SECTION 2

SUBSECTION 2.5

REACTION CONTROL SYSTEM (RCS)
(CSM 106 and subs)

The Apollo command service module includes two separate reaction control systems completely independent designated SM RCS and CM RCS. The SM RCS is utilized to control S/C rates and rotation in all three axis in addition to any minor translation requirements including CSM-S-IVB separation, SPS ullage and CM-SM separation maneuvers. The CM RCS is utilized to control CM rates and rotation in all three axis after CM-SM separation and during entry. The CM RCS does not have automatic translation capabilities.

Both the SM and CM RCS may be controlled either automatically or manually from the command module. Physical location of the RCS engines is shown in figure 2.5-1. Engine firing sequence for specific maneuvers and individual engine circuit breaker power control is shown in figures 2.5-2 through 2.5-6.

2.5.1 SM RCS FUNCTIONAL DESCRIPTION.

The SM RCS consists of four individual, functionally identical packages, located 90 degrees apart around the forward portion (+X axis) of the SM periphery, and offset from the S/C Y and Z axis by 7 degrees 15 minutes. Each package, configuration, called a "quad," is such that the reaction engines are mounted on the outer surface of the panel and the remaining components are inside. Propellant distribution lines are routed through the panel skin to facilitate propellant transfer to the reaction engine combustion chambers. The engine combustion chambers are canted approximately 10 degrees away from the panel structure to reduce the effects of exhaust gas on the service module skin. The two roll engines on each quad are offset-mounted to accommodate plumbing in the engine mounting structure.

Each RCS package incorporates a pressure-fed, positive-expulsion, pulse-modulated, bipropellant system to produce the reaction thrust required to perform the various SM RCS control functions. Acceptable package operating temperature is maintained by internally mounted, thermostatically controlled electric heaters. The SM RCS propellants consist of inhibited nitrogen tetroxide (N_2O_4), used as the oxidizer, and monomethylhydrazine (MMH), used as the fuel. Pressurized helium gas is the propellant transferring agent.

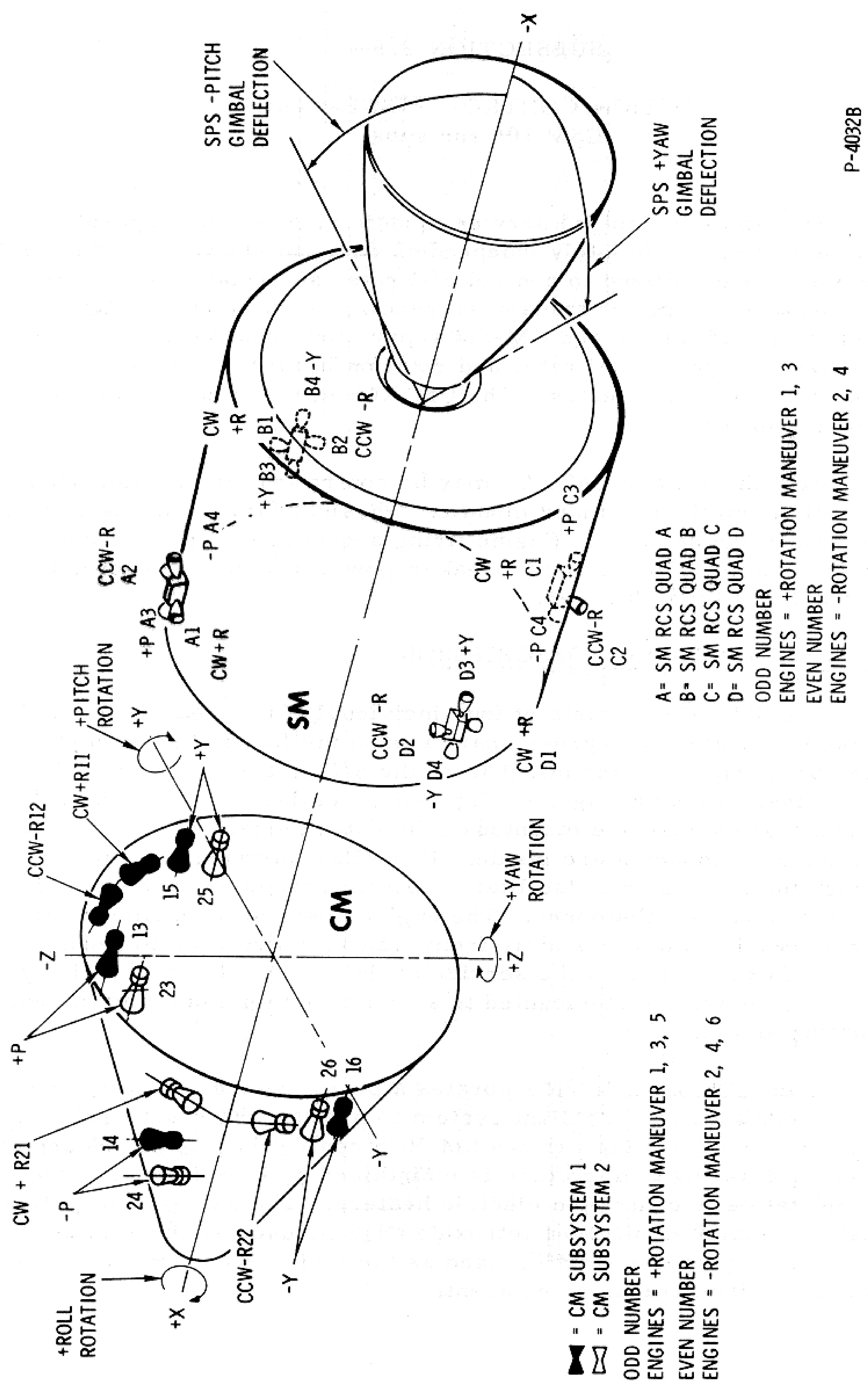

Figure 2.5-1. CM-SM Engine Locations

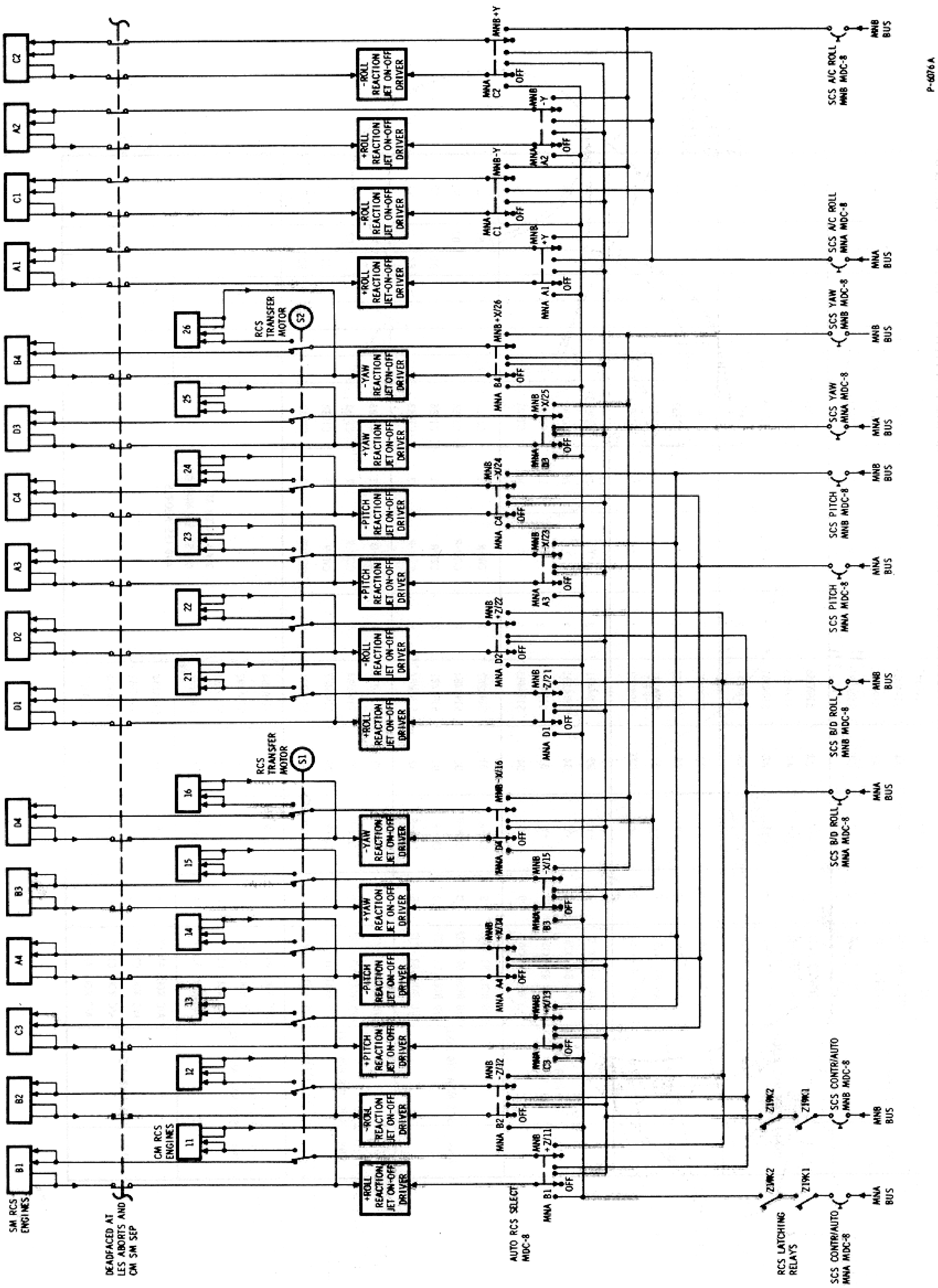

Figure 2.5-2. CSM-RCS Auto Control

BUS POWER	CIRCUIT BREAKER MDC 8	AUTORCS SELECT SWITCHES MDC 8	SM ENGINE				CM ENGINE				SM ENGINE UTILIZATION FOR TRANSLATION MANEUVERS						TRANSFER MOTOR
			QUAD	MANEUVER	SCS NO.	PROP. NO.	SYSTEM	MANEUVER	SCS NO.	PROP. NO.	-X	+X	-Y	+Y	-Z	+Z	
MNA	SCS MNA PITCH	PITCH C3 +X13	C	+P	C3	S19A3B3	1	+P	13	C19B7		C3					S1
		PITCH A4 +X14	A	-P	A4	S19A1B3	1	-P	14	C19B11		A4					S1
		PITCH A3 -X23	A	+P	A3	S19A1B1	2	+P	23	C19B8	A3						S2
		PITCH C4 -X24	C	-P	C4	S19A3B1	2	-P	24	C19B12	C4						S2
MNB	SCS MNB PITCH	PITCH C3 +X13	C	+P	C3	S19A3B3	1	+P	13	C19B7		C3					S1
		PITCH A4 +X14	A	-P	A4	S19A1B3	1	-P	14	C19B11		A4					S1
		PITCH A3 -X23	A	+P	A3	S19A1B1	2	+P	23	C19B8	A3						S2
		PITCH C4 -X24	C	-P	C4	S19A3B1	2	-P	24	C19B12	C4						S2
MNA	SCS MNA YAW	YAW D3 +X25	D	+Y	D3	S19A4B1	2	+Y	25	C19B10		D3					S2
		YAW B4 +X26	B	-Y	B4	S19A2B1	2	-Y	26	C19B2		B4					S2
		YAW B3 -X15	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	B3						S1
		YAW D4 -X16	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	D4						S1
MNB	SCS MNB YAW	YAW D3 +X 25	D	+Y	D3	S19A4B1	2	+Y	25	C19B10		D3					S2
		YAW B4 +X26	B	-Y	B4	S19A2B1	2	-Y	26	C19B2		B4					S2
		YAW B3 -X15	B	+Y	B3	S19A2B3	1	+Y	15	C19B9	B3						S1
		YAW D4 -X16	D	-Y	D4	S19A4B3	1	-Y	16	C19B1	D4						S1
MNA	SCS MNA B/D ROLL	B/D ROLL B1 +X11	B	CW+R	B1	S19A2B2	1	CW+R	11	C19B5						B1	S1
		B/D ROLL D2 +Z22	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4						D2	S2
		B/D ROLL D1 -Z21	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6					D1		S2
		B/D ROLL B2 -Z12	B	CCW-R	B2	S19A2B4	1	CCW-R	12	C19B3					B2		S1
MNB	SCS MNB B/D ROLL	B/D ROLL B1 +X11	B	CW+R	B1	S19A2B2	1	CW+R	11	C19B5						B1	S1
		B/D ROLL D2 +Z22	D	CCW-R	D2	S19A4B4	2	CCW-R	22	C19B4						D2	S2
		B/D ROLL D1 -Z21	D	CW+R	D1	S19A4B2	2	CW+R	21	C19B6					D1		S2
		B/D ROLL B2 -Z12	B	CCW-R	B2	S19A2B4	1	CCW-R	12	C19B3					B2		S1
MNA	SCS MNA A/C ROLL	A/C ROLL A1 +Y	A	CW+R	A1	S19A1B4	DEAD FACED AT CM SM SEPARATION AND LES ABORTS							A1			
		A/C ROLL C2 +Y	C	CCW-R	C2	S19A3B2								C2			
		A/C ROLL C1 -Y	C	CW+R	C1	S19A3B4							C1				
		A/C ROLL A2 -Y	A	CCW-R	A2	S19A1B2							A2				
MNB	SCS MNB A/C ROLL	A/C ROLL A1 +Y	A	CW+R	A1	S19A1B4								A1			
		A/C ROLL C2 +Y	C	CCW-R	C2	S19A3B2								C2			
		A/C ROLL C1 -Y	C	CW+R	C1	S19A3B4							C1				
		A/C ROLL A2 -Y	A	CCW-R	A2	S19A1B2							A2				

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Figure 2.5-3. CM-SM RCS Engine Power Supplies (Automatic)

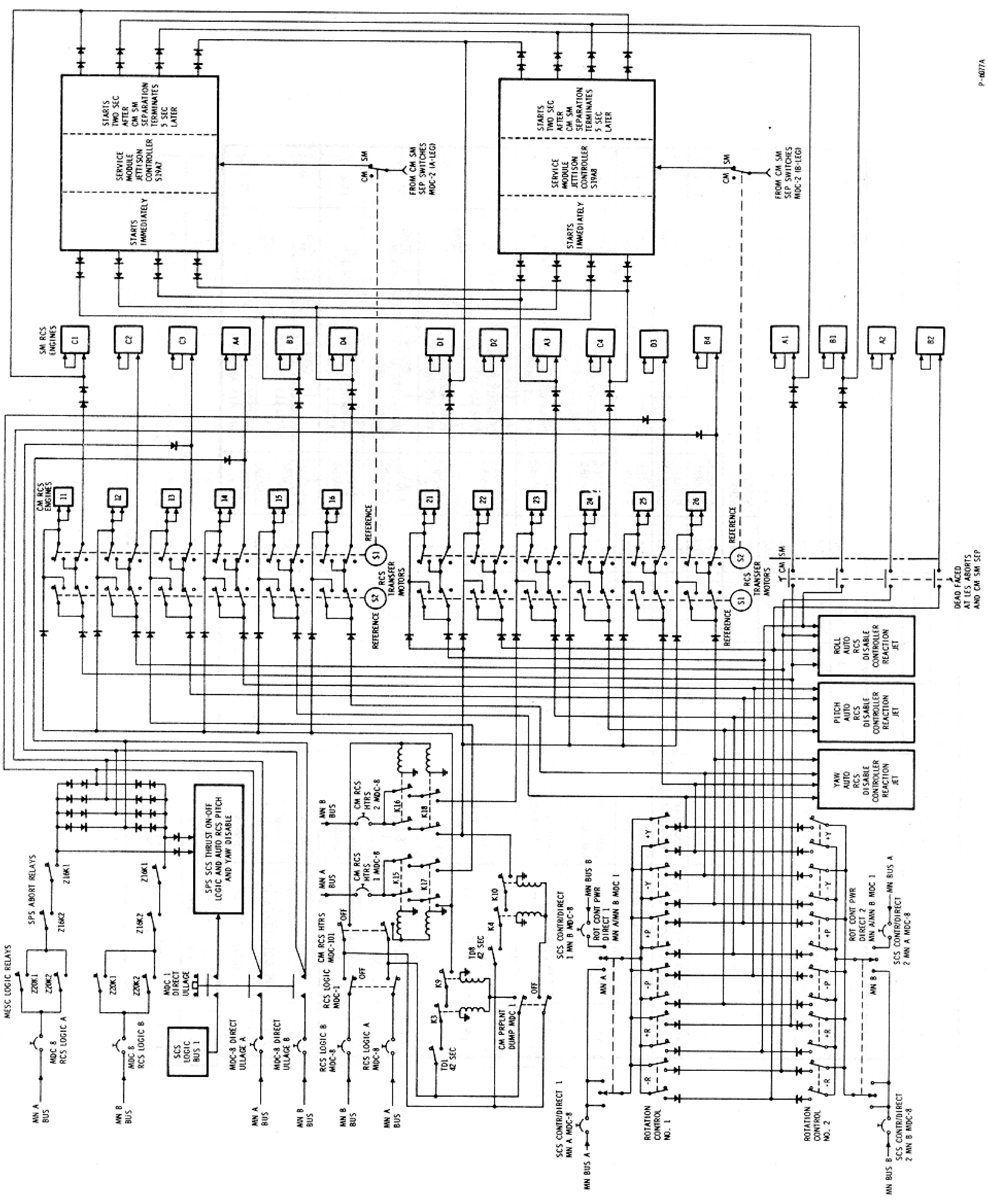

Figure 2.5-4. CSM RCS Direct Control

BUS POWER	CIRCUIT BREAKER MDC-8	DIRECT I SWITCH MDC 1	ROTATION CONTROL	SM ENGINE				CM ENGINE				TRANSFER MOTOR
				QUAD	MANEUVER	SCS NO.	PROP NO.	SYSTEM	MANEUVER	SCS NO.	PROP NO.	
MN A MN B	CONTR/DIRECTRCS 1A CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I+P I+P	C A	+P +P	C3 A3	S19A3B3 S19A1B1	1 2	+P +P	13 23	C19B7 C19B8	S2 & S1 S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I+P I+P	C A	+P +P	C3 A3	S19A3B3 S19A1B1	1 2	+P +P	13 23	C19B7 C19B8	S2 & S1 S1 & S2
MN A MN B	CONTR/DIRECTRCS 1A CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I-P I-P	A C	-P -P	A4 C4	S19A1B3 S19A3B1	1 2	-P -P	14 24	C19B11 C19B12	S2 & S1 S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I-P I-P	A C	-P -P	A4 C4	S19A1B3 S19A3B1	1 2	-P -P	14 24	C19B11 C19B12	S2 & S1 S1 & S2
MN A MN B	CONTR/DIRECTRCS 1A CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I+Y I+Y	B D	+Y +Y	B3 D3	S19A2B3 S19A4B1	1 2	+Y +Y	15 25	C19B9 C19B10	S2 & S1 S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I+Y I+Y	B D	+Y +Y	B3 D3	S19A2B3 S19A4B1	1 2	+Y +Y	15 25	C19B9 C19B10	S2 & S1 S1 & S2
MN A MN B	CONTR/DIRECTRCS 1A CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I-Y I-Y	D B	-Y -Y	D4 B4	S19A4B3 S19A2B1	1 2	-Y -Y	16 26	C19B1 C19B2	S2 & S1 S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I-Y I-Y	D B	-Y -Y	D4 B4	S19A4B3 S19A2B1	1 2	-Y -Y	16 26	C19B1 C19B2	S2 & S1 S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I+R I+R	C A	CW+R CW+R	C1 A1	S19A3B4 S19A1B4	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	11	C19B5	S2 & S1
MN B	CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I+R I+R	D B	CW+R CW+R	D1 B1	S19A4B2 S19A2B2	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	21	C19B6	S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I+R I+R	C A	CW+R CW+R	C1 A1	S19A3B4 S19A1B4	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	11	C19B5	S2 & S1
		MNA R.C. 1 MNA R.C. 1	I+R I+R	D B	CW+R CW+R	D1 B1	S19A4B2 S19A2B2	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	21	C19B6	S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I-R I-R	C A	CCW-R CCW-R	C2 A2	S19A3B2 S19A1B2	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	12	C19B3	S2 & S1
MN B	CONTR/DIRECTRCS 1B	MNA/MNB R.C. 1 MNA/MNB R.C. 1	I-R I-R	D B	CCW-R CCW-R	D2 B2	S19A4B4 S19A2B4	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	22	C19B4	S1 & S2
MN A	CONTR/DIRECTRCS 1A	MNA R.C. 1 MNA R.C. 1	I-R I-R	C A	CCW-R CCW-R	C2 A2	S19A3B2 S19A1B2	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	12	C19B3	S2 & S1
		MNA R.C. 1 MNA R.C. 1	I-R I-R	D B	CCW-R CCW-R	D2 B2	S19A4B4 S19A2B4	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	22	C19B4	S1 & S2

Figure 2.5-5. SM-CM RCS Engine Power Supplies (Direct) Rotation Control No. 1

BUS POWER	CIRCUIT BREAKER MDC-8	DIRECT 2 SWITCH MDC 1	ROTATION CONTROL	SM ENGINE				CM ENGINE				TRANSFER MOTOR
				QUAD	MANEUVER	SCS NO.	PROP NO.	SYSTEM	MANEUVER	SCS NO.	PROP NO.	
MN B MN A	CONTR/DIRECTRCS 2B CONTR/DIRECTRCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2+P 2+P	C A	+P +P	C3 A3	S19A3B3 S19A1B1	1 2	+P +P	13 23	C19B7 C19B8	S2 & S1 S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2+P 2+P	C A	+P +P	C3 A3	S19A3B3 S19A1B1	1 2	+P +P	13 23	C19B7 C19B8	S2 & S1 S1 & S2
MN B MN A	CONTR/DIRECTRCS 2B CONTR/DIRECTRCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2-P 2-P	A C	-P -P	A4 C4	S19A1B3 S19A3B1	1 2	-P -P	14 24	C19B11 C19B12	S2 & S1 S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2-P 2-P	A C	-P -P	A4 C4	S19A1B3 S19A3B1	1 2	-P -P	14 24	C19B11 C19B12	S2 & S1 S1 & S2
MN B MN A	CONTR/DIRECTRCS 2B CONTR/DIRECTRCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2+Y 2+Y	B D	+Y +Y	B3 D3	S19A2B3 S19A4B1	1 2	+Y +Y	15 25	C19B9 C19B10	S2 & S1 S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2+Y 2+Y	B D	+Y +Y	B3 D3	S19A2B3 S19A4B1	1 2	+Y +Y	15 25	C19B9 C19B10	S2 & S1 S1 & S2
MN B MN A	CONTR/DIRECTRCS 2B CONTR/DIRECTRCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2-Y 2-Y	D B	-Y -Y	D4 B4	S19A4B3 S19A2B1	1 2	-Y -Y	16 26	C19B1 C19B2	S2 & S1 S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2-Y 2-Y	D B	-Y -Y	D4 B4	S19A4B3 S19A2B1	1 2	-Y -Y	16 26	C19B1 C19B2	S2 & S1 S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2+R 2+R	C A	CW+R CW+R	C1 A1	S19A3B4 S19A1B4	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	11	C19B5	S2 & S1
MN A	CONTR/DIRECTRCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2+R 2+R	D B	CW+R CW+R	D1 B1	S19A4B2 S19A2B2	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	21	C19B6	S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2+R 2+R	C A	CW+R CW+R	C1 A1	S19A3B4 S19A1B4	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	11	C19B5	S2 & S1
		MNB R.C. 2 MNB R.C. 2	2+R 2+R	D B	CW+R CW+R	D1 B1	S19A4B2 S19A2B2	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CW+R	21	C19B6	S1 & S2
MN B	CONTR/DIRECT RCS 2B	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2-R 2-R	C A	CCW-R CCW-R	C2 A2	S19A3B2 S19A1B2	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	12	C19B3	S2 & S1
MN A	CONTR/DIRECT RCS 2A	MNA/MNB R.C. 2 MNA/MNB R.C. 2	2-R 2-R	D B	CCW-R CCW-R	D2 B2	S19A4B4 S19A2B4	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	22	C19B4	S1 & S2
MN B	CONTR/DIRECTRCS 2B	MNB R.C. 2 MNB R.C. 2	2-R 2-R	C A	CCW-R CCW-R	C2 A2	S19A3B2 S19A1B2	1 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	12	C19B3	S2 & S1
		MNB R.C. 2 MNB R.C. 2	2-R 2-R	D B	CCW-R CCW-R	D2 B2	S19A4B4 S19A2B4	2 DEADFACED AT CM SM SEPARATION AND LES ABORTS	CCW-R	22	C19B4	S1 & S2

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Figure 2.5-6. SM-CM RCS Engine Power Supplies (Direct) Rotation Control No. 2

RCS

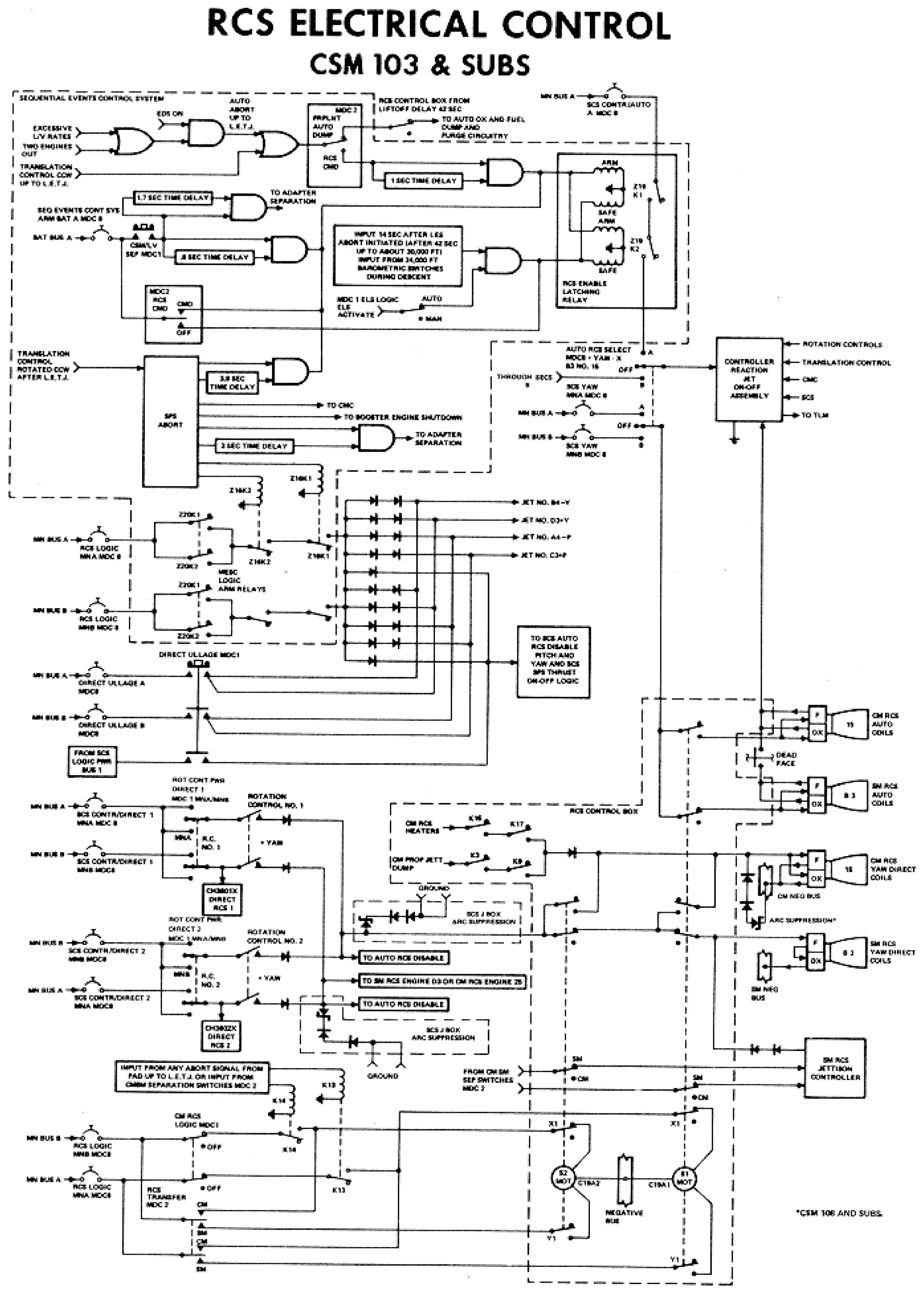
The reaction engines may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short-pulse firing permits attitude-hold modes of operation and extremely accurate attitude alignment maneuvers during navigational sightings. CSM attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines on all four quads. However, in the event of a malfunction or in order to conserve propellants, complete attitude control can be maintained with only two adjacent quads operating.

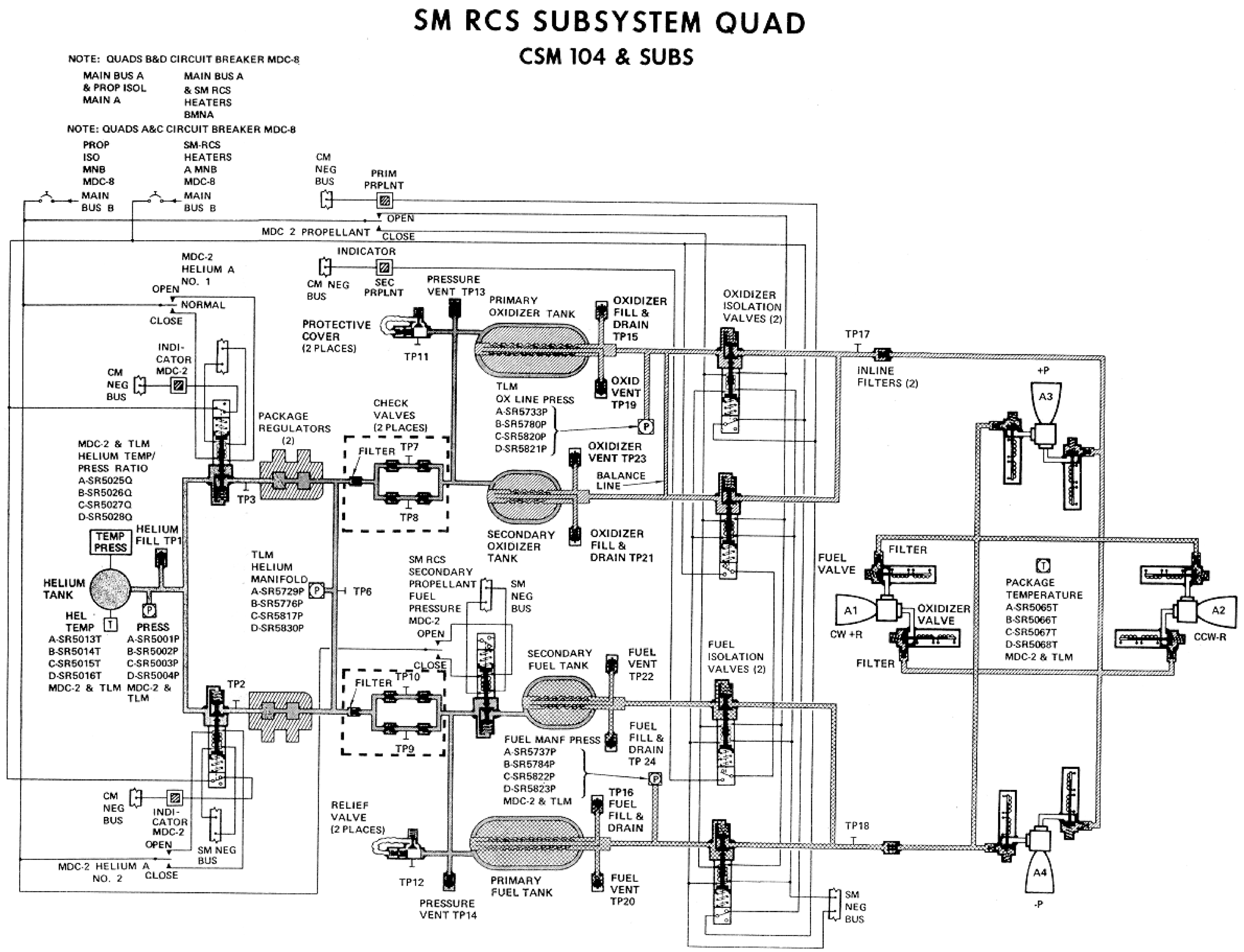
A functional flow diagram for a SM RCS quad is shown in figure 2.5-7. The helium storage vessel supplies helium to two solenoid-operated helium isolation valves that are normally open throughout the mission. This allows allows helium pressure to the regulators, downstream of each helium isolation valve, reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through series-parallel check valves. The check valves permit helium pressure to the fuel and oxidizer tanks, and prevent reverse flow of propellant vapors or liquid. A pressure relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressures.

Helium entering the propellant tanks creates a pressure buildup around the positive expulsion bladders forcing the propellants in the tank to be expelled into the propellant distribution lines. Propellants from the primary fuel and oxidizer tanks flow through the primary propellant isolation valves. Propellants from the secondary fuel and oxidizer tanks flow through the secondary propellant isolation valves. The secondary propellant fuel pressure isolation valve will be opened when the secondary propellant fuel pressure transducer (located downstream of the primary fuel tank) senses a drop in pressure. The drop in pressure indicates the primary fuel tank is at propellant depletion. Opening the secondary propellant fuel pressure valve at this time allows regulated helium pressure to the secondary fuel tank. It has been determined that due to the O/F ratio the fuel tank will deplete ahead of the oxidizer tanks, thus accounting for the secondary propellant fuel pressure isolation valve installation in the helium pressurization path to the secondary fuel tank only.

Oxidizer and fuel is distributed to the four engines by a parallel feed system. The fuel valve on each engine opens approximately two milliseconds prior to the oxidizer valve, to provide proper engine operation. Each valve assembly contains orifices which meter the propellant flow to obtain a nominal 2:1 oxidizer/fuel ratio by weight. The oxidizer and fuel





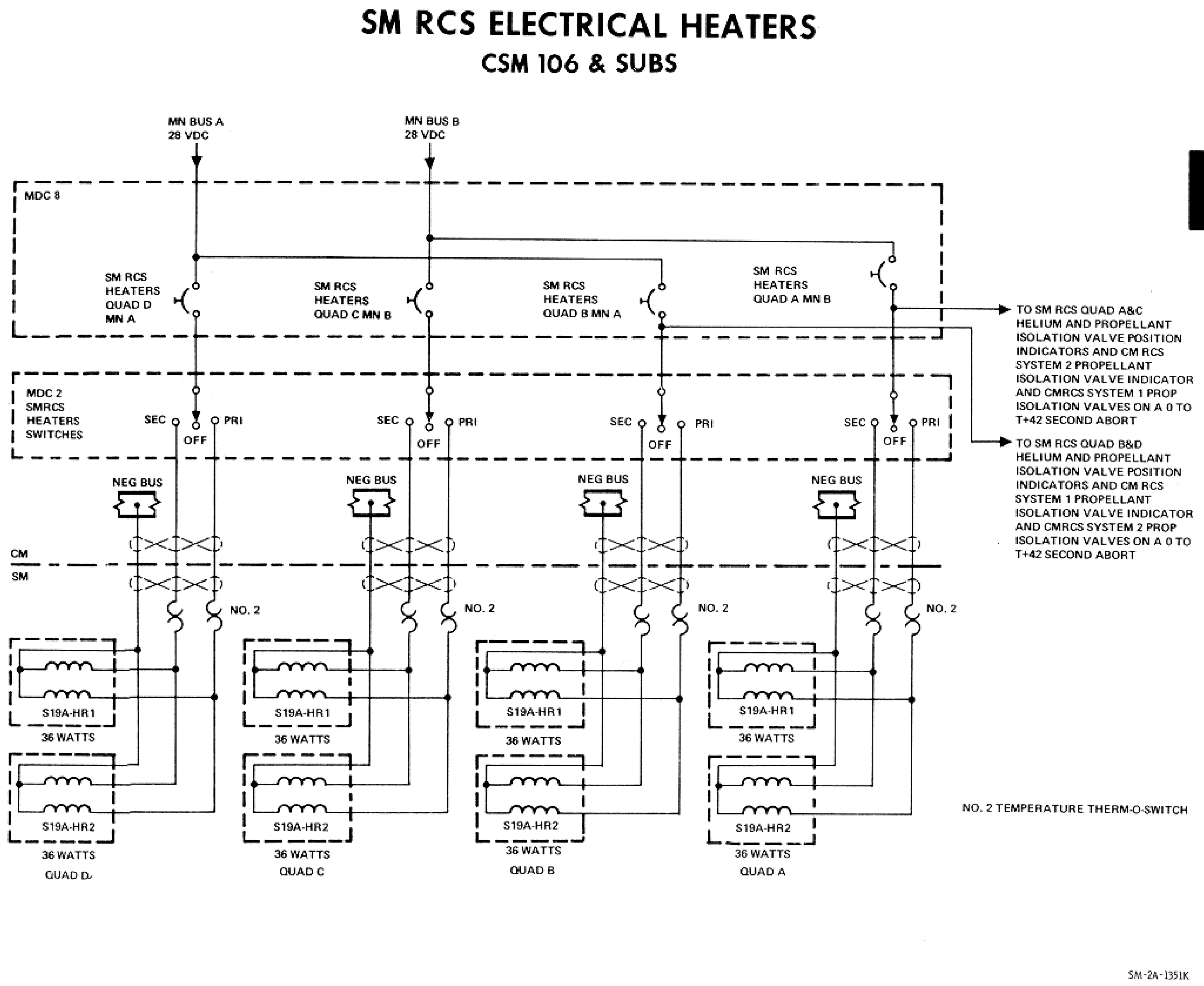


Figure 2.5-7. SM RCS Functional Flow

impinge, atomize, and are ignited by hypergolic reaction within the combustion chamber. The injector valves are controlled automatically by the controller reaction jet ON-OFF assembly. Manual direct control is provided for rotational maneuvers and direct ullage only. The engine injector valves are spring-loaded closed. This system configuration maintains propellants under constant pressure, at the engine injector valves, providing rapid consistent response rates to thrust ON-OFF commands.

2.5.2 SM RCS MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The SM RCS is composed of four separate, individual quads, each quad containing the following four major subsystems:

- Pressurization
- Propellant - primary/secondary
- Rocket engine
- Temperature control system

2.5.2.1 Pressurization Subsystem.

The pressurization subsystem regulates and distributes helium to the propellant tanks (figure 2.5-7). It consists of a helium storage tank, isolation valves, pressure regulators, and lines necessary for filling, draining, and distribution of the helium.

2.5.2.1.1 Helium Supply Tank.

The total high-pressure helium supply is contained within a single-spherical storage tank.

2.5.2.1.2 Helium Isolation Valve.

The helium isolation valves between the helium tank and pressure regulators contain two solenoids: one solenoid is energized momentarily to magnetically latch the valve open; the remaining solenoid is energized momentarily to unlatch the valve, and spring pressure and helium pressure forces the valve closed. The helium isolation valves in each quad are individually controlled by their own individual SM RCS HELIUM switch on MDC-2. The momentary OPEN position energizes the valve into the magnetic latch (open). The momentary CLOSE position energizes the valve to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The valves are normally open in respect to system pressure substantiating the magnetic latching feature for power conservation purposes during the mission in addition to prevent overheating of the valve coil.

A position switch contained within each valve controls a position indicator above each switch on MDC-2. When the valve is open, the position switch is open and the indicator on MDC-2 is gray (same color as the panel), indicating the valve is in its normal position. When the valve is closed, the position switch is closed and the indicator on MDC-2 is barber pole (diagonal lines), indicating the valve is in its abnormal position.

The valve is closed in the event of a pressure regulator unit problem and during ground servicing.

2.5.2.1.3 Pressure Regulator Assemblies.

Helium pressure regulation is accomplished by two regulator assemblies connected in parallel, with one assembly located downstream of each helium isolation valve. Each assembly incorporates two (primary and secondary) regulators connected in series and a filter at the inlet to each regulator. The secondary regulator remains open as the primary regulator functions properly. In the event of the primary regulator failing open, the secondary regulator, in series, will maintain slightly higher but acceptable pressures.

2.5.2.1.4 Check Valve Assemblies.

Two check valve assemblies, one assembly located upstream of the oxidizer tanks and the other upstream of the fuel tanks, permit helium flow in the downstream direction only. This prevents propellant and/or propellant vapor reverse flow into the pressurization system if seepage or failure occurs in the propellant tank bladders. Filters are incorporated in the inlet to each check valve assembly and each test port.

2.5.2.1.5 Pressure Relief Valves.

The helium relief valve contains a burst diaphragm, filter, a bleed device, and the relief valve. The burst diaphragm is installed to provide a more positive seal against helium than that of the actual relief valve. The burst diaphragm ruptures at a predetermined pressure. The burst diaphragm is of the nonfragmentation type, but in the event of any fragmentation, the filter retains any fragmentation and prevents particles from flowing onto the relief valve seat. The relief valve will relieve at a pressure slightly higher than that of the burst diaphragm rupture pressure and relieve the excessive pressure overboard protecting the fuel and oxidizer tanks. The relief valve will reseat at a predetermined pressure.

A pressure bleed device is incorporated between the burst diaphragm and relief valve. The bleed valve vents the cavity between the burst diaphragm and relief valve in the event of any leakage across the diaphragm, or vents the cavity upon completion of performing a checkout of the relief valve from the vent port on the relief valve. The bleed device is normally open and will close when the pressure increases up to a predetermined pressure. The bleed device automatically opens when the pressure decreases to the bleed valve opening pressure.

A protective cover is installed over the relief valve vent port and bleed valve cavity port to prevent moisture accumulation and foreign matter entrance. The covers are left in place at lift-off.

2.5.2.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each RCS quad from the helium storage vessels to the propellant tanks.

2.5.2.1.7 Secondary Propellant Fuel Pressure Isolation Valve.

The secondary propellant fuel pressure isolation valve in the pressurization line to the secondary fuel tank contains two solenoids: one solenoid is energized momentarily to magnetically latch the valve open; the remaining solenoid is energized momentarily to unlatch the valve, and spring pressure and helium pressure forces the valve closed. The secondary propellant fuel pressure isolation valve in each quad is controlled individually by its own individual SM RCS SEC PRPLNT FUEL PRESS switch on MDC-2. The momentary OPEN position energizes the valve into the magnetic latch (open); the momentary CLOSE position energizes the valve to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The valve is normally closed in respect to system pressure.

There is no position indicator talkback of the valve position to the MDC.

The valve will be opened when the secondary propellant fuel pressure decreases, indicating the primary fuel tank is depleted.

2.5.2.2 Propellant Subsystem.

This subsystem consists of two oxidizer tanks, two fuel tanks, two oxidizer and two fuel isolation valves, a fuel and oxidizer inline filter, oxidizer balance line, and associated distribution plumbing.

2.5.2.2.1 Primary and Secondary Oxidizer Tanks.

The oxidizer supply is contained in two titanium alloy, hemispherically domed cylindrical tanks. The tanks are mounted to the RCS panel. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer. The bladder is attached to the diffuser tube at each end of each tank. The diffuser tube acts as the propellant outlet.

When the tanks are pressurized, the helium surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and on out of the tank outlet into the manifold, providing expulsion during zero g's.

An oxidizer fluid balance line is incorporated on the oxidizer tank side of the propellant isolation valves between the primary and secondary oxidizer tanks (figure 2.5-7). In prelaunch, prior to lift-off, the helium and four propellant isolation valves are opened. The primary oxidizer tank will flow oxidizer to the secondary tank because the primary tank is located above the secondary tank. This displaces the ullage area in the secondary tank to the primary and fills the secondary full of oxidizer. If the launch continues normally, this creates no problem. However, if a long hold period occurs, the four propellant isolation valves will be closed and the fluid in the secondary tank will expand because of thermal growth. The fluid balance line allows the oxidizer to bleed from the secondary to the primary tank preventing possible rupture of the secondary tank.

The fuel tanks could have a similar problem except that the secondary propellant fuel pressure valve is closed prior to the opening of the four propellant isolation valves. This prevents transfer of fuel from one tank to the other.

2.5.2.2.2 Primary and Secondary Fuel Tanks.

The fuel supply is contained in two tanks that are similar in material, construction, and operation to that of the oxidizer tanks.

2.5.2.2.3 Propellant Isolation Shutoff Valve.

Each propellant isolation valve contains two solenoids: one that is energized momentarily to magnetically latch the valve open; and the remaining solenoid is energized momentarily to unlatch the magnetic latch, and spring pressure and propellant pressure closes the valve. The propellant isolation valves located in the primary fuel and oxidizer lines, as well as the secondary fuel and oxidizer lines in each quad, are all controlled by a single SM RCS propellant switch on MDC-2. The SM RCS propellant switch on MDC-2 for each quad placed to OPEN momentarily energizes the two primary and secondary fuel and oxidizer isolation valves into the magnetic latch (open); the CLOSE momentary position energizes the valve to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid.

Each quad, primary fuel, and oxidizer tank isolation valve contains a position switch that is in parallel to one PRIM PRPLNT position indicator above the SM RCS propellant switch on MDC-2. When the position indicator switch in each valve is actuated open, the PRIM PRPLNT indicator on MDC-2 is gray (same color as the panel) indicating both valves are open with respect to the fluid flow. Each quad, secondary tank fuel and oxidizer isolation valve contains a position switch that is in series to one SEC PRPLNT position indicator below the SM RCS propellant switch on MDC-2. When the position indicator switch in each valve is actuated closed, the SEC PRPLNT indicator on MDC-2 is gray (same color as the panel) indicating the valves are open to the fluid flow. When the position indicator switch in either primary fuel or oxidizer isolation valve is actuated closed, the PRIM PRPLNT position indicator on MDC-2 is barber pole (diagonal lines) indicating that either valve or both valves are closed in respect to the fluid flow. When the position indicator switch in either secondary fuel or oxidizer isolation valve is actuated open, the SEC PRPLNT position indicator on MDC-2 is barber pole (diagonal lines) indicating that either valve or both valves are closed in respect to the fluid flow.

The primary and secondary fuel and oxidizer isolation valves of each quad are normally open to the fluid flow.

The primary and secondary fuel and oxidizer isolation valves of a quad are closed to the fluid flow in the event of a failure downstream of the propellant isolation valves such as line rupture, runaway thruster, etc.

2.5.2.2.4 Distribution Plumbing.

Propellant distribution plumbing within each quad is functionally identical. Each quad contains separate similar oxidizer and fuel plumbing networks. Propellants, within their respective networks, are directed from the supply tanks through manifolds for distribution to the four engines in the clusters.

2.5.2.2.5 Propellant, In-Line Filters.

In-line filters are installed in the fuel and oxidizer lines downstream of the propellant shutoff valves and prior to the engine manifold contained within the engine housing.

The in-line filters are installed to prevent any particles from flowing into the engine injector valves and engine injector.

2.5.2.3 Engine Assemblies.

The service module reaction control system engines are radiation cooled, pressure fed, bipropellant thrust generators which can be operated in either the pulse or steady state mode. (These modes are defined as a firing duration of less than one second, and one second or more, respectively.)

Each engine has a fuel and oxidizer injector solenoid control valve. The injector solenoid control valves control the flow of propellants by responding to electrical commands (automatic or manual) generated by the controller reaction jet ON-OFF assembly or direct RCS respectively. Each engine contains an injector head assembly which directs the flow of each propellant from the injector solenoid control valves to the combustion chamber where the propellants atomize and ignite (hypergolic) producing thrust. A filter is incorporated at the inlet of each fuel and oxidizer solenoid injector valve. An orifice is installed in the inlet of each fuel and oxidizer solenoid injector valve that meters the propellant flow to obtain a nominal 2:1 oxidizer-fuel ratio by weight.

2.5.2.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The propellant solenoid injector valves utilize two coaxially wound coils, one for automatic and one for direct manual operation. The automatic coil is used when the thrust command originates from the controller reaction jet ON-OFF assembly which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The direct manual coils are used when the thrust command originates at the rotation control (direct mode), direct ullage pushbutton, SPS abort or the SM jettison controller (figure 2.5-7).

The solenoid valves are spring-loaded closed and energized open.

The reaction time of the valves are illustrated in figures 2.5-8 and 2.5-9.

Figure 2.5-8 illustrates a thrusting duration of 15 seconds (steady state). The electrical on signal is received within either the automatic (normal) or manual direct coils of the engine injector valves. At 14 seconds after the receipt of the thrust on signal, the automatic or manual direct coils are deenergized and the injector valves spring-load closed. However, due to the valve lag and residual propellant flow downstream of the injector valves, thrust output continues until the residuals have burned which establishes the cutoff transient.

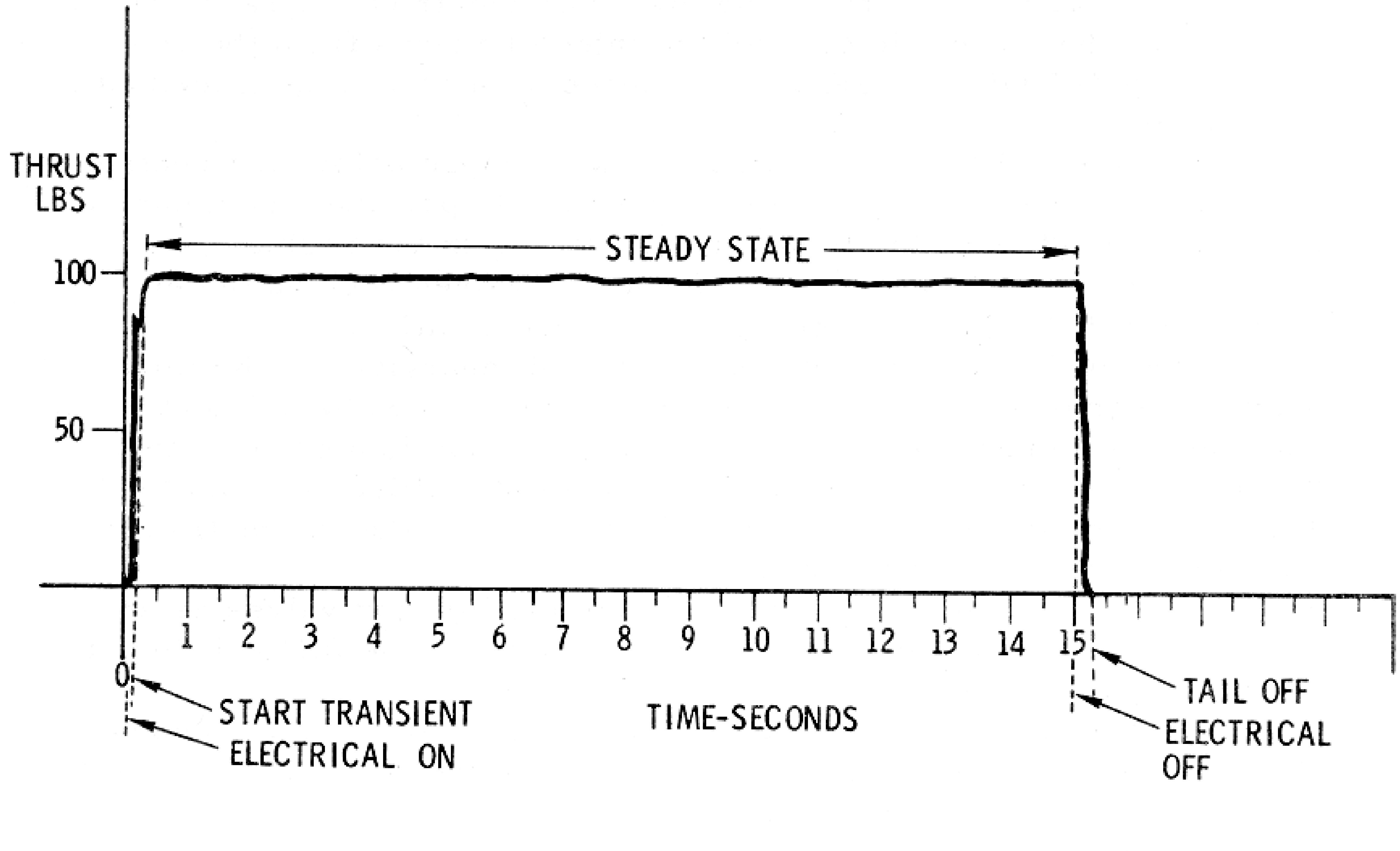


Figure 2.5-8. SM RCS Steady State Operation - Typical

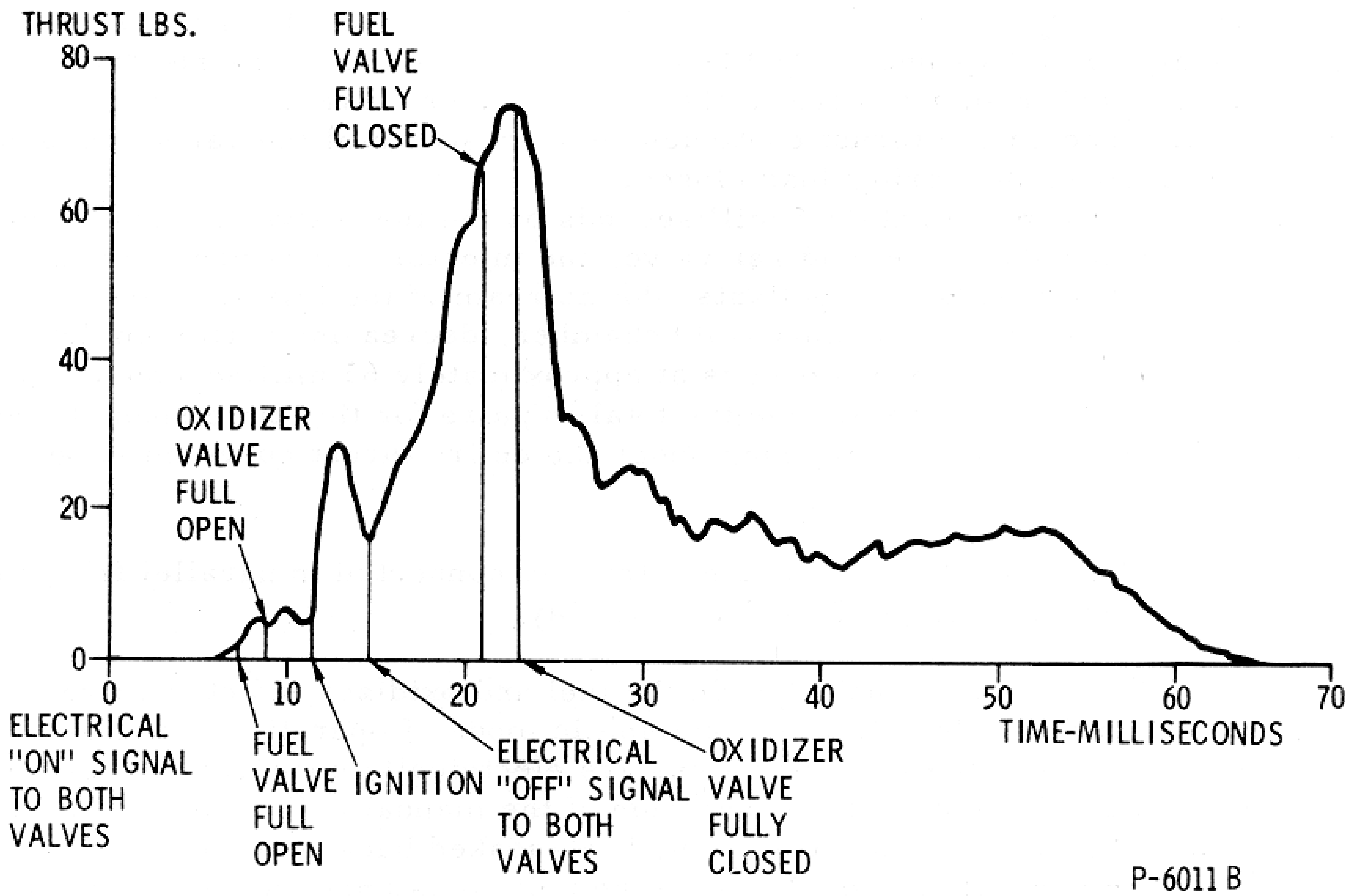


Figure 2.5-9. SM RCS Engine Minimum Total Impulse - Typical

Figure 2.5-9 illustrates the minimum electrical signal that can be provided to the automatic coils of the injector valves from the controller reaction jet ON-OFF assembly. Sequence of operation is described in the subsequent steps:

a. A time of 12 to 18 milliseconds will elapse before the controller reaction jet ON-OFF assembly can electrically provide a command off signal to the automatic coils of injector valves on the engine.

b. When the automatic coils of injector valves receive the electrical on signal, injector valves are energized to open position.

c. The fuel injector valve automatic coil energizes to the fully open position in approximately 7 milliseconds, and the oxidizer injector valve automatic coil energizes to the fully open position in approximately 9 milliseconds, establishing an approximate 2-millisecond fuel lead. This is accomplished by varying the resistance of the automatic coils in the fuel and oxidizer injector valve.

d. The propellants start to flow from the injector valves as soon as they start to open to the premix igniter; however, the fuel will lead the oxidizer by 2 milliseconds.

e. The propellants flow into the premix igniter and the combustion chamber which creates some pressure, gas velocity, and thrust in the combustion chamber even though it is very small because the engine is operating in a space environment.

f. The pressure, gas velocity, and thrust continue to increase slightly until the valves reach the full open position.

g. At approximately 12-1/2 milliseconds, the propellants ignite (hypergolic), producing a spike of thrust upwards into the area of approximately 70 to 80 pounds. At 12 milliseconds minimum, the electrical signal is removed from automatic coils of the injector valves.

h. The engine thrust continues very erratic until the valves become deenergized and spring-load closed.

i. At approximately 7 milliseconds on the fuel valve and approximately 8 milliseconds on the oxidizer valve, the injector valves are fully closed.

j. The residual propellants, downstream of the injector valves, continue to flow into the combustion chamber, decreasing until complete thrust decay of 0 pounds occurs at approximately 65 milliseconds.

k. In order to determine the total impulse for this time span of operation (figure 2.5-9), everything under the entire thrust curve must be integrated.

The automatic coils are electrically connected in parallel from the controller reaction jet ON-OFF assembly.

The direct manual coils in the fuel and oxidizer injector valves provide a direct backup to the automatic mode of operation. The direct manual coils of the injector valves are electrically connected in series. The reason for the series connection of the manual coils are as follows:

a. To insure a fuel lead if any heat-soaked back into the direct manual coil windings, which would change the coil resistance and result in an oxidizer lead if the coils were connected in parallel.

b. The series connection from the fuel direct manual coil is positive to negative and to the oxidizer direct manual coil is negative to positive, then to ground. The reverse polarity on the oxidizer coil increases the arc suppression, reducing the arc at the rotation control in the direct RCS mode of operation. The direct manual coil opening time for the fuel injector valve is 26 milliseconds and the oxidizer is approximately 36 milliseconds. Closing time for the fuel and oxidizer direct manual coils is 55±25 milliseconds.

2.5.2.3.2 Injector.

The main chamber portion of the injector will allow 8 fuel streams to impinge upon 8 oxidizer streams (unlike impingement) for main chamber ignition. There are 8 fuel holes around the outer periphery of the injector which provide film cooling to the combustion chamber walls. There are 8 fuel holes around the premix chamber providing cooling to the premix chamber walls.

The injector contains a premix igniter, and the premix chamber contains a fuel and an oxidizer passage that impinge upon each other (unlike impingement) within the premix igniter chamber. The premix igniter chamber, along with the approximate 2-millisecond fuel lead, provides a smoother start transient primarily in the pulse mode of operation and especially in the area of minimum impulse.

2.5.2.3.3 Combustion Chamber.

The combustion chamber is constructed of unalloyed molybdenum which is coated with molybdenum disilicide to prevent oxidation of the base metal. Cooling of the chamber is by radiation and film cooling.

2.5.2.3.4 Nozzle Extension.

The nozzle extension is attached to the chamber by a waspolloy nut. The nozzle extension is machined from a cobalt base alloy (stainless steel). The stiffener rings are machined.

2.5.2.3.5 RCS Electrical Heaters.

Each of the RCS engine housings contains two electrical strip heaters. Each heater contains two electrical elements. Each heater element is controlled by a No. 2 therm-o-switch (figure 2.5-7). When the SM RCS HEATERS switch on MDC-2 for that quad is placed to PRI, 28 vdc is supplied to the No. 2 therm-o-switch. The therm-o-switch is set at a predetermined range and will automatically open or close because of the temperature range of the therm-o-switch and will control one element in each heater. When the SM RCS HEATERS switch on MDC-2 for that quad is placed to SEC, 28 vdc is supplied to the redundant No. 2 therm-o-switch. The therm-o-switch is set at a predetermined range and will automatically open or close because of the temperature range of the therm-o-switch and will control the redundant element in each heater. The SM RCS HEATERS switches will normally be placed to PR1 at earth orbit acquisition and the SEC position is utilized as a backup.

The OFF position of the SM RCS HEATERS switch on MDC-2 removes power from the SM RCS heaters.

The SM RCS package temperature indicator on MDC-2 may be utilized to monitor the package temperature of any one of the four SM RCS quads by utilizing the SM positions A, B, C or D of the RCS INDICATORS select switch on MDC-2. The SM RCS package temperature transducers will also illuminate the SM RCS A, B, C or D caution and warning lights on MDC-2 if the package temperature becomes too low or too high.

2.5.2.4 Pressure Versus Temperature Measuring System.

The helium tank supply pressure and temperature for each quad is monitored by a pressure/temperature ratio transducer (figure 2.5-7).

The pressure/temperature ratio transducer for each quad provides a signal to the RCS indicator select switch on MDC-2. When the RCS indicator select switch on MDC-2 is positioned to a given SM RCS quad, the pressure/temperature ratio signal is transmitted to the propellant quantity gauge on MDC-2, and the propellant quantity remaining for that quad is indicated in percent.

The helium tank temperature for each quad is monitored by a helium tank temperature transducer. The helium tank temperature is monitored by TLM. The helium tank temperature can be monitored on MDC-2. The SM RCS He TK TEMP/PRPLNT QTY switch and the SM positions A, B, C, or D of the RCS indicators select switch on MDC-2 provides the crew with the capability to monitor either the helium tank temperature/pressure ratio as a percent quantity remaining, or helium tank temperature which can be compared against the helium supply pressure readout on MDC-2. With the use of a nomogram the propellant quantity remaining could be determined in percent through comparison of helium tank temperature and helium supply pressure.

2.5.2.5 Engine Thrusting Logic.

In the SM RCS, the main buses cannot supply electrical power to one leg of the AUTO RCS SELECT switches on MDC-8 and controller reaction jet ON-OFF assembly until the contacts of the RCS latching relay are closed (figure 2.5-7). Closing of these contacts for SM RCS control may be initiated by the following signals:

a. With the launch escape tower jettisoned, and the translation control rotated counterclockwise, an SPS abort or S-IVB separation may be initiated and the following sequence of events occur:

1. Inform the CMC system of an abort initiation.
2. Initiate applicable booster shutdown.
3. Inhibit the pitch and yaw automatic jets of the controller jet ON-OFF assembly and provide a signal to SCS-SPS thrust ON-OFF logic.
4. Initiates an ullage maneuver signal to the required direct manual coils of the SM RCS engines (as long as the translation control is counterclockwise, ullage is terminated when the translation control is returned to the neutral detent).
5. Adapter separation occurs at 3.0 seconds after the above was initiated. In the event the automatic adapter separation did not occur, the CSM/LV SEPARATION pushbutton on MDC-1 can be pressed and held.
6. Energizes the RCS latching relay 3.8 seconds after the abort was initiated allowing the controller reaction jet ON-OFF assembly to provide electrical commands to the automatic coils of the SM RCS engines. If the sequential events control system logic fails to energize the RCS latching relay, the RCS CMD switch on MDC-2, placed to the RCS CMD position, provides a manual backup to the automatic function. In addition, if the CSM/LV SEPARATION pushbutton on MDC-1 is pressed and held for approximately 1 second the RCS latching relay is energized.

b. A normal S-IVB separation sequence may be initiated as follows: The RCS CMD switch on MDC-2 is placed to RCS CMD, enabling the controller reaction jet ON-OFF assembly to provide commands to the automatic coils of the SM RCS engines. Then positioning the translation control to +X (backup of DIRECT ULLAGE pushbutton on MDC-1) provides the signal required to the +X SM RCS engines; and the CSM/LV SEPARATION pushbutton on MDC-1 is held for 2 seconds to initiate adapter separation. (CSM/LV SEPARATION pushbutton on MDC-1 pressed and held for approximately 2 seconds will also energize the RCS latching relay.) The translation control is returned to neutral and the CSM/LV SEP pushbutton on MDC-1 is released.

In the event the translation control is unable to provide an ullage maneuver, the DIRECT ULLAGE pushbutton, on MDC-1, when pressed and held, provides the direct ullage signal to the direct manual coils of the required SM RCS engines providing a +X translation. This provides a manual direct backup to the translation control for the ullage maneuver. The ullage maneuver is terminated upon release of the DIRECT ULLAGE pushbutton.

In the event the controller reaction jet ON-OFF assembly is unable to provide commands to the automatic coils of the SM RCS engines, a backup method is provided. This method consists of two ROT CONT PWR DIRECT RCS switches on MDC-1 and the two rotation controllers. The ROT CONT PWR DIRECT RCS 1 switch supplies power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch, is positioned to MNA/MNB, main buses A and B supply power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch is positioned to MNA, main bus A supplies power only to rotation control 1. The ROT CONT PWR DIRECT RCS 2 switch supplies power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNA/MNB, main buses A and B supply power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNB, main bus B supplies power only to rotation control 2. When the rotation control is positioned fully to its stops in any direction, the rotation control will energize the required direct manual coils for the desired maneuver and provide an inhibit signal to the SM RCS automatic coils.

If the controller reaction jet ON-OFF assembly is unable to provide commands to the automatic coils of the SM RCS engines, it is noted that translation control of the spacecraft is disabled.

2.5.3 SM RCS PERFORMANCE AND DESIGN DATA.

2.5.3.1 Design Data.

The following list is the design data on the SM RCS components.

Helium Tanks (4)	4150±50 psig at 70±5°F during servicing. After servicing setting on launch pad is 70±10°F, capacity 1.35 lb. Internal volume of 910±5 cubic inches. Wall thickness, 0.135 inch.
	Weight 11.5 lb, diameter 12.37 in.
Regulator Units (8)	Primary 181±3 psig with a normal lockup of 183±5 psig.
	Secondary lockup of 187±5 psig. From lockup pressure not to drop below 182 psig or rise above 188 psig. Filter 25 microns nominal, 40 microns absolute at inlet of each regulator unit.

Secondary Fuel Pressure Transducers (4)	Illuminate caution and warning light on MDC-2 (SM RCS A, B, C, or D): Underpressure 145 psia nominal. Overpressure 215 psia nominal.
Check Valve-Filters	40 microns nominal, 74 microns absolute. One at inlet to check valve assembly, one at each test port.
Helium Relief Valves (8)	Diaphragm rupture at 228±8 psig, filter 10 microns nominal, 25 microns absolute. Relief valve relieves at 236.5±11.5 psig, reseats at not less than 220 psig. Flow capacity 0.3 lb/minute at 248 psig at 60°F. Bleed device closes when increasing pressure reaches no more than 179 psig in the cavity and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device reopens when decreasing pressure has reached no less than 20 psig.
Primary Fuel Tank (4)	Combined propellant and ullage volume of 69.1 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter 12.62 in. maximum. Length 23.717 (+0.060, -0.000) in. Wall thickness 0.017 to 0.022 in. Helium inlet port 1/4 in.; fill and drain port 1/2 in.
Primary Oxidizer Tank (4)	Combined propellant and ullage volume of 137.0 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter 12.62 in. maximum, length 28.558 (+0.060, -0.000) in. Wall thickness 0.017 to 0.022 in.

RCS

Secondary Fuel Tank (4)	Combined propellant and ullage volume of 45.2 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Outside diameter 12.62 in. maximum, length 17.329 (+0.040, -0.000) in. Wall thickness 0.022 to 0.027 in.
Secondary Oxidizer Tank (4)	Combined propellant and ullage volume of 89.2 lb, initially at 65°F at 150 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Outside diameter 12.65 in. maximum, length 19.907 (+0.040, -0.000) in. Wall thickness 0.022 to 0.027 in.
Inline Filters (8)	5 microns nominal, 15 microns absolute.
Engine (16)	1000-second service life, 750 seconds continuous, capable of 10,000 operational cycles. Expansion ratio 40 to 1 at nozzle exit. Cooling-film and radiation, injector-type premix ignitor, one on one unlike impingement, 8 fuel annulus for film cooling of premix ignitor, main chamber 8 on 8 unlike impingement, 8 fuel for film cooling of combustion chamber wall.
	Nozzle exit diameter - 5.6 inches
	Fuel lead
	Automatic coils - connected in parallel
	Manual coils - connected in series
	Weight - 4.99 lb
	Length - 13.400 in. maximum
Filters - each injector valve inlet	100 microns nominal, 250 microns absolute
Package Temperature Transducer (4)	Illuminate caution and warning light on MDC-2 (SM RCS A, B, C, or D):
	Below temperature of 75°F nominal.
	Above temperature of 205°F nominal.

Heater Therm-O-Switch	#2
	Close at 115°F
	Open at 134°F
	Minimum spread 9°F
	36±3.6 watts per element nominal two per quad.

2.5.3.2 Performance Data.

Refer to CSM/LM Spacecraft Operational Data Book SNA-8-B-027 CSM (SD 68-447).

2.5.3.3 SM RCS Electrical Power Distribution.

See figure 2.5-10 for electrical power distribution.

2.5.4 SM RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Refer to Volume 2, AOH malfunction procedures.

2.5.5 CM RCS FUNCTIONAL DESCRIPTION.

The command module reaction control subsystems provide the impulses required for controlling spacecraft rates and attitude during the terminal phase of a mission.

The subsystems may be activated by the CM-SM SEPARATION switches on MDC-2 placed to CM-SM SEPARATION position, or by placing the CM RCS PRESSURIZE switch on MDC-2 to the CM RCS PRESS position. The subsystems are activated automatically in the event of an abort from the pad up to launch escape tower jettison. Separation of the two modules occurs prior to entry (normal mode), or during an abort from the pad up to launch escape tower jettison.

The CM RCS consists of two similar and independent subsystems, identified as subsystem 1 and subsystem 2. Both subsystems are pressurized simultaneously. In the event a malfunction develops in one subsystem, the remaining subsystem has the capability of providing the impulse required to perform necessary pre-entry and entry maneuvers. The CM RCS is contained entirely within the CM and each reaction engine nozzle is ported through the CM skin. The propellants consist of inhibited nitrogen tetroxide (N_2O_4) used as the oxidizer and monomethylhydrazine (MMH) used as fuel. Pressurized helium gas is the propellant transferring agent.

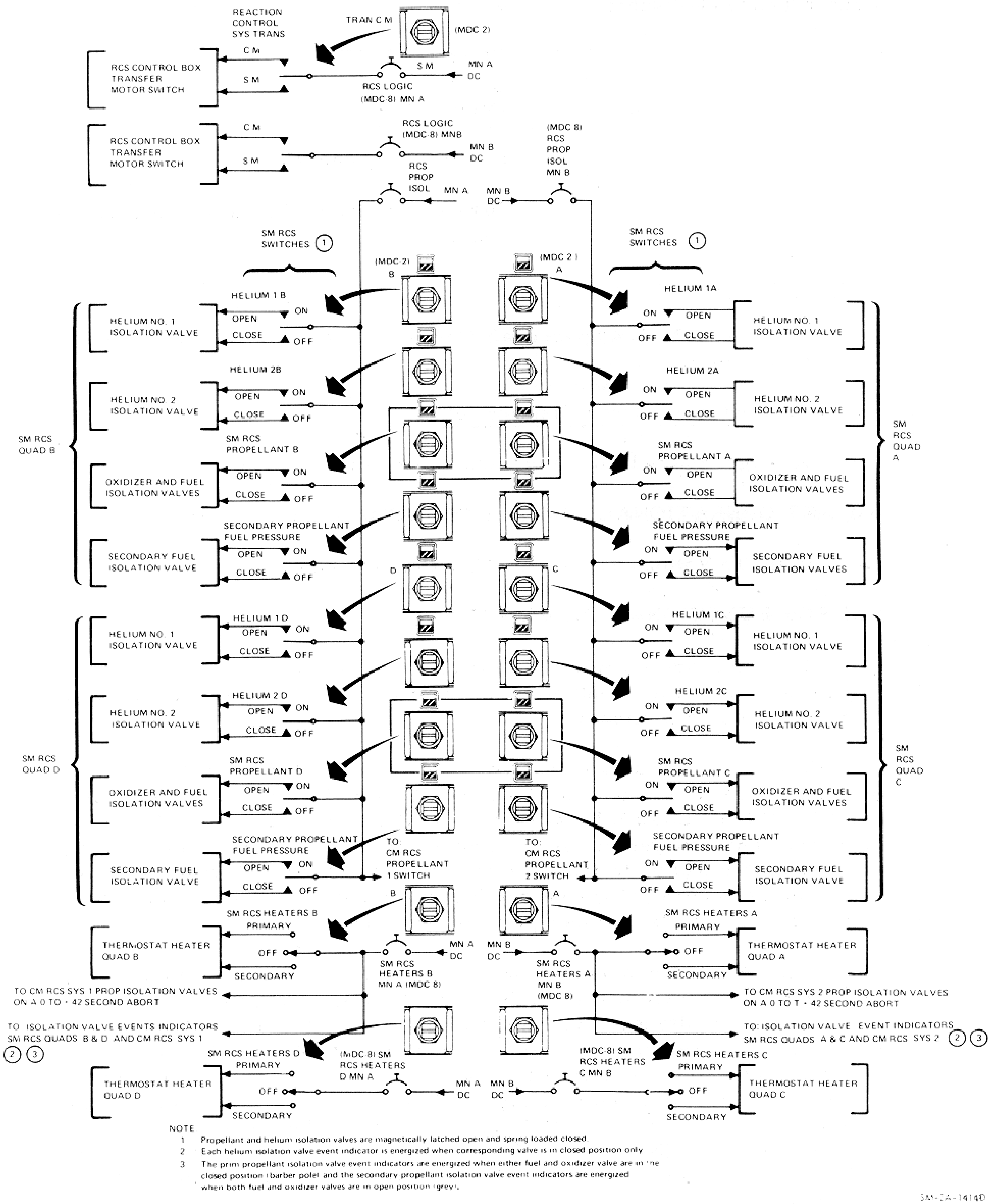


Figure 2.5-10. SM RCS Electrical Power Distribution

The reaction jets may be pulse-fired, producing short thrust impulses or continuously fired, producing a steady state thrust level. CM attitude control is maintained by utilizing the applicable pitch, yaw and roll engines of subsystems 1 and 2. However, complete attitude control can be maintained with only one subsystem.

A functional flow diagram of CM RCS subsystems 1 and 2 is shown in figure 2.5-11. The helium storage vessel of each subsystem supplies pressure to two helium isolation squib valves that are closed throughout the mission until either the CM SM Separation switch on MDC-2, or CM RCS PRESS switch on MDC-2 is activated. When the helium isolation squib valves in a subsystem are initiated open, this allows the helium tank source pressure to the pressure regulators downstream of each helium isolation squib valve. The regulators reduce the high-pressure helium to a desired working pressure.

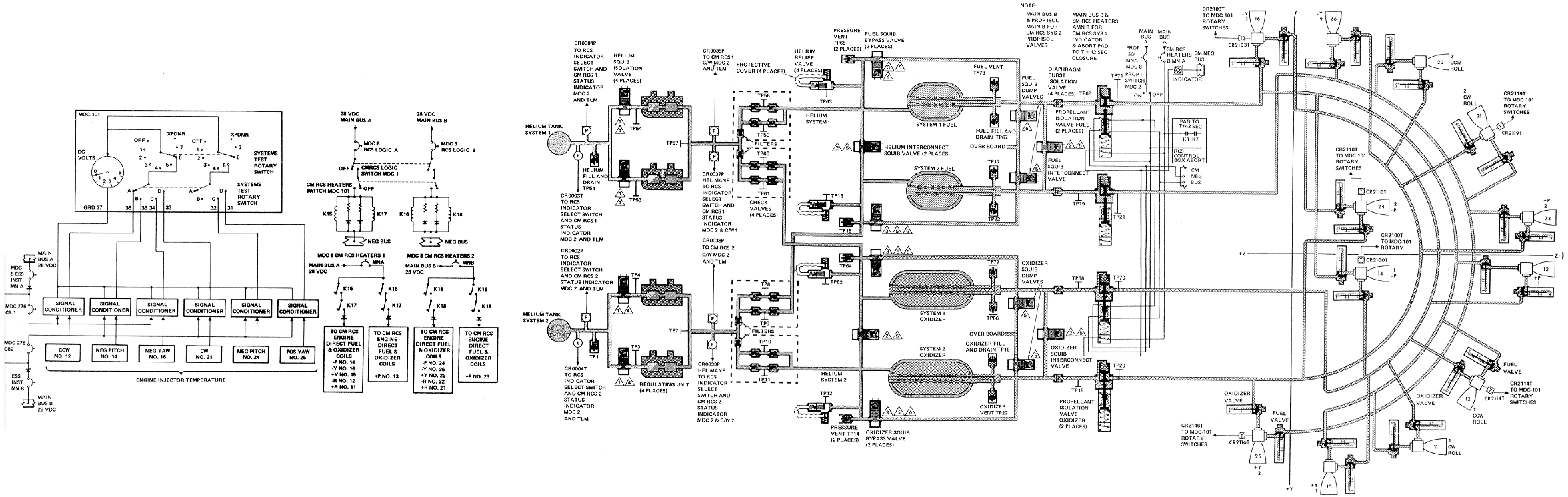
Regulated helium pressure is directed through series-parallel check valves. The check valves permit helium pressure to the fuel and oxidizer tanks and prevent reverse flow of propellant vapors or liquids. A pressure relief valve is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure.

Helium entering the propellant tanks creates a pressure buildup around the propellant positive expulsion bladders, forcing the propellants to be expelled into the propellant distribution lines. Propellants then flow to valve isolation burst diaphragms, which rupture due to the pressurization, and then through the propellant isolation valves. Each subsystem supplies fuel and oxidizer to six engines.

Oxidizer and fuel is distributed to the 12 engines by a parallel feed system. The fuel and oxidizer engine injector valves, on each engine, contain orifices which meter the propellant flow to obtain a nominal 2.1 oxidizer/fuel ratio by weight. The oxidizer and fuel ignite due to the hypergolic reaction. The engine injector valves are controlled automatically by the controller reaction jet ON-OFF assembly. Manual direct control is provided for rotational maneuvers, and the engine injector valves are spring-loaded closed.

CM RCS engine preheating may be necessary before initiating pressurization due to possible freezing of the oxidizer (+11.8°F) upon contact with the engine injector valves. The crew will monitor the engine temperatures and determine if preheating is required by utilizing the engine injector valve solenoids direct manual coils for preheat until acceptable engine temperatures are obtained. The CM RCS HTRS switch, on MDC-101, will be utilized to apply power to the engine injector valve direct manual coils for engine preheating.

RCS



PHASE	SEQUENCE	SQUIB VALVE INDICATION (TOTAL: 16 VALVES)								
		HELIUM ISOLATION (4)	FUEL SIDE HELIUM INTERCONNECT (1)	OXIDIZER SIDE HELIUM INTERCONNECT (1)	FUEL INTERCONNECT (1)	OXIDIZER INTERCONNECT (1)	FUEL TANK BYPASS (2)	OXIDIZER TANK BYPASS (2)	OXIDIZER DUMP (2)	FUEL DUMP (2)
NORMAL ENTRY	1. PRIOR TO CM SM SEPARATION	1 (NORMAL OR BACKUP) / (BACKUP OR NORMAL) 4								
	2. MAIN PARACHUTE LINE STRETCH		2	2	2	2				
	3. AFTER PROPELLANT DEPLETION						3 (NORMAL) / (BACKUP) 6	3 (NORMAL) / (BACKUP) 6		
ABORT PAD TO T + 42 SECONDS	1. SIMULTANEOUS WITH EDS OR MANUAL ABORT INITIATION	4 (NORMAL) / (BACKUP) 1	5	5	5	5			5	
	2. ABORT INITIATION PLUS 5 SECONDS.									5
	3. 13 SECONDS AFTER FUEL DUMP INITIATION						5	5		
ABORT AFTER T + 42 SECONDS	1. SIMULTANEOUS WITH EDS OR MANUAL ABORT INITIATION,	4 (NORMAL) / (BACKUP) 1								
	2. MAIN PARACHUTE LINE STRETCH		2	2	2	2				
	3. AFTER PROPELLANT DEPLETION						3 (NORMAL) / (BACKUP) 6	3 (NORMAL) / (BACKUP) 6		
ALL SPS ABORTS	SAME AS NORMAL ENTRY									

- HELIUM
- OXIDIZER
- FUEL
- P PRESSURE TRANSDUCER
- T TEMPERATURE TRANSDUCER
- C/W CAUTION AND WARNING

LEGEND FOR SQUIB VALVE ACTUATION

1. CM RCS PRESSURIZE, SWITCH MDC 2
2. CM PROPELLANT DUMP SWITCH MDC 1
3. CM PROPELLANT PURGE SWITCH MDC 1
4. AUTOMATIC (CM SM SEPARATION)
5. AUTOMATIC (RCS CONTROL BOX)
6. CM RCS HELIUM DUMP PUSHBUTTON, MDC 1

CM RCS FUNCTIONAL FLOW
CSM 104 AND SUBS

SM-2A-1243R

Figure 2.5-11. CM RCS Functional Flow

Since the presence of hypergolic propellants can be hazardous upon CM impact, the remaining propellants are burned or dumped and purged with helium in addition to depleting the helium source pressure prior to CM impact.

In the event of an abort from the pad up to T + 42 seconds after lift-off, provisions have been incorporated to automatically dump the oxidizer and fuel supply overboard. Then, followed by a helium purge of the fuel and oxidizer systems in addition to depleting the helium source pressure.

2.5.6 CM RCS MAJOR COMPONENTS/SUBSYSTEMS DESCRIPTION.

RCS

The CM RCS is composed of two separate, normally independent subsystems, designated subsystem 1 and subsystem 2. The subsystems are identical in operation, each containing the following four major subsystems:

- Pressurization
- Propellant
- Rocket engine
- Temperature control system heaters.

2.5.6.1 <u>Pressurization Subsystem.</u>

This subsystem consists of a helium supply tank, two dual pressure regulator assemblies, two check valve assemblies, two pressure relief valve assemblies, and associated distribution plumbing.

2.5.6.1.1 Helium Supply Tank.

The total high-pressure helium is contained within a single spherical storage tank for each subsystem. Initial fill pressure is 4150±50 psig.

2.5.6.1.2 Helium Isolation (Squib-Operated) Valve.

The two squib-operated helium isolation valves are installed in the plumbing from each helium tank to confine the helium into as small an area as possible. This reduces helium leakage during the period the system is not in use. Two squib valves are employed in each system to assure pressurization. The valves are opened by closure of the CM RCS PRESS switch on MDC-2 to CM RCS PRESS, or by placing the CM/SM SEP switches on MDC-2 to CM/SM SEP, or upon the receipt of an abort signal from the pad up to the launch escape tower jettison.

2.5.6.1.3 Helium Pressure Regulator Assembly.

The pressure regulators used in the CM RCS subsystems 1 and 2 are similar in type, operation, and function to those used in the SM RCS.

The difference is that the regulators in the CM RCS are set at a higher pressure than those of the SM RCS.

2.5.6.1.4 Helium Check Valve Assembly.

The check valve assemblies used in CM RCS subsystems 1 and 2 are identical in type, operation, and function to those used in the SM RCS.

2.5.6.1.5 Helium Relief Valve.

The helium relief valves used in the CM RCS subsystems 1 and 2 are similar in type, operation, and function to those used in the SM RCS.

The difference being the rupture pressure of the burst diaphragm in the CM RCS is higher than that of the SM RCS and the relief valve relieves at a higher pressure in the CM RCS than that of the SM RCS.

2.5.6.1.6 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium in each subsystem from the helium storage vessels to the propellant tanks.

2.5.6.2 Propellant Subsystem.

Each subsystem consists of one oxidizer tank, one fuel tank, oxidizer and fuel isolation valves, oxidizer and fuel burst diaphragm isolation valves, and associated distribution plumbing.

2.5.6.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer similar to that of the SM RCS secondary tank assemblies. The bladder is attached to the diffuser tube at each end of the tank. The diffuser tube acts as the propellant outlet.

When the tank is pressurized, the helium gas surrounds the entire bladder, exerting a force which causes the bladder to collapse about the propellant, forcing the oxidizer into the diffuser tube assembly and on out of the tank outlet into the manifold.

2.5.6.2.2 Fuel Tank.

The fuel supply is contained in a single titanium alloy, hemispherical-domed cylindrical tank in each subsystem that is similar in material construction and operation to that of the SM RCS secondary fuel tanks.

2.5.6.2.3 Diaphragm Burst Isolation Valve.

The burst diaphragms, downstream from each tank are installed to confine the propellants into as small an area as possible throughout the mission. This is to prevent loss of propellants in the event of line rupture downstream of the burst diaphragm of engine injector valve leakage.

When the helium isolation squib valves are initiated open, regulated helium pressure pressurizes the propellant tanks creating the positive expulsion of propellants into the respective manifolds to the burst diaphragms which rupture and allow the propellants to flow on through the burst diaphragm and the propellant isolation valves to the injector valves on each engine. The diaphragm is of the nonfragmentation type, but in the event of any fragmentation, a filter is incorporated to prevent any fragments from entering the engine injector valves.

2.5.6.2.4 Propellant Isolation Shutoff Valves.

When the burst diaphragm isolation valves are ruptured, the propellants flow to the propellant isolation valves.

The fuel and oxidizer isolation valves in the SYS 1 fuel and oxidizer lines are both controlled by the CM RCS PRPLNT 1 switch on MDC-2. The fuel and oxidizer isolation valves in the SYS 2 fuel and oxidizer lines are both controlled by the CM RCS PRPLNT 2 switch on MDC-2. Each propellant isolation valve contains two solenoids, one that is energized momentarily to magnetically latch the valve open, and the remaining solenoid is energized momentarily to unlatch the magnetic latch and spring pressure and propellant pressure close the valve. The CM RCS PROPELLANT switch on MDC-2 is placed to ON energizing the valve into the magnetic latch (open), the OFF position energizes the valve to unlatch the magnetic latch (closed). The center position removes electrical power from either solenoid. The valves are normally open in respect to the fluid flow.

Each valve contains a position switch which is in parallel to one position indicator above the switch on MDC-2 that controls both valves.

When the position switch in each valve is open, the indicator on MDC-2 is gray (same color as the panel) indicating that the valves are in the normal position, providing a positive open valve indication. When the position switch in either valve is closed, the indicator on MDC-2 is barber pole (diagonal lines) indicating that either valve, or both valves, are closed.

The valves are closed in the event of a failure downstream of the valves, line rupture, run away thruster, etc.

2.5.6.2.5 Distribution Plumbing.

Brazed joint tubing is used to distribute regulated helium to the propellant positive expulsion tanks in subsystems 1 and 2. The distribution lines contain 16 explosive-operated (squib) valves which permit changing the helium and propellant distribution configuration to accomplish various functions within the CM RCS. Each squib valve is actuated by an explosive charge, detonated by an electrical hot-wire ignitor. After ignition of the explosive device, the valve remains open permanently. Two squib valves are utilized in each subsystem to isolate the high-pressure helium supply until RCS pressurization is initiated. Two squib valves are utilized to interconnect subsystems 1 and 2 regulated helium supply which ensures pressurization of both subsystems during dump-burn and helium purge operations. Two squib valves in each subsystem permit helium gas to bypass the propellant tanks which allow helium purging of the propellant subsystem and depletion of the helium source pressure. One squib valve in the oxidizer system permits both oxidizer systems to become common. One squib in the fuel system permits both fuel systems to become common. Two squib valves in the oxidizer system, and two in the fuel system are utilized to dump the respective propellant in the event of an abort from the pad up to T +42 seconds

2.5.6.3 Engine Assembly.

The command module reaction control subsystem engines are ablative-cooled, bi-propellant thrust generators which can be operated in either the pulse mode or the steady-state mode.

Each engine has a fuel and oxidizer injector solenoid valve. The injector solenoid control valves control the flow of propellants by responding to electrical commands generated by the controller reaction jet ON-OFF assembly or by the direct manual mode. Each engine contains an injector head assembly which directs the flow of each propellant from the engine injector valves to the combustion chamber where the propellants atomize and ignite (hypergolic), producing thrust. Estimated engine thrust rise and decay is shown in figure 2.5-12.

2.5.6.3.1 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer).

The injector valves utilize two coaxially wound coils, one for automatic and one for direct manual control. The automatic coil is used when the thrust command originates from the controller reaction jet ON-OFF assembly.

The direct manual coils are used when the thrust command originates at the rotation control (direct RCS).

The engine injector valves are spring-loaded closed and energized open.

The reaction time of the valves, pulse mode of operation, reason for pulse mode, and thrust curve generated by the engine is similar to the SM RCS engines.

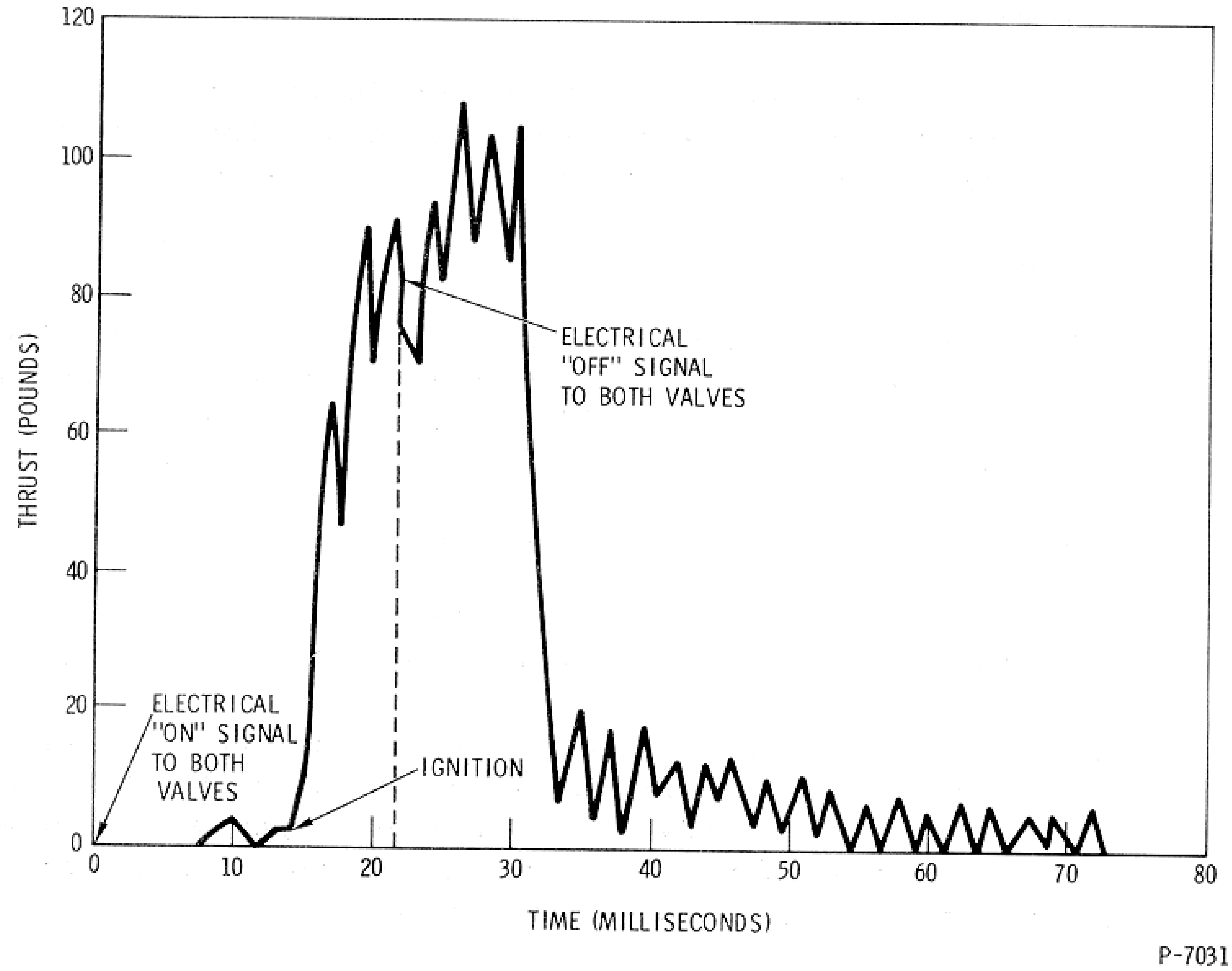


Figure 2.5-12. CM RCS Engine Thrust Rise and Decay Time

The automatic coils in the fuel and oxidizer injector valves are connected in parallel from the controller reaction jet ON-OFF assembly.

The direct manual coils in the fuel and oxidizer injector valves provide a direct backup to the automatic system. The direct manual coils are connected in parallel from the rotation controls.

The engine injector valve automatic coil opening time is 8±1/2 milliseconds, and closing is 6±1/2 milliseconds. The engine injector valve direct manual coil opening time is 16±3 milliseconds and closing time is 7±3 milliseconds.

2.5.6.3.2 Injector.

The injector contains 16 fuel and 16 oxidizer passages that impinge (unlike impingement) upon a splash plate within the combustion chamber. Therefore, the injector pattern is referred to as an unlike impingement splash-plate injector.

2.5.6.3.3 Thrust Chamber Assembly.

The thrust chamber assembly is fabricated in four segments, the combustion chamber ablative sleeve, throat insert, ablative material, asbestos and a fiberglass wrap. The engine is ablative-cooled.

2.5.6.3.4 Nozzle Extension.

The CM RCS engines are mounted within the structure of the CM. The nozzle extensions are required to transmit the gasses from the engine out through the structure of the CM. The nozzle extensions are fabricated of ablative material.

2.5.6.3.5 Engine Solenoid Injector Temperature-Control System.

A temperature-control system of the CM RCS engine is employed by energizing the manual direct coils on each engine (figure 2.5-11).

Temperature sensors are mounted on 6 of the 12 engine injectors. A temperature sensor is installed on the subsystem 1 counterclockwise roll-engine injector, negative yaw-engine injector, negative pitch-engine injector, and on subsystem 2 positive yaw-engine injector, negative pitch-engine injector, and clockwise roll-engine injector.

The temperature transducers have a range from -50° to +50°F. The temperature transducers from the three subsystems 1 and 2 engine injectors provide inputs to the two rotary switches on MDC-101, which are located in the lower equipment bay of the command module. With the rotary switches positioned as illustrated in figure 2.5-11, the specific engine injector temperature is monitored as d-c voltage on the 0- to 5-vdc voltmeter on MDC-101. The 0 vdc is equivalent to -50°F and 5 vdc is equivalent to +50°F.

A CM RCS HEATER switch located on MDC-101 (figure 2.5-11) is placed to the CM RCS HTR position when any one of the instrumented engines are below +28°F (3.9 vdc). The CM RCS LOGIC switch, on MDC-1, must be positioned to CM RCS LOGIC to provide electrical power to the CM RCS HTR switch on MDC-101. When the CM RCS HTR switch is positioned to CM RCS HTRS, relays are energized, which allow electrical power to be provided from the CM HEATERS circuit breakers 1 MNA and 2 MNB on MDC-8, to the direct injector solenoid control valves of the 12 CM RCS engines. The fuel and oxidizer injector solenoid control valve direct coils (of all 12 CM RCS engines) are energized open prior to the pressurization of CM RCS subsystems 1 and 2. A 20-minute maximum heat-up time assures engine injector temperature is at -10°F minimum. At the end of 20 minutes, the CM RCS HTR switch on MDC-101 is positioned to OFF, allowing the injector solenoid control valve direct coils to de-energize, and the injector solenoid control valves spring-load closed. This will prevent the oxidizer from freezing at the engine injector valves upon pressurization of subsystems 1 and 2 and the 20-minute time factor ensures that the warmer engines will not be overheated.

The CM RCS HEATER switch must be placed to OFF prior to CM RCS pressurization.

The operation of the CM RCS HEATER switch in conjunction with the d-c voltmeter and/or heating time insures all other engine valves reach the acceptable temperature levels.

If the CM RCS HEATER switch on MDC-101 fails to energize the direct coils for the CM RCS preheat, the following backup procedure may be utilized:

a. Place CM RCS HEATER switch on MDC-101 to OFF.
b. Place ROTATION CONTROL POWER DIRECT RCS switch 1 and 2 on MDC-1 to OFF.
c. Place RCS TRANSFER switch on MDC-2 to CM.
d. Place SC CONT switch on MDC-1 to SCS.
e. Place MANUAL ATTITUDE PITCH, YAW, and ROLL switches on MDC-1 to ACCEL CMD.
f. Place A/C ROLL AUTO RCS SELECT switches on MDC-8 to OFF.
g. Place ROTATION HAND CONTROLS to soft stops for 10 minutes.
h. If a CM RCS engine temperature that is monitored on MDC-101 fails to increase because of a CM RCS engine direct coils failure, follow above steps a through f, and then place ROTATION HAND CONTROL(S) to soft stop(s) of affected engine for 10 minutes.

2.5.6.3.6 Engine Thrust ON-OFF Logic.

All automatic thrust commands for CM attitude are generated from within the controller reaction jet ON-OFF assembly. These commands may originate at:

- The rotation controls
- The stabilization and control subsystem
- The command module computer.

In the event the controller reaction jet ON-OFF assembly is unable to provide commands to the automatic coils of the SM RCS engines, a backup method is provided. The backup method consists of two ROT CONT PWR DIRECT RCS switches on MDC-1 and the two rotation controllers. The ROT CONT PWR DIRECT RCS 1 switch supplies power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch, is positioned to MNA/MNB, main buses A and B supply power only to rotation control 1. When the ROT CONT PWR DIRECT RCS 1 switch is positioned to MNA, main bus A supplies power only to rotation control 1. The ROT CONT PWR DIRECT RCS 2 switch supplies power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNA/MB, main buses A and B supply power only to rotation control 2. When the ROT CONT PWR DIRECT RCS 2 switch is positioned to MNB, main bus B supplies power only to rotation control 2. When the rotation control is positioned fully to its stops in any direction, the required direct manual coils are energized for the desired maneuver.

When the CM/SM SEP switches on MDC-2 are placed to CM SM SEP position, the switches automatically energize relays in the RCS control box (figure 2.5-7) (providing the CM RCS LOGIC switch on MDC-1 is at CM RCS LOGIC) that transfer the controller reaction jet ON-OFF assembly, and direct manual inputs from the SM RCS engine to the CM RCS engines automatically. These same functions occur automatically on any LES ABORT also, providing the CM RCS LOGIC switch on MDC-1 is at CM RCS LOGIC.

The transfer motors in the RCS control box are redundant to each other in that they ensure the direct manual inputs are transferred from the SM RCS engines to the CM RCS engines in addition to providing a positive deadface.

The RCS transfer motors may also be activated by the RCS TRANSFER switch placed to CM position on MDC-2 which provides a manual backup to the automatic transfer. The CM RCS LOGIC switch on MDC-1 does not have to be on for the manual backup transfer function.

As an example, in the case of the direct manual inputs only to the RCS engines: If the electrical A RCS transfer motor failed to transfer automatically at CM/SM SEP (providing the CM RCS LOGIC switch on MDC-1 is at CM RCS LOGIC); or by use of the manual RCS transfer switch on MDC-2, the electrical B RCS transfer motor would transfer the direct manual inputs from the SM RCS engines to the CM RCS engines in addition to a positive deadfacing to the SM RCS engines.

The CM RCS subsystems 1 and 2 may be checked out prior to CM/SM separation by utilization of the RCS transfer switch on MDC-2. Placing the RCS TRANSFER switch to the CM position, the controller reaction jet ON-OFF assembly and direct manual inputs are transferred to the CM permitting a CM RCS checkout prior to CM/SM separation.

2.5.6.4 Propellant Jettison.

There are two sequences of propellant jettison. One sequence is employed in the event of an abort while the vehicle is on the launch pad and through the first 42 seconds of flight. The second sequence is employed for all other conditions, whether it be a normal entry or an SPS abort mode of operation.

The sequence of events before and during a normal entry is as follows:

a. The CM RCS is pressurized by placing the CM/SM SEP switches on MDC-2 to CM/SM SEP position or by placing the CM RCS PRESS switch on MDC-2 to the CM RCS PRESS position prior to initiating CM-SM separation. The CM RCS PRESS switch or the CM-SM SEP switches initiate the helium isolation squib valves in CM RCS subsystems 1 and 2, thus pressurizing both subsystems (figures 2.5-11 and 2.5-13). The CM RCS LOGIC switch on MDC-1 must be placed to CM RCS LOGIC prior to initiating CM/SM separation to provide the automatic RCS transfer function.

b. The CM RCS provides attitude control during entry. At approximately 24,000 feet, a barometric switch is activated unlatching the RCS latching relay. This inhibits any further commands from the controller reaction jet ON-OFF assembly (providing the ELS LOGIC switch on MDC-1 is in AUTO) (figure 2.5-7). The RCS CMD switch MDC-2, positioned to OFF momentarily provides a manual backup to the 24,000 feet barometric switches.

c. At approximately main parachute line stretch as a normal manual function, the CM RCS PRPLNT-DUMP switch on MDC-1 is placed to the DUMP position. This function initiates the following simultaneously; (CM RCS LOGIC switch on MDC-1 must be placed to CM RCS LOGIC to provide electrical power to the DUMP switch). (See figures 2.5-11 and 2.5-13.)

1. Initiates the two helium interconnect squib valves.
2. Initiates the fuel interconnect squib valves.
3. Initiates the oxidizer interconnect squib valve.
4. The fuel and oxidizer injector valve direct manual coils are energized on all of the CM RCS engines excluding the two + pitch engines. The propellants are jettisoned by burning the propellants remaining through 10 of the 12 engines. The length of time to burn the remaining propellants will vary, depending upon the amount of propellants remaining in the fuel and oxidizer tanks at 24,000 feet. If an entire propellant load remained, as an example, a nominal burn time would be 88 seconds through 10 of the 12 engines. In the worst case of only 5 of the 12 engines (direct manual coils energized), a nominal burn time would be 155 seconds.

RCS

RCS

Figure 2.5-13. CM RCS Squib Valve Power Control Diagram

d. Upon completion of propellant burn, the CM PRPLNT PURGE switch on MDC-1 is placed to the PURGE position as a normal manual function (the CM PRPLNT-DUMP switch supplies electrical power when placed to DUMP position to the PURGE switch). When the PURGE switch is placed to PURGE, the switch initiates the four helium bypass squib valves. This allows the regulated helium pressure to bypass each fuel and oxidizer tank, purging the lines and manifolds out through 10 of the 12 engines, as well as depleting the helium source pressure. Purging requires approximately 15 seconds (until helium depletion).

e. In the event of a CM RCS LOGIC switch and/or CM PRPLNT DUMP switch failure on MDC-1, the remaining propellants may be burned by placing ROT CONT PWR DIRECT RCS switch 1 on MDC-1, to either MNA/MNB or MNA, and/or ROT CONT PWR DIRECT RCS switch 2 on MDC-1, to either MNA/MNB or MNB. Then positioning the two rotation controllers to CCW, CW, -Y, +Y and -P (excluding +P) position. This will energize the direct fuel and oxidizer injector solenoid valve coils of ten of the twelve CM RCS engines and burn the remaining propellants. At the completion of propellant burn the CM RCS HELIUM DUMP pushbutton on MDC-1 would be pressed initiating the four bypass squib valves. This allows the regulated helium pressure to bypass each fuel and oxidizer tank. This purges the lines and manifolds out through ten of the twelve engines as well as depleting the helium source pressure providing the two rotation controllers are positioned to CCW, CW, -Y, and -P (excluding +P).

f. In the event the CM RCS LOGIC and CM PRPLNT DUMP switches on MDC-1 function correctly and the PURGE switch fails, the CM RCS HELIUM DUMP pushbutton on MDC-1 would be pressed, initiating the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, purging the lines and manifolds out through 10 of the 12 engines as well as depleting the helium source pressure.

g. Upon completion of purging, the direct manual coils of the CM RCS engine injector valves will be de-energized by placing the CM RCS LOGIC switch on MDC-1 to OFF, or by placing the CM PRPLNT DUMP switch on MDC-1 to OFF. The CM RCS 1 and 2 PRPLNT switches on MDC-2 will also be placed to the OFF position momentarily closing the fuel and oxidizer propellant isolation valves. These functions will be accomplished prior to impact.

The sequence of events involving an abort from the pad up to 42 seconds are as follows:

a. The ABORT SYSTEM PRPLNT DUMP AUTO switch on MDC-2 is placed to the PRPLNT DUMP AUTO position (figures 2.5-7 and 2.5-13) and the CM RCS LOGIC switch on MDC-1 is placed to the CM RCS LOGIC position at sometime in the countdown prior to T + 0.

b. The following events occur simultaneously upon the receipt of the abort signal. The command may be generated automatically by the sequential events control system or by manually rotating the translation control counterclockwise:

1. When the abort signal is received, the two squib-operated helium isolation valves in each subsystem are initiated open, pressurizing subsystems 1 and 2. Manual backup would be the CM RCS press switch on MDC-2.

2. The squib-operated helium interconnect valve for the oxidizer and fuel tanks are initiated open. If only one of the two squib helium isolation valves was initiated open, both subsystems are pressurized as a result of the helium interconnect squib valve interconnect.

3. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed. This prevents fuel and oxidizer from flowing to the thrust chamber assemblies.

4. The squib-operated fuel and oxidizer interconnect valves are initiated open. If only one of the two oxidizer or fuel overboard dump squib valves was initiated open, the oxidizer and fuel manifolds of each respective system are common as a result of the oxidizer and fuel interconnect squib valve.

5. The squib-operated oxidizer overboard dump valves are initiated open directing the oxidizer to an oxidizer blowout plug, in the aft heat shield of the CM. The pressure buildup causes the pin in the blowout plug to shear, thus blowing the plug and dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 seconds.

6. The RCS latching relay will not energize in the event of an abort from 0 to +42 seconds because of the position of the PRPLNT DUMP AUTO switch (figures 2.5-7 and 2.5-13). Thus, no commands are allowed into the controller reaction jet ON-OFF assembly.

7. The CM-SM RCS transfer motor-driven switches are automatically driven upon receipt of the abort signal, transferring the logic circuitry from SM RCS engines to CM RCS engines.

8. Five seconds after abort initiation, the squib-operated fuel overboard dump valves are initiated open and route the fuel to a fuel blowout plug in the aft heat shield of the CM. The pressure buildup causes the pin in the blowout plug to shear, thus blowing the plug and dumping the fuel overboard. The entire fuel supply is dumped in approximately 13 seconds.

9. Thirteen seconds after the fuel dump sequence was started the fuel and oxidizer bypass squib valves subsystems 1 and 2 are initiated open. This purges the fuel and oxidizer systems out through the fuel and oxidizer overboard dumps, respectively, and depleting the helium source pressure.

During the prelaunch period the MAIN BUS TIE switches on MDC-5 are in the AUTO position. In the event of a pad abort, electrical power is automatically applied to the main buses. Just prior to lift-off the electrical power is applied to the main buses by manually placing the two MAIN BUS TIE switches on MDC-5 to BAT A/C and BAT B/C positions.

The sequence of events if an abort is initiated after 42 seconds up to launch escape tower jettison are as follows:

a. At 42 seconds after lift-off, as a normal manual function the PRPLNT DUMP AUTO switch on MDC-2 is placed to the auto RCS CMD position. This safes the oxidizer, fuel dump, and purge circuitry (figures 2.5-7 and 2.5-13) and sets up the circuitry for the RCS latching relay.

b. The CM RCS LOGIC switch MDC-1 was placed to CM RCS LOGIC prior to T + 0.

c. Initiate both helium isolation squib valves in the CM RCS subsystems 1 and 2. Manual backup would be the CM RCS PRESS switch on MDC-2; thus, pressurizing CM RCS subsystems 1 and 2.

d. Automatically drives the CM SM transfer motors from SM RCS engines to CM RCS engines. Manual backup would be the RCS transfer switch on MDC-2 to CM position.

e. Energize the RCS latching relay one second after receipt of the abort signal. This allows the controller reaction jet ON-OFF assembly to provide electrical commands to the CM RCS. Manual backup would be the RCS CMD switch on MDC-2.

f. Dependent upon the altitude of abort initiation, the launch escape tower canards orient the CM for descent or the CM RCS orients the CM for descent.

g. At 24,000 ft, the barometric switch energizes the RCS latching relay (providing the ELS LOGIC switch on MDC-1 is in AUTO). This removes electrical power from the controller reaction jet ON-OFF assembly, thus the CM RCS engines. Manual backup would be the RCS CMD switch on MDC-2.

h. At main parachute line stretch, as a normal manual function the CM PRPLNT DUMP switch on MDC-1 is placed to DUMP initiating the following functions:

1. Same as in a normal entry sequence.

2.5.7 CM RCS PERFORMANCE AND DESIGN DATA.

2.5.7.1 Design Data.

The following list contains data on the CM RCS components:

Helium Tanks (2)	4150±50 psig at 70° ±5°F during servicing; setting on launch pad 70° ±10°F. Capacity 0.57 lb, inside diameter 8.84 in., wall

RCS

	thickness 0.105 in., internal volume of 365±5 cubic inches at 4150±50 psig, and weight 5.25 lb.
Helium Isolation Squib Valve Filter	Removes 98 percent of all particles whose two smallest dimensions are greater than 40 microns. Removes 100 percent of all particles whose two smallest dimensions are greater than 74 microns.
Regulator Units (4)	Primary 291±4 psig. Lockup pressure minimum of 287 psig and not to exceed 302 psig. Secondary - lockup 287 to 302 psig. Filter 25 microns nominal, 40 microns absolute at inlet of each regulator unit.
Check Valve Filters	40 microns nominal, 74 microns absolute. One at each inlet to check valve assembly, one at each test port.
Helium Relief Valves (4)	Diaphragm rupture at 340±8 psi. Filter 10 microns nominal, 25 microns absolute. Relieve at 346±14 psig. Reseat at no less than 327 psig. Flow capacity 0.3 lb/minute at 60°F and 346±14 psig. Bleed device closes when increasing pressure has reached no more than 179 psig in the cavity, and a helium flow of less than 20 standard cubic centimeters per hour across the bleed device and relief valve assembly combined. The bleed device reopens when decreasing pressure has reached no less than 20 psig.
Helium Manifold Pressure Transducer (4)	Illuminates caution and warning lights on MDC-2 (CM RCS 1 or 2). After helium isolation squib valve actuation: Underpressure 260 psia. Overpressure 330 psia.

Fuel Tanks (2)	See SM RCS secondary fuel tanks.	
Oxidizer Tank (2)	See SM RCS secondary oxidizer tanks.	
Valve Isolation Burst Diaphragm (4)	Rupture at 241±14 psig within 2 seconds after rupture pressure is reached at any temperature between 40° to 105°F. Filter 75 microns nominal, 100 microns absolute.	
Engine	200-second service life, 3000 operational cycles	
	Nominal thrust	93 pounds
	Expansion ratio	9 to 1
	Cooling	Ablation
	Injector type	16 on 16 splash plate
	Combustion chamber-refrasil ablative sleeve and graphite base throat insert.	
	Automatic and manual coils connected in parallel.	
	Weight	8.3 lb
	Length	11.65 in. maximum
	Nozzle exit diameter	2.13 in.
	Nozzle extensions	ablative refrasil
Oxidizer Blowout Plug	Pin shears at approximately 200 psi	
Fuel Blowout Plug	Pin shears at approximately 200 psi	

2.5.7.2 Performance Data.

Refer to CSM/LM Spacecraft Operational Data Book SNA-8-D-027 CSM (SD 68-447).

RCS

2.5.7.3 CM RCS Electrical Power Distribution.

See figure 2.5-14 for electrical power distribution.

2.5.8 CM RCS OPERATION LIMITATIONS AND RESTRICTIONS.

Refer to AOH, Volume 2, Malfunction Procedures.

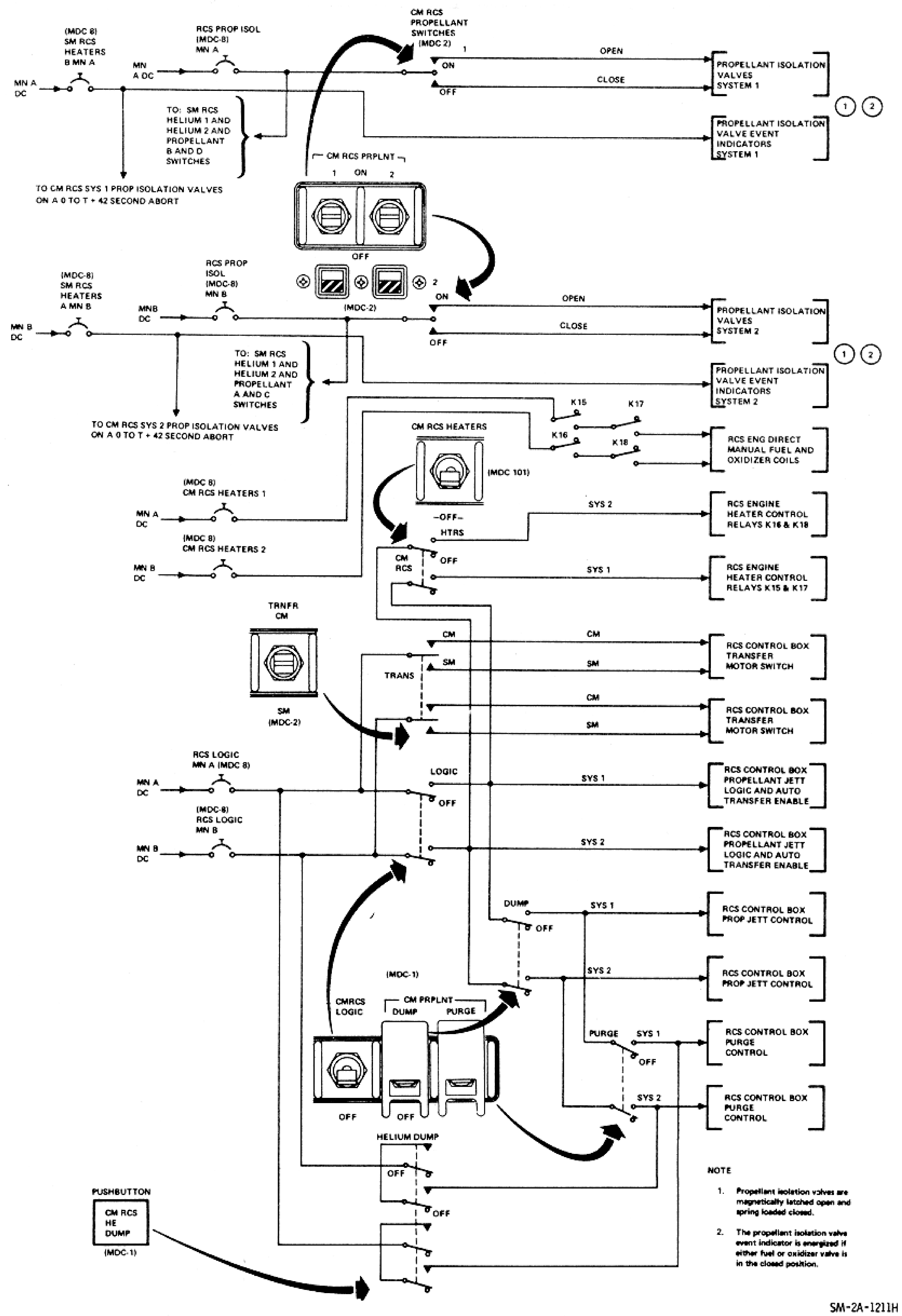


Figure 2.5-14. CM RCS Electrical Power Distribution