JSC-09052

NASA CR-
140302

AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

PERFORMANCE MONITOR SYSTEM FUNCTIONAL SIMULATOR
ENVIRONMENTAL DATA
ORBITER 101 (HFT)

(NASA-TM-X-72028) PERFORMANCE MONITOR SYSTEM FUNCTIONAL SIMULATOR, ENVIRONMENTAL DATA, ORBITER 101(HFT) (NASA) 255 p HC $8.50 CSCL 14B

N75-10136

Unclas
G3/14 53454

DISTRIBUTION AND REFERENCING

[redacted]

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

May 1974

LEC-3093

JSC-09052

AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

PERFORMANCE MONITOR SYSTEM FUNCTIONAL SIMULATOR ENVIRONMENTAL DATA

ORBITER 101(HFT)

PREPARED BY

F. W. Parker

F.W. Parker, Staff Engineer

Lockheed Electronics Company, Inc.

APPROVED BY

Robert W. Moorehead

Robert W. Moorehead

Chief, Communications, Power, and Data Systems Branch

William C. Bradford

William C. Bradford

Chief, Avionics Systems Engineering Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS

May 1974

LEC-3093

PREFACE

This document provides information concerning the Environment component of the Space Shuttle Performance Monitor System Simulator (PMSS). The Shuttle Performance Monitor System (PMS) environment consists of the various vehicle subsystems which are monitored in flight. This document addresses those subsystems which will be operational on the Shuttle Orbiter 101 used for Horizontal Flight Test (HFT). For each of these subsystems which are monitored by PMS, functional paths have been identified and measurements listed which are necessary to adequately monitor the health status of the subsystem.

The primary goal of the PMSS is to provide a facility for systematic development and testing of functional software for the onboard Shuttle PMS. Three evolutionary stages of PMSS development will parallel the three major Shuttle Program development and test phases. These are the Horizontal Flight Test (Phase 1 PMSS), Vertical Flight Test (Phase 2 PMSS), and the Operational Flight Phase (Phase 3 PMSS).

ACKNOWLEDGEMENTS

This document was prepared by Lockheed Electronics Company, Inc., Aerospace Systems Division, Houston, Texas, for the Avionics Systems Engineering Division at the Johnson Space Center, under contract NAS 9-12200, Job Order 22-30. The following LEC personnel are acknowledged for their contributions to this document in the subsystems areas indicated.

Instrumentation	- R. G. Williams
Data Processing	- B. E. Carlton
ECLSS	- L. W. Lew
APU/Hydraulics	- J. R. Harris
Communications and Tracking	- E. E. Dodd
Electrical Power	- P. A. Smyth
Thermal Protection	- H. E. Phillips
Displays and Controls	- F. W. Parker

CONTENTS

CONTENTS

CONTENTS

FIGURES

FIGURES

FIGURES

TABLES

TABLES

TABLES

Note: After completion of this document, it was learned that the "Horizontal Flight Test" (HFT) program for Orbiter 101 has been redesignated "Atmospheric Flight Test" (AFT). All references to HFT in this document are equivalent to AFT.

ACRONYMS

ABE	Air Breathing Engine
AC	Alternating Current
ADTA	Air Data Transducer Assembly
APU	Auxiliary Power Unit
ARS	Atmospheric Revitalization System
ATCS	Active Thermal Control System
BCU	Bus Control Unit
BIT	Built-in Test
BITE	Build-in Test Equipment
BTC	Bus Tie Contactor
CRT	Cathode Ray Tube
C&TS	Communications and Tracking System
C&W	Caution and Warning
DACBU	Data Acquisition and Control Buffer Unit
DC	Direct Current
D&C	Display and Control
DEU	Display Electronic Unit
DFI	Development Flight Instrumentation
DPS	Data Processing System
ECLSS	Environmental Control and Life Support System
EPC	External Power Contactor
EPD&C	Electrical Power Distribution and Control
FC	Flight Control

FDA	Fault Detection and Annunciation
FDM	Frequency Division Multiplex
FM	Frequency Modulation
G&C	Guidance and Control
GCU	Generator Control Unit
G&N	Guidance and Navigation
GSE	Ground Support Equipment
HFT	Horizontal Flight Text
Hyd	Hydraulics
Hx	Heat Exchanger
ID	Identify
IMU	Inertial Measurement Unit
IOB	Input/Output Buffer
LEC	Lockheed Electronics Corporation
MDM	Multiplexer/Demultiplexer
MML	Master Measurement List
MPS	Main Propulsion System
MSBLS	Microwave Scan Beam Landing System
OFI,OI	Operational Flight Instrumentation
OMS	Orbital Maneuvering System
PMS	Performance Monitor System
PMSS	Performance Monitor Simulation System
RCS	Reaction Control System

RI	Rockwell International
SCM	Subsystem Configuration Management
SGLS	Space Ground Link System
SMM	Subsystem Measurement Management
SRB	Solid Rocket Booster
SSME	Space Shuttle Main Engine
STDN	Satellite Tracking Data Network
TCS	Thermal Control System
TPS	Thermal Protection System
TVC	Thrust Vector Control
UHF	Ultrahigh Frequency
VHF	Very High Frequency

1.0 SUMMARY

This document presents Shuttle Orbiter subsystems data which is required by the PMS for the function of Fault Detection and Annunciation (FDA) on the Orbiter Vehicle 101. This subsystem data was developed for the purpose of defining the PMS environment in support of the PMSS simulation effort at JSC.

The data is presented in section 3 of this document and consists of: (1) brief subsystem descriptions; (2) identification of subsystem functional paths which are selectable by the flight crew; (3) identification of operational instrumentation measurements which are necessary to enable the PMS to monitor the health status of subsystem functions paths; and (4) PMS process requirements relative to the measurements which are necessary for FDA. These requirements consist of measurement characteristics, tolerance limits, precondition tests, correlation measurements, etc., which are necessary to detect and annunciate a failed functional path.

The total number of PMS measurements required for FDA is summarized by subsystem in table 1.0-1. These measurements are found on the Master Measurements List (Reference 1), for the most part, but in some cases represent new measurement requirements recommended for health status monitoring of subsystems. These new measurements are summarized in appendix A. Subsystems not installed for HFT (such as Propulsion, RCS, OMS, etc.) have been omitted from this report, but will be included when the report is updated for the Orbiter 103 configuration.

TABLE 1.0-1. – HFT PMS MEASUREMENTS SUMMARY FOR FDA

	Number of Measurements		Total
	Analog	Discrete*	
Instr/DP	30	2 (0)	32
ECLSS	30	27 (19)	57
Hydraulics	41	39 (21)	80
C&TS	8	46 (25)	54
EPDC	15	39 (12)	54
APU	40	32 (26)	72
L&D	9	6 (1)	15
TPS	14	–	14
D&C	–	40 (11)	40
EPG	29	3 (0)	32
TOTAL	216	234 (115)	450

*Numbers shown in parentheses are precondition switch scan measurements (i.e., ECLSS utilizes 27 discretes for FDA, 19 of which are switch scan measurements).

2.0 INTRODUCTION

The PMS provides a software test facility for the development and verification of the Space Shuttle PMS flight software (i.e., basic algorithm verification). This document provides the systems data necessary to define the environment segment of the PMSS for the HFT Vehicle, Orbiter 101.

The functional simulation task is initially intended to support the HFT program. Therefore, the PMS software requirements will evolve from three basic PMS functions:

- Fault Detection and Annunciation (FDA)
- Subsystem Measurement Management (SMM)
- Subsystem Configuration Management (SCM)

A first level definition of the implementation requirements for these functions is provided in table 2.0-1. The data presented in this document is primarily in support of the FDA function. Later revisions to this document will include requirements for SMM and SCM for HFT.

Section 3 of this document contains detailed information relative to the design and operation of Orbiter subsystems for HFT. For each of these subsystems, functional paths are identified to the lowest level at which the crew can control the system functions, and measurement requirements are presented which are necessary to adequately monitor the health status of the system.

Section 4 summarizes for the FDA function those subsystem switches which have been identified as necessary precondition checks (switch-scan) prior to processing the primary and secondary FDA measurements. Later revisions to this document will include switch scan requirements necessary to provide the SCM function.

TABLE 2.0-1. – PMS FUNCTIONAL AND IMPLEMENTATION REQUIREMENTS

FUNCTIONAL REQUIREMENTS	IMPLEMENTATION REQUIREMENTS
1. FDA	
Continuously monitor and assess status of system performance at the functional path level.	Operate on key functional path parameters and compare profile with stored values.
	Compare value with stored soft limits and compute parameter rate of change and time to hard limit if soft limit exceeded.
Continuously monitor and provide fault detection at the functional path level.	Operate on key functional path parameters. Compare value with stored hard limit. Compare parameter with C&W list.
	Operate on secondary functional path data. Compare value with stored limits.
	Operate on system configuration data. Evaluate operating modes allowed.
	Correlate result of above and conclude functional path status.
	Perform multi-comparison/correlation operations.
	Assess number of functional paths remaining and compute criticality and abort criteria.

TABLE 2.0-1. – PMS FUNCTIONAL AND IMPLEMENTATION REQUIREMENTS (Continued)

FUNCTIONAL REQUIREMENTS	IMPLEMENTATION REQUIREMENTS
1. FDA (continued)	
Redundancy switching	Operate on key redundant path parameters. Compare values with stored limits. Compare with C&W list. Correlate to secondary measurements.
	Operate on system configuration. Evaluate operating modes allowed and current modes.
	Operate display system interface, C/W list and audible alarm, system configuration implemented (via auto) or recommended (via man).
	Compute capability of redundancy remaining.
	Assess capability and criticality of functional path in light of failure.
2. SMM	
Display specific groups of subsystem measurement data.	Process display request via keyboard.
	Scale, convert and format data for display.
	Compare parameters to out of limits list and identify any out of limit data.
	Operate on display system interface.

TABLE 2.0-1. – PMS FUNCTIONAL AND IMPLEMENTATION REQUIREMENTS (Concluded)

FUNCTIONAL REQUIREMENTS	IMPLEMENTATION REQUIREMENTS
3. SCM	
Determine vehicle system configuration	Operate on configuration/ mode cues. • Switch positions • Component conditions • Parametric values
	Determine Operating mode.
	Compare operating mode with input configuration check mode.
	Identify delta between operating mode and check mode.
	Determine change in configuration to meet check mode state.

3.0 SUBSYSTEM DATA

This section is designed to provide detailed information relative to the design, operation, and engineering characteristics of the Orbiter systems. The data given pertains to the HFT vehicle configuration. Subsections included are:

- Operational Instrumentation/Data Processing (3.1)
- Environmental Control and Life Support (3.2)
- Hydraulics (3.3)
- Communications and Tracking (3.4)
- Electrical Power Distribution and Control (3.5)
- Auxiliary Power Unit (3.6)
- Thermal Protection (3.7)
- Landing and Deceleration (3.8)
- Displays and Controls (3.9)
- Electrical Power Generation (3.10)

The system data is organized into four categories as follows:

1. System Description - A brief description of the system reflecting the HFT configuration and including operational and engineering data to the level necessary to define system functions and limitations.

2. Functional Paths - A description of each functional path identified for the subsystem. A functional path is defined as a sequential series of one or more functional elements which are controllable or selectable by either manual control or automatic control within the flight hardware.

3. Subsystem/PMS Interfaces - This section describes in tabular form the measurements required to evaluate the health status of each subsystem. Each measurement is correlated to a functional path in the subsystem. For the PMS FDA function, it is necessary that each subsystem functional path have a minimum of two measurements: a primary and a secondary or correlation measurement.

4. PMS Requirements - This section correlates the functional path measurements with specific tests which must be performed for FDA. Precondition tests are tests that are made during each PMS cycle prior to processing the primary measurement. Soft limit check (caution), hard limit check (warning) and backup C&W require definition of tolerance limits for each test, and are included where available. The correlation check identifies a secondary parameter that will be limit checked when a primary parameter fails. Primary measurements are identified in the tables by a (P) and secondary measurements by (S).

The measurement identification numbering system used throughout this document is defined in appendix B, Measurement Number Identification.

Identification of the subsystem functional paths consists of a letter-number scheme in accordance with the following convention:

Subsystem	Code
1. Operational Instrumentation:	
MDM's	Same as MDM ID
Mass Memory	MM1 through MMN

Subsystem	Code
Display Electronic Unit	DE1 through DEN
DPS Computers	DP1 through DPN
Master Timers	MT1 through MTN
Voice Recorders	VR1 through VRN
Maintenance Recorders	MR1 through MRN
PCM Master (DACBU) Units	DA1 through DAN
2. ECLSS:	
ACS	AM1 through AMN
CPS	CP1 through CPN*
WCL	WC1 through CWN
ATCS	AT1 through ATN
FMS	FM1 through FMN*
Waste Mgt.	WM1 through WMN*
Water Mgt.	WT1 through WTN*
FDSS	FD1 through FDN
ALSS	AL1 through ALN*
3. Hydraulics	HY1 through HYN
4. Communications & Tracking	CT1 through CTN
5. Electrical Power Distribution and Control:	
DC Power	DC1 through DCN
AC Power	AC1 through ACN
6. Auxiliary Power Unit	AP1 through APN
7. Thermal Protection System	TP1 through TPN
8. Landing and Deceleration	DL1 through DLN
9. Displays and Control/Lighting	DS1 through DSN

Subsystem	Code
10. Electrical Power Generation	FC1 through FCN
	PO1 through PON
	PH1 through PHN
11. Propulsion:	
MPS	ME1 through MEN*
RCS	RC1 through RCN*
SRB	SR1 through SRN*
OMS	OM1 through OMN*
12. Guidance and Control:	
G&N	GN1 through GNN**
FCS	FC1 through FCN**
13. Thermal Control System	TC1 through TCN*

Those systems marked by an asterisk (*) above are not covered in this report, since these subsystems are not applicable to the HFT vehicle.

Those systems marked by a double asterisk (**) are not covered in this report, but may be added in later revisions of the document when partitioning of G&N and PMS monitoring functions is more firmly established.

Display requirements for the FDA function are the same for all Orbiter HFT subsystems presented in this report. Upon annunciation of a failure, a short description of the failed measurement and its functional path appears on a scratch pad section of the CRT. The crew may then call up subsystems measurement data which identifies the failed parameter and functional path. More detailed information relative to the failed subsystem will require the crew to implement the PMS subsystem measurement management (SSM) data display.

3.1 DATA ACQUISITION, DISTRIBUTION, AND PROCESSING EQUIPMENT

Measurement data required for statusing the health of the subsystem's functional paths are presented in sections 3.2 through 3.10 of this report. This data is generated by sensors and transducers to dedicated displays, recorders, and/or the uplink/downlink command system and to the Subsystems Management Computer for FDA processing. Measurements not included in the subsequent sections are those that provide health status of the equipment associated with acquisition, throughput, distribution and the terminal function of the subsystems measurement data. These measurements are largely Built in Test Equipment (BITE) discretes that are indicative of the operational integrity (GO/NO-GO) of the equipment and are needed by PMS to satisfy one of two basic requirements, depending on the function of the equipment. Measurement data (GO/NO-GO) of equipment included in the processing or transmitting of the subsystems health status data are needed to satisfy the "top level" precondition test requirement. These measurements are interrogated and evaluated at the beginning of each PMS cycle and insure that the equipments that are providing subsystem health status data throughput are properly functioning prior to processing the subsystem data by the PMS software. These equipments are included in the OI Subsystem and the Data Processing Subsystem. Other equipment included in these two subsystems must also be statused for general health information but not as a precondition check for other subsystem FDA measurements.

The OI and Data Processing equipment and associated PMS requirements are presented in the following paragraphs.

3.1.1 System Description

The HFT configuration of the two subsystems of concern consists of the following equipment:

a. General Purpose Computers. 5
b. OI Multiplexer-Demultiplexer 7
c. G&C Multiplexer-Demultiplexer. 8
d. Data Acquisition and Control Buffer Unit 2
e. Master Timing Unit 1
f. Voice Recorder 1
g. Maintenance Recorder 1
h. Mass Memory. 2
i. Input/Output Boxes 5

Figure 3.1.1 functionally illustrates the interfaces of this equipment.

3.1.2 Functional Path Analysis

In general, each of the equipments having BITE is considered a functional path since fault detection and isolation of each is inherent within the PMS. Interfacing equipemnt affecting subsystems measurement data throughput, and which must have precondition checks, includes the computers, MDM's DACBU, Master Timing Unit, and the IOB's. BITE from the other equipment identified in section 3.1.1 are required for FDA processing and process requirements for these measurements are identical to other subsystem measurement data.

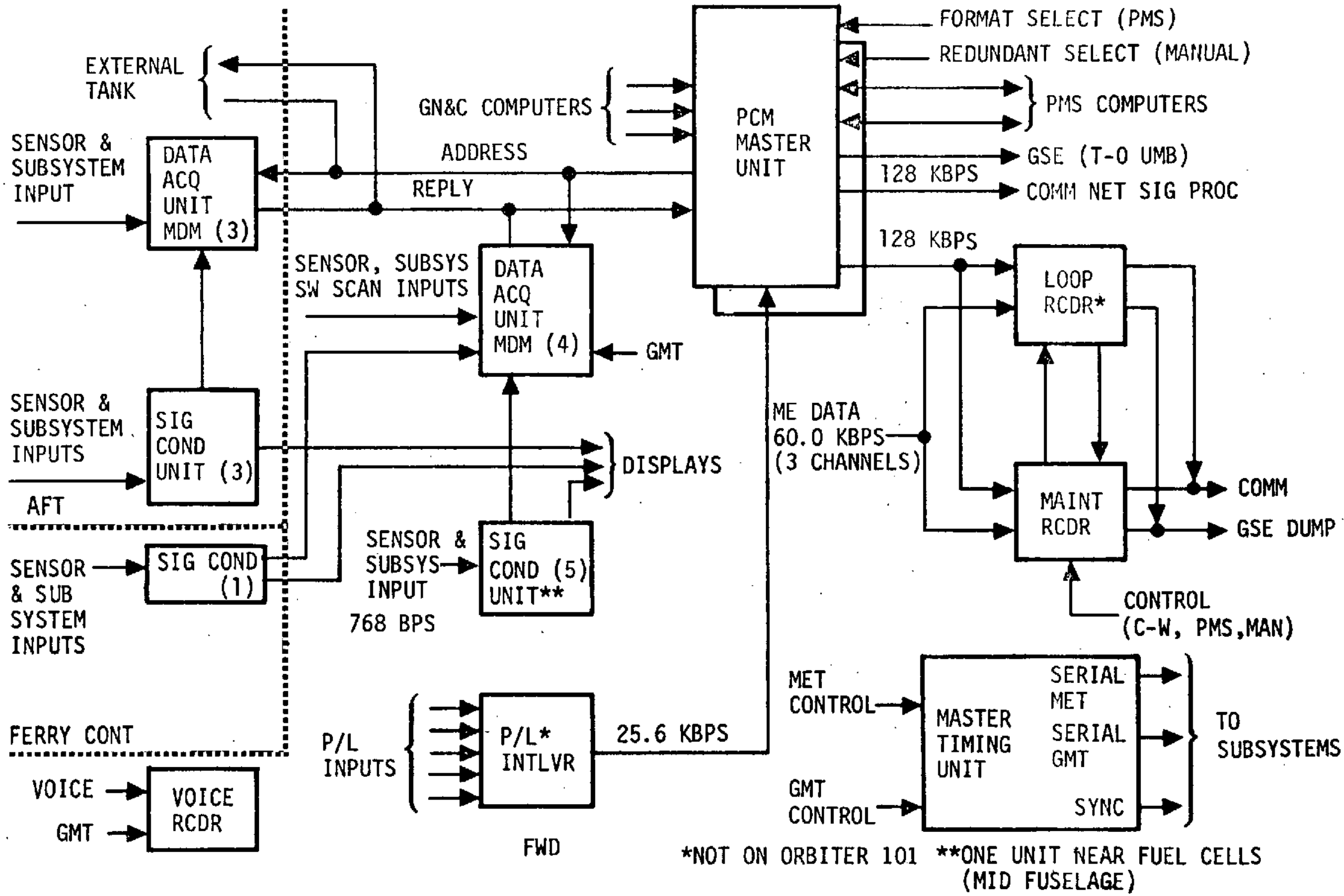


Figure 3.1-1. — Operational instrumentation.

As noted in table 3.1-1, functional path designators have been assigned to each of the equipments. These designators are largely the abbreviations assigned to the units by the Master Measurement List.

3.1.3 PMS Interfaces

Table 3.1-1 summarizes the measurements supplied by the equipment to the PMS and the Remarks column identifies those measurements needed for precondition checks. As noted, the majority of these measurements are BITE discretes that provide indications of the operational integrity of the equipment. It is recognized that these measurements alone are not sufficient to determine the validity of the subsystem measurement data. For example, statusing parity bit and validity bit information are potential PMS requirements. However, this function may be assigned to the GPC input/output buffer, which in turn would "hand-off" to PMS the results of IOB processing. Currently, there is not sufficient information on the IOP to completely scope the PMS requirements relative to the data validity. This problem will be addressed when the IOP requirements capability are better defined.

TABLE 3.1-1.

PMS MEASUREMENT DATA

SUBSYSTEM: OPERATIONAL INSTRUMENTATION/DATA PROCESSING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V72M7290B — DPS MDM Status G&N FA1	Discrete	1/0	FA1	Precondition check for all FDA using this MDM.
V72M7300B — DPS MDM Status G&N MDM FA2	Discrete	1/0	FA2	Precondition check for all FDA using this MDM.
V72M7310B — DPS MDM Status G&N MDM FA3	Discrete	1/0	FA3	Precondition check for all FDA using this MDM.
V727320B — DPS MDM Status G&N MDM FA4	Discrete	1/0	FA4	Precondition check for all FDA using this MDM.
V72M7250B — DPS MDM Status G&N FF1	Discrete	1/0	FF1	Precondition check for all FDA using this MDM.
V72M7260B — DPS MDM Status G&N FF2	Discrete	1/0	FF2	Precondition check for all FDA using this MDM.
V72M7270B — DPS MDM Status G&N FF3	Discrete	1/0	FF3	Precondition check for all FDA using this MDM.
V72M7280B — DPS MDM Status G&N FF4	Discrete	1/0	FF4	Precondition check for all FDA using this MDM.
V72M7500B — MDM OI OA1	Discrete	1/0	OA1	Precondition check for all FDA using this MDM.

TABLE 3.1-1.

PMS MEASUREMENT DATA

SUBSYSTEM: OPERATIONAL INSTRUMENTATION/DATA PROCESSING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V72M7510B – MDM OI OA2	Discrete	1/0	OA2	Precondition check for all FDA using this MDM.
V72M7520B – MDM OI OA3	Discrete	1/0	OA3	Precondition check for all FDA using this MDM.
V72M7530B – MDM OI OF1	Discrete	1/0	OF1	Precondition check – necessary for PMS FDA to check prior to accepting data from this MDM.
V72M7540B – MDM OI OF2	Discrete	1/0	OF2	Precondition check for all FDA using this MDM.
V72M7550B – MDM OI OF3	Discrete	1/0	OF3	Precondition check for all FDA using this MDM.
V72X7430X – DPS DEV. 1 Status	Discrete	1/0	DE1	Discrete BITE for FDA processing.
V72X7440X – DPS DEV. 2 Status	Discrete	1/0	DE2	Discrete BITE for FDA processing.
V72X7450X – DPS DEV. 3 Status	Discrete	1/0	DE3	Discrete BITE for FDA processing.
V72X7460X – DPS DEV. 4 Status	Discrete	1/0	DE4	Discrete BITE for FDA processing.
V72X7011X – DPS Computer No. 1 BITE	Discrete	1/0	DP1	Precondition check for all FDA.
V72X7012X – DPS Computer No. 2 BITE	Discrete	1/0	DP2	Precondition check for all FDA.

TABLE 3.1-1.

PMS MEASUREMENT DATA

SUBSYSTEM: OPERATIONAL INSTRUMENTATION/DATA PROCESSING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V72X7013X — DPS Computer No. 3 BITE	Discrete	1/0	DP3	Precondition check for all FDA.
V72X7014X — DPS Computer No. 4 BITE	Discrete	1/0	DP4	Precondition check for all FDA.
V72X7015X — DPS Computer No. 5 BITE	Discrete	1/0	DP5	Precondition check for all FDA.
V72X7210X — Mass Memory No. 1 BITE	Discrete	1/0	MM1	Precondition check for all FDA.
V72X7220X — Mass Memory No. 2 BITE	Discrete	1/0	MM2	Precondition check for all FDA.
V75X2240E — MTU Primary OSC Failure	Discrete	1/0	MT1	Precondition check for all FDA.
V75X2244E — MTU Secondary OSC Failure	Discrete	1/0	MT2	Precondition check for all FDA.
V75V2500A — Voice Recorder-BITE	Analog	0 to -12 dB	VR1	Discrete BITE for FDA processing.
V75X2518E — Voice Recorder-End-of-Tape	Discrete	1/0	VR2	Discrete event for FDA processing.

TABLE 3.1-1.

PMS MEASUREMENT DATA

SUBSYSTEM: OPERATIONAL INSTRUMENTATION/DATA PROCESSING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V75V2300A — Maintenance Recorder BITE	Analog	0 to -12 dB	MR1	Discrete BITE for FDA processing.
V75X2111D — PCM Master Unit BITE	Discrete	1/0	DA1	Precondition check for all FDA.

3.2 ENVIRONMENTAL CONTROL AND LIFE SUPPORT

3.2.1 Subsystem Description

The environmental control and life support system (ECLSS) consists of subsystems that are necessary in maintaining the life and comfort of the crew. Not all subsystems of the ECLSS will be operational on the HFT vehicle. Subsystems with components that are active for HFT are listed as follows:

- Atmospheric Revitalization Subsystem (ARS).
- Active Thermal Control Subsystem (ATCS).
- Fire Detection and Suppression Subsystem.

3.2.1.1 Atmospheric Revitalization Subsystem (ARS). For HFT, the ARS consists of two subsystems which provide necessary life support to the crew. The subsystems are:

- Atmosphere conditioning subsystem.
- Water coolant loops.

Cabin pressure is maintained by a sealed hatch. Flight duration will be short enough to permit cabin volume to maintain acceptable O_2 and CO_2 partial pressure levels. The crew will have portable face masks and oxygen assemblies for auxiliary O_2 supply.

The atmosphere conditioning subsystem (fig. 3.2-1) controls the temperature of the cabin and the desired humidity by removing excess water from the cabin gases by a cabin condensing heat exchanger. Three fans are available

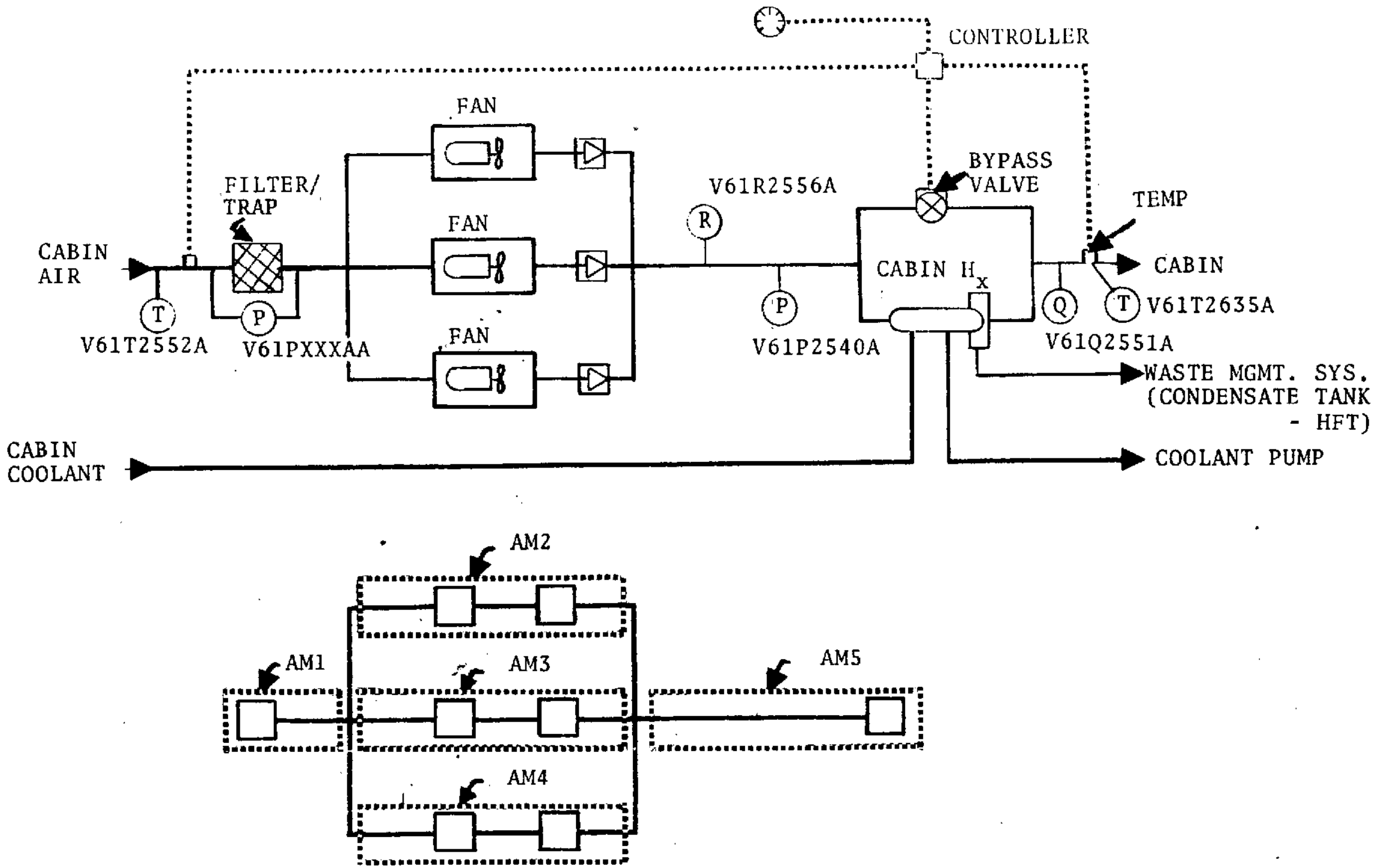


Figure 3.2.1. – ARS – atmosphere conditioning subsystem.

for circulating the air in the cabin, and a condensate tank is provided to collect the condensate.

Thermal control within the cabin and avionics bays is achieved by means of two redundant water coolant loops. The water coolant loops (fig. 3.2-2) remove excess heat generated by the crew and the spacecraft equipment, and transport it to the active thermal control subsystem (ATCS) interchanger. Thermal control of the avionics bays is accomplished by water coolant circulating through coldplates, and by forced air cooling in which the recirculated air is passed through heat exchangers located in the water coolant loops. Sublimators, liquid cooled garment (LCG) and water chiller heat exchangers are not installed for HFT.

3.2.1.2 Active Thermal Control Subsystem (ATCS). The ATCS (fig. 3.2-3) consists of two freon 21 coolant loops which are operated simultaneously to perform three major functions:

- The transport of thermal energy.
- Active thermal control of selected Orbiter equipment.
- Rejection of vehicle thermal energy.

Each loop has redundant dual speed (low and high) pumps. Normal operation requires one pump operating in each coolant loop in low speed. Loss of one coolant loop requires both pumps in the remaining loop to operate in high speed. The ATCS cools the water coolant loops through an interchanger. Heat is rejected in flight by an ammonia evaporator subsystem (fig. 3.2-4), and during ground operations through a GSE heat exchanger. The space radiators, flash evaporator,

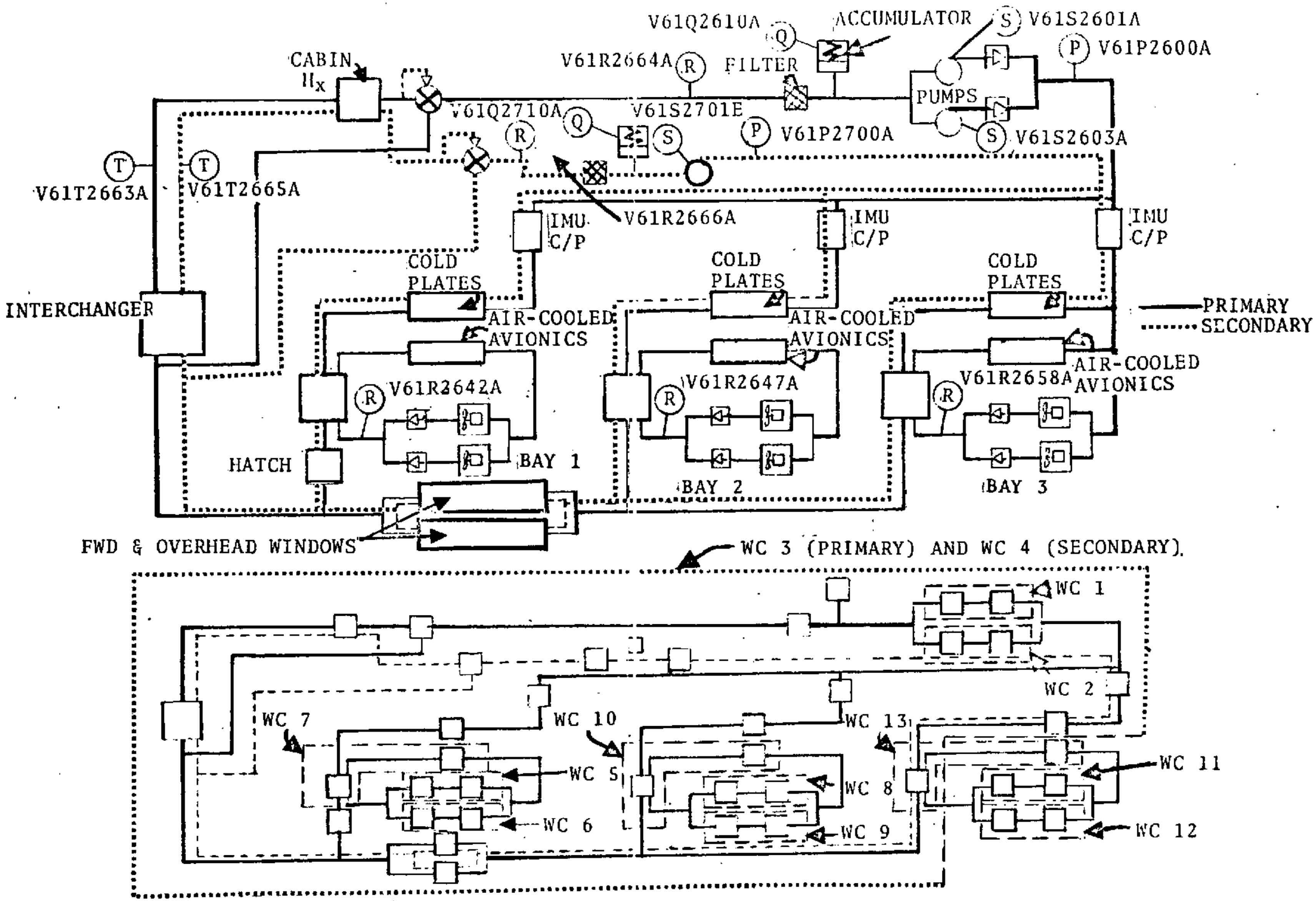


Figure 3.2-2 – ARS ~ water coolant loops.

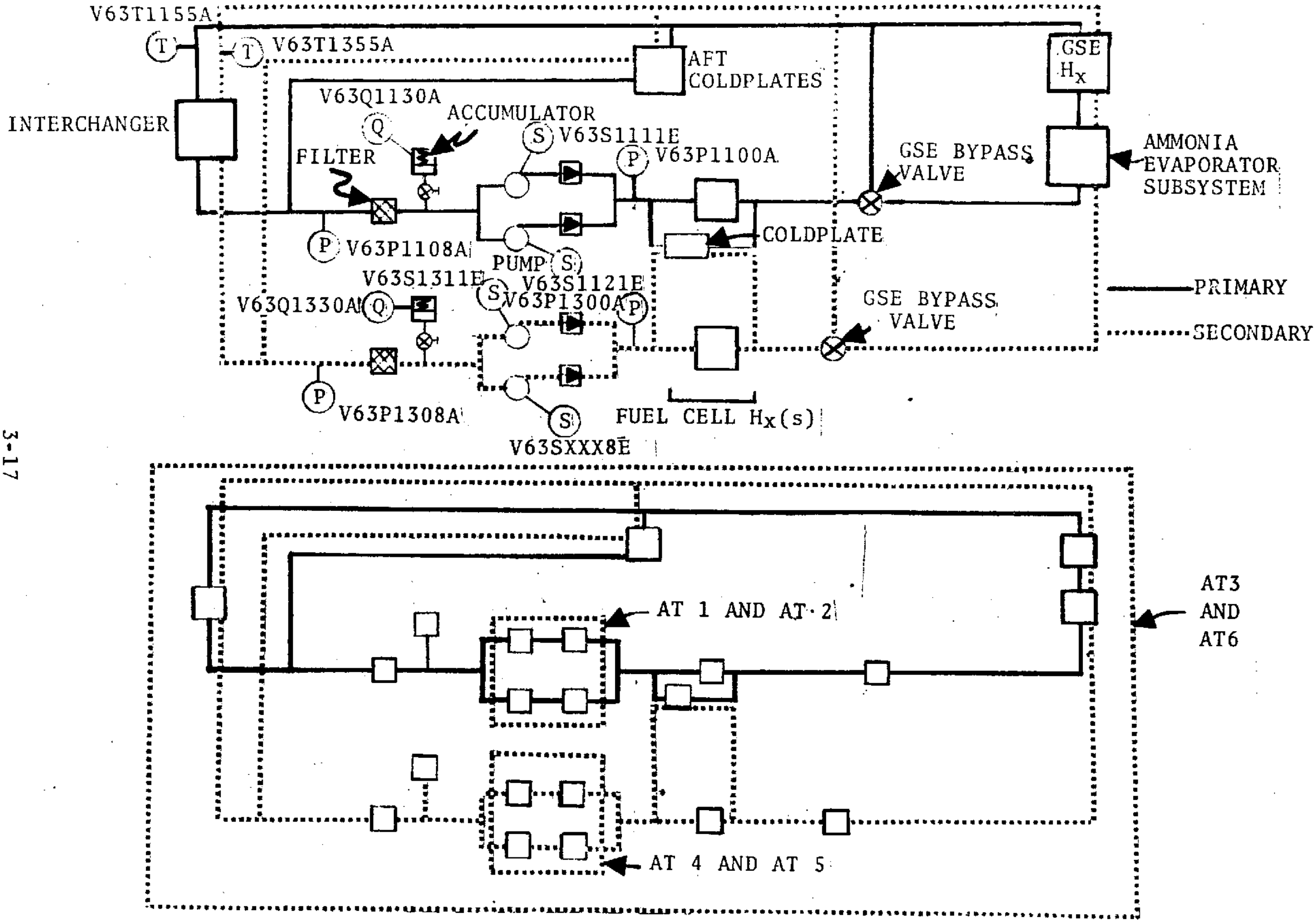


Figure 3.2.3. – Active thermal control subsystem.

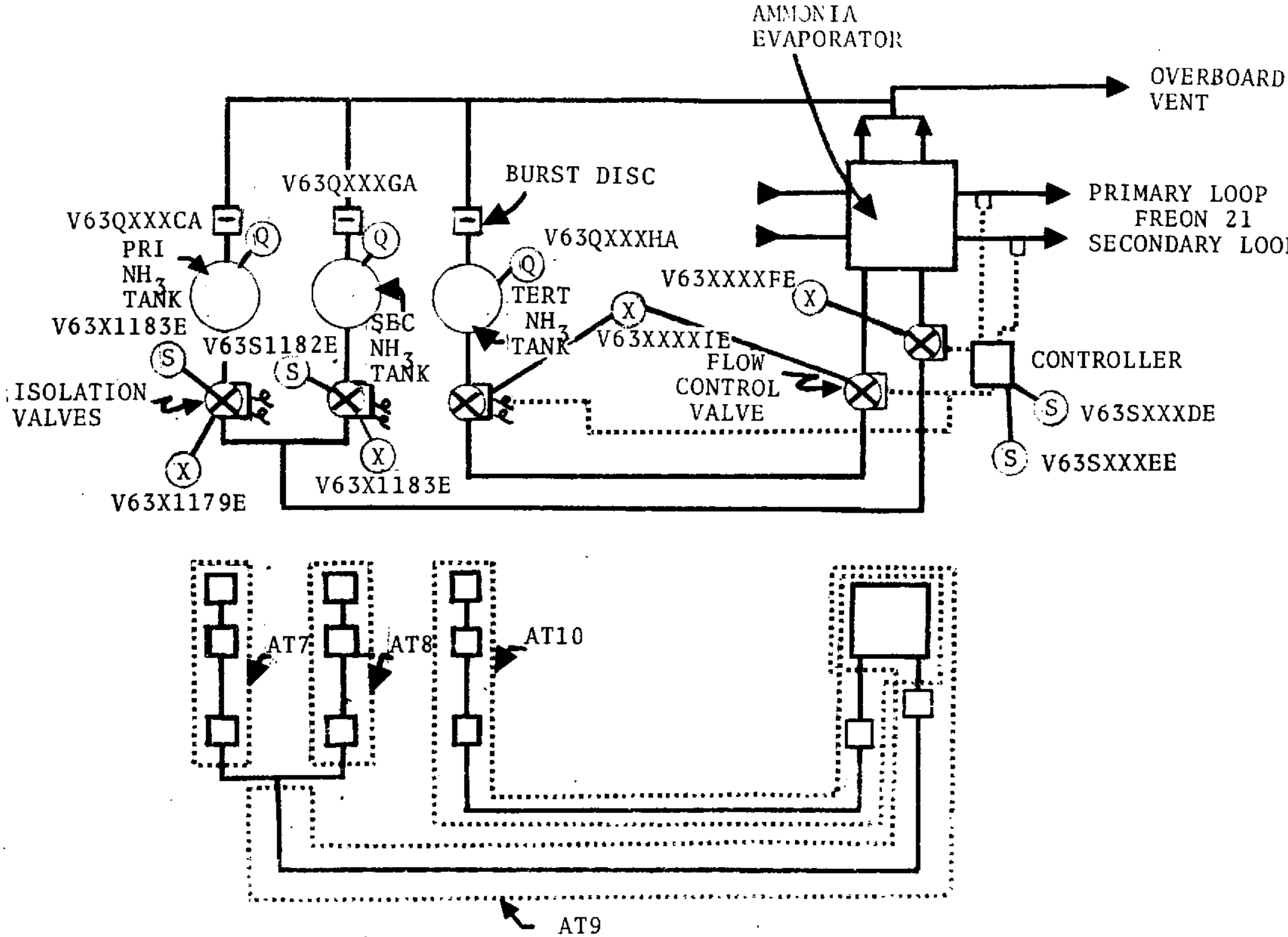


Figure 3.2.4. — ATCS ~ ammonia evaporator subsystem.

payload heat exchanger, and O_2 restrictors are not installed for HFT.

3.2.1.3 Fire Detection and Suppression Subsystem. The fire detection and suppression subsystem provides for early warning and means for suppressing the fire within the crew compartment and the avionics bays. Particle (smoke) and heat sensing element (fire) detectors are used to detect a fire. Particle type detectors operate by sensing any significant increase in the gaseous or particulate products of combustion within the cabin or avionics bays. The heat sensing element type detectors provide a warning of high heat overload or open flame condition when a temperature of 255 ± 15°F is reached. Particle type detectors only are used in the crew compartment; whereas, the avionics bays utilize both types of sensors. Subsystem and functional path analyses were not accomplished on smoke and fire detector components, since they are part of the emergency detection and annunciation system and exercise no active control on the suppression system.

Portable fire extinguishers are available for the Orbiter cabin compartment. The fire extinguishing agent is freon 1301. Since a visual indication is available on the freon container, no PMS measurement is required.

For each avionics bay, freon 1301 is used as the fire extinguishing agent. Each avionics bay is equipped with one freon 1301 container (fig. 3.2-5). The fire suppression subsystem is a high-rate-discharge type. The freon is explosively released from its container when manually initiated by the crew.

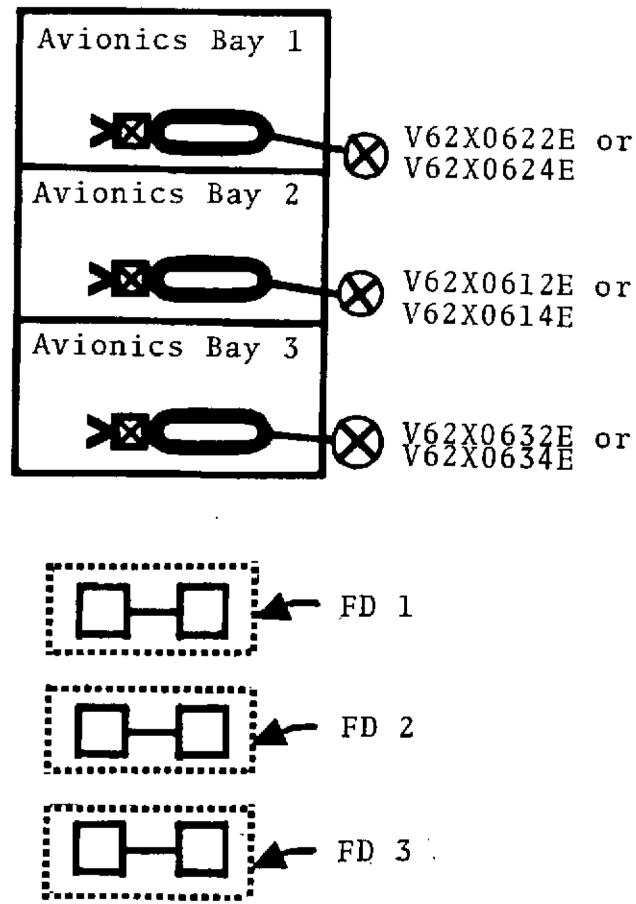


Figure 3.2-5. — ECLSS ~ fire detection and suppression subsystem.

3.2.2 Functional Path Analysis

Functional path analyses were conducted on the HFT active components of the atmospheric revitalization, active thermal control, and avionics bays fire suppression subsystems. For the ECLSS subsystems, functional paths identified are defined as a sequential series of one or more functional elements (selectable or nonselectable) that permits a function to be completed. The hardware functions are defined as functional paths required to accomplish the objectives of the subsystem. Table 3.2-1 presents the identification codes of each respective subsystem functional paths and hardware functions.

A description of the various functional paths and hardware functions are given in the subsequent paragraphs.

3.2.2.1 Atmospheric Revitalization Subsystem (ARS).

- Atmosphere Conditioning Subsystem – The functional paths and hardware functions identified are shown in the following equations (see fig. 3.2-1):

$$AM1 = \text{Filter/Trap} \quad (1)$$

$$AM2 = \text{Fan 1} \cdot \text{Check Valve 1} \quad (2)$$

$$AM3 = \text{Fan 2} \cdot \text{Check Valve 2} \quad (3)$$

$$AM4 = \text{Fan 3} \cdot \text{Check Valve 3} \quad (4)$$

$$AM5 = \text{Cabin Hx} \cdot \text{Bypass Valve} \quad (5)$$

From these equations, the hardware function is derived as follows:

$$AMH1 = AM1 \cdot (AM2 + AM3 + AM4) \cdot AM5 \quad (6)$$

TABLE 3.2-1. – IDENTIFICATION CODES

Subsystem	Functional Path	Hardware Function
ARS		
Atmosphere Conditioning	AM1, AM2, ... AMN	AMH1, AMH2, ... AMHN
Water Coolant Loops	WC1, WC2, ... WCN	WCH1, WCH2, ... WCHN
ATCS	AT1, AT2, ... ATN	ATH1, ATH2, ... ATHN
Fire Detection and Suppression	FD1, FD2, ... FDN	FDH1, FDH2, ... FDHN

From equation 6, it can be seen that a failure in components relating to AM1 or AM5 will disable the entire hardware function.

- Water Coolant Loops – Functional paths and hardware functions were defined for both coolant loops, and for the avionics air cooling systems. The air cooling systems were included as part of this section due to its dependence and interface with the water coolant loops to achieve its operating functions. The functional paths and hardware functions are shown in the following equations:

– Primary Water Coolant Loop (fig. 3.2.2)

$$WC1 = \text{Pump 1} \cdot \text{Check Valve 1} \quad (7)$$

$$WC2 = \text{Pump 2} \cdot \text{Check Valve 2} \quad (8)$$

Let,

$$A = \text{IMU Coldplates 1} \cdot \text{Avionics Bay 1 Coldplates} \cdot \text{Hx} \cdot \text{Hatch Heating} \quad (9)$$

$$B = \text{IMU Coldplates 2} \cdot \text{Avionics Bay 2 Coldplates} \cdot \text{Hx} \quad (10)$$

$$C = \text{IMU Coldplates 3} \cdot \text{Avionics Bay 3 Coldplates} \cdot \text{Hx} \quad (11)$$

D = Forward and Overhead Window Heating (12)

E = Forward and Overhead Window Heating (13)

Then,

$$WC3 = [A + \{(B + C) \cdot (D + E)\}] \cdot \text{Interchanger} \cdot \text{Cabin Hx} \cdot \text{Bypass Valve} \cdot \text{Filter} \cdot \text{Accumulator} \quad (14)$$

From these equations, the hardware function for the primary coolant loop is defined as follows:

$$WCH1 = (WC1 + WC2) \cdot WC3 \quad (15)$$

– <u>Secondary Water Coolant Loop</u> (fig. 3.2.2)

Let,

A_1 = IMU Coldplates 1 • Avionics Bay 1 Coldplates • Hx • Hatch Heating (16)

B_1 = IMU Coldplates 2 • Avionics Bay 2 Coldplates • Hx (17)

C_1 = IMU Coldplates 3 • Avionics Bay 3 Coldplates • Hx (18)

D_1 = Forward and Overhead Window Heating (19)

E_1 = Forward and Overhead Window Heating (20)

Then,

$$WC4 = \text{Pump} \quad [A_1 + \{(B_1 + C_1) \cdot (D_1 + E_1)\}]$$
$$\cdot \text{ Interchanger} \cdot \text{Cabin Hx} \cdot \text{Bypass Valve}$$
$$\cdot \text{ Filter} \cdot \text{Accumulator} \qquad (21)$$

Since the secondary water coolant loop consists of only one functional path, the hardware function is:

$$WCH2 = WC4 \qquad (22)$$

– Air-Cooled Avionics (fig. 3.2.2)

Avionics Bay 1 – The following functional paths are identified:

WC5 = Avionics Bay 1 Fan 1 · Check Valve 1 (23)

WC6 = Avionics Bay 1 Fan 2 · Check Valve 2 (24)

WC7 = Avionics Bay 1 Hx · Air-Cooled Avionics (25)

Combining these equations, the hardware function for avionics bay 1 is:

$$WCH3 = (WC5 + WC6) \cdot WC7 \qquad (26)$$

Avionics Bay 2 — The following functional paths are identified:

$$WC8 = \text{Avionics Bay 2 Fan 1} \cdot \text{Check Valve 1} \quad (27)$$

$$WC9 = \text{Avionics Bay 2 Fan 2} \cdot \text{Check Valve 2} \quad (28)$$

$$WC10 = \text{Avionics Bay 2 Hx} \cdot \text{Air-Cooled Avionics} \quad (29)$$

From these equations, the hardware function for avionics bay 2 is derived as follows:

$$WCH4 = (WC8 + WC9) \cdot WC10 \quad (30)$$

Avionics Bay 3 — The following functional paths are identified:

$$WC11 = \text{Avionics Bay 3 Fan 1} \cdot \text{Check Valve 1} \quad (31)$$

$$WC12 = \text{Avionics Bay 3 Fan 2} \cdot \text{Check Valve 2} \quad (32)$$

$$WC13 = \text{Avionics Bay 3 Hx} \cdot \text{Air-Cooled Avionics} \quad (33)$$

The hardware function for avionics bay 3 is as follows:

$$WCH5 = (WC11 + WC12) \cdot WC13 \quad (34)$$

- Active Thermal Control Subsystem — Included in this section are functional paths and hardware functions on both freon coolant loops and the ammonia evaporator subsystem which is part of the active thermal control subsystem. The identified functional paths and hardware functions are shown as follows in equation forms:

— Primary Freon Coolant Loop (fig. 3.2-3)

$$AT1 = [(\text{Pump } 1_{\text{Low Speed}} \cdot \text{Check Valve 1}) + (\text{Pump } 2_{\text{Low Speed}} \cdot \text{Check Valve 2})] \quad (35)$$

$$AT2 = [(\text{Pump } 1_{\text{High Speed}} \cdot \text{Check Valve 1}) \cdot (\text{Pump } 2_{\text{High Speed}} \cdot \text{Check Valve 2})] \quad (36)$$

$$AT3 = \text{Fuel Cell Hx} \cdot \text{DC Power Coldplates} \cdot \text{GSE Bypass Valve} \cdot \text{Ammonia Evaporator} \cdot \text{GSE Hx} \cdot \text{AFT Coldplates} \cdot \text{Interchanger} \cdot \text{Filter} \cdot \text{Accumulator} \quad (37)$$

— Secondary Freon Coolant Loop

$$AT4 = [(\text{Pump } 1_{\text{Low Speed}} \cdot \text{Check Valve 1}) + (\text{Pump } 2_{\text{Low Speed}} \cdot \text{Check Valve 2})] \quad (38)$$

$$AT5 = [(\text{Pump } 1_{\text{High Speed}} \cdot \text{Check Valve 1}) \cdot (\text{Pump } 2_{\text{High Speed}} \cdot \text{Check Valve 2})] \quad (39)$$

$$AT6 = \text{Fuel Cell Hx} \cdot \text{DC Power Coldplates} \cdot \text{GSE Bypass Valve} \cdot \text{Ammonia Evaporator} \cdot \text{GSE Hx} \cdot \text{AFT Coldplates} \cdot \text{Interchanger} \cdot \text{Filter} \cdot \text{Accumulator} \quad (40)$$

Since both freon coolant loops have redundant dual-speed pumps and are operated simultaneously, the hardware function for the freon coolant loops is defined as follows:

ATH1 = [(AT1 · AT3) · (AT4 · AT6)] + [AT2 · AT3)
+ (AT5 · AT6)] (41)

– Ammonia Evaporator Subsystem (fig. 3.2-4) – Functional paths identified for the ammonia evaporator subsystem is as follows:

AT7 = Burst Disc · Pri NH_3 Tank · Isolation Valve 1 (42)

AT8 = Burst Disc · Sec NH_3 Tank · Isolation Valve 2 (43)

AT9 = Flow Control Valve 1 · Evaporator 1 (44)

AT10 = Burst Disc · Tert NH_3 Tank · Isolation Valve 3
Flow Control Valve 2 · Evaporator 2 (45)

From these equations, the hardware function for the ammonia evaporator subsystem is as follows:

ATH2 = [(AT7 + AT8) · AT9] + AT10 (46)

- Fire Detection and Suppression Subsystem (fig. 3.2-5) – The functional paths identified for the fire suppression subsystems within each avionics bay are given in the following equations:

FD1 = Avionics Bay 1 Freon Container · Actuation Valve (47)

FD2 = Avionics Bay 2 Freon Container • Actuation Valve (48)

FD3 = Avionics Bay 3 Freon Container • Actuation Valve (49)

The hardware functions for each respective avionics bay are as follows:

$$FDH1 = FD1 \quad (50)$$

$$FDH2 = FD2 \quad (51)$$

$$FDH3 = FD3 \quad (52)$$

3.2.3 Subsystems/PMS Interfaces

Since the purpose of the FDA is to evaluate the health status of the ECLSS, this section provides the primary and secondary measurements that are needed to determine and isolate a failure within each ECLSS subsystem. Each required measurement is correlated to a subsystem functional path, and each subsystem operating tolerance limit is provided. This information is given in tables 3.2-2 through 3.2-6.

3.2.4 PMS Requirements

To satisfy PMS FDA requirements, ECLSS must furnish individual measurement data and limits associated with those

TABLE 3.2-2

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ATMOSPHERE CONDITIONING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V61PXXXAA — Filter/Debris Trap Differential Press	Press	0.05-0.15 psid	AM1	New recommended measurement. This measurement provides the capability to isolate a fan or filter/trap failure.
V61R2556A — Cabin Air Flowrate	Rate	1350-1450 lbs/hr	AM2, AM3, and AM4	Measurement will detect a potential fan failure and provide information concerning the status and operating profile of the cabin fans.
V61Q2551A — Cabin Humidity	Humidity	30-70% RH	AM5	Measurement will allow detection and isolation of cabin/humidity Hx component failures.
V61T2635A — Cabin Hx Out Gas Temperature	Temp	45-55°F	AM5	Measurement is presently classified as a ground or LRU isolation type. This measurement needs to be available during flight to detect and isolate either a bypass valve, cabin Hx, or sensor failure within the atmosphere conditioning subsystem.
V61T2552A — Cabin Temperature	Temp	65-80°F	AM5	Measurement serves as a secondary or correlation measurement to V61T2635A.
V61P2540A — CO_2 Partial Pressure	Press	0-5mm Hg	N/A	This serves as a back-up to the Caution and Warning (C&W) CO_2 partial pressure measurement.

TABLE 3.2-3.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-PRESSURE CONTROL SUBSYSTEM

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V61P2405A — Cabin Pressure	Press	14.5-14.9 psia	N/A	The unavailability of a pressurization control system for HFT requires that the cabin pressure be monitored closely. This measurement acts as a back-up to the C&W system.
V61P2511A or V61P2513A — O_2 Partial Pressure	Press	2.95-3.45 psia	N/A	Since the pressurization control subsystem is not installed for HFT, it is necessary that the O_2 partial pressure does not fall below the minimum allowable level. This measurement serves as a back-up to the C&W system.
V61S2561E V61S2562E V61S2563E Cabin Fans 1, 2, & 3 - On	Event	0/1	AM 2 AM 3 AM 4	Precondition configuration status.

TABLE 3.2-4.
PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-WATER COOLANT LOOPS (1 of 3)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V61P2600A — Pri H_2O Pump Outlet Pressure	Press	30-45 psig	WC1 and WC2	Measurement is presently classified as a ground servicing and LRU trend type. This measurement needs to be available during flight to isolate a pump, accumulator, or sensor failure.
V61S2601E — Pri H_2O Pump Control No. 1	Event	Off-On	WC1	Measurement serves as a preconditioning test to determine primary water coolant loop status.
V61S2603E — Pri H_2O Pump Control No. 2	Event	Off-On	WC2	Same as above.
V61T2663A — Interchanger Pri Water Coolant Outlet Temperature	Temp	40-50°F	WC3	Measurement will detect and isolate a potential problem within the water coolant loop. This measurement can serve as a correlation measurement to V63T1155A or V63T1355A (freon coolant loops).
V61R2664A — Pri H_2O Coolant Flowrate	Rate	650-750 lbs/hr	WC3	Measurement serves as a secondary measurement to V61P2600A and V61Q2610A for detection of a pump failure and verification of an accumulator failure indication.
V61Q2610A — Pri H_2O Accumulator Quantity	Quantity	30-80%	WC3	Measurement will detect an accumulator failure or leak in the coolant loop.

TABLE 3.2-4.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-WATER COOLANT LOOPS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V61P2700A — Sec H_2O Pump Outlet Pressure	Pressure	30-45 psig	WC4	Measurement is presently classified as a ground servicing and LRU trend type. This measurement needs to be available during flight to isolate a pump, accumulator, or sensor failure. This measurement is recommended as a primary measurement over a flow-rate type because of better accuracy and reliability considerations.
V61S2701E — Sec H_2O Pump Control	Event	Off-On	WC4	Measurement serves as a preconditioning test to determine secondary water coolant loop status.
V61T2665A — Interchanger Sec Water Coolant Outlet Temperature	Temp	40-50°F	WC4	Measurement will detect an out-of-tolerance condition within the water coolant loop. This measurement can serve as a correlation measurement to V63T1155A or V63T1355A (freon coolant loops).
V61R2666A — Sec H_2O Coolant Flowrate	Rate	650-750 lbs/hr	WC4	Measurement serves as a secondary measurement to V61P2700A and V61Q2710A for detection of a pump failure and verification of an accumulator failure.
V61Q2710A — Sec H_2O Accumulator Quantity	Quantity	30-80%	WC4	Measurement will detect an accumulator failure or leak in the coolant loop. Measurement can be used during the stand-by mode to

TABLE 3.2-4.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-WATER COOLANT LOOPS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
				verify secondary water coolant loop is operational.
V61R2642A — Avionics Bay 1 Air Flow	Rate	2900-3100 lbs/hr	WC5 and WC6	Measurement will detect a fan failure in the avionics bay air coolant loop. No correlation measurement is presently available to isolate possible sensor failure. Criticality of system does not warrant additional measurements.
V61R2647A — Avionics Bay 2 Air Flow	Rate	2900-3100 lbs/hr	WC8 and WC9	Same as above.
V61R2658A — Avionics Bay 3 Air Flow	Rate	2900-3100 lbs/hr	WC11 and WC12	Same as above.
V61S2645E and V61S2646E Avionics Bay 1 Fans A and B-On	Event	0/1	WC 5, WC 6	Precondition configuration status.
V61S2650E V61S2652E Avionics Bay 2 Fans A and B-On	Event	0/1	WC 8, WC 9	Precondition configuration status.
V61S2661E V61S2662E Avionics Bay 3 Fans A and B-On	Event	0/1	WC 11, WC 12	Precondition configuration status.

TABLE 3.2-5.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ACTIVE THERMAL CONTROL (1 of 5)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63P1100A – Pri Coolant Loop Pump Outlet Pressure	Press	200-300 psig	AT1 and AT2	Measurement will allow detection of a pump failure and will verify an accumulator failure indication.
V63S1111E – Pri Freon Coolant Loop Pump No. 1-CMD	Event	Off-On	AT1 and AT2	Measurement serves as a preconditioning test to determine primary freon coolant loop pump 1 status.
V63S1121E – Pri Freon Coolant Loop Pump No.2-CMD	Event	Off-On	AT1 and AT2	Measurement serves as a preconditioning test to determine primary freon coolant loop pump 2 status.
V63T1155A – Pri Freon Coolant Interchanger Inlet Temperature	Temp	40-45°F	AT3	Measurement will detect an out-of-tolerance condition within the freon coolant loop. This measurement can act as a correlation measurement to V61T2663A or V61T2665A (water coolant loops).
V63P1108A – Pri Freon Coolant Pump Inlet Pressure	Press	140-240 psig	AT3	Measurement is presently classified as a ground servicing type. This addition is needed to act as a secondary or correlation measurement to V63P1100A.
V63Q1130A – Pri Freon Coolant Loop Accumulator Quantity	Quantity	25-90%	AT3	Measurement will detect an accumulator failure or leak in the coolant loop.

TABLE 3.2-5.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ACTIVE THERMAL CONTROL (2 of 5)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63P1300A — Sec Freon Coolant Loop Pump Outlet Pressure	Press	200-300 psig	AT4 and AT5	Measurement will allow detection of a pump failure and verify an accumulator failure indication
V63S1311E — Sec Freon Coolant Loop Pump No. 1-CMD	Event	Off-On	AT4 and AT5	Measurement serves as a preconditioning test to determine secondary freon coolant loop pump 1 status.
V63SXXXBE — Sec Freon Coolant Loop Pump No. 2-CMD	Event	Off-On	AT4 and AT5	New recommended measurement. This addition serves as a preconditioning test to determine secondary freon coolant loop pump 2 status.
V63T1355A — Sec Freon Coolant Loop Interchanger Inlet Temperature	Temp	40-45°F	AT6	Measurement will detect an out-of-tolerance condition within the freon coolant loop. This measurement can serve as a correlation measurement to V61T2663A or V61T2665A (water coolant loops).
V63P1308A — Sec Freon Coolant Loop Pump Inlet Pressure	Press	140-240 psig	AT6	Measurement is presently classified as a ground servicing type. This measurement is required to act as a secondary or correlation measurement to V63P1300A.
V63Q1330A — Sec Freon Coolant Loop Accumulator Quantity	Quantity	25-90%	AT6	Measurement will detect an accumulator failure or leak in the freon coolant loop.

TABLE 3.2-5.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ACTIVE THERMAL CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63QXXXCA – Pri NH_3 Tank Quantity	Quantity	30-90%	AT7	New recommended measurement. This measurement is needed to detect and isolate an ammonia tank failure during active and stand-by modes.
V63S1178E – Pri NH_3 Tank Isolation Valve – CMD	Event	Off-On	AT7	Measurement serves as a preconditioning test to determine ammonia evaporator system 1 status.
V63X1179E – Pri NH_3 Tank Isolation Valve Position	Event	Close-Open	AT7	Measurement serves as a secondary measurement to V63S1178E to detect an isolation valve failure.
V63SXXXDE – NH_3 Evaporator Flow Control Valve Command	Event	Off-Auto-Manual	AT9 and AT10	New recommended measurement. This addition is required as a preconditioning test to determine ammonia evaporator status.
V63SXXXEE – NH_3 Evaporator System Select	Event	System 1 – System 2	AT9 and AT10	New recommended measurement. System 2 position actuates flow control valve 2 and tertiary NH_3 tank isolation valve. This measurement is needed as a secondary measurement to isolate whether flow control valve 1 or 2 (or tertiary NH_3 tank isolation valve) has failed.

TABLE 3.2-5.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ACTIVE THERMAL CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63XXXXFE — NH_3 Evaporator Flow Control Valve 1	Event	Close-Open	AT9	New recommended measurement. This measurement will act as a secondary measurement to determine whether the control valve has received signal.
V63QXXXGA — Sec NH_3 Tank Quantity	Quantity	30-90%	AT8	New recommended measurement. This measurement is needed to detect and isolate an ammonia tank failure during active and stand-by modes.
V63S1182E — Sec NH_3 Tank Isolation Valve — CMD	Event	Off-On	AT8	Measurement serves as a preconditioning test to determine ammonia evaporator system 1 status.
V63X1183E — Sec NH_3 Tank Isolation Valve Position	Event	Close-Open	AT8	Measurement serves as a secondary measurement to detect an isolation valve failure.
V63QXXXHA — Tertiary NH_3 Tank Quantity	Quantity	30-90%	AT10	New recommended measurement. This measurement is needed to detect and isolate an ammonia tank failure during active and stand-by modes.

TABLE 3.2-5.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-ACTIVE THERMAL CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63XXXXIE – Tertiary NH_3 Tank Isolation Valve-Flow Control Valve 2 Position	Event	Close-Open	AT10	New recommended measurement. This addition will serve as a secondary measurement to provide information whether tertiary NH_3 tank isolation valve and flow control valve 2 have received signal when ammonia evaporator system 2 is selected.

TABLE 3.2-6.

PMS MEASUREMENT DATA

SUBSYSTEM: ECLSS-FIRE DETECTION AND SUPPRESSION

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V62X0622E/ V62X0624E — Freon Full/Empty Indication — Avionics Bay 1	Event	Empty-Full	FD1	Measurement is presently not monitored by the PMS. This measurement needs to be interrogated by the PMS to detect a defective or failed fire extinguisher system.
V62X0612E/ V62X0614E — Freon Full/Empty Indication — Avionics Bay 2	Event	Empty-Full	FD2	Same as above.
V62X0632E/ V62X0634E — Freon Full/Empty Indication — Avionics Bay 3	Event	Empty-Full	FD3	Same as above.

measurements and must relate the measurements to a functional path from which PMS may then announce the impact of a failure in terms of the loss of a particular functional path.

It is also necessary for ECLSS to identify correlation measurements so that PMS can filter erroneous information (i.e., malfunctioning sensors) from reaching the crew.

This section provides the various tests and their limits that must be performed when an out-of-tolerance condition is detected. These tests basically discriminate between a failure cause, i.e., sensor malfunction, and a failure affect. Correlation or secondary measurements are identified for some primary parameters. The various measurements and their limit checks are provided in tables 3.2-7 through 3.2-11.

In addition, to justify the ECLSS subsystem measurements, simplified fault detection and isolation schematics (figs. 3.2-6 through 3.2-15) are provided. These schematics illustrate the following:

- Primary measurements to provide the most significant system status data.
- Secondary measurements to verify failure conditions and eliminate erroneous primary measurement indications.
- Isolation and identification of the source of failure.
- Corrective action to alleviate the failure condition.

TABLE 3.2-7

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Atmosphere Conditioning

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61PXXXAA (P) • Filter/Debris Trap Differential Press • AM1			0.16 psid	0.04 psid	X	0.20 psid	0.01 psid			R2556
• V61R2556A (P) • Cabin Air Flowrate • AM2, AM3, & AM4			N/A	1340 lbs/hr	X	N/A	1300 lbs/hr			PXXXA T2635
• V61Q2551A (P) • Cabin Humidity • AM5			71% RH	29% RH	X	80% RH	20% RH			T2635
• V61T2635A (P) • Cabin Hx Out Gas Temp • AM5			56° F	44° F	X	60° F	40° F			Q2551 T2552
• V61P2540A (C&W) • CO_2 Partial Press • N/A								7.6 mm Hg	N/A	
• V61T2552A (S) • Cabin Temp • AM5			81° F	64° F	X	85° F	60° F			T2635
• V61S2561E • V61S2562E • V61S2563E • Cabin Fans 1, 2, 3-ON • AM2, AM3, AM4		X X X								

TABLE 3.2-8

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Pressure Control

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61P2405A (C&W) • Cabin Press • N/A								N/A	14.0 psia	
• V61P2511A or V61P2513A (C&W) • O_2 Partial Press • N/A								N/A	2.8 psia	

TABLE 3.2-9

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Water Coolant Loops

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61P2600A (P) • Pri H_2O Pump Outlet Press • WC1 & WC2			46 psig	25 psig	X	50 psig	20 psig			R2664
• V61S2601E (P) • Pri H_2O Pump Control No. 1 • WC1		X								
• V61S2603E (P) • Pri H_2O Pump Control No. 2 • WC2		X								
• V61T2663A (P) • Interchanger Pri Water Coolant Outlet Temp • WC3			51° F	39° F	X	55° F	35° F			V63T1155 V63T1355
• V61R2664A (S) • Pri H_2O Coolant Flowrate • WC3			755 lbs/hr	645 lbs/hr	X	755 lbs/hr	600 lbs/hr			P2600
• V61Q2610A (P) • Pri H_2O Accum Quantity • WC3			81%	29%	X	85%	25%			P2600 R2664

TABLE 3.2-9

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Water Coolant Loops (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61P2700A (P) • Sec H_2O Pump Outlet Press • WC4			46 psig	25 psig	X	50 psig	20 psig			R2666
• V61S2701E (P) • Sec H_2O Pump Control • WC4		X								
• V61T2665A (P) • Interchanger Sec Water Coolant Outlet Temp • WC4			51° F	39° F	X	55° F	35° F			V63T1155 V63T1355 T2635
• V61R2666A (S) • Sec H_2O Coolant Flowrate • WC4			755 lbs/hr	645 lbs/hr	X	775 lbs/hr	600 lbs/hr			P2700
• V61Q2710A (P) • Sec H_2O Accum Quantity • WC4			81%	29%	X	85%	25%			P2700 R2666
• V61R2642A (P) • Avionics Bay 1 Air Flow • WC5 & WC6			N/A	2850 lbs/hr	X	N/A	2700 lbs/hr			

TABLE 3.2-9

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Water Coolant Loops

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61R2647A (P) • Avionics Bay 2 Air Flow • WC8 & WC9			N/A	2850 lbs/hr	X	N/A	2700 lbs/hr			
• V61R2658A (P) • Avionics Bay 3 Air Flow • WC11 & WC12			N/A	2850 lbs/hr	X	N/A	2700 lbs/hr			
• V61S2645E • Avionics Bay 1 Fan A — ON • WC5 & WC6		X								
• V61S2646E • Avionics Bay 1 Fan B — ON • WC5 & WC6		X								
• V61S2650E • Avionics Bay 2 Fan A — ON • WC8 & WC9		X								
• V61S2652E • Avionics Bay 2 Fan B — ON • WC8 & WC9		X								

TABLE 3.2-9

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Water Coolant Loops

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V61S2661E • Avionics Bay 3 Fan A — ON • WC11 & WC12		X								
• V61S2662E • Avionics Bay 3 Fan B — ON • WC11 & WC12		X								

TABLE 3.2-10

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Active Thermal Control

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V63P1100A (P) • Pri FCL Pump Outlet Press • AT1 & AT2			305 psig	195 psig	X	325 psig	175 psig			P1108
• V63S1111E (P) • Pri FCL Pump No. 1 - CMD • AT1 & AT2		X								
• V63S1121E (P) • Pri FCL Pump No. 2 - CMD • AT1 & AT2		X								
• V63T1155A (P) • Pri FCL Interchanger Inlet Temp. • AT3			47° F	38° F	X	50° F	35° F			V61T2663 V61T2665
• V63P1108A (S) • Pri FCL Pumps Inlet Press • AT3			245 psig	135 psig	X	265 psig	115 psig			P1100
• V63Q1130A (P) • Pri FCL Accum Quantity • AT3			91%	24%	X	95%	20%			P1100 P1108
• V63P1300A (P) • Sec FCL Pump Outlet Press • AT4 & AT5			305 psig	195 psig	X	325 psig	175 psig			P1308
• V63S1311E (P) • Sec FCL Pump No. 1 - CMD • AT4 & AT5		X								

TABLE 3.2-10

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Active Thermal Control

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V63XXXXBE (P) • Sec FCL Pump No. 2 - CMD • AT4 & AT5		X								
• V63T1355A (P) • Sec FCL Interchanger Inlet Temp • AT6			47° F	38° F	X	50° F	35° F			V61T2663 V61T2665
• V63P1308A (S) • Sec FCL Pumps Inlet Press • AT6			245 psig	135 psig	X	265 psig	115 psig			P1300
• V63Q1330A (P) • Sec FCL Accum Quantity • AT6			91%	24%	X	95%	20%			P1300 P1308
• V63QXXXCA (P) • Pri NH_3 Tank Quantity • AT7			91%	25%	X	95%	20%			T1155 T1355
• V63S1178E (P) • Pri NH_3 Tank Isolation Valve CMD • AT7		X								
• V63X1179E (S) • Pri NH_3 Tank Isolation Valve Pos • AT7			N/A	N/A		Discrete				S1178 T1155 T1355
• V63SXXXDE (P) • NH_3 Evaporator Flow Control Valve CMD • AT9 & AT10		X								

TABLE 3.2-10

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Active Thermal Control

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V63SXXXEE (S) • NH_3 Evaporator System Select • AT9 & AT10		X								
• V63XXXXFE (S) • NH_3 Evaporator Flow Control Valve 1 Pos • AT9			N/A	N/A		Discrete				SXXXXE T1155 T1355
• V63QXXXGA (P) • Sec NH_3 Tank Quantity • AT8			91%	25%	X	95%	20%			T1155 T1355
• V63X1182E (P) • Sec NH_3 Tank Isolation Valve CMD • AT8		X								
• V63X1183E (S) • Sec NH_3 Tank Isolation Valve Pos • AT8			N/A	N/A		Discrete				S1182 T1155 T1355
• V63QXXXHA (P) • Tertiary NH_3 Tank Quantity • AT10			91%	25%	X	95%	20%			T1155 T1355
• V63XXXXIE (S) • Tertiary NH_3 Tank Isolation Valve - Flow Control Valve 2 Pos • AT10			N/A	N/A		Discrete				SXXXE T1155 T1355

TABLE 3.2-11

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ECLSS/Fire Detection and Suppression

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V62X0622E or V62X0624E (P) • Freon Full/Empty Ind-Avionics Bay 1 • FD1			N/A	N/A		Discrete (Normally Full)				
• V62X0612E or V62X0614E (P) • Freon Full/Empty Ind-Avionics Bay 2 • FD2			N/A	N/A		Discrete (Normally Full)				
• V62X0632E or V62X0634E (P) • Freon Full/Empty Ind-Avionics Bay 3 • FD3			N/A	N/A		Discrete (Normally Full)				

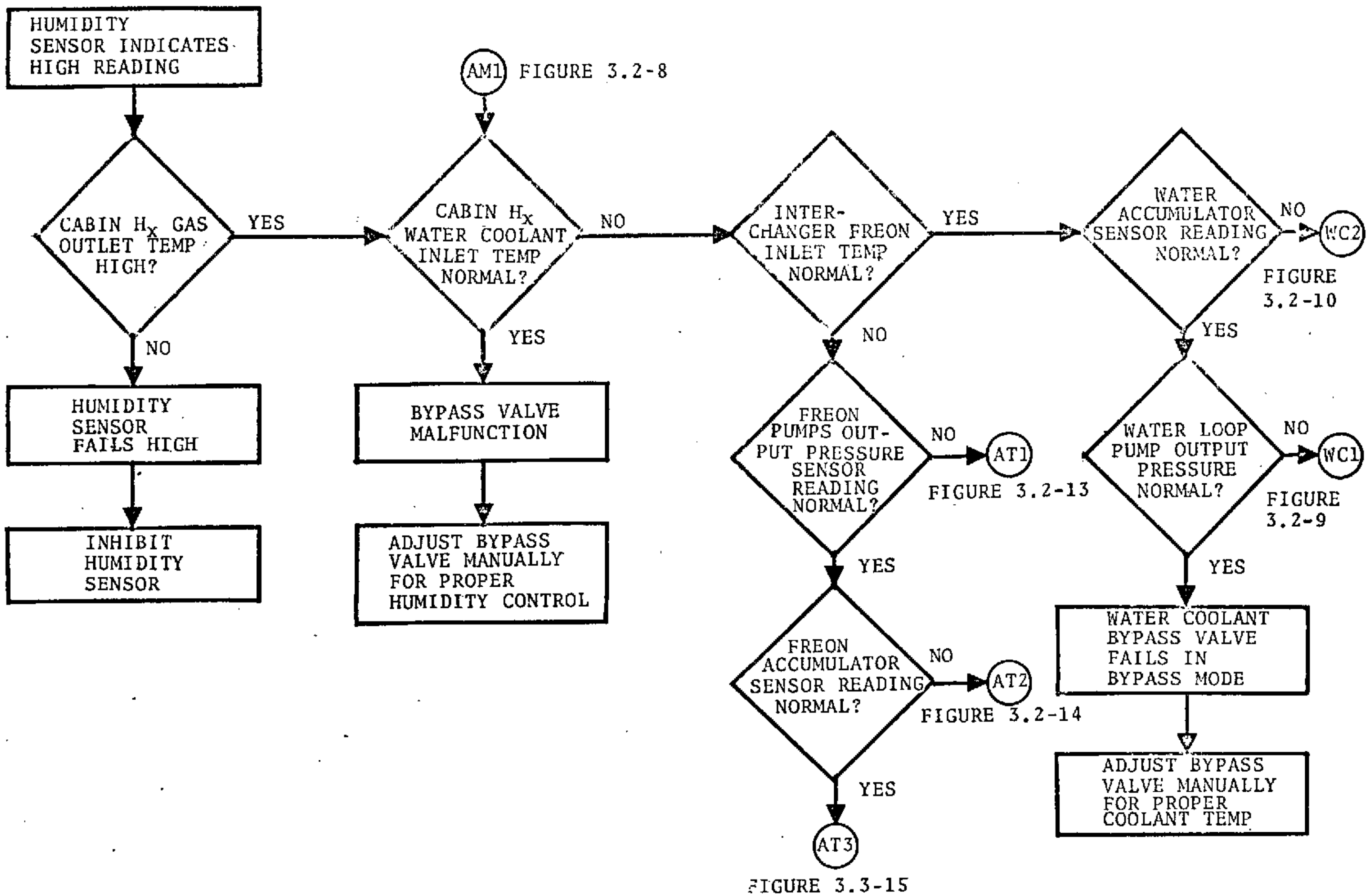


Figure 3.2-6. – Humidity fault detection and isolation.

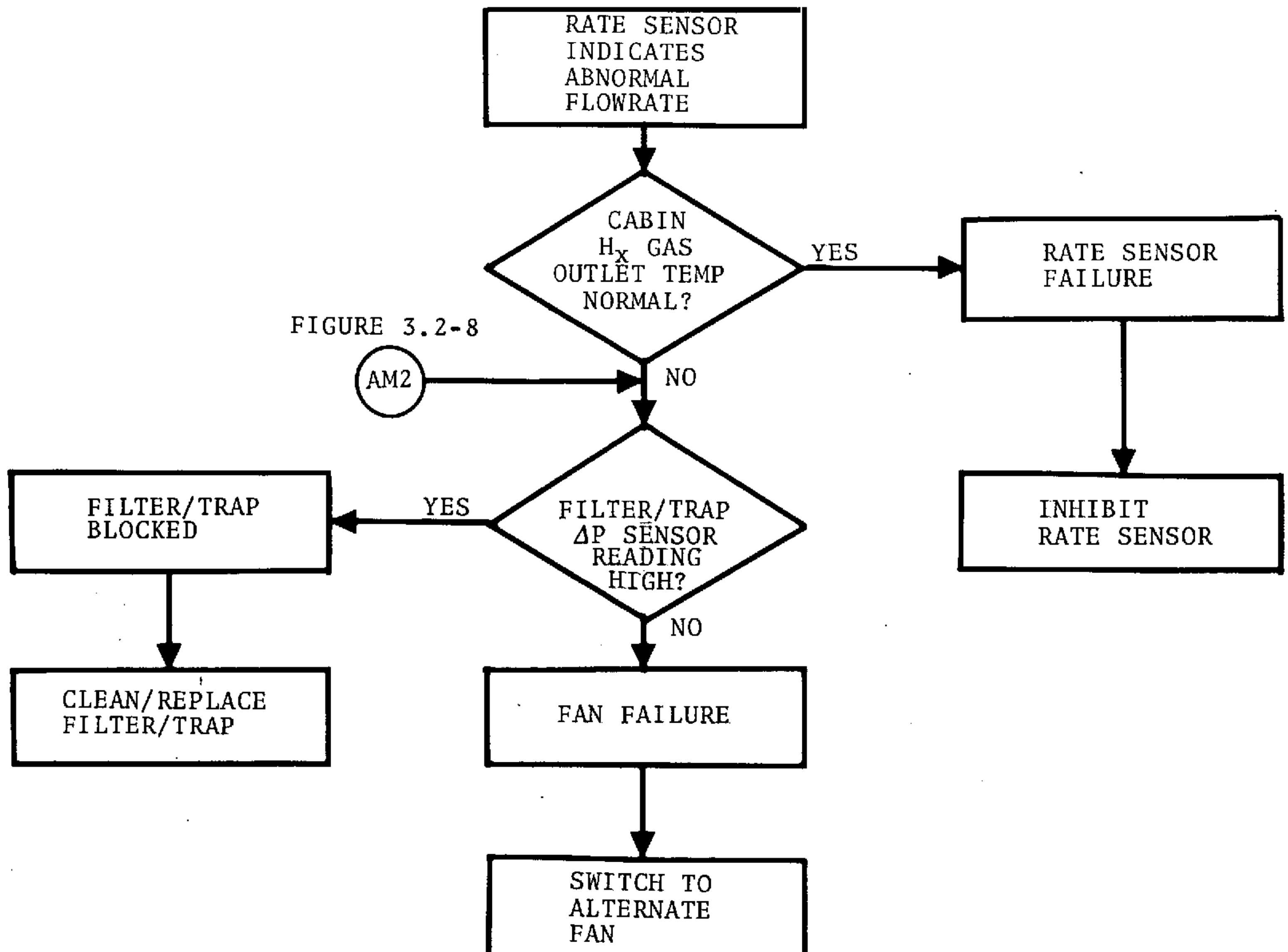


Figure 3.2-7. — Cabin air flowrate fault detection and isolation.

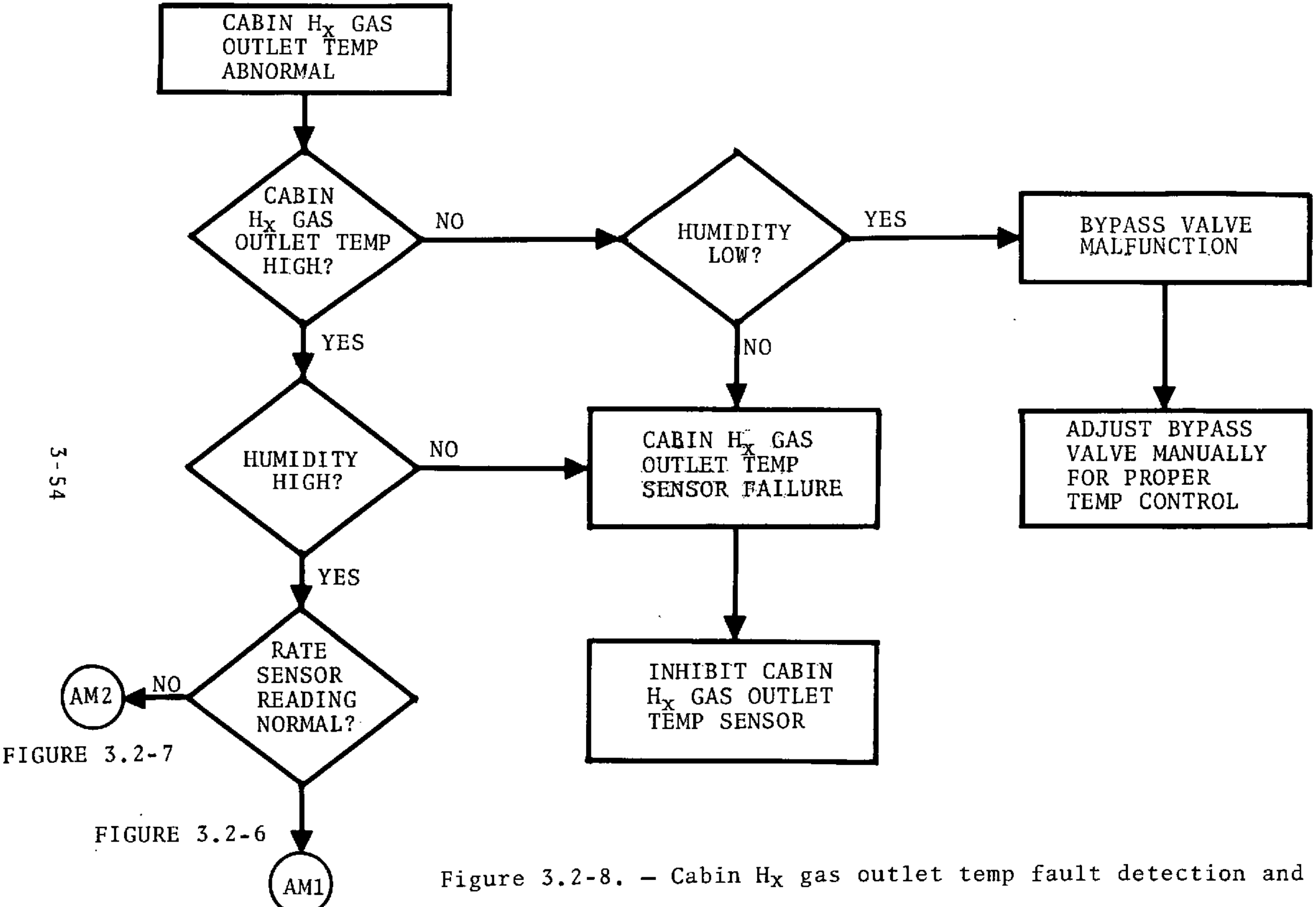


Figure 3.2-8. — Cabin H_x gas outlet temp fault detection and isolation

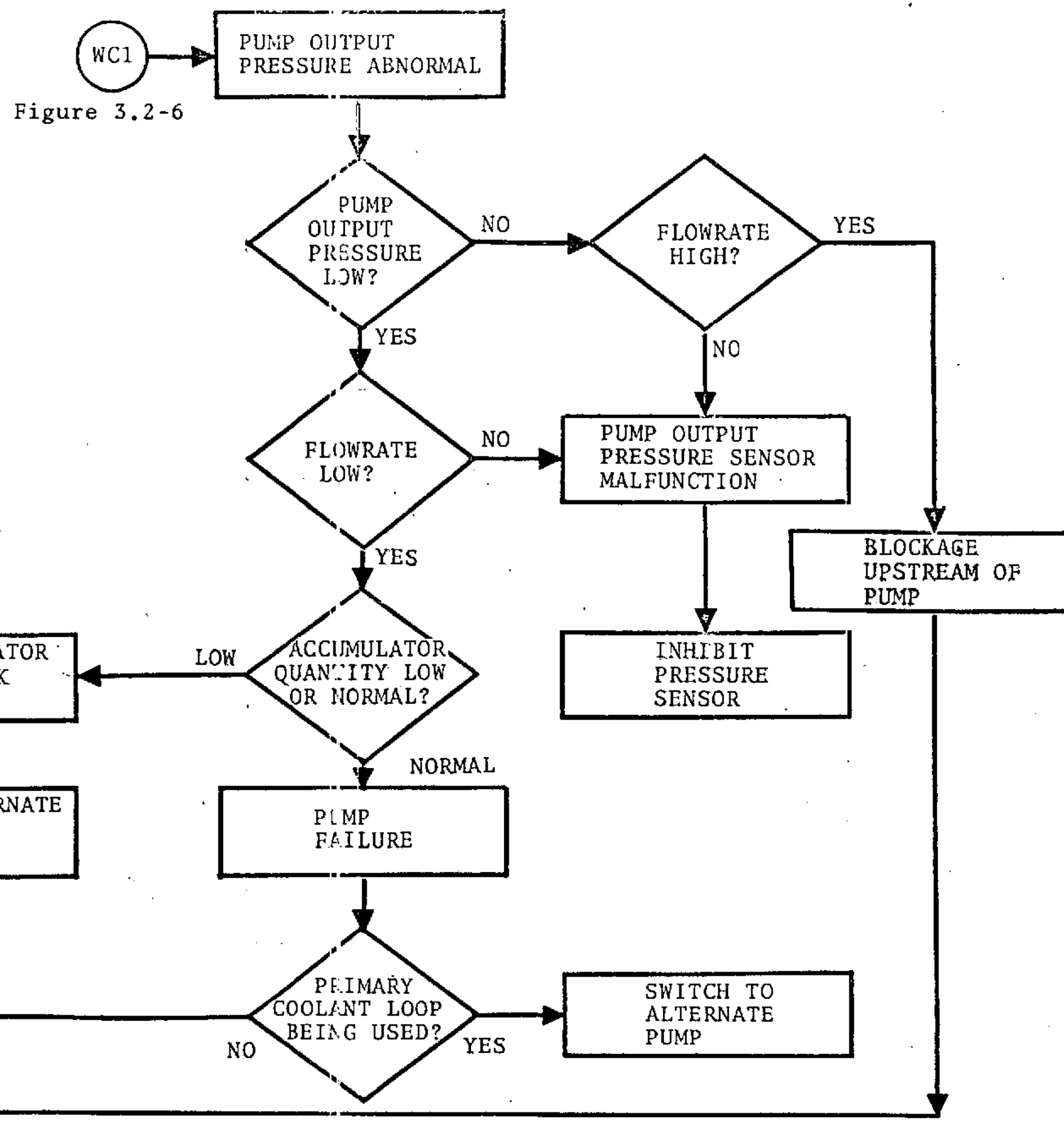


Figure 3.2-9. – Water coolant loop pump pressure fault detection and isolation.

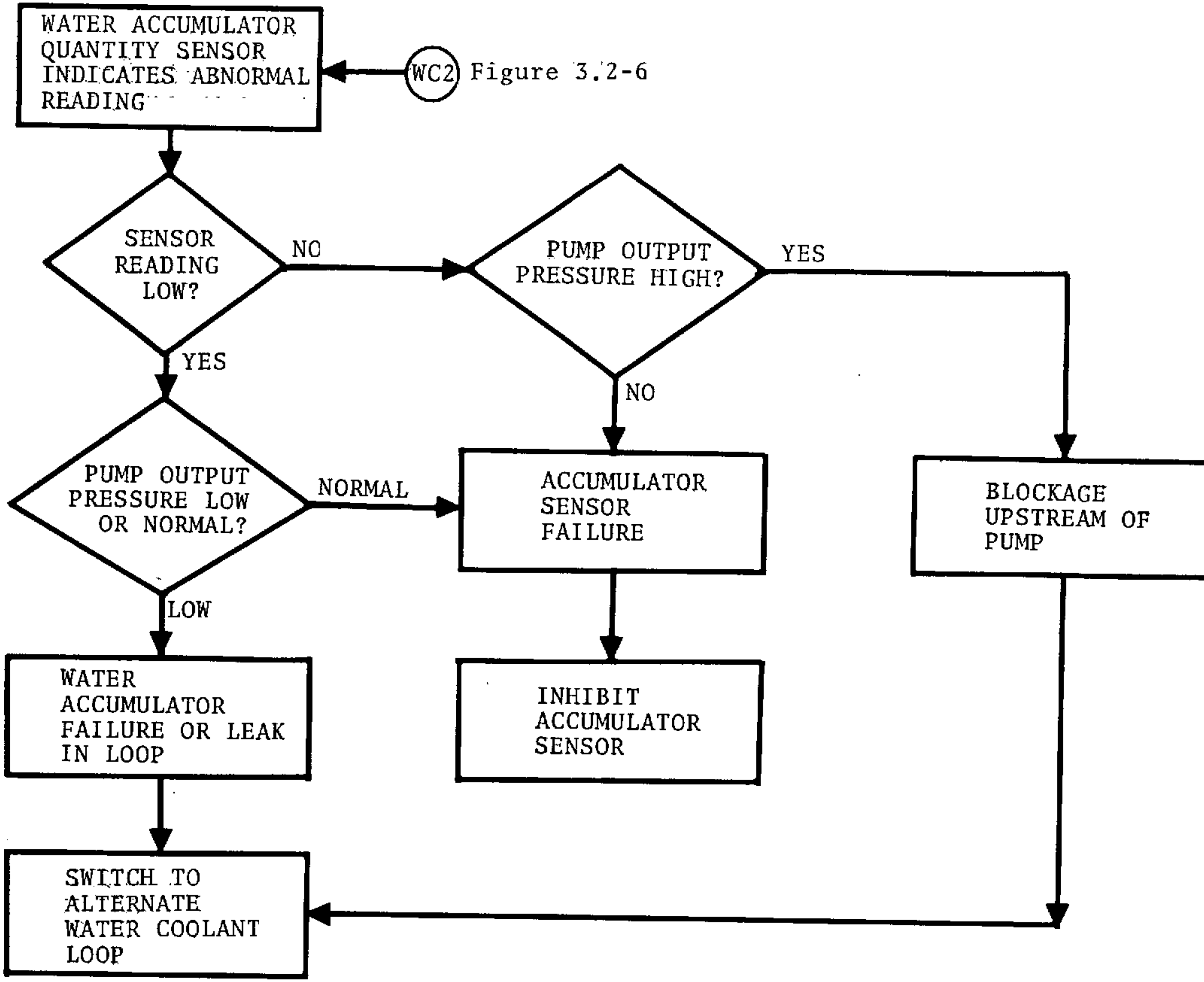


Figure 3.2-10. — Water accumulator fault detection and isolation.

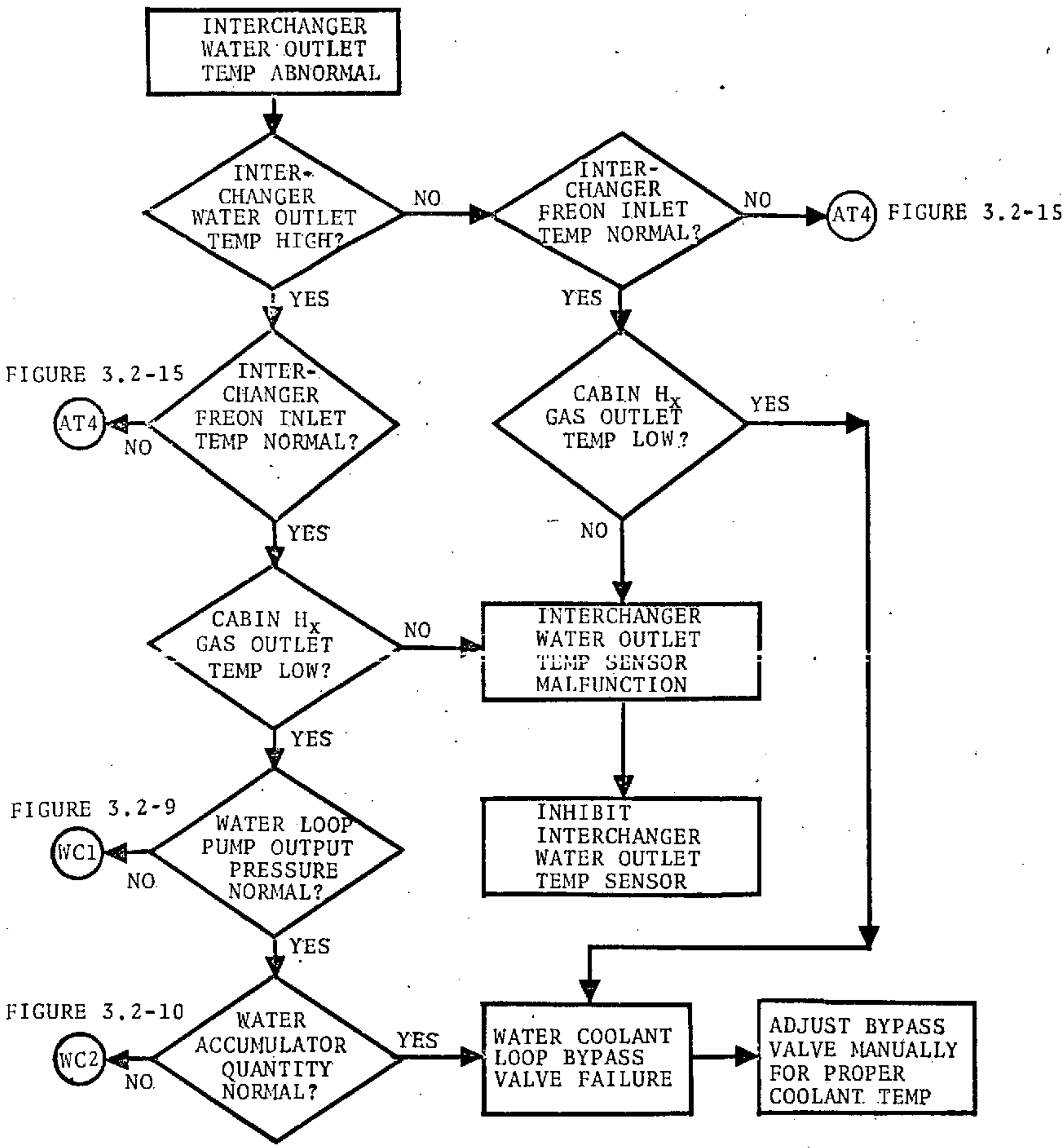


Figure 3.2-11. — Water loop interchanger temp fault detection and isolation.

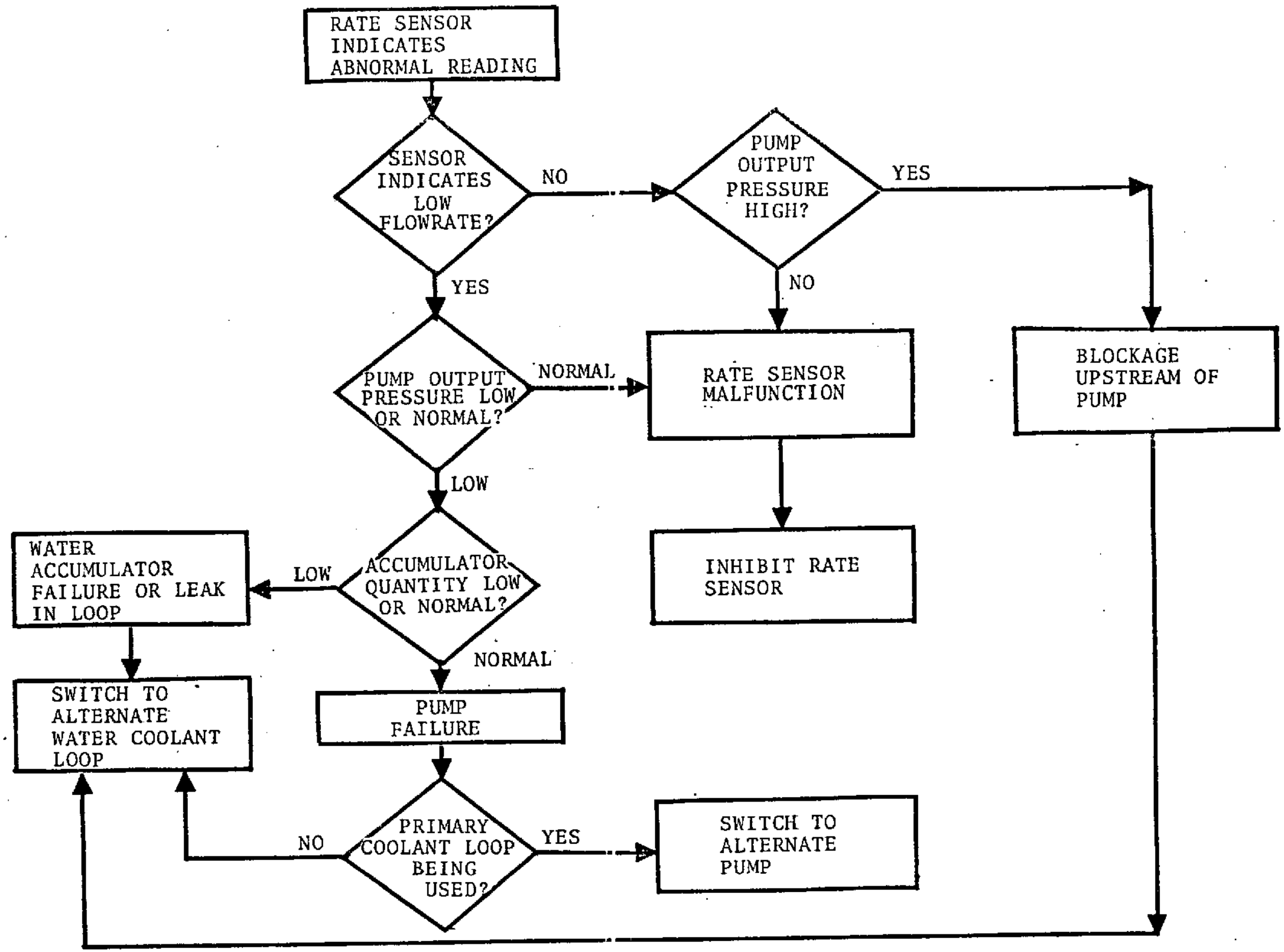


Figure 3.2-12. — Water loop flowrate fault detection and isolation.

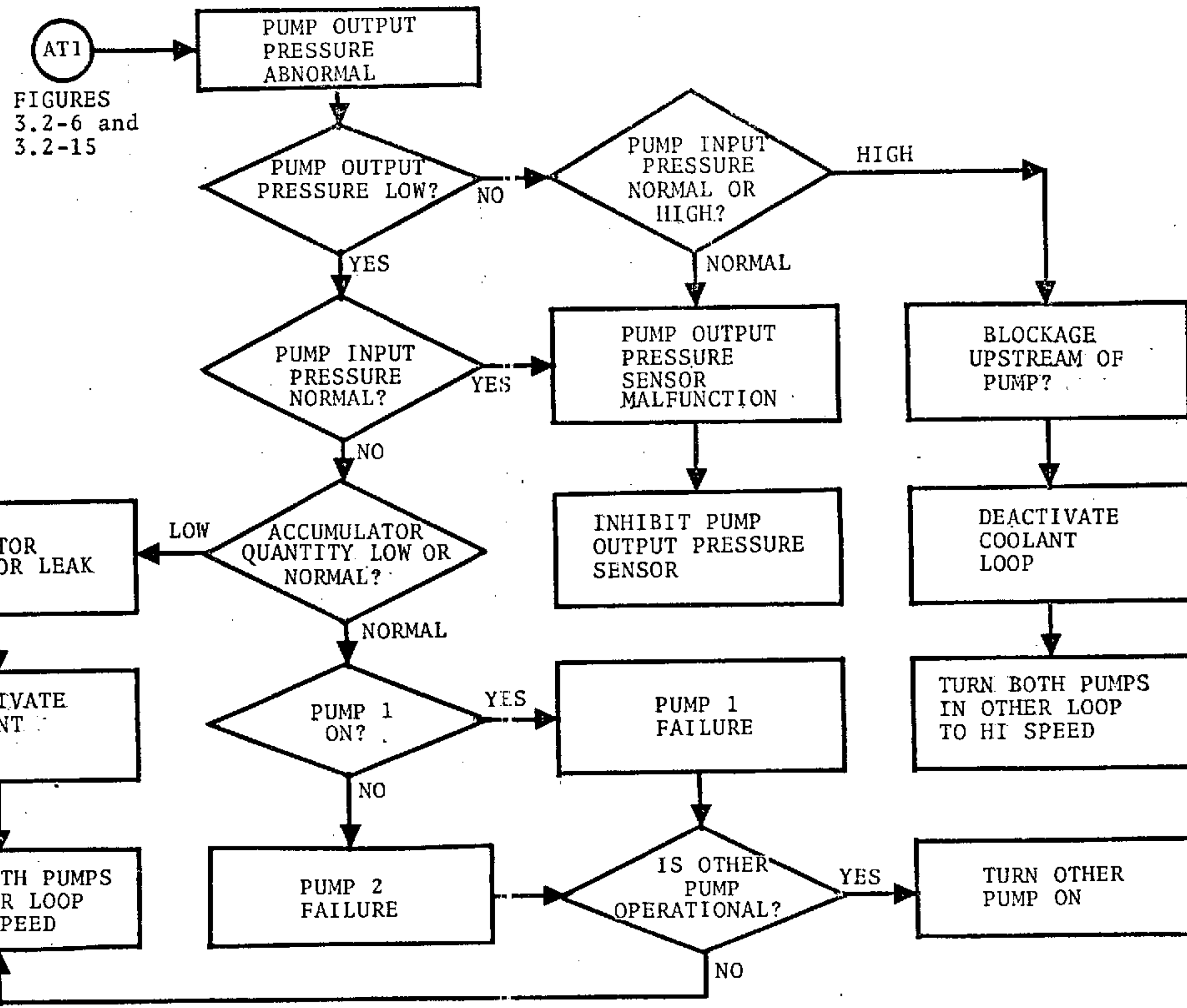


Figure 3.2-13. — Freon loop pump output pressure fault detection and isolation.

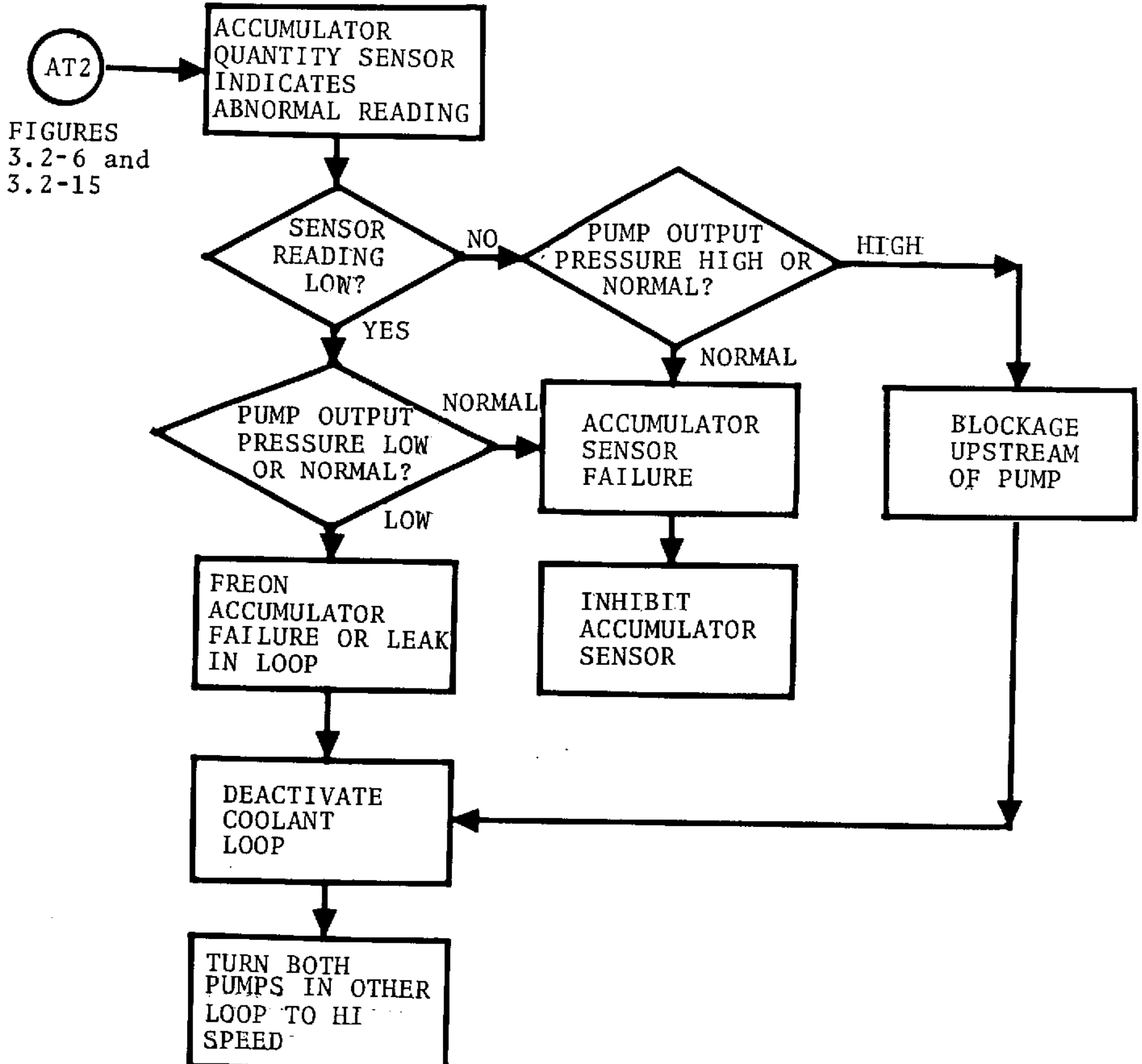


Figure 3.2-14. – Freon loop accumulator fault detection and isolation.

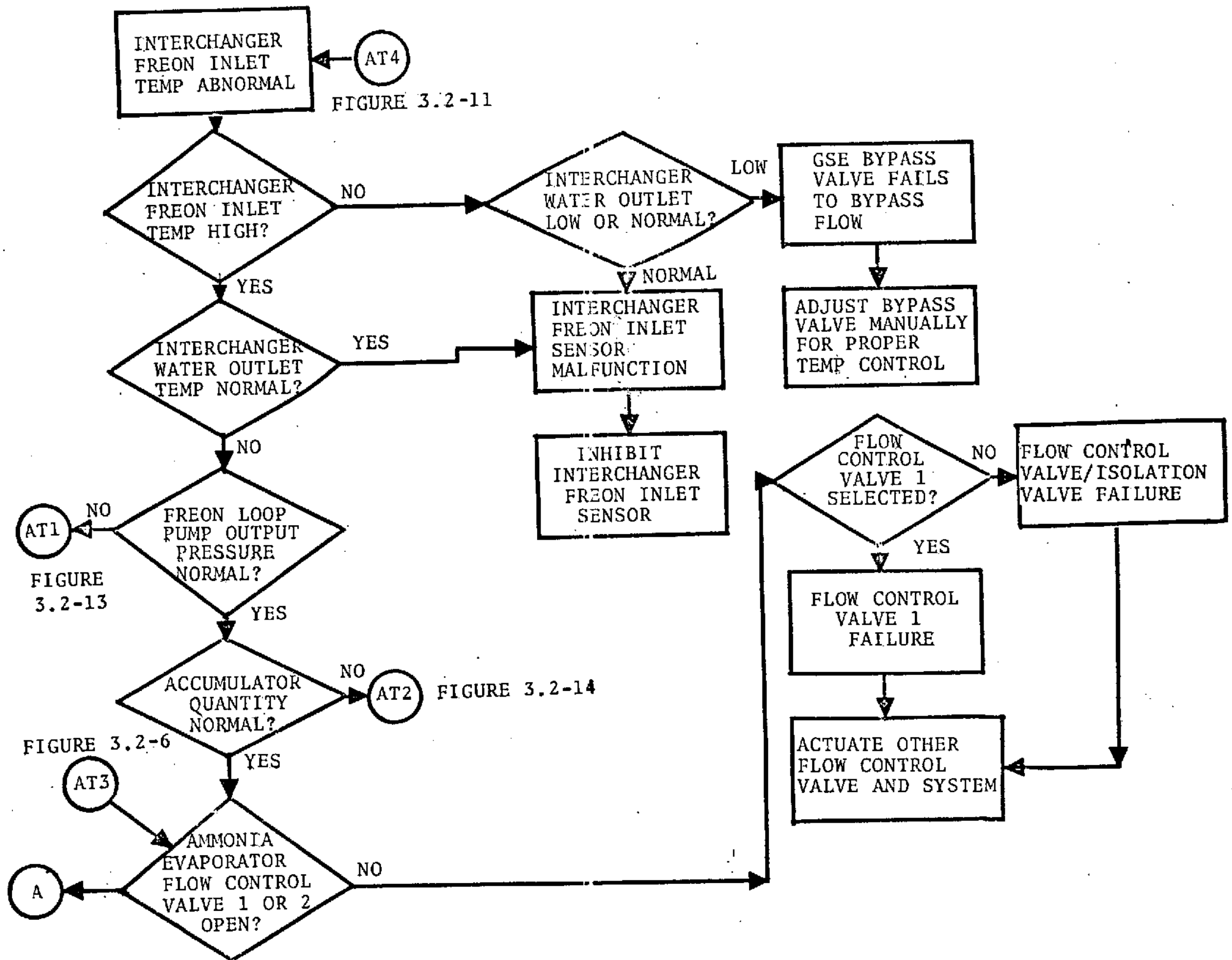


Figure 3.2-15. — Freon loop interchanger inlet temperature fault detection and isolation.

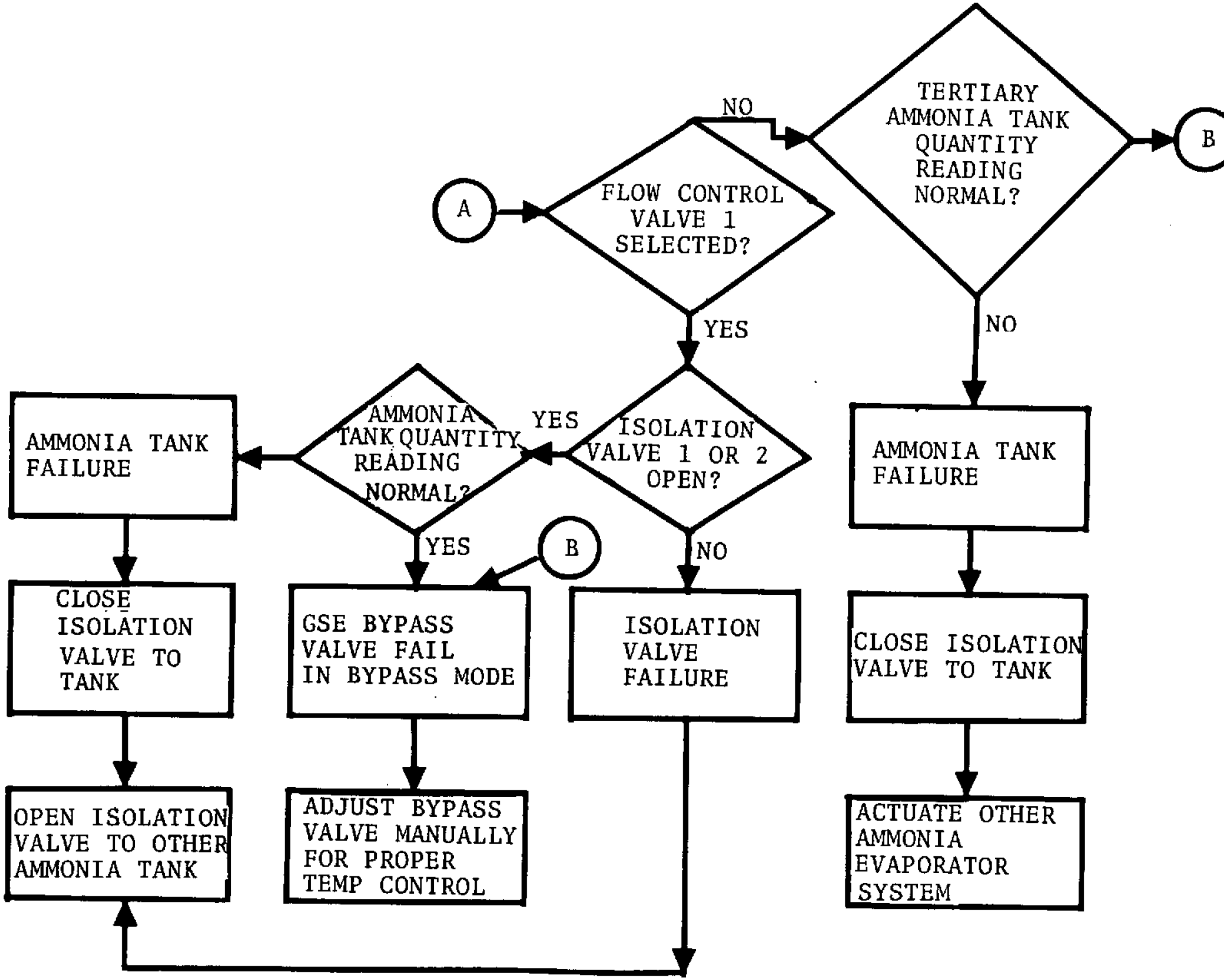


Figure 3.2-15. – Freon loop interchanger inlet temp fault detection and isolation (concluded)

3.3 HYDRAULICS

3.3.1 Subsystem Description

The hydraulic system consists of the components required for generation, control, distribution and monitoring of hydraulic power. Hydraulic power is utilized to operate the aerosurface controls (elevons, rudder, and speedbrake); retract, extend and lock up the landing gear; operate main wheel brakes; and provide nose wheel steering. The hydraulic system supplies power for the above functions during horizontal flight test (HFT). Figures 3.3-1, 3.3-2, and 3.3-3 illustrate schematically the hydraulic system and its major loads.

Hydraulic power is generated by nominal 3000 psi variable delivery pumps. The pumps are driven by Auxiliary Power Units (APU's) for HFT, VFT, and Orbital missions. The hydraulic system is comprised of three independent hydraulic subsystems each having separate pump, reservoir, oil cooler, heat exchanger, controls, displays and distribution equipment. The three subsystems are connected to the various actuators in a manner to provide the required degree of redundancy to insure flight safety in event of a malfunction of up to two systems. Hydraulic power demands will vary over a wide spectrum dependent upon varying aerodynamic loads encountered and/or simultaneous operation of various functions.

The hydraulic subsystem consists of three completely independent power generation, control, and distribution subsystems designated as Subsystems 1, 2, and 3. The power available from the three subsystems is distributed to actuators and hydraulic motors through control and servo-valves. The

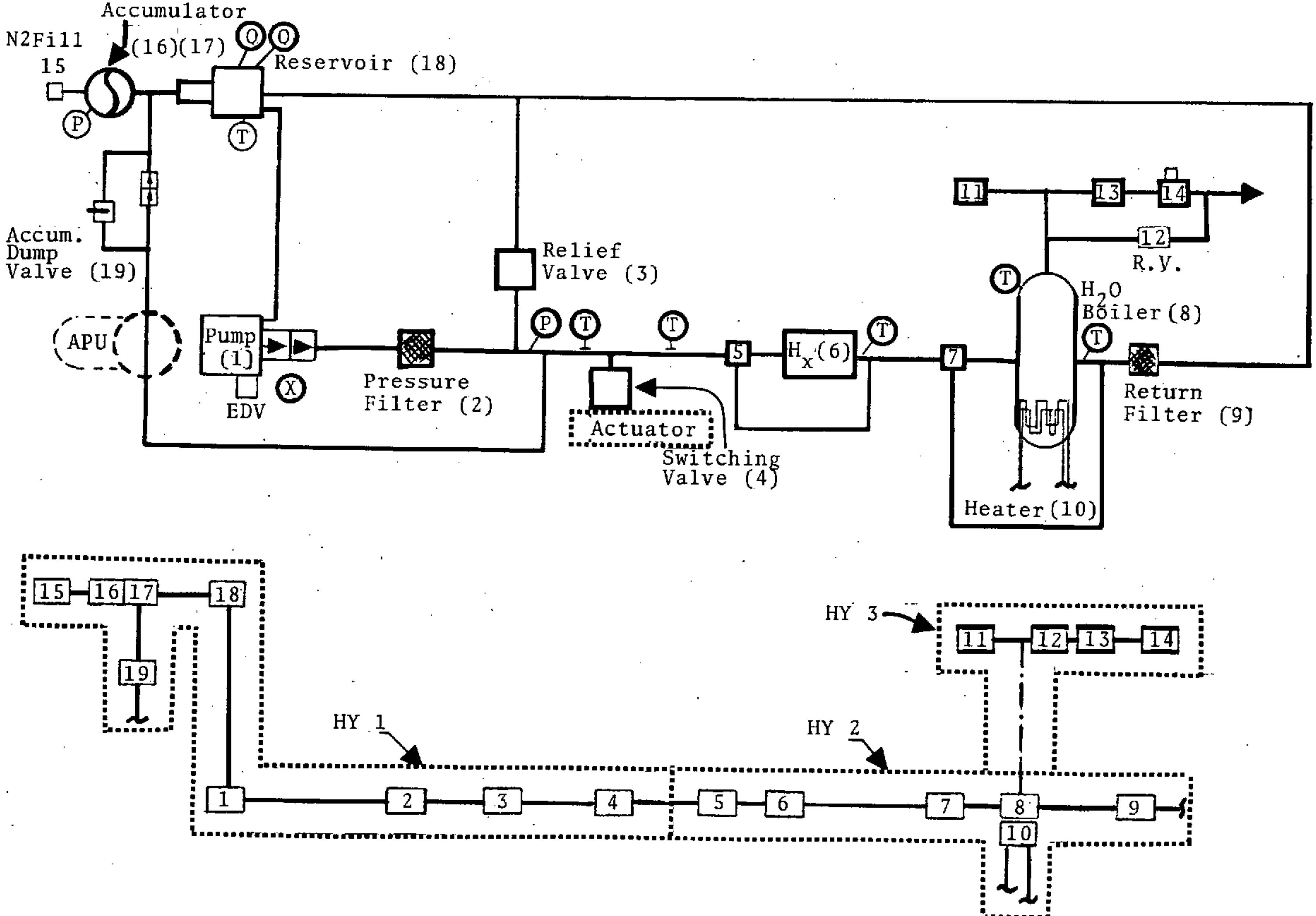


Figure 3.3-1. — Hydraulic system functional paths.

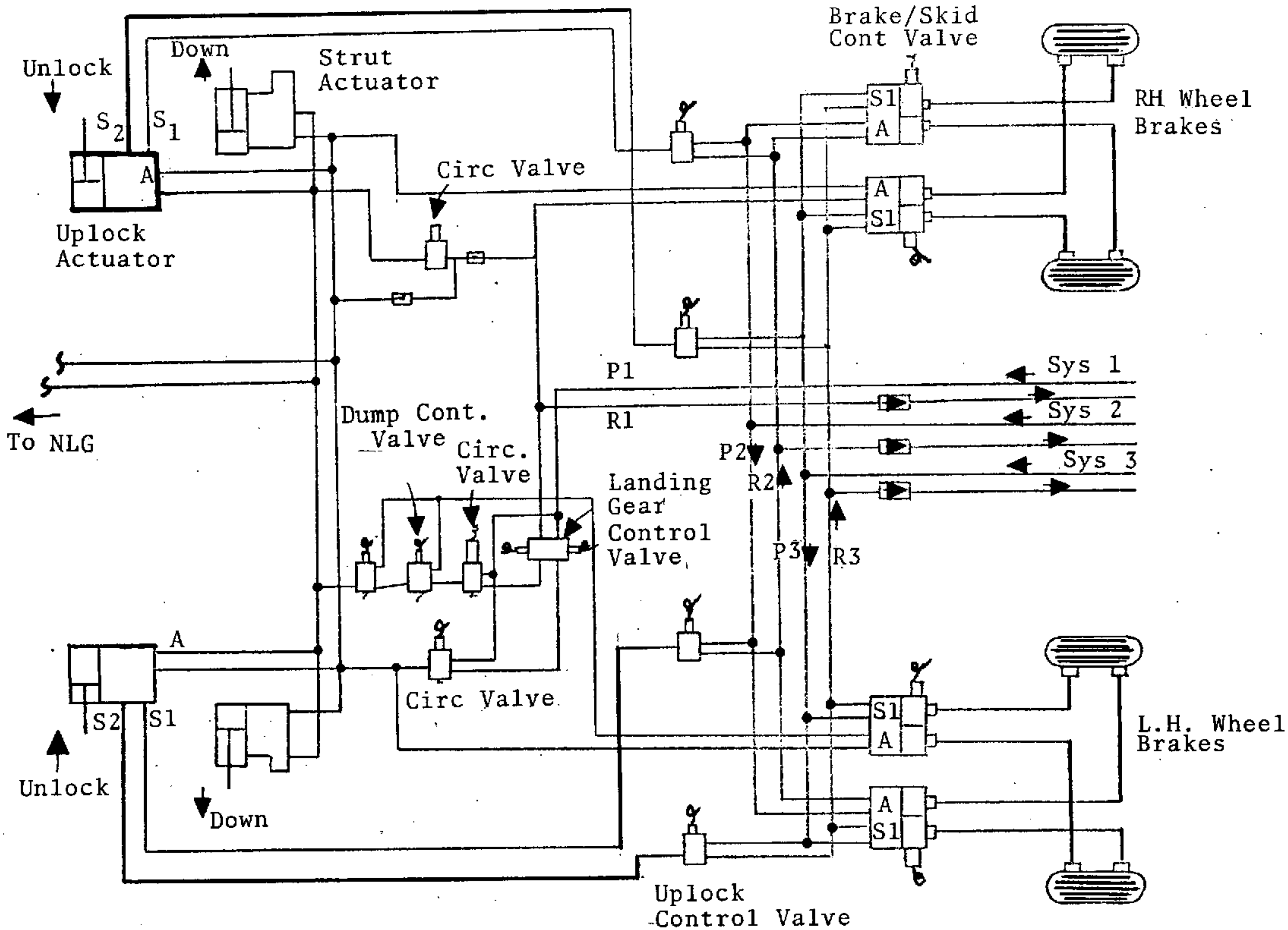


Figure 3.3-2. — Main landing gear and wheel brakes.

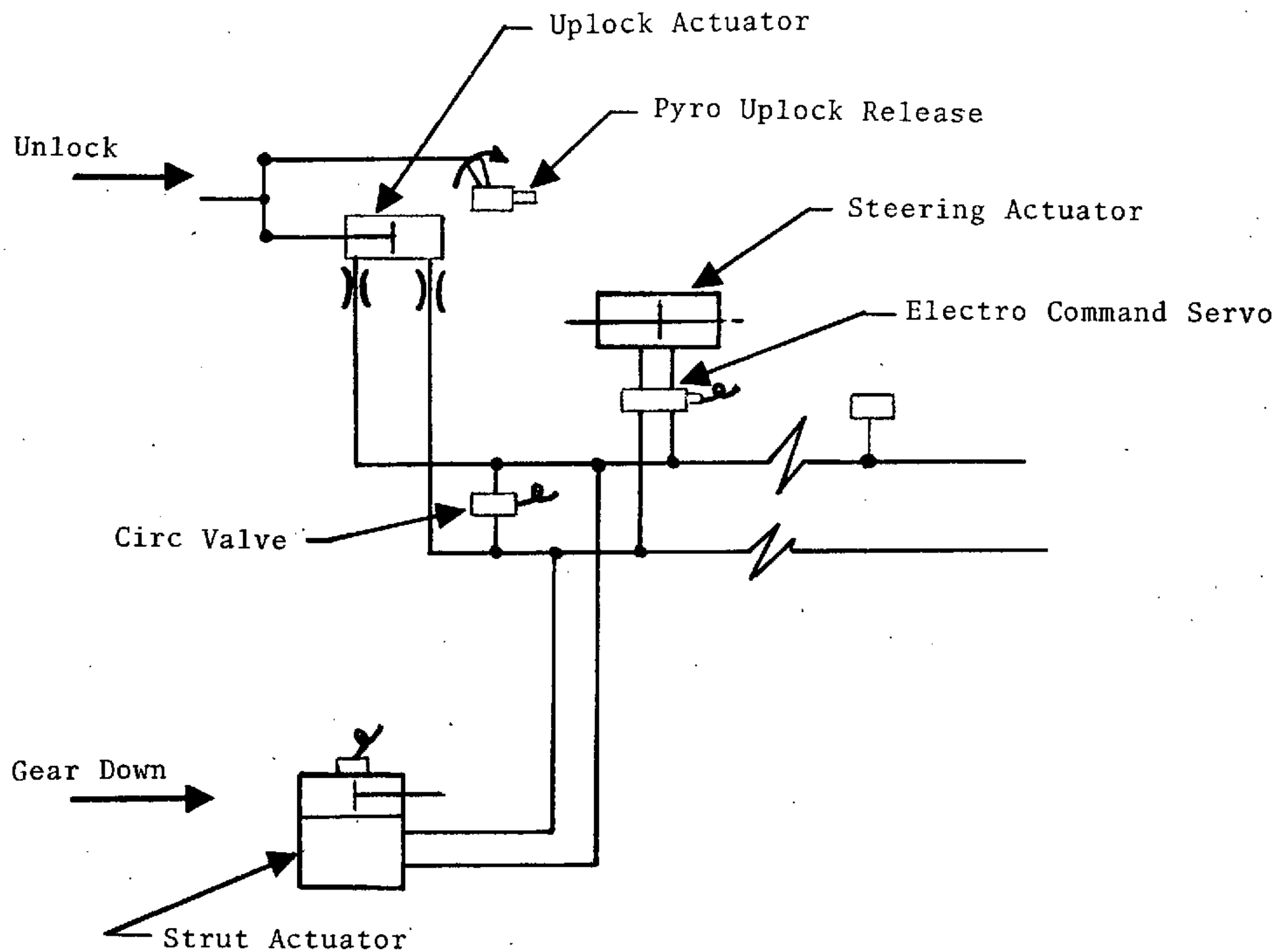


Figure 3.3-3. — Nose landing gear.

hydraulic subsystems have provisions for connection to ground hydraulic power sources for checkout of the subsystems when the APU's are not being operated. The ground power sources are also used to circulate the fluid to fill, flush, and bleed the subsystems.

The hydraulic subsystem incorporates functional redundancy provisions to insure that operation of hydraulic driven components can continue after specified failures. Redundancy is obtained by switching valves which provide the capability for any one of the subsystems connected to the switching valve to supply the function in event of failure of the other connected subsystems.

Provisions are included in each of the three hydraulic subsystems to prevent the hydraulic fluid temperature from exceeding $-65^{\circ}F$ to $275^{\circ}F$ limits. In all portions of the HFT mission, cooling of the hydraulic fluid is provided by the water boiler.

Hardware Elements.- The major components of the HFT Hydraulic System are:

- Main Pump
- Elevon Servoactuators
- Accumulator
- Reservoir
- Rudder/Speed Brake Hydraulic Servomotors
- Water Boiler
- Hydraulic Fluid Heat Exchanger

- Nose Landing Gear Strut Actuator
- Nose Landing Gear Uplock Actuator
- Main Landing Gear Strut Actuator
- Main Landing Gear Uplock Actuator
- Main Landing Wheel Brakes
- Nosewheel Steering

3.3.2 Functional Paths

Functionally, the hydraulic system of the HFT vehicle consists of three power generation and conditioning sources, and four loads. These loads are: Landing Gear, Elevon, Rudder and Speed Brake. The landing gear includes: Gear Activation up and down, Nose Gear Steering, Gear up Lock Actuators and Main Gear Brakes.

Figures 3.3-1, 3.3-4, and 3.3-5 illustrate schematically the hydraulic system. Also shown below the schematic, in these figures, are the functional paths. Each component in the schematic diagram is numbered to aid in identification in the accompanying functional path diagram. Identification of the functional paths is as follows:

- HY1 – Hydraulic Pump and Supply
- HY2 – Return Circuit and Heat Exchangers
- HY3 – Water Boiler
- HY4 – Left Outboard Elevon Actuator
- HY5 – Left Inboard Elevon Actuator

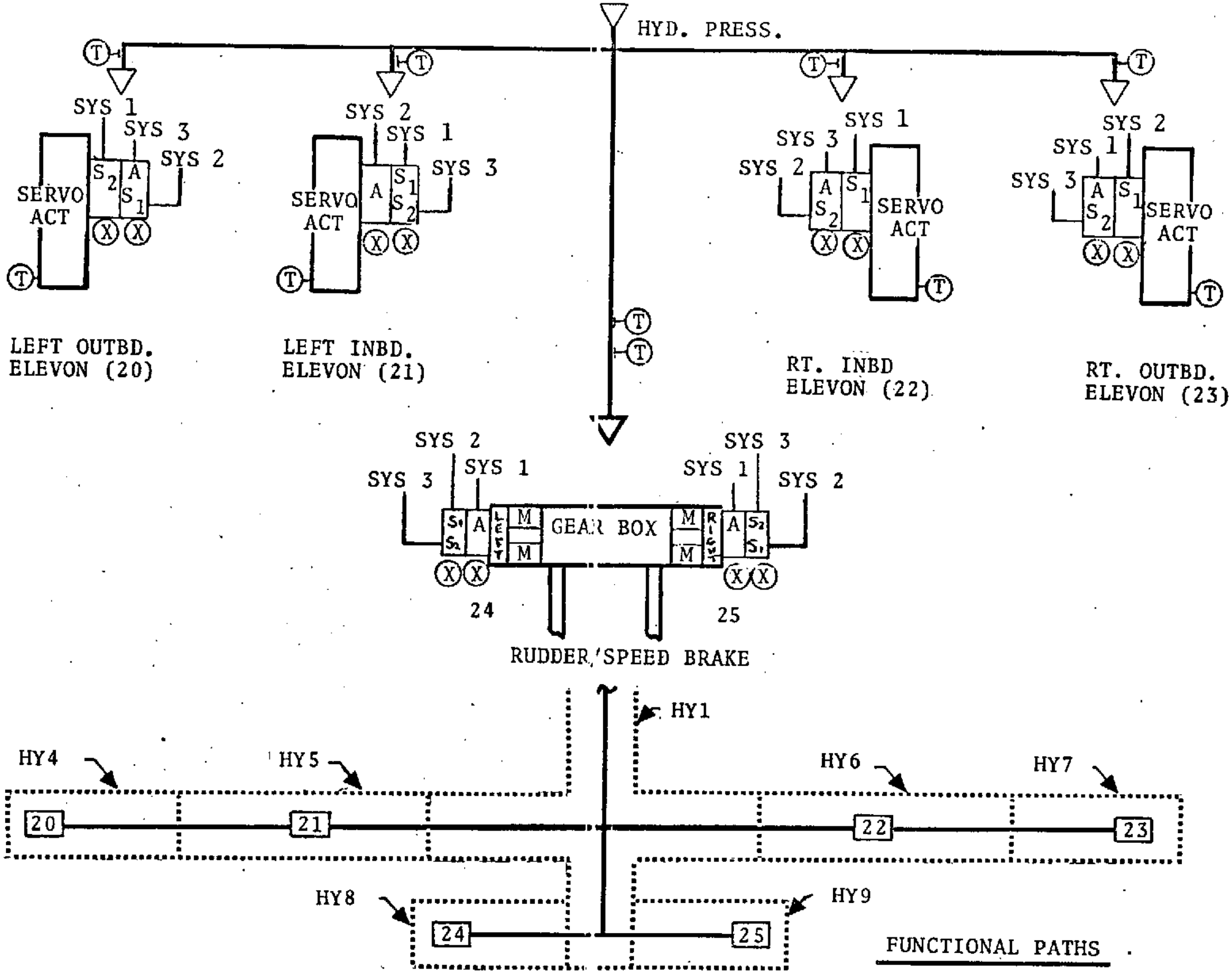


Figure 3.3-.4. – Hydraulic system – flight controls.

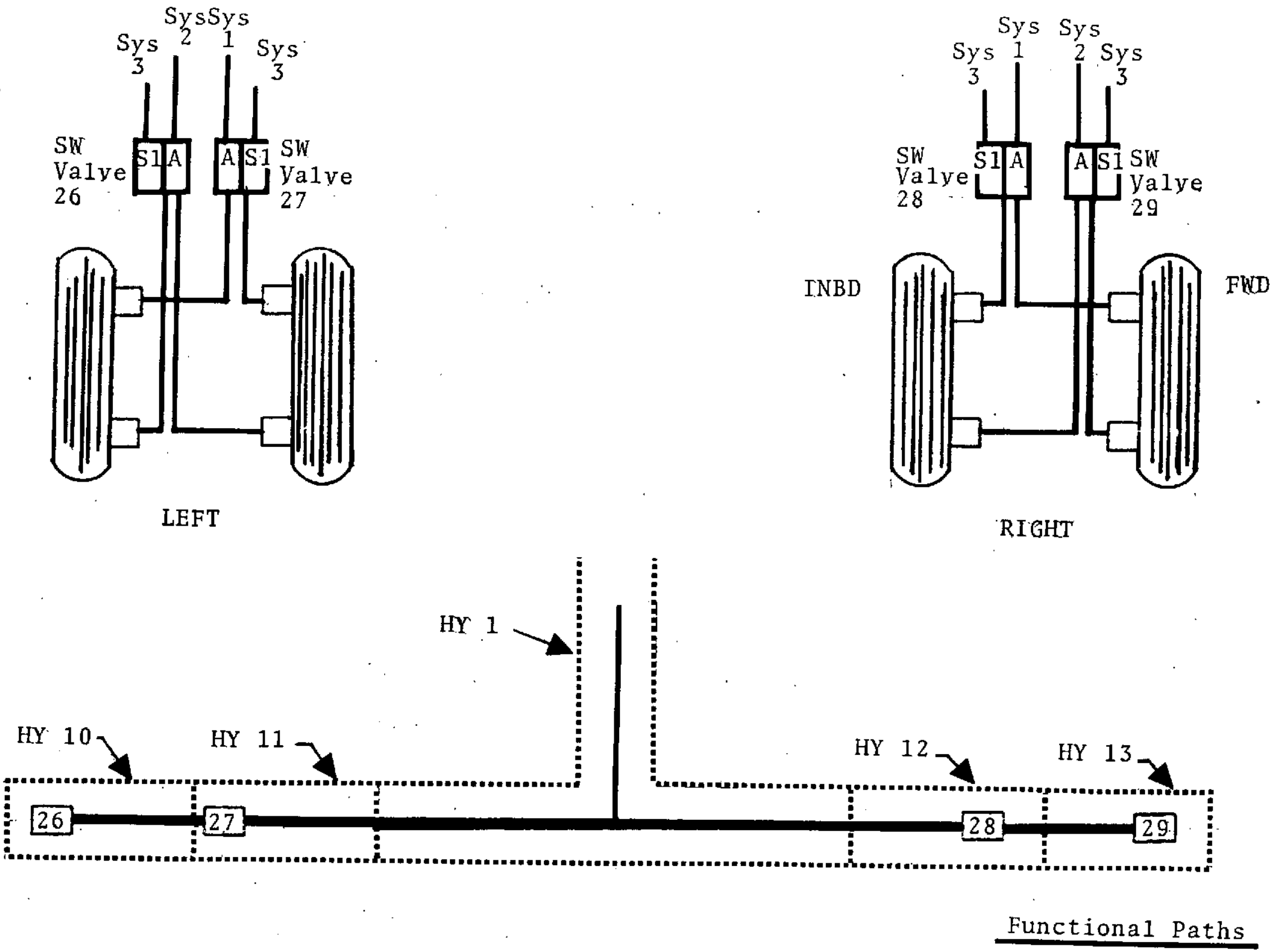


Figure 3.3-5. — Main wheel brake system.

- HY6 — Right Inboard Elevon Actuator
- HY7 — Right Outboard Elevon Actuator
- HY8 — Left Rudder/Speed Brake
- HY9 — Right Rudder/Speed Brake
- HY10 — Left Rear Main Wheel Brake Servo-valve
- HY11 — Left Forward Main Wheel Brake Servo-valve
- HY12 — Right Forward Main Wheel Brake Servo-valve
- HY13 — Right Rear Main Wheel Brake Servo-valve

3.3.3 PMS Interfaces

Figure 3.3-1 shows the schematic for one hydraulic system and the instrumentation which interfaces with the PMS.

The instrumentation is identical for all three hydraulic systems as also are the functional paths HY1 through HY8.

Figures 3.3-4 and 3.3-5 show instrumentation locations for the hydraulic system loads as follows: elevon, rudder, speed-brake and landing gear systems.

Table 3.3-1 lists the measurements which are necessary to monitor the health status of the hydraulic system and its loads.

3.3.4 HFT — PMS System Requirements

The failure detection and annunciation (FDA) for the hydraulic system revolves about the use of two key parameters in the power source. These are the APU-driven hydraulic pump outlet pressure and the hydraulic reservoir quantity.

Temperatures are also monitored although the thermal environment encountered during HFT will be less critical than that encountered during an Orbital mission.

Load data is confined to the primary function of fault detection and temperature monitoring. The position of the switching valves is checked by the PMS to determine switching valve malfunction or hydraulic system failure. The temperature conditions encountered during HFT will not be critical; however, by checking this instrumentation, the PMS will assist in system qualification.

Table 3.3-2 summarizes the FDA measurements for the hydraulic system and indicates measurement limits where applicable.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58T0101A — Hydraulic Power System 1 Reservoir Fluid Temperature	Temp	-40 to +260°F	HY1	Provides temperature of fluid in reservoir for comparison with other fluid temperatures and monitoring of water boiler operation.
V58Q0102A — System 1 Reservoir Fluid Volume	Quantity	50%	HY1	Gives indication of loss of Hydraulic System Fluid (low limit check only).
V58X0103E — System 1 Reservoir Fluid Level Low	Event		HY1	Gives indication of low fluid level.
V58P0114A — System 1 Supply Pressure A	Press	2000-4050 psia	HY1	Supply pressure gives direct indication of system status.
V58P0115A — System 1 Supply Pressure B	Press	TBD	HY1	Supply pressure and gives indication of system status (backup measurement).
V58T0119A — System 1 Fwd Dist P Line Temperature	Temp	-40 to +260°F	HY1	Measures temperature of fluid leaving pump circuit.
V58P0130A — System 1 GN_2 Accumulator Pressure	Press	2000-4050 psia	HY1	Provides system/accumulator status and backup to system pressure (not accessed to PMS).
V58S0146E — System 1 ME Supply Valve Close	Event		HY1	Should be closed for all HFT.

TABLE 3.3-1.
PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58X0155E — System 1 Ready For APU Start-On	Event		HY1	Provides same information as EDV pump sol. open.
V58T0122A — System 1 Aft Compartment Return Line Temperature	Temp	-40 to +260°F	HY2	Fluid temperature returning MPS area.
V58T0161A — System 1 Boiler Water Temperature	Temp	40-230°F	HY2, HY3	Monitors operation of H_2O boiler heater.
				All of the foregoing measurements are repeated for systems 2 and 3 (see Table 3.3-2 for a complete listing).
V58X0800E — Left Hand Inboard Elevon Actuator Switch V Active Position	Event		HY1, HY5	Confirm designated Hydraulic System is providing power for actuator.
V58X0801E — Left Hand Inboard Elevon Actuator Switch V PS2 Position	Event		HY1, HY5	Indicates system malfunction (i.e., that the designated active system is not supplying power).

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58T0830A — Left Hand Inboard Elevon Actuator Temperature	Temp	-65 to +250°F	HY1, HY5	To monitor heat profile for actuator.
V58T0833A — Left Hand Inboard Elevon Switch V Line Temperature	Temp	-45 to	HY1, HY5	Provides hydraulic fluid line temperature to the actuator.
V58T0841A — Left Hand Outboard Brake Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY10	Provides information on landing gear temperatures.
V58T0842A — Left Hand Inboard Brake Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY11	Provides monitoring of landing gear temperatures.
V58R0845A — Right Hand Outboard Brake Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY13	Provides monitoring of landing gear temperatures.
V58T0846A — Right Hand Inboard Brake Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY12	Provides monitoring of landing gear temperatures.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58X0850E – Left Hand Outboard Elevon Active Switch V Activate Position	Event		HY1, HY4	Provides confirmation that the designated active hydraulic system is providing power for the actuator
V58X0851E – Left Hand Outboard Elevon Actuator Switch V PS2 Position	Event		HY1, HY4	Provides indication of system or switching valve malfunction.
V58T0880A – Left Hand Outboard Elevon Actuator Temperature	Temp	-65 to +250°F	HY1, HY4	Provides monitoring of hydraulic system temperatures.
V58T0883A – Left Hand Outboard Elevon Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY4	Provides monitoring of hydraulic system temperatures.
V58X0900E – Right Hand Inboard Elevon Actuator Switch V Active Position	Event		HY1, HY6	Provides confirmation that active hydraulic system is supplying power to the actuator.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58X0901E – Right Hand Inboard Elevon Actuator Switch V PS2 Position	Event		HY1, HY6	Gives indication of active hydraulic system or switching valve failure.
V58T0930A – Right Hand Inboard Elevon Actuator Temperature	Temp	-65 to +250°F	HY1, HY6	Monitors heat profile of actuator.
V58T0933A – Right Hand Inboard Elevon Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY6	Provides monitoring of fluid temperature.
V58X0950E – Right Hand Outboard Elevon Actuator Switch V Active Position	Event		HY1, HY7	Provides verification that the designated active system is providing hydraulic power to the actuator.
V58X0951E – Right Hand Outboard Elevon Actuator Switch V PS2 Position	Event		HY1, HY7	Gives indication of hydraulic system or switching valve failure.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58T0983A — Right Hand Outboard Elevon Actuator Temperature	Temp	-65 to +250°F	HY1, HY7	Monitors actuator temperature for determination of temperature profile.
V58T0983A — Right Hand Outboard Elevon Switch V Line Temperature	Temp	-45 to +260°F	HY1, HY7	Monitors hydraulic fluid temperature.
V58X1000E — Left Hand Rudder Switch V Activate Position	Event		HY1, HY8	Provides verification that the designated active hydraulic system is supplying power to the motor.
V58X1001E — Left Hand Rudder Switch V Pos2 Position	Event		HY1, HY8	Gives indication of hydraulic system or switching valve failure.
V58T1006A — Rudder Switch V Line Temperature A	Temp	-45 to +265°F	HY1	Monitors hydraulic fluid temperature.
V58T1007A — Rudder Switch V Line Temperature B	Temp	-45 to +265°F	HY1	Monitors hydraulic fluid temperature.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58X1008E — Right Hand Rudder Switch V Active Position	Event		HY1, HY9	Provides verification that the designated active hydraulic system is supplying power to the motor.
V58X1009E — Right Hand Rudder Switch V PS2 Position	Event		HY1, HY9	Gives indication of hydraulic system or switching valve failure.
V58T1120A — Main Engine 2 Interface Pressure Line Temperature	Temp	-45 to +260°F	HY1	Needed to monitor hydraulic system fluid temperature.
V58T1140A — Main Engine 3 Interface Pressure Line Temperature	Temp	-45 to +260°F	HY1	Needed to monitor hydraulic system fluid temperature.
V58T1144A — Mid Fuselage Pressure Line Temperature	Temp	-45 to +260°F	HY1	Needed to monitor hydraulic system fluid temperature.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58S0086E Hyd Sys Auto Thermal - On	Event	0/1	HY 1, 2, 4, 5, 6, & 7	Precondition configuration status.
V58S0087E L Otbd. Act. Htr. Auto	Event	0/1	HY 4	Precondition configuration status.
V58S0088E L Otbd Act. Htr. On	Event	0/1	HY 4	Precondition configuration status.
V58S0089E L Inbd Act. Htr. On	Event	0/1	HY 5	Precondition configuration status.
V58S0090E L Inbd. Act Htr. Auto	Event	0/1	HY 5	Precondition configuration status.
V58S0097E R Otbd Act Htr. Auto	Event	0/1	HY 7	Precondition configuration status.
V58S0098E R Otbd Act. Htr. On	Event	0/1	HY 7	Precondition configuration status.
V58S0099E - R Inbd Act Htr-On	Event	0/1	HY 6	Precondition configuration status.

TABLE 3.3-1.

PMS MEASUREMENT DATA

SUBSYSTEM: HYDRAULICS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V58S0108E R Inbd Act Htr.-Auto	Event	0/1	HY 6	Precondition configuration status.
V58S0104E Sys 1 Mn Pmp DPRS-On	Event	0/1	HY 1	Precondition configuration status.
V58S0204E Sys 2 Mn Pmp DPRS-On	Event	0/1	HY 1	Precondition configuration status.
V58S0304E Sys 3 Mn Pmp DPRS-On	Event	0/1	HY 1	Precondition configuration status.
V58S0167E Sys 1 H_2O Blr Htr - On	Event	0/1	HY 3	Precondition configuration status.
V58S0168E Sys 1 H_2O Blr. Htr. - Auto	Event	0/1	HY 3	Precondition configuration status.
V58S0267E Sys 2 H_2O Blr.Htr-On	Event	0/1	HY 3	Precondition configuration status.
V58S0268E Sys 2 H_2O Blr Htr-Auto	Event	0/1	HY 3	Precondition configuration status.
V58S0367E Sys 3 H_2O Blr Htr-Auto	Event	0/1	HY 3	Precondition configuration status.
V58S0368E Sys 3 H_2O Blr Htr-Auto	Event	0/1	HY 3	Precondition configuration status.

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58T0101A (S) • Sys 1 Reservoir Fluid Temp • HY1			240° F	+10° F		+260°F	0°F			V58T0122A
• V58Q0102A (P) • Sys 1 Reservoir Fluid Vol. • HY1				85%	X		50%			V58X0103E
• V58P0114A (P) • Sys 1 Supply Press A • HY1			3200 psia	2500 psia		4050 psia	2000 psia			V58P0115A V58P0130A
• V58P0115A (P) • Sys 1 Supply Press B • HY1			TBD	TBD		TBD	TBD			V58P0130A
• V58T0119A (S) • Sys 1 Fwd Distr. P Line Temp • HY1			240° F	+10° F		260° F	0° F			None
• V58T0122A (S) • Sys 1 Aft Compt Rtn Line Temp • HY2			240° F	+10° F		260° F	0° F			None
• V58P0130A (S) • Sys 1 GN2 Accum Press • HY1			3200 psia	2500 psia		3900 psia	2000 psia			V58P0114A V58P0115A
• V58S0146E (S) • Sys 1 ME Supply Valve Close • HY1		X								None

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58X0155E (P) • Sys 1 Ready for Apu Start-On • HY1		X								
• V58T0161A (S) • Sys 1 Boiler Water Temp • HY3			220° F	45° F		230° F	40° F			
• V58X0103E (S) • Sys 1 Reserve Fluid Lvl Low SW • HY1					X					V58Q0102A
• V58T0201A (S) • Sys 2 Resvr Fluid Temp • HY1			240° F	+10° F		+260° F	0° F			V58T0222A
• V58O0202A (P) • Sys 2 Resvr Fluid Vol • HY1				85%	X		50%			V58X0203E
• V58P0214A (P) • Sys 2 Supply Press A • HY1			3200 psia	2500 psia		4050 psia	2000 psia			V580215A V58P0230A
• V58P0215A (P) • Sys 2 Supply Press B • HY1			TBD	TBD		TBD	TBD			V58P0230A
• V58T0219A (S) • Sys 2 Fwd Distr P Line Temp			240° F	+10° F		260° F	0° F			

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58T0222A (S) • Sys 2 Aft Compt Rtn Line Temp • HY2			240° F	+10° F		260° F	0° F			
• V58P0230A (S) • Sys 2 GN2 Accum Press • HY1			3200 psia	2500 psia		3900 psia	2000 psia			V58P0214A V58P0215A
• V58S0246E (S) • Sys 2 ME Supply Vlv Close • HY1		X								
• V58X0255E (P) • Syst 2 Ready for APU Start-On • HY1		X								
• V58T0261A (S) • Sys 2 Boiler Water Temp • HY3			220° F	45° F	X	230° F	40° F			
• V58X0203E (S) • Sys 2 Resvr Fluid Lvl Low SW • HY1					X					V58Q0202A
• V58T0300E (S) • Sys 3 Resvr Fluid Temp • HY1			240° F	+10° F		200° F	0° F			V58T0322A
• V58Q0302A (P) • Sys 3 Resvr Fluid Vol • HY1				85%	X		50%			V58X0303E

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58P0314A (P) • Sys 3 Supply Press A • HY1			3200 psia	2500 psia		4050 psia	2000 psia			V58P0315A V58P0330A
• V58P0315A (P) • Sys 3 Supply Press B • HY1			TBD	TBD		TBD	TBD			V58P0314A V58P0330A
• V58T0319A (S) • Sys 3 Fwd Distr P. Line Temp • HY1			240° F	+10° F		260° F	0° F			
• V58T0322A (S) • Sys 3 Aft Compt Rtn Line Temp • HY2			240° F	+10° F		260° F	0° F			
• V58P0330A (S) • Sys 3 GN2 Accum Press • HY1			3200 psia	2500 psia		3900 psia	2000 psia			V58P0314A V58P0315A
• V58S0346E (S) • Sys 3 ME Supply Vlv Close • HY1		X								
• V58X0355E (P) • Sys 3 Ready for APU Start-On • HY1		X								
• V58T0361A (S) • Sys 3 Boiler Water Temp • HY3			220° F	45° F		230° F	40° F			

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58X0303E (S) • Sys 3 Resvr Fluid Lvl Low SW • HY1					X					V58Q0302A
• V58X0800E (P) • LH Inbd Elvn Actr SW Vlv Actv Posn • HY1 & HY5		X								V58X0801E
• V58X0801E (S) LH Inbd Elvn Actr Swv PS2 Posn • HY1 & HY5		X								V58X0800E
• V58T0830A (S) • LH inbd Elvn Actr Temp • HY1 & HY5			240° F	0° F	X	250° F	-10° F			V58T0880A
• V58T0833A (S) • LH Inbd Elvn SW V Line Temp • HY1 & HY5			245° F	+10° F	X	260° F	0° F			
• V58T0841A (S) • LH Outbd Brake SW V Line Temp • HY1 & HY10			245° F	+10° F	X	260° F	0° F			
• V58T0842A (S) • LH Inbd Brake SW V Line Temp • HY1 & HY11			245° F	+10° F	X	260° F	0° F			
• V58T0845A (S) • RH Outbd Brake SW V Line Temp • HY1 & HY13			245° F	+10° F	X	260° F	0° F			

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST: HARDWARE STATUS	PRE-CONDITION TEST: CONFIGURATION CHECK	SOFT LIMIT CHECK: HIGH	SOFT LIMIT CHECK: LOW	TREND CHECK	HARD LIMIT CHECK: HIGH	HARD LIMIT CHECK: LOW	BACKUP CAUTION & WARNING: HIGH	BACKUP CAUTION & WARNING: LOW	CORRELATION MEASUREMENT
• V58T0846A (A) • RH Inbd Brake SW V Line Temp • HY1 & HY2			245° F	+10° F		260° F	0° F			
• V58X0850E (P) • LH Outbd Elvn Actr SW V Actv Posn • HY1 & HY4		X								V58X0851E
• V58X0851E (S) • LH Outbd Elvn Actr SW V PS2 Posn • HY1 & HY4		X								V58X0850E
• V58T0880A (S) • LH Outbd Elvn Actr Temp • HY1 & HY4			240° F	+10° F		250° F	0° F			V58T0830A
• V58T0883A (S) • LH Outbd Elvn SW V Line Temp • HY1 & HY4			240° F	+10° F		260° F	0° F			
• V58X0900E (P) • RH Inbd Elvn Actr SW V Actv Posn • HY1 & HY6		X								
• V58X0901E (S) • RH Inbd Elvn Actr SW V PS2 Posn • HY1 & HY6		X								
• V58T0930A (S) • RH Inbd Elvn Actr Temp • HY1 & HY6			240° F	+10° F		250° F	0° F			V58T0980A

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58T0933A (S) • RH Inbd Elvn SW V Line Temp • HY1 & HY6			245° F	+10°F		260° F	0° F			
• V58X0950E (P) • RH Outbd Elvn Actr SW V Actv Posn • HY1 & HY7		X								V58X0951E
• V58X0951E (S) • RH Outbd Elvn Actr SW V PS2 Posn • HY1 & HY7		X								V58X0950E
• V58T0980A (S) • RH Outbd Elvn Actr Temp • HY1 & HY7			240° F	0° F		250° F	-10° F			
• V58T0983A (S) • RH Outbd Elvn SW V Line Temp • HY1 & HY7			240° F	0° F		260° F	-10° F			
• V58X1000E (P) • LH Rudder SW V Actv Posn • HY1 & HY8		X								V58X1001E
• V58X1001E (S) • LH Rudder SW V. PS2 Posn • HY1 & HY8		X								V58X1000E
• V58T1006A (S) • Rudder SW V Line Temp A • HY1			245° F	+10° F		260° F	0° F			

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58T1007A (S) • Rudder SW V Line Temp B • HY1			245° F	+10° F		240° F	0° F			
• V58X1008E (P) • RH Rudder SW V Actv Posn • HY1 & HY9		X								V58X1009E
• V58X1009E (S) • RH Rudder SW V PS2 Posn • HY1 & HY9		X								V58X1008E
• V58T1120A (S) • ME2 Intfc P Line Temp • HY1			245° F	+10° F		260° F	0° F			
• V58T1140A (S) • ME3 Intfc P Line Temp • HY1			245° F	+10° F		260° F	0° F			
• V58T1144A (S) • MID Fuslg P Line Temp • HY1			245° F	+10° F		260° F	0° F			
• V58S0086E • HYD Sys Auto Thermal-On • HY 1, 2,4,5,6 & 7		X								
• V58S0087E • L OTBD ACT HTR-Auto • HY 4		X								

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Continued)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58S0088E • L OTBD ACT Htr - On • HY 4		X								
• V58S0089E • L INBD ACT Htr - On • HY 5		X								
• V58S0090E • L INBD ACT Htr-Auto • HY 5		X								
• V58S0097E • R OTBD ACT Htr - Auto • HY 7		X								
• V58S0098E • R OTBD ACT Htr - On • HY 7		X								
• V58S0099E • R INBD ACT Htr - On • HY 6		X								
• V58S0104E • Sys 1 Mn Pmp DPRS - On • HY 1		X								
• V58S0104E • Sys 1 Mn Pmp DPRS -On • HY 1		X								
• V58S0204E • Sys 2 MN Pmp DPRS - On • HY 1		X								
• V58S0304E • Sys 3 MN Pmp DPRS - On • HY 1		X								

TABLE 3.3-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: Hydraulics (Concluded)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V58S0167E • Sys 1 H_2O BLR Htr-On • HY 3		X								
• V58S0168E • Sys 1 H_2O BLR Htr-Auto • HY 3		X								
• V58S0267E • Sys 2 H_2O BLR Htr-On •		X								
• V58S0268E • Sys 2 H_2O BLR Htr-Auto • HY 3		X								
• V58S0367E • Sys 3 H_2O BLR Htr-On • HY 3		X								
• V58S0368E • Sys 2 H_2O BLR Htr-Auto • HY 3		X								

3.4 COMMUNICATIONS AND TRACKING

The communications and tracking (C&T) subsystem for HFT is restricted by cost and scheduling considerations to the basic HFT support requirements. The HFT C&T subsystem is an abbreviated version of the operational subsystem, and some of the HFT components are interim off-the-shelf items rather than the final operational flight items. Since the HFT C&T subsystem is not yet under configuration control, the following considerations are based on the current subsystem concept.

3.4.1 Subsystem Description

Figure 3.4-1 is a block diagram of the HFT C&T subsystem. The subsystem elements depicted as background layers are redundant functional duplicates of the corresponding foreground elements. The functions of these elements are described in the following subsections.

In addition to the elements shown in figure 3.4-1, the HFT C&T subsystem also includes an L-band ATC transponder and interference blanker in the ferry kit, a strap-on C-band beacon, and an interim aircraft-type audio system. The transponder is used for ferry only and reports vehicle altitude and location to any querying ATC facility within a 200-n.mi. range. The beacon is used for flight test only and returns ground radar interrogation pulses for vehicle range and azimuth determination. The audio system provides audio intercommunications between the commander, pilot, UHF transceivers, voice recorder, TACAN units, C&W system, and ground hardline.

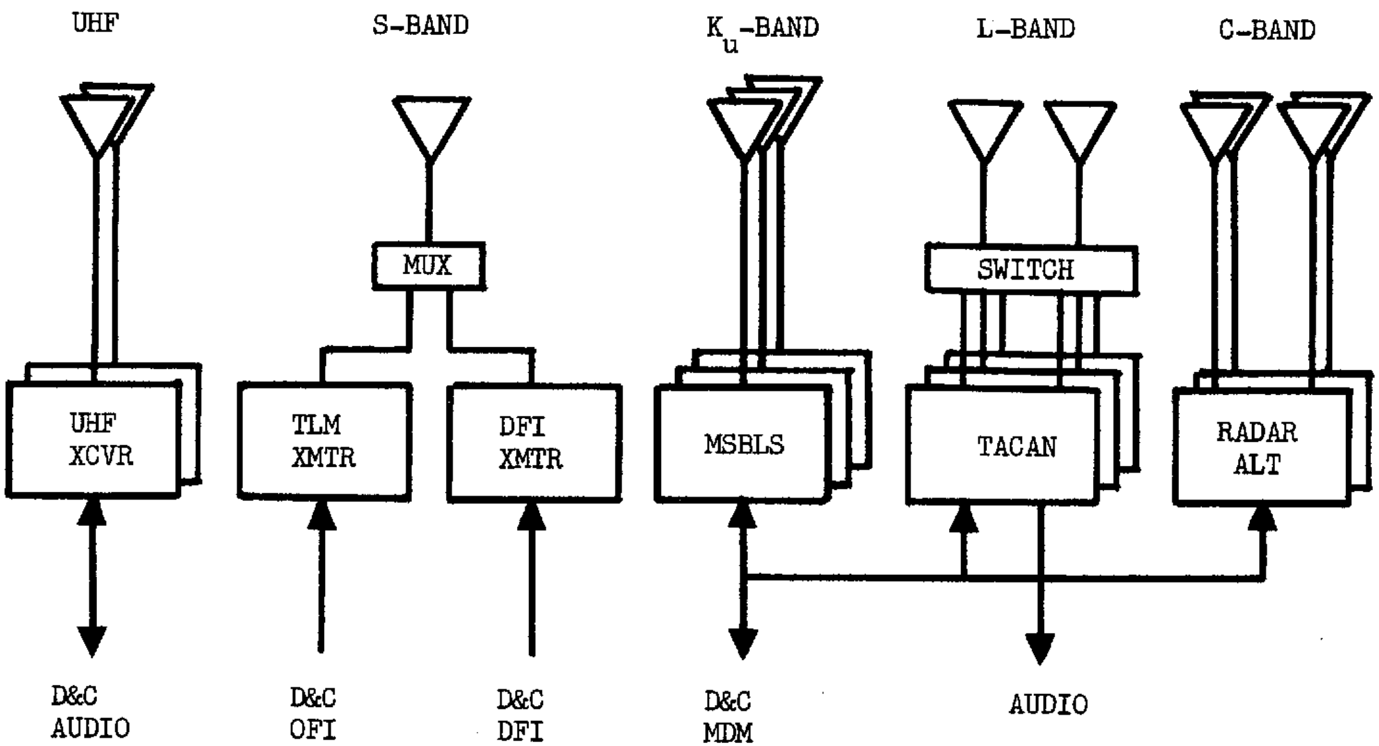


Figure 3.4-1. — HFT C&T subsystem.

The transponder, beacon, and audio system are not monitored by the HFT PMS and are not further discussed.

3.4.1.1 UHF transceiver. Figure 3.4-2 is a block diagram of the UHF transceivers and the audio system.

Each transceiver is directly connected to a dedicated antenna. One antenna is mounted on the fuselage bottom and the other is mounted on top of the fuselage in the vertical stabilizer. (This HFT configuration differs from the operational configuration, which includes only the bottom antenna and adds a UHF switch to connect the antenna to one or the other transceiver.)

The guard receiver is an auxiliary section of the transceiver which is fix-tuned to the emergency channel (243 MHz).

Control of each transceiver via the D&C subsystem consists of power OFF-ON, volume control, squelch OFF-ON, RF channel selection, and guard receiver OFF-ON.

Both transceivers are connected to the same interface lines from the audio system. The push-to-talk (PTT) keyline switches both transceivers to either the transmit or the receive function at the same time, and the transmit and receive voice signals share the same voice line (simplex operation). (This HFT configuration differs from the operational configuration, which uses separate voice lines to each transceiver and independent transmit-receive controls to provide duplex operation.)

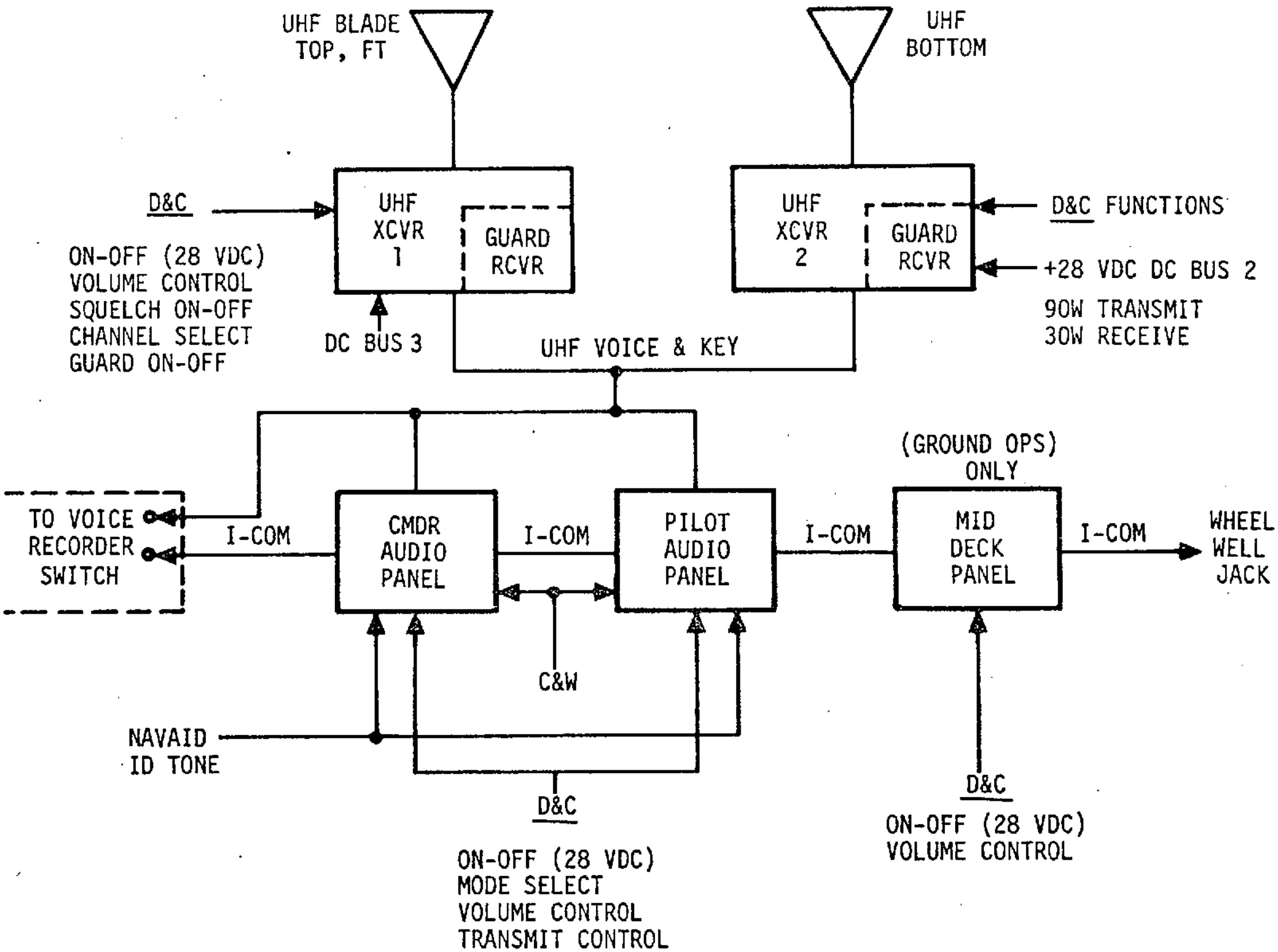


Figure 3.4-2. — Audio-UHF block diagram.

3.4.1.2 S-band transmitters. Figure 3.4-3 is a block diagram of the S-band equipment.

One transmitter is used to transmit the OFI subsystem PCM data (128 kbps), and the other transmitter is used to transmit the DFI subsystem FDM composite data signal. The HFT DFI transmitter is the final operational version. The HFT transmitter for the OFI data will not be the operational S-band FM transmitter, but will be an interim off-the-shelf aircraft telemetry transmitter. Both transmitters use frequency modulation and produce a 5-watt minimum S-band output power. (In the operational C&T subsystem, both of these transmitters and the S-band multiplexer are omitted. The DFI data will not be required, and the OFI data will be transmitted by S-band PM transponders, which are not included in the HFT subsystem.)

Transmitter control consists of separate power OFF-ON switches for each transmitter.

The two transmitter RF power outputs are multiplexed for transmission by a single S-band hemispherical coverage antenna. In the operational subsystem, there are two such antennas mounted in the fuselage top and bottom with an S-band switch to select which antenna is used. The omission of this switch for HFT is still in study. If it is omitted for HFT, the S-band multiplexer output will be connected directly to the upper antenna (not the lower as shown), which is more nearly directed toward the FRC during the steep-descent HFT flight profile.

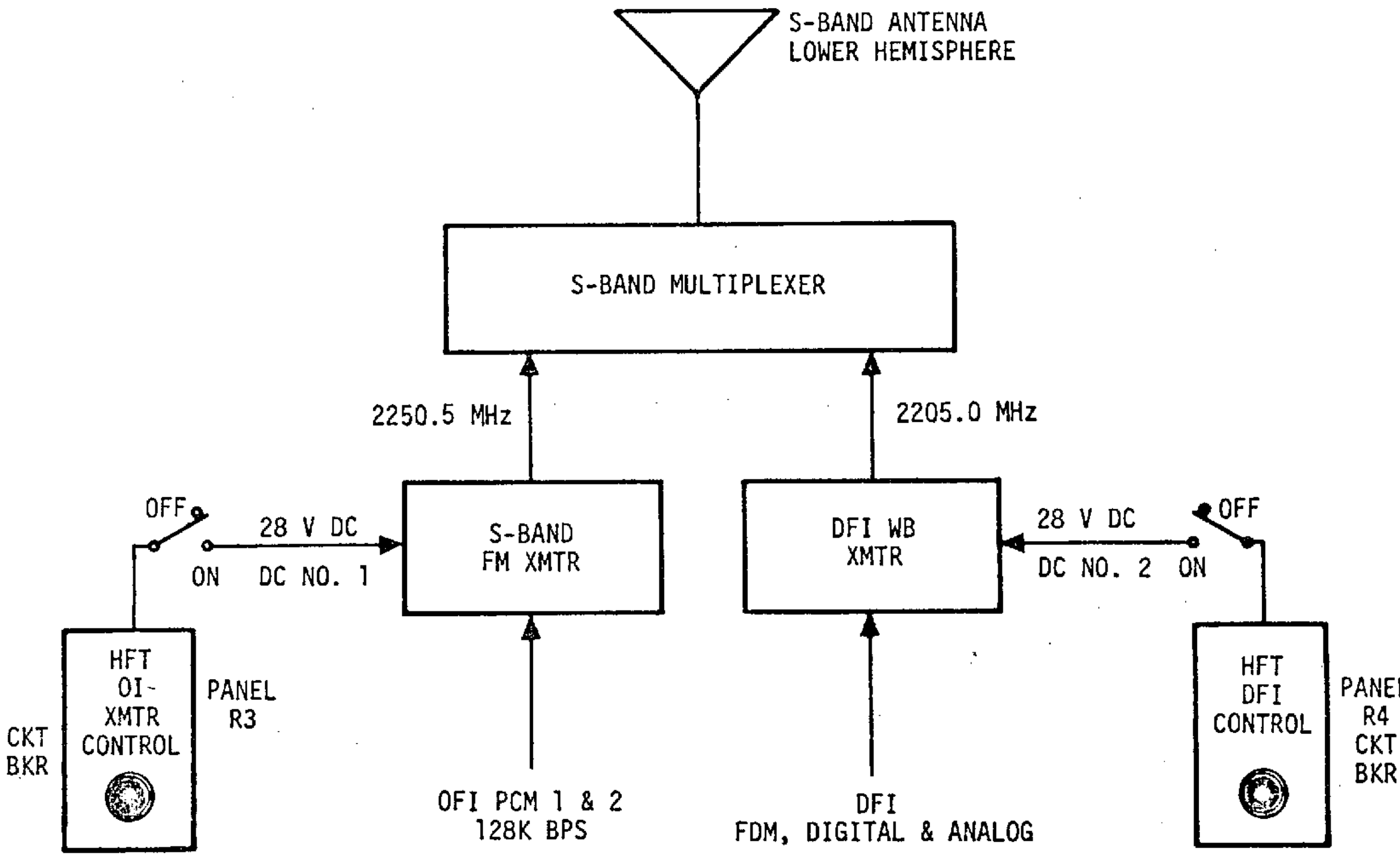


Figure 3.4-3. — S-band equipment block diagram.

3.4.1.3 Ku-band MSBLS. Figure 3.4-4 is a block diagram of the microwave scan beam landing system (MSBLS) equipment.

Each MSBLS string consists of a decoder assembly, an RF assembly, and a dedicated Ku-band horn antenna in the fuselage nose. The three MSBLS strings are identical and can function in any combination simultaneously. Two-way RF transmission between the Orbiter and ground MSBLS equipment allows the decoder assembly to measure range, azimuth, and elevation with respect to the ground equipment with enough accuracy for automatic landing.

Control of each MSLBS string via its control head is shown at the bottom of figure 3.4-5. The controls are power OFF-ON, channel selection, built-in-test (BIT) initiation, and glideslope selection. BIT may also be initiated by the G&N subsystem via an MDM.

Each MSBLS string outputs analog data to the D&C subsystem display driver units and digital data to a G&N subsystem MDM. Both data outputs consist of glideslope deviation (elevation), localizer deviation (azimuth), and the corresponding validity flags. Additional digital data to the MDM's consist of range, range validity flag, channel selection, glideslope selection, and BIT result.

3.4.1.4 L-band TACAN. Figure 3.4-6 is a block diagram of the TACAN equipment.

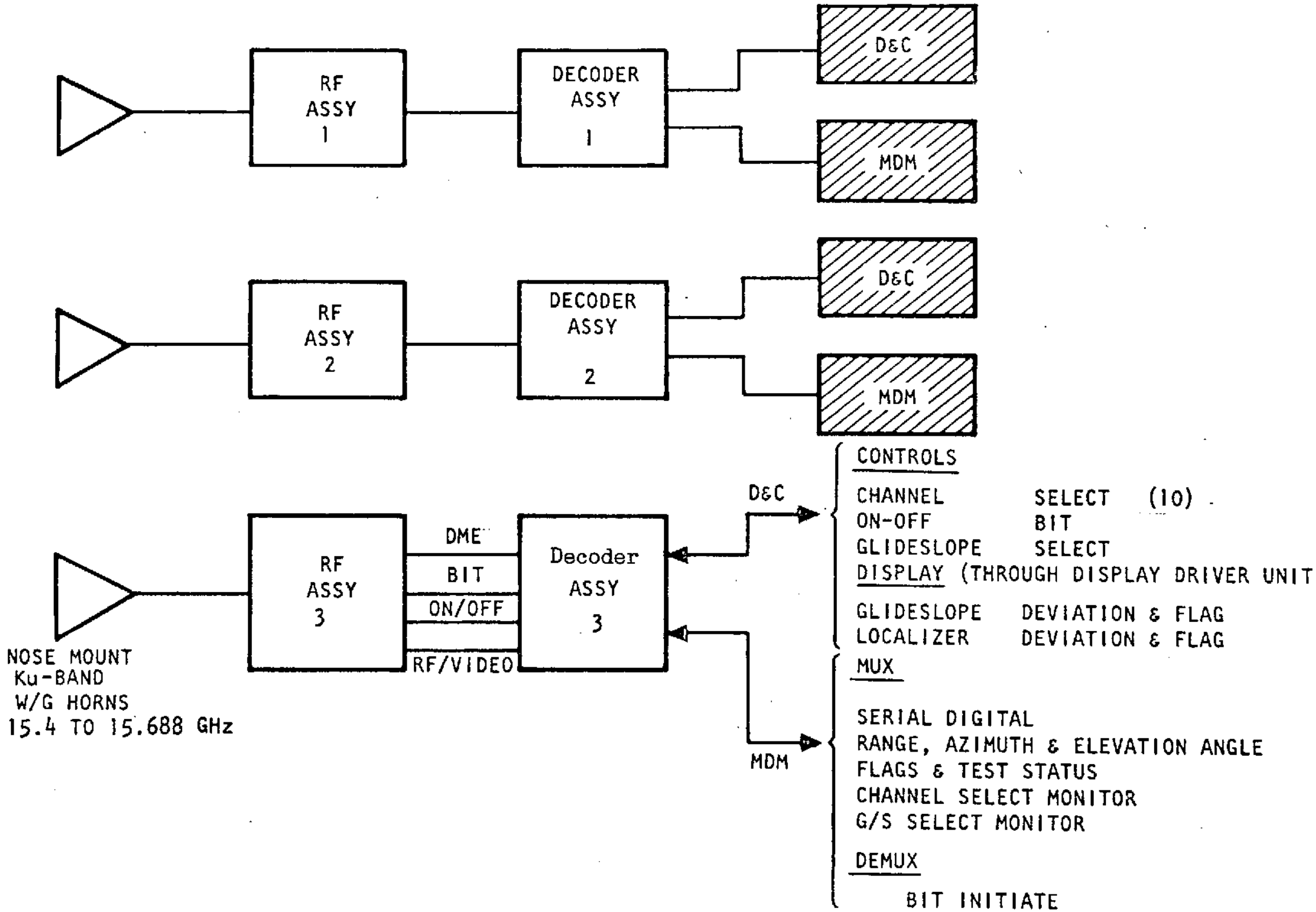


Figure 3.4-4. — MSBLS block diagram.

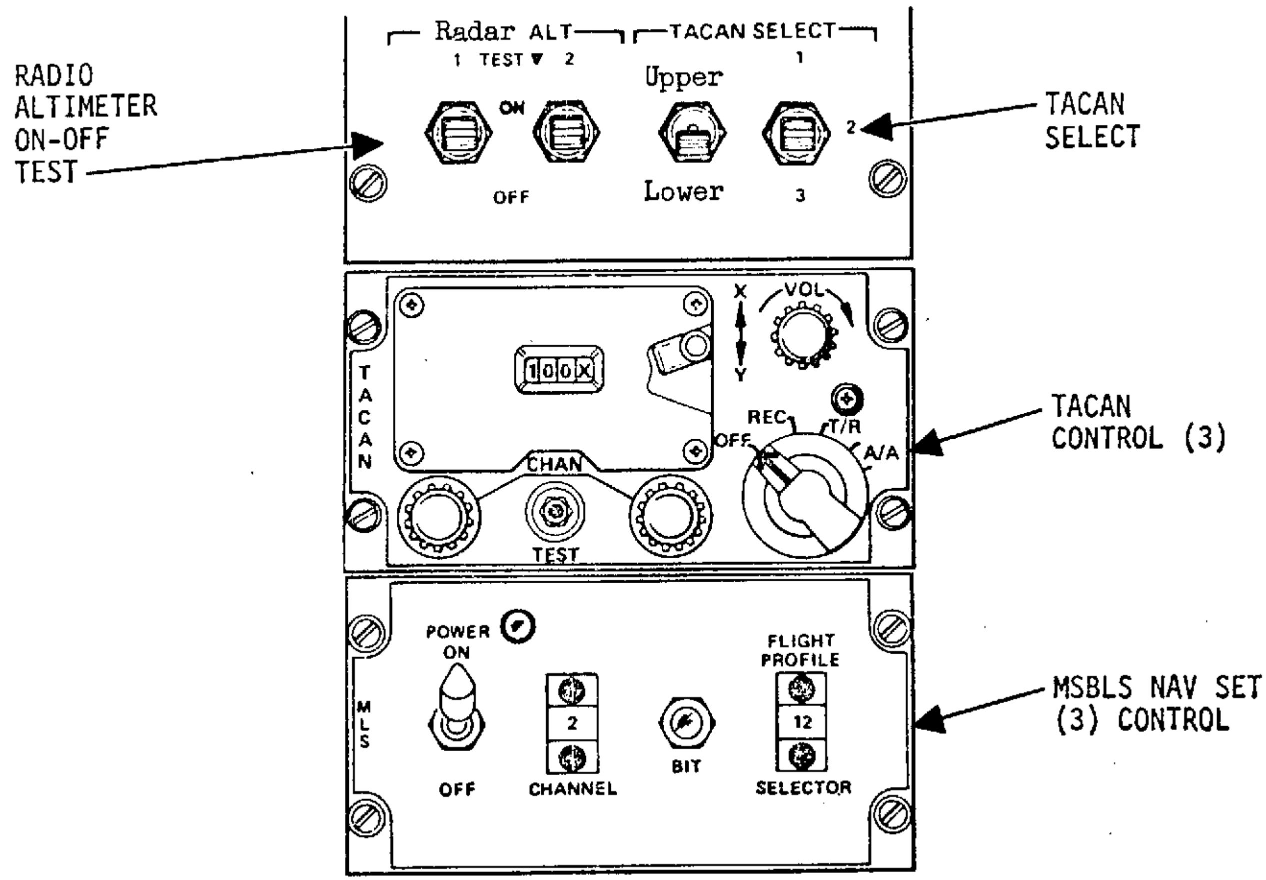


Figure 3.4-5. – Flight test navaid control heads.

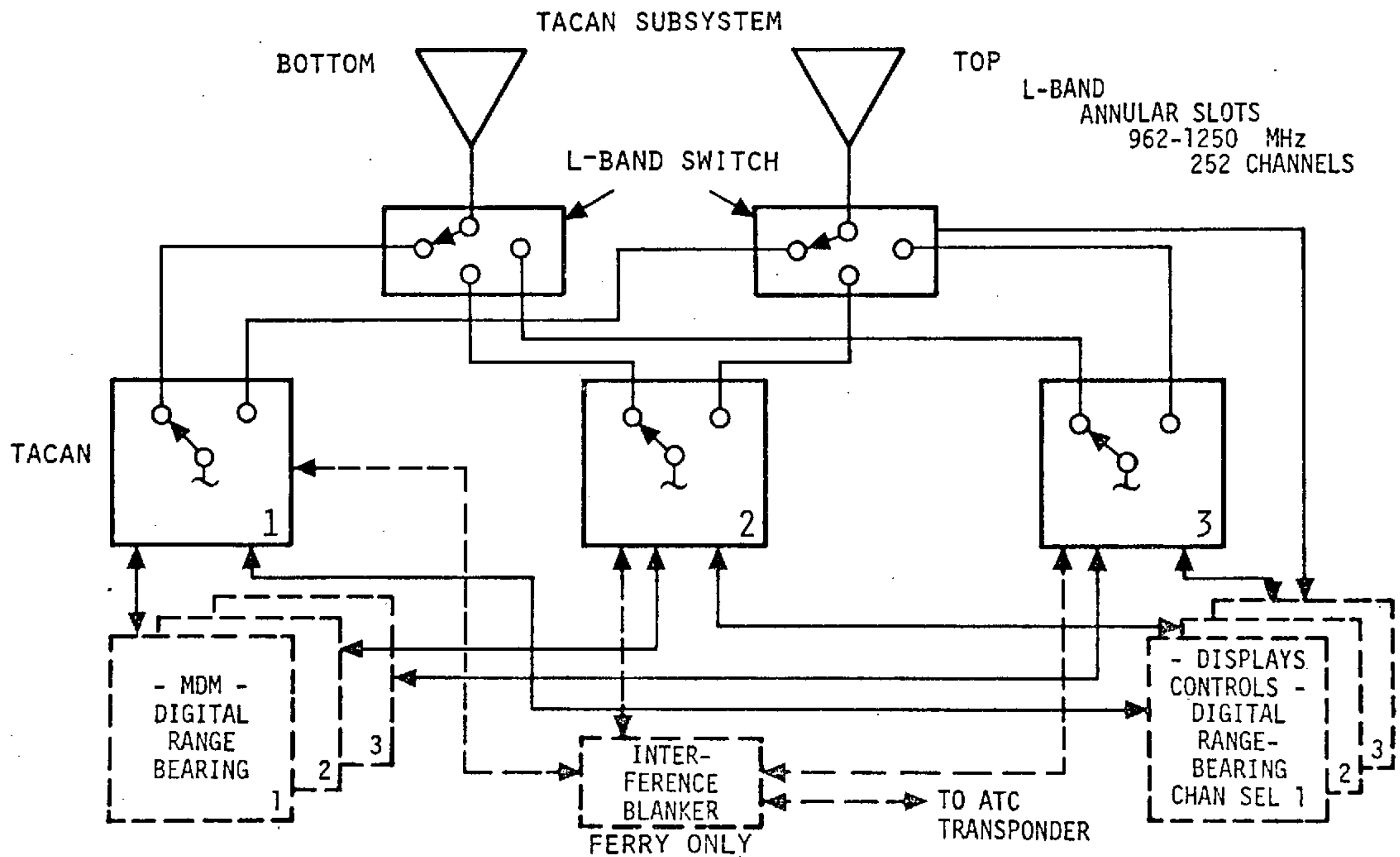


Figure 3.4-6. – TACAN block diagram.

One of the antennas is located on the topside of the fuselage nose. The other antenna is located on the fuselage bottom.

The L-band switch connects both antennas to one of the three TACAN units at a time. Each TACAN unit contains an antenna switch to select which of the two antennas is to be used. At one time, only one of the TACAN antennas can be functionally connected, and only to one TACAN unit. (In the operational C&T subsystem, it will be possible to have one TACAN unit connected to one antenna and another TACAN unit connected to the other antenna at one time.)

Two-way RF transmission between the Orbiter and ground TACAN equipment allows a TACAN unit to measure range and bearing with respect to the ground equipment from post-blackout to landing approach.

Control of the antenna switches via the D&C subsystem is shown at the top of figure 3.4-5. One switch selects which TACAN unit the two antennas are connected to, and the other switch selects whether the upper or lower antenna is to be used.

Control of each TACAN unit via its control head is shown at the center of figure 3.4-5. The controls are power OFF—receive—transmit/receive—air/air, channel select, station ID tone volume, and BIT initiation. BIT may also be initiated by the G&N subsystem via an MDM.

Each TACAN unit outputs digital data both to the D&C subsystem display driver units and to a G&N subsystem MDM. The data outputs consist of range, bearing, and the corresponding validity flags. Additional data to the MDM's consist of the channel selection and the BIT result.

Each TACAN unit also outputs a keyed tone to the audio system for TACAN ground station identification.

3.4.1.5 C-band radar altimeter. Figure 3.4-7 is a block diagram of the radar altimeter equipment.

Each radar altimeter has a dedicated transmit antenna and a dedicated receive antenna. The altimeters may function either one or both at a time. Pulse transmission and ground echo reception allow a radar altimeter to measure vehicle altitude above the ground during landing approach and touchdown.

Control of each radar altimeter via the D&C subsystem consists of a single three-position switch for power OFF—ON—BIT, as shown at the top of figure 3.4-5. BIT may also be initiated by the G&N subsystem via an MDM.

Each radar altimeter outputs analog data to a D&C subsystem display driver unit and digital data to a G&N subsystem MDM. Both data outputs consist of altitude and its validity flag. Additional data to the MDM's consists of the BIT result.

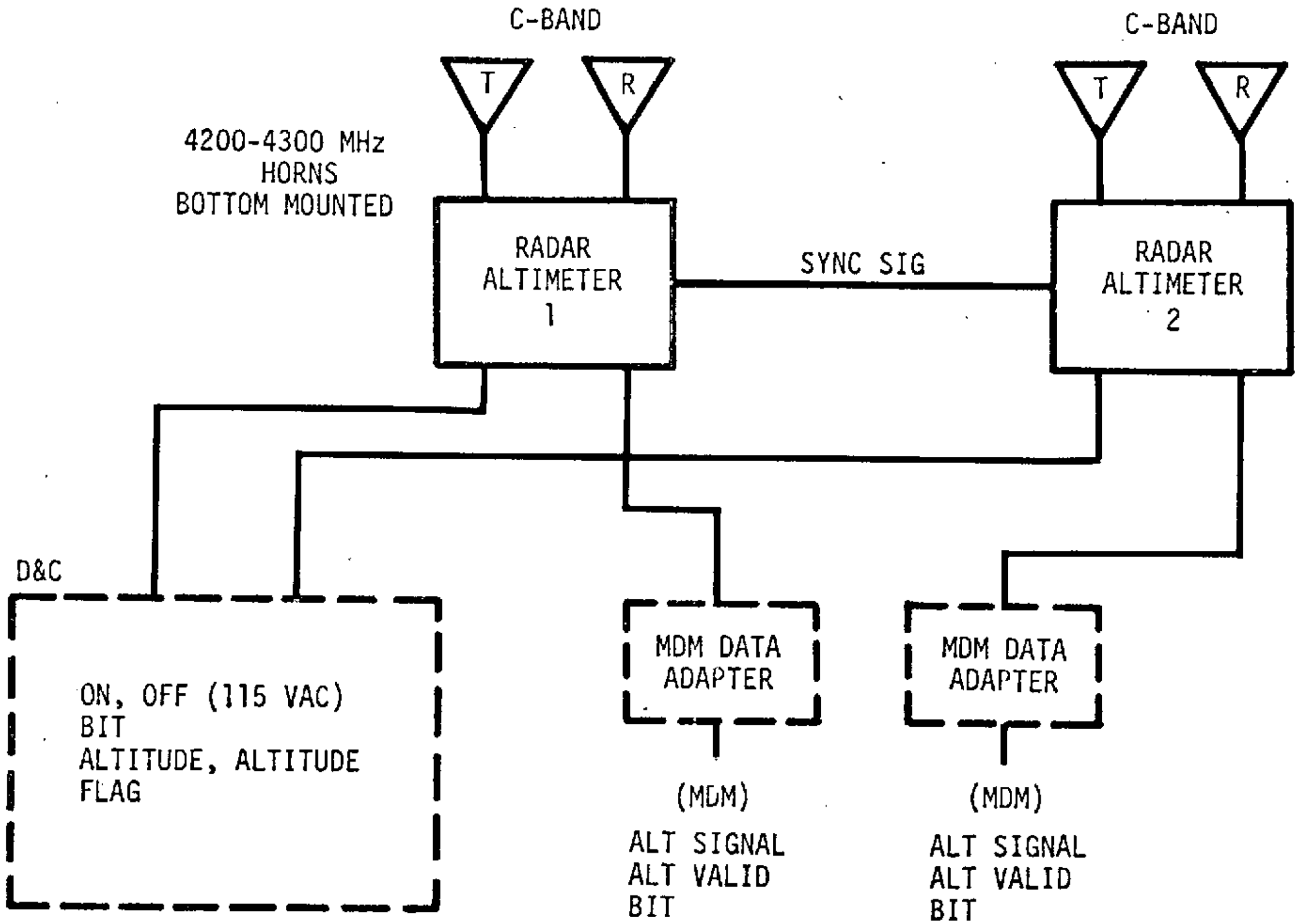


Figure 3.4-7. — Radar altimeter block diagram.

3.4.2 Functional Path Analysis

Figure 3.4-1 shows the HFT C&T subsystem as a collection of 12 functional paths between other subsystems (bottom) and external RF space (top). The larger set of paths represented by functional branching in the more detailed subsystem diagrams is not considered for the PMS because of the lack of selection and control at that level of detail.

Letting duplicate equipment be identified as numbers 1, 2, or 3, the functional paths and associated equipment are:

- CT1 – UHF transceiver #1, UHF antenna #1.
- CT2 – UHF transceiver #2, UHF antenna #2.
- CT3 – TLM transmitter, S-band multiplexer, S-band antenna.
- CT4 – DFI transmitter, S-band multiplexer, S-band antenna.
- CT5 – MSBLS #1, Ku-band antenna #1.
- CT6 – MSLBS #2, Ku-band antenna #2.
- CT7 – MSBLS #3, Ku-band antenna #3.
- CT8 – TACAN #1, L-band switch, both L-band antennas.
- CT9 – TACAN #2, L-band switch, both L-band antennas.
- CT10 – TACAN #3, L-band switch, both L-band antennas.
- CT11 – Radar altimeter #1, transmit and receive C-band antennas #1.
- CT12 – Radar altimeter #2, transmit and receive C-band antennas #2.

NOTE: CT3 and CT4 share the same multiplexer and antenna and CT8, CT9, and CT10 share the same antenna switch and antennas.

3.4.3 Subsystem/PMS Interfaces

Table 3.4-1 lists the HFT C&T subsystem measurements to be used by the PMS for fault detection and annunciation (FDA). The measurements required are a primary and a secondary performance measurement for each functional path and whatever hardware status and configuration check measurements are needed for path precondition tests.

The table does not include all of the measurements listed in the MML but only those pertinent to the HFT PMS FDA function. In some cases, the measurement title has been changed from the MML title to agree with the current HFT subsystem concept.

The table includes some measurements that are not listed in the MML but have been introduced here as needed. These use XX-- for the usual four-digit sequence number (characters 5-8 of the measurement ID number). New measurements are summarized in appendix A.

The table also includes some measurements which are listed in the MML but designated there as not being accessible to the PMS. These are the measurement validity flags output from the navigation aids (MSBLS, TACAN, radar altimeter) to the G&N subsystem MDM's. The critical PMS uses these validity flags together with precondition tests to determine whether the navigation aids are functioning properly and outputs resulting failure event data from the data processing subsystem (V72).

The omission of BIT initiation switch scan and BIT result event measurements from the PMS interface reflects the fact that FDA is an online function during operational performance of a functional path, while BIT initiation interrupts operational performance for about 20 seconds and is properly used for LRU checkout offline. (The current BITE development plan for the TACAN and radar altimeter will allow online BIT by continuing to output measurement data from memory with the measurement flags indicating valid but with an additional flag indicating output from memory.)

3.4.4 PMS Requirements

Table 3.4-2 lists the primary and secondary measurements for each functional path and indicates the corresponding FDA tests to be made during each PMS cycle.

When the first column of the table contains a primary measurement, the correlation check column identifies the corresponding secondary measurement that is to be tested if (and only if) the FDA test on the primary measurement indicates functional path failure. A blank correlation check column indicates that the measurement in the first column is a secondary measurement which is to be tested only if the primary measurement test indicates failure. For the radar altimeter functional paths (CT11 and CT12), the primary measurements are fail discretes detected by the G&C software.

The FDA tests on an analog (type A) measurement consist of tolerance checks against the soft and hard limits given in the table.

The FDA test on an event (type E or X) measurement consists of observing whether the measurement is a logic "1" for valid performance or a logic "0" for invalid performance. In this case, soft limits are not given, and the hard limits column contains the letter E to indicate event testing.

The use of event measurements (validity flags) to verify the performance of the navigation aids recognizes that these units have built-in logic which performs the FDA function during online operation. The validity flags are output at the same update rate as the navigation data outputs and are distinct from the offline BIT. If all elements of a subsystem included the internal logic for output measurement validity indication, the PMS would simply scan the validity flags to detect faults. The opposite extreme is for the PMS to process raw sensor data from all subsystem elements to detect faults. In the HFT C&T subsystem, the navigation aids are well designed to provide their own fault detection, but the UHF and S-band equipment do not even have sufficient OI measurements to allow the PMS to perform fault detection. (The UHF and S-band measurements in tables 3.4-1 and 3.4-2 are specified for the current PMS development.)

The precondition columns of table 3.4-2 identify the switch scan and event measurements which indicate whether the functional path should be operating and therefore subject to FDA tests. In general, all of the precondition scans and events must be "ON" for the path to be operating. The exceptions are the TACAN paths CT8, CT9, and CT10, whose precondition tests involve OR and NOT logic.

TABLE 3.4-1.

PMS MEASUREMENT DATA

SUBSYSTEM: COMMUNICATION & TRACKING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74VXXX1A — UHF Transceiver No.1 RF Output	A	0-5 Vdc	CT1	New recommended measurement.
V74V0201A — UHF Transceiver No.1 AGC	A	0-5 Vdc	CT1	Not for FDA on MML.
V74SXXX3E — UHF Transceiver No.1 Power - ON	E		CT1	New recommended measurement.
V74XXXX5E — UHF Transceiver No.1 Transmit	E		CT1	New recommended measurement.
V74XXXX7E — UHF Transceiver No.1 Receive	E		CT1	New recommended measurement.
V74VXXX2A — UHF Transceiver No.2 RF Output	A	0-5 Vdc	CT2	New recommended measurement.
V74V0211A — UHF Transceiver No.2 AGC	A	0-5 Vdc	CT2	Not for FDA on MML.
V74SXXX4E — UHF Transceiver No.2 Power - ON	E		CT2	New recommended measurement.
V74XXXX6E — UHF Transceiver No.2 Transmit	E		CT2	New recommended measurement.

TABLE 3.4-1.

PMS MEASUREMENT DATA

SUBSYSTEM: COMMUNICATION & TRACKING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74XXXX8E — UHF Transceiver No.2 Receive	E	0-5 Vdc	CT2	New recommended measurement.
V74V0484A — TLM Transmitter RF Output	A	0-5 Vdc	CT3	ID used for FM transmitter no. 1 on MML.
V74VXXX9A — TLM Transmitter DC Power	A	0-5 Vdc	CT3	New recommended measurement.
V74SXX11E — TLM Transmitter Power - ON	E		CT3	New recommended measurement.
V74V0488A — DFI Transmitter RF Output	A	0-5 Vdc	CT4	ID used for FM Transmitter no. 2 on MML.
V74VXX10A — DFI Transmitter DC Power	A		CT4	New recommended measurement.
V74SXX12E — DFI Transmitter Power -ON	E		CT4	New recommended measurement.
V74X0111X — MSBLS No. 1 Range Flag	X		CT5	Not for PMS on MML.
V74X0112X — MSBLS No. 1 Elevation Flag	X		CT5	Nor for PMS on MML.

TABLE 3.4-1.

PMS MEASUREMENT DATA

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74S0109E – MSBLS No. 1 Power - ON	E		CT5	
V74X0121X – MSBLS No. 2 Range Flag	X		CT6	Not for PMS on MML.
V74X0122X – MSBLS No. 2 Elevation Flag	X		CT6	Not for PMS on MML.
V74S0119E – MSBLS No. 2 Power - ON	E		CT6	
V74X0131X – MSBLS No. 3 Range Flag	X		CT7	Not for PMS on MML.
V74X0132X – MSBLS No. 3 Elevation Flag	X		CT7	Not for PMS on MML.
V74S0129E – MSBLS No. 3 Power - ON	E		CT7	
V74X0143X – TACAN No. 1 Bearing Flag	X		CT8	Not for PMS on MML.
V74X0145X – TACAN No. 1 Range Flag	X		CT8	Not for PMS on MML.

TABLE 3.4-1.

PMS MEASUREMENT DATA

SUBSYSTEM: COMMUNICATION & TRACKING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74S0859E — TACAN No. 1 Receive	E		CT8	New recommended switch scan.
V74S0856E — TACAN No. 1 T/R	E		CT8	
V74S0862E — TACAN No. 1 A/A	E		CT8	
V74S0166E — TACAN Select No. 1	E		CT8	
V74X0191E — L-Band Coupling Network TACAN Active No. 1	E		CT8	Not for PMS on MML.
V74X0153X — TACAN No. 2 Bearing Flag	X		CT9	Not for PMS on MML.
V74X0155X — TACAN No. 2 Range Flag	X		CT9	Not for PMS on MML.
V74S0860E — TACAN No. 2 Receive	E		CT9	New recommended switch scan.
V74S0857E — TACAN No. 2 T/R	E		CT9	

TABLE 3.4-1.

PMS MEASUREMENT DATA

SUBSYSTEM: COMMUNICATION & TRACKING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74S0863E — TACAN No. 2 A/A	E		CT9	
V74X0192E — L-Band Coupling Network TACAN Active No. 2	E		CT9	Not for PMS on MML.
V74X0163X — TACAN No. 3 Bearing Flag	X		CT10	Not for PMS on MML.
V74X0165X — TACAN No. 3 Range Flag	X		CT10	Not for PMS on MML.
V74S0861E — TACAN No. 3 Receive	E		CT10	New recommended switch scan.
V74S0858E — TACAN No. 3 T/R	E		CT10	
V74S0864E — TACAN No. 3 A/A	E		CT10	
V74S0168E — TACAN Select No. 3	E		CT10	
V74X0193E — L-Band Coupling Network TACAN Active No. 3	E		CT10	Not for PMS on MML.

TABLE 3.4-1.

PMS MEASUREMENT DATA

SUBSYSTEM: COMMUNICATION & TRACKING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74X0172X — RADAR Alt. No. 1 Flag	X		CT11	Not for PMS on MML.
V74S0175E — RADAR Alt. No. 1 ON	E		CT11	
V74X0182X — RADAR Alt. No. 2 Flag	X		CT12	Not for PMS on MML.
V74S0185E — RADAR Alt. No. 2 ON	E		CT12	
V74SXX13E ATC XPNDR - On	Event	0/1	N.A.	New recommended measurement.
V74SXX14E C-Band BCN-On	Event	0/1	N.A.	New recommended measurement.
V74SXX15E AUD PNL, CDR -On	Event	0/1	CT 1, CT 2	New recommended measurement.
V74SXX16E AUD PNL, Pilot - On	Event	0/1	CT 1, CT 2	New recommended measurement.
V74SXX17E AUD PNL, Mid Deck - On	Event	0/1	CT 1, CT 2	New recommended measurement.

TABLE 3 4-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: COMMUNICATION AND TRACKING

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V74VXXX1A • UHF XCVR No. 1 RF Output • CT1	XXX3	XXX5	3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			0201
• V74V0201A • UHF XCVR No. 1 AGC • CT1	XXX3	XXX7	3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			
• V74VXXX2A • UHF XCVR No. 2 RF Output • CT2	XXX4	XXX6	3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			0211
• V74V0211A • UHF XCVR No. 2 AGC • CT2	XXX4	XXX8	3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			
• V74V0484A • TLM XMTR RF Output • CT3	XX11		3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			XXX9
• V74VXXX9A • TLM XMTR DC Power • CT3	XX11		3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			
• V74V0488A • DFI XMTR RF Output • CT4	XX12		3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			XX10

TABLE :.4-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: COMMUNICATION & TRACKING (2 of 4)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V74VXX10A • DFI XMTR DC Power • CT4	XX12		3.2 Vdc	2.5 Vdc		4.0 Vdc	2.0 Vdc			
• V74X0111X • MSBLS No. 1 Range Flag • CT5	0109					E	E			0112
• V74X0112X • MSBLS No. 1 Elevation Flag • CT5	0109					E	E			
• V74X0121X • MSBLS No. 2 Range Flag • CT6	0119					E	E			0122
• V74X0122X • MSBLS No. 2 Elevation Flag • CT6	0119					E	E			
• V74X0131X • MSBLS No. 3 Range Flag • CT7	0129					E	E			0132
• V74X0132X • MSBLS No. 3 Elevation Flag • CT7	0129					E	E			

TABLE 3.4-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: COMMUNICATION & TRACKING

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V74X0145X • TACAN No. 1 Range Flag • CT8	0166 and 0856 or 0862	0191				E	E			0143
• V74X0143X • TACAN No. 1 Bearing Flag • CT8	0166 and 0856 or 0859 or 0862	0191				E	E			
• V74X0155X • TACAN No. 2 Range Flag • CT9	0857 or 0863 not 0166 not 0168	0192				E	E			0153
• V74X0153X • TACAN No. 2 Bearing Flag • CT9	0857 or 0860 or 0863 not 0166 not 0168	0192				E	E			
• V74X0165X • TACAN No. 3 Range Flag • CT10	0168 and 0858 or 0864	0193				E	E			0163
• V74X0163X • TACAN No. 3 Bearing Flag • CT10	0168 and 0858 or 0861 or 0864	0193				E	E			

TABLE 3.4-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: COMMUNICATION & TRACKING

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V74X0172X • Radar Alt No. 1 Flag • CT11	0175					E	E			0172
• V74X0182X • Radar Alt No. 2 Flag • CT12	0185					E	E			0182
• V74SXX13E • ATC XPNDR - On • NA		X								
• V74SXX14E • C-Band BCN - On • NA		X								
• V74SXX15E • CDR Aud PNL - On • CT1, CT2		X								
• V74SXX16E • Pilot Aud Pnl - On • CT1, CT2		X								
• V74SXX17E • Mid Deck Aud Pnl-On • CT1, CT2		X								

3.5 ELECTRICAL POWER DISTRIBUTION AND CONTROL (EPDC)

3.5.1 Subsystem Description

The EPDC configuration for Horizontal Flight Test vehicle, Orbiter 101, will be a modified version of the operational EPDC. Primary power is provided by three hydrogen-oxygen fuel cell power plants (see section 3.10).

EPDC consisting of buses, switches, cables, sensors, and other devices required to condition, distribute, and control power, may be catorgorized into four major subsystem elements:

- DC Distribution and Control.
- Essential/Control (ESS/CONT) Bus.
- Inverter AC Distribution and Control.
- Master Events Controllers (MEC's) and Load Control Assemblies (LCS's).

As illustrated in figure 3.5-1, each of three main DC buses are normally connected to a dedicated fuel cell. Configuration options exist to connect any main DC bus to any other main DC bus(s) via a DC tie bus and, hence, any other fuel cell and/or GSE ground power. DC power is distributed from each main bus to local loads via forward, midbody, and aft local DC buses. Appropriate typical loads (as illustrated) are in turn supplied by local buses via protective circuit devices [i.e., Remote Power Controller (RPC), Remote Control Circuit Breakers (RCCB), and isolation fuses].

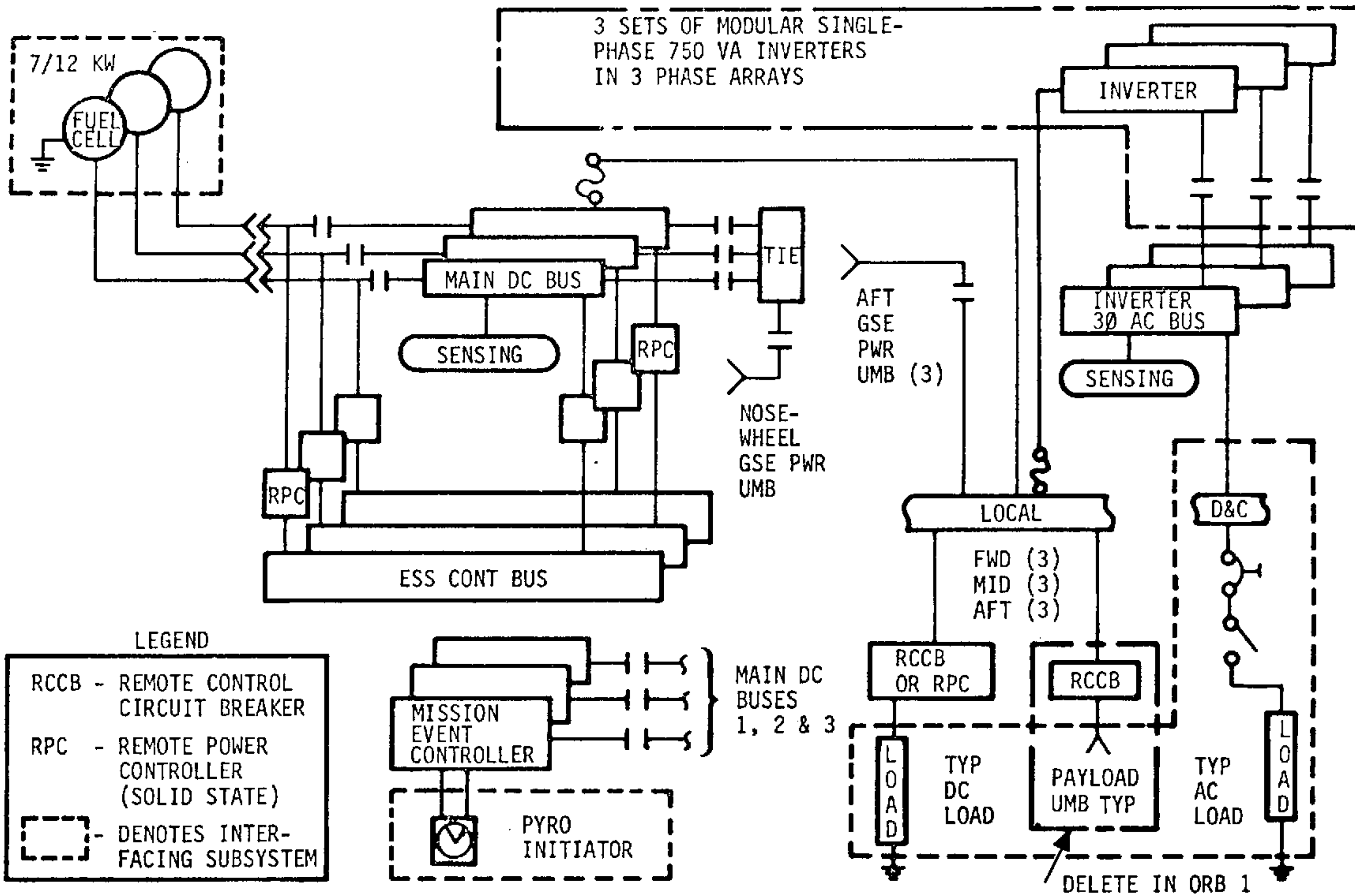


Figure 3.5-1. — Electrical power distribution and control subsystem.

Each inverter bus, utilizing a specific forward local DC bus for source power, is driven by modular single phase 750VA Inverters in 3ϕ arrays.

The ESS/CONT buses supply power to reinitialize main bus power from a power-off emergency power state, and supply power to caution and warning, fire detectors and actuators, and emergency lighting. Each ESS/CONT bus is supplied by one (unique) disassociated main DC bus and the normally associated fuel cell (directly via a dedicated electromechanical contactor).

3.5.1.1 Main DC and ESS/CONT distribution. Figure 3-5-2 is a block diagram of the main DC distribution system for bus 3. This illustration is typical of each main bus ESS/CONT bus configuration. As illustrated, each main DC bus may be supplied by a normally dedicated fuel cell, a forward tie bus connecting GSE external power or the other two main DC buses, and an aft GSE power connection via the aft local bus. These various power sources may be connected in any combination limited logically only by ground or airborne operation, and tie bus actuation may connect any given main bus to the remaining main bus(es) as either a power source or load. This interactive characteristic will require, during dynamic modeling activities, an introduction of DC system modes, to treat the intra-main bus sensitivities (taken as a set) and all interbus dependencies (main-ESS/CONT-AC).

The ESS/CONT bus is interfaced, as illustrated, directly to a fuel cell and a separate main DC bus. Specific mechanization of these interfaces, directed by CCA69 "Electrical Power System Reconfiguration to delete the batteries, etc." (March 4, 1974), are not presently available.

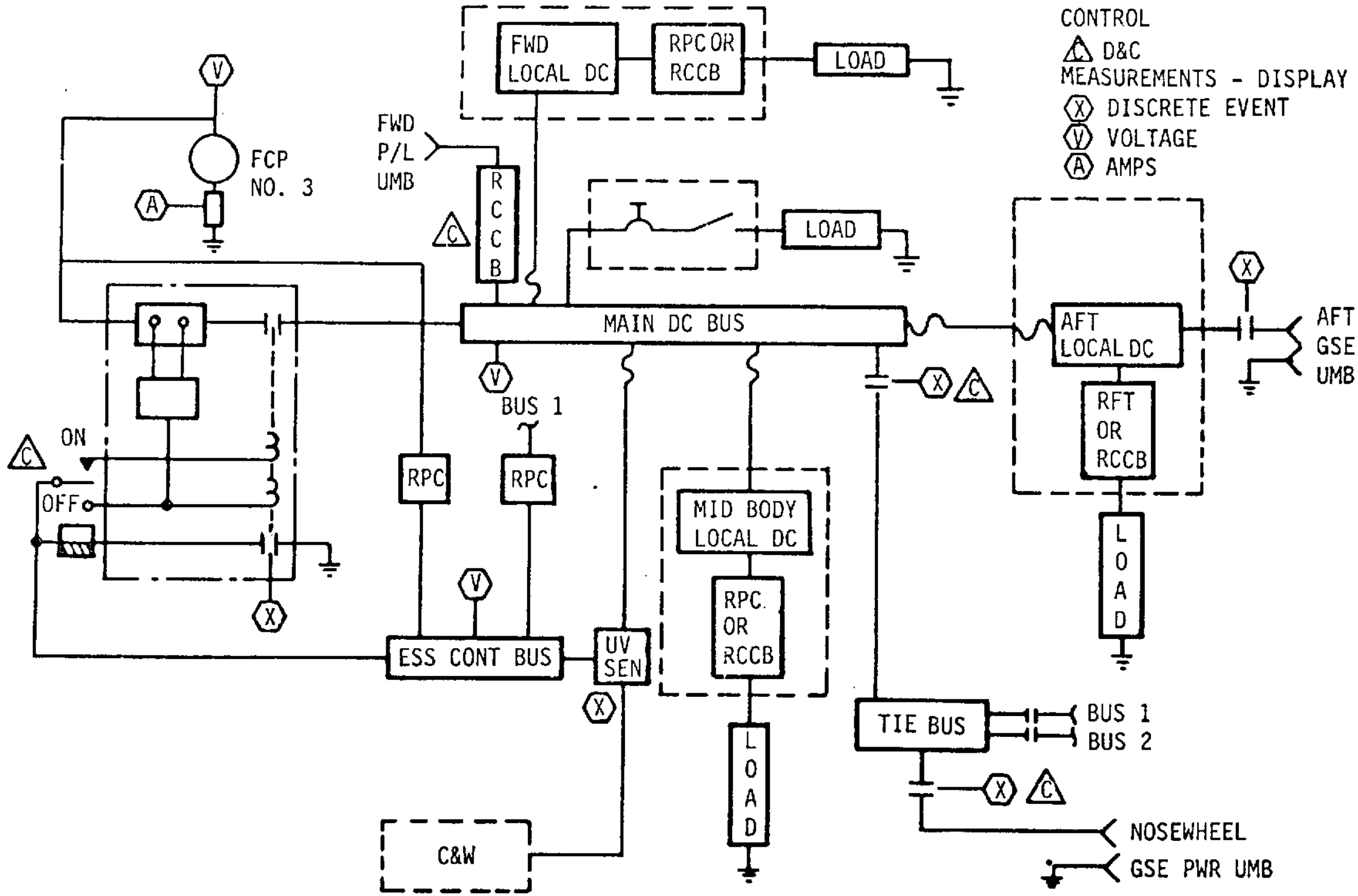


Figure 3.5-2. — Main DC distribution block diagram.

Also illustrated are sensor points and types, local buses and typical loads, and D&C and C&W interfaces.

3.5.1.2 Inverter AC distribution and control. Figure 3-5-3 is a block diagram of the inverter distribution and control elements. The inverter groups are comprised of three sets of modular single-phase 750VA inverters arranged in three phase arrays. Each forward local DC bus supplies primary power to one converter set which in turn supplies 115/200 V, 3ϕ, 400 ∿ to one inverter bus, (i.e., main DC 1 to inverter set 1 to inverter bus 1). Figure 3-5-3 illustrates this scheme for AC bus 2, which is typical of the remaining two AC buses. Also illustrated are sensor points and type, typical loads represented by various CB panels, and interfaces with D&C and C&W subsystems.

3.5.1.3 Master events controllers (MEC's) load control assemblies (LCA's). Currently under study by appropriate NASA offices are the partitioning of functions requiring interfaces with MEC's or LCA's.

Presently, insufficient data is available to determine their specific roles, the manner of mechanization or associated instrumentation details. When data becomes available, necessary functional path analysis will be undertaken, results documented, and released either as a revision to this document or as a part of successor documents originated by this activity.

3.5.2 Functional Path Analysis

Figure 3-5-1 shows the HFT EPDC subsystem as a collection of nine functional paths (excluding MEC's and LCA's) which will

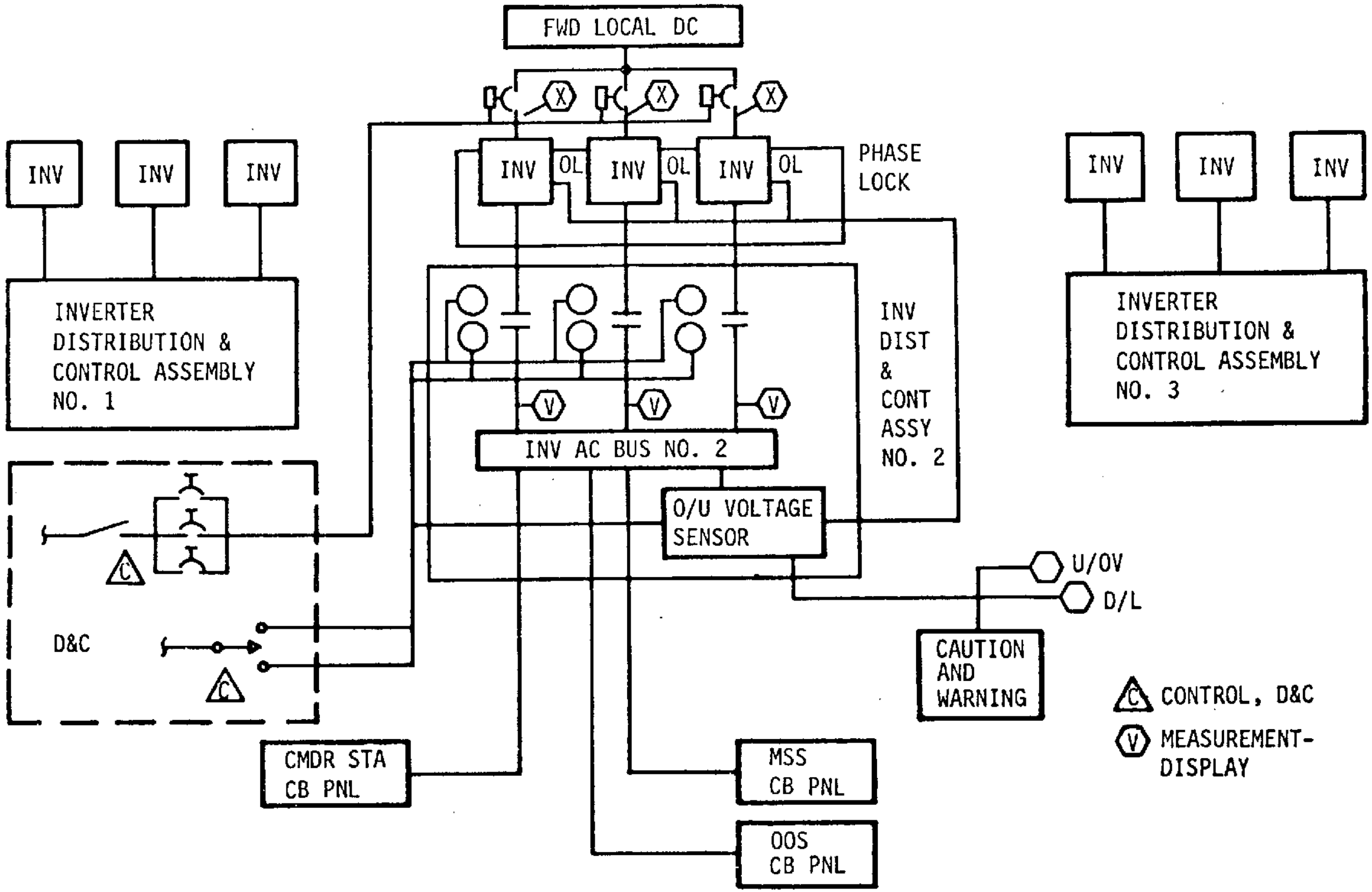


Figure 3.5-3. — AC distribution block diagram.

be treated in a subsequent revision to this document. Analysis shows that all local DC buses (forward, midbody, and aft) may be regarded logically as extensions of their respective main buses. As illustrated in figure 3-5-1, each bus in a given main DC bus set is separated (only) by isolation fuses. Each fuse, in close physical proximity to the main bus, is highly transparent to momentary overloads; fusing occurs only in the event of a severe overload. All local loads have circuit protection (i.e., RPC, RCCB, internal fuses, etc.) and events resulting in their interruption will not fault the bus isolation fuses. For these reasons, only the main bus requires instrumentation to satisfy PMS FDA requirements, and main DC and local DC buses are regarded logically as identical entities.

The resulting nine functional paths are identified below.

DC1 – Main DC Bus 1, associated local buses, and Bus tie contactor four (BTC-4).

DC2 – Main DC bus 2, associated local buses, and BTC-5.

DC3 – Main DC bus 3, associated local buses, and BTC-6.

DC4 – ESS/CONT Bus 1.

DC5 – ESS/CONT Bus 2.

DC6 – ESS/CONT Bus 3.

AC1 – Inverter Bus 1, Inverter set 1, associated input/output contactors.

AC2 – Inverter Bus 2, Inverter set 2, associated input/output contactors.

AC3 – Inverter Bus 3, Inverter set 3, associated input/output contactors.

3.5.3 Subsystem/PMS Interfaces

Table 3-5-1 lists the HFT EPDC subsystem measurements to be utilized by PMS in Fault Detection/Annunciation (FDA) processes. Measurements tabulated for each identified functional path include a primary and secondary sensor. Configuration status data required for interpretation (i.e., fault isolation) of failure annunciation must be supplied by the PMS SCM modules or by FDA precondition tests. Correlation processes and requirements for identity equations are discussed in section 3.5.4.

3.5.4 PMS Requirements

Table 3.5-2 lists the primary and secondary measurements for each functional path previously identified. No preconditions are indicated or required at the EPDC subsystem level in as much as all power buses, both AC and DC are required to be normally powered. Precondition testing is required at the beginning of each major PMS cycle to status each EPDC functional path. It may be assumed that this precondition applies to any configuration/reconfiguration actively initializing a power bus. Treatment of this matter is covered in documents (i.e., FSSR) addressing system level PMS software requirements.

A "detected" fault requires data input to (or from) the SCM module in order to properly interpret fault occurrences and perform specific fault isolations. Each primary power bus is a mode sensitive passive device (i.e., a copper bar) providing service takeoffs for various loads and/or sensors. Each bus is therefore regarded as a dependent variable, driven by the specific subsystem configuration in effect at any given point in time. Adequate fault isolation (i.e., a process that avoids alarming cascading effects or masking influences resulting from varying configurations) requires (1) a statement of the initialized configuration or the configuration in effect immediately prior to fault detection, (2) power transfer statements, (3) effecter status statements, and (4) an identity statement (derived from the preceeding three items) which permits a logical derivation of bus power status at any given point in time. Such an identity correlation process permits both sensor validation and provides a vehicle by which specific fault isolation processes may occur. These techniques are usually employed in dynamically modeled systems, placing further treatment and/or discussion outside the scope of this document. (Results of preliminary analysis concerning system modes, probable crew procedures, and correlation processes are documented in previous reports originated by this activity.)

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76K0160E—Fuel Cell 1 to Main Bus 1 Indicator	Event	0/1	DC-1	Precondition — hardware status.
V76X0106E — Fwd Main DC Bus 1 Tie Indicator	Event	0/1	DC-1	Precondition — hardware status.
V76X0101E — Main DC Bus 1 Under-Voltage	Event	0/1	DC-1	Event for Bus 1 undervoltage; C&W Alarm (Required PMS Alarm)
V76V0100A — Main DC Bus 1 Voltage	Analog	24.0-32.0 Volts DC	DC-1	(Out of limits condition requires PMS Alarm)
V76X0260E — Fuel Cell 1 to Main Bus 1 Indicator	Event	0/1	DC-2	Precondition — hardware status.
V76X0206E — Fwd Main DC Bus 1 Tie Indicator	Event	0/1	DC-2	Precondition — hardware status.
V76X0201E — Main DC Bus 2 Under-voltage	Event	0/1	DC-2	Event for Bus 2 undervoltage; C&W Alarm (Requires PMS Alarm)

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76V0200A — Main DC Bus 2 Voltage	Analog	24.0 - 32.0 Volts DC	DC-2	(Out of limits condition requires PMS Alarm)
V76S0360E — Fuel Cell 3 to Main Bus 3 Indicator	Event	0/1	DC-3	Precondition — hardware status.
V76S0306E — Fwd Main DC Bus 1 Tie Indicator	Event	0/1	DC-3	Precondition — hardware status.
V76X0301E — Main DC Bus 3 Under-voltage	Event	0/1	DC-3	Event for Bus 3 undervoltage; C&W Alarm (Requires PMS Alarm)
V76V0300A — Main DC Bus 3 Voltage	Analog	24.0 - 32.0 Volts DC	DC-3	(Out of limits condition requires PMS Alarm)
V76XXXXXE — ESS/ Cont. Bus 1 Under-voltage	Event	0/1	DC-4	Change directed by CCA 69 and MCR 0662 deleting ABES; Specific instumentation of RAC's unavail-able. (N=unassigned MML ID) C&W Alarm (Requires PMS Alarm)
V76V0130A — ESS/ Cont. Bus 1 Voltage	Analog	23.0 - 40.0 Volts DC	DC-4	Comment as above; (out of limits condition requires PMS Alarm.

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76S0131E — Main Bus 1 to ESS Bus 1 - On	Event	0/1	DC-4	Precondition configuration status.
V76S0334E — Main Bus 3 to ESS Bus 1 - On	Event	0/1	DC-4	Precondition configuration status.
V76XXXXXE — ESS/ Cont Bus 2 Undervoltage	Event	0/1	DC-5	C
V76V0230A — ESS/ Cont Bus 2 Voltage	Analog	23.0 - 40.0 Volts DC	DC-5	
V760134E — Mn Bus 1 to ESS Bus 2 - On	Event	0/1	DC-5	Precondition configuration status
V760231E — Mn Bus 2 to ESS Bus 2 - On	Event	0/1	DC-5	Precondition configuration status
V76XXXXXE — ESS/ Cont Bus 3 Undervoltage	Event	0/1	DC-6	

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76V1500A — Inverter Bus 1 ϕA Voltage	Analog	110-120 Volts RMS	AC-1	Note: Inverter AC System currently under revision, Instrumentation details soft. (Out of limits condition requires PMS Alarm)
V76V1501A — Inverter Bus 1 ϕB Voltage	Analog	110 - 120 Volts RMS	AC-1	(Out of limits condition requires PMS Alarm)
V76V1502A — Inverter Bus 1 ϕC Voltage	Analog	110-120 Volts RMS	AC-1	(Out of limits condition requires PMS Alarm)
V76X1505E — Inverter Bus 1 over/under voltage	Event	0/1	AC-1	Event for over or under voltage; C&W Alarm.
V76X1506E — Inverter Bus 1 Overload	Event	0/1	AC-1	Event for overload; C&W Alarm.
V76S1511E Inverter Bus 1-on	Event	0/1	AC-1	Precondition configuration status
V76S1531E Bus 1 DC Input to Inverter 1-PhA	Event	0/1	AC-1	Precondition configuration status

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76X1537E—Inverter 1 Ph A Output - On	Event	0/1	AC-1	Precondition hardware status.
V76X1538E—Inverter 1 Ph B Output - On	Event	0/1	AC-1	Precondition hardware status.
V76X1539E—Inverter 1 Ph C Output - On	Event	0/1	AC-1	Precondition hardware status.
V76V1700A — Inverter Bus 3 ϕA Voltage	Analog	110-120 Volts RMS	AC-3	Note: Inverter AC System currently under revision; Instrumentation details soft. (Out of limits condition requires PMS Alarm)
V76V1701A — Inverter Bus 3 ϕB Voltage	Analog	110-120 Volts RMS	AC-3	(Out of limits condition requires PMS Alarm)
V76V1702A — Inverter Bus 3 ϕC Voltage	Analog	110-120 Volts RMS	AC-3	(Out of limits condition requires PMS Alarm)
V76X1605E — Inverter Bus over/under voltage	Event	0/1	AC-3	Event for over or under voltage; C&W Alarm.

TABLE 3.5-1

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76X1606E — Inverter Bus 3 Overload	Event	0/1	AC-3	Event for overload; C&W Alarm.
V76X1711E — Inverter Bus 3-On	Event	0/1	AC-3	Precondition configuration status.
V76X1731E Bus 3 DC Input to Inverter 3 Ph A	Event	0/1	AC-3	Precondition configuration status.
V76X1737E — Inverter 3 Ph A Output - On	Event	0/1	AC-3	Precondition hardware status.
V76X1738E — Inverter 3 Ph B Output - On	Event	0/1	AC-3	Precondition hardware status.
V76X1739E — Inverter 3 Ph C Output - On	Event	0/1	AC-3	Precondition hardware status.

TABLE 3.5-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID • SECONDARY/CORRECTION	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V76X0101E (P) • Main DC Bus 1 under-voltage • DC 1	V76X-0160E V76X-0106E	None	None	None	None	None	Event		Event	V76V0100A
• V76V0100A (S) • Main DC Bus 1 Voltage • DC 1	None	None	None	None	None	32.0 VDC	24.0 VDC	None	None	
• V76X0201E (P) • Main DC Bus 2 Under Voltage • DC 2	V76X-0260E V76X 0206E	None	None	None	None	None	Event		Event	V76V0200A
• V76V0200A (S) • Main DC Bus 2 Voltage • DC 3	None	None	None	None	None	32.0 VDC	24.0 VDC	None	None	
• V76X0301E (P) • Main DC Bus 3 Under-voltage • DC 3	V76X-0360E V76X-0306E	None	None	None	None	None	Event		Event	V76V0300A
• V76V0300A (S) • Main DC Bus 3 Voltage • DC 3	None	None	None	None	None	32.0 VDC	24.0 VDC	None	None	
*• V76XNNNNE (p) • ESS/Cont Bus 1 Under-Voltage • DC 4	None	V76S-0131E V76S-0334E	None	None	None	None	Event	None	Event	V76V0130A
• V76V0130A (S) • ESS/Cont Bus 1 Voltage • DC 4	None	None	None	None	None	40.0 VDC	23.0 VDC	None	None	

*Measurement assigned but ID not presently available.

TABLE 3.5-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID • SECONDARY/CORRECTION	PRE-CONDITION TEST: HARDWARE STATUS	PRE-CONDITION TEST: CONFIGURATION CHECK	SOFT LIMIT CHECK: HIGH	SOFT LIMIT CHECK: LOW	TREND CHECK	HARD LIMIT CHECK: HIGH	HARD LIMIT CHECK: LOW	BACKUP CAUTION & WARNING: HIGH	BACKUP CAUTION & WARNING: LOW	CORRELATION MEASUREMENT
* • V76XNNNE (P) • ESS/Cont. Bus 2 Undervoltage • DC 5	None	V76S-0134E V76S-0231E	None	None	None	None	Event	None	Event	V76V0230A
• V76V0230A (S) • ESS/Cont Bus 2 Voltage • DC 5	None	None	None	None	None	40.0 VDC	23.0 VDC	None	None	
* • V76XNNNE (P) • ESS/Cont Bus 3 Undervoltage • DC 6	None	V76S-0234E V65S-0331E	None	None	None	None	Event	None	Event	V76V0330A
• V76V0330A (S) • ESS/Cont Bus 3 Voltage • DC 6	None	None	None	None	None	40.0 VDC	23.0 VDC	None	None	
• V76X1505E (P) • Inverter Bus 1 over/under voltage • AC 1	None	V76S-1511E V76S-1531E	None	None	None	Event	Event	Event	Event	V76V1500A V76V1501A V76V1502A
• V76V1500A (S) • Inverter Bus 1 φBVolts • AC 1	V76X-537E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1505E
• V76V1501A (S) • Inverter Bus 1φ BVolts • AC 1	V76X-1538E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1505E
• V76V1502A (S) • Inverter Bus 1 φC Volts • AC 1	V76X-1539E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1505E
• V76X1506E (P) • Inverter Bus 1 Over-load • AC 1	None	None	None	None	None	Event	None	Event	None	None

* Measurement assigned but ID not presently available.

TABLE 3.5-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID •	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V76X1605E (P) • Inverter Bus 2 Over/undervoltage • AC 2	None	V76S-1611E V76S-1631E	None	None	None	Event	Event	Event	Event	V76V1600A V76V1601A V76V1602A
• V76V1600A (S) • Inverter Bus 2 φA V • AC 2	V76X-1637E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1605E
• V76V1601A (S) • Inverter Bus 2 φB V • AC 2	V76X-1638E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1605E
• V76V1602A (S) • Inverter Bus 2 φC V • AC 2	V76X 1639E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76X1605E
• V76X1606E (P) • Inverter Bus 2 overload • AC 2	None	None	None	None	None	Event	None	Event	None	None
• V76X1705E (P) • Inverter Bus 3 over/under voltage • AC 3	None	V76S-1711E V76S-1731E	None	None	None	Event	Event	Event	Event	V76V1700A V76V1701A V76V1702A
• V76V1700A (S) • Inverter Bus 3 φ A V • AC 3	V76X-1737E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76V1705E
• 76V1701A (S) • Inverter Bus 3 φ B V • AC 3	V76X-1738E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76V1705E
• V76V1702A (S) • Inverter Bus 3φ C V • AC 3	V76X-1739E	None	None	None	None	120 VRMS	110 VRMS	None	None	V76V1705E

TABLE 3.5-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION AND CONTROL

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V76X1706E (P) • Inverter Bus 3 Overload • AC 3	None	None	None	None	None	Event	None	Event	None	None

3.6 AUXILIARY POWER UNITS

3.6.1 Subsystem Description

The APU subsystem provides mechanical shaft power for the hydraulic pumps for HFT, VFT, and orbital missions during pre-launch, ascent, MPS Dump, entry and landing. Each APU drives a hydraulic pump which supplies hydraulic power for one of the three hydraulic systems.

The hydraulic pumps provide power to actuate the aero-dynamic surfaces (elevons and rudder/speed brakes), main engine thrust vector controls, main engine controls, landing gear, brakes and steering.

The APU utilizes a monopropellant hydrazine N_2H_4 which is decomposed in the gas generator catalytic bed. Propellant fuel pressure is maintained by helium gas pressure across a diaphragm.

Propellant quantity is determined from pressure and temp-erature sensors in the helium side of the fuel tanks.

Radiation heaters are used to maintain a temperature of $70^{o}F$ for the propellant.

Prior to APU start-up, the gas generator thermal bed is electrically heated for approximately 15 minutes (to approxi-mately $800^{o}F$.). As the propellant contacts the catalyst, it instantly decomposes, producing a gas which drives a two-stage turbine at 74,000 RPM. Heat of decomposition ranges from $1600^{o}F$ to $2300^{o}F$ depending on the amount of NH_3 produced during the hydrazine decomposition. Pressures of 1000 psia to 1300 psia are developed during this phase of operation. A fuel pump increases the fuel pressure (from tank pressure) to that required to produce maximum peak power (nominal 1300 psi).

The turbine design conditions for fuel consumption calculations are based on an inlet temperature of approximately 1700°F. The turbine shaft is coupled to the loads through an all-attitude, zero-g oil mist lubricated gearbox. The turbine exhausts are ducted to the fuselage outer surface where the gas is vented overboard through propulsive vents. The approximate makeup of the exhaust gas from the decomposed hydrazine is hydrogen (6.3 percent by weight), nitrogen (58.3 percent), and ammonia (35.4 percent).

The APU controller provides for speed control, logic for APU start-up and shutdown, and malfunction protection. Automatic shutdown of a single APU is executed if turbine speed exceeds the prescribed limits. An energy absorbing turbine housing designed for burst containment is provided as protection against turbine wheel failure.

3.6.2 Functional Paths

A schematic diagram of the system and the functional paths used during the review of this system are shown in figure 3.6.1. The functional paths are identified as follows:

AP1 - APU Module System

AP2 - Gearbox and Lube System

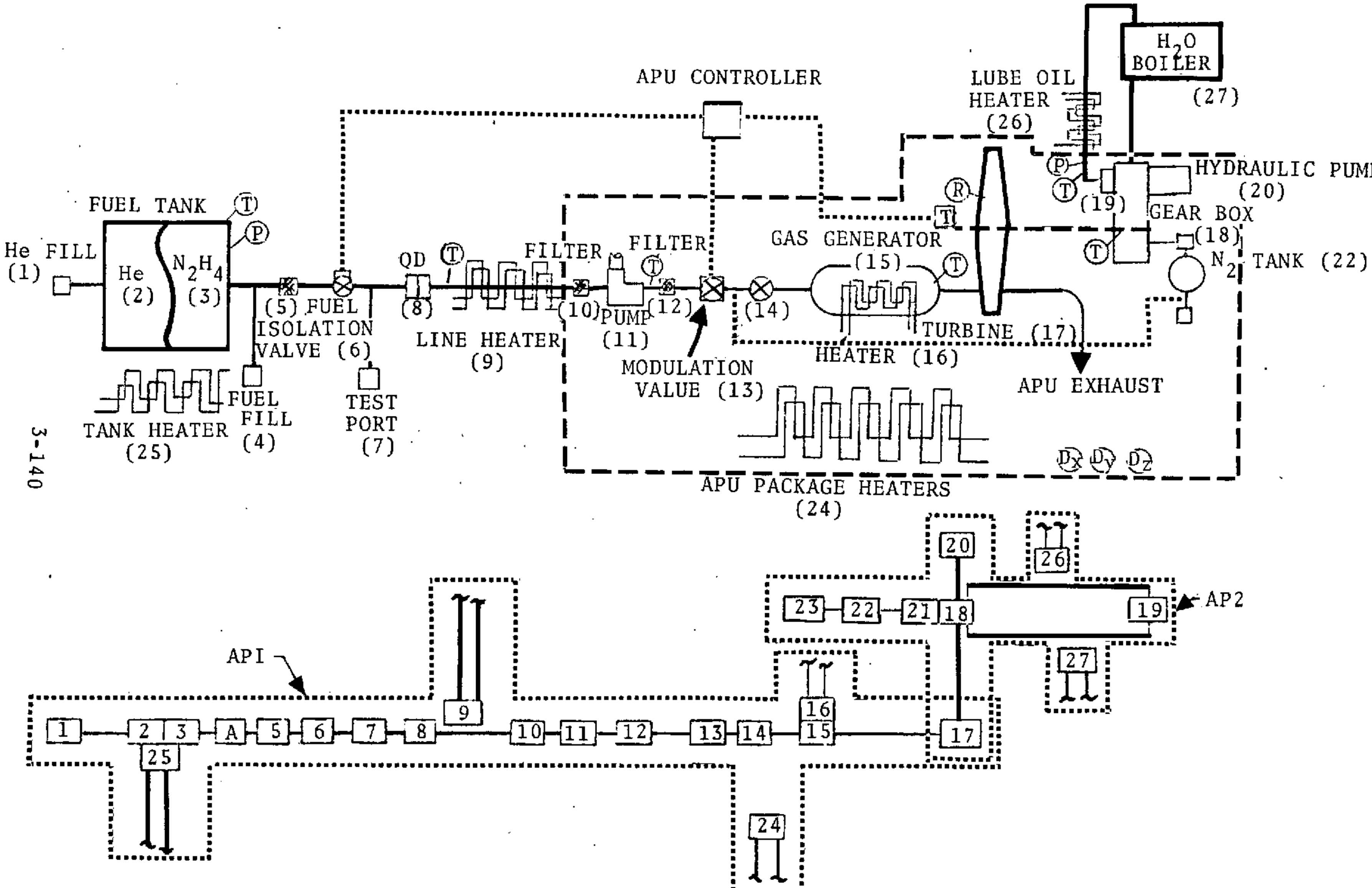


Figure 3.6-1. — Auxiliary power unit (APU) functional paths.

3.6.3 PMS Interfaces

Each APU has instrumentation which monitors the operation of the main components and is interfaced with the PMS. Continuous monitoring of this information will provide system status and early fault identification. Table 3.6-1 lists the measurements required to evaluate the health status of the APU subsystem. All measurements shown are in the MML.

3.6.4 PMS Requirements

The primary and secondary APU measurements required for FDA are summarized in table 3.6-2. This figure also indicates correlation measurements and measurement limits where applicable.

TABLE 3.6-1.

PMS MEASUREMENT DATA

SUBSYSTEM: AUXILIARY POWER UNIT

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V46X0099E — APU 1-3 Shut Down Inhibit Command	Event		AP1	Determines system status for all three APU's (i.e., operational mode or quiescent).
V46P0100A — APU 1 Propellant Tank Pressure	Press	90-440 psia	AP1	Gives readout of fuel pressure of hydrazine needed for determination of system status.
V46T0101A — APU 1 Propellant Tank Temperature	Temp	50-150°F	AP1	The hydrazine propellant has a normal temperature of 70°F. This temperature is maintained by the tank heaters.
V46S0106E — APU Tank 1/2 Heater Element A	Event		AP1	This heater maintains temperature of hydrazine propellant at a nominal 70°F.
V46T0108A — APU 1 Discharge Line Temperature	Temp	50-150°F	AP1	Measures temperature of the hydrazine in the line from the fuel tank.
V46S0109E — APU 1 Line Heater Element A-B On	Event	ON	AP1	Heats fuel line from tank to the gas generator. Operation is monitored by discharge line temperature measurement.
V46P0111A — Fuel Pump Discharge Pressure	Temp	0-250 psia	AP1	Verifies pump operation.
V46S0113E — APU 1 Package Heater Element A-B On	Event	Off-On	AP1	Heater is used to maintain APU package temperature within operating units in the On-Orbit phase.

TABLE 3.6-1.

PMS MEASUREMENT DATA

SUBSYSTEM: AUXILIARY POWER UNIT

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V46S0114E – APU 1 Fuel Isolation Valve – Open Command	Event	Closed-Open	AP1	Allows fuel flow from the tank to the gas generator for APU operation.
V46X0115E – APU 1 Fuel Isolation Valve Position	Event	Closed-Open	AP1	Confirms valve open command execution and gives systems status (i.e., when open is in run condition).
V46S0118E – APU 1 Thermal Bed Heater A On	Event	On-Off	AP1	Heaters used to raise gas generator bed temperature prior to start-up.
V46S0119E – APU 1 Thermal Bed Heater B On	Event	On-Off	AP1	Heater maintains external temperature of the gas generator (measurement required for system status).
V46T0122A – APU 1 Gas Generator Bed Temperature	Temp	1350-2200 °F	AP1	Provides indication that the gas generator bed heater is operating and provides a measurement for system status.
V46S0124E – APU 1 Controller Power On Command	Event	On-Off	AP1	Provides information for determination of system configuration.
V46S0126E – APU 1 Start Command	Event		AP1	Provides information for system configuration check.
V46R0135A – APU 1 Turbine Speed	Rate	0-80,000	AP1	Confirms execution of start command and provides indication of system operation. The Turbine

TABLE 3.6-1.

PMS MEASUREMENT DATA

SUBSYSTEM: AUXILIARY POWER UNIT

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
				drives the hydraulic pump through the gearbox. Therefore, this measurement provides indication of hydraulic power being available.
V46D0180A – APU 1 Acceln X-Axis	Vibration	TBD	AP1	Measures turbine vibration trend. Measurement will give indication of impending turbine and/or bearing failure.
V46D0181A – APU 1 Acceln Y-Axis	Vibration	TBD	AP1	Same as above.
V46D0182A – APU 1 Acceln Z-Axis	Vibration	TBD	AP1	Same as above.
V46S0116E – APU 1 Lube Oil Heater Element A-B On	Event	On-Off	AP2	Heaters maintain oil temperature used for gearbox lubrication.
V46T0150A – APU 1 Gearbox Lube Oil Temperature	Temp	40-230°F	AP2	Temperature of lube oil is dependent upon heater and H_2O boiler operation.
V46P0151AA – APU 1 Gearbox Lube Oil Pressure	Press	75-105	AP2	Monitors gearbox operation.
V46T0161A – APU 1 Gearbox Bearing Temperature No. 1	Temp	40-450°F	AP2	Provides correlation of lube oil temperature and trend measurement will give indication of impending bearing failure.

TABLE 3.6-1.

PMS MEASUREMENT DATA

SUBSYSTEM: AUXILIARY POWER UNIT

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V46T0131A – APU1 Turbine Inlet Temperature	Analog	0-1750°F	AP1	Provide backup to turbine speed (V46R0135A) new measurement for PMS.
V46S0116E – APU1 Lube Oil Heater Element A-B ON	Event	On-Off	AP2	Heater maintains oil temperature used for gearbox lubrication.
				The information above is repeated for systems 2 and 3 (see table 3.6-2 for a complete listing).

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID / PMS ACTIVITY	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0099E (P) • APU1-3 Shut Down Inhibit CMD • AP1		X								None
• V46P0100A (P) • APU1 Propellant Tank Pressure • AP1			420 psia	100 psia	X	440 psia	90 psia			V46P0110A
• V46T0101A (S) • APU1 Propellant Tank Temperature • AP1			90° F	60° F		150° F	50° F			V46T0108A
• V46S0106E (S) • APU Tank 1/2 Heater Element A — ON • AP1		X								V46T0101A
• V46T0108A (S) • APU1 Discharge Line Temperature • AP1			90° F	60° F		150° F	50° F			V46T0101A
• V46S0109E (S) • APU1 Line Heater Element A-B — ON • AP1		X								V46T0108A
• V46P0110A (S) • APU1 Fuel Inlet Pressure • AP1			420 psia	100 psia		440 psia	90 psia			V46P0100A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0113E (S) • APU1 Package Heater Element A-B — ON • AP1		X								
• V46S0114E (P) • APU1 Fuel Isolation Valve-OPEN CMD • AP1		X								V46X0115A
• V46X0115E (P) • APU1 Fuel Isolation Valve Position • AP1		X								V46P0110A
• V46S0116E (S) • APU1 Lube Oil Heater Element A-B ON • AP1		X								V46T0150A
• V46S0118E (S) • APU1 Thermal Bed Heater A ON • AP1		X								V46T0122A
• V46S0119E (S) • APU1 Thermal Bed Heater B ON • AP1		X								V46T0122A
• V46T0122A (S) • APU1 Gas Generator Bed Temperature • AP1			1900° F	1500° F	X	2200° F	1350° F			None

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0124E (P) • APU1 Controller Power ON CMD • AP1		X								None
• V46S0126E (P) • APU1 Start Command • AP1		X								None
• V46R0135A (P) • APU1 Turbine Speed • AP1			77,000 rpm	0	X	80,000 rpm	0			V46T0131A
• V46P0151A (P) • APU1 Gearbox Lube Oil Pressure • AP2			95 psia	85 psia		105 psia	75 psia			V46T0150A
• V46T0150A (S) • APU1 Gearbox Lube Oil Temperature • AP2			200° F	40° F	X	230° F	40° F			V46T0161A
• V46T0161A (S) • APU1 Gearbox Brg. Temperature No. 1 • AP2			480° F	None	X	480° F	None			V46T0150A
• V46D0180A (P) • APU1 Acceln X-Axis • AP1			TBD	TBD	X	None	None			V46D0181A V46D0182A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46D0181A (P) • APU1 Acceln. Y-Axis • AP1			TBD	TBD	X	NONE	NONE			V46D0180A V46D0182A
• V46D0182A (P) • APU1 Acceln. Z-Axis • AP1			TBD	TBD	X	NONE	NONE			V46D0180A V46D0181A
• V46T0131A (S) • APU1 Turbine Inlet Temperature • AP1			NONE	NONE		1750° F	NONE			V46R0135A
• V46P0200A (P) • APU2 Propellant Tank Temperature • AP1			410 psia	100 psia	X	440 psia	90 psia			V46P0210A
• V46T0201A (S) • APU2 Propellant Tank Temperature • AP1			90° F	60° F		150° F	50° F			V46T0208A
• V46S0206E (S) • APU Tank 1/2 Heater Element B ON • AP1		X								V46T0201A
• V46T0208A (S) • APU2 Discharge Line Temperature • AP1			90° F	60° F		150° F	50° F			V46T0201A

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0209E (S) • APU2 Line Heater Element A-B ON • AP1		X								V46T0208A
• V46P0210A (S) • APU2 Fuel Inlet Pressure • AP1			420 psia	90 psia		440 psia	90 psia			V46P0200A
• V46S0213E (S) • APU2 Package Heater Element A-B ON • AP1		X								
• V46S0214E (P) • APU2 Fuel Isolation Valve-Open CMD • AP1		X								V46X0215A
• V46X0215A (P) • APU2 Fuel Isolation Valve Position • AP1		X								V46P0210A
• V46S0216E (S) • APU2 Lube Oil Heater Element A-B ON • AP1		X								V46T0250A
• V46S0218E (S) • APU2 Thermal Bed Heater A ON • AP1		X								V46T0222A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0219E (S) • APU2 Thermal Bed Heater B ON • AP1		X								V46T0222A
• V46T0222A (P) • APU2 Gas Generator Bed Temperature • AP1			1900° F	1500° F	X	2200° F	1350° F			None
• V46S0224E (P) • APU2 Controller Power On CMD • AP1		X								None
• V46S0226E (P) • APU2 Start Command • AP1		X								None
• V46R0235A (P) • APU2 Turbine Speed • AP1			77,000 rpm	0	X	80,000 rpm	0			V46T0231A
• V46P0251A (P) • APU2 Gearbox Lube Oil Pressure • AP2			95 psia	85 psia		105 psia	75 psia			V46T0250A
• V46T0250A (S) • APU2 Gearbox Lube Oil Temperature • AP2			200° F	40° F	X	230° F	40° F			V46T0261A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46T0261A (S) • APU2 Gearbox Brg. Temperature No. 1 • AP2			480° F	None	X	480° F	None			V46T0250A
• V46D0280A (P) • APU2 Acceln. X-Axis • AP1			TBD	TBD	X	None	None			V46D0281A V46D0282A
• V46D0281A (P) • APU2 Acceln. Y-Axis • AP1			TBD	TBD	X	None	None			V46D0280A V46D0282A
• V46D0282A (P) • APU2 Acceln. Z-Axis • AP1			TBD	TBD	X	None	None			V46D0280A V46D0281A
• V46T0231A (S) • APU2 Turbine Inlet Temperature • AP1			None	None		1750° F	None			V46R0235A
• V46P0300A (P) • APU3 Propellant Tank Pressure • AP1			410 psia	100 psia	X	440 psia	90 psia			V46P0310A
• V46T0301A (S) • APU3 Propellant Tank Temperature • AP1			90° F	60° F		150° F	50° F			V46T0308A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0306E (S) • APU Tank 3 Heater Element A-ON • AP1		X								V46T0301A
• V46T0308A (S) • APU3 Discharge Line Temperature • AP1			90° F	60° F		150° F	50° F			V46T0301A
• V46S0309E (S) • APU3 Line Heater Element A-B ON • AP1		X								V46T0308A
• V46P0310A (S) • AP3 Fuel Inlet Pres Pressure • AP1			420 psia	90 psia		440 psia	90 psia			V46P0300A
• V46S0313E (S) • APU1 Package Heater Element A-B ON • AP1		X								
• V46S0314E (P) • APU3 Fuel Isolation Valve-OPEN CMD • AP1		X								V46X0315A
• V46X0315E (P) • APU3 Fuel Isolation Valve Position • AP1		X								V46P0310A

TABLE 3.6-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46S0316E (S) • APU3 Lube Oil Heater Element A-B ON • AP1		X								V46T0350A
• V46S0318E (S) • APU3 Thermal Bed Heater A ON • AP1		X								V46T0322A
• V46S0319E (S) • APU3 Thermal Bed Heater B ON • AP1		X								V46T0322A
• V46T0322A (S) • APU3 Gas Generator Bed Temperature • AP1			1900° F	1500° F	X	2200° F	1350° F			None
• V46S0324E (P) • APU3 Controller Power ON CMD • AP1		X								None
• V46S0326E (P) • APU3 Start Command • AP1		X								None
• V46R0335A (P) • APU3 Turbine Speed • AP1			77,000 rpm	0	X	80,000 rpm	0			V46T0331A

TABLE 3.6-2

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: AUXILIARY POWER UNIT

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• V46P0351A (P) • APU 3 Gear Box Lube Oil Press • AP1			95 psia	85 psia		105 psia	75 psia			V46T0150A
• V46T0350A (S) • APU 3 Gear Box Lube Oil Temp • AP2			200 °F	40 °F		230 °F	40 °F			V46T0361A
• V46T0361A (S) • APU 3 Gear Box BRG Temp No. 1 • AP2			480 °F	None		480 °F	None			V46T0350A
• V46D0380A (P) • APU 3 Accel X-Axis • AP1			TBD	TBD		None	None			V46D0381A V46D0382A
• V46D0381A (P) • APU 3 Accel • AP1			TBD	TBD		None	None			V46D0380A V46D0382A
• V46D0382A (P) • APU 3 Accel Z-Axis • AP1			TBD	TBD		None	None			V46D0380A V46D0381A
• V46T0331A (S) • APU 3 Turbine Inlet Temp • AP1			None	None		1750 °F	None			V46P0335A

3.7 THERMAL PROTECTION SYSTEM (TPS)

3.7.1 Subsystem Description

The TPS consists of materials applied externally to the primary structural shell of the Orbiter vehicle; these materials maintain the airframe outer skin to within acceptable temperature limits. The TPS supports mission requirements by providing the subassemblies (shown in fig. 3.7-1) to maintain acceptable primary structure temperatures:

- High temperature reusable surface insulation (HRSI) and structural attachment components including joints and interface to special function singularities, when exposed to temperatures between 1200°F and 2300°F under design heating conditions.
- Low temperature reusable surface insulation (LRSI) and structural attachment components, including joints and interface to special function singularities, when exposed to temperatures below 1200°F under design heating conditions.
- Reinforced carbon-carbon (RCC) on areas such as leading edge, nose cap, chine, and structural attachments along with internal insulation, when exposed to temperatures greater than 2300°F under design heating conditions.

3.7.2 Functional Paths

There are no functional paths currently identified for this system on the HFT vehicle.

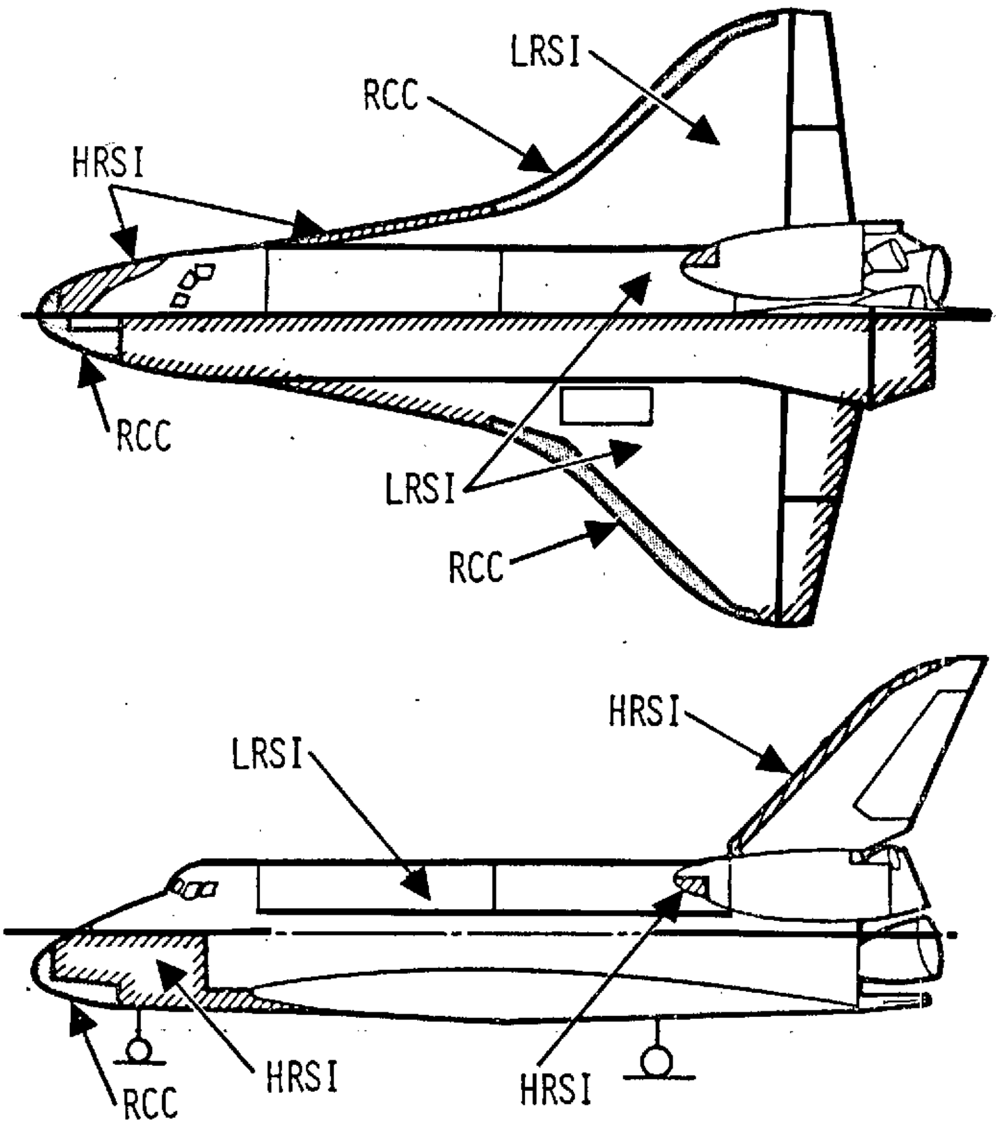


Figure 3.7-1. — Thermal Protection Subsystem (TPS).

3.7.3 PMS Interface

Table 3.7-1 shows the measurements available for PMS interrogation on the HFT vehicle. These consist of 14 temperature measurements located at strategic points on the vehicle.

3.7.4 HFT - PMS System Requirements

The only PMS requirements for the Thermal Protection Control system is to display the temperature data on request. No FDA function for TPS/TCS has been identified.

TABLE 3.7-1.

PMS MEASUREMENT DATA

SUBSYSTEM: THERMAL PROTECTION (TPS)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V09T1510A — Forward Fuselage Bondline Temperature No. 5	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.
V09T1514A — Forward Fuselage Bondline Temperature No. 7	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.
V09T1516A — Forward Fuselage Bondline Temperature No.8	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.
V09T1524A — Forward Fuselage Bondline Temperature No. 12	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.
V09T1580A — LH Forward Payload Bay Door Bondline Temperature No. 1	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.
V09T1582A — LH Forward Payload Bay Door Bondline Temperature No. 2	Temp	-300 to +500°F	N/A	Required for Subsystem Measurement Management (SMM) only.

TABLE 3.7-1.

PMS MEASUREMENT DATA

SUBSYSTEM: THERMAL PROTECTION (TPS)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V09T1584A — LH Forward Payload Bay Door Bond-line Temperature No. 3	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1590A — RH Forward Payload Bay Door Bond-line Temperature No. 1	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1592A — RH Forward Payload Bay Door Bond-line Temperature No. 2	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1594A — RH Forward Payload Bay Door Bond-line Temperature No. 3	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1616A — Cargo Bay Bond-line Temperature No. 9	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1624A — Cargo Bay Bond-line Temperature No. 13	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.

TABLE 3.7-1.

PMS MEASUREMENT DATA

SUBSYSTEM: THERMAL PROTECTION (TPS)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V09T1702A – Aft Fuselage Bond-line Temperature No. 2	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.
V09T1724A – Aft Fuselage Bond-line Temperature No. 13	Temp	-300 to +500°F	NA	Required for Subsystem Measurement Management (SMM) only.

3.8 LANDING/DECELERATION SYSTEM

3.8.1 Subsystem Description

The Space Shuttle's landing/deceleration system consists of a conventional, dual wheel, forward retract/free fall, aircraft-type landing system. The two main gears and the nose gear have the same material and components found on commercial airlines. The nose gear is equipped with a combination shimmy damper/steering system which is steerable 30 degrees either side of center. The main gears house an anti-skid brake system with locked wheel protection at touchdown. The brakes and nose gear steering are contolled electrically, using the rudder pedals. Gear actuation, steering, and brakes are powered hydraulically. Figures 3.8-1 through 3.8-4 illustrate schematically the functions of the landing/deceleration system.

Provisions for emergency fail-safe free-fall release of the main gear is provided hydraulically. Pyrotechnic release of uplocks is provided for the nose gear to eliminate the need to provide an additional hydraulic power system in the nose of the vehicle. The anti-skid brake system provides the capability to stop the Orbiter within 6,000 feet on a dry runway and 10,000 feet on a wet runway.

Although the main function of the landing system is to provide for mission landings, there are the secondary operation and development of horizontal flight test which impact the design criteria.

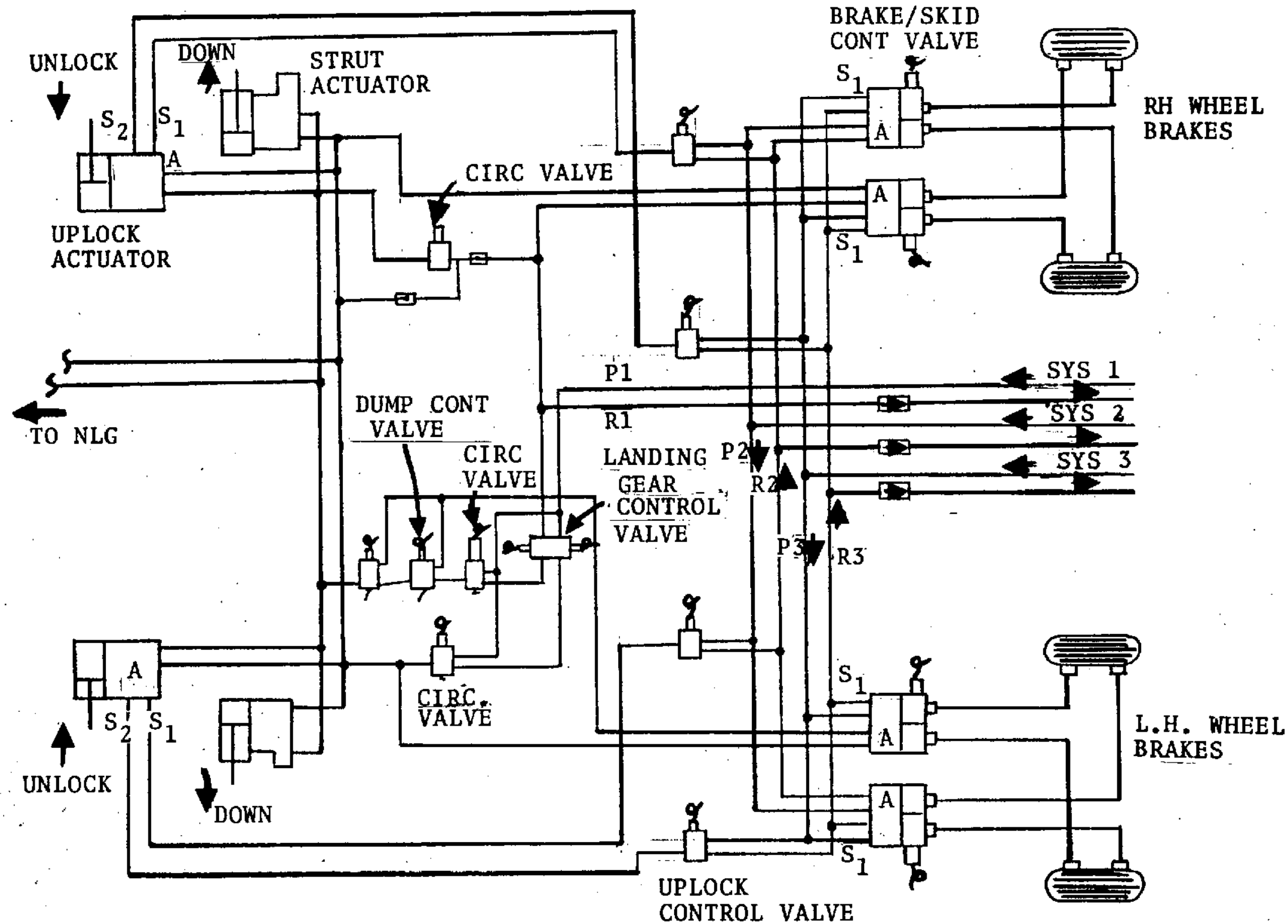


Figure 3.8-1. — Main landing gear system.

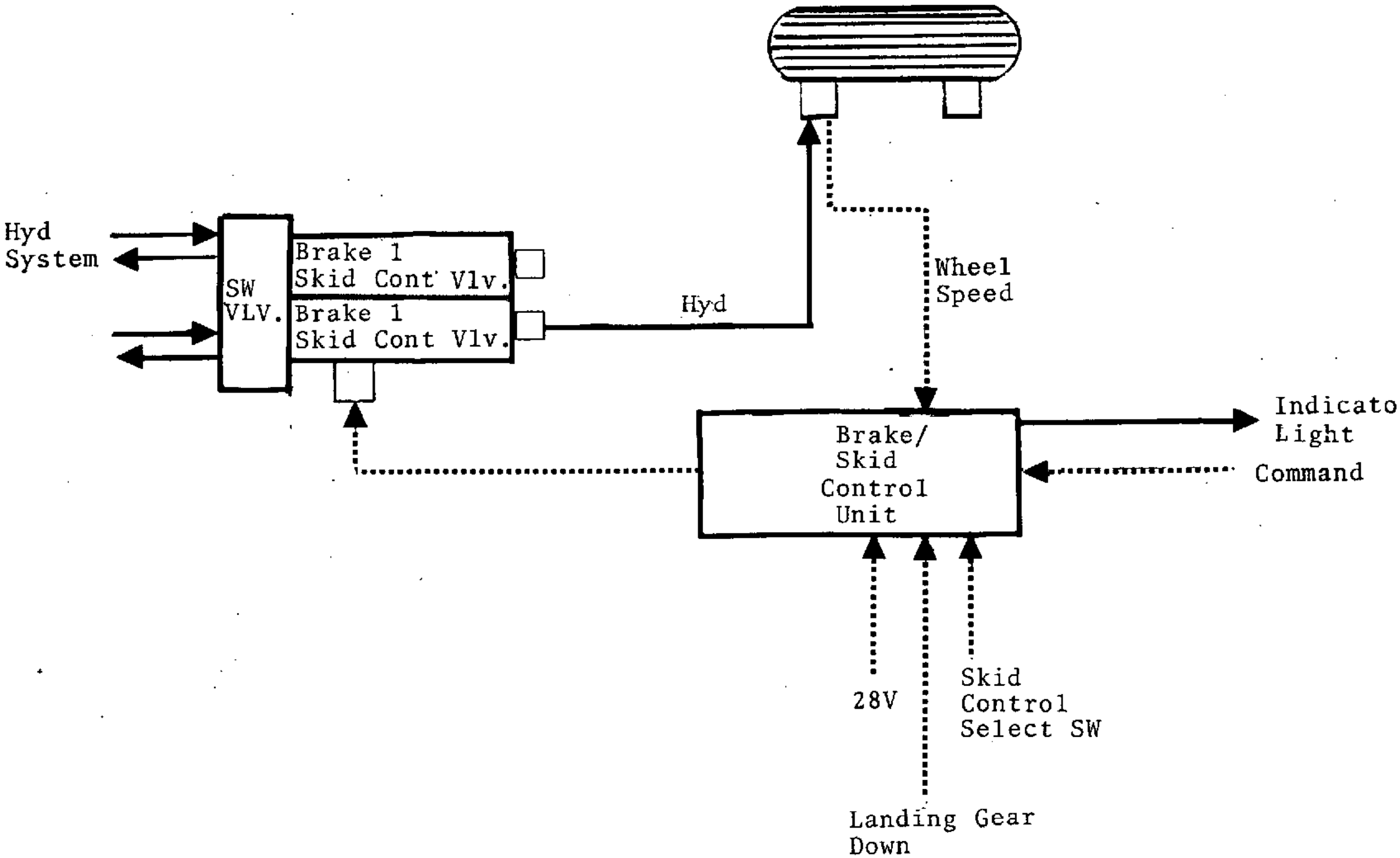


Figure 3.8-2. — Brake system.

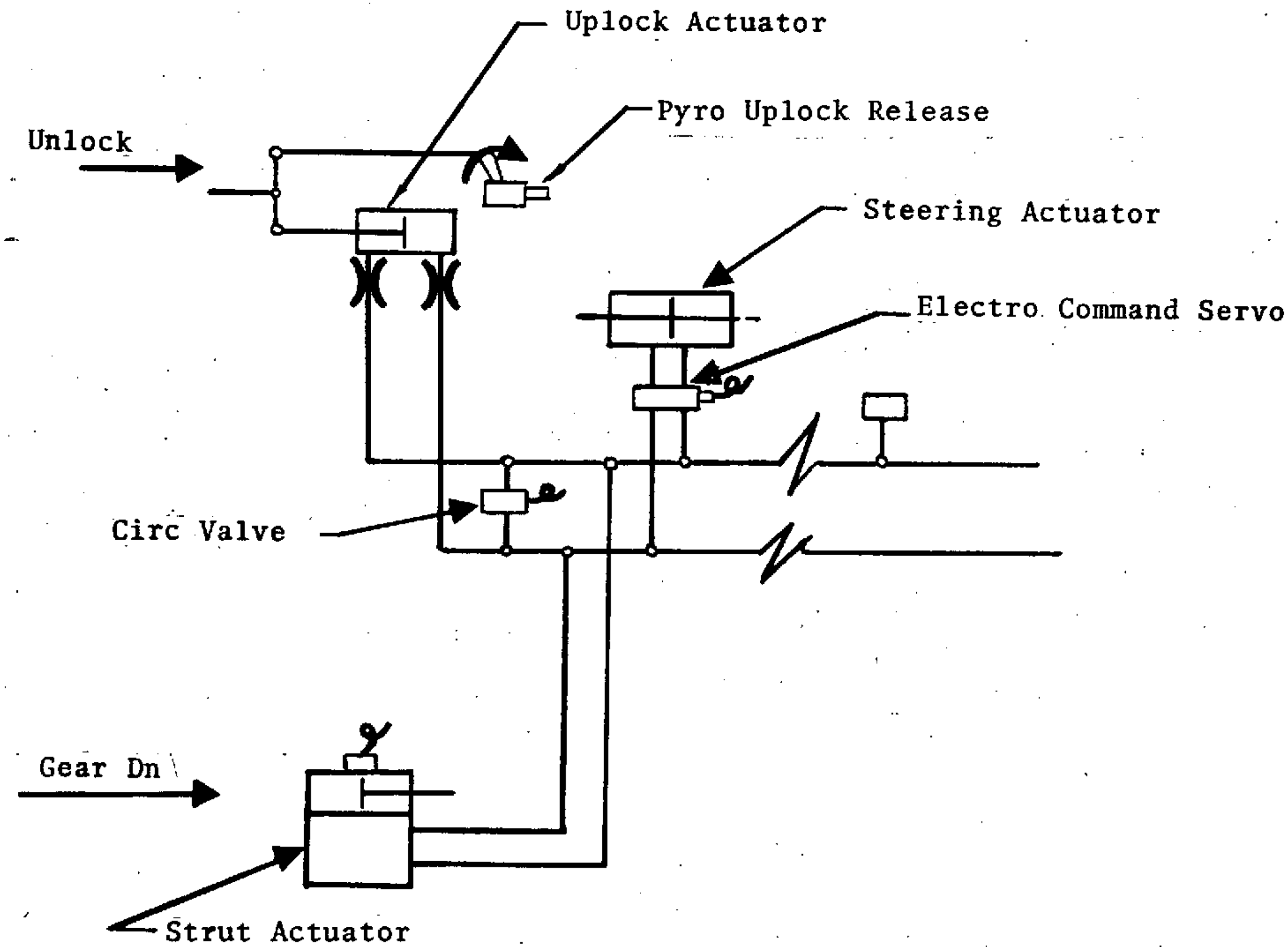


Figure 3.8-3. — Nose landing gear.

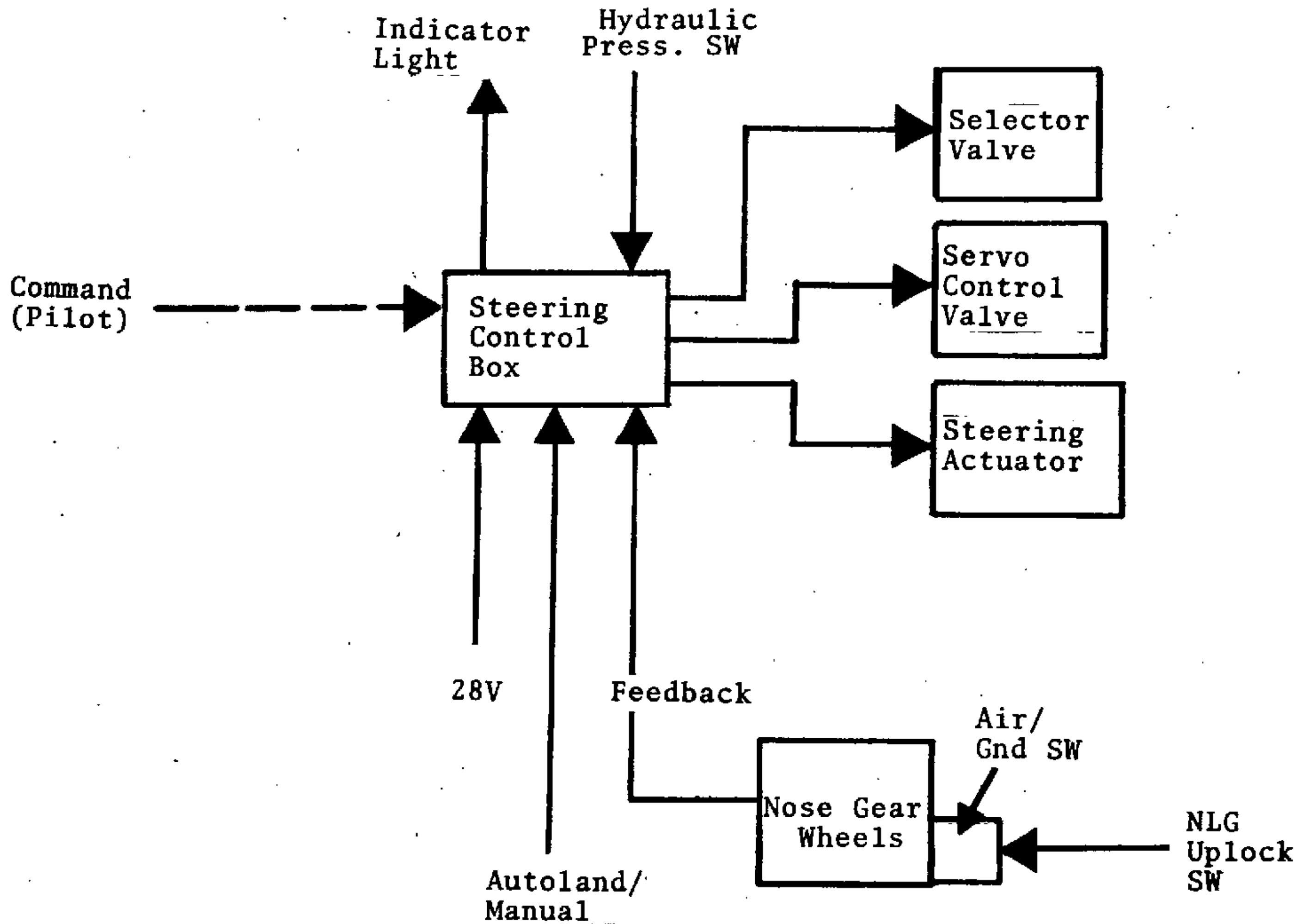


Figure 3.8-4. — Nose gear steering.

3.8.2 Functional Paths

The functions currently identified which this system performs are the following (fig. 3.8-5 shows the functional paths used in the review of this system):

- Braking – Main gear hydraulic brakes with anti-skid device (functional paths DL3 and DL4).
- Steering – Nose gear steering, using hydraulic actuators (functional path DL2).
- Landing gear activation – (functional path DL1).

3.8.3 PMS Interfaces

The instrumentation currently proposed for this system limits the operations and monitoring which can be performed by the PMS. Analysis of the deceleration and landing system in conjunction with the capability of the PMS resulted in the following definitions:

(1) System condition checks

- Hydraulic pressure (confirm pressure available at the landing gear selector).
- Electrical power available to all valves.
- Temperature limits not exceeded during mission.

(2) System operation monitoring

- Landing gear down (must be from independent source to produce backup capability to normal system).

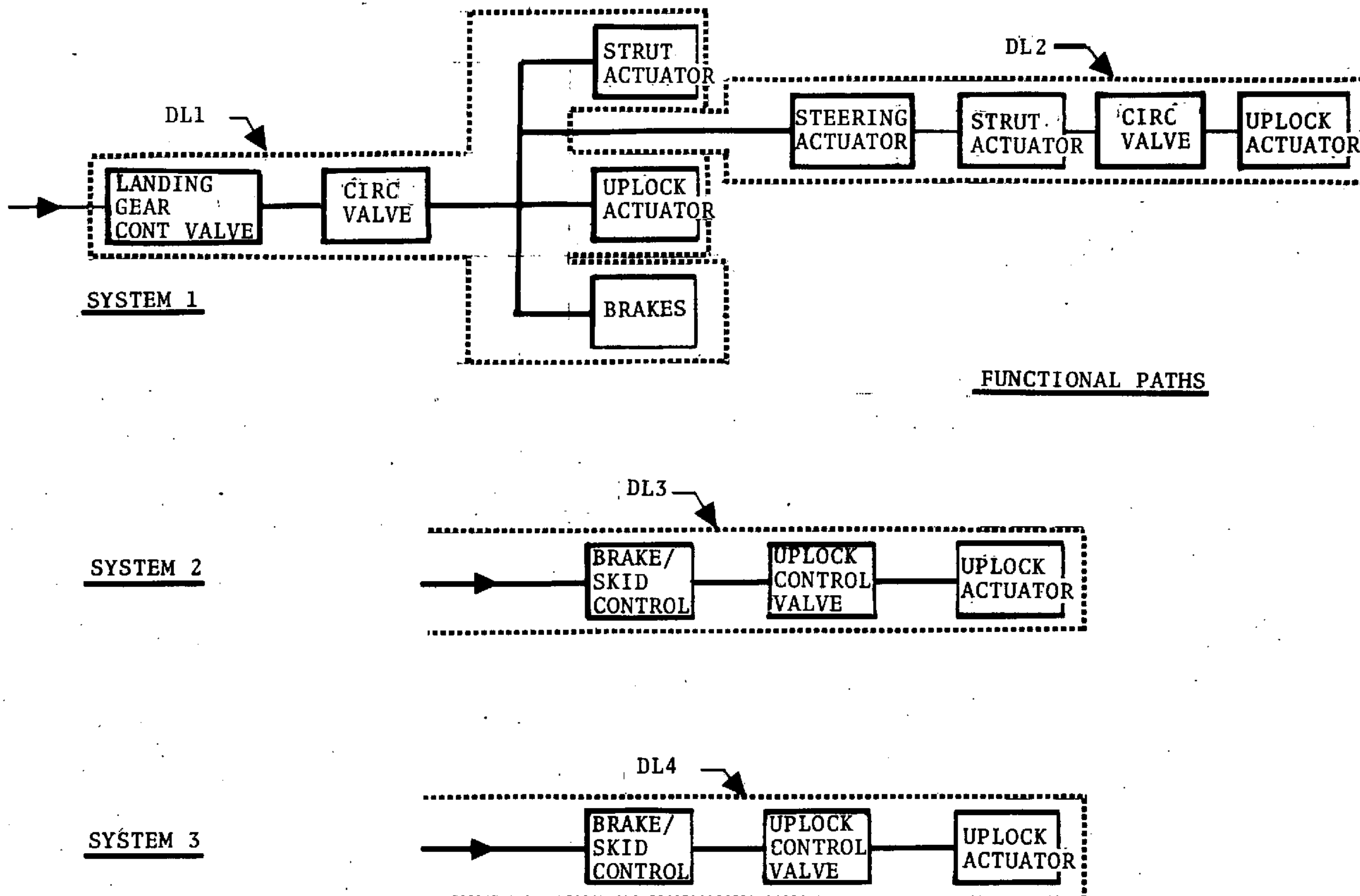


Figure 3.8-5. — Landing gear and wheel brakes.

- Provide warning of landing gear not down (time dependent from gear down command or selection event).
- Electrical power available for brake/steering systems.
- Wheel brake temperatures for taxi tests.

Table 3.8-1 provides a summary of the measurements required to evaluate the health status of the landing/deceleration system. It should be noted that 10 out of 14 of these measurements are not currently included in the MML.

3.8.4 HFT - PMS System Requirements

The PMS-FDA functions implemented for this system should be the following:

(1) Provide system status checks prior to deployment of the landing gear.

(2) Determine that all gears are down and locked prior to touchdown, and provide failure indication if malfunction occurs.

(3) Check status of brake/steering system.

(4) Monitor brake temperatures during taxi-tests.

Figures 3.8-1 through 3.8-3 are block diagrams of the main landing gear control functions and the nose landing gear, respectively. These diagrams show the electrical, mechanical, hydraulic, and operation interaction. Figure 3.8-4 is a schematic of the nose gear steering system. These figures show the interrelation of the hydraulic power supply to these functions.

Table 3.8-2 summarizes the FDA measurements for the L&D subsystem and gives measurement limits where applicable.

C-3

TABLE 3.8-1.

PMS MEASUREMENT DATA

SUBSYSTEM: DECELERATION & LANDING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
Hydraulic Pressure at Landing Gear Control Valve System 1	Press	2000-4050 psia	DL1	New Measurement recommended. Required for the precondition check. Determination of hydraulic power available for landing gear actuation.
Electrical Power To Landing Gear Control Valve, Uplock Valves, Circulation Valves, Dump Con- Control Valves	Event		DL1	New measurement recommended. Required for precondition check. Determination of system status prior to landing gear selection.
V51S0005E — Landing Gear HDL UP SW	Event		DL1	Determine selection of landing gear up or down.
V51X0125E — Left Main Gear Downlocked	Event		DL1	Will provide backup to normal system providing instrumentation source is independent of cockpit system.
V51X0225E — Right Main Gear Downlocked	Event		DL1	Same as above.
V51X0325E — Nose Gear Downlocked			DL1	Same as above.
LH Forward Brake Press.	Press	2000-4050 psia	DL1, (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.

TABLE 3.8-1.

PMS MEASUREMENT DATA

SUBSYSTEM: DECELERATION & LANDING

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
LH Rear Brake Pressure	Press	2000-4050 psia	DL2 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.
RH Forward Brake Pressure	Press	2000-4050 psia	DL1 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.
RH Rear Brake Pressure	Press	2000-4050 psia	DL2 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake acutation.
LH Inboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
LH Outboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
RH Inboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
RH Outboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.

TABLE 3.8-2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: LANDING & DECELERATION (1 of 2)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• New Measurement (P) • HYD Press. Landing Gear Control Valve • DL1			3200 psia	2500 psia		4050 psia	2000 psia			V58P0114A
• New Measurement (P) • Elec. Pwr. For Landing Gear Valves • DL1		✓								
• V51S0005E (P) • Landing Gear HDL Up Switch • DL1		✓								V51X0125E V51X0225E V51X0325E
• V51X0125E (P) • LMG Downlocked • DL1		✓								V51S0005E
• V51X0225E (P) • RMG Downlocked • DL1		✓								V51S0005E
• V51X0325E (P) • NLG Downlocked • DL1		✓								V51S0005E
• New Measurement (P) • LH FWD Brake Pressure • DL1 (DL3)			3200 psia	2500 psia	✓	4050 psia	2000 psia			V51P0114A

TABLE 3.8 2.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: LANDING & DECELERATION

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
• New Measurement (P) • LH Rear Brake Press. • DL2 (DL3)			3200 psia	2500 psia	✓	4050 psia	2000 psia			V58P0214A
• New Measurement (P) • RH Fwd Brake Press. • DL1 (DL3)			3200 psia	2500 psia	✓	4050 psia	2000 psia			V58P0114A
• New Measurement (P) • RH Rear Brake Press. • DL2 (DL3)			3200 psia	2500 psia	✓	4050 psia	2000 psia			V58P0214A
• New Measurement (P) • LH Inboard Brake Temperature • DL1, DL2			TBD	Not Reqd.		TBD	Not Reqd.			
• New Measurement (P) • LH Outboard Brake Temperature • DL1, DL2			TBD	Not Reqd.		TBD	Not Reqd.			
• New Measurement (P) • RH Inboard Brake Temperature • DL1, DL2			TBD	Not Reqd.		TBD	Not Reqd.			
• New Measurement (P) • RH Outboard Brake Temperature • DL1, DL2			TBD	Not Reqd.		TBD	Not Reqd.			

3.9 DISPLAYS AND CONTROLS

3.9.1 Subsystem Description

The displays and controls (D&C) subsystem consists of those equipments and devices in the Orbiter crew compartment which allow the crew to supervise, control, and monitor the functions of the Shuttle vehicle and its subsystems. The D&C subsystem includes all D&C panels; flight instruments; manual controllers; CRT displays, keyboards, and associated electronics; decoding and conversion electronics associated with interfacing instruments and manual controllers; crew compartment interior and integral lighting; and the caution and warning subsystem.

In addition to displaying PMS information to the crew, certain D&C components are themselves candidates for PMS FDA. Excluding D&C panels and lighting, the following electronic and electromechanical components comprise the D&C subsystem.

a. Flight Displays

Attitude Direction Indicator (3)	
Horizontal Situation Indicator (2)	
Airspeed/Mach Indicator (2)	
Altitude/Vertical Velocity Indicator (2)	
G-Meter (1)	
Mission Event Tower (2)	
Event Timer (2)	
CRT Display Unit (4)	Delete 1 for HFT
Keyboard (3)	Delete 1 for HFT
Alpha Meter (1)	

Cross Pointers (1)
Radar Altimeter Indicator (1)
C&W Annunciator Assembly (1)
Surface Position Indicator (1) Add 1 for HFT
Total Air Temperature Indicator (1) HFT only

b. <u>Flight Controls</u>

Rotation Hand Controller (3) Delete 1 for HFT
Master Thrust Controller (1) Delete for HFT
Translation Hand Controller (2) Delete for HFT
Manipulator Hand Controller (1) Delete for HFT
Rudder Pedal Transducer Assembly (2)
Speed Brake Hand Controller (2)

c. <u>Display and Subsystem Interface Electronics</u>

Display Electronics Unit (4) Delete 1 for HFT
Display Driver Unit - Fwd (2)
Display Driver Unit - Aft (1) Delete for HFT
Caution and Warning Unit (1)
Performance Monitor Electrical Unit (1)

d. <u>D&C for Subsystem Management</u>

Dedicated meters, tape indicators, digital displays, and flag and illuminated event indicators are employed for display of subsystem data. Controls consist of toggle switches, rotary switches, thumb wheels, push button switches, circuit breakers, valves, knobs, and handles.

Figure 3.9-1 illustrates schematically some of the major components and interfaces within the D&C subsystem.

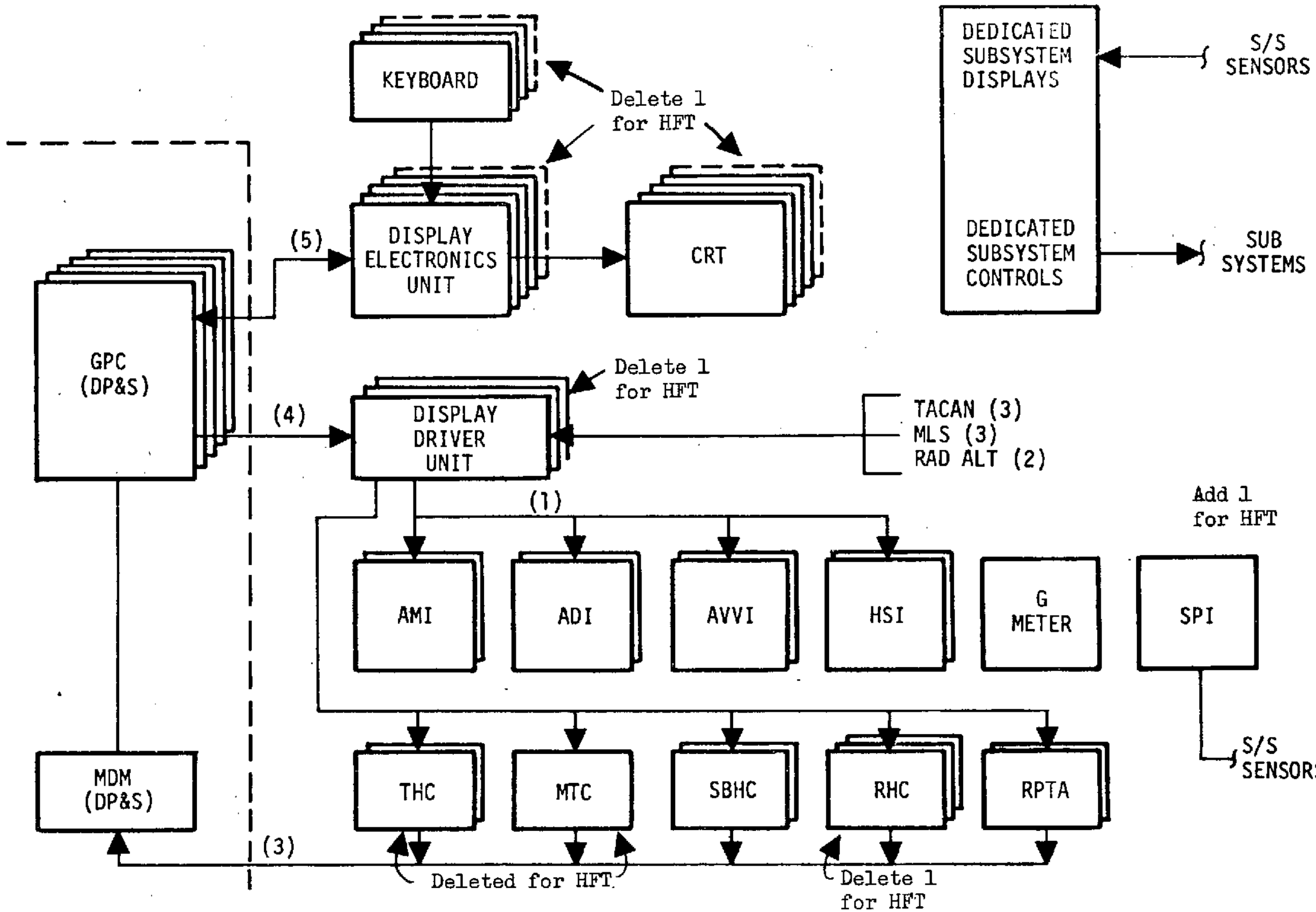


Figure 3.9-1. — Displays and controls.

3.9.2 Functional Paths

In general, each of the D&C components having BITE is considered a functional path, since fault detection and isolation of each is inherent within the PMS. Equipment which affects subsystem measurement data throughput, and which must be checked as a precondition for FDA includes the Display Electronic Units, Display Driver Units, Performance Monitor Electrical Unit, Keyboards, and CRT Display Units. These units should have BITE signals available for FDA processing as precondition tests. BITE measurements from other D&C components would be processed as FDA health status measurements for the D&C subsystem.

Generally, those equipments identified previously in sections 3.9.1 (a) and 3.9.1 (c) are candidates for BITE. Some of these equipments will be more amenable to BITE than others (i.e., those that are software driven, etc.). Studies are currently being done by the Shuttle contractor and potential subcontractors to define BITE applicability for these equipments.

The equipments listed in 3.9.1 (b) are generally more amenable to crew-initiated test sequences prior to use, since they do not function continuously during all phases of the mission. These equipments are not considered candidates for continuous FDA monitoring.

Contingent on results of BITE analyses for these equipments, the following preliminary functional path identifications are assigned:

Attitude Direction Indicators	DC1, DC2, DC3
Horizontal Situation Indicators	DC4, DC5
Airspeed/Mach Indicator	DC6, DC7
Attitude/Vertical Velocity Indicator	DC8, DC9
G-Meter	DC10
Mission Event Timers	DC11, DC12
Event Timers	DC13, DC14
CRT Display Units	DC15, DC16, DC17
Keyboards	DC18, DC19
Alpha Meter	DC20
Radar Altimeter Indicator	DC21
C&W Annunciator Assembly	DC22
Surface Position Indicators	DC23, DC24
Total Air Temperature Indicator	DC25
Display Electronic Units	(see Table 3.1.1)
Display Driver Units	DC26, DC27
Caution and Warning Unit	DC28
Performance Monitor Electrical Unit	DC29

3.9.3 PMS Interfaces

Table 3.9-1 summarizes the measurement requirements for the D&C functional paths discussed above. The majority are BITE discretes that provide indications of the operational integrity of the equipment.

TABLE 3.9-1

PMS MEASUREMENT DATA

SUBSYSTEM: DISPLAY & CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V73X 1311E	Discrete	I/O	DC4 (HSI)	Discrete BITE for FDA Processing
V73X 1411E	Discrete	I/O	DC5 (HSI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC1 (ADI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC2 (ADI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC3 (ADI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC6 (AMI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC7 (AMI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC8 (AVVI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC9 (AVVI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC10 (G-Meter)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC11 (MET)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC12 (MET)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC13 (ET)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC14 (ET)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC20 (Alpha)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC21 (Rad/Alt)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC22 (C&W)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC23 (SPI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC24 (SPI)	Discrete BITE for FDA Processing
New Measurement	Discrete	I/O	DC25 (TATI)	Discrete BITE for FDA Processing

TABLE 3.9-1

PMS MEASUREMENT DATA

SUBSYSTEM: DISPLAY & CONTROL

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V73X 1300E	Discrete	I/O	DC26 (DDU)	Precondition test for all FDA on the D&C System (BITE)
V73X 1400E	Discrete	I/O	DC27 (DDU)	" " " " "
New Measurement	Discrete	I/O	DC29 (PM Unit)	" " " " "
New Measurement	Discrete	I/O	DC15 (CRT)	" " " " "
New Measurement	Discrete	I/O	DC16 (CRT)	" " " " "
New Measurement	Discrete	I/O	DC17 (CRT)	" " " " "
New Measurement	Discrete	I/O	DC18 (K/B)	" " " " "
New Measurement	Discrete	I/O	DC19 (D/B)	" " " " "
V73S2065E	Discrete	I/O	DC19, DE2	Precondition Configuration Status
V73S2066E	Discrete	I/O	DC19, DE2	Precondition Configuration Status
V73S2061E	Discrete	I/O	DC18, DE1	Precondition Configuration Status
V73S2062E	Discrete	I/O	DC18, DE1	Precondition Configuration Status
V73S2063E	Discrete	I/O	DC18, DE2	Precondition Configuration Status
V73S2001E	Discrete	I/O	DE1	Precondition Configuration Status
V73S2002E	Discrete	I/O	DE1	Precondition Configuration Status
V73S2011E	Discrete	I/O	DE2	Precondition Configuration Status
V73S2012E	Discrete	I/O	DE2	Precondition Configuration Status
V73S2021E	Discrete	I/O	DE3	Precondition Configuration Status
V73S2022E	Discrete	I/O	DE3	Precondition Configuration Status

3.10 ELECTRICAL POWER GENERATION SUBSYSTEM

3.10.1 Subsystem Description

For HFT, primary power is supplied by three fuel cells. The EPG system consists of two major subsystem elements which, as installed, will be less complex than similar systems on operational vehicles. The two elements are:

- Power Reactant Storage and Distribution (PRSD).
- The fuel cell power plants (FCP).

Because of the short flight times involved, high pressure gaseous O_2, H_2, and appropriate tankage will be used instead of cryogenic reactants and tankage. Also, H_2O products are routed to a collection tank instead of being passed to the ECLSS for eventual crew usage.

3.10.1.1 FCP. The FCP is the primary source of electrical power for all Orbiter systems. Three FCP's are utilized in the EPG subsystem to supply three normally isolated main DC buses. These buses in turn feed all other distribution buses and/or loads. The FCP illustrated in figure 3.10-1 consists of those components, subassemblies, and assemblies necessary to produce electrical power and potable product water (not used on HFT) while consuming gaseous hydrogen and oxygen supplied by the PRSD. Waste heat generated during operation of the FCP's is rejected to ECLSS by means of an external coolant loop. The FCP includes a reactor stack and reactant control, thermal control, water removal, purge devices, instrumentation, and electrical control. For purposes of functional path analysis, as described in subsequent discussions, each FCP is considered an LRU.

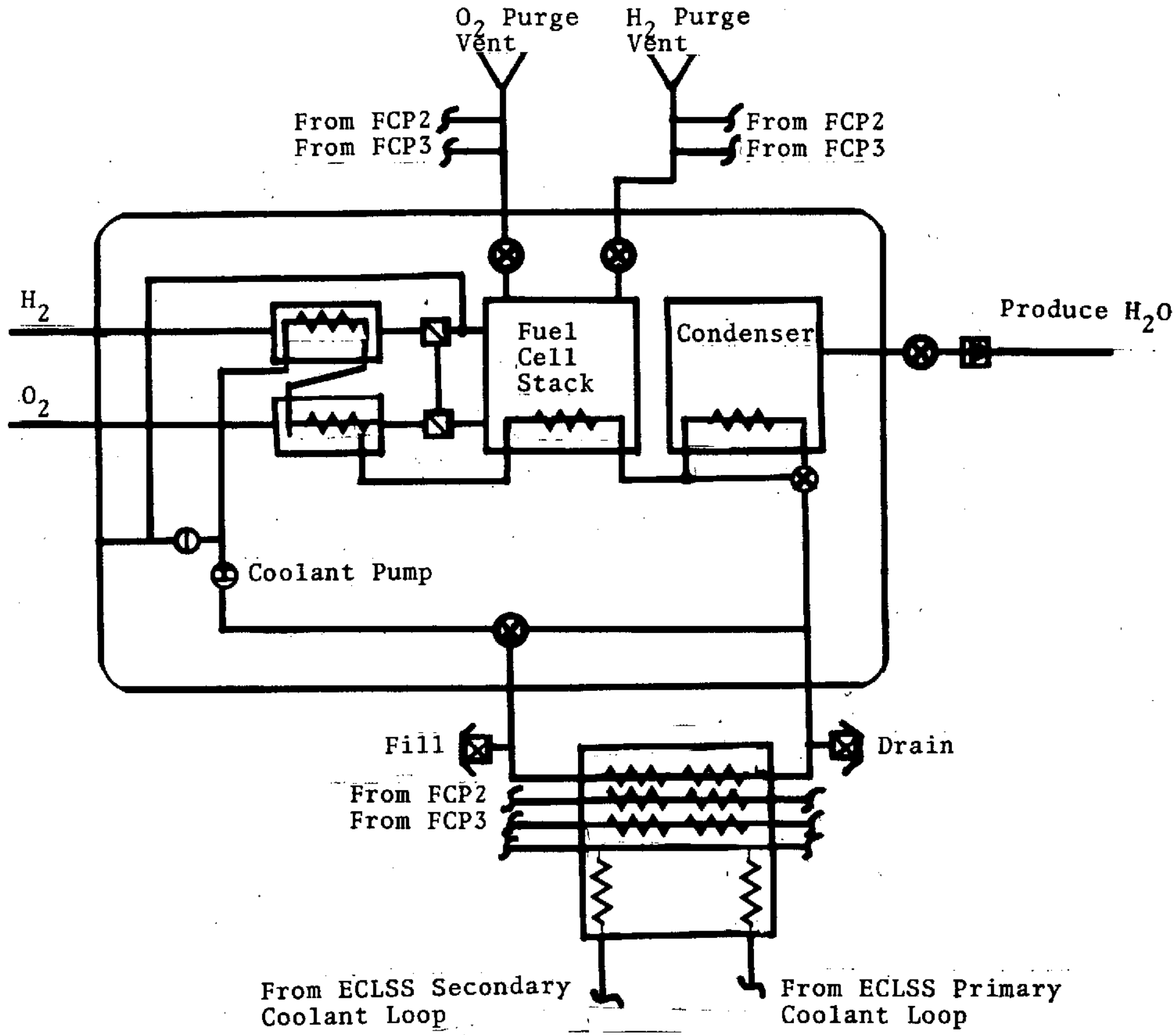


Figure 3.10-1. – Orbiter fuel cell power plant No. 1 (typical).

Each FCP is characterized as supplying 27.5 to 32.5 Vdc over a power range of 2.0 to 12.0 kW. Steadystate supply is 2.0 to 7.0 kW with a peakload capability of 12.0 kW for 15 minutes.

3.10.1.2 PRSD. PRSD consists of necessary tankage, plumbing, valves, regulators, filters, instrumentation, etc., to contain, distribute, and control the gaseous H_2/O_2 reactants required by the FCP's. In the HFT configuration illustrated in figure 3.10.2, the PRSD assemblies (from the H_2 and O_2 isolation subassembly input backward) are modified. Carry-on high-pressure tanks are arranged in two three-tank clusters for H_2 and two two-tank clusters for O_2. The use of noncryogenic fuels permits use of the simple plumbing, regulation, and vent relief installation illustrated. Design requirements contained in MCR0628/0664 provide the following sizing detail:

- Total Energy 25.2 kWH
- Peak Design Power Level 15.3 kW

	H_2	O_2
• Usable Reactants — LBS	2.6	20.8
• Maximum Flow Rate — LB/Hr	1.43	11.4
• Operating Pressure — PSIA	250-150	900-200
• Maximum Supply Pressure — PSIA	335	1050

The following reactant flow profile for baseline missions is also provided for "Drop" and Landing:

	H_2	O_2
• Cruise — Lb/Hr	0.88	7.0
• Peak Flow — Lb/Hr	1.44	11.45

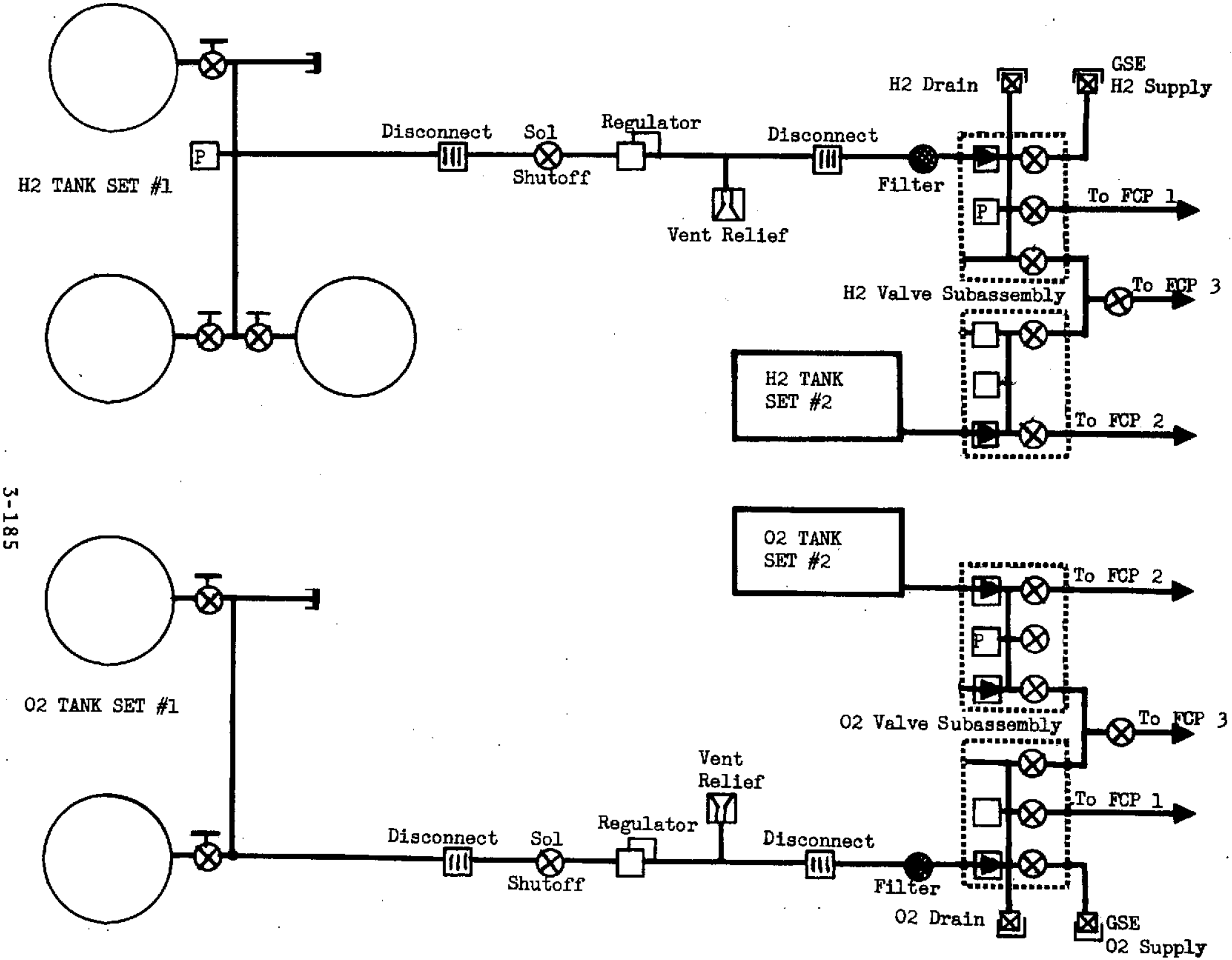


Figure 3.10-2. — High pressure gas storage system (Orbiter 101 MCR 0628/0664).

3.10.2 Functional Path Analysis

An analysis has been conducted on the EPG subsystem elements to identify the number of functional paths, as previously defined in section 3.0, requiring PMS services. Methodology employed identifies and tabulates involved components and/or LRU groupings, then categorizes and tabulates these groupings into hardware functions, and finally tabulates those hardware functions satisfying the functional path definition statements. The PRSD O_2, H_2, and FCP assemblies are treated separately for analytical purposes. Appropriate sketches and tables are included to support these analyses at each level of detail. Resulting functional paths are summarized as "major subsystem functions."

Table 3.10-1 summarizes the coding scheme employed to identify/categorize component groupings, hardware functions, and resulting functional paths.

FCP component functions are illustrated by figure 3.10-3 and are summarized in table 3.10-2. Resulting hardware functions and functional paths are summarized in table 3.10-3.

PRSD O_2 component functions are illustrated by figure 3.10-4 and summarized in table 3.10-4. PRSD O_2 hardware functions and functional paths are summarized in table 3.10-5.

PRSD H_2 component functions are illustrated by figure 3.10-5 and are summarized in table 3.10-6. PRSD H_2 hardware functions and functional paths are summarized in table 3.10-7.

TABLE 3.10-1. — EPG FUNCTIONAL ANALYSIS CODES

Subsystem Element	FP Code	Hardware Function Analysis Code		Component Function Analysis Code	
Fuel Cells	FPI--FPN	FCHx-y	x = Code No. y = Fuel Cell No. y=0 = Common path	FCxy	x = Fuel Cell No. x=0 = Common path y = Component/grouping code
PRSD O_2	POI--PON	ROFx-y	x = Code No y = Fuel cell/ Tank set No. y=0 = Common path	ROxy	x = Tank set No y = Component/grouping code
PRSD H_2	PHI--PHN	RHFx-y	x = Code No. y = Fuel Cell/ Tank set No. y=0 = Common path	RHxy	x = Tank set No. y = Compact Grouping code

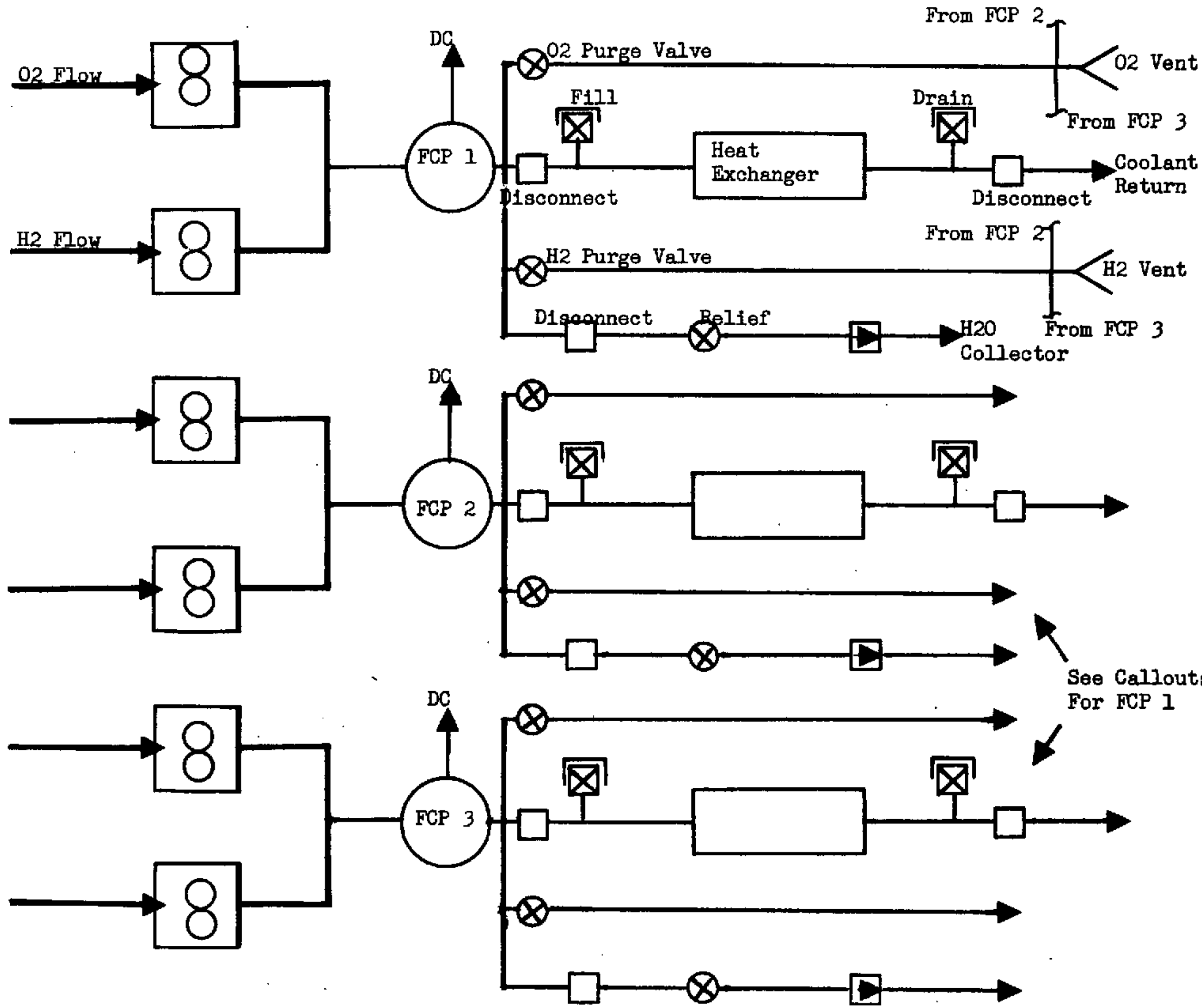


Figure 3.10-3. – Fuel cell plant component functions.

TABLE 3.10-2. — FUEL CELL COMPONENT FUNCTIONS

FCP#1

FC11 = O_2 Flow · H_2 Flow · Fuel Cell 1
FC12 = O_2 Purge Valve
FC13 = H_2 Purge Valve
FC14 = H_2O Disconnect · H_2O Relief Valve · H_2O Check Valve
FC15 = Disconnect · Heat Exchanger · Disconnect

FCP#2

FC21 = O_2 Flow · H_2 Flow · Fuel Cell 2
FC22 = O_2 Purge Valve
FC23 = H_2 Purge Valve
FC24 = H_2O Disconnect · H_2O Relief Valve · H_2O Check Valve
FC25 = Disconnect · Heat Exchanger · Disconnect

FCP#3

FC31 = O_2 Flow · H_2 Flow · Fuel Cell 3
FC32 = O_2 Purge Valve
FC33 = H_2 Purge Valve
FC34 = H_2O Disconnect · H_2O Relief Valve · H_2O Check Valve
FC35 = Disconnect · Heat Exchanger · Disconnect

COMMON

FC06 = DC Bus 1 + DC Bus 2 + DC Bus 3
FC07 = H_2O Tankage
FC08 = O_2 Vent Port
FC09 = H_2 Vent Port

Code:
FCXY
x = Fuel Cell No.
y=0 = Common function
y = component/grouping No.
FCP(I) = Fuel Cell Power Plant; I = 1, 2, 3

TABLE 3.10-3. — FUEL CELL HARDWARE FUNCTIONS AND PMS FUNCTIONAL PATHS

HARDWARE FUNCTIONS

FCH1 - Electrical Power Output

FCH2 - Product H_2O

FCH3 - Fuel Cell Coolant Loop

FCH4 - O_2 Purge

FCH5 - H_2 Purge

FCH1-1 = (FC11)(FC06)

FCH1-2 = (FC21)(FC06)

FCH1-3 = (FC31)(FC06)

FCH2 = FC07 [FC14 + FC24 + FC34]

FCH3-1 = (FC11)(FC15)

FCH3-2 = (FC21)(FC25)

FCH3-3 = (FC31)(FC35)

FCH4-1 = (FC11)(FC12)(FC08)

FCH4-2 = (FC21)(FC22)(FC08)

FCH4-3 = (FC31)(FC32)(FC08)

FCH5-1 = (FC11)(FC13)(FC09)

FCH5-2 = (FC21)(FC23)(FC09)

FCH5-3 = (FC31)(FC33)(FC09)

PMS FUNCTIONAL PATHS

FP1 = FCH1-1

FP2 = FCH1-2

FP3 = FCH1-3

Code:

FCHx-y

x = Hardware function No.

y = Fuel Cell No.

y=0 = Common path

FCH = Fuel Cell Hardware

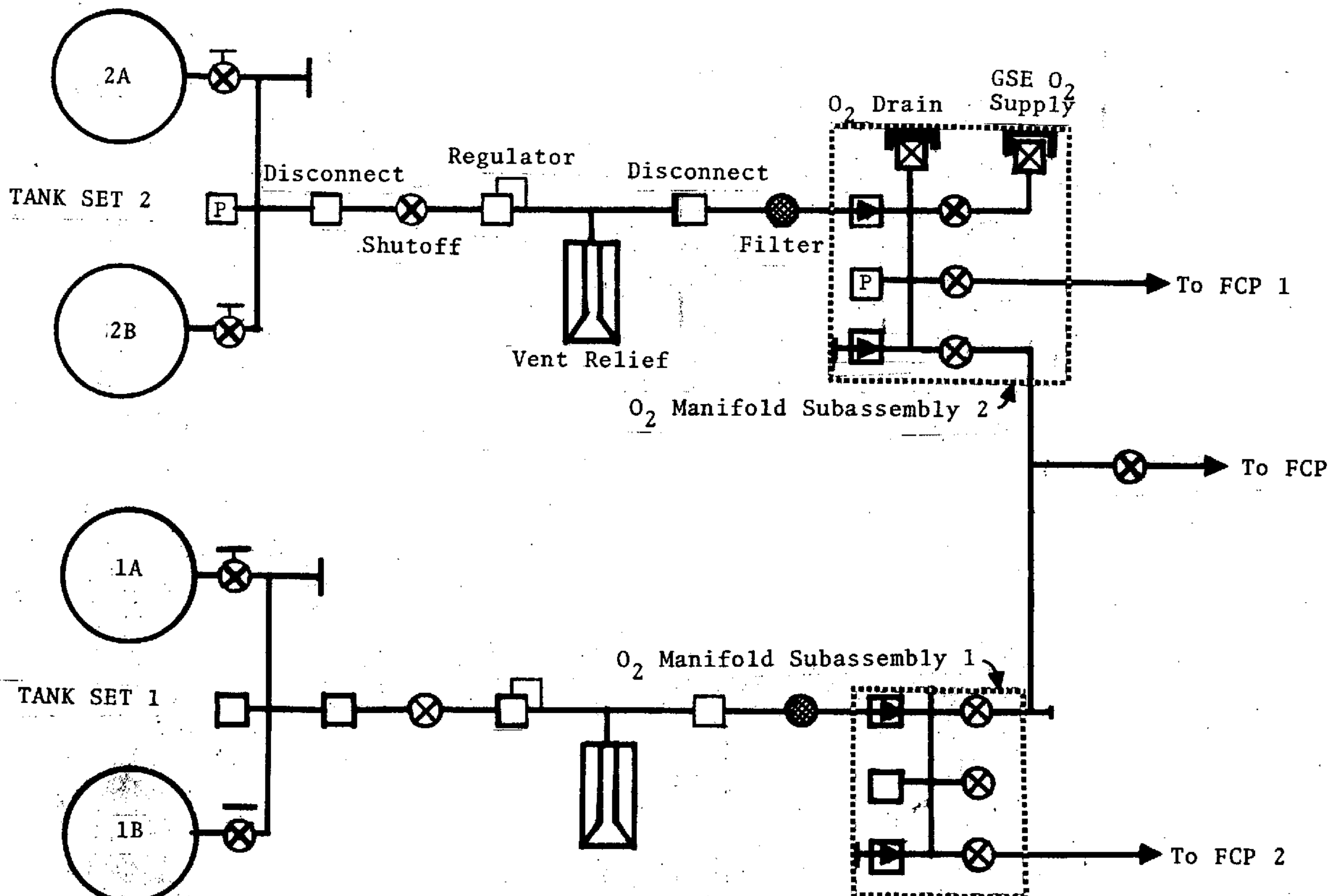


Figure 3.10-4. — Oxygen PRSD functions.

TABLE 3.10-4. — PRSD O_2 COMPONENT FUNCTIONS

ROA1 = Tank 1a · Manual Valve 1a
ROA2 = Tank 1b · Manual Valve 1b
ROA3 = Capped line
ROA4 = Disconnect 1a · S01 Shutoff Valve · Regulator
ROA5 = Vent Relief
ROA6 = Disconnect 1b · Filter · Check Valve 1a
ROA7 = Shutoff Valve 1a
ROA8 = Shutoff Valve 1b
ROA9 = Check Valve 1b · Capped line
ROA10 = Shutoff Valve 1c
ROA11 = Shutoff Valve 1d
ROB1 = Tank 2a · Manual Valve 2a
ROB2 = Tank 2b · Manual Valve 2b
ROB3 = Capped line
ROB4 = Disconnect 2a · S01 Shutoff Valve · Regulator
ROB5 = Vent Relief
ROB6 = Disconnect 2b · Filter · Check Valve 2a
ROB7 = Shutoff Valve 2a
ROB8 = Shutoff Valve 2b
ROB9 = Capped line · Check Valve 2b
ROB10 = Drain Cap
ROB11 = GSE Supply Cap and Shutoff Valve

Code:
ROxy
x = Tank set No.
y = Component/grouping No.

TABLE 3.10-5. – PRSD O_2 HARDWARE FUNCTIONS AND PMS FUNCTIONAL PATHS

HARDWARE FUNCTIONS

ROF1-x = Supply O_2 to Fuel Cells, x = 1, 2, or 3

ROF2 = O_2 Drain Purge

ROF3-x = Vent Relief, x = 1, or 2

ROF4-x = GSE O_2 Supply to Fuel Cells, x = 1, 2, or 3

ROF1-1 = ROB7 [(ROA1 + ROA2)(ROA4)(ROA6)(ROA10)(ROB8) + (ROB1 + ROB2)(ROB4)(ROB6)]

ROF1-2 = ROA8 [(ROA1 + ROA2)(ROA4)(ROA6) + (ROB1 + ROB2)(ROB4)(ROB6)(ROB8)(ROA10)]

ROF1-3 = ROA11 [(ROA1 + ROA2)(ROA4)(ROA6)(ROA10) + (ROB1 + ROB2)(ROB4)(ROB6)(ROB8)]

ROF2 = ROB10 [(ROB1 + ROB2 + ROB3)(ROB4)(ROB6) + (ROA1 + ROA2 + ROA3)(ROA4)(ROA6)(ROA10)(ROB8)]

ROF3-1 = (ROA1 = ROA2)(ROA4)(ROA5)

ROF3-2 = (ROB1 + ROB2)(ROB4)(ROB5)

ROF4-1 = (ROB11)(ROB7)

ROF4-2 = (ROB11)(ROB8)(ROA10)(ROA8)

ROF4-3 = (ROB11)(ROB8)(ROA11)

PMS FUNCTIONAL PATHS

PO1 = (ROA1 + ROA2)(ROA4)(ROA6)

PO2 = (O_2 Manifold 1 Subassembly)

PO3 = (ROB1 + ROB2)(ROB4)(ROB6)

PO4 = (O_2 Manifold 2 Subassembly)

Code:

ROFx-y

ROF = Reactant Oxygen Function

x = Hardware function - No.

y = Fuel Cell/Tank set No.

y=0 = Common

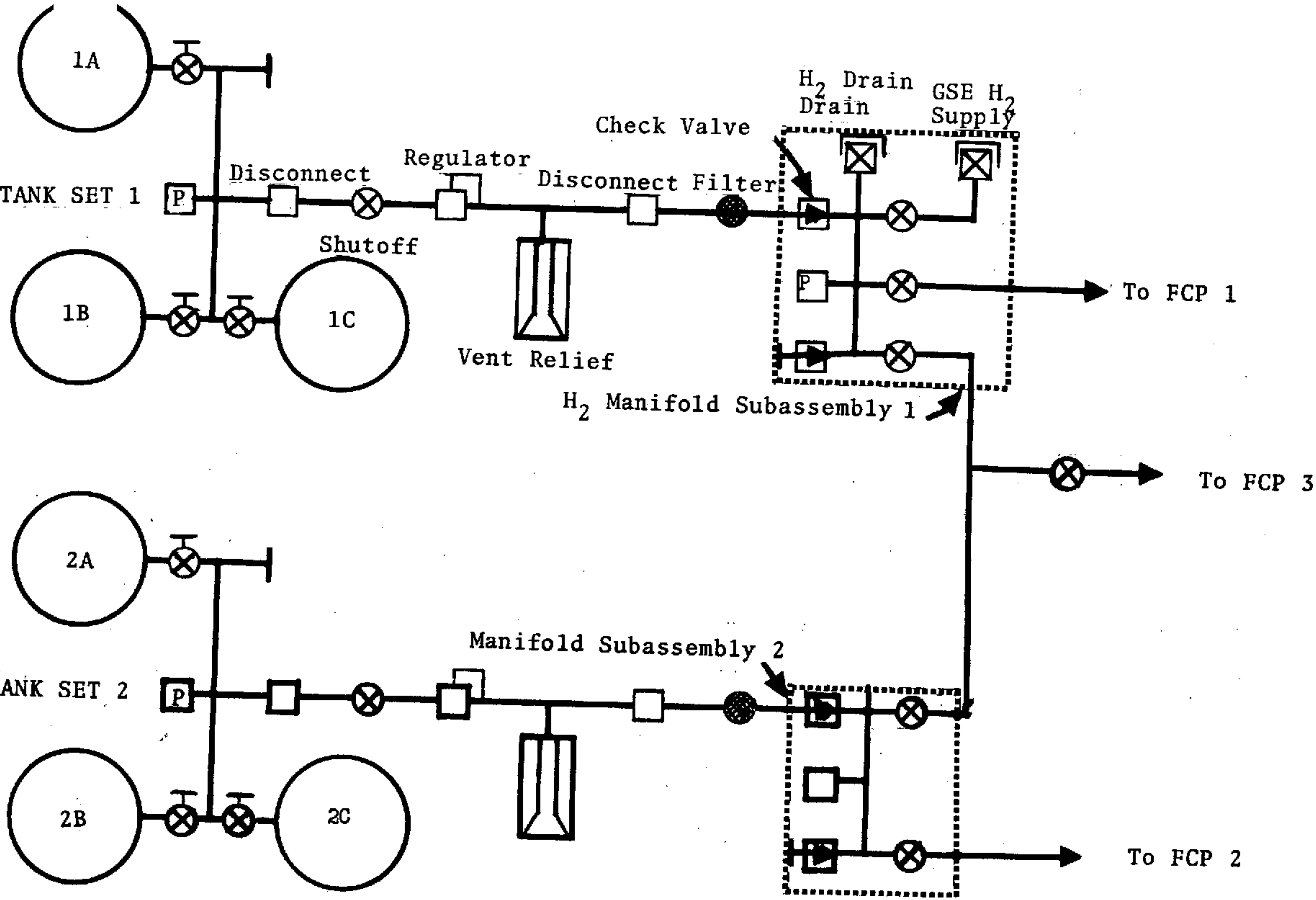


Figure 3.10-5. — Hydrogen PRSD component functions.

TABLE 3.10-6. — PRSD H_2 COMPONENT FUNCTIONS

RHA1	=	Tank 1a · Manual Valve 1a
RHA2	=	Tank 1b · Manual Valve 1b
RHA3	=	Tank 1c · Manual Valve 1c
RHA4	=	Capped line 1
RHA5	=	Disconnect 1a · S01 Shutoff Valve · Regulator
RHA6	=	Vent Relief
RHA7	=	Disconnect 1b · Filter · Check Valve 1a
RHA8	=	Capped line · Check Valve 1b
RHA9	=	Shut off Valve 1a
RHA10	=	Shut off Valve 1b
RHA11	=	Shut Off Valve 1c
RHA12	=	H_2 Drain Cap
RHA13	=	GSE H_2 Supply Valve and Cap
RHB1	=	Tank 2a · Manual Valve 2a
RHB2	=	Tank 2b · Manual Valve 2b
RHB3	=	Tank 2c · Manual Valve 2c
RHB4	=	Capped Line 2
RHB5	=	Disconnect 2a · S01 Shutoff Valve 2 · Regulator 2
RHB6	=	Vent Relief 2
RHB7	=	Disconnect 2b · Filter 2 · Check Valve 2a
RHB8	=	Capped line 2 · Check Valve 2b
RHB9	=	Shutoff Valve 2a
RHB10	=	Shutoff Valve 2b

Code:

RHxy

RH = Reactant Hydrogen

x = Tank set No.

y = Component/grouping No.

TABLE 3.10-7. – PRSD H_2 HARDWARE FUNCTIONS AND PMS FUNCTIONAL PATHS

HARDWARE FUNCTIONS

1 - RHF1 = Supply H_2 to Fuel Cells No 1, 2, 3

2 - RHF2 = H_2 Drain/Purge

3 - RHF3 = Vent Relief

4 - RHF4 = GSE H_2 Supply to Fuel Cells

RHF1-1 = RHA10 [(RHA1 + RHA2 + RHA3)(RHA5)(RHA7) + (RHB1 + RHB2 + RHB3)(RHB5)(RHB7)(RHB9)(RHA9)]

RHF1-2 = RHB10 [(RHA1 + RHA2 + RHA3)(RHA5)(RHA7)(RHB9) + (RHB1 + RHB2 + RHB3)(RHB5)(RHB7)]

RHF1-3 = RHA11 [(RHA1 + RHA2 + RHA3)(RHA5)(RHA7)(RHA9) + (RHB1 + RHB2 + RHB3)(RHB5)(RHB7)(RHB9)]

RHF2 = RHA12 [(RHA1 + RHA2 + RHA3 + RHA4)(RHA5)(RHA7) + (RHB1 + RHB2 + RHB3 + RHB4)(RHB5) (RHB7) (RHB9)(RHA9) + (RHA13) + (RHB8)(RHB9)(RHA9) + (RHA8)]

RHF3-1 = RHA6 [(RHA1 + RHA2 + RHA3)(RHA5)]

RHF3-2 = RHB6 [(RHB1 + RHB2 + RHB3)(RHB5)]

RHF 4-1 = RHA13 [RHA10]

RHF4-2 = RHA13 [(RHA9)(RHB9)(RHB10)]

RHF4-3 = RHA13 [(RHA9)(RHB9)(RHB10)]

FUNCTIONAL PATHS

PH1 = (RHA1 + RHA2 + RHA3)(RHA5)(RHA7)

PH2 = (H_2 Manifold 1 Subassembly)

PH3 = (RHB1 + RHB2 + RHB3)(RHB5)(RHB7)

PH4 = (H_2 Manifold 2 Subassembly)

Code:

RHFxy

x = Hardware Funct. No.

y = Fuel Cell/Tank Set No.

y=0 = Common

The EPG functional paths and resulting major functions are illustrated and summarized in figure 3.10-6.

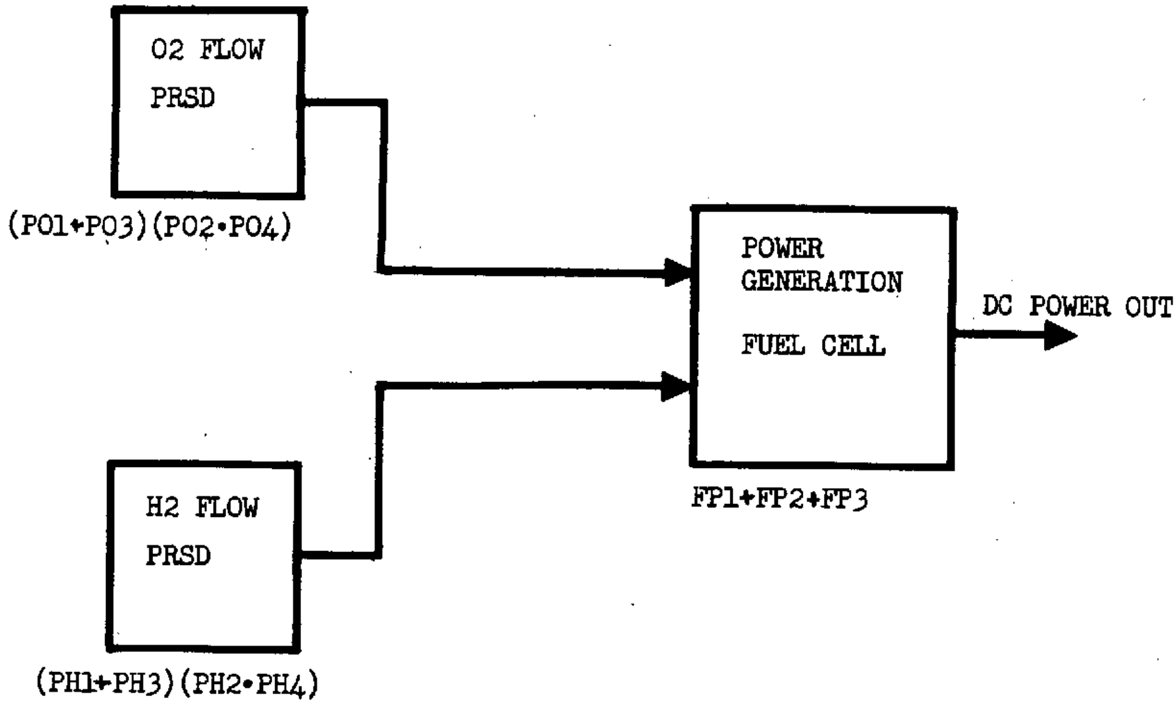
3.10.3 EPG Subsystem/PMS Interfaces

Table 3.10-8 summarizes the operational instrumentation measurements necessary to perform PMS fault detection and annunciation (FDA) for the EPG subsystem.

3.10.4 PMS Requirements

Table 3.10-9 lists the primary and secondary measurements for each EPG functional path previously identified.

Correlation measurements where indicated must be regarded as preliminary, and, in general, are directly complementary to primary measurements. FDA processes indicated are predicated on a viable subsystem configuration as determined by crew procedures for manual functions, and by SCM sources and/or crew procedures in subsystem modes/submodes where instrumentation is available.



$$\text{Fuel Cell 1 Power Out} = \left[(PO1+PO3)(PO2\cdot PO4)\right]\left[(PH1+PH3)(PH2\cdot PH4)\right] FP1$$

$$\text{Fuel Cell 2 Power Out} = \left[(PO1+PO3)(PO2\cdot PO4)\right]\left[(PH1+PH3)(PH2\cdot PH4)\right] FP2$$

$$\text{Fuel Cell 3 Power Out} = \left[(PO1+PO3)(PO2\cdot PO4)\right]\left[(PH1+PH3)(PH2\cdot PH4)\right] FP3$$

Figure 3.10-6. – EPG functional path summary.

TABLE 3.10-8.

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER GENERATION

(1 of 3)

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V45V0100A — FC #1 Voltage	Voltage	27.5-32.5 VDC	FP 1	Precondition: V45X0105E — FC # 1 Ready
V45C0101A — FC #1 Current	Current	0 - 500 Amps	FP 1	Precondition: V45X0105E — FC # 1 Ready
V45P0165A — FC #1 O_2 Req. Pres.	Pressure	0-100 psia	FP 1	C&W; correlation V45R0160A — FC # 1 O_2 Flow
V45P0175A — FC #1 H_2 Req. Pres.	Pressure	0-100 psia	FP 1	C&W; correlation V45R0170A — FC # 1 H_2 Flow
V45T0120A — FC #1 Stack cool out temp	Temp	-50° +300°F	FP 1	C&W Precondition - TBD
V45V0200A — FC #2 Voltage	Voltage	27.5-32.5 VDC	FP 2	Precondition: V45X0205E — FC # 2 Ready
V45C0201A — FC #2 Current	Current	0-500 Amps	FP 2	Precondition: V45X205E — FC # 2 Ready
V45P0265A — FC #2 O_2 Req. Pres.	Pressure	0-100 psia	FP 2	C&W; correlation V45R0260A — FC # 2 O_2 Flow
V45P027SA — FC #2 H_2 Req. Pres.	Pressure	0-100 psia	FP 2	C&W; correlation V45R0270A — FC # 2 H_2 Flow

TABLE 3.10-8.

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER GENERATION

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V45T0220A — FC#2 stack cool out Temp	Temp	-50° +300°F	FP 2	C&W; Precondition TBD
V450300A — FC#3 Voltage	Voltage	27.5-32.5 VDC	FP 3	Precondition: V45X0305E — FC # 3 Ready
V450301A — FC#3 Current	Current	0-500 Amps	FP 3	C&W; correlation V45X0305E — FC #3 Ready
V45P0365A — FC#3 O_2 Req. Pressure	Pressure	0-100psia	FP 3	C&W; correlation V45R360A — FC #3 O_2 Flow
V45P0375A — FC#3 H_2 Req. Pressure	Pressure	0-100psia	FP 3	C&W; correlation V45370A — FC #3 H_2 Flow
V45T0320A — FC#3 Stack Cool Out Temp	Temp	-50° +300°F	FP 3	C&W; Precondition , TBD
V45P1140A — O_2 Manifold 1 Pressure	Pressure	900 ± 5 psia	PO 2	Correlation: V45P1145A — O_2 Manifold 2 Pressure
V45P1145A — O_2 Manifold 2 Pressure	Pressure	900 ± 5 psia	PO 4	Correlation: V45P1140A — O_2 Manifold 1 Pressure
V45P1100A — Tank (set) 1 O_2 Pres	Pressure	2200 200 psia	PO 1	C&W; correlation TBD

TABLE 3.10-8.

PMS MEASUREMENT DATA

SUBSYSTEM: ELECTRICAL POWER GENERATION

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V45P1200A — Tank (set) 2 O_2 Pres.	Pressure	2200 200 psia	PO 3	C&W; correlation TBD
V45P2140A — H_2 Manifold 1 Pres	Pressure	250 ± 5 psia	PH 2	Correlation: V45P2145A — H_2 Manifold 2 Pressure
V45P2145A — H_2 Manifold 2 Pressure	Pressure	250 ± 5 psia	PH 4	Correlation: V45P2140A — H_2 Manifold 1 Pressure
V45P2100A — H_2 Tank (set) 2 Pressure	Pressure	2400 150 psia	PH 1	C&W; correction: TBD
V45P2200A — H_2 Tank (set) 2 Pressure	Pressure	2400 150 psia	PH 3	C&W; correlation TBD

TABLE 3.10-9.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER GENERATION (1 of 4)

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
V45V0100A — FCP 1 Voltage FP 1	✓	V45X-0105E	TBD	TBD	N/A	32-5 VDC	27-5 VDC	N/A	N/A	
V45C0101A — FCP 1 Current FP 1	✓	V45X-0105E	TBD	TBD	TBD	500 Amps	0	N/A	N/A	
V45P0105A — FCP 1 O_2 Req. Press FP 1	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Req'd.)	TBD (Req'd)	V45R0160A
V45P0175A — FCP 1 H_2 Req. Press. FP 1	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Req'd.)	TBD (Req'd.	V45R0170A
V45T0120A — FCP 1 Stack Cool Out Temp	✓	✓	TBD	TBD	TBD	+300°F	-50°F	+300°F	-50°F	TBD
V45X0105E — FCP 1 Ready FP 1	✓	✓	N/A	N/A	N/A	Event	Event	N/A	N/A	N/A
V45R0160A — FCP 1 O_2 Flow FP 1	✓	✓	TBD	TBD	TBD	TBD	TBD	N/A	N/A	V45P0165A
V45R0170A — FCP 1 H_2 Flow FP 1	✓	✓	TBD	TBD	TBD	TBD	TBD	N/A	N/A	V45P0175A
V45V0200A — FCP 2 Voltage FP 2	✓	V45X-0205E	TBD	TBD	N/A	32.5 VDC	27.5 VDC	N/A	N/A	
V45C0201A — FCP 2 Current FP 2	✓	V45X-0205E	TBD	TBD	TBD	500 Amps	0	N/A	N/A	

TABLE 3.10-9.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER GENERATION

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
V45P0265A — FCP 2 O_2 Req. Press. FP 2	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Reqd)	TBD (Reqd)	V45R0260A
V45P0275A — FCP 2 H_2 Req. Press. FP 2	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Reqd)	TBD (Reqd)	V45R0270A
V45T0220A — FCP 2 Stack Cool Out Temp FP 2	✓	✓	TBD	TBD	TBD	+300°F	-50°F	+300°F	-50°F	TBD
V45X0205E — FCP 2 Ready FP 2	✓	✓	N/A	N/A	N/A	Event	Event	N/A	N/A	N/A
V45R0260A — FCP 2 O_2 Flow FP 2	✓	✓	TBD	TBD	TBD	TBD	TBD	N/A	N/A	V45P0265A
V45R0270A — FCP 2 H_2 Flow FP 2	✓	✓	TBD	TBD	TBD	TBD	TBD	N/A	N/A	V45P0275A
V450300A — FCP 3 Voltage FP 3	✓	V45X-0305E	TBD	TBD	N/A	32.5 VDC	27.5 VDC	N/A	N/A	
V45C0301A — FCP 3 Current FP 3	✓	V45X-0305E	TBD	TBD	TBD	500 Amps	0	N/A	N/A	
V45P0365A — FCP 3 O_2 Req. Press. FP 3	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Reqd)	TBD (Reqd)	V45R0360A
V45P0375A — FCP 3 H_2 Req. Press. FP 3	✓	✓	TBD	TBD	TBD	100 psia	TBD	TBD (Reqd)	TBD (Reqd)	V45R0370A

TABLE 3.10-9.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER GENERATION

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
V45T0320A – FCP 3 Stack Cool Out Tmp FP 3	✓	✓	TBD	TBD	TBD	+300°F	-50°F	+300°F	-50°F	TBD
V45X0305E – FCP 3 Ready FP 3	✓	✓	N/A	N/A	N/A	Event	Event	N/A	N/A	N/A
V45R0360A – FCP 3 O_2 Flow FP 3	✓	✓	TBD	TBD	TBD	TBD	N/A	N/A	N/A	V45P0365A
V45R0370A – FCP 3 H_2 Flow FP 3	✓	✓	TBD	TBD	TBD	TBD	N/A	N/A	N/A	V45P0375A
V45P1140A – O_2 Manifold 1 Press. PO 2	✓	✓	N/A	N/A	N/A	905 psia	895 psia	N/A	N/A	V45P1145A
V45P1145A – O_2 Manifold 2 Press. PO 4	✓	✓	N/A	N/A	N/A	905 psia	895 psia	N/A	N/A	V45P1140A
V45P1100A – Tank (set) 1 O_2 Pressure	✓	✓	N/A	N/A	N/A	2200 psia	200 psia	2200 psia	200 psia	TBD
V45P1200A – Tank (set) 2 O_2 Pressure PO 3	✓	✓	N/A	N/A	N/A	2200 psia	200 psia	2200 psia	200 psia	TBD
V45P2140A – H_2 Manifold 1 Pressure PH 2	✓	✓	N/A	N/A	N/A	255 psia	245 psia	N/A	N/A	V45P2145A
V45P2145A – H_2 Manifold 2 Pressure PH 4	✓	✓	N/A	N/A	N/A	255 psia	245 psia	N/A	N/A	V45P2140A

TABLE 3.10-9.

PMS MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION

SUBSYSTEM: ELECTRICAL POWER GENERATION

PMS ACTIVITY / SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH ID	PRE-CONDITION TEST		SOFT LIMIT CHECK		TREND CHECK	HARD LIMIT CHECK		BACKUP CAUTION & WARNING		CORRELATION MEASUREMENT
	HARDWARE STATUS	CONFIGURATION CHECK	HIGH	LOW		HIGH	LOW	HIGH	LOW	
V45P2100A — H_2 Tank (set) 1 Pressure PH 1	✓	✓	N/A	N/A	N/A	2400 psia	150 psia	2400 psia	150 psia	TBD
V45P2200A — H_2 Tank (set) 2 Pressure PH 3	✓	✓	N/A	N/A	N/A	2400 psia	150 psia	2400 psia	150 psia	TBD

4.0 SUBSYSTEM CONFIGURATION DATA FOR FDA

Status data needed to determine the correctness of the vehicle subsystems configuration, at predetermined points in the mission timeline, will include switch scan data and possible subsystem function status data from operational instrumentation. The requirements for subsystem configuration management (SCM) are not treated in this document, but will doubtless require scanning most vehicle switches for a complete configuration check. Switch scan requirements for FDA will be for precondition checks on key subsystem switches whose positions affect the limit check measurements being made on the subsystem. These switches scanned for FDA are a subset of the SCM switch scan requirements.

Table 4.0-1 summarizes for each Orbiter 101 subsystem the number of switches which should be scanned for FDA together with the total number of switch scan measurements. The number of scan measurements per switch varies depending on the number of switch positions avaiable. The switch scan philosophy currently employed by the Orbiter contractor appears to be to scan three positions of a four-position switch, one position of a two-position switch, etc. This same philosophy was used in preparing the requirements given herein. A tradeoff must obviously be made to determine which switch scan method is more effective: i.e., scan all but one pole and use software to deduce the last position; or scan all positions and reduce software, but increase the total number of scan measurements.

TABLE 4.0-1. – SWITCH SCAN SUMMARY FOR
FDA-ORBITER 101 (HFT)

SUBSYSTEM		NO. SWITCHES	NO. MEASUREMENTS
1.	OI/DPS	--	--
2.	ECLSS	18	19
3.	HYDRAULICS	14	21
4.	C&TS	18	25
5.	EPDC	12	12
6.	APU	26	26
7.	TPS	--	--
8.	L&D	1	1
9.	D&C	8	11
10.	EPG	--	--
	Totals	97	115

Table 4.0-2 lists for each Orbiter subsystem the switch scan measurements which are recommended as precondition measurements for FDA. The majority of these measurements are available and were obtained from the Shuttle Master Measurement List. Those new measurements which are recommended are identified by using X's or N's in field 4 of the measurement ID.

TABLE 4.0-2. — HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

Measurement Number	Description
	OPERATIONAL INSTRUMENTATION/DATA PROCESSING
	No FDA switch scan requirements identified.
	ENVIRONMENT CONTROL/LIFE SUPPORT
V61S2561E	Cabin Fan 1 — ON
V61S2562E	Cabin Fan 2 — ON
V61S2563E	Cabin Fan 3 — ON
V61S2601E	Primary H_2O Pump Control No. 1 — ON
V61S2603E	Primary H_2O Pump Control No. 2 — ON
V61S2701E	Secondary H_2O Pump Control — ON
V61S2645E	Avionics Bay 1 Fan A — ON
V61S2646E	Avionics Bay 1 Fan B — ON
V61S2650E	Avionics Bay 2 Fan A — ON
V61S2652E	Avionics Bay 2 Fan B — ON
V61S2661E	Avionics Bay 3 Fan A — ON
V61S2662E	Avionics Bay 3 Fan B — ON
V63S1178E	NH_3 System Automatic 1 Mode Command
V63S1182E	NH_3 System Automatic 2 Mode Command
V63S1111E	Primary Freon Loop Coolant Pump No. 1 CMD
V63S1121E	Primary Freon Loop Coolant Pump No. 2 CMD
V63S1311E	Secondary Freon Loop Pump No. 1 CMD

TABLE 4.0-2. – HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

Measurement Number	Description
V63SXXXXE	NH_3 Evaporator Flow Control Valve CMD
V63SXXXXE	Secondary Freon Loop Pump No. 2 CMD
	HYDRAULICS
V58S0086E	Hydraulic System Automatic Thermal Control – ON
V58S0087E	Hydraulic System Left Outboard Elevon Actuator Heater – AUTO
V58S0088E	Hydraulic System Left Outboard Elevon Actuator Heater – ON
V58S0089E	Hydraulic System Left Inboard Elevon Actuator Heater – ON
V58S0090E	Hydraulic System Left Inboard Elevon Actuator Heater – AUTO
V58S0097E	Hydraulic System Right Outboard Elevon Actuator Heater – AUTO
V58S0098E	Hydraulic System Right Outboard Elevon Actuator Heater – ON
V58S0099E	Hydraulic System Right Inboard Elevon Actuator Heater – ON
V58S0108E	Hydraulic System Right Inboard Elevon Actuator Heater – AUTO
V58S0104E	Hydraulic System 1 Main Pump Depress – ON
V58S0167E	Hydraulic System 1 H_2O Boiler Heater – ON
V58S0168E	Hydraulic System 1 H_2O Boiler Heater – AUTO
V58S0204E	Hydraulic System 2 Main Pump Depress – ON
V58S0246E	Hydraulic Power System 2 Main Engine Supply Valve – CLOSE

TABLE 4.0-2. — HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

(3 of 7)

Measurement Number	Description
V58S0267E	Hydraulic System 2 H_2O Boiler Heater — ON
V58S0268E	Hydraulic System 2 H_2O Boiler Heater — AUTO
V58S0304E	Hydraulic System 3 Main Pump Depress — ON
V58S0346E	Hydraulic Power System 3 Main Engine Supply Valve — CLOSE
V58S0367E	Hydraulic System 3 H_2O Boiler Heater — ON
V58S0368E	Hydraulic System 3 H_2O Boiler Heater — AUTO
V58S0146E	Hydraulic Power System 1 Main Engine Supply Valve — CLOSE
	COMMUNICATION & TRACKING
V74SXXX3E	UHF Transceiver No. 1 Power — ON
V74SXXX4E	UHF Transceiver No. 2 Power — ON
V74SXX11E	TLM Transmitter Power — ON
V74SXX12E	DFI Transmitter Power — ON
V74S0109E	MSBLS No. 1 Power — ON
V74S0119E	MSBLS No. 2 Power — ON
V74S0129E	MSBLS No. 3 Power — ON
V74S0859E	TACAN No. 1 Receive Power — ON
V74S0856E	TACAN No. 1 T/R Power — ON
V74S0862E	TACAN No. 1 A/A Power — ON
V74S0860E	TACAN No. 2 Receive Power — ON
V74S0857E	TACAN No. 2 T/R Power — ON
V74S0863E	TACAN No. 2 A/A Power — ON

TABLE 4.0-2. – HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

Measurement Number	Description
V74S0861E	TACAN No. 3 Receive Power – ON
V74S0858E	TACAN No. 3 T/R Power – ON
V74S0864E	TACAN No. 3 A/A Power – ON
V74S0166E	L-Band Switch TACAN No. 1
V74S0168E	L-Band Switch TACAN No. 3
V74S0175E	Radar Altimeter 1 Power – ON
V74S0185E	Radar Altimeter 2 Power – ON
V74SXX13E	ATC Transponder Power – ON
V74SXX14E	C-Band Beacon Power – ON
V74SXX15E	Audio Panel, CMDR, Power – ON
V74SXX16E	Audio Panel, Pilot, Power – ON
V74SXX17E	Audio Panel, Mid-Deck, Power – ON
	ELECTRICAL POWER DISTRIBUTION & CONTROL
V76S0131E	Main Bus 1 to ESS Bus 1 – ON
V76S0134E	Main Bus 1 to ESS Bus 2 – ON
V76S0231E	Main Bus 2 to ESS Bus 2 – ON
V76S0234E	Main Bus 2 to ESS Bus 3 – ON
V76S0331E	Main Bus 3 to ESS Bus 3 – ON
V76S0334E	Main Bus 3 to ESS Bus 1 – ON
V76S1511E	Inverter Bus 1 – ON
V76S1611E	Inverter Bus 2 – ON
V76S1711E	Inverter Bus 3 – ON
V76S1531E	Bus No. 1 dc Input to Inverter 1 – PHA

TABLE 4.0-2. — HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

(5 of 7)

Measurement Number	Description
V76S1631E	Bus No. 2 dc Input to Inverter 2 — PHA
V76S1731E	Bus No. 3 dc Input to Interter 3 — PHA
	AUXILIARY POWER UNIT
V46S0099E	APU1 Through 4 Shutdown Inhibit CMD
V46S0126E	APU1 Start Command
V46S0226E	APU2 Start Command
V46S0326E	APU3 Start Command
V46S0106E	APU Tank 1/2 Heater Element A — ON
V46S0206E	APU Tank 1/2 Heater Element B — ON
V46S0306E	APU Tank 3/4 Heater Element A — ON
V46S0109E	APU1 Line Heater Element A-B — ON
V46S0114E	APU1 Fuel Isolation Valve — OPEN COMMAND
V46S0116E	APU1 Lubrication Oil Heater Element A-B — ON
V46S0118E	APU1 Thermal Bed Heater A — ON
V46S0119E	APU1 Thermal Bed Heater B — ON
V46S0124E	APU1 Controller Power — ON COMMAND
V46S0209E	APU2 Line Heater Element A-B — ON
V46S0214E	APU2 Fuel Isolation Valve — OPEN COMMAND
V46S0216E	APU2 Lubrication Oil Heater Element A-B — ON
V46S0218E	APU2 Thermal Bed Heater A — ON
V46S0219E	APU2 Thermal Bed Heater B — ON
V46S0224E	APU2 Controller Power — ON COMMAND
V46S0309E	APU3 Line Heater Element A-B — ON

TABLE 4.0-2. – HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

Measurement Number	Description
V46S0314E	APU3 Fuel Isolation Valve – OPEN COMMAND
V46S0316E	APU3 Lubrication Oil Heater Element A-B – ON
V46S0318E	APU3 Thermal Bed Heater A – ON
V46S0319E	APU3 Thermal Bed Heater B – ON
V46S0324E	APU3 Controller Power – ON COMMAND
	DECELERATION & LANDING
V51S0005E	Landing Gear Handle – UP
	DISPLAY & CONTROL
V73S2065E	Forward Right Keyboard – CTR DEU. Select A – ENABLE
V73S2066E	Forward Right Keyboard – CTR DEU. Select B – ENABLE
V73S2061E	Forward Left Keyboard – Left DEU. Select A – ENABLE
V73S2062E	Forward Left Keyboard – Left DEU. Select B – ENABLE
V73S2063E	Forward Left Keyboard – CTR DEU. Select A – ENABLE
V73S2001E	Forward Left DEU. Power – ON
V73S2002E	Forward Left DEU. Power – STANDBY
V73S2011E	Forward Center DEU. Power – ON
V73S2012E	Forward Center DEU. Power – STANDBY

TABLE 4.0-2. — HFT ORBITER 101 SWITCH SCAN MEASUREMENTS FOR FDA

Measurement Number	Description
V73S2021E	Forward Right DEU. Power — ON
V73S2022E	Forward Right DEU. Power — STANDBY

ELECTRICAL POWER GENERATION

No FDA switch scan requirements identified. Fuel cell "ready" events (V45X0105E, 0205E, 0305E) are used as precondition tests to establish system configuration readiness for FDA.

5.0 REFERENCES

1. Orbiter Program Astronaut Orientation System Description Briefings, Rockwell International, Space Division SSV 74-6, January 28, 1974.

2. Orbiter Requirements Definition Documents, Rockwell International, Space Division SD-72-SH-0100 Series, January 31, 1974.

3. Orbiter 101 Preliminary Design Review (PDR) Briefings, Rockwell International Space Division SSV 74-4, February 4, 1974.

4. RI/SD Ltr. 395-001-73-060, "Measurement/Stimuli for Operational Phase of Shuttle Flight Hardware," E. P. Smith, March 21, 1973.

5. Shuttle Master Measurement List (MML) Baseline Draft, SD 72-SH 0096, November 16, 1973.

APPENDICES

APPENDIX A

PMS — NEW MEASUREMENTS — SUMMARY

PMS — NEW MEASUREMENTS — SUMMARY

SUBSYSTEM	ANALOG	DISCRETES	DIGITAL	TOTAL
ECLSS	1	5	3	9
ELECTRICAL POWER	0	3	0	3
DECELERATION AND LANDING	9	1	0	10
COMMUNICATIONS AND TRACKING	6	15	0	21
TOTALS	16	24	3	43

SUBSYSTEM: ECLSS – NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V61PXXXAA – Filter/Debris Trap Differential Pressure	Pressure	0.05-0.15		Provides capability to isolate a fan or filter/trap failure.
V63SXXXBE – Secondary Freon Coolant Loop Pump #2 CMD	Event	Off-On		Serves as a precondition test to determine secondary freon coolant loop pump 2 status.
V63QXXXCA – Primary NH_3 Tank Quanity	Quantity	30-90%		Needed to detect and isolate an ammonia tank failure during active standby modes.
V63SXXXDE – Evaporator Flow Control Valve Command	Event	Off/Auto/Man		Required as a precondition test to determine ammonia evaporator status.
V63SXXXEE – NH_3 Evaporator System Select	Event	System 1 System 2		System 2 position actuates flow control valve 2 and tertiary NH_3 tank isolation valve. Needed as a secondary measurement to isolate whether flow control valve 1 or 2 (or tertiary NH_3 tank isolation) has failed.

SUBSYSTEM: ECLSS — NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V63XXXXFE — NH_3 Evaporator Flow Control Valve 1	Event	Close-Open		New recommended measurement. This measurement will act as a secondary measurement to determine whether the control valve has received signal.
V63QXXXGA — Sec NH_3 Tank Quantity	Quantity	30-90%		New recommended measurement. This measurement is needed to detect and isolate an ammonia tank failure during active and standby modes.
V63QXXXHA — Tertiary NH_3 Tank Quantity	Quantity	30-90%		New recommended measurement. This measurement is needed to detect and isolate an ammonia tank failure during active and standby modes.
V63XXXXIE — Tertiary NH_3 Tank Isolation Valve-Flow Control Valve 2 Position	Event	Close-Open		New recommended measurement. This addition will serve as a secondary measurement to provide information whether tertiary NH_3 tank isolation valve and flow control valve 2 have received signal when ammonia evaporator system 2 is selected.

SUBSYSTEM: ELECTRICAL POWER DISTRIBUTION

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V76XNNNNE – ESS/ Cont. BUS 1 Under Voltage	E	0/1		Change directed by CCA 60, and MCR 0662 deleting ABES; specific instrumentation of RAC's unavaiable (N= Unassigned MCA ID) (C&W Alarm).
V76XNNNNE – ESS/ Cont. BUS 2 Under Voltage	E	0/1		C
V76XNNNNE – ESS/ Cont. BUS 3 Under Voltage	E	0/1		

SUBSYSTEM: DECELERATION AND LANDING — NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V51PXXXXX — Hydraulic Pressure at Landing Gear Control Valve System 1	Press	2000-4050 psia		New measurement — required for the precondition check. Determination of hydraulic power available for landing gear actuation.
V51XYYYYYE — Electrical Power to Landing Gears Control Valve, Uplock Valve, Circulation Valves, Dump Control Valves	Event	1/0		New measurement recommended — required for precondition check. Determination of system status prior to landing gear selection.
V51PXXXXXA — LH Forward Brake Pressure	Press	2000-4050 psia		Provides verification of hydraulic pressure for brake actuation.
LH Rear Brake Pressure	Press	2000-4050 psia	DL2 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.
RH Forward Brake Pressure	Press	2000-4050 psia	DL1 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.
RH Rear Brake Pressure	Press	2000-4050 psia	DL2 (DL3 secondary)	New measurement recommended. Provides verification of hydraulic pressure for brake actuation.

SUBSYSTEM: DECELERATION AND LANDING – NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
LH Inboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
LH Outboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
RH Inboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.
RH Outboard Brake Temperature	Temp	TBD	DL1, DL2	New measurement recommended to insure brakes are not over-heated during taxi tests.

SUBSYSTEM: COMMUNICATIONS AND TRACKING — NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74VXXX1A — UHF Transceiver No.1 RF Output	A	0-5 Vdc	CT1	New recommended measurement.
V74SXXX3E — UHF Transceiver No.1 Power - ON	E		CT1	New recommended measurement.
V74XXXX5E — UHF Transceiver No.1 Transmit	E		CT1	New recommended measurement.
V74XXXX7E — UHF Transceiver No.1 Receive	E		CT1	New recommended measurement.
V74VXXX2A — UHF Transceiver No.2 RF Output	A	0-5 Vdc	CT2	New recommended measurement.
V74SXXX4E — UHF Transceiver No.2 Power - ON	E		CT2	New recommended measurement.
V74XXXX6E — UHF Transceiver No.2 Transmit	E		CT2	New recommended measurement.
V74XXXX8E — UHF Transceiver No.2 Receive	E	0-5 Vdc	CT2	New recommended measurement.

SUBSYSTEM: COMMUNICATIONS AND TRACKING — NEW MEASUREMENTS

MEASUREMENT	TYPE	RANGE	FUNCTIONAL PATH	REMARKS
V74VXXX9A — TLM Transmitter DC Power	A	0-5 Vdc	CT3	New recommended measurement.
V74SXX11E — TLM Transmitter Power - ON	E		CT3	New recommended measurement.
V74VXX10A — DFI Transmitter DC Power	A		CT4	New recommended measurement.
V74SXX12E — DFI Transmitter Power - ON	E		CT4	New recommended measurement.
V74SXX13E ATC XPNDR - On	Event	0/1	N.A.	New recommended measurement.
V74SXX14E C-Band BCN - On	Event	0/1	N.A.	New recommended measurement.
V74SXX15E AUD PNL, CDR - On	Event	0/1	CT1, CT2	New recommended measurement.
V74SXX16E AUD PNL, Pilot - On	Event	0/1	CT1, CT2	New recommended measurement.
V74SXX17E AUD PNL, Mid Deck - On	Event	0/1	CT1, CT2	New recommended measurement.

APPENDIX B

MEASUREMENT NUMBER IDENTIFICATION

APPENDIX B

MEASUREMENT NUMBER IDENTIFICATION

Each measurement has a unique identification number. The number consists of six fields. The program element, the subsystem, and the type of measurement are specified by fields 1 through 3, respectively. Fields four and five provide the identification of the measurement within the subsystem and the type of signal, respectively. Field six is used to identify signals with peculiar characteristics. The identification number is an alphanumeric consisting of nine characters and one symbol. These characters and symbols are identified as follows:

FIELD NO. 1	2	3	4	5	6
V	45	T	2222	A	*

FIELD NUMBER 1

The first character is an alpha character identifying a major element of the Shuttle program.

A — Ground Test Article

B — Booster (SRB)

E — Main Engine

F — Facility Ground Support Equipment

G — Ground Support Equipment

P — Payload or Experiment

T — External Tank

V — Orbiter Vehicle

FIELD NUMBER 2

The second and third characters are numerical and designate the subsystem.

09 Orbiter TPS/TCS
10 Wing L/R
11 Wing Leading Edge
12 Wing Box
13 Elevon
19 Wing TPS
20 Vertical Stabilizer
21 Vertical Stabilizer Leading Edge
22 Vertical Fin
23 Rudder/Speed Brake
29 Vertical Stabilizer TPS
30 NA
31 Fuselage, Upper FWD
32 Fuselage, Lower FWD
33 Crew Module
34 Fuselage, MID
35 Fuselage, AFT
36 NA
37 Payload Bay Doors
38 Purge and Vent
39 Fuselage TPS
40 NA
41 Main Propulsion
42 Reaction Control
43 Orbit Maneuver
44 Air Breathing
45 Electrical Power Generation
46 Auxiliary Power Unit

47 Solid Rocket Booster
48 External Tank
49 NA
50 NA
51 Landing Gear
52 Deceleration
53 Docking
54 Payload Accommodation
55 Ordinance
56 Attachment Separation
57 Aerosurface Flight Control
58 Hydraulic
59 Miscellaneous Systems
60 NA
61 Atmospheric Revitalization
62 Life Support
63 Thermal Control
64 Airlock Subsystem (ALS)
65 Crew Accommodation
66 Crew Equipment
67 Biomedical
68 NA
69 NA
70 Flight Control
71 Guidance and Navigation
72 Data Processing
73 Display and Control
74 Communication and Tracking
75 Instrumentation Oper.
76 Electrical Power Distribution and Control
77 Automated Wire List
78 Instrumentation, Development
79 Wire Installation

FIELD NUMBER 3

The fourth character is an alpha identifying the type of measurement.

A — Acceleration
B — Phase, Electrical
C — Current
D — Vibration
E — Power
F — Frequency
G — Force
H — Position/Attitude
J — Biomedical
K — Stimulus
L — Velocity
M — Multi-data
N — Resistance
P — Pressure
Q — Quantity/Humidity
R — Rate
S — Switch Scan
T — Temperature
U — Radiation
V — Voltage
W — Time
X — Discrete Event
Y — Acoustics
Z — Ph Acidity/Silver Ion

FIELD NUMBER 4

Characters five through eight are numbers assigned sequentially within the subsystem.

FIELD NUMBER 5

Character nine is an alpha which identifies the type of signal.

A — Analog
B — Digital Serial Software Signal
C — Analog Software Signal
D — Digital Serial
E — Discrete Event
F — Frequency Modulation (FM)
S — Step Function
V — Video
X — Discrete Event Software Signal

FIELD NUMBER 6

The tenth character may be an asterisk that identifies a signal that has peculiar characteristics. It is used as a flag to alert the user to look elsewhere (such as remarks) for information.