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PHASE III
BOEING MODEL 2707

SUPERSONIC TRANSPORT DIVISION

D6A10113-1

Phase III

Supersonic Transport Development Program

BOEING MODEL 2707

AIRCRAFT ENGINE INSTALLATION SUBSYSTEM SPECIFICATION

D6A10113-1

PREPARED BY ____________ APPROVED BY ____________

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DDC

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Prepared for

FEDERAL AVIATION ADMINISTRATION

Office of Supersonic Transport Development Program

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THE **BOEING** COMPANY
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ISSUE NO. B

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REVISION RECORD

Original release.

June 30, 1966

Document completely revised to reflect the Phase III Proposal Configuration of the 2707.

September 6, 1966

Document extensively revised to (a) reflect the 2707-100 configuration, (b) incorporate revisions requested by the FAA as documented in D6A10490-1, and (c) incorporate and identify contractual performance and compliance test requirements as documented in D6A10494-1.

December 31, 1966

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1. SCOPE

This specification defines the objectives, criteria, and configuration, and establishes the requirements for performance, design, test, and qualification for the Aircraft Engine Installation Subsystem (AEIS) for the prototype model supersonic transport airplane. Differences between the prototype and production airplanes are described in Supplement I. The subsystem provides the total propulsive power required by the airplane for accomplishing its intended functions. The subsystem also provides mechanical and pneumatic power for supporting airframe accessory, environmental and air inlet subsystems. The subsystem contains the engine, exhaust and thrust reverser assembly, engine accessories, engine mounting provisions, engine controls, cowling, bleed air ducting, instrumentation plumbing and wiring.

The statements printed **in bold face type** in this document are contractual requirements in accordance with D6A10494-1, Prototype Airplane Systems Performance and Compliance Requirements - Phase III Statement of Work. Changes to any of these statements will be contractual changes in accordance with Article XV of the Contract Schedule. With regard to compliance requirements shown **in bold face type** in Sec. 9.0, it should be noted that only that aspect or portion of the compliance requirement applicable to the specific performance requirement of D6A10494-1 is to be considered contractual in the terms stated above.

2. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced herein and the requirements specified by this specification, the requirements of this specification shall take precedence.

2.1 Specifications.

D6A10078-1	31 Dec 1966	Starting Subsystem Specification
D6A10089-1	31 Dec 1966	Accessory Drive Subsystem Specification
D6A10090-1	31 Dec 1966	Aircraft Integrated Data Subsystem Specification
D6A10107-1	31 Dec 1966	Airframe Subsystem Specification
D6A10109-1	31 Dec 1966	Flight Deck Subsystem Specification
D6A10111-1	31 Dec 1966	Propulsion Performance Specification (General Electric)
D6A10112-1	31 Dec 1966	Propulsion Performance Specification (Pratt & Whitney)
D6A10114-1	31 Dec 1966	Air Induction Subsystem Specification

D6A10115-1	31 Dec 1966	Fire Detection & Extinguishing Subsystem Specification
D6A10116-1	31 Dec 1966	Fuel Subsystem Specification
D6A10117-1	31 Dec 1966	Inlet Anti-Icing Subsystem Specification
D6A10118-1	31 Dec 1966	Air Induction Control Subsystem Specification
D6A10119-1	31 Dec 1966	Electrical Power Subsystem Specification
D6A10120-1	31 Dec 1966	Flight Control and Hydraulic Subsystem Specification
D6A10121-1	31 Dec 1966	Environmental Control Subsystem Specification
D6A10180-1	6 Sept 1966	Ground Support Equipment Requirements Specification

2.2 Standards.

None

2.3 Other Publications.

Federal

FAR 25	14 Nov 1965	Federal Aviation Regulation Part 25, Airworthiness Standards: Transport Category Airplanes, including the Tentative Airworthiness Standards for Supersonic Aircraft, dated 1 Nov 1965

The Boeing Company

D6A10198-1	31 Dec 1966	Engine-Airframe Technical Agreement (GE)
D6A10199-1	6 Sept 1966	Engine-Airframe Technical Agreement (P&WA)
D6-16328	28 Sept 1965	Electrical Requirements for Installed Equipment
D6A10064-14	6 Sept 1966	Reliability Analysis Document - Engine Installation and Fire Detection/Extinguishing Subsystems
D6-9458	6 Sept 1966	Maintenance Design Guide - Commercial Supersonic Transport

3. SUBSYSTEM DESIGN OBJECTIVES

3.1 Functions. The aircraft engine installation subsystem shall provide the following functions:

a. Generate, control and transmit thrust to the airframe for airplane flight, ground deceleration, and ground acceleration

b. Transmit engine-generated mechanical power to the airplane accessory drive and air inlet hydraulic control subsystems

c. Transmit engine-generated pneumatic power to the airplane environmental control, air inlet anti-icing and engine cross-starting subsystems

d. Provide integration of the engine installation with the airframe fuel and air inlet subsystems.

3.2 Performance. The performance objectives for the aircraft engine installation subsystem include the following:

a. Satisfactory performance of the subsystem functions over the entire flight operation envelope and environment of the airplane

b. Capability to control each engine independently

c. Capability to support supersonic flight with one engine out

d. Provide pod positioning and contours to achieve favorable airflow to supersonic inlet and lifting surface.

4. SUBSYSTEM DESIGN CRITERIA

4.1 Operability. The allocation of the reliability and maintainability defined herein has been accomplished by analysis and experience and may be revised as long as the overall airplane requirements as specified in specification D6A10107-1 are satisfied. The operability requirements below are dependent, in part, upon the reliability and maintainability definitions listed in Pars. 6.1.1 and 6.1.2 of the specification D6A10107-1. The values included for flight dispatch delays interact so closely with the values included in unscheduled maintenance task time that a change in either will probably require a change in both.

4.1.1 Reliability. After 18 months of scheduled airline operation, flight turnbacks or deviations due to malfunction of the AEIS shall not average more than 0.106 per 1,000 scheduled flights. See Par. 6.3 of D6A10198-1 (GE) or D6A10199-1 (P&WA) for engine reliability values. Dispatch delays caused by malfunction of the AEIS shall not average more than 0.077 per 100 scheduled departures. For reliability purposes, the term flight is interpreted to mean a nominal supersonic flight of 1.75 hr duration. Normal maintenance of the system is assumed.

4.1.2 Maintainability. The AEIS shall be so designed that after 18 months of scheduled airline oepration, the direct maintenance manhours per 1,000 flight hr shall not exceed a mean value of 550, not including servicing of consumables, and the mean unscheduled maintenance task time at a transit or turnaround service shall be 48 min. Refer to Par. 6.5 of specification D6A10198-1 (GE) or D6A10199-1 (P&WA) for engine maintainability requirements.

4.1.2.1 Maintenance and Repair Cycles. Time change items shall be kept to a minimum. Whenever possible component replacement shall be on a failure or impending failure (on condition) basis, rather than on a scheduled or time controlled basis. The scheduled check intervals for the aircraft and the down times established for these checks are shown below. All scheduled maintenance, inspections, and servicing shall be fitted within one of these cycles.

Scheduled Check	Time Interval	Elapsed Time
Transit service	Not applicable	1/2 hr
Turnaround service	Not applicable	1 1/2 hr
Daily check	50 Flight hours	1 hr
Intermediate check	300 Flight hours	4 hr
Periodic check	1,200 Flight hours	16 hr
Basic check	8,400 Flight hours	5 Days

4.1.2.2 Servicing and Access. The following features shall be provided in the aircraft engine installation subsystem:

a. The subsystem and component assemblies shall be readily accessible to the maintenance technician for fault isolation, adjustment, servicing, and replacement.

b. Quick access to accessories and components on the engine shall be provided by non-structural cowl panels that can be opened and removed. No special tools shall be required to release cowl panels.

c. Separate access doors shall be provided in the cowl panels for components requiring frequent servicing or inspections, such as oil tanks and hydraulic reservoirs. Access doors shall be non-structural and provide for quick opening without use of special tools.

d. Pressure and gravity fill provisions shall be furnished for servicing the engine oil system

e. The AEIS shall provide for replacement of the engine as a single functional unit with the capability of allowing either the inlet assembly or exhaust assembly to be removed separately without removing the engine from the airframe.

f. All maintenance and servicing tasks shall be within the skill levels of maintenance personnel trained for subsonic jet aircraft.

4.1.3 Useful Life. The AEIS shall have a useful life commensurate with that of the airplane (50,000 hr) assuming normal maintenance of equipment. The time before overhaul (TBO) of individual components shall be specified in the component specifications when applicable.

4.1.4 Environmental. The AEIS shall perform its intended functions under the applicable operating conditions defined in Par. 3.1.2.4 of specification D6A10107-1.

4.1.4.1 Nacelle Environment (B-2707-100 GE)

The major accessories will be contained in a capsule in which the maximum air temperature shall not exceed 450°F. The maximum temperature of the stagnant air surrounding the accessory capsule shall not exceed 850°F. The engine lube and hydraulic oil tanks will be located outside of the accessory capsule; however, the maximum stabilized oil temperature shall not exceed 425°F for lube oil and 370°F for hydraulic oil.

4.1.4.2 Nacelle Environment (B-2707-100 P&WA)

The maximum air temperature in the area of the accessories is 650°F

4.1.5 Human Performance. Human performance requirements will be considered in the design of the AEIS subsystem and related controls and displays. Specific requirements are as follows:

a. A fail-safe design shall be provided in those areas where failure will disable the system or cause catastrophe through damage to equipment, injury to personnel, or inadvertent operation of critical equipment.

b. The information displayed to an operator shall be limited to that which is necessary for him to perform specific actions or make necessary decisions.

c. Information shall be presented in a directly usable form. Requirements for decoding, transposing, computing, interpolation, etc., shall be kept to a minimum.

d. All controls, displays, or items of equipment that must be located, identified, read, or manipulated shall be appropriately and clearly labeled to facilitate rapid and accurate human performance.

e. Controls shall be selected so that the direction of movement of the control will be consistent with the related movement of an associated display, equipment component, or airplane.

f. Controls shall normally be located adjacent to their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

g. Controls shall be so designed and located that they are not susceptible to being moved accidentally.

h. Labels shall be located in a consistent manner throughout the equipment and system.

i. Labels shall be as concise as possible without distorting the intended meaning or information.

j. Equipment shall be designed to facilitate rapid and positive fault detection and easy removal, replacement, and repair.

k. Access openings provided for adjusting and handling units or components shall be sufficiently large to permit the required operations and where possible, provide an adequate view of the components being maniuplated.

l. Units shall be so located and mounted that access to them can be achieved without danger from electrical charge, heat, or toxic substances.

4.1.6 Safety. The subsystem shall be designed to include safety features which will minimize potentially hazardous conditions to the airplane and personnel in flight and on the ground.

4.1.6.1 Flight Safety. The following features shall be provided to enhance safety of flight:

a. Warning devices and procedures shall provide timely indications so that failures can be detected and corrective action taken before conditions become hazardous.

b. Mechanical position feedback and safety interlocks shall be provided to prevent unsafe operation of the thrust reverser system. (Refer to FAR 25.1155) Means shall be provided to reduce engine thrust to the interlock limit if the reverser moves from the flight deck thrust lever command position.

c. Means shall be provided to prevent inadvertent engine windmill brake actuation.

d. The engine mounts and fittings shall prevent separation of an engine from the airplane under all probable conditions of engine failure, extreme flight maneuvers, or engine fires. In the unlikely event of an engine separating from the airplane, the separation shall not cause structural damage to the primary airframe structure or rupture a fuel tank.

e. Isolation of the engines from the airplane shall be complete so that airplane safety will not be jeopardized by a propulsion pod fire. Firewall isolation shall meet the requirements of FAR 25.1191.

f. Provisions shall be made for detecting fire conditions and for extinguishing engine fires. (Refer to FAR 25.1203.)

g. The engine installation design shall prevent any contained failure condition from progressing beyond that resulting from complete power loss in one engine.

h. Relief panels shall be provided in the cowling to protect against cowl overpressure in the event of bleed air duct failure.

i. The main fuel components of the engines shall be located on the side of the engine for safety in an emergency wheels-up landing and to preclude a fire hazard in the event of fuel leakage.

j. Fuel and oil sumps and drains shall be located remotely from ignition sources.

k. Electrical subsystem components, wiring, and connections shall be located above or isolated from fuel and oil lines within the pod wherever possible.

l. All fuel and hydraulic lines in the engine compartment shall be fireproof.

4.1.6.2 Ground Safety. Means shall be provided to assure adequate protection of the AEIS during maintenance and other ground operations. Supports for open cowl panels shall be provided. Suitable external warning markings on each pod shall define the turbine wheel plane area of avoidance and other hazardous areas or conditions. In addition, the requirements of Par. 4.1.6.1 are applicable to ground safety. Cowl panel supports shall contain positive means for preventing access panels from falling and injuring ground personnel.

4.2 FAR Requirements.

4.2.1 Engine Mounts and Fittings. The engine mounts and fittings shall be capable of reacting seizure loads caused by sudden engine stoppage as defined in FAR 25.361.b.

4.2.2 Engine Instrumentation. The instrumentation system shall meet the requirements of FAR 25.1305. The instrument lines shall meet the requirements of FAR 25.1337.

4.2.3 Fire Protection and Detection. The fire protection and detection provisions shall comply with the requirements of FAR 25.1191 and 25.1203.

4.2.4 Plumbing. All plumbing shall comply with FAR 25.1183 for fire zone requirements.

4.2.5 Thrust Reverser. Mechanical position feedback and safety interlocks shall be provided to prevent unsafe operation of the thrust reverser system. (Refer to FAR 25.1155.)

5. SUBSYSTEM DESIGN REQUIREMENTS

5.1 Engine Installation. The AEIS shall be capable of meeting the requirements contained in the following:

5.1.1 Engine (2707-100 GE). The AEIS shall incorporate, at each of four locations, an engine in accordance with Boeing document D6A10198-1. The subsystem shall be capable of satisfying the following power requirements:

a. Propulsive. The installed subsystem shall provide thrust to satisfy airplane flight performance as defined in specification D6A10111-1.

b. Mechanical. Each of the individual engine installations shall provide mechanical power as specified in Par. 3.2.3 of document D6A10198-1 for driving an aircraft accessory drive subsystem (specification D6A10089-1) and hydraulic pumps for the air inlet control subsystem (specification D6A10118-1).

c. Engine Bleed Air. Each of the engine installations shall provide bleed air for pneumatic power as specified in Par. 3.2.2 of document D6A10198-1 for support of aircraft environmental control (specification D6A10121-1), engine inlet anti-icing (specification D6A10117-1) and engine starting (specification D6A10078-1).

5.1.2 Engine (2707-100 P&WA). The aircraft engine installation subsystem shall incorporate, at each of four locations, an engine in accordance with Boeing document D6A10199-1. The subsystem shall be capable of satisfying the following power requirements:

a. Propulsive. The installed subsystem shall provide thrust to satisfy airplane flight performance as defined in specification D6A10112-1.

b. Mechanical. Each of the individual engine installations shall provide mechanical power as specified in Par. 3.2.3 of document D6A10199-1 for driving an aircraft accessory drive subsystem (specification D6A10089-1) and hydraulic pumps for the air inlet control subsystem (specification D6A10118-1).

c. Engine Bleed Air. Each of the engine installations shall provide bleed air for pneumatic power as specified in Par. 3.2.2 of document D6A10199-1 for support of aircraft environmental control (specification D6A10121-1), engine inlet anti-icing (specification D6A10117-1), and engine starting (specification D6A10078-1).

5.2 Thrust Reversal Capability shall be provided to reverse engine thrust for airplane deceleration during ground roll. Exhaust gases during thrust reversal shall be directed to minimize impingement on airplane structure and control surfaces such that surface temperature does not exceed 500°F. During thrust reversal, ingestion of reverse exhaust gases shall not cause engine surge or stall above an airplane speed of 60 kn TAS at maximum reverse power with 90 deg crosswind velocities of 30 kn.

5.2.1 B-2707-100 (GE) The net effective reverse thrust discounting ram drag, shall be at least 50-percent maximum forward unaugmented thrust.

5.2.2 B-2707-100 (P&WA) The net effective reverse thrust discounting ram drag, shall be at least 40-percent maximum forward unaugmented thrust.

5.3 Controls. It shall be possible to control operation of engine start, engine thrust, and engine shutdown upon commands from the flight deck. Operational control shall include the capability to set and vary engine thrust and adjust engine variables to obtain optimum performance within the limits of safe operation. The following controls shall be provided:

a. Control levers shall be provided on the control stand for setting and varying engine thrust. The levers shall operate from idle to maximum power and, in addition, control the thrust reverser. The range of travel from reverse to maximum power setting shall be 80 ±1 deg of arc. Separate levers shall be provided for mode control including starting, run, and shutdown. The range of travel shall be 45 ±1 deg of arc. Separate thrust and mode control levers, easily accessible to the pilot, shall be provided for controlling each engine.

b. Trim controls shall be provided to conform to requirements outlined in documents D6A10198-1 (GE) and D6A10199-1 (P&WA).

5.3.1 Response. The thrust reverser shall be actuated and the safety interlock shall release, within 2 sec. when the thrust lever reaches the REVERSE THRUST position to permit power application.

5.3.2 Actuation. Actuation of controls shall be as follows:

a. Thrust and mode selector lever movement shall be smooth, with no sticking or binding. Springback and lost motion shall not exceed 0.5 degrees of lever travel.

b. The force required to move the thrust and mode control levers over their entire range of travel shall not exceed 7.0 lb for each lever or 28.0 lb when all four levers are moved simultaneously with the engines inoperative.

c. An automatic clutch/brake device shall be incorporated into the thrust control system to prevent thrust lever creep as a result of vibration, structural deflection, or engine feedback.

d. Rapid movement of the thrust lever shall at no time cause the engine to surge, stall, flameout, or in any other manner behave erratically.

e. **The time delay between thrust lever actuation and corresponding movement in the engine fuel control shall not exceed 0.5 seconds.**

5.3.3 Manual Override. It shall be possible to override the autothrottle controls as provided by specification D6A10120-1, Par. 5.3.2, at any time by manual repositioning of the thrust levers.

5.3.4 Interlock.

a. Reverser interlocks shall be incorporated to prevent increasing power in the reverse-thrust direction above 85 percent engine rpm unless the reverser is in the reverse-thrust position. Similarly, it shall not be possible to increase power in the forward thrust direction above 85 percent engine rpm unless the reverser is in the forward-thrust position. If, in any power condition, the reverser moves from the position dictated by the thrust lever position, engine power shall be reduced to idle. The time delay between thrust lever actuation and corresponding movement in the engine fuel control shall be 0.5 second or less.

b. An interlock shall be incorporated to prevent actuation of the windmill brake unless the engine has been shutdown by placing the mode selector in SHUTDOWN.

5.3.5 Engine Shutdown. Two independent methods shall be provided for shutting the engine down.

5.3.6 Lever Positioning. Control-lever positioning shall be as follows.

a. The thrust-lever position shall remain within the specified tolerance over the extreme limits of airframe flexure and thermal expansion. Positive detents shall be incorporated to retain the mode selector in each position to prevent inadvertent movement of the lever from the desired position.

b. The mode selector control system shall position the engine control shaft within 3 deg of the position of the mode selector.

c. A high-lift stop shall be incorporated into the mode selector quadrant of the control stand to prevent the mode selector from being moved from the operating range into the shutdown position, except by deliberate action.

5.3.7 Alignment. Alignment shall be as follows:

a. The thrust control system shall position the corresponding shaft on the engine within 1-1/2 deg of the nominal position of the thrust lever over the complete throttle range.

b. The coordinated design of the thrust control system shall permit all four thrust levers to align in the MAX DRY, IDLE, and the MIN REVERSE THRUST positions. At any other position, the thrust levers shall align within one-half knob width for a given thrust level.

c. The mode control shaft on the engine shall remain positioned within the specified tolerance over the entire range of airframe flexure and thermal expansion.

5.4 Engine Mounting. The mounting system for the engine shall provide the primary support for the entire propulsion pod, consisting of the air inlet, the engine external fairing, and the engine assembly, including the exhaust nozzle and thrust reverser. The mounting system shall provide for transfer of engine thrust and pod loads to the airframe and shall react forward and aft engine-thrust loads, pod vertical and side loads, and loads caused by thermal changes. The mounting system shall be capable of reacting seizure loads, caused by sudden engine stoppage occurring in 0.3 second and longer.

5.4.1 Loads.

5.4.1.1 Engine Mount Loads. The engine-mounting system shall be designed to withstand the loads specified in the engine/airframe technical agreements.

5.4.1.2 Inlet Attachment Loads. The engine inlet support flange shall be designed to support the supersonic inlet loads (specification D6A10114-1) as specified in the engine/airframe technical agreements.

5.4.2 Vibration Isolation. The engine shall be supported by vibration-isolator mounts to reduce cabin noise, eliminate engine beat, and reduce structure fatigue in the vicinity of the pod.

5.5 Cowling. Cowling shall be provided to enclose the engine, engine accessories, and installation components. The cowl panels shall be designed for a working load of 3.0 psi differential pressure with an ultimate load factor of two times the working load. The maximum pressure differential on the cowl panels, caused by normal engine air leakage, is 1.0 psi. Pressure relief provisions shall be incorporated for protection against cowl overpressure. The relief provisions shall relieve pressure in excess of 4.0 psi. Cowl panel design shall incorporate flow paths to allow fluid leakages into the pod to drain to a collection point at the bottom of the pod. Cowl latches shall be capable of withstanding cowl loads during flight.

5.6 Drainage Disposal. Provisions shall be incorporated to permit automatic disposal of accumulated drainage during engine operation. Drainage from all normal drain points shall be collected in a drain tank capable of holding all of the fluid drainage associated with one normal engine shutdown plus two unsuccessful start attempts. An ejector system shall discharge the total contents of a full drain tank into the engine exhaust nozzle within 8 minutes after the engine is started. Drainage collected from one normal shutdown will be ejected within 3 minutes after the engine is started. In flight, the ejector flow shall be sufficient to keep the drain tank purged of all normal fluid drainage and fluid vapors.

Drainage provisions in the cowling directs fluid that leaks into the pod to a collection point for an ejector system that discharges into the engine exhaust nozzle. The fluid pumping capacity of the ejector shall be 1/2 gallon per minute.

5.7 Bleed Air Equipment. Distribution ducts for supplying engine bleed air to the airplane environmental subsystem, engine-starting crossfeed manifold, and the inlet anti-icing subsystem shall be designed to withstand a maximum operating pressure of 190 psi and temperature of 1,100°F. Duct failure shall not cause damage to the engine pod or airplane. Design load factors of 1.5 for proof and 2.5 for burst shall be used for duct design. Testing and analysis will verify the strength of the ducts.

A means shall be provided to prevent backflow of bleed air from the crossfeed manifold back into an engine.

5.7.1 Bleed Air Duct Connections. Provisions for connection to the engine shall be in accordance with the engine/airframe technical agreements.

5.8 Fire Protection. Fire protection features shall be provided to isolate combustible material from ignition sources and to confine fires within the engine fire zones. Fluid lines conveying flammable fluid to a fire zone shall incorporate shutoff valves located outside of the fire zone. Air ducts leading to or from a fire zone shall incorporate shutoff valves located either outside of the fire zone or, if located inside the fire zone the valve and the duct or connection between the valve and the firewall shall be fire proof. Where air ducts or fluid lines penetrate a fire wall, the fittings and seals shall be fire proof. Air ducts, fluid lines, seals and fittings within the fire zone shall be fire resistant in accordance with FAR 25.1183.

The maximum airflow limits through the fire zones, for achievement of the low airflow concept, vary with operating conditions. The airflow per unit volume will be comparable to that on current commercial jet aircraft.

The subsystem shall accommodate means for detecting fire and for extinguishing engine fires. Functional requirements and requirements for determining locations of fire detectors and extinguishing components are given in specification D6A10115-1. The engine firewall which separates the engine pod from the airplane shall be capable of withstanding 2000°F for 15 minutes under simulated environmental conditions. There shall be no flame impingement on the horizontal stabilizer during the 15 minute period.

5.9 Instrumentation. Sensors and indicating instruments shall be provided for flight deck display and monitoring of the engine installation operation parameters. The instrumentation system shall meet the requirements of FAR 25.1305. The engine parameters displayed shall include those shown in Table I and shall permit the following:

a. Evaluation and adjustment of engine power output to meet airplane operating requirements

b. Evaluation of engine operating condition

c. Notification to flight crew of hazardous engine operating conditions

5.10 Engine Starting. Engine ground starting shall be accomplished through the accessory drive power takeoff shaft by the starting subsystem as defined in specification D6A10078-1. Inflight starting shall be accomplished by rotor windmilling at airspeeds of M=0.5 and above. Capability for starting assist by the starting subsystem shall be provided for use during flight below an airspeed of M=0.5.

5.11 Windmill Brake.

5.11.1 2707-100 (GE). It shall be possible to reduce rotor speed of an engine shutdown in flight to no more than 20-percent rpm at airplane cruise conditions. The control of the brake shall originate at the flight deck. It shall be possible to reopen the windmill brake in flight after shut down and brake actuation.

5.11.2 2707-100 (P&WA). It shall be possible to reduce the engine high compressor rotor rpm to no more than 40-percent when an engine is shut down in flight at airplane cruise conditions. The control of the brake shall originate at the flight deck. It shall be possible to reopen the windmill brake in flight after shut down and brake actuation.

5.12 Selection of Specifications. Selection of specifications shall be in accordance with Par. 3.3.2 of specification D6A10107-1.

5.13 Materials, Parts, and Processes. Materials, parts, and processes shall be in accordance with Par. 3.3.3 of specification D6A10107-1.

5.14 Standard and Commercial Parts. Standard and commercial parts shall be in accordance with Par. 3.3.4 of specification D6A10107-1.

5.15 Moisture and Fungus Resistance. Moisture and fungus resistance shall be in accordance with Par. 3.3.5 of specification D6A10107-1.

5.16 Corrosion of Metal Parts. Corrosion of metal parts shall be in accordance with Par. 3.3.6 of specification D6A10107-1.

5.17 Interchangeability and Replaceability. Common parts and assemblies subject to removal from the engine and engine installation for routine maintenance shall be interchangeable or replaceable-interchangeable. Each engine installation shall be interchangeable between pod positions and airplanes. The built-up engine assemblies shall be interchangeable at all four pod locations. Engine and accessories shall be completely interchangeable. Cowl panels shall be interchangeable among engines.

5.18 Workmanship. Workmanship shall be in accordance with Par. 3.3.8 of specification D6A10107-1.

5.19 Electromagnetic Interference. Electromagnetic interference shall be in accordance with Par. 3.3.9 of specification D6A10107-1.

5.20 Identification and Marking. Identification and marking shall be in accordance with Par. 3.3.10 of specification D6A10107-1.

5.21 Storage. Storage shall be in accordance with Par. 3.3.11 of specification D6A10107-1.

5.22 Subsystem Weight.

5.22.1 2707-100 (GE). The weight of the aircraft engine installation subsystem shall not exceed 48,760 lb. This weight is an allocation of the overall airplane weight based on analysis and design experience and may be revised as long as the overall airplane weight defined in specification D6A10107-1 is not exceeded.

5.22.2 2707-100 (P&WA). The weight of the aircraft engine installation subsystem shall not exceed 44,610 lb. This weight is an allocation of the overall airplane weight based on analysis and design experience and may be revised as long as the overall airplane weight defined in specification D6A10107-1 is not exceeded.

TABLE I. Engine Instrumentation - Flight Deck Display

Function	Sensor	Indicator	Range and accuracy
Exhaust gas temperature	Thermocouples*	Dial	0° C to 2,500° C (accuracy ±10° C)
Net thrust	Thrust link	Dial	-50% to +100% rating -40,000 to +70,000 lb (accuracy ±5%)
Fuel temperature inlet	Thermistor	Dial	-50°F to 500°F (accuracy ±10°F)
Lube oil temperature	Thermistor	Dial	0° F to 500° F (accuracy ±10°F)

*Supplied with engine

TABLE I. (Continued)

Function	Sensor	Indicator	Range and accuracy
Lube oil pressure	Pressure transducer	Dial	0 to 100 psi (accuracy ±2 psi)
Low-pressure warning, lube oil	Pressure switch	Lamp	
Differential pressure-warning, lube oil filter	Pressure switch	Lamp	
Thrust reverser in reverse position	Switch*	Lamp	On-Off
Windmill brake on	Switch*	Lamp	On-Off
Seconary air valve(s) posi-	Position transducer(s)*	Dial	0 to 100% open (accuracy ±5% range)
Vibration, compressor	Mass accelerometer	Dial	0 to 0.010 in. double amplitude (accuracy ±5%)
Vibration, Turbine	Mass accelerometer	Dial	0 to 0.010 in. double amplitude (accuracy ±5%)
Fire Detector	Continuous element	Lamp and bell	1,200°F ON (accuracy ±85°F)
2707-100 (GE) Only			
Fuel flow,	Mass flowmeter main	Dial	0 to 65,000 pph (accuracy ±2%)
Fuel flow, augment (afterburner)	Mass flowmeter	Dial	0 to 60,000 pph (accuracy ±2%)
Fuel temperature, nozzle inlet	Thermocouple*	Tape	0°F to 400°F (accuracy ±10°F)

*Supplied with engine

TABLE I. (Continued)

Function	Sensor	Indicator	Range and accuracy
Quantity, hydraulic oil	Probe, magnetic switching	Dial	0 to 3 gal (accuracy ±3%)
Rotor, speed	Tachometer generator	Dial	0 to 110% max. rpm (accuracy ±1.5%)
Thrust reverser in transit	Switch*	Lamp	
Nozzle area, primary	Position transducer*	Dial	500 tc 2,000 sq in. (accuracy ±3.0%)
Engine and inlet anti-icing	Pressure switch*	Lamp	
Turbine cooling valve-open	Position switch*	Lamp	
Nozzle cooling valve-open	Position switch*	Lamp	
2707-100 (P&WA) Only			
Rotor speed, N1	Speed counter*	Dial	0 to 110% max. rpm (accuracy ±1.5%)
Rotor speed, N2	Tachometer generator	Dial	0 to 110% max. rpm (accuracy ±1.5%)
Fuel flow, main	Mass flowmeter	Dial	0 to 35,000 pph (accuracy ±2%)
Fuel flow, augment (duct	Mass flowmeter	Dial	0 to 100,000 pph (accuracy ±2%)
Nozzle area, fan duct	Position transducer*	Dial	500 to 2,000 sq in. (accuracy ±3%)

*Supplied with engine

Table I. (Concluded)

Function	Sensor	Indicator	Range and accuracy
Thrust reverser in transit	Position transducer*	Dial	0 to 100% (accuracy ±5% range)
Supersonic inlet anti-icing	Pressure switch	Lamp	

*Supplied with engine

6. SUBSYSTEM DESCRIPTION

6.1 Interfaces. Structural, mechanical, electrical and fluid interfaces in the aircraft engine installation include those between engine manufacturer-supplied equipment and airframe manufacturer-supplied equipment and those between the engine installation and other airframe subsystems.

6.1.1 Interface Schematic. The aircraft engine installation interfaces are identified in Figs. 1 and 2.

6.1.2 Interface Definition. The individual interfaces existing between the engine, engine installation, and airframe subsystem are in Tables II and III.

6.2 Component Identification.

6.2.1 Government-Furnished Property.

6.2.1.1 B-2707 (GE). The engine, engine accessories, and exhaust-nozzle-thrust reverser are provided as defined in document D6A10198-1.

6.2.1.2 B-2707 (P&WA). The engine, engine accessories, and exhaust-nozzle-thrust reverser are provided as defined in D6A10199-1.

6.2.2 Contractor-Furnished Property. Equipment furnished by the airframe manufacturer and installed on the engine assembly include mounting provisions, cowling, bleed air ducting, instrumentation, fire-protection provisions, inlet hydraulic pumps, and engine-to-airframe plumbing and wiring. In addition, the airframe manufacturer furnishes the control equipment required for controlling engine operation from the flight deck.

6.3 Subsystem Design Features. The AEIS consists of four separate propulsion pods, controls, and monitoring equipment. Two pods are mounted on each side of the airplane on the horizontal stabilizer lower surface. The subsystem design permits independent operation and control of each of the propulsion pods. Each pod installation (Figs. 3 and 4) contains a

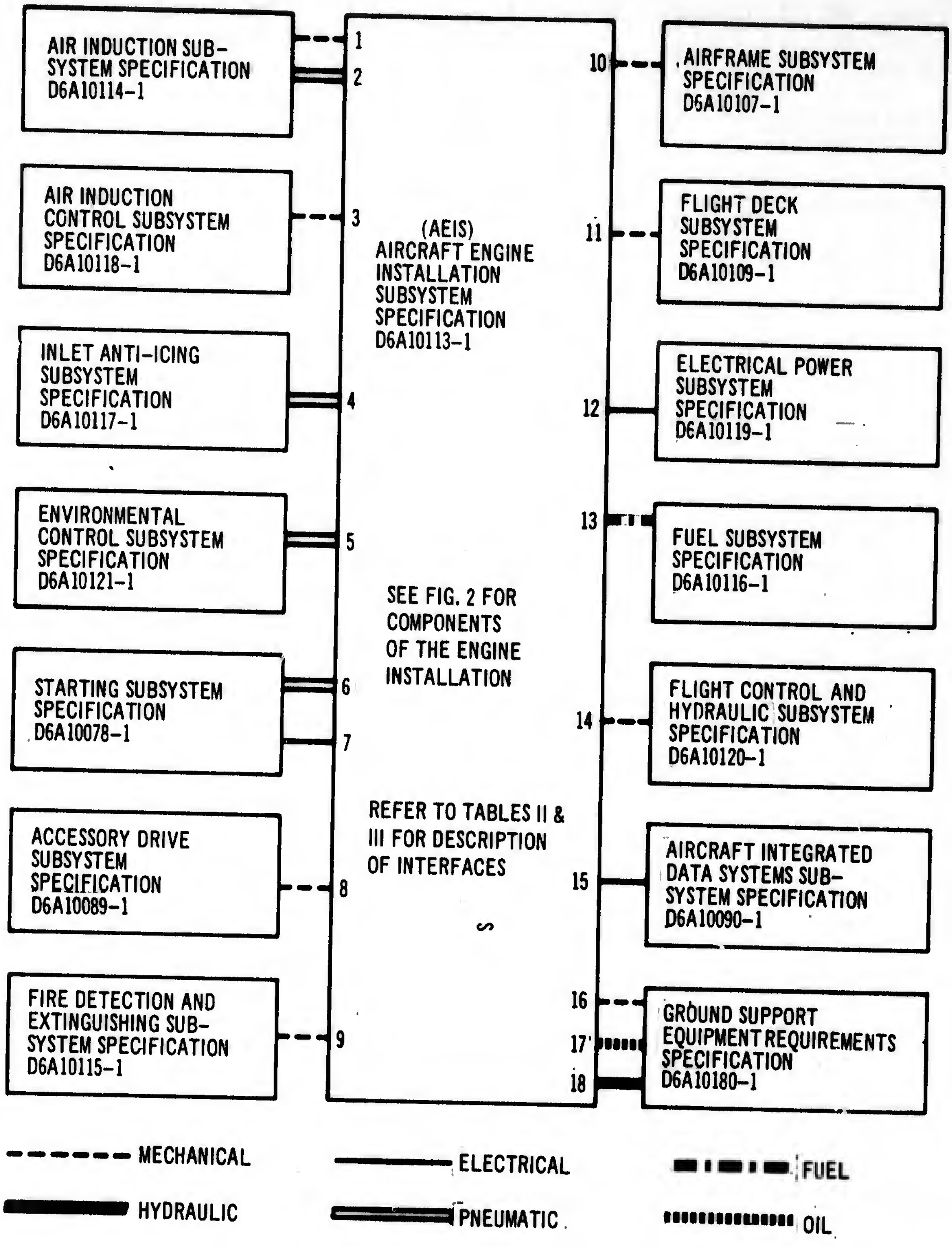


Figure 1. Interface Diagram

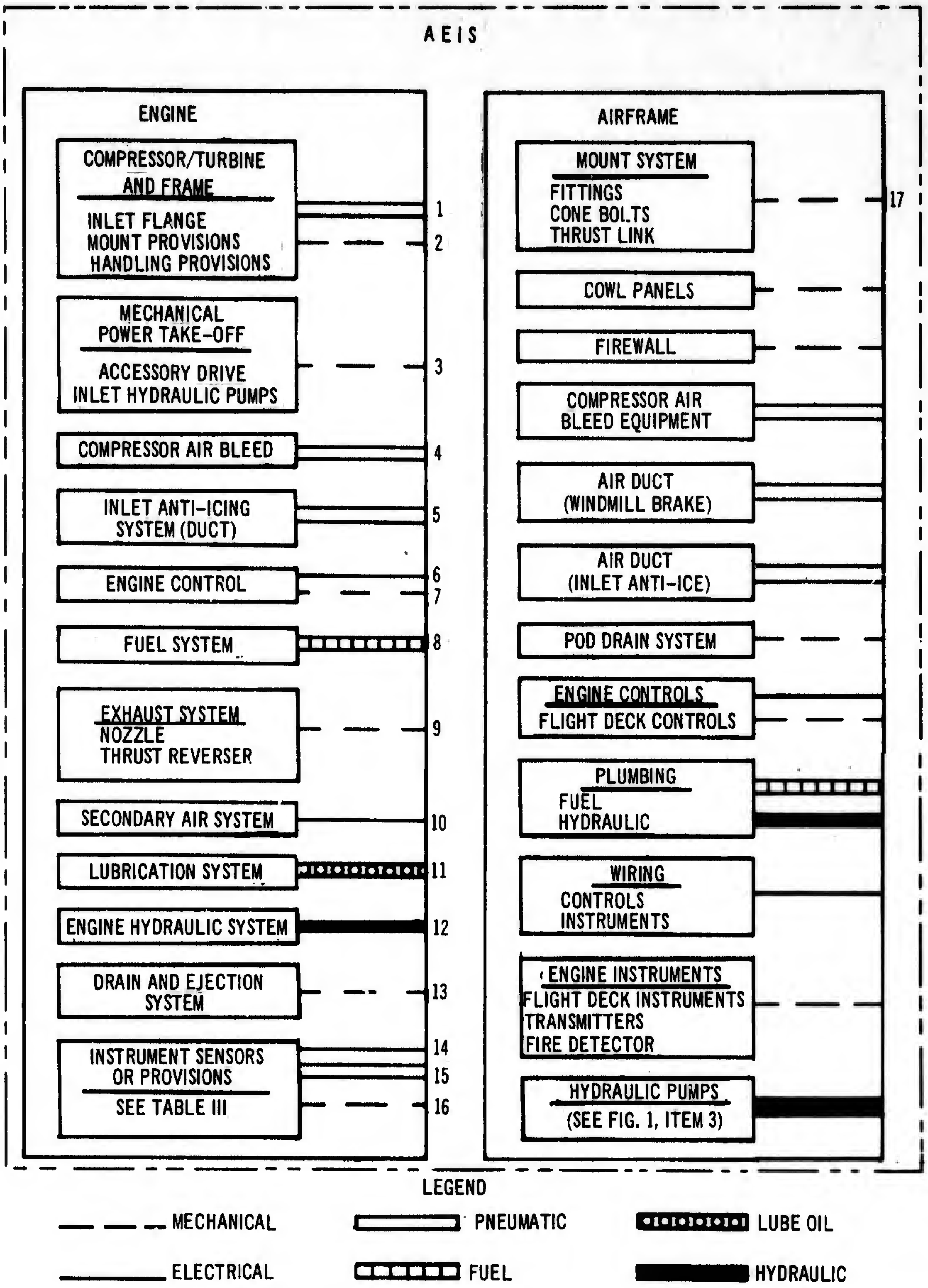
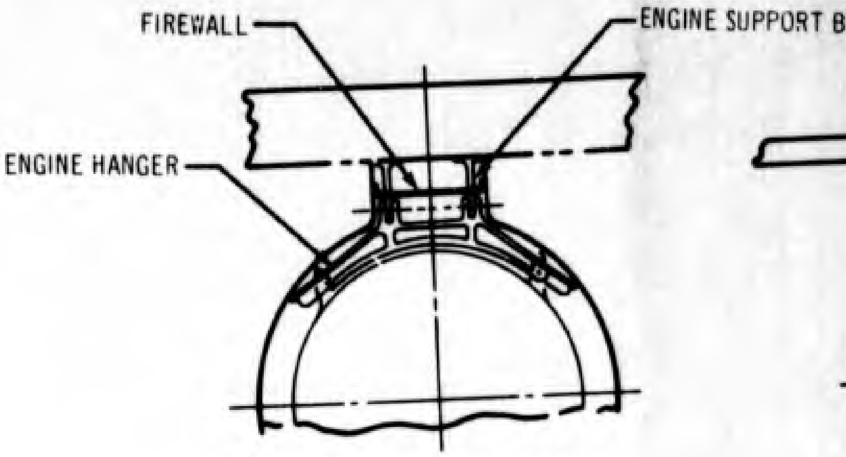
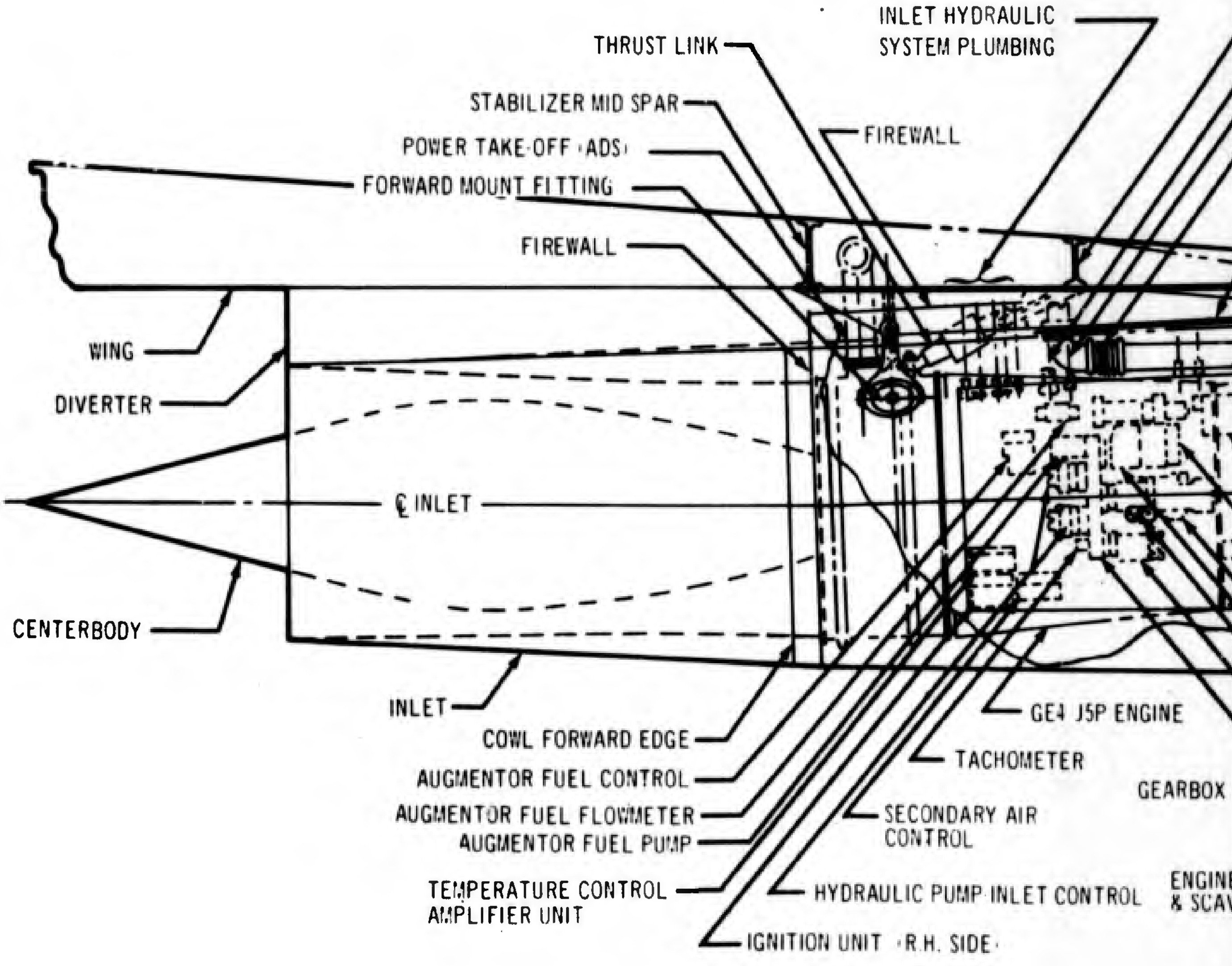


Figure 2. Engine Installation Subsystem Engine/Airframe Components



FORWARD ENGINE MOUNT



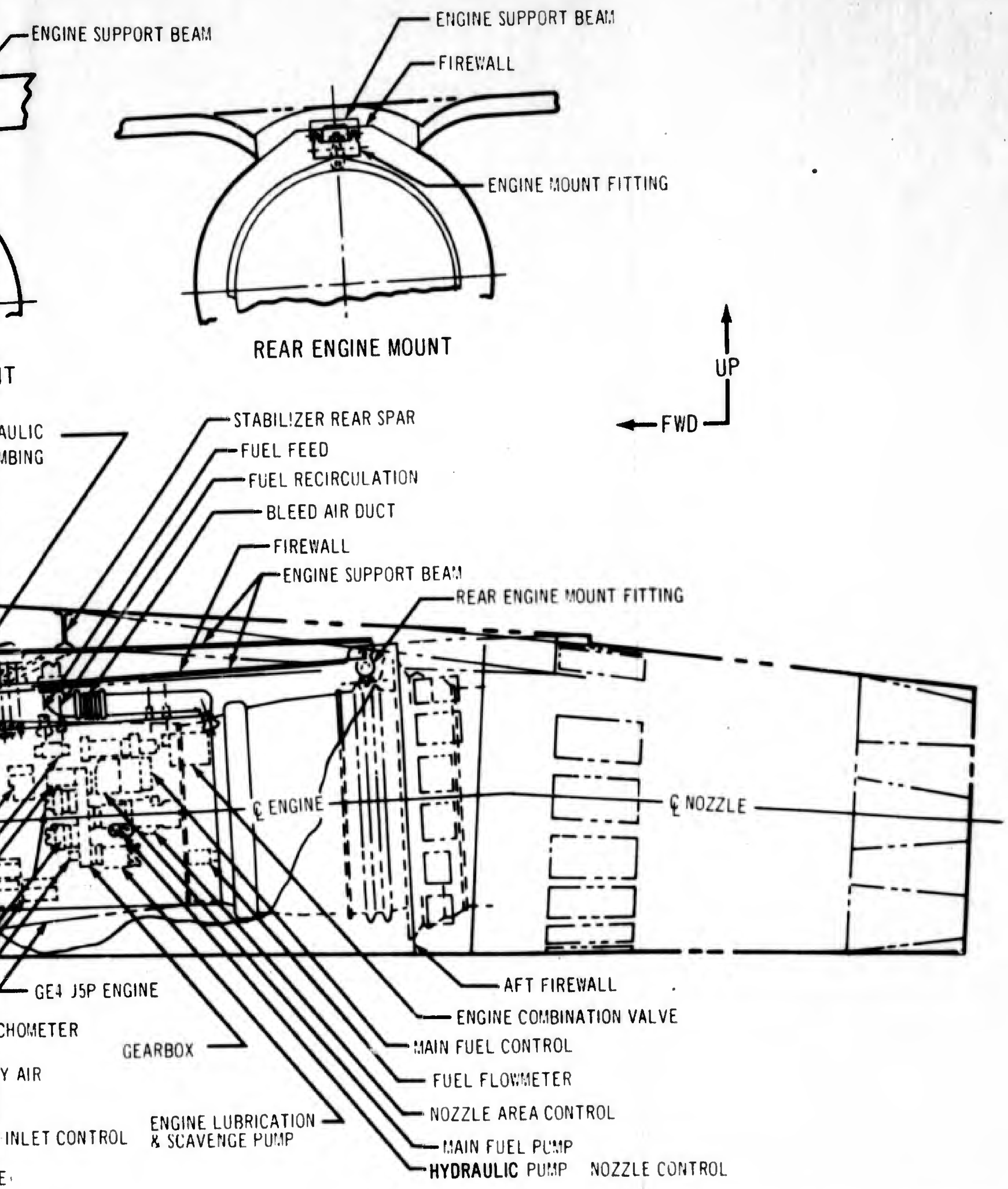
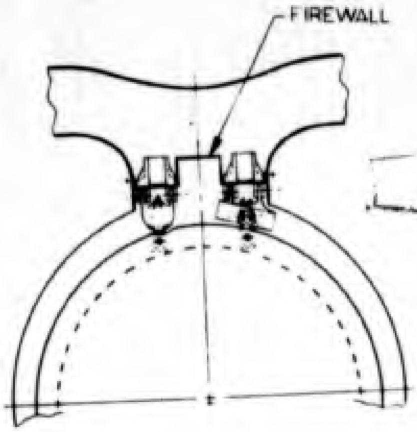
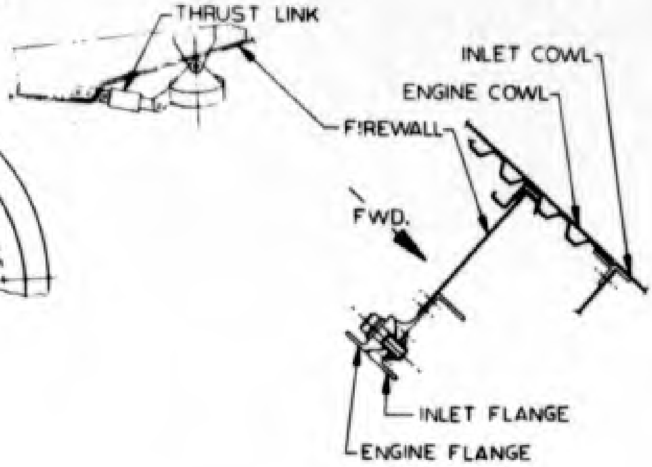


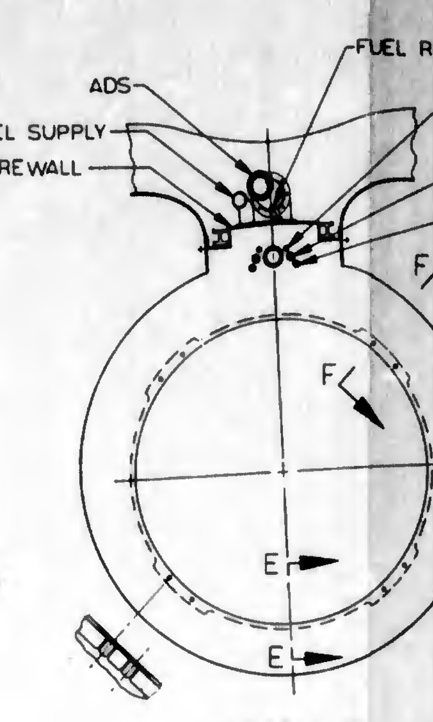
Figure 3. Propulsion Installation (GE)



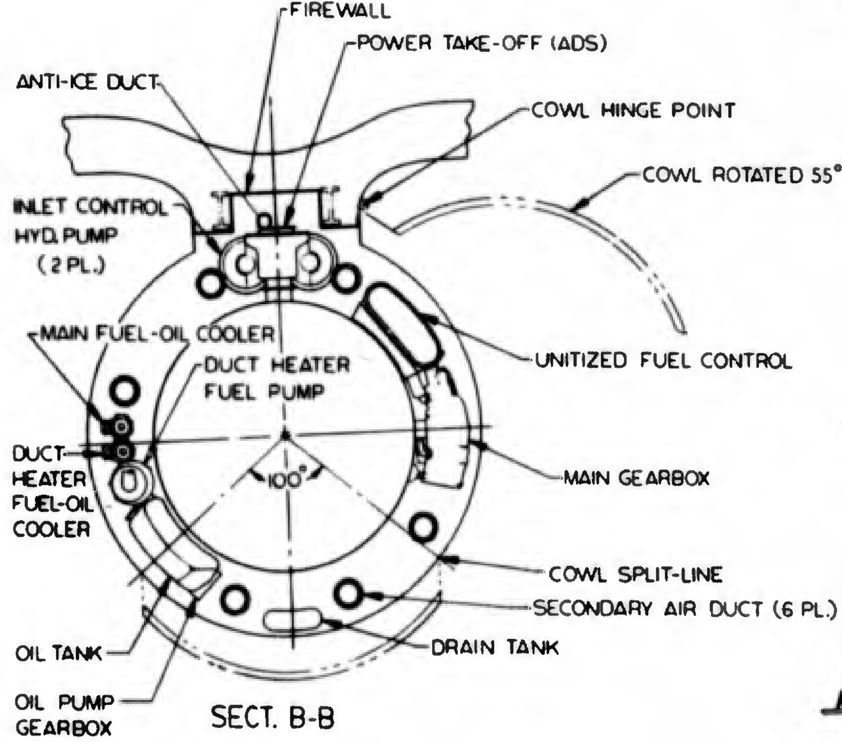
SECT. A-A
FWD.ENGINE MOUNT



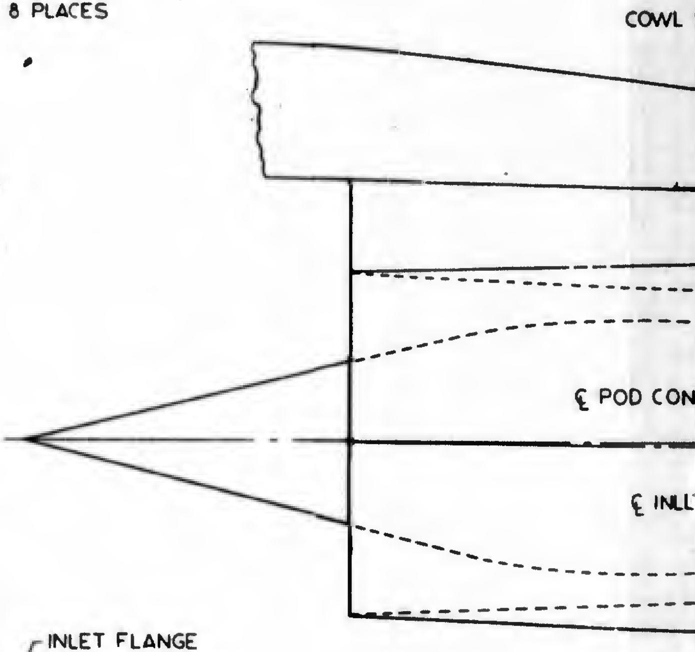
SECT. F-F
TYP. 8 PLACES

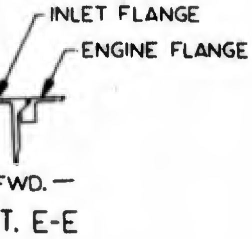


SECT. D-D



SECT. B-B





SECT. E-E

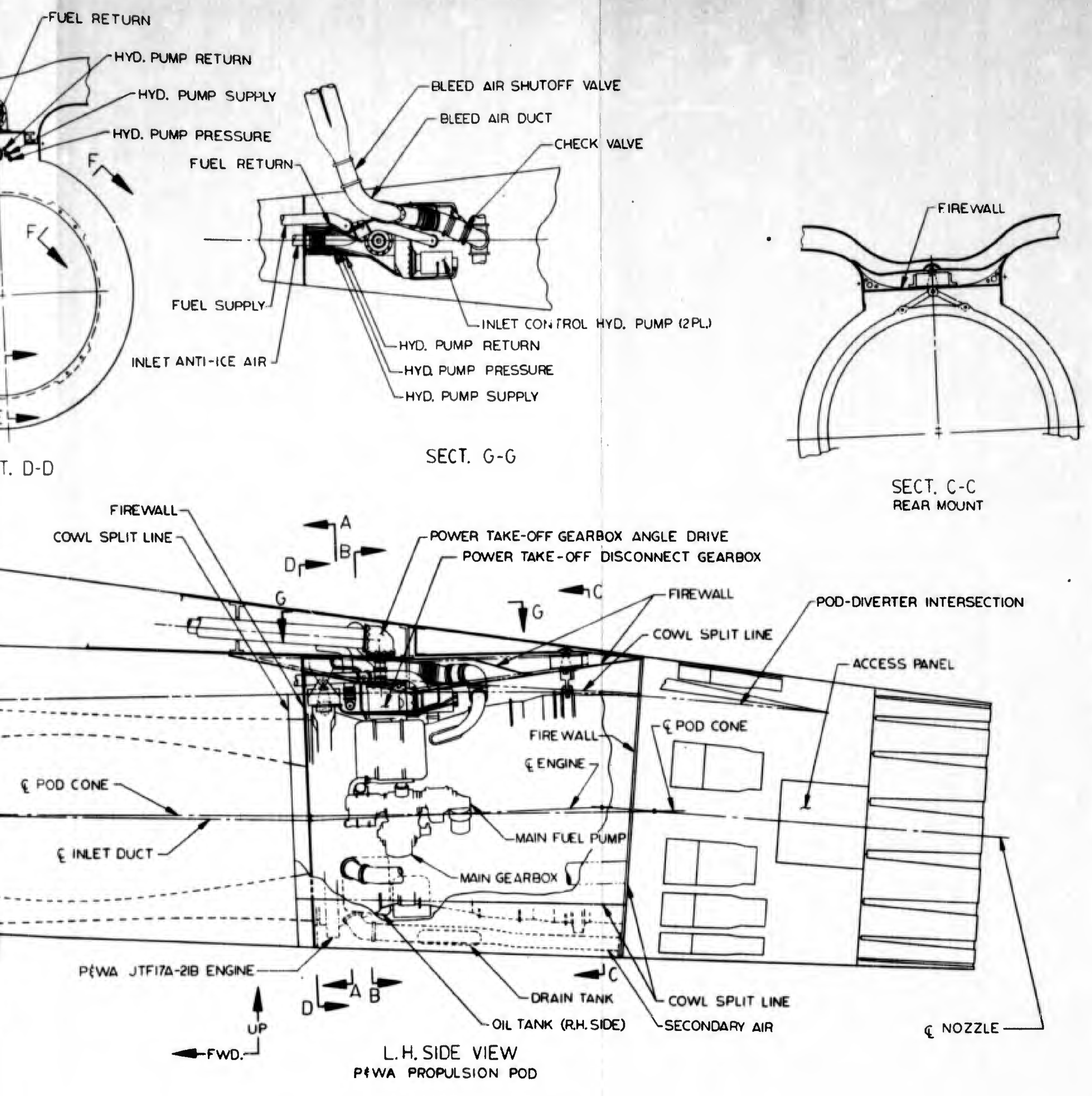


Figure 4. Propulsion Pod Installation (P&WA)

2

Table II. Interface List

Fig. 1 ref.	Adjoining subsystem	Nature of interface with AEIS	Physical nature	Function	Quantitative values and tolerances
1	Air induction subsystem	Structural support output	Bolted inlet flange*	Mount air inlet assembly on engine front face	T/A, Par. 3.2.4.2.1**
2	Air induction subsystem	Air supply input	Air coupling*	Engine intake air supply	T/A, Par. 3.2.19**
3	Air induction control subsystem	Hydraulic fluid flow output	Hydraulic couplings (6)	Provide hydraulic power	
4	Inlet anti-icing subsystem	Pneumatic supply output	Duct coupling*	Supply bleed air for air inlet anti-icing	T/A Par. 3.2.2.2**
5	Environmental control subsystem	Pneumatic supply output	Airflow	Supply compressor bleed air for airplane environmental control	T/A Par. 3.2.2**
6	Starting subsystem	Pneumatic supply output	Duct coupling*	Supply compressor bleed air for cross-airplane engine starting (also supply bleed air for environmental control subsystem)	T/A Par. 3.2.2**

* Interface with the engine as supplied by engine contractor.

** T/A = Engine/Airframe Technical Agreements D6A10198-1 (GE) or D6A10199-1 (P&WA)

Table II. (Continued)

Fig. 1 ref.	Adjoining subsystem	Nature or interface with AEIS	Physical nature	Function	Quantitative values and tolerances
6	Starting subsystem	Pneumatic source input	Duct coupling*	Receive cross-airplane manifold bleed air for actuation of windmill brake.	T/A, Par. 3.2.20.1**
7	Starting subsystem	Electrical output	Wiring and connectors	Supply signal for initiating airflow for engine starting through accessory drive system	
8	Accessory drive subsystem	Mechanical power output	Rotating shaft*	Drive the airframe accessory drive system	T/A, Par. 3.2.3**
9	Fire detection and extinguishing subsystem	Structural support output	Holes, clips, and brackets*	Support continuous fire detector sensing element and associated equipment	
10	Airframe subsystem	Structural support input	Cone bolts connections	Mount engine	T/A, Par. 3.2.4**
10	Airframe subsystem	Aerodynamic seal	Mechanical faying surface	Fairing, cowl to stabilizer (diverter)	
11	Flight deck subsystem	Structural support input	Control stand and instrument panel	Support engine control levers, cabling, rods, switches, and wiring. Support engine instruments and wiring for crew display.	

Table II. (Continued)

Fig. 1 ref.	Adjoining subsystem	Nature of interface with AEIS	Physical nature	Function	Quantitative values and tolerances
12	Electrical power subsystem	Electrical input	Connectors and wiring	Receive electrical power for operating control systems and instrumentation systems	
13	Fuel subsystem	Fuel input and output	Mechanical couplings	Receive fuel supply for engine and deliver recirculation fuel from engine for return to tanks.	T/A, Par. 3.2.9**
14	Flight Controls and hydraulics subsystem	Mechanical power input	Cable connection	Provide auto throttle operation	
15	Aircraft integrated data subsystem	Electrical output	Connectors and wiring, sensors/ transmitters	Deliver signals for specified engine operating parameters for recording during the flight mission	
16	Ground support equipment	Structural support output	Mount pads and/or lugs and bolt holes*	Provide attachment features for engine assembly support and transportation dolly for maintenance and assembly usage	T/A, Par. 3.2.5**
17	Ground support equipment	Lube oil input	Fill port (capped)*	For gravity replenishing the lubricating oil tank contents.	T/A, Par. 3.2.10.4**

Table II. (concluded)

Fig. 1 ref.	Adjoining subsystem	Nature of interface with AEIS	Physical nature	Function	Quantitative values and tolerances
17	Ground support equipment	Lube oil input	Tube coupling*	For pressure refilling the lubricating oil tank contents	T/A, Par. 3.2.10.4**
18	Ground support equipment B-2707 (GE) only	Hydraulic oil input	Fill port (capped)	For gravity replenishing the hydraulic oil tank contents	
18	Ground support equipment B-2707 (GE) only	Hydraulic oil input	Tube coupling*	For pressure refilling the hydraulic oil tank contents	

Table III. Engine and Components Interface List

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
	Compressor turbine and frame				
1	Inlet flange	Mechanical	Duct coupling*	Air to engine	
2	Inlet flange	Mechanical	Bolted flange*	Support inlet	
2	Mount provisions	Mechanical	Flange, bolt pad, bolt holes*	Engage engine thrust and support mount fitting	T/A, Par. 3.2.4**
2	Handling provisions	Mechanical	Mount pads and/or lugs and bolt holes*	Engage handling dolly fittings	
2	Support brackets	Mechanical	Brackets, clips, pads	Mount provisions for wiring, plumbing, cowl panels, transmitters, instruments, and equipment added by the airframe manufacturer	

* Interface with the engine as supplied by engine contractor

** Engine/Airframe Technical Agreements D6A10198-1 (GE) or D6A10199-1 (P&WA)

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
	Mechanical power take-off				
3	Accessory drive	Mechanical power (Fig. 1, Item 8)	Mechanical drive pad*	Drive the airframe accessory drive system	T/A,**
3	Inlet hydraulic pumps (2)	Mechanical power (Fig. 1, Item 3)	Mechanical drive pad (2 required)*	Mount and drive inlet hydraulic pumps (2)	
4	Compressor air bleed	Pneumatic supply (Fig. 1, Items 5 and 6)	Duct coupling* to bleed port	Furnish compressor bleed air for airplane environmental control and cross-airplane engine starting	
5	Inlet anti-icing system	Pneumatic supply (Fig. 1, Item 4)	Duct coupling* to bleed port	Supply bleed air for air inlet anti-icing	
5	Anti-icing control valve	Electrical	Pin-socket	Control bleed air flow to inlet anti-icing distribution system	
6	Engine control	Electrical	Pin-socket connectors*	Accept flight deck control command signals and supply feed-back signals	

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
7	Engine control Throttle Mode selector	Mechanical	Push-pull linkage or crank arms*	Operate mechanical engine control mechanisms in response to flight deck control settings	
8	Fuel system	Fuel	Tube coupling* (2 required)	Receive fuel supply for engine and deliver recirculation fuel from engine for return to tanks	T/A, Par. 3.2.9**
9	Exhaust system				
	Cowling	Mechanical support (Fig. 1, Item 10)	Faying surface	Provide fairing seal between engine and pod cowl panels	
10	Secondary air system	Electrical	Pin socket connection	Transmit electrical power for valve control	
11	Lubrication system	Oil servicing (Fig. 1, Item 17)	Fill port (capped)*	For gravity fill of oil tank	
		Mechanical connection	Coupling*	For pressure refilling of hydraulic oil tank	

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
12	Engine hydraulic system B-2707 (GE) only	Oil servicing (Fig. 1, Item 18)	Fill port (capped)*	For gravity fill of hydraulic oil	
12	Engine hydraulic system B-2707 (GE) only	Mechanical connection (Fig. 1, Item 18)	Tube coupling*	For pressure refilling of hydraulic oil tank	
13	Drain and ejection system	Mechanical	Tube Connection*	Provision for connection of pod drain ejection plumbing to engine drain ejector system	
	Instrument sensors				
14	Exhaust gas temperature	Electrical	Pin-socket connectors*	Self-generate signal (from thermocouple probes) to indicate exhaust gas temperature	
14	Thrust Reverser in reverse position	Electrical	Pin-socket connector*	Use airframe power to provide signals to indicate reverser actuator open-closed positions	

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative Values and tolerances
14	Windmill brake	Electrical	Pin-socket connector*	Use airframe power to provide signals to indicate ON position	
14	Secondary air valve position	Electrical	Pin-socket connector*	Use airframe power to provide signal to indicate valve position	
14	Nozzle area	Electrical	Pin-socket connector*	Use airframe power to provide analog signal to indicate nozzle position	
14	Thrust reverser in transit	Electrical	Pin-socket connector*	Use airframe power to provide ON signal whenever reverse actuator is not in full-on or full-off position	
14	Engine anti-icing flow sensor B-2707 (GE) only	Electrical	Pin-socket	Use airframe power to provide signal to indicate engine inlet anti-icing flow	
14	Fuel nozzle inlet temperature	Electrical	Pin-socket connector*	Provide signal from sensor to indicate fuel temperature	

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
14	Turbine cooling valve Nozzle cooling valve B-2707 (GE) only	Electrical	Pin-socket connector*	Use airframe power to provide valve position	
14	Low pressure (N_1) rotor speed B-2707 (P&WA) only	Electrical	Pin-socket connector*	Self-generate signal to indicate N_1 rpm	
	Instrument provisions				
16	Thrust link B-2707 (GE) only	Mechanical (structural)	Lug and bolt hole*	Provide means of attaching airframe-supplied thrust measuring transducer (link)	
16	Fuel supply temperature	Mechanical	Threaded boss*	For mounting airframe resistance bulb to measure temperature of fuel supplied to engine	
16	Lube oil quantity	Mechanical	Threaded boss*	For mounting airframe level sensor to measure quantity of lubrication oil in tank	

Table III. (Continued)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
16	Lube oil temperature	Mechanical	Threaded boss*	For mounting airframe resistance bulb to measure oil temperature	
16	Lube oil pressure	Mechanical	Threaded boss*	For mounting airframe lube connection or pressure transducer for measuring oil pressure	
16	Low lube oil pressure warning	Mechanical	(Use lube oil pressure threaded well)	For mounting airframe tube connection or pressure transducer for sensing low-oil-pressure warning	
16	Lube oil filter pressure drop warning	Mechanical	Threaded bosses*	For mounting airframe sensor for Max differential pressure warning	
16	Compressor vibration	Mechanical	Support bracket*	For mounting airframe accelerometer to sense engine frame vibration	
16	Turbine vibration	Mechanical	Support bracket*	For mounting airframe accelerometer to sense engine frame vibration	

Table III. (concluded)

Fig. 2 ref.	Component	Nature of interface at engine	Physical nature engine interface	Function	Quantitative values and tolerances
16	Fire detector	Mechanical	Support bracket*	For mounting continuous sensing elements	
16	Rotor Speed B-2707 (GE) only	Electrical	Pin-socket connection*	3-wire signal (from GE supplied tachometer generator) to indicate rotor speed	
16	High pressure (N_2) rotor speed B-2707 (P&WA) only	Mechanical	Drive shaft and mount pad*	For mounting airframe supplied tachometer generator to indicate N_2 rotor speed	
16	Main fuel flow	Mechanical	Tube connections* (2)	For connecting airframe supplied mass flowmeter in fuel line	
16	Augment Fuel Flow	Mechanical	Tube connections* (2)	For connecting airframe supplied mass flowmeter in fuel line	
16	Hydraulic oil quantity B-2707 (GE)	Mechanical	Threaded boss	For mounting airframe level sensor to measure quantity of hydraulic fluid in tank	
17	Mount System Fittings Cone bolts Thrust link	Mechanical	Structure	Attach engine mount fitting to airframe structure via cone bolt sockets and thrust link attachment	

complete engine build-up (EBU) assembly having components which serve the engine, airframe, and the air inlet subsystems. When these are installed and integrated with the air inlet subsystem and structure, they form a complete propulsion pod.

6.3.1 Exhaust Nozzle-Thrust Reverser The engine exhaust nozzle-thrust reverser and actuation equipment is a separate assembly provided as part of the engine assembly. Design shall allow its installation or removal with the engine in place on the airplane. Engine-supplied hydraulic power is used to actuate the variable-area nozzle and the exhaust thrust-reverser positioning mechanism. Instrumentation for reverser position and nozzle area sensing for flight deck display is included in the nozzle reverser system.

6.3.2 Windmill Brake The windmill brake and actuation system furnished on the engine is used to reduce the speed of the engine rotor when the engine is shutdown in flight. A pneumatic actuator, using air pressure from the airplane crossover manifold, is used to drive a row of compressor stators to a closed position. The actuator incorporates a device to hold the brake in the committed position if actuation pressure is lost. A shutoff valve, actuated from the flight deck is used to control brake actuation. Instrumentation is incorporated to provide flight deck indication of the brake position.

6.3.3 Secondary Air Nozzle Cooling System Secondary air is directed from the forward face of the engine to the nozzle area through ducts. Each duct contains a valve to regulate and shut off secondary airflow. The regulating valve is automatically positioned by a control unit as a function of Mach number and thrust-lever angle. An override capability is provided to allow closure of the secondary air valves and fire protection when the fire switch is activated from the flight deck.

6.3.4 Engine Lubrication System The engine lubrication system is furnished with the engine assembly. With the exception of instrumentation, the system is self-contained on the engine and does not require support from airplane subsystems. The oil tank contains provisions to permit either gravity filling or pressure filling and contains an oil-level dip stick. Fuel oil coolers are used for cooling the lubrication system during engine operation. Sensors and transmitters are installed to provide flight deck indication.

6.3.5 Engine Fuel System The engine fuel system is provided as part of the engine assembly. All components required for automatic management and distribution of fuel to the burners are engine-mounted. Included are the fuel pumps, control units, filters, shutoff valves, and associated plumbing. A fuel bypass is incorporated into the system to allow recirculation of fuel back to the airframe fuel tanks. The engine fuel control unit is connected to the airframe engine control system and responds to power setting commands from the flight deck. Plumbing is installed for connecting the airframe fuel supply to the engine fuel inlet connection and for connecting the engine fuel recirculation system to the airframe fuel tanks.

A fuel flowmeter is installed in the primary engine fuel system and in the augmentor fuel system to allow flight deck monitoring of fuel flow during engine operation. The system incorporates provisions to allow flight deck monitoring of fuel temperature.

6.3.6 Engine Ignition System, 2707-100 (GE). For engine starting, a dual 16-joule (high-energy) system is used. A dual 4-joule (low-energy) system is provided in the main system for sustaining combustion during, takeoff, turbulent air and icing conditions, and landing. A single 4-joule (low-energy) system is used for augmentor ignition. (See Fig. 5) Electrical power to the ignition system is provided by the airplane electrical subsystem, specification D6A10119-1. Electrical equipment using power from the main airplane power system shall be in accordance with electrical requirements for installed equipment in accordance with document D6-16328.

6.3.7 Engine Ignition System, 2707-100 (P&WA). The engine ignition system (Fig. 6) incorporates a 4-joule (low-energy) system for both the main and augmentor combustors. The system is also used to sustain combustion during takeoff, turbulent air and icing conditions, and landing. Electrical power to the ignition system is provided by the airplane electrical subsystem, specification D6A10119-1. Electrical equipment using power from the main airplane power system shall be in accordance with electrical requirements for installed equipment in accordance with document D6-16328.

6.3.8 Engine Power Takeoff. The engine provides a power takeoff to drive a remotely located aircraft accessory drive system in accordance with specification D6A10089-1. A disconnect is provided to permit engine installation or removal without requiring removal of the accessory drive system. Mounting pads are provided for driving two hydraulic pumps to power the engine air inlet actuation system in accordance with specification D6A10118-1.

6.3.9 Engine Controls. Mechanical linkages are providedon the engine control units to allow for translation of power setting and thrust-reverser-positioning signals from the flight deck to the engine. (See Figs. 7 and 8)

6.3.10 Drain System. The engine is provided with a drain system which includes accessory pad drains, fuel manifold and combustion chamber drains, and a collector tank. The tank is sized to contain manifold and combustion chamber drainage from one normal engine shutdown plus two unsuccessful start attempts. Miscellaneous leakage within the pod is collected at a low point in the bottom cowl panel. The collected drainage from the engine an pod is ejected into the exhaust during engine operation. Check valves and flame arrestors in the ejector systems are provided to minimize fire hazards. Engine vent lines are routed separately from drain lines, and vent ports are located to prevent closure from icing conditions.

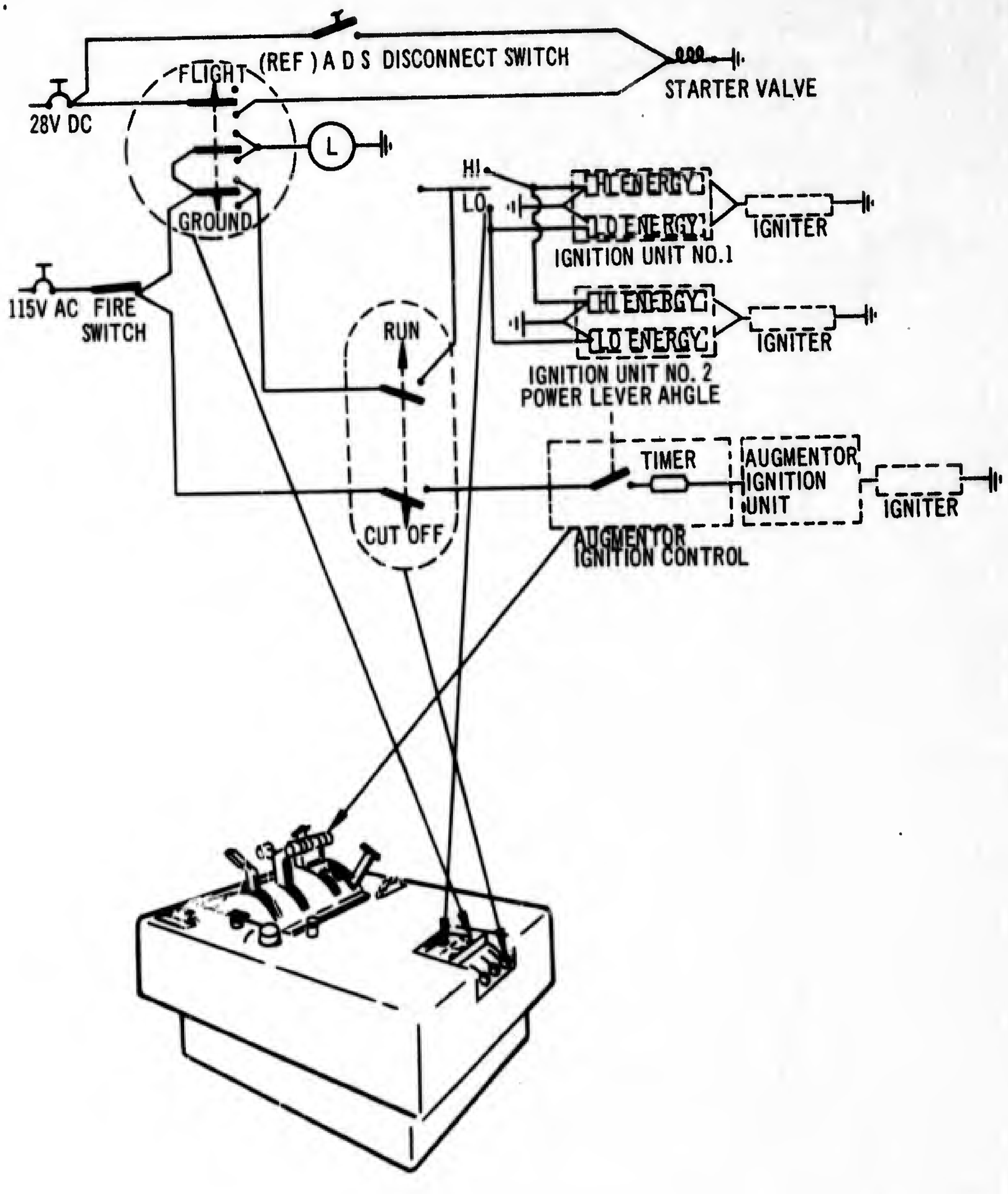


Figure 5. GE Ignition and Start Schematic

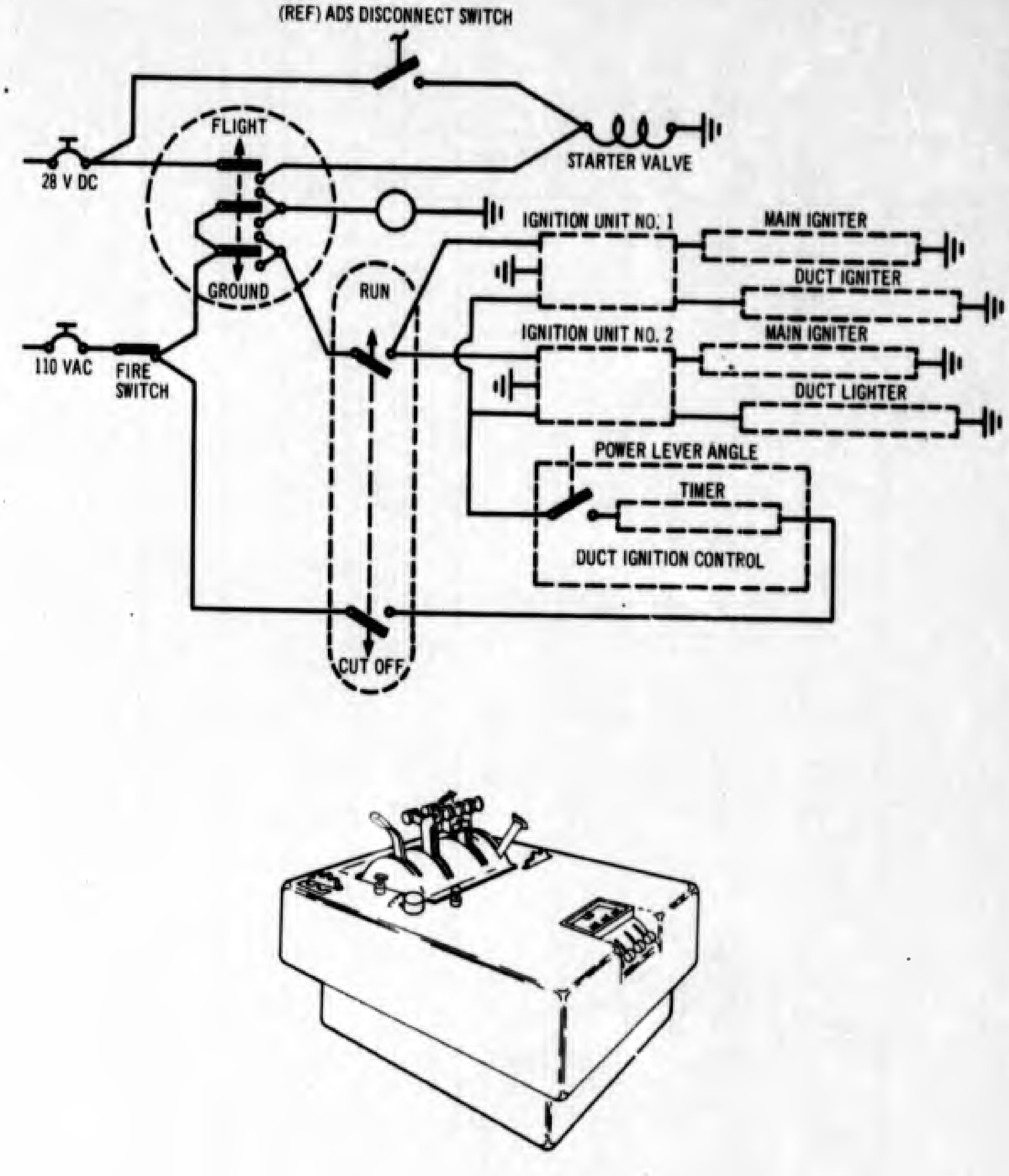
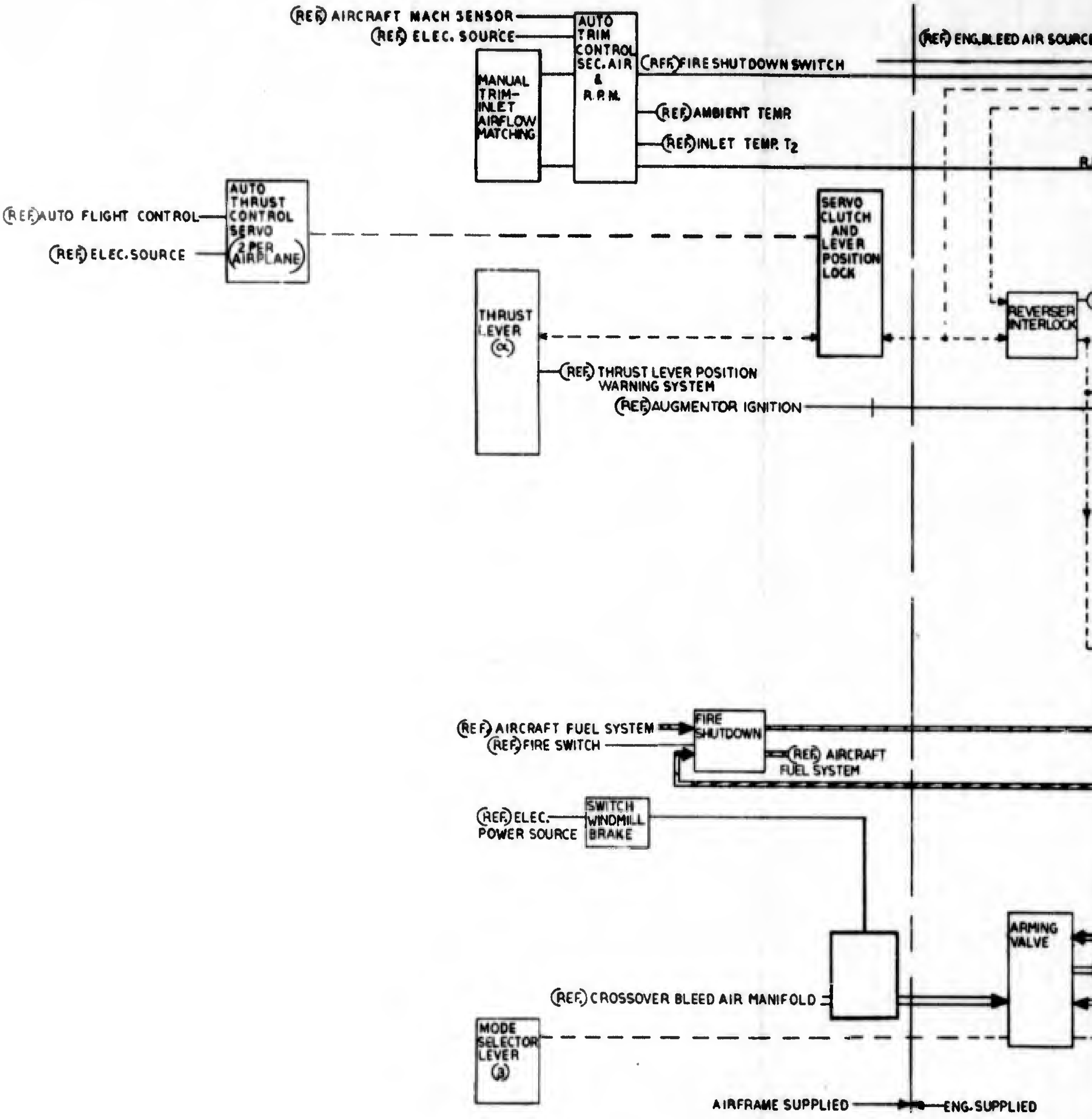


Figure 6. P&WA Ignition and Start Schematic


(REF) AIRCRAFT MACH SENSOR
(REF) ELEC. SOURCE
AUTO TRIM CONTROL SEC. AIR & R.P.M.
MANUAL TRIM-INLET AIRFLOW MATCHING
(REF) FIRE SHUTDOWN SWITCH
(REF) AMBIENT TEMP.
(REF) INLET TEMP. T2
(REF) ENG. BLEED AIR SOURCE
(REF) AUTO FLIGHT CONTROL
(REF) ELEC. SOURCE
AUTO THRUST CONTROL SERVO (2 PER AIRPLANE)
SERVO CLUTCH AND LEVER POSITION LOCK
REVERSER INTERLOCK
THRUST LEVER (α)
(REF) THRUST LEVER POSITION WARNING SYSTEM
(REF) AUGMENTOR IGNITION
(REF) AIRCRAFT FUEL SYSTEM
(REF) FIRE SWITCH
FIRE SHUTDOWN
(REF) AIRCRAFT FUEL SYSTEM
(REF) ELEC. POWER SOURCE
SWITCH WINDMILL BRAKE
(REF) CROSSOVER BLEED AIR MANIFOLD
ARMING VALVE
MODE SELECTOR LEVER (β)
AIRFRAME SUPPLIED
ENG. SUPPLIED

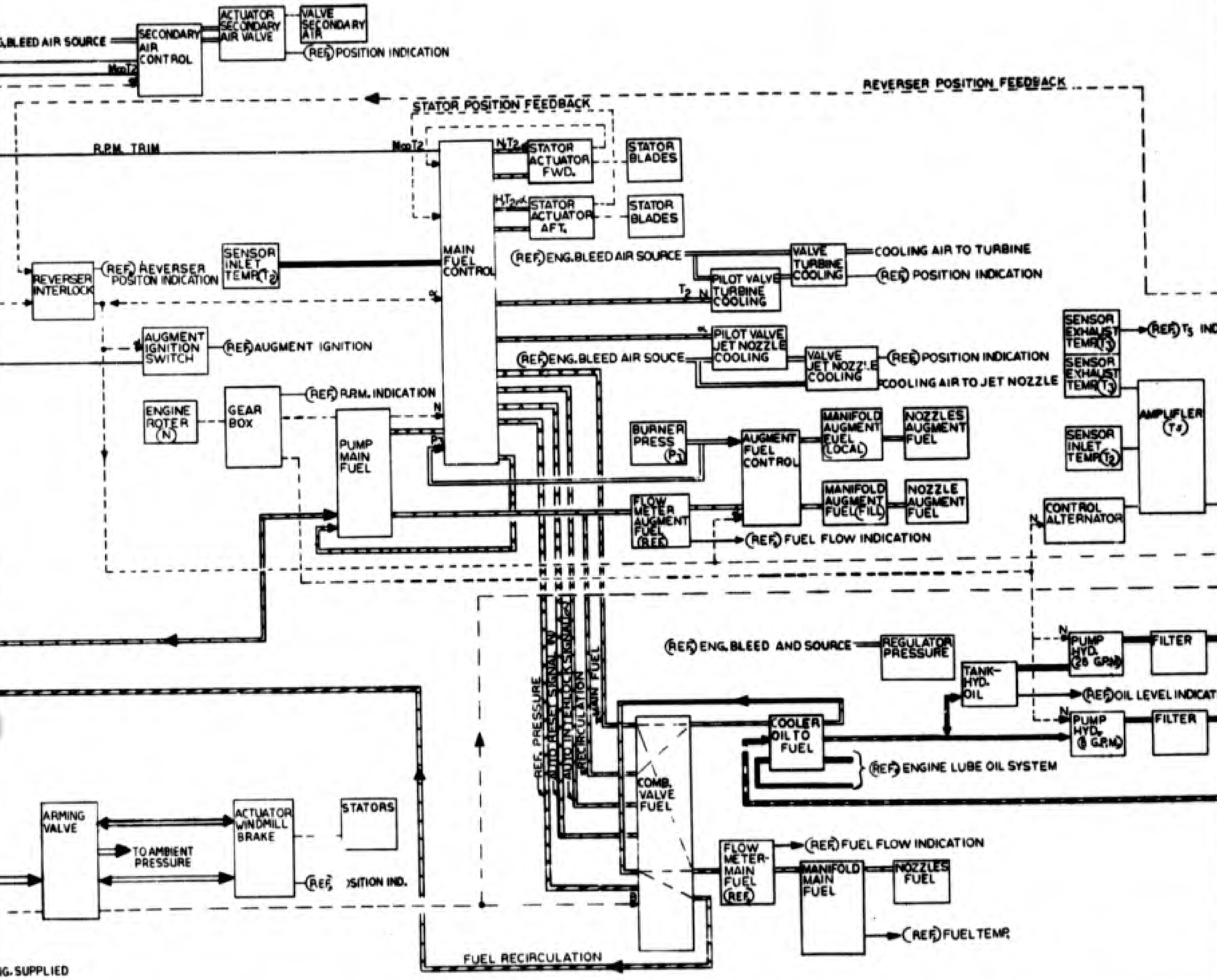


Figure 7. Engine Control Sche

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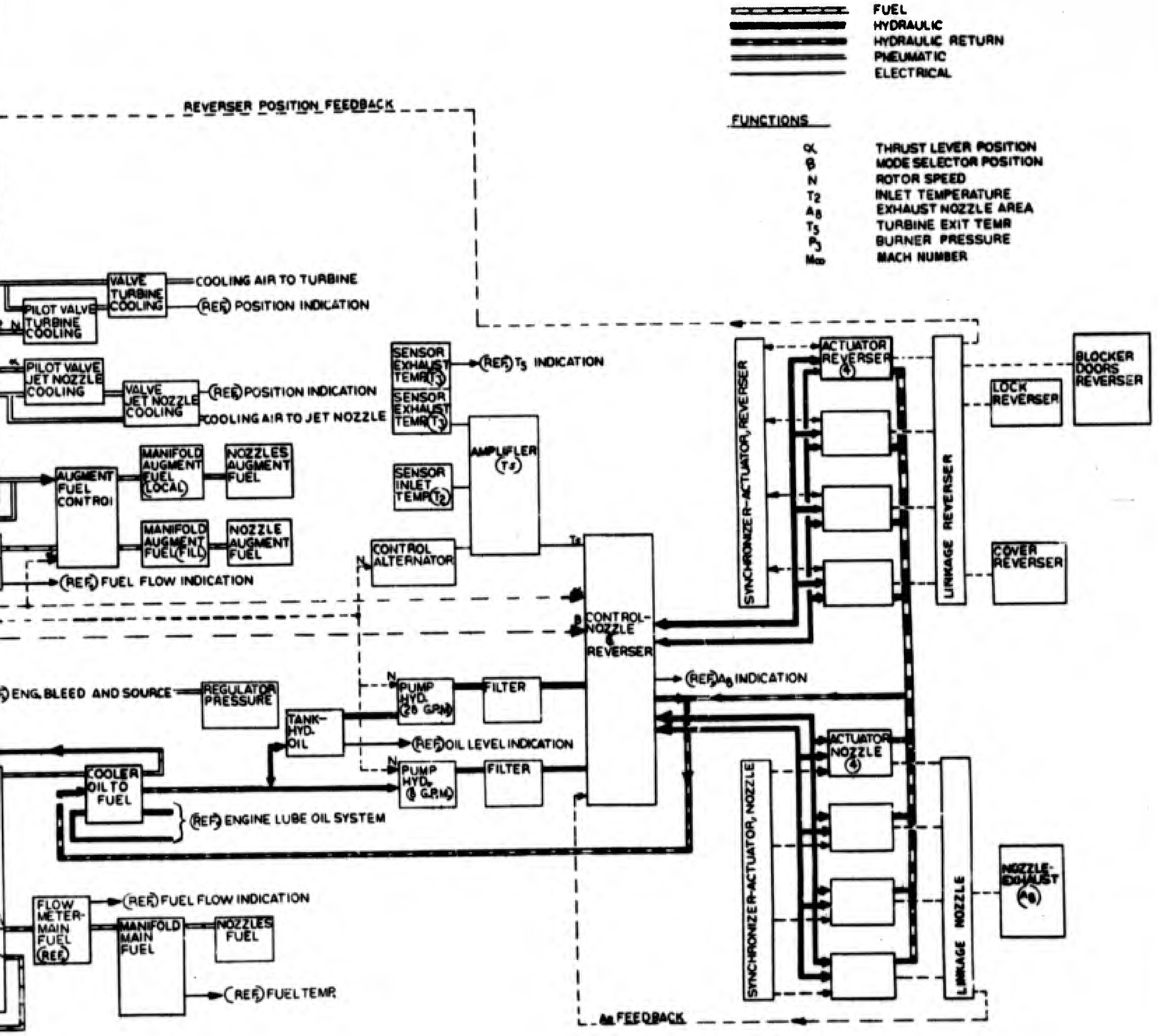
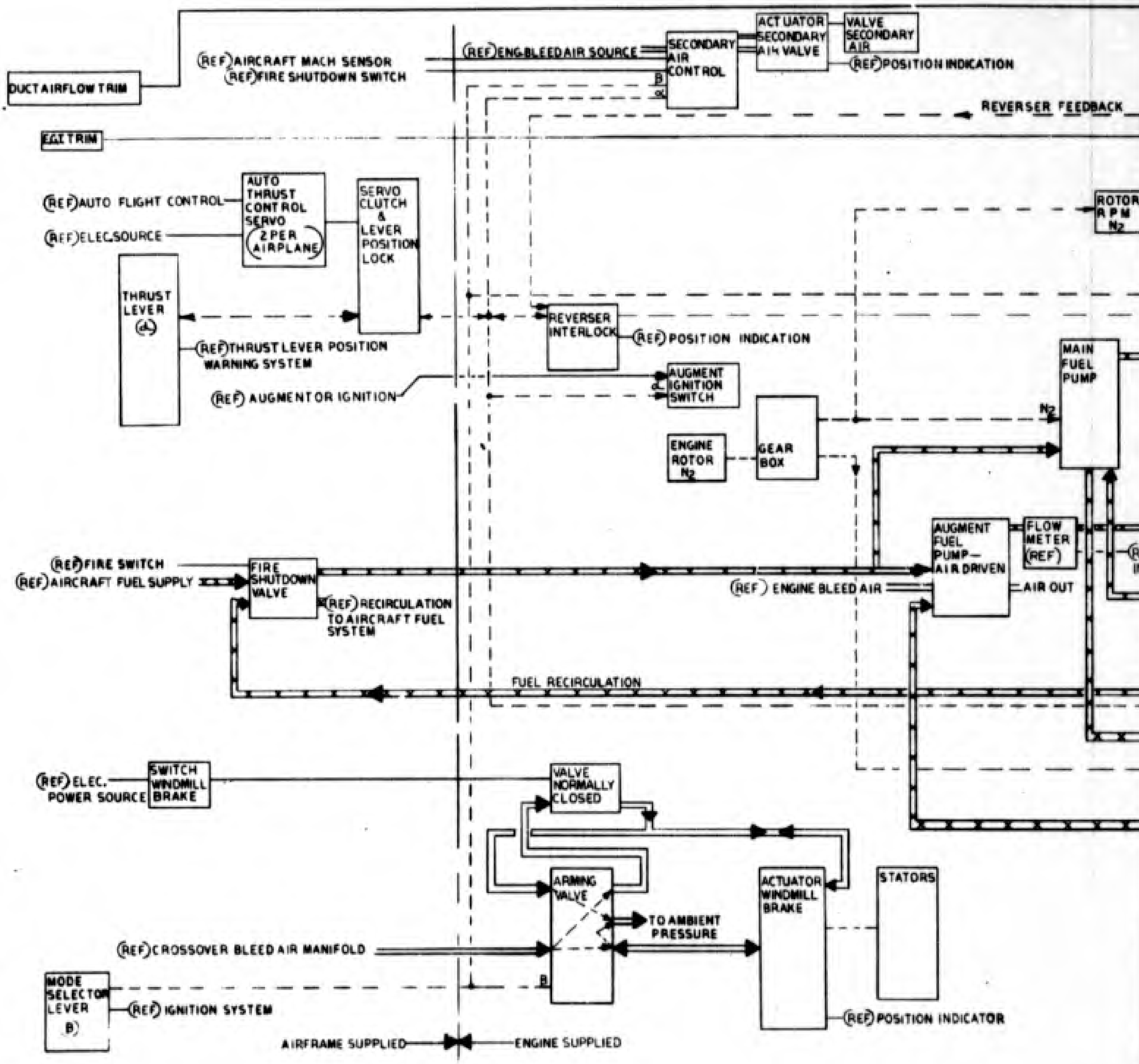


Figure 7. Engine Control Schematic (GE)

3


DUCT AIRFLOW TRIM
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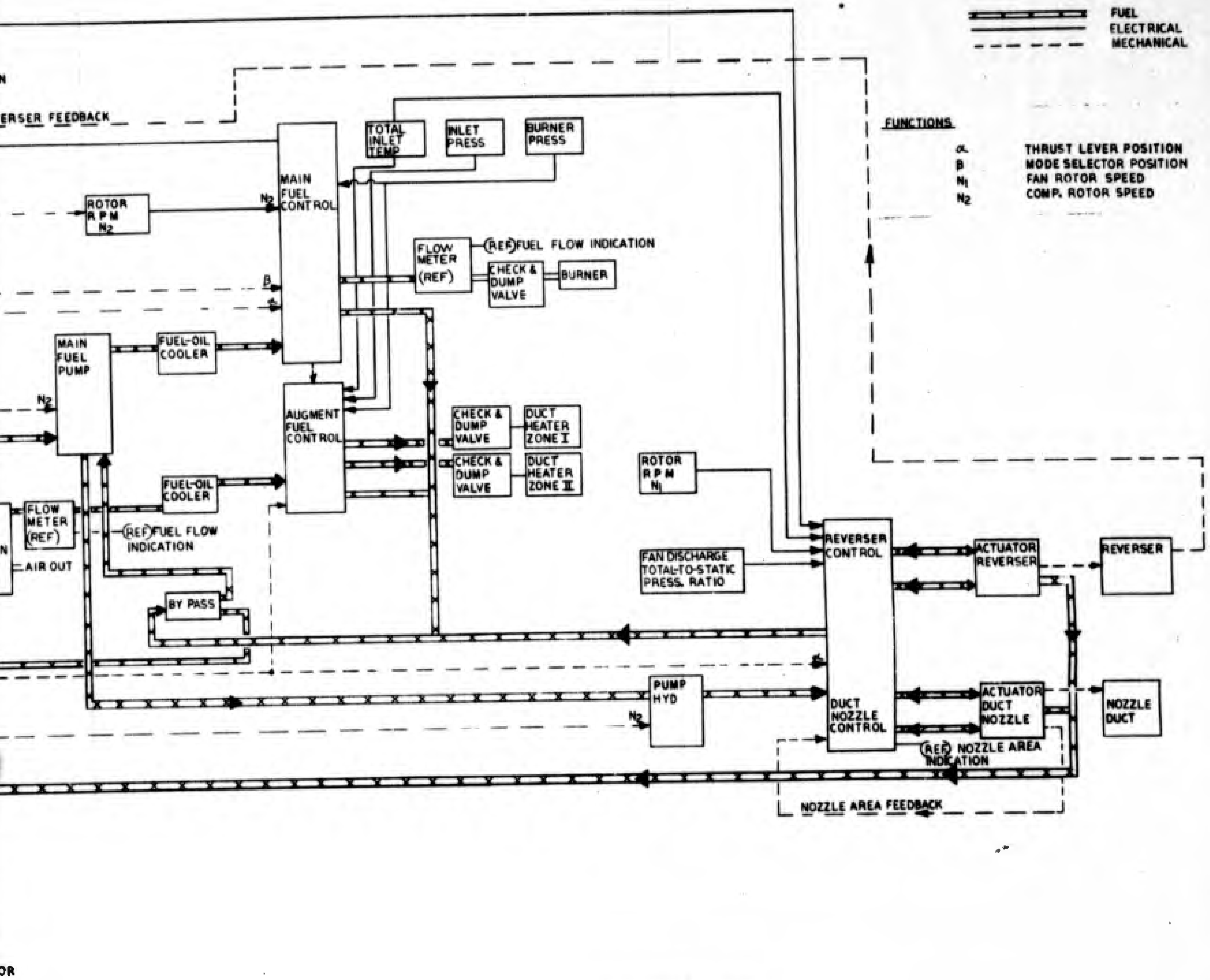
(REF) FIRE SHUTDOWN SWITCH
(REF) ENG.BLEED AIR SOURCE
SECONDARY AIR CONTROL
B
α
ACTUATOR SECONDARY AIR VALVE
VALVE SECONDARY AIR
(REF) POSITION INDICATION
REVERSER FEEDBACK
EGT TRIM
(REF) AUTO FLIGHT CONTROL
(REF) ELEC.SOURCE
AUTO THRUST CONTROL SERVO (2 PER AIRPLANE)
SERVO CLUTCH & LEVER POSITION LOCK
ROTOR RPM N2
THRUST LEVER (α)
(REF) THRUST LEVER POSITION WARNING SYSTEM
REVERSER INTERLOCK
(REF) POSITION INDICATION
MAIN FUEL PUMP
(REF) AUGMENTOR IGNITION
α
AUGMENT IGNITION SWITCH
N2
ENGINE ROTOR N2
GEAR BOX
AUGMENT FUEL PUMP— AIR DRIVEN
FLOW METER (REF)
(REF) FIRE SWITCH
(REF) AIRCRAFT FUEL SUPPLY
FIRE SHUTDOWN VALVE
(REF) RECIRCULATION TO AIRCRAFT FUEL SYSTEM
(REF) ENGINE BLEED AIR
AIR OUT
FUEL RECIRCULATION
(REF) ELEC. POWER SOURCE
SWITCH WINDMILL BRAKE
VALVE NORMALLY CLOSED
ARMING VALVE
TO AMBIENT PRESSURE
ACTUATOR WINDMILL BRAKE
STATORS
(REF) CROSSOVER BLEED AIR MANIFOLD
MODE SELECTOR LEVER (B)
(REF) IGNITION SYSTEM
B
(REF) POSITION INDICATOR
AIRFRAME SUPPLIED
ENGINE SUPPLIED



ENG SCHEMATIC P&W

Figure 8. Engine Control Schematic (P&WA)

2

6.3.11 Engine Hydraulic System, 2707 (GE). The engine hydraulic system is an integral part of the engine assembly, providing for actuation of the variable-area exhaust nozzle and for actuation of the thrust reverser mechanism. The system includes a pump, a reservoir, and associated plumbing and controls. The system uses the same type of fluid as the engine lubrication system. Fluid quantity monitoring is provided for flight deck information.

6.3.12 Engine Hydraulic System, 2707 (P&WA). The engine hydraulic system is an integral part of the engine assembly, providing for actuation of the variable-area duct nozzle and for actuation of the thrust-reverser mechanism. The system uses fuel from the main fuel system and includes an engine-driven pump and associated plumbing and controls.

6.3.13 Engine Mounting. The engine mounts and fittings support and orient the propulsion pod, which includes the air inlet, engine assembly, exhaust nozzle-thrust reverser, and the cowl panels. The air inlet is attached to the engine front flange. The engine may be removed from the airplane without having to remove the air inlet. (Refer to specification D6A10114-1.) The engine-mount system consists of structural fittings for attachment to the engine mount rings. To facilitate engine installation, the fittings terminate in self-aligning cone bolts for attachment to the airframe. For engine installation, the cone bolts are seated into airframe mating cone fittings. Nuts are installed on the cone bolts. Self-aligning bearings and hinged supports in the mount system permit radial and longitudinal expansion of the engine resulting from thermal changes (See Figs. 3 and 4). Vibration isolators are installed at each of the cone-bolt connections. The mount system incorporates a thrust link which transmits engine thrust load to the airframe and also senses and transmits thrust information to the flight deck.

6.3.14 Cowling. The engine cowling consists of three engine-mounted cowl panels capable of being opened or removed for access to the engine accessories. The side panels are hinged at the upper edges with track and roller hinges. The bottom panel is latched snug to the two side panels with cowling latches similar to the screwdriver-actuated latches currently in use.

Either of the side panels can be easily rotated to the open position. Telescoping tubular braces are provided to secure the side panels in the open position. The bottom panel may be removed by unlatching the side panels and releasing auxiliary latches, which do not carry panel loads during airplane operation.

The engine cowling incorporates the following features:

a. A pressure relief door with an integral burnout panel is provided in each cowl panel.

b. The lower cowl panel has provisions for draining any accumulated fluid into a sump.

c. Quick access for oil servicing is provided by a separate small access door in the cowl panel.

d. Latches will be quick-release type.

e. Removability of cowl panels will allow use of standard tools.

6.3.15 Bleed Air. The bleed-air system contains the components to provide high-pressure, high-temperature air to the airplane pneumatic supply system and to the inlet anti-icing system. The airplane pneumatic supply includes a duct assembly, a check valve, and a shutoff valve. The duct assembly is attached to an engine-supplied port and terminates downstream to interface with the airframe system at the firewall connection.

6.3.16 Air-Inlet Anti-Icing, 2707-100 (GE). The engine anti-icing ducting contains connections between the engine anti-icing duct and the air-inlet anti-icing system.

6.3.17 Air-Inlet Anti-Icing, 2707-100 (P&WA). An inlet anti-icing duct is installed between an engine bleed-air port and the air-inlet anti-icing system. A pressure switch and shutoff valve are installed in the duct system. The engine port is defined in Par. 3.2.2.2 of document D6A10199-1.

6.3.18 Engine Instrumentation. Engine instrumentation to monitor engine operation is provided for display of the information on the flight deck as specified in Table I. Pressure and temperature transmitters, fuel-flow transmitters, and vibration accelerometers will be of current design. A direct thrust-measuring system is used which directly measures the force exerted by the engine against the airframe.

6.3.19 Fire Protection. Dual-element, continuous, heat-sensitive, shrouded sensors are installed on the engine and are used for detection of fire conditions and to supply warning signals for display on the flight deck. High-rate discharge nozzles are provided into designated fire zones for discharging a bromotrifluoromethane fire-extinguishing agent as described in specification D6A10115-1. An engine-pod/horizontal-stabilizer isolating compartment firewall capable of withstanding a 2,000°F flame for 15 min is provided for isolation of the engine from the horizontal stabilizer. All services entering the compartment from the horizontal stabilizer, or leaving the compartment from the engine, are sealed at the point of entry, or exit, to maintain firewall integrity. The fire-protection provisions comply with the requirements of FAR 25.1191.

6.3.20 Plumbing. Fuel lines from the engine interface to the pod/airframe interface are installed for supplying fuel to the engine and for recirculation of fuel from the engine to the airframe tanks. Supply, pressure, and return hydraulic fluid lines are installed between the engine-mounted inlet hydraulic pumps and the interface with the air induction control hydraulic system. Rigid tubing is used insofar as possible. Flexible lines are used only as necessary to accommodate movement. The number of connections are kept at a minimum, consistent with assembly and installation requirements. All plumbing complies with FAR 25.1183 for fire zone requirements and is capable of withstanding engine compartment environmental conditions. Swivel couplings are used for the fuel supply line on the engine assembly.

Hydraulic lines for the engine-mounted hydraulic pumps use quick-disconnect, self-closing-type couplings at the interface connection.

6.3.21 Engine Wiring System. The electrical wiring serving the various engine functions is collected into bundles that terminate in fireproof connectors at the pod-to-airframe interface. Wires are routed in groups or separately insulated and shielded, wherever possible, to minimize possibility of instrumentation loss caused by shorts or breakage. Selective routing and protective features isolate wiring from fluid-carrying lines. Wiring will withstand the thermal, chemical, and physical environments of the installation and is flame-resistant. Electrical wiring in the engine installation subsystem meets the requirements of specification D6A10119-1.

6.3.22 Control System.

6.3.22.1 Thrust Controls. Thrust and mode control are accomplished with mechanical cable and push-rod control systems as shown in Fig. 9. Four thrust levers, one for each engine, are used for setting and varying engine thrust. The levers are located on the pilot's control stand (See Figs. 10 and 11). Push rods attach each thrust lever to an autothrottle electrical servo assembly consisting of a no-back clutch, a gearbox, and dual servo motors. The servo motors drive through an irreversible gear into shafts that drive the individual clutches to each throttle cable system. The servo motors and all other electrical components may be removed and replaced without disturbing any other components.

Removal and replacement of one clutch assembly can be accomplished without affecting the rigging of the other engine systems. Control-cable rigging is easily accomplished by the use of a single rig-pin for each clutch assembly. The clutch is normally engaged so that an input is accomplished by supplying an overriding force from the throttle handle. The servo drive can be overriden by application of a 0.5-lb maximum load on the thrust lever. The need for a friction brake in the throttle system is eliminated by utilizing the clutch as an anticreep device.

A torque limiter is located between the servo drum and the drive input and is set at a value above the maximum required to drive the throttle system. This feature is included to provide reversibility for the thrust-reverser interlock system and provides the pilot with override capability in the event of a clutch malfunction.

Push rods attach the servo assembly to cable drums that contain tension regulators that compensate for thermal expansion and structural

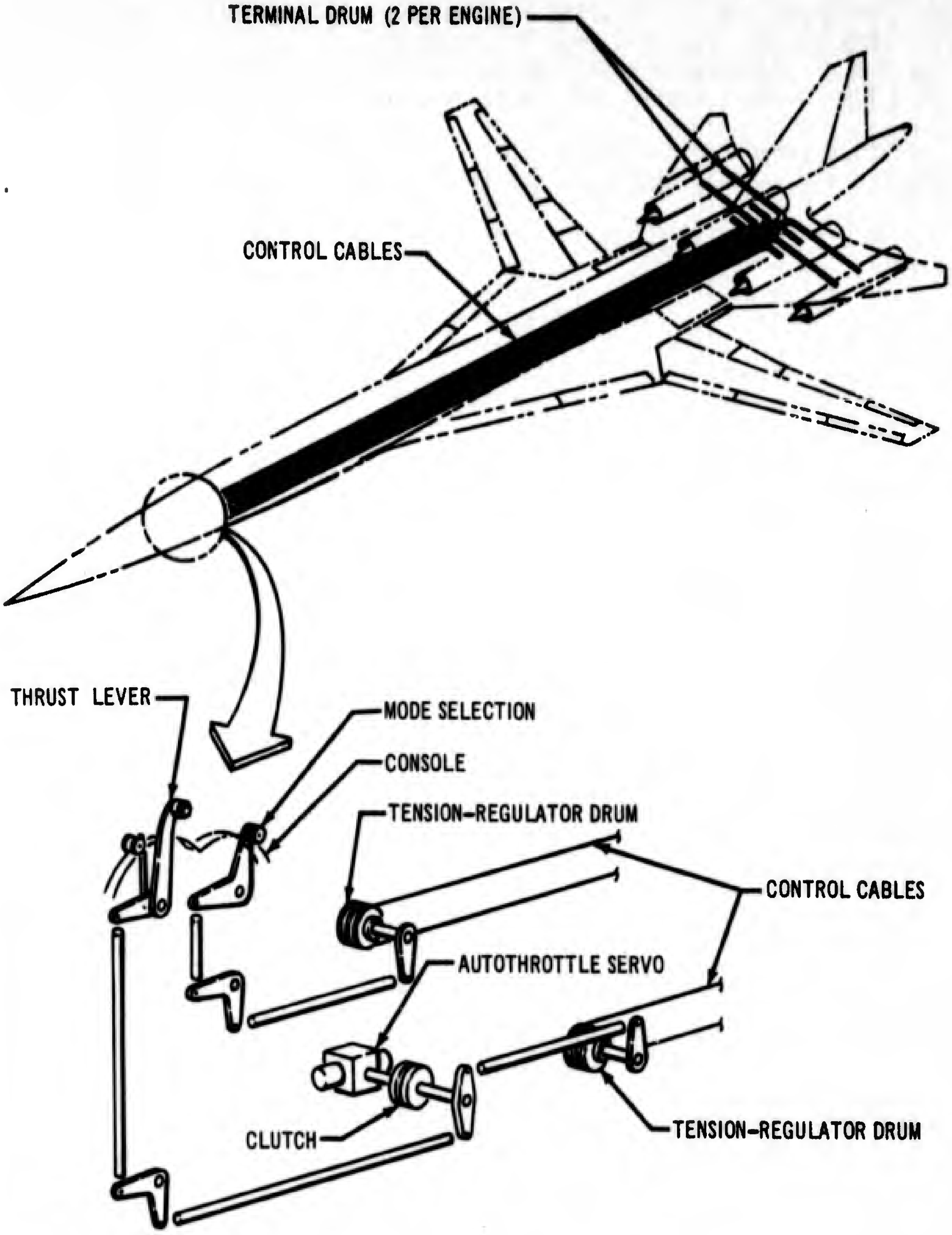


Figure 9. Thrust and Mode Control System Schematic

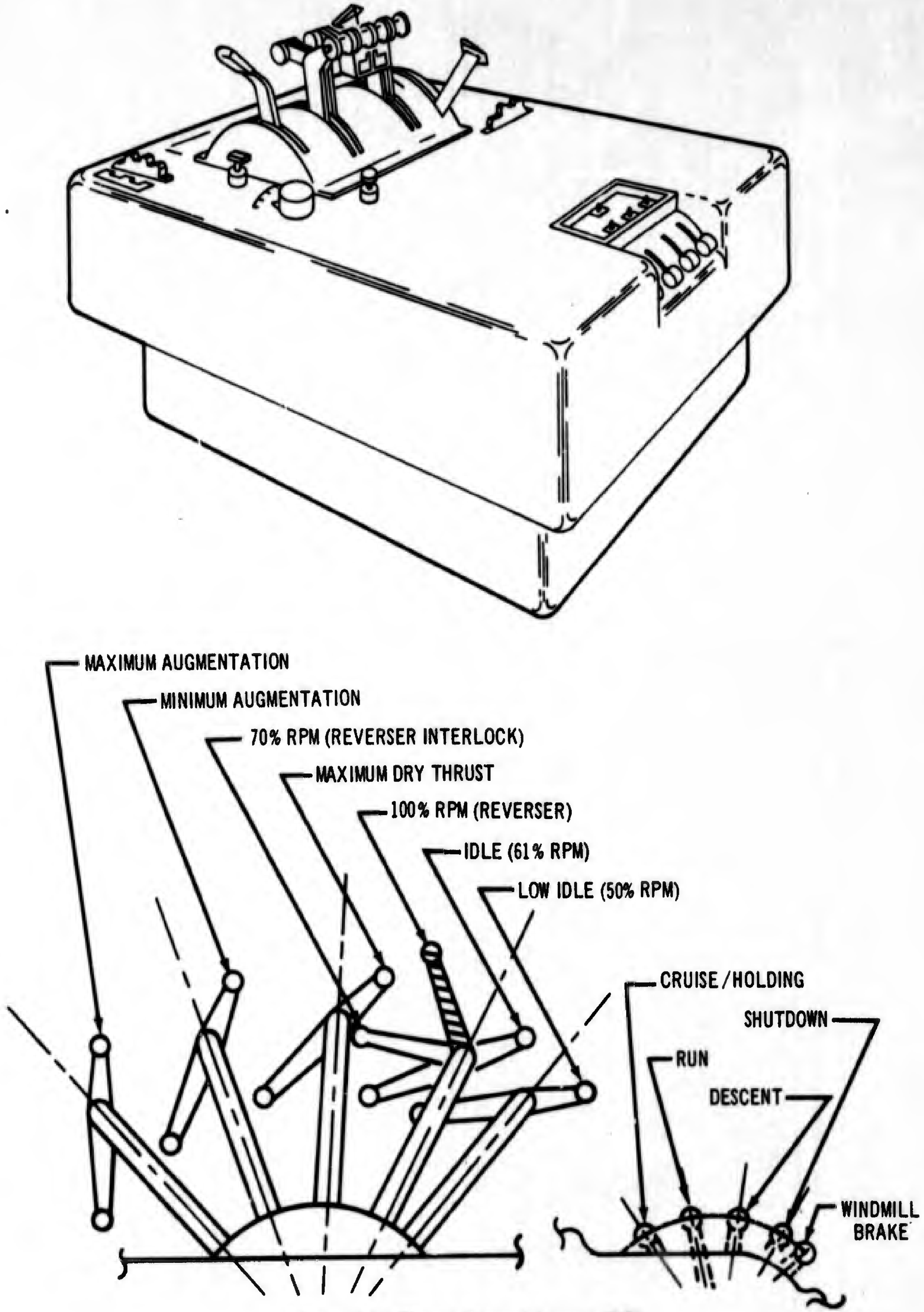


Figure 10. Thrust Control Levers (GE)

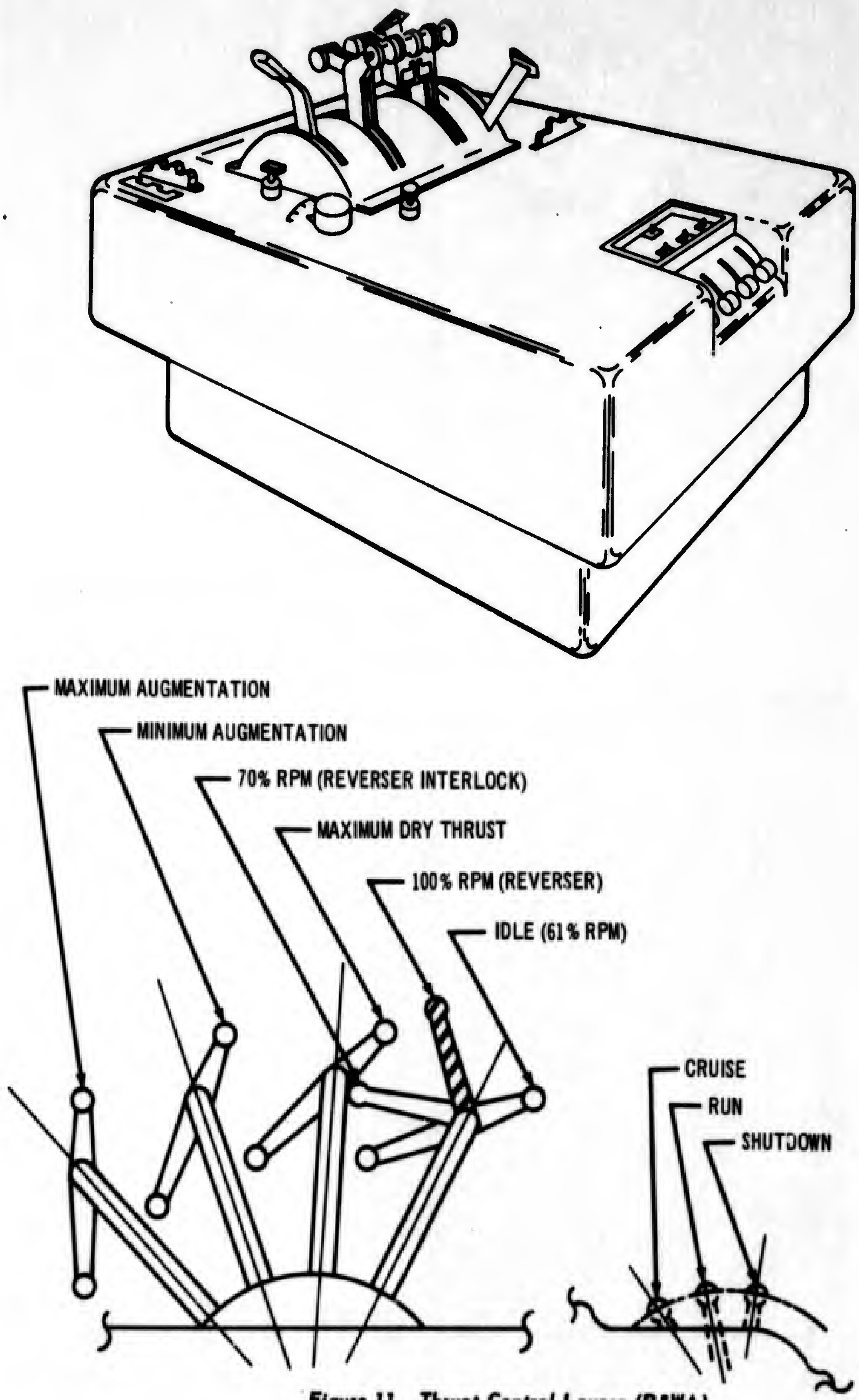


Figure 11. Thrust Control Levers (P&WA)

deflection. Cables are used between the cable-tension-regulator drums and terminal drums located above each engine. The cables are 3/32-in. diameter lock-clad steel to minimize cable stretch. Idler pulleys of 1-in. diameter are located approximately every 200 in. along the cable run to support the cables. Large pulleys of 5- to 6-in. diameter are used where control cables change direction. Where cable pass through pressurized bulkheads, pressure seals of recently developed split-ball type, fabricated from teflon material, are used. Push rods connect the cable terminal drum above each engine to the power-control shaft on the engine. A bolt, nut, and cotter pin connection are used at the engine disconnect point to the control system to facilitate engine change.

Reverse thrust is controlled by levers pivoted on, and extending forward from, the thrust levers. An interlock is incorporated to prevent increase in reverse thrust if the reverser fails to move in the direction commanded and to reduce thrust to the interlock limit if the reverser moves out of its committed position.

6.3.22.2 Mode Selector. Mode control is accomplished by mode-selector levers located on the pilot's control stand aft of the thrust levers. The mode selector lever is connected to the mode control shaft on the engine by a mechanical cable system similar to that connecting the thrust lever. Mode-selector positions are as follows:

a. 2707-100 (GE). The mode selector lever on the pilot's control stand has five positions: CRUISE/HOLDING, RUN, DESCENT, SHUTDOWN and WINDMILL BRAKE (See Fig. 10.).

b. 2707-100 (P&WA). The mode selector lever on the pilot's control stand has three positions: CRUISE, RUN AND SHUTDOWN (See Fig. 11).

6.3.22.3 Trim Controls.

a. 2707-100 (GE). A temperature trim control knob is provided on the flight engineers panel to permit manual trim adjustment for engine to inlet matching.

b. 2707-100 (P&WA). A duct airflow trim control knob is provided on the flight engineer's panel to allow input of electrical signals to the fuel control unit on the engine for varying duct-nozzle base point. An engine exhaust-gas-temperature (EGT) trim control knob is provided on the flight engineers panel to allow adjustment of the maximum primary fuel flow.

6.3.22.4 Windmill Brake. A guarded, two-position switch is provided for each engine. The switches are located on the overhead panel in the flight deck.

7. SUBSYSTEM PERFORMANCE (Deleted)

8. SUBSYSTEM OPERATION

8.1 Engine Starting. To start an engine on the ground, the airplane bleed-air cross-over manifold must be pressurized from either a ground air source or from an engine which has already been started. A receptacle is provided on the No. 4 nacelle to connect a pneumatic ground source to the cross-over manifold. The air source provides power to drive the pneumatic starters.

The procedure for starting an engine on the ground is as follows:

a. Place the thrust lever in IDLE.

b. Place the mode selector in SHUTDOWN.

c. Place the start switch in GROUND START.

d. When the engine reaches approximately 12-percent rpm, move the mode selector to the RUN position.

e. After the engine rpm reaches starter cutoff speed, return the art switch to OFF.

8.2 Forward Thrust. Forward thrust is controlled through the unaugmented and the augmented range by a single thrust lever for each engine. Detents are incorporated in the control quadrant at the MAX DRY and the MIN AUGMENT positions to provide the pilot with feel for locating these positions.

8.2.1 2707-100 (GE) Ground Operation. For ground operation, including taxi, the thrust lever may be placed in LOW IDLE (50% rpm) to reduce engine thrust to a minimum.

8.3 Reverse Thrust. Reverse thrust is controlled by reverse-thrust control levers pivoted piggy-back-style on the forward thrust lever as shown in Figs. 10 and 11. An interlock in the control stand prevents moving the reverse-thrust lever unless the forward-thrust lever is in the idle position. With the forward-thrust lever in the idle position, the reverse-thrust lever is rotated aft to actuate the reverser. A mechanical interlock on the engine prevents moving the reverse-thrust lever beyond the interlock position if, for any reason, the reverser does not actuate into the reverse-thrust position. With the reverser in the reverse-thrust position, further aft movement of the reverse-thrust lever increases reverse-thrust to maximum.

To return to forward-thrust operation, the reverse-thrust lever is rotated forward to the idle position. In the event that the reverser does not return to the forward-thrust position, the interlock on the engine prevents the forward-thrust lever from being moved in the forward-thrust direction beyond the interlock position.

8.4 Engine Shutdown. Two independent methods are provided for shutting the engine down. The normal method is by moving the mode selector to SHUTDOWN, thereby cutting off fuel to the engine fuel nozzles. The emergency method is by pulling the fire switch, closing the electrically actuated fuel firewall valve.

8.5 Mode Control, 2707-100 (GE). The RUN position permits fuel flow to the fuel nozzles, activates the ignition system, and cuts off fuel recirculation. In addition, a mechanical input from the mode-control shaft to the nozzle-control unit causes the variable engine nozzle to follow a roof or open-nozzle schedule to reduce engine noise during takeoff, climb, letdown, and landing. A detent in the mode-selector quadrant prevents the mode-selector lever from moving out of the RUN position.

The CRUISE/HOLDING position of the mode selector causes the variable engine nozzle to follow a floor or closed-nozzle schedule for maximum efficiency during subsonic cruise and holding operation. At power settings of maximum dry and greater, the roof and floor schedules are identical. A detent in the mode-selector quadrant prevents the mode selector from moving out of the CRUISE/HOLDING position.

The DESCENT position of the mode selector permits fuel recirculation when the thrust lever is moved IDLE.

Fuel is recirculated from the engine to the airplane fuel tanks during high-speed descent from cruise altitude to dissipate heat generated in the fuel, oil, and hydraulic systems of the engine. Fuel recirculation is cut off if the thrust lever is advanced out of IDLE. A detent holds the mode-selector lever in the DESCENT position. Also, a high-lift stop between the DESCENT and SHUTDOWN positions prevents inadvertent movement of the mode-selector lever into the SHUTDOWN position.

The SHUTDOWN position cuts off fuel flow to the engine nozzles, deactivates the ignition system, and permits fuel recirculation.

The WINDMILL BRAKE position accomplishes all of the functions of the SHUTDOWN position and, in addition, arms the windmill brake.

8.6 Mode Control 2707-100 (P&WA). The mode selector control for the Pratt & Whitney Aircraft engine has three positions: CRUISE, RUN, and SHUTDOWN. (See Fig. 11.)

The SHUTDOWN position cuts off fuel flow to the engine fuel nozzles, deactivates the ignition system, and arms the windmill brake system.

The RUN position permits fuel flow to the engine fuel nozzles and activates the ignition system. This position is used for all operating conditions except supersonic cruise.

The CRUISE position reduces secondary air flow to match the cooling and nozzle filling requirements for maximum efficiency at supersonic cruise.

A detent at each position of the mode-control quadrant prevents the mode-selector lever from moving out the selected position. In addition, a high-lift stop is incorporated between the RUN and SHUTDOWN positions to prevent inadvertent shutdown of the engine.

Fuel recirculation is controlled automatically as a function of fuel temperature rather than by mode-selector position.

8.7 Windmill Braking. The windmill brake actuation can be accomplished only by placing the mode-selector lever in the SHUTDOWN (P&WA) or WINDMILL BRAKE (GE) position and then actuating a guarded, two-position switch located on the overhead panel. One switch is provided for each engine.

An arming valve, actuated by the mode-control lever, is used to permit actuation of the windmill brake only when the mode-control lever is in the proper position.

8.8 Engine Airflow Trim, 2707-100 (GE). Trim controls are incorporated to trim engine airflow to obtain maximum efficiency of the inlet during supersonic cruise. The trim control is manually adjusted by the TEMP TRIM control knob on the flight engineer's panel to match the engine to the inlet for standard day conditions. Trim is then automatically maintained during nonstandard day conditions. Trim is then automatically maintained during nonstandard day conditions by the trim-control system as a function of Mach number and inlet total temperature.

8.9 Engine Airflow Trim 2707-100 (P&WA). Engine trim is performed manually to match inlet and engine airflow at supersonic cruise. The DUCT AIRFLOW TRIM control knob, located on the flight engineer's panel, provides an electrical input to the fuel-control unit on the engine to vary the duct-nozzle base point.

8.10 EGT Trim 2707-100 (P&WA). The engine requires a trim adjustment to set the maximum fuel flow of the primary gas generator to limit exhaust-gas temperature to a safe limit. The EGT TRIM control knob on the flight engineer's panel provides an electrical signal to the fuel-control unit on the engine to adjust maximum primary fuel flow.

Once EGT Trim has been accomplished, it is necessary to retrim only occasionally as engine-aging tends to increase EGT.

8.11 Ignition and Start. Starter actuation and ignition are controlled by a guarded, three-position START switch located on the pilot's control stand. One switch is provided for each engine. The three positions of the start switch are: OFF (midposition), GROUND START (down position), and FLIGHT START (up position).

A caution light is illuminated whenever the start switch is in the flight-start or the ground-start position to remind the pilot that the ignition system is activated.

Safety switches, activated by the mode-selector lever, ensure that the ignition system is deactivated when the engine is shut down and that inadvertent tripping of the start switch will not activate the ignition to the possible detriment of maintenance personnel.

Augmentor ignition is controlled by a switch located on the engine that is actuated when the thrust lever is advanced into the augment range. A time switch deactivates augmentor ignition after lightup.

8.12 Secondary Air System. Secondary air is directed from the forward face of the engine to the nozzle area through ducts. Each duct contains a valve to regulate and shut off secondary airflow. The regulating valve is automatically positioned by a control unit as a function of Mach number and thrust-lever angle. For ground operation and takeoff, the secondary air valves are closed. When the ENGINE FIRE SWITCH is pulled, an override circuit closes the secondary air valves.

9. SUBSYSTEM TESTING

The following tests and analysis shall be performed to verify the performance and design requirements of this specification. Verification methods of the requirements referred to in other specifications shall be specified in those specifications.

9.1 Engineering Test and Evaluation. Engineering test and evaluation tests shall be performed as an integral part of the subsystem development process. The results of these tests, as well as of tests conducted by component suppliers, shall supplement and support formal qualification tests.

9.1.1 Pressure Tests. Pressure tests shall be conducted to verify strength and sealing capabilities of engine cowl panels. Test conditions will include static loads and simulated operational environment. (Refer to Par. 5.5.)

Pressure tests shall be conducted on bleed air ducts to verify capability to withstand maximum operating pressures and temperatures under static conditions. (Refer to Par. 5.7).

9.1.2 Structural Tests. Engine mounting provisions shall be tested to verify ultimate design loads. Tests shall be conducted under static conditions. (Refer to Par. 5.4.) Verification of engine-inlet-attachment loads capability shall be accomplished by the engine manufacturer. (Refer to Par. 5.4).

9.2 Preliminary Qualification Test. Not applicable.

9.3 Formal Qualification Test. Formal qualifications shall verify that the AEIS and its component systems meet all assigned requirements when integrated with the airplane subsystems. Formal qualification shall be conducted using approved test equipment, test methods, and procedures. Accomplishment of the following verification constitutes acceptance of design and development.

9.3.1 Inspection. Inspections shall include visual examination and dimensional measurement to verify that the subsystem components, equipment, and design features have been provided and that they have been fabricated, assembled, and installed in accordance with the applicable drawings and specifications. The inspection shall verify that the physical interfaces of the subsystems meet the requirements and are compatible with those subsystems or equipments with which they interface. Functional performance of installed equipment shall be verified during ground test programs. Verification of the following will be accomplished by inspection:

9.3.1.1 Engine. An inspection shall be made of the engines, and documentation from the engine manufacturer, at the time of receiving the first qualification-test engines to verify that the engines satisfy the requirements of the engine model specification, including components, proper assembly, physical dimensions, and interfaces.

9.3.1.2 Cowling. An inspection shall be conducted during formal qualification to verify that the cowling complies with the envelope, fit, and clearance requirements for engine-pod-mounted accessories in accordance with applicable drawings.

9.3.1.3 Fire-Protection System. Inspection shall be made to verify that the isolation provisions for fire-confinement have been installed in accordance with applicable drawings.

9.3.1.4 Safety. Inspections shall be conducted to verify that the safety features have been provided and have been installed in accordance with applicable control drawings and specifications.

9.3.1.5 Subsystem Design Features. Inspections shall be made to verify that the requirements for the following component systems, equipments, and design features have been provided and installed according to applicable control drawings and specifications:

6.3.1	Exhaust Nozzle-Thrust Reverser
6.3.2	Windmill Brake
6.3.3	Secondary Air Nozzle Cooling System
6.3.4	Engine Lubrication System
6.3.5	Engine Fuel System
6.3.6	Engine Ignition System, 2707 (GE)
6.3.7	Engine Ignition System, 2707 (P&WA)
6.3.8	Engine Power Takeoff
6.3.9	Engine Controls
6.3.10	Drain System
6.3.17	Anti-Icing Ducting
6.3.18	Engine Instrumentation
6.3.19	Fire Detection
6.3.20	Plumbing
6.3.21	Engine Wiring
6.3.22	Controls

9.3.16 Engine Mounting. An inspection shall be conducted to verify that structural support provisions are provided and have been installed in accordance with requirements of applicable drawings.

9.3.1.7 Engine Bleed Air. Inspection shall be made to verify that the bleed air duct includes the check valve and that the physical interfaces have been accomplished in accordance with applicable control drawings.

9.3.2 Analysis. An analysis of all data relating to the AEIS shall be conducted. The analysis shall establish the reliability of the subsystem to perform its functions and will determine the effects of the subsystem on airplane performance when it is integrated with airplane subsystems.

9.3.2.1 Maintainability. The maintainability requirements of Par. 4.1.2 and subsequent paragraphs represent the mature system operated in representative scheduled airline revenue service. Projections of the requirements above shall be verified by analysis of data acquired as a result of, and in conjunction with, mockup evaluations, qualification tests, developmental tests, engineering ground tests, and flight tests. Activities involving scheduled checks, repairs, and servicing of line replaceable units (LRU) shall be observed and data recorded. The suitability of service and access provisions shall be determined by observation of technicians performing maintenance and servicing tasks on the subsystem.

9.3.2.2 Useful Life. Analytical review of applicable design, tests, and service data shall be provided to justify useful life requirements of Par. 4.1.3.

9.3.2.3 Safety. The safety requirements in Par. 4.1.6 shall be verified analytically by the identification of compensating revisions for each failure mode defined in the failure mode effect and criticality analysis and by inspection during the engineering safety review.

9.3.3 Demonstrations. Satisfactory operation of all functioning equipment shall be demonstrated during ground rig testing and airplane ground and flight testing.

9.3.4 Tests. Testing shall be conducted on an engine ground test rig or during prototype airplane testing. The tests will verify performance compatibility between the engine installation components, propulsion pod, and other subsystems. The complete pod, including the engine with the inlet, nozzle, thrust reverser, cowling, accessories, controls, instrumentation, accessory drive system, and engine mounts, shall be tested.

The engine manufacturer shall conduct engine-development tests according to documents D6A10198-1 or D6A10199-1. Full-scale prototype tests shall be conducted in a calibration stand and simulated-altitude facility. The tests shall establish the installed performance of the inlet/engine and provide data to determine the effects of inlet recovery, inlet distortion, power extractions, and secondary airflow as defined in specification D6A10111-1 or D6A10112-1. (Refer to Par. 5.1).

9.3.4.1 Test Programs.

9.3.4.1.1 Development Tests. The engine-installation-development tests shall be conducted in three stages to ensure that the complete system meets its requirements. Boeing shall conduct the following tests:

a. Evaluation of the complete engine installation on a ground test rig

b. Calibration and testing of the engine installation on the prototype airplane.

c. Evaluate the performance parameters of the engine installation during the 100-hr flight-test programs.

In addition, an aircraft integrated data system (AIDS) shall be evaluated during the ground- and flight-test programs.

9.3.4.1.2 Engine Ground-Rig Testing. Two calibrated engines, of the same type and model as the prototype flight engine, shall be installed in ground-test rigs closely simulating the airplane propulsion pod installation. The test rigs shall include the inlet, engine, and afterburner with controls, nozzle, reverser, cowling, accessories, instrumentation, engine fuel and oil systems, accessory drive and starting system, and engine mounts. The following aspects of the engine installation will be evaluated.

9.3.4.1.3 Engine Capability Test. Tests shall verify the capability of the installed engine to meet the thrust and mechanical power extraction requirements of document D6A10198-1 or D6A10199-1.

Satisfactory steady-state and transient engine operation, from idle to maximum augmented power, shall be demonstrated with fuel inlet conditions corresponding to normal boost-pump operation and with fuel-inlet temperatures up to the maximum limits recommended by the engine manufacturer.

The ability of the engine to operate without boost-pump operation and the effects of switching to the fuel cross-feed system will be evaluated.

9.3.4.1.4 Thrust Reversal. Performance and operation tests shall be conducted to determine reverse-thrust effectiveness and reverser exhaust-gas ingestion and impingement characteristics. Tests shall be conducted on the ground test rig and during ground operation of the airplane.

9.3.4.1.5 Accessory Drive System. The compatibility of the accessory drive system (ADS) and decoupler with the engine power take-off and airplane accessories at various engine steady- and transient-power settings, and with various accessory loads, shall be demonstrated.

9.3.4.1.6 Engine Starting System. With the airplane accessories unloaded, the ability of the starting system to meet the engine-starting requirements under various ambient conditions shall be demonstrated. The adequacy of the starter installation shall be verified by continuous monitoring of the system throughout the test period.

9.3.4.1.7 Controls. Tests shall be conducted to verify that the elements of the control system meet the requirements for control of engine and actuation of thrust controls, mode-selector controls, and thrust-reverser controls. Tests shall also include verification of thrust-reverser interlocks operation and capability of manually overriding automatic control. Accomplishment of these tests shall satisfy requirements of Par. 5.3.

9.3.4.1.8 Engine and Nacelle Drain System. The fuel- and oil-drain quantities resulting from an engine shutdown and two unsuccessful starts shall be measured and checked against the engine and nacelle drain-tank capacities. The ability of the engine-bleed-ejector pumps to scavenge the engine-drain tank and nacelle drain system shall be demonstrated.

9.3.4.1.9 Nacelle Environment! Temperature, pressure, and vibration surveys of the engine and nacelle environment shall be taken at various steady and transient engine power settings, including thrust–reverser operation. The effect of surface conditions and engine leakage on the pod temperature and pressure levels shall be investigated.

9.3.4.1.10 Fire Protection. Data obtained from the engine and nacelle environment survey shall be used to confirm correct location of the fire-detection and extinguishing system and verify the structural suitability of the installation. Flame resistance of firewalls and fire shields will be verified by bench tests.

9.3.4.1.11 Instrumentation. The engine, inlet, and accessory instrumentation shall be calibrated and evaluated during ground rig testing to demonstrate specified accuracies and response rates and the ability to monitor propulsion system health and performance during steady-state and transient operation.

In particular, the direct-reading thrust-measuring system shall be calibrated against thrust stand measurements at power settings from full reverse, through idle, to maximum augmented thrust. Data shall be obtained during power lever advance and retard to demonstrate repeatability and acceptable hysteresis effects.

9.3.4.1.12 Bleed Air Equipment The pressure containment capability of the bleed manifold and ducts will be verified by testing and analysis.

9.3.4.1.13 Airplane Ground Tests. Engineering ground tests shall be conducted on the complete propulsion system installed in the prototype airplane to obtain sufficient data to provide flight clearance and permit preflight calibration of the propulsion system instrumentation.

To generate the required data, selected tests from the engine ground rig tests shall be repeated. In particular, the nacelle environmental tests shall be extended to include those parts of the airplane structure influenced by the propulsion system. The engine controls shall be checked for rigging tolerances and satisfactory operation from the flight deck.

9.3.4.1.14 Prototype Flight Tests. During the 100-hr prototype flight test program, sufficient test data shall be obtained to thoroughly evaluate the complete engine installation.

The tests conducted during the engine ground rig tests shall be extended to flight conditions throughout the test envelope. In addition, the general structural suitability of the installation and the ability of the propulsion system instrumentation to adequately monitor system health and performance shall be demonstrated.

9.4 Reliability Test and Analysis. The reliability criteria of Par. 4.1 represents a mature system operated in representative scheduled airline revenue service. Inasmuch as the tests and data specified in Par. 9.3.4 are limited and the hardware may be of a prototype nature, assessment of meeting the criteria of Par. 4.1 shall be accomplished as follows:

9.4.1 Reliability Tests. Tests specifically designed to verify the reliability of the subsystem shall not be conducted Data obtained from tests conducted under Par. 9. shall be applied to the reliability analysis specified in Par. 9.4.2, extrapolated to anticipated airlines operational conditions.

9.4.2 Reliability Analysis. A reliability analysis shall be performed to demonstrate that the requirements of Par. 4.1 can be achieved. This shall be accomplished as follows:

a. A reliability growth forecast curve shall be established, based on historical experience.

b. A Phase III target reliability level shall be established to measure achievement toward the mature reliability.

c. Design data and test results shall be applied to a reliability analysis model incorporating the following:

   (1) Block diagrams summarizing the logical relationships between components success/malfunction and system/malfunction

   (2) A mathematical reliability model derived from (1) and incorporating minimum equipment requirements for continued flight.

   (3) A mathematical reliability model simulating typical airline operations and routes.

10. PREPARATION FOR DELIVERY

The subsystem shall be delivered as part of the prototype airplane, delivered as defined by specification D6A10107. Delivery requirements for the subsystem or components shall be defined by the contract.

11. NOTES

11.1 Supporting Data

11.1.1 Definitions. Definitions are listed in Sec. 6 of specification D6A10107-1.

11.1.2 Reliability Analysis. Reliability analyses to show compliance with the requirements of Par. 4.1.1 and to assess the verification data required in Par. 9.2.4 will be included in document D6A10064-14.

11.1.3 Maintenance Design Guide. The maintenance design guide, D6-9458, may be used for subsystem maintainability design guidance.

SUPPLEMENT I

There are no differences in the Aircraft Engine Installation Subsystems for the prototype and production airplanes.