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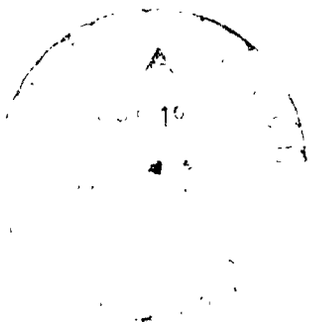
AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

ORBITAL MANEUVERING SUBSYSTEM FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION



National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

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ORBITAL MANEUVERING SUBSYSTEM FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION

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ABBREVIATIONS

Aux	Auxiliary
Eng	Engine
GN_2	Gasseous Nitrogen
He	Helium
Injr	Injector
Isln	Isolation
L	Left
MMH	Monomethalhydrazine
N_2O_4	Nitrogen Tetroxide
OMS	Orbital Maneuver Subsystem
OX or Oxid	Oxidizer
PNEU	Pneumatic
Pos	Position
Press	Pressure
Prop	Propellant
R	Right
RCS	Reaction Control Subsystem
SOV	Shut-off Valve
Temp	Temperature
XFD	Crossfeed

1.0 SUMMARY

The Orbital Maneuver Subsystem (OMS) 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.

Twenty-three 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:

- GN_2 monitoring 10 ea
- Shut-off valve positions 8 ea
- Redundant helium source pressures 3 ea
- Cargo bay tank pressures 2 ea

2.0 INTRODUCTION

2.1 Purpose

This document defines the functional paths of the Orbital Maneuver Subsystems (OMS) 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 Orbital Maneuver Subsystem. The OMS is a pressure-fed rocket engine propulsion subsystem. One complete OMS shares each of the two auxiliary propulsion subsystem pods with a reaction control subsystem (RCS).

Each OMS is composed of a pressurization system, a propellant tanking system and a gimbaled rocket engine.

2.2.2 OMS components. The pressurization system consists of a helium storage bottle, helium solenoid valves, pressure regulators, vapor isolation valves, check valves, relief valves, and test and fill ports.

The OMS propellant system is composed of fuel, oxidizer, propellant storage tanks, isolation valves, pod interconnect lines, and distribution lines.

The OMS engine consists of a series redundant bi-propellant valve, an injector, a thrust chamber, a nozzle extension and gimbal actuators. A gimbaling/thrust mount attaches the engine to the auxiliary propulsion subsystem.

2.2.3 OMS propellant supply. The hypergolic OMS propellants are nitrogen tetroxide (N_2O_4) and monomethalhydrazine (MMH). Each OMS is normally supplied propellants from its own dedicated set of tanks. Crossfeed lines provide the capability to supply propellant to either OMS engine from each of the following additional sources:

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

2.2.4 OMS configuration status. OMS preliminary design review is presently in progress. Future changes are expected, especially in the area of pneumatic valve control. Changes are not expected to impact performance monitoring, fault detection and annunciation.

3.0 FUNCTIONAL PATH ANALYSIS OF THE OMS

3.1 Functional Path Identification

The OMS functional paths are shown in figures 1 and 2. They are identified as OMXX. Functional paths are combined into operating functional paths and identified as OOMXX.

3.2 Functional Path Analysis of OMS Propellant Paths

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 218 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.

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.

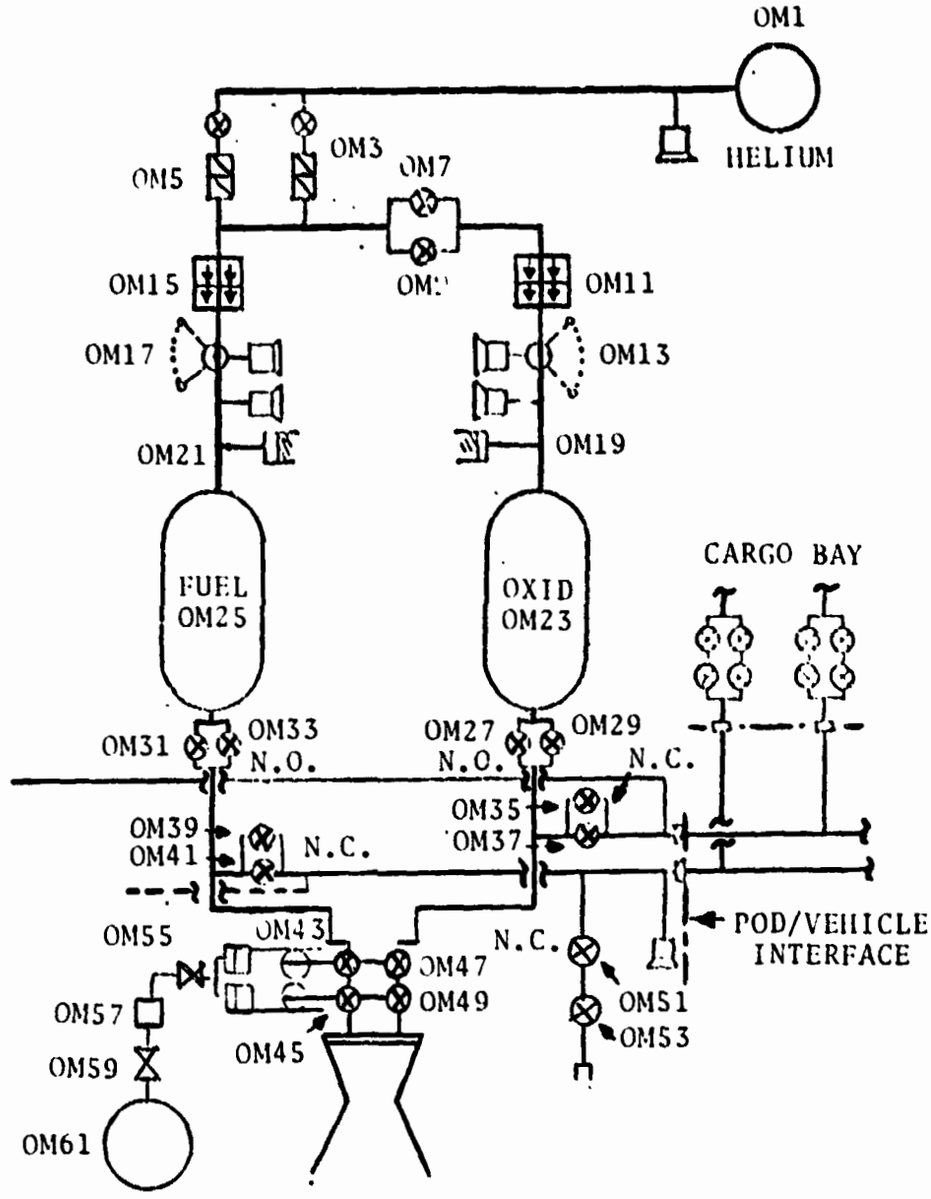

Figure 1. – Left pod OMS functional paths.

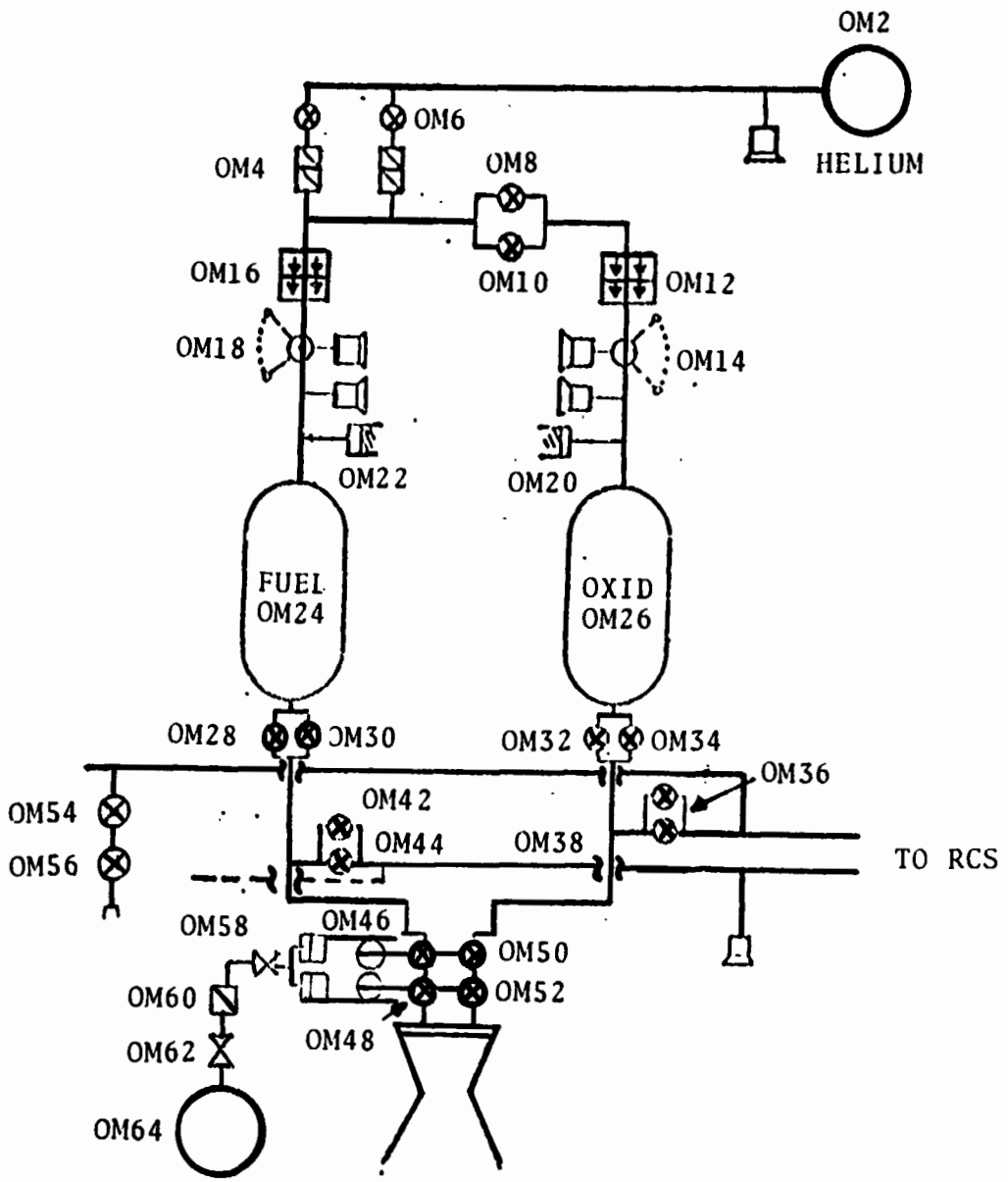

Figure 2. – Right pod OMS functional paths.

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.

OM41, OM42, OM44, and OM35 through OM39 are pairs of parallel redundant shut-off valves. These valves connect the OMS manifolds to the crossfeed lines.

OM43, OM45, OM46, and OM48 are series redundant engine fuel inlet ball valves. OM47, OM49, OM50, and OM52 are series redundant engine oxidizer inlet ball valves. One fuel and one oxidizer valve are controlled by a single actuator. Operation of either pair of inlet valves insures shutdown of the associated engine.

OM61 and OM64 are GN_2 source bottles which supply the pressure for engine ball valve control. OM59 and OM62 are shut-off valves which control the flow of GN_2 to the GN_2 regulators, OM57 and OM60.

OM55 and OM58 are 3-way valves used to control the ball valve actuators. Pressure applied to the ball valves causes the valves to open. The valves are spring loaded closed and will close when the actuator pressure is vented overboard.

An additional GN_2 source tank is being considered for each engine. This would provide a separate source tank for each set of engine ball valves.

OM51 and OM53 are fuel dump valves used to dump fuel overboard.

OM54 and OM56 are oxidizer dump valves used to dump oxidizer overboard.

3.3 Problem Areas

3.3.1 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 the RCS helium regulators regulate higher than the helium regulators in the cargo bay kit, and an RCS crossfeed valve fails open, the RCS propellant will be depleted through the OMS engine.

Consideration is being given to changing the RCS and OMS propellant ullage pressures to a common pressure of approximately 240 psia to eliminate this problem.

3.3.2 Tank shut-off valves and crossfeed valves. Helium from the RCS tanks is presently used to control the tank shut-off valves and the crossfeed valves. The use of helium from the RCS tanks for valve control introduces additional errors in the RCS propellant gauging.

3.4 Operating Functional Paths

3.4.1 Left OMS. The operating functional paths used for engine monitoring of the left OMS are defined as follows:

- Left OMS fuel operating functional path
  OOM5 = (OM1) (OM3 + OM5) (OM15) (OM17)
  (OM25) (OM31 + OM33) (OM43) (OM45)
- Left (OMS) oxidizer operating functional path
  OOM7 = (OM1) (OM3 + OM5) (OM7 + OM9)
  (OM11) (OM13) (OM23) (OM27 + OM29)
  (OM47) (OM49)
- Pneumatic valve control operating functional path
  OOM9 = (OM61) (OM59) (OM57) (OM55)

3.4.2 Right OMS. The operating functional paths used for engine monitoring of the right OMS are defined as follows:

- Right OMS fuel operating functional path
  OOM6 = (OM2) (OM4 + OM6) (OM16) (OM18)
  (OM24) (OM28 + OM30) (OM46) (OM48)
- Right OMS oxidizer operating functional path
  OOM8 = (OM2) (OM4 + OM6) (OM8 + OM10) (OM12)
  (OM14) (OM26) (OM32 + OM34) (OM50) (OM52)
- Pneumatic valve control operating functional path
  OOM10 = (OM64) (OM62) (OM60) (OM58)

4.0 MEASUREMENT REQUIREMENTS FOR FAULT DETECTION AND ANNUNCIATION – LEFT AND RIGHT OMS

4.1 FDA Measurements

Tables 1 and 2 list the primary, correlation, and preconditioning measurements required for fault detection and annunciation for the right and left OMS. The tables identify 16 new measurements not included in the Master Measurements List, dated November 16, 1973. Measurement justification is also included in tables 1 and 2. Figures 3 and 4 show the approximate location of the aft 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 fails, the system status and propellant remaining cannot be determined; therefore, redundant source pressure measurements should be added to both helium tanks.

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

4.2.3 Manifold pressures. Tank outlet SOV's and OMS crossfeed valve positions provide precondition checks for manifold pressure checks.

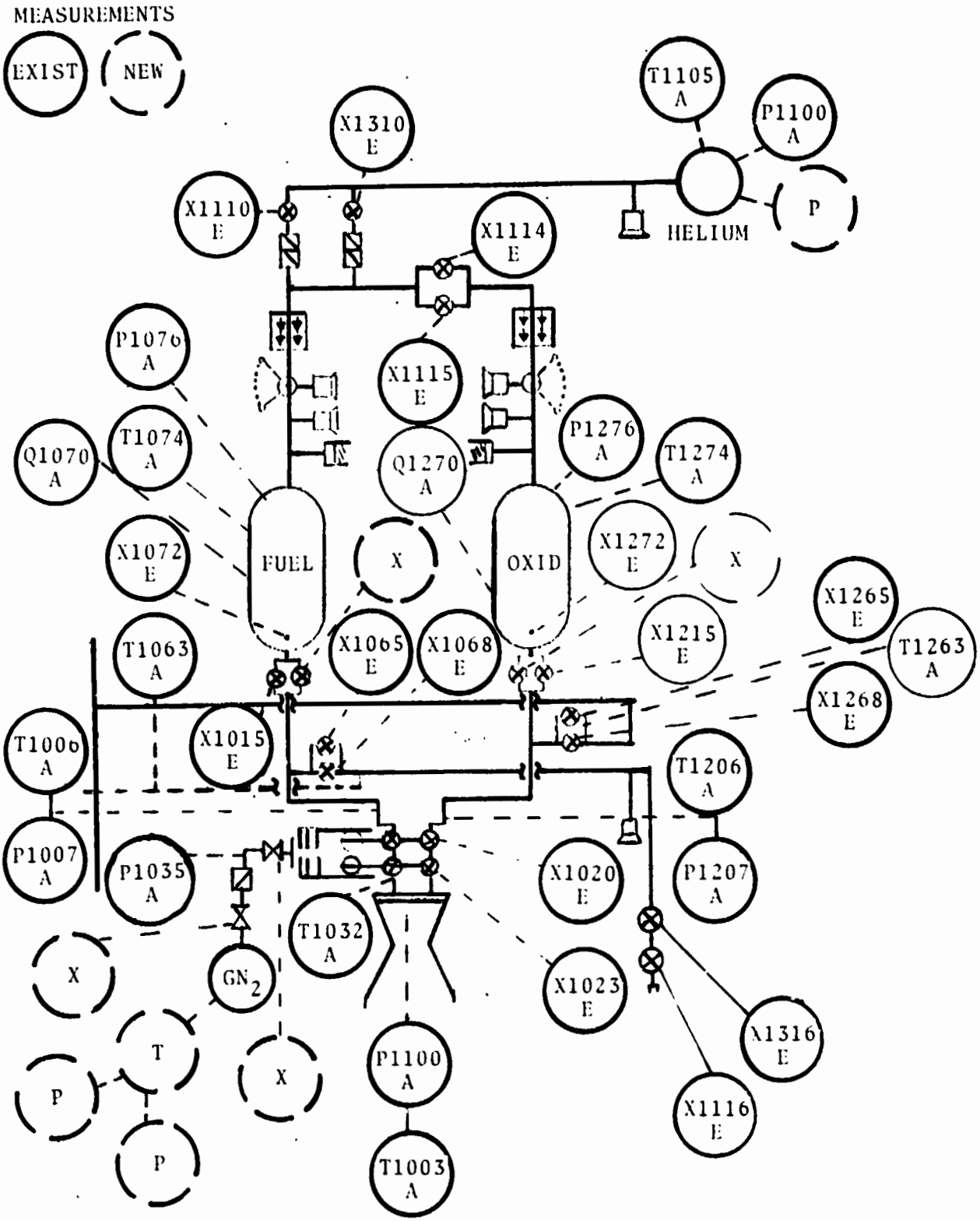

Figure 3. – Left OMS measurements for FDA.

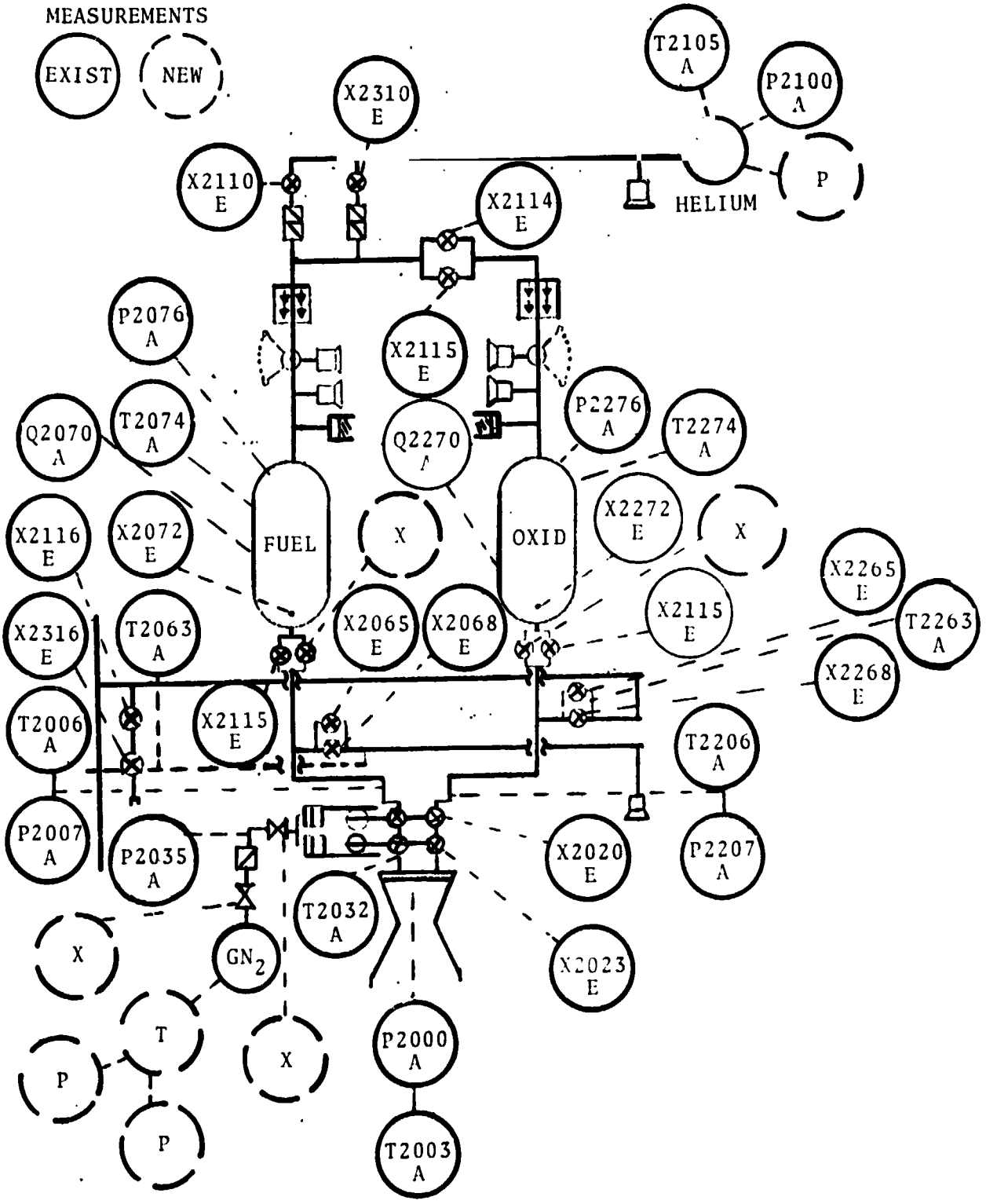

Figure 4. – Right OMS measurements for FDA.

4.2.4 Engine bi-propellant valve positions. Bi-propellant valve positions are monitored during engine burns. Failure of either valve in a closed position results in engine shutdown. If either valve fails open prior to a burn the engine will not be used since redundant shutdown capability has been lost.

4.2.5 Engine parameters. Chamber pressure and injector temperature provide overall system status monitoring during OMS burns.

4.2.6 GN_2 monitoring. Source pressure, SOV positions, and regulator pressure provide status of the bi-propellant valves GN_2 supply. The bi-propellant valves are spring loaded closed if the GN_2 supply is lost.

4.3 Leak Detection

Helium source pressure for fuel and oxidizer are supplied from the same bottle. A leak may be isolated by closing the helium SOV's and monitoring tank pressures.

TABLE 1.– LEFT OMS MEASUREMENTS FOR FDA

Measurement	*Use	Soft limit High	Soft limit low	Hard limit High	Hard limit low	Correlation measurement	Operating functional path	Justification	Status**
V43X1215E OMS-L Eng OX Isln valve position	P	NA	NA	NA	NA		OOM7 OM27 OOM2	Verify propellant flow path	
V43T1263A OMS-L Eng OX XFD line temp	X	TBD	TBD	TBD	TBD		OOM2 OOM7	Verify line condition	
V43X1310E OMS-L Eng He OX Isln valve position	P	NA	NA	NA	NA		OM3 OOM2 OOM7	Insure flow path	
V43X1316E OMS-L Eng OX dump valve position	X	NA	NA	NA	NA		OOM2 OOM7	Verify closed line	
V43X1265E OMS-L Eng OX XFD valve 1 position	P	NA	NA	NA	NA		OM35 OOM7 OOM2	Insure flow path	

*P = Primary
C = Correlation
X = Precondition

** X = New Measurement Required

TABLE 1.– LEFT OMS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status**
		High	low	High	low				
V43X1065E OMS-L Eng fuel XFD valve 1	P	NA	NA	NA	NA		OM39 OOM1 OOM5	Insure flow path	
V43X1068E OMS-L Eng fuel XFD valve 2	P	NA	NA	NA	NA		OM41 OOM5 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 OOM5	System management	
V43X1072E OMS-L Eng fuel tank low level	P	NA	NA	NA	NA		OOM1 OOM5	Leak monitor	
V43T1074A OMS-L Eng fuel tank temp	P	TBD	TBD	TBD	TBD		OM25 OOM5 OOM1	System management	

TABLE 1.– LEFT OMS 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**
V43Q1270A OMS-L Eng Oxid tank quantity	P			Mission dependent			OOM2 OOM7	Consumables management leak detection	
V43X1116E OMS-L Eng fuel dump valve position	X	NA	NA	NA	NA		OOM1 OOM5	Verify closed line	
V43X1272E OMS-L Eng OX tank low level	P	TBD	TBD	TBD	TBD		OOM2 OOM7	System management	
V43T1274A OMS-L Eng OX tank temp - lower	P	TBD	TBD	270	200		OM23 OOM2 OOM7	Leak detection	
V43P1276A OMS-L Eng OX tank ullage pressure	P	NA	NA	NA	NA		OM23 OOM7 OOM2	Insure path flow	

TABLE 1.– LEFT OMS 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**
V43P1076A OMS-L Eng fuel tank ullage pressure	P	TBD	TBD	270	200		OM25 OOM5 OOM1	Leak monitor	
V43P1100A OMS-L Eng He tank pressure	P	TBD	TBD	Propellant remaining dependent			OM1 OOM5 OOM1 OOM7 OOM2	System status leak detection	
V43T1105A OMS-L Eng He tank temp	P	TBD	TBD	TBD	TBD		OM1 OOM5 OOM1 OOM7 OOM2	System management	
V43X1110L OMS-L Eng He fuel isln valve position	P	NA	NA	NA	NA		OM3 OOM5 OOM1 OOM7 OOM2	Verify flow path	
V43X1114L OMS-L vapor isln valve 1 position	P	NA	NA	NA	NA		OM7 OOM7 OOM2	Verify flow path	
V43X1115L OMS-L vapor isln valve 2 position	P	NA	NA	NA	NA		OM9 OOM7 OOM2	Verify flow path	

TABLE 1.– LEFT OMS 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**
V43X1268E OMS-L Eng OX XFD valve 2 position	P	NA	NA	NA	NA		OM37 OOM7 OOM2	Verify flow path	
OMS-L He tank pressure No 2	P	TBD	TBD	Propellant remaining dependent			M1 OOM7 OOM1 OOM5 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 OOM7 OOM1 OOM5 OOM2	Verify flow path	N
OMS-L Eng fuel Isln valve No 2 position	P	NA	NA	NA	NA		OM31 OOM5 OOM1	Insure open line	N
V43X1013E OMS-L Eng fuel Isln valve position	P	NA	NA	NA	NA		OM33 OOM5 OOM1	Insure open line	

TABLE 1.– LEFT OMS 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**
V43T1006A OMS-L eng fuel inlet temp	P	TBD	TBD	TBD	TBD		OOM5	Engine monitor	
V43P1007A OMS-L eng fuel inlet press	P	TBD	TBD	TBD	TBD		OOM5	Engine monitor	
V43T1206A OMS-L eng oxid inlet temp	P	TBD	TBD	TBD	TBD		OOM7	Engine monitor	
V43P1207A OMS-L eng oxid inlet press	P	TBD	TBD	TBD	TBD		OOM7	Engine monitor	
V43T1032A OMS-L eng bi-prop fuel valve temp	P	TBD	TBD	TBD	TBD		OM43 OM45 OOM5	Engine monitor	
Left OMS GN_2 tank pressure #1	P	TBD	TBD	TBD	TBD	GN_2 Pressure #2	OM61 OOM9	Leak monitor	N

TABLE 1.– LEFT OMS MEASUREMENTS FOR FDA – Concluded

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status**
		High	low	High	low				
Left OMS GN_2 tank pressure #2	C	TBD	TBD	TBD	TBD		OM61 OOM9	Leak monitor	N
Left OMS GN_2 tank temp	P	TBD	TBD	TBD	TBD		OM61 OOM9	System management	N
Left OMS GN_2 high press SOV	P	NA	NA	NA	NA		OM59 OOM9	System status	N
Left OMS GN_2 low press SOV	P	NA	NA	NA	NA		OM55 OOM9	System status	N
V43X1020E OMS-L eng bi-prop vlv 1 position	P	NA	NA	NA	NA		OOM5 OOM7	Engine monitor	
V43P1000A OMS-L eng chamber press	P	TBD	TBD	TBD	TBD		OOM5 OOM7	Engine monitor	
V43T1003A OMS-L eng injr temp	P	TBD	TBD	TBD	TBD		OOM5 OOM7	Engine monitor	
V43P1035A OMS-L eng pneu supply press	P	TBD	TBD	TBD	TBD		OM57 OOM9	Engine monitor	

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA

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 OOM6	Consumables management leak detection	
V43X2072E OMS-R Eng fuel tank low level	P	NA	NA	NA	NA		OOM3 OOM6	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		OOM6 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 2.– RIGHT OMS 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**
V43P2100A OMS-R Eng He tank pressure No 1	P	TBD	TBD	Propellant remaining dependent			OM2 OOM6 OOM3 OOM8 OOM4	System status leak check	
OMS-R Eng He tank pressure No 2	P	TBD	TBD	Propellant remaining dependent			OM2 OOM6 OOM3 OOM8 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 OOM6 OOM3	Verify flow path	
V43X2114E OMS-R Vapor isln valve No 1 position	P	NA	NA	NA	NA		OM8 OOM8 OOM4	Verify flow path	
V43X2115E OMS-R Vapor isln valve No 2 position	P	NA	NA	NA	NA		OM10 OOM8 OOM4	Verify flow path	

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA – 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 OOM8 OOM4	Consumables management leak detection	
V43X2272E OMS-R Eng OX tank low level	P	NA	NA	NA	NA		OOM4 OOM8	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 OOM8 OOM4	Leak detection	
V45X2510E OMS-R Eng He OX isln valve position	P	NA	NA	NA	NA		OOM4 OOM8	Insure path flow	

TABLE 2.– RIGHT OMS 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**
V43X2116E OMS-R Eng fuel dump valve position	X	NA	NA	NA	NA		OOM3 OOM6	Verify closed line	
V43X2516E OMS-R Eng OX dump valve position	X	NA	NA	NA	NA		OOM4 OOM8	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 OOM8	Verify propellant flow path	N

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status**
		High	low	High	low				
V43X2015E OMS-R Eng fuel isln valve 1	P	NA	NA	NA	NA		OOM3 OOM6	Insure open line	
OMS-R Eng fuel isln valve 2	P	NA	NA	NA	NA		OOM3 OOM6	Insure open line	N
V43T2063A OMS-R Eng fuel XFD line temp	X	TBD	TBD	TBD	TBD		OOM3 OOM6	Verify line condition	
V43X2065E OMS-R Eng fuel XFD valve No 1 position	P	NA	NA	NA	NA		OOM3 OOM6	Insure flow path	
V43X2068E OMS-R Eng fuel XFD valve No 2 position	P	NA	NA	NA	NA		OOM3 OOM6	Insure flow path	

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA – Continued

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 OOM8	Verify line condition	
V43X2265E OMS-R Eng OX XFD valve No 1 position	P	NA	NA	NA	NA		OOM8 OM32 OOM4	Insure flow path	
V43X2268E OMS-R Eng OX XFD valve No 2 position	P	NA	NA	NA	NA		OOM8 OM34 OOM4	Insure flow path	
Right OMS GN_2 tank press #1	P	TBD	TBD	TBD	TBD	GN_2 pressure #2	OM64 OOM10	Leak monitor	N
Right OMS GN_2 tank press #2	C	TBD	TBD	TBD	TBD		OM64 OOM10	Leak monitor	N
Right OMS GN_2 tank temp	P	TBD	TBD	TBD	TBD		OM64 OOM10	System management	N
Right OMS GN_2 high press SOV	P	TBD	TBD	TBD	TBD		OM62 OOM10	System status	N

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA – Continued

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status**
		High	low	High	low				
Right OMS GN_2 low press SOV	P	TBD	TBD	TBD	TBD		OM58 OOM10	System status	N
V43T2006A OMS-R eng fuel inlet temp	P	TBD	TBD	TBD	TBD		OOM6	Engine monitor	
V43P2007A OMS-R eng fuel inlet press	P	TBD	TBD	TBD	TBD		OOM6	Engine monitor	
V43T2206A OMS-R eng oxid inlet temp	P	TBD	TBD	TBD	TBD		OOM8	Engine monitor	
V43P2207A OMS-R eng oxid inlet press	P	TBD	TBD	TBD	TBD		OOM8	Engine monitor	
V43T2032A OMS-R eng bi-prop fuel valve temp	P	TBD	TBD	TBD	TBD		OM46 OM48 OOM6	Engine monitor	

TABLE 2.– RIGHT OMS MEASUREMENTS FOR FDA – Concluded

Measurement	*Use	Soft limit		Hard limit		Correlation measurement	Operating functional path	Justification	Status**
		High	low	High	low				
V43X2020E OMS-R eng bi-prop valve 1 position	P	NA	NA	NA	NA	NA	OM50 OM46 OOM6 OOM8	Engine monitor	
V43X2023E OMS-R eng bi-prop valve 2 position	P	NA	NA	NA	NA	NA	OM52 OM48 OOM6 OOM8	Engine monitor	
V43P2000A OMS-R eng chamber press	P	TBD	TBD	TBD	TBD	NA	OOM6 OOM8	Engine monitor	
V43T2003A OMS-R eng injr temp	P	TBD	TBD	TBD	TBD	NA	OOM6 OOM8	Engine monitor	
V43P2035A OMS-R eng pneu press supply	P	TBD	TBD	TBD	TBD	NA	OM60 OOM10	Engine monitor	

5.0 OMS INTERCONNECT TO CARGO BAY AUXILIARY PROPELLANT KIT

Additional propellant flow operating functional paths are available to the OMS 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 5. The functional paths are identified as CKXX and are combined into operating functional paths identified as OCKXX.

5.1 Functional Path Analysis of Cargo Bay Kit 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.

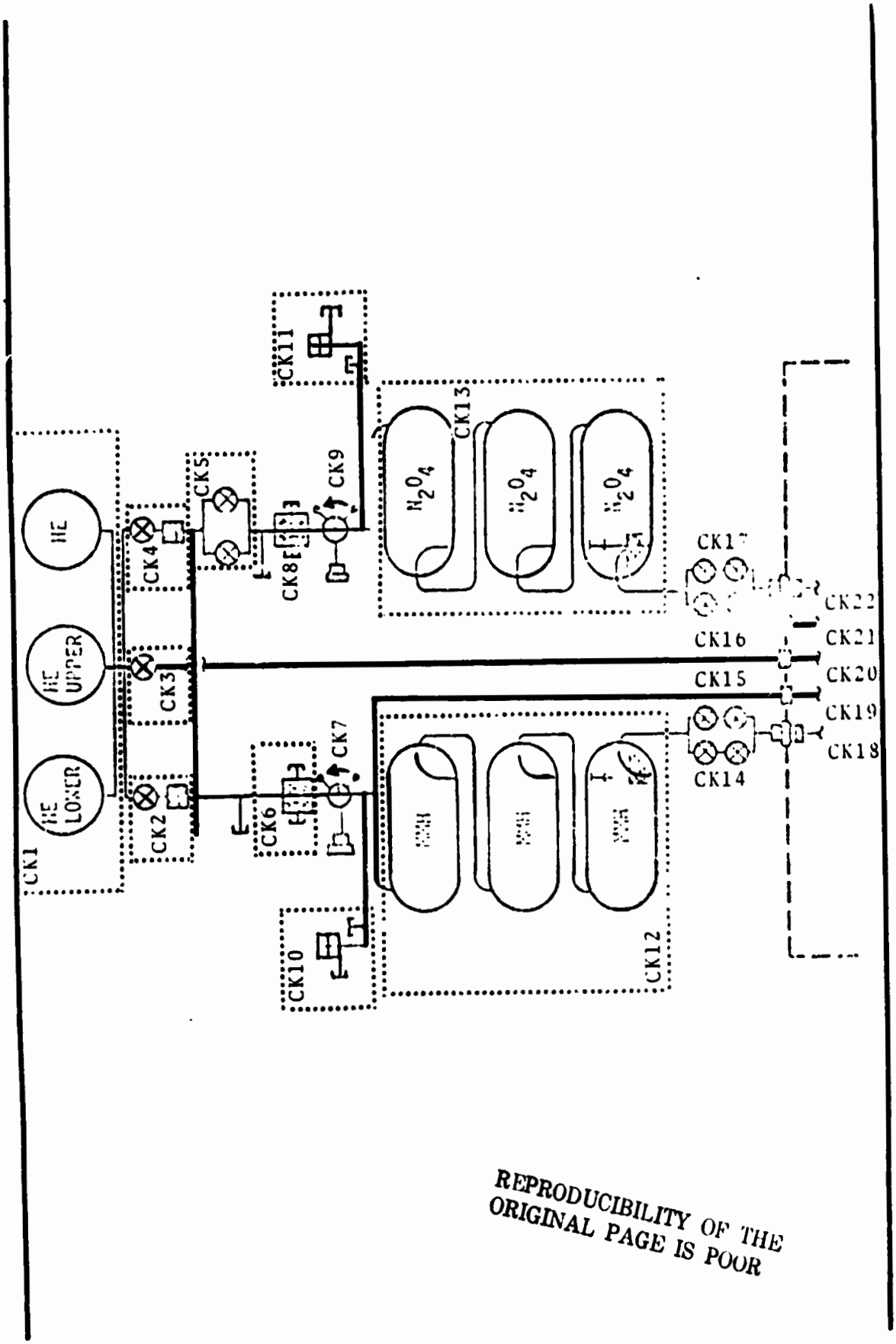

Figure 5. – Cargo bay kit functional paths.

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.

5.2 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. 5):

- 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)

5.3 Cargo Bay Kit Operating Functional Paths to OMS Engines

The operating functional paths of the auxiliary propellant from the cargo bay kit to the OMS engines are defined as follows (see figs. 6 and 7):

- Left OMS fuel operating functional path
  OCK3 = (OCK1) (OM39 + OM41) (OM43) (OM45)
- Left OMS oxidizer operating functional path
  OCK4 = (OCK2) (OM35 + OM37) (OM47) (OM49)
- Right OMS fuel operating functional path
  OCK5 = (OCK1) (OM42 + OM44) (OM46) (OM48)
- Right OMS oxidizer operating functional path
  OCK6 = (OCK2) (OM36 + OM38) (OM50) (OM52)

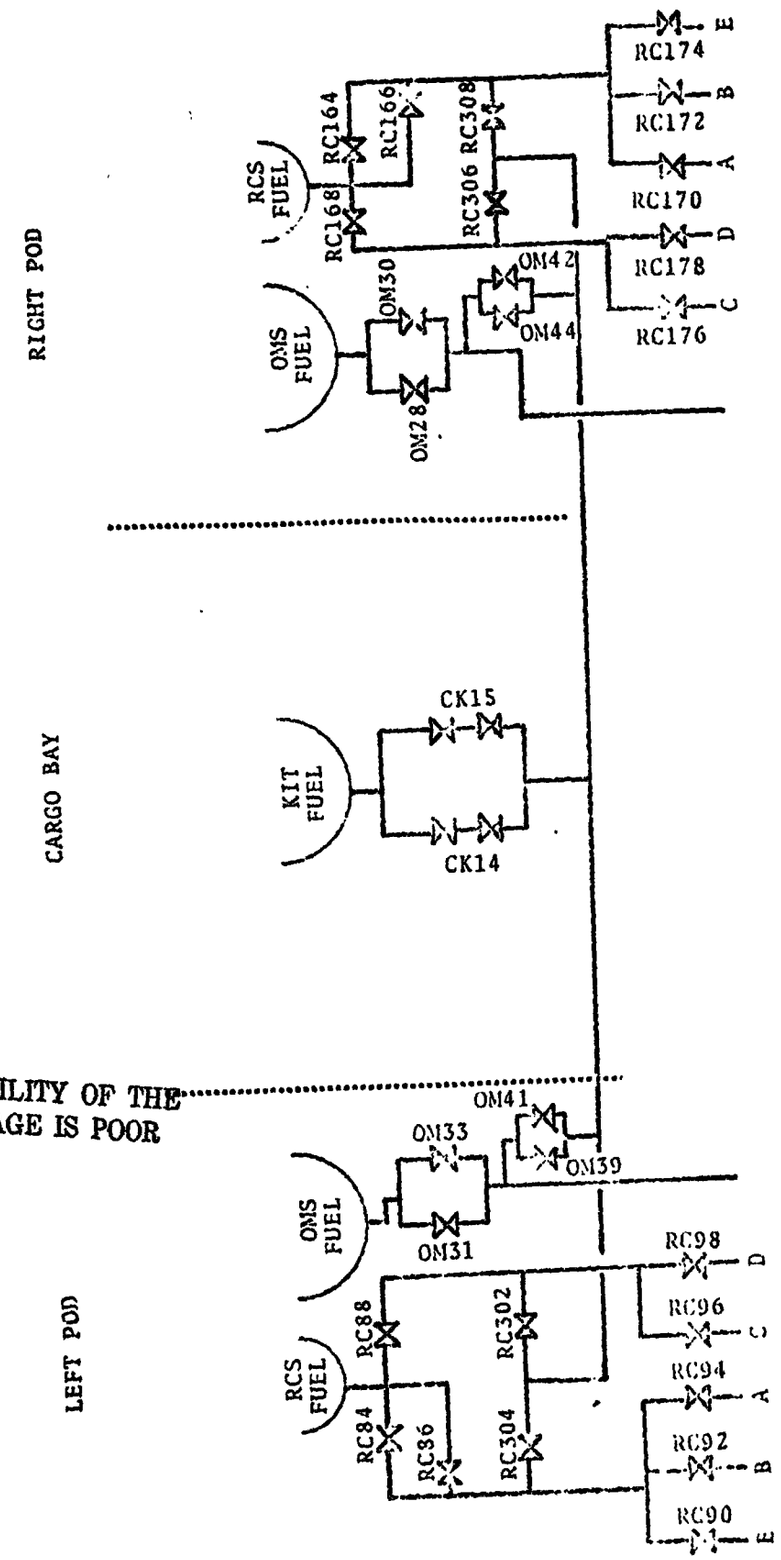

Figure 6. – Fuel crossfeed.

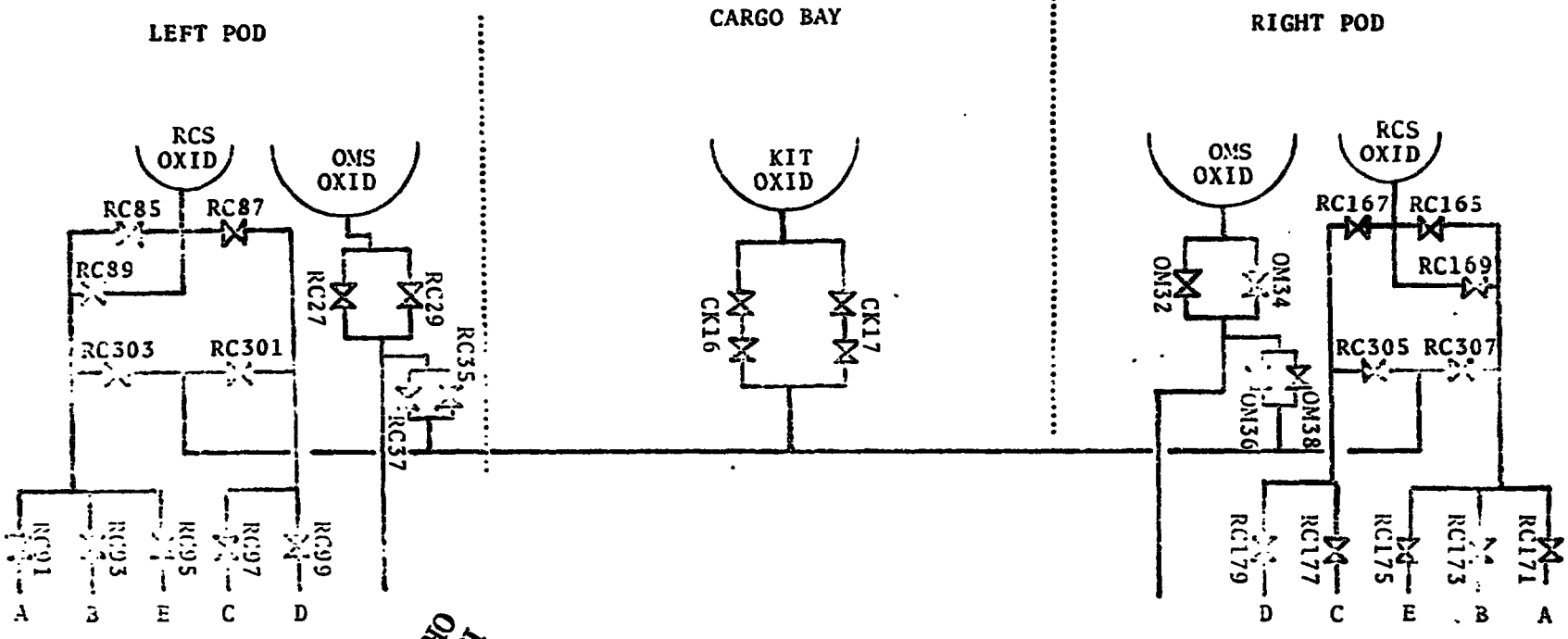

Figure 7. — Oxidizer crossfeed.

5.4 FDA Measurements for Cargo Bay Kit

The measurements required for OMS fault detection and annunciation are listed in table 3. Seven 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 3.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR OMS 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

XX N = New Measurement Required

TABLE 3.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR OMS 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	N

TABLE 3.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR OMS 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 3.– AUXILIARY PROPELLANT KIT MEASUREMENTS REQUIRED FOR OMS 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	

6.0 OMS CROSSFEED OPERATION

6.1 Functional Paths for OMS Crossfeed

The OMS functional paths used for OMS crossfeed are shown in figures 6 and 7. They are identified as OMXX. Functional paths are combined into operating functional paths and identified as OOMXX.

6.2 Functional Path Analysis of OMS Propellant Path to Crossfeed lines

All functional paths used in OMS crossfeed are described in section 3 except the crossfeed shut-off valves and the crossfeed lines. The crossfeed lines provide a propellant transfer path from the left pod OMS tanks to the right pod OMS engines and from the right pod OMS tanks to the left pod OMS engine.

OM39 and OM41 are parallel redundant shut-off valves that connect the left pod OMS fuel manifold to the fuel crossfeed line.

OM42 and OM44 are parallel redundant shut-off valves that connect the right pod OMS fuel manifold to the fuel crossfeed line.

OM35 and OM37 are parallel redundant shut-off valves that connect the left pod OMS oxidizer manifold to the crossfeed line.

OM36 and OM38 are parallel redundant shut-off valves that connect the right pod OMS oxidizer manifold to the oxidizer crossfeed line.

6.3 OMS Operating Functional Paths to the Crossfeed Lines

Operating functional paths for OMS propellant to the crossfeed lines are defined as follows (see figs. 1 and 2):

- 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 crossfeed line
  OOM4 = (OM2) (OM4 + OM6) (OM8 + OM10) (OM12) (OM14) (OM26) (OM32 + OM34) (OM36 + OM38)

6.4 Operating Functional Paths for Interconnect Left OMS Tanks to Right OMS Engine

The operating functional paths for supplying propellant from the left pod OMS tanks to the right pod OMS engine are defined as follows (see figs. 1 and 2):

- Fuel
  OOM11 = (OOM1) (OM42 + OM44) (OM46) (OM48)

- Oxidizer
  OOM12 = (OOM2) (OM36 + OM38) (OM50) (OM52)

6.5 Operating Functional Paths for Crossfeed Right OMS Tanks to Left OMS Engine

The operating functional paths for supplying propellant from the right pod OMS tanks to the left pod OMS engine are defined as follows (see figs. 1 and 2):

- Fuel
  OOM13 = (OOM3) (OM39 + OM41) (OM43) (OM45)
- Oxidizer
  OOM14 = (OOM4) (OM35 + OM37) (OM47) (OM49)

6.6 FDA Measurements for Crossfeed Operations

No additional measurements are required for fault detection and annunciation during crossfeed operation.

7.0 FLIGHT CONTROL SYSTEM/ORBITAL MANEUVER SYSTEM INTERFACES

7.1 OMS Engine On/Off Control

Two command inputs are provided for each valve from two MDM's. Failure of either input command results in the loss of associated OMS engine control by the failed reaction jet OMS driver. Redundant control is available from the other reaction jet OMS driver.

Failure logic sets a control valve failed bit for the following conditions:

- Legitimate on command with no driver output.
- No on command with a driver output.
- An illegal command.

7.2 OMS Thrust Vector Control (TVC) Drivers

OMS TVC pitch and yaw actuator drivers are organized in a dual redundant (active-standby) configuration. Each actuator servo loop shall accept actuator position command signals from the MDM, compare them to the actual actuator position, and convert the difference to drive signals.

A differential comparator measures the misstrack level between command and position. A failure is set when misstrack level exceeds a predefined level.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 System Definition

The OMS 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.

8.2 OMS Measurements

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

The new measurements are identified as follows:

- GN_2 source pressure 4 ea
- Propellant isolation valve positions 4 ea
- GN_2 source temperatures 2 ea
- Helium source pressure 2 ea
- GN_2 shut-off valves 4 ea

8.3 Cargo Bay Kit

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

The new measurements are identified as follows:

- Propellant tank pressures 2 ea
- Propellant shut-off valve position 4 ea
- Helium source pressures 1 ea

8.4 OMS Crossfeed Operation

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 helium regulators may regulate at a higher pressure than the cargo bay tank regulators. 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.

Consideration is being given to changing the RCS and OMS propellant ullage pressures to a common ullage pressure of approximately 240 psia to eliminate this problem.

8.5 Helium Source for OMS Valve Control

RCS helium source pressure is presently used for OMS propellant and crossfeed shut-off valve control. This introduces additional errors into the RCS PVT gauging system. An independent control source should be considered for the OMS valves.