Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 20	2.4-1	Ball Valve Position 4	SP0025H	+0 +90 deg		11A113	HI	PCM	Open or closed
	2.4-1	Temperature Oxidizer Engine Feed Line	SP0049T	+0 +200°F					Variable
Panel 20	2.4-1	Temperature Fuel Engine Feed Line	SP0048T	+0 +200°F					+40 to +120°F
	2.4-1	Temperature Engine Valve Body	SP0045T	+0 +200°F					Variable
Panel 11	2.4-1	Temperature Combustion Chamber Outer Skin 1	SP0020T	+0 +500°F	Collins C28-1A5 S28AR60	10A84	HI	PCM	Illuminates C&W light at 380°F
	2.4-1	Temperature Nozzle Outer Skin 1	SP0050T	-260 +2500°F		10A85	HI	PCM	Variable
		Pitch Actuator Case Temperature	SP2055T	+0 +200°F		10A68	HI	FQ	Variable
		Yaw Actuator Case Temperature	SP2054T	+0 +200°F		11A119	HI	FQ	Variable
		SPS Solenoid Driver Out 1	CH4320X			51E-09	E1	PCME	Event
		SPS Solenoid Driver Out 2	CH4321X			51E-10	E1	PCME	Event
		Yaw Position Feedback	CH1034H	-8.5 +8.5 vdc		51A7	HI	PCM	Variable
		Pitch Position Feedback	CH0034H	-6 +6 vdc		51A3	HI	PCM	Variable

*Analog measurements digitally coded into 8 bit words
Analog measurements - 0 to 5 vdc
FQ - Flight qualification measurements
H1 - High bit rate
H2 - High and low bit rate
E1 - High bit rate

Channel code example: 10A68
Significant number - 1
How many zeros after most significant number is amount of samples per second. } 0 } 1 sample per second

Analog - A
Event - E
Channel Code - 68

SECTION 2

SUBSECTION 2.5

REACTION CONTROL SYSTEM (RCS)

2.5.1 INTRODUCTION.

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

Both the S/M and C/M RCS are 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 are shown in figure 2.5-2.

2.5.2 S/M RCS FUNCTIONAL DESCRIPTION.

The S/M RCS consists of four individual, functionally identical packages, located 90 degrees apart around the forward portion (+X-axis) of the S/M periphery and offset from the S/C Y- and Z-axes 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 S/M RCS control functions. Acceptable package operating temperature is maintained by internally mounted, thermostatically controlled electric heaters. The S/M RCS propellants consist of nitrogen tetroxide (N_2O_4), used as the oxidizer; monomethylhydrazine (MMH) used as the fuel. Pressurized helium gas is the propellant transferring agent.

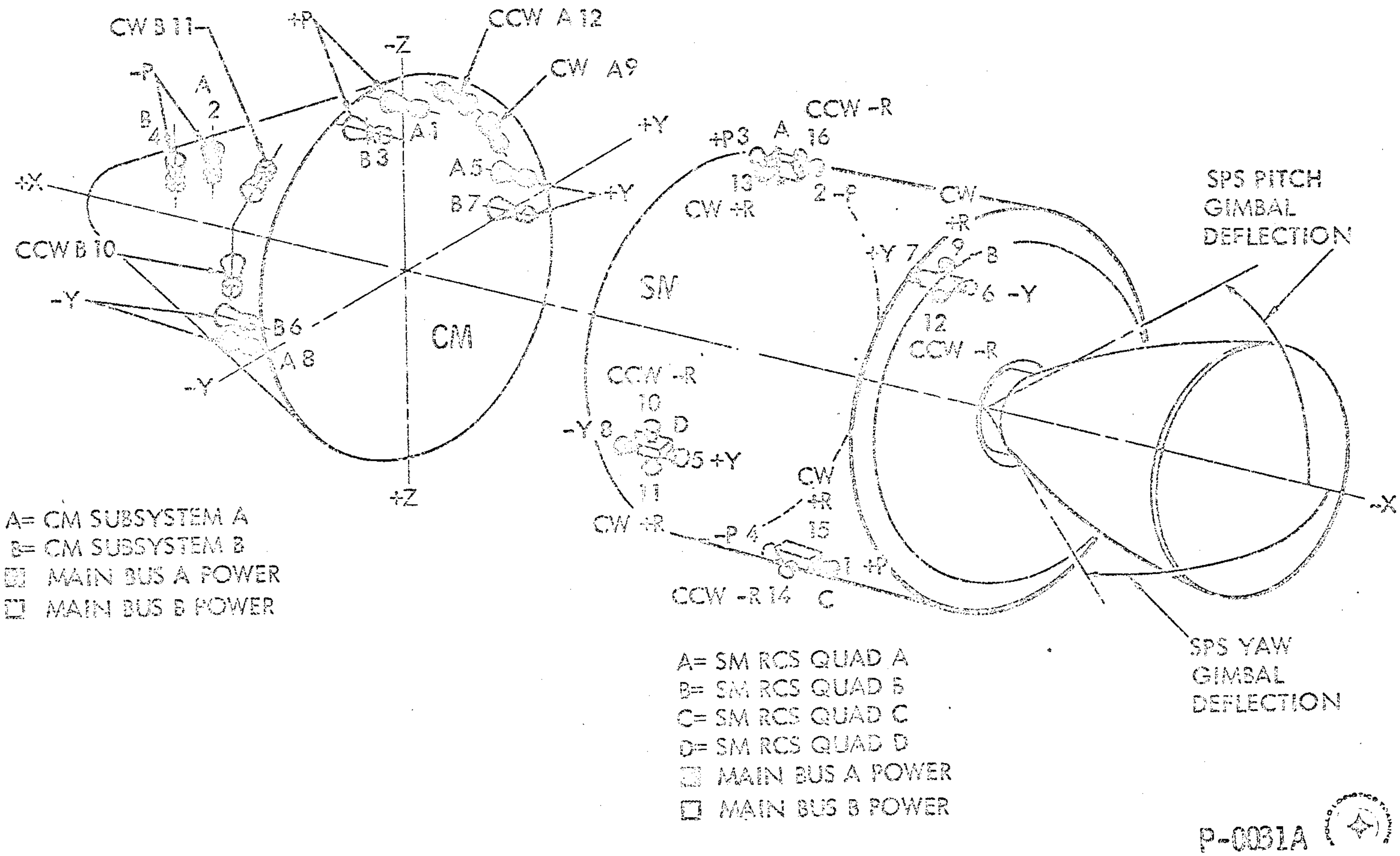

Figure 2.5-1. C/M-S/M Engine Locations

BUS POWER	CIRCUIT BREAKER	SM ENGINE				CM ENGINE				SM ENGINE UTILIZATION FOR TRANSLATION MANUEVERS						CHANNEL SWITCHES PANEL 8
		QUAD	MANUEVER	SCS NO.	PROP NO.	SYSTEM	MANUEVER	SCS NO.	PROP NO.	-X	+X	-Y	+Y	-Z	+Z	
MN A	SCS MN A 1 PITCH C15A6CB40 PANEL 25	C A	+P -P	1 2	S19A3B3 S19A1B3	A A	+P -P	1 2	C19B7 C19B11		1 2					PITCH
MN A	SCS MN A 1 YAW C15A6CB32 PANEL 25	B D	+Y -Y	7 8	S19A2B3 S19A4B3	A A	+Y -Y	5 8	C19B9 C19B1	7 8						YAW
MN A	SCS MN A B&D ROLL C15A6CB34 PANEL 25	B B	CW+R CCW-R	9 12	S19A2B2 S19A2B4	A A	CW+R CCW-R	9 12	C19B5 C19B3					12	9	B&D ROLL
MN A	SCS MN A A&C ROLL C15A6CB36 PANEL 25	A A	CCW-R CW+R	16 13	S19A1B2 S19A1B4	DEADFACED AT CM SM SEPARATION OR LES ABORT						16	13			A&C ROLL
MN B	SCS MN B 2 PITCH C15A6CB39 PANEL 25	C A	-P +P	4 3	S19A3B1 S19A1B1	B B	-P +P	4 3	C19B12 C19B8	4 3						PITCH
MN B	SCS MNB 2 YAW C15A6CB31 PANEL 25	B D	-Y +Y	6 5	S19A2B1 S19A4B1	B B	-Y +Y	6 7	C19B2 C19B10		6 5					YAW
MN B	SCS MN B B&D ROLL C15A6CB33 PANEL 25	D D	CCW-R CW+R	10 11	S19A4B4 S19A4B2	B B	CCW-R CW+R	10 11	C19B4 C19B6					11	10	B&D ROLL
MN B	SCS MN B A&C ROLL C15A6CB35 PANEL 25	C C	CCW-R CW+R	14 15	S19A3B2 S19A3B4	DEADFACED AT CM SM SEPARATION OR LES ABORT						15	14			A&C ROLL
MN A	SCS MN A DIRECT CONTROL C15A6CB42 PANEL 25	C D B	+P -Y +Y	1 8 7	S19A3B3 S19A4B3 S19A2B3	A A A	+P -Y +Y	1 8 5	C19B7 C19B1 C19B9	8 7	1					DIRECT RCS SWITCH PANEL 8
		A	CCW-R	16	S19A1B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		B B	CCW-R CW+R	12 9	S19A2B4 S19A2B2	A A	CCW-R CW+R	12 9	C19B3 C19B5							
		A C	CW+R CW+R	13 15	S19A1B4 S19A3B4	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		A	-P	2	S19A1B3	A	-P	2	C19B11		2					
MN B	SCS MN B DIRECT CONTROL C15A6CB41 PANEL 25	C A B D D	-P +P -Y +Y CCW-R	4 3 6 5 10	S19A3B1 S19A1B1 S19A2B1 S19A4B1 S19A4B4	B B B B B	-P +P -Y +Y CCW-R	4 3 6 7 10	C19B12 C19B8 C19B2 C19B10 C19B4	4 3	6 5					
		C	CCW-R	14	S19A3B2	DEADFACED AT CM SM SEPARATION AND LES ABORTS										
		D	CW+R	11	S19A4B2	B	CW+R	11	C19B6							

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Figure 2.5-2. S/M-C/M RCS Engine Power Supplies

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, complete attitude control can be maintained with only two adjacent quads operating. This two-quad capability does not include the execution of translation and ullage maneuvers.

A functional flow diagram of one S/M RCS quad is shown in figure 2.5-3. The helium storage vessel supplies pressure to two solenoid-operated helium isolation valves that are normally open throughout the mission. This allows helium pressure to the pressure regulators downstream of each helium isolation valve reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through a series parallel combination of four independent 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 pressure increase.

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 through the normally open propellant isolation valves.

Oxidizer and fuel is distributed to the eight fuel and oxidizer injector valves by a parallel feed system. The fuel valve on each engine opens 2 milliseconds prior to the oxidizer valve to obtain 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 impinge, atomize, and ignition due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The 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.

2.5.3 S/M RCS MAJOR COMPONENT/SUBSYSTEM DESCRIPTION.

The S/M RCS is composed of four separate, individual packages; each package containing the following five major subsystems:

- Pressurization
- Propellant
- Rocket engine

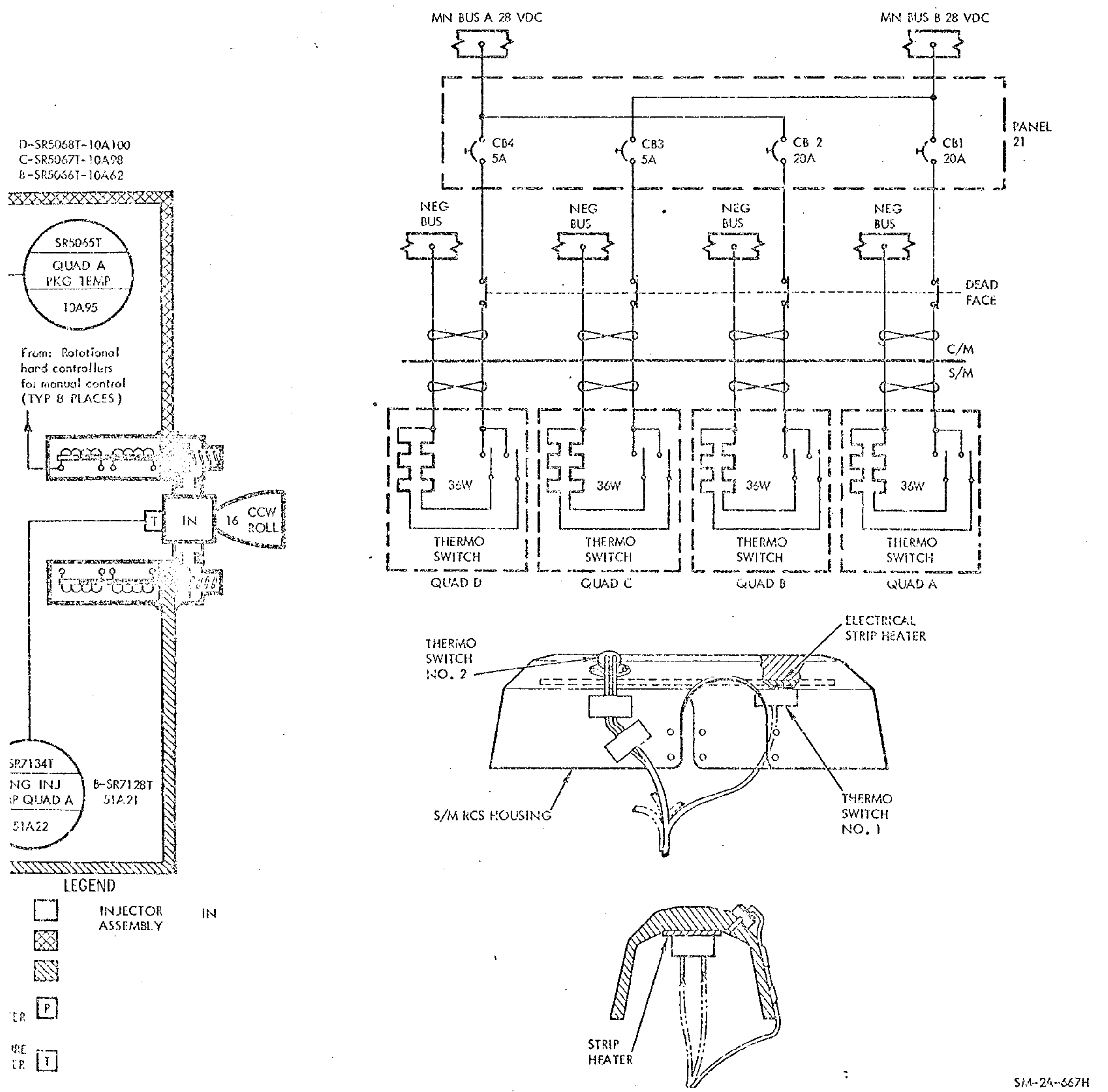
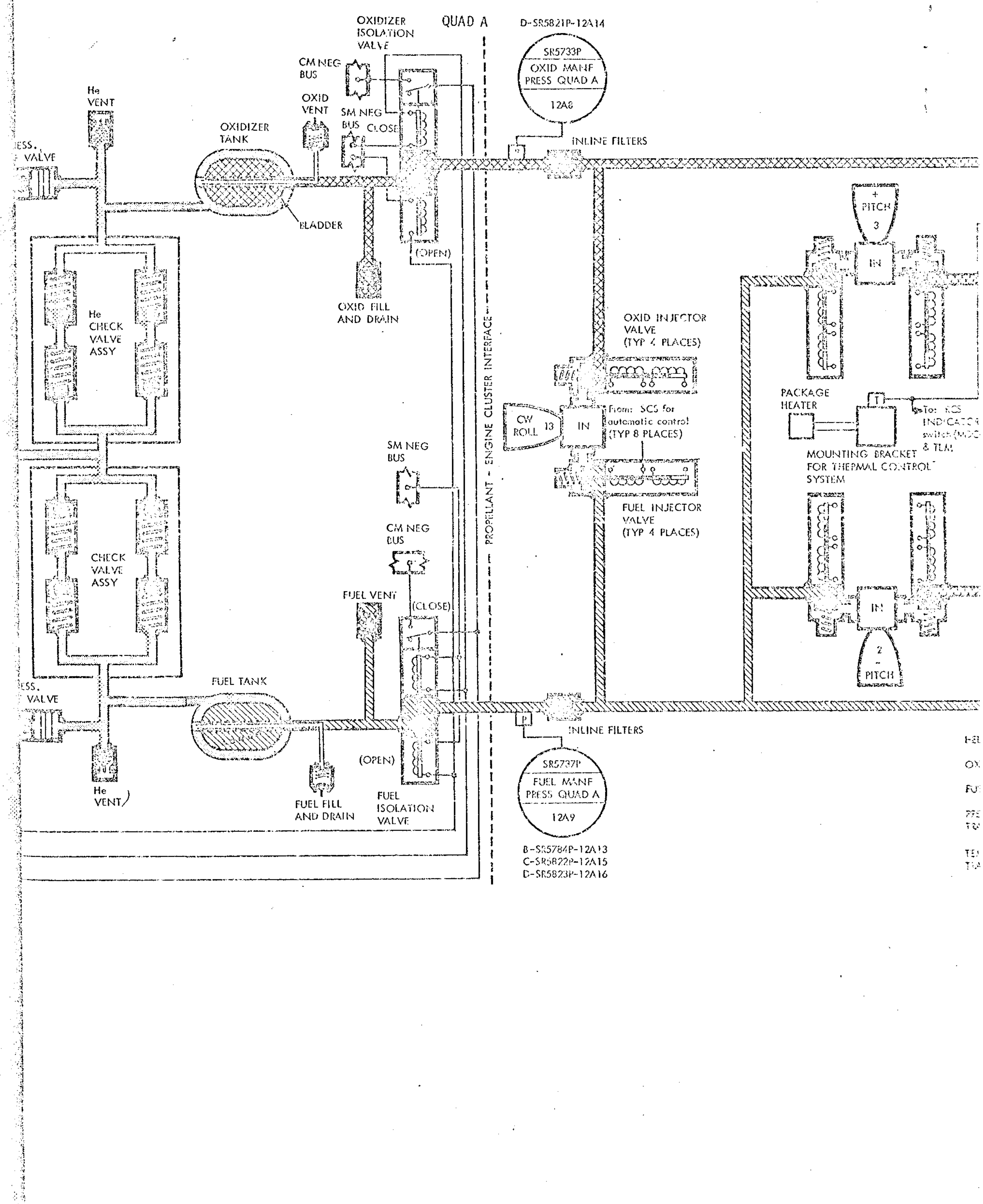
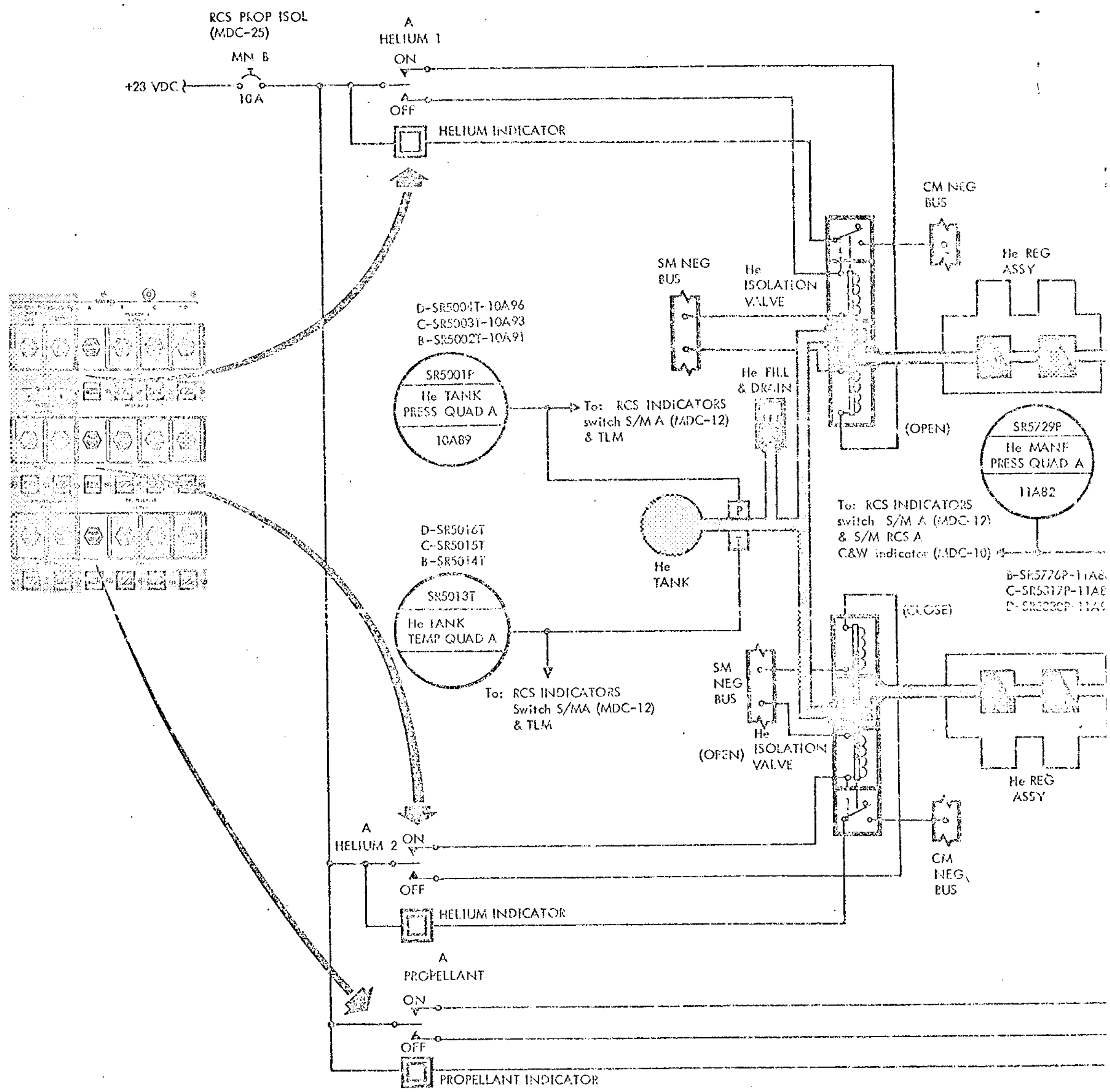
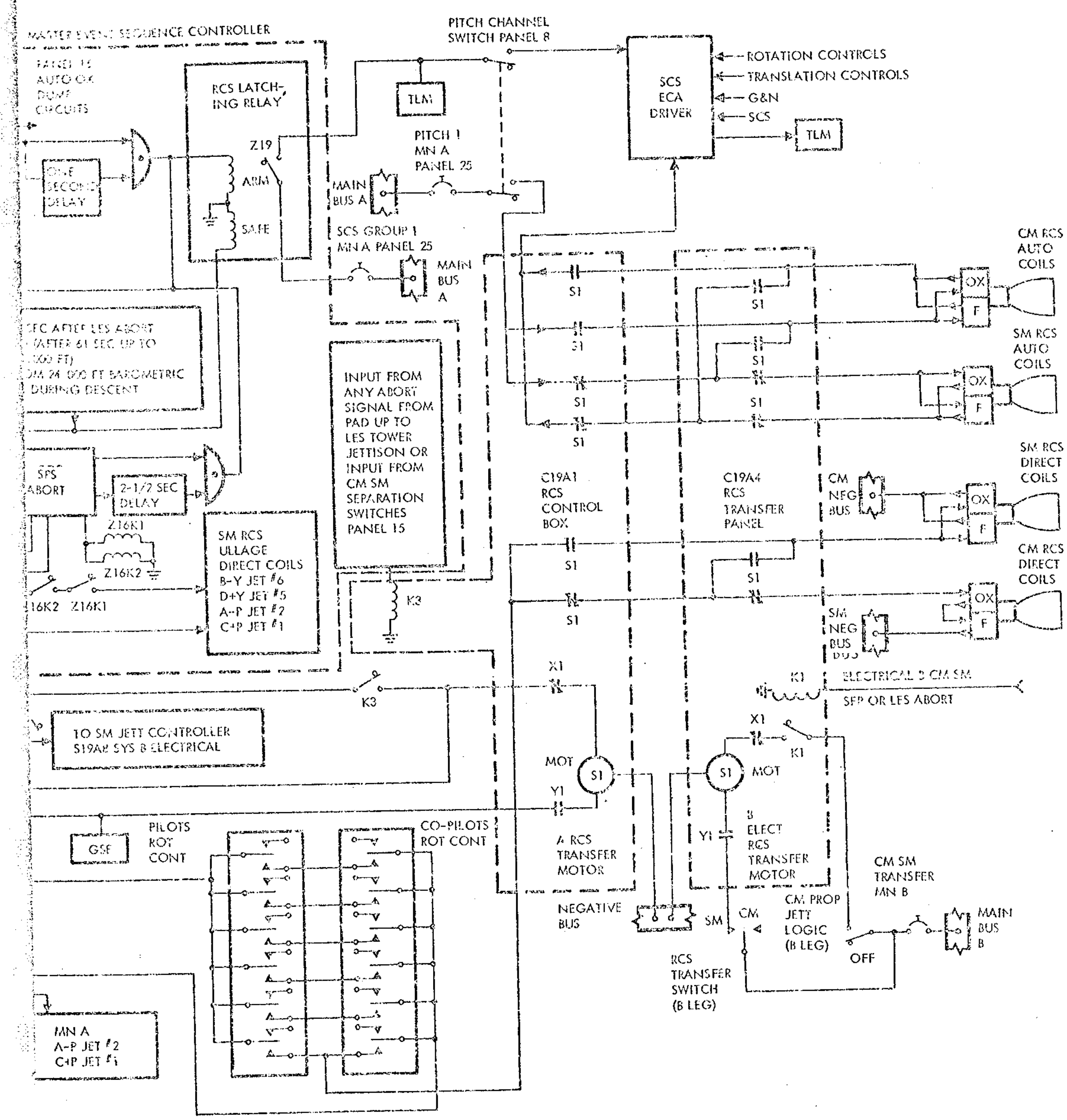


Figure 2.5-3. S/M RCS Functional Flow Diagram (Quad A)

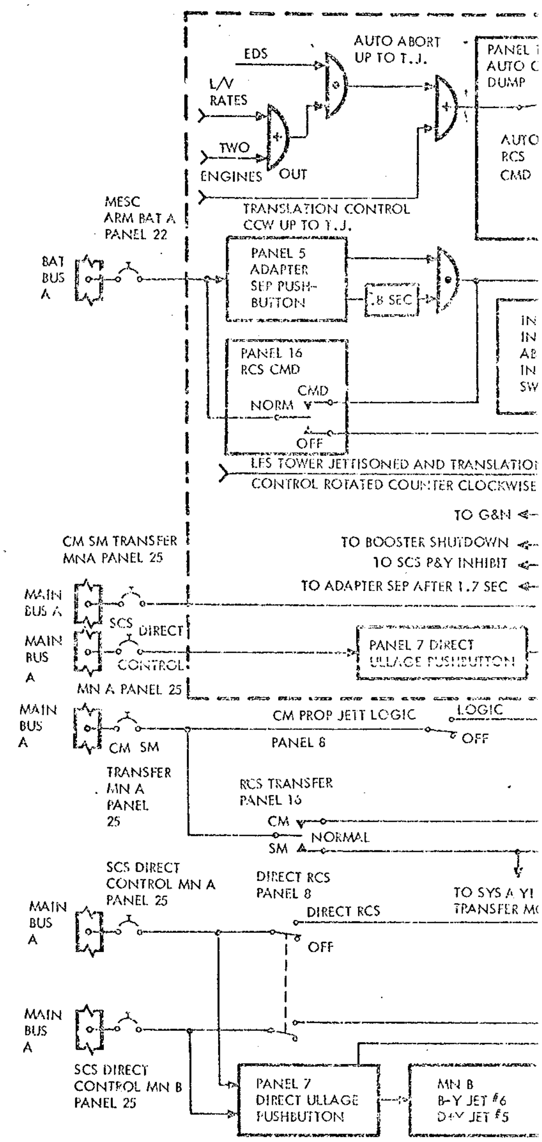

OXIDIZER ISOLATION VALVE
QUAD A
D-SR5821P-12A14
SR5733P
OXID MANF PRESS QUAD A
12A8
CM NEG BUS
OXID VENT
SM NEG BUS
CLOSE
He VENT
OXIDIZER TANK
INLINE FILTERS
BLADDER
(OPEN)
OXID FILL AND DRAIN
He CHECK VALVE ASSY
+ PITCH 3
IN
OXID INJECTOR VALVE (TYP 4 PLACES)
PACKAGE HEATER
CW ROLL 13
From: SCS for automatic control (TYP 8 PLACES)
MOUNTING BRACKET FOR THERMAL CONTROL SYSTEM
SM NEG BUS
FUEL INJECTOR VALVE (TYP 4 PLACES)
PROPELLANT - ENGINE CLUSTER INTERFACE
CM NEG BUS
CHECK VALVE ASSY
FUEL VENT
(CLOSE)
2 - PITCH
FUEL TANK
INLINE FILTERS
(OPEN)
SR5737P
FUEL MANF PRESS QUAD A
12A9
He VENT
FUEL FILL AND DRAIN
FUEL ISOLATION VALVE
B-SR5784P-12A13
C-SR5822P-12A15
D-SR5823P-12A16



RCS PROP ISOL
(MDC-25)
MN B
+28 VDC
10A
A
HELIUM 1
ON
OFF
HELIUM INDICATOR
CM NEG BUS
SM NEG BUS
He ISOLATION VALVE
He REG ASSY
D-SR5004T-10A96
C-SR5003T-10A93
B-SR5002T-10A91
SR5001P
He TANK PRESS QUAD A
10A89
To: RCS INDICATORS switch S/M A (MDC-12) & TLM
He FILL & DRAIN
(OPEN)
SR5729P
He MANF PRESS QUAD A
11A82
He TANK
To: RCS INDICATORS switch S/M A (MDC-12) & S/M RCS A C&W indicator (MDC-10)
D-SR5016T
C-SR5015T
B-SR5014T
SR5013T
He TANK TEMP QUAD A
(CLOSE)
To: RCS INDICATORS Switch S/MA (MDC-12) & TLM
SM NEG BUS
He ISOLATION VALVE
(OPEN)
He REG ASSY
A
HELIUM 2
ON
OFF
HELIUM INDICATOR
CM NEG BUS
A
PROPELLANT
ON
OFF
PROPELLANT INDICATOR



MASTER EVENT SEQUENCE CONTROLLER
PITCH CHANNEL SWITCH PANEL 8
ROTATION CONTROLS
TRANSLATION CONTROLS
G&N
SCS
SCS ECA DRIVER
TLM
TLM
RCS LATCHING RELAY
Z19
ARM
SAFE
PITCH 1 MN A PANEL 25
MAIN BUS A
SCS GROUP 1 MN A PANEL 25
MAIN BUS A
ONE SECOND DELAY
CM RCS AUTO COILS
SM RCS AUTO COILS
SM RCS DIRECT COILS
CM RCS DIRECT COILS
OX
F
S1
INPUT FROM ANY ABORT SIGNAL FROM PAD UP TO LES TOWER JETTISON OR INPUT FROM CM SM SEPARATION SWITCHES PANEL 15
SPS ABORT
2-1/2 SEC DELAY
Z16K1
Z16K2
SM RCS ULLAGE DIRECT COILS
B-Y JET #6
D+Y JET #5
A-P JET #2
C+P JET #1
Z16K2
Z16K1
K3
C19A1 RCS CONTROL BOX
C19A4 RCS TRANSFER PANEL
CM NEG BUS
SM NEG BUS
K1
ELECTRICAL B CM SM SEP OR LES ABORT
K3
X1
TO SM JETT CONTROLLER S19A8 SYS B ELECTRICAL
MOT
Y1
A RCS TRANSFER MOTOR
X1
K1
MOT
Y1
B ELECT RCS TRANSFER MOTOR
CM SM TRANSFER MN B
GSE
PILOTS ROT CONT
CO-PILOTS ROT CONT
NEGATIVE BUS
SM
CM
CM PROP JETT LOGIC (B LEG)
OFF
MAIN BUS B
RCS TRANSFER SWITCH (B LEG)
MN A
A-P JET #2
C+P JET #1


EDS
AUTO ABORT UP TO T.J.
L/V RATES
TWO ENGINES OUT
TRANSLATION CONTROL CCW UP TO T.J.
PANEL
AUTO
DUMP
AUTO RCS CMD
MESC ARM BAT A PANEL 22
BAT BUS A
PANEL 5 ADAPTER SEP PUSH-BUTTON
.8 SEC
PANEL 16 RCS CMD
CMD
NORM
OFF
LES TOWER JETTISONED AND TRANSLATION
CONTROL ROTATED COUNTER CLOCKWISE
TO G&N
TO BOOSTER SHUTDOWN
TO SCS P&Y INHIBIT
TO ADAPTER SEP AFTER 1.7 SEC
CM SM TRANSFER MNA PANEL 25
MAIN BUS A
SCS DIRECT CONTROL
MN A PANEL 25
PANEL 7 DIRECT ULLAGE PUSHBUTTON
CM PROP JETT LOGIC
PANEL 8
LOGIC
OFF
CM SM TRANSFER MN A PANEL 25
RCS TRANSFER PANEL 16
CM
NORMAL
SM
TO SYS A
TRANSFER
SCS DIRECT CONTROL MN A PANEL 25
DIRECT RCS PANEL 8
DIRECT RCS
OFF
SCS DIRECT CONTROL MN B PANEL 25
PANEL 7 DIRECT ULLAGE PUSHBUTTON
MN B
B-Y JET #6
D+Y JET #5

- Propellant quantity gauging
- Temperature control system

2.5.3.1 Pressurization Subsystem.

The pressurization and propellant feed stores, regulates, and distributes helium to the propellant tanks, and stores and distributes propellant to the engine assemblies (figure 2.5-3). It consists of storage tanks, isolation valves, pressure regulators, and the lines and valves necessary for filling, draining and distributing the fluids.

2.5.3.1.1 Helium Supply Tank.

The total high-pressure helium supply is contained within a single spherical storage tank. Initial fill pressure is 4150±50 psig at 70°F. The limit working pressure is 5000 psig to accommodate pressure transients during filling. Proof pressure is 6667 psig and the burst pressure is 7500 psig.

2.5.3.1.2 Helium Isolation Valve.

The helium isolation valves are a two-solenoid valves and are mechanically latched open and spring-loaded closed. The helium isolation valves are individually controlled by their own helium switch on panel 15. The valves are normally open in respect to system pressure substantiating the mechanical latching feature for power conservation purposes during the mission, in addition to preventing overheating of the valve coils.

A position switch contained within each valve controls a position indicator below each switch on panel 15. When the valve is open, the position switch is open; and the indicator on panel 15 is grey (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 panel 15 is 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.

2.5.3.1.3 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) separate regulators connected in series. The secondary regulator remains open as long as the primary regulator functions properly. In the event of the primary regulator failing open, the secondary regulator will maintain slightly higher, but acceptable pressures.

2.5.3.1.4 Check Valve Assemblies.

Two check valve assemblies, one assembly located downstream of each regulator assembly, permit helium flow in the downstream direction only. This prevents propellant and/or propellant vapor backflow into the pressurization system if seepage or failure occurs in the propellant tank bladders.

2.5.3.1.5 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 diaphram is of the nonfragmentation type, but in the event of any fragmentation, the filter filters out any fragmentation and prevents any 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 tank. 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 from the diaphragm, or vents the cavity upon completion of performing a checkout of the relief valve from the test 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.

2.5.3.1.6 Distribution Plumbing.

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

2.5.3.2 Propellant Subsystem.

This subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.3.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single titanium alloy hemispherically domed cyclindrical tank. The tank is cradle-mounted to the RCS panel. The 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 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 out of the tank outlet into the manifold, providing expulsion during zero g's. Tank has a working pressure of 248 psig; proof pressure of 331 psig.

2.5.3.2.2 Fuel Tank.

The fuel supply is contained in a single tank that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.3.2.3 Propellant Isolation Shutoff Valve.

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are magnetically latch opened and spring-loaded closed. The valves are normally open in respect to fluid flow. This, again, establishes a power conservation.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel) indicating to the crew that the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines indicating to the crew that the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, runaway thruster, etc.

2.5.3.2.4 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 cluster.

2.5.3.2.5 Propellant, In-Line Filters.

In-line filters are installed in the fuel and oxidizer manifolds 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.

2.5.3.3 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 modulated or the steady state mode. (These modes are defined as a firing of less than one-second duration, and one-second duration or more, respectively.)

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic or manual) generated by the guidance and navigation subsystem and/or stabilization and control subsystem or by the crew; and an injector head assembly, which directs the flow of each propellant from the propellant control valves to the combustion chamber where the propellants atomize and ignite (hypergolic) to produce thrust.

2.5.3.3.1 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 jet selection logic, which is the electronic circuitry that selects the required automatic coils to be energized for a given maneuver. The manual coils are used when the thrust command originates at the rotation control (direct mode), direct ullage pushbutton, SPS abort, or the C/M S/M SEP switch (figure 2.5-3).

The solenoid valves are spring-loaded closed and energized open. The reaction time of the valves are illustrated in figures 2.5-4 and 2.5-5.

Figure 2.5-4 illustrates a thrusting duration of 15 seconds (steady state). The electrical on signal is received within either the automatic (normal) or manual (backup) coils of the engine injector valves. The solenoid injector valves are energized open allowing fuel and oxidizer to

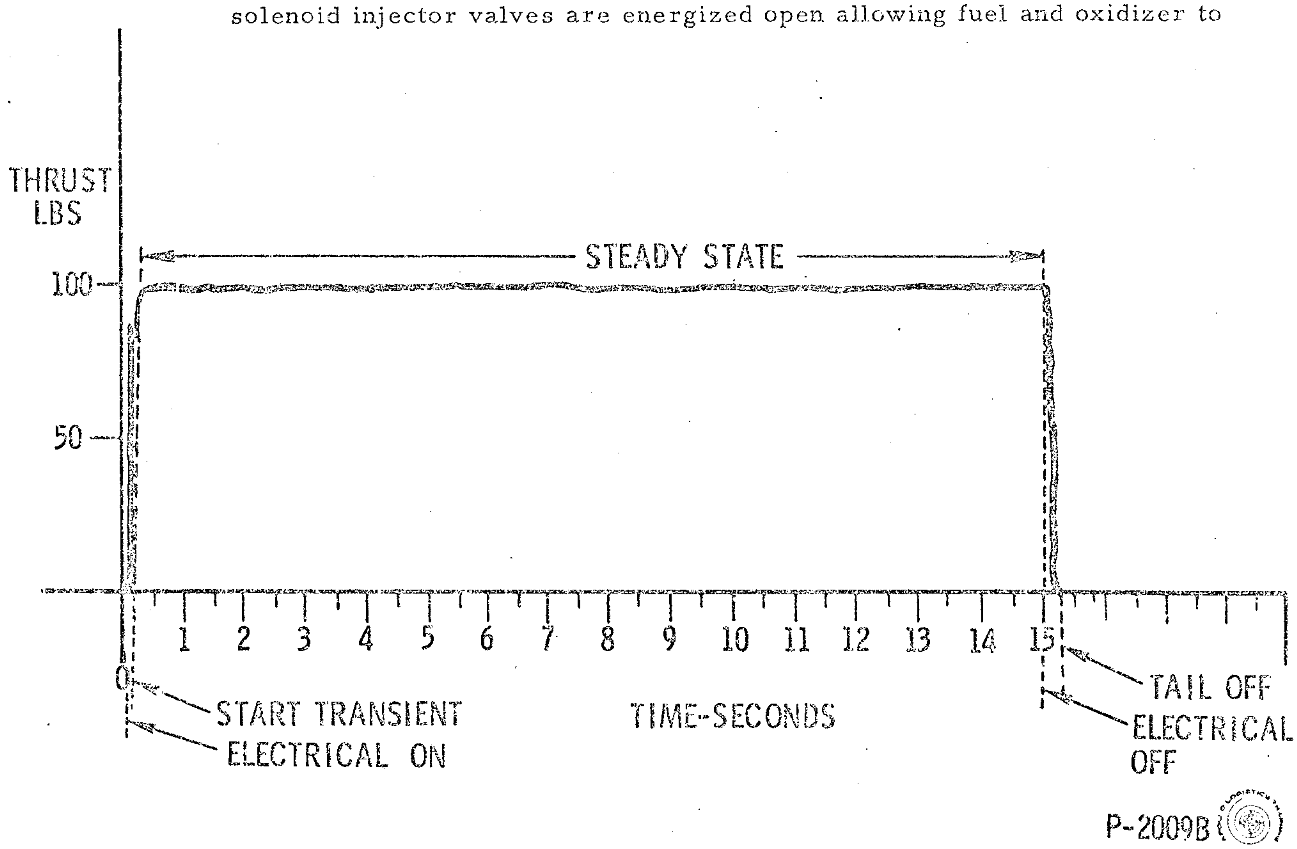


Figure 2.5-4. S/M RCS Steady-State Operation (Typical 15 Seconds)

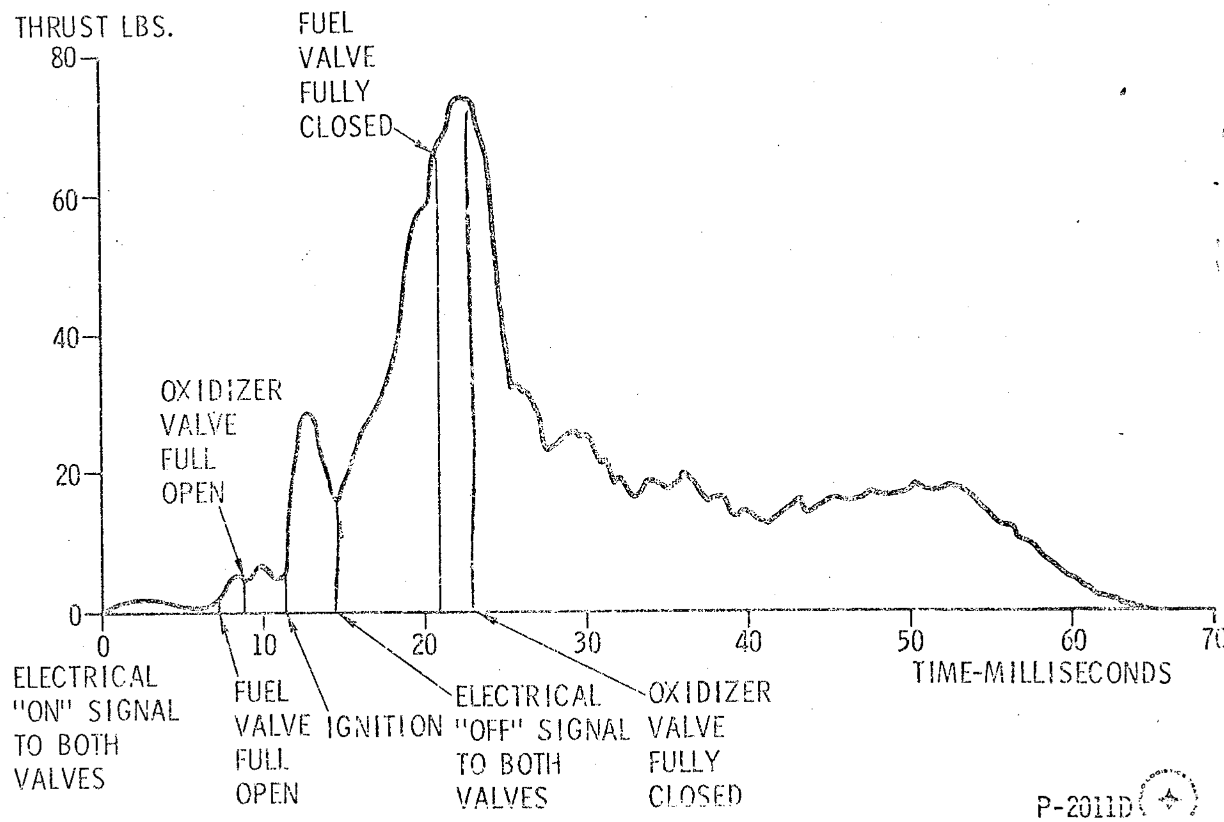


Figure 2.5-5. S/M RCS Engine Minimum Total Impulse (Typical)

flow through the injector into the combustion chamber. The propellants, being hypergolic, ignite, providing the start transient. The engine, as a result of propellant ignition, produces chamber pressure, gas velocity, and thrust. At 15 seconds after the receipt of the thrust-on signal, the automatic or manual coils are de-energized and the injector valves spring-load closed. However, due to the closing time and residual propellant flow downstream of the injector valves into the combustion chamber, thrust output continues until the propellants have burned completely allowing the chamber pressure, gas velocity, and thrust to decay to 0 pounds, establishing the cutoff transient.

Figure 2.5-5 illustrates the minimum electrical signal that can be provided to the automatic coils of the injector valves from the stabilization control subsystem jet selection logic. The following describes the sequence of operation and reasons why.

a. A time of 18±4 milliseconds (14 milliseconds minimum) will elapse before the stabilization control subsystem (SCS) can electrically provide a command-off signal to the automatic coils of the injector valves on the engine.

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

c. The fuel injector automatic coil energizes to the fully open position in 4.5±1.5 milliseconds, and the oxidizer injector automatic coil energizes to the fully open position in 6.0±1.5 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 flow from the injector valves as soon as they both start to open to the premix igniter. However, the fuel will lead the oxidizer by two milliseconds.

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

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

g. At approximately 12-1/2 milliseconds, the propellants ignite (hypergolic), producing a spike of thrust upwards into the area of 70 to 80 pounds. At 14 milliseconds minimum, the SCS removes the electrical signal from the automatic coils of the injector valves.

h. The thrust of the engine continues very erratically, while the valves become de-energized and spring-load closed.

i. At approximately 21 milliseconds (closing time of 7.5 milliseconds) on the fuel valve and 23 milliseconds (closing time of 8.0 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 2.5-5), everything under the entire thrust curve must be integrated.

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

a. Prevent a mismatch between the opening and closing of the valves due to any heat soak-back into the manual coils, which would change the resistance of the manual coils and result in a mismatch if the coils were connected in parallel. The direct manual opening time for fuel is 13 milliseconds and oxidizer is 23 milliseconds. The closing time for fuel and oxidizer is 55±25 milliseconds.

b. The series connection from the fuel manual coil (positive to negative) to the oxidizer manual coil (negative to positive), then to ground, is to increase the arc suppression, reducing the arc at rotation control in the direct RCS mode of operation.

2.5.3.3.2 Injector.

The injector contains a premix igniter. The premix igniter 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 2-millisecond fuel lead, provides a smoother start transient primarily in the pulse mode of operation and especially in the area of minimum impulse.

The main chamber portion of the injector will allow eight fuel streams to impinge upon eight oxidizer streams (unlike impingement) for main chamber ignition. There are also eight fuel holes around the outer periphery of the injector, which provides film cooling to the combustion chamber.

2.5.3.3.3 Combustion Chamber.

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

Nozzle Extension. The nozzle extension is attached to the engine by a Waspolloy nut. The nozzle extension is machined from a cobalt base alloy. The stiffener rings are machined.

2.5.3.3.4 RCS Electrical Heaters.

Each of the RCS engine housings contain an electrical strip heater (figure 2.5-3). The electrical strip heaters provide propellant temperature control by conductance to the engine housing and engine injector valves; thus the propellants. Each heater has two thermo switches that maintain the temperature at a given range.

2.5.3.4 Pressure Versus Temperature Measuring System.

The helium tank supply temperature measurement and helium tank supply pressure measurement (figure 2.5-3) for each quad are utilized by the crew and TLM to determine the quantity of propellants remaining in the respective quad.

The nomogram (figure 2.5-6) depicts how to determine the propellant quantity remaining in percentage. The helium supply pressure is determined in psia on panel 12 by the crew, also the helium supply temperature

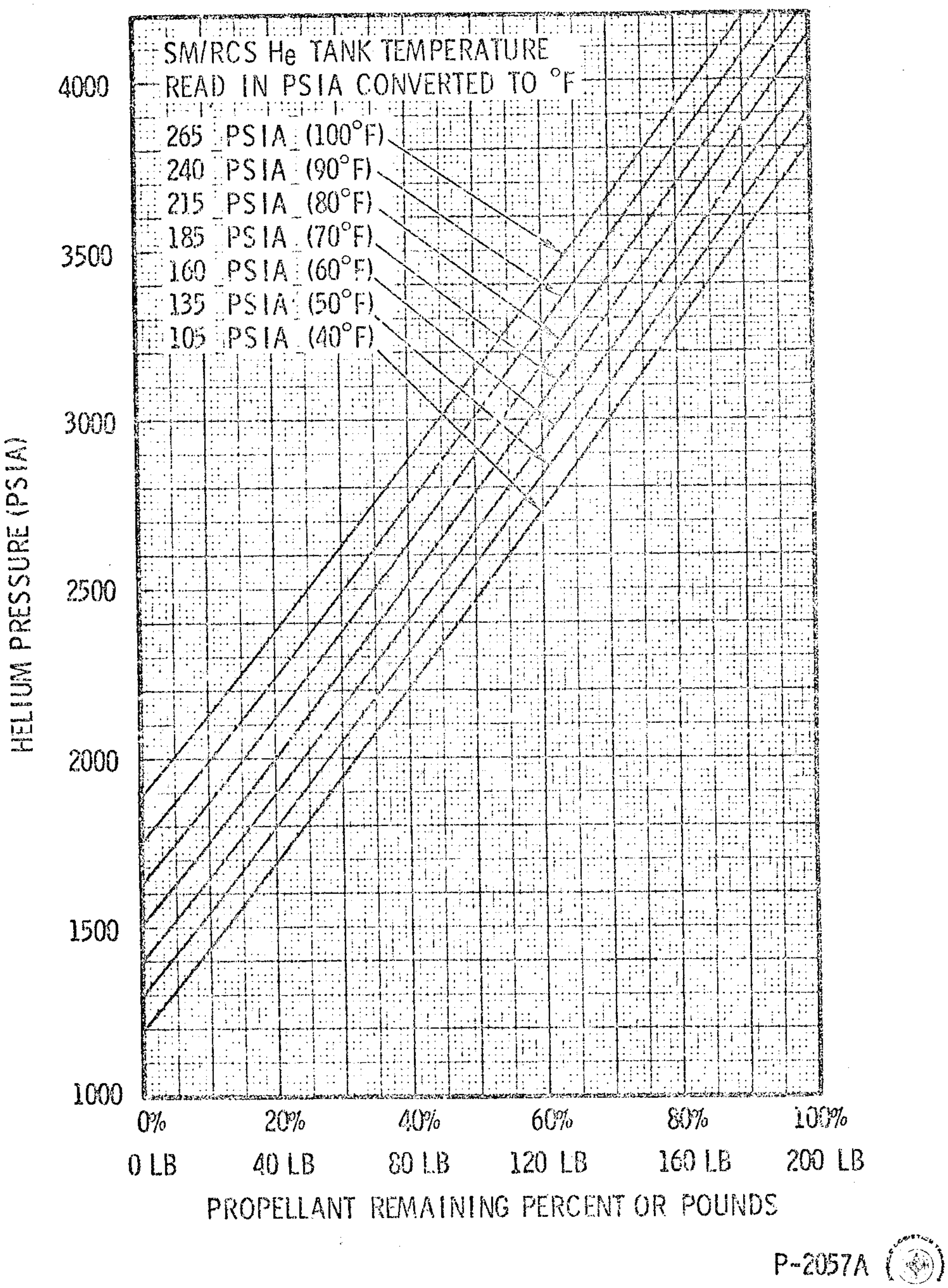


Figure 2.5-6. S/M RCS Nomogram Typical Propellant Remaining

reads in psia. The helium supply temperature readout of 0 psia is equivalent to 0°F and 400 psia is equivalent to 150°F.

As an example, if the crew readout on panel 12 for a given quad reads 3400 psia helium supply pressure and 265 psia helium supply temperature (which is equivalent to 100°F), the quantity of propellants remaining is approximately 60 percent or 120 pounds. The crew would utilize the RCS indicator select switch on panel 12 to select the quad desired in order to obtain the helium tank supply pressure and temperature, and determine the propellant quantity remaining in percent.

2.5.3.5 Engine Thrusting Logic.

In the S/M RCS, the commands from the stabilization and control system cannot be supplied to the SCS channel switches until the contacts of the RCS latching relay are closed. Closing of these contacts for S/M RCS control may be initiated by the following signals (figure 2.5-3):

a. With the launch escape tower jettisoned and the translation control rotated counterclockwise, an S/M abort or a normal S-IVB separation is initiated and the following sequence of events occurs.

1. Inform the G&N system of an abort initiation.
2. Initiate applicable booster shutdown.
3. Inhibit the pitch and yaw automatic jets of the SCS.
4. Initiates an ullage maneuver signal to the required manual coils of the S/M RCS engines (as long as the translation control is in counterclockwise, ullage is terminated when the translation control is returned to the neutral detent).
5. Adapter separation occurs at 1.7 seconds after the abort was initiated.
6. Energizes the RCS latching relay 2-1/2 seconds after the abort was initiated allowing the SCS to provide electrical commands to the automatic coils of the S/M RCS engines. In the event the logic fails to energize the RCS latching relay, the RCS CMD switch on panel 16 is placed to the ON position, providing a manual backup to the automatic function. In addition, if the ADAPTER SEPARATION pushbutton on panel 5 is pressed and held for approximately 1 to 2 seconds, the RCS latching relay is energized.

b. In a backup to the normal S-IVB separation sequence, the RCS CMD switch is momentarily placed to the ON position, energizing the RCS latching relay; the translation control is positioned forward, providing a translation through the SCS to the required automatic coils of the S/M RCS engine for a +X translation; and the ADAPTER SEPARATION pushbutton on panel 5 is held for 2 seconds to initiate adapter separation. (ADAPTER SEPARATION pushbutton pressed and held for approximately 1 to 2 seconds will also energize the RCS latching relay.)

In the event the translation controls are unable to provide an ullage maneuver, the DIRECT ULLAGE pushbutton on panel 7, when depressed and held, provides the direct ullage signal to the manual coils of the RCS engines, to be energized to provide a +X translation. This provides a manual direct backup to the two translation controls for the ullage maneuver to be performed by the S/M RCS. The ullage maneuver is terminated upon release of the DIRECT ULLAGE pushbutton.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation controls only. When the rotation control is positioned fully to its stops in any direction, the rotation control will energize the required manual coils for the desired maneuver.

If the SCS and/or the jet selection logic is unable to provide commands to the automatic coils of the S/M RCS engines, it is noted that translation control of the spacecraft is disabled.

2.5.4 S/M RCS PERFORMANCE AND DESIGN DATA.

2.5.4.1 Design Data.

The following list is the design data of the S/M RCS components.

HELIUM TANKS (4)	4150±50 psig at 70±5°F during servicing; after servicing sitting on launch pad 70±10°F. Capacity 0.57 lb, inside diameter 8.84 in., wall thickness 0.105 in., and internal volume 0.205 cu ft.
REGULATOR UNITS (8)	Primary - 181±4 psig with a normal lockup of 183±5 psig. From lockup pressure, not drop below 177 psig or rise above 185 psig and stabilize to 181±2 psig within 2 sec.
	Secondary - Lockup of 187±5 psig. From lockup pressure, not drop below 177 psig or rise above 194 psig and stabilize at 185±3 psig within 2 sec.
PRESSURE TRANSDUCERS (4) COMMON MANIFOLD	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D). Underpressure 155 psia. Overpressure 215 psia.
HELIUM RELIEF VALVES (8)	Diaphragm rupture at 228±8 psig.
	Filter - 10 micron normal, 25 micron absolute.

	Relief valve relieves at 236.5±11.5 psig.
	Relief valve reseats at not less than 220 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 shall reopen when decreasing pressure has reached no less than 20 psig.
FUEL TANK (4)	Combined propellant and ullage volume of 69.0 lbs, initially at 60°F at 30±2 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter maximum 12.62 in., length 23.717 (+0.060, -0.000) in. Wall thickness 0.017 in. to 0.022 in.
	Helium inlet port 1/4 in., fill and drain port 1/2 in.
OXIDIZER TANK (4)	Combined propellant and ullage volume of 137.0 lbs, initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 215 psia when heated to 85°F. Outside diameter maximum 12.62 in., length 28.55 (+0.060, -0.000) in.
	Wall thickness 0.017 in. to 0.022 in.
INLINE FILTERS ENGINES (16)	5-micron nominal; 15-micron absolute - 1000-sec service life, capable of 10,000 operational cycles.
	Thrust 100 lbs ±5 percent.
	Expansion ratio 40:1 at nozzle exit.
	Cooling Film and radiation
	Injector type.
	Premix igniter one on one unlike impingement. Eight fuel annulus for film cooling of premix igniter, main chamber eight on eight unlike impingement, eight fuel for film cooling of combustion chamber wall.

	Nozzle extension	L-605 material
	Nozzle exit diameter 5.6 in.	
	Fuel lead.	
	Automatic coils - Connected in parallel.	
	Manual coils - Connected in series.	
	Weight - 4.99 lbs.	
	Length - 13.375 in.	
PACKAGE TEMPERATURE TRANSDUCER (4)	Illuminate CAUTION and WARNING light on panel 10 (S/M RCS A, B, C, or D) Under temperature 63°F. Over temperature 175°F.	
	One in Each Quad	One in Each Quad
HEATERS THERMO-SWITCH	Close at 77 (+10, -7)°F	Close at 115°F
	Open at 104±14°F	Open at 134°F
	36±3.6 watts per heater	36±3.6 watts per heater

2.5.4.2 Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.4.3 Power Consumption Data S/M RCS and C/M RCS.

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
Reaction control Service module RCS						
Engine heaters	RCS HEATER CB (4)	8		*36.0		288.0
RCS engine coils	SCS JET SELECTION LOGIC or DIRECT	32		*AUTO = 3.687		118.0
				*DIRECT = 1.062		34.0

Subsystem and Component	Control	No. of Units	Watts per Unit		Total Watts	
			AC	DC	AC	DC
He isolation valves	He VALVE CB (2) He sw (8)	8		6.750		54.0
Propellant isolation valves	PROP. ISOL. CB (2) PROP. ISOL. sw (4)	8		6.125		49.0
Command module RCS						
Isolation valves	(Ref. S/M/RCS ISOL. CB) PROP. ISOL. sw (2)	4		12.250		49.0
RCS engine coils	SCS JET SELECTION LOGIC OR DIRECT	24		*AUTO = 4.208		105.0
				*DIRECT = 2.187		52.5

*Intermittent operating components.

2.5.4.4 S/M RCS Electrical Power Distribution.

See figure 2.5-7 for electrical power distribution.

2.5.5 S/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Operational limitations and restrictions on the testing of system valves in a dry unserviced propulsion system are as follows:

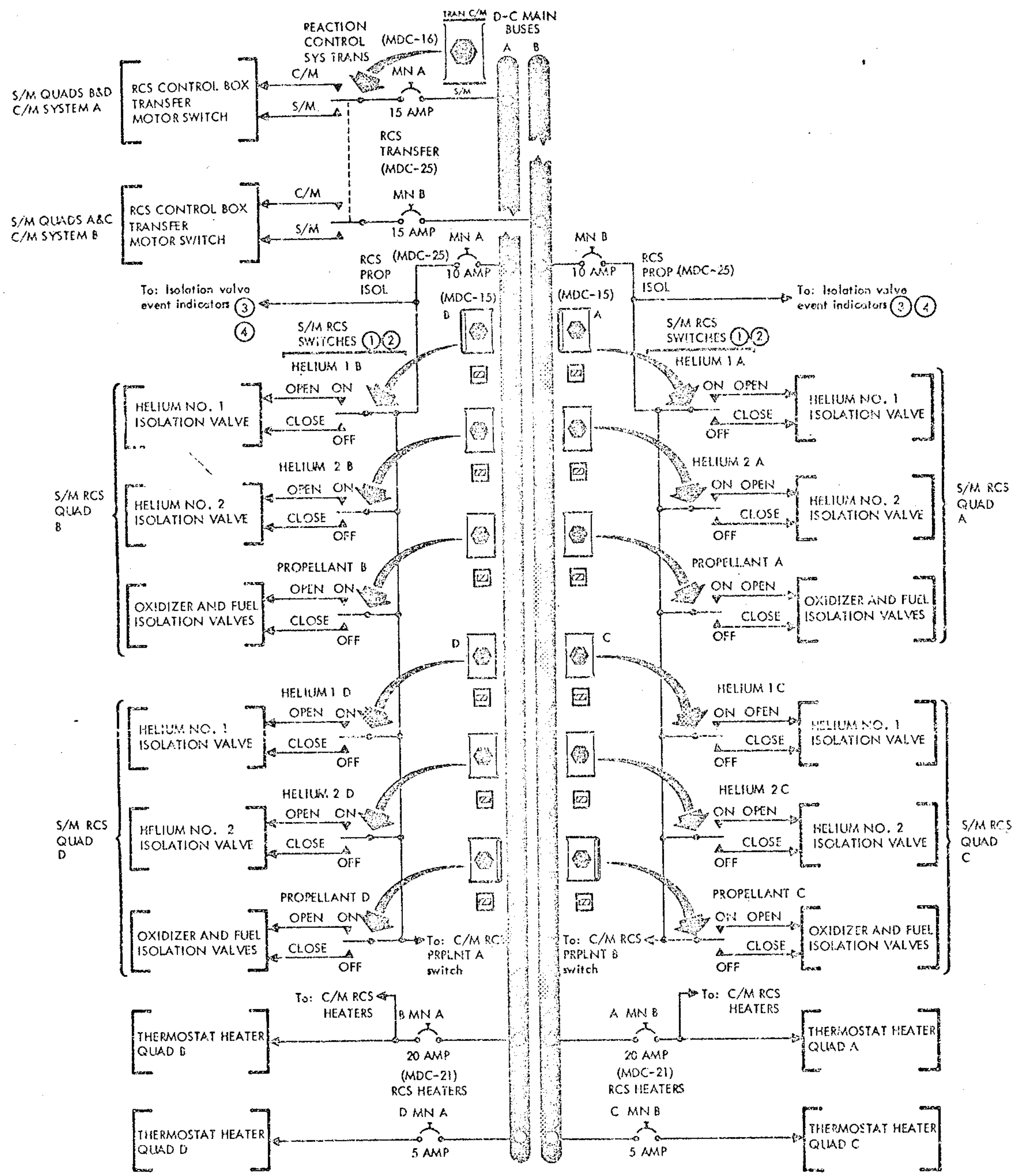
a. Helium isolation valves and propellant isolation valves minimum energization time of 0.2 second and not to exceed 5 seconds.

b. Engine injector valve automatic coil energization not to exceed 2 minutes on time during any 15-minute period with voltage not exceeding 32 vdc.

c. Engine injector valve direct coil energization on time not exceed 45 minutes during any 60-minute period and voltage not exceed 16 vdc to either coil separately or 32 vdc to two coils in series.

2.5.6 S/M RCS TELEMETRY MEASUREMENTS.

The subsequent list is of all S/M RCS telemetry data that is monitored by flight controllers and ground support personnel.



NOTES: 1. Helium isolation valves are mechanically latched open and spring-loaded closed.

2. Propellant isolation valves are magnetically latched open and spring-loaded closed.

3. Each helium isolation valve event indicator is energized when corresponding valve is in closed position only.

4. The propellant isolation valve event indicator is energized if either fuel or oxidizer valve is in the closed position.

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Figure 2.5-7. S/M RCS Electrical Power Distribution Diagram

Crew Display	Figure	Measurements	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 12	2.5-3	Helium Tank Temperature A	SR5013T	0 +150°F	S28AR164(S19A1)				70±10°F on launch pad, variable during mission.
Panel 12	2.5-3	Helium Tank Temperature B	SR5014T	0 +150°F	S28AR164(S19A2)				
Panel 12	2.5-3	Helium Tank Temperature C	SR5015T	0 +150°F	S28AR164(S19A3)				
Panel 12	2.5-3	Helium Tank Temperature D	SR5016T	0 +150°F	S28AR164(S19A4)				
Panel 12	2.5-3	Helium Tank Supply Pressure A	SR5001P	+0 +5K psia	S28AR36(S19A1)	10A89	H2	PCM	4150±5°F psia and decreases with engine firings.
Panel 12	2.5-3	Helium Tank Supply Pressure B	SR5002P	+0 +5K psia	S28AR36(S19A2)	10A91	H2	PCM	
Panel 12	2.5-3	Helium Tank Supply Pressure C	SR5003P	+0 +5K psia	S28AR36(S19A3)	10A93	H2	PCM	
Panel 12	2.5-3	Helium Tank Supply Pressure D	SR5004P	+0 +5K psia	S28AR36(S19A4)	10A96	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure A	SR5729P	+0 +400 psia	S28AR44(S19A1)	11A82	H2	PCM	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure B	SR5776P	+0 +400 psia	S28AR44(S19A2)	11A88	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure C	SR5817P	+0 +400 psia	S28AR44(S19A3)	11A89	H2	PCM	
Panel 10 and 12	2.5-3	Regulated Helium Manifold Pressure D	SR5830P	+0 +400 psia	S28AR44(S19A4)	11A91	H2	PCM	
	2.5-3	Oxidizer Feed Line Pressure A	SR5733P	+0 +300 psia		12A8	H1	FQ	Launch pad 193 to 207 psia decreasing to 178 to 192 psia in a space environment.
	2.5-3	Fuel Feed Line Pressure A	SR5737P	+0 +300 psia		12A9	H1	FQ	
	2.5-3	Fuel Feed Line Pressure B	SR5784P	+0 +300 psia		12A13	H1	FQ	
	2.5-3	Oxidizer Manifold Pressure D	SR5821P	+0 +300 psia		12A14	H1	FQ	
	2.5-3	Fuel Feed Line Pressure C	SR5822P	+0 +300 psia		12A15	H1	FQ	
	2.5-3	Fuel Feed Line Pressure D	SR5823P	+0 +300 psia		12A16	H1	FQ	
Panel 10 and 12	2.5-3	Temperature Package A + P Engine 3	SR5065T	+0 +300°F	S28AR40(S19A1)	10A95	H1	PCM	Pad 115 to 134°F Flight 115°F to 175°F
Panel 10 and 12	2.5-3	Temperature Package B - Y Engine 6	SR5066T	+0 +300°F	S28AR40(S19A2)	10A62	H1	PCM	

Crew Display	Figure	Measurements	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
Panel 10 and 12	2.5-3	Temperature Package C - P Engine 4	SR5067T	+0 +300°F	S28AR40(S19A3)	10A98	H1	PCM	Pad 115 to 134°F Flight 115°F to 175°F
Panel 10 and 12	2.5-3	Temperature Package D + Y Engine 5	SR5068T	+0 +300°F	S28AR40(S19A4)	10A100	H1	PCM	
	2.5-3	Temperature Injector Head B + Y Engine	SR7128T	+0 +500°F		51A21	H1	FQ	Variable
	2.5-3	Temperature Injector Head A CCW R Engine	SR7134T	+0 +500°F		51A22	H1	FQ	Variable
	2.5-3	Direct Ullage On A (Z16 Relay)	CD0140X	OFF ON event		11E12-06	E2	PCME	Event
	2.5-3	Direct Ullage On B (Z16 Relay)	CD0141X	OFF ON event		11E12-08	E2	PCME	Event
	2.5-3	RCS Activate Signal A (Z19 Relay)	CD0170X	OFF ON event		11E13-06	E2	PCME	Event
	2.5-3	RCS Activate Signal B (Z19 Relay)	CD0171X	OFF ON event		11E13-07	E2	PCME	Event
		Tower Jettison A	CD0105X			11E28-02	E2	PCME	Event
		Tower Jettison B	CD0106X			11E28-03	E2	PCME	Event

*Analog measurements digitally coded into 8 bit words.
Analog measurements - 0 to 5 vdc
FQ - Flight qualification measure
H1 - High bit rate
H2 - High and low bit rate
E2 - High and low bit rate

Channel Code Example: 10A89

Significant number - 1
How many zeros after significant number is amount of samples per second } 0 } 1 sample per second

Analog - A
Event - E
Channel code - 89

2.5.7 C/M RCS FUNCTIONAL DESCRIPTION.

The command module reaction control subsystem provides the impulse required for controlling spacecraft attitude during the terminal phases of a mission.

The subsystems are activated normally by the crew placing the C/M-S/M SEPARATION switches to C/M-S/M SEPARATION position or by placing the C/M RCS PRESSURIZE switch to the ON position prior to initiating C/M-S/M separation (C/M RCS PRESSURIZE switch may also be utilized as a manual backup to the C/M-S/M SEPARATION switches). 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 C/M-S/M consists of two identical and independent subsystems, identified as subsystem A and subsystem B. Both subsystems are operated 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 C/M RCS is contained entirely within the C/M and each reaction engine nozzle is ported through the C/M skin. The propellants consist of nitrogen tetroxide (N_2O_4) used as oxidizer and monomethylhydrazine (MMH) used as fuel. Pressurized helium gas is the propellant transferring agent.

The reaction jets may be pulse-fired, producing short-thrust impulses or continuously fired, producing a steady-state thrust level. The short firing permits attitude modes of operation. C/M attitude control is normally maintained by utilizing the applicable pitch, yaw, and roll engines of subsystems A and B. However, complete attitude control can be maintained with only one subsystem.

A functional flow diagram of C/M RCS subsystems A and B is shown in figure 2.5-8. The helium storage vessel of each subsystem supplies pressure to two helium isolation squib valves that are normally closed throughout the mission until C/M-S/M separation or C/M RCS pressurize is activated. The helium isolation squib valves in a subsystem are initiated open, allowing pressure to the pressure regulators downstream of each helium isolation squib valve, reducing the high-pressure helium to a desired working pressure.

Regulated helium pressure is directed through a series-parallel combination of four independent 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 is installed in the pressure lines between the check valves and propellant tanks to protect the propellant tanks from any excessive pressure increase.

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, and through the propellant isolation valves. Each subsystem supplies fuel and oxidizer to six engines.

Oxidizer and fuel is distributed to the 12 fuel and oxidizer injector valves by a parallel feed system. The fuel and oxidizer 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 impinge, atomize, and ignite due to the hypergolic propellants. The injector valves are controlled automatically by the G&N system or the SCS. Manual override direct control is provided for rotational maneuvers and direct ullage only. The injector valves are spring-loaded closed.

Extremely cold temperature of the C/M exterior is anticipated prior to entry operations; therefore, C/M 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. This is accomplished by the crew monitoring the engine temperatures and energizing the injector valve solenoids until acceptable engine temperatures are obtained. The C/M RCS HTRS switch on panel 200 will apply power to the injector valve solenoids for engine preheating.

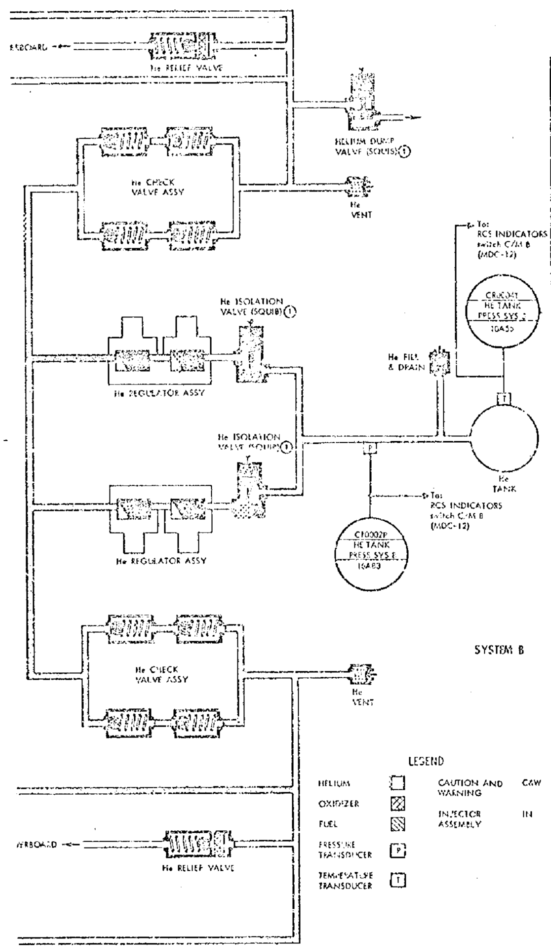
Since the presence of hypergolic propellants can be hazardous upon C/M impact, the remaining propellants are burned off and the RCS purged with helium prior to C/M landing.

In the event of an abort from the pad up to T + 61 seconds after liftoff, provisions have been incorporated to automatically dump the oxidizer supply overboard, followed by a helium purge of the oxidizer tanks and dumping of the remaining helium supply. The fuel is retained on board due to insufficient time for dumping and the C/M impacts with fuel tanks full, but depressurized.

2.5.8 C/M RCS MAJOR COMPONENTS/SUBSYSTEM DESCRIPTION.

The C/M RCS is composed of two separate, normally independent systems, designated system A and system B. The systems are identical to operation, each containing the following four major subsystems:

- Pressurization
- Propellant
- Rocket engine
- Temperature control system



C/M RCS SQUIB VALVE ACTIVATION CONTROL MATRIX

Phase	Sequence	He Isolation (4)	Fuel Side He Interconnect (1)	Oxidizer Side He Interconnect (1)	Fuel Interconnect (1)	Oxidizer Interconnect (1)	Fuel Tank Bypass (2)	Oxidizer Tank Bypass (2)	Oxidizer Dump (2)	He Dump (1)
		SQUIB VALVE IDENTIFICATION (TOTAL: 15 VALVES)								
Normal Entry	1. Prior to C/M-S/M separation	1 (NORMAL) / 4 (BACKUP)								
	2. Main parachute line stretch		2	2	2	2				
	3. After propellant depletion						3 (NORMAL) / 6 (BACKUP)	3 (NORMAL) / 6 (BACKUP)		
Abort (Pad to lift-off plus 61 seconds)	1. Simultaneous with EDS or manual abort initiation	4 (NORMAL) / 1 (BACKUP)		4		4			4	
	2. Abort initiation plus 10 seconds		5					5		5
Abort (Lift-off plus 61 seconds to tower jettison)	1. Simultaneous with EDS or manual abort initiation	4 (NORMAL) / 1 (BACKUP)								
	2. Main parachute line stretch		2	2	2	2				
	3. After propellant depletion						3 (NORMAL) / 6 (BACKUP)	3 (NORMAL) / 6 (BACKUP)		
All SPS Aborts	Same as normal entry									

LEGEND FOR SQUIB VALVE ACTIVATION METHODS

1. C/M RCS PRESS. switch (MDC-16)
2. C/M PROP. JETT DUMP switch (MDC-8)
3. C/M PROP. JETT PURGE switch (MDC-8)
4. Automatic (MESC at C/M-S/M separation)
5. Automatic (RCS control box time delay relay)
6. C/M RCS He DUMP switch (MDC-26)

NOTES:
1. See matrix for squib valve activation sequence.
2. Relay is controlled by MESC and provides for automatic valve closure during pad up to 61 second abort

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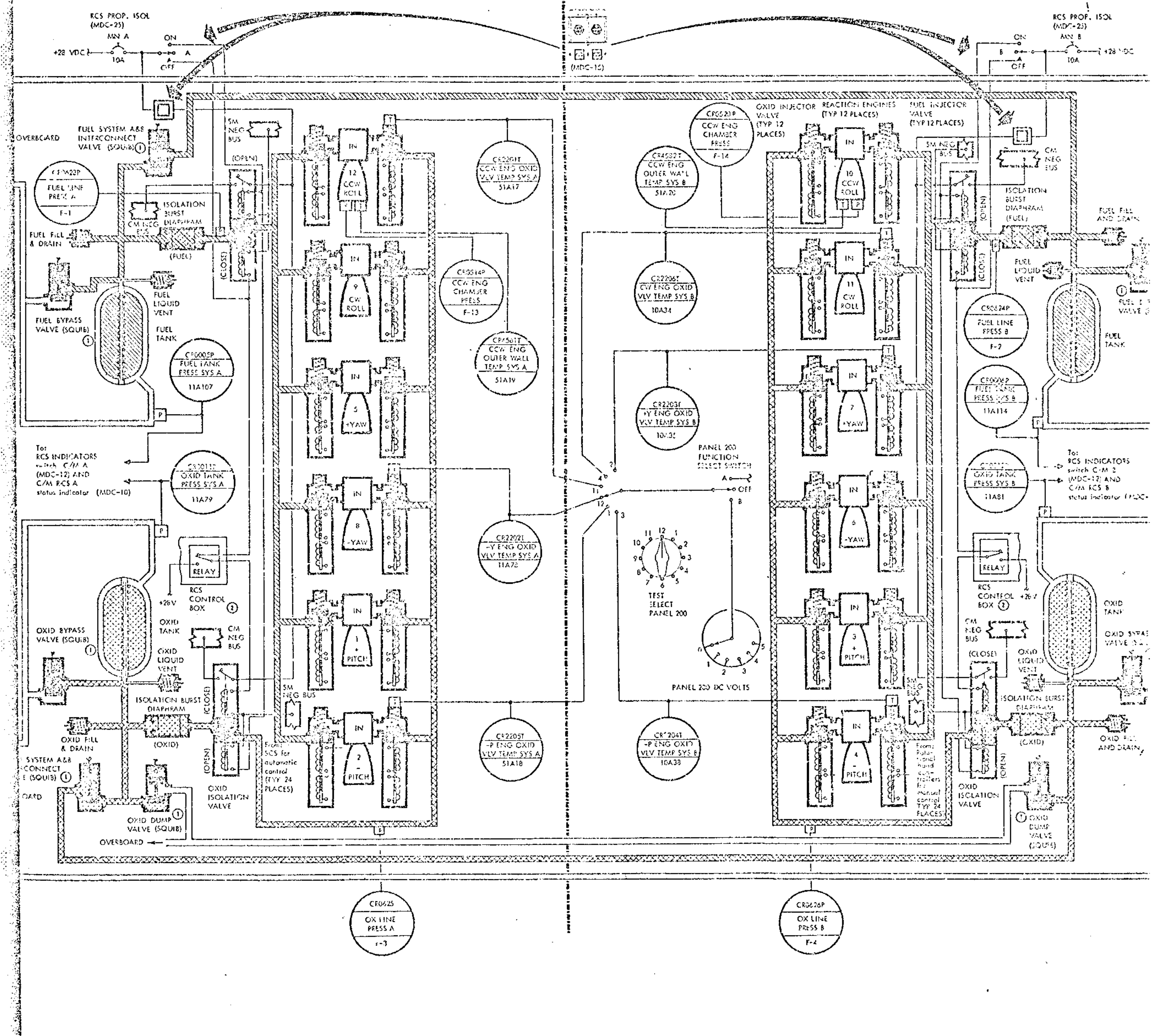
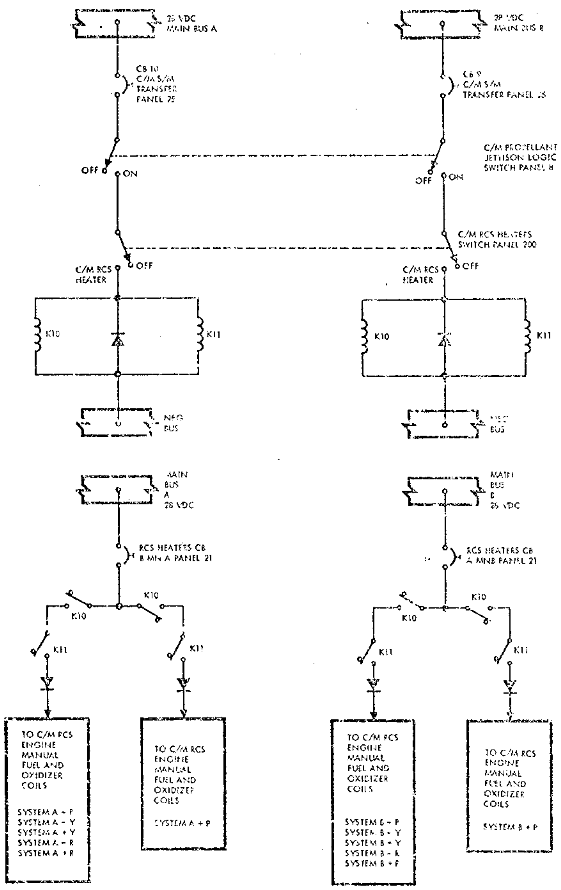
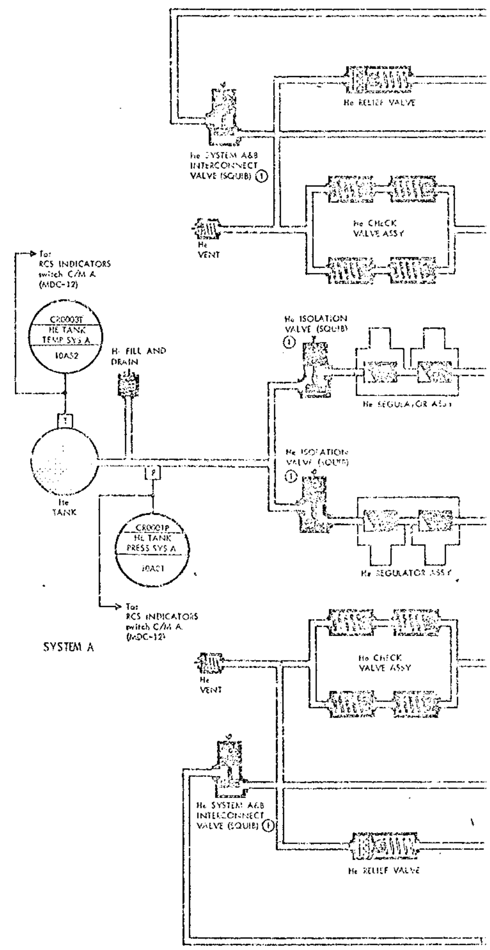
Figure 2.5-8. C/M RCS Functional Flow Diagram



RCS PROP. ISOL (MDC-23)
MN A
MN B
+28 VDC
ON
OFF
10A
(MDC-10)
OVERBOARD
FUEL SYSTEM A&B INTERCONNECT VALVE (SQUIB)
FUEL LINE PRESS A
ISOLATION BURST DIAPHRAGM
CM NEG BUS
FUEL FILL & DRAIN
(FUEL)
(CLOSE)
(OPEN)
SM NEG BUS
FUEL LIQUID VENT
FUEL BYPASS VALVE (SQUIB)
FUEL TANK
FUEL TANK PRESS SYS A
11A107
To: RCS INDICATORS switch C/M A (MDC-12) AND C/M RCS A status indicator (MDC-10)
OXID TANK PRESS SYS A
11A79
RELAY
RCS CONTROL BOX
+28V
OXID BYPASS VALVE (SQUIB)
OXID TANK
OXID LIQUID VENT
ISOLATION BURST DIAPHRAGM
OXID FILL & DRAIN
(OXID)
OXID ISOLATION VALVE
OXID DUMP VALVE (SQUIB)
From SCS for automatic control (TYP 24 PLACES)
IN
CCW ROLL
CW ROLL
+YAW
-YAW
+ PITCH
- PITCH
CCW ENG OXID VLV TEMP SYS A
51A17
CCW ENG CHAMBER PRESS
F-13
CCW ENG OUTER WALL TEMP SYS A
51A19
+Y ENG OXID VLV TEMP SYS A
11A72
-P ENG OXID VLV TEMP SYS A
51A18
OXID INJECTOR VALVE (TYP 12 PLACES)
REACTION ENGINES (TYP 12 PLACES)
FUEL INJECTOR VALVE (TYP 12 PLACES)
CCW ENG CHAMBER PRESS
F-14
CCW ENG OUTER WALL TEMP SYS B
51A70
CW ENG OXID VLV TEMP SYS B
10A34
+Y ENG OXID VLV TEMP SYS B
-P ENG OXID VLV TEMP SYS B
10A38
PANEL 200 FUNCTION SELECT SWITCH
TEST SELECT PANEL 200
PANEL 200 DC VOLTS
FUEL LINE PRESS B
F-2
FUEL TANK PRESS SYS B
11A114
OXID TANK PRESS SYS B
11A81
To: RCS INDICATORS switch C/M B (MDC-12) AND C/M RCS B status indicator (MDC-10)
FUEL FILL AND DRAIN
OXID FILL AND DRAIN
OXID DUMP VALVE (SQUIB)
OX LINE PRESS A
F-3
OX LINE PRESS B
F-4


25 VDC MAIN BUS A
CB 10 C/M S/M TRANSFER PANEL 25
C/M PROPELLANT JETTISON LOGIC SWITCH PANEL 8
OFF
ON
C/M RCS HEATERS SWITCH PANEL 200
C/M RCS HEATER
K10
K11
NEG BUS
MAIN BUS A 28 VDC
RCS HEATERS CB B MN A PANEL 21
MAIN BUS B 28 VDC
RCS HEATERS CB A MNB PANEL 21
TO C/M RCS ENGINE MANUAL FUEL AND OXIDIZER COILS
SYSTEM A - P
SYSTEM A - Y
SYSTEM A + Y
SYSTEM A - R
SYSTEM A + R
SYSTEM A + P
SYSTEM B - P
SYSTEM B - Y
SYSTEM B + Y
SYSTEM B - R
SYSTEM B + R
SYSTEM B + P


He RELIEF VALVE
He SYSTEM A&B INTERCONNECT VALVE (SQUIB) (1)
He CHECK VALVE ASSY
He VENT
To: RCS INDICATORS switch C/M A (MDC-12)
CR0003T HE TANK TEMP SYS A 10A52
He FILL AND DRAIN
He ISOLATION VALVE (SQUIB) (1)
He REGULATOR ASSY
He TANK
CR0001P HE TANK PRESS SYS A 10A01
SYSTEM A

2.5.8.1 Pressurization Subsystem.

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.

2.5.8.1.1 Helium Supply Tank.

The total high-pressure helium is contained within a single spherical storage tank. Initial fill pressure is 4150±50 psig. The limit working pressure is 5000 psig to accommodate pressure transients during filling. The proof pressure is 6667 psig and burst pressure is 7500 psig.

2.5.8.1.2 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 to as small an area as possible to reduce 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 PRESS switch on panel 16, the C/M-S/M SEP switches on panel 15, or upon the receipt of an abort signal from the pad up to launch escape tower jettison.

2.5.8.1.3 Helium Pressure Regulator Assembly.

The pressure regulators used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the regulators in the C/M RCS are set at a higher pressure than those of the S/M RCS.

2.5.8.1.4 Helium Check Valve Assembly.

The check valve assemblies used in C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS.

2.5.8.1.5 Helium Relief Valve.

The helium relief valves used in the C/M RCS subsystems A and B are similar in type, operation, and function to those used in the S/M RCS. The differences are that the rupture pressure of the burst diaphragm in the C/M RCS is higher than that of the S/M RCS, and the relief valve relieves at a higher pressure in the C/M RCS than that of the S/M RCS.

2.5.8.1.6 Distribution Plumbing.

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

2.5.8.2 Propellant Subsystem.

Each subsystem consists of one oxidizer tank, one fuel tank, one oxidizer and fuel isolation valve, and associated distribution plumbing.

2.5.8.2.1 Oxidizer Tank.

The oxidizer supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank to each system. Each tank contains a diffuser tube assembly and a teflon bladder for positive expulsion of the oxidizer similar to that of the S/M RCS tank assemblies. The difference is the C/M RCS tank assemblies are smaller in size. 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, thus forcing the oxidizer into the diffuser tube assembly and out of the tank outlet into the manifold. Working pressure is 360 psig; proof pressure is 480 psig; and the burst pressure is 540 psig.

Fuel Tank. The fuel supply is contained in a single, titanium alloy, hemispherical-domed, cylindrical tank for each system that is similar in material, construction, and operation to that of the oxidizer tank.

2.5.8.2.2 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 or 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, allowing the propellants to flow through 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.

2.5.8.2.3 Propellant Isolation Shutoff Valves.

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

The isolation valves in the fuel and oxidizer lines are both controlled by a single switch on panel 15. The valves are two-solenoid valves and are magnetically latched open and spring-loaded closed. The valves are normally open in respect to fluid flow. The C/M propellant switches A and B on panel 15 will be placed to ON after T + 61 seconds and will remain in that position until orbit insertion to ensure that the propellant isolation valves remain open when systems A and B are pressurized upon abort initiation. The switches will also be placed to ON prior to C/M-S/M separation and remain in that position until completion of propellant jettison to again ensure that the valves remain in the open position. The switches are placed to center-neutral position after tower jettison until prior to C/M-S/M separation, removing electrical power from the valves.

Each valve contains a position switch which is in parallel to one position indicator below the switch on panel 15 that controls both valves. When the position switch in each valve is open, the indicator on panel 15 is grey (same color as the panel), indicating to the crew the valves are in the normal position. When the position switch in each valve or one valve is closed, the indicator on panel 15 is diagonal lines, indicating to the crew the valve or valves are closed. The valves are closed in the event of a failure downstream of the valves, line rupture, or runaway thruster, etc. The valve will operate at 0 to 360 psig at both the inlet and outlet ports.

The proof pressure is 540 psig and the burst pressure is 720 psig. The solenoid is a 28-vdc type with a pull-in voltage of not more than 15 volts dc, and the current not to exceed 2 amperes at 30 volts dc. The valve assembly response is 200 milliseconds maximum for one-cycle operation (open-to-closed or closed-to-open).

2.5.8.2.4 Distribution Plumbing.

Brazed joint tubing is used to distribute pressurized helium gas to the propellant positive expulsion tanks in system A and system B. The distribution lines contain 11 explosive-operated (squib) valves which permit changing the helium distribution configuration to accomplish various functions within the C/M RCS. Each squib valve is actuated by an explosive charge detonated by an electrical hotwire igniter. After ignition of the explosive device, the valve remains open permanently. Two squib valves are utilized in each system to isolate the high-pressure helium gas supply to the storage tanks until RCS pressurization is commanded. Two squib valves are utilized to interconnect system A and system B regulated helium supply, which ensures pressurization of both systems during dump-burn and helium purge operations. Two squib valves in each system permit helium gas to bypass the propellant tanks, allowing helium purging of the propellant subsystem. One squib valve is installed in system B regulated helium line to permit helium depressurization in the event of a low-altitude abort (pad to T + 61 second abort).

2.5.8.3 Engine Assembly.

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

Each engine consists of a fuel and oxidizer control valve, which controls the flow of propellants by responding to electrical commands (automatic) generated by the guidance and navigation subsystem and/or stabilization control subsystem or by the crew (manually) and an injector head assembly which directs the flow of each propellant from the propellant control valves to the combustion chamber and the combustion chamber in which the propellants are burned to produce thrust. Estimated engine thrust rise and decay is shown in figure 2.5-9.

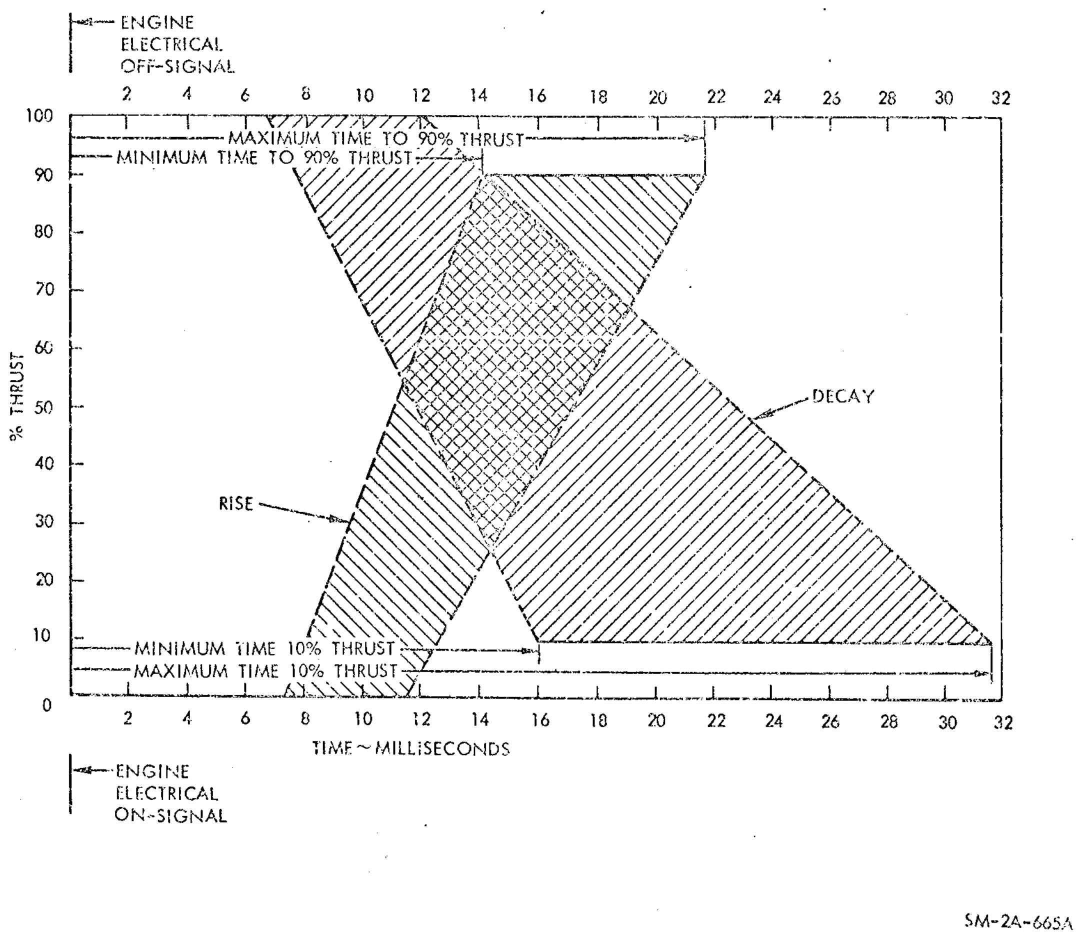


Figure 2.5-9. C/M RCS Engine Thrust Rise and Decay Time (Typical)

2.5.8.3.1 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 jet selection logic. The manual coils are used when the thrust command originates at the rotation control (direct mode).

The solenoid 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 S/M RCS engines.

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

Engine injector valve opening time of 5±2 milliseconds and closing of 6±2 milliseconds for the automatic coils and opening time of 7 milliseconds and closing of 16 to 18 milliseconds for the direct manual coils. The actuation time shall not vary by more than +50 or -25 percent operating time between +40 to +200°F.

2.5.8.3.2 Injector.

The injector, contains a fuel and oxidizer passage 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. There are 16 fuel and 16 oxidizer passages in the injector face.

2.5.8.3.3 Thrust Chamber Assembly.

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

2.5.8.3.4 Nozzle Extension.

The C/M RCS engines are mounted within the structure of the C/M. The nozzle extensions are required to transmit the gases from the engine out through the structure of the C/M. The nozzle extensions are fabricated of ablative material.

2.5.8.3.5 Engine Solenoid Injector Valve Temperature Control System.

A temperature control system of the C/M RCS engine valves is employed by energizing the manual direct coils on each engine.

Temperature transducers are mounted on the engine injector valve oxidizer solenoids. A temperature transducer is installed on the subsystem. A counterclockwise roll oxidizer valve, negative yaw oxidizer valve, negative pitch oxidizer valve and on subsystem B positive yaw oxidizer valve, negative pitch oxidizer valve, and clockwise roll oxidizer valve. These engine injector solenoid oxidizer valves were selected as the coldest engines.

The temperature transducers have a range from -50°F to +250°F. The temperature transducers from the three subsystem A and B engine oxidizer injector valves provide inputs the the TEST SELECT switch on panel 200, which is located in the lower equipment bay of the command module. With the FUNCTION SELECT switch on panel 200 placed to position B and the TEST SELECT rotary switch on panel 200 placed to positions 1, 2, 3, 4, 11, and 12, respectively, the specific engine oxidizer valve temperature is monitored as a d-c voltage on the 0- to 5-vdc voltmeter. Zero vdc is equivalent to -50°F and 5 vdc is equivalent to +250°F.

A C/M RCS HEATER switch is located on panel 200. The C/M RCS HEATER switch is placed to the ON position when any one of the instrumented engines are below +64°F, approximately 1.80 vdc. This must be accomplished within 26 minutes prior to C/M-S/M separation, providing the C/M propellant jettison LOGIC switch is ON. The fuel and oxidizer injector valve manual coils of all C/M RCS engines are energized open (prior to pressurization of C/M RCS subsystems A and B). A 13-minute heatup time maximum or 100°F, which is monitored on the d-c voltmeter on panel 200 as 2.50 vdc, assures engine injector valve temperature is at +20°F minimum. If +100°F, 2.50 vdc on the d-c voltmeter is reached from the coldest instrumented engine before 13 minutes, the C/M RCS HEATER switch is placed to OFF, which de-energizes the engine injector valves and the injector valves spring-load closed. If a time of 13 minutes is reached before +100°F, 2.50 vdc on the d-c voltmeter, the C/M RCS HEATER switch is placed to OFF. This will prevent the oxidizer from freezing at the engine injector valves upon pressurization of subsystems A and B.

The C/M RCS HEATER switch must be placed to OFF prior to C/M RCS pressurization. The operation of the C/M RCS HEATER switch in conjunction with the d-c voltmeter and/or heating time ensures all other engine valves reach the acceptable temperature levels. The +100°F, 2.50 vdc, or thirteen-minute time limit assures that the warmest engine valve will be less than +200°F.

2.5.8.3.6 Engine Thrust ON-OFF Logic.

All thrust commands for C/M attitude pass through the stabilization and control subsystem and the jet selection logic. These commands may originate at the following:

a. The rotation controls
b. The stabilization and control subsystem
c. The guidance and navigation subsystem.

In the event the SCS and/or jet selection logic is unable to provide commands to the automatic coils of the C/M RCS engines, placing the DIRECT RCS switch on panel 8 to the ON position provides power to the rotation control. When the rotation control is positioned fully to its stops in any direction, the rotation control energizes the required manual coils for the desired maneuver.

When the CM SM SEP switches on panel 15 are placed to CM SM SEP position, the switches automatically energize relays in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) (figure 2.5-10) (providing the CM PROP JETT LOGIC switch on panel 8 is ON) that transfers the SCS and direct manual inputs from the S/M RCS engine th the C/M RCS engines automatically. (These same functions occur on any LES ABORT.)

The transfer motors in the RCS transfer panels (C19A4) and in the RCS control boxes (C19A1) are redundant to each other in that they ensure the SCS and direct manual inputs are transferred from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS control boxes (C19A1) are automatically activated by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON); in addition, they may also be activated by the manual backup of the RCS TRANSFER switch on panel 16. The transfer motors in the RCS transfer panels (C19A4) are activated automatically only by the CM SM SEP switches (providing the CM PROP JETT LOGIC switch is ON).

As an example, if the RCS transfer motor in C19A1 failed to transfer automatically at CM SM SEP, the RCS transfer motor in C19A4 would still automatically transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines (providing the CM PROP JETT LOGIC switch is ON). In addition, the RCS TRANSFER switch on panel 16 provides a manual backup to the C19A1 RCS transfer motors only.

Another example, the C/M RCS subsystems could be checked out prior to CM SM SEP by placing the RCS TRANSFER switch on panel 16 to CM position, and only the RCS transfer motors (C19A1) in the RCS control boxes would transfer the SCS and direct manual inputs from the S/M RCS engines to the C/M RCS engines. The transfer motors in the RCS transfer panels (C19A4) would not transfer until C/M S/M SEP (providing the C/M PROP JETT LOGIC switch is ON) and then start the SM jettison controllers.

2.5.8.4 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 61 seconds of flight. The second sequence is employed for all other conditions, whether it be a normal or an abort mode of operation. The sequence of events before and during a normal re-entry is as follows:

a. The crew will place the C/M S/M SEPARATION switches to the C/M S/M SEPARATION position on panel 15 or place the C/M RCS PRESS switch on panel 16 to the ON position, prior to initiating C/M S/M separation. The C/M RCS PRESS switch or the C/M S/M SEP switches initiates the helium isolation squib valves in C/M RCS subsystems A and B, thus pressurizing both subsystems (figures 2.5-8 and 2.5-10). The C/M RCS PRESS switch provides a backup to the C/M S/M SEP switches and the RCS LOGIC switch on panel 8 must be ON, prior to initiating C/M-S/M separation to provide an automatic RCS transfer.

b. The C/M continues to descend after re-entry into the earth atmosphere. At 24,000 feet, barometric switch is activated which unlatches the RCS latching relay, inhibiting any commands from the SCS to the jet selection logic (figure 2.5-3) (manual backup of RCS CMD switch panel 16).

c. At main parachute line stretch, the RCS propellant jettison DUMP switch on panel 8 is placed to the DUMP position as a normal manual function by the crew, initiating the following functions, simultaneously. The RCS LOGIC switch on panel 18 must be ON prior to placing DUMP switch to DUMP position.

1. Initiates the two helium interconnect squib valves
2. Initiates the fuel interconnect squib valve
3. Initiates the oxidizer interconnect squib valve
4. The fuel and oxidizer injector valve manual coils are energized on all of the C/M RCS engines, excluding the + pitch engines. The + pitch engines are not energized due to their location being adjacent to the steam vent. The propellants are jettisoned by burning the propellants remaining in 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 (manual coils energized), a nominal burn time would be 155 seconds.

d. Upon completion of propellant burn, the C/M propellant jettison PURGE switch on panel 8 is placed to the PURGE position as a normal manual function by the crew. When the PURGE switch is on, the switch initiates the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, thus purging the manifolds through 10 of the 12 engines. Purging requires approximately 15 seconds or until helium depletion.

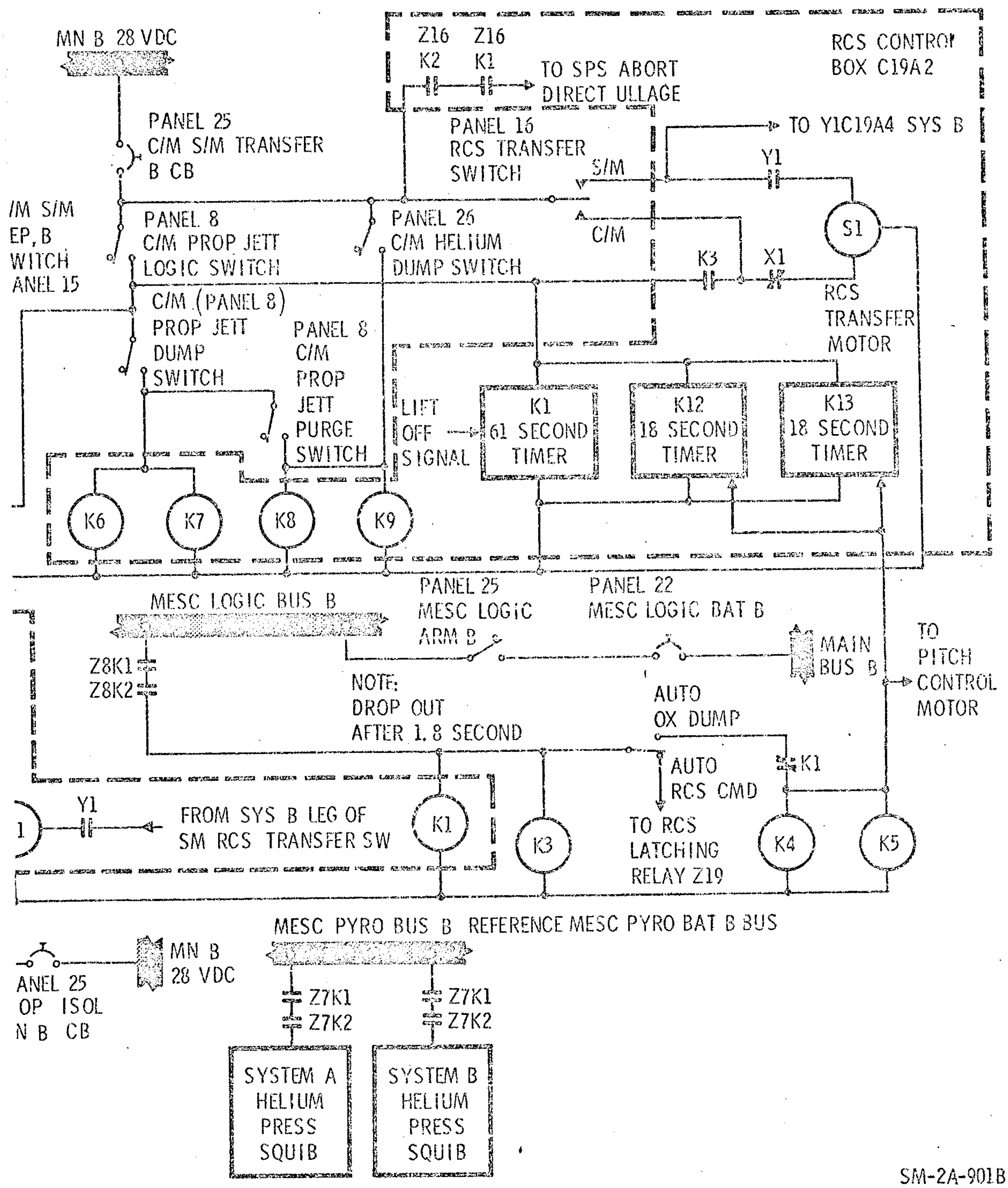
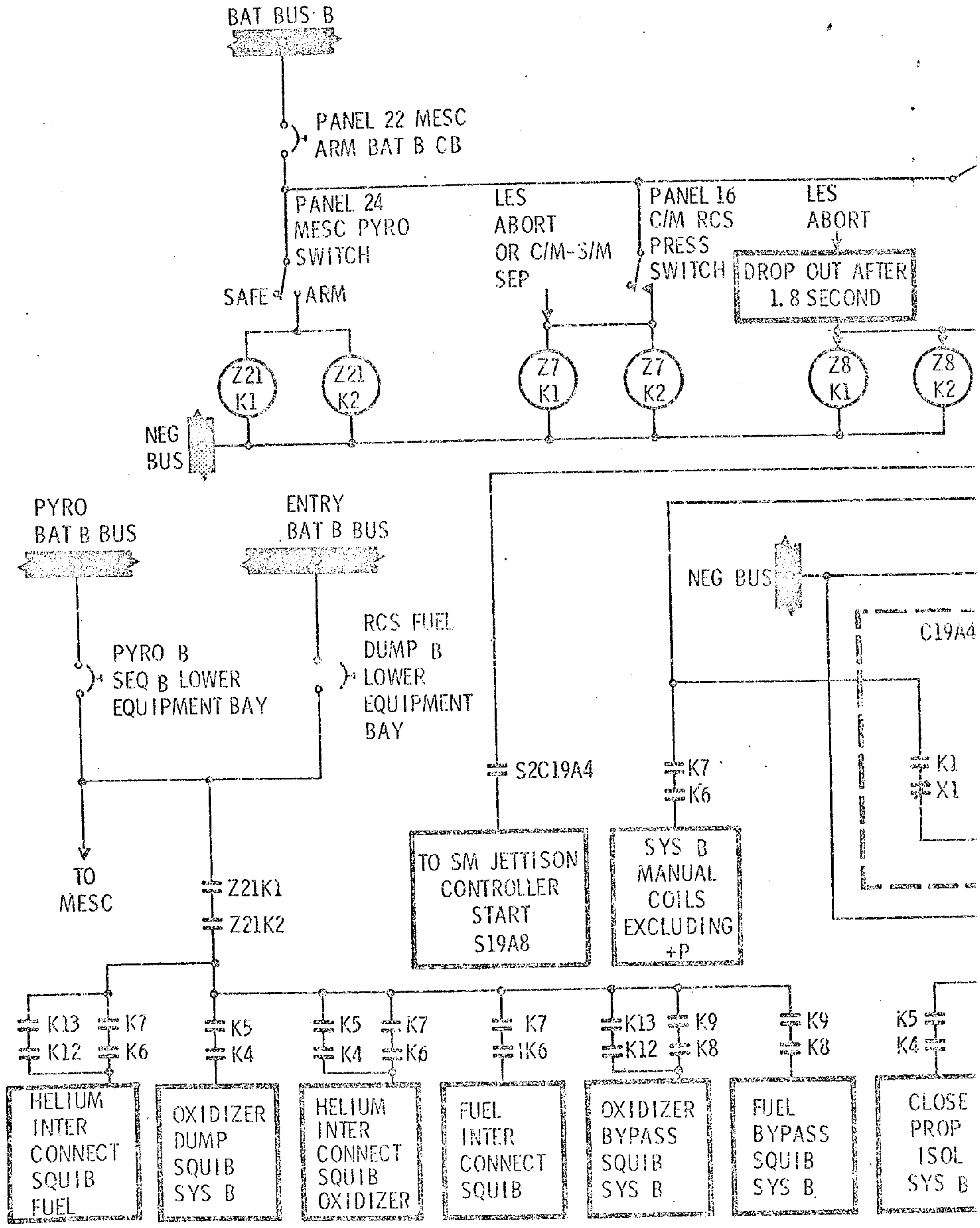
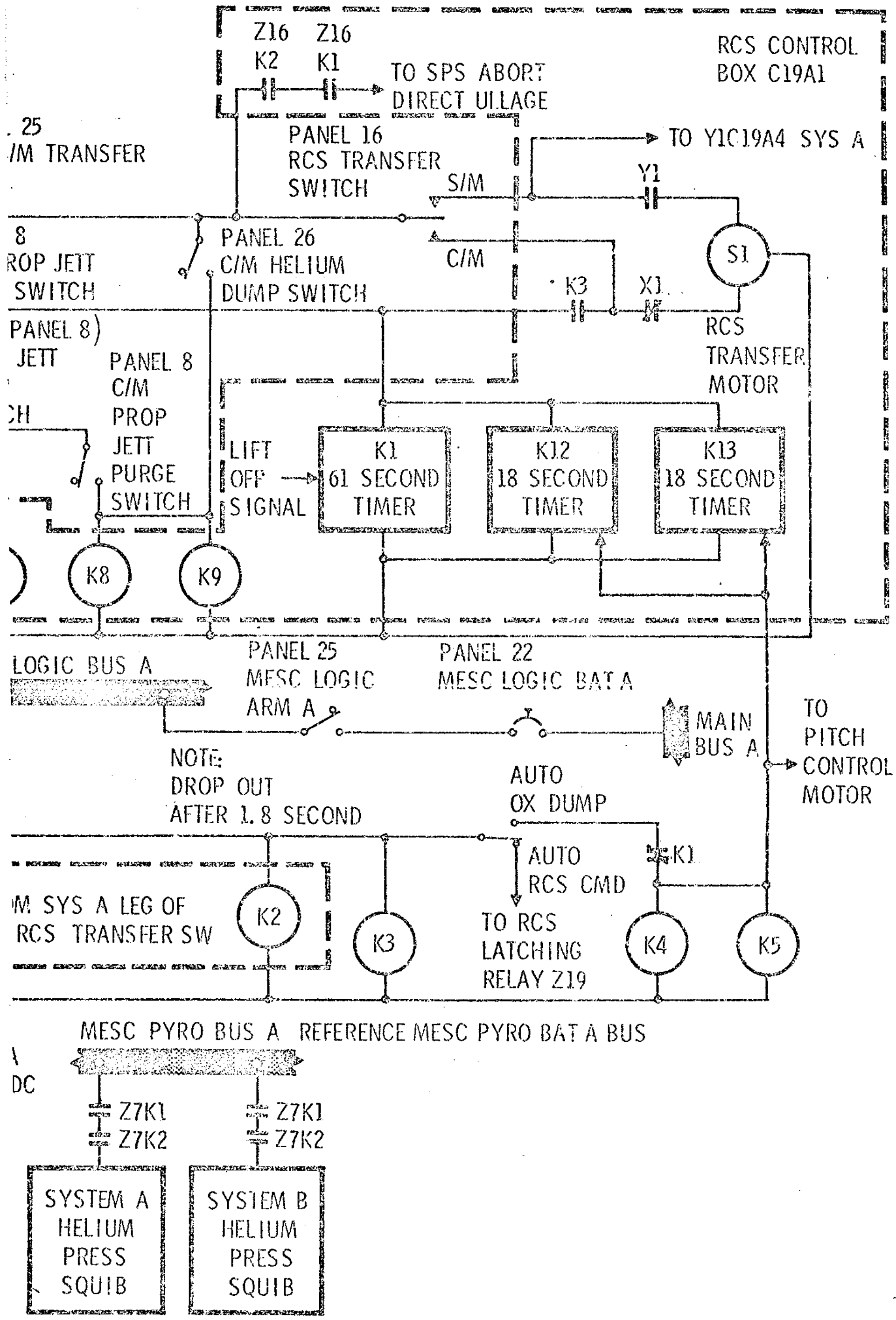


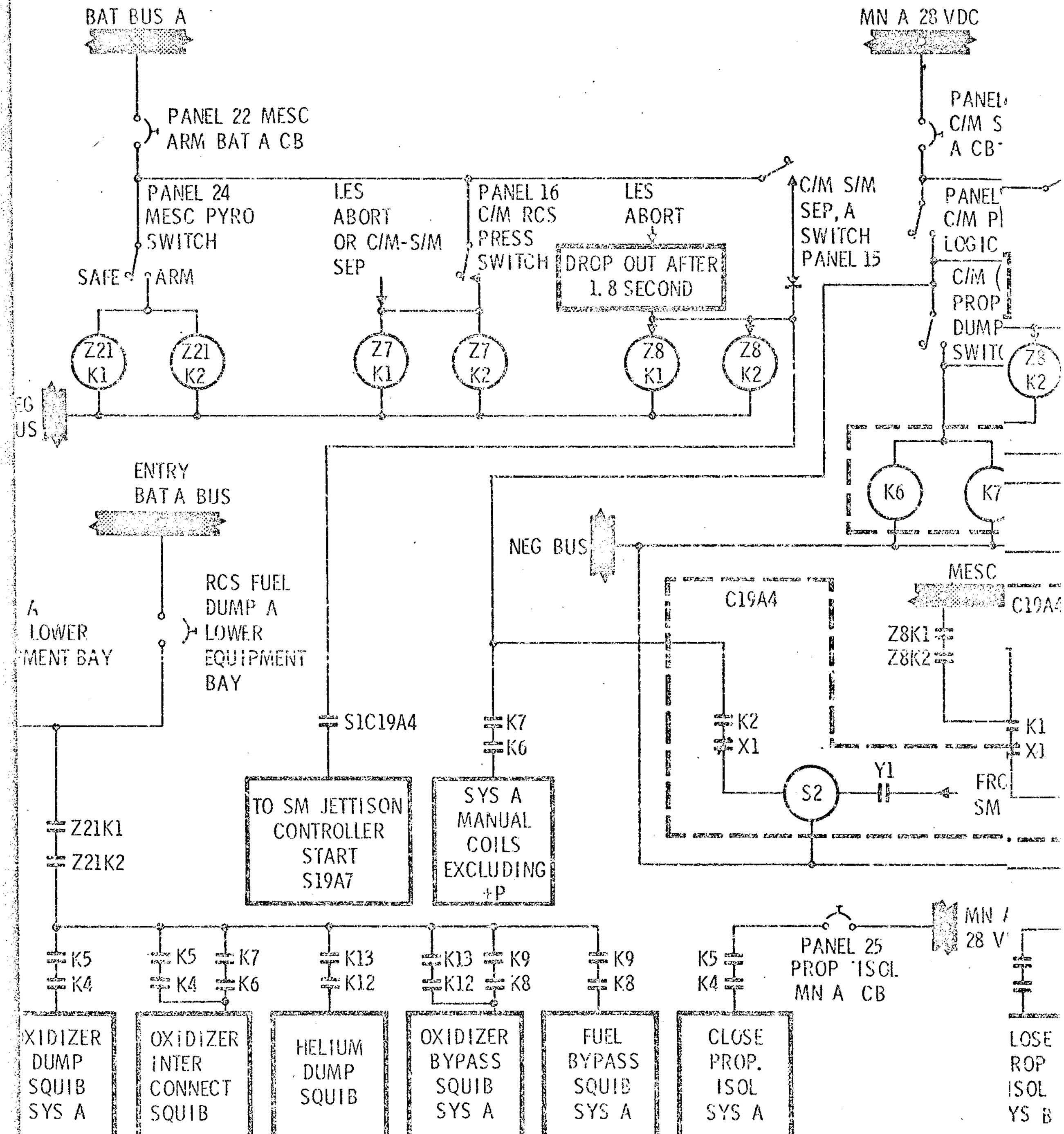
Figure 2.5-10. C/M RCS Squib Valve Power Control Diagram



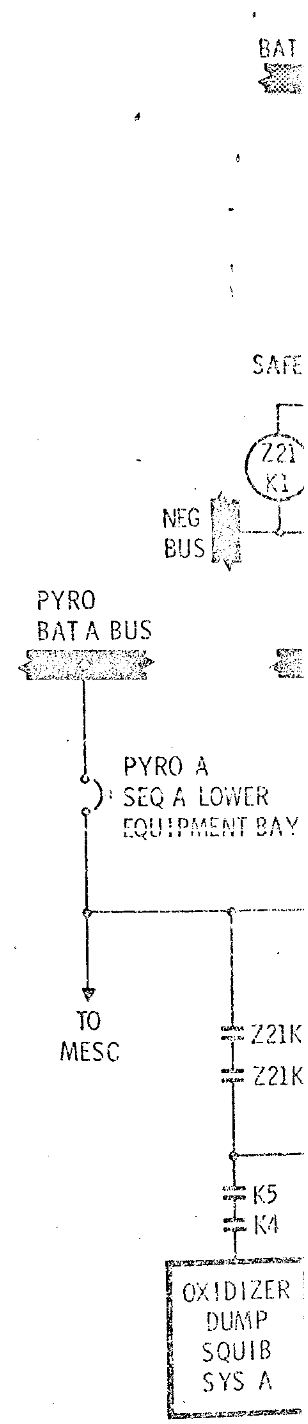
BAT BUS B
PANEL 22 MESC
ARM BAT B CB
PANEL 24
MESC PYRO
SWITCH
SAFE
ARM
LES
ABORT
OR C/M-S/M
SEP
PANEL 16
C/M RCS
PRESS
SWITCH
LES
ABORT
DROP OUT AFTER
1.8 SECOND
Z21 K1
Z21 K2
Z7 K1
Z7 K2
Z8 K1
Z8 K2
NEG BUS
PYRO
BAT B BUS
ENTRY
BAT B BUS
NEG BUS
C19A4
RCS FUEL
DUMP B
LOWER
EQUIPMENT
BAY
PYRO B
SEQ B LOWER
EQUIPMENT BAY
S2C19A4
K7
K6
K1
X1
TO
MESC
Z21K1
Z21K2
TO SM JETTISON
CONTROLLER
START
S19A8
SYS B
MANUAL
COILS
EXCLUDING
+P
K13
K12
K7
K6
K5
K4
K5
K4
K7
K6
K7
K6
K13
K12
K9
K8
K9
K8
K5
K4
HELIUM
INTER
CONNECT
SQUIB
FUEL
OXIDIZER
DUMP
SQUIB
SYS B
HELIUM
INTER
CONNECT
SQUIB
OXIDIZER
FUEL
INTER
CONNECT
SQUIB
OXIDIZER
BYPASS
SQUIB
SYS B
FUEL
BYPASS
SQUIB
SYS B
CLOSE
PROP
ISOL
SYS B



Z16
K2
Z16
K1
TO SPS ABORT
DIRECT ULLAGE
RCS CONTROL
BOX C19A1
. 25
/M TRANSFER
PANEL 16
RCS TRANSFER
SWITCH
TO Y1C19A4 SYS A
S/M
Y1
C/M
S1
8
ROP JETT
SWITCH
PANEL 26
C/M HELIUM
DUMP SWITCH
K3
X1
RCS
TRANSFER
MOTOR
PANEL 8)
JETT
PANEL 8
C/M
PROP
JETT
PURGE
SWITCH
LIFT
OFF
SIGNAL
K1
61 SECOND
TIMER
K12
18 SECOND
TIMER
K13
18 SECOND
TIMER
K8
K9
LOGIC BUS A
PANEL 25
MESC LOGIC
ARM A
PANEL 22
MESC LOGIC BAT A
MAIN
BUS A
TO
PITCH
CONTROL
MOTOR
NOTE:
DROP OUT
AFTER 1.8 SECOND
AUTO
OX DUMP
AUTO
RCS CMD
K1
M SYS A LEG OF
RCS TRANSFER SW
K2
K3
TO RCS
LATCHING
RELAY Z19
K4
K5
MESC PYRO BUS A
REFERENCE MESC PYRO BAT A BUS
DC
Z7K1
Z7K2
Z7K1
Z7K2
SYSTEM A
HELIUM
PRESS
SQUIB
SYSTEM B
HELIUM
PRESS
SQUIB



BAT BUS A
PANEL 22 MESC
ARM BAT A CB
PANEL 24
MESC PYRO
SWITCH
SAFE
ARM
LES
ABORT
OR C/M-S/M
SEP
PANEL 16
C/M RCS
PRESS
SWITCH
LES
ABORT
DROP OUT AFTER
1.8 SECOND
C/M S/M
SEP, A
SWITCH
PANEL 15
MN A 28 VDC
Z21 K1
Z21 K2
Z7 K1
Z7 K2
Z8 K1
Z8 K2
ENTRY
BAT A BUS
RCS FUEL
DUMP A
LOWER
EQUIPMENT
BAY
NEG BUS
K6
K7
C19A4
MESC
Z8K1
Z8K2
S1C19A4
K7
K6
K2
X1
K1
S2
Y1
Z21K1
Z21K2
TO SM JETTISON
CONTROLLER
START
S19A7
SYS A
MANUAL
COILS
EXCLUDING
+P
K5
K4
K13
K12
K9
K8
PANEL 25
PROP ISOL
MN A CB
OXIDIZER
INTER
CONNECT
SQUIB
HELIUM
DUMP
SQUIB
OXIDIZER
BYPASS
SQUIB
SYS A
FUEL
BYPASS
SQUIB
SYS A
CLOSE
PROP.
ISOL
SYS A


BAT
SAFE
Z21 K1
NEG BUS
PYRO BAT A BUS
PYRO A SEQ A LOWER EQUIPMENT BAY
TO MESC
Z21K
Z21K
K5
K4
OXIDIZER DUMP SQUIB SYS A

e. In the event of the C/M propellant jettison LOGIC switch and/or DUMP switch failure, the remaining propellants may be burned by placing the DIRECT RCS switch on panel 8 to ON and positioning the two rotation controllers to CCW, CW, -Y, +Y and -P (excluding +P) position, energizing the manual fuel and oxidizer injector valve solenoid coils of 10 of the 12 C/M RCS engines burned. At the completion of propellant burn, the C/M RCS HELIUM DUMP switch on panel 26 would be placed ON initiating the four bypass squib valves, allowing the regulation helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines providing the two rotation controllers are positioned to CCW, CW, -Y, +Y and -P (excluding +P).

f. In the event the C/M propellant jettison LOGIC switch and DUMP switch on panel 8 function correctly and the PURGE switch fails, the C/M HELIUM DUMP switch on panel 26 would be placed to ON; thus initiating the four helium bypass squib valves, allowing the regulated helium pressure to bypass around each fuel and oxidizer tank, and purging the manifolds through 10 of the 12 engines.

g. Prior to water impact the LOGIC switch on panel 8 may be placed to the OFF position, which would de-energize the manual coils of the engine injector valves allowing the engine injector valves to spring-load closed, preventing sea water from entering the manifolds through the engine. The DUMP switch placed to the OFF position will accomplish the same function.

The sequence of events involving an abort from the pad up to 61 seconds is as follows:

a. The OXIDIZER DUMP switch on panel 16 is placed in the AUTO OX DUMP position, and the RCS LOGIC switch on panel 8 is placed in the ON position at some time 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 sequence events controller subsystem or by manually rotating the translation control counterclockwise.

1. When the abort signal is received, the two squib-operated helium isolation valves in each system are initiated open, pressurizing subsystems A and B. Manual backup of the C/M PRESS switch, panel 16.
2. The squib-operated helium interconnect valve for the oxidizer tanks is initiated open. If only one of the two squib helium isolation valves was initiated open, both systems are pressurized as a result of the helium interconnect squib valve interconnect.
3. The solenoid-operated fuel and oxidizer isolation shutoff valves are closed to prevent fuel and oxidizer from flowing to the thrust chamber assemblies.
4. The squib-operated oxidizer interconnect valve is initiated open. If only one of the two oxidizer overboard dump squib valves was initiated open, the oxidizer manifolds of each system are common as a result of the oxidizer interconnect squib valve.

5. The squib-operated oxidizer overboard dump valves route the oxidizer to a blow-out plug in the aft heat shield of the C/M which shears a pin due to the pressure buildup and blows the plug out, dumping the oxidizer overboard. The entire oxidizer supply is dumped in approximately 13 to 15 seconds.

6. The RCS latching relay will not energize in the event of an abort from 0 to +61 seconds due to the position of the AUTO OX DUMP switch (figures 2.5-3 and 2.5-10). Thus, no commands are allowed into the jet selection logic from the SCS.

7. The C/M-S/M RCS transfer motor-driven switches are automatically driven upon the receipt of the abort signal, allowing electrical signals to be supplied to the C/M RCS engine injector valves. Manual backup of RCS transfer switch, panel 16.

c. Eighteen seconds after the abort signal is initiated, the following events automatically occur simultaneously:

1. The helium interconnect squib valve between the fuel tanks is initiated open.

2. The helium overboard dump squib valve is initiated open, dumping the helium pressure overboard into the aft equipment compartment, releasing the helium pressure from both fuel tanks.

3. The bypass squib valve to the subsystems A and B oxidizer tank is initiated open, purging both oxidizer systems out through the overboard dump in the aft heatshield.

4. Fuel remains onboard at impact with no pressure on the fuel tanks.

The sequence of events of an abort, initiated after 61 seconds up to launch escape tower jettison, are as follows:

a. At 61 seconds after lift-off, the crew as a normal manual function will place the AUTO OX DUMP switch on panel 16 to the AUTO RCS CMD position.

b. The RCS LOGIC switch was placed to the ON position prior to T+0.

1. Initiate both helium isolation squib valves in C/M RCS, subsystems A and B. Manual backup of C/M RCS PRESS switch on panel 16; thus, pressurizing C/M RCS subsystems A and B.

2. Drives the C/M S/M RCS transfer motors to the C/M RCS position. Manual backup of RCS TRANSFER switch on panel 16 for C19A1 RCS transfer motors only.

3. RCS latching relay energized one second after receipt of the abort signal.

d. At main parachute line stretch, as a normal manual function, the RCS propellant and jettison DUMP switch on panel 8 is placed to the DUMP position initiating functions the same as a normal entry.

2.5.9 C/M RCS PERFORMANCE AND DESIGN DATA.

2.5.9.1 Design Data.

The following list contains data of 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 lbs, inside diameter 8.84 in., wall thickness 0.105 in. and internal volume of 365±5 cubic in. at 4150±50 psig.
HELIUM ISOLATION SQUIB VALVE FILTER	Remove 98 percent of all particles whose two smallest dimensions are greater than 40 microns.
	Remove 100 percent of all particles whose two smallest dimensions are greater than 74 microns.
REGULATOR UNITS (4)	Primary - Initial of 291±6 psig and stabilize within 2 seconds to 291±4 psig. Lockup pressure minimum of 284 psig and not exceed 302 psig.
	Secondary - Lockup 287 to 308 psig and stabilize at 294.5±7.5 psig within 2 seconds.
HELIUM RELIEF VALVES (4)	Diaphragm rupture at 340±8 psi
	Filter - 10 microns nominal, 25 microns absolute
	Relief valves relieves at 346±14 psig
	Relief valve reseats at no less than 327 psig
	Flow capacity 0.3 lb/min 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 and relief valve assemblies combined. The bleed device shall reopen when decreasing pressure has reached no less than 20 psig.

PRESSURE TRANSDUCERS FUEL AND OXIDIZER	Illuminates caution and warning light on panel 10 (C/M RCS A or B) After helium isolation, underpressure 265 psia Squib valve actuation, overpressure 325 psia
FUEL TANKS (2)	Combined propellant and ullage volume of 45.2 lbs, initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 105°F. Length 17.329 (+0.040, -0.000) in., outside diameter maximum 12.62 in., wall thickness 0.022 in. to 0.027 in.
OXIDIZER TANK (2)	Combined propellant and ullage volume of 89.2 pounds initially at 65°F at 30±2 psig, resulting in a tank pressure of no more than 205 psia when heated to 85°F. Length 19.907 (+0.040, -0.000) in., maximum outside diameter 12.62 in., wall thickness 0.022 to 0.027 in.
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 lbs
	Length, 11.65 in. maximum
	Nozzle exit diameter, 2.13 inches
	Nozzle extensions, ablative refrasil
OXIDIZER DUMP BLOWOUT PLUG	Pin shears at 100 psig

2.5.9.2 Performance Data.

Refer to Mission Modular Data Book, SID 66-1177.

2.5.9.3 Power Consumption Data.

Refer to paragraph 2.5.4.3.

2.5.10 C/M RCS OPERATIONAL LIMITATIONS AND RESTRICTIONS.

A propellant isolation valve switch must be placed to ON momentarily prior to lift-off and returned to neutral. At T+61 seconds after lift-off the switches must be placed to ON until orbit insertion to ensure that the valves will remain open if an LES abort is initiated; then at orbit insertion, the switches may be placed to neutral. The switches must be placed to ON prior to C/M RCS pressurization to ensure valves remain open throughout entry.

2.5.10.1 C/M RCS Electrical Power Distribution.

See figure 2.5-11 for electrical power distribution.

2.5.11 C/M RCS TELEMETRY MEASUREMENTS.

The following is a complete list of the C/M RCS telemetry data that is monitored by the flight controllers and ground support personnel.

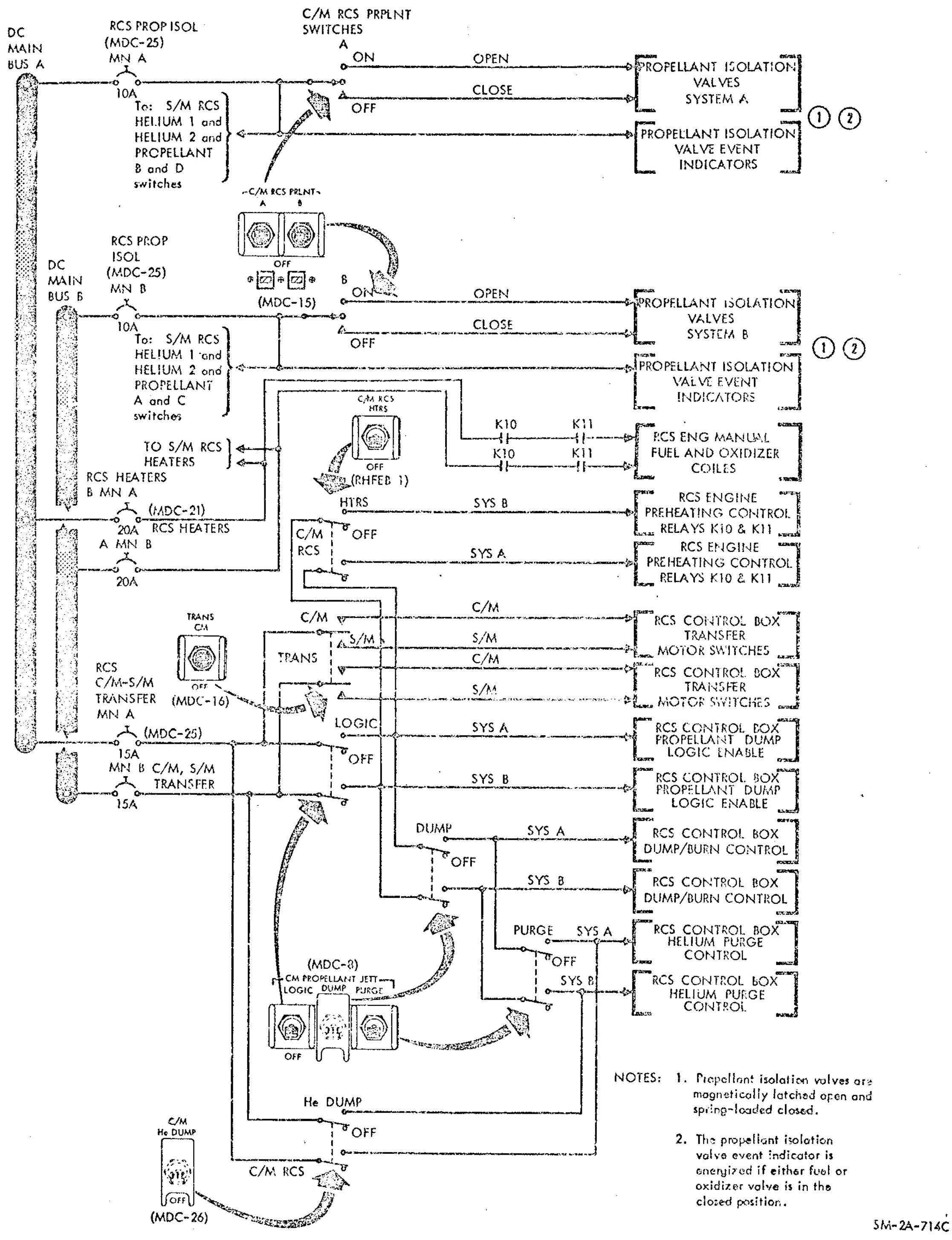


Figure 2.5-11. C/M RCS Electrical Power Distribution Diagram

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel	Bit Rate*	*	Operating Range
Panel 12	2.5-7	Helium Tank Supply Pressure A	CR0001P	+0 +5K psia	C28AR31	10A81	H2	PCM	4150±50 psia and decrease during mission.
Panel 12	2.5-7	Helium Tank Supply Pressure B	CR0002P	+0 +5K psia	C28AR32	10A83	H2	PCM	
Panel 12	2.5-7	Helium Tank Supply Temperature A	CR0003T	+0 +300°F	C28AR33	10A52	H1	PCM	70±10°F on launch pad variable during mission.
Panel 12	2.5-7	Helium Tank Supply Temperature B	CR0004T	+0 +300°F	C28AR34	10A55	H1	PCM	
Panels 10 and 12	2.5-7	Fuel Tank A Pressure	CR0005P	+0 +400 psia	C28AR35	11A107	H2	PCM	After pressurization 287 to 308 psia until propellant purge
Panels 10 and 12	2.5-7	Fuel Tank B Pressure	CR0006P	+0 +400 psia	C28AR36	11A114	H2	PCM	
Panels 10 and 12	2.5-7	Oxidizer Tank A Pressure	CR0011P	+0 +400 psia	C28AR38	11A79	H2	PCM	
Panels 10 and 12	2.5-7	Oxidizer Tank B Pressure	CR0012P	+0 +400 psia	C28AR39	11A81	H2	PCM	
	2.5-7	Fuel Line Pressure A	CR0623P	+0 +400 psia		F-1		FQ	Flight recorder.
	2.5-7	Fuel Line Pressure B	CR0624P	+0 +400 psia		F-2		FQ	
	2.5-7	Oxidizer Line Pressure A	CR0625P	+0 +400 psia		F-3		FQ	
	2.5-7	Oxidizer Line Pressure B	CR0626P	+0 +400 psia		F-4		FQ	
Panel 97	2.5-7	Temperature Oxidizer Valve CCW R Engine A	CR2201T	-50 +250°F	C28AR295	51A17	H1	PCM	Variable during mission, prior to separation turn heaters on if below +64°F, turn off in 13 minutes time or 100°F, whichever is reached first.
Panel 97	2.5-7	Temperature Oxidizer Valve -Y Engine A	CR2202T	-50 +250°F	C28AR296	11A78	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine A	CR2205T	-50 +250°F	C28AR299	51A18	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve +Y Engine B	CR2203T	-50 +250°F	C28AR297	10A35	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve -P Engine B	CR2204T	-50 +250°F	C28AR298	10A38	H1	PCM	
Panel 97	2.5-7	Temperature Oxidizer Valve CWR Engine B	CR2206T	-50 +250°F	C28AR300	10A34	H1	PCM	
	2.5-7	CCW Roll Engine Chamber Pressure A	CR0514P	+0 +250 psia		F-13		FQ	Flight recorder.
	2.5-7	CCW Roll Engine Chamber Pressure B	CR0520P	+0 +250 psia		F-14		FQ	
	2.5-7	CCW Roll Engine Wall Temperature A	CR4361T	+0 +1000°F		51A19	H1	FQ	Variable

Crew Display	Figure	Measurement	Measurement Number	Range	Signal Conditioner	Channel Code*	Bit Rate*	*	Operating Range
	2.5-7	CCW Roll Engine Wall Temperature B	CR4582T	+0 +1000°F		51A20	H1	FQ	Variable
	2.5-9	C/M-S/M SEP Relay Close A (Z9 to Z7)	CD0023X	OFF ON event		11E12-03	E2	PCME	Event
	2.5-9	C/M-S/M SEP Relay Close B (Z9 to Z7)	CD0024X	OFF ON event		11E12-04	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal A (Z9 to Z7)	CD0002X	OFF ON event		11E12-01	E2	PCME	Event
	2.5-9	LES Abort Initiate Signal B (Z9 to Z7)	CD0062X	OFF ON event		11E12-07	E2	PCME	Event
	2.5-9	RCS Actuate Signal A (Z19)	CD0170X	OFF ON event		11E13-06	E2	PCME	Event
	2.5-9	RCS Activate Signal B (Z19)	CD0171X	OFF ON event		11E13-07	E2	PCME	Event
	2.5-9	C/M Pressurize Signal A (Z9 to Z7)	CD0173X	OFF ON event		11E13-08	E2	PCME	Event
	2.5-9	C/M Pressurize Signal B (Z9 to Z7)	CD0174X	OFF ON event		11E14-01	E2	PCME	Event
	2.5-9	Barometric Switch Lock In Close Relay A	CE0007X	CLOSE OPEN event		11E14-08	E2	PCME	Event
	2.5-9	Barometric Switch Relay Lock In Close Relay B	CE0008X	CLOSE OPEN event		11E15-01	E2	PCME	Event
	2.5-9	Lift-Off Signal A	BS0060X			11E25-03	E2	PCME	Event
	2.5-9	Lift-Off Signal B	BS0061X			11E25-04	E2	PCME	Event

*Analog measurements digitally coded into 8 bit words.
Analog measurements -0 (+0.15 -0) vdc to 5 (+0, -0.15) vdc
FQ - Flight qualification measurements
H1 - High bit rate
H2 - High and low bit rate
E2 - High and low bit rate

Channel Example: 10A81

Significant number - 1
How many zeros after significant number is amount of samples per second } 0
} 1 sample per second

SECTION 2

SUBSECTION 2.6

ELECTRICAL POWER SYSTEM (EPS)

2.6.1 INTRODUCTION.

The electrical power system (figure 2.6-1) supplies all electrical power required by the spacecraft to complete its scheduled mission. D-C electrical power is provided by three fuel cell power plants, two S/M jettison controller batteries located in the service module, and five batteries (2 pyro and 3 entry) located in the command module. A-C electrical power is provided by one, or two, of the three inverters located in the lower equipment bay of the command module. Controls and displays for the EPS are positioned in the command module near the astronaut responsible for controlling and monitoring the system. The EPS can be divided into four subsystems as follows:

- Energy storage: cryogenic storage; pyrotechnic, entry, and S/M jettison controller batteries
- Power generation: fuel cell power plants
- Power conversion: solid state inverters, battery charger
- Power distribution: d-c power distribution, a-c power distribution, sensing circuits, controls and displays.

2.6.2 FUNCTIONAL DESCRIPTION.

2.6.2.1 Energy Stowage.

The primary source of energy for the EPS is provided by the cryogenic storage system. There are two hydrogen (fuel) and two oxygen (oxidizer) cryogenic storage tanks. Each tank has its associated controls, heaters, and fans designed to give, in an automatic mode, a single-phase reactant to its load throughout the tank-density range, when operating at normal pressures.

A secondary source of energy storage is provided by batteries. The batteries supply sequencer logic and pyro power at all times, supplemental d-c power for high-peak loads, and all electrical power required during the entry and postlanding phases after CSM separation.

2.6.2.2 Power Generation.

Three Bacon-type fuel cell power plants in the service module generate the d-c power required for spacecraft systems. The fuel cell power plants are activated prior to launch and operate continuously throughout the mission until CSM separation. Normally, fuel cell power plant 1 is connected to main d-c bus A, power plant 3 to main d-c bus B, and power plant 2 to both main d-c buses A and B. However, the capability is provided to also connect fuel cell power plant 1 to main d-c bus B and fuel cell power plant 3 to main d-c bus A.

Each fuel cell is rated to produce 29±2 volts dc between 563 and 1420 watts of power. Two fuel cell power plants are capable of providing the normal power requirements of all spacecraft systems. If two fuel cell power plants malfunction, some of the electrical components must be shut down to conserve power, and the remaining power plant with battery backup will supply sufficient power to carry the load and insure successful mission termination. One fuel cell with complete battery backup can provide maximum power required by mission burns, if the cryogenics are available and fuel cell temperature is above 425°F.

2.6.2.3 Power Conversion.

Primary d-c power is converted into a-c power by solid-state inverters. The inverters provide 115-volt 400-cps 3-phase a-c power up to 1250 volt-amperes each. The a-c power is connected to the two a-c buses which supply power to a-c loads. During normal operation, one inverter will power both a-c buses while the two remaining inverters act as redundant sources. For peak loads, each a-c bus will be powered by a separate inverter. In case of an a-c or d-c bus failure, the inverters and remaining buses can be isolated. Inverter switching circuits prevent connecting two inverters on one bus, but simultaneous operation of two inverters is possible if each is connected to a separate bus. A phase synchronizing unit provides in-phase power when a separate inverter is powering each bus.

The battery charger is a secondary power conversion unit, which is used to keep entry batteries charged. The charger is a solid-state device converting a-c power from the inverters and using d-c power from the fuel cells to provide charging voltage.

2.6.2.4 Power Distribution.

Distribution of primary d-c power is accomplished by two redundant d-c buses in the command module. Additional buses consist of two separate nonessential buses for servicing nonessential loads, a battery relay bus for power distribution switching, two battery buses, and a flight and postlanding bus to service certain communications and the postlanding circuits. A-C power is distributed by two redundant a-c buses.