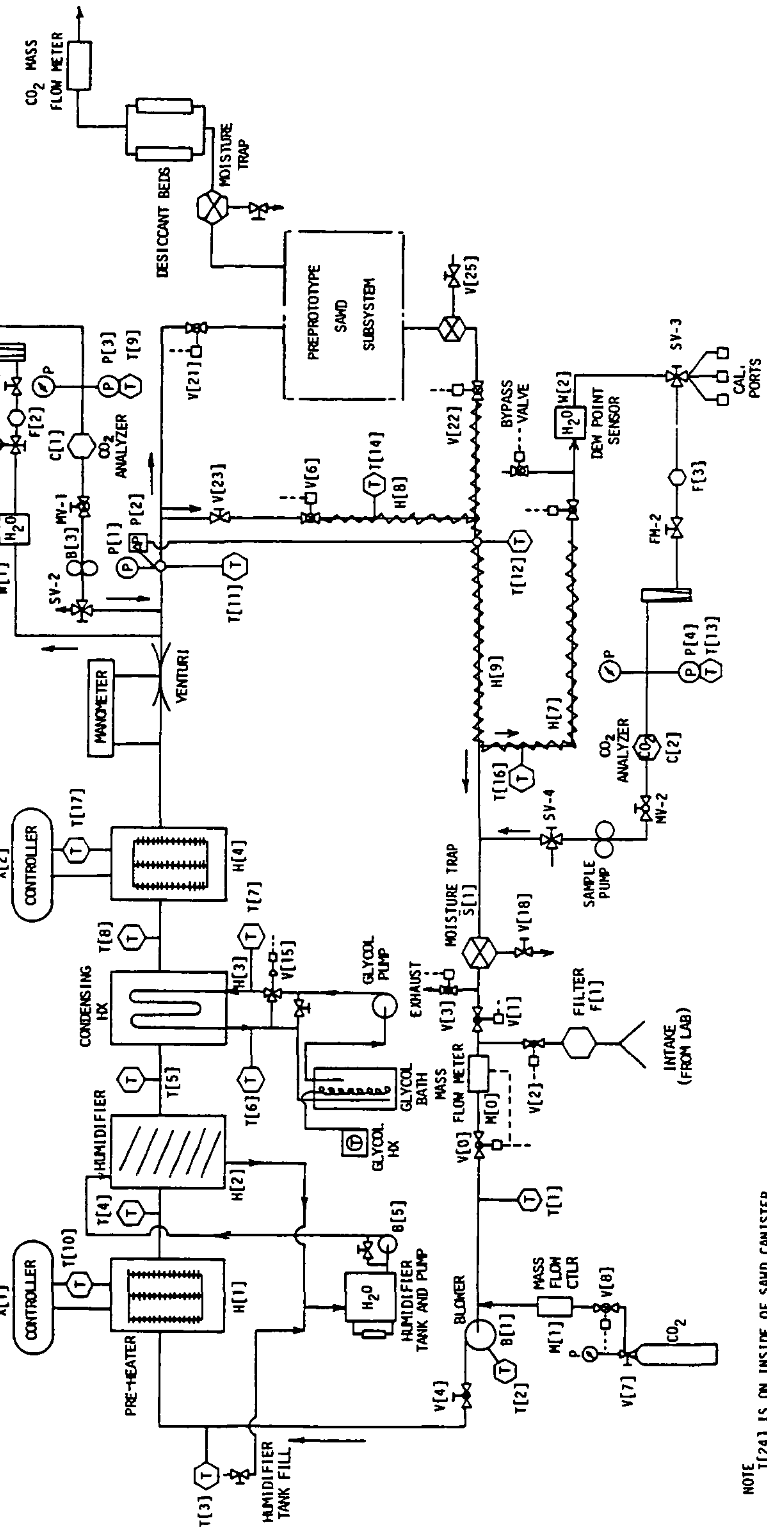


FIGURE 40

MULTIPURPOSE AIR RIG (RIG 88)

The individual acceptance test data sheets tabulate the average relative humidity, the absorption and desorption durations, the moisture content, CO_2 loading, CO_2 removal rate, and accumulated operating time for each cycle of operation. The relative humidity values are calculated from the inlet air dew point and the canister inlet temperature, T1. The absorption time is calculated from the control algorithm, as a function of the average relative humidity experience during the absorption itself. The desorption duration is the sum of DES2 (time from end of preheat, DES1, to the initiation of CO_2 flow) and DES3 (time from the initiation of CO_2 flow to the termination of the desorption cycle). The total cycle duration is the sum of ABS (absorption time), DES1 (steam generator preheat time), DES2, and DES3. The CO_2 removal rate, for operation in the CO_2 overboard mode, is calculated from the CO_2 loading and the total cycle duration. (Average CO_2 removal rate equals CO_2 loading multiplied by dry amine weight divided by the total cycle duration.) For operation in the CO_2 reduction mode, the CO_2 removal rate is the average CO_2 delivery rate (over the total cycle duration) from the accumulator. During operation in the CO_2 reduction mode, the CO_2 flow meter was mounted at the accumulator outlet and the flow rate is therefore directly measured. Because this precludes direct measurement of the CO_2 loading on the amine (and therefore also precludes calculation of the bed moisture content), the symbol "N/A" for not applicable is printed in the Bed Loading columns for SAWD operation in the CO_2 reduction mode.

<u>CO_2 Overboard Mode Operation</u> - Acceptance tests 101, 102, 104, 105, and 106 present the data for operation in the CO_2 overboard mode and the average performance of these data are shown in Table 29. These data are representative of SAWD subsystem operation over the design range of relative humidity from 35 to 70% and demonstrate attainment of the design performance level for a total of 178 hours (128 cycles). A comparison of these acceptance test results with the predicted preprototype SAWD subsystem performance is presented in Figure 41. The plotted acceptance test points are the overall averages that are presented in Table 29. These performance averages show very good correlation with the predicted performance for the SAWD subsystem.

The data from Tests 104, 105, and 106 demonstrate several significant details regarding SAWD performance, which are:

1. The SAWD subsystem response, in terms of bed moisture content stability to changes in the ambient relative humidity is extremely slow.

2. Essentially no CO_2 removal performance degradation occurs as a result of the slow moisture content return to steady state conditions.

3. The moisture content of the SAWD is quite sensitive to relatively small absorption duration changes during operation at 35% relative humidity conditions.

Table 29

AVERAGE ACCEPTANCE TEST PERFORMANCE

(Averages Of The Data For Each Cycle)

Test	Relative Humidity (%)	Moisture Content (%)	CO_2 Removal Rate [kg/hr(lb/hr)]	Absorption Duration (min.)
101	51.8	23.4	0.143(0.315)	54.6
102-A	61.2	25.0	0.139(0.305)	81.3
102-B	64.6	24.0	0.132(0.290)	96.0
102-C	67.9	23.8	0.122(0.269)	112.0
104	37.1	25.8	0.122(0.268)	35.3
105	36.8	22.1	0.121(0.266)	33.2
106	35.3	25.9	0.125(0.276)	31.3

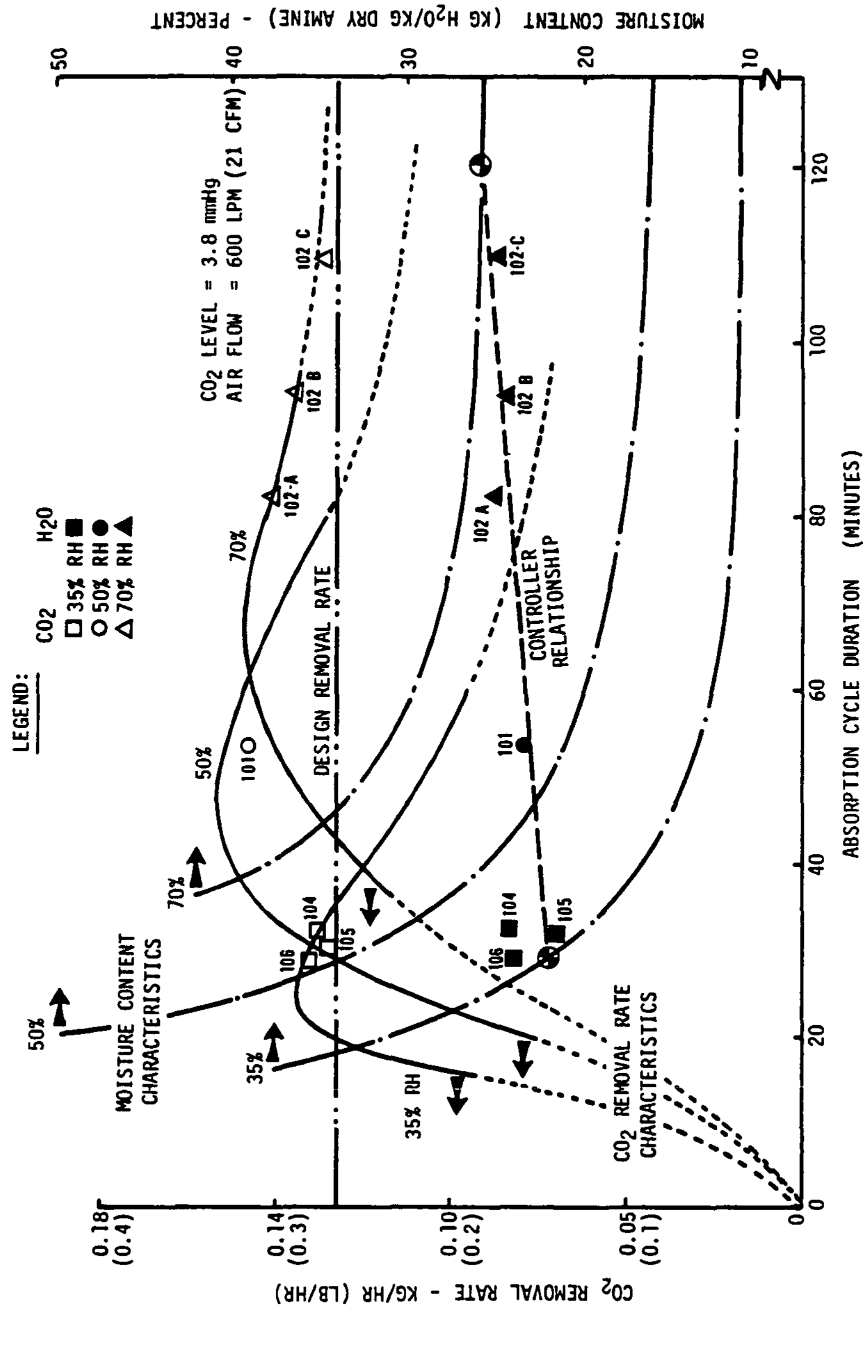


FIGURE 41

CYCLIC SAWD PERFORMANCE

Test 105 can be viewed as a continuation of Test 104 and Test 106 as a repeat of Test 104. Examination of the Test 104 data (which began with a 26% moisture content that is representative of operation at 70% relative humidity conditions) revealed that steady state moisture content conditions had not yet been achieved. The moisture content had decreased from 26% to 24.5%, but had not stabilized. The Test 105 data show a further moisture content decrease from 23.3% to 20.8 during 24.5 hours of operation. However, throughout this period of operation (42.6 hours total), the CO_2 performance remained at or above the design specification level. Test 106 began with a moisture content near 26% and appeared to be trending downward after 24-25 hours of operation (25.1% àt cycle 23). At this time the absorption duration was reduced by six (6) minutes. Ten hours later (cycle 33) it was observed that the moisture content was increasing, and the absorption duration reduction was changed to shorten absorption by only four (4) minutes. Operation under these conditions held the moisture content essentially steady at slightly above 26% for the remainder of Test 106. The average CO_2 removal performance throughout these tests (89.6 hours total) was 0.124 kg/hr (0.272 lb/hr). The specific performance that resulted from the absorption duration variations during Test 106 is summarized in the following tabulation.

Test	Cycle	% RH	% H_2O	CO_2 Removal Rate [kg/hr (lb/hr)]	Absorption Duration (min.)
106	1-23	35.2	25.9	0.128(0.283)	33.5
106	24-33	35.5	25.6	0.121(0.267)	27.9
106	34-43	35.2	26.3	0.122(0.269)	29.6

While conducting Test 102-B, the test rig humidity control and CO_2 supply ceased to operate during the sixth cycle. For the remainder of the test, the relative humidity flucuated between 62-35% and only ambient CO_2 levels were supplied to the SAWD. For this period (7.5 hours total), the SAWD subsystem demonstrated the ability to maintain the bed moisture content stable while the inlet conditions were highly unstable.

<u>CO_2 Reduction Mode Operation</u> - Acceptance tests 103, 107, and 108 were conducted with SAWD operation in the CO_2 reduction mode. These tests were run for a total of 103 hours (80 cycles) over the relative humidity range from 35-51%. The data from these tests are shown in Tables 23, 27 and 28, and are summarized on Table 20.

Because the CO_2 flow meter was located downstream of the accumulator, the CO_2 process rates, shown in Table 20, are the average CO_2 flow rate from the accumulator during the entire cycle (absorption plus desorption duration). Therefore, no meaningful direct comparison of actual SAWD performance with predicted performance can be made on Figure 41. However, the average CO_2 delivery rate met or exceeded the design specification for CO_2 delivery for all three tests.

The data for Test 107, which was conducted at 35% relative humidity show a CO_2 delivery rate of 0.114 kg/hr (0.25 lb/hr) for the first 13 cycles (14.2 hours) of operation. This occurred because the delivery rate was not adjusted until cycle 14. After adjustment at cycle 14, the CO_2 delivery rate remained above specification for the final 23.5 hours (22 cycles) of the test.

Acceptance Test 108 was conducted with a transient inlet dew point (and therefore transient inlet relative humidity) to evaluate CO_2 delivery performance under variable relative humidity conditions. The overall relative humidity variation was between 44.1 and 56.7%. In addition, the test was initiated with the accumulator pressure at 101 kPa (14.7 psia) to determine the number of cycles needed to initiate CO_2 delivery. The data, shown on Table 28, show CO_2 delivery began near the end of the second cycle and was essentially at the design delivery rate thereafter. The average CO_2 delivery rate for the test was 0.123 kg/hr (0.270 lb/hr) for the sixteen cycles of CO_2 delivery and 0.11 kg/hr (0.24 lb/hr) for the entire test. These data show that two full cycles of SAWD operation raise the accumulator to 262 kPa (38 psia) and initiate CO_2 delivery.

Fan Noise Evaluation - The design objective specified for fan noise is for noise suppression to less than 70 dB at 3 feet from the SAWD subsystem when operated in an open air loop.

The fan noise measurements are presented in Figure 42 and data are plotted for both open and closed loop SAWD operation. The open loop testing was conducted with the inlet air filter (I1) and air outlet silencer (E1) installed. The closed loop measurements were taken with the fan exhaust plumbed to the fan inlet.

Subjective noise evaluation was conducted with a variety of muffler arrangements and no significant noise reduction was observed beyond the suppression provided by a single muffler. The single muffler installation resulted in noise level reduction to 77.7 dB "A". The major noise contribution is due to that at the blade passing frequency and only a noise level reduction at this frequency will further reduce the overall noise level.

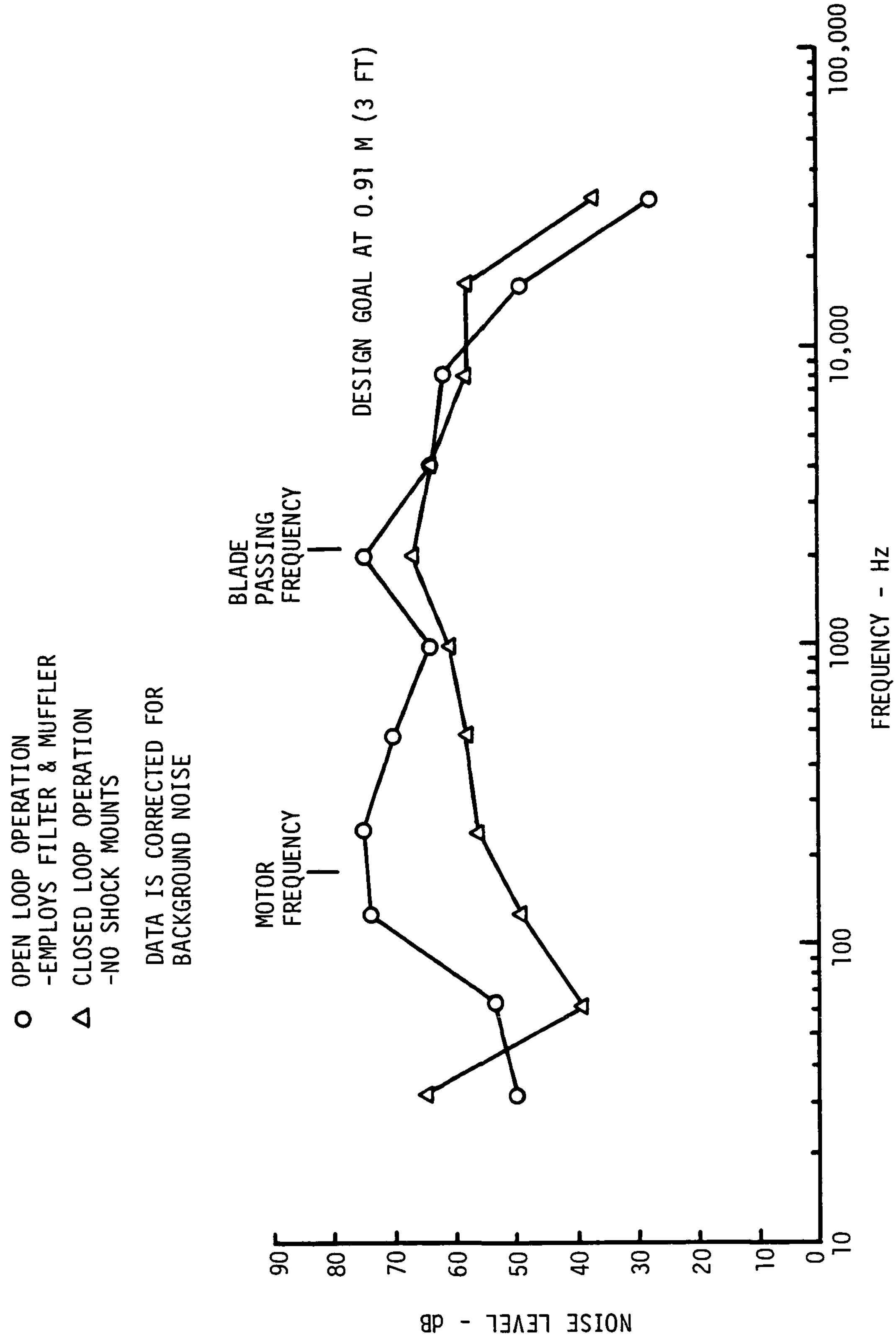


FIGURE 42

FAN NOISE MEASUREMENTS

APPENDIX A

Statement of Work

The following modifications to the subject contract amended the Statement of Work to provide for a Preprototype SAWD Subsystem. Modification 32S added the design, fabrication, testing and delivery of the Preprototype SAWD subsystem to the contract. Modifications 33S and 34S implemented modification of the SAWD subsystem's preprototype canister, incorporation of monitoring instrumentation and controller capabilities, and the reduction of airborne noise (by the design and fabrication of a subsystem fan enclosure). Modification 35C incorporated hardware and software modifications to allow the SAWD subsystem to operate in the CSD Life Test Laboratory. Modification 35C also provided for engineering support on the installation and initial start-up of the SAWD subsystem in the CSD's Life Test Lab.

STANDARD FORM 30, JULY 1966
GENERAL SERVICES ADMINISTRATION
FED PROC REG (41 CFR) 1-16 101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO	4. PROJECT NO. (If applicable)
32S	12-23-81	1-161-020 (Complete)	

5. ISSUED BY CODE
NASA Johnson Space Center
R&T Procurement Branch
Attn: Faye Henry/BC72(6)
Houston, TX 77058

6. ADMINISTERED BY (If other than block 5) CODE
Same

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS (Street, city, county, state, and ZIP Code)
Hamilton Standard Division
United Technologies Corporation
Attn: Dave Hennessey
Windsor Locks, CT 06096

8.
☐ AMENDMENT OF SOLICITATION NO. ____
DATED ____ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS 9-13624
DATED 8-01-73 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)
906-54-13-01-EC-2511-EC31
802/30108 Increase: L.O.G.O. $99,905.10 PPC:DK

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ____
The Changes set forth in block 12 are made to the above numbered contract/order

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of The Changes Clause, Limitation of Government's Obligation Clause, and agreement of the parties.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

(a) ARTICLE I - SCOPE OF WORK - is amended to read as follows:

The contractor shall furnish all necessary personnel, facilities, equipment, and materials to perform the work set forth in Exhibit "A," Statement of Work, as modified by the attached addendum dated April 22, 1981, attached hereto and made a part of this contract. The attached addendum modifies the current Statement of Work to provide for a Preprototype SAWD Subsystem.

The Preprototype SAWD Subsystem is to be designed, built, acceptance tested and delivered to NASA, JSC in accordance with the attached addendum to the SOW. Contract end items for the Preprototype SAWD Subsystem are as follows:

(1) Preprototype SAWD Subsystem
(2) Installation/Operations Manual
(3) Applicable drawings and specifications

Except as provided herein, all terms and conditions of the document referenced in block 8 as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY William O. Horner
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY James W. Wilson
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
William O. Horner Manager-Contracts Administration	3/30/82	James W. Wilson	APR 2 1982

30-101

NASA-JSC

3.2.7.11: Preprototype SAWD Support - The contractor shall provide up to 5 days service as JSC within a period of 6 months subsequent to subsystem delivery for the purposes of test support, integration, and interface demonstration.

Change Figure 1, Work Breakdown Structure, to read:

9.0 Final Report (See SOW Section 3.2.6, 3.2.7.5, 3.2.7.6).

Delete the current contents and substitute the following in lieu thereof in Figure 1, Work Breakdown Structure:

13 Preprototype SAWD System

14 Preprototype SAWD Test

15 Preprototype SAWD Documentation

16 Preprototype SAWD Subsystem Delivery

17 Preprototype SAWD Support

EXHIBIT "A"

STATEMENT OF WORK ADDENDUM 4-22-81

Delete the current SOW contents of paragraphs 3.2.7.7 through 3.2.7.11 and substitute the following in lieu thereof.

3.2.7.7: Preprototype SAWD System - The preprototype SAWD CO_2 removal system shall be designed and built based on a 3-man nominal metabolic load, 3.8 mmHg CO_2 level. The system must be capable of operating in either a CO_2 dump mode or a continuous CO_2 feed to a Sabatier CO_2 reduction subsystem mode. The system shall be designed to fit within a 22 inch wide X 24.5 inch high X 31 inch deep envelope exclusive of the remotely located controller and CO_2 accumulator. The system shall be capable of integrating with the existing air supply unit located in CSD's Development Laboratory. The system shall use one of the existing preprototype SAWD canisters and steam generator assemblies. The system controller and other ancillary components shall be defined as required.

3.2.7.8: Preprototype SAWD Test - A minimum of 120 hours of accumulated test time shall be utilized to conduct tests to verify operation of the system.

3.2.7.9: Preprototype SAWD Documentation - The following documentation shall be submitted as defined by the program schedule:

- Installation and Operating Instructions: An installation and operating manual shall define system interfaces and operating procedures.
- Test Plan: A test plan shall define component and system checkout testing.
- Failure Modes and Effects Analysis (FMEA): An FMEA shall define the failure modes and resultant effects for the system.
- Non-metallics List: All non-metallics used in the system shall be defined as to type, quantity and exposed area exclusive of the remotely located cycle controller.
- Final Report: A Final Report shall describe the Preprototype SAWD System activity.

3.2.7.10: Preprototype Subsystem Delivery - At the conclusion of testing, the SAWD subsystem shall be inspected, refurbished as required, and prepared for shipment to JSC. Subsystem operating instructions and the drawings and specifications which are prepared for the manufacturing and purchase of this subsystem shall accompany this shipment of the hardware.

(b) ARTICLE II - COMPLETION OF WORK - is amended to read as follows:

Delete December 31, 1981, and substitute May 2, 1983.

(c) ARTICLE VIII - ESTIMATED COST AND FIXED FEE - is amended to read as follows:

"The estimated cost of this contract is $1,128,611.00, exclusive of the fixed fee of $79,935.00. The total estimated cost and fixed fee is $1,208,546.00."

(d) ARTICLE XVII - LIMITATION OF GOVERNMENT'S OBLIGATION - is marked "Reserved." This modification modifies and fully funds the contract.

(e) All references to Frank Collier as technical monitor shall be changed to:

Robert J. Cusick
EC3
X-3343

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GENERAL SERVICES ADMINISTRATION
FED. PROC. REG (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
33S	03-02-83	3-048-032 (Partial)	

5. ISSUED BY CODE
NASA Johnson Space Center
R&T Procurement Branch
Attn: Faye Henry/BC72(6)
Houston, TX 77058

6. ADMINISTERED BY (If other than block 5) CODE
Same

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS (Street, city, county, state, and ZIP Code)
Hamilton Standard Division
United Technologies Corporation
Attn: Dave Hennessey
Windsor Locks, CT 06096

8.
☐ AMENDMENT OF SOLICITATION NO. ______
DATED ______ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS 9-13624
DATED 08-01-73 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)
506-64-37-38-EC2511-EC31
803/40108 Increase: $25,000.00 PPC:DK

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ______
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of The Changes clause, Limitation of Cost Clause, and agreement of the parties.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

(a) The Contractor is hereby directed to implement the following changes to Exhibit "A," Statement of Work.

Add the following to SOW paragraph 3.2.7.7, Preprototype SAWD System:

- Modify the existing preprototype canister, SVSK103199, to incorporate temperature and pressure sensors compatible with interfacing with NASA's RLSE laboratory's data acquisition system. One (1) pressure and seven (7) temperature sensors shall be provided; temperature shall consist of air inlet, air outlet and five (5) bed sensors equally spaced in the axial direction.

- Incorporate adequate instrumentation and controller capability to monitor system operation, detect malfunctions, and shut down the system to a safe hold condition.

- Design and fabricate an enclosure for the subsystem fan to reduce airborne noise to less than 70 dB at 3 feet from the preprototype system.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY William O. Horner
(Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY ______
(Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
William O. Horner Manager-Contracts Administration	3/15/83		

- Update drawings and the Installationand Operating Manual to reflect above changes.

(b) For the pruposes of the clause entitled "Limitation of Cost," the Estimated Cost of the contract has been provisionally increased in the amount of $25,000.00. This provisional increase results from undefinitized contract changes resulting from Statement of Work changes contained in this modification.

The parties shall promptly hereafter enter into negotiations directed towards establishing the final negotiated dollar amount. Failure of the parties to agree with respect to the definitive estimated cost, shall be considered to be a dispute concerning a question of fact subject to the clause entitled "Disputes." Nothing in this modification shall be derogation of the contractor's right as set forth in the clause entitled "Limitation of Cost."

(c) The total estimated cost and fixed fee of this contract, inclusive of the provisional increase is as follows:

Estimated Cost	$1,128,611.00
Provisional Increase	25,000.00
Total Estimated Cost	$1,153,611.00
Fixed Fee	79,935.00
Total Estimated Cost and Fixed Fee	$1,233,546.00

(d) Pursuant to the Changes Clause, a technical and cost proposal shall be submitted within 30 days to cover the contractual impact of above SOW changes.

(e) ARTICLE II - COMPLETION OF WORK - is amended to read as follows:

Delete May 2, 1983, and substitute July 2, 1983.

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1. AMENDMENT/MODIFICATION NO. 34S	2. EFFECTIVE DATE 06-10-83	3. REQUISITION/PURCHASE REQUEST NO. (See Below)	4. PROJECT NO (If applicable)
5. ISSUED BY CODE NASA Johnson Space Center R&T Procurement Branch Attn: Faye Henry/BC72(6) Houston, TX 77058		6. ADMINISTERED BY (If other than block 5) CODE Same	

7. CONTRACTOR CODE FACILITY CODE
NAME AND ADDRESS (Street, city, county, state, and ZIP Code)

Hamilton Standard Division
United Technologies Corporation
Attn: Daniel C. Lee
Windsor Locks, CT 06096

8.
☐ AMENDMENT OF SOLICITATION NO. ________
DATED ________ (See block 9)
☐ MODIFICATION OF CONTRACT/ORDER NO. NAS 9-13624
DATED 08-01-73 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)

506-64-37-38-EC2511-EC31 (PR 3-048-032 - $15,000 - Complete) Increase: $15,320.00
506-64-37-31-EC2511-EC31 (PR 3-095-003 - $ 320.00 - Partial) 803/40108 PPC:DK

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☐ This Change Order is issued pursuant to ________
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☒ This Supplemental Agreement is entered into pursuant to authority of The Changes Clause, Limitation of Cost Clause, and agreement of the parties.
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

(a) This Supplemental Agreement No. 34S is executed to definitize and incorporate into the contract the final negotiated agreement resulting from Contract Modification 33S and Contractor's proposal No. HSC-HS-12 dated May 4, 1983. This Supplemental Agreement No. 34S represents a full and complete equitable adjustment.

(b) ARTICLE I - SCOPE OF WORK - is amended as follows:

Add the following to SOW paragraph 3.2.7.7, Preprototype SAWD System:

- Modify the existing preprototype canister, SVSK103199, to incorporate temperature and pressure sensors compatible with interfacing with NASA's RLSE laboratory's data acquisition system. One (1) pressure and seven (7) temperature sensors shall be provided; temperature shall consist of air inlet, air outlet and five (5) bed sensors equally spaced in the axial direction.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ~~☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT~~ ☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT ~~AND RETURN~~ 3 COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR		17. UNITED STATES OF AMERICA	
BY William O. Horner (Signature of person authorized to sign)		BY David F. Bruce (Signature of Contracting Officer)	
15. NAME AND TITLE OF SIGNER (Type or print) William O. Horner Manager-Contracts Administration	16. DATE SIGNED 6/28/83	18. NAME OF CONTRACTING OFFICER (Type or print) DAVID F. BRUCE	19. DATE SIGNED JUN 30 1983

NASA-JSC

- Incorporate adequate instrumentation and controller capability to monitor system operation, detect malfunctions, and shut down the system to a safe hold condition.

- Modify the subsystem fan installation to reduce airborne noise to less than 70 dB at 3 feet from the preprototype system.

- Update drawings and the Installation and Operating Manual to reflect above changes.

(c) ARTICLE II - COMPLETION OF WORK - is amended to read as follows:

Delete July 2, 1983, and substitute February 29, 1984.

(d) ARTICLE VIII - ESTIMATED COST AND FIXED FEE - is amended to read as follows:

"The estimated cost of this contract is $1,166,117.00, exclusive of the fixed fee of $82,749.00. The total estimated cost and fixed fee is $1,248,866.00."

The above represents an increase to the contract as follows:

Cost:	$37,506,00
Fee:	2,814.00
Total:	$40,320.00

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GENERAL SERVICES ADMINISTRATION
FED. PROC. REG. (41 CFR) 1-16.101

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

PAGE 1 OF 2

1. AMENDMENT/MODIFICATION NO.	2. EFFECTIVE DATE	3. REQUISITION/PURCHASE REQUEST NO.	4. PROJECT NO. (If applicable)
35C	12-1-83	3-307-043(Partial)	

5. ISSUED BY CODE
NASA Johnson Space Center
R&T Procurement Branch
Attn: Faye Henry/BC72(6)
Houston, TX 77058

6. ADMINISTERED BY (If other than block 5) CODE
Same

7. CONTRACTOR NAME AND ADDRESS (Street, city, county, state, and ZIP Code) CODE FACILITY CODE
Hamilton Standard Division
United Technologies Corporation
Attn: Gary Steinberg
Windsor Locks, CT 06096

8.
☐ AMENDMENT OF SOLICITATION NO. ________
DATED ________ (See block 9)
☒ MODIFICATION OF CONTRACT/ORDER NO. NAS 9-13624
DATED 8-1-73 (See block 11)

9. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 12. The hour and date specified for receipt of Offers ☐ is extended, ☐ is not extended.

Offerors must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended, by one of the following methods:

(a) By signing and returning ____ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If, by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

10. ACCOUNTING AND APPROPRIATION DATA (If required)
906-54-15-01-EC-2511-EC31 804/50108 Increase: $28,000.00 PPC:DK

11. THIS BLOCK APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS

(a) ☒ This Change Order is issued pursuant to The Changes clause, Limitation of Cost Clause
The Changes set forth in block 12 are made to the above numbered contract/order.

(b) ☐ The above numbered contract/order is modified to reflect the administrative changes (such as changes in paying office, appropriation data, etc.) set forth in block 12.

(c) ☐ This Supplemental Agreement is entered into pursuant to authority of ________
It modifies the above numbered contract as set forth in block 12.

12. DESCRIPTION OF AMENDMENT/MODIFICATION

a. The Contractor is hereby directed to implement the following changes to Exhibit "A," Statement of Work. Add the following to SOW paragraph 3.2.7.7.

- Modify the intake/exhaust system, incorporating a filter (not exceeding a 40u average particle size) to filter out airborne particulate matter and a muffler to suppress fan noise at less than 70 dB at 3 feet from the subsystem when operated in an open air loop.

- Design, fabricate, and install a mounting frame for the subsystem package to provide maintenance access to subsystem components.

- Provide the mechanical and electrical provisions for a dewpoint signal interface and modify necessary software to adjust cycle time and to automatically shut down the subsystem if dewpoint limits are exceeded.

Except as provided herein, all terms and conditions of the document referenced in block 8, as heretofore changed, remain unchanged and in full force and effect.

13. ☒ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT ☐ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN ____ COPIES TO ISSUING OFFICE

14. NAME OF CONTRACTOR/OFFEROR
BY ________ (Signature of person authorized to sign)

17. UNITED STATES OF AMERICA
BY Daryl W Chilcutt (Signature of Contracting Officer)

15. NAME AND TITLE OF SIGNER (Type or print)	16. DATE SIGNED	18. NAME OF CONTRACTING OFFICER (Type or print)	19. DATE SIGNED
		Daryl W. Chilcutt	12-6-83

30-101 NASA-JSC

- Provide and install a water pressure transducer along with software modifications to monitor and shut down the SAWD subsystem if water pressure at the steam generator input exceeds allowable levels.

- Modify the software to provide printout of a historical record of key instrumentation measurements over a reasonable time period.

- Undate the documentation to reflect changes.

- Provide engineering field support on the installation and operation of the SAWD subsystem in CSD's Life Test Laboratory.

b. For purposes of the clause entitled "Limitation of Cost," the estimated cost of this contract has been provisionally increased in the amount of $28,000.00. This provisional increase results from undefinitized contract changes resulting from Statement of Work changes authorized in this modification.

The parties shall promptly hereafter enter into negotiations directed towards establishing the final negotiated dollar amount. Failure of the parties to agree with respect to the definitive estimated cost shall be considered to be a dispute concerning a question of fact subject to the "Disputes" clause. Nothing in this modification shall be derogation of the contractor's rights as set forth in the "Limitation of Costs" clause.

c. The total estimated cost and fixed fee of this contract, inclusive of the provisional increase is as follows:

Estimated Cost	$1,166,117.00
Provisional Increase	28,000.00
Total Estimated Cost	$1,194,117.00
Fixed Fee .	82,749.00
Total Estimated Cost and Fixed Fee	$1,276,866.00

d. Pursuant to the Changes clause, a technical and cost proposal shall be submitted within 30 days to cover the contractual impact of above SOW changes.