### COMPONENT DESCRIPTIONS

APOLLO FUEL CELL



16.218

# Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

EAST HARTFORD, CONNECTICUT

### COMPONENT DESCRIPTIONS

APOLLO FUEL CELL

### H<sub>2</sub> PUMP-SEPARATOR

### 1. Function

- Circulates  $H_2$  from fuel cell stack through condenser, regenerator and inline heater, back to stack.
- Removes free water from H<sub>2</sub> loop and discharges to S/C water system.

### 2. Description - Block I

- a) H<sub>2</sub>O Separator Section
  - . H<sub>2</sub> and entrained free H<sub>2</sub>O passes through 100 micron filter screen into separator section.
  - Rotating metal sponge allows H<sub>2</sub> to pass through into pump section but causes free water to be slung to periphery of separator cup.
  - . Labyrinth seal prevents H<sub>2</sub>O carry-over into pump section.
  - . Total pressure of rotating H<sub>2</sub>O "doughnut" in cup, measured by stationary probes, is applied to H<sub>2</sub>O discharge valve diaphragm.
  - . Whenever H2O total pressure exceeds H2 static pressure by preset amount, H2O discharge valve opens to permit flow to S/C H2O system.
  - . Check valve prevents H2O back flow into separator during launch (6.5 minute storage capacity).

### b) Pump Section

. Comprised of 3 carbon vanes, aluminum rotor, steel liner and side plates.

### c) Drive Motor

. Twenty two-pole, 400 cps, 3 phase induction motor direct drives pump and separator at approximately 2200 rpm.

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- . Recirculating H<sub>2</sub> and H<sub>2</sub>O vapor passes through motor, to avoid rotating shaft seals.
- . Motor stator varnish impregnated for moisture resistance.

### d) Mechanical

Common motor, pump, separator shaft turns in three grease-packed, sealed ball bearings.

### 3. Description - Block II

### a) H<sub>2</sub>O Separator Section

Same as Block I except 100 micron filter at inlet replaced by 40 micron filter between separator probes and H2O discharge valve.

### b) Pump Section

Same as Block I except incorporates fixed internal bypass bleed to achieve proper flow match with Block II H<sub>2</sub> circulation loop.

### c) Drive Motor

- . Four pole 400 cps, 3 phase induction motor operates at approximately 11,500 rpm.
- . Recirculating H2 and H2O vapor passes through motor, to avoid rotating shaft seals.
- . Motor stator encapsulated in epoxy to provide increased moisture resistance.
- . Electrical connector sealed from hot wet H<sub>2</sub> by static o-seal.

### d) Mechanical

- 5.3: 1 reduction gear between motor and pump incorporates polyurethane drive pinion; steel driven gear.
- Pump-separator ass'y and motor assembly each turn in own pair of dry-lube ball bearings.

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BLOCK I

### HYDROGEN CIRCULATING PUMP & WATER SEPARATOR



### Hydrogen Pump-Separator Assembly

The pump-separator circulates the primary loop hydrogen-water mixture and removes free water from the hydrogen gas stream. The hydrogen pump-separator assembly consists of a vane pump to handle wet hydrogen, a centrifugal water separator, and a 400-cycle, 200/115 volt, 3-phase drive motor.

BLOCK I



H\_ PUMP-SEPARATOR

BLOCK II



### GLYCOL PUMP

### 1. Function

Circulates glycol/water coolant through condenser, regenerator, preheaters, and S/C radiators.

### 2. Description - Block I

- a) Pump
  - . 40 micron filter of 0.6 in.<sup>2</sup> effective area upstream of pumping section.
  - . Pump cartridge comprised of four steel vanes, steel rotor, steel liner, leaded bronze bearings and side plates. All clearances fixed.
  - . Incorporates a fixed internal bypass bleed to achieve proper flow-pressure schedule.

### b) Motor

- . Eight-pole, 400 cps, 3 phase induction motor direct drives pump at approximately 5800 rpm.
- . Motor rotor is submerged in pumped fluid to avoid rotating shaft seals.
- . Motor stator is "canned" in stainless steel to isolate windings and electrical connector from pumped fluid.
- . Rotor shaft turns in a pair of ball bearings, lubricated by pumped fluid.

### 3. Description - Block II

### a) Pump

- . 75 micron filter of 6.0 in.<sup>2</sup> effective area, upstream of pumping section.
- . Pump cartridge comprised of a pair of steel gears, invar liner, carbon bearing and side plates. All clearances fixed.

Gear tip clearance adjusted at ass'y to achieve proper flow-pressure schedule.

### b) Motor

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- . Same as Block I except rotor turns in a pair of carbon journal bearings.
- 4. Description Block I Retrofit Pump
  - a) Pump
    - Same as Block II except gear tip clearance fixed and a fixed internal bypass bleed is used to achieve proper flow-pressure schedule.
  - b) Motor
    - Same as Block I.

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### Glycol Pump Assembly

The glycol pump circulates a glycol/water mixture through the secondary coolant loop of the powerplant to the spacecraft radiator. This component is a vane pump driven by a three-phase, 400-cycle, wye-connected induction motor.

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### BLOCK I





### PRIMARY REGENERATOR BYPASS VALVE

### 1. Function

Controls temperature of fuel cell stack by scheduling flow of recirculated H<sub>2</sub> through (or bypass around) the primary regenerator.

### 2. Description

- . H2 flow from fuel cell stack flows over bimetal thermostat.
- . Thermostat positions regenerator and bypass valves to obtain correct regenerator flow (full flow through regenerator at low stack temperature, full bypass flow at high stack temperature, mixed flow within controlled temperature range).

### 3. Changes Between Block I and Block II

- . Cover clamped in Block I, welded in Block II.
- . Block II has contoured bypass valve to optimize schedule for Block II performance characteristics.

## PRIMARY REGENERATOR BYPASS VALVE

BLOCK I







### SECONDARY REGENERATOR BYPASS VALVE

### 1. Function

Controls temperature of H<sub>2</sub> plus H<sub>2</sub>O exiting condensor by scheduling flow of glycol/water through (or bypass around) the secondary regenerator.

### 2. Description

- . H<sub>2</sub> from condensor flows over fluid filled thermostat.
- . Thermostat positions regenerator and bypass values to obtain correct regenerator flow to maintain constant condenser-exit  $H_2$  temperature.

### 3. Changes Between Block I and Block II

Valves recontoured to achieve optimum stability for Block II flow schedule.





### Secondary Bypass Control Valve

The secondary bypass control modulates the coolant flow passing through the cold side of the secondary regenerator to maintain the condenser outlet temperature within a specified range. The control senses the condenser exit hydrogen temperature and bypasses more of the glycol flow if this temperature is too high, or less if the temperature is too low.

This unit uses a liquid-filled bellows and subassembly to sense hydrogen gas temperature at the condenser exit. Expansion of the liquid in the bellows actuates a double poppet valve in order to maintain a preset exit temperature.

### PRESSURE REGULATORS

### 1. Function

- a) Inert-Gas Regulator
  - . Maintains preset N2 blanket pressure regardless of N2 supply pressure and demand flow.

### b) Reactant-Gas Regulators

. Maintain preset  $H_2$  - to -  $N_2$  and  $O_2$  - to -  $N_2$  differential pressures regardless of reactant supply pressures and demand flows.

### 2. Description

- a) Inert-Gas Regulator
  - Regulated pressure, sensed at evacuated bellows, balanced against spring.
  - . Error in regulated pressure causes bellows to compress or extend, opening vent or supply valves, respectively, causing regulated pressure to decrease or increase, restoring balance.
  - . Double bellows for redundancy.
  - . Resilient-seat valves are leak-tight when closed.

### b) Reactant-Gas Regulators

- Regulated pressure sensed at bellows, balanced against spring and regulated N2 pressure (i.e., difference between reactant and N2 pressure balanced against spring).
- Error in regulated pressure causes bellows to compress or extend, opening vent or supply valves, respectively, causing regulated pressure to decrease or increase, restoring balance.
- . Double bellows for redundancy.
- Resilient-seat valves are leak-tight when closed.

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NITROGEN PRESSURE REGULATOR

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### **REACTANT PRESSURE REGULATOR**



### PURGE VALVES

### 1. Function

. Manually actuated solenoids open values to vent reactants overboard, to purge impurities from fuel cell reactant-gas manifolds.

### 2. Description

- . Spherical steel ball seats against resilient orifice.
- . Ball held against orifice by force of spring and force due to reactant manifold pressure.
- . Solenoid armature pushes ball off seat to cause overboard reactant flow.
- . Purge flow rate controlled by fixed bleed downstream of valve orifice.
- . Pressure switch closes whenever valve is open.

### 3. Changes Between Block I and Block II

- . Larger ball and seat permits better manufacturing quality control.
- . Radial guide surrounds ball to assure proper seating alignment.
- . Inlet filter changed from .036 in. and 100 micron to .35 in. and 18 micron.
- . Inlet and outlet fittings made integral with body to minimize chip-generation during installation.
- Solenoid housing changed from plated carbon steel to stainless steel.









### N<sub>2</sub> FILL VALVE

### 1. Function

• Manually actuated solenoid value admits N2 from GSE supply to Powercel N2 tank and prevents overboard leakage from tank when GSE supply removed.

### 2. Description

- a) Block I
  - . Tapered-pintle valve closes against preformed plastic seat.
  - . Valve held against seat by forcing spring and force due to N2 tank pressure.
  - . Solenoid armature pulls valve away from seat to permit N<sub>2</sub> flow into tank from GSE supply.

### b) Block II

Same as Block I except:

- . Dual redundant valves and solenoids for increased reliability.
- . 18-micron filters at inlet and outlet and between redundant valves.
- . All welded construction to eliminate possibility of leakage to ambient.
- . Inlet and outlet fittings made integral with body to minimize chip-generation during installation.





### IN-LINE HEATER

### 1. Function

Provides heat input to fuel cell stack whenever external load otherwise too low for self-sustaining operation.

### 2. Description

- . Electrical resistance heater element submerged in H2 recirculation loop, at inlet to fuel cell stack.
- . Solid-state control unit senses temperature of recirculating H<sub>2</sub> leaving fuel cell stack and connects heater across fuel cell electric output.
- . Control unit powered by fuel cell electric power.
- External switch, in S/C, in series with control unit power supply, must be opened (to prevent heater actuation) whenever fuel cell stack temperature is too low to permit impressing heater electrical load upon fuel cell.



### Inline Heater (Cartridge Heater) and Minimum Power Sustainer

The inline heater and minimum power sustainer provide sufficient heat during low power operation to maintain the power stack operating temperature.

