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AVIONICS SYSTEMS ENGINEERING DIVISION

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RCS PROPULSION FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION

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RCS PROPULSION FUNCTIONAL PATH ANALYSIS
FOR
PERFORMANCE MONITORING FAULT DETECTION
AND
ANNUNCIATION

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ABBREVIATIONS

Aux	Auxiliary
Eng	Engine
FCS	Flight Control Svstem
Fu	Fuel
Fwd	Forward
He	Helium
Injr	Injector
Isln	Isolation
L	Left
Manf	Manifold
OMS	Orbital Maneuvering System
Ox or Oxid	Oxidizer
Pos	Position
Prplt	Propellant
R	Right
RCS	Reaction Control System
Rlf	Relief
Rgltr	Regulator
SOV	Shut-off valve
Temp	Temperature
Tk	Tank
XFD	Crossfeed

1.0 SUMMARY

The Reaction Control System (RCS) is not completely defined at this time. The configuration considered in this document is shown in the illustrations included in this document.

Future configuration changes should have little impact on the measurements required for fault detection and annunciation.

One hundred and eleven measurements have been identified for use in fault detection and annunciation, that are not included in the Master Measurements List, dated November 16, 1973.

These measurements are divided into the following categories:

- Burn through monitors 44 ea
- Engine temperatures 4 ea
- Manifold pressures 30 ea
- Shut-off valve positions 22 ea
- Redundant helium source pressures 9 ea
- Cargo bay tank pressures 2 ea

Consideration should be given to including the following in the design of the reaction jet drivers:

- Redundant chamber pressure sensors.

- Jet driver output monitors.
- Jet driver electrical-ON failure isolation capability.
- Single jet driver power isolation capability.
- Failure identification annunciation.

2.0 INTRODUCTION

2.1 Purpose

This document defines the functional paths of the RCS and defines the operational flight instrumentation required for performance monitoring fault detection and annunciation.

A functional path, as used in this document, is defined as one or more functional elements which may be combined into operating functional paths which are controllable or selectable by the flight crew for systems management.

2.2 System Description

2.2.1 Reaction Control System (RCS). The RCS, operating in conjunction with the Guidance Navigation and Control Subsystem, employs 38 bipropellant primary and six vernier thrusters to provide precise attitude control and three-axis translation during separation from the external tank, orbit insertion, orbital and reentry phases of flight.

In addition, the RCS provides roll control during single engine orbital maneuvering system burns.

2.2.2 RCS organization. The RCS consists of three independent propulsion packages. One module, comprising 14 primary thrusters and two verniers, is located in the forward fuselage and the other two modules, each containing 12 primary thrusters and two vernier thrusters, are contained in the auxiliary propulsion subsystem mounted on each side of the aft fuselage.

2.2.3 RCS components. Each RCS Propulsion Package contains a propellant storage and distribution system, a helium pressurant gas storage regulation and distribution system, a thermal control assembly, and electrical and flight instrumentation system. Each primary thruster produces approximately 900 pounds thrust. The vernier thrusters provide approximately 25 pounds thrust each.

2.2.4 RCS propellant supply. The hypergolic RCS propellants are nitrogen tetroxide (N_2O_4) and monomethalhydrazine. Each RCS is normally supplied propellants from its own dedicated set of tanks. Crossfeed lines provide the capability to supply propellant to either aft RCS thrusters from one of the following sources:

- OMS propellant tanks
- Cargo bay kit tanks
- Pod tanks from the opposite RCS

2.2.5 RCS activation. During liftoff and ascent, the RCS is inactive with the helium isolation valves closed and the propellant isolated from the thruster bipropellant valve inlets by the propellant isolation valves. Prior to external tank jettison, the propellant isolation valves, the helium isolation valves, and the RCS doors are commanded open and the RCS propellant and pressurization subsystems are ready for operation

2.2.6 RCS reentry configuration. The forward RCS is not used during reentry. Prior to reentry, the forward RCS jets are deactivated, and the RCS doors are closed.

2.2.7 Failed thruster monitoring. Guidance and control will monitor for failed thrusters. It is assumed that a fault word will be provided from the guidance and control computer for performance monitoring fault annunciation.

2.2.8 RCS configuration status. Several areas of the RCS are not defined at this time. For the purpose of this report, these areas are assumed to be as shown on the system prints in this document.

Vernier jet location and manifold connections, RCS door instrumentation, and the guidance and control monitors are likely change points.

3.0 FUNCTIONAL PATH ANALYSIS OF THE FORWARD RCS

3.1 Functional Path Identification

The functional paths for the forward RCS are identified as RCXX on figures 1 through 3.

3.2 Functional Path Description

RC1 is the helium source bottle for supplying helium pressure to the fuel tank. The bottle has a volume of approximately 2.02 cubic feet and is pressurized to 3600 psia prior to liftoff. RC2 provides the same function for the oxidizer tank.

RC3 through RC6 are helium isolation valves in series with two helium regulators. They provide helium source isolation and regulate source pressure to a propellant tank pressure of approximately 280 psia.

RC7 and RC8 are series parallel check valves that isolate propellant from the helium regulators.

RC9 and RC10 provide over pressure relief for the fuel and oxidizer tanks. They consist of a normally open shut-off valve (SOV) in series with a burst disc and a poppet relief valve. Over pressure will rupture the burst disc allowing excess helium to be vented. In the event the poppet valve fails to reseat, the SOV is closed by the crew.

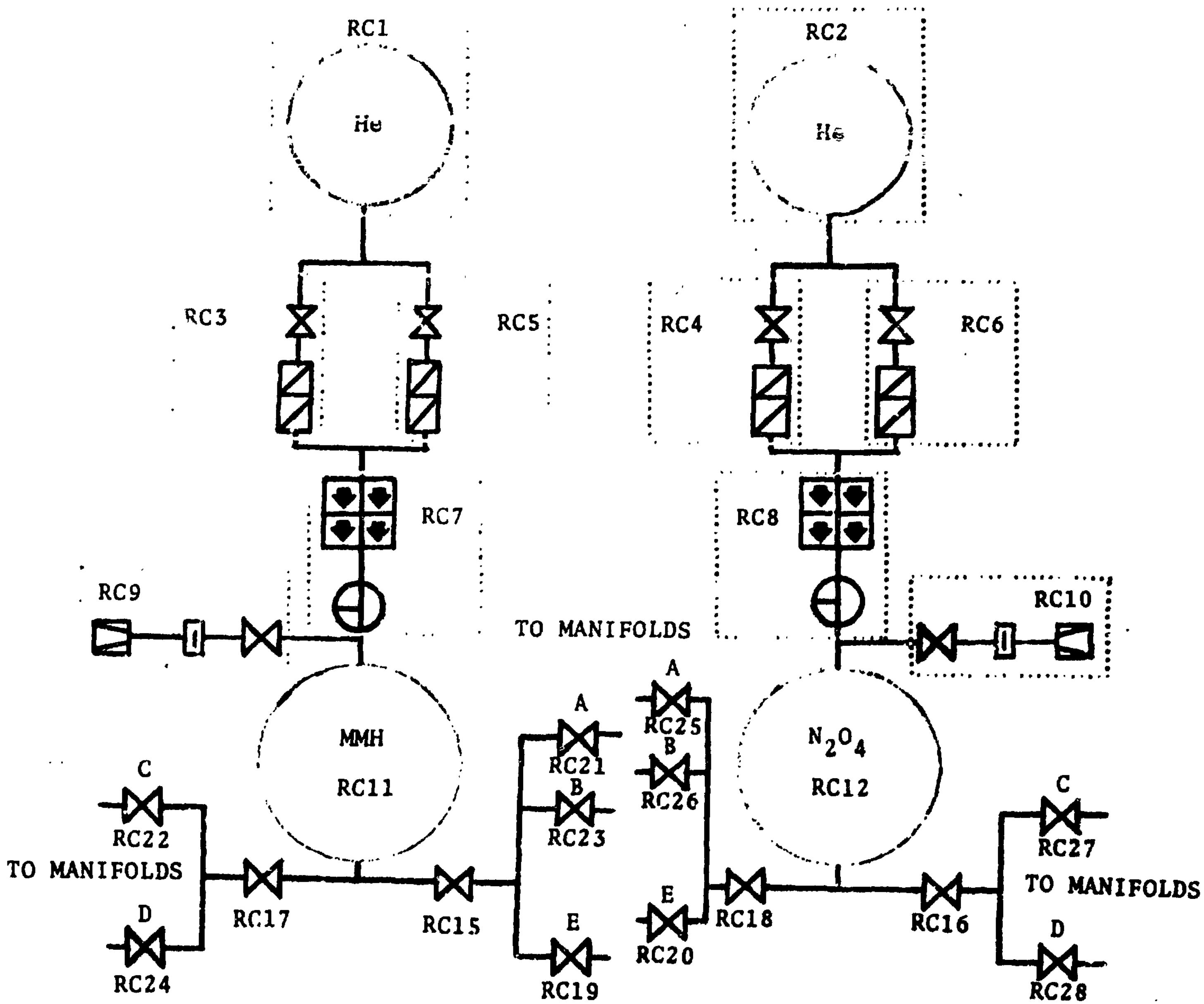

Figure 1. - Forward RCS propellant supply functional paths.

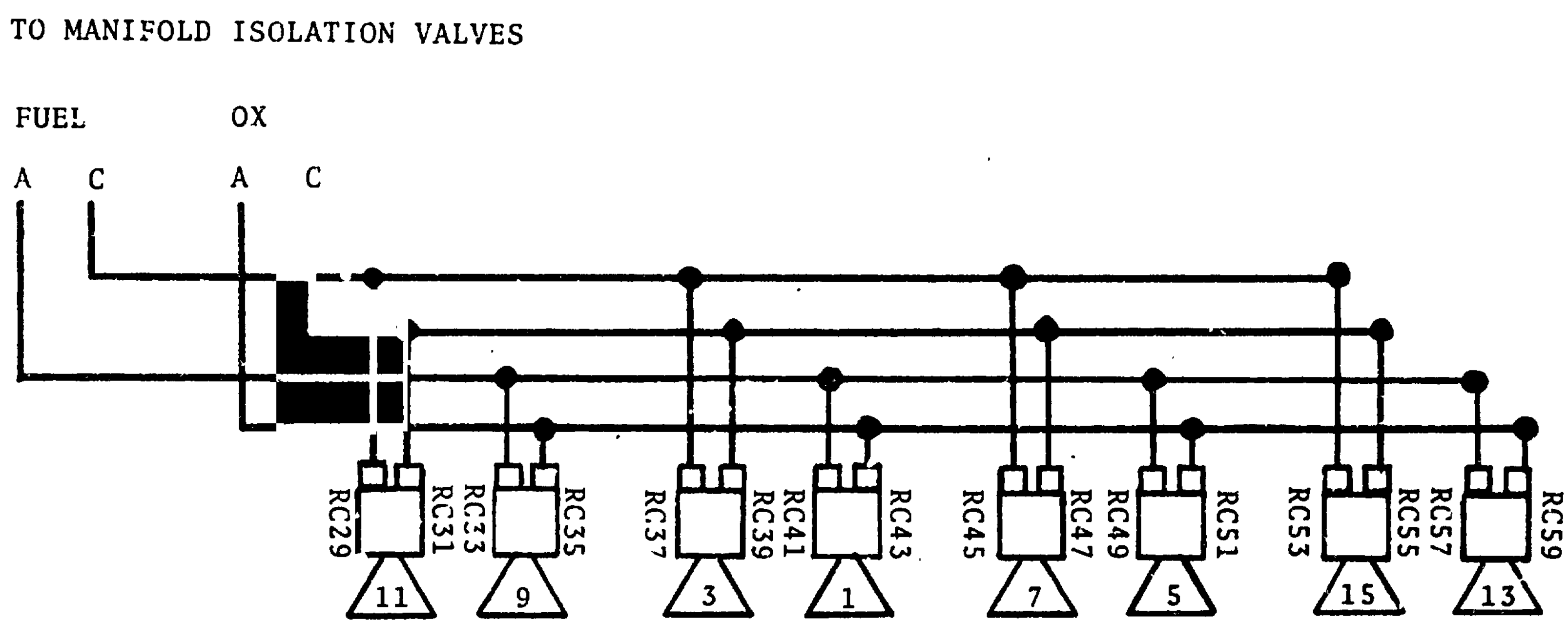

Figure 2. - Functional paths forward RCS A and C manifold thrusters.

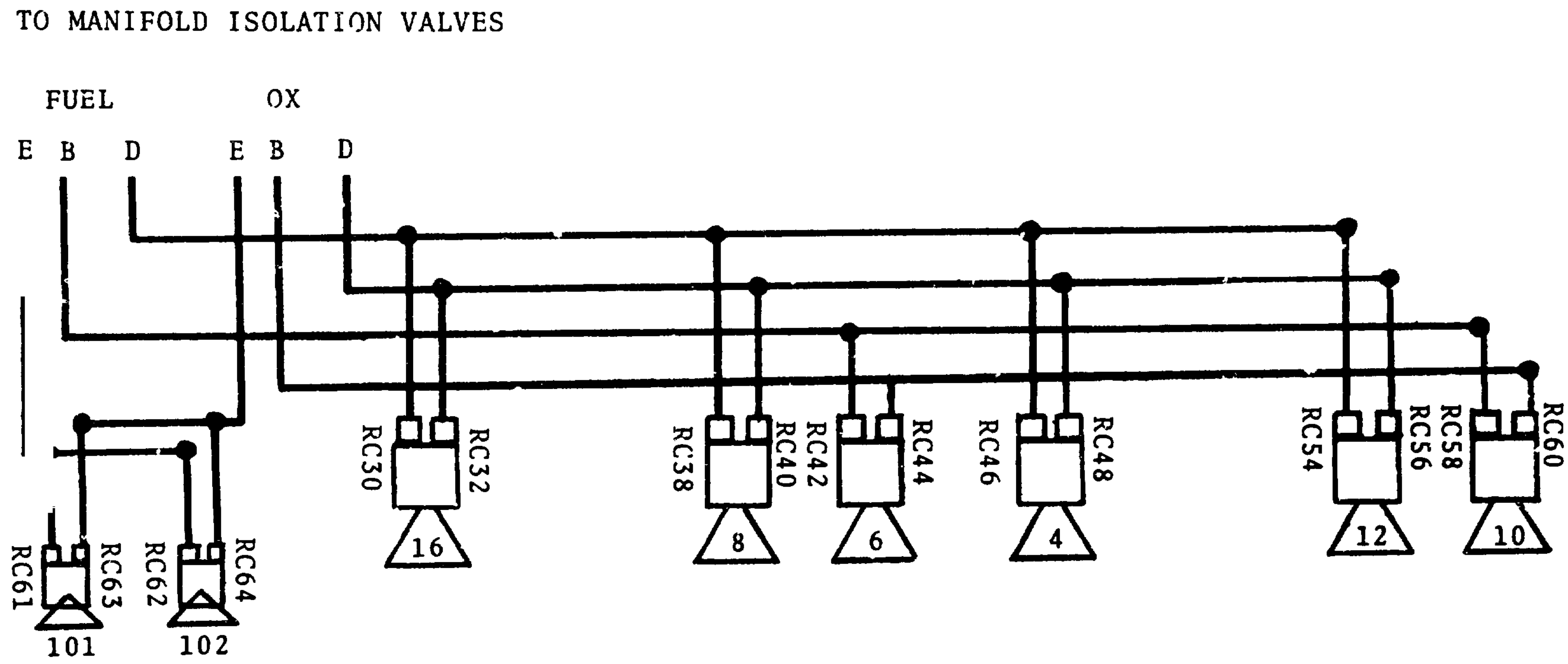

Figure 3. - Functional paths forward RCS E, B, and D manifolds.

RC11 and RC12 are propellant holding tanks. Each tank has a volume of approximately 14 cubic feet.

RC15 through RC18 are tank isolation valves used to isolate propellant flow from the propellant tanks to the manifold isolation valves.

RC19 through RC28 are manifold isolation valves. Each valve controls the flow of fuel or oxidizer to the inlet of four primary or two vernier jets. In the event of a failed-on thruster or a leak, both the fuel and oxidizer manifold isolation valves associated with the failure are closed.

RC29 through RC64 are engine inlet valves for fuel and oxidizer. Each engine has a dedicated jet driver which opens and closes the fuel and oxidizer inlet valves on command.

3.3 Operating Functional Paths

Functional paths are combined into operating functional paths for fault detection and annunciation. The operating functional paths are identified as ORCXX. A total of 16 fuel and 16 oxidizer functional paths exist in the forward RCS system.

All functional paths for fuel are identical from the helium source to the fuel tank isolation valves.

ORC1 = (RC1) (RC3 + RC5) (RC7) (RC11)

In addition, two sets of eight engines have a common path through the fuel tank isolation valves.

ORC2 = (ORC1) (RC15)

ORC3 = (ORC1) (RC17)

Five groups of engines have common fuel paths through the manifold isolation valves.

ORC4 = (ORC2) (RC21) for Manifold A

ORC5 = (ORC3) (RC22) for Manifold C

ORC6 = (ORC2) (RC23) for Manifold B

ORC7 = (ORC3) (RC24) for Manifold D

ORC8 = (ORC2) (RC19) for Manifold E

The complete fuel flow path for each engine is the manifold path combined with the engine inlet. The fuel flow paths for the engines are:

ORC9 = (ORC4) (RC41) for Jet 1

ORC10 = (ORC4) (RC49) for Jet 5

ORC11 = (ORC4) (RC33) for Jet 9

ORC12 = (ORC4) (RC57) for Jet 13

ORC13 = (ORC5) (RC37) for Jet 3

ORC14 = (ORC5) (RC45) for Jet 7

ORC15 = (ORC5) (RC29) for Jet 11

ORC16 = (ORC5) (RC53) for Jet 15

ORC18 = (ORC6) (RC42) for Jet 6

ORC19 = (ORC6) (RC58) for Jet 10

ORC21 = (ORC7) (RC46) for Jet 4

ORC22 = (ORC7) (RC38) for Jet 8

ORC23 = (ORC7) (RC54) for Jet 12

ORC24 = (ORC7) (RC30) for Jet 16

ORC51 = (ORC8) (RC61) for Jet 101

ORC52 = (ORC8) (RC62) for Jet 102

Oxidizer flow paths are similar and compiled as follows:

- <u>Common Path to Tank Isolation Valves</u>

ORC25 = (RC2) (RC4 + RC6) (RC8) (RC12)

- <u>Common Paths through Tank Isolation valves</u>

  ORC26 = (ORC25) (RC18)

  ORC27 = (ORC25) (RC16)

- <u>Common Paths to Manifolds</u>

  ORC28 = (ORC26) (RC25) A Manifold

  ORC29 = (ORC27) (RC27) C Manifold

  ORC30 = (ORC26) (RC26) B Manifold

  ORC31 = (ORC27) (RC28) D Manifold

  ORC32 = (ORC26) (RC20) E Manifold

- <u>Oxidizer Flow Paths to Jets</u>

  ORC33 = (ORC28) (RC43) for Jet 1

  ORC34 = (ORC28) (RC51) for Jet 5

  ORC35 = (ORC28) (RC35) for Jet 9

  ORC36 = (ORC28) (RC59) for Jet 13

  ORC37 = (ORC29) (RC39) for Jet 3

  ORC38 = (ORC29) (RC47) for Jet 7

ORC39 = (ORC29) (RC31) for Jet 11

ORC40 = (ORC29) (RC55) for Jet 15

ORC42 = (ORC30) (RC44) for Jet 6

ORC43 = (ORC30) (RC60) for Jet 10

ORC45 = (ORC31) (RC48) for Jet 4

ORC46 = (ORC31) (RC40) for Jet 8

ORC47 = (ORC31) (RC56) for Jet 12

ORC48 = (ORC31) (RC32) for Jet 16

ORC49 = (ORC32) (RC63) for Jet 101

ORC50 = (ORC32) (RC64) for Jet 102

4.0 MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION - FORWARD RCS

4.1 FDA Measurements

Table 1 lists the primary, correlation, and preconditioning measurements required for fault detection and annunciation. The table identifies 28 new measurements not included in the Master Measurements List, dated November 16, 1973. Measurement justification is also included in table 1. Figures 4 through 6 show the approximate location of the forward RCS measurements.

4.2 Description of Parameters to be Monitored

4.2.1 Helium source pressure. Helium source pressure is used for propellant gauging and is the best overall indicator of system integrity. In the event the source pressure measurement is lost, the system status and propellant remaining cannot be determined; therefore, redundant source pressure measurements should be added.

4.2.2 Propellant pressures. Helium SOV positions provide a precondition check to determine if the system is static or dynamic. Regulator output is required to isolate leaks and failed components such as regulators, helium SOV's, and vent valves.

Tank outlet pressure provides a correlation check for regulator output pressure.

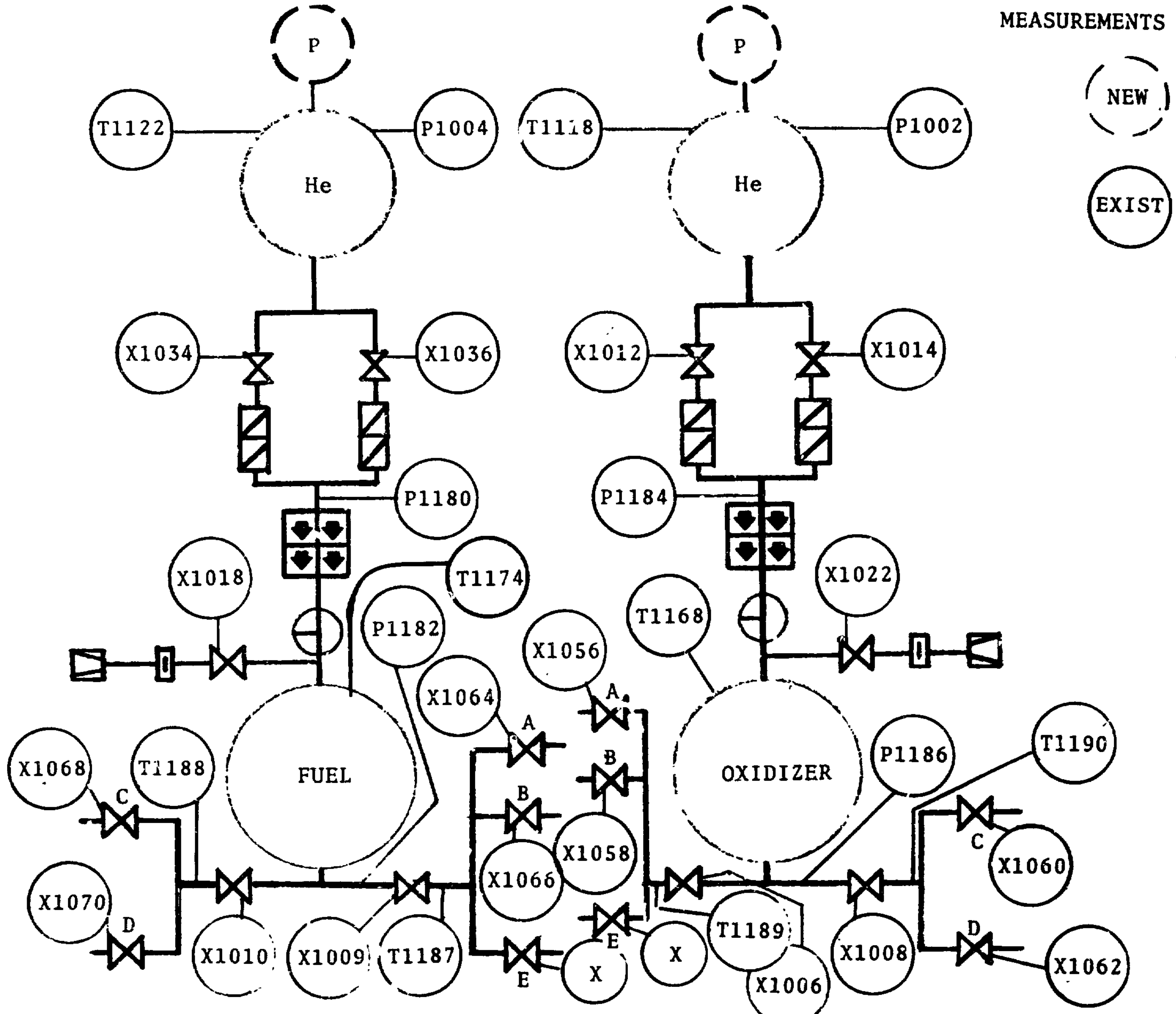

Figure 4. – Forward RCS propellant supply instrumentation.

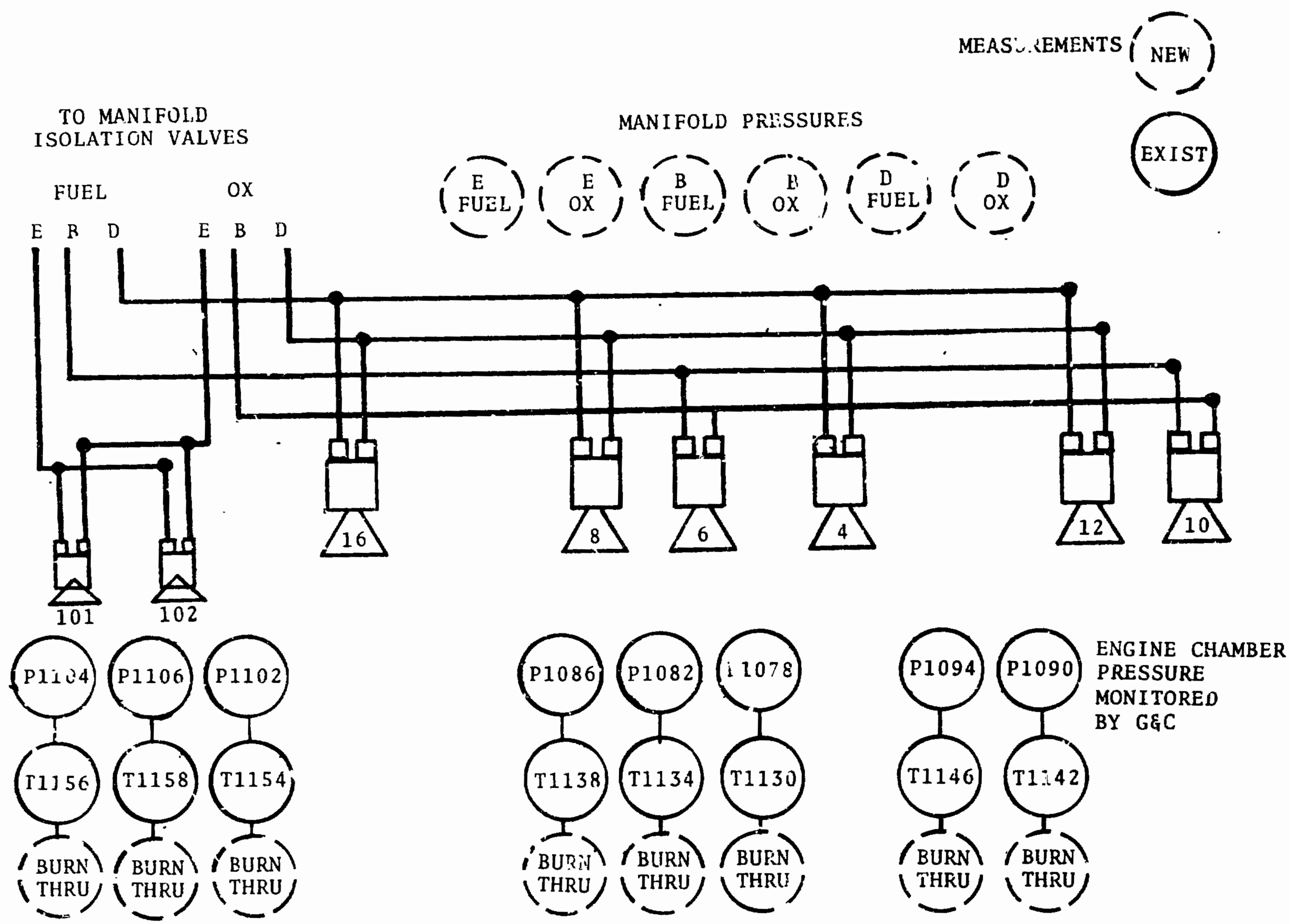

Figure 5. – Forward manifolds B, D, and E instrumentation.

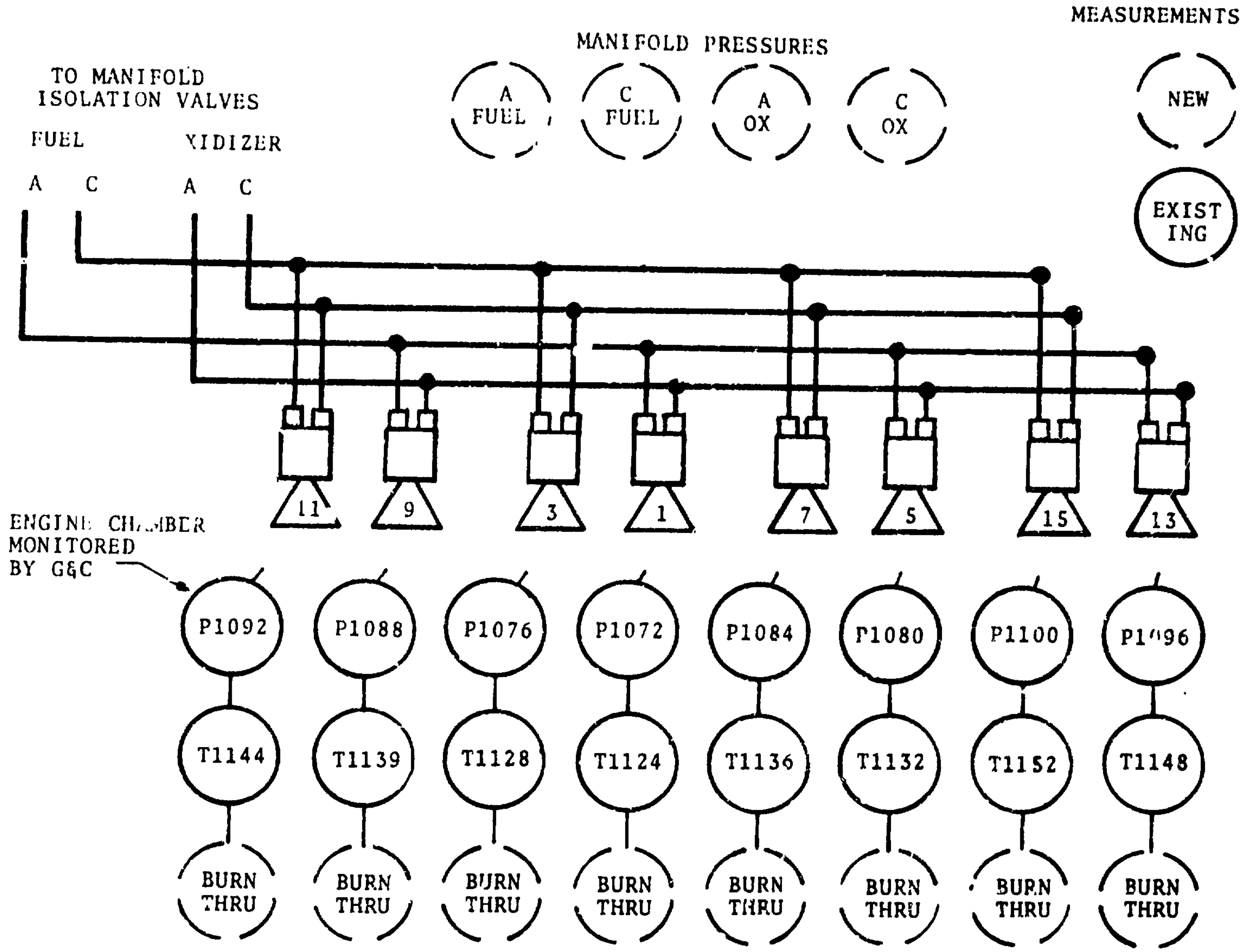

Figure 6. — Forward manifolds A and C instrumentation.

4.2.3 Manifold pressures. Tank outlet SOV's and manifold isolation valves provide precondition checks for manifold pressure checks.

Manifold pressure transducers should be added to provide rapid leak isolation capabilities. Heat soak back monitoring for failed manifolds would also be provided by these transducers.

4.2.4 Thruster temperature. Thruster temperature transducers should be monitored for overtemperature during burns and for leak indications during quiescent periods.

In addition, the engine procurement specification provides for burn-through monitors on each engine. It is anticipated that they will be monitored by PMS.

4.3 Leak Detection Methods

4.3.1 Quantity remaining. Premission helium profiles are not adequate for helium monitoring. Leaks can be detected by correlating helium source pressure with quantity of propellant remaining. Since quantity remaining is gauged by helium pressure, volume, and temperature, quantity measurements become inaccurate when a leak is introduced into the system. A thruster-on time multiplied by flow rate calculation should be correlated with quantity remaining.

4.3.2 Delta pressure. The helium source pressure delta for fuel and oxidizer should be nearly constant, since equal volumes of fuel and oxidizer are being consumed. A change in the delta pressure is indicative of a leak.

TABLE 1.– MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status **
V42P1004A RCS fwd He fuel tk press	P	NA	NA	Propellant remaining dependent		T1120A T1122A	RC1 ORC1	System status and leak monitor	
RCS fwd He fuel tk press	P	NA	NA	Propellant remaining dependent		T1120A	RC1 ORC1	System status lost if P1004 fails. Should be redundant	N
V42P1120A RCS fwd He fuel tk temp 1	C	TBD	TBD	TBD	TBD	NA	RC1 ORC1	Heat and cold soak. Leak monitor.	
V42X1034E RCS fwd He fu RGLTR Isln valve 1	X	NA	NA	NA	NA	NA	RC3 ORC1	Position defines type of monitoring static or dynamic	
V42X1036E RCS fwd He fu RGLTR Isln valve 2	X	NA	NA	NNA	NA	NA	ORC 1 RC 5	Position defines type of monitoring static or dynamic	

*P = Primary

C = Correlation

X = Precondition

**N = New Measurement Required

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V42P1180A RCS fwd fu RGLTR out press	P	TBD	TBD	300 psig	275 psig	P1182A T1172A T1174A	ORC 1	System status and leak and over-pressurization monitor	
V42P1182A RCS fwd fu propellant manf press	C	NA	NA	300 psig	275 psig	NA	ORC 1	Tank pressure monitor if reg pressure transducer fails	
V42T1172A RCS fwd fu storage tank shell temp	P	TBD	TBD	TBD	TBD	NA	ORC 1 RC11	Heat and cold soak. Leak detection.	
V42X1009E RCS fwd fu tank shut-off valve 1	X	NA	NA	NA	NA		RC17 ORC2	Note: Measurement No. may change on new configuration	
V42T1187A RCS fwd fu manifold temp No 1	P	TBD	TBD	TBD	TBD		ORC2	Heat soakback	
V42T1188A RCS fwd fu manifold temp No 2	P	TBD	TBD	TBD	TBD		ORC3	Heat soakback	

TABLE 1.-- MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42X1064E RCS fwd fu thruster Isln valve A	P	NA	NA	NA	NA		RC21 ORC4	Isolated manifold monitor	
V42X1068E RCS fwd fu thruster Isln valve C	P	NA	NA	NA	NA		ORC6 RC23	Isolated manifold monitor	
V42X1066E RCS fwd fu thruster Isln valve B	P	NA	NA	NA	NA	NA	RC22 ORC6	Isolated manifold monitor	
V42X1070E RCS fwd fu thruster Isln valve D	T	NA	NA	NA	NA	NA	RC24 ORC7	Isol.ted manifold monitor	
A manifold fu press	P	NA	NA	TBD	TBD	P1182A	ORC4	Leak isolation heat soakback	N
B manifold fu press	P	NA	NA	TBD	TBD	P1182A	ORC6	Leak isolation heat soakback	N
C manifold fu press	P	NA	NA	TBD	TBD	P1182A	ORC5	Leak isolation heat soakback	N
D manifold fu press	P	NA	NA	TBD	TBD	P1182A	ORC7	Leak isolation heat soakback	N

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42P1002A RCS fwd He oxid tk press	P	NA	NA	Propellant remaining dependent		T1116A	RC2 ORC25	System status leak monitoring	
RCS fwd He oxid tk press	P	NA	NA	Propellant remaining dependent		T1116A	RC2 ORC25	System status lost if P1002A fails. Should be redundant	N
V42T1116A RCS fwd He oxdzr tank temp No 1	C	TBD	TBD	TBD	TBD	NA	RC2 ORC25	Heat and cold soak leak monitor	
V42X1012E RCS fwd He oxid RGLTR Isln valve 1	X	NA	NA	NA	NA	NA	RC4 ORC25	Position defines type of monitoring static or dynamic	
V42X1014E RCS fwd He oxid RGLTR Isln valve 2	X	NA	NA	NA	NA	NA	RC6 ORC25	Position defines type of monitoring static or dynamic	
V42P1184A RCS fwd He oxid RGLTR out press	P	285 psig	275 psig	300 psig	275 psig	P1186A	ORC25	System status leak and over-pressurization monitoring	

TABLE 1.– MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42P1186A RCS fwd oxid propellant manf press	C	NA	NA	300 psig	275 psig	NA	ORC25	Tank pressure monitor if reg pressure transducer fails	
V42T1168A RCS fwd oxid stor tank shell temp	P	TBD	TBD	TBD	TBD	NA	RC12 ORC25	Heat and cold soak leak detection	
V42X1006E RCS fwd oxid tank shut-off valve No 1	X	NA	NA	NA	NA	NA	RC18 ORC25	Determine tank use Note: Measurement No. may change on new configuration	
V42X1008E RCS fwd oxid tank shut-off valve No 2	X	NA	NA	NA	NA	NA	RC16 ORC25	Determine tank use Note: Measurement No. may change on new configuration	
V42T1189A RCS fwd oxid manifold temp No 1	P	TBD	TBD	TBD	TBD	NA	ORC26	Heat soakback	

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD RCS FAULT DETECTION AND ANNUNCIATION – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T1190A RCS fwd oxid manifold temp No 2	P	TBD	TBD	TBD	TBD	NA	ORC27	Heat soakback	
V42X1056E RCS fwd oxid thruster Isln valve A	P	NA	NA	NA	NA	NA	RC25 ORC28	Isolated manifold monitor	
V42X1060E RCS fwd oxid thruster Isln valve C	P	NA	NA	NA	NA	NA	RC27 ORC29	Isolated manifold monitor	
V42X1058E RCS fwd oxid thruster Isln valve B	P	NA	NA	NA	NA	NA	RC26 ORC30	Isolated manifold monitor	
V42X1062E RCS fwd oxid thruster Isln valve D	P	NA	NA	NA	NA	NA	RC28 ORC31	Isolated manifold monitor	
RCS fwd A manifold oxid press	P	NA	NA	TBD	TBD	P1186A	ORC28	Leak isolation heat soakback	N

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS fwd B manifold oxid press	P	NA	NA	TBD	TBD	P1186A	ORC30	Leak isolation heat soakback	N
RCS fwd C manifold oxid press	P	NA	NA	TBD	TBD	P1186A	ORC29	Leak isolation heat soakback	N
RCS fwd D manifold oxid press	P	NA	NA	TBD	TBD	P1186A	ORC31	Leak isolation heat soakback	N
V42T1124A RCS fwd thruster injn temp No 1	P	TBD	TBD	TBD	TBD	NA	ORC4 ORC33 Jet 1	Overtemp and leak monitor	
V42T1128A RCS fwd thruster injn temp No 3	P	TBD	TBD	TBD	TBD	NA	ORC5 ORC37 Jet 3	Temp and leak monitor	
V42T1132A RCS fwd thruster injn temp No 5	P	TBD	TBD	TBD	TBD	NA	ORC10 ORC34 Jet 5	Temp and leak monitor	
V42T1136A RCS fwd thruster injn temp No 7	P	TBD	TBD	TBD	TBD	NA	ORC14 ORC38 Jet 7	Temp and leak monitor	

TABLE 1.– MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T1139A RCS fwd thruster injn temp No 9	P	TBD	TBD	TBD	TBD	NA	ORC11 ORC35 Jet 9	Temp and leak monitor	
V42T1144A RCS fwd thruster injn temp No 11	P	TBD	TBD	TBD	TBD	NA	ORC15 ORC39 Jet 11	Temp and leak monitor	
V42T1148A RCS fwd thruster injn temp No 13	P	TBD	TBD	TBD	TBD	NA	ORC12 ORC36 Jet 13	Temp and leak monitor	
V42T1152A RCS fwd thruster injn temp No 15	P	TBD	TBD	TBD	TBD	NA	ORC16 ORC40 Jet 15	Temp and leak monitor	
V42T1130A RCS fwd thruster injn temp No 4	P	TBD	TBD	TBD	TBD	NA	ORC21 ORC45 Jet 4	Overtemp and leak monitor	
V42T1134A RCS fwd thruster injn temp No 6	P	TBD	TBD	TBD	TBD	NA	ORC18 ORC42 Jet 6	Overtemp and leak monitor	

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T1138A RCS fwd thruster injn temp No 8	P	TBD	TBD	TBD	TBD	NA	ORC22 ORC46 Jet 8	Overtemp and leak monitor	
V42T1142A RCS fwd thruster injn temp No 10	P	TBD	TBD	TBD	TBD	NA	ORC19 ORC43 Jet 10	Overtemp and leak monitor	
V42T1146A RCS fwd thruster injn temp No 12	P	TBD	TBD	TBD	TBD	NA	ORC23 ORC47 Jet 12	Overtemp and leak monitor	
V42T1154A RCS fwd thruster injn temp No 16	P	TBD	TBD	TBD	TBD	NA	ORC24 ORC48 Jet 16	Overtemp and leak monitor	
V42T1156A RCS fwd thruster injn temp No 101	P	TBD	TBD	TBD	TBD	NA	ORC51 ORC49 Jet 101	Overtemp and leak monitor. Note: Injn No may change	
V42T1158A RCS fwd thruster injn temp No 102	P	TBD	TBD	TBD	TBD	NA	ORC52 ORC50 Jet 101	Overtemp and leak monitor. Note: Injn No may change	

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
RCS fwd thruster burn thru No 1	P	NA	NA	NA	NA	NA	ORC9 ORC33 Jet 1	Safety monitor	N
RCS fwd thruster burn thru No 3	P	NA	NA	NA	NA	NA	ORC13 ORC37 Jet 3	Safety monitor	N
RCS fwd thruster burn thru No 5	P	NA	NA	NA	NA	NA	ORC10 ORC34 Jet 5	Safety monitor	N
RCS fwd thruster burn thru No 7	P	NA	NA	NA	NA	NA	ORC14 ORC38 Jet 7	Safety monitor	N
RCS fwd thruster burn thru No 9	P	NA	NA	NA	NA	NA	ORC11 ORC35 Jet 9	Safety monitor	N
RCS fwd thruster burn thru No 11	P	NA	NA	NA	NA	NA	ORC15 ORC39 Jet 11	Safety monitor	N
RCS fwd thruster burn thru No 13	P	NA	NA	NA	NA	NA	ORC12 ORC36 Jet 13	Safety monitor	N
RCS fwd thruster burn thru No 15	P	NA	NA	NA	NA	NA	ORC16 ORC40 Jet 15	Safety monitor	N

TABLE 1.— MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS fwd thruster burn thru No 4	P	NA	NA	NA	NA	NA	ORC21 ORC45 Jet 4	Safety monitor	N
RCS fwd thruster burn thru No 6	P	NA	NA	NA	NA	NA	ORC18 ORC42 Jet 6	Safety monitor	N
RCS fwd thruster burn thru No 8	P	NA	NA	NA	NA	NA	ORC22 ORC46 Jet 8	Safety monitor	N
RCS fwd thruster burn thru No 10	P	NA	NA	NA	NA	NA	ORC19 ORC43 Jet 10	Safety monitor	N
RCS fwd thruster burn thru No 12	P	NA	NA	NA	NA	NA	ORC23 ORC47 Jet 12	Safety monitor	N
RCS fwd thruster burn thru No 16	P	NA	NA	NA	NA	NA	ORC24 ORC48 Jet 16	Safety monitor	N
RCS fwd thruster burn thru No 101	P	NA	NA	NA	NA	NA	ORC49 ORC51 Jet 101	Safety monitor	N
RCSfwd thruster burn thru No 102	P	NA	NA	NA	NA	NA	ORC50 ORC52 Jet 102	Safety monitor	N

TABLE 1.– MEASUREMENTS REQUIRED FOR FORWARD FAULT DETECTION AND ANNUNCIATION – Concluded

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
E manifold fuel press	P	NA	NA	TBD	TBD	NA	ORC8	Leak isolation	N
E manifold oxid press	P	NA	NA	TBD	TBD	NA	ORC32	Leak isolation	N
V42X1052E E manifold fu Isln valve position	P	NA	NA	NA	NA	NA	ORC8	Failed manifold monitor	
V42X1049E E manifold ox Isln valve position	P	NA	NA	NA	NA	NA	ORC32	Failed manifold monitor	
V42X1018 vent valve SOV	P	NA	NA	NA	NA	NA	RC9	Safety	
V42X1022 vent valve SOV	P	NA	NA	NA	NA	NA	RC10	Safety	

5.0 FUNCTIONAL PATH ANALYSIS OF THE AFT RCS

5.1 Functional Path Identification

The functional paths for the aft RCS are identified as RCXX on figures 7 through 10.

5.2 Functional Path Description - Aft Left RCS

RC70 is the helium source bottle for supplying helium pressure to the fuel tank. The bottle has 2.02 cubic feet volume and is pressurized to 3600 psia prior to liftoff.

RC71 provides the same function for the oxidizer tanks.

RC72 through RC75 are helium isolation valves in series with two helium regulators. They provide helium isolation and regulate source pressure to a propellant tank pressure of approximately 280 psia.

RC76 and RC77 are series parallel check valves that isolate propellants from the helium regulators.

RC80 and RC81 provide over pressure relief for the fuel and oxidizer tanks. They consist of a normally open SOV in series with a burst disc and a poppet relief valve. Over pressure will rupture the burst disc allowing excess helium to be vented. In the event the poppet valve fails to reseat, the SOV is closed by the crew.

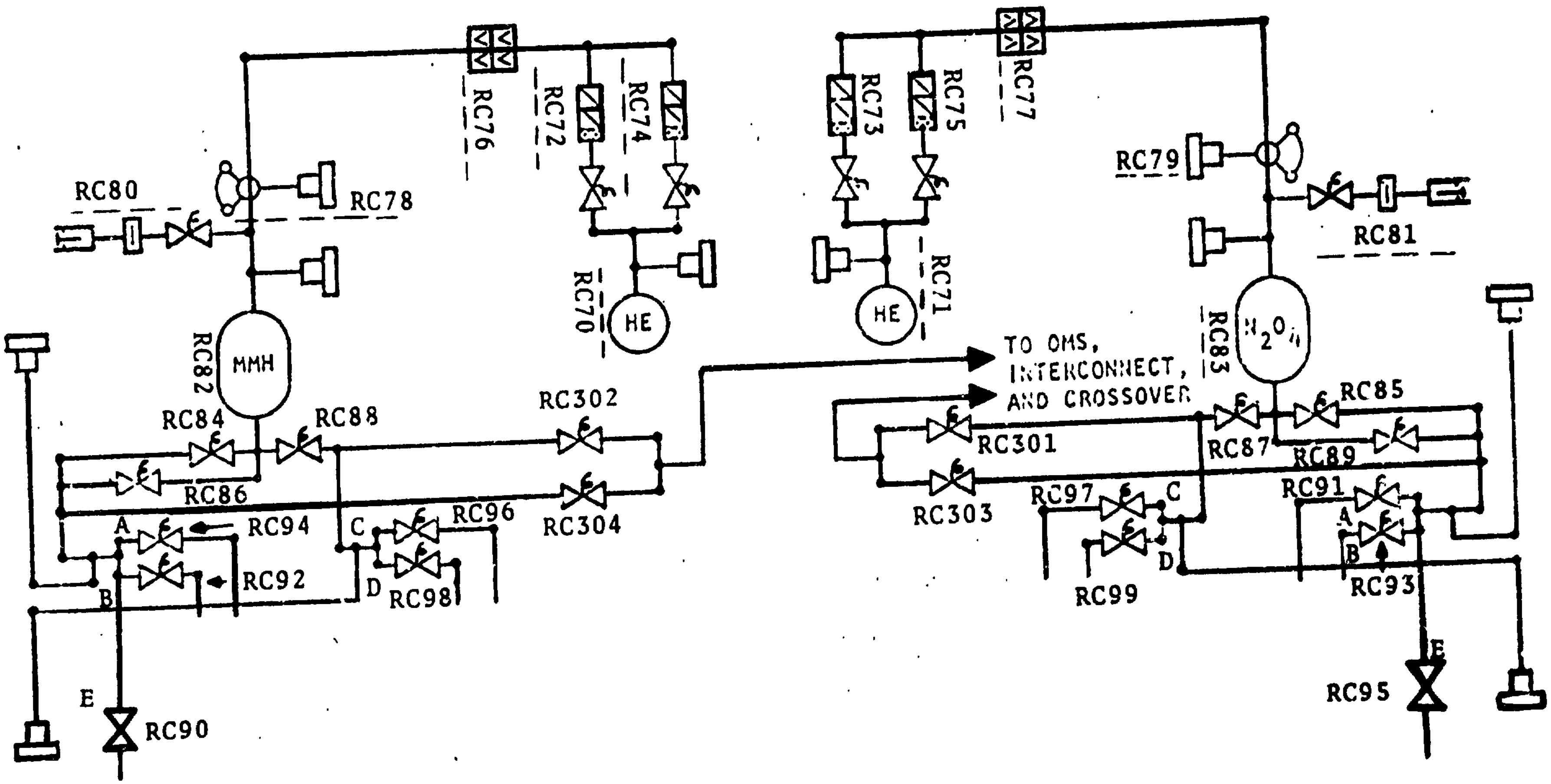

Figure 7. — Left aft RCS functional paths.

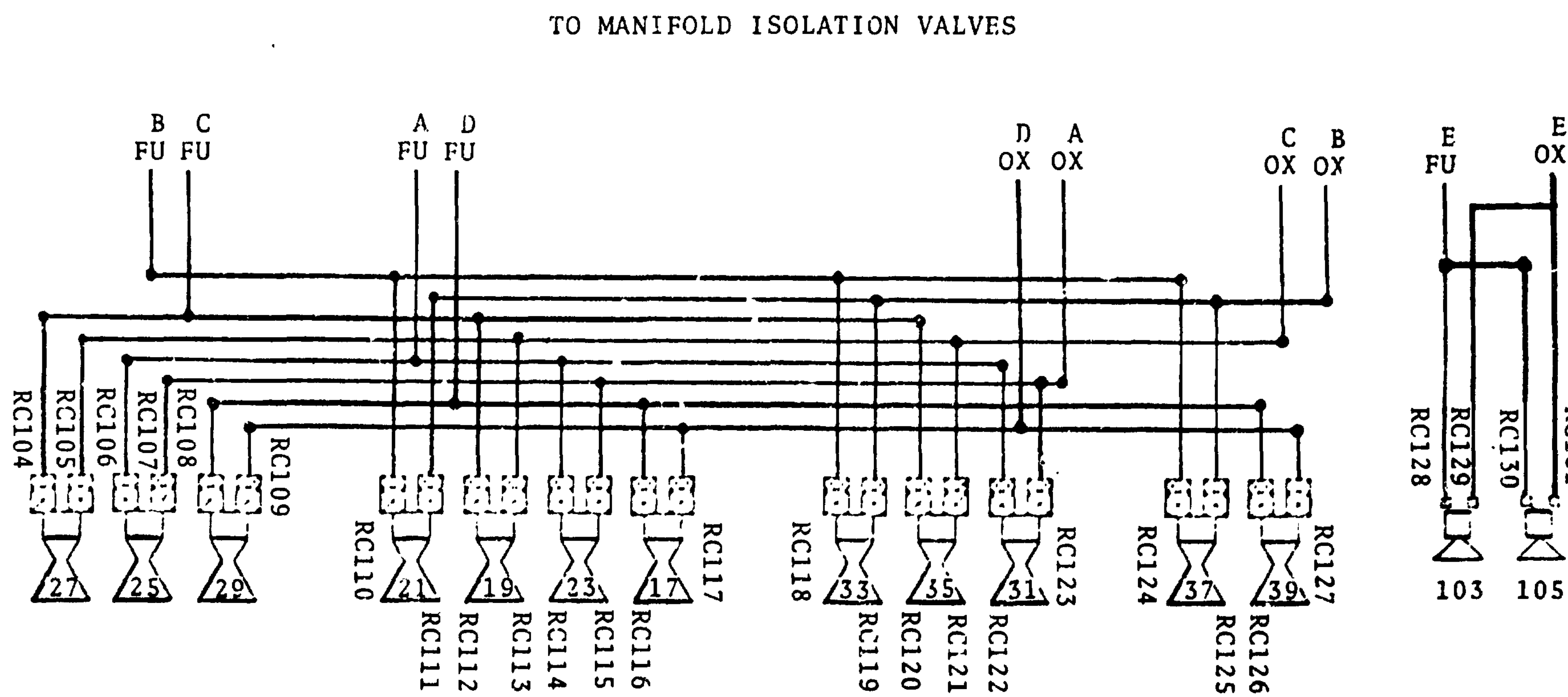

Figure 8. – Left aft RCS functional path.

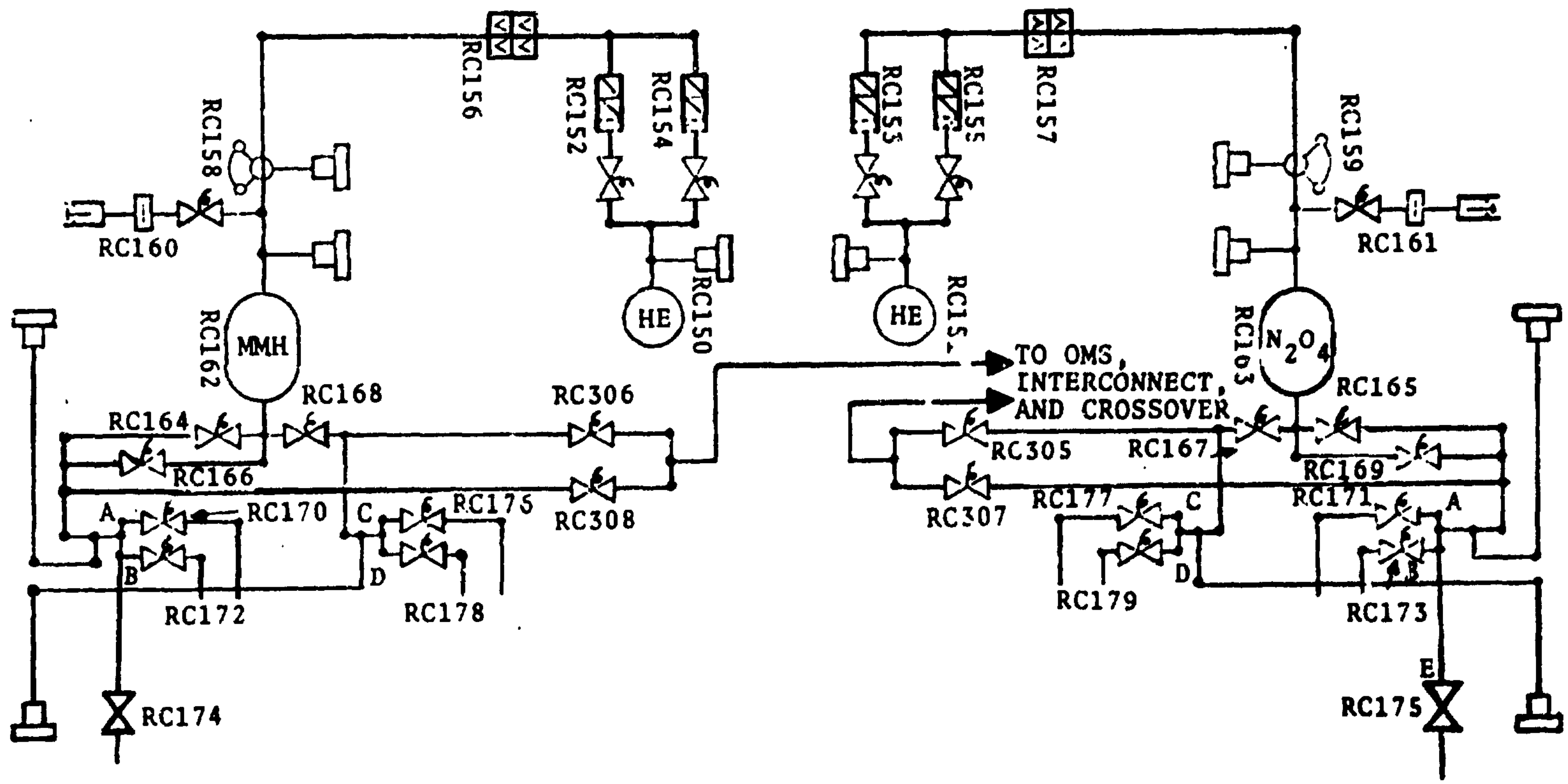

Figure 9. – Right aft RCS functional paths.

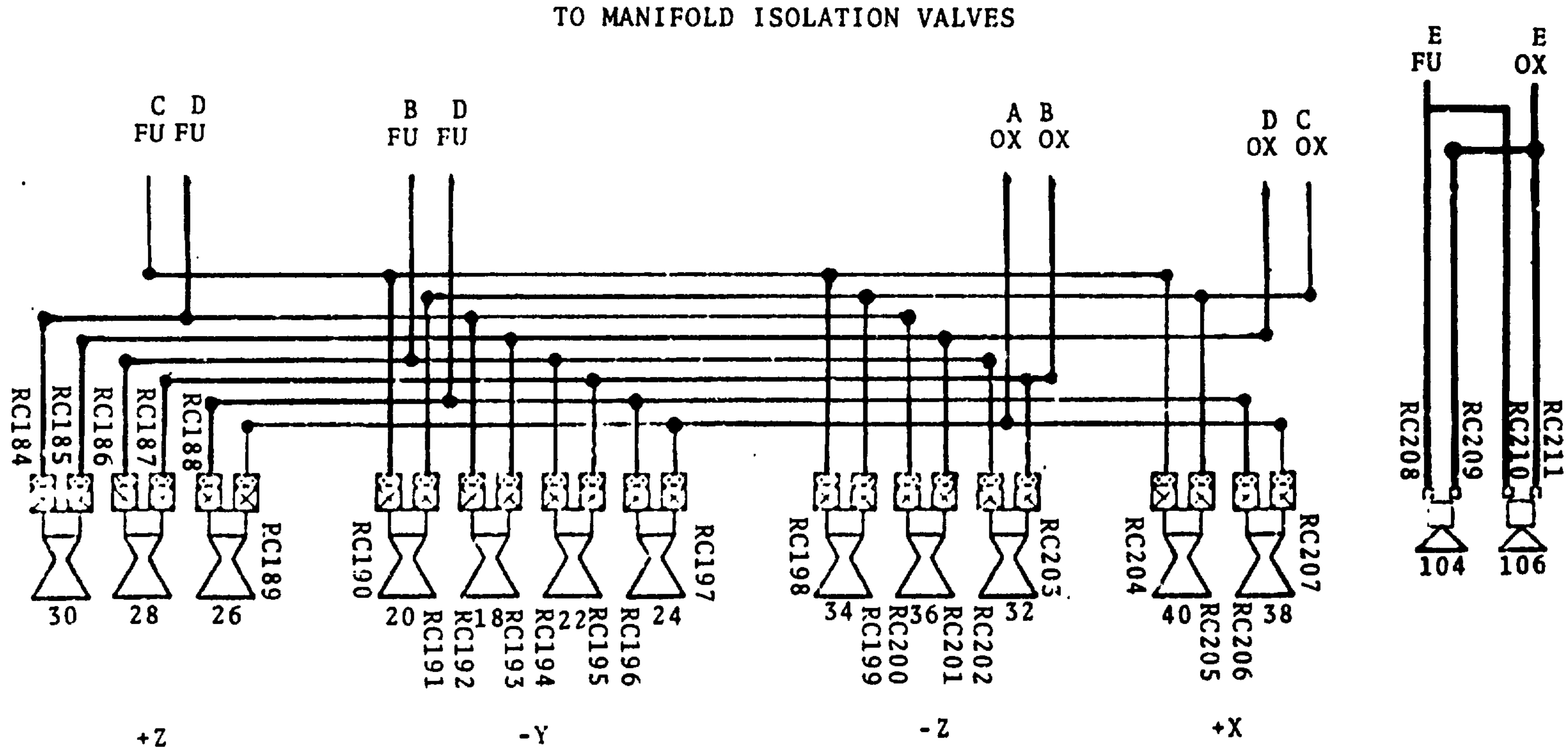

Figure 10. – Right aft RCS manifold functional paths.

RC82 and RC83 are propellant holding tanks. Each tank has a volume of approximately 14 cubic feet.

RC84 through RC89 are tank isolation valves used to isolate propellant flow from the propellant tanks to the thruster manifolds.

RC90 through RC99 are manifold isolation valves used to control the flow of propellant to three primary jets or two vernier jets. In the event of a failed-on thruster or a leak, the fuel and oxidizer manifold isolation valves associated with the failure are closed.

RC104 through RC131 are engine inlet valves for fuel and oxidizer. Each engine has a dedicated jet driver which opens and closes the fuel and oxidizer inlet valves on command.

5.3 Functional Path Description of Right Aft RCS

The right aft RCS has components identical to those in the left aft RCS. The functional path description is, therefore, the same as the left aft RCS except for the functional path numbering

5.4 Operating Functional Paths

The functional paths of the aft RCS are combined into operating functional paths for fault detection and annunciation. The operating functional paths are identified as ORCXXX. A total of 14 fuel and 14 oxidizer operating functional paths exist in each aft RCS.

5.4.1 Fuel operating functional paths - aft left RCS. All 14 functional paths for fuel are identical from the helium source to the tank isolation valves. The common fuel path is identified as:

ORC100 = RC70 (RC72 + RC74) (RC76) (RC78) (RC82)

In addition, eight engines have a common fuel path through parallel tank isolation valves and the remaining six engines have a common path through the remaining tank isolation valve. The fuel paths are identified as:

ORC101 = (ORC100) (RC84 + RC86)

ORC102 = (ORC100) (RC88)

Past the tank isolation valves the functional paths branch to the manifolds as follows:

ORC103 = (ORC101) (RC94) Manifold A

ORC104 = (ORC101) (RC92) Manifold B

ORC105 = ORC101 (RC90) Manifold E

ORC106 = ORC102 (RC96) Manifold C

ORC107 = ORC102 (RC98) Manifold D

The complete fuel flow functional paths for the engines are given below:

ORC108 = (ORC103) (RC106) Engine 25

ORC109 = (ORC103) (RC114) Engine 23

ORC110 = (ORC103) (RC122) Engine 31

ORC111 = (ORC104) (RC110) Engine 21

ORC112 = (ORC104) (RC118) Engine 33

ORC113 = (ORC104) (RC124) Engine 37

ORC114 = (ORC105) (RC128) Engine 103

ORC115 = (ORC105) (RC130) Engine 105

ORC116 = (ORC106) (RC112) Engine 19

ORC117 = (ORC106) (RC104) Engine 27

ORC118 = (ORC106) (RC120) Engine 35

ORC119 = (ORC107) (RC108) Engine 29

ORC120 = (ORC107) (RC116) Engine 17

ORC121 = (ORC107) (RC126) Engine 39

5.4.2 Oxidizer operating functional paths - aft left RCS. The oxidizer operating functional paths are similar to the fuel operating functional paths and are compiled as follows.

The common path to the tank isolation valve is:

ORC122 = (RC71) (RC73 + RC75) (RC77) (RC79 (RC83)

The common oxidizer paths through the tank isolation paths are:

ORC123 = (ORC122) (RC85 + RC89)

ORC124 = (ORC122) (RC87)

The common oxidizer paths to the oxidizer manifolds are:

ORC125 = (ORC123) (RC91) Manifold A

ORC126 = (ORC123) (RC93) Manifold B

ORC127 = (ORC123) (RC95) Manifold E

ORC128 = (ORC124) (RC97) Manifold C

ORC129 = (ORC124) (RC99) Manifold D

The oxidizer operating functional flow paths to the engines are defined as follows:

ORC130 = (ORC125) (RC107)   Engine 25

ORC131 = (ORC125) (RC115)   Engine 23

ORC132 = (ORC125) (RC123)   Engine 31

ORC133 = (ORC126) (RC111)   Engine 21

ORC134 = (ORC126) (RC119)   Engine 33

ORC135 = (ORC126) (RC125)   Engine 37

ORC136 = (ORC127) (RC129)   Engine 103

ORC137 = (ORC127) (RC131)   Engine 105

ORC138 = (ORC128) (RC113)   Engine 19

ORC139 = (ORC128) (RC105)   Engine 27

ORC140 = (ORC128) (RC121)   Engine 35

ORC141 = (ORC129) (RC109)   Engine 29

ORC142 = (ORC129) (RC117)   Engine 17

ORC143 = (ORC129) (RC127)   Engine 39

5.4.3 Fuel operating functional paths - aft right RCS. The operating functional fuel path from the helium source to the propellant tank SOV's is common to all 14 engines, and is identified as:

ORC200 = (RC150) (RC152 + RC154) (RC156) (RC158) (RC162)

The operating functional fuel flow path divides into two paths at the tank SOV's. They are defined as follows:

ORC201 = (ORC200) (RC164 + RC166)

ORC202 = (ORC200) (RC168)

The five operating functional fuel flow paths to the fuel manifolds are defined by:

ORC203 =	(ORC201)	(RC170)	Manifold A
ORC204 =	(ORC201)	(RC172)	Manifold B
ORC205 =	(ORC201)	(RC174)	Manifold E
ORC206 =	(ORC202)	(RC176)	Manifold C
ORC207 =	(ORC202)	(RC178)	Manifold D

The complete operating functional fuel flow paths for the engines are given below:

ORC208 =	(ORC203)	(RC188)	Engine 26
ORC209 =	(ORC203)	(RC196)	Engine 24
ORC210 =	(ORC203)	(RC206)	Engine 38
ORC211 =	(ORC204)	(RC186)	Engine 28
ORC212 =	(ORC204)	(RC194)	Engine 22
ORC213 =	(ORC204)	(RC202)	Engine 32
ORC214 =	(ORC205)	(RC208)	Engine 104
ORC215 =	(ORC205)	(RC210)	Engine 106
ORC216 =	(ORC206)	(RC190)	Engine 20
ORC217 =	(ORC206)	(RC189)	Engine 34
ORC218 =	(ORC206)	(RC204)	Engine 40
ORC219 =	(ORC207)	(RC184)	Engine 30
ORC220 =	(ORC207)	(RC192)	Engine 18
ORC221 =	(ORC207)	(RC200)	Engine 36

5.4.4 <u>Oxidizer operating functional paths - aft right RCS</u>. The oxidizer operating functional flow path from the helium source to tank SOV's is common to all engines and is defined as:

ORC222 = (RC151) (RC153 + RC155) (RC157) (RC159) (RC163)

The oxidizer operating functional flow paths through the tank SOV's are defined as:

ORC223 = (ORC222) (RC165 + RC169)

ORC224 = (ORC222) (RC167)

The oxidizer operating functional flow paths to the oxidizer manifolds are:

ORC225 = (ORC223) (RC171)		Manifold A
ORC226 = (ORC223) (RC173)		Manifold B
ORC227 = (ORC223) (RC175)		Manifold E
ORC228 = (ORC224) (RC177)		Manifold C
ORC229 = (ORC224) (RC179)		Manifold D

The complete oxidizer operating functional flow paths for the engines are given below:

ORC230 = (ORC225) (RC189)		Engine 26
ORC231 = (ORC225) (RC197)		Engine 24
ORC232 = (ORC225) (RC207)		Engine 38
ORC233 = (ORC226) (RC203)		Engine 32
ORC234 = (ORC226) (RC195)		Engine 22
ORC235 = (ORC226) (RC187)		Engine 28
ORC236 = (ORC227) (RC209)		Engine 104

ORC237 = (ORC227) (RC211) Engine 106

ORC238 = (ORC228) (RC205) Engine 40

ORC239 = (ORC228) (RC199) Engine 34

ORC240 = (ORC228) (RC191) Engine 20

ORC241 = (ORC229) (RC185) Engine 30

ORC242 = (ORC229) (RC193) Engine 18

ORC243 = (ORC229) (RC201) Engine 36

6.0 MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION - AFT RCS

6.1 FDA Measurements

Tables 2 and 3 list the primary, correlation, and preconditioning measurements required for fault detection and annunciation for the right and left aft RCS. The tables identify 72 new measurements not included in the Master Measurements List, dated November 16, 1973. Measurement justification is also included in tables 2 and 3. Figures 11 through 14 show the approximate location of the aft RCS measurements.

6.2 Description of Parameters to be Monitored

6.2.1 Helium source pressure. Helium source pressure is used for propellant gauging and is the best overall indicator of system integrity. In the event the source pressure measurement fails, the system status and propellant remaining cannot be determined; therefore, redundant source pressure measurements should be added to the four helium tanks.

6.2.2 Propellant pressures. Helium SOV positions provide a precondition check to determine if the system is static or dynamic. Regulator output is required to isolate leaks and failed components such as regulators, helium SOV's, and vent valves.

Tank outlet pressure provides a correlation check for regulator output pressure.

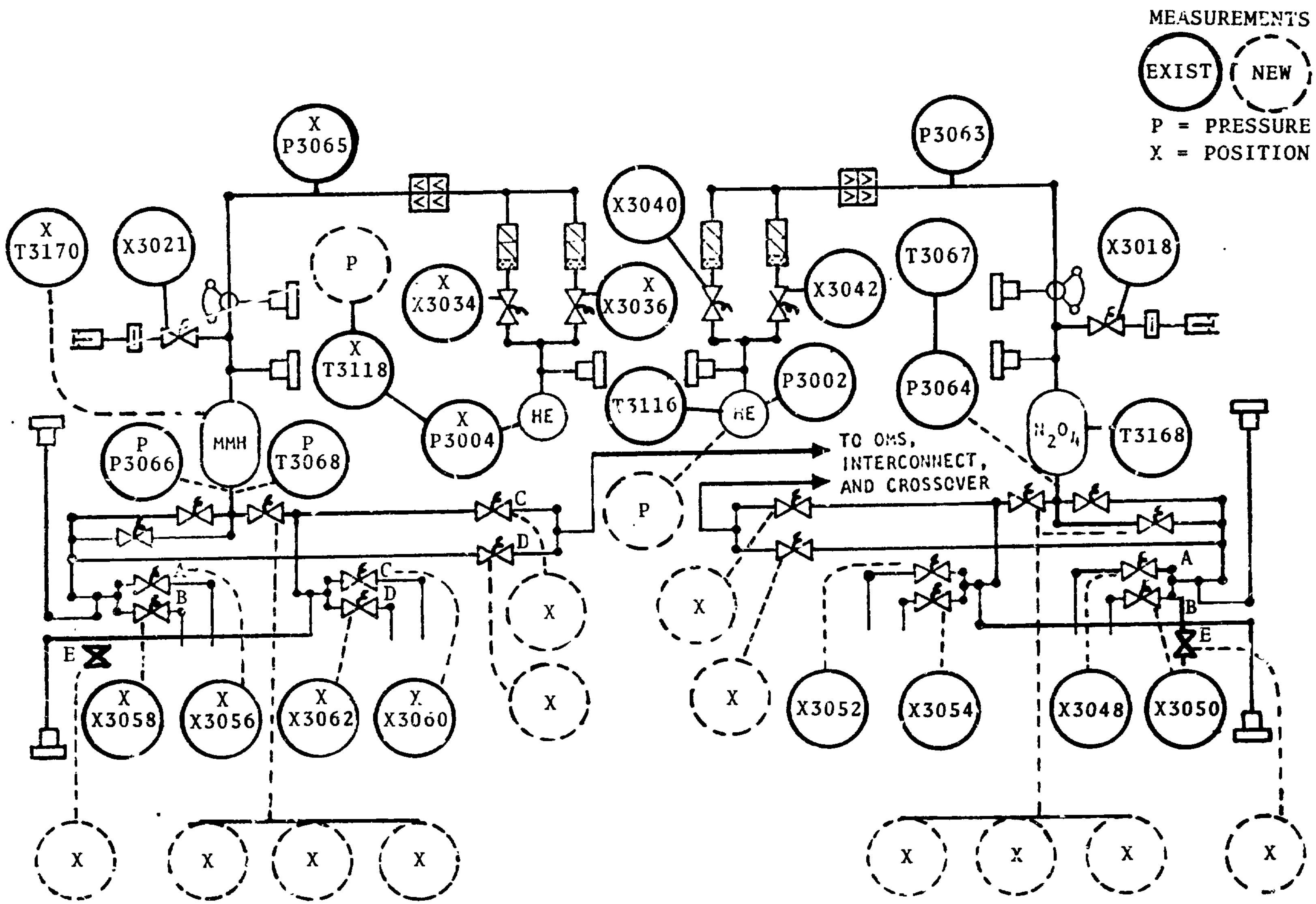

Figure 11. – Left aft RCS measurements for FDA.

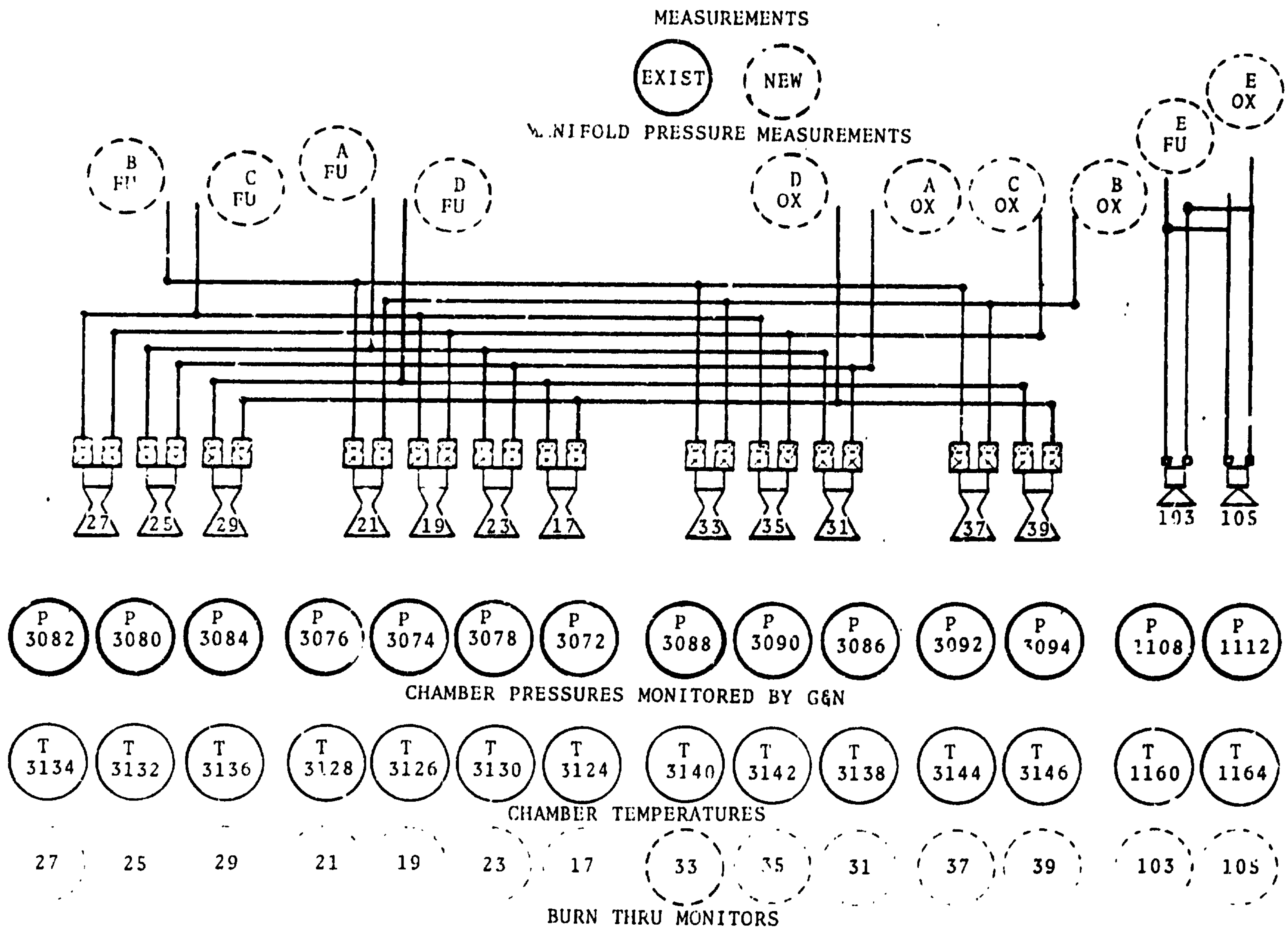

Figure 12. – Left aft RCS manifold measurements for FDA.

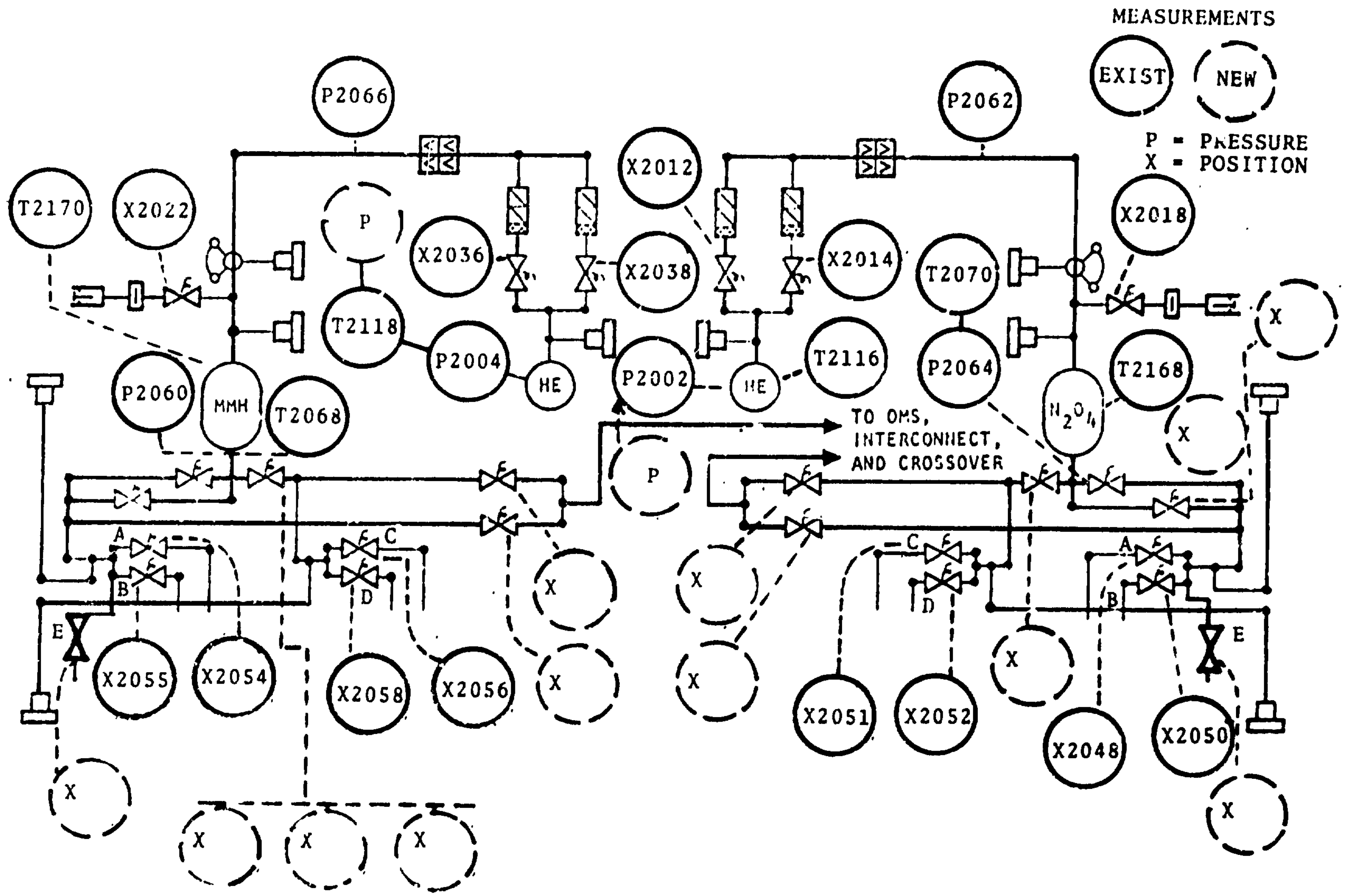

Figure 13. – Right aft RCS measurements for FDA.

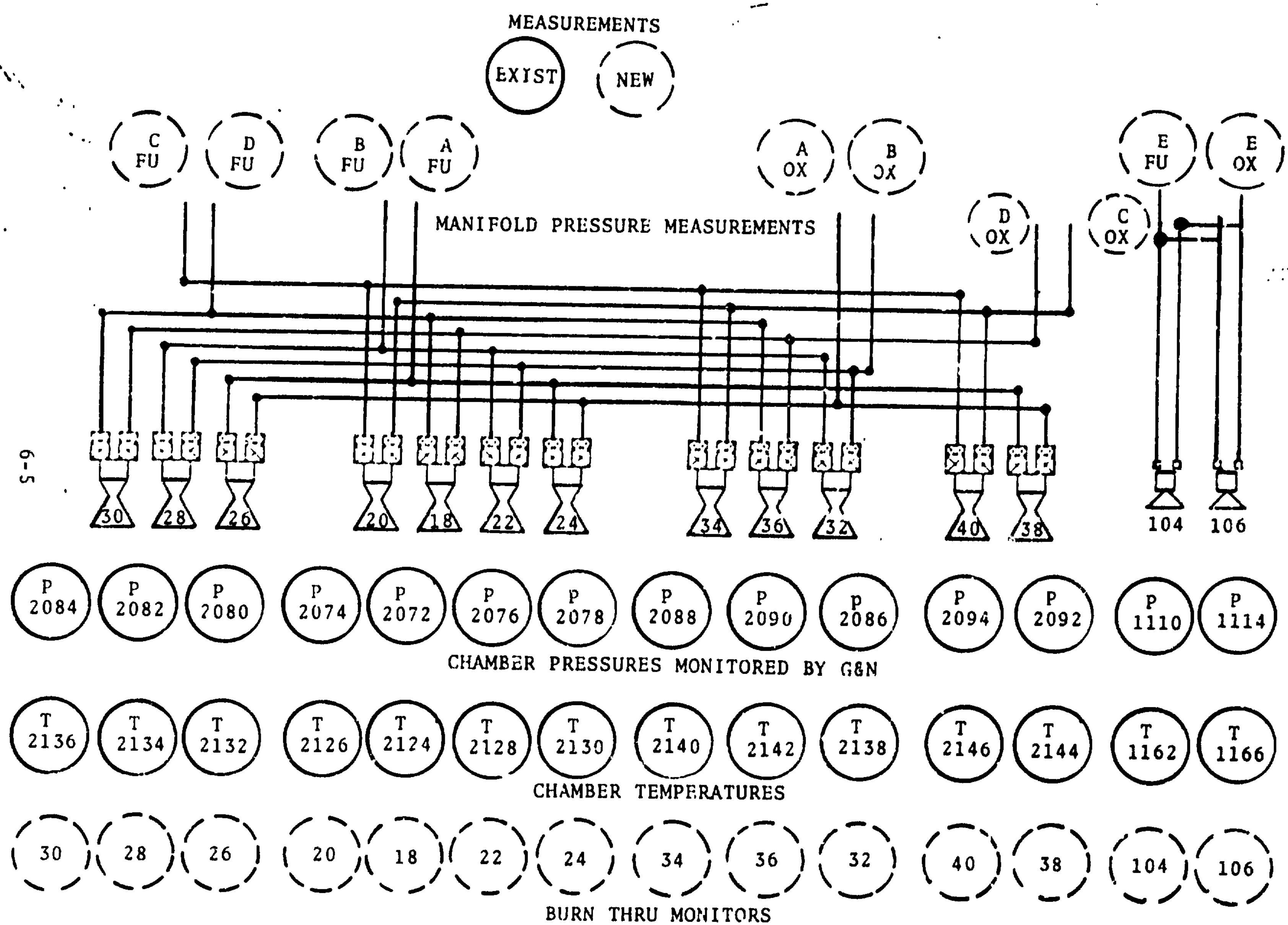

Figure 14. – Right aft RCS measurements.

6.2.3 Manifold pressures. Tank outlet SOV's, manifold isolation valves, and RCS crossfeed valve positions provide precondition checks for manifold pressure checks.

Manifold pressure transducers should be added to provide rapid leak isolation capability and engine inlet pressure monitoring during crossfeed operation. Heat soak back monitoring for isolated manifolds would also be provided by these transducers.

6.2.4 Thruster temperature. Thruster temperature transducers should be monitored for overtemperature during burns and for leak indications during quiescent periods.

In addition, the engine procurement specification provides for burn through monitors on each engine. It is anticipated that they will be monitored by PMS.

6.3 Leak Detection Methods

6.3.1 Quantity remaining. Premission helium profiles are not adequate for helium monitoring. Leaks can be detected by correlating helium source pressure with the quantity of propellant remaining. Since quantity remaining is gauged by helium pressure, volume, and temperature, quantity measurements become inaccurate when a leak is introduced into the system. A thruster-on time multiplied by flow rate calculation should be correlated with quantity remaining. Care must be exercised to charge propellant to the proper tanks during crossfeed operation.

6.3.2 Delta pressure. The helium source pressure delta for fuel and oxidizer should be nearly constant, since equal volumes of fuel and oxidizer are being consumed. A change in the delta pressure is indicative of a leak.

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status**
V42P2004A RCS R-aft He fuel tank pressure	P			Propellant remaining dependent			RC150 ORC200	System status propellant gauging leak monitoring	
RCS R-aft He fuel tank pressure #2	P			Propellant remaining dependent			RC150 ORC200	Status and gauging lost if P2004A fails	N
V42P2002A RCS R-aft He oxid tank pressure	P			Propellant remaining dependent			RC151 ORC222	System status propellant gauging leak monitoring	
RCS R-aft He oxid tank pressure	P			Propellant remaining dependent			RC151 ORC222	Status and gauging lost if P2002A fails	N
V42X2012E RCS R-aft He OX rgltr Isln valve 1	X	NA	NA	NA	NA	NA	RC153 ORC222	Position defines type of monitoring static or dynamic	

*P = Primary

C = Correlation

X = Precondition

**N = New Measurement Required

TABLE 2.-- RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42X2014E RCS R-aft He OX rgltr valve 2	X	NA	NA	NA	NA	NA	RC155 ORC222	Position defines type of monitoring static or dynamic	
V42X2018E RCS R-aft He OX RLF valve	X	NA	NA	NA	NA	NA	RC161 ORC222	Safety insures vent line open	
V42X2022E RCS R-aft He fu RLF valve	X	NA	NA	NA	NA	NA	RC160 ORC200	Safety insures vent line open	
V42X2036E RCS R-aft He fuel rgltr Isln valve 1	X	NA	NA	NA	NA	NA	RC152 ORC200	Position defines type of monitoring static or dynamic	
V42X2038E RCS R-aft He fuel rgltr Isln valve 2	X	NA	NA	NA	NA	NA	RC154 ORC200	Position defines type of monitoring static or dynamic	
V42X2048E RCS R-aft oxdzr thruster Isln valve A	P	NA	NA	NA	NA	NA	RC171 ORC225	Isolated manifold monitor	

TABLE 2.– RIGHT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V42X2050E RCS R-aft oxdzr thruster Isln valve B	P	NA	NA	NA	NA	NA	RC173 ORC226	Isolated manifold monitor	
V42X2051E RCS R-aft oxdzr thruster Isln valve C	P	NA	NA	NA	NA	NA	RC177 ORC228	Isolated manifold monitor	
V42X2052E RCS R-aft oxdzr thruster Isln valve D	P	NA	NA	NA	NA	NA	RC179 ORC229	Isolated manifold monitor	
V42X2054E RCS R-aft fu thruster isol valve A	P	NA	NA	NA	NA	NA	RC170 ORC201	Isolated manifold monitor	
V42X2055E RCS R-aft fu thruster isol valve B	P	NA	NA	NA	NA	NA	RC172 ORC204	Isolated manifold monitor	

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42X2056E RCS R-aft fu thruster isol valve C	P	NA	NA	NA	NA	NA	RC176 ORC205	Isolated manifold monitor	
V42X2058E RCS R-aft fu thruster isol valve D	P	NA	NA	NA	NA	NA	RC178 ORC207	Isolated manifold monitor	
V42P2060A RCS R-aft fuel prplt manf press	C	TBD	TBD	TBD	TBD	NA	ORC200	Correlation CK for RGLTR pressure	
V42P2066A RCS R-aft fuel rgltr outlet press	P	TBD	TBD	300 psia	270 psia	P2060A	ORC200	Tank over-pressure monitor leak detection	
V42P2062A RCS R-aft oxdzr rgltr outlet press	P	TBD	TBD	300 psia	270 psia	P2064A +1	ORC222	Tank over-pressure monitor leak detection	
V42P2064A RCS R-aft oxdzr prplt manf press	C	TBD	TBD	TBD	TBD	NA	ORC222	Correlation for P2062A	

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T2068A RCS R-aft fuel mani-fold temp	P	TBD	TBD	TBD	TBD	P2170A	ORC200	Heat and cold soak	
V42T2070A RCS R-aft oxdzr mani-fold temp	P	TBD	TBD	TBD	TBD	P2168A	ORC222	Heat and cold soak	
V42T2116A RCS R-aft He oxdzr tk temp	P	TBD	TBD	TBD	TBD	NA	RC151	Heat and cold soak	
V42T2118A RCS R-aft He fuel tank temp	P	TBD	TBD	TBD	TBD	NA	RC150	Heat and cold soak	
V42T2124A RCS R-aft thruster injn temp No 18	P	TBD	TBD	TBD	TBD	NA	ORC220 ORC242	Temp and leak monitor	
V42T2126A RCS R-aft thruster injn temp No 20	P	TBD	TBD	TBD	TBD	NA	ORC216 ORC240	Temp and leak monitor	

TABLE 2.– RIGHT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation	Operating functional path	Justification	Status
		High	low	High	low	measurement			
V42T2128A RCS R-aft thruster injr temp No 22	P	TBD	TBD	TBD	TBD	NA	ORC234 ORC212	Temp and leak monitor	
V42T2130A RCS R-aft thruster injr temp No 24	P	TBD	TBD	TBD	TBD	NA	ORC231 ORC209	Temp and leak monitor	
V42T2132A RCS R-aft thruster injr temp No 26	P	TBD	TBD	TBD	TBD	NA	ORC208 ORC230	Temp and leak monitor	
V42T2134A RCS R-aft thruster injr temp No 28	P	TBD	TBD	TBD	TBD	NA	ORC211 ORC235	Temp and leak monitor	
V42T2136A RCS R-aft thruster injr temp No 30	P	TBD	TBD	TBD	TBD	NA	ORC219 ORC241	Temp and leak monitor	
V42T2138A RCS R-aft thruster injr temp No 32	P	TBD	TBD	TBD	TBD	NA	ORC213 ORC233	Temp and leak monitor	

TABLE 2.– RIGHT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T2140A RCS R-aft thruster injr temp No 34	P	TBD	TBD	TBD	TBD	NA	ORC217 ORC239	Temp and leak monitor	
V42T2142A RCS R-aft thruster injr temp No 36	P	TBD	TBD	TBD	TBD	NA	ORC221 ORC243	Temp and leak monitor	
V42T2144A RCS R-aft thruster injr temp No 38	P	TBD	TBD	TBD	TBD	NA	ORC211 ORC232	Temp and leak monitor	
V42T2146A RCS R-aft thruster injr temp No 40	P	TBD	TBD	TBD	TBD	NA	ORC218 ORC238	Temp and leak monitor	
V42T2168A RCS R-aft oxdzr tank shell temp	C	NA	NA	TBD	TBD	NA	ORC163	Correlation for T2070A	
V42T2170A RCS R-aft fuel tank shell temp	C	NA	NA	TBD	TBD	NA	ORC162	Correlation for T2068A	

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
RCS R-aft fuel manifold A	P	TBD	TBD	TBD	TBD	NA	ORC203	Leak isolation	N
RCS R-aft fuel manifold B	P	TBD	TBD	TBD	TBD	NA	ORC204	Leak isolation	N
RCS R-aft fuel manifold C	P	TBD	TBD	TBD	TBD	NA	ORC206	Leak isolation	N
RCS R-aft fuel manifold D	P	TBD	TBD	TBD	TBD	NA	ORC207	Leak isolation	N
RCS R-aft fuel manifold E	P	TBD	TBD	TBD	TBD	NA	ORC205	Leak isolation	N
RCS R-aft ox manifold A	P	TBD	TBD	TBD	TBD	NA	ORC225	Leak isolation	N
RCS R-aft ox manifold B	P	TBD	TBD	TBD	TBD	NA	ORC226	Leak isolation	N
RCS R-aft ox manifold C	P	TBD	TBD	TBD	TBD	NA	ORC228	Leak isolation	N

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS R-aft ox manifold D	P	TBD	TBD	TBD	TBD	NA	ORC229	Leak isolation	N
RCS R-aft ox manifold E	P	TBD	TBD	TBD	TBD	NA	ORC227	Leak isolation	N
RCS R-aft thruster burn thru No 18	P	NA	NA	NA	NA		ORC220 ORC242	Safety	N
RCS R-aft thruster burn thru No 20	P	NA	NA	NA	NA		ORC216 ORC240	Safety	N
RCS R-aft thruster burn thru No 22	P	NA	NA	NA	NA		ORC234 ORC212	Safety	N
RCS R-aft thruster burn thru No 24	P	NA	NA	NA	NA		ORC231 ORC209	Safety	N
RCS R-aft thruster burn thru No 26	P	NA	NA	NA	NA		ORC208 ORC230	Safety	N
RCS R-aft thruster burn thru No 28	P	NA	NA	NA	NA		ORC211 ORC235	Safety	N

TABLE 2.– RIGHT AFT RCS MEASUREMENTS FOR FDA -- Continued

Measurement	* Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS R-aft thruster burn thru No 30	P	NA	NA	NA		NA	ORC219 ORC241	Safety	N
RCS R-aft thruster burn thru No 32	P	NA	NA	NA		NA	ORC213 ORC233	Safety	N
RCS R-aft thruster burn thru No 34	P	NA	NA	NA		NA	ORC217 ORC23[illegible]	Safety	N
RCS R-aft thruster burn thru No 36	P	NA	NA	NA		NA	ORC221 ORC243	Safety	N
RCS R-aft thruster burn thru No 38	P	NA	NA	NA		NA	ORC211 ORC232	Safety	N
RCS R-aft thruster burn thru No 40	P	NA	NA	NA		NA	ORC218 ORC238	Safety	N
RCS R-aft thruster burn thru No 104	P	NA	NA	NA		NA	ORC236 ORC214	Safety	N
RCS R-aft thruster burn thru No 106	P	NA	NA	NA		NA	ORC237 ORC215	Safety	N

TABLE 2.— RIGHT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS R-aft E fu manifold Isln valve position	P	NA	NA	NA	NA	NA	RC174 ORC205	Failed manifold monitor	N
RCS R-aft E OX manifold Isln valve position	P	NA	NA	NA	NA	NA	RC175 ORC227	Failed manifold monitor	N
RCS R-aft vernier 104 temp	P	TBD	TBD	TBD	TBD	NA	ORC236 ORC214	Over temperature and leak monitor	N
RCS R-aft vernier 106 temp	P	TBD	TBD	TBD	TBD	NA	ORC237 ORC215	Over temperature and leak monitor	N
RCS R-aft fu tank SOV 1	X	NA	NA	NA	NA	NA	ORC202	Configuration	N
RCS R-aft fu tank SOV 2	X	NA	NA	NA	NA	NA	ORC201	Configuration	N
RCS R-aft fu tank SOV 3	X	NA	NA	NA	NA	NA	ORC201	Configuration	N

TABLE 2.– RIGHT AFT RCS MEASUREMENTS FOR FDA – Concluded

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS R-aft ox tank SOV 1	X	NA	NA	NA	NA	NA	ORC224	Configuration	N
RCS R-aft ox tank SOV 2	X	NA	NA	NA	NA	NA	ORC223	Configuration	N
RCS R-aft ox tank SOV 3	X	NA	NA	NA	NA	NA	ORC223	Configuration	N

TABLE 3.– LEFT AFT RCS MEASUREMENTS FOR FDA

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status**
V42P3002A RCS L-aft He oxdzr tk press	P	TBD	TBD	Propellant remaining dependent			RC71 ORC122	System status propellant gauging leak monitor	
RCS L-aft He oxdzr tk press	P	TBD	TBD	Propellant remaining dependent		P3002A	RC71 ORC122	Status and gauging lost if P3002A fails	N
V42X3018E RCS L-aft He ox RLF Isln valve	X	NA	NA	NA	NA	NA	RC81	Safety insures tank vent line open	
V42X3021E RCS L-aft He fu RLF Isln valve	X	NA	NA	NA	NA	NA	RC80	Safety insures tank vent line open	
V42X3034E RCS L-aft He fu RGLTR Isln valve 1	X	NA	NA	NA	NA	NA	RC72 RC100	Position defines type of monitoring static or dynamic	
V42X3036E RCS L-aft He fu RGLTR Isln valve 2	X	NA	NA	NA	NA	NA	RC74 RC100	Position defines type of monitoring static or dynamic	

*P = Primary

C = Correlation

X = Precondition

**N = New Measurement Required

TABLE 3.– LEFT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42X3040E RCS L-aft He ox RGLTR Isln valve 1	X	NA	NA	NA	NA	NA	RC73 ORC122	Position defines type of monitoring static or dynamic	
V42X3042E RCS L-aft He ox RGLTR Isln valve 2	X	NA	NA	NA	NA	NA	RC75 ORC122	Position defines type of monitoring static or dynamic	
V42P3004A RCS L-aft He fuel tk press	P	TBD	TBD	Propellant remaining dependent			RC70 RC100	System status propellant gauging leak monitor	
RCS L-aft He fuel tk press #2	P	TBD	TBD	Propellant remaining dependent		P3004A	RC70 RC100	System status and propellant gauging lost if P3004A fails	N
V42X3048E RCS L-aft oxdzr thruster Isln valve A	P	NA	NA	NA	NA		RC91 ORC125	Isolated manifold monitor	
V42X3050E RCS L-aft oxdzr thruster Isln valve B	P	NA	NA				RC93 ORC126	Isolated manifold monitor	

TABLE 3.— LEFT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42X3052E RCS L-aft oxdzr thruster Isln valve C	P	NA	NA	NA	NA	NA	RC97 ORC128	Isolated manifold monitor	
V42X3054E RCS L-aft oxdzr thruster Isln valve D	P	NA	NA	NA	NA	NA	RC99 ORC129	Isolated manifold monitor	
V42X3056E RCS L-aft fu thruster Isln valve A	P	NA	NA	NA	NA	NA	RC94 ORC103	Isolated manifold monitor	
V42X3058E RCS L-aft fu thruster Isln valve B	P	NA	NA	NA	NA	NA	RC92. ORC104	Isolated manifold monitor	
V42X3060E RCS L-aft fu thruster Isln valve C	P	NA	NA	NA	NA	NA	RC96 ORC106	Isolated manifold monitor	
V42X3062E RCS L-aft fu thruster Isln valve D	P	NA	NA	NA	NA	NA	RC98 ORC107	Isolated manifold monitor	

TABLE 3.— LEFT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42P3063A RCS L-aft ox RGLTR outlet press	P	TBD	TBD	300 psia	270 psia	P3064A	RC73 RC75 RC122	Tank overpress leak isolation	
V42P3064A RCS L-aft ox PRPLT manf press	C	TBD	TBD	300 psia	270 psia	NA	RC73 RC75 ORC122	Correlation for P3063A	
V42P3065A RCS L-aft fuel RGLTR outlet press	P	TBD	TBD	300 psia	270 psia	P3066A	RC72 RC74 ORC100	Tank overpress leak isolation	
V42P3066A RCS L-aft fuel PRPLT manf press	C	TBD	TBD	300 psia	270 psia	NA	RC72 RC74 ORC100	Correlation for P3065A	
V42T3067A RCS L-aft ox manf temp	P	TBD	TBD	TBD	TBD	T3116A	ORC122	Heat and cold soak	
V42T3068A RCS L-aft fuel manf temp	P	TBD	TBD	TBD	TBD	T3118A	ORC100	Heat and cold soak	

TABLE 3.— LEFT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T3116A RCS L-aft He ox tk temp	C	TBD	TBD	TBD	TBD	NA	RC71	Correlation for T3067A	
V42T3118A RCS L-aft He fuel tk temp	C	TBD	TBD	TBD	TBD	NA	RC70	Correlation for T3068A	
V42T3124A RCS L-aft thruster injr temp No 17	P	TBD	TBD	TBD	TBD	NA	ORC142 ORC120	Temp and leak monitor	
V42T3126A RCS L-aft thruster injr temp No 19	P	TBD	TBD	TBD	TBD	NA	ORC138 ORC116	Temp and leak monitor	
V42T3128A RCS L-aft thruster injr temp No 21	P	TBD	TBD	TBD	TBD	NA	ORC133 ORC111	Temp and leak monitor	
V42T3130A RCS L-aft thruster injr temp No 23	P	TBD	TBD	TBD	TBD	NA	ORC131 ORC109	Temp and leak monitor	

TABLE 3.– LEFT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V42T3132A RCS L-aft thruster injr temp No 25	P	TBD	TBD	TBD	TBD	NA	ORC130 ORC108	Temp and leak monitor	
V42T3134A RCS L-aft thruster injr temp No 27	P	TBD	TBD	TBD	TBD	NA	ORC139 ORC117	Temp and leak monitor	
V42T3136A RCS L-aft thruster injr temp No 29	P	TBD	TBD	TBD	TBD	NA	ORC141 ORC119	Temp and leak monitor	
V42T3138A RCS L-aft thruster injr temp No 31	P	TBD	TBD	TBD	TBD	NA	ORC132 ORC110	Temp and leak monitor	
V42T3140A RCS L-aft thruster injr temp No 33	P	TBD	TBD	TBD	TBD	NA	ORC134 ORC112	Temp and leak monitor	
V42T3142A RCS L-aft thruster injr temp No 35	P	TBD	TBD	TBD	TBD	NA	ORC140 ORC118	Temp and leak monitor	

TABLE 3.— LEFT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V42T3144A RCS L-aft thruster injr temp No. 37	P	TBD	TBD	TBD	TBD	NA	ORC135 ORC113	Temp and leak monitor	
V42T3146A RCS L-aft thruster injr temp No 39	P	TBD	TBD	TBD	TBD	NA	ORC143 ORC121	Temp and leak monitor	
V42T3168A RCS L-aft oxid tank shell temp	P	TBD	TBD	TBD	TBD	NA	RC83	Heat and cold soak	
V42T3170A RCS L-aft fuel tank shell temp	P	TBD	TBD	TBD	TBD	NA	RC82	Heat and cold soak	
Burn thru thruster 17	P	NA	NA	NA	NA	NA	ORC142 ORC120	Safety	N
Burn thru thruster 19	P	NA	NA	NA	NA	NA	ORC138 ORC116	Safety	N
Burn thru thruster 21	P	NA	NA	NA	NA	NA	ORC133 ORC111	Safety	N
Burn thru thruster 23	P	NA	NA	NA	NA	NA	ORC131 ORC109	Safety	N

TABLE 3.— LEFT AFT RCS MEASUREMENTS FOR FDA — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
Burn thru thruster 25	P	NA	NA	NA	NA	NA	ORC130 ORC108	Safety	N
Burn thru thruster 27	P	NA	NA	NA	NA	NA	ORC139 ORC117	Safety	N
Burn thru thruster 29	P	NA	NA	NA	NA	NA	ORC141 ORC119	Safety	N
Burn thru thruster 31	P	NA	NA	NA	NA	NA	ORC132 ORC110	Safety	N
Burn thru thruster 33	P	NA	NA	NA	NA	NA	ORC134 ORC112	Safety	N
Burn thru thruster 35	P	NA	NA	NA	NA	NA	ORC140 ORC118	Safety	N
Burn thru thruster 37	P	NA	NA	NA	NA	NA	ORC135 ORC113	Safety	N
Burn thru thruster 39	P	NA	NA	NA	NA	NA	ORC143 ORC121	Safety	N
Burn thru thruster 103	P	NA	NA	NA	NA	NA	ORC136 ORC114	Safety	N
Burn thru thruster 105	P	NA	NA	NA	NA	NA	ORC137 ORC115	Safety	N

TABLE 3.– LEFT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS L-aft fuel manifold A	P	TBD	TBD	TBD	TBD	NA	ORC103	Leak isolation	N
RCS L-aft fuel manifold B	P	TBD	TBD	TBD	TBD	NA	ORC104	Leak isolation	N
RCS L-aft fuel manifold C	P	TBD	TBD	TBD	TBD	NA	ORC106	Leak isolation	N
RCS L-aft fuel manifold D	P	TBD	TBD	TBD	TBD	NA	ORC107	Leak isolation	N
RCS L-aft fuel manifold E	P	TBD	TBD	TBD	TBD	NA	ORC105	Leak isolation	N
RCS L-aft ox manifold A	P	TBD	TBD	TBD	TBD	NA	ORC125	Leak isolation	N
RCS L-aft ox manifold B	P	TBD	TBD	TBD	TBD	NA	ORC126	Leak isolation	N
RCS L-aft ox manifold C	P	TBD	TBD	TBD	TBD	NA	ORC128	Leak isolation	N

TABLE 3.– LEFT AFT RCS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
RCS L-aft ox manifold D	P	TBD	TBD	TBD	TBD	NA	ORC129	Leak isolation	N
RCS L-aft ox manifold E	P	TBD	TBD	TBD	TBD	NA	ORC127	Leak isolation	N
RCS L-aft E fu manifold Isln valve position	P	NA	NA	NA	NA	NA	RC90 ORC105	Failed manifold monitor	N
RCS L-aft E ox manifold Isln valve position	P	NA	NA	NA	NA	NA	RC95 ORC127	Failed manifold monitor	N
RCS L-aft vernier 103 temp	P	TBD	TBD	TBD	TBD	NA	ORC136 ORC128	Over temperature and leak monitor	N
RCS L-aft vernier 105 temp	P	TBD	TBD	TBD	TBD	NA	ORC137 ORC130	Over temperature and leak monitor	N
RCS L-aft fu tank SOV 1	X	NA	NA	NA	NA	NA	ORC101	Configuration	N

TABLE 5.— LEFT AFT RCS MEASUREMENTS FOR FDA — Concluded

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
RCS L-aft fu tank SOV 2	X	NA	NA	NA	NA	NA	ORC102	Configuration	N
RCS L-aft fu tank SOV 3	X	NA	NA	NA	NA	NA	ORC102	Configuration	N
RCS L-aft ox tank SOV 1	X	NA	NA	NA	NA	NA	ORC124	Configuration	N
RCS L-aft ox tank SOV 2	X	NA	NA	NA	NA	NA	ORC123	Configuration	N
RCS L-aft ox tank SOV 3	X	NA	NA	NA	NA	NA	ORC123	Configuration	N

7.0 RCS CROSSFEED OPERATION

7.1 Configuration

Additional fuel and oxidizer functional flow paths to the RCS manifolds are available from each tank on the crossfeed line.

The crossfeed configuration is shown in figures 15 and 16.

7.2 Operational Guidelines

To avoid propellant transfer due to differential pressure, only one propellant tank at a time is connected to its respective crossfeed line. To insure equal manifold pressure, the fuel and oxidizer tank connected to their respective crossfeed line are from the same subsystem.

The left and right aft RCS may be operated simultaneously from the crossfeed lines.

7.3 Crossfeed Components

Two additional shut-off valves connect each crossfeed line to the aft left and right RCS. These valves are identified as RC301 through RC308 (see figs. 15 and 16).

7.4 Propellant Operating Functional Paths for RCS Crossfeed

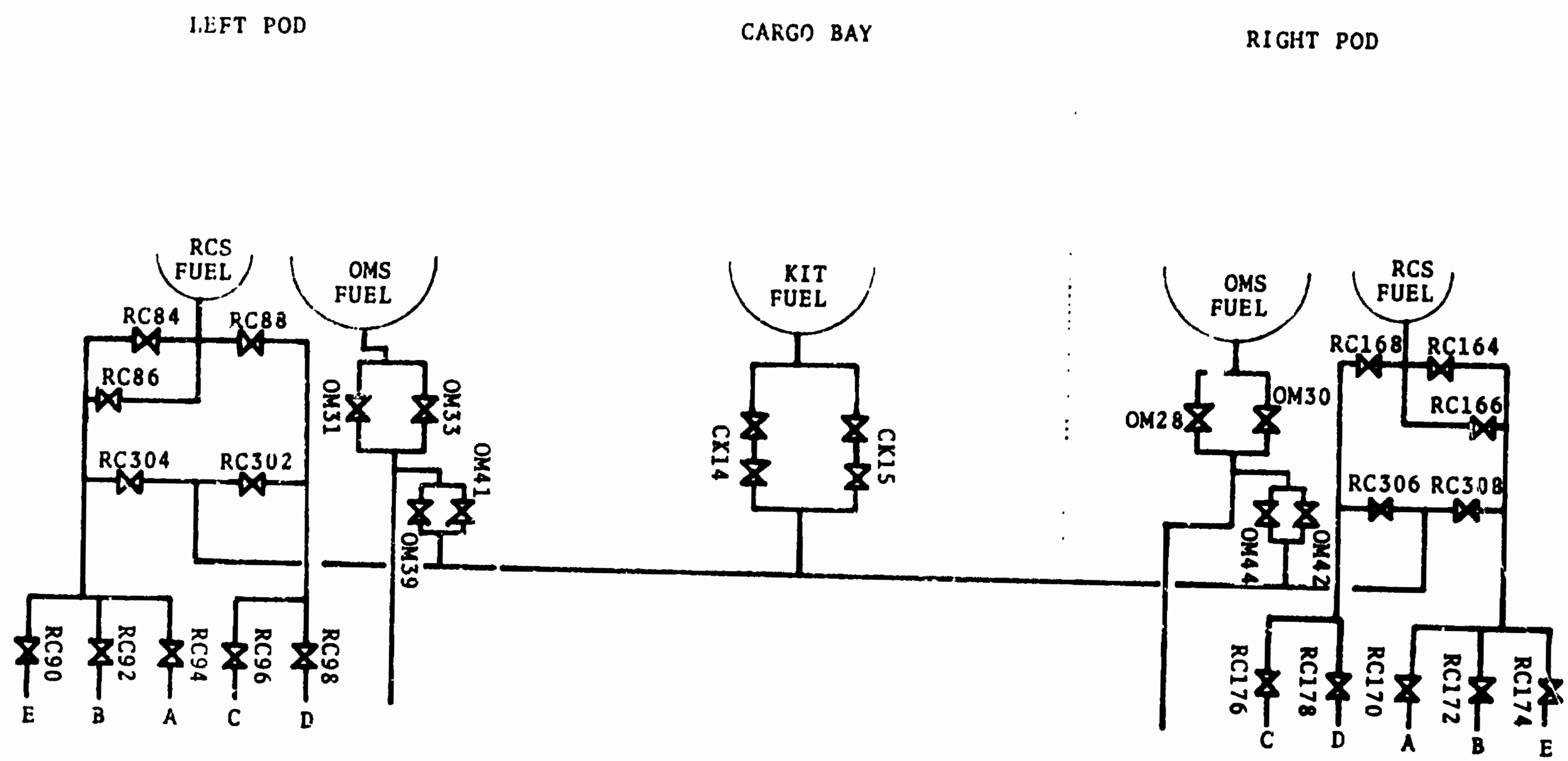

Figure 15. – Fuel crossfeed.

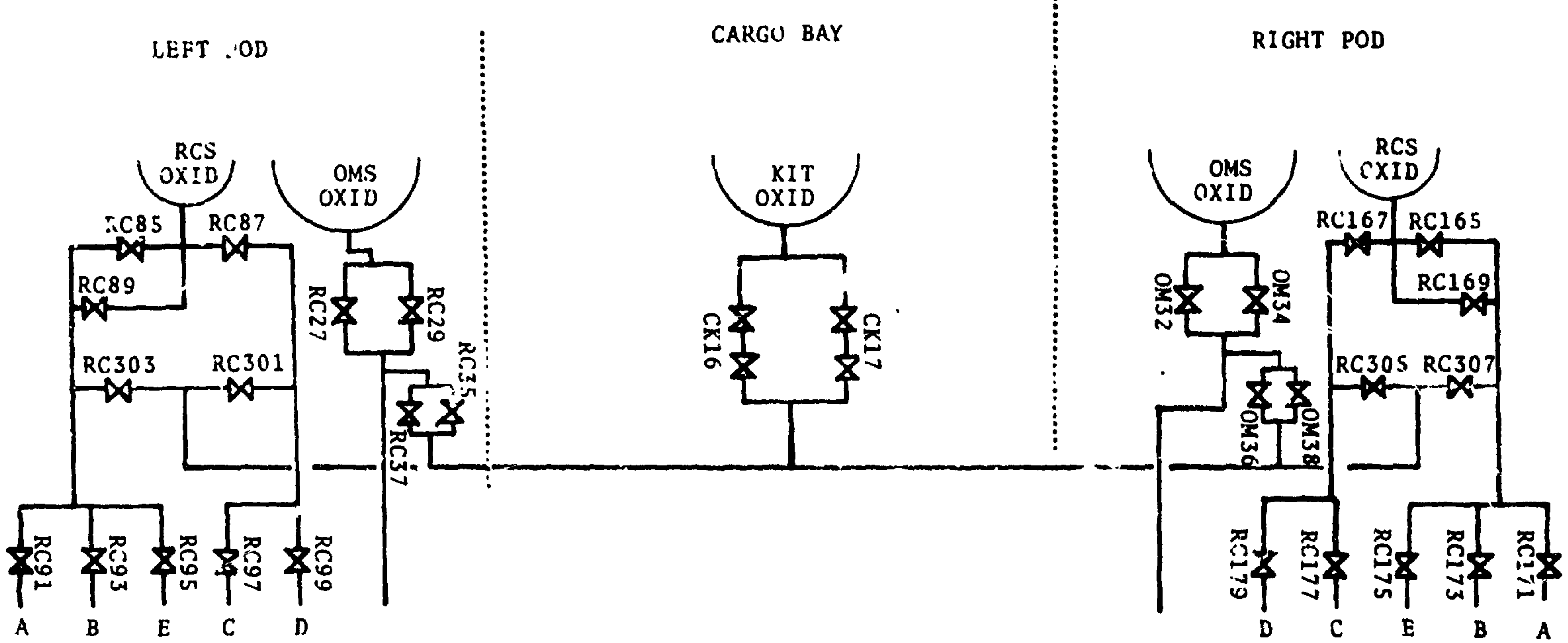

Figure 16. — Oxidizer crossfeed.

7.4.1 <u>RCS fuel tanks to crossfeed line</u>. The fuel operating functional paths from the tanks to the crossfeed lines are defined as follows:

Left aft RCS (ref. section 5.4.1)

ORC320 = (ORC100) [(RC84 + RC86) (RC304) + (RC88) (RC302)]

Right aft RCS (ref. section 5.4.3)

ORC300 = (ORC200) [(RC164 + RC166) (RC308) + (RC168) (RC306)]

7.4.2 <u>RCS oxidizer tanks to crossfeed lines</u>. The oxidizer functional paths from the tanks to the crossfeed lines are defined as follows:

Left aft RCS (ref. section 5.4.2)

ORC321 = (ORC122) [(RC85 + RC89) (RC303) + (RC87) (RC301)]

Right aft RCS (ref. section 5.4.4)

ORC301 = (ORC222) [(RC165 + RC169) (RC307) + (RC167) (RC305)]

7.4.3 <u>Crossfeed from aft right RCS tanks to aft left RCS manifolds</u>. The operating functional flow paths from the right aft RCS propellant tanks to the left aft RCS manifolds are given below (ref. sections 7.4.1 and 7.4.2):

- A Fuel Manifold
  ORC302 = (ORC300) (RC304) (RC94)
- B Fuel Manifold
  ORC303 = (ORC300) (RC304) (RC92)

- E Fuel Manifold
  ORC304 = (ORC300) (RC304) (RC90)
- C Fuel Manifold
  ORC305 = (ORC300) (RC302) (RC96)
- D Fuel Manifold
  ORC306 = (ORC300) (RC302) (RC98)
- A Oxidizer Manifold
  ORC307 = (ORC301) (RC303) (RC91)
- B Oxidizer Manifold
  ORC308 = (ORC301) (RC303) (RC93)
- E Oxidizer Manifold
  ORC309 = (ORC301) (RC303) (RC95)
- C Oxidizer Manifold
  ORC310 = (ORC301) (RC301) (RC97)
- D Oxidizer Manifold
  ORC311 = (ORC301) (RC301) (RC99)

7.4.4 Crossfeed from aft left RCS tanks to aft right RCS manifolds. The operating functional flow paths from the left aft RCS propellant tanks to the right aft RCS manifolds are given below (ref. sections 7.4.1 and 7.4.2):

- A Fuel Manifold
  ORC322 = (ORC320) (RC308) (RC170)
- B Fuel Manifold
  ORC323 = (ORC320) (RC308) (RC172)
- E Fuel Manifold
  ORC324 = (ORC320) (RC308) (RC174)

- C Fuel Manifold
  ORC325 = (ORC320) (RC306) (RC176)
- D Fuel Manifold
  ORC326 = (ORC320) (RC306) (RC178)
- A Oxidizer Manifold
  ORC327 = (ORC321) (ORC307) (RC171)
- B Oxidizer Manifold
  ORC328 = (ORC321) (ORC307) (RC173)
- E Oxidizer Manifold
  ORC329 = (ORC321) (ORC307) (RC175)
- C Oxidizer Manifold
  ORC330 = (ORC321) (ORC305) (RC177)
- D Oxidizer Manifold
  ORC331 = (ORC321) (ORC305) (RC179)

7.5 Measurements

No additional measurements are required for RCS cross-feed operation.

8.0 RCS, OMS INTERCONNECT OPERATION

8.1 Functional Paths for OMS/RCS Interconnect

The OMS functional paths used for RCS interconnect are shown in figure 17. Th are identified as OMXX. Functional paths are combined into operating functional paths and identified as OOMXX.

8.2 Functional Path Analysis of OMS Propellant Path to Crossfeed Lines

OM1 and OM2 are helium source tanks. Each tank has a volume of 15.4 cubic feet. The tanks are pressurized to approximately 4000 psia prior to launch.

OM3 through OM6 are helium isolation shut-off valves in series with a primary and secondary helium regulator. Tank pressure is regulated to approximately 213 psig.

OM7 through OM10 are shut-off valves to isolate oxidizer from the helium manifold during periods when tanks are not in use.

OM11, OM12, OM15, and OM16 are series parallel check valves to isolate propellant from the helium manifold.

OM13, OM14, OM17, and OM18 are manual shut-off valves used for ground servicing only.

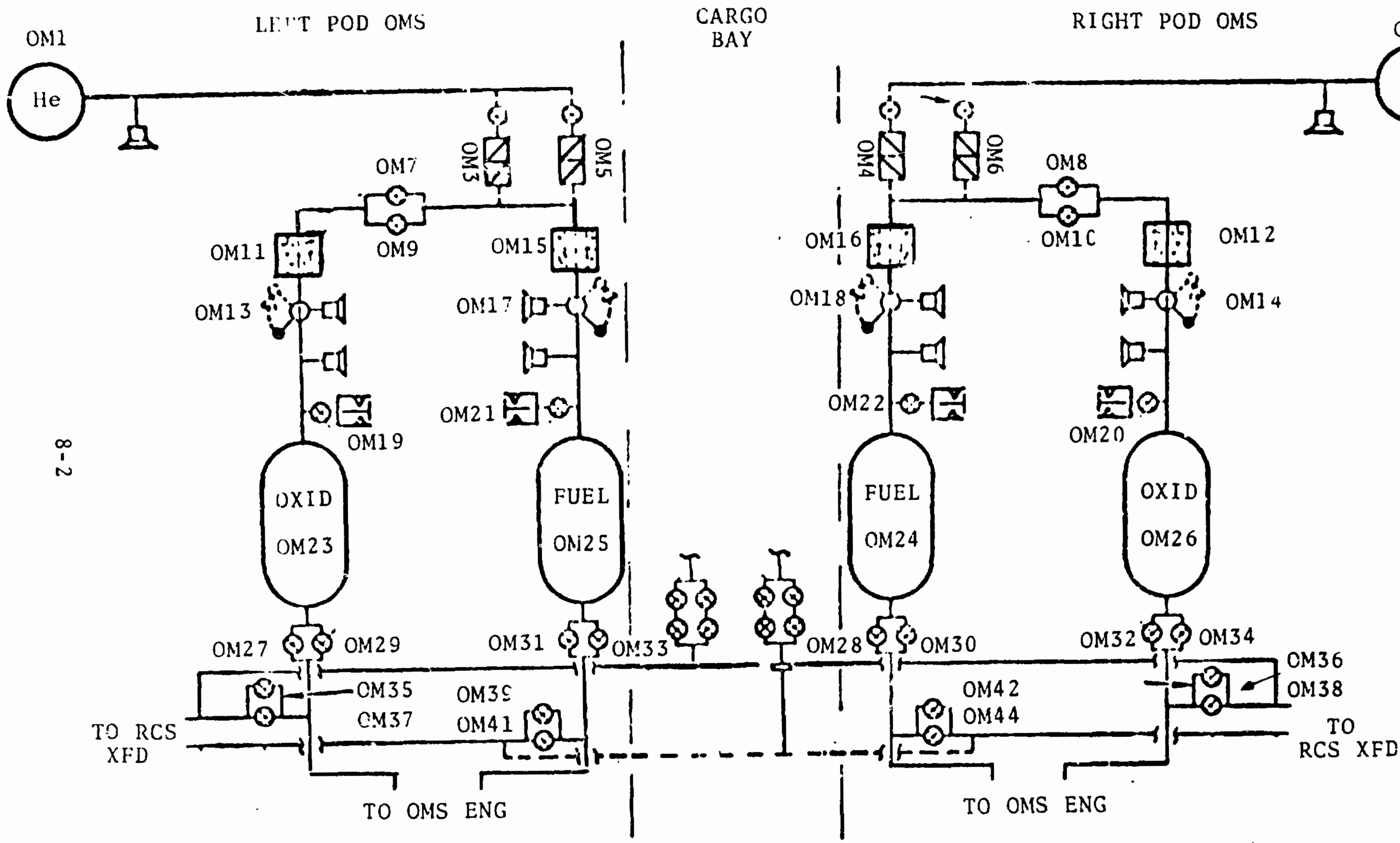

Figure 17. - Functional paths for OMS/RCS interconnect.

OM19 through OM22 are burst disc in series with poppet relief valves for relieving helium overboard, in the event a failure results in over pressurization of the tank.

OM23 through OM26 are propellant holding tanks. Each tank has a volume of approximately 89.5 cubic feet.

OM27 through OM34 are pairs of parallel redundant shut-off valves. Either valve in a pair can flow enough propellant to support an OMS engine burn.

OM35 through OM39 and OM41 through OM44 are pairs of parallel redundant shut-off valves. These valves connect the OMS manifolds to the crossfeed lines.

8.3 OMS Operating Functional Paths to the Crossfeed Lines

Operating functional paths for OMS propellant to the crossfeed lines are defined as follows (see fig. 17):

- Left pod OMS fuel to crossfeed line
  OOM1 = (OM1) (OM3 + OM5) (OM15) (OM17) (OM25)
  (OM31 + OM33) (OM39 + OM41)
- Left pod OMS oxidizer to crossfeed line
  OOM2 = (OM1) (OM3 + OM5) (OM7 + OM9) (OM11) (OM13)
  (OM23) (OM27 + OM29) (OM35 + OM37)
- Right pod OMS fuel to crossfeed line
  OOM3 = (OM2) (OM4 + OM6) (OM16) (OM18) (OM24)
  (OM28 + OM30) (OM42 + OM44)

- Right pod OMS oxidizer to crossfield line
  OOM4 = (OM2) (OM4 + OM6) (OM8 + OM10) (OM12)
  (OM14) (OM26) (OM32 + OM34) (OM36 + OM38)

8.4 Operating Functional Paths for Interconnect Left OMS to Left RCS Manifolds

The operating functional paths for supplying propellant from the left pod OMS tanks to the left pod RCS manifolds are defined as follows (ref. section 8.3):

- Left RCS fuel manifold A
  ORC340 = (OOM1) (RC304) (RC94)
- Left RCS fuel manifold B
  ORC342 = (OOM1) (RC304) (RC92)
- Left RCS fuel manifold E
  ORC344 = (OOM1) (RC304) (RC90)
- Left RCS fuel manifold C
  ORC346 = (OOM1) (RC302) (RC96)
- Left RCS fuel manifold D
  ORC348 = (OOM1) (RC302) (RC98)
- Left RCS oxidizer manifold A
  ORC341 = (OOM2) (RC303) (RC91)
- Left RCS oxidizer manifold B
  ORC343 = (OOM2) (RC303) (RC93)
- Left RCS oxidizer manifold E
  ORC345 = (OOM2) (RC303) (RC95)
- Left RCS oxidizer manifold C
  ORC347 = (OOM2) (RC301) (RC97)

- Left RCS oxidizer manifold D
  ORC349 = (OOM2) (RC301) (RC99)

8.5 Operating Functional Paths for Interconnect Right OMS to Left RCS Manifolds

The operating functional paths for supplying propellant from the right pod OMS tanks to the left pod RCS manifold are defined as follows (ref. section 8.3):

- Left RCS fuel manifold A
  ORC350 = (OOM3) (RC304) (RC94)
- Left RCS fuel manifold B
  ORC352 = (OOM3) (RC304) (RC92)
- Left RCS fuel manifold E
  ORC354 = (OOM3) (RC304) (RC90)
- Left RCS fuel manifold C
  ORC356 = (OOM3) (RC302) (RC96)
- Left RCS fuel manifold D
  ORC358 = (OOM3) (RC302) (RC98)
- Left RCS oxidizer manifold A
  ORC351 = (OOM4) (RC303) (RC91)
- Left RCS oxidizer manifold B
  ORC353 = (OOM4) (RC303) (RC93)
- Left RCS oxidizer manifold E
  ORC355 = (OMM4) (RC303) (RC95)
- Left RCS oxidizer manifold C
  ORC357 = (OMM4) (RC301) (RC97)

- Left RCS oxidizer manifold D
  ORC359 = (OMM4) (RC301) (RC99)

8.6 Operating Functional Paths for Interconnect Left OMS to Right RCS Manifolds

The operating functional paths for supplying propellant from the left OMS pod to the right RCS manifolds are defined as follows (ref. section 8.3):

- Right RCS fuel manifold A
  ORC360 = (OOM1) (RC308) (RC170)
- Right RCS fuel manifold B
  ORC362 = (OOM1) (RC308) (RC172)
- Right RCS fuel manifold E
  ORC364 = (OOM1) (RC308) (RC174)
- Right RCS fuel manifold C
  ORC366 = (OOM1) (RC306) (RC176)
- Right RCS fuel manifold D
  ORC368 = (OOM1) (RC306) (RC178)
- Right RCS oxidizer manifold A
  ORC361 = (OOM2) (RC307) (RC171)
- Right RCS oxidizer manifold B
  ORC363 = (OOM2) (RC307) (RC173)
- Right RCS oxidizer manifold E
  ORC365 = (OOM2) (RC307) (RC175)
- Right RCS oxidizer manifold C
  ORC367 = (OOM2) (RC305) (RC177)

- Right RCS oxidizer manifold D
  ORC369 = (OOM2) (RC305) (RC179)

8.7 Operating Functional Paths for Interconnect Right OMS to Right RCS Manifolds

The operating functional paths for supplying propellant from the right OMS pod to the right RCS manifolds are defined as follows (ref. section 8.3).

- Right RCS fuel manifold A
  ORC370 = (OOM3) (RC308) (RC170)
- Right RCS fuel manifold B
  ORC372 = (OOM3) (RC308) (RC172)
- Right RCS fuel manifold E
  ORC374 = (OOM3) (RC308) (RC174)
- Right RCS fuel manifold C
  ORC376 = (OOM3) (RC306) (RC176)
- Right RCS fuel manifold D
  ORC378 = (OOM3) (RC306) (RC178)
- Right RCS oxidizer manifold A
  ORC371 = (OOM4) (RC307) (RC171)
- Right RCS oxidizer manifold B
  ORC373 = (OOM4) (RC307) (RC173)
- Right RCS oxidizer manifold E
  ORC375 = (OOM4) (RC307) (RC175)
- Right RCS oxidizer manifold C
  ORC377 = (OOM4) (RC305) (RC177)
- Right RCS oxidizer manifold D
  ORC379 = (OOM4) (RC305) (RC179)

8.8 Crossfeed Single Point Failure

During OMS burns when the OMS engines are being supplied propellant (from the cargo bay kit) through the crossfeed lines, the RCS crossfeed valves are a single point failure. If an RCS crossfeed valve fails open, the OMS engine will be supplied from the RCS tank, since it is at a higher pressure than the cargo bay kit. In addition to depleting the RCS propellant, the OMS inlet delta pressure limit will be exceeded.

A study is presently being conducted to determine if this problem can be resolved by changing the RCS and CMS ullage pressure.

8.9 Measurements

The measurements required for fault detection and annunciation for OMS/RCS interconnect operation are given in tables 4 and 5.

Six new measurements have been identified to be added to the Master Measurements List.

Four new measurements are required for monitoring valve position of new tank SOV's that were added to the system. In addition, redundant helium source pressure transducers should be added. System status is lost if helium source pressure cannot be determined.

TABLE 4.– LEFT OMS MEASUREMENTS FOR FDA DURING LEFT OMS/RCS INTERCONNECT

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating function path	Justification	Status**
V43X1215E OMS-L Eng OX Isln valve position	P	NA	NA	NA	NA		OM27 OOM2	Verify propellant flow path	
V43T1263A OMS-L Eng OX XFD line temp	X	TBD	TBD	TBD	TBD		OOM2	Verify line condition	
V43X13[illegible]0E OMS-L Eng He OX Isln valve position	P	NA	NA	NA	NA		OM3 OOM2	Insure flow path	
V43X1316E OMS-L Eng OX dump valve position	X	NA	NA	NA	NA		OOM2	Verify closed line	
V43X1265E OMS-L Eng OX XFD valve 1 position	P	NA	NA	NA	NA		OM35 OOM2	Insure flow path	

*P = Primary
C = Correlation
X = Precondition

**N = New Measurement Required

TABLE 4. - LEFT OMS MEASUREMENTS FOR FDA DURING LEFT OMS/RCS INTERCONNECT - Continued

Measurement	*Use	Soft limit		Hard limit		Correlation	Operating functional	Justification	Status
		High	low	High	low	measurement	path		
V43X1065E OMS-L Eng fuel XFD valve 1	P	NA	NA	NA	NA		OM39 OOM1	Insure flow path	
V43X1068E OMS-L Eng fuel XFD valve 2	P	NA	NA	NA	NA		OM41 OOM1	Insure flow path	
V43T1063A OMS-L Eng fuel XFD line temp	X	TBD	TBD	TBD	TBD		OOM1	Verify line condition	
V43Q1070A OMS-L Eng fuel tank quantity	P			Mission dependent			OOM1	System management	
V43X1072E OMS-L Eng fuel tank low level	P	NA	NA	NA	NA		OOM1	Leak monitor	
V43T1074A OMS-L Eng fuel tank temp	P	TBD	TBD	TBD	TBD		OM25 OOM1	System management	

TABLE 4.– LEFT OMS MEASUREMENTS FOR FDA DURING LEFT OMS/RCS INTERCONNECT – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43Q1270A OMS-L Eng Oxid tank quantity	P			Mission dependent			OOM2	Consumables management leak detection	
V43X1116E OMS-L Eng fuel dump valve position	X	NA	NA	NA	NA		OOM1	Verify closed li. e	
V43X1272E OMS-L Eng OX tank low level	P	TBD	TBD	TBD	TBD		OOM2	System management	
V43T1274A OMS-L Eng OX tank temp - lower	P	TBD	TBD	270	200		OM23 OOM2	Leak detection	
V43P1276A OMS-L Eng OX tank ullage pressure	P	NA	NA	NA	NA		OM23 OOM2	Insure path flow	

TABLE 4. - LEFT OMS MEASUREMENTS FOR FDA DURING LEFT OMS/RCS INTERCONNECT — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43P1076A OMS-L Eng fuel tank ullage pressure	P	TBD	TBD	270	200		OM25 OOM1	Leak monitor	
V43P1100A OMS-L Eng He tank pressure	P	TBD	TBD	Propellant remaining dependent			OM1 OOM1 OOM2	System status leak detection	
V43T1105A OMS-L Eng He tank temp	P	TBD	TBD	TBD	TBD		OM1 OOM1 OOM2	System management	
V43X1110E OMS-L Eng He fuel isln valve position	P	NA	NA	NA	NA		OM3 OOM1 OOM2	Verify flow path	
V43X1114E OMS-L vapor isln valve 1 position	P	NA	NA	NA	NA		OM7 OOM2	Verify flow path	
V43X1115E OMS-L vapor isln valve 2 position	P	NA	NA	NA	NA		OM9 OOM2	Verify flow path	

TABLE 4.- LEFT OMS MEASUREMENTS FOR FDA DURING LEFT OMS/RCS INTERCONNECT — Concluded

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43X1268E OMS-L Eng OX XFD valve 2 position	P	NA	NA	NA	NA		OM37 OOM2	Verify flow path	
OMS-L He tank pressure No 2	P	TBD	TBD	Propellant remaining dependent			OM1 OOM1 OOM2	Loss of P1100A results in loss of system status	N
OMS-L Eng OX Isln valve No 2 position	P	NA	NA	NA	NA		OM3 OOM1 OOM2	Verify flow path	N
OMS-L Eng fuel Isln valve No 2 position	P	NA	NA	NA	NA		OM31 OOM1	Insure open line	N
V43X1015E OMS-L Eng fuel Isln valve position	P	NA	NA	NA	NA		OM33 OOM1	Insure open line	

TABLE 5.– RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status**
V43Q2070A OMS-R Eng fuel tank quantity	P			Mission dependent			OM24 OOM3	Consumables management leak detection	
V43X2072E OMS-R Eng fuel tank low level	P	NA	NA	NA	NA		OOM3	Insure no propellant depletion	
V43T2074A OMS-R Eng fuel tank temp	P	TBD	TBD	TBD	TBD		OM24	System management	
V43P2070A OMS-R Eng fuel tank ullage pressure	P	TBD	TBD	270	200		OM24 OOM3	Leak monitor	
V43T2105A OMS-R Eng He tank temp	P	TBD	TBD	TBD	TBD		OM2	System management	

*P = Primary

C = Correlation

X = Precondition

**N = New Measurement Required

TABLE 5.– RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43P2100A OMS-R Eng He tank pressure No 1	P	TBD	TBD	Propellant remaining dependent			OM2 OOM3 OOM4	System status leak check	
OMS-R Eng He tank pressure No 2	P	TBD	TBD	Propellant remaining dependent			OM2 OOM3 OOM4	Loss of P2100 would result in loss of status	N
V43X2110E OMS-R Eng He fuel isln valve position	P	NA	NA	NA	NA		OM4 OOM3	Verify flow path	
V43X2114E OMS-R Vapor isln valve No 1 position	P	NA	NA	NA	NA		OM8 OOM4	Verify flow path	
V43X2115E OMS-R Vapor isln valve No 2 position	P	NA	NA	NA	NA		OM10 OOM4	Verify flow path	

TABLE 5.– RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V43Q2270A OMS-R Eng OX tank quantity	P			Mission dependent			OM26 OOM4	Consumables management leak detection	
V43X2272E OMS-R Eng OX tank low level	P	NA	NA	NA	NA		OOM4	Insure no propellant depletion	
V43T2274A OMS-R Eng OX tank temp	P	TBD	TBD	TBD	TBD		OM26	System management	
V43P2276A OMS-R Eng OX tank ullage pressure	P	TBD	TBD	270	200		OM26 OOM4	Leak detection	
V43X2310E OMS-R Eng He OX isln valve position	P	NA	NA	NA	NA		OOM4	Insure path flow	

TABLE 5.— RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43X2116E OMS-R Eng fuel dump valve position	X	NA	NA	NA	NA		OOM3	Verify closed line	
V43X2316E OMS-R Eng OX dump valve position	X	NA	NA	NA	NA		OOM3	Verify closed line	
V43X2215E OMS-R Eng OX isln valve position	P	NA	NA	NA	NA		OOM4	Verify propellant flow path	
OMS-R Eng OX isln valve position	P	NA	NA	NA	NA		OOM4	Verify propellant flow path	N

TABLE 5.— RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT — Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43X2015E OMS-R Eng fuel isln valve 1	P	NA	NA	NA	NA		OOM3	Insure open line	
OMS-R Eng fuel isln valve 2	P	NA	NA	NA	NA		OOM3	Insure open line	N
V43T2063A OMS-R Eng fuel XFD line temp	X	TBD	TBD	TBD	TBD		OOM3	Verify line condition	
V43X2065E OMS-R Eng fuel XFD valve No 1 position	P	NA	NA	NA	NA		OOM3	Insure flow path	
V43X2068E OMS-R Eng fuel XFD valve No 2 position	P	NA	NA	NA	NA		OOM3	Insure flow path	

TABLE 5.– RIGHT OMS MEASUREMENTS FOR FDA DURING RIGHT OMS/ RCS INTERCONNECT – Concluded

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V43T2263A OMS-R Eng OX XFD line temperature	X	TBD	TBD	TBD	TBD		OOM4	Verify line condition	
V43X2265E OMS-R Eng OX XFD valve No 1 position	P	NA	NA	NA	NA		OM32 OOM4	Insure flow path	
V43X2268E OMS-R Eng OX XFD valve No 2 position	P	NA	NA	NA	NA		OM34 OOM4	Insure flow path	

9.0 RCS INTERCONNECT TO CARGO BAY AUXILIARY PROPELLANT KIT

Additional propellant flow operating functional paths are available to the RCS manifolds from the cargo bay auxiliary propellant kits.

The functional paths of the auxiliary propellant from the cargo bay kit to the crossfeed lines are shown in figure 18. The functional paths are identified as CKXX and are combined into operating functional paths identified as OCKXX.

9.1 Functional Path Analysis of Auxiliary Propellant to Crossfeed Line

The cargo bay kits are added when more OMS delta velocity is required than can be supplied by the dedicated OMS tanks. Each kit consists of a fuel tank, an oxidizer tank, and a helium source bottle. One to three kits may be added to the cargo bay. The propellant tanks are connected in series, and the helium tanks are added in parallel.

CK1 consists of from one to three helium source bottles connected to a common manifold. Each bottle has a volume of 15.4 cubic feet.

CK3 is a shut-off valve allowing helium to be loaded from a ground source during servicing.

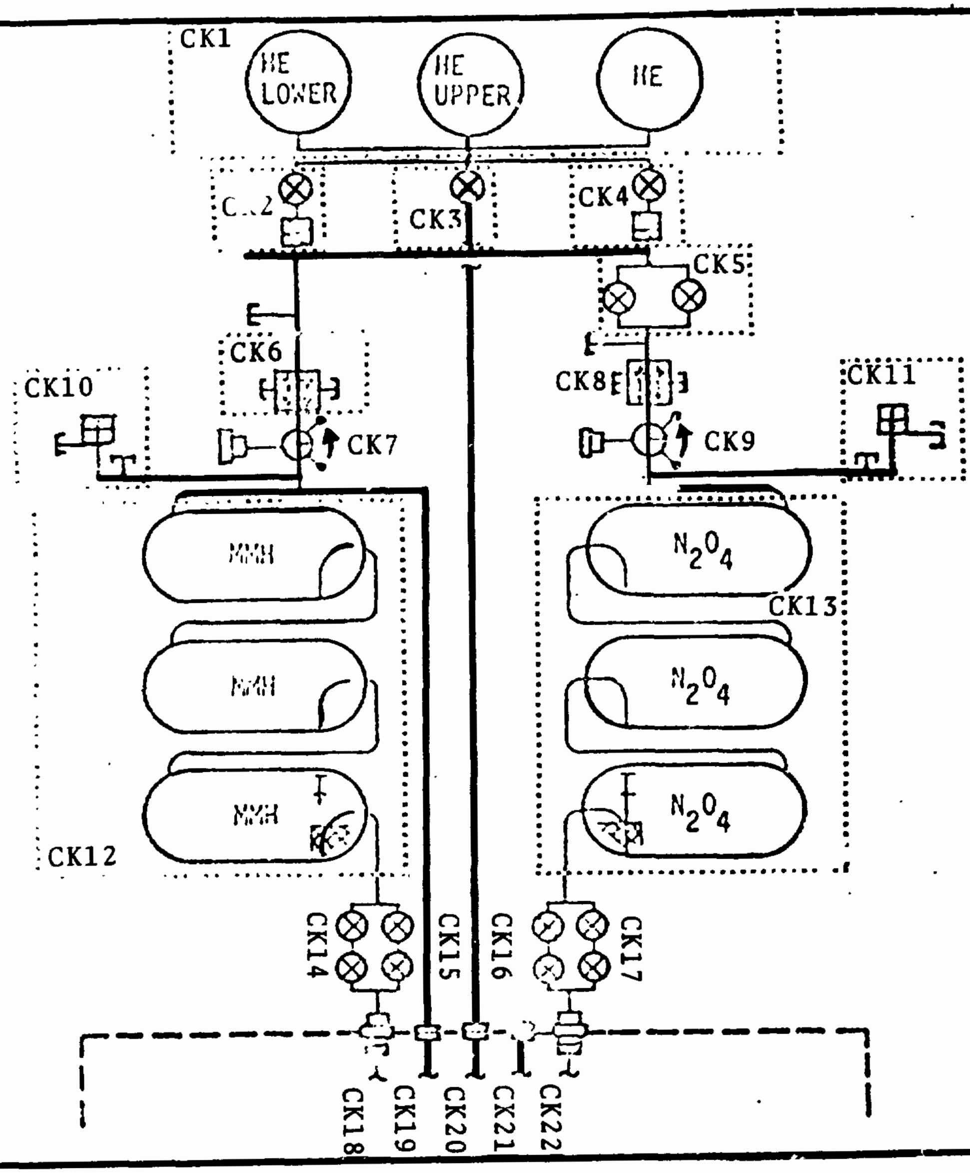

Figure 18. – Cargo bay kit functional paths.

CK2 and CK4 consist of helium isolation valves in series with a primary and secondary helium pressure regulator. The primary regulator regulates the output to 218 psig.

CK5 consists of two helium isolation valves in parallel used for positive isolation of N_2O_4 from the helium manifold. These valves remain closed when the cargo bay kits are not in use.

CK6 and CK8 are series parallel check valves which isolate propellants from the helium manifold.

CK7 and CK9 are manual shut-off valves used during ground servicing only.

CK10 and CK11 consist of a burst disc and poppet relief valve. In the event the tanks are subjected to over pressure, the burst disc ruptures and the excess helium vents overboard through the poppet relief valve.

CK12 and CK13 are propellant holding tanks. Each tank has a volume of approximately 89.5 cubic feet. Each kit contains a fuel and an oxidizer tank. A maximum of three kits may be installed in a vehicle.

CK14 through CK17 are series parallel shut-off valves which isolate the cargo bay kit propellants from the cross-feed lines.

CK18 through CK22 are bulkhead disconnects and feed-throughs from the cargo bay to the aft fuselage.

9.2 Cargo Bay Kit Operating Functional Paths to the Crossfeed Lines

Operating functional paths, for auxiliary propellant from the cargo bay kit to the crossfeed lines, are defined as follows (see fig. 18):

- Cargo bay auxiliary fuel to crossfeed line
  OCK1 = (CK1) (CK2 + CK4) (CK6) (CK7)
  (CK12) (CK14 + CK15) (CK18)
- Cargo bay auxiliary oxidizer to crossfeed line
  OCK2 = (CK1) (CK2 + CK4) (CK5) (CK8)
  (CK9) (CK13) (CK16 + CK17) (CK22)

9.3 Cargo Bay Kit Operating Functional Paths to Aft Left RCS Manifolds

The functional paths of the auxiliary propellant from the cargo bay kit to the left aft RCS manifolds are defined as follows (see figs. 11 and 12):

- Left aft RCS fuel manifold A
  OCK380 = (OCK1) (RC304) (RC94)
- Left aft RCS fuel manifold B
  OCK382 = (OCK1) (RC304) (RC92)
- Left aft RCS fuel manifold E
  OCK384 = (OCK1) (RC304) (RC90)
- Left aft RCS fuel manifold C
  OCK386 = (OCK1) (RC302) (RC96)
- Left aft RCS fuel manifold D
  OCK388 = (OCK1) (RC302) (RC96)

- Left aft RCS oxidizer manifold A
  OCK381 = (OCK2) (RC303) (RC91)
- Left aft RCS oxidizer manifold B
  OCK383 = (OCK2) (RC303) (RC93)
- Left aft RCS oxidizer manifold E
  OCK385 = (OCK2) (RC303) (RC95)
- Left aft RCS oxidizer manifold C
  OCK387 = (OCK2) (RC301) (RC97)
- Left aft RCS oxidizer manifold D
  OCK389 = (OCK2) (RC301) (RC99)

9.4 Cargo Bay Kit Operating Functional Paths to Aft Right RCS Manifolds

The functional paths of the auxiliary propellant from the cargo bay kit to the right aft RCS manifolds are defined as follows (see figs. 11 and 12):

- Right aft RCS fuel manifold A
  OCK390 = (OCK1) (RC308) (RC170)
- Right aft RCS fuel manifold B
  OCK392 = (OCK1) (RC308) (RC172)
- Right aft RCS fuel manifold E
  OCK394 = (OCK1) (RC308) (RC174)
- Right aft RCS fuel manifold C
  OCK396 = (OCK1) (RC306) (RC176)
- Right aft RCS fuel manifold D
  OCK398 = (OCK1) (RC306) (RC178)

- Right aft RCS oxidizer manifold A
  OCK391 = (OCK2) (RC307) (RC171)
- Right aft RCS oxidizer manifold B
  OCK393 = (OCK2) (RC307) (RC173)
- Right aft RCS oxidizer manifold E
  OCK395 = (OCK2) (RC307) (RC175)
- Right aft RCS oxidizer manifold C
  OCK397 = (OCK2) (RC305) (RC177)
- Right aft RCS oxidizer manifold D
  OCK399 = (OCK2) (RC305) (RC179)

9.5 Measurements

The measurements required for RCS fault detection and annunciation are listed in table 6. Five new measurements (not in the Master Measurements List), dated November 16, 1973, are identified.

Since helium pressure provides the best overall system status as well as a means of propellant gauging, the measurement should be redundant.

Tank pressures are required for leak isolation and overpressure monitoring. At least one pressure transducer should be added to the fuel and oxidizer tanks.

Position indicators are required to indicate the position of the SOV's in functional paths CK14 through CK17. An indicator should be added to monitor the status of each path or, preferably, the status of each valve.

TABLE 6.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR RCS FDA

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status**
V43P0100A OMS He tank pressure aux	P			Propellant remaining dependent			CK1 OCK1 OCK2	System status leak monitor	
OMS He tank pressure aux No 2	P			Propellant remaining dependent		P0100A	CK1 OCK1 OCK2	System status lost if P0100A fails	N
V43X0310E OMS-He OX Isln valve pos aux	X	NA	NA	NA	NA		CK4 OCK2	Crossfeed configuration	
V43X0110E OHMS-He fuel Isln valve pos aux	X	NA	NA	NA	NA		CK2 OCK1	Crossfeed configuration	
Fuel tank No 1 pressure	P	TBD	TBD	210	260		CK12	Overpressure monitor leak monitor	N

*P = Primary

C = Correlation

X = Precondition

**N = New Measurement Required

TABLE 6.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR RCS FDA – Continued

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
OX tank No 1 pressure	P	TBD	TBD	210	260		CK13 OCK 2	Overpressure monitor leak monitor	N
V43X0314E OMS vapor Isln valve No 1 pos - aux	X	NA	NA	NA	NA		CK5 OCK2	Crossfeed configuration	
V43X0315E OMS vapor Isln valve No 1 pos - aux	X	NA	NA	NA	NA		CK5 OCK2	Crossfeed configuration	
V43X0215E OMS OX Isln valve pos - aux	X	NA	NA	NA	NA		CK16 OCK2	Crossfeed configuration	N
OMS oxidizer Isln valve pos - aux	X	NA	NA	NA	NA		CK17 OCK2	Crossfeed configuration	

TABLE 6.— AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR

RCS FDA — Continued

Measurement	Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status
V43X0015E OMS-fuel Isln valve pos - aux	X	NA	NA	NA	NA		CK14 OCK1	Crossfeed configuration	N
OMS fuel Isln valve No 2 pos - aux	X	NA	NA	NA	NA		CK15 OCK1	Crossfeed configuration	N
V43X0072E OMS fuel tank No 1 level low	P	NA	NA	NA	NA		OCK1	Insure no depletion burns	
V43X0272E OMS OX tank No 1 level low	P	NA	NA	NA	NA		OCK2	Insure no depletion burns	
V43T0074A OMS fuel tank No 1 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK12 OCK1	System management	
V43T0075A OMS fuel tank No 2 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK12 OCK1	System management	

TABLE 6.- AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR RCS FDA — Concluded

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status
		High	low	High	low				
V43T0076A OMS fuel tank No 3 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK12 OCK1	System management	
V43T0274A OMS-OX tank No 1 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK13 OCK2	System management	
V43T0275A OMS-OX tank No 2 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK13 OCK2	System management	
V43T0276A OMS-OX tank No 3 bulk temp - aux	X	TBD	TBD	TBD	TBD		CK13 OCK2	System management	

10.0 FLIGHT CONTROL SYSTEM/REACTION CONTROL SYSTEM INTERFACES

The interface between the flight control system (FCS) and the reaction control system (RCS) is not fully defined. The basic FCS/RCS interface is shown in figure 19.

10.1 Interface Operation

Redundant ON commands from the guidance and control computer are routed through two flight critical MDM's to the reaction jet driver input buffer. Loss of either ON command to the input buffer, or either command failed on, results in an illegal command signal to the computer. The failed jet is then removed from the jet select logic.

A valid ON command turns on the switching amplifier which applies +28 VDC to the dual solenoid valve coils, that open the engine inlet valves. The propellants then impinge and ignite in the thrust chamber. As chamber pressure builds up, the chamber pressure switches close sending a signal back to the monitor to indicate a good fire sequence.

10.2 Detectable Failure

Failure of one of the ON commands in either state results in an illegal command signal to the computer.

A legal ON command without a pressure switch closure results in a no-fire signal to the computer. In either case, the computer removes the thruster from the jet select logic.

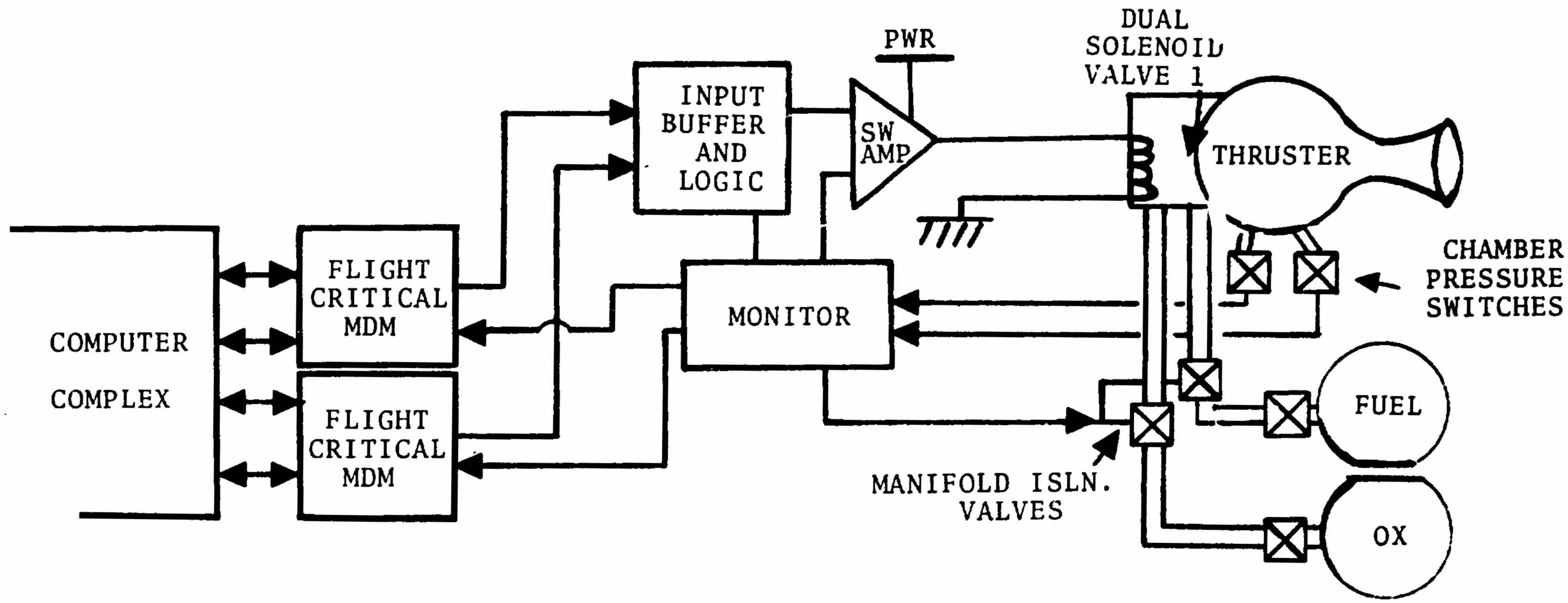

Figure 19. – Basic FCS/RCS interface.

A thrust chamber pressure switch closure without a valid ON command results in a failed on signal. The monitor closes the manifold isolation valves and the computer removes all jets on the manifold from the jet select logic.

10.3 Undetectable Failures

Switching amplifier on failures cannot be isolated except as a failed on jet. This failure presently results in the loss of all jets on the manifold. The addition of a switching amplifier output measurement and a circuit breaker, between the bus line and the amplifier, would allow single jet isolation for a switching amplifier on failure. Other methods to preclude a pressure switch failure from failing the whole manifold are being studied.

Failure of a single thruster inlet valve in the open position can only be detected as a leak. Addition of position indicators on the thruster inlet valves would eliminate this problem. The addition of manifold pressure measurements downstream of the thruster isolation valves is required, if the leak isolation method is used to isolate this failure.

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 System Definition

The RCS is not fully defined at this time; however, the basic measurement requirements for fault detection and annunciation should be nearly identical to those listed in this document.

11.2 Forward RCS

Twenty-eight new measurements not presently included in the Master Measurement List, dated November 16, 1973, have been identified as requirements for FDA. These measurements should be added to the Master Measurement List.

The new measurements are identified as follows:

- Engine burn through monitors 16 ea
- Manifold pressures 10 ea
- Helium source pressure 2 ea

Due to lack of configuration information on the forward RCS doors, monitoring of the RCS doors has not been considered in this report. Door monitoring will be required during operational missions.

11.3 Left and Right Aft RCS

Seventy-two new measurements not presently included in the Master Measurement List, dated November 16, 1973, have been identified as requirements for FDA. These measurements should be added to the Master Measurement List.

The new measurements are identified as follows:

- Engine burn through monitors 28 ea
- Manifold pressures 20 ea
- Manifold and tank SOV's 16 ea
- Helium source pressures 4 ea
- Engine temperatures 4 ea

11.4 RCS Crossfeed/Interconnect Operation

Eleven new measurements are required for crossfeed monitoring. They are identified as follows:

- OMS crossfeed SOV position 4 ea
- OMS helium source pressure 2 ea
- Auxiliary propellant helium source pressure 1 ea
- Auxiliary propellant tank pressures 2 ea
- Auxiliary propellant SOV positions 2 ea

The RCS crossfeed valves are single point failures, which could result in depleting the RCS propellant tank associated with the failed valve during some OMS engine burns.

The RCS propellant tanks operate at a higher pressure than the cargo bay tanks. If the OMS engine is being supplied by the cargo bay propellant tanks, and an RCS crossfeed valve fails open, the associated RCS tank will be depleted. A study is being conducted by Rockwell International to resolve this problem. Consideration is being given to equalizing OMS and RCS ullage pressures.

11.5 FCS/RCS Interface

Consideration should be given to the following in the design of the reaction jet drivers.

As a minimum, the reaction jet drivers should provide the following:

- Redundant chamber pressure sensors.
- Jet driver output monitors.
- Jet driver electrical-ON failure isolation capability.
- Single jet driver power isolation capability.
- Failure identification annunciation.