2.20 REACTION CONTROL SYSTEM (RCS)

CONTENTS

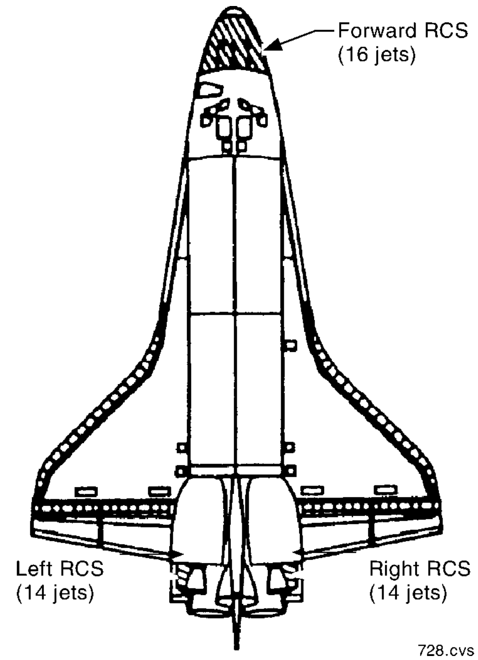
Description

The orbiter's RCS consists of forward and aft control jets, propellant storage tanks, and distribution networks located in three vehicle modules: forward, left, and right. The forward module is contained in the nose area, forward of the cockpit windows. The left and right (aft) modules are collocated with the orbital maneuvering system (OMS) in the left and right OMS/RCS pods near the tail of the vehicle. Each RCS consists of high-pressure gaseous helium storage tanks, pressure regulation and relief systems, a fuel and oxidizer tank, a propellant distribution system, reaction control jets, and electrical jet and pod heaters.

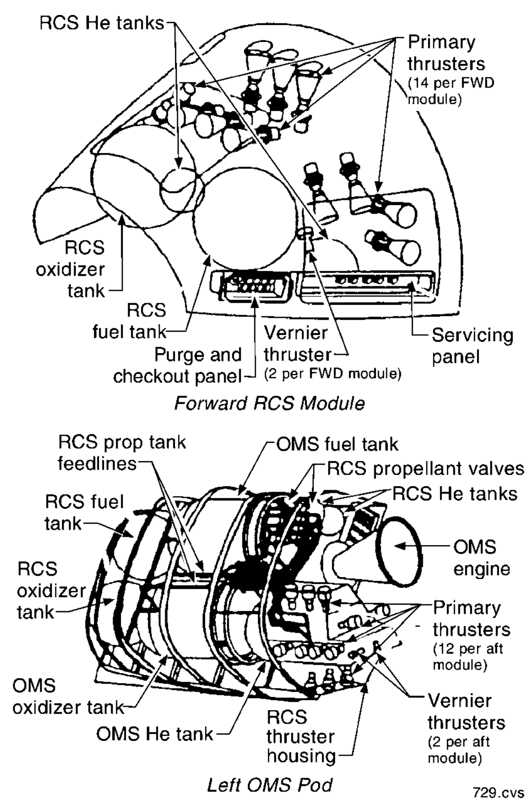
The RCS units provide propulsive forces from a collection of jet thrusters to control the motion of the orbiter. Each jet is permanently fixed to fire in a general direction: up, down, left, right, forward, or aft. The selective firing of individual jets or specific combinations of jets provides thrust for:

- Attitude control
- Rotational maneuvers (pitch, yaw, roll)
- Small velocity changes along the orbiter axes (translational maneuvers)

Each RCS jet is identified by the propellant manifold that supplies the jet and by the direction of the jet plume. The first identifier designates a jet as forward (F), left aft (L), or right aft (R) RCS. The second identifier, number 1 through 5, designates the propellant manifold. The third identifier designates the direction of the jet plume: A (aft), F (forward), L (left), R (right), U (up), D (down). For example, jets F2U, F3U, and F1U are forward RCS jets receiving propellants from forward RCS manifolds 2, 3, and 1, respectively; the jet plume direction is up.



Forward, Left, and Right RCS Modules



Left and Forward RCS Modules

Manual RCS use is accomplished through the rotational and translational hand controllers, and automatic use is handled by the digital autopilot (DAP) and the general purpose computers (GPCs).

Nominal uses of the RCS occur during ascent, orbit, and entry. During ascent, the RCS is used for rotational control during mated coast with the external tank. It is also used to provide –Z translation at external tank separation, using all 10 down (–Z) primary jets. This is the only RCS translational maneuver done automatically. The RCS is also used during ascent to maneuver to OMS burn attitude and to trim residuals post-burn, if required.

During orbit, the RCS provides attitude control, including pointing and attitude hold, and rendezvous maneuvers.

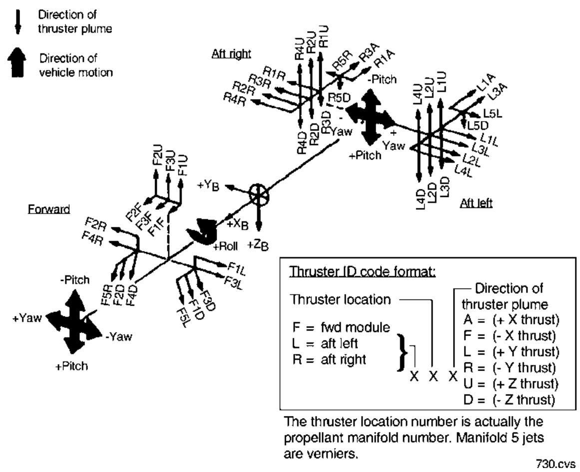
During entry, the RCS provides for center of gravity (c.g.) management through the forward propellant dump. Also during entry, yaw, roll, and pitch control is provided by the aft left/right (Y) and up/down (Z) jets.

The RCS is also used during off-nominal situations. In the case of loss of two SSMEs on ascent, the OMS-to-RCS interconnect is automatically commanded, and the RCS provides single-engine roll control. If the OMS gimballing system is not performing adequately to control vehicle attitude during an OMS burn, RCS jets are used to help maintain attitude. This is also known as "RCS wraparound." The RCS is also used to adjust an orbit if the OMS fails prematurely. During aborts, the RCS may be used to assist with ascent propellant dumps to decrease vehicle weight, improve performance, and control center of gravity.

NOTE

> RCS jets assist in OMS and/or RCS dumps by burning propellant in either propulsive or non-propulsive (null) burns.

There are a total of 44 RCS jets; 38 primary and 6 vernier. The vernier jets are only used on orbit for fine attitude control. The forward RCS has 14 primary and 2 side-firing vernier jets. The aft RCS has 12 primary and 2 vernier jets in each pod for a total of 28. One set of aft vernier jets is side-firing, and the other set is down-firing. The primary RCS jets provide 870 pounds of vacuum thrust each, and the vernier RCS jets provide 24 pounds of vacuum thrust each for precise maneuvering. The vernier jets are used for tight attitude dead bands and fuel conservation.



RCS Jet Identification

NOTE

> The loss of one down-firing vernier jet results in the loss of the entire vernier mode due to the loss of control authority. If one side-firing vernier jet is lost, control can be maintained, except for some RMS-loaded operations.

Two helium tanks supply gaseous helium pressure to the oxidizer and fuel tanks. The oxidizer and fuel are then supplied under pressure to the RCS jets. Nitrogen tetroxide (N_2O_4) is the oxidizer, and monomethyl hydrazine (MMH) is the fuel. The propellants are toxic, liquid at room temperature, and hypergolic (they ignite upon contact with each other). The propellants are supplied to the jets, where they atomize, ignite, and produce a hot gas and thrust.

CAUTION

On-orbit leak of MMH fuel may cause a module fire on entry when MMH mixes with atmospheric oxygen.

The primary jets are operable in a maximum steady-state mode of 1 to 150 seconds, with a maximum single-mission contingency of 800 seconds for the RCS aft (+X) jets and 300 seconds maximum for the RCS forward (–X) jets. The multiple primary jets provide redundancy. The vernier jets are operable in a steady-state mode of 1 to 125 seconds maximum and are used for finite maneuvers and stationkeeping (long-time attitude hold). The vernier jets are not redundant.

The forward RCS module and OMS/RCS pods can be removed to facilitate orbiter turnaround, if required.

Jet System

The jet system combines fuel and oxidizer to produce hypergolic combustion (hot gas thrust). The system's major components are the reaction jet driver, fuel and oxidizer valves, injector head assembly, combustion chamber, nozzle, and electrical junction box.

The reaction jet driver converts GPC fire commands into the required voltage for opening the bipropellant valves, thus initiating the combustion process. The driver also generates chamber pressure discretes and sends them to redundancy management as an indication of actual jet firings.

Each primary and vernier RCS jet has one fuel and one oxidizer solenoid-operated pilot poppet valve that is energized open by an electrical thrust-on command, permitting the propellant hydraulic pressure to open the main valve poppet and allow the respective propellant to flow through the injector into the combustion chamber. When the thrust-on command is terminated, the valves are deenergized and closed by spring and pressure loads.

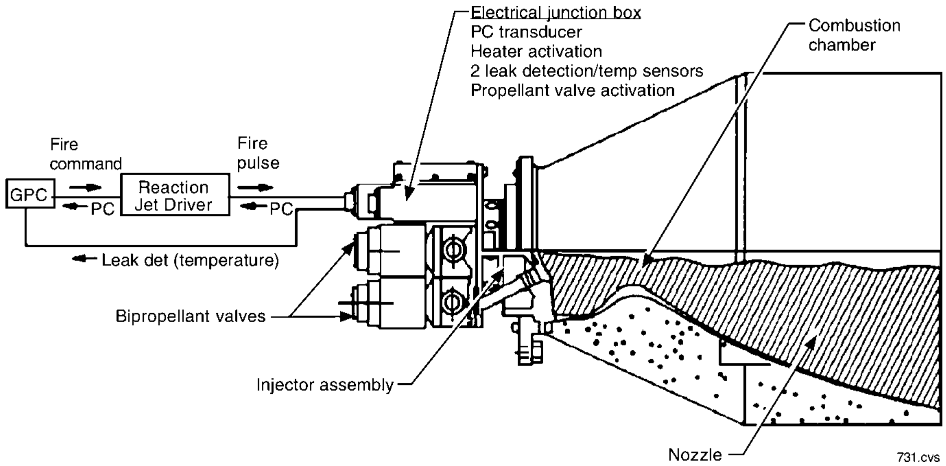
The injector assembly directs the flow of propellants to the combustion chamber. The primary thrusters have injector hole pairs (one fuel, one oxidizer), called doublets, canted toward each other for stream impingement of the propellants in the combustion chamber. Each primary jet has 84 doublets arranged in a "showerhead" circular pattern in the combustion chamber. Additional fuel holes are provided near the outer edge of the injector assembly for cooling the combustion chamber walls.

Each of the six vernier RCS jets has a single pair of fuel and oxidizer injector holes canted to cause impingement of the fuel and oxidizer streams for combustion.

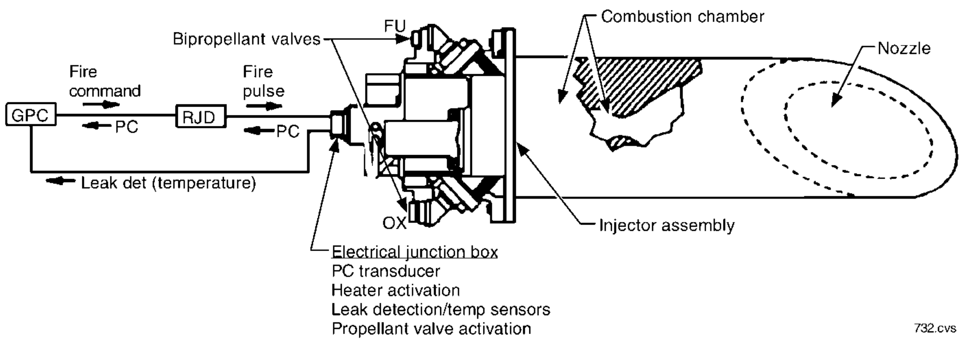
The combustion chamber of each RCS jet is constructed of columbium with a columbium disilicide coating to prevent oxidation. The nozzle of each RCS jet is tailored to match the external contour of the forward RCS module or the left and right aft RCS pods. The nozzle is radiation-cooled, and insulation around the combustion chamber and nozzle prevents the excessive heat of 2,000° to 2,400° F from radiating into the orbiter's structure.

The electrical junction box for each RCS jet has electrical connections for an electrical heater, a chamber pressure transducer, oxidizer and fuel injector temperature transducers (to detect propellant leaks) for each valve, and the propellant valves.

There is a small possibility of random but infrequent combustion instability of the primary RCS jets, causing a burnthrough in the combustion chamber wall of an RCS primary jet in a very few seconds. An instability protection system is incorporated into each of the 38 primary RCS jets. The electrical power wire of each primary RCS jet fuel and oxidizer valve is wrapped around the outside of each primary RCS jet combustion chamber wall. If instability occurs within a primary RCS jet, the burnthrough would cut the electrical power wire to that primary RCS jet's valves, remove electrical power to the valves, close the valves, and render the jet inoperative for the remainder of the mission.



Primary Jet



Vernier Jet

Propellant System

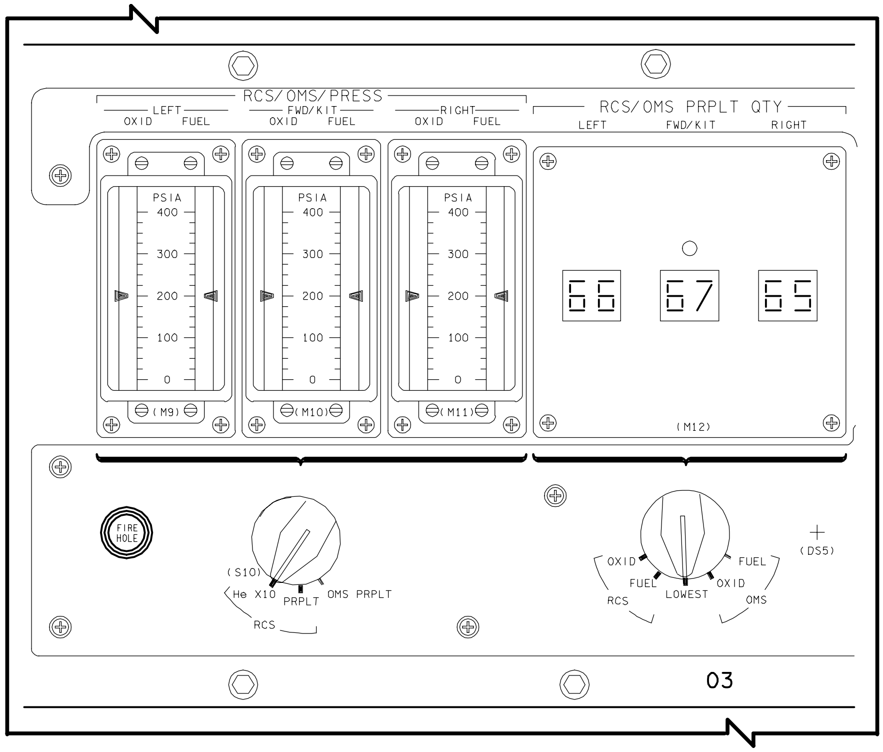
The system that distributes the propellants to the RCS jets consists of fuel and oxidizer tanks, tank isolation valves, manifold isolation valves, crossfeed valves, distribution lines, and filling and draining service connections.

Propellant Tanks

Each RCS module contains two propellant tanks, one for fuel and one for oxidizer. The nominal full load of the forward and aft RCS tanks in each pod is 1,464 pounds in the oxidizer tanks and 923 pounds in the fuel tanks.

Each tank is pressurized with helium, which expels the propellant into an internally mounted, surface-tension, propellant acquisition device that acquires and delivers the propellant to the RCS jets. The propellant acquisition device is required because of the orbiter's orientation during ascent, on orbit, and during entry. The device is also needed to deal with the various accelerations, which range from very high during ascent, entry, or abort to very low during orbital operation. The forward RCS propellant tanks have propellant acquisition devices designed to operate primarily in a low-gravity environment, whereas the aft RCS propellant tanks are designed to operate in both high and low gravity, ensuring adequate propellant flow during all phases of flight. A compartmental tank with individual wire mesh screen devices in both the upper and lower compartments supplies propellant independent of tank load or orientation. A barrier separates the upper and lower compartments in each tank.

The aft RCS propellant tanks incorporate an entry collector, sumps, and gas traps to ensure proper operation during abort and entry mission phases.



RCS/OMS/PRESS Meters and Rotary Switch and RCS/OMS PRPLT QYT LEDs and Switch on Panel O3 (Note: Information on these meters is from a different source than the information on PASS GNC SYS SUMM 2)

The left, forward, and right RCS fuel and oxidizer tank ullage pressures (pressures within an RCS propellant tank used for expelling propellant and calculating propellant volume) can be monitored on panel O3. When the left-hand rotary switch on panel O3 is positioned to *RCS PRPLT*, the pressures are displayed on the three RCS/OMS/PRESS meters. The *LEFT RCS*, *FWD RCS*, or *RIGHT RCS* red caution and warning light on panel F7 will illuminate if a module's tank ullage pressure is less than 200 psia or higher than 300 psia.

RCS Propellant Quantity

The RCS quantity monitor uses the GPC to calculate the usable percent of fuel and oxidizer in each RCS module. The quantities are computed based on the pressure, volume, and temperature method, which requires that pressure and temperature measurements be combined with a unique set of constants to calculate the percent remaining in each of the six propellant tanks. Correction factors are included for residual tank propellant at depletion, gauging inaccuracy, and trapped line propellant. The computed quantity represents the usable (rather than total) quantity for each module and makes it possible to determine if the difference between each pair of tanks exceeds a preset tolerance (leak detection).

The sequence assumes that helium flows to the propellant tanks to replace propellant leaving. As a result, the computed quantity remaining in a propellant tank will be decreased by normal usage, propellant leaks, or helium leaks.

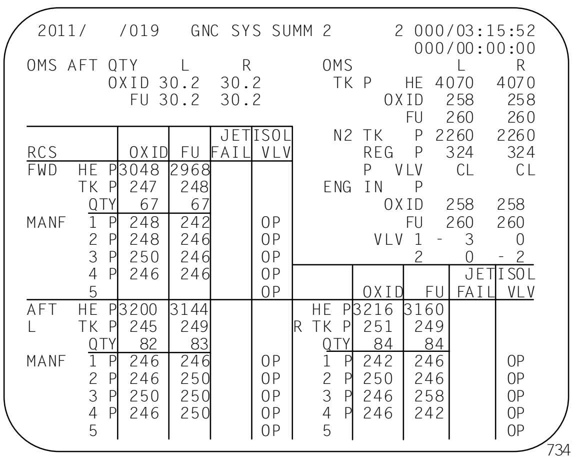
NOTE

> Erroneous temperature and/or pressure transducer readings will cause erroneous propellant quantity calculations.

The left, right, and forward RCS fuel and oxidizer quantities are displayed to the flight crew by the RCS/OMS PRPLT QTY LEDs on panel O3. When the rotary switch on panel O3 below the LEDs is positioned to the *RCS FUEL* or *OXID* position, the LEDs will indicate, in percent, the amount of fuel or oxidizer. If the switch is positioned to *RCS LOWEST*, the gauging system selects whichever is lower (fuel or oxidizer) for display on the LED.

The left, right, and forward RCS quantities also are sent to PASS GNC SYS SUMM 2 (RCS L QTY, R QTY, FWD QTY), and in the event of failures, substitution of alternate measurements and the corresponding quantity will be displayed. If no substitute is available, the quantity calculation for that tank is suspended with a fault message.

The sequence also provides automatic closure of the high-pressure helium isolation valves on orbit when the propellant tank ullage pressure is above 300 psia. When the tank ullage pressure returns below these limits, the close command is removed.



734

PASS GNC SYS SUMM 2 Display

Exceeding a preset absolute difference of 9.5 percent between the fuel and oxidizer propellant quantities will illuminate the respective *LEFT RCS*, *RIGHT RCS*, or *FWD RCS* red caution and warning light on panel F7, activate the *BACKUP C/W ALARM*, and cause a fault message to be sent to the CRT. A bias of 9.5 percent is added when a leak is detected so that subsequent leaks in that same module may be detected in the PASS. BFS will annunciate a leak only once.

Tank Isolation Valves

The valves located between the propellant tanks and the manifold isolation valves isolate the propellant tanks from the remainder of the propellant distribution system. The isolation valves are ac-motor-operated and consist of a lift-off ball flow control device and an actuator assembly that contains a motor, gear train, and actuator gear. One pair of valves (one fuel and one oxidizer) isolates the propellant tanks from the 1/2 manifold (manifolds are referenced by number: 1/2/3/4/5) in the forward and aft left and right RCS. One pair of valves isolates the propellant tanks from the 3/4/5 manifold in the forward RCS. Two pairs of valves, in parallel, identified as A and B, isolate the propellant tanks from the 3/4/5 manifold in the aft left and right RCS.

The forward RCS tank isolation valves are controlled by the *FWD RCS TANK ISOLATION 1/2* and *3/4/5* switches on panel O8. The aft left RCS tank isolation valves are controlled by the *AFT LEFT RCS TANK ISOLATION 1/2* and *3/4/5 A* and *B* switches on panel O7, and the aft right tank isolation valves are controlled by the *AFT RIGHT RCS TANK ISOLATION 1/2* and *3/4/5 A* and *B* switches on panel O7. These permanent-position switches have three settings: *OPEN*, *GPC*, and *CLOSE.*

When the *FWD RCS TANK ISOLATION 1/2* and *3/4/5* switches on panel O8 are positioned open, fuel and oxidizer from the propellant tanks are allowed to flow to the corresponding manifold isolation valves. Electrical power is provided to an electrical motor controller assembly that supplies power to the ac-motor-operated valve actuators. Once the valve is in the commanded position, logic in the motor controller assembly removes power from the actuator.

Microswitches in each pair of valves control talkback indicators above each tank's isolation switch on panel O8. The talkback indicator shows *OP* or *CL* when that pair of valves is open or closed and barberpole when the valves are in transit, or one valve is open, and the other is closed, or for some microswitch failures. The *OPEN* and *CLOSE* positions of the *FWD RCS TANK ISOLATION 1/2* and *3/4/5* switches on panel O8 permit manual control of the corresponding pair of valves. The GPC position is not supported.

The *OPEN*, *GPC*, and *CLOSE* positions of the *AFT LEFT RCS TANK ISOLATION 1/2* and *3/4/5 A* and *B* and *AFT RIGHT RCS TANK*

ISOLATION 1/2 and *3/4/5 A* and *B* switches on panel O7 are the same type as those of the forward RCS tank isolation switches and are controlled electrically in the same manner. A talkback indicator above each switch indicates the position of the pair of valves as in the forward RCS. The *3/4/5 A* and *B* switches control parallel fuel and oxidizer tank isolation valves to permit or isolate propellants to the respective aft left and aft right RCS manifold isolation valves 3, 4, and 5.

Unlike the forward tank isolation valves, the aft tank isolation valves can be commanded open or closed when in the GPC position.

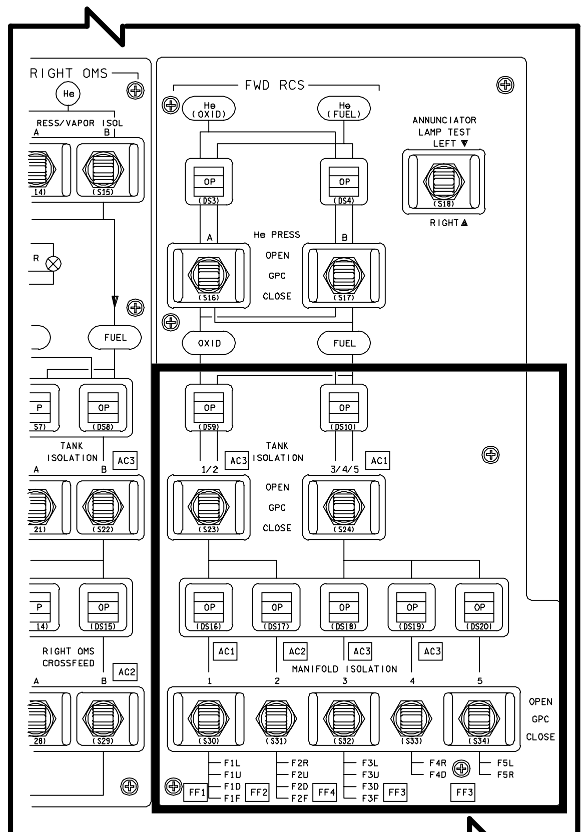
Manifold Isolation Valves

The forward RCS manifold isolation valves are between the tank isolation valves and the forward RCS jets. The valves for manifolds 1, 2, 3, and 4 are the same type of ac-motor-operated valves as the propellant tank isolation valves and are controlled by the same type of motor-switching logic. The forward RCS manifold valve pairs are controlled by the *FWD RCS MANIFOLD ISOLATION 1, 2, 3, 4,* and *5* switches on panel O8. Each MANIFOLD ISOLATION switch controls a pair of valves (one fuel and one oxidizer), which allow propellant to flow to the jets on the corresponding manifold. A talkback indicator above each of the five switches on panel O8 indicates the status of that pair of valves. The talkback indicator is controlled in the same manner as the tank isolation valve indication. The *OPEN* and *CLOSE* positions of the switch permit control of the corresponding oxidizer and fuel valves. The GPC position is not supported.

NOTE

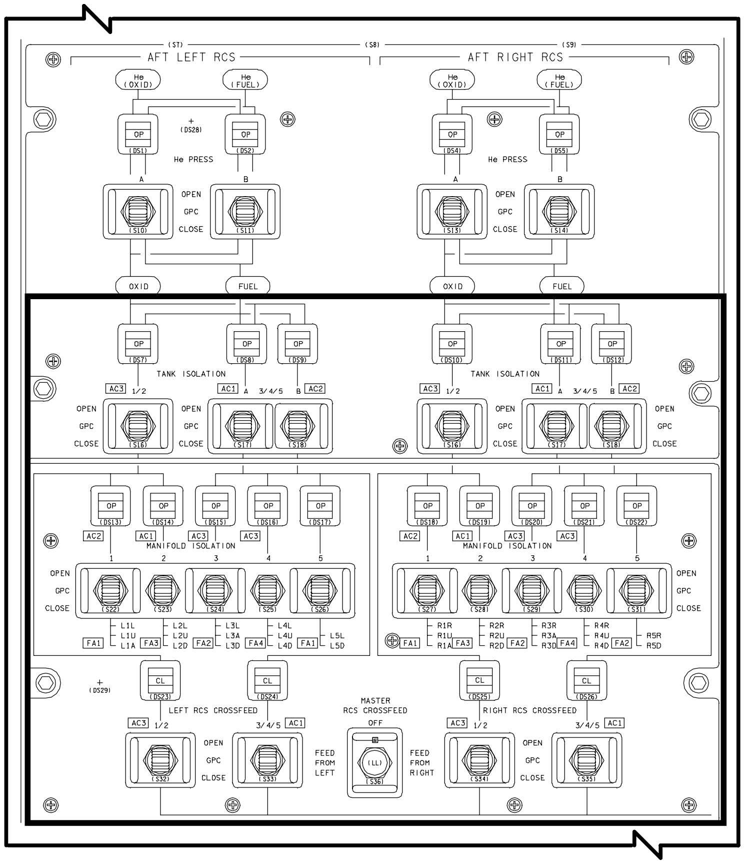
The manifold isolation valves have a backflow capability when the manifold is closed, and the manifold pressure is 30 to 50 psi higher than the tank leg.

The *FWD RCS MANIFOLD ISOLATION 5* switch on panel O8 controls the manifold 5 fuel and oxidizer valves, which control propellants for the forward vernier RCS jets only. The switch is spring-loaded in the *GPC* position. When the switch is moved to the *OPEN* position, electrical power is momentarily applied through logic in an electrical load controller assembly to energize the solenoid valves open and magnetically latch the valves. To close the valves, electrical power is momentarily applied to energize the solenoids surrounding the magnetic latches of the valves, which allows spring and propellant pressure to force the valves closed. A position microswitch in each valve indicates valve position to an electrical controller assembly and controls a talkback indicator above the switch. When both valves are open, the indicator shows *OP*; when both valves are closed, it indicates *CL*. If one valve is open, and the other is closed, the talkback indicator shows barberpole.



FWD RCS TANK ISOLATION and MANIFOLD ISOLATION Switches and Talkbacks on Panel O8

The *AFT LEFT RCS MANIFOLD ISOLATION 1, 2, 3, 4, 5* and *AFT RIGHT RCS MANIFOLD ISOLATION 1, 2, 3, 4, 5* switches are on panel O7. The *OPEN, GPC,* and *CLOSE* positions of each switch are the same type as the forward switches and are controlled electrically in the



AFT TANK ISOLATION, AFT MANIFOLD ISOLATION, and RCS CROSSFEED Switches and Talkbacks on Panel O7

same manner. The *AFT LEFT* and *AFT RIGHT RCS MANIFOLD 1*, *2*, *3*, and *4* switches provide corresponding tank propellants to the applicable primary RCS jets or isolate the propellants from the jets. The *AFT LEFT* and *AFT RIGHT RCS MANIFOLD 5* switches provide corresponding tank propellants to the applicable vernier RCS jets or isolate the propellants from the jets.

RCS Crossfeed Valves

If either aft RCS pod's propellant system must be isolated from its jets, the other aft RCS propellant system can be configured to crossfeed propellant. The aft RCS crossfeed valves that tie the crossfeed manifold into the propellant distribution lines below the tank isolation valves can be configured so that one aft RCS propellant system can feed both left and right RCS jets. The aft RCS crossfeed valves are ac-motor-operated valve actuators and identical in design and operation to the propellant tank isolation valves. The aft RCS crossfeed valves are controlled by the *AFT LEFT* and *AFT RIGHT RCS CROSSFEED 1/2* and *3/4/5* switches on panel O7. The positions of the four switches are *OPEN*, *GPC*, and *CLOSE*. The *GPC* position allows the orbiter computer to automatically control the crossfeed valves, and the *OPEN* and *CLOSE* positions enable manual control. The *OPEN* position of the *AFT LEFT RCS CROSSFEED 1/2* and *3/4/5* switches permits the aft left RCS to supply propellants to the aft right RCS crossfeed valves, which must be opened by placing the *AFT RIGHT RCS CROSSFEED 1/2* and *3/4/5* switches to the *OPEN* position for propellant flow to the aft right RCS jets. (Note that the *AFT RIGHT* receiving *RCS TANK ISOLATION 1/2* and *3/4/5 A* and *B* valves must be closed.) The *CLOSE* position of the *AFT LEFT* and *AFT RIGHT RCS CROSSFEED 1/2* and *3/4/5* switches isolates the crossfeed capability. The crossfeed of the aft right RCS to the left RCS would be accomplished by positioning the *AFT RIGHT* and *LEFT RCS CROSSFEED* switches to *OPEN* and positioning the *AFT LEFT RCS TANK ISOLATION 1/2* and *3/4/5 A, B* switches to *CLOSE*.

Helium System

Each RCS has two helium storage tanks, four helium isolation valves, four pressure regulators, two check valves, two relief valves, and servicing connections for draining and filling.

Helium Tanks

The two helium tanks in each RCS supply gaseous helium individually, one to the fuel tank and one to the oxidizer tank.

NOTE

> The helium tanks provide ullage pressure for the propellant tanks. Each propellant tank has a specific quantity where, should the helium tank fail, the nominal ullage pressure would result in the maximum delta V. This quantity is referred to as max blowdown. Max blowdown for the forward RCS is 22 percent; for the aft RCS, it is 24 percent propellant quantity remaining.

Helium Isolation Valves

Two parallel helium isolation valves are located between the helium tanks and the pressure regulators in each RCS. When open, the helium isolation valves permit the helium source pressure to flow to the propellant tank. The helium isolation valves are controlled by the *FWD RCS He PRESS A* and *B* switches on panel O8 and the *AFT LEFT RCS He PRESS A* and *B* and *AFT RIGHT RCS He PRESS A* and *B* switches on panel O7. Each switch controls two helium isolation valves, one in the oxidizer helium line and one in the fuel helium line. The switch positions are *OPEN*, *GPC,* and *CLOSE*. When the switch is positioned to *GPC*, the pair of valves can be closed automatically upon command from the orbiter computer. The *OPEN/CLOSE* positions permit manual control of that pair of valves.

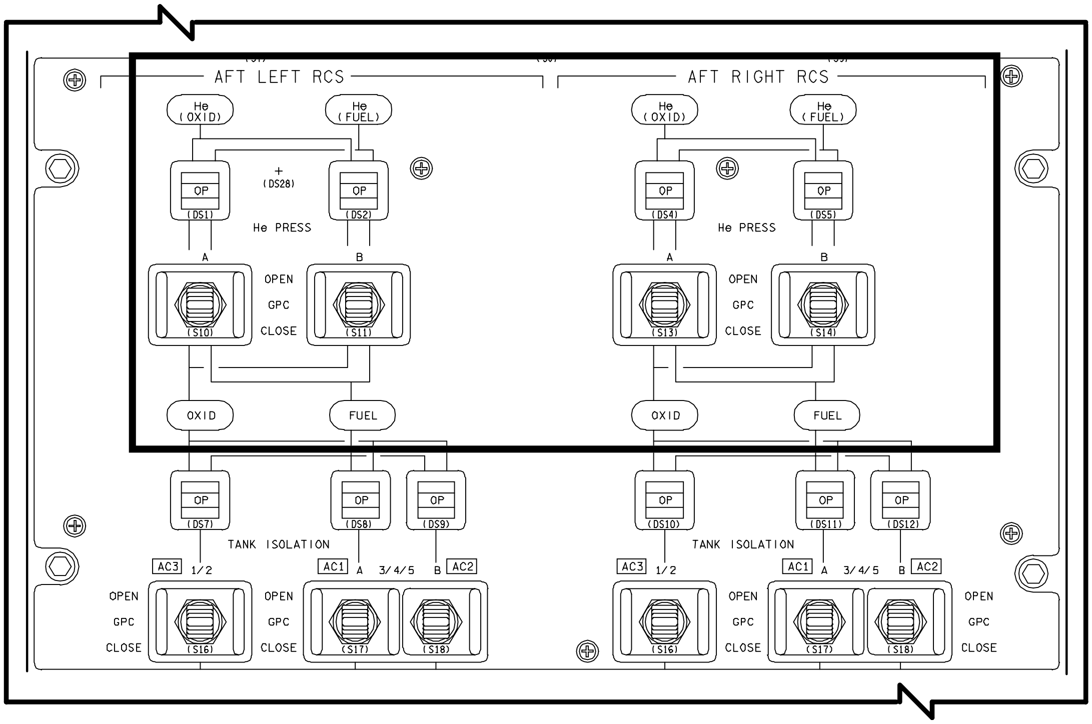
Electrical power is momentarily applied through logic in an electrical load controller assembly to energize the two helium isolation solenoid valves open and to magnetically latch the valves open. To close the two helium isolation valves, electrical power is momentarily applied through the load controller to energize a solenoid surrounding the magnetic latch of the two helium isolation valves, which allows spring and helium pressure to force the valve closed.

A position microswitch in each valve indicates valve position to an electrical controller assembly and controls a position indicator (talkback) above each switch on panels O7 and O8. When both valves (helium fuel and helium oxidizer) are open, the talkback indicates *OP*; when both valves are closed, the talkback indicates *CL*. If one valve is open, and the other is closed, the talkback indicates barberpole.

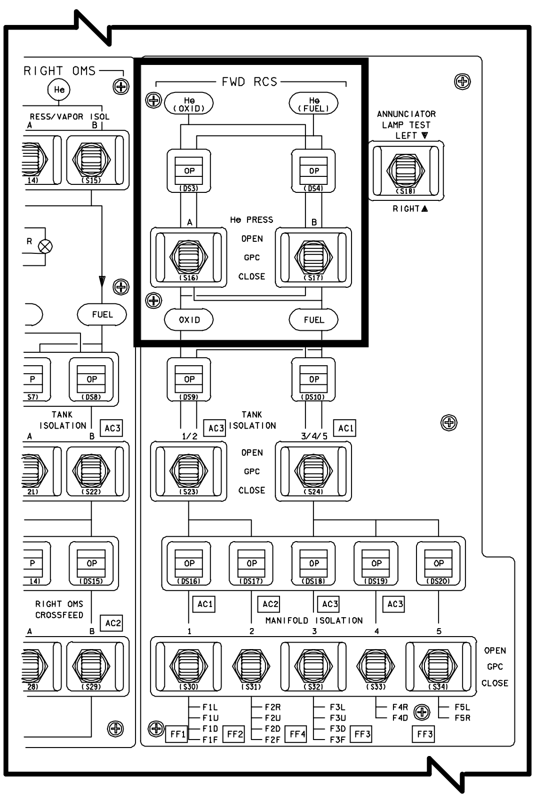
The RCS helium supply pressure is monitored on panel O3. When the rotary switch on panel O3 is positioned to *RCS He X10*, the forward and aft RCS helium pressures are displayed on the RCS/OMS/PRESS OXID and FUEL meters on panel O3.

Helium Pressure Regulators

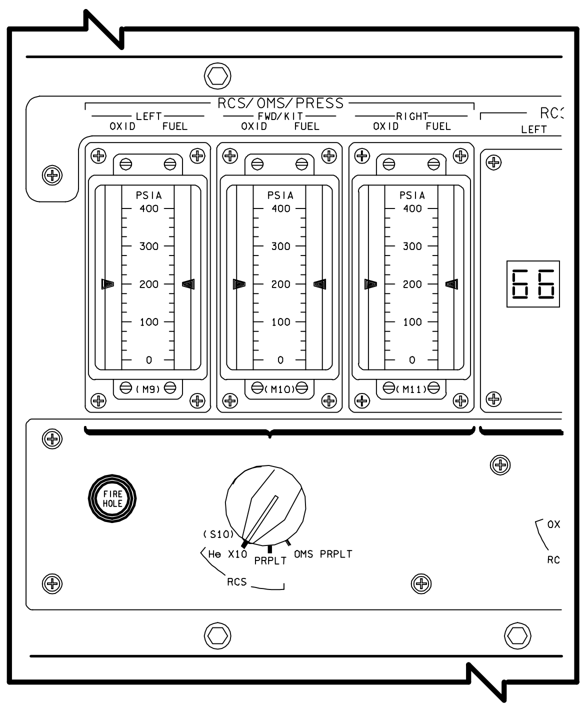
Helium pressure is regulated by two regulator assemblies, connected in parallel, downstream of the helium isolation valves. Each assembly contains two stages, a primary and a secondary, connected in series. If the primary stage fails open, the secondary stage regulates the pressure. The primary regulates the pressure at 242 to 248 psig, the secondary at 253 to 259 psig.



AFT RCS He PRESS Switches and Talkbacks on Panel O7



FWD RCS He PRESS Switches and Talkbacks on Panel O8



RCS/OMS Meters and Rotary Switch on Panel O3 (Note: ***Information on these meters is the same as the information on SPEC 23 and BFS GNC SYS SUMM 2.)***

Check Valves

The check valve assembly, which consists of four poppets in a series-parallel arrangement, is located between the pressure regulator assemblies and the propellant tank. The series arrangement limits the backflow of propellant vapor and maintains propellant tank pressure integrity in the event of an upstream helium leak. The parallel arrangement ensures the flow of helium pressure to the propellant tank if a series check valve fails in the closed position.

Pressure Relief Valve

A helium pressure relief valve assembly located between the check valve assemblies and propellant tank will vent excessive pressure overboard before it reaches the propellant tank. Each valve consists of a burst diaphragm, filter, and relief valve. The non-fragmentation diaphragm, which provides a positive seal against helium leakage, will rupture between 324 and 340 psig. The filter prevents any particles of the burst diaphragm from reaching the relief valve seat. The relief valve relieves at 315 psig minimum and reseats at 310 psig. The relief valve is sized to handle, without damaging the propellant tank, helium pressure flow volume if a regulator malfunctions to a full-open position.

Thermal Control

Electrical heaters are provided in the forward RCS module and the OMS/RCS pods to maintain the propellants in the module and pods at safe operating temperatures and to maintain safe operating temperatures for the injector of each primary and vernier RCS jet.

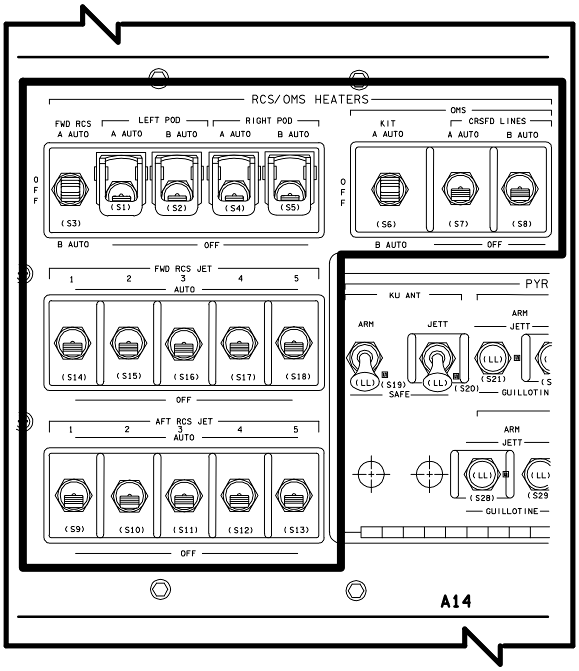
Each primary RCS jet has a 20-watt heater, except the four aft-firing jets, which have 30-watt heaters. Each vernier RCS jet has a 10-watt heater.

The forward RCS has six heaters mounted on radiation panels in six locations. Each OMS/RCS pod is divided into nine heater zones. Each zone is controlled in parallel by an A and B heater system. The aft RCS jet housing contains heaters for the yaw, pitch up, pitch down, and vernier jets in addition to the aft OMS/RCS drain and purge panels.

The forward RCS panel heaters are controlled by the *FWD RCS* switch on panel A14. When the switch is positioned to *A AUTO* or *B AUTO*, thermostats on the forward left-side panel and right-side panel automatically control the respective forward RCS heaters. When the respective forward RCS panel temperature reaches a minimum of approximately 55° F, the respective panel heaters are turned on. When the temperature reaches a maximum of approximately 75° F, the heaters are turned off. The *OFF* position of the switch removes all electrical power from the forward RCS heaters.

The aft RCS heaters are controlled by the *LEFT POD A AUTO* and *B AUTO* and *RIGHT POD A AUTO* and *B AUTO* switches on panel A14. When the switches are positioned to either *A AUTO* or *B AUTO*, thermostats automatically control the nine individual heater zones in each pod. Each heater zone is different, but generally the thermostats control the temperature between approximately 55° F minimum to approximately 75° F maximum. The *OFF* position of the respective switch removes all electrical power from that pod heater system.

The forward and aft RCS primary and vernier jet heaters are controlled by the *FWD* and *AFT RCS JET 1*, *2*, *3*, *4*, and *5* switches on panel A14. When the switches are positioned to *AUTO*, individual thermostats on each jet automatically control the individual heaters on each jet. The primary RCS jet heaters turn on between approximately 66° to 76° F, and they turn off between approximately 94° to 109° F. The vernier RCS jet heaters turn on between approximately 140° to 150° F and off between approximately 184° to 194° F. The *OFF* position of the switches removes all electrical power from the jet heaters. The 1, 2, 3, 4 and 5 designations refer to propellant manifolds. There are two to four jets per manifold.



RCS/OMS HEATERS Switches on Panel A14

RCS Redundancy Management

RCS redundancy management (RM) software includes RCS jet failure detection and annunciation, jet availability, SPEC 23 RCS, SPEC 51 BFS OVERRIDE, and manifold status processing.

Jet failure modes detected and annunciated are fail-off, fail-on, and fail-leak. Fault annunciation is a class 2 alarm consisting of a master alarm, illumination of the yellow *RCS JET* and red *BACKUP C/W ALARM* lights on panel F7, and a fault summary message (F (L,R) RCS A (D, R, U) JET).

All statuses, flags, counters, and related RCS RM data are carried across OPS transitions. However, when BFS is engaged, all flags, statuses, and counters are cleared and reinitialized.

The jet parameters used in RM are the Pc discrete, CMD B, driver out discrete, and the oxidizer and fuel injector temperatures. Pc discrete is turned on when the jet chamber pressure reaches 36 psi and remains on until the chamber pressure falls below 26 psi. Individual fail detection and response parameters are as follows.

```
 2011/023/            RCS            1 000/03:14:16
                                       000/00:00:00
RCS FWD 1      PRI  JET    OMS PRESS ENA
      L 2   4 FAIL LIM 2     L OMS 5      OMS=RCS QTY
      R 3*                   R OMS 6        L  0.00
                               OFF 7*       R  0.00
 JET FAIL DES JET PTY
          INH DES                        OXID  FU
 R4R        8   9   2        HE        P 3376  3360
   2R      10  11   1        PRPLT TK  P  247   250
 Y 3R      12  13   2                  T   77    79
   1R      14  15   1                QTY   90    91
 R4U       16  17   2        MANF P    1  242   246
   2U      18  19   1                  2  250   246
 Z 1U      20  21   3                  3  248   248
 R         22  23   2                  4  246   242
   4D      24  25   1        MANF VLVS    STAT  OVRD
   2D      26  27   2                  1   OP    40
   3D      28  29   1                  2   OP    41
 R1A       30  31   1                  3   OP    42
 X 3A      32  33   3                  4   OP    43
           34  35   2                  5   OP    44
 R5R       36  37                XFEED P  254   254
 V 5D      38  39                JET RESET  45
                                                    678
```

SPEC 23 RCS Display

```
  3011/051/         OVERRIDE          5 006/09:38:04
                                    BFS 000/00:17:56
 ABORT MODE                     ENTRY FCS
  TAL        1       ELEVON    FILTER    ATMOSPHERE
  ATO        2     AUTO  17*   NOM 20*   NOM    22*
 ABORT       3     FIXED 18    ALT 21    N POLE 23
 MAX THROT   4       SSME REPOS 19 ENA   S POLE 24
    PROPLT DUMP     IMU DES ATT     AA     RGA  SURF
                     1  25    2  LRU DES   DES  DES
 INH ICNCT 5         2  26         1  31    35   39
 OMS DUMP            3  27         2  32    36   40
    ARM    6                       3  33    37   41
    START  7                       4  34    38   42
    STOP   8
  9 QUAN/SIDE 041
 OMS DUMP TTG 227
                       ET SEP          ROLL MODE
 AFT RCS 13   INH        AUTO   28       WRAP MODE 45
   14 TIME    000        SEP    29
                                       VENT DOOR CNTL
 FWD RCS 15   INH        ET UMB DR       OPEN   43
   16 TIME    000        CLOSE  30       CLOSE  44
                                                    741b
```

SPEC 51 BFS OVERRIDE Display

Jet Fail-Off

Detection:

- CMD B present with no Pc Discrete for three consecutive cycles.
- RM is suspended for an MDM or LRU commfault.
- RM is unable to detect a fail-off jet when the Pc transducer is failed high.

RM Response:

- Fail-off flag is set.
- Message is annunciated.
- Jet is deselected unless the pod limit has been reached.

Jet Fail-On

Detection:

- Driver out discrete is present when a CMD B is not issued for three consecutive cycles.
- RM is suspended for an MDM or LRU commfault.
- RM is unable to detect a fail-on jet when the driver out discrete is failed low.

RM Response:

- Fail-on flag is set.
- Message is annunciated.

Jet Fail-Leak

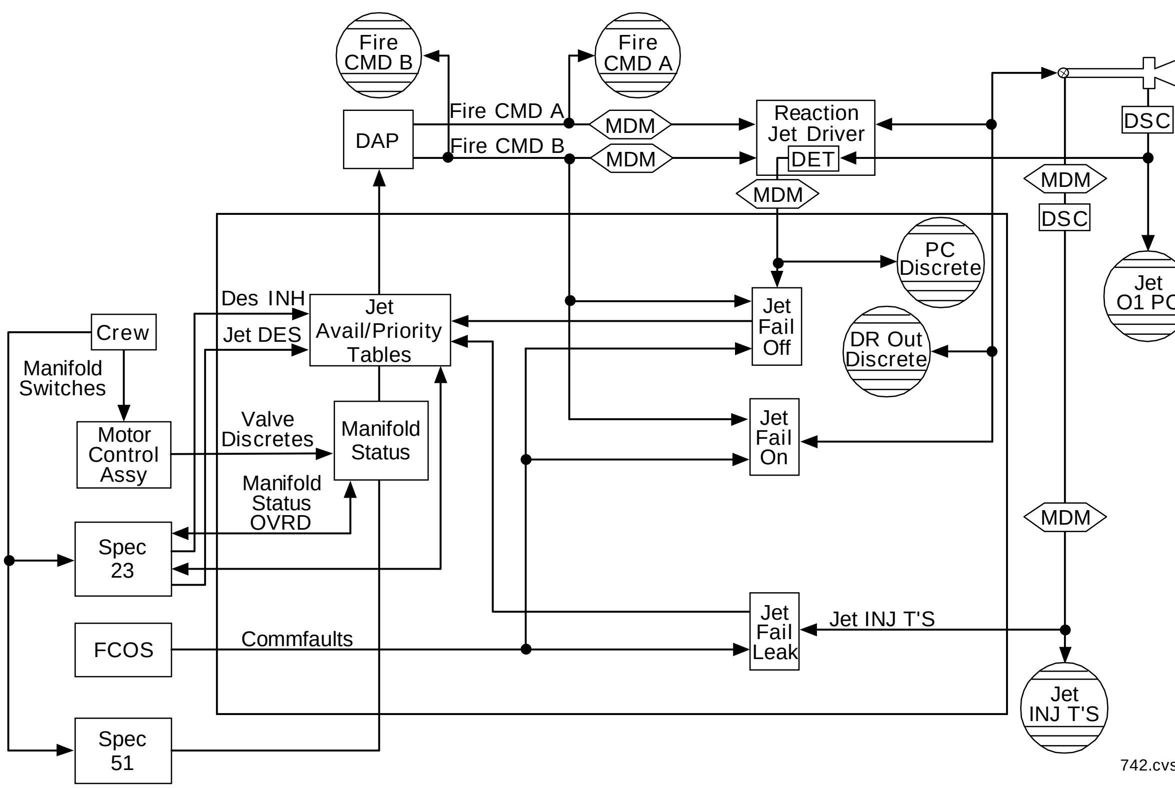
Detection:

- Either oxidizer or fuel injector temperature is below the RCS RM injector temperature limit for three consecutive cycles.
- RM is suspended for an MDM or LRU commfault.
- RM is unable to detect a fail-leak jet for a failed-high temperature transducer.
- A failed-low injector temperature transducer will trip RM.

RM Response:

- Fail-leak flag is set.
- Message is annunciated.
- Jet is deselected unless the pod limit has been reached.

Once RM has annunciated a failure for a jet, that failure will not be reannunciated until the fail flag is reset. The remaining failure modes that were not detected can be annunciated. Vernier jet failures are annunciated in OPS 2 and 8 only.



RCS Redundancy Management Schematic

Nomenclature

To clarify nomenclature, a few RCS RM definitions are listed below.

Deselected Jet — A jet that is not available and will not be commanded to fire.

Reselected Jet — A jet that was previously not available and is now available and could be commanded to fire.

Auto-Deselected Jet — A jet that has been deselected by RCS RM software. RM will auto-deselect a jet for fail-off and fail-leak detection.

Manually Deselected Jet — A jet that has been deselected by SPEC 23 item entry.

Manually Reselected Jet — A jet that is reselected via SPEC 23 item entry. This is the only method to reselect an individual jet that was auto-deselected by RCS RM. (A whole manifold of jets can be reselected via SPEC 51 and SPEC 23 item entry.)

Pod Counter — The internal RCS RM counter that counts the number of jets per pod that have been auto-deselected by RCS RM.

Pod (Fail) Limit — The PRI JET FAIL LIM on SPEC 23 (item 4) that limits the number of primary jets that can be auto-deselected per pod.

Pod Counter is Full — Pod counter equals pod fail limit. Typically, this means two jets have failed and have been auto-deselected in a pod.

Override a Manifold Open (Closed) — An action performed via item entry on SPEC 23 that toggles the RCS RM manifold status to open (closed). The RCS RM manifold status is an independent variable that may differ from the actual manifold valve position. Overriding a manifold closed will deselect all the jets on that manifold.

Deselection Candidate — Any jet that is annunciated fail-off or fail-leak by RCS RM becomes a deselection candidate, unless the jet has been deselect inhibited.

Jet Availability Table — An array that contains a bit for each jet. The bit is on if the associated jet is available and may be commanded to fire by DAP. The bit is off when the jet is not available as determined by RCS RM. Unavailable jets will not be commanded to fire.

Jet Pod Counter and Pod Limit

RCS SPEC 23 displays the PRI JET FAIL LIM. This limit is the number of primary jets that RCS RM will deselect for the pod (forward, left, or right) currently displayed on SPEC 23. This number is I-loaded to 2 and can be changed via SPEC 23.

RCS RM will auto-deselect primary jets until the pod counter equals the pod limit. RM will continue to annunciate all jet failures not previously annunciated when the pod counter is full; however, no new jets will be auto-deselected.

Manually reselecting an auto-deselected jet will reduce the pod counter by one. Manually reselecting a jet that was manually deselected via SPEC 23 will not have an impact on the pod counter.

The pod counter is not affected by subsequent jet failures on a previously deselected jet. Decreasing the pod limit does not reselect jets. If the pod limit is at two, and two jets are currently auto-deselected, changing the limit to one will not reselect one of the auto-deselected jets.

Once a jet is annunciated fail-off or fail-leak, that jet is a deselection candidate. Assume the pod limit is two. If the pod counter is full, and a third (or more) jet becomes a deselect candidate, this jet will not be auto-deselected, as expected. If one of the jets on the same pod is then manually reselected, the pod counter is decremented to one, also as expected. However, the deselection candidate that could not previously be auto-deselected since the pod counter was at the limit will now be auto-deselected, and the pod counter will be incremented to two again. All deselect candidates remain "deselectable" until their fail-flags are cleared.

RCS Manifold RM

RCS RM contains an independent evaluation of RCS manifold valve status. Input to this processing includes the actual manifold valve status, commfault protection, and crew display item entry processing. The RCS RM manifold status can differ from the actual valve positions.

Manifold status is reevaluated when valve discretes change, a commfault occurs, or manifold status is changed by crew display item entries. A commfault is declared when the data path for the manifold valve microswitch discrete is failed. A commfault occurs when an MDM or GPC fails, or a BCE BYPASS is declared.

If RCS RM sets the manifold status to closed, all jets on the affected manifold will be removed from the availability table. Manifold status is set to closed by RCS RM in four cases: manually closing the valve, commfault, crew display item entry, and some dilemma cases.

RCS RM will set the manifold status to closed for MDM commfaults on the associated microswitch channelization. An I/O RESET will force RCS RM to reevaluate the manifold status. Thus, if an I/O RESET clears the commfault, the manifold status will be set to open.

Crew item entries on SPEC 23 can toggle a manifold status open or closed.

RCS Manifold RM can detect two failure modes: power fail and dilemma. Input to these failure detection processes are the four manifold microswitch discretes: OX OP, OX CL, FU OP, and FU CL.

Actual electrical bus voltages are not used in power fail determination. The manifolds are paired by common microswitch buses, and power fails are issued only if both manifolds indicate loss of power to their microswitches.

RCS RM Manifold Dilemma

Detection — Three cases of microswitch indications result in an RCS RM manifold dilemma:

- 1 OP indication + 1 or 0 CL indications
- 2 OP indications + 2 CL indications
- 0 OP indications + 0 CL indications (FRCS manifolds 1, 2, 4, and 5 only).

Indications can be OX and/or FU microswitches. These conditions must exist for three consecutive passes.

RM Response — Issue "RCS RM DLMA" message. In summary, if the number of open indications is greater than the number of closed indications, the manifold status is open; otherwise, the manifold status is closed.

RCS Manifold Power Fail

Detection — All four manifold microswitch discretes are 0 for six consecutive passes. Power fail processing is performed on the following manifold pairs: FRCS M3/4, ARCS L1/R1, L2/R2, L3/R3, L4/R4, and L5/R5.

RM Response — Issue "RCS PWR FAIL" message. Manifold status is unchanged.

Forward manifolds 1, 2, and 5 are not analyzed for power fail conditions. If these manifolds suffer a power fail to their microswitches, an "RCS RM DLMA" will be issued, rather than an "RCS PWR FAIL."

Forward manifold 3 microswitches are redundantly powered by MN A FPC1 and MN C FMC3. Forward manifold 4 microswitches are powered only by MN C FMC3. Both MN A FPC1 and MNC FMC3 must be lost for RCS RM to issue a power fail for this manifold pair. Because of the low probability of this case, forward manifold 3/4 power fails are rarely detected. However, for the loss of MN C FMC3, an "RCS RM DLMA" message is annunciated, FRCS manifold 4 is declared closed, and the associated jets are declared unavailable.

Jet Selection

The DAP jet-select module contains default logic in certain instances. When the orbiter is mated to the ET, roll rate default logic inhibits roll rotation, and yaw commands are normally in the direction of favorable yaw-roll coupling. During insertion, a limit of seven aft RCS jets per tank set applies for ET separation and for return-to-launch-site aborts. If negative Z and plus X translation commands are commanded simultaneously, both will be degraded. A limit of four aft RCS jets per tank set normally applies. If plus X and negative Z translations are commanded simultaneously, plus X is given priority. Multi-axis translation and rotation commands may require more jets than allowed and result in degraded control and excessive propellant usage.

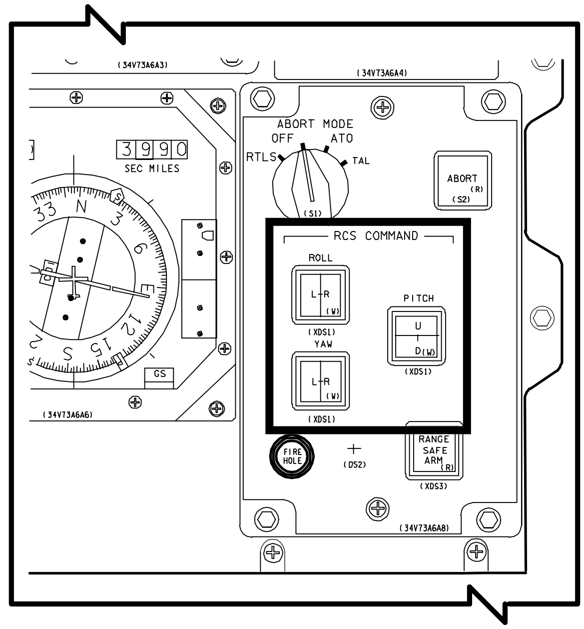
The DAP jet-select module determines which aft RCS jets (right, left, or both) must be turned on in response to the pitch, roll, and yaw jet commands from the entry flight control system. The forward RCS jets are not used during entry. After entry interface, only the four Y-axis and six Z-axis RCS jets on each aft RCS pod are used. No X-axis or vernier jets are used. The DAP sends the discretes that designate which aft RCS jets are available for firing (a maximum of four RCS jets per pod may be fired). During reconfiguration, or when the RCS crossfeed valves are open, the DAP determines the maximum combined total number of yaw jets available during certain pitch and roll maneuvers.

During ascent or entry, the DAP jet-select logic module in the flight control system receives both RCS rotation and translation commands. By using a table lookup technique, the module outputs 38 jet on/off commands to the RCS command subsystem operating program, which then generates dual fire commands A and B to the individual RCS reaction jet drivers to turn each of the 38 primary RCS jets on or off. The fire commands A and B for each of the 38 primary RCS jets are set equal to the digital autopilot RCS commands. Commands are issued to the six RCS vernier jets similarly on orbit.

Jet Fire Indications

ROLL, PITCH, and *YAW* white indicator lights on panel F6 indicate the presence of an RCS command during orbit and early entry. The indicators are *L* and *R* for roll and yaw left or right and *U* and *D* for pitch up and down.

From entry interface until the dynamic pressure is greater than 10 pounds per square foot, the *ROLL L* and *ROLL R* lights indicate that left or right roll commands have been issued by the digital autopilot. The minimum light-on duration is extended to allow the light to be seen even for a minimum impulse firing. When a dynamic pressure of 10 pounds per square foot has been sensed, neither *ROLL* light will be illuminated until 50 pounds per square foot has been sensed, and more than two RCS yaw jets are commanded on.



Jet Fire Indicator Lights on Panel F6

The *PITCH* lights indicate up and down pitch jet commands until a dynamic pressure of 20 pounds per square foot is sensed, after which the pitch jets are no longer used. When 50 pounds per square foot is sensed, the *PITCH* lights assume a new function. Both *PITCH* lights will be illuminated whenever the elevon surface drive rate exceeds 20° per second (14° per second if only one hydraulic system is remaining).

The *YAW* lights function as yaw jet command indicators throughout entry until the yaw jets are disabled at Mach 1 (approximately 45,000 feet). The *YAW* lights have no other function.

Operations

After main engine cutoff, the forward and aft jets are used to maintain attitude hold until external tank separation. Then the RCS provides a negative Z translation maneuver of about 4 feet per second to move the orbiter away from the external tank. Upon completion of the maneuver, the RCS holds the orbiter attitude until it is time to maneuver to the OMS-2 burn attitude. Although the targeting data for the OMS-2 burn are selected before launch, the target data in the onboard general-purpose computers can be modified by the flight crew via the CRT and keyboard, if necessary, before the OMS burn.

The OMS-2 burn uses both OMS engines to raise the orbiter to a predetermined circular orbit. (OMS-1 burns are only planned for standard insertions.) During the OMS-2 burn, vehicle attitude is maintained by gimbaling (swiveling) the OMS engines. The RCS normally does not operate during an OMS burn. If, during an OMS burn, the gimbal rate or gimbal limits are exceeded, RCS roll control would be required; or if only one OMS engine is used during a burn, RCS roll control may be required.

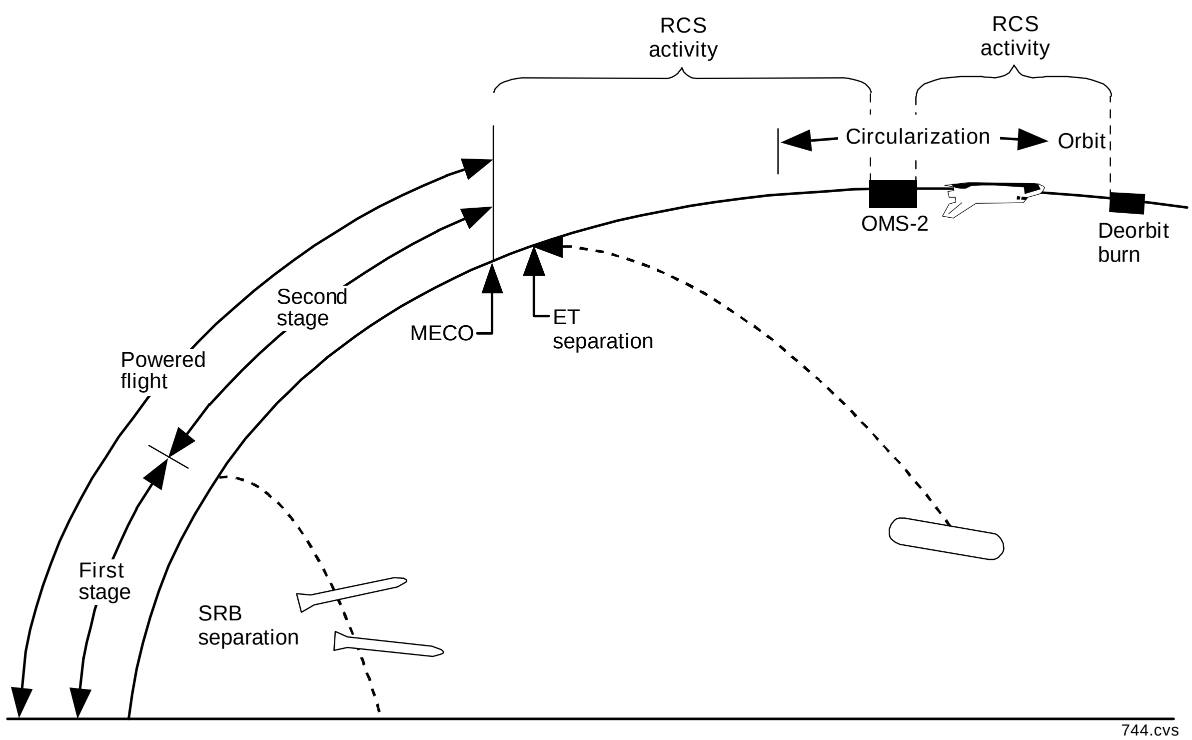
Upon completion of the OMS-2 burn, the RCS can be used to null any residual velocities, if required. It is then used for attitude hold and minor translation maneuvers as required for on-orbit operations. The flight crew can select primary or vernier RCS jets for attitude control in orbit. Normally, the vernier jets are selected for on-orbit attitude hold.

On orbit, the vernier jets are used for fine attitude control, and the primary jets are used for coarse attitude control and minor translations.

Before the deorbit burn, the flight crew maneuvers the spacecraft to the desired attitude using RCS jets. After the OMS burn, the RCS is used to null any residual velocities, if required. The spacecraft is then maneuvered to the proper entry interface attitude using the RCS. The remaining propellants aboard the forward RCS may be dumped by burning the propellants through the forward RCS yaw jets before entry interface if orbiter center-of-gravity control is necessary.

The RCS aft (+ X) jets can be used to complete any OMS deorbit burn if an OMS engine fails. In this case, the OMS-to-aft-RCS interconnect can be used to feed OMS propellant to the aft RCS.

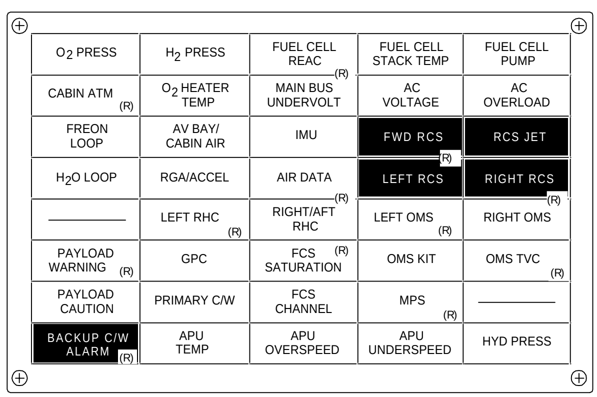
From an entry interface of 400,000 feet, the orbiter is controlled in roll, pitch, and yaw with the aft RCS jets. The orbiter's ailerons are used starting at a dynamic pressure (q-bar) of 2 pounds per square foot (psf), and the aft RCS roll jets are deactivated at a q-bar of 10 psf. At a q-bar of 2 psf, the orbiter's elevons are active, and the aft RCS pitch jets are deactivated at a q-bar of 40 psf. The rudder is activated at Mach 5.0, and the aft RCS yaw jets are deactivated at Mach 1 (approximately 45,000 feet).



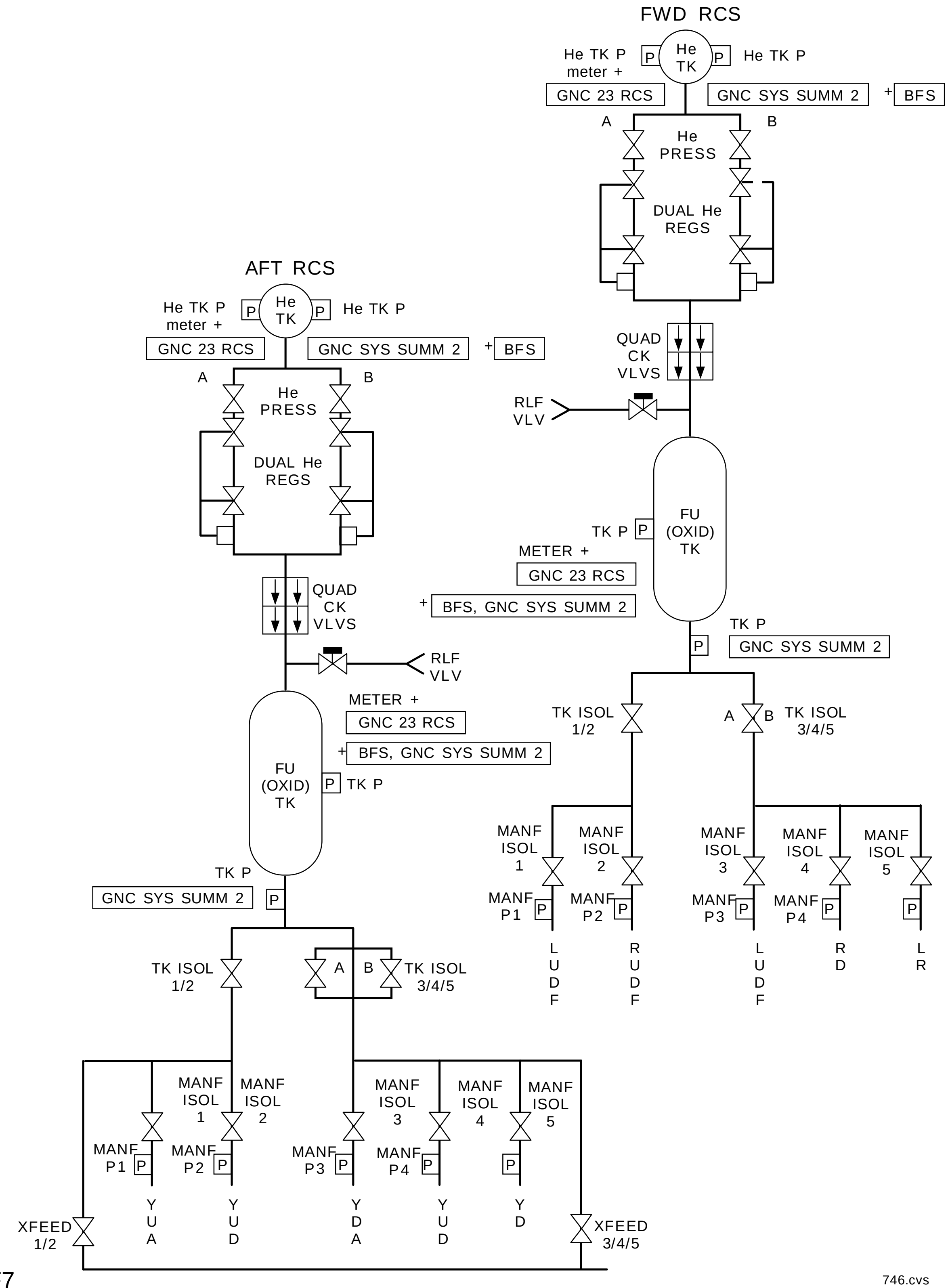
Nominal Ascent Profiles

RCS Caution and Warning Summary

- There are class 2 and 3 alerts for the RCS.
- Class 2 alerts can occur in all the OPS and generate a MASTER ALARM light and tone and a light on the Caution and Warning matrix on panel F7.
- A class 3 alert is generated by the primary GNC or SM software in OPS 2 and 8 or by the BFS software in other OPS.
- The red *LEFT RCS, FWD RCS,* or *RIGHT RCS* light will illuminate if propellant tank ullage pressure is less than 200 psia or higher than 312 psia. Exceeding a preset difference of 9.5 percent between fuel and oxidizer propellant quantities will also illuminate the appropriate one of these lights, activate the *BACKUP C/W ALARM*, and send a fault message to the CRT.
- RCS jet failure illuminates the yellow *RCS JET* and red *BACKUP C/W ALARM* lights and sends a fault message to the CRT.
- An F(L,R) RCS X JET (where X=U,D,L,R,F or A) fault message will be displayed in the PASS when a jet fail ON, jet fail OFF, or jet fail LEAK occurs. (OPS 1,2,3,6,8)
- An F(L,R) JET fault message will be displayed in the BFS when a jet fail ON or jet fail OFF occurs when the BFS is engaged. (OPS 1,3,6)
- An F(L,R) He P fault message will be displayed when helium pressure (FU or OX) in the affected pod is below 500 psi. (PASS OPS 2,8; BFS OPS 1,3,6)
- An F(L,R) RCS LEAK fault message will be displayed when propellant quantities (FU and OX) in any one pod differ by more than 9.5 percent. (PASS OPS 2,3,8; BFS OPS 1,3,6)
- An F(L,R) RCS PVT fault message will be displayed in the PASS when there is loss of pressure or temperature data that is needed for RCS quantity calculations. (OPS 2,3,8)
- An F(L,R) RCS TK P fault message will be displayed when propellant tank pressure exceeds upper (312 psi) or lower (200 psi) limits. (PASS OPS 2,8; BFS OPS 1,3,6)
- A G23 RCS SYSTEM F(L,R) fault message will be displayed in the PASS when propellant tank outlet pressure exceeds upper (300 psi) or lower (220 psi) limits or propellant tank temperature exceeds upper (90° F) or lower (50° F) limits. (OPS 2,8)
- An RCS PWR FAIL fault message will be displayed in the PASS when there is loss of valve logic power to the manifold isolation valves. (OPS 1,2,3,6,8)
- An RM DLMA MANF fault message will be displayed in the PASS when a dilemma is detected in the manifold valve status (FU and OX valve positions disagree). (OPS 1,2,3,6,8)
- An S89 PRPLT THRM RCS fault message will be annunciated when the temperature in the affected structure exceeds I-loaded upper or lower limits. (OPS 2)

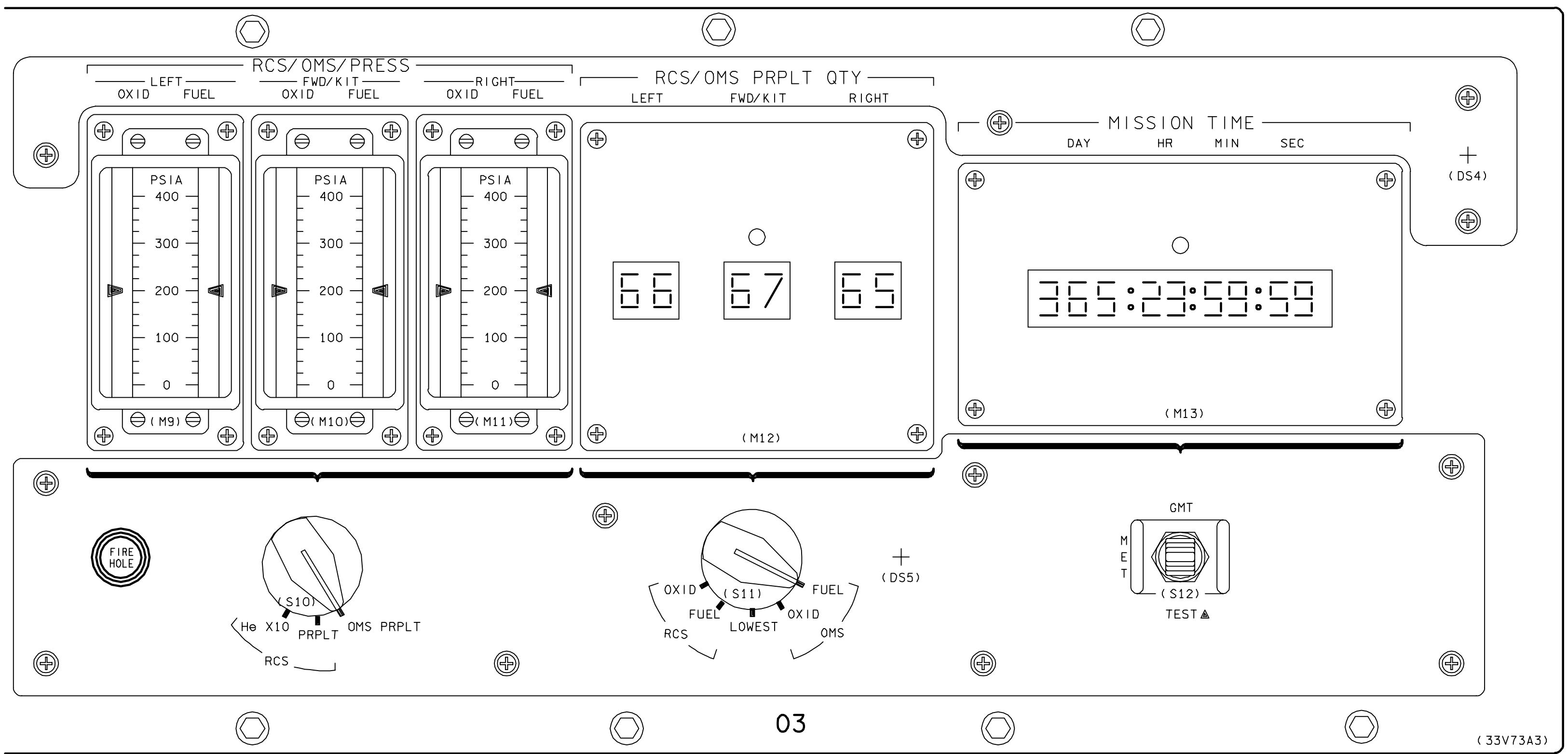


RCS Caution and Warning Lights on Panel

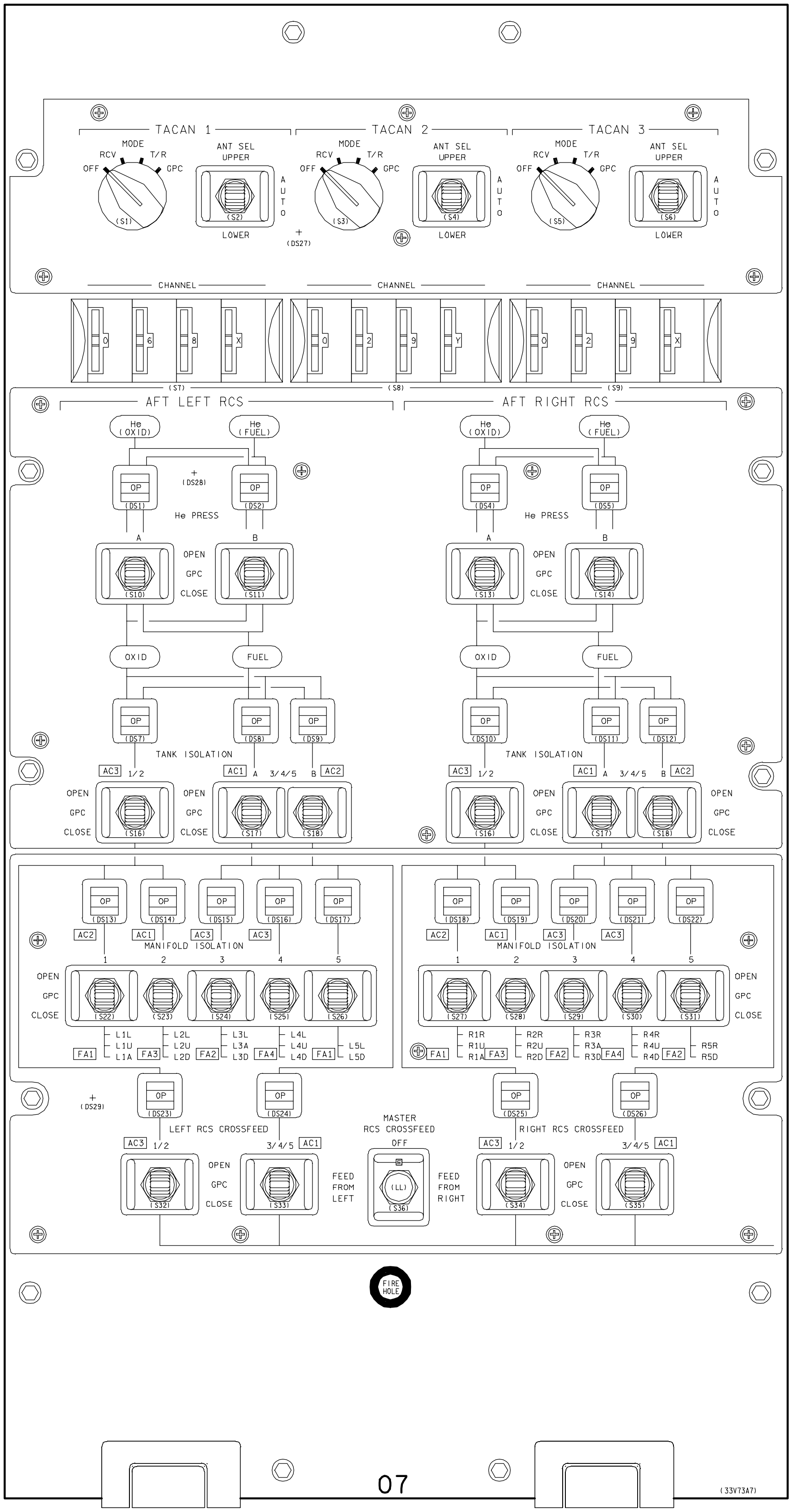


F7

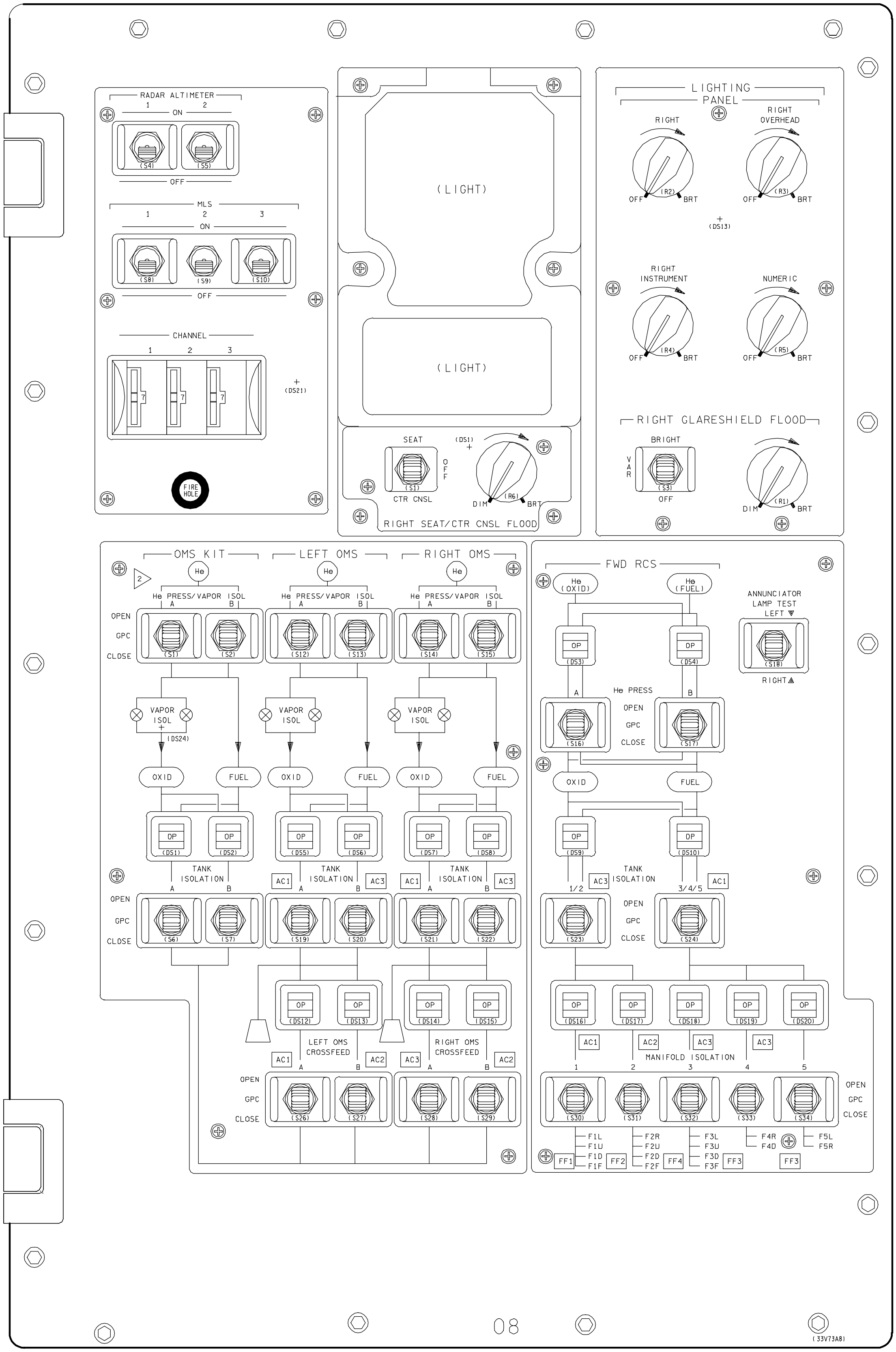
Reaction Control System


RCS/OMS/PRESS
LEFT
OXID
FUEL
FWD/KIT
OXID
FUEL
RIGHT
OXID
FUEL
PSIA
400
300
200
100
0
(M9)
(M10)
(M11)
RCS/OMS PRPLT QTY
LEFT
FWD/KIT
RIGHT
66
67
65
(M12)
MISSION TIME
DAY
HR
MIN
SEC
365:23:59:59
(M13)
(DS4)
FIRE HOLE
(S10)
He X10
PRPLT
OMS PRPLT
RCS
OXID
FUEL
(S11)
LOWEST
FUEL
OXID
RCS
OMS
(DS5)
GMT
MET
(S12)
TEST
O3
(33V73A3)

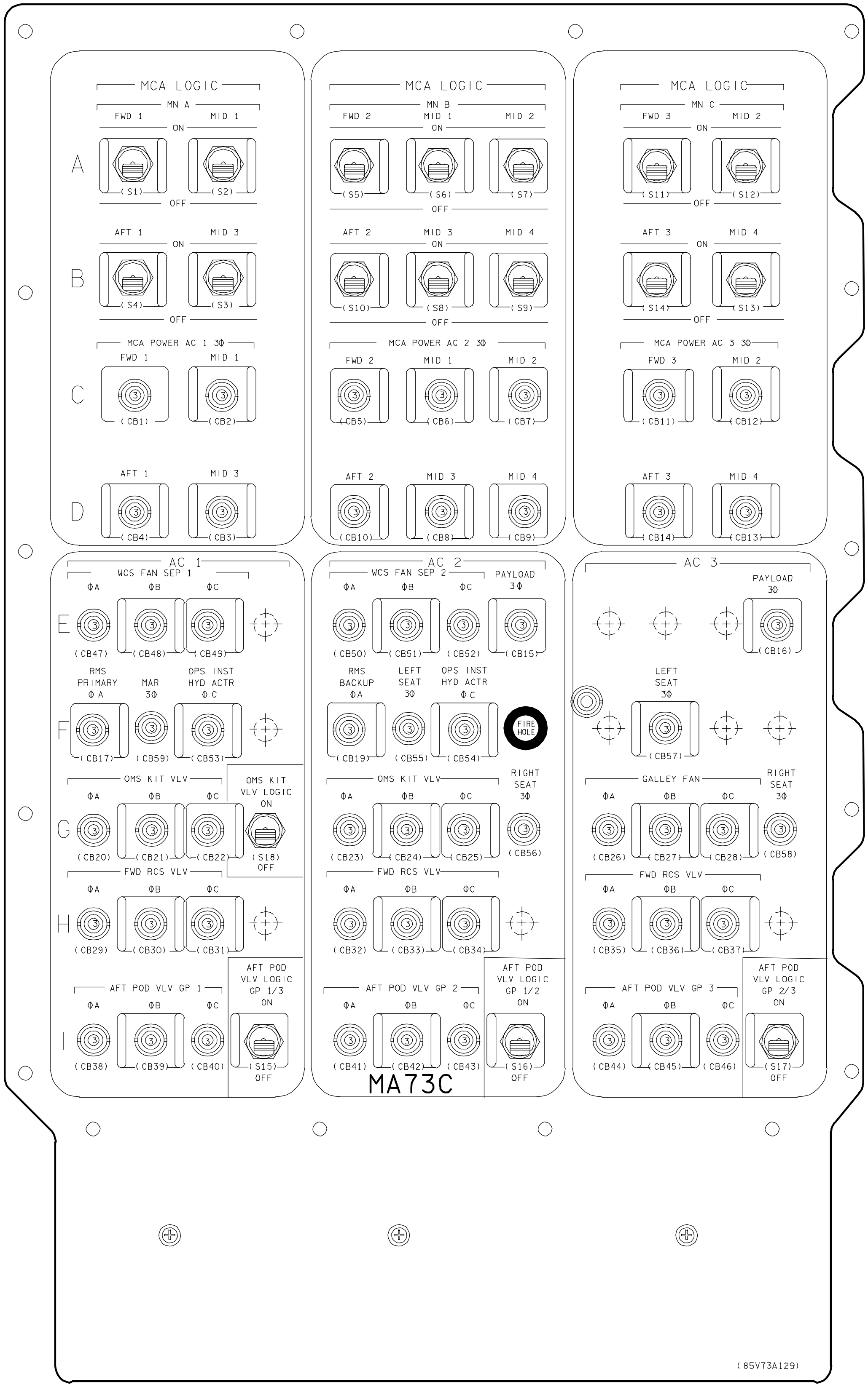
Panel O3


TACAN 1
TACAN 2
TACAN 3
MODE
OFF
RCV
T/R
GPC
ANT SEL
UPPER
AUTO
LOWER
CHANNEL
AFT LEFT RCS
AFT RIGHT RCS
He (OXID)
He (FUEL)
He PRESS
OPEN
GPC
CLOSE
OXID
FUEL
TANK ISOLATION
1/2
3/4/5
MANIFOLD ISOLATION
LEFT RCS CROSSFEED
RIGHT RCS CROSSFEED
MASTER
RCS CROSSFEED
FEED FROM LEFT
FEED FROM RIGHT
FIRE HOLE
O7

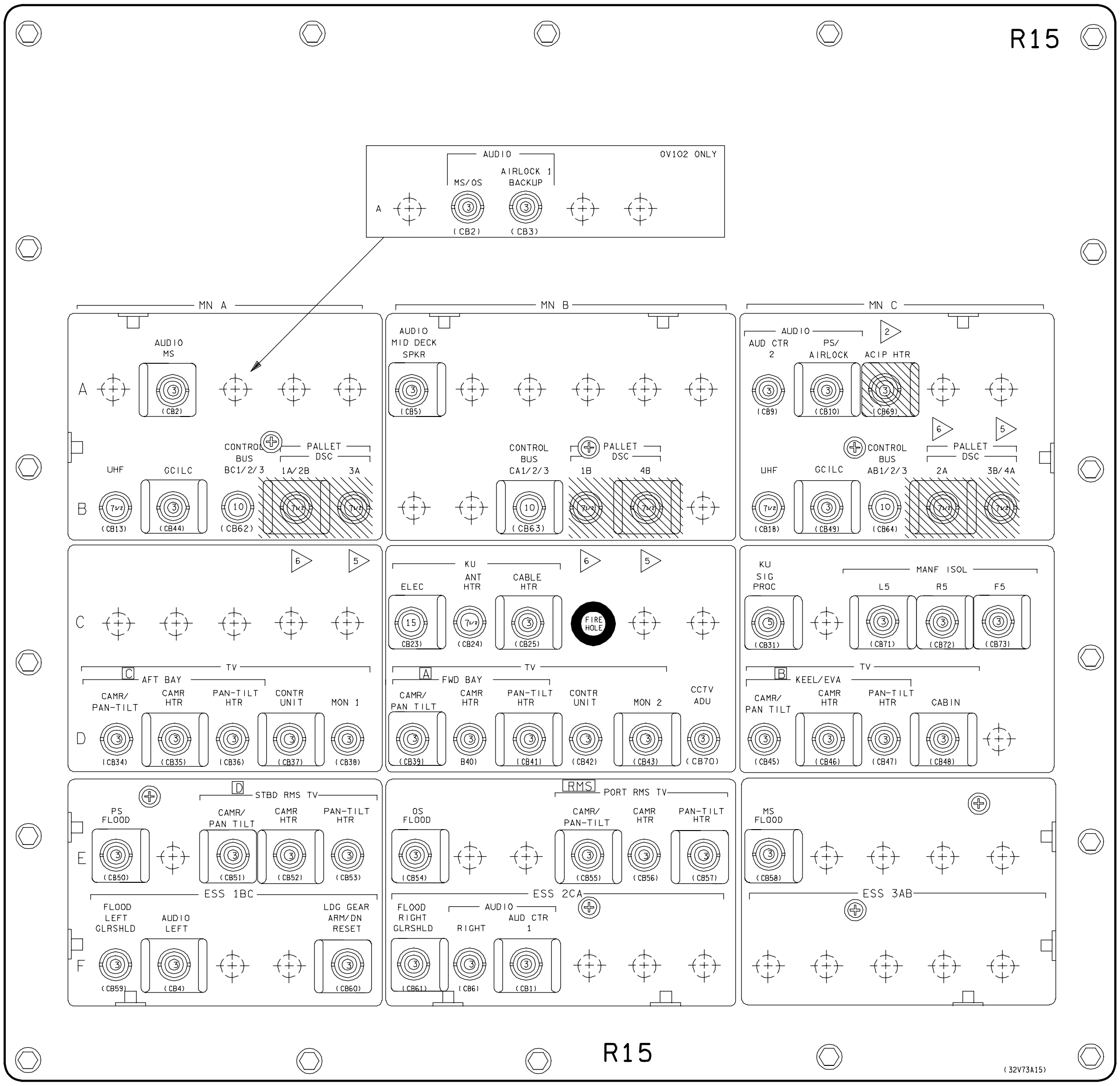
Panel O7


RADAR ALTIMETER
1
2
ON
(S4)
(S5)
OFF
MLS
1
2
3
ON
(S8)
(S9)
(S10)
OFF
CHANNEL
1
2
3
(DS21)
FIRE HOLE
(LIGHT)
(LIGHT)
SEAT
(DS1)
OFF
(S1)
CTR CNSL
DIM
(R6)
BRT
RIGHT SEAT/CTR CNSL FLOOD
LIGHTING
PANEL
RIGHT
RIGHT OVERHEAD
OFF
(R2)
BRT
OFF
(R3)
BRT
(DS13)
RIGHT INSTRUMENT
NUMERIC
OFF
(R4)
BRT
OFF
(R5)
BRT
RIGHT GLARESHIELD FLOOD
BRIGHT
VAR
(S3)
OFF
DIM
(R1)
BRT
OMS KIT
LEFT OMS
RIGHT OMS
He
He PRESS/VAPOR ISOL
A
B
OPEN
GPC
CLOSE
(S1)
(S2)
(S12)
(S13)
(S14)
(S15)
VAPOR ISOL
(DS24)
OXID
FUEL
OP
(DS1)
(DS2)
(DS5)
(DS6)
(DS7)
(DS8)
TANK ISOLATION
AC1
AC3
(S6)
(S7)
(S19)
(S20)
(S21)
(S22)
(DS12)
(DS13)
(DS14)
(DS15)
LEFT OMS CROSSFEED
RIGHT OMS CROSSFEED
AC2
(S26)
(S27)
(S28)
(S29)
FWD RCS
He (OXID)
He (FUEL)
ANNUNCIATOR LAMP TEST
LEFT ▼
(S18)
RIGHT ▲
(DS3)
(DS4)
He PRESS
(S16)
(S17)
(DS9)
(DS10)
1/2
3/4/5
(S23)
(S24)
(DS16)
(DS17)
(DS18)
(DS19)
(DS20)
MANIFOLD ISOLATION
1
2
3
4
5
(S30)
(S31)
(S32)
(S33)
(S34)
F1L
F1U
F1D
F1F
F2R
F2U
F2D
F2F
F3L
F3U
F3D
F3F
F4R
F4D
F5L
F5R
FF1
FF2
FF4
FF3
FF3
O8
(33V73A8)

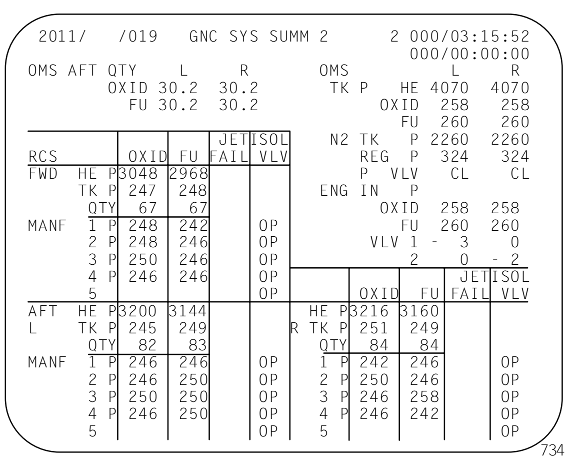
Panel O8


MCA LOGIC
MN A
FWD 1
MID 1
ON
OFF
AFT 1
MID 3
MCA POWER AC 1 3Φ
MN B
FWD 2
MID 2
AFT 2
MID 4
MCA POWER AC 2 3Φ
MN C
FWD 3
AFT 3
MCA POWER AC 3 3Φ
A
B
C
D
AC 1
WCS FAN SEP 1
AC 2
WCS FAN SEP 2
PAYLOAD 3Φ
AC 3
E
F
G
H
I
RMS PRIMARY ΦA
MAR 3Φ
OPS INST HYD ACTR ΦC
RMS BACKUP ΦA
LEFT SEAT 3Φ
FIRE HOLE
OMS KIT VLV
OMS KIT VLV LOGIC
RIGHT SEAT 3Φ
GALLEY FAN
FWD RCS VLV
AFT POD VLV GP 1
AFT POD VLV GP 2
AFT POD VLV GP 3
AFT POD VLV LOGIC GP 1/3
AFT POD VLV LOGIC GP 1/2
AFT POD VLV LOGIC GP 2/3
MA73C
(85V73A129)

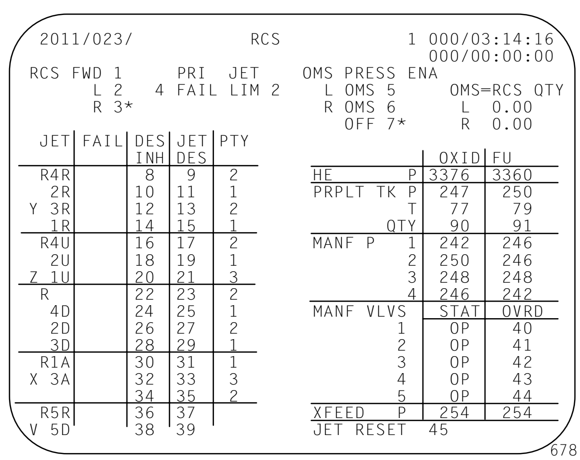
Panel MA73C



Panel R15



PASS GNC SYS SUMM 2 Display



SPEC 23 RCS Display

RCS Summary Data

- The RCS consists of forward and aft systems of control jets, propellant storage tanks, and distribution networks located in three separate vehicle modules.
- The forward module is in the nose area, and the left and right aft modules are in the left and right OMS/RCS pods near the tail of the vehicle.
- The forward RCS has 14 primary and two vernier jets; the aft RCS has 12 primary and two vernier jets per pod.
- Primary jets provide 870 pounds each of vacuum thrust; vernier 24 each. The vernier jets are only used on orbit for fine attitude control.
- Each jet is permanently fixed to fire in a general direction. The selective firing of individual jets or combinations of jets provides thrust for attitude control, rotational maneuvers, and translational maneuvers.
- Manual RCS use is through the rotational and translational hand controllers, and automatic use is handled by the digital autopilot and the general purpose computers.
- Nominal uses of the RCS include mated coast, ET separation, and trim residuals during ascent; attitude control and maneuvers in orbit; and entry flight control and center of gravity management.
- Off-nominal uses include single-engine roll control, RCS wraparound during OMS burn, OMS completions, and abort dumps
- RCS jets are fueled with N_2O_4 and MMH. The propellants are liquid at room temperature and hypergolic.
- Propellant quantities are monitored on panel O3.
- Most RCS control switches are distributed over panel O7 and O8.
- Thermal control switches are located on panel A14.
- RCS information display and control is through the GNC SYS SUMM 2 and SPEC 23 RCS displays.

RCS Rules of Thumb

- 1% RCS prop = 1 fps ΔV.
- 1% RCS prop = 22 lbs.
- 1,000 lbs of ARCS prop moves X c.g. 1.2. in, Y c.g. ± 0.4 in.
- 1,000 lbs of FRCS prop moves X c.g.-3.5 in.
- ARCS max blowdown qty 24%.
- FRCS max blowdown qty 22%.
- Loss of a single downfiring vernier jet is loss of vernier mode.
- If fuel tank pressure is 20 psi higher than the oxidizer tank pressure, then verniers are no-go.
- Always secure the RCS from the manifolds up to the helium tanks.
- Always open the RCS from the helium tanks down to the manifolds.
- A momentary barberpole talkback may be seen when adjacent “A” or “B” RCS helium isolation valves are operated due to vibration form the operating valve.