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A Survey on Reaction Control System (RCS)

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Abstract

This document gives Information About the Reaction Control Systems used for space shuttle for Maneuvering, Steering and Attitude control of the Spacecraft during its flight.

Keywords: *RCS; Maneuvering; Vernier.*

1. Introduction

A **reaction control system** (**RCS**) is a subsystem of a spacecraft whose purpose is attitude control and steering by the use of thrusters. A RCS system provides little amount of thrust in any desired direction or combination of directions. A RCS is also capable of providing torque to allow control of rotation (roll, pitch, and yaw). This is in contrast to a spacecraft's main engine, which only provides thrust in one direction.

RCS systems use combinations of large and small vernier thrusters, to let different levels of response from the combination. A vernier thruster is used on a spacecraft for attitude control, is a smaller thrust motor and is used for fine adjustments to the attitude of a spacecraft. A vernier rocket is used for attitude control in alignment with a bigger spacecraft propulsion engine. Due to their weight and the plumbing required for their operation, vernier rockets are randomly used.

2. Basic Structure of RCS

The orbiter's reaction control system comprises the forward and aft RCS. The forward RCS is located in the forward fuselage nose area. The aft (right and left) RCS is located with the orbital maneuvering system in the OMS/RCS pods.

Each RCS consists of high-pressure gaseous helium storage tanks, pressure regulation and relief systems, a fuel and oxidizer tank, a system that distributes propellant to its engines, and thermal control systems (electrical heaters).

The forward and aft RCS units provide the thrust for attitude (rotational) maneuvers (pitch, yaw and roll) and for small velocity changes along the orbiter axis (translation maneuvers).

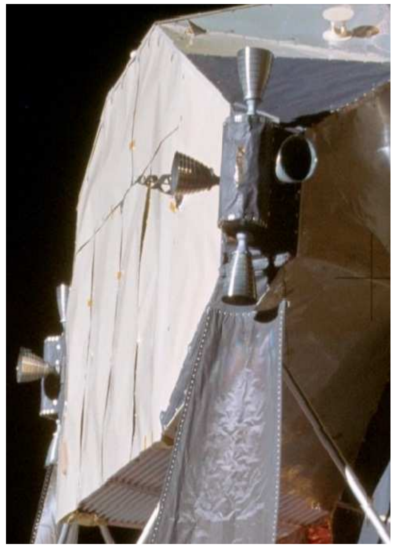

Fig 1 RCS blocks on the Apollo Lunar Module

The ascent profile of a mission determines the interaction of the RCS units, which depends on the number (1 or 2) of OMS thrusting periods. After main engine cutoff, the forward and aft thrusters are used to maintain attitude hold until external tank separation. Then the RCS provides a minus 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-1 thrusting attitude.

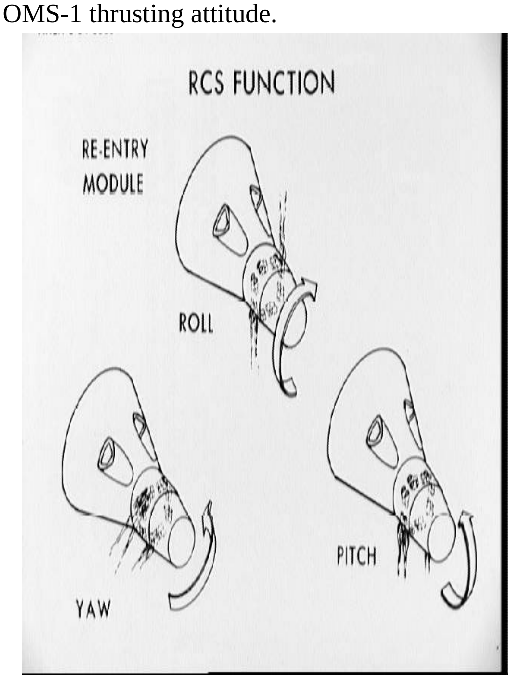

Fig 2 Functions of RCS during Re-Entry

The first thrusting period of the orbital maneuvering system (OMS-1) uses both OMS engines to raise the orbiter to a predetermined elliptical orbit. During the OMS-1 thrusting period, vehicle attitude is maintained by gimbaling (swiveling) the OMS engines. The reaction control system normally does not operate during an OMS thrusting

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period. If, during an OMS thrusting period, the gimbal rate or gimbal limits are exceeded, RCS roll control would be required; or if only one OMS engine is used during a thrusting period, RCS roll control may be required.

For the deorbit thrusting maneuver, the two OMS engines are used. Target data for the deorbit maneuver is computed on the ground, loaded in the onboard general-purpose computers by uplink and voiced to the flight crew for verification of loaded values. The flight crew then initiates an OMS gimbal test by item entry in the CRT keyboard unit.

Before the deorbit thrusting period, the flight crew moves the spacecraft to the desired attitude using the thrusters. After the OMS thrusting period, the RCS is used to null any residual velocities, if required. The spacecraft is then moved to the proper entry interface attitude using the RCS. The remaining propellants aboard the forward RCS are dumped by burning the propellants through the forward RCS yaw thrusters before entry interface if orbiter center-of-gravity control is necessary.

The aft RCS plus X jets can be used to complete any OMS deorbit thrusting period 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.

3. Pressurization System

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

The helium storage tanks are composite spheres and consist of a titanium liner with a Kevlar structural overwrap having a dry weight of 24.2 pounds. Each helium tank's diameter is 18.71 inches and volume of 3040 cubic inches. Each helium tank is pressurized to 3600 psi.

There are two parallel helium isolation valves between the helium tanks and the pressure regulators. When open, the helium isolation valves allows the helium pressure to flow into the propellant tank. The helium isolation valves are controlled by the forward RCS.

A helium pressure relief valve assembly is located between the check valve assemblies and propellant tank. Each valve consists of a burst diaphragm, relief valve and a filter. The non-fragmentation diaphragm provides a positive seal against helium leakage and will rupture between 324 to 340 psi. The filter prevents any particles of the burst diaphragm from reaching the relief valve seat. The relief valve relieves at 315 psi minimum.

4. Propellant Systems

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

Each RCS contains two spherical propellant tanks, one for fuel and one for oxidizer, which are constructed of titanium.

The Full load of the forward and aft RCS tanks in each pod is 1460 pounds in the oxidizer tanks & the dry weight of the forward tanks is 70 pounds and the nominal full load of 925 pounds in the fuel tanks with the dry weight of the aft tanks measures 77 pounds.

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 thrusters on demand. The forward RCS propellant tanks have propellant acquisition devices designed to operate in a low-gravity environment, whereas the aft RCS propellant tanks are designed to operate in both high and low gravity.

A compartmental tank with individual screen devices supplies propellant. The devices are made of stainless steel and are placed in the titanium tank shells. A barrier divides the upper and lower compartments.

At orbiter and external tank separation and for orbital operations, propellant flows from the upper compartment bulk region, to the upper compartment transfer tube and into the lower compartment bulk region. This flow continues until a gas is absorbed into the upper compartment device and transferred to lower compartment.

The aft RCS propellant tanks incorporate an entry collector, sinks and gas traps to ensure proper operation during abort and entry mission phases. Because of these components, the aft RCS propellant tanks are approximately 7 pounds heavier than the forward RCS propellant tanks.

The left, forward and right RCS fuel and oxidizer tank pressures can be monitored on panel O3. When the rotary switch on panel O3 is positioned to RCS propellant, the pressures is displayed on the RCS/OMS press fuel. The pressures will light up the left RCS, forward RCS or right RCS red caution & warning light on panel F7, respectively, if that module's tank's pressure is below 200 psi or above 312 psi.

RCS QUANTITY MONITOR

The RCS quantity monitor sequence uses the general-purpose computer to calculate the usable percent of fuel and oxidizer in each RCS module. The RCS 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 (leakage detection).

The calculations include effects of helium gas compressibility, helium pressure vessel expansion at high pressure, oxidizer vapour pressure as a function of temperature, and oxidizer and fuel density as a function of temperature and pressure. 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.

The left, right and forward RCS quantities are displayed to the flight crew on panel O3. When the rotary switch on panel O3 is positioned to the RCS fuel or oxide position, the RCS/OMS qty meters on panel O3 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 RCS/OMS propellant quantity, left, fwd and right meter.

The left, right and forward RCS quantities also are sent to the cathode ray tube, and in the event of failures, substitution of alternate measurements and the corresponding quantity will be displayed on the CRT. 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 pressure is above 312 psi. The caution and warning red light on panel F7 is illuminated for the respective forward, left or right RCS, and a fault message is sent to the CRT. When the tank pressure returns below this limit, the close command is removed.

Exceeding a preset absolute difference of 12.6 percent between the fuel and oxidizer propellant masses will illuminate the respective left RCS, right RCS or fwd RCS red caution and warning light on panel F7; activate the backup caution and warning light; and cause a fault message to be sent to the CRT. A bias of 12.6 percent is added when a leak is detected so that subsequent leaks in that same module may be detected.

5. RCS Engines

Each RCS engine contains a fuel and an oxidizer valve, combustion chamber, nozzle, injector head assembly and electrical junction box.

Each primary RCS engine 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 permits the respective propellant to flow through the injector into the combustion chamber.

Each of the vernier RCS engine has one fuel and oxidizer solenoid-operated poppet valves. The valves are energized open by an electrical thrust-on command. When the thrust-on command is terminated, the valves are de-energized and closed by spring and pressure loads.

Each of the six vernier RCS engines has a single pair of fuel and oxidizer injector holes slanted to cause

encroachment of the fuel and oxidizer streams for combustion.
The nozzle of each RCS engine 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 2000 to 2400 F from radiating into the orbiter structure.

6. Heaters

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 thruster.
Each primary RCS thruster has a 20-watt heater, except the four aft-firing thrusters, which have 30-watt heaters. Each vernier RCS thruster 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 thruster housing contains heaters for the yaw, pitch up, pitch down and vernier thrusters in addition to the aft OMS/RCS drain and purge panels. The OMS/RCS heater switches are located on panel A14.
The forward RCS panel heaters are controlled by the fwd RCS auto A, B, off switch on panel A14. When the fwd RCS switch is positioned to auto A or B, 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 removes all electrical power from the forward RCS heaters.
The aft RCS heaters are controlled by the left pod auto A and auto B and right pod auto A and auto B switches on panel A14. When the switches are positioned to either auto A or auto B, 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 thruster 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 thruster automatically control the individual heaters on each thruster. The primary RCS thruster heaters turn on between approximately 66 to 76 F and turn off between approximately 94 to 109 F. The vernier RCS thruster 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 thruster heaters. The 1, 2, 3, 4 and 5 designations refer to propellant manifolds. There are two to four thrusters per manifold.

7. Applications of RCS

Reaction control systems are used:

- For attitude control during re-entry;
- For station keeping in orbit;
- For close maneuvering during docking procedures;
- For control of orientation, or 'pointing the nose of the spacecraft;
- As a backup means of deorbiting.

8. Conclusion

The Reaction control system for the space craft is the primary flight control systems for the altitudes above 70,000 ft. after all its engines except the main engine are expelled out in staging process. RCS is for maneuvering, steering and attitude control for that processes. Hence, a Reaction control system is useful for Attitude control and re-entry purpose.

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