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UTILITY
FLIGHT MANUAL
X-22A V/STOL
RESEARCH AIRCRAFT

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DON'T GAMBLE WITH YOUR LIFE

SCOPE

This manual contains the necessary information for operation of the X-22A aircraft. These instructions provide you with a general knowledge of the aircraft, its characteristics, and specific normal and emergency operating procedures. Description and procedures for systems peculiar to V/STOL operation have been emphasized. You will find the procedures adequate for normal operating conditions; they are not intended as a substitute for the good judgement required to handle multiple emergencies, adverse weather, etc.

PERMISSABLE OPERATION

The flight manual takes a "positive approach" and normally states only what you can do. Unusual operations **or** flight configurations not covered in this manual should not be attempted.

WARNINGS, CAUTIONS, AND NOTES

The following definitions apply to"Warnings", "Cautions", and "Notes" found throughout the manual:

WARNING - Operating procedures, techniques, etc., which will result in personnel injury or loss of life if not carefully followed.

CAUTION - Operating procedures, techniques, etc., which will result in damage to equipment if not carefully followed.

Note - An operating procedure, technique, etc., which is considered essential to emphasize.

SECTION I - DESCRIPTION

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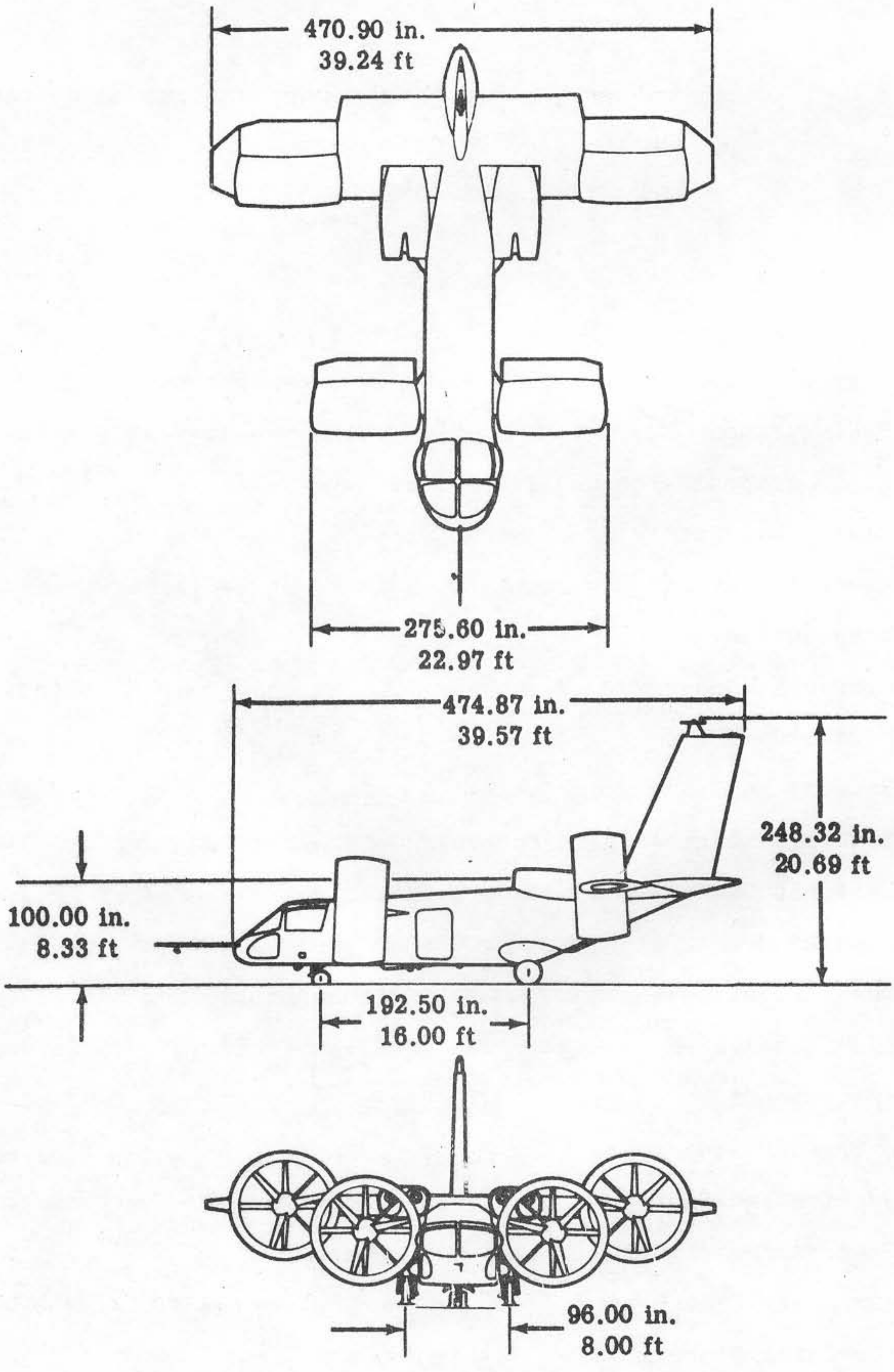

470.90 in.
39.24 ft
275.60 in.
22.97 ft
474.87 in.
39.57 ft
248.32 in.
20.69 ft
100.00 in.
8.33 ft
192.50 in.
16.00 ft
96.00 in.
8.00 ft

Figure 1-1

THE AIRPLANE

The mission of the X-22A Aircraft is to conduct an extensive research program to explore the mechanical and aerodynamic characteristics of the dual-tandem ducted propeller V/STOL concept and to evaluate the military potential of this concept of flight. Features of the aircraft are as follows:

Four T-58-8 turboshaft engines interconnected to propellers by shafting and gearboxes; automatic engine declutching.

Four interconnected ducted propeller units rotatable through 90 degrees.

Automatic integration of conventional and V/STOL flight controls during transition.

Automatic stability augmentation is provided in all three axes by means of dual hydraulically powered systems and associated electronics.

Trim and artifical feel is provided in all modes of flight by means of an electronic feel and trim system.

Two thrust control systems are incorporated to provide a pitch control mode and a power control mode.

Dual hydraulic systems to provide increased reliability.

Two engine cruising capability; three engine V/STOL capability.

A variable stability control system (VSS) is incorporated to provide the capability of simulating other V/STOL aircraft, to evaluate handling qualities requirements, define optimum and minimum handling VTOL qualities, and simulate changes in the aircraft to evaluate different concepts and modifications. The VSS further incorporates a fly by wire (FBW) mode.

The general arrangement of the aircraft is illustrated in Figure 1-2.

The arrangement of flight deck consoles, instrument panels, and miscellaneous controls and indicators is illustrated in Figures 1-3 through 1-8.

DIMENSIONS

The overall dimensions of the aircraft under normal conditions of gross weight, tire and gear inflation are as follows:

Wing Span	39.24 feet
Length	39.57 feet
Height	20.69 feet
Wheel Base	16.00 feet
Wheel Tread	8.00 feet

Refer to Section II for minimum turning radius and ground clearances.

POWERPLANTS

Each of the four powerplants consists of a YT58-GE-8 turboshaft engine; an engine starting circuit; engine power controls; engine overspeed protection system; temperature, fuel flow and rpm indicating circuits; air induction, cooling, and exhaust provisions. Controls and indicators for the powerplant system are as follows:

Index and Figure No.	Nomenclature	Function
27, figure 1-3	Engine master/start switch	ON-applies power to the fuel boost pump.
		START-applies power to the engine starter and ignition system.
		OFF-deactivates the start relay and activates the anti-icing system.

GENERAL ARRANGEMENT

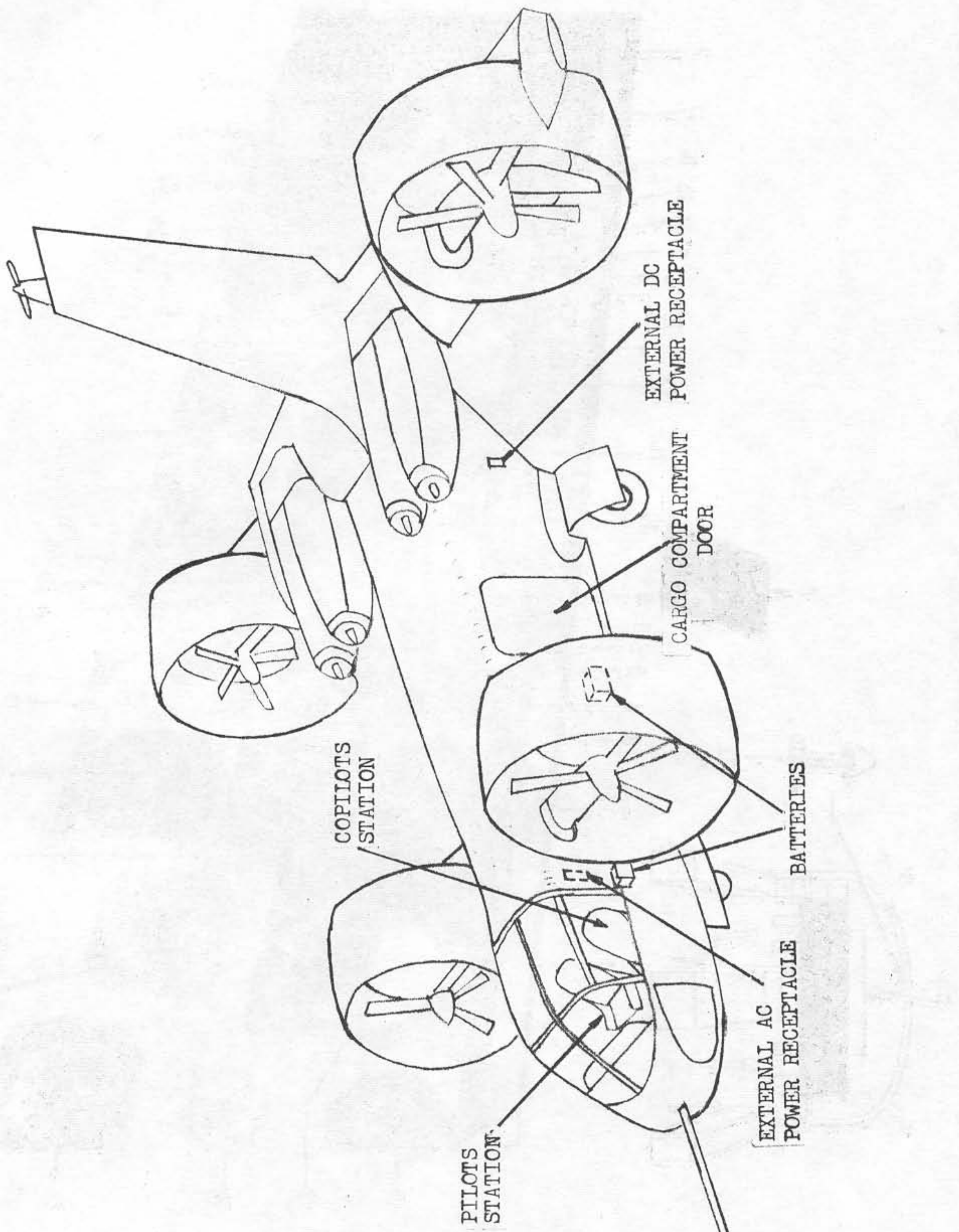


Figure 1-2

MAIN INSTRUMENT PANEL

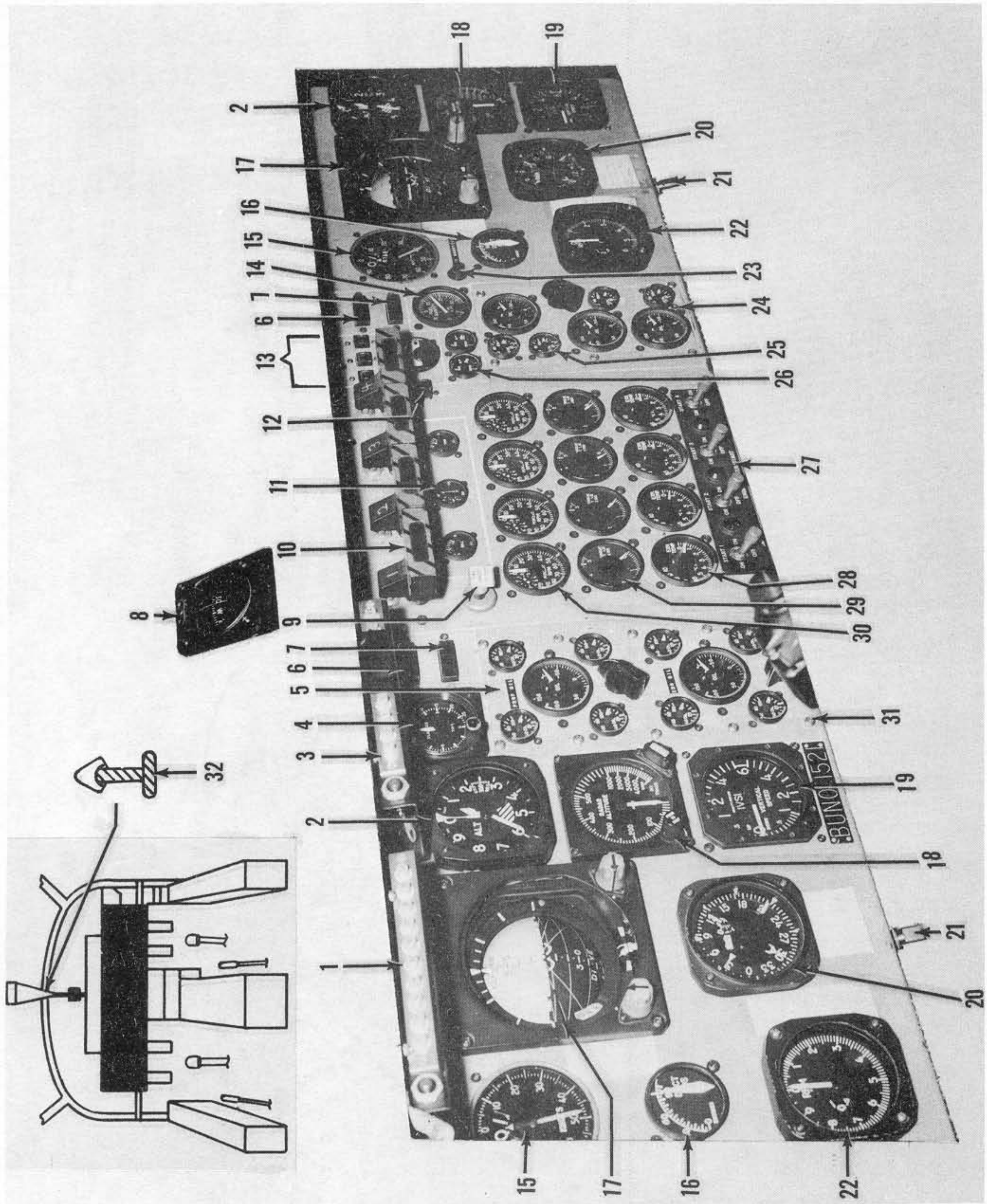
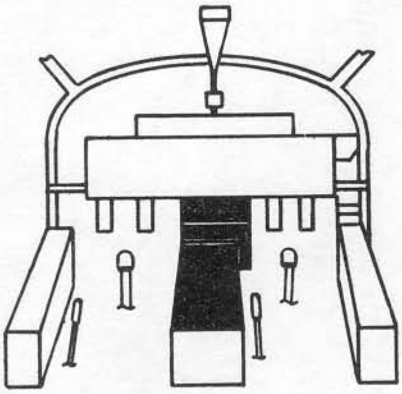


FIGURE 1-3 (SHEET 1 OF 2)

1. CHIP DETECTOR CAUTION LIGHT PANEL
2. ALTIMETER
3. OIL PRESSURE CAUTION LIGHT PANEL
4. ELAPSED TIME CLOCK
5. PROPELLER GEARBOX OIL PRESSURE/ TEMPERATURE PANEL
6. MASTER FIRE WARNING LIGHTS
7. MASTER CAUTION LIGHTS
8. STANDBY COMPASS
9. FIRE PRESS TO TEST SWITCH
10. ENGINE FIRE HANDLES AND DISCHARGE SWITCHES
11. TRIM INDICATOR PANEL
12. VSS TRIP INDICATOR
13. VSS INDICATOR PANEL
14. FUEL QUANTITY INDICATOR
15. AIRSPEED INDICATOR
16. DUCT POSITION INDICATOR
17. ATTITUDE INDICATOR
18. RADAR ALTIMETER
19. VERTICAL VELOCITY INDICATOR
20. BEARING-DISTANCE-HEADING INDICATOR
21. RUDDER PEDAL ADJUSTMENT SWITCH
22. PROPELLER RPM INDICATORS
23. FUEL QUANTITY TEST SWITCH
24. FUSELAGE GEARBOX OIL PRESSURE/ TEMPERATURE PANEL
25. ENGINE GEARBOX OIL PRESSURE/ TEMPERATURE PANEL
26. HYDRAULIC PRESSURE INDICATORS
27. ENGINE MASTER/START SWITCHES
28. TURBINE INLET TEMPERATURE INDICATORS
29. FUEL FLOW INDICATORS
30. ENGINE RPM INDICATORS
31. ENGINE OIL PRESSURE/TEMPERATURE PANEL
32. FUEL DUMP LEVER

FIGURE 1-3 (SHEET 2 OF 2)

CENTER CONSOLE



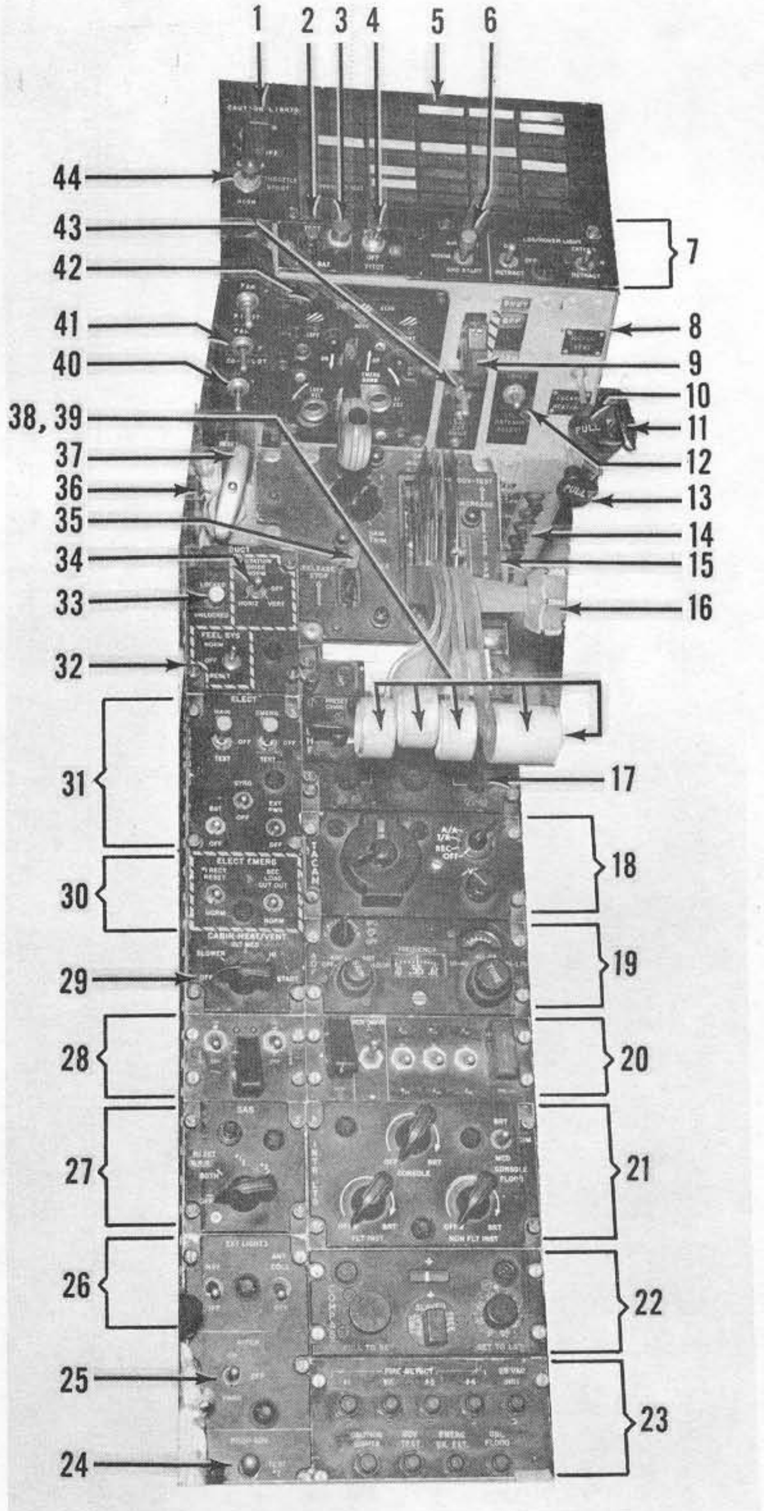
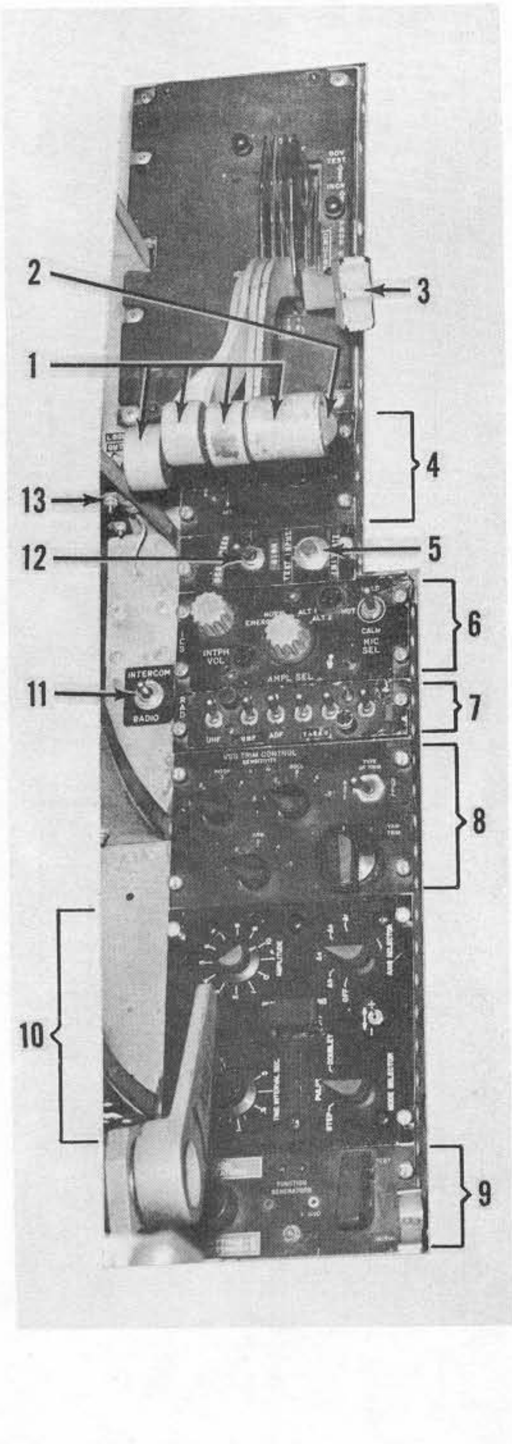


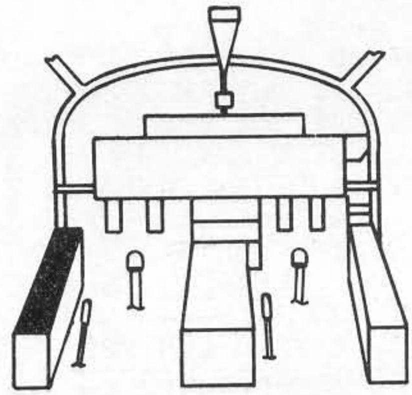
FIGURE 1-4 (SHEET 1 OF 2)

1. CAUTION LIGHT SWITCH (GUARDED)
2. FEEL BATTERY TEST SWITCH
3. FEEL BATTERY TEST INDICATOR
4. PITOT HEAT SWITCH
5. CAUTION LIGHT PANEL (SEE FIGURE 1-7)
6. AIR START/GROUND START SWITCH
7. LANDING/HOVER LIGHT CONTROL PANEL
8. CIRCUIT BREAKERS (SEE FIGURE 1-12)
9. IGNITION SWITCH
10. DEFOG DAMPER CONTROL
11. PARKING BRAKE HANDLE
12. UHF ANTENNA SELECTOR SWITCH
13. COCKPIT HEAT/AIR DAMPER CONTROL
14. CIRCUIT BREAKERS (SEE FIGURE 1-12)
15. THROTTLE FRICTION LOCK
16. PROPELLER RPM LEVER
17. AN/ARC-51A RADIO CONTROL PANEL
18. AN/ARN-52(V) TACAN CONTROL PANEL
19. ADF RADIO CONTROL PANEL
20. VSS MODE CONTROL PANEL
21. INTERIOR LIGHTING CONTROL PANEL
22. MA-1 GYRO COMPASS CONTROL PANEL
23. CIRCUIT BREAKERS (SEE FIGURE 1-12)
24. PROPELLER GOVERNOR TEST SWITCH
25. WIPER CONTROL SWITCH
26. EXTERNAL LIGHTING CONTROL PANEL
27. SAS CONTROL PANEL
28. VSS MASTER CONTROL PANEL
29. CABIN HEAT/VENT SELECTOR SWITCH
30. ELECTRICAL EMERGENCY PANEL
31. ELECTRICAL CONTROL PANEL
32. FEEL SYSTEM AND RESET SWITCH
33. DUCT LOCK SWITCH
34. DUCT ROTATION OVERRIDE SWITCH
35. THROTTLE RELEASE STOP LEVER
36. DUCT STOP RESET SWITCH
37. COPILOT SEAT ADJUSTMENT HANDLE
38. DUCT ROTATION SWITCH (ON SIDE OF NO. 4 THROTTLE)
39. THROTTLES
40. FRESH AIR FAN SWITCHES
41. MECHANICAL TRIM SWITCH PANEL (3 AXES IN "POWER CONTROL" ONLY)
42. LANDING GEAR CONTROL PANEL
43. SAS CUTOFF OVERRIDE SWITCH
44. THROTTLE BOOST SWITCH

FIGURE 1-4 (SHEET 2 OF 2)

LEFT HAND CONSOLE

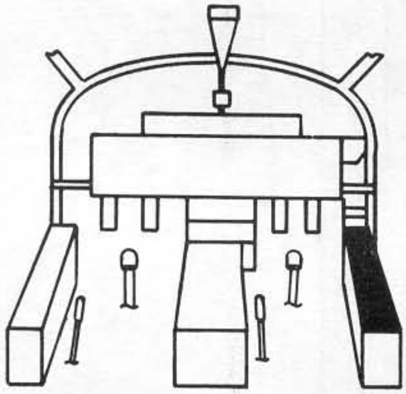


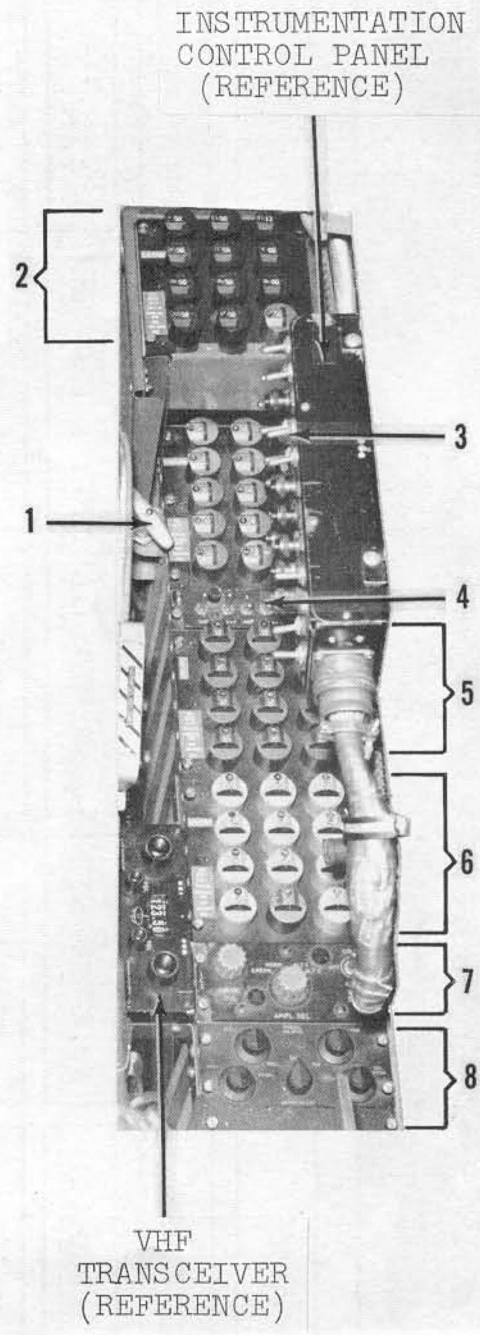


1. THROTTLES
2. DUCT ROTATION SWITCH
3. PROPELLER RPM LEVER
4. VSS FEEL ENGAGE CONTROL PANEL
5. TEST INPUT INITIATE SWITCH
6. AN/AIC-14 INTERCOM CONTROL PANEL
7. RADIO SELECTOR CONTROL PANEL
8. VSS TRIM CONTROL PANEL
9. FUNCTION GENERATOR CONTROL PANEL
10. TEST AND SIMULATION CONTROL PANEL
11. INTERCOM/RADIO SELECTOR SWITCH
12. OSCILLOGRAPH SPEED SELECTOR SWITCH
13. VSS SAFETY TRIP LOCKOUT SWITCH (GUARDED)

FIGURE 1-5

RIGHT HAND CONSOLE





1. PILOT SEAT ADJUSTMENT HANDLE
2. THRUST AXIS DIGITROLS (11, CODED GREEN)
3. PITCH AXIS DIGITROLS (17, CODED BRONZE)
4. RADIO SELECTOR CONTROL PANEL
5. YAW AXIS DIGITROLS (12, CODED BLUE)
6. ROLL AXIS DIGITROLS (11, CODED GREY)
7. AN/AIC-14 INTERCOM CONTROL PANEL
8. VSS MANUAL BALANCE CONTROL PANEL

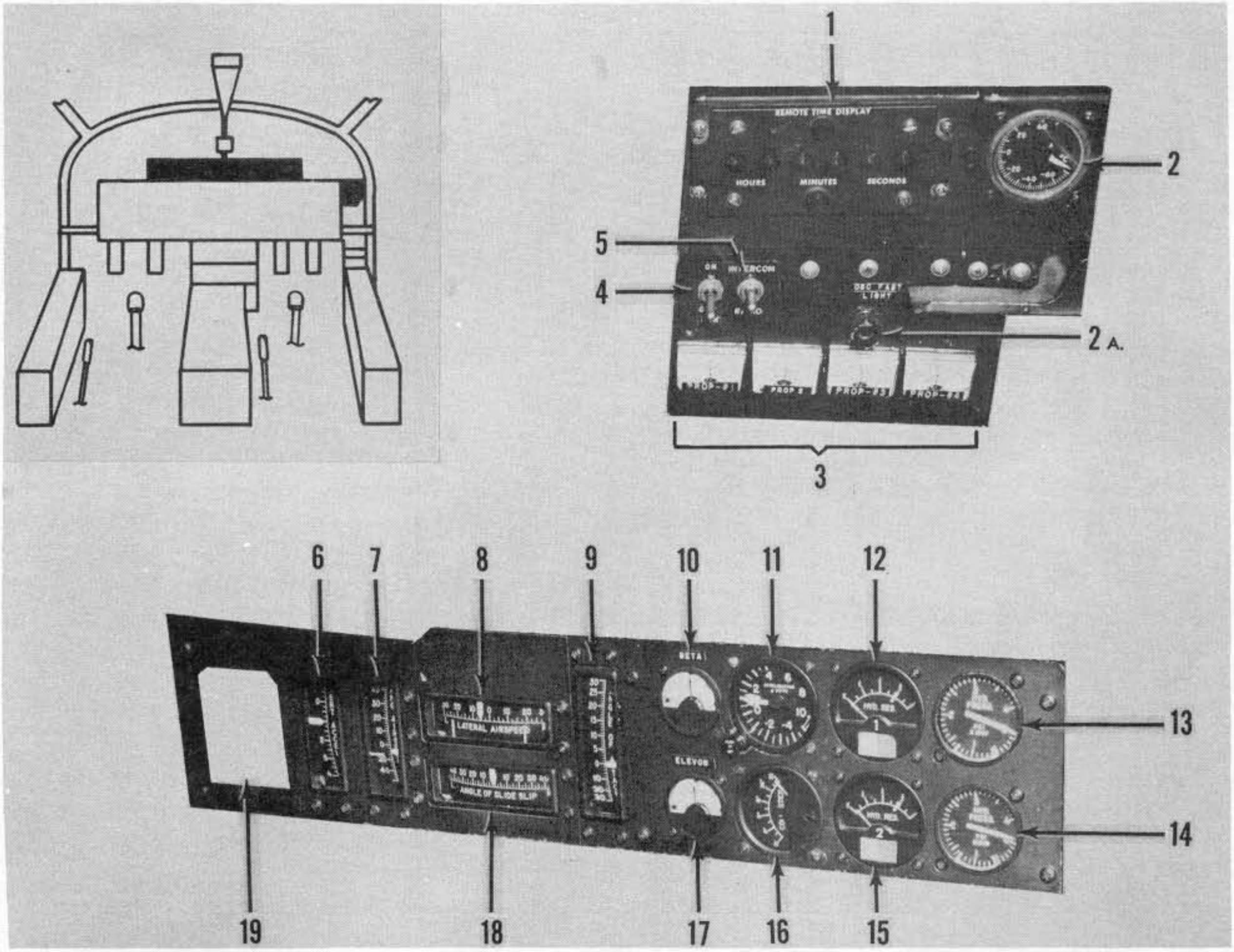
FIGURE 1-6

CAUTION LIGHT PANEL

SAS	DONOT EXCEED 200 KNOTS	PITCH SPRING BACK UP	NO.1 PROP GOV	NO.2 PROP GOV
MAIN GEN	NO.1 RECT	NO. 2 RECT	EMERG GEN	CSD PRESS LOW
NO.1 ENG OIL	NO.2 ENG OIL	NO.3 ENG OIL	NO. 4 ENG OIL	NO.1 HYD PRESS
BLANK	BLANK	BLANK	BLANK	NO.2 HYD PRESS
NO.1 AND NO.2 ENG G/B OIL	FUEL PUMP	FUEL LOW	NO.3 AND NO.4 ENG G/B OIL	TRANS G/B
HYD RES #1 LOW	BLANK	PILOT LIGHT	DUCT STOP	TRANS OIL LOW
HYD RES #2 LOW	BLANK	SEAT UNLOCKED	ST CUT OFF	RECORDER
PRESS TO TEST	FEEL BATTERY	FEEL SYS	CSD CHIP	CSD HOT

Figure 1-7

AUXILIARY INSTRUMENT PANELS



1. REMOTE TIME DISPLAY
2. FREE AIR TEMPERATURE INDICATOR
2a. OSCILLOGRAPH FAST LIGHT
3. PROPELLER PITCH INDICATORS
4. PILOTS VENTILATION FAN SWITCH
5. INTERCOM/RADIO SWITCH
6. VERTICAL ACCELERATION INDICATOR
7. LONGITUDINAL AIRSPEED INDICATOR
8. LATERAL AIRSPEED INDICATOR
9. ANGLE OF ATTACK INDICATOR
10. BETA NULL METER
11. ACCELEROMETER
12. NO. 1 HYDRAULIC RESERVOIR OIL LEVEL INDICATOR
13. NO. 1 PROPELLER GOVERNOR PRESSURE INDICATOR
14. NO. 2 PROPELLER GOVERNOR PRESSURE INDICATOR
15. NO. 2 HYDRAULIC RESERVOIR OIL LEVEL INDICATOR
16. COLLECTIVE STICK POSITION INDICATOR
17. ELEVON NULL INDICATOR
18. ANGLE OF SIDESLIP INDICATOR
19. COMPASS CORRECTION CARD

FIGURE 1-8

Index and Figure No.	Nomenclature	Function
9, figure 1-4	Ignition switch (hooded)	NORM-activates two relays which close a series ignition circuit for all engines OFF-Allows motoring of engines without the ignition system being activated.
6, figure 1-4	Air start/ground start switch	AIR START-connects the 10KVA generator to No. 1 Transformer/Rectifier Unit. NORMAL-connects the No. 1 Transformer/Rectifier Unit to the essential dc bus. GROUND START-removes the No. 1 Transformer/Rectifier Unit from the essential dc bus and connects it to the start bus.
37, figure 1-4	Center Console throttles (4)	Controls engine power. Used to start and stop engines.
1, figure 1-5	Left-hand console throttles (4)	Same as above.
35, figure 1-4	Throttle release stop lever	Prevents engines from being inadvertently shutdown until lever is pushed forward.
15, figure 1-4	Throttle friction lock	Provides locking and operating friction for throttles.
28, figure 1-3	Turbine inlet temperature indicators (4)	Indicate gas temperature at each engine power turbine inlet.
30, figure 1-3	Gas gen. indicators (4)	Indicate % of RPM.
29, figure 1-3	Engine fuel flow indicators (4)	Indicate fuel flow of indivisual engines,
figure 1-7	STARTER CUT OFF caution light	Extinguishes when starter current draw is within 100±15 amperes.

Index and Figure No.	Nomenclature	Function
figure 1-7	No. 1 ENG OIL No. 2 " " caution No. 3 " " lights No. 4 " "	ON-indicates high oil temperature or low oil pressure.
31 figure 1-3	Engine oil pressure indicators (4)	Indicates oil pressure of each engine.
31, figure 1-3	Engine oil temperature indicator	Indicates the oil temperature for each engine selected.
31, figure 1-3	Engine oil temperature selector switch	A four position selector switch which permits reading of engine oil temperature for each engine selected.
44, figure 1-4	Throttle boost switch	NORM-provides normal operation of throttle boost system. EMERG-shuts off throttle boost oil in case a boost oil line breaks in the cockpit.

ENGINE

The YT58-GE-8 engine contains a gas generator section, a power turbine and exhaust section, a lubricating system, a fuel system, and an electrical system. The gas generator section consists of a 10-stage compressor, annular combustor, and a 2-stage turbine which drives the compressor.

The power turbine section consists of a single stage turbine located directly behind the gas generator turbine, a power shaft, and an exhaust casing which deflects the exhaust stream downward. The engine lubrication system is made up of the engine supply, the pressure system, and the scavenge and vent systems. Oil is supplied to the engine by the pressure pump element of a five-element pressure-scavenge pump. Oil is scavenged from the engine and returned to the four scavenge elements of the pressure-scavenge pump. The vent system is connected to the engine supply tank, which is vented to the atmosphere.

The engine fuel system pressurizes and schedules fuel to the combustion section and provides pressurized fuel to operate the variable stator vanes. Principal components of the fuel system are a fuel control, a fuel pump and filtering system, a flow divider, two fuel manifolds, 16 fuel nozzles and a stator vane actuator.

Fuel is supplied by the aircraft fuel system to the dynamic filter. The filtered fuel then flows to the fuel pump. From the pump, fuel flows to the fuel control where it is filtered and metered. Metered fuel is delivered to the flow divider and into the fuel manifolds. Fuel is then sprayed into the combustion chamber through 16 fuel nozzles. The fuel control is a hydromechanical fuel metering unit which senses engine operating parameters and schedules fuel flow to maintain desired engine performance.

Incoming signals are supplied to the control servo system and are combined to meter fuel and position the variable stator vanes. The control also provides a protective device to prevent the power turbine from destructive overspeed.

The fuel pump and dynamic filter are mounted on the accessory drive gear box. The fuel pump houses two pumping units: one a centrifugal boost pump, the other a single element-displacement type gear pump. Fuel is discharged from the boost element to the inlet of the gear pump. The dynamic filter removes fuel contaminants by centrifugal action. When the engine is operating at 100% speed the filtering element spins at 4200 rpm.

The engine electrical system operates on 28 vdc. The system consists of an ignition unit, two ignitor plugs, a stator vane actuator, anti-icing solenoid, and components of the powerplant indicating circuits.

Engine ignition is provided by a dual-output capacitor-discharge ignition unit. Ignition of the fuel air mixture is accomplished by an intense electrical spark produced at two ignitor plugs immersed in the combustor. Sparking ceases automatically upon completion of the starting cycle, combustion being self-sustaining once ignition has been accomplished.

ENGINE STARTING CIRCUIT

The starting circuit of each engine consists of a master/start, switch, a common ignition switch for all four engines, an ignition relay, and a current sensitive start relay. The circuit controls ignition and starting system operation. Each engine is motored by a 28 vdc compound motor combining the features of a series and shunt motor to provide the proper torque-versus-speed characteristics for engine starting. A torque-limiting device protects the starter and engine during initial starter engagement. The starter can be re-engaged during the starting cycle without damage.

When the ignition switch is placed in NORM it activiates two relays which are in series with the ignition circuit for all engines. The ignition circuit to each individual engine is not completely activated until the engine master/start switch is placed in START position. This position activates the engine start relay, which in turn motors the engine starter and closes the ignition circuit. As the engine starts and accelerates to a self-sustaining speed (approx. 42% rpm), the current sensitive start relay senses the reduced current draw on the starter and breaks the starter and ignition circuitry. The STARTER CUTOFF caution light on the annunciator panel extinguishes when the current sensitive relay drops out.

The CUTOFF position of the ignition switch permits motoring the engines without the ignition system being activated.

ENGINE POWER CONTROLS

The engine power controls regulate engine power by mechanically positioning the engine fuel control power shaft. The controls consist of throttles on the center and left-hand consoles, and the connecting linkage to the engines.

In the "Power" thrust control mode (-D engine fuel control), when throttle position is changed, the engine fuel control changes the amount of fuel metered to the engine gas generator. This increases or decreases gas generator rpm and power output but does not necessarily change power turbine speed which is independently controlled by propeller blade angle (load). Power turbine torque does change and produces increased or decreased thrust as propeller blade angle increases or decreases to maintain selected speed. Four throttles are mounted on the center console and four are mounted on the left-hand console. The two sets of throttles are connected by linkage and operate together. Boost actuators are provided in the throttle linkage to ease throttle movement. The center console throttles are provided with a release stop lever which prevents the engines from being inadvertently shutdown by either set of throttles until the release stop lever is pushed forward. In this installation either set of throttles may be used to start or stop the engines. In this mode the propeller rpm control lever selects the propeller speed which is controlled by a master governor.

In the "Pitch" power control mode (-B engine fuel control), the engine throttles control fuel flow only during starting and low power operation. When the throttles are moved forward the power turbine speed governor controls fuel flow dependent upon the load generated by blade pitch lever control. The throttles set each individual engine speed governor and are trimmed collectively to set propeller speed, and individually to match engine powers.

ENGINE OVERSPEED PROTECTION

An overspeed shutoff valve is provided to prevent destructive engine overspeed in the event of a complete loss of load because of failure of a power shaft or other load creating component in the system. Under such a condition, the acceleration of the power turbine is so great that other means of control could not react in time. The valve closes at approximately 110% power turbine speed and is attached to the power turbine speed governor servo piston. When the power turbine speed governor senses anything above this speed range, it actuates the servo piston and closes the overspeed shutoff valve. Control discharge fuel ceases to flow and engine shutdown occurs.

ENGINE INSTRUMENTS

The turbine inlet temperature indicators display gas temperature at the inlet of each engine power turbine. The temperature is sensed by 8 chromel-alumel thermocouples arranged in the form of a single harness mounted on the 2nd-stage turbine casing. The 8 thermocouples are connected in parallel to provide an electrical output which is the arithmetical average of the temperatures sensed by the individual thermocouples. Each indicator dial is graduated in major increments of 100°C and minor increments of 10°C. Overall range is 0 to 1000°C. The indicators are internally lighted by 400-cps ac power.

An engine tachometer for each engine indicates gas generator speed in percent rpm. A tachometer generator is located on the accessory drive gearbox of each engine. The four % of rpm indicators are grouped on the main instrument panel. Each indicator has a main dial and a subdial. The main dial is graduated in major 10% increments and minor 2% increments. The subdial provides a vernier scale range of 10% in 1% increments. The overall range of the instrument is 0 to 110%. 100% reading is provided by the main dial and an additional 10% is provided by the vernier subdial. The indicators are actuated by the electrical signal voltage developed by the tachometer generator. They are internally lighted by 400-cps ac power.

The fuel flow indicating system indicates the rate at which fuel is delivered to each engine. Four indicators are located on the main instrument panel and one transmitter on each engine fuel line. The indicator dials are calibrated in 50 pph increments and have a maximum indication of 1000 pph.

Abnormal engine oil conditions are indicated on four ENG OIL caution lights. Each light is numbered to indicate its respective engine. The caution lights respond to low oil pressure.

AIR INDUCTION, COOLING, AND EXHAUST

Engine air inducation and cooling are provided by the nacelle configuration. The engine inlet contour geometry provides satisfactory operation in hovering with no ram, and also gives the nacelle pod good drag characteristics at high forward flight speeds. Perforations in the upper and lower cowling sections provide for circulation of cooling air within the nacelle. The engine exhaust system deflects the exhaust stream backward and downward at approximately a 60° angle.

FUEL SYSTEM

The fuel system (figure 1-9) stores and delivers fuel to the engines. The system consists of the fuel supply tank, pressure and suction feed provisions, fuel dump system, a quantity indicating circuit, and caution light circuits. The fuel supply line for the cockpit heater is also connected to the fuel system. Controls and indicators are as follows:

Index and Figure No.	Nomenclature	Function
14, figure 1-3	Fuel quantity indicator	Provides indication of fuel quantity.
23, figure 1-3	Fuel quantity test switch	Pressed-checks fuel quantity indicator
figure 1-7	FUEL LOW caution light	ON-indicates fuel is at the 650 lb level.
figure 1-7	FUEL PUMP caution light	ON-indicates that the fuel pump is not functioning.
32, figure 1-3	Fuel dump lever	Permits jettisoning fuel. to 680 lb level.
29, figure 1-3	Fuel flow indicator (4)	Indicate fuel flow to each engine.

FUEL STORAGE

The fuel storage system consists of the fuel supply tank, vents and

FUEL SYSTEM

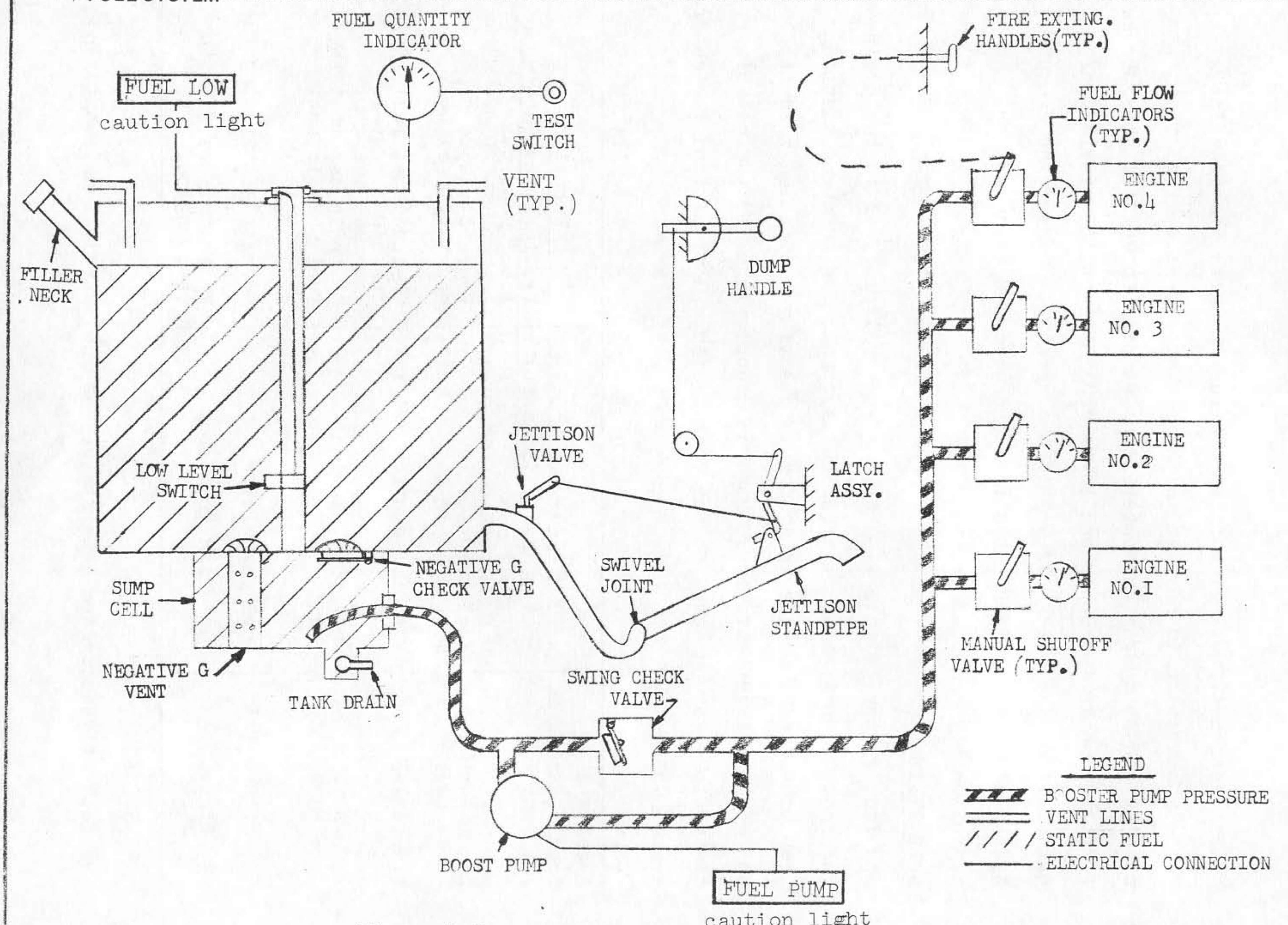


Figure 1-9

jettison system. The supply tank is located approximately at the center of gravity of the airplane to minimize unbalance as fuel is consumed. Fuel quantity data is as follows:

FUEL QUANTITY DATA

US Gal	JP-4 Lb	JP-5 Lb
465	3023	3162

The fuel tank is equipped with a three dimensional vent system which provides adequate venting in all flight attitudes. The negative "G" sump contains 10 seconds of fuel at maximum flow. The fuel dump system incorporates gravity feed. When the fuel dump lever is pulled, it simultaneously opens the jettison valve and unlatches the jettison standpipe permitting the pipe to drop to its dump position.

Note

The fuel jettison system has not been evaluated in flight test.

ENGINE FEED

Fuel feed to the engines is provided by an electrical-fuel booster pump. The pump is actuated by the ON position of one or more of the master/start switches. When the pump is operating, its suction side closes the swing check valve and bypasses pressurized fuel around the valve. In the event pump malfunction occurs, the suction created by the individual engine fuel pumps opens the swing check valve and permits normal engine operation by suction feed. It is necessary to operate the booster pump before starting the engines, however, once the engines are operating they will sustain themselves on suction feed. A suction pickup swing tube is utilized in the sump cell of the fuel tank to accommodate various flight attitudes. Manual shutoff valves are incorporated in each engine fuel line.

Their operation is covered under the Fire Extinguisher System section.

FUEL QUANTITY INDICATOR AND TEST SWITCH

The fuel quantity indicator is actuated by a capacitance type probe unit immersed in the supply tank. The indicator is graduated in 50 lb. increments and has a scale range of 0 to 3150 lbs. The fuel quantity test switch provides a calibration check of the quantity indicator. When the switch is pressed and held, the quantity indicator should go to zero.

CAUTION CIRCUITS

A low level sensor unit is attached to the capacitance probe unit at the 650 lb. level. It actuates the FUEL LOW caution light when the fuel reaches that level. A pressure switch is incorporated in the fuel booster pump system. In the event the fuel booster pump malfunctions the pressure switch actuates the FUEL PUMP caution light.

POWER TRANSMISSION AND PROPELLERS

The power transmission and propeller systems (figure 1-10) consists of four propellers and integral gearboxes, propeller control and governing system, and power transmission shafting and gear boxes. Controls and indicators for the system are as follows:

POWER TRANSMISSION AND PROPELLERS

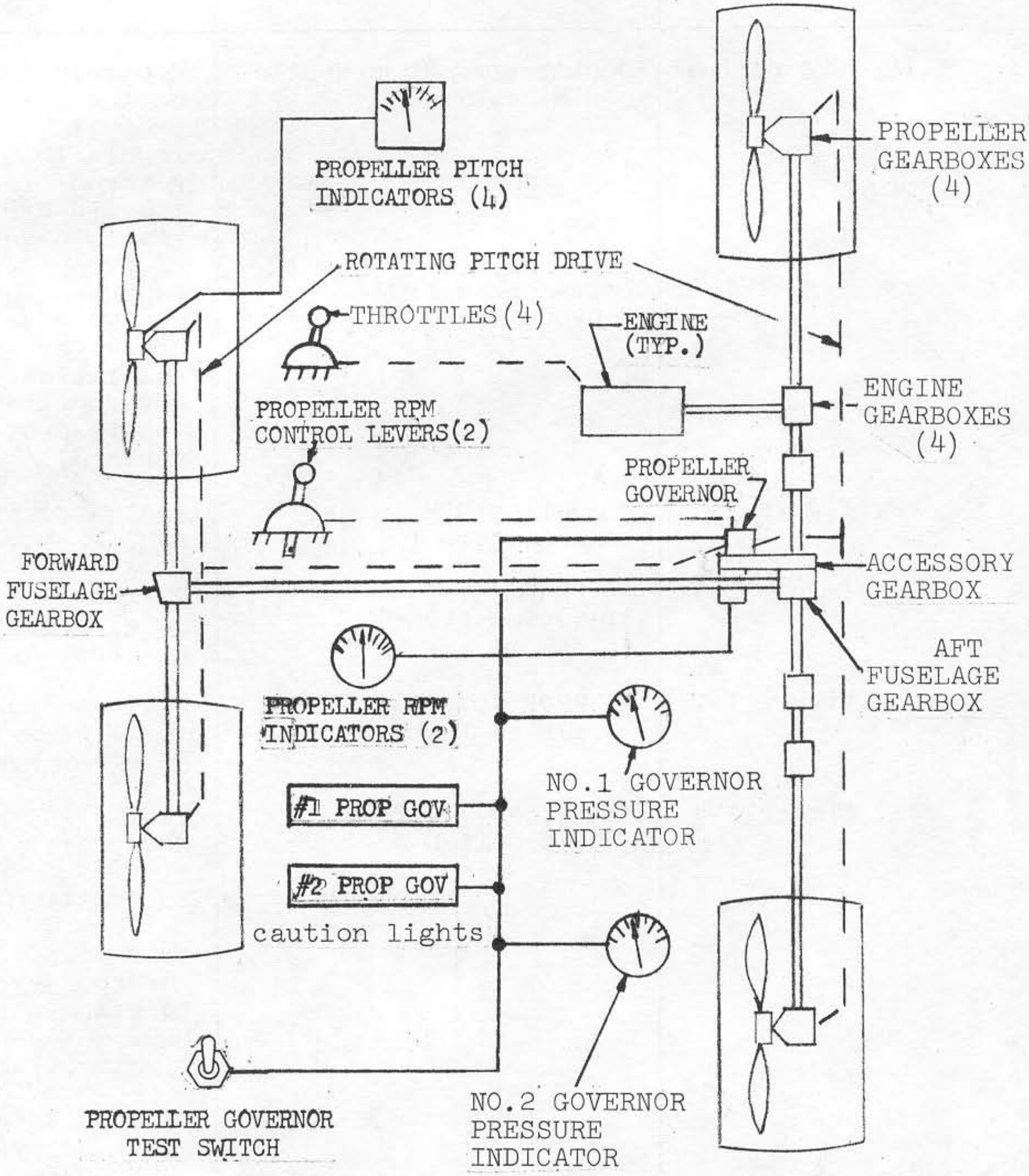


Figure 1-10

Index and Figure No.	Nomenclature	Function
16, figure 1-4	Center console propeller RPM lever	Controls input to master governor for propeller speed regulation. A governor test position is provided (full forward).
3, figure 1-5	Left-hand console propeller RPM lever	Controls input to master governor for propeller speed regulation. A governor test position is provided (full forward).
22, figure 1-3	Propeller RPM indicators (2)	Indicates propeller RPM.
figure 1-7	#1 PROP GOV caution light	ON-indicates low pressure in #1 propeller governor system.
figure 1-7	#2 PROP GOV caution light	ON-indicates low pressure in #2 propeller governor system.
24, figure 1-4	Propeller governor test switch	TEST #1-disables #1 governor system - #1 PROP GOV caution light illuminates. NORM-permits both governor systems to function-neither PROP GOV caution lights illuminated. TEST #2-disables #2 governor system-#2 PROP GOV caution light illuminates.

3, figure 1-8	Propeller pitch indicators (4)	Indicate pitch angle of each propeller.
13, figure 1-8	#1 Propeller governor hydraulic pressure indicator	Indicates operating pressure of governor system-#1.
14, figure 1-8	#2 Propeller governor hydraulic pressure indicator	Indicates operating pressure of governor system-#2.

PROPELLERS AND INTEGRAL GEARBOXES

Each propeller has three variable pitch blades and a control hub. The blades are made up of a composite structure consisting of a primary load-carrying steel spar and a fiberglass shell. The leading edge of each blade is capped with a metal strip to minimize erosion. Pitch change of the blades is accomplished by a steel crankpin and cam roller fastened to the blade butt and mated with a steel yoke which is translated by a hydraulically-operated power piston. The power piston is duplicated in tandem for greater reliability.

The integral gearboxes provide a right angle drive and a 2.74 to 1 gear reduction with respect to their lateral drive shafts. Since the gear boxes are within the propeller slipstream, their housing is aerodynamically smooth.

PROPELLER CONTROL AND GOVERNOR SYSTEM

Each propeller incorporates a dual servo control consisting of two identical systems, each supplied by one of the aircraft hydraulic systems. In the event of a malfunction in either of the systems, a distributor valve regulates the required pitch pressure through the operative system. The servo system receives control inputs from the master governor and flight control systems through a rotary drive system and in turn controls the propeller pitch actuators.

In the power control mode the master governor is driven from the accessory drive gearbox and thereby senses the speed of the drive system. Selective speed setting is made by the pilot through the RPM lever which connects to the input control on the governor. The master governor is made up of two systems which are identical and operate in parallel. Each system consists of a hydraulic pump, a normal speed governor, an overspeed governor, an output actuator, a manually controllable normal-to-standby switch-over circuit, speed set linkages, and various associated valves. Normally the two governor systems work together and share the load equally, however, should one system fail, the remaining system assures complete control and continues to govern at not more than 50 rpm lower than before. Selection of one or the other systems in the event of failure as evidenced by the illumination of one of the PROP GOV caution lights, is accomplished by the propeller governor test switch. Pressure gages are provided for each system to identify the failed system. The normal speed governor accomplishes governing by varying the servo pressure. When the governor is "on-speed", servo pressure exactly balances out the reference pressure and the actuator output shaft remains stationary. When propeller system rpm increases, the governor acts to reduce servo pressure and the actuator rotates in a direction to cause a resultant increase in blade angle until the propeller system rpm is lowered to the "on-speed" condition. When propeller system rpm decreases, the governor acts to increase servo pressure and the actuator rotates in a direction to cause a resultant decrease in blade angle until the propeller system rpm is increased to the "on-speed" condition.

POWER TRANSMISSION SHAFTING AND GEARBOXES

The transmission system includes all power transmitting components between the engine power takeoff and the propellers, and consists of the engine high speed power takeoff shaft, engine gearboxes, fuselage gearboxes, accessory drive gearbox, interconnecting shafts, shaft couplings and bearing hangers. The propeller gearboxes have been covered as a separate item (See Propellers and Integral Gearboxes).

High speed drive shafts connect the output of the engines to the engine gearboxes. These gearboxes provide a gear reduction ratio of 2.74 to 1. Each of the boxes incorporates a free wheeling sprag clutch which permits automatic engine disconnect in the event of an engine failure or intentional engine shutdown. The boxes are configured in the shape of a "T" and are connected to the aft cross shaft which drives the aft propellers and aft fuselage gearbox. The aft fuselage gearbox drives a longitudinal shaft which in turn drives the forward fuselage gearbox. The forward box is connected to the forward cross shaft which drives the forward propellers. The overall gear reduction between engines and propellers is 7.51 to 1.

Shaft couplings and bearing are used to reduce the shaft length of the transmission system. Four bearing hangers are used on the lateral shafts and three hangers are used on the longitudinal shaft.

Mechanical, hydraulic, and electrical aircraft power requirements are extracted from the accessory drive gearbox located adjacent to, and driven from, the aft fuselage gearbox. The accessory drive gearbox drives the propeller tachometer generator, master governer, two AC generators, two hydraulic pumps, lubrication pumps, and the oil cooler fan.

ELECTRICAL SUPPLY

The primary electrical power generating system consists of two brushless 115/208 volt, three phase 400 cps generators. The main generator, rated at 20 KVA is driven by a constant speed drive (CSD) which is powered by the accessory drive gear box. The voltage and frequency levels are regulated to approximately

1% from 1800 propeller rpm (prpm) to 2650 prpm. Caution is advised not to drive the CSD above 2735 prpm. The emergency generator is powered directly by the accessory drive gear box. The frequency of this generator is unregulated. However, the voltage and frequency between 2350 and 2650 prpm is sufficient for aircraft equipment use. The main generator is capable of furnishing the entire electrical load requirements in all modes of operation. The emergency generator is not utilized except in the event of a main generator failure at which time the emergency generator automatically takes over at reduced capability (non-essential loads are dropped) to permit mission completion. The emergency generator is also utilized for engine restarts in the air. Individual supervisory panels monitor each generator for voltage level, frequency, and phase relationship and prevent the generators from energizing their respective buses until proper output limits are present.

Aircraft dc power is provided by two 28 volt, 200 ampere transformer rectifiers. The #1 T.R. unit is associated with the emergency generator and is normally used for engine restarts in the air. Also, when on ground external power, this unit is used for engine starting. The #2 T.R. unit is associated with the essential dc bus to supply normal aircraft dc power requirements. In the event the #2 T.R. unit fails while operating on the emergency generator, the #1 T.R. unit may be put into service by placing the #1 RECT RESET Switch to RESET position.

A battery provides emergency power for the following, in case of a total electrical failure:

a. Caution lights

b. Console flood lights

c. Emergency landing gear extension

d. Master governor test

e. Fire detector

f. Pitch back-up

g. Feel system relief valves

h. Feel system by-pass

i. Duct rotation system

j. Fire extinguisher

k. VHF radio/intercom

l. Ventilation fans

The battery is activated automatically through the battery switch, although the battery will not take the load unless the essential bus fails. The battery will provide approximately 20 minutes of operation.

When operating on external ac power, a phase sequence sensor provides aircraft electrical equipment protection by preventing maladjusted external ac power from being applied to the essential ac bus. Ac external power will provide the aircraft with all normal power, including engine starting power.

When operating on external dc power, only the engine start buses are energized.

INSTRUMENTATION POWER

The instrumentation system requires ac and dc power for normal operation. This system is powered by the following aircraft buses: essential and secondary ac, essential and secondary dc. A battery is also provided to supply power to the "safety of flight" telemetry system in case of a total electrical failure. This battery will supply power for approximately fifteen (15) minutes with the instrumentation panel "set" for the checklist. Failures in the normal aircraft electrical system will automatically trigger "dropouts" of certain portions of the instrumentation system to coincide with the aircraft electrical system.

Controls and indicators for the electrical supply system are as follows:

Index and Figure No.	Nomenclature	Function
31, figure 1-4	Main generator switch	ON - connects main generator to ac essential bus. TEST - If output is within limits MAIN GEN caution light is extinguished. OFF - Disconnects main generator.

31, figure 1-4	Emergency generator switch	ON - Connects emergency generator to ac essential bus. TEST - If output is within limits, EMERG GEN caution light is extinguished. OFF - Disconnects emergency generator.
31, figure 1-4	Battery switch	BAT - arms battery for connection to dc essential bus. OFF - Disconnects battery from dc essential bus.
31, figure 1-4	External power switch	EXT PWR - Provides control from the airplane for energizing the ac bus from external power. OFF - Disconnects external power from the ac bus.
30, figure 1-4	#1 Rectifier reset switch	RESET - Provides a means of switching in #1 transformer rectifier unit if #2 transformer rectifier unit goes out while on emergency generator. NORM - Connects transformer rectifier unit for normal operation.

30, figure 1-4	Secondary load cutout switch	CUT OUT - Provides a means of rapidly reducing power utilization in an emergency. NORM - Connects secondary buses to essential buses.
figure 1-7	MAIN GEN caution light	ON - indicates generator output is not within limits.
figure 1-7	EMERG GEN caution light	ON - Indicates generator output is not within limits.
figure 1-7	#1 RECT caution light	ON - Indicates failure in #1 transformer/rectifier unit.
figure 1-7	#2 RECT caution light	ON - Indicates failure in #2 transformer/rectifier unit.

ELECTRICAL POWER DISTRIBUTION

The power distribution system (figure 1-11) distributes electrical power from the external power supply system, the main generator system and the emergency generating system.

ELECTRICAL SUPPLY AND DISTRIBUTION SYSTEM

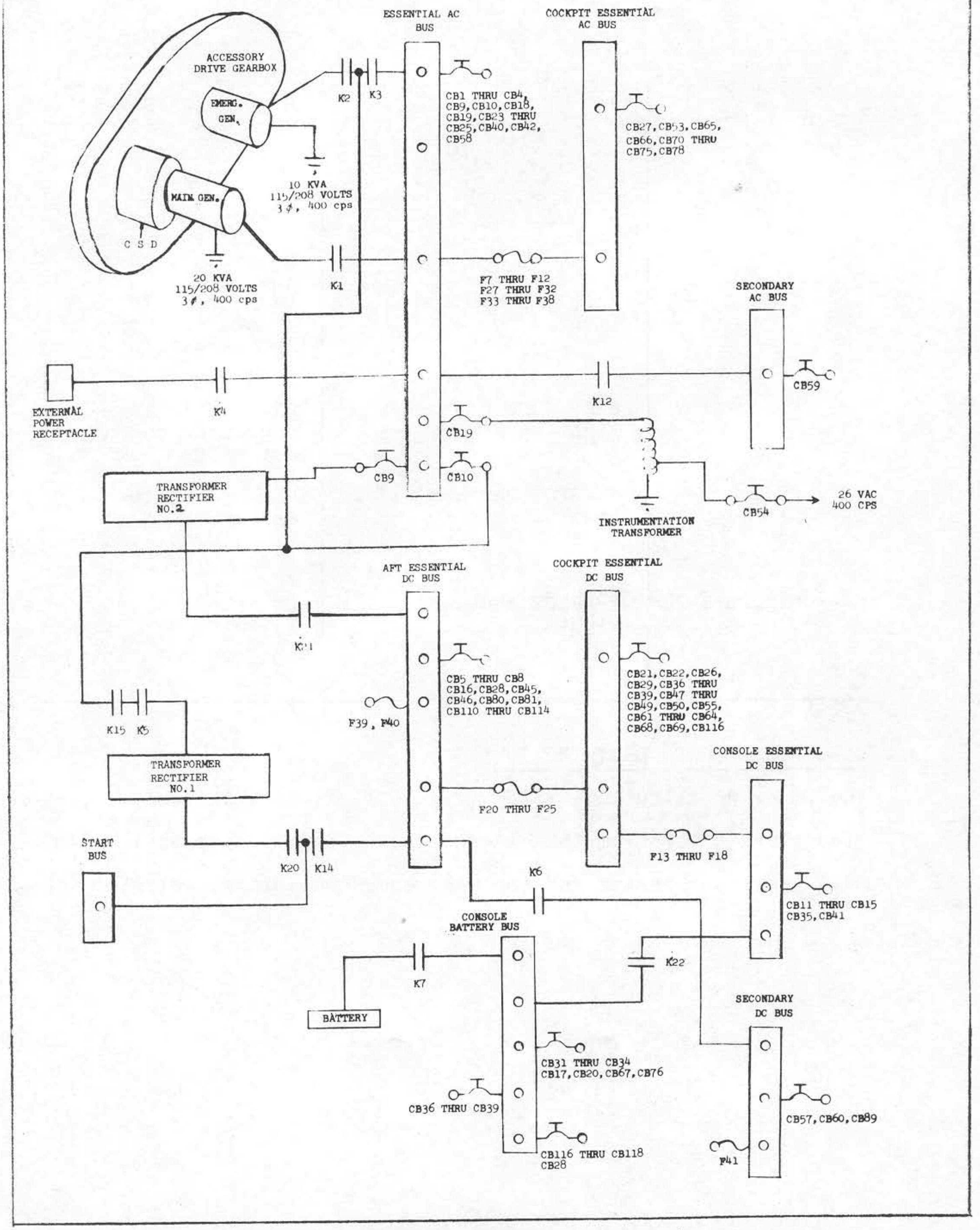


Figure 1-11(Sheet 1 of 3)

POWER RELAY	NOMENCLATURE	FUNCTION
K1	Main generator line contactor	Energized with main generator switch in ON to connect main generator to essential ac bus.
K2	Emergency generator line contactor	Energized with emergency generator switch in ON to connect emergency generator to essential ac bus when transfer relay K3 is energized by an emergency condition.
K3	AC power transfer relay	Connects emergency generator to essential ac bus when main generator is de-energized.
K4	AC external power relay	Energized with external power switch in EXT PWR to connect external power source to essential ac bus.
K5	#1 transformer rectifier cutout relay	Disconnects #1 transformer/rectifier when emergency generator is energized. May be re-connected in the event of failure of #2 transformer rectifier by placing #1 rectifier reset switch in RESET.
K6	DC bus tie relay	Disconnects secondary dc bus when secondary load cutout switch is in CUT OUT.
K7	Battery tie-in relay	Energizes battery bus.
K12	AC bus tie relay	Disconnects secondary ac bus when secondary load cutout switch in CUT OUT.
K14	Start bus isolation relay	Disconnects #1 transformer/rectifier from essential dc bus and connect it to the start bus.

Figure 1-11 (Sheet 2 of 3)

POWER RELAY	NOMENCLATURE	FUNCTION
K15	#1 transformer/rectifier transfer relay	Energized with air start/ground start switch in AIR START to transfer input power to #1 transformer/rectifier.
K20	#1 transformer/rectifier reverse current relay	Energized by CB10 to activate #1 transformer/rectifier.
K21	#2 transformer/rectifier reverse current relay	Energized by CB9 to activate #2 transformer/rectifier.
K22	Battery bus relay	Connects main bus to battery bus through CB5.

Figure 1-11 (Sheet 3 of 3)

AC power is distributed through three buses:

Essential ac bus

Cockpit essential ac bus

Secondary ac bus

DC power is distributed through five buses:

Aft essential dc bus

Cockpit essential dc bus

Console essential dc bus

Secondary dc bus

Battery bus

Electrical loads which are essential for the safety of flight are connected to the essential buses. The secondary buses carry loads considered non-essential to the safety of flight and are automatically disconnected in the event the emergency generator is carrying the flight load.

Circuit protection is provided by circuit breakers and fuses. The majority of circuit breakers are located in the cockpit on the overhead circuit breaker panel and on the center console (figure 1-12 and 1-13). Other circuit breakers are located on the ac and dc power shields within the cargo compartment. For power distribution by buses, see figure 1-14. The fuses in this installation (figure 1-15) are employed primarily as protection for bus-tie circuitry rather than electrical equipment protection.

OVERHEAD CIRCUIT BREAKER PANEL

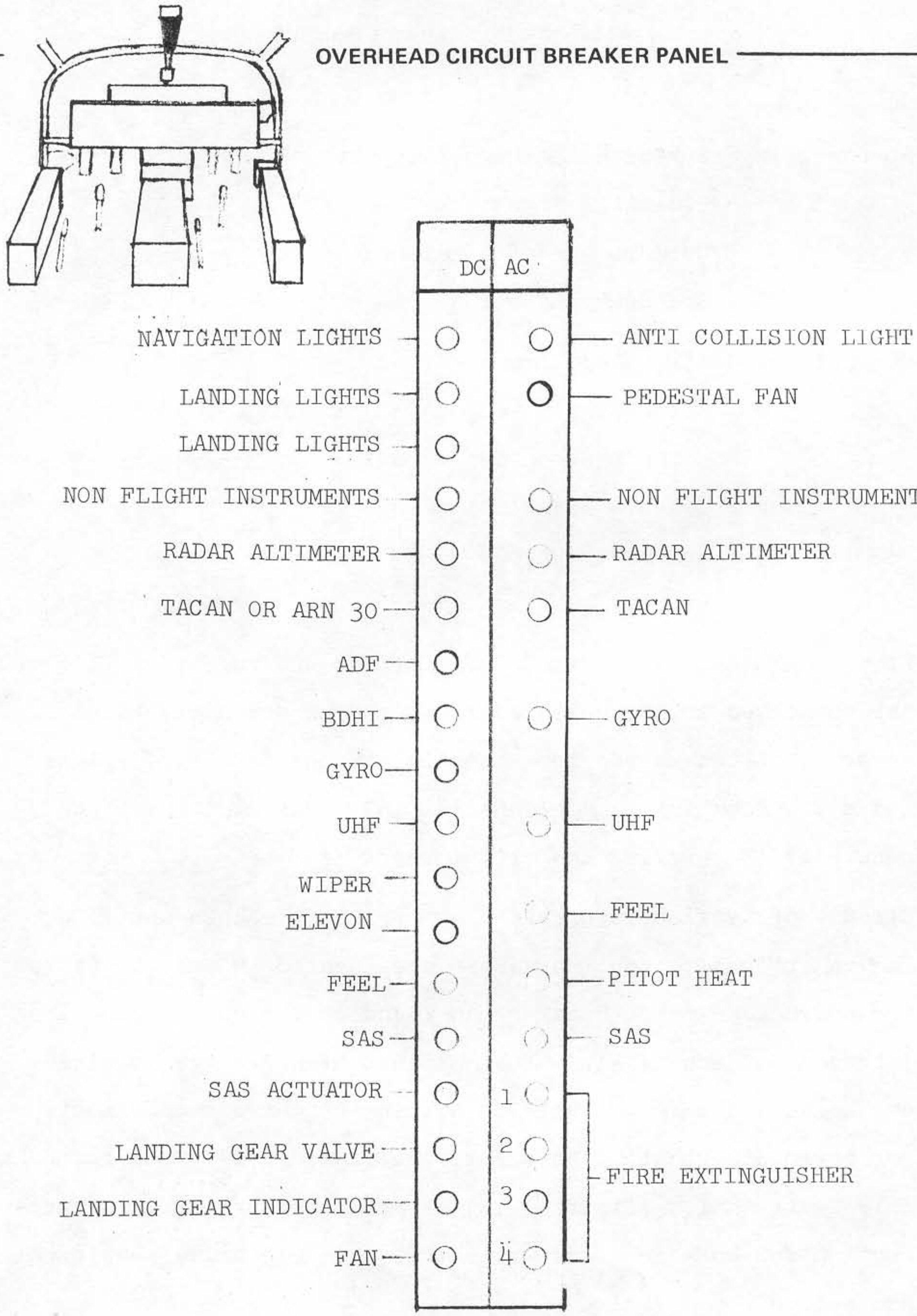


Figure 1-12

CENTER CONSOLE CIRCUIT BREAKER PANELS

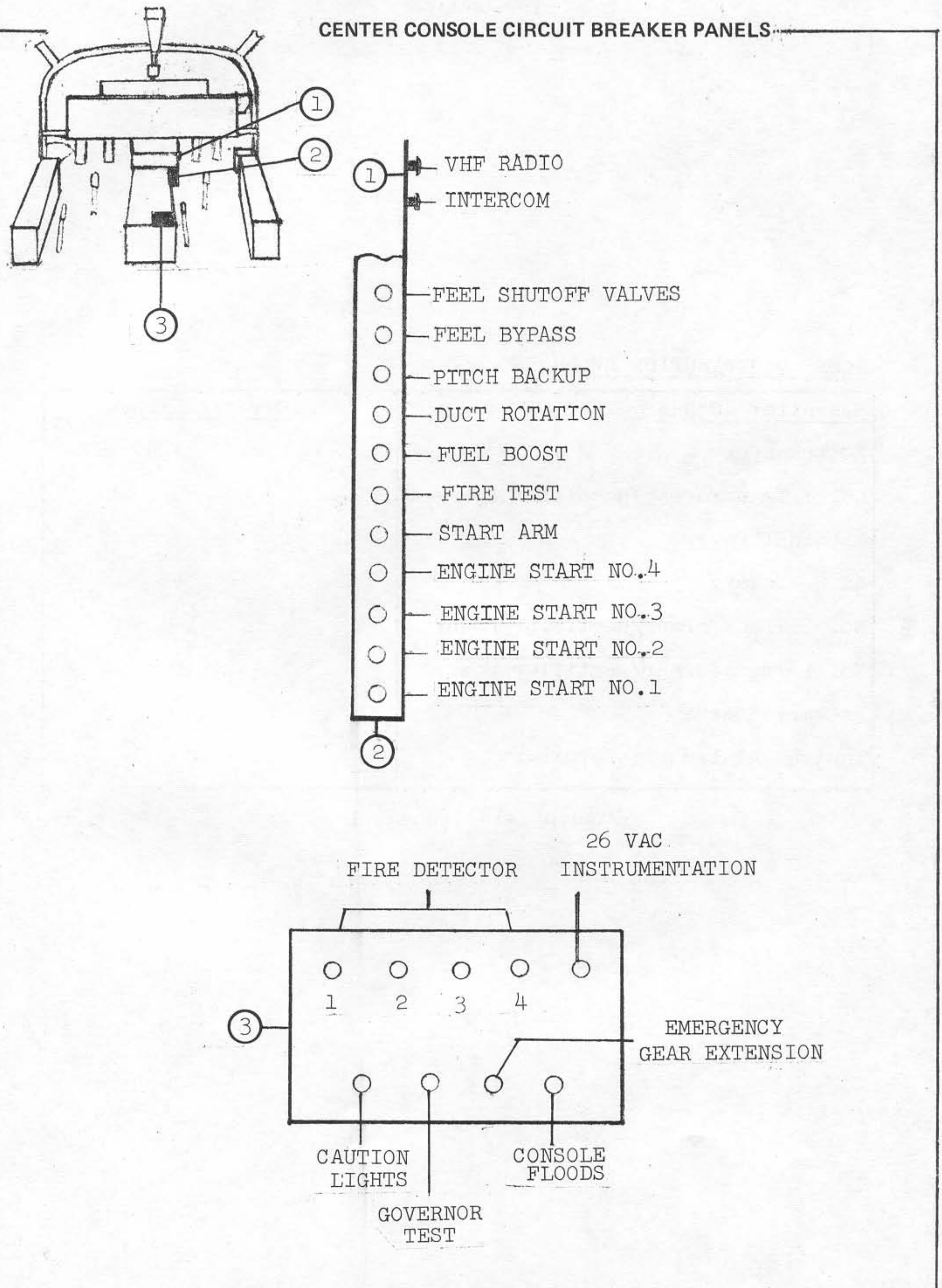


Figure 1-13

POWER DISTRIBUTION BY BUSES

Essential AC Bus	Circuit Breaker No.
AC Transfer	1
No. 1 Transformer/Rectifier Power	2
External Power	3
AC Secondary	4
No. 2 Transformer/Rectifier Power	9
No. 1 Transformer/Rectifier Power	10
Battery Charge	18
Instrumentation Transformer	19

Figure 1-14 (Sheet 1 of 5)

Essential AC Bus	Circuit Breaker No.
Flight Instrumentation Lights	23
Non Flight Instrumentation Lights	24
Console Panel Lights	25
Stability Augmentation	40
Fuel Boost	42
Heater Blower	58
Cockpit Essential AC Bus	
Anti Collision Light	27
Gyro	53
Feel	65
Feel	66
Pitot Heat	70
Radar Altimeter	71
TACAN	72
Stability Augmentation System	73
Stability Augmentation System	74
Non Flight Instruments	78
Secondary AC Bus	
Variable Stability System	59
26 VAC Instrumentation	54

Figure 1-14 (Sheet 2 of 5)

Aft Essential DC Bus	Circuit Breaker No.
No. 2 DC Indicator	5
No. 2 DC Control	6
No. 1 DC Indicator	7
No. 1 DC Control	8
AC Secondary Bus Control No. 2	16
Stability Augmentation System	45
Caution Light Dimmer	46
No. 1 Generator Control Power	80
No. 2 Generator Control Power	81
Stability Augmentation System Actuator	110
Feel	111
No. 1 Transformer/Rectifier Test	112
Duct Indicator	113
Ignition Cut	114
Cockpit Essential DC Bus	
Landing Lights	21
Landing Lights	22
Navigation Lights	26
Non Flight Instruments	29
Fire Extinguisher 1	36
Fire Extinguisher 2	37
Fire Extinguisher 3	38
Fire Extinguisher 4	39

Figure 1-14 (Sheet 3 of 5)

Cockpit Essential DC Bus	Circuit Breaker No.
UHF Radio	47
UHF Radio	48
Wiper	50
Gyro	53
Gyro	55
Bearing-Distance - Heading-Indicator	61
TACAN	62
Automatic Direction Finder	63
Radar Altimeter	64
Fan	67
Landing Gear Indicator	68
Landing Gear Valve	69
Console Essential DC Bus	
Start Arm	11
Engine Start No. 4	12
Engine Start No. 3	13
Engine Start No. 2	14
Engine Start No. 1	15
VHF Radio	30
Fire Test	35
Fuel Boost	41

Figure 1-14 (Sheet 4 of 5)

Console Battery Bus	Circuit Breaker No.
Caution Lights	17
Console Flood	20
Duct Rotation	28
Fire Detector #1	31
Fire Detector #2	32
Fire Detector #3	33
Fire Detector #4	34
Intercom	49
Emergency Gear Extension	67
Governor Test	76
Feel Valves	116
Feel Bypass	117
Pitch Backup	118
Secondary DC Bus	
Heater	57
Pedal Adjust	60
Variable Stability System	89

Figure 1-14 (Sheet 5 of 5)

FUSE LOCATION AND CIRCUIT

Fuse No.	Circuit	Rating (Amperes)	Location
7	Cockpit 115V essential bus, Phase A	10	Overhead Circuit Breaker Panel
8	" " " " " "	10	" "
9	" " " " " "	10	" "
10	115V essential AC bus, Phase A	10	AC Power Shield
11	" " " " " "	10	" " "
12	" " " " " "	10	" " "
13	Console essential DC bus	10	Center Console
14	Cockpit " " "	10	Ovehhead Circuit Breaker Panel
15	Console " " "	10	Center Console
16	Cockpit " " "	10	Overhead Circuit Breaker Panel
17	Console " " "	10	Center Console
18	Cockpit " " "	10	Overhead Circuit Breaker Panel
20	" " " "	10	" "
21	" " " "	10	" "
22	" " " "	40	" "
23	" " " "	40	DC Power Shield
24	" " " "	40	" " "
25	" " " "	40	" " "
27	Cockpit 115V essential bus, Phase B	10	Overhead Circuit Breaker Panel
28	" " " " " "	10	" "
29	" " " " " "	10	" "
30	Cockpit 115V essential bus, Phase C	10	" "
31	" " " " " " "	10	" "
32	" " " " " "	10	" "
33	115V essential AC bus, Phase B	10	AC Power Shield
34	" " " " "	10	" " "
35	" " " " "	10	" " "

Figure 1-15 (Sheet 1 of 2)

Fuse No.	Circuit	Rating (Amperes)	Location
36	115V essential AC bus, Phase C	10	AC Power Shield
37	" " " " " "	10	AC Power Shield
38	" " " " " "	10	" " "
39	Reverse current relay #2	130	DC Power Shield
40	" " " #1	130	" " "
41	Heater ignition	3	Station 95 bulkhead
	<u>Instrumentation Power "J" Box</u>		
14	Fresh air supply fan	2	Forward of Cargo Door
18	" " " "	2	" " "

Figure 1-15 (Sheet 2 of 2)

LUBRICATION

The aircraft utilizes nine independent and self-contained lubrication systems for lubrication of the engines, gearboxes, and constant speed drive. The systems consist of four identical engine lubrication systems; four identical propeller integral gearbox lubrication systems; and the main lubrication system which includes engine gearboxes, fuselage gearboxes, accessory drive gearbox, and the constant speed drive. Indication of systems operation is provided by caution lights which indicate the following unsatisfactory conditions: low pressure, high temperature, low oil level, and metal particle accumulation. Indicators for the lubrication systems are as follows:

Index and Figure No.	Nomenclature	Function
figure 1-7	#1 and #2 ENG G/B OIL caution light	ON - Indicates low oil pressure.
"	#3 and #4 ENG G/B OIL caution light	ON - Indicates low oil pressure.
"	TRANS OIL LOW caution light	ON - Indicates a low level of oil in the transmission system supply tank.
"	CSD HOT caution light	ON - Indicates high oil temperature in the constant speed drive.
"	TRANS G/B caution light	ON-indicates low oil pressure.
"	CSD CHIP caution light	ON - Indicates metal particle accumulation.
"	CSD PRESS LOW caution light	ON-Indicates low oil pressure in the cons-tant speed drive.
5, figure 1-3	Propeller gearbox oil pressure indicator (4)	Indicates oil pressure in each propeller gearbox.
24, figure 1-3	Forward gearbox oil pressure indicator	Indicates oil pressure in the forward gearbox.

Index and Figure No.	Nomenclature	Function
24, figure 1-3	Aft gearbox oil pressure indicator	Indicates oil pressure in the aft gearbox.
25, figure 1-3	Left engine gearbox oil pressure indicator	Indicates the oil pressure in both left engine gear-boxes.
25, figure 1-3	Right engine gearbox oil pressure indicator	Indicates the oil pressure in both right engine gear-boxes.
5, figure 1-3	Propeller gearbox oil temperature indicator (4)	Indicates the oil temperature of each propeller gearbox selected.
5, figure 1-3	Propeller gearbox oil temperature selector switch	A four position selector switch which permits reading propeller gearbox oil temper-ature for each gear-box selected.
24, figure 1-3	Forward gearbox oil temperature indicator	Indicates the oil temperature of the forward gearbox.
24, figure 1-3	Aft gearbox oil tempera-ture indicator	Indicates the oil temperature of the aft gearbox.
31, figure 1-3	Engine gearbox oil temperature indicator	Indicates the oil temperature of each engine gearbox selected.

Index and Figure No.	Nomenclature	Function
31, figure 1-3	Engine gearbox oil temperature selector switch	A four position selector switch which permits reading engine gearbox oil temperature for each gearbox selected.
1, figure 1-3	Chip detector caution light panel	Indicates metal particle accumulation in a transmission system and prop gearbox.
1, figure 1-3	Chip detector panel press-to-test switch.	Provides a means of testing chip detector caution lights.
3, figure 1-3	Oil pressure caution light panel	Indicates low gearbox oil pressure in the propeller and forward and aft gearboxes.
3, figure 1-3	Oil pressure panel press-to-test switch	Provides a means of testing oil pressure caution lights.

ENGINE LUBRICATION

Each engine lubrication system consists of the supply tank, a pressure-scavenge pump, check valve, oil filter, relief valve, and oil cooler. The supply tank is contoured to straddle the forward section of the engine. It is equipped with a sight level gage and filler neck which are accessible through access plates on the nacelle.

The oil supply is gravity fed to the pressure element of the pressure-scavenge pump. Oil pressure is regulated by a spring-loaded poppet valve which bypasses oil to the sump. The regulated-pressure oil is pumped through an anti-leak check valve and a filter before entering the engine. If the oil filter becomes clogged, a bypass valve will open allowing unfiltered oil to be circulated through the engine. Oil is scavenged from the engine by the four scavenge elements of the pressure-scavenge pump. The scavenged oil is returned to the supply tank through the oil cooler which is regulated by a temperature-sensitive bypass valve.

Temperature and pressure pickups are located within each engine lubrication system. They illuminate their associated caution lights in the event of an unsatisfactory condition.

PROPELLER INTEGRAL GEARBOX LUBRICATION

Each propeller integral gearbox lubrication system is completely self-contained with the gearbox. The system consists of an oil level sight gage, oil reservoir, three element pressure-scavenge pump, and relief valve.

The multi-element pump is submerged in an annular oil sump surrounding the shaft end of the propeller housing. The pressure element picks up the oil from the sump and distribution is made to the various lubrication points by means of coned passages. A relief valve maintains the desired oil pressure. Two scavenge elements are provided to assure transfer of the oil to the sump from the forward case for either the vertical or horizontal position or the ducts. An integral oil reservoir forms a portion of the pump system to provide a constant head of oil. Oil cooling is through the side wall of the gearbox housing which is in the propeller air stream. A sight gage is provided on the outboard side of each gearbox to visually determine oil level. Chip detectors and temperature and pressure pickups are located within each propeller integral gearbox. They illuminate their associated caution lights in the event of an unsatisfactory condition.

MAIN LUBRICATION SYSTEM

The main lubrication system supplies lubrication to the following components: fuselage gearboxes, engine gearboxes, accessory drive gearbox, and the constant speed drive.

Pressure for lubricating the gearboxes is supplied by a pump mounted on and driven by the accessory drive gearbox. Oil is pumped from the supply tank and distributed to the individual gearboxes under pressure. The gearboxes contain integral scavenge pumps which return the oil through the air-oil cooler which incorporates a thermostatically controlled bypass valve. The cooled oil is then returned to the supply tank. Cooling air is forced through the oil cooler by a blower driven from the accessory drive gearbox. The oil supply tank capacity is 14 U.S.

gallons and normal servicing is 10 U.S. gallons. A sight gage in the oil supply tank provides a visual check of the oil level in the tank.

Each serviced component in the system is equipped with chip detectors and temperature and pressure pickups which illuminate their associated caution lights in the event of an unsatisfactory condition.

HYDRAULIC SYSTEM

The aircraft hydraulic system consists of two separate and independent systems (figure 1-16). The No. 1 system provides power to the flight control system, while the No. 2 system supplies redundant power to the flight control system, plus power for landing gear actuation and operation of the variable stability system. Indicators for the systems are as follows:

Index and Figure No.	Nomenclature	Function
26, figure 1-3	#1 Hydraulic pressure indicator	Indicates pressure of No. 1 hydraulic system.
26, figure 1-3	#2 Hydraulic pressure indicator	Indicates pressure of No. 2 hydraulic system.
12, figure 1-8	#1 Reservoir oil level indicator	Indicates amount of oil in #1 hydraulic reservoir.

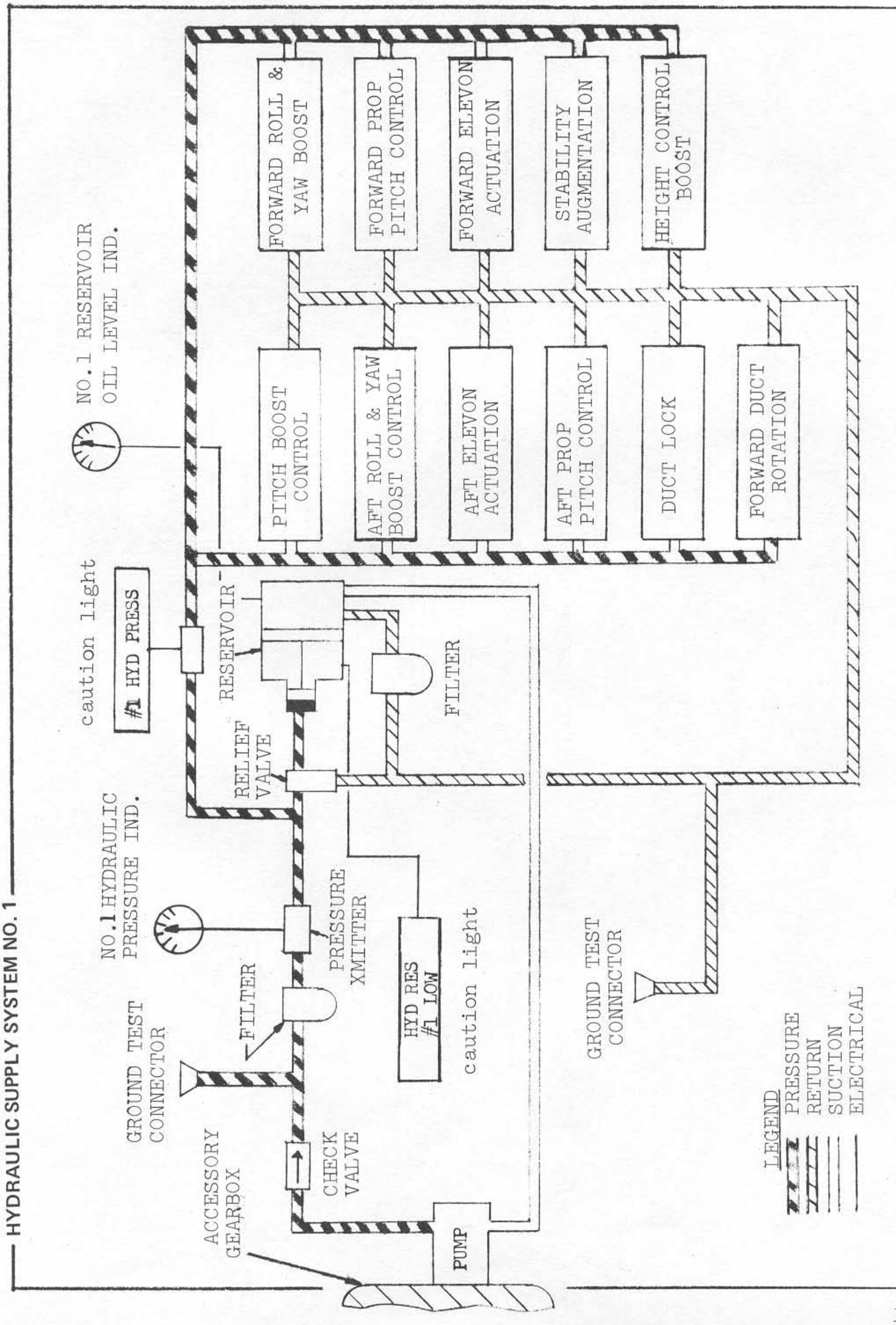


Figure 1-16 (Sheet 1 of 2)

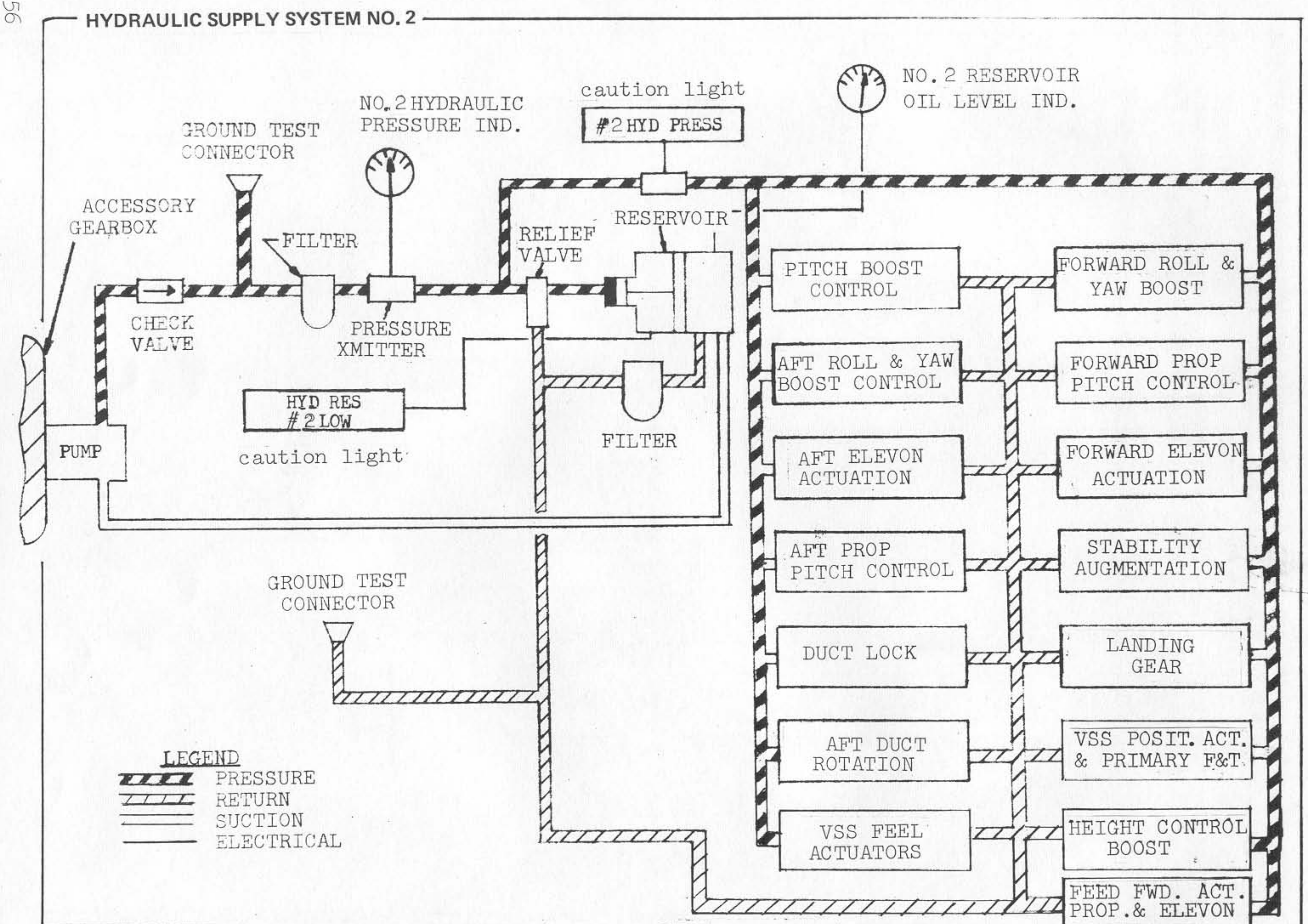


Figure 1-16 (Sheet 2 of 2)

(continued)

Index and Figure No.	Nomenclature	Function
15, figure 1-8	#2 Reservoir oil level indicator	Indicates amount of oil in #2 hydraulic reservoir.
figure 1-7	#1 HYD PRESS caution light	ON - Indicates the pressure of No. 1 hydraulic system is below 1350 psi.
"	#2 HYD PRESS caution light	ON - Indicates the pressure of No. 2 hydraulic system is below 1350 psi.
"	HYD RES #1 LOW caution light	ON - Indicates the hydraulic oil in the No. 1 reservoir is at a low level.
"	HYD RES #2 LOW caution light	ON - Same as above except for No. 2 reservoir.

SUPPLY SYSTEMS

The two hydraulic power supply systems are identical in configuration. Pressure for each supply system is generated by a variable volume, pressure compensated pump driven from the accessory drive gearbox. The pumps are rotated at 6,000 rpm when the engines are operated at full military power. The rated output of each pump at this speed is 22.5 gpm and the rated pressure is 3,000 psi.

The reservoirs which supply oil to the pump are piston air-oil separated types (bootstrap). System pressure is used to pressurize the reservoir to 60 psig to assure sufficient inlet pressure to the pump under all operating conditions. An internal spring maintains a low positive pressure on the oil when the system is not operating to prevent air from leaking at the seal during changes in temperature.

A mechanical relief valve provides over-fill protection.

Sintered stainless steel mesh filters, rated at 15 microns absolute, are used in the outlet line of the hydraulic pump and the return line to the reservoir. Both filters have differential pressure indicators to give a warning of contamination buildup. The filter in the pressure line is the non-bypass type, while the return filter has an integral bypass valve. Additional filtration is provided at each servo actuator, either directly on the valve spool or in the fittings supplying pressure to the unit. Relief valves are used to protect the system against over pressurization in the event that the compensator on the pump fails. The valves are set to crack at 3,450 psi.

Ground test connections for each system provide a means of servicing the systems with an external hydraulic test stand. Gauges and caution lights are provided to monitor the operation of each hydraulic system.

FLIGHT CONTROLS

The primary flight control system is a power operated system utilizing two completely independent hydraulic systems simultaneously commanded by a single mechanical system consisting of push-pull tubes, bellcranks, and rotating shafting and gearboxes. Conventional controls are provided in the cockpit and consist of stick (figure 1-17) and rudder pedals. Control levers for thrust control are conventional throttle type controls. Alternate thrust control in pitch control mode is provided by collective pitch levers (figure 1-17). Duct rotation controls are conveniently located on the conventional flight controls.

The flight control forces are achieved by means of thrust modulation, created by differential and collective propeller pitch change and by deflection of elevons located in the ducts. These controls are integrated for both vertical and level flight to achieve the correct direction and amount of control. Controls and indicators for the flight control system are as follows:

Index and Figure No.	Nomenclature	Function
	Control stick	Lateral movement - controls aircraft movement about the roll axis during all modes of flight. Fore and aft movement -controls aircraft movement about the pitch axis during all modes of flight.

CONTROL STICK GRIP AND COLLECTIVE LEVER GRIP

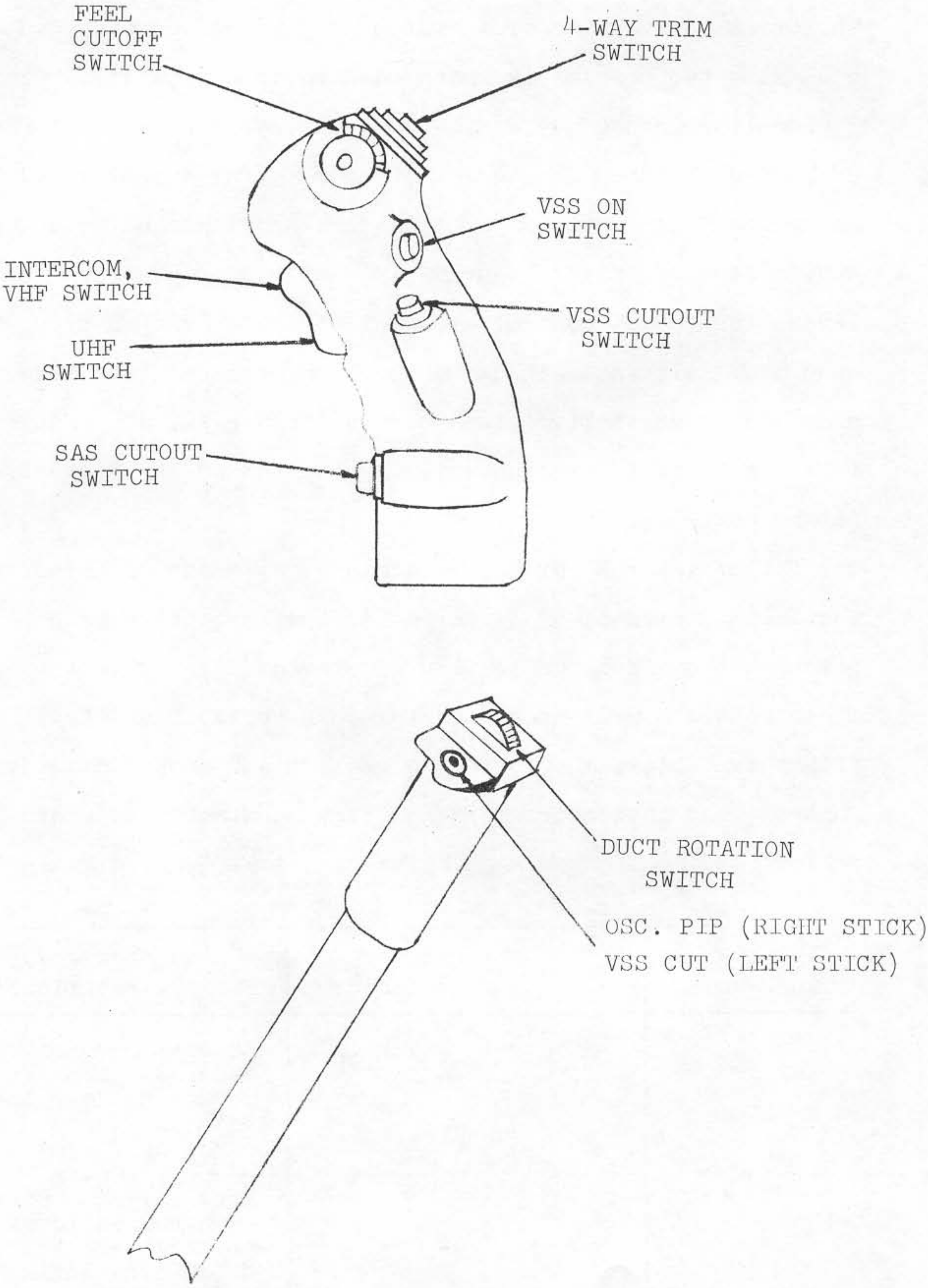


Figure 1-17

Index and Figure No.	Nomenclature	Function
	Rudder pedals	Depressed - controls aircraft movement about the yaw axis during all modes of flight.
21, figure 1-3	Rudder pedal adjust switches	Permit adjustment of rudder pedal positioning.
L/H side of pilot and co-pilot seats.	Collective levers (2)	Provides control inputs to the propeller collective control system.
Between seats	Collective lever friction lock	Provides locking and operating friction for collective levers.
16, figure 1-8	Collective stick indicator	Indicates the degree of collective pitch.
37, figure 1-4 1, figure 1-5	Throttles (4)	Provides engine power control.
38, figure 1-4 2, figure 1-5 figure 1-17	Duct rotation switches	Controls synchronous rotation of ducts between vertical and horizontal position limits.
33, figure 1-4	Duct lock-unlock switch	LOCKED - Applies signal to engage horizontal duct rotation valves when ducts are within 5° of horizontal position. UNLOCKED - Applies arming voltage to duct rotation switches.
34, figure 1-4	Duct rotation override switch	NORM - Permits normal usage of duct rotation switches.

Index and Figure No.	Nomenclature	Function
		HORIZ - Permits override of duct rotation switches in the event a duct rotation switch malfunctions in the horizontal position. VERT - Permits override of duct rotation switches in the event a duct rotation switch malfunctions in the vertical position. OFF - Deactivates all rotation switches.
16, figure 1-3	Duct position indicator	Indicates the thrust angle of the ducts relative to a horizontal vehicle reference line.
figure 1-7	DUCT STOP caution light	ON - Indicates an over-torque condition in the controls mixing unit.
36, figure 1-4	Duct Stop reset switch	Extinguishes DUCT STOP caution light if over-torque condition has been relieved.
31, figure 1-4	GYRO switch	GYRO - activates the attitude indicating system. OFF - turns off the attitude indicating system.

ATTITUDE CONTROL

Aircraft control is provided by conventional flap control surfaces (elevons) located in the exit planes of all four ducts and by differential thrust variation between pairs of ducts through propeller blade pitch change (figure 1-18). The elevon control surfaces provide pitch and roll control in level flight and yaw control in hover. Thrust variation between pairs of ducts is used to provide pitch and roll control in hovering; thrust variation between the left and right ducts provides yaw control in level flights. The elevon deflections and propeller blade angle travels used for control about each axis during transition are varied as a function of duct angle to minimize roll due to yaw control, and yaw due to roll control. Figure 1-19 lists cockpit control and control surface movements.

The elevon actuation system is located in the aft portion of each propeller gearbox. The assembly consists of an output and feedback linkage, a tandem servovalve, and a pair of push-pull actuators each fed from one of the two aircraft hydraulic systems. The mechanical inputs are fed into a tandem spool valve, which modulates and directs the flow of hydraulic fluid into the actuators according to the degree and direction of displacement of the spool from the neutral position. The output motions of the actuators rotate the elevon about its pivot point. Elevon motion is fed back through a set of linkages and is algebraically summed with the input to reposition the servo-valve to neutral when the steady-state elevon position is

PITCH CONTROL SYSTEM

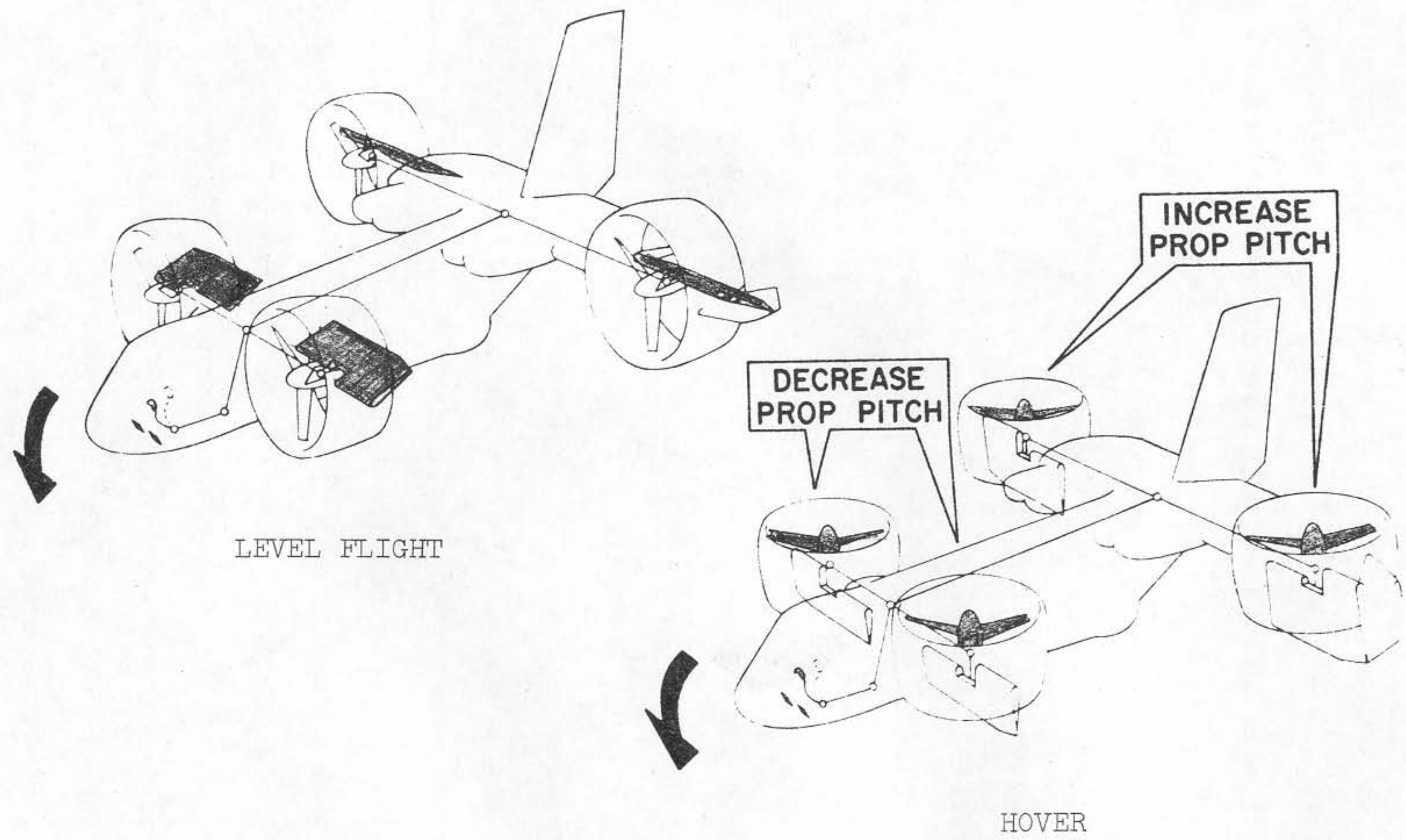


Figure 1-18(Sheet 1 of 3)

ROLL CONTROL SYSTEM

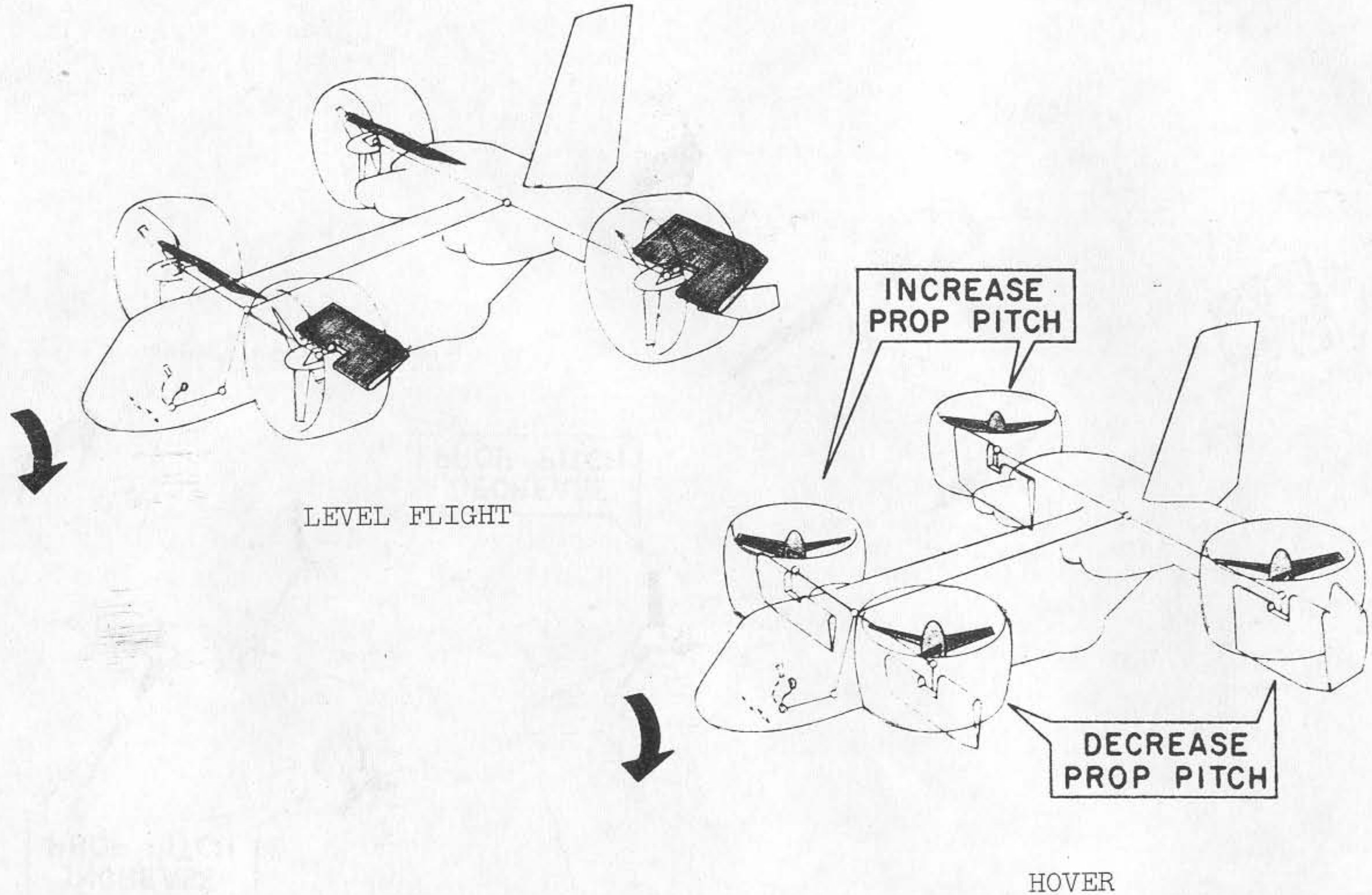


Figure 1-18(Sheet 2 of 3)

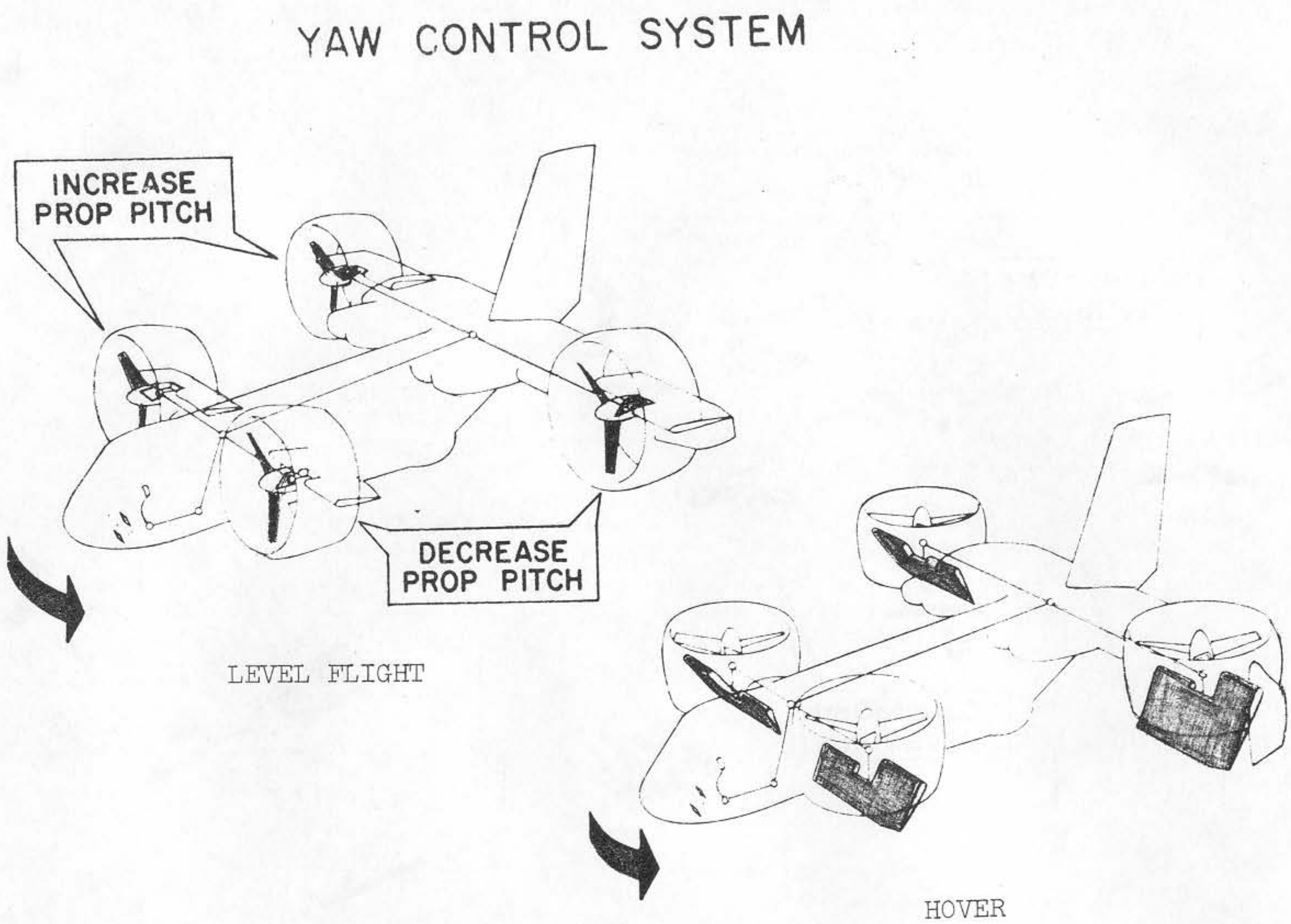


Figure 1-18(Sheet 3 of 3)

COCKPIT CONTROL AND SURFACE MOVEMENTS

Cockpit Control Movements (Max.)	
Control Stick, Longitudinal	± 5.6 in.
Control Stick, Lateral	± 5.2 in.
Directional Control Pedals	±3.25 in.
Height Stick	12.0 in.
" " (VSS)	30°

Elevon Travel (Max.)	Hover	Level Flt
Longitudinal		± 28°
Lateral		± 20°
Directional	±28°	

Propeller Blade Pitch Change Limits		Beta	VSS
Manual Operation:	Level Flight - Yaw	± 3.0°	± 3.0°
	Level Flight - Roll (Yaw/Roll Coupling)	± 1.62°	± 1.9°
	Hover - Pitch	± 7.0°	± 11°
	Hover - Roll	± 4.1°	± 4.9°
Height Stick Operation:	Hover	25°* 30°* 35°*	32°
*Ground rigged to provide any one of these three limits			

Figure 1-19

reached. The servovalve incorporates a load pressure feedback mechanism which acts in a direction to close the servovalve with increasing load pressure.

Propeller pitch control is accomplished by means of a mechanical rotating drive shaft system which drives a signal converter located in each propeller hub resulting in blade pitch angle changes both collectively and differentially. The differential signals are introduced into this system by the control stick and rudder pedals. The collective signals are introduced by means of the particular thrust control system in use. See Thrust Control paragraph below. Control mixing during transition is accomplished by a variable-ratio bellcrank system. The variable-ratio bellcranks are basically screw and nut type commanded by duct angle. Each varies the amount of output signal from the pilot control input from full command in some cases to lockout in other cases. These output signals go to the mixing levers which determine the direction the signal shall take or which system shall move. A take-off gearbox on the left forward duct support tube drives the system as the ducts are rotated. The shafting and associated gearbox system provides synchronous changeover in the control system from the elevon to the propeller pitch system. Since the pitch and roll bellcranks in the propeller pitch control system must be fully effective from vertical to $54\frac{1}{2}°$ of duct rotation, these two bellcranks are operated separately from a "geneva type motion box" in the system.

THRUST CONTROL

Two basic thrust control systems are provided and are designated as pitch control and power control. Since the aircraft cannot accommodate both systems simultaneously it must be ground rigged to utilize one or the other system configurations.

PITCH CONTROL SYSTEM

In the pitch control mode propeller blade angle is controlled directly by the collective levers and the engine governors control power to maintain constant rpm. Forward flight in this mode is limited to approximately 150 knots. The following rigging is necessary for this mode of operation: The collective lever input gearbox is coupled to the propeller pitch rotating drive shaft system by a section of removable gear box (removed for power control mode). Another section of removable shafting between the propeller master governor and the propeller pitch rotating drive shaft system is removed to disable the propeller master governor. The engine fuel control units are changed to "speed control type" (-B fuel controls).

POWER CONTROL SYSTEM

In the power control mode collective pitch signals are introduced directly into the propeller pitch rotating drive system through a gearbox driven by the propeller master governor. The master governor holds propeller rpm constant by change of blade pitch angle for varying commands from the throttles and propeller rpm lever. The following rigging is necessary for this mode of operation:

The collective lever input gearbox is removed. The master governor is connected to its associated gearbox by installing a section of removable shafting. The engine fuel control units are changed to "power control type" (-D fuel controls).

DUCT ROTATION SYSTEM

The duct rotation system is illustrated in figure 1-20. Each duct is mounted on a cantilever tube which is support on two needle bearings pressed into an inboard and outboard rib of the wing structure (and equivalent fuselage structure at the forward ducts). The inboard end of the duct support tube terminates in a mechanical, adjustable stop system which reacts with the inboard support structure.

Each duct is driven by a hydraulic motor through reduction gearing (17 to 2 ratio) which engages with a bull gear on a harmonic drive system. The harmonic drive system provides a further reduction ratio of 300 to 1. A pinion engaging the bull gear drives a cross shaft to the opposite duct and synchronizes the ducts so that they rotate equally. A bevel gear drive on each cross shaft engages with a fore and aft shaft to synchronize front and rear ducts. The forward ducts are powered by hydraulic system No. 1 and the rear ducts by hydraulic system No. 2. In the event either hydraulic system fails, the remaining system will supply sufficient power to rotate all ducts.

DUCT ROTATION SYSTEM

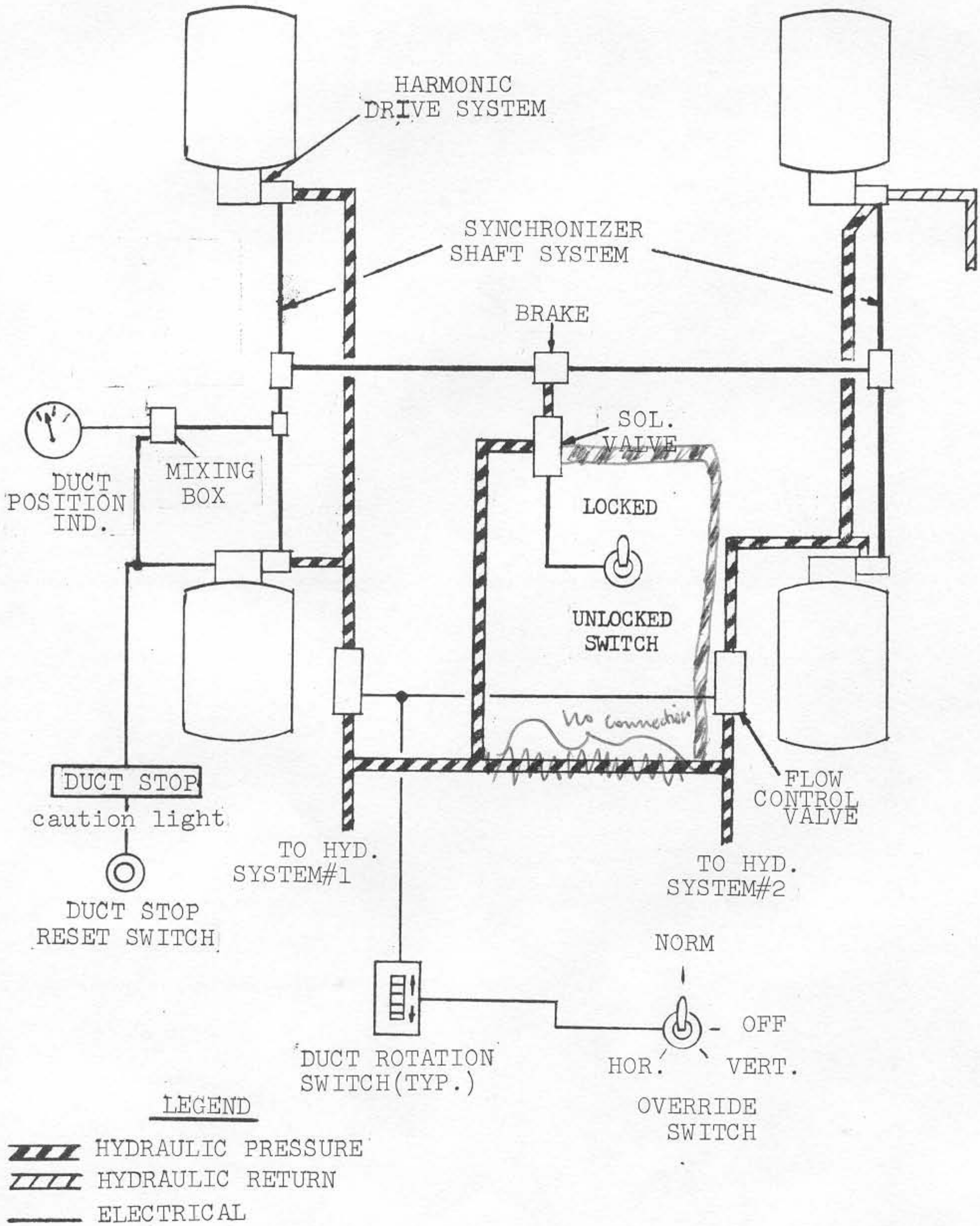


Figure 1-20

Duct rotation is limited to air speeds below 150 kts. and in flight the rotation moment (air load and propeller torque reaction) is always positive (i.e. , tends to rotate the duct from the horizontal to the vertical position). Dual locking provisions are provided for horizontal flight. Hydraulic power is kept on the hydraulic motors, holding the ducts rigidly against the mechanical stops and thus preloading the harmonic drive system, eliminating backlash and increasing the torsional stiffness of the duct support tube. In addition, mechanical locking is provided at the duct locking brake. Duct locking is also provided in all positions by the mechanical locking brake when normal duct rotation switches are not activated.

In the nominal cruise configuration, the forward ducts are locked at two degrees incidence with the fuselage reference line and the aft ducts at minus three degrees. The duct incidence settings can be ground adjusted plus or minus two degrees from the nominal in one degree increments. For vertical takeoff and landing, the ducts rotate together at a maximum rate of 5 deg/sec. The pilot may transition at any rate desired by "beeping" his rotation switch. The normal rate tapers in the last five degrees of travel before the stops to 1 deg/sec. The maximum angular travel from the cruise duct incidence combination is 93° for the forward pair and 98.34° for the aft pair.

Duct rotation is initiated by rotating any one of the four rotation switches located on both collective levers and both No. 4 engine throttles, or by the duct override switch which is provided to permit overriding a malfunction of the conventional rotation switches.

A duct rotation position indicator is provided on the main panel to display the thrust angle of the ducts relative to a horizontal vehicle reference line. The instrument is actuated by a position pickup driven from the mixer box.

The DUCT STOP caution light when illuminated, indicates an over-torque condition in the duct rotation input to the control system mixing box. The light is illuminated by a relay which is actuated by any one of a series of torque sensor switches located in various positions in the duct rotation input to the mixing box. The over-torque sensing automatically disables the duct rotation system.

CAUTION

In the event the DUCT STOP caution light comes on, no further attempt should be made to rotate the ducts until the over-torque condition has been investigated, even if the over-torque was only momentary and the caution light can be extinguished.

PRIMARY FEEL AND TRIM SYSTEM

The primary artificial feel and trim system provides the control stick and rudder pedal feel forces which would be normally encountered in a manually operated flight control system (figure 1-21).

Controls and indicators for the primary feel and trim system are as follows:

Index and Figure No.	Nomenclature	Function
32, figure 1-4	Feel system and reset switch	NORM-takes the VSS actuators out of by-pass to allow normal operation of the electro-hydraulic Feel System. OFF - places the VSS position actuator in hydraulic by-pass. Also deactivates a malfunction warning audio signal and caution light. RESET - resets the system to normal operation and shuts off an audio warning signal and caution light if a failure no longer exists.
2 & 3, figure 1-4	Feel battery test switch and indicator	Provides a means of checking the condition of the feel battery.
figure 1-17	Control stick trim switch	Fore-aft movement trims pitch feel force. Lateral movement trims roll force.

FEEL AND TRIM SYSTEM - PITCH AND ROLL

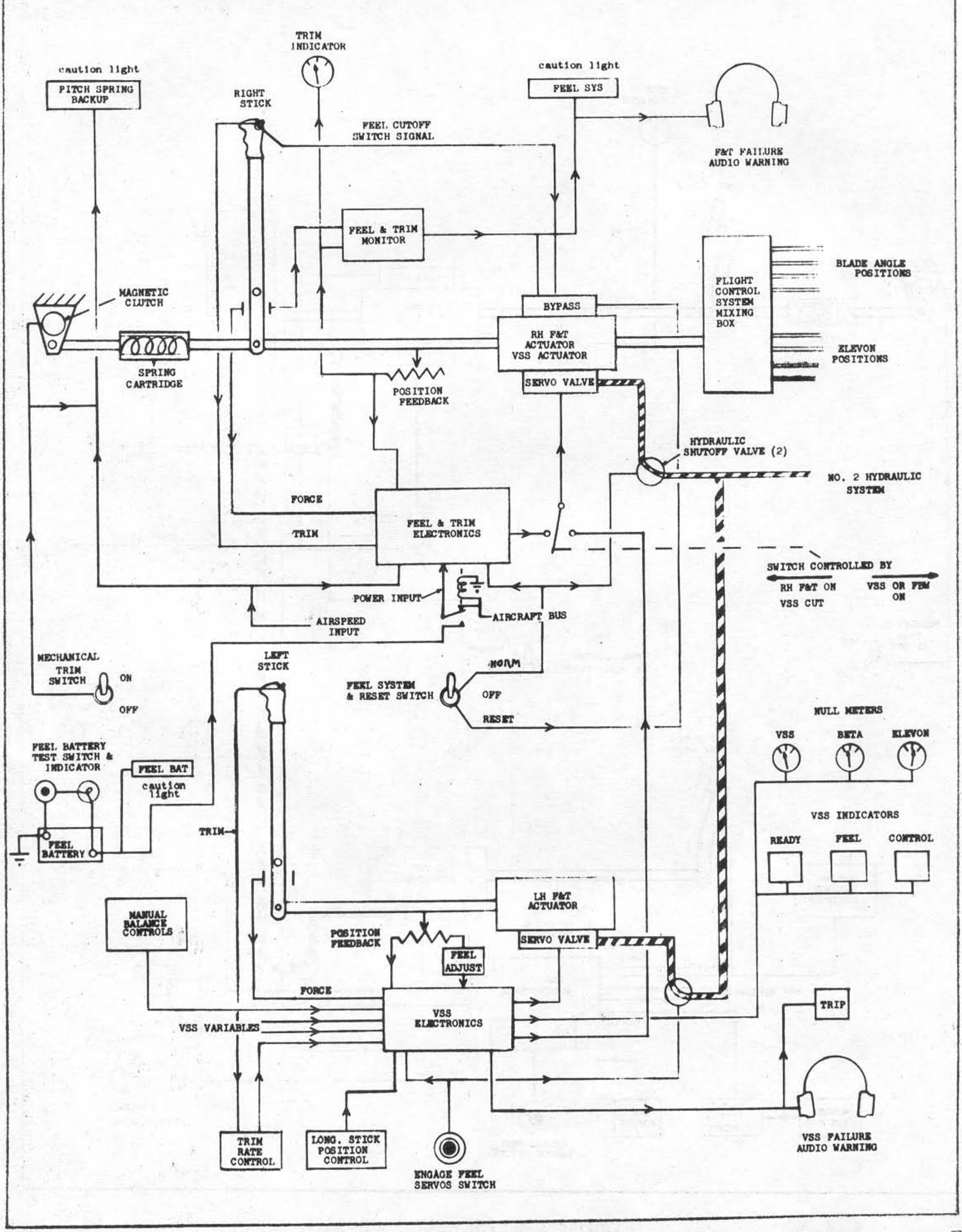


Figure 1-21(Sheet 1 of 2)

FEEL AND TRIM SYSTEM - YAW

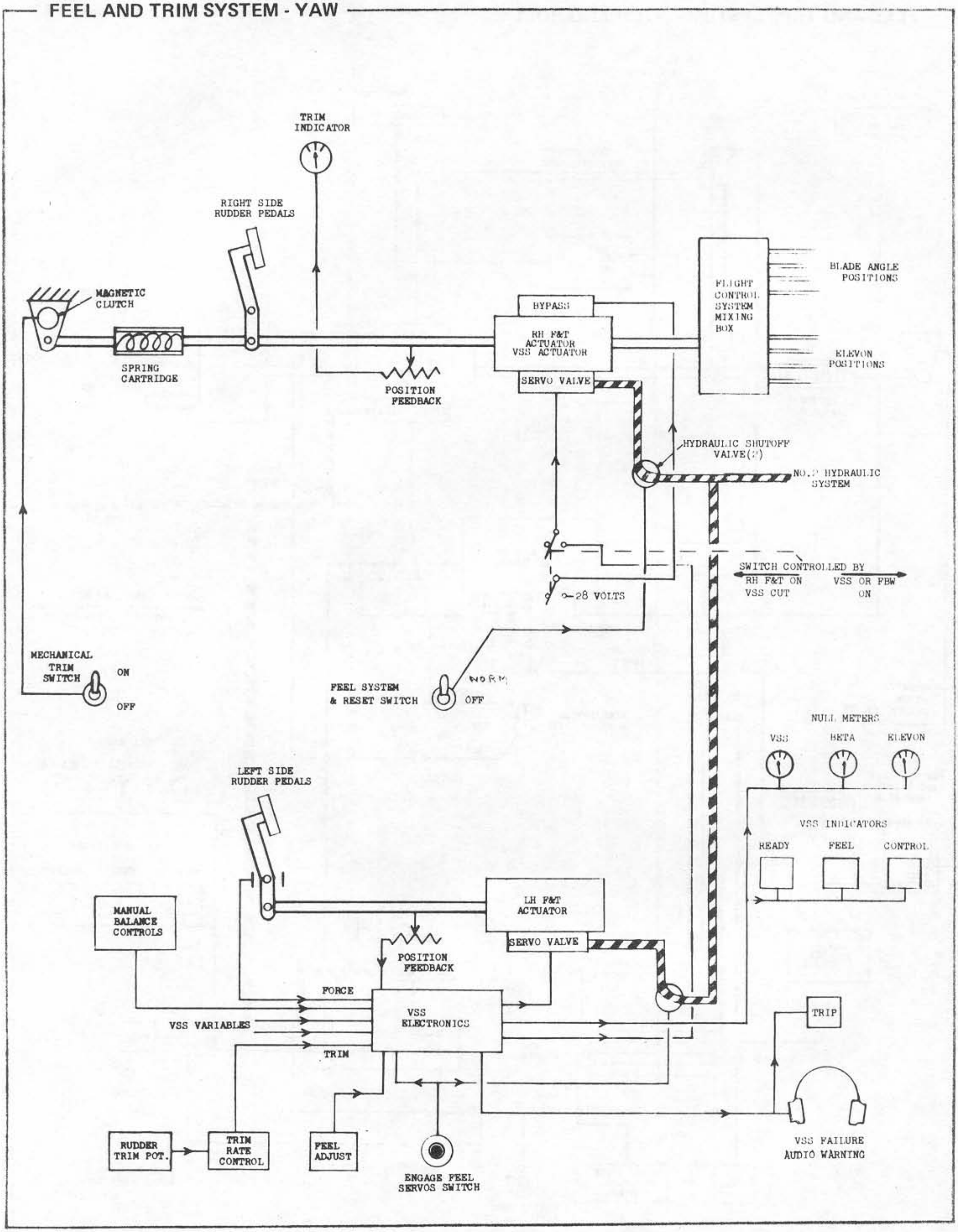


Figure 1-21(Sheet 2 of 2)

Index and Figure No.	Nomenclature	Function
11, figure 1-3	Pitch, roll, and yaw, trim indicators	Provides a visual means of setting up control positions.
figure 1-7	FEEL SYS caution light	ON - indicates a malfunction in the electro-hydraulic system of the primary artificial feel and trim system.
	<u>Mechanical Trim</u>	
41, figure 1-4	Yaw switch	ON - engages yaw spring feel forces at existing control position.
		OFF - disengages yaw spring feel forces.
41, figure 1-4	Pitch switch	ON - engages pitch spring feel forces at existing control position.
		OFF - disengages pitch spring feel forces.
41, figure 1-4	Roll switch	ON - engages roll spring feel forces at existing control position.
		OFF - disengages roll spring feel forces.
figure 1-7	FEEL BAT caution light	ON - indicates the feel and trim system is operating on battery power.
figure 1-7	PITCH SPRING BACKUP caution light	ON - indicates 150 kt or greater, airspeed.

Index and Figure No.	Nomenclature	Function
figure 1-17	Feel cutoff switch	ROTATED - provides a means of deactivating the feel and trim system by placing the VSS actuators in by-pass.

The primary artificial feel and trim system has two (2) modes of operation:

(1) An electro-hydraulic primary mode (pitch and roll).

(2) A mechanical backup mode (pitch, roll, and yaw).

The electro-hydraulic primary system utilizes strain gages located on both sticks (manual operation; left-hand stick only for VSS/FBW operation) to generate force command signals. These signals are transmitted through electronic amplification and gain shaping circuitry to power amplifiers which drive the variable stability system position actuators. These actuators in turn position the respective pilot controls to reflect the applied forces. A removable linkage is provided between the two control sticks, and is ground removed when the variable stability system is to be operated by the left-hand pilot (evaluation pilot). This permits the right-hand pilot to function as a safety pilot since his controls remain mechanically engaged in the system at all times.

The feel forces in the pitch and roll axes are varied as functions of equivalent airspeed by "q" sensing transducers which are coupled to the aircraft pitot-static system. Feel forces in the yaw axis are mechanical spring forces engaged at the pilots discretion (recommend: engage when ducts are horizontal and locked).

Pitch and roll feel forces are trimmed at rates measured in pounds per second. Yaw forces are trimmed when springs are used by means of a magnetic clutch instantaneous system.

Fore-aft actuation of the trim switch on top of the control sticks trims out pitch feel forces while lateral actuation trims out roll forces.

A monitor circuit is provided to automatically detect any electrical malfunction in the feel and trim system. Should a failure occur during flight, the feel and trim system will "fail soft"; i.e. the variable stability position actuators will automatically go into bypass, placing the system in the mechanical backup mode of operation.

Above 150 knots, the feel and trim system should be turned OFF and the mechanical springs clutched in for pitch, roll, and yaw.

Note

The pitch and roll springs are installed in the aircraft for the power control mode only.

Auxiliary battery power is automatically provided to operate the feel and trim system electronics for a limited period (60 seconds minimum) in the event the primary, aircraft electrical system fails.

The FEEL BAT caution light indicates the feel and trim system is operating on battery power.

The FEEL SYS caution light and an accompanying headset-audio warning indicate a malfunction within the feel and trim system, detected by the feel and trim monitor.

The RESET position of the feel system and reset switch resets the system to normal operation and shuts off the audio warning and FEEL SYS caution light if a momentary failure occurs within the feel and trim system. The system is re-engaged following RESET by setting the switch to ON position while holding the flight controls in a fixed position.

The feel and trim system is automatically switched to off when the VSS or FBW is disengaged, and must be re-engaged by following the reset procedure above.

VSS/FBW FEEL AND TRIM SYSTEM

The VSS/FBW feel and trim system makes use of the following VSS controls and indicators:

Index and Figure No.	Nomenclature	Function
4, figure 1-5	<u>Feel Engage Panel</u> Engage feel servo switch	Momentarily depressed-energizes the VSS hydraulic feel pressure solenoid through operation of a latching relay thereby engaging the VSS feel system. The VSS nulling servos are engaged at the same time.
	Stick position potentiometer	Rotated forward or aft-permits the evaluation pilot to trim the left hand control stick in pitch without changing trim of the airplane.
8, figure 1-5	<u>VSS Trim Control Panel</u> - Type of trim switch	RATE - provides force rate trim for the pitch and roll axis. NULL - provides nulling trim for the pitch and roll axis. **Note** If stick force commands have been selected for either pitch or roll axes (i.e. either F_{ES} of F_{AS}) then this switch is bypassed and rate trim is provided on both pitch and roll axes.
	Sensitivity - pitch selector switch	Establishes the sensitivity of the pitch trim switch on the left hand control stick. The 5 detented positions1 through 5 correspond to trimming rates of 1, 2, 5, 10, and 20 pounds per second, respectively.

Index and Figure No.	Nomenclature	Function
	Sensitivity - roll selector switch	Same as above except for roll trim.
	Sensitivity - yaw selector switch	Establishes the trim range of the YAW TRIM control. The 5 detented positions correspond to 5, 10, 20, 50, and 100% of maximum available trim.
	Yaw trim potentiometer	Permits the evaluation pilot to manually trim out forces on the rudder pedals up to 150 pounds.
figure 1-17 (left hand stick only)	Trim switch	Fore-aft movement provides pitch trim. Lateral movement provides roll trim. **Note** In the FBW configuration rate trim only is provided. In the VSS configuration, the type of trim and rate of nulling depends on the settings of the following controls: TYPE OF TRIM $F_{ES} - \delta_{ES}$ and $F_{AS} - \delta_{AS}$.
13, figure 1-3	Feel indicator	Displays an ON flag when the VSS feel servos have been engaged.
12, figure 1-3	Trip indicator	Displays a blinking ON flag when anyone of 14 signals causes the safety trip monitor to disengage the VSS (operation of the TRIP indicator is accompanied by an audio alarm in the intercom system.

The VSS feel and trim system is used for both VSS and FBW operation and must be engaged prior to selecting VSS or FBW flight control modes.

The VSS feel and trim system utilizes strain gages on the left hand control stick and rudder pedals to generate force command signals. These signals are transmitted through amplification and shaping networks to power amplifiers which drive the left hand control position actuators. The feel forces in the VSS mode are controlled by settings of the TYPE OF TRIM switch on the VSS trim control panel and by settings on the VSS gain control panel.

Pitch and roll feel forces are trimmed by operation of the trim switch on the left hand control stick. Fore and aft movement of the trim switch trims out pitch forces and lateral movement trims out roll forces. Rudder pedal forces are trimmed by means of the YAW TRIM potentiometer on the VSS trim control panel.

Monitor circuits are provided in the VSS electronics to disengage VSS feel and trim and revert to right hand (safety pilot) control in the event of VSS feel and trim system failures. The VSS TPIP Indicator and headset audio warning indicate disengagement of left hand (evaluation pilot) control.

VSS feel and trim is engaged by momentary depression of the ENGAGE FEEL SERVO switch on the VSS feel engage panel. The left hand stick and rudder pedal forces and position may be trimmed as desired without effect on flight control by the safety pilot until either VSS or FBW mode is engaged by appropriate selection of VSS controls.

When VSS or FBW mode is engaged, the evaluation pilot's controls provide inputs to the VSS flight control electronics and the safety pilot's controls follow the control command signals generated by VSS/FBW and command aircraft response.

STABILITY AUGMENTATION SYSTEM

The stability augmentation system (SAS) augments the natural stability of the airplane in the pitch, roll, and yaw axes (figure 1-22). The system utilizes dual channel capability which permits the pilot to select full, one-half or no SAS authority. A "q" sensing system reduces and finally phases out SAS authority at varied rates in the three axes as a function of increasing air speed. Fail-safe features are incorporated into the system. Controls and indicators for the system are as follows:

Index and Figure No.	Nomenclature	Function
27, figure 1-4	SAS channel selector switch	OFF - Deactivates the stability augmentation system.

STABILITY AUGMENTATION SYSTEM

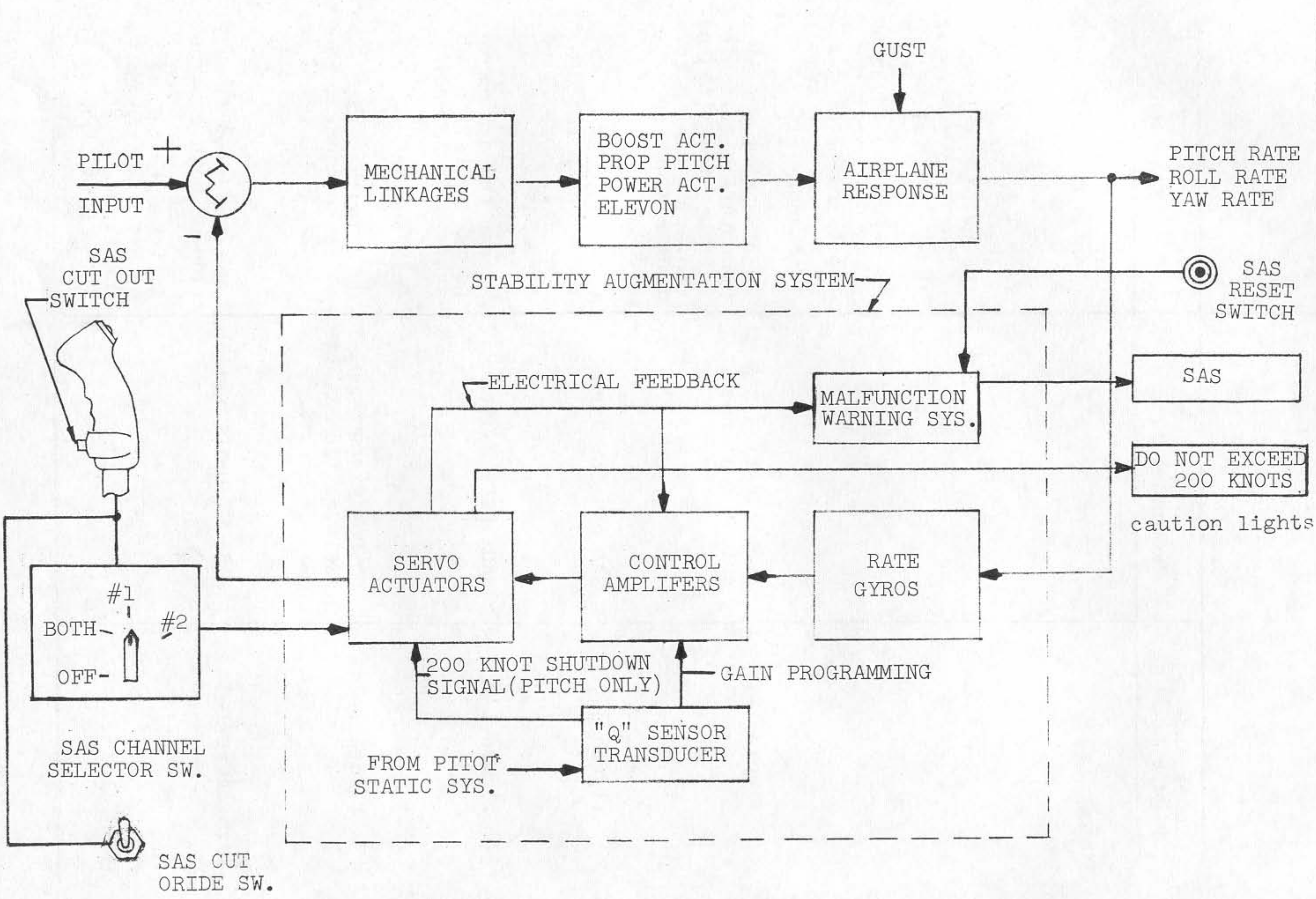


Figure 1-22

Index and Figure No.	Nomenclature	Function
		BOTH - Turns on both channels in all three axes. #1 - Turns off channel #2 by de-energizing the by-pass solenoids of the servo-actuators in channel #2. #2 - Turns off channel #1 by de-energizing the by-pass solenoids of the servo-actuators in channel #1.
figure 1-17	Control stick SAS cutout switches (2)	Provides a means of momentarily switching out the stability augmentation system for test evaluation purposes.
figure 1-7	SAS caution light	ON - Indicates a malfunction in the SAS system in any of the three axes.
27, figure 1-4	SAS RESET switch	Resets the system to normal operation and shuts off SAS caution light if a momentary failure occurs.
figure 1-7	DO NOT EXCEED 200 KNOTS caution light	ON - Indicates the SAS system has not automatically centered and locked in the pitch axis.
43, figure 1-4	SAS CUT ORIDE switch	ON - Provides an override of both control stick SAS cutout switches in the event of stick switch malfunction. OFF - Permits normal stick switch usage.

Augmentation signals generated by rate gyros for each axis are fed into their respective control amplifiers. The amplified signals are introduced into dual electrohydraulic actuators which are connected in parallel with each other and with the appropriate control system so that their output motions are additive. Electrical transducers, internally mounted, provide position feedback for each actuator. The output from each rate gyro signal is added algebraically to the position-feedback signal from the actuators and the sum controls the servo valve to drive the actuator in a direction to null the sum.

As the need for stability augmentation decreases with speed, the "q" sensing transducers which are coupled to the pitot-static system gradually program the control amplifier gains to phase out the SAS. The three axes gains are reduced at different rates, the pitch axis being the last one to drop out at approximately 160 knots.

Fail-safe features are incorporated in the pitch, roll, and yaw axes of SAS such that a single malfunction or failure in any axis of the system will not affect safety of flight. A malfunction or failure of one channel in the pitch, roll, or yaw axes will not cause the other SAS channel to shut down or be rendered inoperative. Electrical signals from the two transducers in the dual servo actuator in the pitch, roll and yaw axes are compared in a differential amplifier and detector. Any difference between transducers indicates imparement of the SAS function and is indicated by the SAS caution light. It can be determined if the malfunction is of a momentary nature by pressing the SAS RESET switch.If the SAS caution light extinguishes after reset, the malfunction can be considered as momentary. If the caution light does not extinguish the SAS channel selector switch is used to determine if there is a remaining good channel.

An automatic shutdown and lockout of the SAS is incorporated in the pitch axis only to prevent a hard-over electrical malfunction from causing a catastrophic failure to the aircraft when flying at speeds in excess of 200 knots. As this speed is approached, a "q" sensitive switch opens, de-energizing the solenoid valves which shuts off hydraulic pressure to the pitch servo-actuators. Opening the "q" switch also applies power to piston lock switches on the pitch servo actuators and momentarily turns on the DO NOT EXCEED 200 KNOTS caution light. As hydraulic pressure in the servo-actuators drops below 3000 psi, the pistons center and lock in the neutral position. When both actuator pistons center and lock, the locking devices mechanically actuate piston lock switches to the open position. Opening the piston lock switches extinguishes the caution light. In the event the pistons do not center and lock, the caution light remains on.

VARIABLE STABILITY SYSTEM (VSS)

The VSS is a research tool which provides a means of modifying the pilot's feel and aircraft control inputs such that the aircraft handling characteristics are changed. A single parameter can be changed or a number of parameters such that another quite different V/STOL aircraft can be simulated. The research use of a VSS aircraft generally involves the evaluation of the suitability of a specified set of flying qualities for a designated mission or task. The specified flying qualities, in turn, may be related to a basic research program or evaluation of a particular airplane design.

There are four VSS control axes - thrust, pitch, roll, and yaw. Electrohydraulic servos are employed in each axis. When the aircraft is rigged for VSS flight, the left hand flight controls are mechanically disconnected from the right hand flight controls and the primary flight control system. This is accomplished by a ground removable linkage. Tie-in of the VSS and primary flight control system is illustrated in figure 1-23. The evaluation pilot occupies the left hand seat and the safety pilot occupies the right hand seat. The VSS thrust servo operates the boost servo for the collective pitch system and the VSS pitch, roll and yaw servos operate the right hand flight controls, moving the same linkages which are moved manually by the right hand pilot in normal flight. Phasing of these control motions to the propellers and elevons is accomplished by the

VSS AND PRIMARY FLIGHT CONTROL TIE-IN

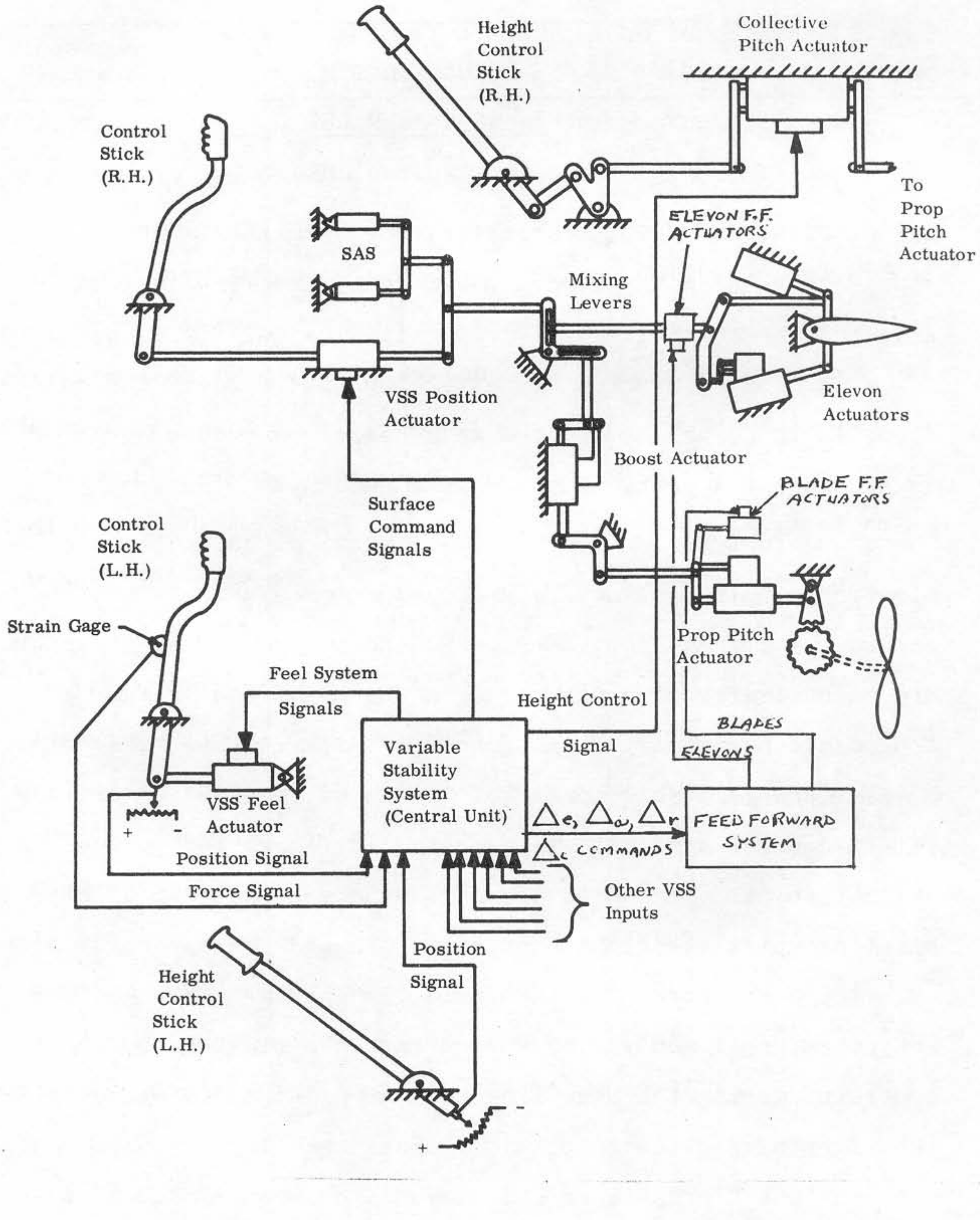


Figure 1-23

mechanical mixing system as for normal flight. For VSS operation the thrust control system is operated in the pitch control mode as this mode provides significantly shorter response time than the power control mode.

The safety pilot can change many of the variable characteristics in flight by resetting the gains in the system with the digitrol potentiometers located on the gain control panels on his right. Changes in the variations of forces and moments with speed, however, require changes in the system function generator cards. There are printed circuit cards which essentially plot the nonlinear gain variation desired. The cards are readily changeable, but it is necessary to open the system to do so and this will normally be done on the ground prior to flight.

The overall VSS consists of input sensor equipment, signal processing equipment, gain setting and programming equipment, variable electrohydraulic feel servos, electrohydraulic servomechanisms for driving the aircraft control systems and subsystems for controlling, interlocking, and monitoring system operation. A recording instrumentation system associated with the VSS is installed in the aircraft to record pertinent parameters of VSS flights. In addition, a test input unit is provided for test purposes in evaluating aircraft response.

Controls and indicators for the VSS are as follows:

Index and Figure No.	Nomenclature	Function
28, figure 1-4	VSS Master Panel	
	VSS switch	ON - supplies all electrical power to the VSS. OFF- removes all electrical power from the VSS.
	LORAS switch	ON -energizes the low range airspeed system (LORAS) spin motor. OFF -de-energizes the LORAS spin motor.
	VSS - FBW switch	VSS-permits engagement of the VSS in the VSS configuration (i.e., the configuration set up on the R/H gain control console). FBW-permits engagement of the VSS in the fly-by-wire configuration (i.e., the stability characteristics of the basic aircraft with SAS operating but with force gradients on the evaluation pilot's controls limited to two discrete levels). NOTE Whenever the VSS is disengaged, automatically or manually, the VSS-FBW switch returns to the FBW position.

Index and Figure No.	Nomenclature	Function
20, figure 1-4	<u>Mode Panel</u>	
	TRANSITION - FOP switch	TRANSITION - places the VSS in the transition mode. FOP - places the VSS in the fixed-operating-point mode.
	FCN DRIVE switch	λ - connects the duct position as the driving source for VSS function generators. u - connects long. airspeed from the LORAS as the driving source for the VSS function generators. **Note** This switch is active only in the FOP mode of operation.
	F_{ES} - δ_{ES} switch	F_{ES} - connects the evaluation pilot's elevator stick force as the command to the VSS pitch servo. δ_{ES} - connects the evaluation pilot's elevator stick position as the command to the VSS pitch servo.
	F_{AS} - δ_{AS} switch	F_{AS} - connects the evaluation pilot's aileron stick force as the command to the VSS pitch servo. δ_{AS} - connects the evaluation pilot's aileron stick position as the command to the VSS pitch servo.

Index and Figure No.	Nomenclature	Function
	F_{RP} - δ_{RP} switch	F_{RP} - connects the evaluation pilot's pedal force as the command to the VSS yaw servo. δ_{RP} - connects the evaluation pilot's pedal position as the command to the VSS yaw servo. **Note** The above three switches are in-active in the FBW configuration.
	AUTO BAL switch (guarded)	ON (guarded) - permits the four VSS servo amplifiers (thrust, pitch, roll, and yaw) to be automatically nulled when the feel system is engaged. OFF (unguarded) - locks out the nulling servos. Balancing must be performed manually before engaging the VSS.
8, figure 1-6	<u>Manual Balance Panel</u>	
	METER SELECT switch	PITCH - connects the VSS null meter to the pitch servo amplifier output. ROLL - same as above except for roll servo amplifier. YAW - same as above except for yaw servo amplifier.

Index and Figure No.	Nomenclature	Function
		COL PITCH - same as above except for collective pitch servo amplifier.
		SUM - same as above except connects the sum of all amplifier outputs.
	PITCH potentiometer	Provides a means of manually balancing the VSS pitch servo.
	ROLL potentiometer	Same as above except for roll servo.
	YAW potentiometer	Same as above except for yaw servo.
	COL PITCH potentiometer	Same as above except for collective pitch servo.
2,3,5,6, figure 1-6	Gain Control Panels (4)	
	Thrust axis digitrols (11, color coded green)	Provides a means of setting up the variable stability and control system gains in the thrust axis.
	Pitch axis digitrols (17, color coded bronze)	Same as above except for pitch axis.
	Yaw axis digitrols (12, color coded blue)	Same as above except for yaw axis.
	Roll axis digitrols (11, color coded grey)	Same as above except for roll axis.
	Note See Tables I - IV for definition of digitrol functions.	

Index and Figure No.	Nomenclature	Function
figure 1-17	<u>Control Stick Grips</u>	
	VSS ON switch	Momentarily depressed -energizes latching relays that transfer the VSS servo-valves from the primary feel and trim system to the VSS.
	VSS CUT switch	Momentarily depressed -disengages the VSS, restoring control of the aircraft to the safety pilot.
	TRIM switch	Fore-aft movement provides pitch trim. Lateral movement provides roll trim. **Note** In the FBW configuration rate trim only is provided. In the VSS configuration, the type of trim and rate of nulling depends on the settings of the controls on the VSS trim control panel.

Index and Figure No.	Nomenclature	Function
figure 1-17	<u>Collective Stick Grip</u>	
	VSS CUT switch	Momentarily depressed- provides the safety pilot with an alternate means of disengaging the VSS.
4, figure 1-5	<u>Feel Engage Panel</u>	
	ENGAGE FEEL SERVO switch	Momentarily depressed - energizes the VSS hydraulic feel pressure solenoid through operation of a latching relay thereby engaging the VSS feel system. The VSS nulling servos are engaged at the same time.
	STICK POSITION potentiometer	Rotated forward or aft - permits the evaluation pilot to trim the left hand control stick in pitch without changing trim of the airplane.
8, figure 1-5	<u>VSS Trim Control Panel</u>	
	TYPE OF TRIM switch	RATE - provides force rate trim for the pitch and roll axis. NULL - provides nulling trim for the pitch and roll axis. **Note** If stick force commands have been selected for either pitch or roll axes (i.e., either F_{ES} or F_{AS}) then this switch is bypassed and rate trim is provided on both pitch and roll axes.

Index and Figure No.	Nomenclature	Function
	SENSITIVITY-PITCH selector switch	Establishes the sensitivity of the pitch trim switch on the left-hand control stick. The 5 detented positions, 1 through 5, correspond to trimming rates of 1, 2, 5, 10 and 20 pounds per second. respectively.
	SENSITIVITY-ROLL selector switch	Same as above except for roll trim.
	SENSITIVITY-YAW selector switch	Establishes the trim range of the YAW TRIM control. The 5 detented positions correspond to 5, 10, 20, 50 and 100% of maximum available trim.
	YAW TRIM potentiometer	Permits the evaluation pilot to manually trim out forces on the rudder pedals up tothe limit set by the yaw sensitivity switch above.
9, figure 1-5	<u>Function Generator Panel</u>	
	TEST-NORMAL switch (guarded)	NORMAL (guarded) -permits the function generators to operate as a function of velocity or λ. TEST (unguarded) -Permits the function generator digitrol to operate as the control input to the function generators rather than velocity or λ. This position is normally used for ground operation.

Index and Figure No.	Nomenclature	Function
	Function generator digitrol	Provides a variable test signal to simulate velocity commands to the function generators. **Note** This control can be used to command the function generators to a position such that the VSS signals bypass the function cards and are directly coupled to the gain control panels.
13, figure 1-3	<u>VSS Panel</u>	
	NULL METER	Displays the balance or null of the VSS servo amplifiers before engagement of the VSS. After VSS engagement, the null meter monitors the primary feel and trim systems pitch servo amplifier.
	RDY indicator	Displays an ON flag when the VSS master switch is in the ON position denoting "shared instrumentation" signals are available to the oscillograph and tape system.
	FEEL indicator	Displays an ON flag when the VSS feel servos have been engaged.

Index and Figure No.	Nomenclature	Function
	CONT indicator	Displays an ON flag when the VSS servo valves (and therefore the flight controls) are connected to the VSS servo amplifiers.
12, figure 1-3	TRIP indicator	Displays a blinking ON flag when any one of 14 signals causes the safety trip monitor to disengage the VSS (operation of the TRIP indicator is accompanied by an audio alarm in the intercom system).
	<u>Auxilary Instrument Panels</u>	
9, figure 1-8	ANGLE OF ATTACK indicator	Indicates angle of attack.
8, figure 1-8	LATERAL AIRSPEED indicator	Indicates lateral airspeed.
18, figure 1-8	ANGLE OF SIDESLIP indicator	Indicate angle of sideslip.
6, figure 1-8	VERT ACCEL indicator	Indicates vertical acceleration
7, figure 1-8	LONG AIRSPEED indicator	Indicates longitudinal airspeed
10, figure 1-5	<u>Test and Simulation Panel</u>	
	Axis selector switch	Selects the desired test axis as follows: ΔB - thrust axis Δe - pitch axis Δa - roll axis Δr - yaw axis

Index and Figure No.	Nomenclature	Function
	Mode selector switch	STEP - injects a step input into the selected axis. **Note** A step input is terminated by placing the ARM-DISARM switch in DISARM position. PULSE - injects a pulse input into the selected axis. DOUBLET - injects a doublet input into the selected axis.
	Time interval selector potentiometer	Selects the duration of the pulse or doublet input over a range of .1 to 4.6 seconds.
	Amplitude % selector potentiometer	Selects the amplitude of the input mode. Full scale amplitude is approximately 10% of VSS actuator motion (except yaw 30%).
	- + Selector Switch	- - provides negative control inputs (nose left, nose down, left roll). + - provides positive control inputs (nose right, nose up, right roll).
	Arm - disarm switch (guarded)	ARM - activates the test input initiation switch. DISARM (guarded) - deactivates the test input initiation switch.

Index and Figure No.	Nomenclature	Function
	Miscellaneous	
10, figure 1-8	Beta null indicator	Indicates satisfactory condition of feed forward system electronics prior to VSS engagement.
17, figure 1-8	Elevon null indicator	Indicates satisfactory condition of feed forward system electronics prior to VSS engagement.
13, figure 1-5	VSS safety trip lockout switch	NORMAL (guarded) - permits normal safety trip operation. LOCKOUT - locks out VSS safety trip parameters.
5, figure 1-5	Test input initiate switch	Momentarily depressed - initiates the test function setup on the test and simulation panel.

OPERATING MODES

There are two basic VSS operating modes and one secondary mode. The basic modes are the transition mode and the fixed-operating-point mode (F.O.P.). The secondary mode is the fly-by-wire(FBW) mode.

TABLE I

FUNCTION OF GAINS IN THRUST CONTROL SYSTEM (GREEN DIGITROLS)

Digitrol Number	Digitrol Symbol	Gain	Purpose
1	w	$\Delta'_\beta/\bar{\omega}$	To vary time constant of one root of characteristic equation in hover; height damping.
2	ES	$\Delta'_\beta/\bar{\delta}_{ES}$	Control input coupling. Thrust change due to elevator stick displacement.
3	βS	$\Delta'_\beta/\bar{\delta}_{\beta S}$	Control input. $\frac{\bar{\delta}_{\beta S}}{\delta_{\beta S}} = \frac{1}{1+\tau s}$
4	$\|V\|$	$\Delta'_\beta/\|V\|$	To change static gains in fixed operating point; change vertical force with forward speed and lateral speed.
5	α	$\Delta'_\beta/\Delta\alpha_V$	To vary primary term in numerator of $\dot{\theta}/\delta_e$ and to change n_z/α.
6	τ	τ	Lag in thrust buildup.
7	$\Delta\lambda$	$\Delta'_\beta/\Delta\lambda$	Variation of thrust with duct angle; provides linear variation with duct angle of thrust vs. velocity in transition.
8	W_0	W/W_0	Change reference collective pitch blade angle with speed or duct angle, to compensate for changes in duct exit dynamic pressure (pitch, roll and yaw axes).
9	β_0	$\Delta'_\beta/\delta_{\beta S_0}$	Change from X-22A trim position of the collective pitch stick.
10	AS	$\Delta'_\beta/\delta_{AS}$	Control input coupling. Thrust change due to aileron stick displacement.
11	δ^2	$\Delta'_\beta/\delta^2_{AVG}$	Vary nonlinear change in Z-force due to elevon deflection, especially to compensate (remove) effect present in basic aircraft.

TABLE II

FUNCTION OF GAINS IN PITCH CONTROL SYSTEM (BRONZE DIGITROLS)

Digitrol Number	Digitrol Symbol	Gain	Purpose
12	δ^2	Δ'_e/δ^2_{RMS}	Vary nonlinear change in pitching moments due to elevon deflection, especially to compensate (remove) effect present in basic aircraft.
13	β_c	$\Delta'_e/\Delta_{\beta_c}$	Dynamic control cross-coupling. Used for decoupling basic X-22A.
14	w	$\Delta'_e/\bar{\omega}$	To vary M_ω for all flight conditions. Changes short period frequency and damping ratio in cruise flight. Changes short period and long period modes in transition. Equivalent to M_α.
15	ES	Δ'_e/Δ_{ec}	Variable elevator gearing, M_{δ_e}.
16	$\dot{\alpha}$	$\Delta'_e/\Delta\dot{\alpha}_V$	To vary $M_{\dot{\alpha}}$. Changes short period damping in cruise and transition.
17	α	$\Delta'_e/\Delta\alpha_V$	To vary M_α. Primary influence is on short period mode for all flight conditions. Affects stability of long period mode in transition.
18	SS	δ_{ES}/F_{es}	Force gradient adjustment (stick softness).
19	q	$\Delta'_e/\bar{q}$	To vary M_q. Pitch damper in cruise and transition. $\dot{q}$ used for lead compensation.
20	θ	$\Delta'_e/\Delta\theta$	To vary M_θ. Very powerful in stabilizing the long period mode for all flight conditions. Increases frequency of short period mode. Pitch loop of attitude stabilization system.

TABLE II

FUNCTION OF GAINS IN PITCH CONTROL SYSTEM (CONTINUED)

Digitrol Number	Digitrol Symbol	Gain	Purpose
21	BO		Breakout force adjustment
22	u	$\Delta'_e/\Delta u_i$	To vary M_u in fixed operating point mode only. Influence phugoid frequency in cruise flight and both high and low frequency roots in hover.
23	$\dot{q}$	$F_{ES}/\dot{q}$	Stick force variation with pitch acceleration.
24	n_z	F_{ES}/n_z	Bob-weight effect.
25	$\Delta\lambda$	$\Delta'_e/\Delta\lambda$	Variation of pitching moment with duct angle; provides linear variation with duct angle of trim stick position vs. velocity in transition.
26	Δ_e	Δ'_e/Δ_{e_0}	To generate a moment-required-to-trim function that differs from that of the basic aircraft. Influences elevator stick position through transition.
27	βS	$\Delta'_e/\bar{\delta}_{\beta S}$	Control cross-coupling. To vary M_{β_c}.
50		$\Delta'_e/\dot{u}$	To vary $M_{\dot{u}}$. Effective in stabilizing the long period mode in forward flight.

TABLE III

FUNCTION OF GAINS IN YAW CONTROL SYSTEM (BLUE DIGITROLS)

Digitrol Number	Digitrol Symbol	Gain	Purpose
28	A	Δ_r'/Δ_a'	Variable rudder yaw control input from roll control to modify coupling (control phasing) of basic X-22A.
29	V	Δ_r'/v	Provide for variable N_v at low speed.
30	RP	Δ_r'/Δ_{RC}	Variable rudder gearing, N_{δ_r}.
31	$\dot{\beta}$	$\Delta_r'/\dot{\beta}_V$	Provide for variable $N_{\dot{\beta}}$ derivative. Change Dutch roll damping.
32	β	$\Delta_r'/\bar{\beta}_V$	Provide for variable N_β derivative. Change Dutch roll frequency, $\omega_\phi/\omega_{n_{DR}}$, ϕ/β. $\dot{\beta}_V$ used for lag compensation.
33	PS	δ_{RP}/F_{RP}	Force gradient adjustment. (Pedal softness.)
34	r	$\Delta_r'/\bar{r}$	Provide for variable N_r derivative. Change Dutch roll damping.
35	ψ	Δ_r'/ψ	Heading hold, attitude stabilization.
36	BO		Breakout force adjustment.
37	p	$\Delta_r'/\bar{p}$	Provide for variable N_p derivative. Affects most dynamic characteristics to some degree. Dutch roll damping and roll to yaw ratio. $\dot{p}$ used for lag compensation.
38	ϕ	Δ_r'/ϕ	Provide for variable N_ϕ derivative. Change spiral root. Coupling for attitude stabilization.
39	AC	Δ_r'/Δ_{AC}	Variable yawing moment due to aileron stick, N_{δ_a}. Control input coupling.

TABLE IV

FUNCTION OF GAINS IN ROLL CONTROL SYSTEM (GRAY DIGITROLS)

Digitrol Number	Digitrol Symbol	Gain	Purpose
40	r	Δ'_a/Δ'_r	Variable aileron roll control input due to yaw control to modify coupling (control phasing) of basic X-22A.
41	v	Δ'_a/v	Provide for variable L_v at low speed.
42	AS	Δ'_a/Δ_{AC}	Variable aileron gearing, $L_{\delta_{AS}}$.
43			Spare.
44	β	$\Delta'_a/\bar{\beta}_V$	Provide for variable L_β at high speed. Affects most dynamic characteristics. Also $\omega_\phi/\omega_{n_{DR}}$, ϕ/β. β_V used for lag compensation.
45	SS	$\delta_{AS}/\bar{F}_{AS}$	Force gradient adjustment. (Stick softness.)
46	p	$\Delta'_a/\bar{p}$	Provide for variable L_p derivative. Provide for variable roll root. $\dot{p}$ used for lag compensation.
47	ϕ	Δ'_a/ϕ	Provide for variable L_ϕ derivative. Changes long period lateral mode at low speed, analogously to M_θ in longitudinal modes. Roll loop of attitude stabilization system.
48	BO		Breakout force adjustment.
49	r	$\Delta'_a/\bar{r}$	Provide for variable L_r. Affects spiral root, and ϕ/β. $\dot{r}$ used for lag compensation.
50			See Pitch Control System.
51	RC	Δ'_a/Δ_{RC}	Variable rolling moment due to rudder pedal, $L_{\delta_{RP}}$. Control input coupling.

Transition Mode

In the transition mode the appropriate response feedback gains and control gains are programmed with velocity. Once the VSS is engaged in hovering flight, the airplane can be flown througn an accelerating transition to forward flight and through a deceler-ating transition to hovering flight without any adjustment of the VSS gains by the safety pilot. The acceleration can be high or low and can be terminated at intermediate transition velocities. A basic X-22A limitation on VSS transition flights is that air-speeds exceeding 150 knots cannot be achieved in collective pitch mode. This effectively means that the X-22A is a four control-axis VSS airplane in the speed range of 0 to 150 knots.

F.O.P. Mode

In the F.O.P. mode of VSS operation, the airplane is flown to a particular flight condition as defined by altitude, airspeed and duct angle. The required VSS gains are then set by the safety pilot and the VSS is engaged, giving control of the airplane to the evaluation pilot. The evaluation pilot then looks at the flying qualities for small perturbations from the trim or F.O.P. conditions. If the trim flight conditions deviate very much from the prescribed conditions, the configuration examined by the safety pilot will not be the desired configuration.

It is the duty of the safety pilot to monitor the trim flight conditions.

FBW Mode

The FBW mode of VSS operation is provided as a convenience and a safety feature. Every time the VSS is engaged, it is automatically engaged in the FBW mode unless the evaluation pilot or safety pilot has pressed the magnetically reset VSS-FBW switch to the VSS position just prior to engagement. In the FBW mode the evaluation pilot flies the basic X-22A plus the SAS through the left-hand control stick and pedals. However, only two discrete sets of control force gradients are available for FBW operation - one for low speed flight and one for high speed flight. Selection between these two levels of force gradients is automatically accomplished by a switch which is actuated at a duct angle of $+5^{\circ}$. The FBW feature is convenient because it enables the evaluation pilot to fly the aircraft while the safety pilot is setting up a VSS configuration on the gain console. This enables the safety pilot to devote full attention to setting up the gains which may take several minutes. An additional safety feature of this mode is that it provides a "limited" two-pilot capability in the event of disablement of the safety pilot during VSS flight operations.

SAFETY FEATURES

An automatic safety monitor circuit disengages the VSS/FBW, including the feel servos, whenever anyone of the following parameters exceeds a pre-set limit:

1. RH elevator stick rate
2. RH roll stick rate
3. RH rudder pedal rate
4. RH collective stick rate
5. LH elevator stick rate
6. LH roll stick rate
7. LH rudder pedal rate
8. LH collective stick rate
9. pitch acceleration
10. roll acceleration
11. yaw acceleration
12. longitudinal acceleration
13. lateral acceleration
14. normal acceleration

Whenever the VSS has been disengaged by operation of the safety monitor circuit, the TRIP indicator is actuated and is accompanied by an audio alarm to alert the safety pilot to take control of the aircraft. On assuming control, the safety pilot feel and trim is disengaged and should be re-engaged as soon as possible.
The VSS may also be disengaged by the VSS CUT switches located on the grips of both control sticks. In addition, the safety pilot at all times during VSS operation can operate a disengage switch on the right hand collective stick grip. He may use this switch to disengage the VSS upon observation of any operation of the flight control system or condition of the airplane which he

considers unsafe. The VSS may be disengaged by turning the VSS switch to the OFF position, thereby removing all electrical power from the VSS system and the shared instrumentation. The safety pilot can override VSS control activity in pitch, roll, and collective by applying control forces in excess of 16 pounds to his controls. Hydraulic pressure relief valves across each actuator limit the actuator output forces regardless of VSS command signals. Overriding VSS commands in these right hand controls will trip out the VSS.

Note

The rudder pedals will also disengage the VSS by this method, but the safety pilot cannot overpower the rudder actuators.

The safety pilot may put the pitch, roll, and collective actuators in bypass by turning the feel and trim system off. All VSS command signals on these actuators are then nullified and the safety pilot's controls command the aircraft. In the event the safety pilot becomes physically disabled, the evaluation pilot may actuate the VSS safety trip switch, thereby eliminating the possibility of false trips if he must continue to fly on FBW or (VSS).

TYPICAL VSS FLIGHT OPERATION

During a typical VSS flight, the activities of the flight crew will be as follows: The safety pilot will request the evaluation pilot to engage his feel servos and trim as necessary. If the VSS nullmeter on the instrument panel indicates all servos are properly nulled, the safety pilot will request the evaluation pilot to fly the airplane in the FBW mode while a new VSS configuration is being set up on the gain console. In addition to the gain console, the safety pilot will set the various switches as required to select control displacements or control forces as pilot inputs, select the transition or F.O.P. mode, and, if the transition mode is selected, select the LORAS or duct position as the source of function generator drive. After the new VSS configuration is set up, the safety pilot will take control of the airplane momentarily, place the VSS-FBW switch to the VSS position, and request the evaluation pilot to re-engage and trim the feel servos. The feel servo characteristics will now be determined by the settings on the gain console. When the evaluation pilot is ready to take the airplane, and if the servo error signal is zero on the nullmeter, the safety pilot will engage the VSS by pushing the VSS ON switch on his stick grip. While the VSS is engaged the nullmeter indicates the out-of-null condition in the pitch-axis of the primary flight control system. The safety pilot will monitor this indication. The pitch control forces will be in trim when control reverts to the primary system. Reversion to the primary system will occur when the evaluation pilot has completed his evaluation of a configuration or when one of the safety monitor limits has been exceeded as a result of maneuvering or turbulence. At the conclusion of evaluating a configuration, the evaluation pilot will request the safety pilot to fly the airplane.

LANDING GEAR SYSTEM

The retractable landing gear is of the tricycle type consisting of two main gears and a nose gear. The gear is hydraulically operated and electrically controlled, with emergency extension provided by a pneumatic system (figure 1-24). Controls and indicators for the landing gear system are as follows:

Index and Figure No.	Nomenclature	Function
42, figure 1-4	Landing gear handle	UP - With weight off gear, electrically cycles selector valve to retract gear. DN - Electrically cycles a selector valve to extend gear.
"	Landing gear handle light	ON - Indicates landing gear is in motion. OFF - Indicates gear has reached up or down position and is locked.
"	LT TEST switch	Depressed, applies +28 VDC to landing gear handle lights to check bulb condition.

LANDING GEAR SYSTEM

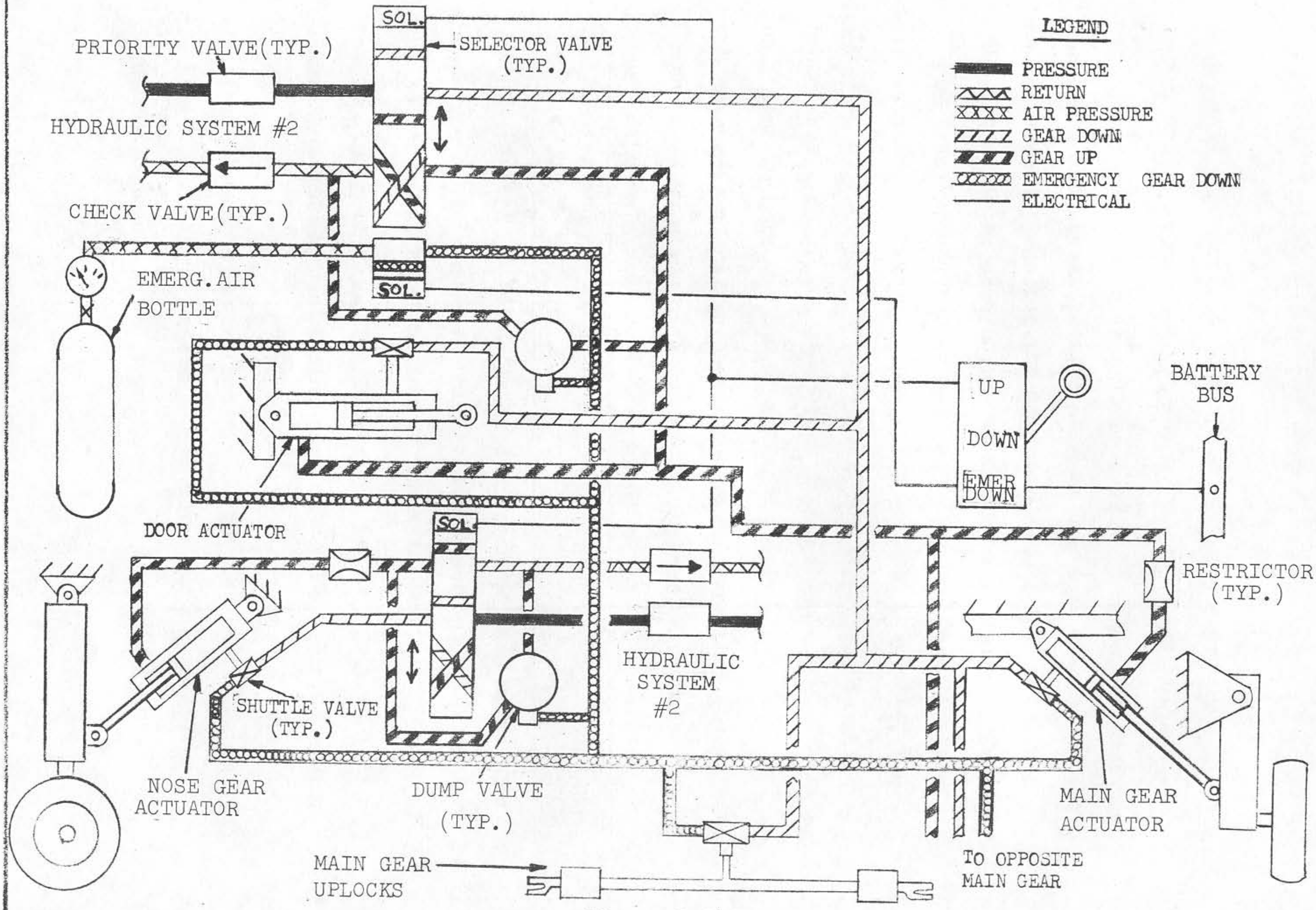


Figure 1-24

Index and Figure No.	Nomenclature	Function
42, figure 1-4	Landing gear position indicators (3)	Indicates corresponding gear is up and locked or down and locked according to indication.
"	LOCK REL finger release	IN normal position - Locks landing gear handle in down position to prevent inadvertent operation when weight is on the gear.
"	EMERG DOWN finger release	Depressed downward, permits landing gear handle to travel downward to energize emergency pneumatic system. In normal position it prevents landing gear handle from energizing pneumatic system.

The nose gear is equipped with dual wheels and high pressure 16 x 4.4 tires. Each main gear uses a single wheel equipped with a 24 x 5.5 high pressure tire. Conventional air-oil struts are utilized for shock absorbing purposes. Both the main gear and nose gear are fully retracted into the fuselage during flight.

The nose gear is equipped with a self centering cam to return the wheels to the full trail position before retraction. The gear is capable of 360° swiveling action and is equipped with a viscous type shimmy damper. Uplock and downlock action of the nose gear is accomplished by spring loaded over-center linkage in the drag brace mechanism. No nose wheel steering is provided.

Each main gear strut incorporates an integral drag brace member and attachment lugs for the main door. The gear retracts inboard and is secured in the up position by mechanical uplocks with spring loaded over-center toggle mechanisms. The uplocks are unlocked by hydraulic power for landing gear extension. The main gear is locked in the extended position by the over-center position of the side brace link which is secured by a ball type lock in the end of each main gear actuator.

The nose gear doors are operated during retraction and extension of the gear by means of a cam and linkage which engages the strut. The main gear doors are attached to their related struts by linkages and are mechanically operated by gear retraction and extension. A pair of hydraulically operated flipper doors are provided to cover the inboard portion of each main wheel. These doors are sequence controlled to open before extension and to close after retraction of the main gear.

The landing gear is controlled by the landing gear control handle located on the sloping portion of the center console. Placing the handle in UP or DN position actuates a switch which applies 28 volt dc power from the cockpit essential dc bus to initiate the gear up or down cycle which is electrically sequenced by means of microswitches and solenoid valves.

EMERGENCY PNEUMATIC SYSTEM

Emergency extension of the landing gear is provided by a 3000 psi nitrogen storage bottle. A solenoid valve, actuated by the emergency down position of the landing gear control handle, releases the stored gas to the gear and door actuators. Shuttle valves at the actuators prevent gas from entering the hydraulic system and dump valves across the normal system solenoid valves protect against line blockage by a stuck solenoid valve. When not in use, the pneumatic lines are vented to the atmosphere to prevent inadvertent shuttling of the shuttle valves due to temperature increases or leakage through the solenoid valve.

WHEEL BRAKE SYSTEM

The wheel brake system is a self-contained manually operated system (figure 1-25). Controls are as follows:

Index and Figure No.	Nomenclature	Function
On Rudder Pedals	Brake pedals (pilot and co-pilot)	Provides right or left main wheel braking when pedal is depressed.
11, figure 1-4	Parking brake handle	Brakes are applied at pedals and locked on with parking brake handle. Release is accomplished by depressing pedals.

WHEEL BRAKE SYSTEM

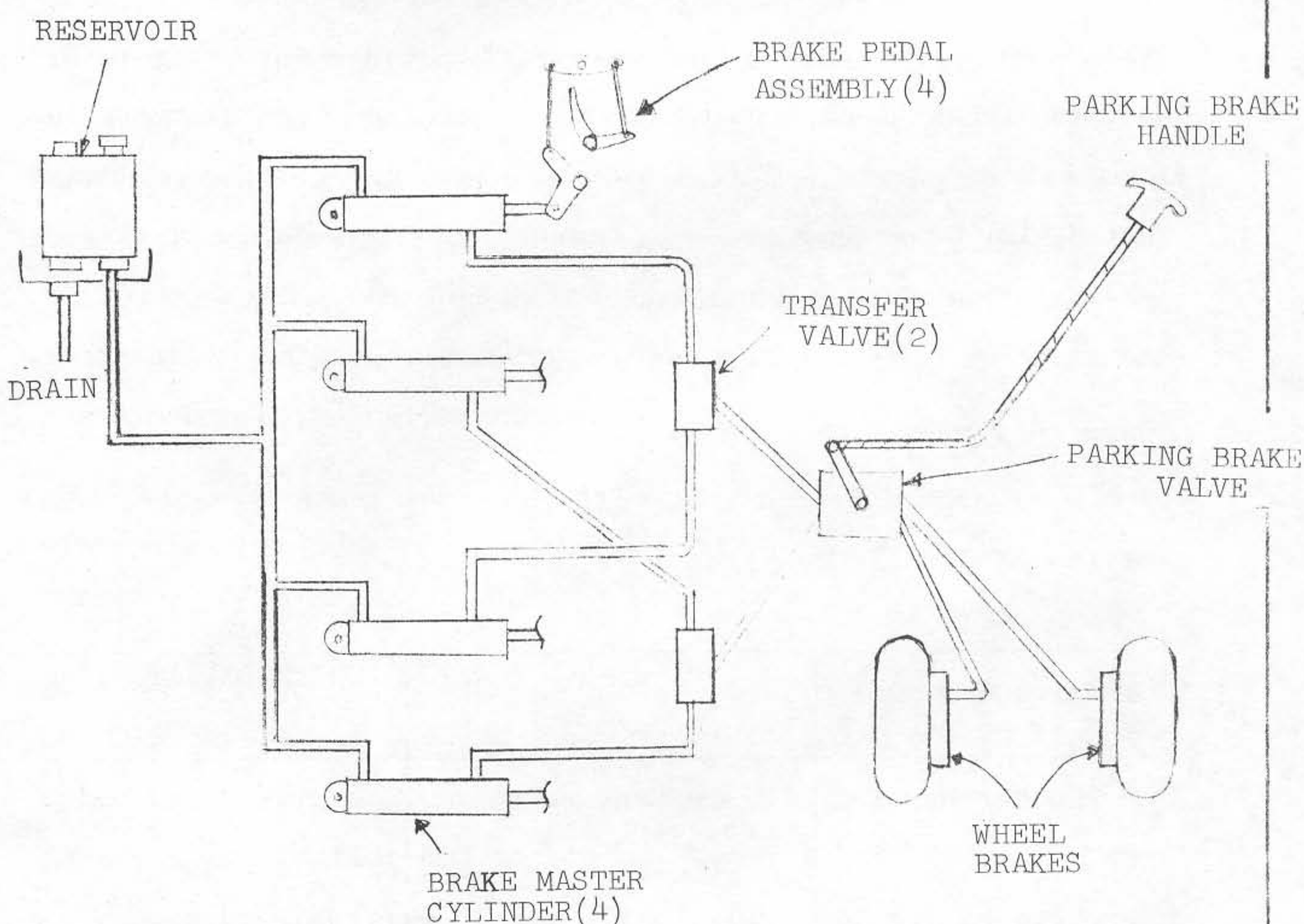


Figure 1-25

Braking action is applied to each wheel from either pilot station by depressing the rudder brake pedals. Each pedal is mechanically connected to an individual master cylinder which transmits fluid under pressure to the corresponding wheel brake assembly. Release of pedal force returns the fluid into the master cylinder and allows the brake disc to rotate freely between the inner and outer lining. Make-up fluid is supplied from the reservoir to compensate for leakage. Transfer valves are installed to permit either simultaneous or individual braking from both pilot stations.

The parking brake valve locks fluid in both main wheel brakes when the brakes are applied and the handle set to the park position. This unit is equipped with individual accumulators to maintain brake pressure when parked and to compensate for thermal expansion of the fluid.

The wheel brake assembly is self adjusting and is bolted to the lower half of each main strut. As pressure enters the housing, it acts on three pistons simultaneously forcing them against the brake lining. The lining acts as a clamp on both sides of the rotating disc. When pressure is released, piston return springs force the piston away from the lining to prevent the brake from dragging. As the brakes wear the lining is automatically advanced to maintain a fixed clearance between linings and disc.

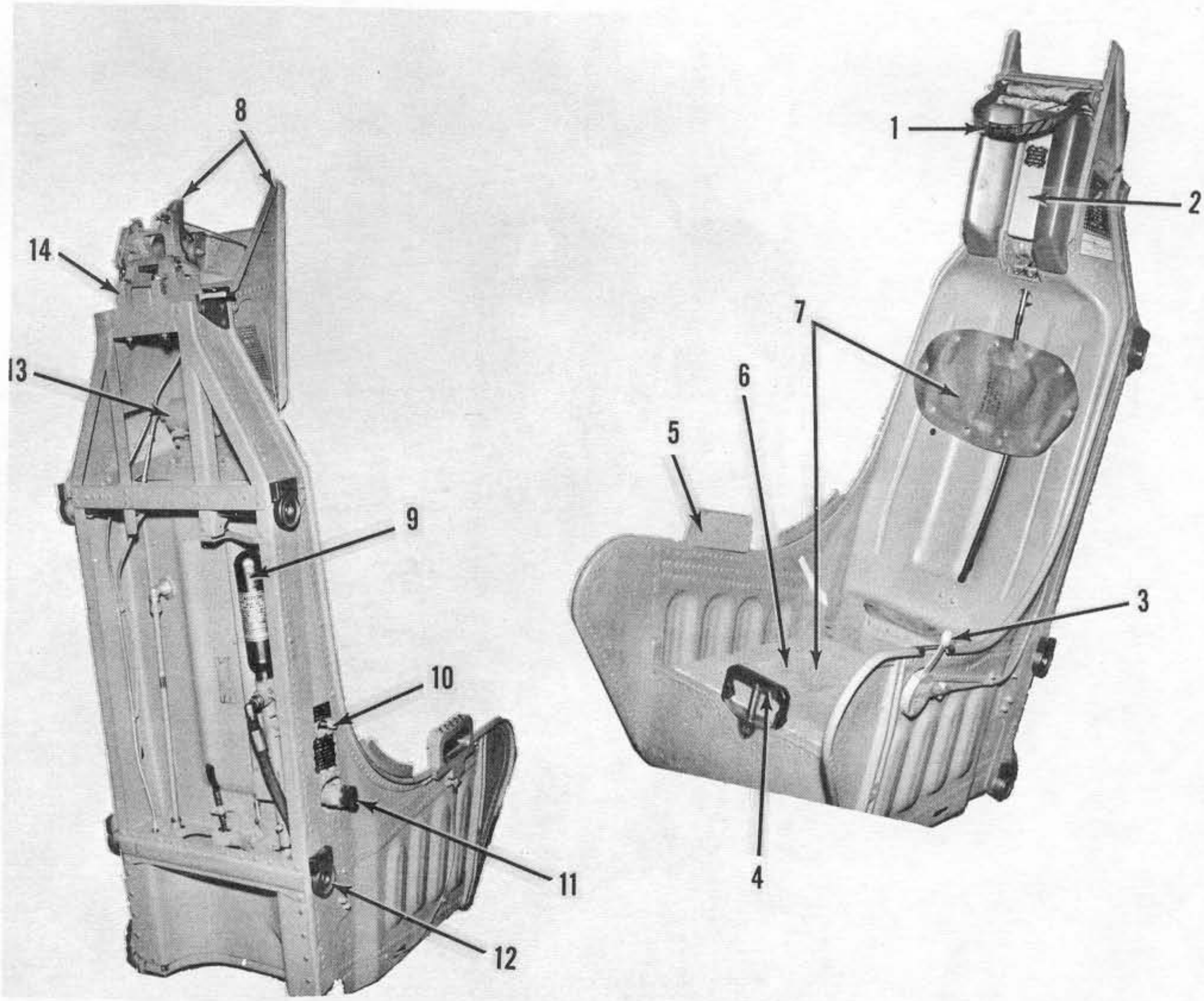
EJECTION SYSTEM

The ejection system consists of a Douglas ESCAPAC ID-1, zero-zero ejection seat, equipped with the DART stabilization system, a modified NB-5 parachute assembly, a foam filler block, and seat pan assembly. The pilot and co-pilot ejection seats (figure 1-26) are identical in configuration. The seat utilizes an overhead face curtain ejection control handle which protrudes over the pilot's headgear for easy grip. A secondary ejection handle is located on the forward seat panel between the pilot's legs and permits initiating the ejection sequence when high accleration forces or other conditions prevent use of the face curtain handle. The parachute assembly (figure 1-27) opens within 2 seconds after arming. With this ejection system it is necessary that the pilot and co-pilot wear a type MA-2 torso harness.

DART STABILIZATION SYSTEM

The DART system is used to correct for pitching moments introduced by tip-off and center-of-gravity displacement between the man/seat combination and the thrust line of the rocket. Tip-off is caused by the force of the rocket during the short period of time when only the last set of seat rollers are still in the seat rails.

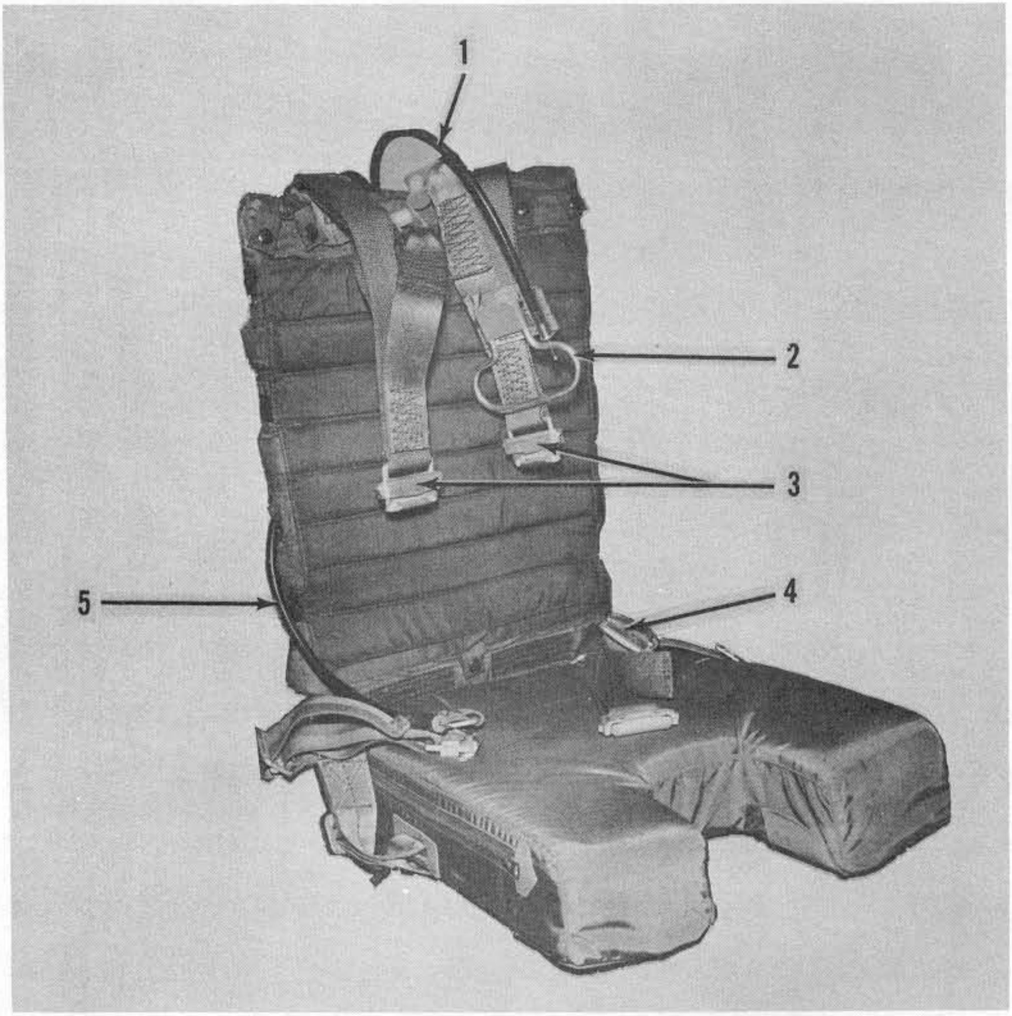
EJECTION SEAT



1. FACE CURTAIN EJECTION HANDLE
2. EJECTION CONTROLS SAFETY HANDLE
3. INERTIA REEL CONTROL LEVER
4. SECONDARY EJECTION CONTROL HANDLE
5. HARNESS RELEASE HANDLE
6. FOAM FILLER BLOCK
7. SEPARATION BLADDERS (SEAT BLADDER IS UNDER FOAM FILLER BLOCK)
8. CANOPY BREAKER POINTS
9. NITROGEN BOTTLE
10. HARNESS RELEASE ACTUATOR DETENT PIN
11. HARNESS RELEASE FIRING PIN SEAR
12. RAIL ROLLERS
13. SHOULDER HARNESS INERTIA REEL
14. T-30 INITIATOR

FIGURE 1-26

PARACHUTE ASSEMBLY



1. SHOULDER HARNESS ROLLER FITTINGS
2. MANUAL RIPCORD
3. SHOULDER HARNESS STRAPS
4. LAP BELT STRAPS
5. PARACHUTE ACTUATOR ARMING LANYARD

FIGURE 1-27

DART consists of a slack line, a brake line, force control brakes and a bridle assembly. The slack line is played out as the seat moves up the rails and into rocket firing. No corrections are put into the system by the slack line. At the end of the slack line, the brake line becomes effective. This line runs through the force control brakes which apply a controlled tension in the brake line. Corrections through the bridle to the seat are continuous throughout the length of the brake line and are proportional to any displacement error in seat pitch caused by tip-off or C.G. misalignment.

In the event an ejection must be made, normal procedure entails grasping the face curtain ejection handle (or the secondary ejection handle) and pulling to actuate the initiator firing pin. The initiator fires and ignites the rocket catapult booster stage. As the rocket catapult raises the seat, the zero delay parachute arming lanyard pulls the parachute arming lanyard, thus starting the 2-second time delay before parachute deployment. The pilot's communication cable also breaks away at this time. Force of the acceleration draws the pilot's legs down and back against the front panel of the seat. At the same time, the harness release actuator hits the striker plate on the guide rail removing the seat which arms the MK 86 Mod 0 3/4-second delay cartridge located in the actuator. As the seat nears the top of the guide rails, the rocket sustainer portion of the catapult is ignited, forcing the pilot and the seat through the upper cockpit plexiglass and out of the aircraft. Thrust from the rocket catapult accelerates the seat up from the aircraft. After 3/4 second, the MK 86 Mod 0 delay cartridge fires, causing the piston within the harness release actuator to rise and break the nitrogen bottle diaphram. The piston also actuates a bellcrank attached to the clevis at the lower end of the piston. The bellcrank rotates, releasing the lap belt retaining pins, shoulder harness retaining pins and firing control disconnect. The pilot at this time is no longer secured to the ejection seat.

When the nitrogen bottle is ruptured by the piston in the harness release actuator, compressed nitrogen inflates two separation bladders, one behind the parachute and one under the seat pan assembly. As the bladders inflate, the pilot is separated from the seat. The firing control disconnect assembly releases cables attached to the face curtain and/or the secondary ejection handle, allowing the seat to separate from the pilot if he inadvertently holds on to the ejection handle. (Sequence of ejection is illustrated in figure 1-28).

The parachute will automatically open upon free fall to the preset altitude of approximately 10,000 feet (controlled by barometric delay) or, if below the preset altitude, approximately 1 second after the pilot separates from the seat. The parachute can also be opened by pulling the manual ripcord ring. Controls for the ejection system are as follows:

EJECTION SEQUENCE

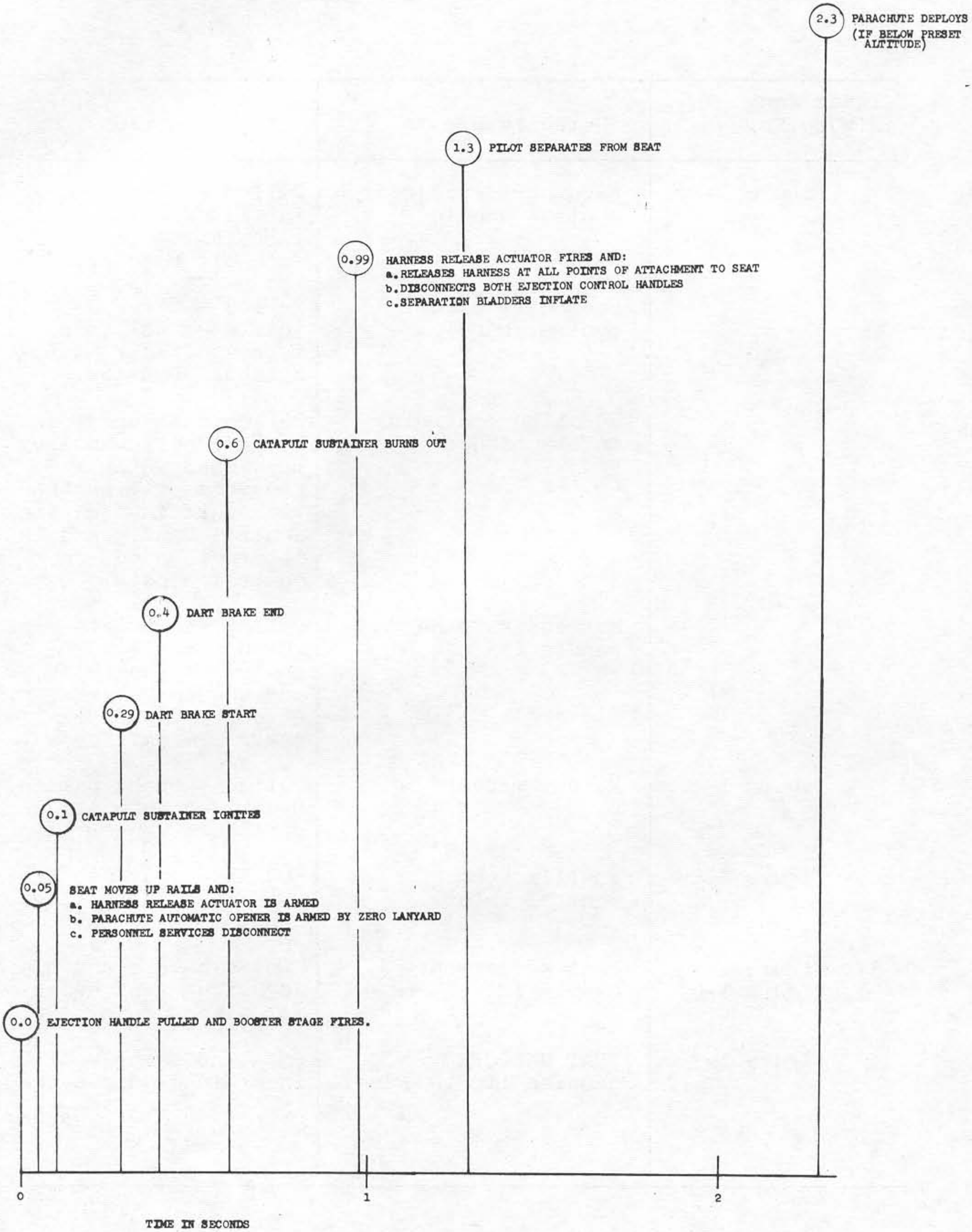


Figure 1-28.

Index and Figure No.	Nomenclature	Function
figure 1-26	Face curtain ejection control handle	Pulled - fires T-30 initiator which in turn ignites rocket catapult booster.
"	Secondary ejection control handle	Pulled - fires T-30 initiator which in turn ignites rocket catapult booster.
"	Ejection controls safety handle	Pulled down and locked-locks ejection pulley mechanism which prevents pulling the face curtain ejection control handle and the alternate ejection control handle.
"	Harness release handle	Pulled - retracts pins which release left and right lap belt and shoulder hardness. Also releases para-chute arming lanyard.
figure 1-27	Manual ripcord	Pulled - opens parachute. Overrides automatic parachute opener.
figure 1-26	Inertia reel control lever	LOCKED - prevents for-ward movement of the shoulder harness.
37, figure 1-4 1, figure 1-6	Seat adjustment handle (2)	Providing a means of adjusting seat height for pilot comfort.
figure 1-7	SEAT UNLOCKED caution light	ON - Indicates seat lock pin is disengaged.

INSTRUMENTS

Only those instruments which are not a part of another system are discussed here. Instruments that are components of a particular system are included in the discussion of that system.

ELAPSED TIME CLOCK

One, type MS28020L1 elapsed time clock is mounted on the pilot's side of the main instrument panel (4, figure 1-3) as an aid for navigation, duration , control of fuel, and maneuvers.

AIRSPEED INDICATORS

Two, type AW28112AT02 airspeed indicators, one on the pilot's side and one on the co-pilot's side of the main instrument panel (15, figure 1-3), use differential pitot-static air pressure to determine airspeed. The pitot static head is mounted on a boom at the nose of the aircraft. Airspeed is indicated by a single needle on a dial calibrated in knots. The dial is marked in increments of 5 knots from 10 to 40 knots, and in increments of 10 knots from 40 knots to 400 knots.

ALTIMETERS

Two, type MB-1A barometric altimeters, one on the pilot's side and one on the co-pilot's side of the main instrument panel (2, figure 1-3), sense static pressure and display altitude. The instrument has three pointers which indicate altitude in hundreds of feet, thousands of feet, and tens of thousands of feet, respectively. Field barometric pressure can be set into the altimeter by manually rotating the adjusting knob on the lower left-hand corner. The barometric pressure selected appears in a window on the right side of the indicator face. A flag indicator near the bottom of the indicator face drops when the instrument is in operation. The instrument is integrally lighted.

STANDBY COMPASS

A type AN5766-4 magnetic compass is mounted on the center windshield frame above the main instrument panel. It is a floating card compass that indicates the direction the aircraft is headed with respect to magnetic north.

ATTITUDE INDICATORS

Two, type 140100-02-01 attitude indicators, one on the pilot's side and one on the co-pilot's side of the main instrument panel (17, figure 1-3), indicate pitch, and roll attitude as sensed by their associated attitude gyros. Pitch scale graduation on the ball are in 5° increments. A roll scale is provided on the upper half of the ball mask with a roll pointer which moves the roll gimbal. A standard turn-rate indicator inclinometer is located just below the ball. The indicator may be manually adjusted for both pitch and roll trim by knobs located at the lower corners of the case. An "OFF" flag on the indicator face drops from view when the instrument is in operation. The instrument is integrally lighted.

VERTICAL VELOCITY INDICATORS

Two, type D6HLR vertical velocity indicators, one on the pilot's side and one on the co-pilot's side of the main instrument panel (19, figure 1-3), sense the rate of static pressure change as the aircraft climbs or descends and indicate attitude change in feet per minute.

FREE AIR TEMPERATURE INDICATOR

A type 16282A temperature indicator is provided on the co-pilot's side above the main instrument panel (2, figure 1-8). The instrument is actuated by a pickup located on the aft right hand side of the fuselage which measures outside temperature. The indicator range is from -70° to $+50^{\circ}$ C in 2° increments.

EMERGENCY EQUIPMENT

FIRE DETECTION AND EXTINGUISHING

The fire detection and extinguishing system (figure 1-29) is electrically controlled and operated. Fire detection and extinguishing equipment is installed in each engine nacelle.

The fire detection system consists of thermistor-type continuous sensing elements contained within each nacelle and associated control units to actuate master fire warning lights and a fire warning light for each fire zone.

FIRE EXTINGUISHING SYSTEM

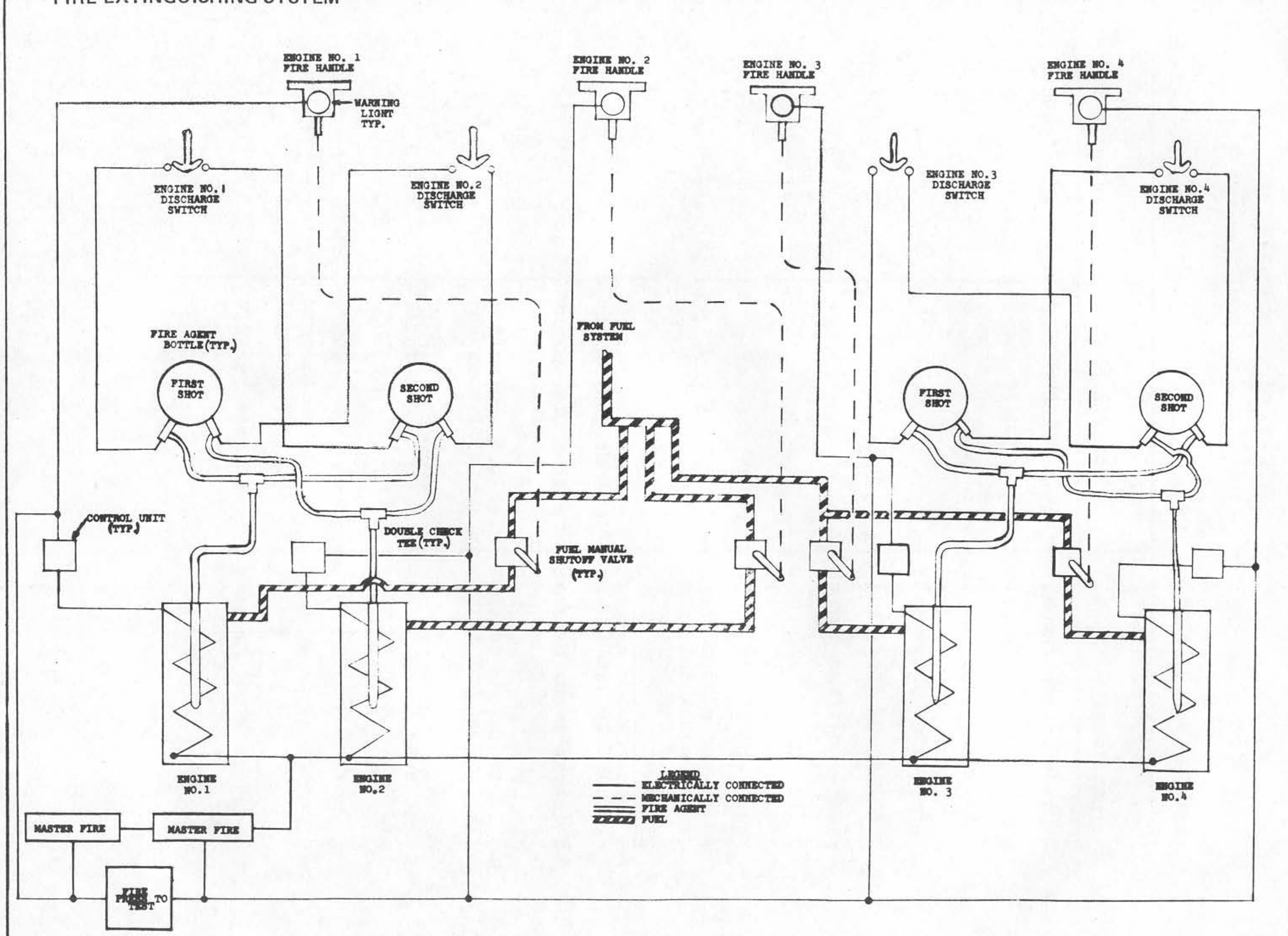


Figure 1-29

The fire extinguishing system consists of two central extinguishing systems located in the aft fuselage section. Each central system consists of two agent containers filled with 2.5 pounds of bromotrifluoromethane (CF_3BR) pressurized to 600 psi with nitrogen gas. Two electrically operated discharge heads are installed on each container. The two containers of each central system are interconnected through double check tees which provides the capability of discharging an initial charge and if necessary, a reserve charge at a given fire condition. Each container is equipped with a pressure indicator to implement system inspection while on the ground. Frangible discs are provided for thermal relief purposes.

Controls for the fire extinguishing system consist of four fire handles, one for each nacelle and four agent discharge switches which are exposed when their associated fire handles are pulled. Control and indicator functions are as follows:

Index and Figure No.	Nomenclature	Function
10, figure 1-3	Engine No. 1 fire handle	Pulled - closes engine No. 1 fuel shutoff valve and exposes engine No. 1 discharge switch.
"	Engine No. 2 fire handle	Same as above except for engine No. 2
"	Engine No. 3 fire handle	Same as above except for engine No. 3

Index and Figure No.	Nomenclature	Function
10, figure 1-3	Engine No. 4 fire handle	Same as above except for engine No. 4
"	Engine No. 1 discharge switch	DISCH NO. 1 - electrically detonates an explosive squib at fire agent bottle and releases agent for first shot to engine No. 1. Center position - normal inactive position. DISCH NO. 2 - electrically detonates an explosive squib at fire agent bottle and release agent for second shot to engine No. 1.
"	Engine No. 2 discharge switch	Same as above except for engine No. 2.
"	Engine No. 3 discharge switch	Same as above except for engine No. 3.
"	Engine No. 4 discharge switch	Same as above except for engine No. 4.
"	FIRE #1 warning light	ON - indicates fire in engine No. 1 nacelle (the warning light is located in its associated fire handle)
"	FIRE #2 warning light	Same as above except for engine No. 2.
"	FIRE #3 warning light	Same as above except for engine No. 3.

Index and Figure No.	Nomenclature	Function
10, figure 1-3	FIRE #4 warning light	Same as above except for engine No. 4.
6, figure 1-3	MASTER FIRE warning lights (2)	ON - indicates an over-temperature in one or more of the fire zones.
9, figure 1-3	FIRE PRESS TO TEST switch	Depressed -illuminates the four fire control handles and the two master fire warning lights for test purposes.

If a fire occurs in one of the nacelles, the resultant heat causes the resistance of the sensing element to decrease and activate the control unit which in turn applies electrical power to the applicable fire warning light in the control handle. The master fire warning lights also come on to assist in calling the flight crews attention to a fire condition. The illuminated handle indicates fire location.

When the illuminated handle is pulled, the fuel-manual shutoff valve is closed cutting off the fuel supply to the engine. The engine will continue to operate for a few seconds until the fuel on the engine side of the shutoff valve is consumed. Pulling the handle exposes the discharge switch, allowing it to be activated to either of its positions. Normally, the switch should first be placed in DISCH NO. 1 position. If the fire condition persists, the switch should then be placed in DISCH NO. 2 position to allow a second charge of agent to be released.

Should a handle be pulled and the decision is made not to activate the discharge switch, the handle may be returned to its normal position. The engine may then be restarted if it is felt conditions warrant it.

Note

> Restart may take longer than a normal start since fuel replenishment must take place in the line which was voided by fuel shutoff.

Each of the fire detector control units contains discriminator circuitry which prevents a short circuit or moisture condition from triggering a false alarm. Depressing the FIRE PRESS TO TEST switch should illuminate the four fire handles and the two MASTER FIRE warning lights. If the lights do not illuminate, it is indicative of either a discontinuous sensing element loop or an inoperative control unit.

HAND FIRE EXTINGUISHER

A type 2TA fire extinguisher (1, figure 3-1), is installed in the aircraft at the forward end of the left hand console.

FIRST AID KIT

An aeronautical first aid kit (4, figure 3-1), is installed in the aircraft at the forward end of the right hand console.

CANOPY

Both canopy panels above the flight crew positions are breakable and equipped with jettison provisions for ground emergency escape. The canopies are not jettisoned during the ejection sequence. During ejection, the panels are fragmented by canopy breaker points on the ejection seats as the seats are forced up the guide rails. The canopy panels may be opened and discarded from the inside or the outside during ground emergencies to provide a route of quick escape or rescue of flight crew members. Manual canopy breakers are provided for emergency egress.

WARNING AND CAUTION LIGHT CIRCUITS

CAUTION LIGHTS

Many of the aircraft systems are provided with sensing devices which detect abnormal operating conditions and alert the pilot by means of master caution lights (main panel), and individual system lights grouped on the center console (figure 1-7). When an abnormal condition is detected, both master caution lights will illuminate and the applicable caution panel light will flash on and off. Pushing to reset either master caution light will turn off both master caution lights and cause the caution panel light to cease flashing and remain steadily on. The panel light will then remain illuminated until the fault no longer exists. A press to test switch on the caution panel checks the bulb condition of the system caution lights and the master caution lights. The PILOT LIGHT on the caution panel indicates that power is being applied to the panel.

The caution light panel blower switch (1a, figure 1-4) actuates a fan which is utilized to cool the caution light panel circuitry.

WARNING LIGHTS

A fire or over-temperature conditions in any of the four engine nacelles will illuminate two master fire warning lights (6, figure 1-3) and the applicable fire warning handle (10, figure 1-3). The warning system cannot be reset, and affected lights will remain illuminated until the condition is corrected. However, a subsequent fire in another area will illuminate the applicable fire warning handle. Refer to "emergency equipment", this section, for additional information.

EXTERNAL SAFETY PINS, CLIPS AND COVERS

External safety pins, clips and covers are illustrated in figure 1-30.

SERVICING DIAGRAM

Figure 1-31 is a servicing diagram of the aircraft.

AUXILIARY EQUIPMENT

The description and operation of the following equipment is contained in Section IV, AUXILIARY EQUIPMENT:

Heating and Ventilation

Ice Protection

Lighting System

Communications and Navigation Systems

Instrumentation System(Flight Test)

EXTERNAL SAFETY PINS, CLIPS, AND COVERS

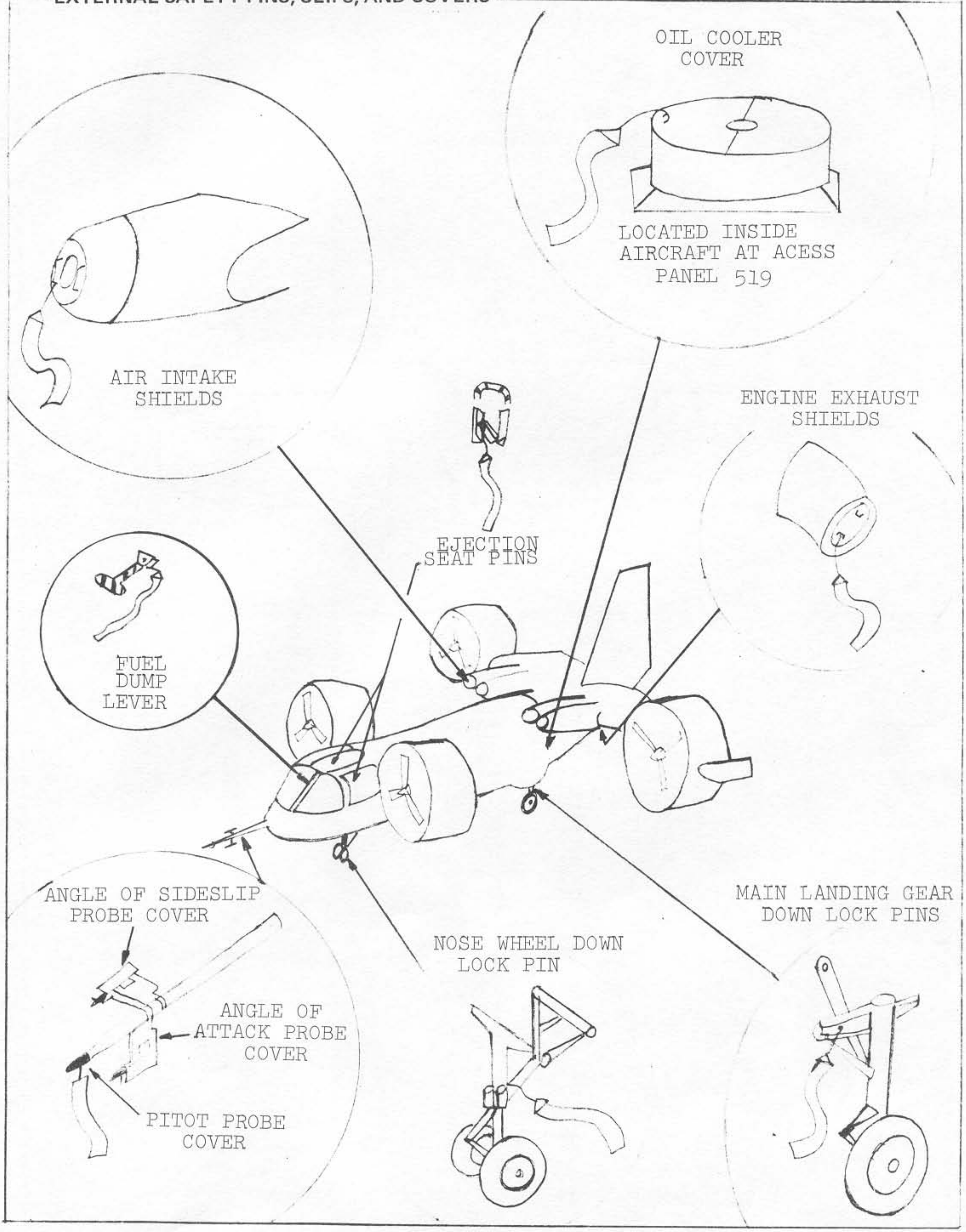


Figure 1-30

SERVICING DIAGRAM

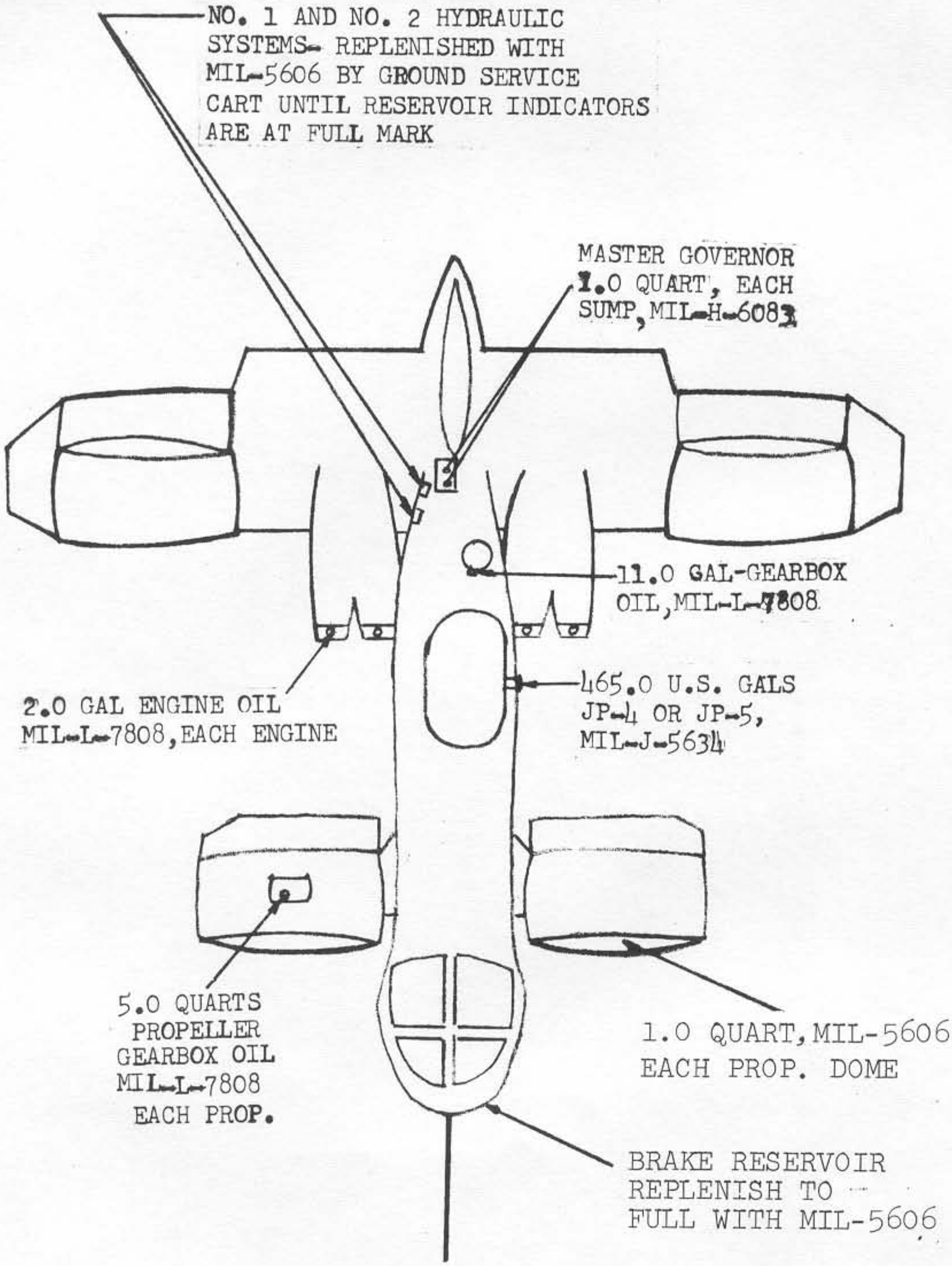


Figure 1-31

SECTION II - NORMAL PROCEDURES

TABLE OF CONTENTS

(CONT'D)

VSS/FBW MODE CHECK LIST

PREPARATION FOR FLIGHT

FLIGHT RESTRICTIONS

Refer to Section V for information concerning operating limitations.

FLIGHT PLANNING

For operating data necessary to plan and complete the proposed mission, refer to charts and tables in the Appendix.

WEIGHT AND BALANCE

Refer to Section V for weight limitations, and check takeoff and anticipated landing gross weights for type of landing to be made.

In completing the weight and balance clearance form, make certain that weight and balance clearance is current and correct.

CHECK LISTS

This section and Section III contain check lists of normal and emergency procedures. The check lists are of the challenge type. The copilot reads the numbered items aloud as a challenge to the pilot. After the required check has been completed, the crew member indicated in parentheses responds with the words identified by capital letters.

Three complete sets of check lists are provided for each of the modes in which the aircraft may be flown, i.e., power control mode, pitch control mode, and VSS/FBW mode.

The operation of flight test instrumentation equipment is listed in the check lists in proper operational sequence but is offset to the right side of the page since usage of the equipment may not be required for every flight.

Note

Figures 2-3 through 2-6 referenced in the check lists are located at the end of this section.

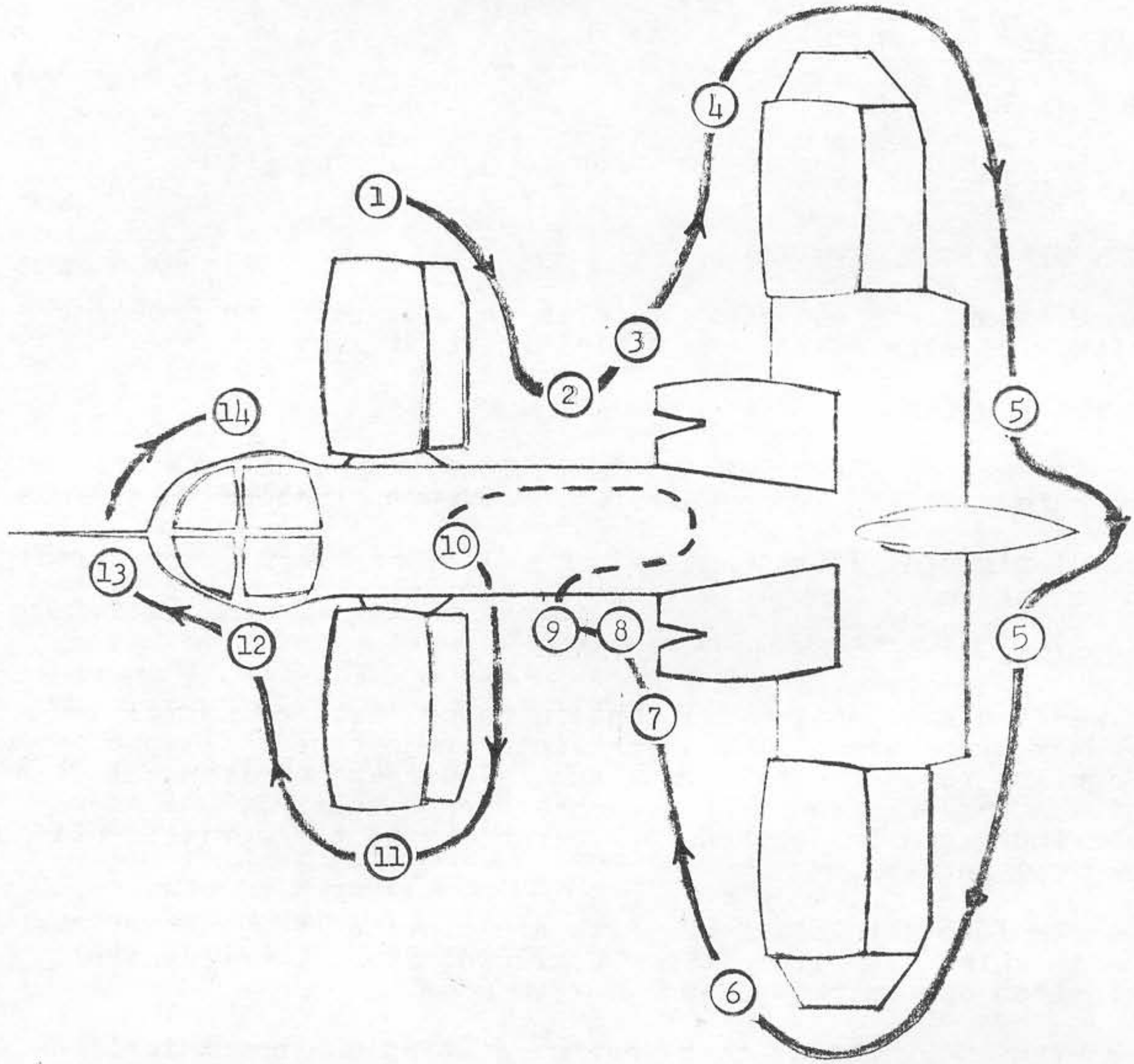
EXTERIOR-INTERIOR INSPECTION

The pilot is responsible for making sure that the interior and exterior visual inspection (figure 2-1) is conducted. Form 3760-2 will be checked to determine aircraft status and to ensure that the maintenance preflight inspection has been accomplished.

EJECTION SEAT INSPECTION

Perform the ejection seat inspection in accordance with figure 2-2.

EXTERIOR - INTERIOR INSPECTION



(1) RIGHT FORWARD DUCT

Control surfaces, propeller ducts, struts, stator beams for aerodynamic smoothness.
Access doors and fairings for security.
Propellers and spinners for nicks, scratches, dents, cleanliness and aerodynamic smoothness. Check for evidence of fiberglass separation.
Blades for excessive play.
Propeller dome and gearbox area for leakage.
Inner surface of ducts for evidence of fiberglass separation.

(2) RIGHT LANDING GEAR WELL

Downlock installed.
Hydraulic lines for security and leakage.
Exposed surface of pistons for cleanliness.
Doors, struts and linkages for alignment and security.
Electrical wiring for chafing or damage.
Brakes for wear, cuts, chafing, security, cleanliness and leakage.
Tires for cuts, chafing, wear, alignment on rim, slippage marks and proper inflation (280 psi)

Figure 2-1(Sheet 1 of 3)

(3) RIGHT WING AND ENGINES

Cowling for security and aerodynamic smoothness.
Intake shield removed.
Intake for aerodynamic smoothness and free of obstructions.
Exhaust shield removed.
Exhaust casing for cracks and deformation.
Vent lines free of obstructions.
Wing access panels for security.

(4) RIGHT AFT DUCT

Perform same inspection as on right forward duct.
Outboard horizontal stabilizer for aerodynamic smoothness and security.

(5) AFT FUSELAGE SECTION

Right hand side access doors and escape hatch for security.
Bottom access doors for security.
Vent lines free of obstructions.
Fuel jettison standpipe for security.
Left hand side access doors for security.

(6) LEFT AFT DUCT

Perform same inspection as on right aft duct.

(7) LEFT WING AND ENGINES

Perform same inspection as on right wing and engines.

(8) LEFT LANDING GEAR WELL

Perform same inspection as on right landing gear well.

(9) LEFT FUSELAGE MIDSECTION

Lower fuselage antennas for security.
Anti-collision lens for security and cracks.
Cargo door lock for proper functioning.

(10) CARGO COMPARTMENT

No loose equipment.
Longitudinal fuselage shafts, couplings and bearing hangers for damage, security, cleanliness and evidence of leakage.
Fluid lines for security and leakage.
Electrical cabling for security and damage.
Exposed control cabling for damage or fouling.

(11) LEFT FORWARD DUCT

Perform same inspection as on right forward duct.

Figure 2-1(Sheet 2 of 3)

(12) LEFT NOSE SECTION

Canopy handle for security and flush position.
Nose access panel for security.
Landing light for cracks, flush with fuselage.
Windshield for cracks or excessive crazing.
Pitot tube for alignment, covers removed, no obstructions.
Skin for obvious damage
Step door for alignment and security.
Nose vent lines for no obstructions.

(13) NOSE WHEEL WELL

Downlock installed.
Hydraulic lines for security and leakage.
Exposed surface of pistons for cleanliness.
Doors and struts for alignment and security.
Electrical wiring for chafing or damage.
Tires for cuts, chafing, wear, alignment on rim, slippage marks and proper inflation (125 psi).
Shimmy damper for alignment and security.

(14) RIGHT FORWARD NOSE SECTION

Windshield wiper for security and proper stowage.
Windshield for cracks and excessive crazing.
Canopy handle for security and flush position.
Skin for obvious damage.
Step door for alignment and security.

Figure 2-1(Sheet 3 of 3)

EJECTION SEAT INSPECTION

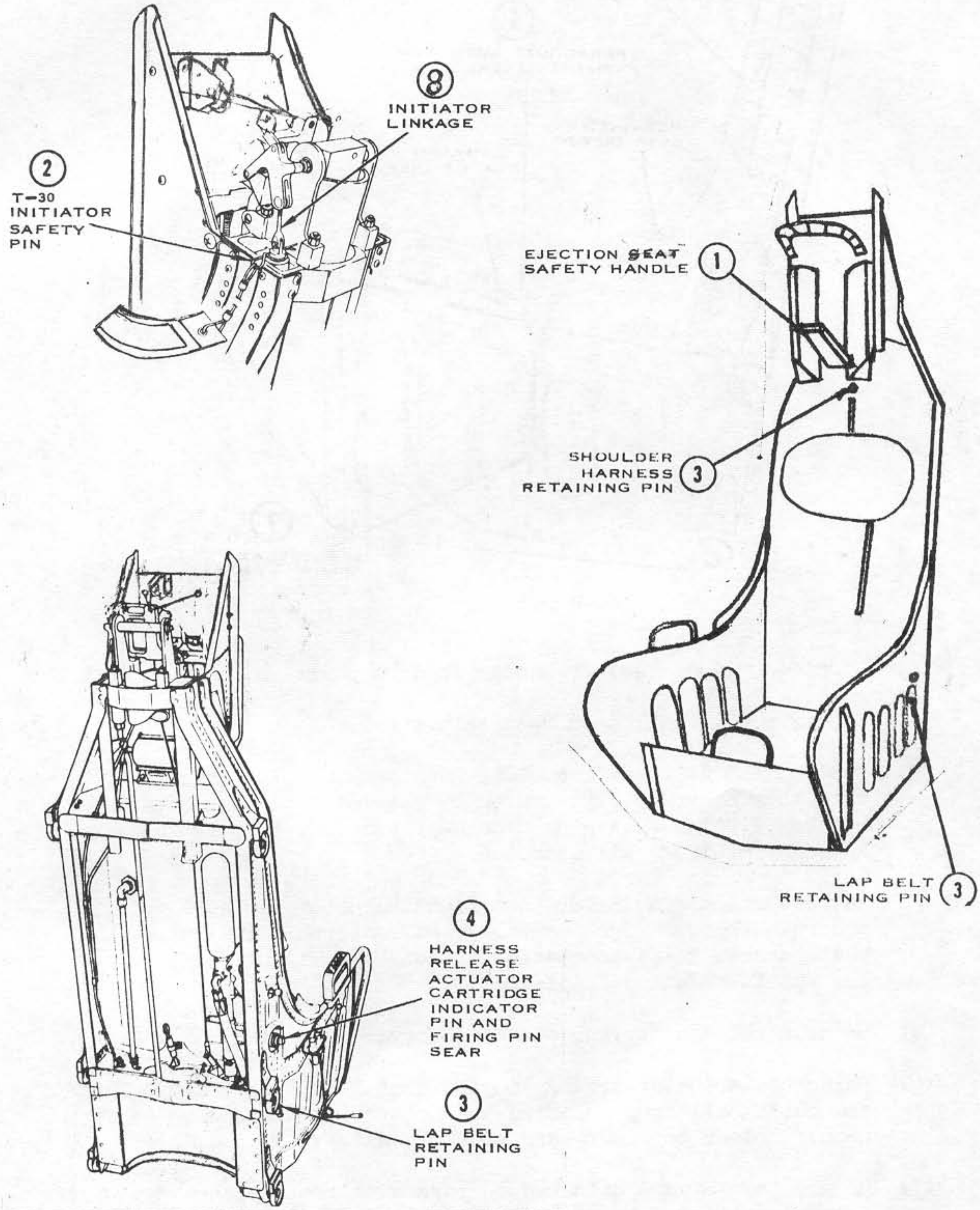
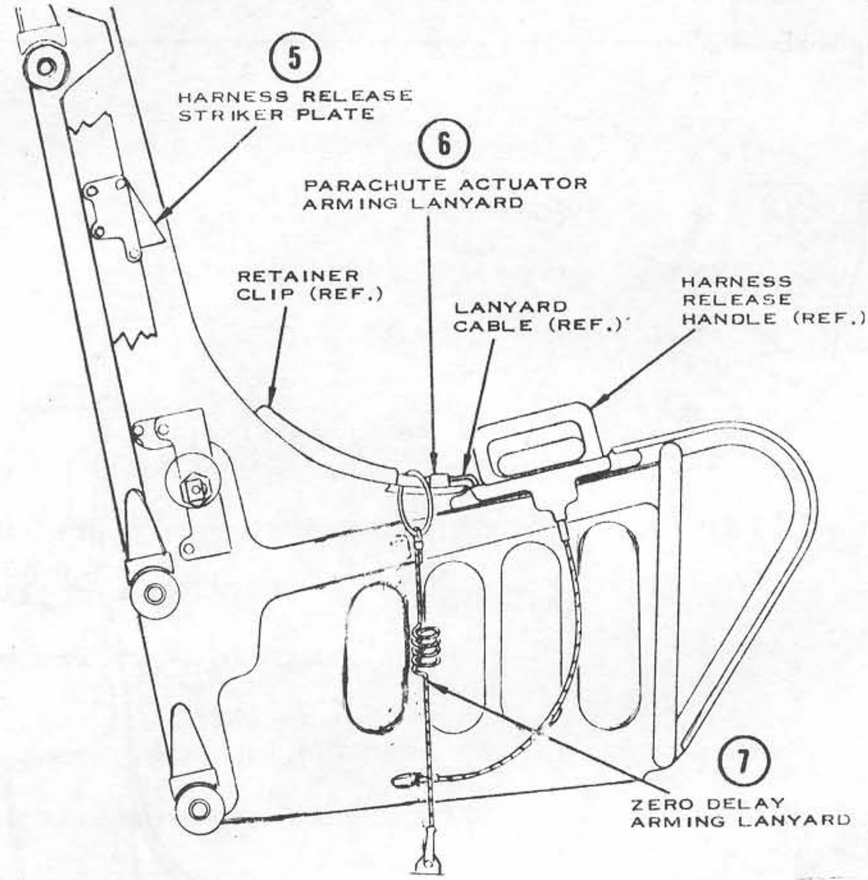


Figure 2-2(Sheet 1 of 2)



1. Ejection seat safety handle in down position.

2. Safety pin installed in T-30 initiator.

3. Pull on lap belts and shoulder harness straps to make sure they are properly secured by retaining pins. Shoulder harness fitting retaining pins must protrude through fittings 1/16 in. minimum full diameter.

4. Harness release actuator cartridge indicator pin does not protrude through right-hand side of seat (this indicates that harness release actuator is loaded). Firing mechanism hex nut is safetied in place.

5. Harness release striker plate in forward position.

6. Parachute actuator arming lanyard installed in retainer clips and cable-ball stop inserted and secured in harness release handle holder on right-hand side of seat.

7. Zero delay lanyard attached to parachute arming lanyard and securely attached to cockpit floor.

8. Initiator linkage connected. Remove safety pin after pilot entry.

Note

It is recommended that the safety handle be placed in full-up position by the pilot after entering the cockpit.

Figure 2-2(Sheet 2 of 2)

POWER CONTROL MODE

BEFORE STARTING ENGINES

1. External power switch-EXTERNAL POWER (P)
2. Intercom switch - ON (P, CP)
3. VHF radio - FREQUENCY SET (P)
4. Torso harness - FASTENED (P, CP)
5. Rudder pedals - ADJUSTED (P, CP)

5a. Parking brake - SET (P)

6. Ejection seats - ADJUSTED (P, CP)
7. Overhead circuit breakers - ALL IN (P)
8. Fuel dump handle - FORWARD AND SAFETY PIN REMOVED (P)
9. Instrumentation control panel set as follows: (P)
   a) Master power switch - ON
   b) Battery power switch - ON
   c) Time code power switch - ON
   d) Telemetry power switch - ON
   e) Temperature calibration switch - CALIBRATE
10. Engine fire handles - ALL IN (P)
11. Fire warning lights - CHECK (P)
12. All instruments - STATICALLY CHECKED (P, CP)
13. Engine master/start switches - OFF (P)
14. Caution light panel and chip detector lights - CHECKED (P, CP)
    . Check by pressing PRESS TO TEST switches.
15. Throttle boost switch - NORMAL (P)
16. Pitot heat switch - OFF (P)
17. Air start/ground start switch - NORMAL (P)
18. Pitch, roll, and yaw switches - OFF (CP)
19. Gear handle - DOWN AND LIGHT CHECKED (P)
    . Check light by pressing LT TEST switch.
20. Ignition switch - NORMAL (cover down) (P)
21. SAS cutoff override switch - ON (cover down) (P)

22. UHF antenna switch - UPPER (P)

23. Throttle release - FORWARD (P)

24. Throttles - CHECK FULL TRAVEL, THEN CLOSE (P)

25. Propeller RPM lever - CHECK FULL TRAVEL, THEN FULL INCREASE (P)

26. Duct lock switch - UNLOCKED (P)

27. Duct rotation override switch - NORMAL (P)

28. Feel system and reset switch - OFF (P)

29. Main and emergency generator switches - OFF (P)

30. Gyro switch - OFF (P)

31. Battery switch - BATTERY (P)

32. Feel battery - CHECKED (P)
    - Check by pressing test switch and observing indicator.

33. Electrical emergency panel switches - NORMAL (P)

34. Heater - AS DESIRED (P)

35. LORAS switch - ON AND CHECKED (P)
    - Check by observing lateral and longitudinal airspeed indicators against existing wind speed.

36. SAS channel selector switch - OFF (P)

37. Exterior lights - AS REQUIRED (P)

38. Wiper switch - AS REQUIRED (P)

39. Propeller governor test switch - NORMAL AND LOCKED (P)

40. Center console cover - UP AND LOCKED (P)

41. Center console aft circuit breakers - ALL IN (P)

42. Interior lights - AS REQUIRED (P)

43. Communication and navigation equipment - OFF (P)

44. Center console lower right hand circuit breakers - ALL IN (P)

45. Recorder power switch - ON (P)

46. Check list complete

STARTING ENGINES

Engine starting sequence is normally 2, 1, 3, 4.

1. Parking brake - RESET (P)
2. Air start/ground start switch - GROUND START (P)
3. Canopies - AS REQUIRED (P)
4. Fire Guard - POSTED AND CLEAR (P)
   - A fire guard shall be posted and an all clear signal received from ground crew. See figure 2-3 for danger areas.
5. Engine No. 2 - START (P)
   - Ignition switch - NORMAL
   - No. 2 engine master/start switch - ON
   - FUEL PUMP caution light extinguishes
   - No. 2 engine master/start switch - START (momentary) then released to ON position.
   - ST CUTOFF caution light on.
   - Advance No. 2 throttle to - IDLE at 21% gas generator rpm (approx. 10 seconds). Light-off should occur.
   - Do not exceed 595° turbine inlet temperature.
   - After satisfactory start with engine stabilized at 56% gas generator rpm, advance throttle to 1800 rpm idle.
   - Request ground crew to pull landing gear pins.
6. No. 2 engine oil pressure and temperature - CHECK (P)
7. Propeller G/B oil pressure and temperature - CHECK (P)
8. Engine G/B oil pressure and temperature - CHECK (P)
9. Fuselage G/B oil pressure and temperature - CHECK (P)
10. Hydraulic oil pressure - CHECK (P)
11. Propeller governor oil pressure - CHECK (P)
12. Engine No. 1 - START (P)
    - Repeat No. 2 engine start procedure
    - Match throttles to maintain 1800-2200 rpm.
13. Engine No. 3 - START (P)
    - Repeat above start procedure.
    - Match throttles to maintain 1800-2200 rpm.
14. Engine No. 4 - START (P)
    - Repeat above start procedure.
    - Match all throttles to maintain 2000-2200 rpm.
15. Air start/ground start switch - NORMAL (P)

16. Main generator switch - TEST, THEN ON (P)

17. External power switch - OFF (P)

18. Instrumentation battery power switch - OFF (P)

UNSATISFACTORY ENGINE STARTS

HOT START

If turbine inlet temperature rises abnormally at a rate that will exceed 621°C, immediately:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Monitor turbine inlet temperature. If temperature exceeds 260°C:

4. Master/start switch - START (P)
   - Motor engine until temperature indicates a positive rate of reduction.

COLD START

If engine starts, but does not accelerate properly.

1. Throttle - CLOSED (P)

FAILURE TO START

If engine does not light-off within 15 seconds after the throttle has been advanced to idle:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Before attempting another start, allow the engine to stop rotating and wait at least 3 minutes to allow fuel to drain from the mainfolds, combustion chamber, and exhaust hood.

4. Repeat normal start procedure (P)

BEFORE TAXI

1. Feel and trim system - CHECK (P)
   - Main generator switch - OFF
   - Move the control stick in all directions to ascertain that stick feel is normal.

- Battery switch - OFF
- Move the control stick in all directions. Stick should be movable but sluggish.

2. Battery switch - BATTERY (P)

3. Main generator - ON (P)

4. Emergency generator - ON (P)

5. Instrumentation control panel set as follows: (P)

   a) Battery power switch - ON

   b) Recorder and oscillograph switches - AS REQUIRED

   c) Time code switch - RUN

6. Feel system and reset switch - ON (P)

7. SAS channel selector switch - BOTH (P)

8. Communication and navigation equipment - AS REQUIRED (P)

9. Gyro compass control - SET (P)

10. Flight instruments - SET (P, CP)

11. SAS cutout switches - CHECK (P, CP)
    - Check by placing SAS channel selector switch progressively in each of its positions and activating the cutout switch at each position. Observe the hydraulic pressure indicator for a fluctuation as the cutout switch is depressed.

    - Return the SAS channel selector switch to BOTH position.

12. Feel cutoff switch - CHECK AND RESET (P)
    - Check by observing increased feel forces, presence of audio warning, and FEEL SYS caution light illuminated.
    - Reset system with feel system and reset switch.

13. Trim - SET (P)

14. Propeller ducts - ROTATE TO 0° (P)

15. Perform control checks - AS REQUIRED (P)

16. Propeller ducts - ROTATE TO 90° (P)

17. Perform control checks - AS REQUIRED (P)

18. Oscillograph - OFF (P)

19. Propeller governor - CHECK (P)

- Slowly advance throttles to obtain positive blade angle.
- Set propeller rpm selector for 2450 rpm.
- Place propeller governor test switch in TEST #1 position and observe that governor pressure is within limits. Also observe that #1 PROP GOV caution light illuminates.
- Place propeller governor test switch in TEST #2 position and observe that governor pressure is within limits. Also observe that #2 PROP GOV caution light illuminates.
- Place propeller governor test switch in NORM position and observe that governor pressures are within limits. PROP GOV caution lights should be extinguished.

20. Canopies - CLOSED (P, CP)

21. Pitch, roll, and yaw switches - OFF (CP)

22. Checklist complete

TAXING

See figure 2-4 for turning radius diagram.

1. Duct angle - 30° SET OR AS REQUIRED (P)

2. Propeller rpm lever - SET FOR 2000 RPM (P)

3. Throttles - FLIGHT IDLE (P)

4. Parking brake - RELEASED (P)

Taxi should commence when the parking brake is released; if it does not, move the propeller rpm lever backward slightly to commence taxi. Check rudder pedal brakes. Check RMI and turn and bank needles for correct response during ground maneuvering. Adjust propeller RPM lever to control speed. Avoid extensive high speed taxi. Use elevon control and rudder as necessary to maintain desired heading.To control speed use duct rotation and brakes.

BEFORE TAKEOFF

1. Parking brake - SET (P)

2. Blade angle and propeller rpm lever - CHECKED AND SET FOR TAKEOFF(P)

- Slowly advance throttles to obtain positive blade angle.
- Set propeller rpm lever for 2425 rpm.
- Adjust throttle friction as desired.

NOTE

2425 rpm is satisfactory for vertical and short takeoff modes.

3. Duct angle - SET FOR TAKEOFF (P)
   . Set between 80 to 87° for vertical takeoff.
   . Set between 15 to 75° for short takeoff.

4. Trim - SET FOR TAKEOFF (P)

5. Yaw switch - STOL (ON) (P)
   VTOL (OFF)

6. Anti-collision light - ON (P)

7. Shoulder harness - LOCKED (P, CP)

8. Parking brake - RELEASED (P)

TAKEOFF

See figure 2-5 for typical takeoff presentation.

Vertical Takeoff

Advance throttles maintaining directional control with rudder pedals and longitudinal control with control stick. Readjust throttles to balance engine power while maintaining hover. The copilot shall monitor all engine and propeller instruments during the takeoff for proper performance and immediately inform the pilot of any abnormal indication.

Short Takeoff

Align aircraft with takeoff direction and release brakes. Advance throttles to maximum power. Start applying back pressure on the control stick at approximately 10 knots less than takeoff speed. The copilot shall monitor all engine and propeller instruments during the takeoff for proper performance and immediately inform the pilot of any abnormal indication.

AFTER TAKEOFF

1. Landing gear handle - UP (CP)
   . When aircraft is airborne with a positive rate of climb, raise gear. Check landing gear position indicator for locked indication and gear handle light off.

CAUTION

Do not attempt to raise landing gear if airspeed is above 100 KIAS.

2. Duct angle - SET (P)

3. Trim - AS NECESSARY (P)

4. Climb power - SET (P)

5. Engine and gearbox instruments - CHECK (CP)

CRUISE

Refer to appendix I for cruise information.

Maintain climb power after level-off until cruise airspeed is obtained.

1. Propeller RPM - SET (P)

2. Oil temperature and pressures - CHECK (CP)

Note

> If cruise is to exceed 150 KIAS, accomplish the following at the 150 knot point:
>
> - Duct Lock Switch - LOCKED (CP)
> - LORAS Switch - OFF (P)
> - SAS Channel selector switch - OFF (P)
> - FEEL System Switch - OFF (P)
> - Pitch Switch - ON (P)
> - Yaw Switch - OPTIONAL (P)
> - Roll Switch - ON (P)

FLIGHT CHARACTERISTICS

Refer to Section VI for information on flight characteristics.

BEFORE LANDING

Enter a normal traffic pattern (figure 2-6) at 150 KIAS or below.

SHORT LANDING (Figure 2-6, Sheet 1)

1. Duct Switch - UNLOCKED (P)
2. LORAS Switch - ON (P)
3. SAS Switch - BOTH (P)
4. Feel System Switch - NORMAL (P)
5. Pitch Switch - OFF (P)
6. Yaw Switch - ON (P)
7. Roll Switch - OFF (P)
8. Duct Angle - SET (P)
   - Set in accordance with duct angle/airspeed information for STOL operation contained in Appendix 1.
9. Landing Gear handle - DOWN (P)
   - Check landing gear position indicators for locked down indication.
   - Check that gear handle light is not illuminated.
10. Shoulder Harness - LOCKED (P,CP)
11. Parking Brake - OFF (P)

VERTICAL LANDING (Figure 2-6, Sheet 2)

1. Duct Switch - UNLOCKED (P)
2. LORAS Switch - ON (P)
3. SAS Switch - BOTH (P)
4. Feel System Switch - NORMAL (P)
5. Pitch Switch - OFF (P)
6. Yaw Switch - OFF (P)
7. Roll Switch - OFF (P)
8. Landing gear handle - DOWN (P)
   - Check landing gear position indicators for locked down indication.
9. Duct rotation schedule - INITIATE (P)
   - Rotate in accordance with duct angle/airspeed information for VTOL Operation contained in Appendix 1.
10. Shoulder Harness - LOCKED (P,CP)
11. Parking Brake - OFF (P)

LANDING

Refer to Section VI for stall speeds and to Appendix I for rate of sink information.Retard throttles to flight idle after making firm ground contact.After touchdown during a short landing maintain direction with flight controls and use brakes as required.

AFTER LANDING

Ducts - SET FOR PROPER TAXI SPEED (P)

GO-AROUND

If a go-around becomes necessary and the ducts are at an angle of greater than 30° rotate ducts to 30° while simultaneously applying power as required.

ENGINE SHUTDOWN

1. Parking brake - SET (P)

2. Heater - OFF (P)

3. Throttles - FLIGHT IDLE (P)

4. Duct position - 35° (P)

5. Instrumentation control panel set as follows: (P)

   a) Run cal switch - CALIBRATE

   b) Telemetry calibrate switch - CALIBRATE

   c) Recorder calibration switch - LO position for 5 seconds CENTER position for 5 seconds HI position for 5 seconds, then released to center.

   d) Recorder and oscillograph power switches - OFF

6. External power - PLUGGED IN AND OPERATING (P)

7. Duct position - 90° (P)
7a. Duct rotation override switch -OFF (CP)
8. Feel system and reset switch - OFF (P)

9. Emergency generator switch - OFF (P)

10. Gyro switch - OFF (P)

11. Battery switch - OFF (P)

12. All communication and navigation equipment switches - OFF (P)

13. LORAS switch - OFF (P)

14. SAS channel selector switch - OFF (P)

15. Anti-collision light - OFF (P)

16. External power switch - EXTERNAL POWER (P)

17. Main generator - OFF (P)

18. Throttles - GROUND IDLE (P)
    . Check that idle speed is approximately 53%.

19. Throttles - CLOSED (P)

20. Engine master/start switches - OFF (P)

<u>BEFORE LEAVING THE AIRCRAFT</u>

1. Ejection seat - DISARMED (P, CP)
    . Place safety handle in full down position.
    . Install T-30 initiator safety pin and streamer.

2. Parking brake - SET (P)

<u>POST FLIGHT</u>

1. Ducts - CHECK FOR:
    . Hydraulic oil or lube oil leakage.
    . Evidence of damage to ducts, elevons, and propellers.
    . Security of all panels and fairings.

2. Engine nacelles - CHECK FOR:
    . Damage and fuel oil leakage.
    . Security of all panels, fairings, and doors.

3. Fuselage - CHECK FOR:
    . Evidence of damage and fuel or oil leakage.

4. Landing gear - CHECK FOR:
    . Tires for cuts, bruises, and slippage.
    . Wheel wells for general condition and security of area.

5. Protective Covers - INSTALLED.

Note

In the event any limits in the Flight Manual have been exceeded, make appropriate entries in Form 3760-2. Entries must also be made to report any system defects, or unusual conditions, such as hard landings, excessive braking, etc.

PITCH CONTROL MODE

BEFORE STARTING ENGINES

1. External power switch - EXTERNAL POWER (P)
2. Intercom switch - ON (P, CP)
3. VHF radio - FREQUENCY SET (P)
4. Torso harness - FASTENED (P, CP)
5. Rudder pedals - ADJUSTED (P, CP)

5a. Parking brake- SET (P)

6. Ejection seats - ADJUSTED (P, CP)
7. Overhead circuit breakers - ALL IN (P)
8. Fuel dump handle - FORWARD AND SAFETY PIN REMOVED (P)
9. Instrumentation control panel set as follows: (P)
   a) Master power switch - ON
   b) Battery power switch - ON
   c) Time code power switch - ON
   d) Telemetry power switch - ON
   e) Temperature calibration switch - CALIBRATE
10. Engine fire handles - ALL IN (P)
11. Fire warning lights - CHECKED (P)
    . Check by pressing FIRE PRESS TO TEST switch.
12. All instruments - STATICALLY CHECKED (P, CP)
13. Engine master/start switches - OFF (P)
14. Caution light panel and chip detector lights - CHECKED (P, CP)
    . Check by pressing PRESS TO TEST switches.
15. Throttle boost switch - NORMAL (P)

16. Pitot heat switch - OFF (P)

17. Air start/ground start switch - NORMAL (P)

18. Yaw switch - OFF (CP)

19. Gear handle - DOWN AND LIGHT CHECKED (P)
    . Check light by pressing LT TEST switch.

20. Ignition switch - NORMAL (cover down) (P)

21. SAS cutoff override switch - ON (cover down) (P)

22. UHF antenna switch - UPPER (P)

23. Throttle release - FORWARD (P)

24. Throttles - CHECK FULL TRAVEL, THEN CLOSE (P)

25. Duct lock switch - UNLOCKED (P)

26. Duct rotation override switch - NORMAL (P)

27. Feel system and reset switch - OFF (P)

28. Main and emergency generator switches - OFF (P)

29. Gyro switch - OFF (P)

30. Battery switch - BATTERY (P)

31. Feel battery - CHECKED (P)
    . Check by pressing test switch and observing indicator.

32. Electrical emergency panel switches - NORMAL (P)

33. Heater - AS DESIRED (P)

34. LORAS switch - ON and CHECKED (P)
    . Check by observing lateral and longitudinal airspeed indicator against existing wind speed.

35. SAS channel selector switch - OFF (P)

36. Exterior lights - AS REQUIRED (P)

37. Wiper switch - AS REQUIRED (P)

38. Propeller governor test switch - NORMAL AND LOCKED (P)

39. Center console cover - UP AND LOCKED (P)

40. Center console aft circuit breakers - ALL IN (P)

41. Interior lights - AS REQUIRED (P)

42. Communication and navigation equipment - OFF (P)

43. Center console lower right hand circuit breakers - ALL IN (P)

44. Recorder power switch - ON (P)

45. Check list complete.

STARTING ENGINES

Engine starting sequence is normally 2, 1, 3, 4.

1. Parking brake - RESET (P)
2. Air start/ground start switch - GROUND START (P)
3. Canopies - AS REQUIRED (P)
4. Fire Guard - POSTED AND CLEAR (P)
   - A fire guard shall be posted and an all clear signal received from ground crew. See Figure 2-3 for danger areas.
5. Engine No. 2 - START (P)
   - Ignition switch - NORMAL
   - No. 2 engine master/start switch - ON
   - FUEL PUMP caution light extinguishes.
   - No. 2 engine master/start switch - START (momentary) then released to ON position.
   - ST CUTOFF caution light on.
   - Advance No. 2 throttle to - IDLE at 21% gas generator rpm (approx. 10 seconds). Light-off should occur.
   - Do not exceed 595° turbine inlet temperature.
   - After satisfactory start with engine stabilized at 56% gas generator rpm, advance throttle to 1800 rpm idle.
   - Request ground crew to pull landing gear pins.
6. No. 2 engine oil pressure and temperature - CHECK (P)
7. Propeller G/B oil pressure and temperature - CHECK (P)
8. Engine G/B oil pressure and temperature - CHECK (P)
9. Fuselage G/B oil pressure and temperature - CHECK (P)
10. Hydraulic oil pressure - CHECK (CP)
11. Engine No. 1 - START (P)
    - Repeat No. 2 engine start procedure.
    - Match throttles to maintain 1800-2200 rpm.

12. Engine No. 3 - START (P)
    - Repeat above start procedure.
    - Match throttles to maintain 1800-2200 rpm.

13. Engine No. 4 - START (P)
    - Repeat above start procedure.
    - Match all throttles to 2000-2200 rpm.

14. Air start/ground start switch - NORMAL (P)

15. Main generator switch - TEST, THEN ON (P)

16. External power switch - OFF (P)

17. Instrumentation battery power switch - OFF (P)

UNSATISFACTORY ENGINE STARTS

HOT START

If turbine inlet temperature rises abnormally at a rate that will exceed 621°C, immediately:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Monitor turbine inlet temperature. If temperature exceeds 260°C:

4. Master/start switch - START (P)
   - Motor engine until temperature indicates a positive rate of reduction.

COLD START

If engine starts, but does not accelerate properly.

1. Throttle - CLOSED (P)

FAILURE TO START

If engine does not light-off within 15 seconds after the throttle has been advanced to idle:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Before attempting another start, allow the engine to stop rotating and wait at least 3 minutes to allow fuel to drain from the manifolds, combustion chamber, and exhaust hood.

4. Repeat normal start procedure (P)

BEFORE TAXI

1. Feel and trim system - CHECK (P)
   - Main generator switch - OFF
   - Move the control stick in all directions to ascertain that stick feel is normal.
   - Battery switch - OFF
   - Move the control stick in all directions. Stick should be movable but sluggish.
2. Battery switch - BATTERY (P)
3. Main generator - ON (P)
4. Emergency generator - ON (P)
5. Instrumentation control panel set as follows: (P)

   a) Battery power switch - ON

   b) Recorder and oscillograph switches - AS REQUIRED

   c) Time code switch - RUN
6. Feel system and reset switch - ON (P)
7. SAS channel selector switch - BOTH (P)
8. Communication and navigation equipment - AS REQUIRED (P)
9. Gyro compass control - SET (P)
10. Flight instruments - SET (P, CP)
11. SAS cutout switches - CHECK (P, CP)
    - Check by placing SAS channel selector switch progressively in each of its positions and activating the cutout switch at each position. Observe the hydraulic pressure indicator for a fluctuation as the cutout switch is depressed.
    - Return the SAS channel selector switch to BOTH position.
12. Feel cutoff switch - CHECK AND RESET (P)
    - Check by observing increased feel forces, presenece of audio warning, and FEEL SYS caution light illuminated.
    - Reset system with feel system and reset switch.
13. Trim - SET (P)
14. Propeller ducts - ROTATE TO 0° (P)

15. Perform control checks - AS REQUIRED (P)

16. Propeller ducts - ROTATE TO 90° (P)

17. Perform control checks - AS REQUIRED (P)

18. Oscillograph - OFF (P)

19. Canopies - CLOSED (P, CP)

20. Yaw switch - OFF (CP)

21. Checklist complete

TAXING

See figure 2-4 for turning radius diagram.

1. Collective lever - FULL DOWN (P)

2. Duct angle - 35° SET OR AS REQUIRED (P)

3. Throttles - SET FOR 2000 RPM (P)

4. Parking brake - RELEASED (P)
   . Taxi should commence when the parking brake is released; if it does not, raise the collective lever slightly to commence taxi. Check rudder pedal brakes. Check RMI and turn and bank needles for correct response during ground maneuvering.Adjust collective lever and duct position to control speed.Avoid extensive high speed taxi.Use elevon and rudder as necessary to maintain proper heading.To stop aircraft,lower collective lever to full down position,rotate ducts if necessary,and use brakes.

BEFORE TAKEOFF

1. Parking brake - SET (P)

2. Collective lever - FULL DOWN (P)
   . Adjust collective friction as desired.

3. Throttles - SET FOR 2550 RPM (P)
   . Match engines by observing RPM indicators.
   . Adjust throttle friction as desired.

Note

2550 rpm is satisfactory for vertical and short takeoff modes.

4. Duct angle - SET FOR TAKEOFF (P)

5. Trim - SET FOR TAKEOFF (P)

6. Yaw switch - STOL (ON) (P)
   VTOL (OFF)

7. Anti-collison light - ON (P)

8. Shoulder harness - LOCKED (P, CP)

9. Parking brake - RELEASED (P)

TAKEOFF

See figure 2-5 for typical takeoff presentation.

Vertical Takeoff

Raise collective lever maintaining directional control with rudder pedals and longitudinal control with control stick. Rematch engines as required. The copilot shall monitor all engine and propeller instruments during the takeoff for proper performance and immediately inform the pilot of any abnormal indication.

Short Takeoff

Align aircraft with takeoff direction and release brakes. Raise collective lever. Start applying back pressure on the control stick at approximately 10 knots less than takeoff speed. The copilot shall monitor all engine and propeller instruments during the takeoff for proper performance and immediately inform the pilot of any abnormal indication.

Note

At light gross weights, the aircraft will probably become airborne before maximum power is reached.

AFTER TAKEOFF

1. Landing gear handle - UP (CP)
   - When aircraft is airborne with a positive rate of climb, raise gear. Check landing gear position indicator for locked indication and gear handle light off.

CAUTION

Do not attempt to raise landing gear if airspeed is above 100 KIAS.

2. Duct angle - SET (P)

3. Trim - AS NECESSARY (P)

4. Climb power - SET (P)

5. Engine and gearbox instruments - CHECK (CP)

CRUISE

Refer to Appendix I for cruise information.

Maintain climb power after level off until cruise airspeed is obtained.

1. Propeller RPM - SET (P)

2. Oil temperature and pressures - CHECK (P)

Note

If cruise is to exceed 150 KIAS, accomplish the following at the 150 knot point:

- Duct Lock Switch - LOCKED (P)
- LORAS Switch - OFF (P)
- SAS Channel selector switch - OFF (P)
- Yaw Switch - OPTIONAL (P)
- FEEL System Switch - OFF (P)

FLIGHT CHARACTERISTICS

Refer to Section VI for information on flight characteristics.

BEFORE LANDING

Enter a normal traffic pattern (figure 2-6) at 150 KIAS or below.

SHORT LANDING (Figure 2-6, Sheet 1)

1. Duct switch - UNLOCKED (P)
2. LORAS switch - ON (P)
3. SAS switch - BOTH (P)
4. Feel system and reset switch - ON (P)
5. Yaw switch - AS REQUIRED (P)
6. Duct angle - SET (P)
   - Set in accordance with duct angle/airspeed information for STOL operation contained in Appendix 1.
7. Landing gear handle - DOWN (CP)
   - Check landing gear position indicators for locked down indication.
8. Shoulder harness - LOCKED (P, CP)
9. Parking brake - OFF(P)

VERTICAL LANDING (Figure 2-6, Sheet 2)

1. Duct switch - UNLOCKED (P)
2. LORAS switch - ON (P)
3. SAS switch - BOTH (P)
4. Feel system and reset switch - ON (P)
5. Yaw switch - AS REQUIRED (P)
6. Landing gear handle - DOWN (CP)
   - Check landing gear position indicators for locked down indication.
7. Duct rotation schedule - INITIATE (P)
   - Rotate in accordance with duct angle/airspeed information for VTOL operation contained in Appendix 1.
8. Shoulder harness - LOCKED (P, CP)
9. Parking brake - OFF(P)

LANDING

Refer to Section VI for stall speeds and to Appendix 1 for rate of sink information. When firmly on the ground lower collective pitch lever. After touchdown during a short landing maintain direction with flight controls and use brakes as required.

AFTER LANDING

Ducts - 30° SET OR AS REQUIRED (P)

GO-AROUND

If a go-around becomes necessary and the ducts are at an angle of greater than 30°, rotate ducts to 30° while simultaneously applying power as required.

ENGINE SHUTDOWN

1. Parking brake - SET (P)
2. Heater - OFF (P)
3. Throttles- FLIGHT IDLE (P)
4. Duct position - 35° (P)

5. Instrumentation control panel set as follows: (P)
   a) Run cal switch - CALIBRATE
   b) Telemetry calibration switch - CALIBRATE
   c) Recorder calibration switch - LO position for 5 seconds CENTER position for 5 seconds H1 position for 5 seconds then released to CENTER
   d) Recorder and oscillograph power switches - OFF

5. External power - PLUGGED IN AND OPERATING (P)
6. Duct position - 90° (P)

6a. Duct rotation override switch - OFF (CP)

7. Feel system and reset switch - OFF (P)
8. Emergency generator switch - OFF (P)
9. Gyro switch - OFF (P)
10. Battery switch - OFF (P)
11. All communication and navigation equipment switches - OFF (P)
12. LORAS switch - OFF (P)

13. SAS channel selector switch - OFF (P)
14. Anti-collison light - OFF (P)
15. External power switch - EXTERNAL POWER (P)
16. Main generator - OFF (P)
17. Throttles - GROUND IDLE (P)
18. Throttles - CLOSED (P)
19. Engine master/start switches - OFF (P)

BEFORE LEAVING THE AIRCRAFT

1. Ejection seat - DISARMED (P, CP)
   - Place safety handle in full down position.
   - Install T-30 initiator safety pin and streamer.
2. Parking brake - SET (P)

POST FLIGHT

1. Ducts - CHECK FOR:
   - Hydraulic oil or lube oil leakage.
   - Evidence of damage to ducts, elevons, and propellers.
   - Security of all panels and fairings.
2. Engine nacelles - CHECK FOR:
   - Damage and fuel or oil leakage.
   - Security of all panels, fairings, and doors.
3. Fuselage - CHECK FOR:
   - Evidence of damage and fuel or oil leakage.
4. Landing gear - CHECK FOR:
   - Tires for cuts, bruises, and slippage.
   - Wheel wells for general condition and security of area.
5. Protective covers - INSTALLED.

Note

In the event any limits in the Flight Manual have been exceeded, make appropriate entries in Form 3760-2. Entries must also be made to report any system defects, or unusual conditions, such as hard landings, excessive braking, etc.

VSS/FBW MODE

BEFORE STARTING ENGINES

1. External power switch - EXTERNAL POWER (P)

2. Intercom switch - ON (P, CP)

3. VHF radio - FREQUENCY SET (P)

4. Torso harness - FASTENED (P, CP)

5. Rudder pedals - ADJUSTED (P, CP)
5a. Parking brake - SET (P)
6. Ejection seats - ADJUSTED (P, CP)

7. Overhead circuit breakers - ALL IN (P)

8. Fuel dump handle - FORWARD AND SAFETY PIN REMOVED (P)

9. Instrumentation control panel set as follows: (P)

   a) Master power switch - ON

   b) Battery power switch - ON

   c) Time code power switch - ON

   d) Telemetry power switch - ON

   e) Temperature calibration switch - CALIBRATE

10. VSS gain controls - SET (P)
    . Set as required by flight plan.

11. Engine fire handles - ALL IN (P)

12. Fire warning lights - CHECKED (P)
    . Check by pressing FIRE PRESS TO TEST switch.

13. All instruments - STATICALLY CHECKED (P, CP)

14. Engine master/start switches - OFF (P)

15. Caution light panel and chip detector lights - CHECK (P, CP)
    . Check by pressing PRESS TO TEST switches.

16. Throttle boost switch - NORMAL (P)

17. Pitot heat switch - OFF (P)

18. Air start/ground start switch - NORMAL (P)

19. Yaw switch - OFF (CP)

20. Gear handle - DOWN AND LIGHT CHECKED (P)
    . Check light by pressing LT TEST switch.

21. Ignition switch - NORMAL (cover down) (P)

22. SAS cutoff override switch - ON (cover down) (P)

23. UHF antenna switch - UPPER (P)

24. Throttle release - FORWARD (P)

25. Throttles - CHECK FULL TRAVEL, THEN CLOSE (P)

26. Duct lock switch - UNLOCKED (P)

27. Duct rotation override switch - NORMAL (P)

28. Feel system and reset switch - OFF (P)

29. Main and emergency generator switches - OFF (P)

30. Gyro switch - OFF (P)

31. Battery switch - BATTERY (P)

32. Feel battery - CHECK (P)
    . Check by pressing test switch and observing indicator.

33. Electrical emergency panel switches - NORMAL (P)

34. Heater - AS DESIRED (P)

35. VSS switch - ON (P)

36. VSS cutout switch - MOMENTARILY DEPRESS AND CHECK VSS/FBW SWITCH IN FBW (P)

37. LORAS switch - ON AND CHECKED (P)
    . Check by observing lateral and longitudinal airspeed indicators against existing wind speed.

38. SAS channel selector switch - OFF (P)

39. Exterior lights - AS REQUIRED (P)

40. Wiper switch - AS REQUIRED (P)

41. Propeller governor test switch - NORMAL AND LOCKED (P)

42. Center console cover - UP AND LOCKED (P)

43. Center console aft circuit breakers - ALL IN (P)

44. Interior lights - AS REQUIRED (P)

45. VSS mode control panel as follows: (P)

    a) Auto balance switch - ON (cover down)

    b) All other switches - AFT

46. Communication and navigation equipment - OFF (P)

47. Center console lower right hand circuit breakers - ALL IN (P)

48. Stick position potentiometer - CENTER (P)

49. VSS trim control panel as follows: (P)

    a) Pitch selector switch - POSITION ONE

    b) Roll selector switch - POSITION ONE

    c) Yaw selector switch - POSITION ONE

    d) Type of trim switch - RATE

    e) Yaw trim potentiometer - CENTER

50. Function generator control panel as follows: (P)

    a) Test-normal switch - NORMAL (cover down)

    b) Function generator digitrol - 00

51. Recorder power switch - ON (P)

52. Check list complete

STARTING ENGINES

Engine starting sequence is normally 2, 1, 3, 4.

1. Parking brake - RESET (P)

2. Air start/ground start switch - GROUND START (P)

3. Canopies - AS REQUIRED (P)

4. Fire Guard - POSTED AND CLEAR (P)
   - A fire guard shall be posted and an all clear signal received from ground crew. See Figure 2-3 for danger areas.

5. Engine No. 2 - START (P)
   - Ignition switch - NORMAL
   - No. 2 engine master/start switch - ON
   - FUEL PUMP caution light extinguishes.
   - No. 2 engine master/start switch - START (momentary) then released to ON position.

- ST CUTOFF caution light on.
- Advance No. 2 throttle to - IDLE at 21% gas generator rpm (approx. 10 seconds). Light-off should occur.
- Do not exceed 595° turbine inlet temperature.
- After satisfactory start with engine stabilized at 56% gas generator rpm, advance throttle to 1800 rpm idle.
- Request ground crew to pull landing gear pins.

6. No. 2 engine oil pressure and temperature - CHECK (P)

7. Propeller G/B oil pressure and temperature - CHECK (P)

8. Engine G/B oil pressure and temperature - CHECK (CP)

9. Fuselage G/B oil pressure and temperature - CHECK (CP)

10. Hydraulic oil pressure - CHECK (CP)

11. Engine No. 1 - START (P)
    - Repeat No. 2 engine start procedure.
    - Match throttles to maintain 1800-2200 rpm.

12. Engine No. 3 - START (P)
    - Repeat above start procedure.
    - Match throttles to maintain 1800-2200 rpm.

13. Engine No. 4 - START (P)
    - Repeat above start procedure.
    - Match all throttles to 2000 - 2200 rpm.

14. Air start/ground start switch - NORMAL (P)

15. Main generator switch - TEST, THEN ON (P)

16. External power switch - OFF (P)

17. Instrumentation battery power switch - OFF (P)

UNSATISFACTORY ENGINE STARTS

HOT START

If turbine inlet temperature rises abnormally at a rate that will exceed 621°C, immediately:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Monitor turbine inlet temperature. If temperature exceeds 260°C:

4. Master/start switch - START (P)
   - Motor engine until temperature indicates a positive rate of reduction.

COLD START

If engine starts, but does not accelerate properly.

1. Throttle - CLOSED (P)

FAILURE TO START

If engine does not light-off within 15 seconds after the throttle has been advanced to idle:

1. Throttle - CLOSED (P)

2. Master/start switch - OFF (P)

3. Ignition switch - OFF (P)
   Before attempting another start, allow the engine to stop rotating and wait at least 3 minutes to allow fuel to drain from the manifolds, combustion chamber and exhaust hood.

4. Repeat normal start procedure (P).

BEFORE TAXI

1. Feel and trim system - CHECK (P)
   - Main generator switch - OFF
   - Move the control stick in all directions to ascertain that stick feel is normal.
   - Battery switch - OFF
   - Move the control stick in all directions. Stick should be movable but sluggish.

2. Battery switch - BATTERY (P)

3. Main generator - ON (P)

4. Emergency generator - ON (P)

5. Instrumentation control panel set as follows: (P)

   a) Battery power switch - ON

   b) Recorder and oscillograph switches - AS REQUIRED

   c) Time code switch - RUN

5. Feel system and reset switch - ON (P)

6. SAS channel selector switch - BOTH (P)

7. Communication and navigation equipment - AS REQUIRED (P)

8. Gyro compass control - SET (P)

9. Flight instruments - SET (P, CP)

10. SAS cutout switches - CHECK (P, CP)
    - Check by placing the SAS channel selector switch progressively in each of its positions and activating the cutout switch at each position. Observe the hydraulic pressure indicator for a fluctuation as the cutout switch is depressed.
    - Return the SAS channel selector switch to BOTH position.

11. Feel cutoff switch - CHECK AND RESET (P)
    - Check by observing increased feel forces, presence of audio warning, and FEEL SYS caution light illuminated.
    - Reset system with feel system and reset switch.

12. Trim - SET (P)

13. Instrumentation control panel set as follows: (P)

    a) Run cal switch - CALIBRATE

    b) Telemetry calibration switch - CALIBRATE, THEN RELEASED

    c) Recorder calibration switch - LO position for 5 seconds CENTER position for 5 seconds H1 position for 5 seconds, then released to CENTER

    d) Run cal switch - RUN

14. Propeller ducts - ROTATE TO 0° (P)

15. Perform normal control checks-AS REQUIRED (P,CP)

16. Perform FBW control checks-CHECK AS FOLLOWS (P,CP)
    - Engage feel servos by momentarily pressing switch.
    - Put VSS/FBW switch in FBW.
    - Engage FBW with VSS switch on control stick and observe that left hand pilot has control.
    - Perform control checks- AS REQUIRED.

17. Perform VSS control checks-CHECK AS FOLLOWS (P,CP)
    - Set digitrols in accordance with flight plan.
    - Re-engage feel and trim system.
    - Put VSS/FBW switch in VSS.
    - Engage feel servos by momentarily pressing switch.
    - Engage VSS with control stick switch and observe that left hand pilot has control.
    - Perform control checks-AS REQUIRED (CP)
18. Propeller ducts-ROTATE TO 90° (P)
19. Repeat above steps 15,16,and17,then press VSS cutout switch.
20. Oscillograph-OFF (P)
21. Canopies-CLOSED (P,CP)
22. Yaw switch-OFF (CP)
23. Checklist complete.

TAXIING

See figure 2-4 for turning radius diagram.

1. Collective lever - FULL DOWN (P)
2. Duct angle - 30° SET OR AS REQUIRED (P)
3. Throttles - SET FOR 2000 RPM (P)
4. Parking brake - RELEASED (P)
   - Taxi should commence when the parking brake is released; if it does not, raise the collective lever slightly to commence taxi. Check rudder pedal brakes. Check RMI and turn and bank needles for correct response during ground maneuvering. Adjust collective lever and duct position to control speed.Avoid extensive high speed taxi.Use elevon and rudder as necessary to maintain proper heading.To stop aircraft,lower collective lever to full down position,rotate ducts as necessary,and use brakes.

BEFORE TAKEOFF

1. Parking brake - SET (P)
2. Collective lever - FULL DOWN (P)
   - Adjust collective friction as desired.

3. Throttles - SET FOR 2550 RPM (P)
   - Match engines by observing RPM indicators.
   - Adjust throttle friction as desired.

Note

2550 RPM is satisfactory for vertical and short takeoff modes.

4. Duct angle - SET FOR TAKEOFF (P)

5. Trim - SET FOR TAKEOFF (P)

6. Yaw switch - STOL (ON) VTOL(OFF) (P)

7. Engage feel servos switch-MOMENTARILY DEPRESSED (CP)

8. Anti-collision light - ON (P)

9. Shoulder harness - LOCKED (P, CP)

10. Parking brake - RELEASED (P)

TAKEOFF

See figure 2-5 for typical takeoff presentation.

Vertical Takeoff

Raise collective lever maintaining directional control with rudder pedals and longitudinal control with control stick. Rematch engines as required. The copilot shall monitor all engine and propeller instruments during the takeoff for proper performance and immediately inform the pilot of any abnormal indication.

Short Takeoff

Align aircraft with takeoff direction and release brakes. Raise collective lever. Start applying back pressure on the control stick at approximately 10 knots less than takeoff speed. The copilot shall monitor all engine and propeller instruments during the takeoff fcr proper performance and immediately inform the pilot of any abnormal indication.

Note

At light gross weights, the aircraft will probably become airborne before maximum power is reached.

AFTER TAKEOFF

1. Landing gear handle - UP (CP)
   . When aircraft is airborne with a positive rate of climb, raise gear. Check landing gear position indicator for locked indication and gear handle light off.

CAUTION

Do not attempt to raise landing gear if airspeed is above 100 KIAS.

2. Duct angle - SET (P)
   . Set duct angle for desired rate of climb using duct rotation switch.

3. Trim - AS NECESSARY (P)

4. Duct lock switch - LOCKED (P)
   . Actuate switch when duct angle is 0°.

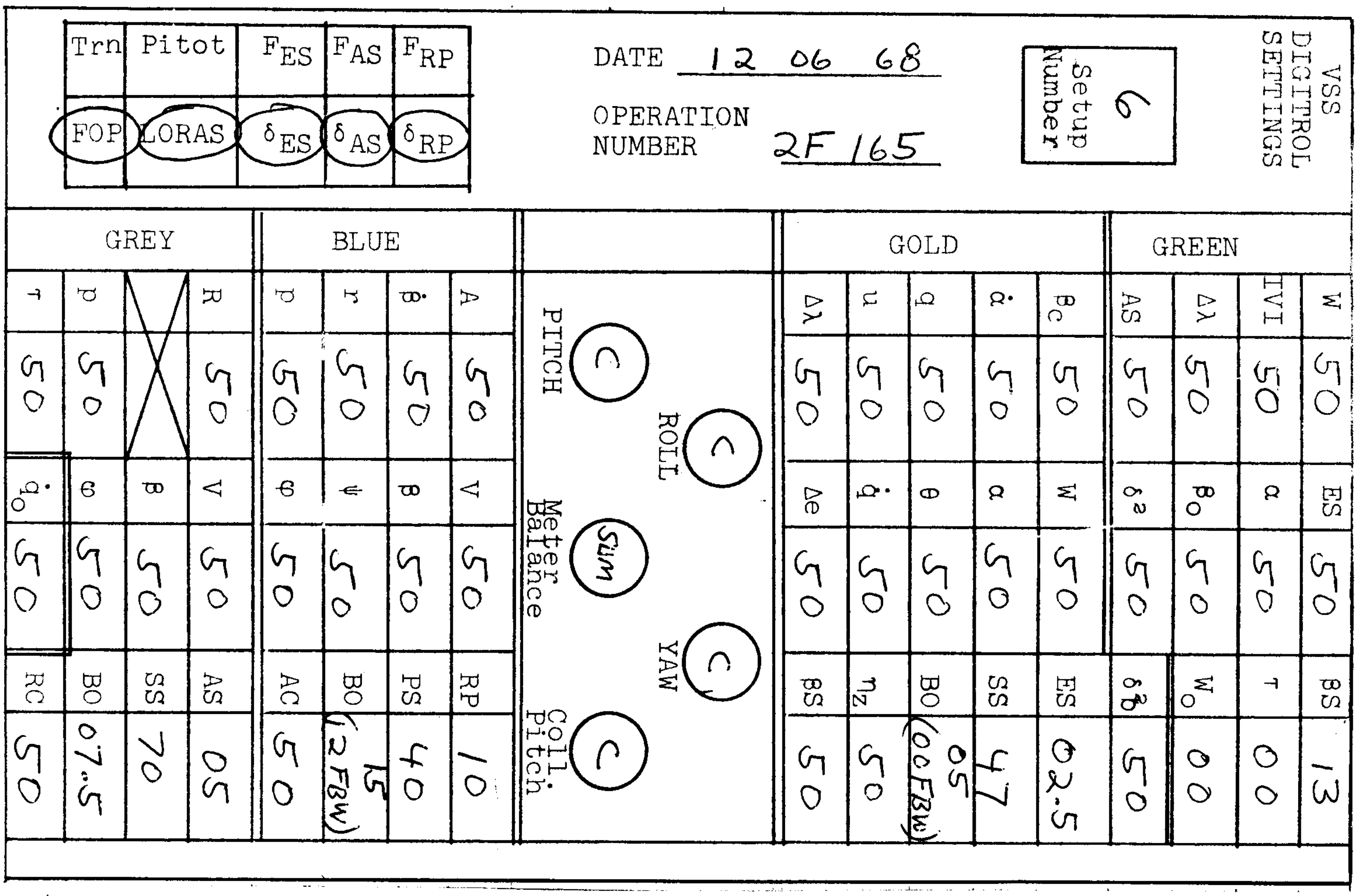
5. Climb power - SET (P)

6. Engine and gearbox instruments - CHECK (CP)

AIRBORNE VSS OPERATION

Airborne operation of the VSS is conducted in accordance with the specific requirements of the flight plan.

The method used by the contractor during the flight test program of the X-22A was to utilize cards of the type illustrated below. The card or cards are filled in with the desired flight parameters and form a part of the flight plan. The cards may be an entity in themselves, the flight plan merely specifying fly in accordance with setup number 6, or the flight plan may specify "in flight" variances for a given card setup. This was found to be a satisfactory and expeditious method of conducting VSS flight tests.



BEFORE LANDING

Enter a normal traffic pattern (figure 2-6) at 150 KIAS or below.

SHORT LANDING (Figure 2-6, Sheet 1)	VERTICAL LANDING (Figure 2-6, Sheet 2)
1. Duct switch - UNLOCKED (P)	1. Duct switch - UNLOCKED (P)
2. LORAS switch - ON (P)	2. LORAS switch - ON (P)
3. SAS switch - BOTH (P)	3. SAS switch - BOTH (P)
4. Feel system and reset switch - ON (P)	4. Feel system and reset switch - ON (P)
5. Yaw switch - AS REQUIRED (CP)	5. Yaw switch - AS REQUIRED (CP)
6. Engage feel servos switch - ON (CP)	6. Engage feel servos switch - ON (CP)
7. Duct angle - SET (P) . Set in accordance with duct angle/airspeed information for STOL operation contained in Appendix 1.	7. Landing gear handle - DOWN (CP) . Check landing gear position indicators for locked down indication.
8. Landing gear handle - DOWN (CP) . Check landing gear position indicators for locked down indication.	8. Duct rotation schedule - INITIATE (CP) . Rotate in accordance with duct angle/airspeed information for VTOL operation contained in Appendix 1.
9. Shoulder harness - LOCKED (P,CP)	9. Shoulder harness - LOCKED (P,CP)
10. Parking brake - OFF (P)	10. Parking brake - OFF (P)

LANDING

Refer to Section VI for stall speeds and to Appendix 1 for rate of sink information. When firmly on the ground lower collective pitch lever. After touchdown during a short landing maintain direction with flight controls and use brakes as required.

AFTER LANDING

Ducts - 30° SET OR AS REQUIRED (P)

ENGINE SHUTDOWN

1. Parking brake - SET (P)
2. Heater - OFF (P)
3. Throttle - FLIGHT IDLE (P)
4. Duct position - 35° (P)

4a. Instrumentation control panel set as follows: (P)

a) Run cal switch - CALIBRATE

b) Telemetry calibration switch - CALIBRATE

c) Recorder calibration switch -
LO position for 5 seconds
CENTER position for 5 seconds
HI position for 5 seconds, then released to CENTER.

d) Recorder and oscillograph power switches - OFF

5. External power - PLUGGED IN AND OPERATING (P)
6. Duct position - 90° (P)

6a. Duct rotation override switch - OFF (CP)

7. Feel system and reset switch - OFF (P)
8. VSS cutout switch - MOMENTARILY DEPRESSED (P)
9. Emergency generator switch - OFF (P)
10. Gyro switch - OFF (P)
11. Battery switch - OFF (P)
12. All communication and navigation equipment switches - OFF (P)
13. VSS switch - OFF (P)
14. LORAS switch - OFF (P)
15. SAS channel selector switch - OFF (P)
16. Anti-collision light - OFF (P)
17. External power switch - EXTERNAL POWER (P)
18. Main generator - OFF (P)

19. Throttles - GROUND IDLE (P)
    . Check that idle speed is approximately 53%.

20. Throttles - CLOSED (P)

21. Engine master/start switches - OFF (P)

BEFORE LEAVING THE AIRCRAFT

1. Ejection seat - DISARMED (P, CP)
    . Place safety handle in full down position.
    . Install T-30 initiator safety pin and streamer.

2. Parking brake - SET (P)

POST FLIGHT

1. Ducts - CHECK FOR:
    . Hydraulic oil or lube oil leakage.
    . Evidence of damage to ducts, elevons, and propellers.
    . Security of all panels and fairings.

2. Engine nacelles - CHECK FOR:
    . Damage and fuel or oil leakage.
    . Security of all panels, fairings, and doors.

3. Fuselage - CHECK FOR:
    . Evidence of damage and fuel or oil leakage.

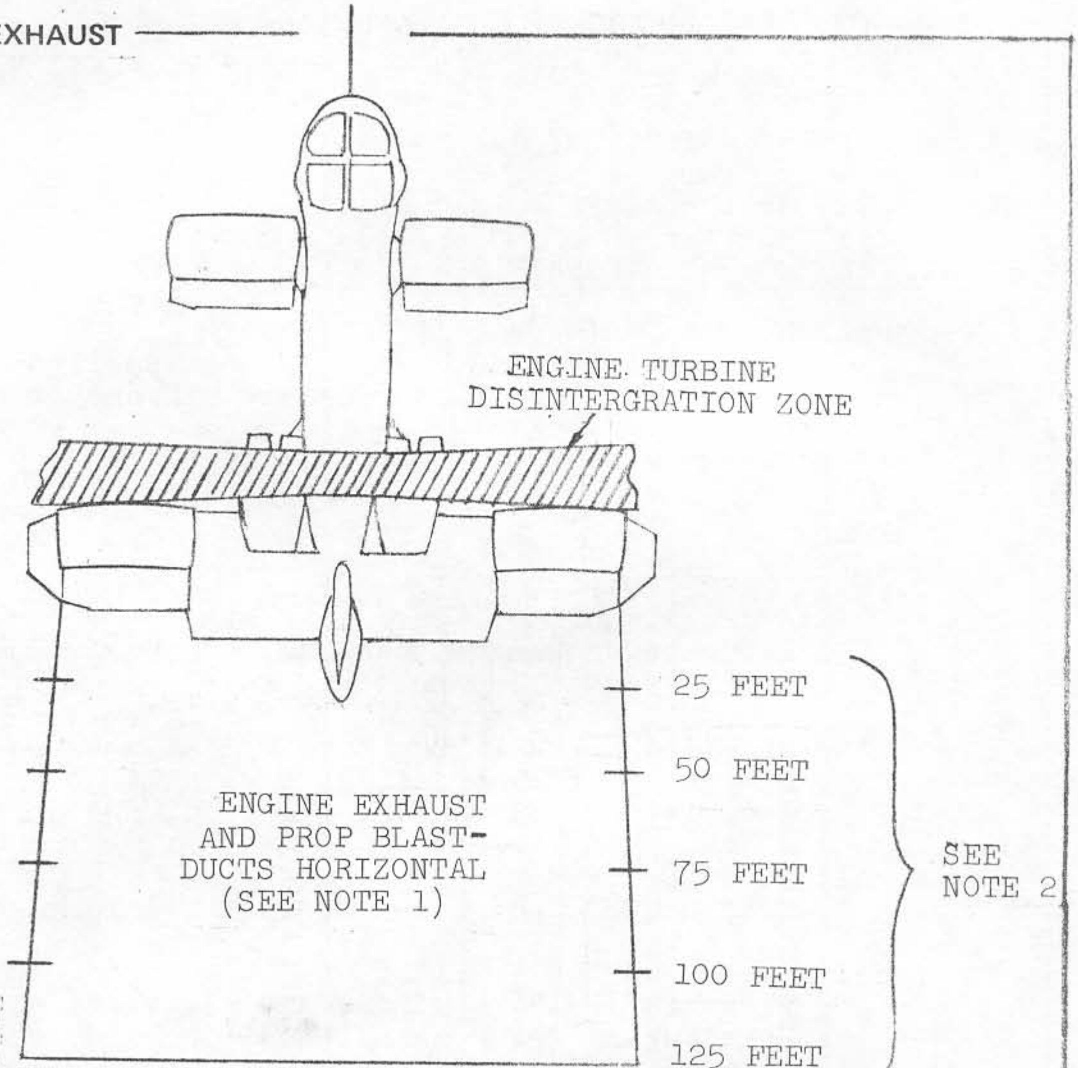
4. Landing gear - CHECK FOR:
    . Tires for cuts, bruises, and slippage.
    . Wheel wells for general condition and security of area.

5. Protective covers - INSTALLED

Note

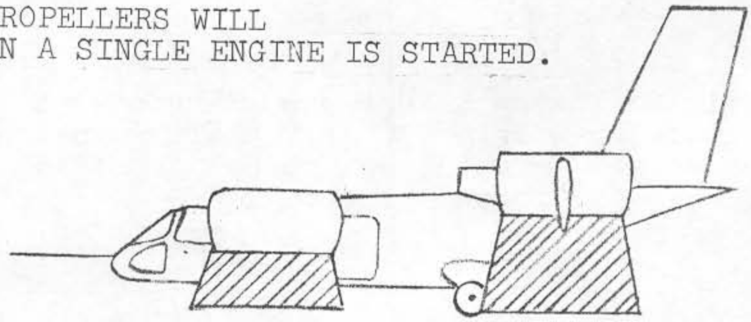
In the event any limits in the Flight Manual have been exceeded, make appropriate entries in Form 3760-2. Entries must also be made to report any system defects, or unusual conditions, such as hard landings, excessive braking, etc.

DANGER AREAS - EXHAUST



WARNING

ALL FOUR PROPELLERS WILL ROTATE WHEN A SINGLE ENGINE IS STARTED.



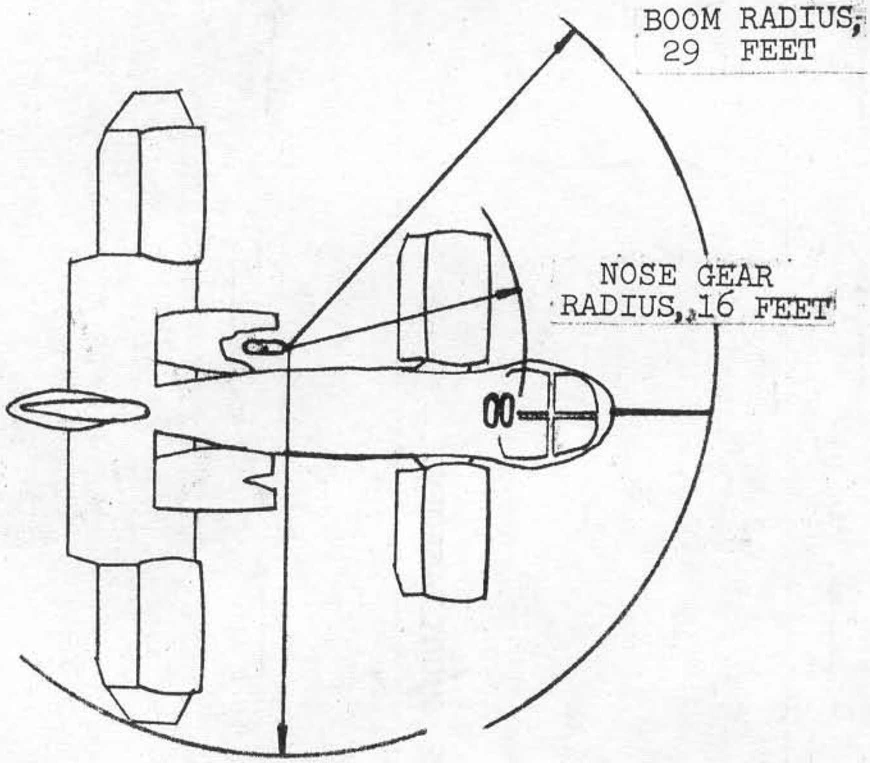
PROP BLAST
DUCTS VERTICAL
(SEE NOTE 1)

NOTES

1. BLAST ZONES WILL VARY ACCORDING TO PREVAILING WINDS.
2. VELOCITY VALUES TO BE FURNISHED AT A LATER DATE.

Figure 2-3

TURNING RADIUS AND GROUND CLEARANCE

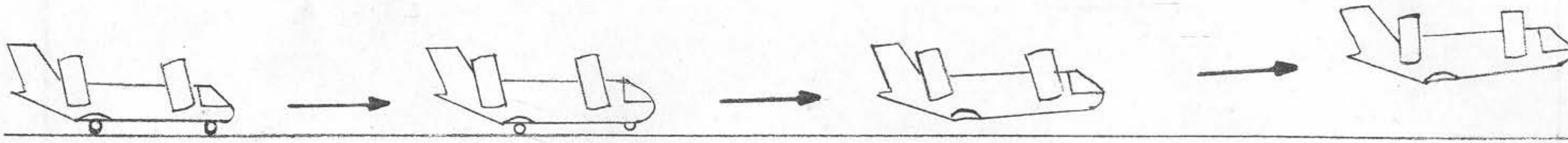


GROUND CLEARANCES -
FUSELAGE-18.00 INCHES
VERTICAL CLEARANCE-20.69 FEET

NOTE
CLEARANCES VARY SLIGHTLY ACCORDING TO LOADING AND STRUT AND TIRE SERVICING

Figure 2-4

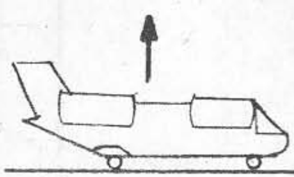
TAKEOFF



DUCT ANGLE AS DESIRED. RELEASE BRAKES. RAISE COLLECTIVE LEVER (PITCH CONTROL). ADVANCE THROTTLES TO MAX. POWER(POWER CONTROL).	MAINTAIN DIRECTION. CHECK ENGINE INSTRUMENTS. APPLY BACKWARD STICK PRESSURE APPROX. 10 KNOTS LESS THAN TAKE-OFF SPEED.	GEAR UP AFTER POSITIVELY AIRBORNE. DUCT ANGLE FOR DESIRED RATE OF CLIMB. DUCT SWITCH LOCKED IF AT 0° ANGLE.	CLIMB POWER SET.

SHORT TAKEOFF

HOLD TRANSITION ATTITUDE. BALANCE ENGINE POWER. BEGIN DUCT ROTATION.	CONTINUE DUCT ROTATION. ADJUST POWER AS NECESSARY TO MAINTAIN TRANSITION SCHEDULE.	DUCT ANGLE FOR DESIRED RATE OF CLIMB. DUCT SWITCH IN LOCKED POSITION IF AT 0° DUCT ANGLE. GEAR UP.	CLIMB POWER SET.



VERTICAL TAKEOFF

DUCT ANGLE AS REQUIRED.
RAISE COLLECTIVE LEVER (PITCH CONTROL).
ADVANCE THROTTLES TO TAKEOFF POWER(POWER CONTROL).
CHECK ENGINE INSTRUMENTS.

Figure 2-5

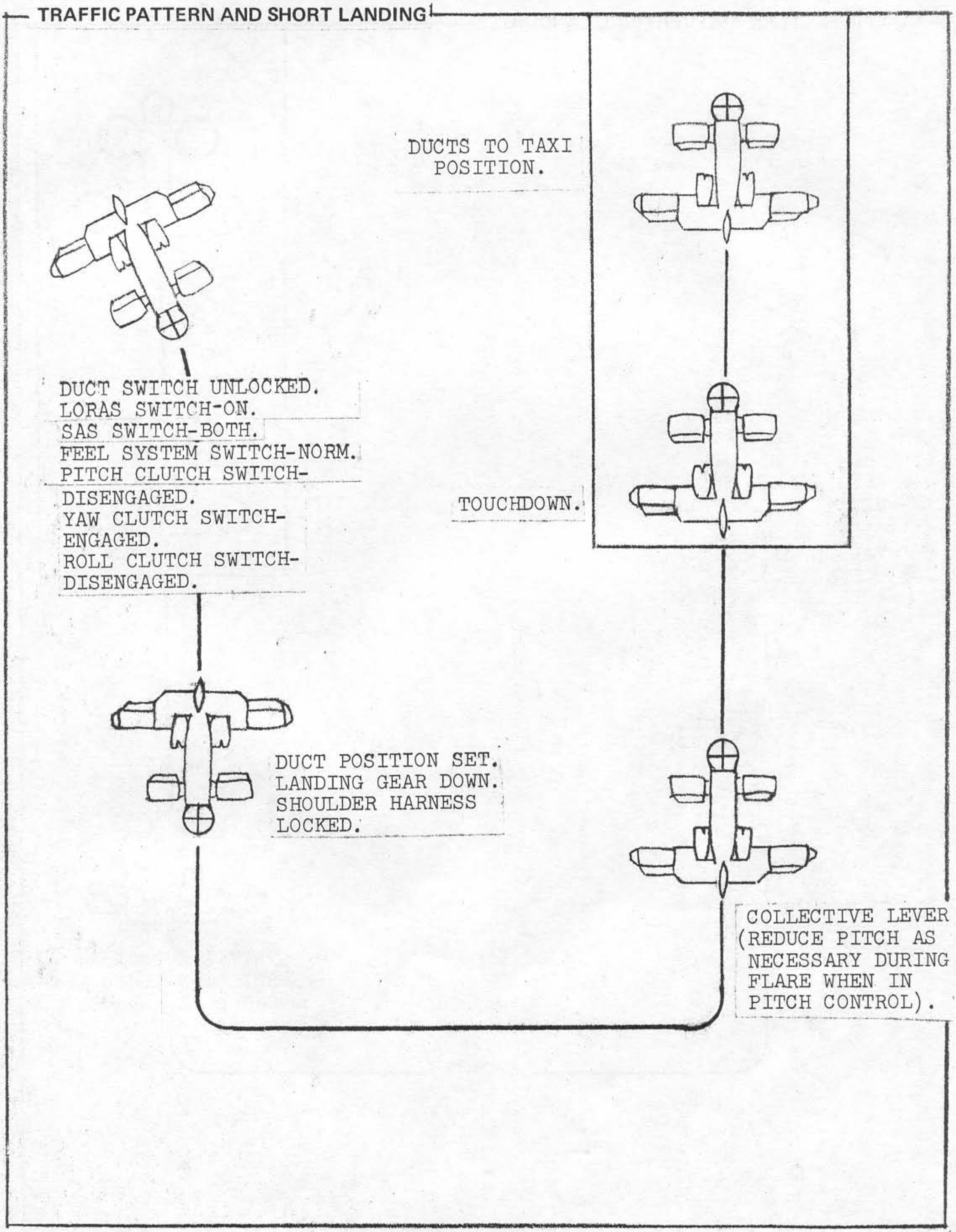


Figure 2-6(Sheet 1 of 2)

TRAFFIC PATTERN AND VERTICAL LANDING

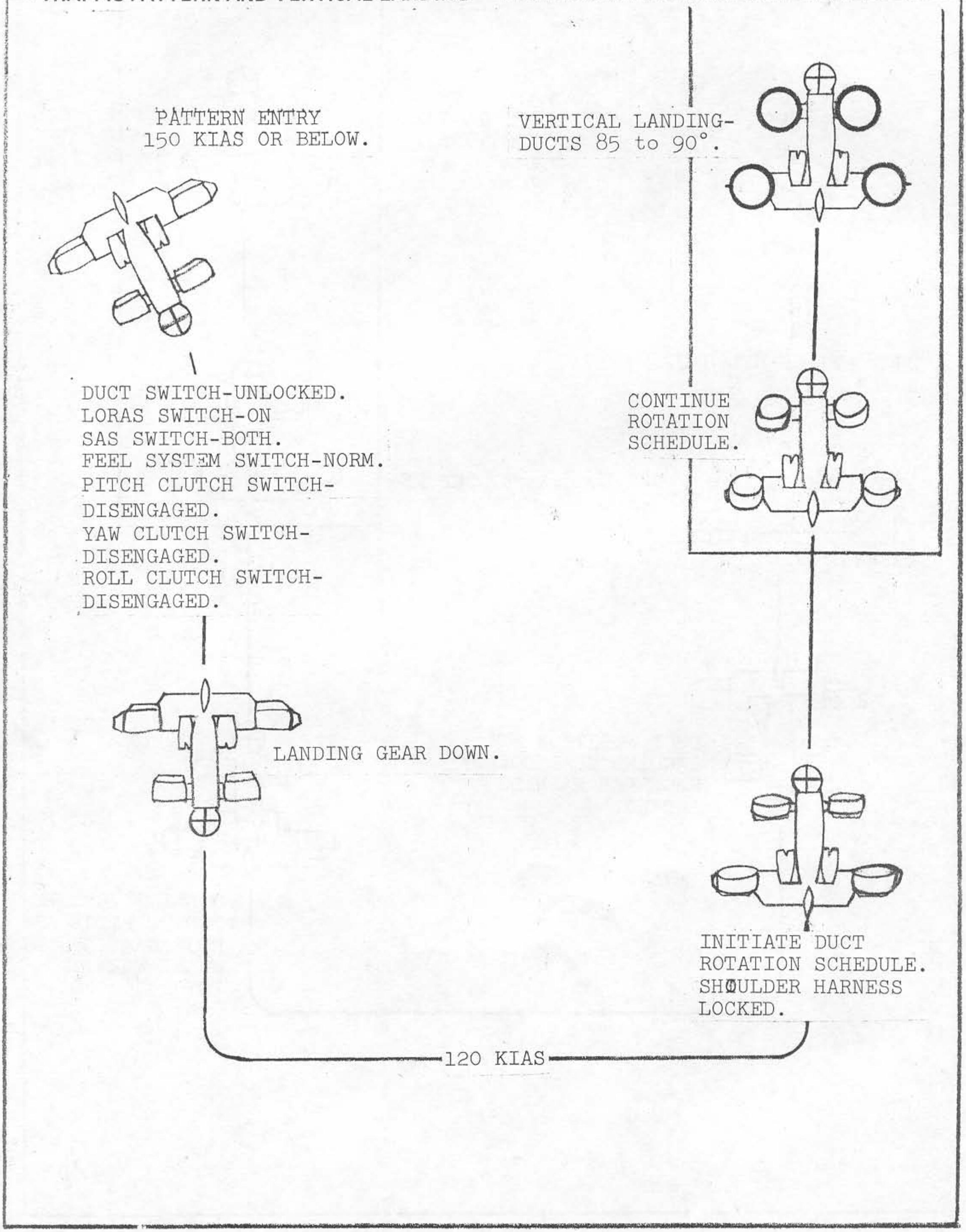


Figure 2-6(Sheet 2 of 2)

SECTION III - EMERGENCY PROCEDURES

TABLE OF CONTENTS

INTRODUCTION

This section describes the emergency procedures to be used in coping with various emergency situations which may be encountered during flight. The procedures are based on currently available information and take anticipated emergencies into account. The flight crew's thorough understanding of the aircraft systems will greatly assist in evaluating multiple emergencies and taking whatever action is required to keep control of the aircraft.

The following symbols are used throughout this section:

(P) - Pilot - designates action to be taken by the pilot in the right seat. (i.e. safety pilot in the VSS mode)

(CP) - Copilot - designates action to be taken by the pilot in the left seat. (i.e. evaluation pilot in the VSS mode)

* - Applies to pitch control mode only

** - Applies to power control mode only

Note

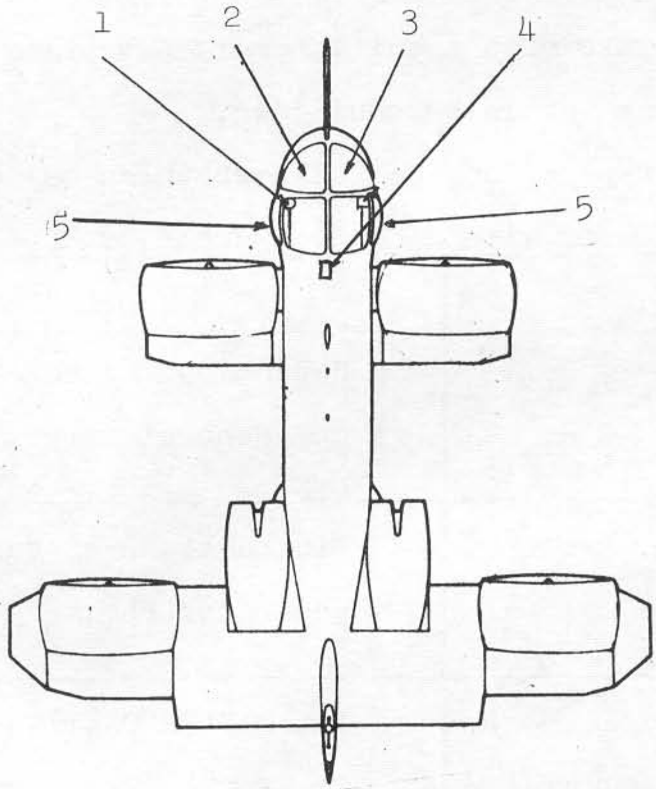
Pushing the master caution lights to extinguish a caution indication is standard procedure and will not be repeated in each emergency procedure.

See figure 3-1 for the location of emergency equipment.

ENGINE FAILURE

Because the engines and propellers are tied together by common shafting, the usual sensory indications of engine failure (such as yaw) will not be present in this aircraft. For this reason, it is important to monitor engine instruments at all times, especially during takeoff and landing. Engine shutdown has no effect on transmission or propeller operation.

EMERGENCY EQUIPMENT



1. HAND FIRE EXTINGUISHER
2. COPILOT EMERGENCY EXIT
3. PILOT EMERGENCY EXIT
4. FIRST AID KIT
5. CANOPY BREAKERS

Figure 3-1

Emergencies which involve engine malfunction or failure require that primary emphasis be placed on maintaining control of the aircraft. If the nature of a specific emergency permits enough time, the affected engine should be shut down.

The type of engine failures which may occur and the indications associated with each type are tabulated below:

MALFUNCTION	INDICATION
Engine Flameout	Rapid loss of exhaust temperature and gas generator rpm.
Erratic Operation	Fluctuations or surges in gas generator rpm.
High oil temperature and/or low oil pressure	1. MASTER CAUTION light on. 2. No. 1 (2, 3, or 4) ENG. OIL light on Annunciator Panel flashing. 3. Affected ENG. OIL pressure below 20 psi. 4. Affected ENG OIL temperature above 121°C.
Engine Stall Out and/or Foreign Object Damage	1. Sudden rise in exhaust temperature. 2. Loss of gas generator rpm and engine torque. 3. Auditory - loud rumble.
Broken transmission component	Overspeed governor shuts down engine. Do not attempt restart.

CONVENTIONAL OR SHORT TAKEOFF

During conventional and short takeoff configurations, engine failure will result in longer ground roll and reduced rate of climb after takeoff. During mission planning, determine the point at which takeoff will be aborted in case of emergency. Generally, if engine failure occurs before takeoff speed is obtained, the takeoff should be aborted.

Abort Procedure

1. *Collective lever - DOWN (P)

   **Throttles - RETARDED (P)

2. Brakes - AS DESIRED (P)

When the aircraft is under control, shut down the affected engine. If the possibility of fire exists, perform procedure under "Fires", this section.

If the engine fails after takeoff speed is reached, the pilot may elect to continue takeoff.

Takeoff Continued

1. * Collective lever - AS REQUIRED (P)

   - Adjust for necessary power and to prevent RPM from drooping below limits.

   ** Throttles - ADVANCE AS REQUIRED (P)

   - Advance all throttles as necessary to retain power for takeoff.

2. Affected engine throttle - CLOSED (P)

3. Affected engine fire handle - PULLED (CP)

   - Fire handle is pulled to actuate fuel shutoff valve as a precaution against fire. If the decision is made to abort takeoff after aircraft is airborne, reduce power with *collective lever or **throttles as necessary for a normal rate of descent to touchdown.

VERTICAL TAKEOFF

At high gross weights engine failure during vertical takeoff requires immediate recognition of power loss.

Hovering operations should be planned with not less than 1.05 thrust to weight ratio, available under prevailing atmospheric conditions, after one engine failure.

At lower weights single engine failure in the pitch control mode may not be detected as the governor will increase power on the remaining engines. In the power control mode a small throttle increase will be necessary to maintain altitude.

AIR STARTING

Use the following procedure to start an engine in flight:

1. Insure that throttle is - CLOSED (CP)
2. Fire Handle - IN (CP)
3. Air start/ground start switch - AIR START (CP)
4. Engine master/start switch - START (momentary) then released to ON (CP)

5. Throttle - IDLE at 21% rpm, then as desired (CP)
6. Air start/ground start switch (after starter dropout)-NORMAL(CP)

LANDING WITH ENGINE (S) OUT

ONE ENGINE OUT

Because the common shafting between engines and propellers distributes power equally to all propellers, landing with an engine out is accomplished by using 4-engine STOL land procedures. Duct angle should be approximately 30°. Unless operational necessity or emergency situation dictates, hover flight or vertical landings are not recommended.

TWO ENGINES OUT

Landing with two engines out is accomplished by using 4-engine STOL landing procedures. Duct angle should be 20°.

GO-AROUND

Determine necessity for go-around as far out on final approach as possible. Go-arounds are accomplished by:

1. * Collective lever - AS REQUIRED (P)
   ** Throttles - AS REQUIRED (P).
   • Monitor rpm.
2. Landing gear handle - AS REQUIRED (CP)

PROPELLER SYSTEM FAILURES

PROPELLER GOVERNOR FAILURES

Propeller governor failures are only applicable when operating in the power control mode. Various types of failures are tabulated below.

MALFUNCTION AND INDICATION	ACTION	CAPABILITY
Pressure reduction valve jammed in closed position. Propeller will underspeed and govern at slightly lower rpm.	Place propeller governor test switch in TEST #1 position and observe if original propeller rpm is restored. If not, place switch in TEST #2 position. Land as soon as possible.	Other system will govern after malfunctioning system has been dumped.
Pressure reduction valve jammed in open position. Propeller will overspeed and govern at slightly higher rpm.	Same as above.	Same as above.
Pressurizing valve jammed. Governing unstable - transients to high pitch. No. 1 PROP GOV and No. 2 Prop GOV caution lights may glow intermittently.	Same as above.	Same as above.
Rotary drive actuator jammed. No governing action.	Adjust power to maintain propeller rpm. Land as soon as possible.	Propellers will operate in fixed pitch.

MALFUNCTION AND INDICATION	ACTION	CAPABILITY
Low oil pressure in No. 1 governing system. No. 1 PROP. GOV caution light on.	Return to base.	No. 2 governing system assumes governing authority.
Low oil pressure in No. 2 governing system. No. 2 PROP GOV caution light on.	Return to base.	No. 1 governing system assumes governing authority.
Low oil pressure in both governing systems No. 1 and No. 2 PROP GOV caution lights on.	**WARNING** Rapid throttle action to reduce RPM's is imperative to prevent engine over-speed system from shutting down engines. **CAUTION** Do not dump either governor system. Make conventional landing at nearest available site.	Propeller blade drops to minimum angle. Conventional landing possible.

COLLECTIVE SYSTEM

CAUTION

When operating in the pitch control mode sufficient friction should be applied to the collective lever to prevent it dropping.

TRANSMISSION SYSTEM FAILURES

Normally the first indication of a malfunctioning gearbox will be an increase of temperature above the stabilized indication, therefore, monitoring the temperature and pressure indicators may reveal a malfunctioning gearbox before the applicable caution light illuminates.

Early detection and rapid action can possibly prevent further gearbox damage.

If a gearbox caution light illuminates, monitor the pressure and temperature of the affected gearbox for an abnormal condition. If an abnormal condition exists, reduce rpm and land immediately at the first satisfactory landing site. If a chip detector caution light illuminates, monitor the pressure and temperature of the associated gearbox, if normal, return to base, otherwise reduce rpm and land immediately at the first satisfactory landing site.

A duct position should be selected which will allow a minimum power landing to be made. A STOL landing at 30° duct angle is recommended if the landing surface will permit.

FIRES

Fire detection and extinguishing equipment is installed in each engine nacelle. The detection system illuminates the master fire warning lights and the associated engine fire handle when a fire is detected.

ENGINE FIRE ON GROUND

Request assistance from controlling agency.

1. Illuminated fire handle - PULL (CP)
2. Discharge switch - DISCH NO. 1 (CP)
3. All throttles - CLOSED (CP)
4. All master/start switches - OFF (CP)

Note

The light in the engine fire handle should go out when the fire is extinguished.

If fire persists:

5. Discharge switch - DISCH NO. 2 (CP)

If fire continues to persist:

6. Parking brakes - ON (CP)
7. Battery, generator, and external power switches - OFF (P)

Evacuate the aircraft.

ENGINE FIRE IN FLIGHT

When a fire warning is indicated, reduce engine power of the affected engine and check engine instruments for abnormal indications which may confirm that fire actually exists.

1. Throttle - CLOSED (CP)
2. Illuminated fire handle - PULL (CP)
3. Discharge switch - DISCH NO. 1 (CP)
4. Master/start switch - OFF (P)

If fire persists:

5. Discharge switch - DISCH NO. 2 (CP)

WARNING

Use DISCH NO. 2 switch position only when considered absolutely necessary. The operative engine on the same side as the affected engine will have no fire protection when both DISCH NO. 1 and DISCH NO. 2 have been activated.

CAUTION

An engine that has been shut down because of fire should not be restarted unless the pilot determines that the additional engine power is absolutely necessary.

If a two engine fire occurs simultaneously on the same side:

1. Applicable throttles - CLOSED (P)
2. Illuminated fire handles - PULL (CP)
3. Applicable master/start switches - OFF (CP)
4. First engine discharge switch - DISCH NO. 1 (CP)
5. Second engine discharge switch - DISCH NO. 2 (CP)

WARNING

> When using the fire extinguishers for both engines on the same side, only one shot is available for each engine.

FUSELAGE FIRE

If fire is in the cockpit area shut down the cockpit heating and ventilation system. Use the portable fire extinguisher to combat the fire. Direct the extinguishing agent as near the base of fire as possible. After fire is out, turn on fresh air supply fan and adjust cockpit side ventilators to rid the area of smoke and fumes.

Since it is impractical to reach the central or aft portion of the cargo area from the cockpit, the extent of a fire in this area should be rapidly appraised and the decision made to land immediately or abandon the aircraft (see "Crash Landing" and "Ejection" paragraphs, this section).

A fire immediately aft of the cockpit area may be reached by opening the zippered curtain and using the portable fire extinguisher.

WING FIRE

Because of the short configuration of the wing, (the nacelle areas occuping practically the full length of the wing) follow the procedure for "two engine fire simultaneously on the same side", this section. If fire cannot be arrested, make decision to land immediately or abandon the aircraft (see "Crash Landing" and "Ejection" paragraphs, this section).

ELECTRICAL FIRE

If smoke or fire is due to an electrical system malfunction, attempt to isolate the affected system. Turn off all systems not required for flight and turn them on again one at a time. When the defective component or system is determined, pull applicable system circuit breaker(s). If fire is present, use the portable fire extinguisher as necessary. After fire is extinguished eliminate smoke and fumes in accordance with the following procedure.

Note

All secondary loads may be immediately dropped by placing the SEC load switch in CUT OUT position.

SMOKE OR FUME ELIMINATION

1. Ventilation system - ON (CP).
2. Cockpit side ventilators - ADJUST FOR MAXIMUM VENTILATION (P, CP).
3. Open zippered curtain to provide an increased area for smoke and fume dissapation.
4. Fresh air supply fans -ON (P,CP)

EJECTION

Under conditions where ejection must be made without hesitation, grasp the face curtain ejection control handle and pull down steadily until seat ejects. If acceleration loads do not permit the face curtain control handle to be pulled, pull the secondary ejection control handle located between the legs.

Under more favorable conditions requiring ejection, where the pilot has control of the airplane, the following procedure should be used.

1. Prior to ejecting, inverted and severe yaw positions should be corrected and every attempt should be made to reduce speed below 250 KIAS.
2. If time permits, contact controlling agency and give nature of difficulty, position, and intentions. If unable to contact controlling agency, transmit MAYDAY.
3. Place intertia reel control lever in LOCKED position.
4. Sit erect in seat, head firmly against headrest, feet on rudder pedals.
5. Pull face curtain or secondary ejection control handle as desired.
   - Grasp face curtain handle with both hands, elbows in, thumbs outboard. Pull face curtain out and downward with one firm continuous motion until seat fires.
   - If the secondary handle is used, grasp handle with either hand, grasp wrist with other hand, and pull handle up sharply. Take particular care to hold elbows in and keep head and shoulders back against seat.

   In the event seat separation does not occur immediately after ejection, pull the harness, release handle, push away from the seat and pull the manual ripcord ("D" ring).

LANDING EMERGENCIES

In emergencies involving failure of landing gear to extend, flat tires, and landing on unprepared surfaces, utilize the vertical landing capability of the aircraft.

FAILURE OF LANDING GEAR TO EXTEND

1. Landing gear fails to extend (doors not open)
   - Recycle gear as required - request "outside observer" assistance if available.
   - If gear still full up - perform "pullouts" in attempt to break gear loose.
   - If gear still full up - actuate emergency system.
   - If gear still up - land vertically on hard surface if available.

2. Nose or main gear partially extended.
   - Recycle gear as required - request "outside observer" assistance.
   - If gear still partially extended - perform yaw or translations in the appropriate direction in attempt to lock gear down.
   - If gear still partially extended - actuate emergency system.
   - If gear still partially extended -

     a) Nose gear down - main gear up - land vertically on hard surface.

     b) Nose gear up - main gear down - land vertically on hard surface.

     c) Nose gear up or down - one main gear up, other down - retract gear and land vertically on hard surface.

3. Nose or main gear down but indicators show "not locked."
   - Recycle gear as required - request "outside observer" assistance.
   - If any gear still does not indicate down-yaw, translate or perform pullouts in attempt to obtain locked indication.
   - If any gear still does not indicate down-actuate emergency system.
   - If any gear still does not indicate down - land vertically on hard surface.

EMERGENCY LANDING GEAR OPERATION

In the event the landing gear cannot be extended and locked by normal means, push the EMERG DOWN finger release downward and push the landing gear handle downward to the bottom of its travel.

EMERGENCY VERTICAL LANDING

Perform a prelanding check for vertical landing.

Establish a minimum rate descent to touchdown. Shut off the combustion heater to reduce possibility of fire.

After touchdown:

1. * Collective lever - FULL DOWN (P)
2. Throttles - CLOSED (P)
3. All master/start switches - OFF (P)

Evacuate aircraft (refer to "Emergency Entrance and Exit," this section). The pilot and copilot should pull the ejection seat safety handle out before leaving cockpit.

CRASH LANDING

If time permits, accomplish the following:

1. Heat/vent switch - OFF (CP)
2. Non-essential electrical equipment - OFF (CP)

   As soon as possible after contact:

3. Pull all fire handles (CP)
4. Battery and generator switches - OFF (CP)
5. Abandon the aircraft.

DITCHING

Specific ditching characteristics of the aircraft are not known. If circumstances permit, vertical landing procedures are recommended.

EMERGENCY ENTRANCE

Emergency entrance may be made to the cockpit area by pushing and turning the external canopy handles in the direction indicated on each side of the fuselage. The handles are further identified by the word "RESCUE" painted on arrows pointing to the handles.

EMERGENCY EXIT

With the ducts horizontal or vertical, the canopy can be released by pulling the emergency release handle and pushing the canopy outboard from the center hinges. With the ducts in an intermediate position this will not be possible because the ducts will not allow the canopy to be pushed outboard. In this case it will be necessary to first pull the emergency release handle, push canopy until canopy hits ducts,then pull the normal canopy handle.The canopy is then disconnected from the aircraft but must be pushed free by the occupant. In the event the canopy jams,use the canopy breakers.

FUEL JETTISONING

Jettisoning of fuel is recommended only when a reduction of the gross weight of the aircraft is necessary to obtain required safe performance. The overhead fuel dump handle should be pulled to the full aft position. Fuel is dumped at the rate of 455 lbs/min. up to a minimum remaining fuel of 680 lbs. When the required amount of fuel has been dumped, the fuel dump handle should be pushed forward to the closed position. Observe caution in landing, since the fuel dump nozzle remains in the extended position, and cannot be retracted in flight.

FUEL SYSTEM FAILURE

FUEL BOOST PUMP FAILURE

Fuel boost pump failure is indicated by illumination of the FUEL PUMP caution light. Since the engines will automatically go on suction feed if pump failure occurs, no further action is required except to check if the FUEL BOOST circuit breaker is out. If it is not out, it should be pulled out since failure could have occurred from a sheared shaft and the motor portion of the pump may still be running.

ELECTRICAL POWER SYSTEM FAILURES

MAIN GENERATOR FAILURE

If the main generator fails, as indicated by the MAIN GEN caution light, the emergency generator system will be automatically activated. The output of the generator is unregulated, however, the voltage and frequency between 2350 and 2650 rpm is sufficient for aircraft equipment use. When operating on the main generator care should be taken to insure that rpm does not drop below 2350, as this will allow the emergency generator to drop off the line. Failure of the main generator automatically reduces the electrical load by dropping the secondary bus loads. Return to base and land.

If the CSD HOT caution light illuminates land as soon as possible.

EMERGENCY GENERATOR FAILURE

Failure of the emergency generator while the main generator is operating is indicated by the EMERG GEN caution light. Check to insure that propeller rpm is above 2350 and return to base and land.

EMERGENCY GENERATOR FAILURE WHILE OPERATING ON EMERGENCY GENERATOR

If the emergency generator should fail while delivering power to the aircraft, the aircraft battery will provide power for a limited time for the following essential systems:

1. Caution lights
2. Console flood lights
3. Emergency landing gear extension
4. Master governor test
5. Fire detectors
6. Pitch backup spring
7. Feel System
8. Duct rotation
9. Fire extinguishers
10. VHF/ICS
11. Fresh air supply fans.

Return to base and land immediately.

NO. 2 TRANSFORMER RECTIFIER FAILURE WHILE ON EMERGENCY GENERATOR

Failure of the No. 2 transformer rectifier while operating on the emergency generator is indicated by illumination of the No. 2 RECT caution light. Initiate operation of the No. 1 transformer rectifier unit by placing the #1 RECT RESET switch in RESET position. Return to base as soon as possible.

HYDRAULIC POWER SYSTEM FAILURES

LOSS OF NO. 1 HYDRAULIC SYSTEM

System deterioration or failure is indicated by one or more of the following:

#1 HYD PRESS caution light on, low pressure on #1 hydraulic pressure gauge, HYD RES #1 LOW caution light on, low fluid level on #1 reservoir gauge. Below 200 knots the SAS caution light will come on. Normal operation is provided by the #2 hydraulic system with reduced power and 1/2 damping control. Switch SAS to #2 position and return to base and land.

LOSS OF NO. 2 HYDRAULIC SYSTEM

System deterioration or failure is indicated by one or more of the following:

#2 HYD PRESS caution light on, low pressure on #2 hydraulic pressure gauge, HYD RES #2 LOW caution light on, low fluid level on #2 reservoir gauge. Below 200 knots the SAS caution light will come on. The feel and trim system failure caused by the lack of hydraulic pressure will be detected by the feel and trim monitor and the system automatically disengaged. Initiate the following procedure and return to base and land using a 30° STOL approach if conditions allow:

1. FEEL system switch - OFF (P)
2. SAS channel selector switch - #1 (P)
3. Initiate emergency landing gear extension (CP)

LOSS OF BOTH HYDRAULIC SYSTEMS

Failure of both hydraulic systems constitutes a critical emergency since loss of control of the flight control system occurs. Momentary attitude control may be available, however, depending upon how rapidly the hydraulic pressure decays. If control response is present, attempt to put the aircraft in a desirable ejection attitude, reduce power and eject, otherwise eject immediately. Failure of both hydraulic systems is indicated by two or more of the following:

#1 and #2 HYD PRESS caution lights on, low pressure on #1 and #2 hydraulic pressure gauges, HYD RES #1 and #2 LOW caution lights on, low fluid level on #1 and #2 reservoir gauges.

FLIGHT CONTROL SYSTEM AND STABILIZATION FAILURES

DUCT ROTATION SYSTEM FAILURE

Failure of the duct rotation system when duct rotation is initiated is indicated by the DUCT STOP caution light. No further attempt should be made to rotate the ducts when the DUCT STOP light is on as this is indicative of an over-torque condition in the control mixing box. Press the duct stop reset switch to determine if the DUCT STOP light extinguishes. If it does, it indicates relief of the over- torque condition, however, do not rotate the ducts. Land as soon as possible with ducts in existing position.

STABILITY AUGMENTATION SYSTEM FAILURES

Fail safe features are incorporated in the pitch, roll and yaw axes of the SAS such that a single malfunction or failure in any axis of the system will not affect safety of flight. A malfunction or failure of one channel in the pitch, roll, or yaw axes will not cause the other channel of the SAS to shut down or be rendered inoperative. Impairment of the SAS function is indicated by the SAS caution light.

The caution light will illuminate anytime there is a mismatch in any of the three axes actuators. When the malfunction is temporary, the caution light is extinguishable by the SAS RESET switch.

The aircraft is capable of being flown on half SAS authority or with SAS inoperative. A SAS selector switch is used to turn the SAS system on, off, or select channel #1 or #2. SAS cut out switches on each stick grip turn SAS off as long as the switch is depressed.

Possible types of SAS failures are listed below:

Malfunction/Indication	Action	Capability
SAS out on one system	Land as soon as possible	Operation at 1/2 SAS
One SAS hardover SAS caution light ON Aircraft out of trim	Search for good channel or cut out both channels Return to base	Operation without SAS or 1/2 SAS
Both SAS systems inoperative SAS light ON Decreased stability	SAS switch - OFF 30° STOL landing	Operation without SAS

FEEL AND TRIM SYSTEM FAILURES

The artificial feel and trim system operates under an electro-hydraulic normal or primary operating mode and under a mechanical backup mode. The primary system uses the variable stability system position actuators for trim and feel while the mechanical system uses springs and clutches.

The system contains a standby battery, which allows it to operate for periods of at least sixty seconds without power from the aircraft primary electrical system.

A feel and trim monitor circuit is provided which monitors stick force, stick position and servo position. If an inconsistantcy occurs, it will disengage the feel and trim system. In this instance the aircraft can be controlled, but with unharmonious control forces (high breakout and no gradient). The pitch and roll springs may be used to obtain a positive roll force gradient. The FEEL SYS caution light and an audio (headset) alarm are provided to both pilots to indicate that the system has failed. The feel and trim system may be turned off manually by means of the console feel system switches or the FEEL CUTOFF switch on the right hand control stick.

When resetting the feel and trim system in flight, it is necessary to trim the aircraft for hands off flight. Press the FEEL SYS switch to the RESET position until the caution light extinguishes, then place the switch to the ON position. Control forces should not be applied to the control stick during the reset procedure.

If it is necessary to land with the feel and trim system off, return to base and make a 30° duct angle STOL landing.

Flying characteristics for specific failures are as follows:

Hover and transition (to 150 knots)

In hovering mode of flight no single failure or combination of an overt failure and a hidden failure is serious enough to degrade the aircraft handling qualities below acceptable limits.

All of the various electronic and hydraulic failure possibilities are classified as follows:

1. Hardover control
2. Limp control (feel forces zero)
3. Small amplitude high frequency oscillation
4. Frozen control (up to load relief valve setting)
5. Excessive feel gradient
6. Sluggish response

The most serious type of failure is one which causes a hardover control motion. When this happens, the excessive hydraulic pressure which is trying to build up across the piston of the failed feel axis is relieved through a dual relief valve so that the maximum stick force is about 18 pounds in pitch and about 12 pounds in roll.

The frozen control and excessive feel gradient failures produce the same action except that the pilot's motion of the stick produces sufficient hydraulic pressure to open the relief valves. In effect, he must now fly through a greater amount of breakout force.

The majority of the above failures will be detected by the feel and trim monitor which will immediately shut down the feel and trim system.

Level Flight Mode (above 150 knots)

Above 150 knots, the feel and trim system should be switched off, and the backup springs engaged.

GENERAL PRECAUTIONARY APPROACH PROCEDURE

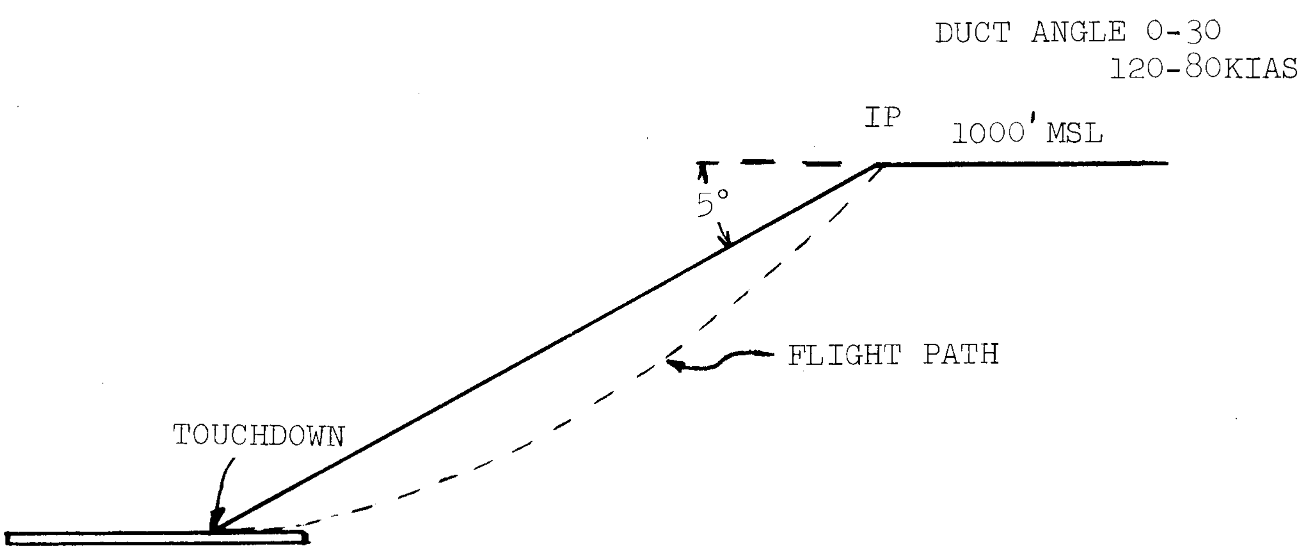
In the event of failures which indicate an impending loss of control, the following procedure is recommended:

1. Set ducts to 30° to 0° range (if rotation system can be operated safely.)
2. Fly to the initial point (IP) on the most suitable runway. Pilot judgment will prevail on choice of runway. Factors such as winds, braking action, traffic and estimated time available before loss of control must be considered.
3. The initial point is defined as a point at 1000 ft MSL on a 5°

glide slope to the touchdown point. Touchdown should be planned for a suitable distance from the threshold.

4. Upon approach to the IP, the pilot should decide if control of the aircraft will remain for one minute. If there are indications that control cannot be maintained for one minute (e.g. stiffening controls, zero hydraulic quantity in both systems, high gearbox lube oil temperatures accompanied by torque pulsing, zero oil pressure, etc.) he should eject.

5. If the pilot feels that a safe landing can be made, he will perform a maneuver as sketched below. Power for level flight should be held throughout the maneuver, unless adjustment is required to assure a safe landing.



6. When firmly on the runway, reduce power and rotate ducts upward to reduce speed.

7. In the event that ducts cannot be rotated to the 0-30 degree range, a maximum rate of descent of 800 FPM should be used below 1000 ft.

SECTION IV - AUXILIARY EQUIPMENT

TABLE OF CONTENTS

GB

HEATING AND VENTILATION

The heating and ventilation system (figure 4-1), provides cockpit heating and ventilation and windshield defogging. Controls are as follows:

Index and Figure No.	Nomenclature	Function
29, figure 1-4	Cabin heat/vent selector switch	START - Activates the fuel shutoff valve, ignitor, and blower. HI - Provides high heat range. INT/MED - Provides medium heat range. BLOWER - Activates ventilation blower. OFF - Turns off heater/ ventilation system.
10, figure 1-4	Defog damper	Controls flow of air to windshield for defogging.
13, figure 1-4	Cockpit heat/ air damper	Controls flow of heating or ventilation air in cockpit.
4, figure 1-8 and left of main instrument panel	Floor fan switches (2)	ON - Turns on floor fans. OFF - Turns off floor fans.
40, figure 1-4	Fresh air supply fan switches (2)	FAN - Turns on pilot's fan. PILOT - Turns off pilot's fan. FAN - Turns on copilot's fan. COPILOT - Turns off copilot's fan.

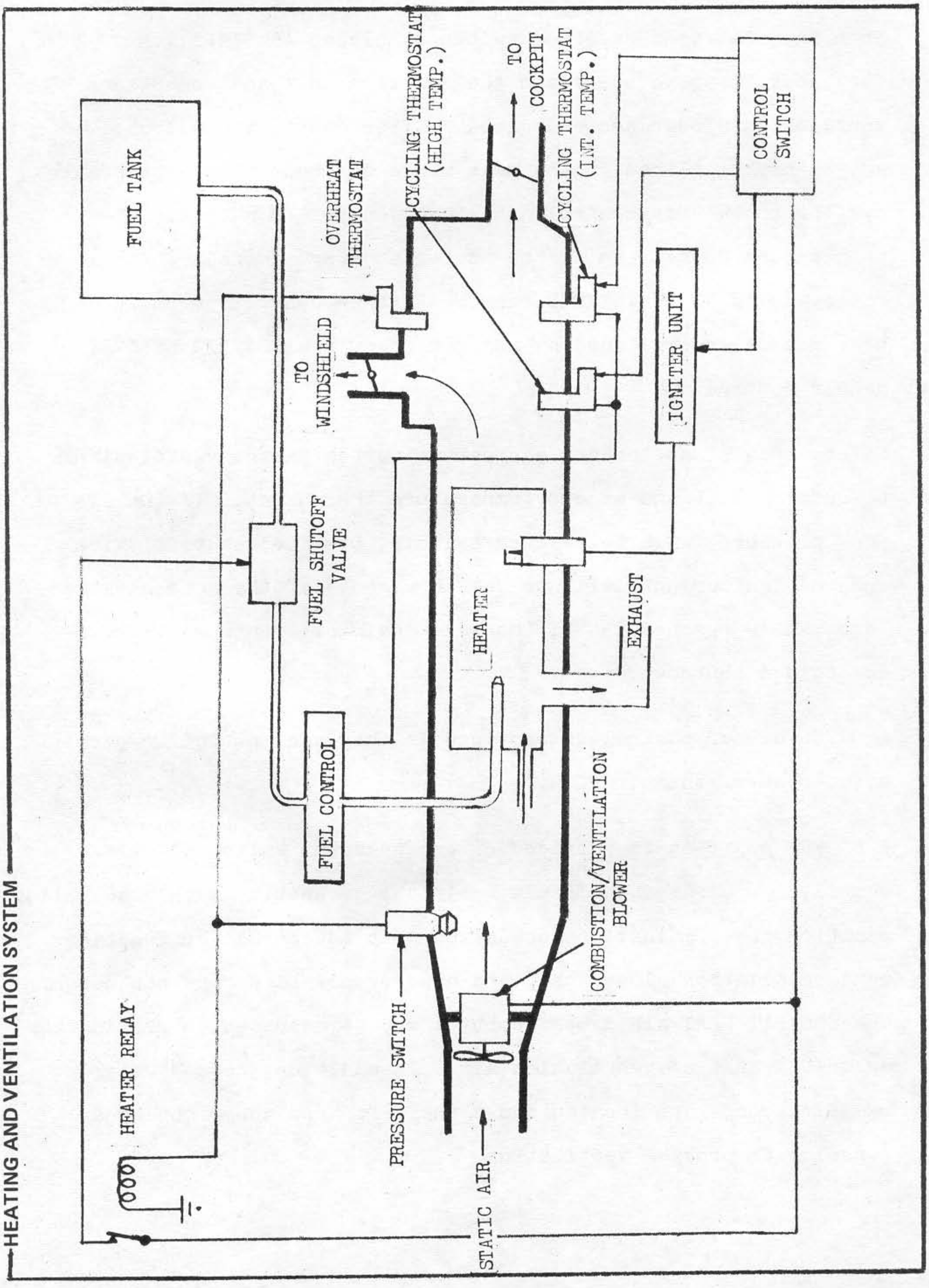

HEATING AND VENTILATION SYSTEM
FUEL TANK
OVERHEAT THERMOSTAT
CYCLING THERMOSTAT (HIGH TEMP.)
TO COCKPIT
CYCLING THERMOSTAT (INT. TEMP.)
CONTROL SWITCH
TO WINDSHIELD
IGNITER UNIT
FUEL SHUTOFF VALVE
HEATER
EXHAUST
FUEL CONTROL
COMBUSTION/VENTILATION BLOWER
HEATER RELAY
PRESSURE SWITCH
STATIC AIR

Figure 4-1

When the heat/vent selector switch is placed in START, the fuel shutoff valve opens and the ignition unit and combustion/ventilation blower are energized. After start, the selector switch may be placed in the heat range desired. The appropriate cycling thermostat controls the fuel control to maintain the temperature downstream of the heater at approximately 250°F in HI range and 180°F in INT/MED range. Further control of cockpit heat may be accomplished by adjustment of the COCKPIT HEAT/AIR damper control.

Safety provisions include a pressure switch in the ventilation/combustion duct and an overtemperature thermostat. If the air flow pressure falls below a safe limit, the fuel shutoff valve and the igniter unit will be de-energized. If the heater outlet temperature reaches 350°F, the same chain of events will occur to achieve shutdown.

A DEFOG damper control is provided in the defog outlet to permit adjustment of the air flow.

A BLOWER position is provided on the selector switch to allow ventilation air to be circulated in the cockpit. In this selected position the combination combustion/ventilation blower functions as a ventilation blower only and heater operation does not occur. The COCKPIT HEAT/AIR damper control may be adjusted to provide the desired amount of ventilation air. In addition, two adjustable ram air scoops are located above the left hand and right hand consoles to provide ventilation.

Two floor mounted fans are also provided on the pilot and co-pilot sides to further enhance cockpit ventilation.

In addition, a fresh air supply system is provided to direct air to the flight crew at approximately head level.

ICE PROTECTION

ENGINE ANTI-ICING

Engine compressor bleed air prevents icing of the engine air inlet ducts. Control for the system is as follows:

Index and Figure No.	Nomenclature	Function
27, figure 1-3	Engine master/start switches (4)	OFF-Activates the anti-icing system. ON - Deactivates the anti-icing system.

The anti-icing air valve controls the flow of anti-icing air from the 10th stage of the engine compressor to the internal anti-icing air passages. The air valve for each engine is actuated by placing the related engine master/start switch in OFF position. In this position the switch removes 28 volts dc from the air valve solenoid. De-energization of the solenoid places the air valve in the "ON" position. This is a fail-safe circuit which ensures a flow of anti-icing air in the event of an electrical power failure.

PITOT ANTI-ICING

The pitot anti-icing system prevents ice from forming on the pitot head during flight under icing conditions. The pitot head contains a heater which is powered from the 115-volt dc power source. An ON/OFF switch on the center console controls the pitot heater.

LIGHTING SYSTEM

The lighting system consists of groups of exterior and interior lights and their associated controls.

EXTERIOR LIGHTS

The exterior lighting system consists of navigation, anti-collision, and landing lights all of which are controlled from the center console.

NAVIGATION LIGHTS

The navigation lights consist of a red light on the left wing tip, a green light on the right wing tip, and a white light on the tail fairing. All of the lights function in a steady state.

ANTI-COLLISION LIGHTS

The anti-collision lights are located on the top of the vertical stabilizer and the lower mid-fuselage section. The two lights consist of a lamp rotating mechanism contained within a red lens assembly. When turned on from the center console switch, the lamps illuminate and rotate.

LANDING/HOVER LIGHT

The landing/hover light consists of a positionable light assembly located on the lower-forward fuselage section. A filament switch controls electrical power to the lamp and a position switch controls the direction of the light beam. This enables the light position to be varied as desired during landing, hover and taxi operations. The filament switch also provides a RETRACT position which automatically centers the lights to the "stow" position.

INTERIOR LIGHTS

The interior lights consist of console lights, flight instrument lights, and non-flight instrument lights. Controls for the lights are located on the center console. Console lights and instrument lights are controlled by individual variable step transformers. Rotating the controls clockwise from OFF applies electrical power to the applicable lamps causing them to illuminate. Lamp intensity increases as the controls are rotated toward BRT. The console flood lights are controlled by a 3-position switch. Bright, medium and dim positions are provided to allow selection of the desired amount of illumination.

Controls and indicators for the lighting system are as follows:

Index and Figure No.	Nomenclature	Function
26, figure 1-4	Navigation lights switch	NAV - turns on navigational lights. OFF - turns off navigational lights.
26, figure 1-4	Anti-collision light switch	ANT COLL - illuminates and rotates anti-collision lights. OFF - turns off anti-collision lights.
7, figure 1-4	Landing/hover light filament switch	ON - illuminates filament of landing/hover light. OFF - turns off filament of landing/hover light. RETRACT - retracts landing/hover light to stow position.

Index and Figure No.	Nomenclature	Function
7, figure 1-4	Landing/hover light positioning switch	L - turns light to the left. R - turns light to the right.
21, figure 1-4	Console flood light switch	BRT - Provides bright illumination from console flood lights. DIM - Provides dim illumination from console flood lights. MED - Provides medium illumination from console flood lights.
21, figure 1-4	Console lights brilliance control	From OFF to BRT - permits adjusting light intensity to desired level.
21, figure 1-4	Flight instrument lights brilliance control	From OFF to BRT - permits adjusting light intensity to desired level.
21, figure 1-4	Non-flight instrument lights brilliance control	From OFF to BRT - permits adjusting light intensity to desired level.

COMMUNICATION AND NAVIGATION SYSTEMS

The aircraft communication system provides intercommunication between the crew, and two-way voice communication between the aircraft and a ground station or between aircraft.The system consists of an intercommunication system, a UHF receiver/ transmitter system and a VHF transceiver. Navigation systems include a TACAN navigation set, an automatic direction finder, a radar altimeter, and a compass and gyro system. For a complete identification of communication and navigation systems, refer to figure 4-2. For antenna locations, see figure 4-3.

INTERCOMMUNICATION SYSTEM

The intercommunication system provides control of all audio communication within the aircraft. The system consists of microphone switches and interphone control stations within the aircraft. Three-position microphone switches for the pilot and copilot are located on both control sticks. In addition, pilot and copilot switches are located on the left console and right instrumentation panel. A two position microphone switch is provided in the intercom cordage for the remaining intercom station. Cockpit intercom stations are located on the left console for the copilot and on the right console for the pilot. A third intercom station is located on the right side of cargo area opposite the fuel tank.

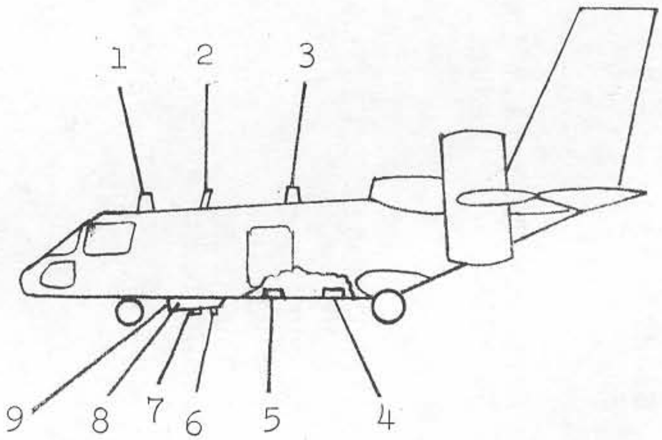
The three-position microphone trigger switches on the control stick grips are used by the pilot and copilot to control voice transmission to the intercom/VHF radio, and the UHF radio.

COMMUNICATIONS AND ASSOCIATED ELECTRONIC EQUIPMENT

TYPE	DESIGNATION	FUNCTION	PRIMARY OPERATOR	RANGE	LOCATION OF CONTROLS
INTERCOMMUNICATION SYSTEM	AN/AIC-14	CREW INTERCOMMUNICATION	ALL CREW MEMBERS	WITHIN THE AIRCRAFT	LH CONSOLE, RH CONSOLE, REAR CARGO COMPARTMENT
UHF COMMUNICATION	AN/ARC-51A	TWO-WAY VOICE COMMUNICATIONS IN THE FREQUENCY RANGE OF 225 mc to 399.9 mc.	PILOT AND COPILOT	LINE OF SIGHT	CENTER CONSOLE
VHF TRANSCEIVER	BE1-990	TWO-WAY COMMUNICATIONS IN THE FREQUENCY RANGE OF 118.0 TO 126.9 mc	PILOT AND COPILOT	APPROXIMATELY 50 MILES	MAIN INSTRUMENT PANEL (RH SIDE)
AUTOMATIC DIRECTION FINDER (ADF)	DF-203, COLLINS	PROVIDES VISUAL INDICATION OF BEARING OF RADIO TRANSMITTERS IN THE FREQUENCY RANGE OF 0.19 mc to 1.75 mc.	PILOT AND COPILOT	APPROXIMATELY 100 MILES, DEPENDING ON TIME OF DAY AND WEATHER CONDITIONS	CENTER CONSOLE
TAGAN NAVIGATION SET	AN/ARN-52(V)	PROVIDES BEARING AND SLANT-RANGE DISTANCE INFORMATION FROM FIXED-FREQUENCY RADIO TRANSMITTERS	PILOT AND COPILOT	LINE OF SIGHT	CENTER CONSOLE
GYRO COMPASS	MA-1	PROVIDES VISUAL HEADING INDICATION	PILOT AND COPILOT		CENTER CONSOLE
RADAR ALTIMETER	YG7091B	PROVIDES VISUAL INDICATION OF AIRCRAFT HEIGHT ABOVE TERRAIN	PILOT AND COPILOT	5,000 FEET	MAIN INSTRUMENT PANEL

FIGURE 4-2

ANTENNA LOCATION



INDEX	ANTENNA	SYSTEM
1	37R-2U	BEI-990 VHF RADIO
2	AT-840	AN/ARC-51 UHF RADIO
3	AT-741/A	AN/ARN-52(V) TACAN RADIO
4	DLG 81A	YG7091B RADAR ALTIMETER
5	DLG 81A	YG7091B RADAR ALTIMETER
6	AT-741/A	AN/ARN-52(V) TACAN RADIO
7	AT-840	AN/ARC-51 UHF RADIO
8	437M-1*	DF-203 AUTOMATIC DIRECTION FINDER
9	137A-4	DF-203 AUTOMATIC DIRECTION FINDER

* THE 437M-1 ANTENNA IS CONTAINED WITHIN THE HOUSING OF THE 137A-4 ANTENNA.

Figure 4-3

The switches are spring loaded to the off position. Squeezing the lower portion provides UHF radio transmission. Squeezing the upper portion of the switch provides both VHF transmission and intercom transmission.

Each of the intercom control stations in the cockpit includes an amplifier selector switch, a volume control, and a microphone selector switch. In the event of a malfunction of a stick trigger switch the INTERCOM microphone switches may be used. The amplifier selector switch is normally positioned in NORM. Should a malfunction occur in one or the other amplifiers, two alternate positions are provided. Should total amplifier malfunction occur the EMERG position can be selected, however, no further intercom or vhf operation is possible but operation of the UHF ratio system is still available. The volume control adjusts the audio output to the desired level.

The radio selector control operates in conjunction with the intercom system. It provides UHF, VHF, TACAN, and ADF on/off switches to permit these radio systems to be monitored as desired.

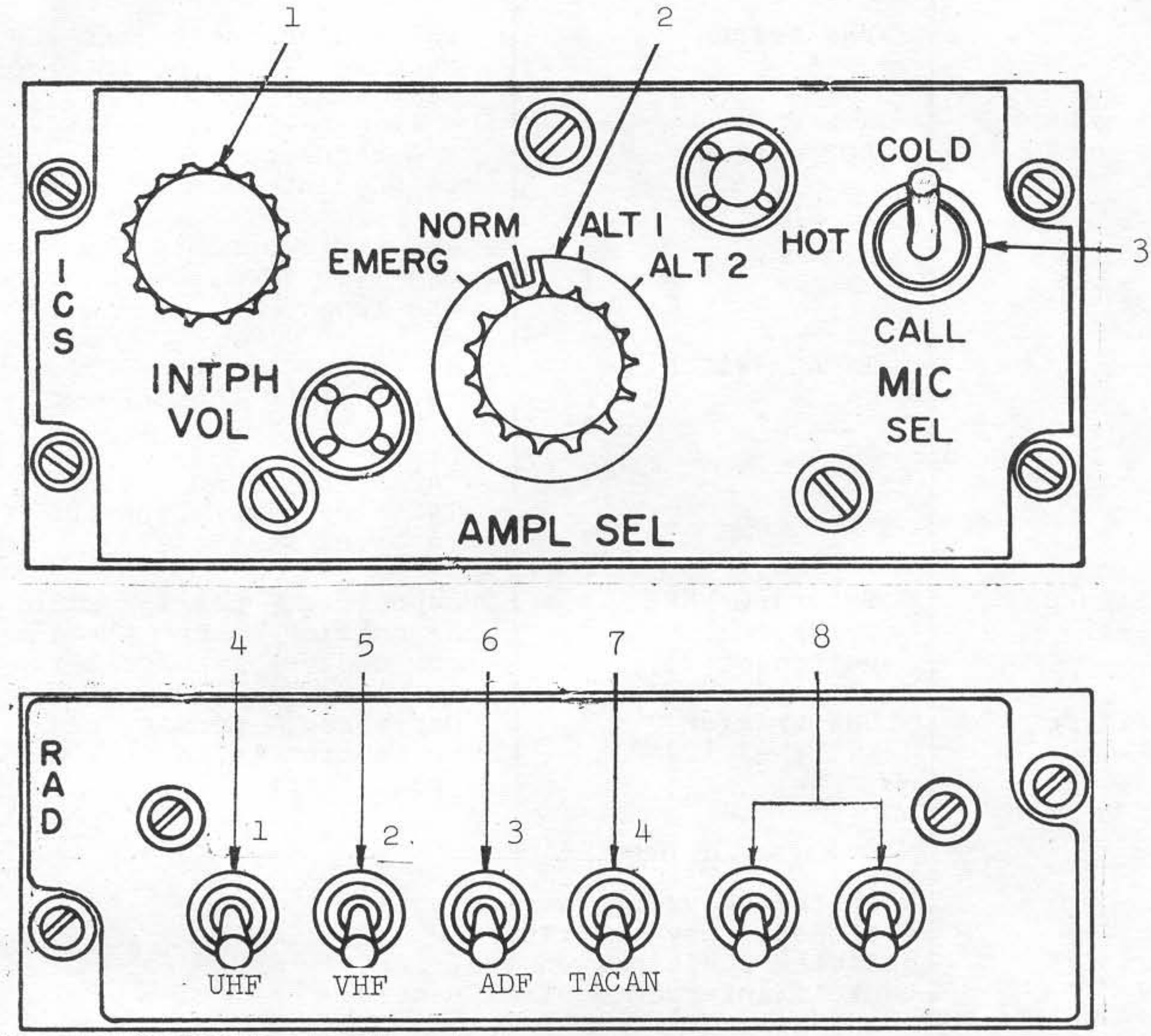
The interphone station located in the cargo area may be used for ground operations. Only a volume control is provided at this station. The microphone switch is incorporated into the 35 foot long cordage which is provided for ground operations.

For intercommunication system operating instructions refer to NAVWEPS 16-30AIC14-1.

Controls for the intercommuncation system are as follows:

Index and Figure No.	Nomenclature	Function
figure 4-4	Cockpit intercom control panels	Control audio communications within the aircraft.
	Intercom volume control	Adjusts headset audio level
	Amplifier selector switch	EMERG - Permits limited receiver, transmitter operation in the event of a dc-power failure.
		NORM - Permits the intercom and isolation amplifiers to operate in their normal manner.
		ALT 1 - Permits the isolation amplifier to amplify signals if the intercom amplifier malfunctions.
		ALT 2 - Permits the intercom amplifier to amplify signals if the isolation amplifier malfunctions.
	Mike selector switch	COLD - De-energizes the microphone.
		HOT - Not used.
		CALL - Permits intercom signals to be heard at all stations.
figure 4-4	Radio selector control panel	Connects the selected radio system to the intercom stations.
	UHF switch	1 - Connects the UHF receiver to the intercom stations.
		UHF - Disconnects the UHF receiver from the intercom stations.
	VHF switch	2 - Connects the VHF receiver to the intercom stations.

INTERCOM AND RADIO SELECTOR CONTROLS



INDEX NO.	NOMENCLATURE
1	VOLUME CONTROL
2	AMPLIFIER SELECTOR SWITCH
3	MICROPHONE SELECTOR SWITCH
4	UHF SWITCH
5	VHF SWITCH
6	ADF SWITCH
7	TACAN SWITCH
8	SPARE SWITCHES

Figure 4-4

Index and Figure No.	Nomenclature	Function
	VHF switch	VHF - disconnects the VHF receiver from the intercom stations.
	ADF switch	3 - connects the ADF receiver to the intercom stations.
		ADF - disconnects the ADF receiver from the intercom stations.
	TACAN switch	4 - connects the TACAN receiver to the intercom stations.
		TACAN - disconnects the TACAN receiver from the intercom stations.
figure 1-17	Intercom/VHF trigger switches (2)	Depressed - permits pilot or copilot to key the intercom and VHF transmitter.
figure 1-17	UHF trigger switches (2)	Depressed - permits pilot or copilot to key the UHF transmitter.

Note

When the above trigger switches are used, they override the HOT and CALL positions on the cockpit intercom control panels.

Index and Figure No.	Nomenclature	Function
11, figure 1-5 5, figure 1-8	Intercom/radio switches (2)	INTERCOM - permits pilot or copilot to key the intercom and VHF transmitter.
		RADIO - permits pilot or copilot to key the UHF transmitter.

TACAN

The TACAN navigational system provides bearing and slant range distance information in conjunction with a ground radio beacon. This information is supplied to the bearing-distance-heading indicator (BDHI) where it provides an indication of bearing and distance to the fixed-frequency ground station. The system operates in the frequency range from 962 mc to 1,213 mc, and operating range is approximately 300 miles. Bearing to the station is displayed by the double bar pointer on the BDH1 and distance is displayed in the distance indicator window on the BDHI.

Identification audio signals can be received by actuating the TACAN switch on the radio selector control panel. For TACAN operating instructions, refer to NAVWEPS 16-30ARN52-1. Figure 4-5 illustrates the TACAN control panel.

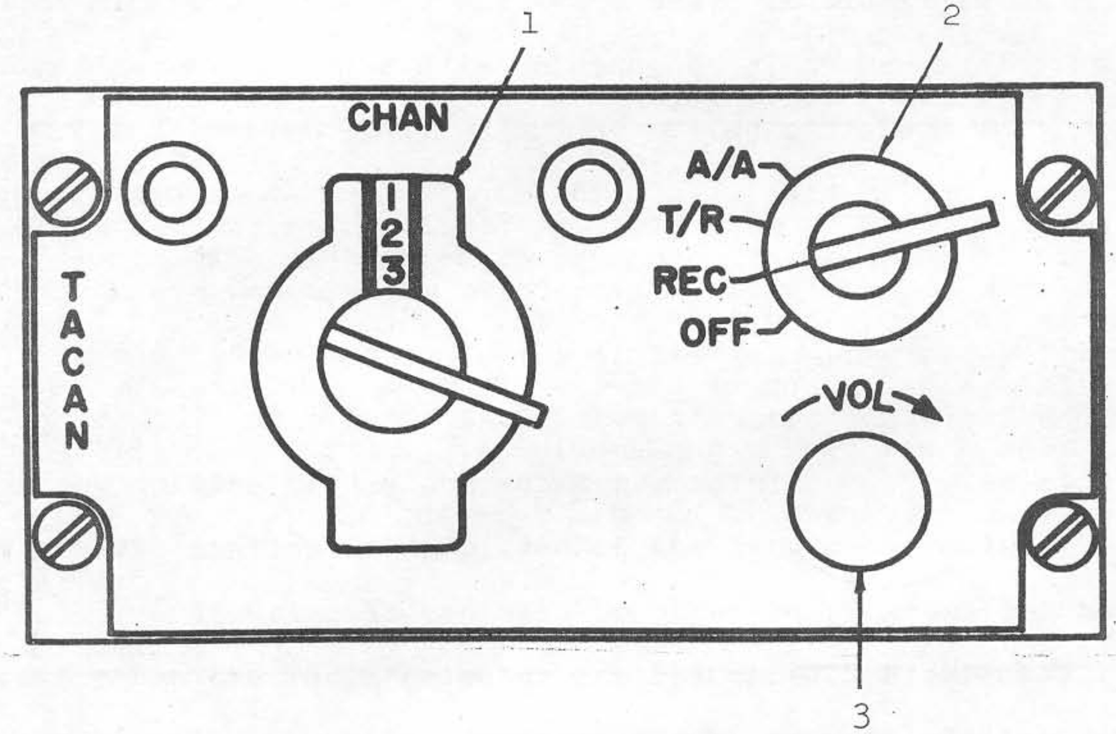
GYRO COMPASS

The gyro compass system provides an accurate, stabilized indication of aircraft heading through 360° azimuth. The heading indication is displayed on the compass card of the BDHI. For gyro compass operating instructions refer to NAVER 05-15C-501. Figure 4-6 illustrates the gyro compass control panel.

RADAR ALTIMETER

The radar altimeter provides a continuous visual indication of the height of the aircraft above the terrain. Range of effective operation is 0 to 5,000 feet above the terrain with an accuracy of

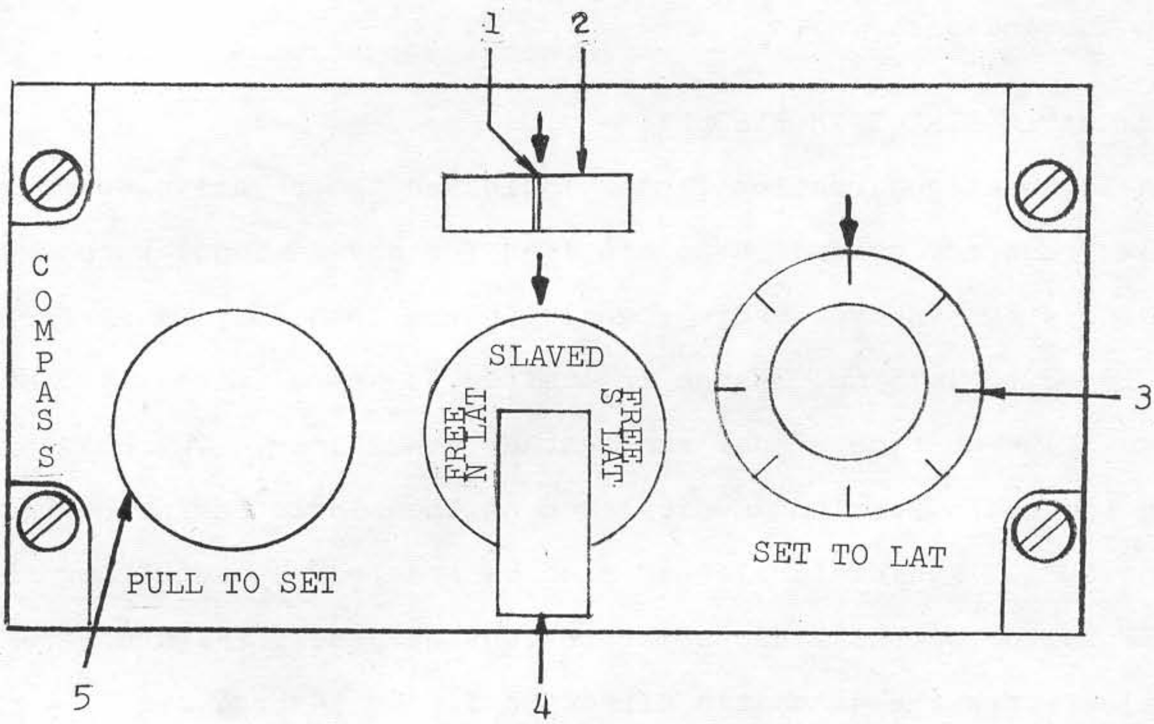
TACAN CONTROL



INDEX NO.	NOMENCLATURE
1	CHANNEL SELECTOR
2	FUNCTION SWITCH
3	IDENTITY TONE LEVEL CONTROL

Figure 4-5

GYRO COMPASS CONTROL



INDEX NO.	NOMENCLATURE
1	SYNCHRONIZATION INDICATOR
2	POWER FAILURE INDICATOR
3	SET TO LATITUDE KNOB
4	MODE SELECTOR SWITCH
5	HEADING SET KNOB

Figure 4-6

1.5 feet plus 0.5 percent of altitude. Linear-scaled indicators are provided on the main instrument panel for the pilot and copilot (18, figure 1-3). A push to test and set control is located on the indicator.

AUTOMATIC DIRECTION FINDER

The automatic direction finder indicates the relative bearing of low frequency ground radio stations for navigational purposes. The system receives radio signals in the frequency range from 0.19 mc to 1.75 mc. Range is limited to approximately 100 miles depending on time of day and weather conditions. The bearing to the radio station is displayed on the single bar pointer on the BDHI. Audio signals can also be received by actuating the ADF switch on the radio selector control panel. Figure 4-7 illustrates the automatic direction finder control panel.

AUTOMATIC DIRECTION FINDER NORMAL OPERATION

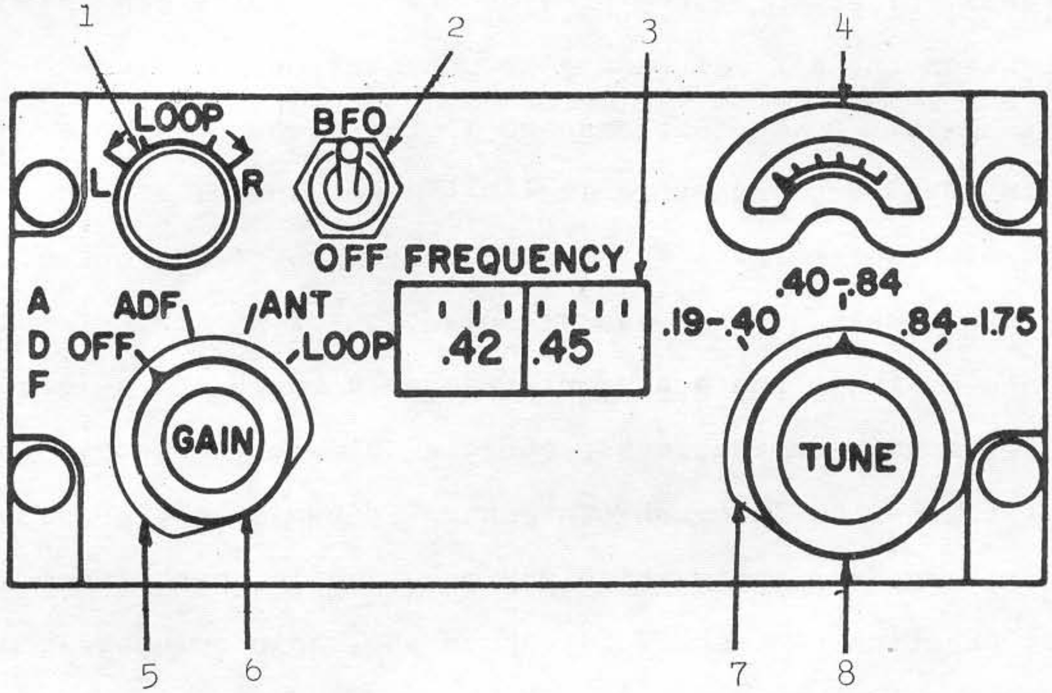
1. Place function switch in ADF position.
2. Place band switch in desired range.
3. Tune desired station with tune control.

Note

On a weak station the BFO switch may be placed in BFO position allowing "zero beat" tuning to the carrier center frequency.

4. To turn off the automatic direction finder, place the function switch in OFF position.

AUTOMATIC DIRECTION FINDER CONTROL



INDEX NO.	NOMENCLATURE
1	LOOP SWITCH
2	BEAT FREQUENCY OSCILLATOR SWITCH
3	FREQUENCY DIAL
4	TUNING METER
5	FUNCTION SWITCH
6	GAIN CONTROL
7	BAND SWITCH
8	TUNING CONTROL

Figure 4-7

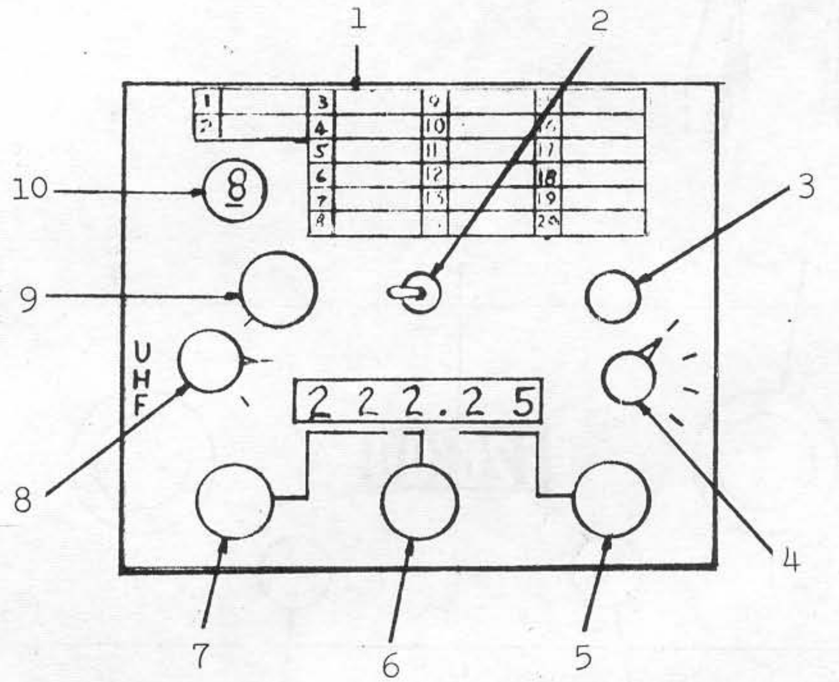
UHF COMMUNICATION SYSTEM

The UHF communication system provides two-way voice communications between the aircraft and a ground station or between other aircraft. Communications are in the frequency range from 225 mc to 399.9 mc, and range is limited to line of sight. The UHF control panel permits the remote selection of any one of 20 preset channels, or the manual selection of any one of the 3500 chanels within the equipment frequency range. A selector switch is provide on the center console to permit selection of either the upper or lower UHF antenna. Proper selection aids in eliminating dead spots which may occur while operating on the ground. Acuation of the UHF switch on the radio selector control panel connects the UHF communication system to the intercom station. For operating instructions of the UHF system, refer to NAVWEPS 16-30ARC51-1. Figure 4-8 illustrates the UHF radio control panel.

VHF COMMUNICATION SYSTEM

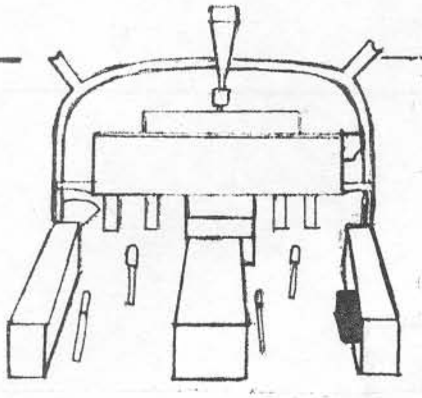
The VHF communication system provides two-way voice communications between the aircraft and a ground station or between other aircraft. Communications are in the frequency range from 118 mc to 126.9 mc. Range is limited to approximately 50 miles depending upon weather conditions and terrain. 90 simplex channels are available. Actuation of the VHF switch on the radio selector control panel connects the VHF communication system to the intercom station. Figure 4-9 illustrates the VHF transceiver.

UHF RADIO CONTROL

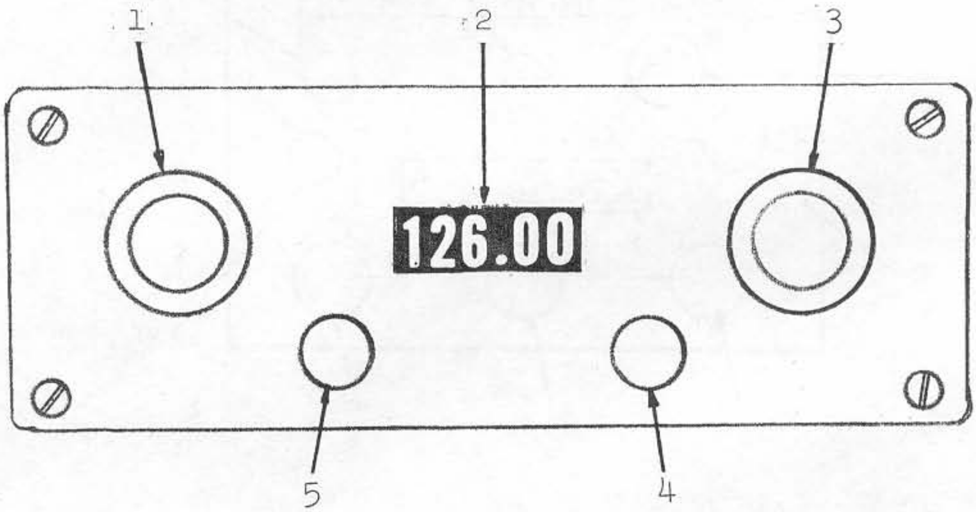


INDEX NO.	NOMENCLATURE
1	CHANNEL CHART
2	SQUELCH DISABLE SWITCH
3	VOLUME CONTROL
4	FUNCTION SELECTOR SWITCH
5	0.1 MANUAL FREQ. SELECT KNOB
6	1 MC MANUAL FREQ. SELECT KNOB
7	10 MC MANUAL FREQ. SELECT KNOB
8	MODE SELECTOR SWITCH
9	PRESET CHANNEL SELECTOR KNOB
10	PRESET CHANNEL INDICATOR

Figure 4-8



VHF TRANSCEIVER



INDEX NO.	NOMENCLATURE
1	WHOLE MEGACYCLE CHANNEL SELECTOR
2	FREQUENCY INDICATOR
3	TENTHS MEGACYCLE CHANNEL SELECTOR
4	SQUELCH CONTROL
5	ON/OFF VOLUME CONTROL

Figure 4-9

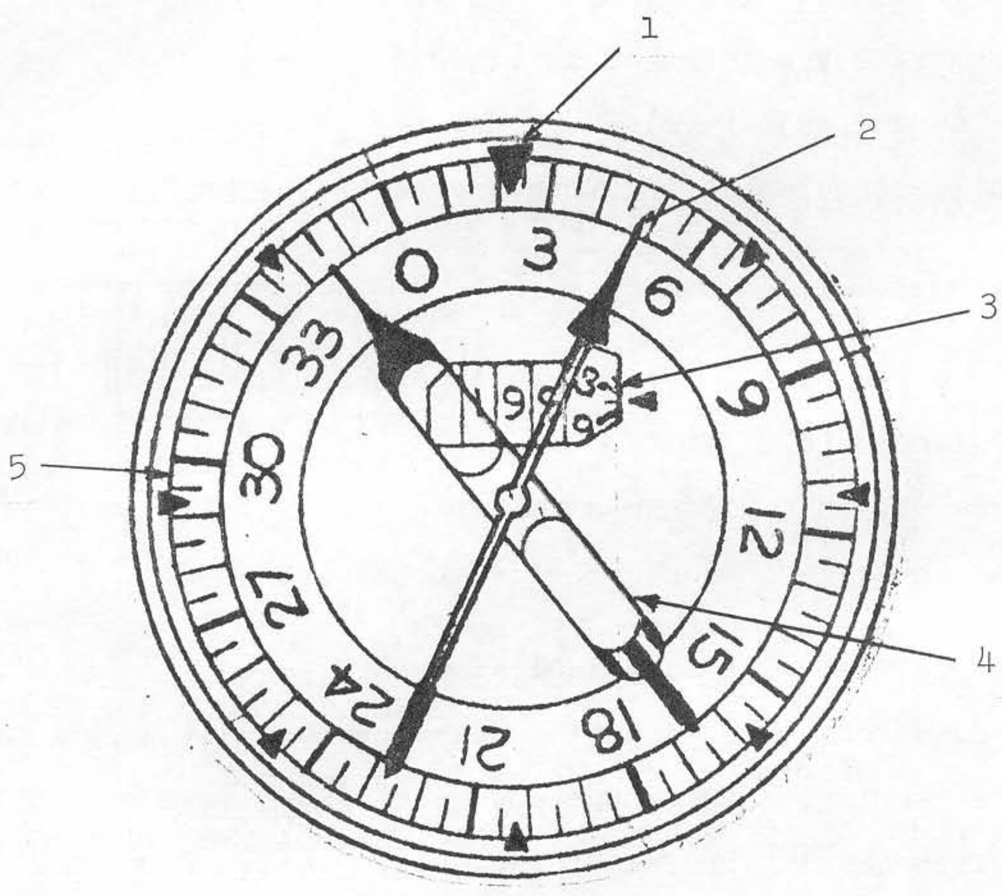
VHF COMMUNICATION SYSTEM NORMAL OPERATION

1. Rotate the volume control switch clockwise to ON position and adjust volume to desired level.
2. Select desired operating frequency by rotating the channel selection knobs.
3. Adjust squelch control (SQL) to the position that unwanted RF noise interference or undesired signals just disappear.
4. To turn off the VHF communication system rotate the volume control counterclockwise to OFF position.

BEARING - DISTANCE - HEADING INDICATOR (BDHI)

The BDHI functions in conjunction with the navigation systems to provide bearing, slant range and heading indications. The BDHI receives bearing and slant range information from TACAN and displays it on the double bar pointer and the distance indicator, respectively. An "OFF" flag partially covers the distance indicator if no slant range information is being received. The bearing information developed by the ADF system is displayed on the single bar pointer. The compass card receives heading signals from the MA-1 compass system and displays the aircraft heading under the stationary lubber line at the top of the indicator. Figure 4-10 illustrates the BDHI.

BEARING-DISTANCE-HEADING INDICATOR



INDEX NO.	NOMENCLATURE
1	LUBBER LINE
2	ADF INDICATOR
3	TACAN SLANT RANGE DISTANCE INDICATOR
4	TACAN INDICATOR
5	COMPASS CARD

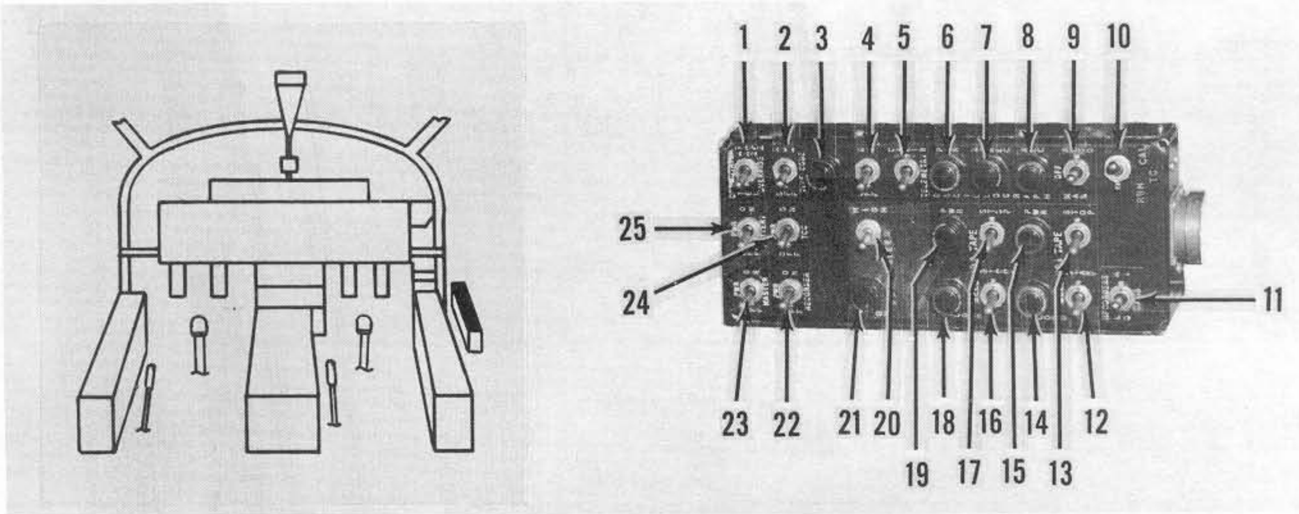
Figure 4-10

INSTRUMENTATION SYSTEM

The instrumentation system provides a means of acquiring data for test and research purposes. Controls and indicators for the instrumentation system are as follows (figure 4-11)

Index and Figure No.	Nomenclature	Function
1	Commutator override switch	TEL - transfers certain preselected channels from the tape recorders and substitutes them in place of the existing telemetry channels. MAG TAPE - restores transferred channels to the tape recorders.
2	Time code switch	RUN - turns on time code generator. OFF - turns off time code generator.
3	Telemetry indicator light	ON - indicates telemetry system is on.
4	Telemetry power switch	ON - turns on telemetry system.
5	Telemetry calibrate switch	CALIB - transmits telemetry calibration signal.
6	Oscillograph power indicator light	ON - indicates power is available for the oscillograph (light illuminates when master power switch is in ON position).
7	No record indicator	ON - indicates oscillograph is not recording (has exhausted paper supply or some other malfunction is preventing recording).
8	Record indicator light	ON - indicates oscillograph is recording.

INSTRUMENTATION CONTROL PANEL



1. COMMUTATOR OVERRIDE SWITCH
2. TIME CODE SWITCH
3. TELEMETRY INDICATOR LIGHT
4. TELEMETRY POWER SWITCH
5. TELEMETRY CALIBRATE SWITCH
6. OSCILLOGRAPH POWER INDICATOR LIGHT
7. NO RECORD INDICATOR LIGHT
8. RECORD INDICATOR LIGHT
9. OSCILLOGRAPH/MANUAL/AUTOMATIC SELECTOR SWITCH
10. TEMPERATURE CALIBRATE SWITCH
11. RECORDER CALIBRATION SWITCH
12. START SWITCH
13. STOP SWITCH
14. RECORD INDICATOR LIGHT
15. POWER INDICATOR LIGHT
16. START SWITCH
17. STOP SWITCH
18. RECORD INDICATOR LIGHT
19. POWER INDICATOR LIGHT
20. OSCILLOGRAPH SPEED SELECTOR SWITCH
21. HIGH SPEED INDICATOR LIGHT
22. RECORDER POWER SWITCH
23. MASTER POWER SWITCH
24. TIME CODE GENERATOR POWER SWITCH
25. BATTERY POWER SWITCH

FIGURE 4-11

Index and Figure No.	Nomenclature	Function
9	Oscillograph manual/ automatic selector switch	MAN - puts oscillograph into manual operation, under which condition it will continue to run until manually turned off. OFF - turns off oscillograph. AUTO - puts oscillograph into automatic operation, under which condition it will run for a preset time then automatically turn itself off.
10	Temperature calibration switch	CAL - provides a calibration reference for recorded temperature parameters. RUN - provides normal run position for recording temperature parameters.
11	Recorder calibration switch	HI - provides positive calibration level for recorded parameters. LO - provides negative calibration level for recorded parameters.
	<u>BELL NO. 1 TAPE</u>	
12	Start switch	START - starts recorder.
13	Stop switch	STOP - stops recorder.
14	Record indicator light	Flashing - indicates recorder is recording.
15	Power indicator light	ON - indicates power is available for the recorder (light illuminates when recorder power switch is in ON position).

Index and Figure No.	Nomenclature	Function
	BELL NO. 2 TAPE	
16	Start switch	START - starts recorder
17	Stop switch	STOP - stops recorder
18	Record indicator light	Flashing - indicates recorder is recording.
19	Power indicator light	ON - indicates power is available for the recorder (light illuminates when recorder power switch is in ON position).
20	Oscillograph speed selector switch	LOW - operates oscillograph at normal speed.
		HIGH - operates oscillograph at 10 times normal speed.
21	High speed indicator light	ON - indicates oscillograph is operating at high speed.
22	Recorder power switch	ON - applies source power for recorders.
		OFF - removes source power for recorders.
23	Master power switch	ON - applies master power to instrumentation system.
		OFF - removes master power from instrumentation system.
24	Time code generator switch	ON - applies source power for time code generator
		OFF - removes source power for time code generator.
25	Battery power switch	ON - applies emergency standby battery power which is automatically connected to the instrumentation system in the event of aircraft electrical power failure. Also provides operating power for the time code generator.

Index and Figure No.	Nomenclature	Function
1, figure 1-8	Remote time display	Visually displays time code.
2, figure 1-8	Free air temperature indicator	Provides an indication of outside air temperature.
figure 1-17	OSC - PIP switch	Pressed - provides an instrumentation identification marker.
2a, figure 1-8	OSC FAST light	Indicates the oscillograph is operating at 10 times faster than normal speed.
12, figure 1-5	Oscillograph speed selector switch	LOW - operates oscillograph at normal speed. HIGH - operates oscillograph at 10 times normal speed.

Data collection is accomplished by the following basic systems in the aircraft: A 50 channel oscillograph is utilized for calibration and testing of the variable stability system. There are approximately 72 parameters and control inputs related to the variable stability system which may be patched into the oscillograph as required for a specific mission.

Two 14 channel magnetic tape recorders are available for recording low and high frequency parameters. The tape recording sytem includes commutated provisions.

A telemetry system of the FM/FM and PDM/FM/FM type is installed in the aircraft. The system incorporates five continuous channels and one commutated channel.

A patch panel is provided to permit patching in selected parameters required for a given flight. Adequate recording capability with a minimum number of recording channels is possible with this system.

INSTRUMENTATION SYSTEM NORMAL OPERATION

1. Place master power switch in ON position.
2. Place battery power swithc in ON position.
3. Place recorder power switch to ON position.
4. Place time code generator power switch to ON position.
5. The remainder of the instrumentation system controls are used in accordance with the data acquisition requirements of each specific flight.

Note

> Sequential operation of the instrumentation system is included in the normal operation checklists in Section II.

MISCELLANEOUS EQUIPMENT

The miscellneous equipment consists of the windshield wiper.

WINDSHIELD WIPER

A windshield wiper is provided for the right-hand windshield. Control for the windshield wiper is as follows:

Index and Figure No.	Nomenclature	Function
Center Console	Wiper control switch	OFF - Removes electrical power from wiper motor to stop wiper movement. ON - Applies electrical power to operate wiper motor. PARK - Momentarily applies power to wiper motor to drive wiper to normal position.

The windshield wiper is powered from the essential dc bus. Control is accomplished by the wiper control switch. Placing the switch in PARK position applies electrical power to the wiper motor which drives the wipers to their normal (PARK) position. The PARK position is spring loaded to OFF.

CAUTION

Do not operate the windshield wiper on a dry windshield as damage to the wipers and windshield surface will result.

SECTION V - OPERATING LIMITATIONS

TABLE OF CONTENTS

OPERATING LIMITATIONS

This section contains aircraft and engine limitations which must be observed during normal operation. The instrument marking illustration (Figure 5-1) presents part of the overall limitations and must be referred to since the limitations cited therein are not necessarily repeated in the test. Limitations are based on contractor flight test data.

MINIMUM CREW REQUIREMENTS

The minimum aircrew requirement for this aircraft is one pilot and one copilot.

INSTRUMENT MARKINGS

Instrument markings are illustrated in Figure 5-1.

ENGINE LIMITATIONS

Engine limitations are shown in Figure 5-1. Also see Appendix I for engine operating limits.

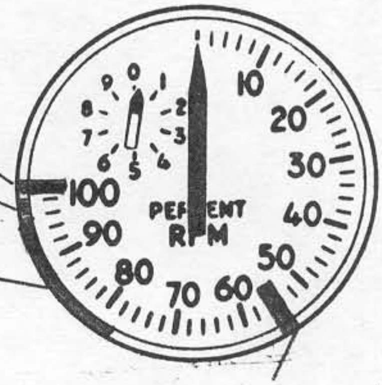
TRANSMISSION SYSTEM LIMITATIONS

Transmission system limitations are shown in Figure 5-1.

PROPELLER LIMITATIONS

Operation below 1800 rpm should be avoided. Normal flight rpm band is 2400 to 2600. Maximum rpm for ground operation is 2650. If propeller speed inadvertently reaches above 2735 rpm, the constant speed drive should be inspected for possible damage.

INSTRUMENT MARKINGS



RED---100%
MAXIMUM ALLOWABLE

YELLOW--96 to 98%
CAUTION

GREEN--78 to 96%
NORMAL

RED-MINIMUM--55%
IDLE

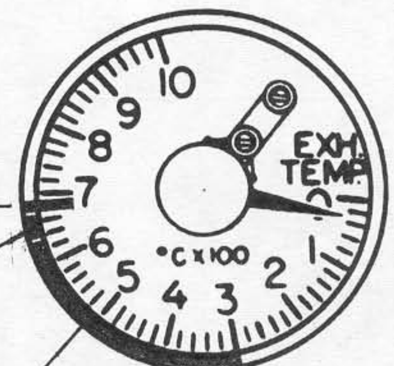
LIMITS

MAXIMUM CONTINUOUS--96%

MILITARY POWER(30 min.)--100%

MAXIMUM(TRANSIENT 15 sec.)--103%

GAS GENERATOR RPM



RED--680°C
MAXIMUM ALLOWABLE

YELLOW--640 to 680°C
CAUTION

GREEN--300to640°C
NORMAL

LIMITS

MAXIMUM CONTINUOUS--635°C

MILITARY POWER(30min.)-677°C

POWER TURBINE INLET TEMPERATURE

Figure 5-1 (Sheet 1 of 4)

INSTRUMENT MARKINGS

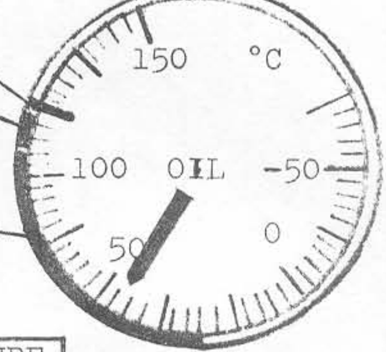
LIMITS

MAXIMUM--121°C

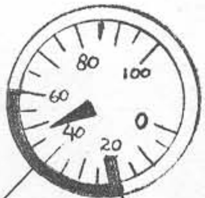
RED--121°C
MAXIMUM ALLOWABLE

YELLOW--110 to 121°C
CAUTION

GREEN--25 to110°C
NORMAL



PROPELLER GEARBOX OIL TEMPERATURE



LIMITS

MINIMUM---20PSI

GREEN--20to60PSI
NORMAL

RED--20PSI
MINIMUM
ALLOWABLE (FLIGHT _ - PROP. RPM)

PROPELLER GEARBOX OIL PRESSURE

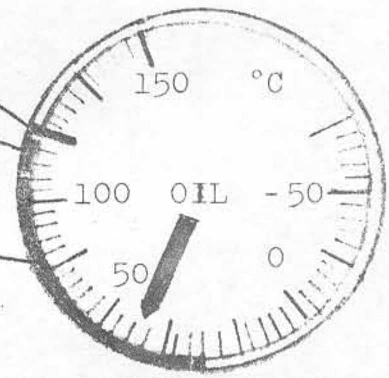
LIMITS

MAXIMUM--121°C

RED--121°C
MAXIMUM ALLOWABLE

YELLOW--110 to I21°C
CAUTION

GREEN--25 to110°C
NORMAL



ENGINE OIL TEMPERATURE

LIMITS

MINIMUM---------20PSI
FOR NORMAL OPERATION

IDLE-------10 to 20PSI

GREEN--25 to 60PSI
NORMAL

RED--20PSI
MINIMUM ALLOWABLE

ENGINE OIL PRESSURE

Figure 5-1 (Sheet 2 of 4)

INSTRUMENT MARKINGS

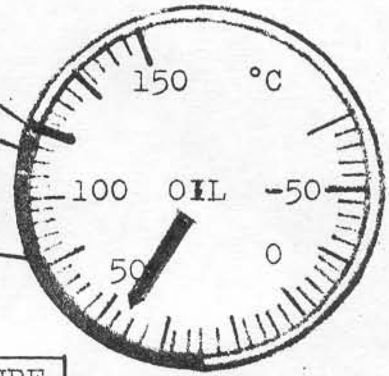
LIMITS

MAXIMUM--121°C

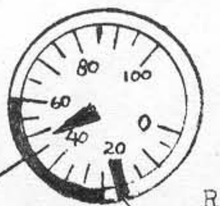
RED--121°C
MAXIMUM ALLOWABLE

YELLOW--110 to 121°C
CAUTION

GREEN--25 to110°C
NORMAL



ENGINE GEARBOX OIL TEMPERATURE



LIMITS

MINIMUM---------20PSI

GREEN--25 to 60PSI
NORMAL

RED--20PSI
MINIMUM ALLOWABLE
(FLIGHT - PROP. RPM)

ENGINE GEARBOX OIL PRESSURE

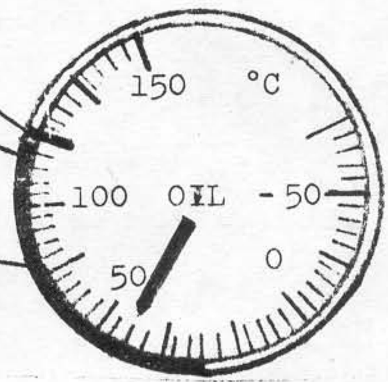
LIMITS

MAXIMUM--121°C

RED--121°C
MAXIMUM ALLOWABLE

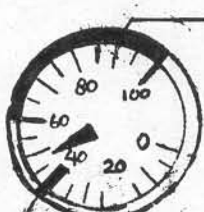
YELLOW--110 to 121°C
CAUTION

GREEN--25 to110°C
NORMAL



FUSELAGE GEARBOXES-OIL TEMPERATURE

GREEN--60to100 PSI
NORMAL



LIMITS
MINIMUM---40PSI

RED--40PSI
MINIMUM ALLOWABLE (FLIGHT - PROP. RPM)

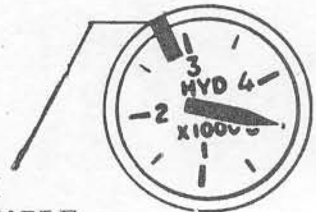
FUSELAGE GEARBOXES-OIL PRESSURE

Figure 5-1 (Sheet 3 of 4)

INSTRUMENT MARKINGS

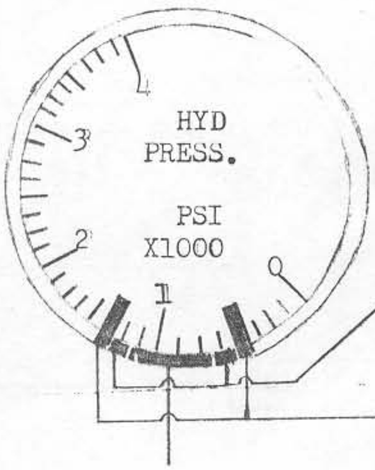
LIMITS

NORMAL MINIMUM--2800 PSI
(EXCLUDING TRANSIENT LOADS)



RED--2800 PSI
MINIMUM ALLOWABLE

HYDRAULIC PRESSURE



LIMITS
MINIMUM OPERATIONAL*--500 PSI
MAXIMUM OPERATIONAL--1300 PSI

*SYSTEM MAY DROP BELOW THIS
MINIMUM WHEN DUMPED

YELLOW-500 to 550 PSI
1150 to 1300 PSI
CAUTION

RED-- 500 PSI MIN. ALLOW.
1300 PSI MAX. ALLOW.

GREEN--550 to 1150 PSI
NORMAL

GOVERNOR PRESSURE

Figure 5-1 (Sheet 4 of 4)

AIRSPEED LIMITATIONS

Airspeed limitations are shown in Figure 5-2.

Airspeed in the pitch control mode is self limiting at approximately 150 KEAS with the available collective pitch range.

Landing Gear

Extended - 150KEAS

Cycling - 100 KEAS

Ducts

Maximum duct unlock speed - 150 KEAS

Loras

Maximum operational speed - 150 KEAS

Above 150 KEAS LORAS should be turned off.

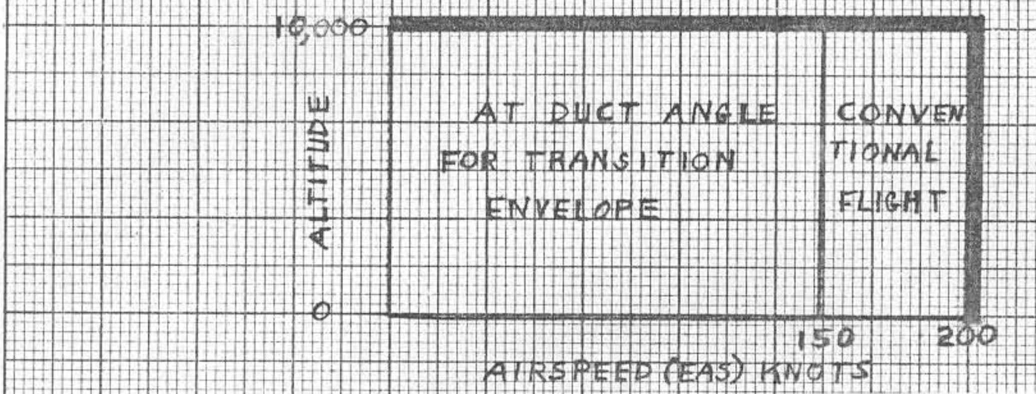
MANEUVERS

The aircraft is considered nonaerobatic in nature and intentional loops, rolls, and spins are prohibited.

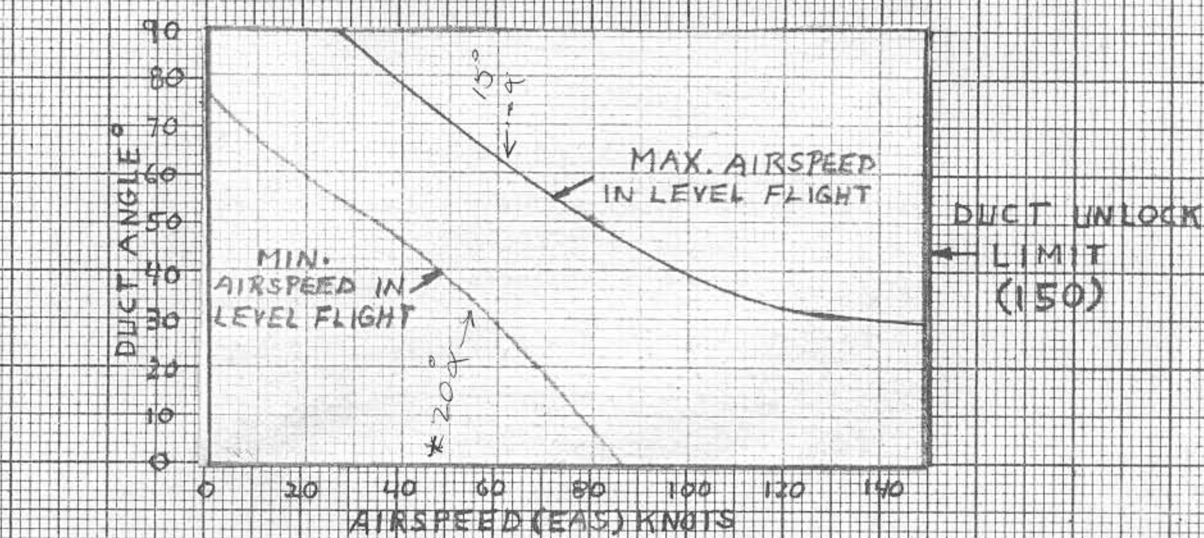
Maximum abrupt control motion should be limited to 75% of control throw from mid to extreme position in all flight cases exeept hovering where roll control shall not exceed 50%. Rapid deflection of the collective stick shall not exceed 2.5°

In the VSS mode the VSS safety trips provide control rate limits and aircraft angular and linear acceleration limits. The values

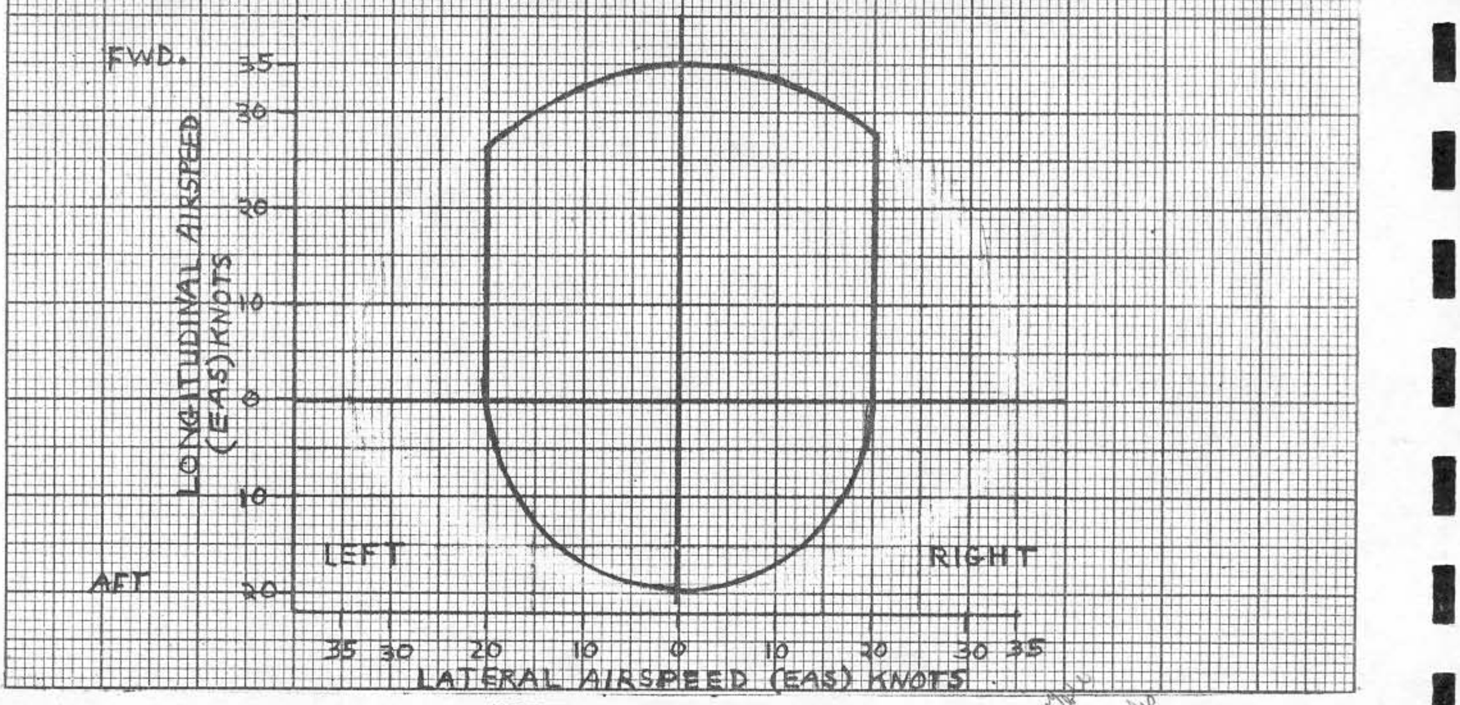
AIRSPEED LIMITATIONS



CONVENTIONAL FLIGHT ENVELOPE



TRANSITION FLIGHT ENVELOPE



HOVER FLIGHT ENVELOPE

Figure 5-2

for safety trip settings are as follows:

$\dot{\Delta}_{\beta S}$	=	60°/sec	$\dot{p}$	=	120°/sec^2
$\dot{\Delta}_{ES}$	=	46°/sec	$\dot{q}$	=	124°/sec^2
$\dot{\delta}_{ES}$	=	46°/sec	$\dot{r}$	=	30°/sec^2
$\dot{\Delta}_{AS}$	=	73°/sec	N_X	=	$\pm$.625 g
$\dot{\delta}_{AS}$	=	73°/sec	N_Y	=	$\pm$.5 g
$\dot{\Delta}_{RP}$	=	12 in./sec	ΔN_Z	=	$\pm$1.29 g
$\dot{\delta}_{RP}$	=	12 in./sec			

Bank Angle

Conventional Flight - 65°

Transition - 45°

Sideslip Angle

Maximum sideslip angle versus airspeed is shown in Figure 5-3.

Rate of Descent

Maximum rate of descent is shown in Figure 5-4.

Extreme Angle of Attack

Above 40 KEAS - +20° indicated

-15° indicated

ACCELERATION LIMITATIONS

Symmetrical Flight

Normal acceleration limitations for symmetrical flight based on gross weight of 14,700 lb at sea level, are shown in Figure 5-5.

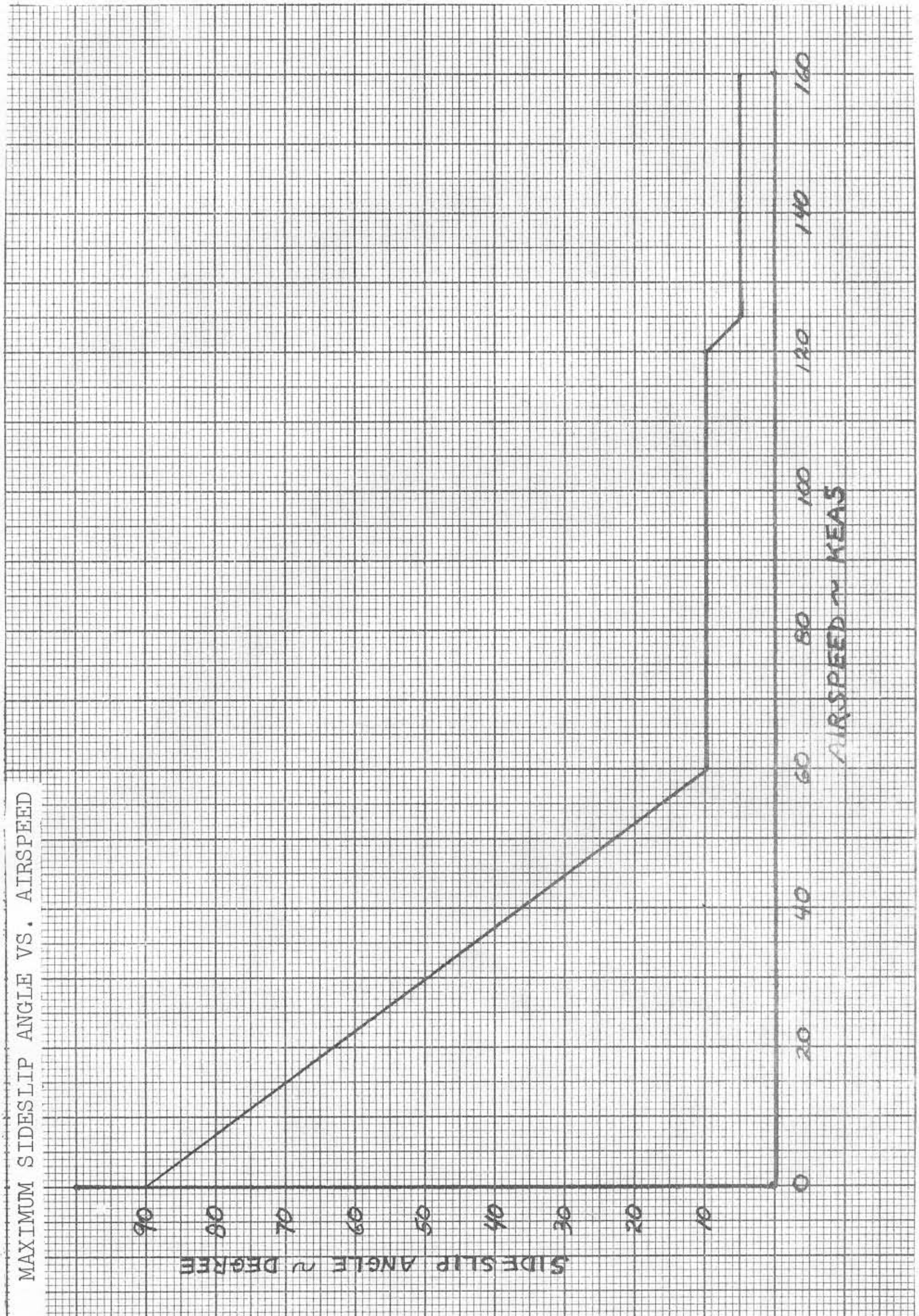

MAXIMUM SIDESLIP ANGLE VS. AIRSPEED
SIDE SLIP ANGLE ~ DEGREE
90
80
70
60
50
40
30
20
10
AIRSPEED ~ KEAS
0
20
40
60
80
100
120
140
160

Figure 5-3

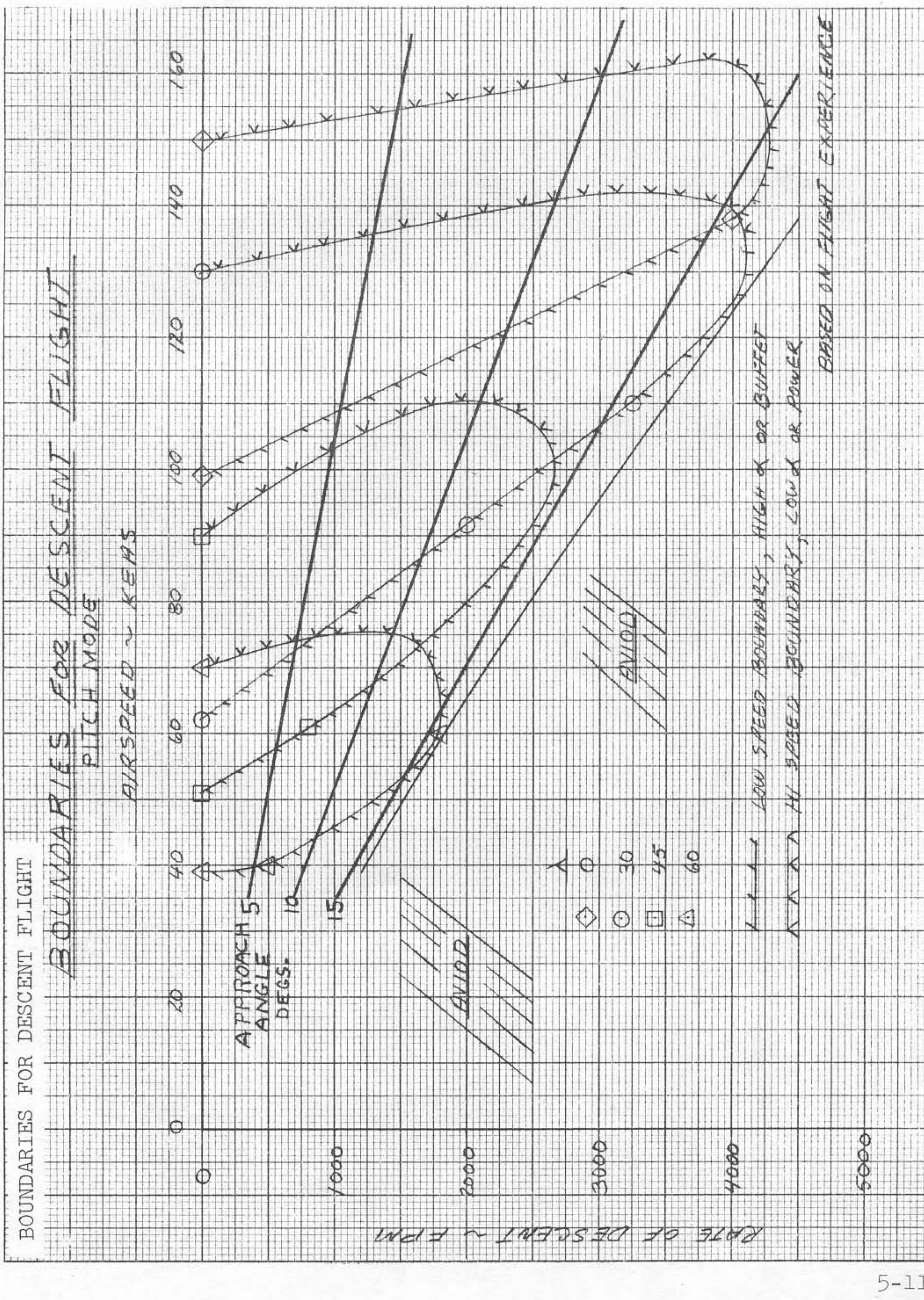

BOUNDARIES FOR DESCENT FLIGHT
BOUNDARIES FOR DESCENT FLIGHT
PITCH MODE
AIRSPEED ~ KEAS
0
20
40
60
80
100
120
140
160
RATE OF DESCENT ~ FPM
0
1000
2000
3000
4000
5000
APPROACH ANGLE DEGS.
5
10
15
AVOID
AVOID
◇ 0
⊙ 30
□ 45
△ 60
LOW SPEED BOUNDARY, HIGH α OR BUFFET
HI SPEED BOUNDARY, LOW α OR POWER
BASED ON FLIGHT EXPERIENCE

Figure 5-4

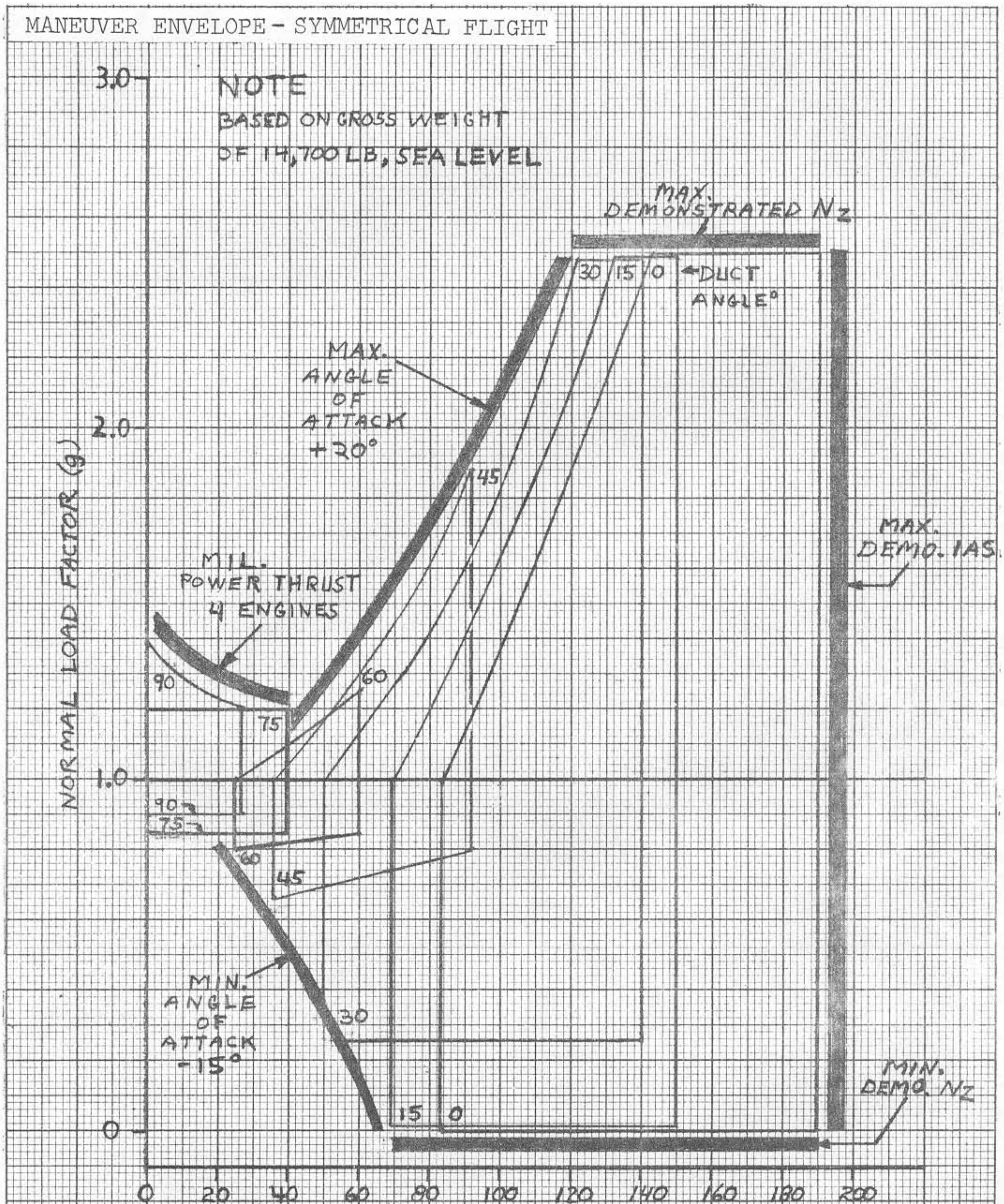

MANEUVER ENVELOPE - SYMMETRICAL FLIGHT
NOTE
BASED ON GROSS WEIGHT
OF 14,700 LB, SEA LEVEL
MAX.
DEMONSTRATED Nz
30 15 0 ←DUCT
ANGLE°
MAX.
ANGLE
OF
ATTACK
+20°
45
MAX.
DEMO. IAS
MIL.
POWER THRUST
4 ENGINES
90
75
60
90
75
60
45
MIN.
ANGLE
OF
ATTACK
-15°
30
MIN.
DEMO. Nz
15
0
NORMAL LOAD FACTOR (g)
3.0
2.0
1.0
0
0
20
40
60
80
100
120
140
160
180
200
AIRSPEED (IAS) KNOTS

Figure 5-5

The envelopes shown for 0, 15, and 30° duct angle may be applied over the altitude range of 0 to 10,000 feet. Above 30° duct angle the thrust decay will degrade the maneuvering capability at altitude.

Rolling Pullout

Maximum normal acceleration in a rolling pullout with 75% roll control displacement shall not exceed 2.0 g (based on 14,700 lb gross weight) at duct angles between 30 and 0° at airspeeds of 140 to 200 knots. This limitation is applicable from 0 to 10,000 feet altitude..

HOVERING LIMITATIONS

To maintain an adequate power margin in the event of engine failure in hovering, do not operate at gross weight in excess of that shown in Figure 5-6, which provides for a thrust-to-weight ratio of 1.05 on three engines. This data shall apply for all permitted wind velocities (see Figure 5-2, Hover Flight Envelope)

DEAD MANS CURVE

No height/velocity avoid curve applies to the X-22A if operated in or near hovering in accordance with the hovering limitations cited above.

Operation close to the ground at high rate of descent should be avoided as it may be difficult to arrest vertical velocity with the available T/W ratio from low altitude. Figure 5-7 may be

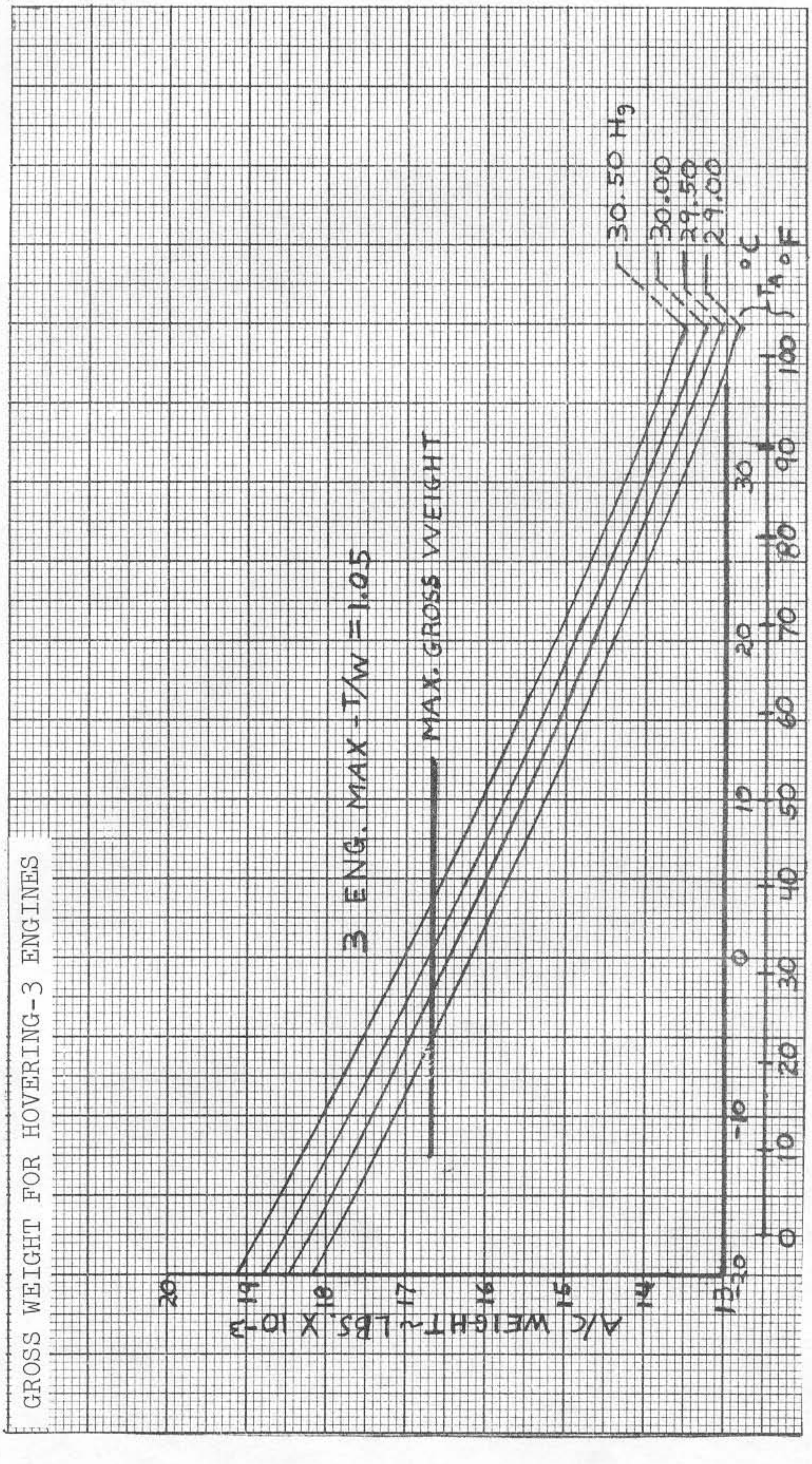

GROSS WEIGHT FOR HOVERING-3 ENGINES
3 ENG. MAX -T/W = 1.05
MAX. GROSS WEIGHT
A/C WEIGHT ~ LBS. X 10-3
20
19
18
17
16
15
14
13
30.50 Hg
30.00
29.50
29.00
°C
TA °F
-20
-10
0
10
20
30
0
10
20
30
40
50
60
70
80
90
100

Figure 5-6

VERTICAL DECELERATION PERFORMANCE

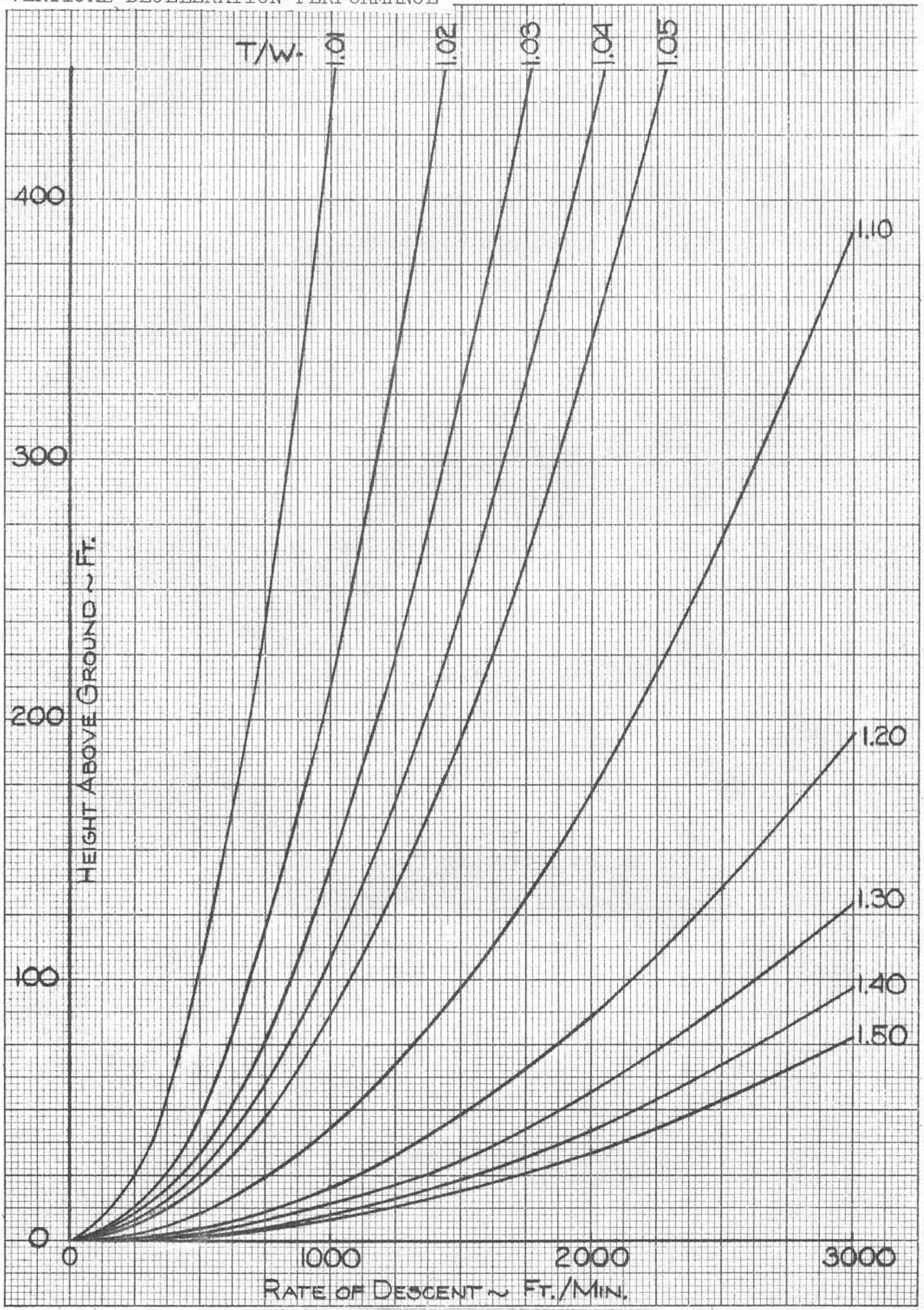


Figure 5-7

used as a guide, but exact values of T/W available are difficult to predict in low airspeed rapid descents.

CENTER OF GRAVITY LIMITATIONS

Flight tests have been conducted with c.g. position varying from 308.3" to 309.7" Sta. at gross weights between 14,000 and 16,000 lb. No significant c.g. effects on handling, stability or flight limitations is evident for this range of conditions.

WEIGHT LIMITATIONS

Maximum gross weight for takeoff - 16,700 lb. Normal maximum gross weight - 15,700 lb. Minimum fuel for landing - 400 lb.

NOTE

1. Operation at weights in excess of 15,700 lb is restricted to 30° duct angle takeoff and landing.
2. No fuel jettisoning is permitted in flight

Figure 5-8 shows maximum hovering gross weight for T/W ratio of 1.0 for four engine operation as compared with the weight for T/W ratio of 1.05 for three engine operation.

GROSS WEIGHT FOR HOVERING-3 AND 4 ENGINES

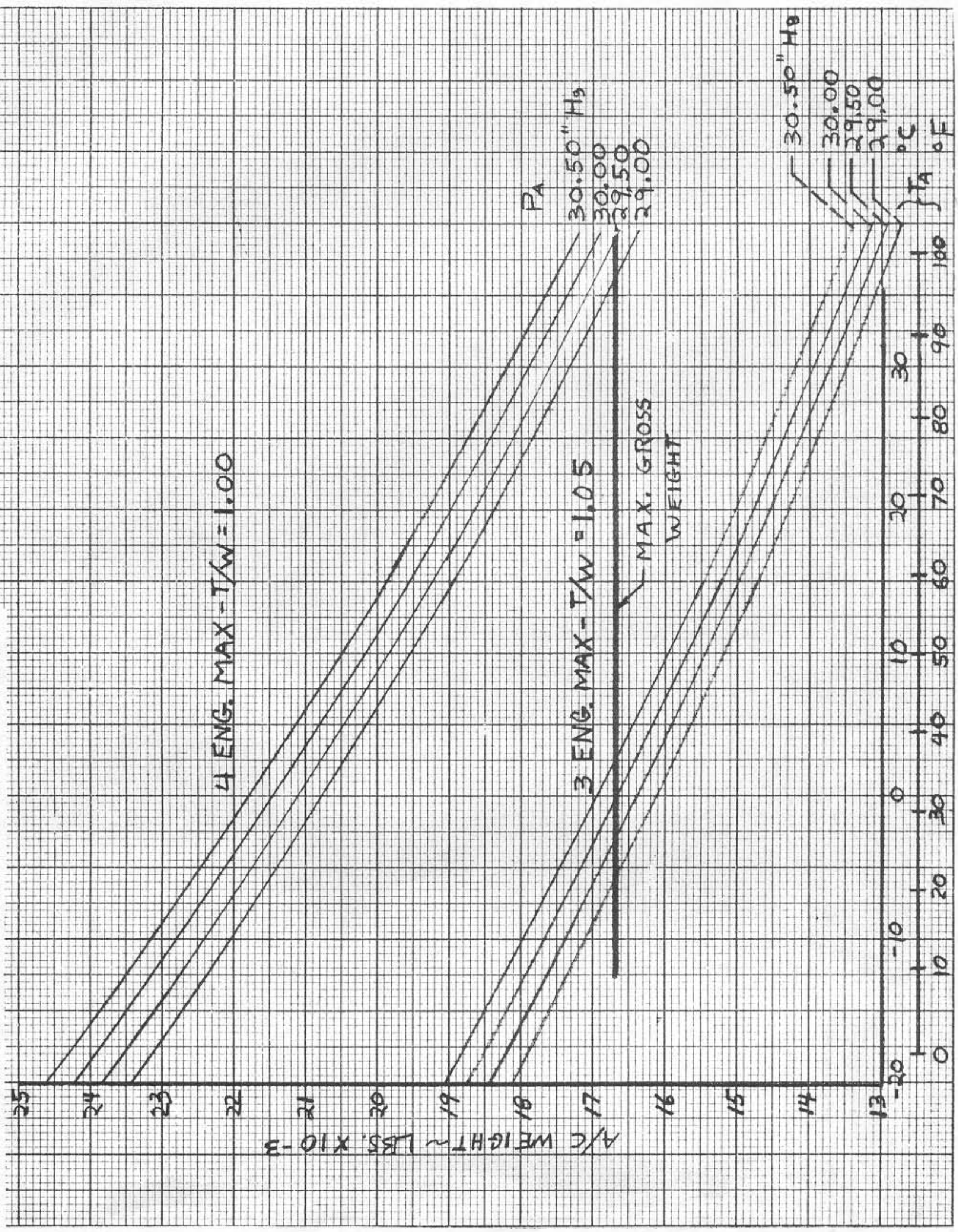


Figure 5-8

MISCELLANEOUS LIMITATIONS

Surface Wind Limitations

Maximum wind velocity (including gusts) is as follows:

VTOL or hovering - 35 KEAS

STOL or conventional - 35 KEAS

STOL or conventional crosswind component - 15 KEAS

Pressure Altitude

Maximum pressure altitude - 10,000 feet

Duct Buzz

Maximum duct "K" strut oscilliatory load - $\pm$2,500 lb.

VSS Operation

Takeoff and landing is not permitted in the VSS mode of control from the LH pilots controls. Emergency landing on FBW is permitted in the event of RH pilot disability.

Safe Ejection Limits

Ejection seat recovery envelopes are shown in Figure 5-9. These data does not include any time delay in initiating ejection.

CAUTION

Flight test evaluations of the X-22A have been limited to operations avoiding flight or prolonged ground exposure in precipitation conditions. This precaution has been adopted to prevent water damage to flight test instrumentation installations. Exposure of the aircraft to precipitation should be avoided to protect the overall instrumentation system reliability.

RECOVERY ENVELOPE X-22 EJECTION SEAT

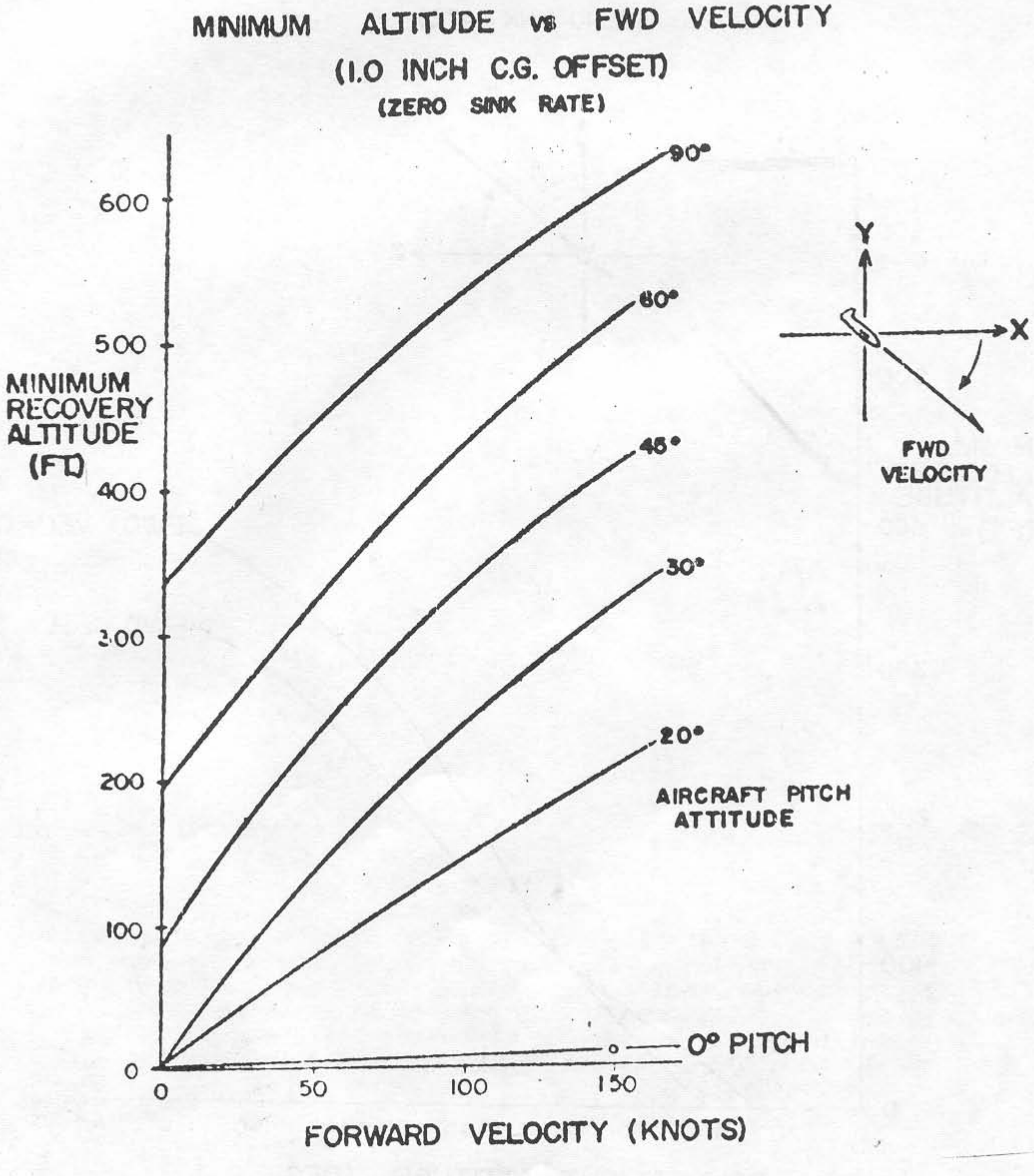


Figure 5-9 (Sheet 1 of 4)

RECOVERY ENVELOPE
X-22 EJECTION SEAT

MINIMUM ALTITUDE vs A/C ROLL ANGLE
(1.0 INCH C.G. OFFSET)
(ZERO SINK RATE)

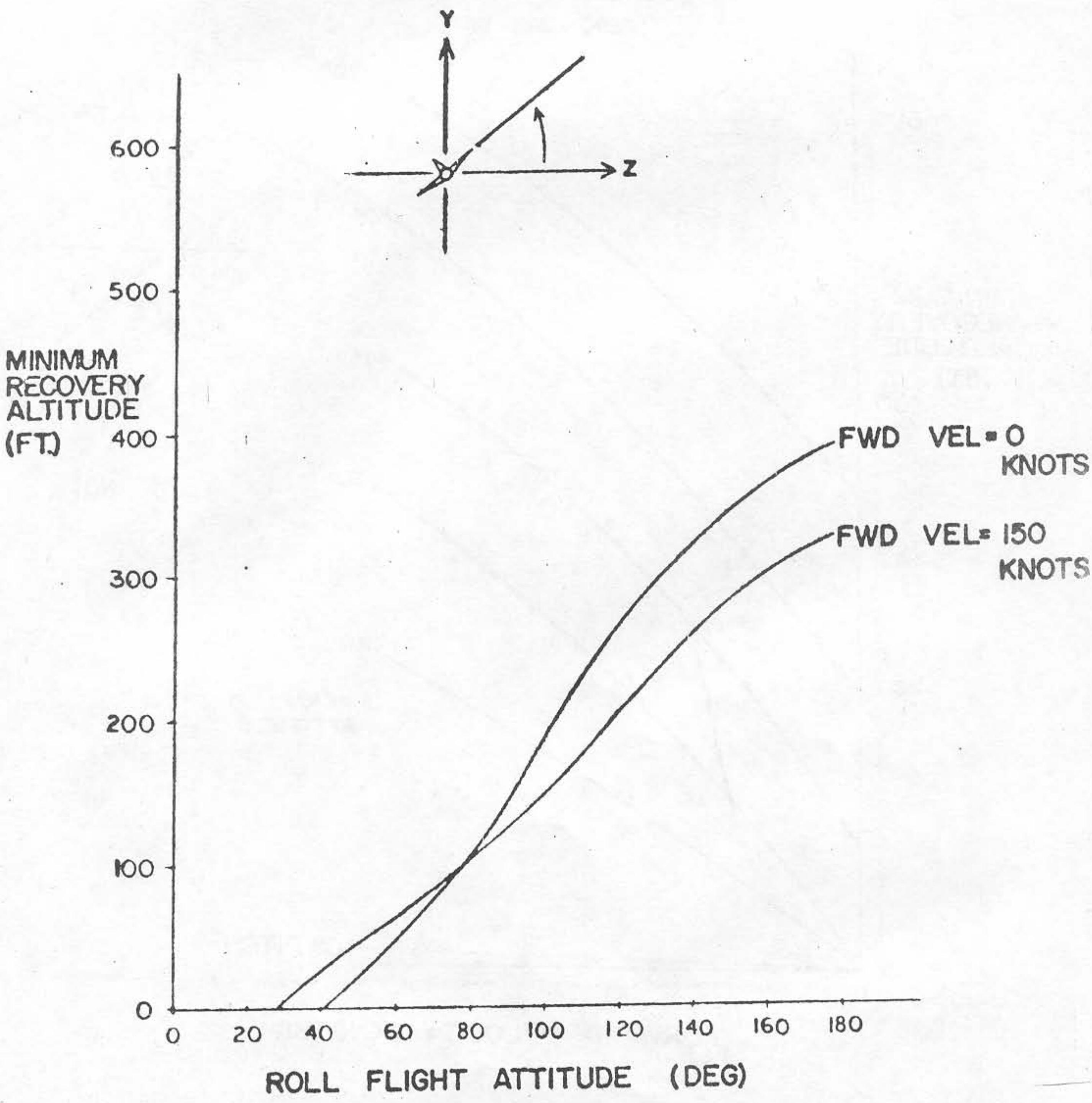


Figure 5-9 (Sheet 2 of 4)

RECOVERY ENVELOPE
X-22 EJECTION SEAT

MINIMUM ALTITUDE vs FWD VELOCITY
(1.0 INCH C.G. OFFSET)

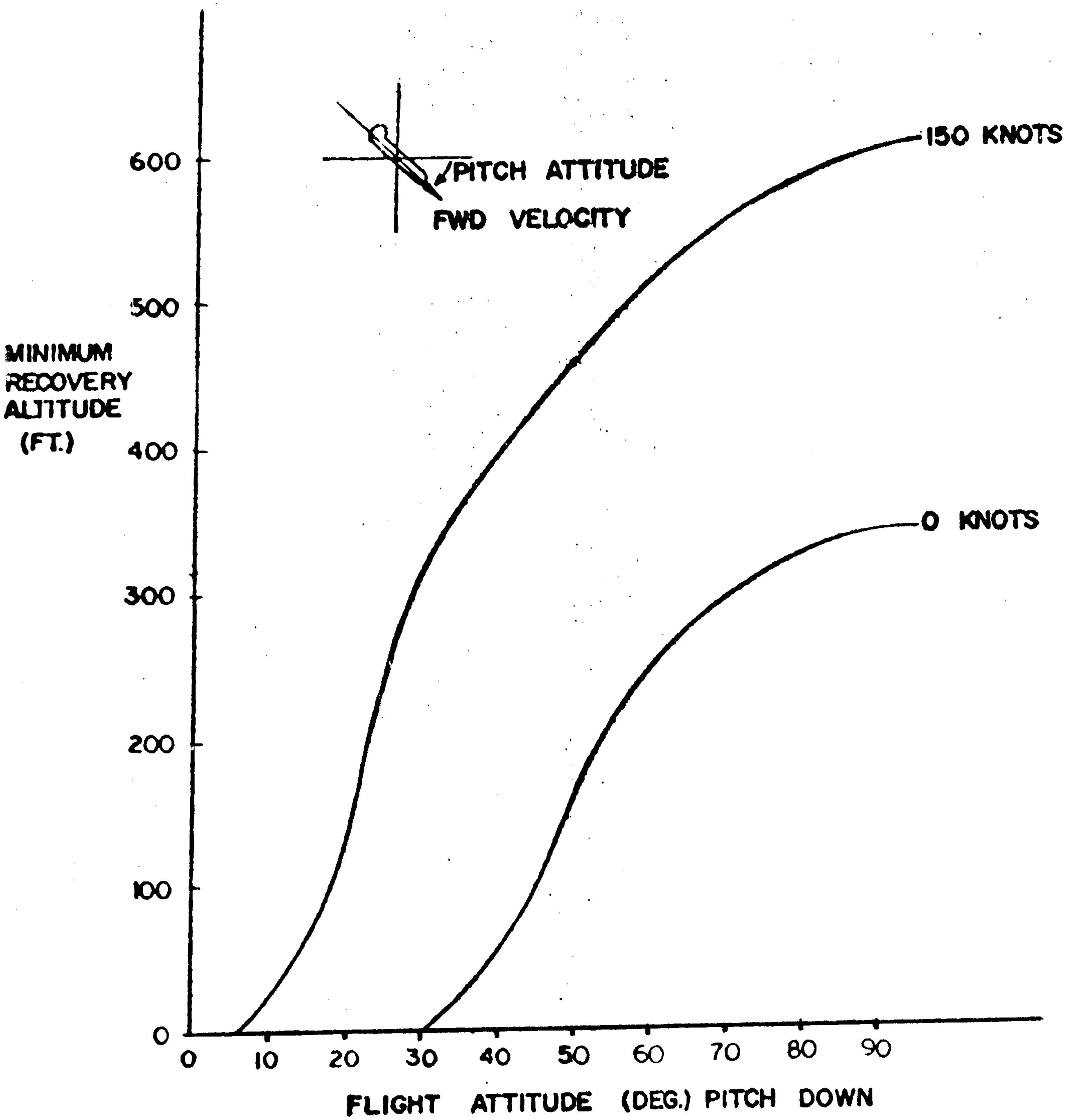


Figure 5-9 (Sheet 3 Of 4)

RECOVERY ENVELOPE
X-22 EJECTION SEAT

MINIMUM ALTITUDE vs SINK RATE
(1.0 INCH C.G. OFFSET)

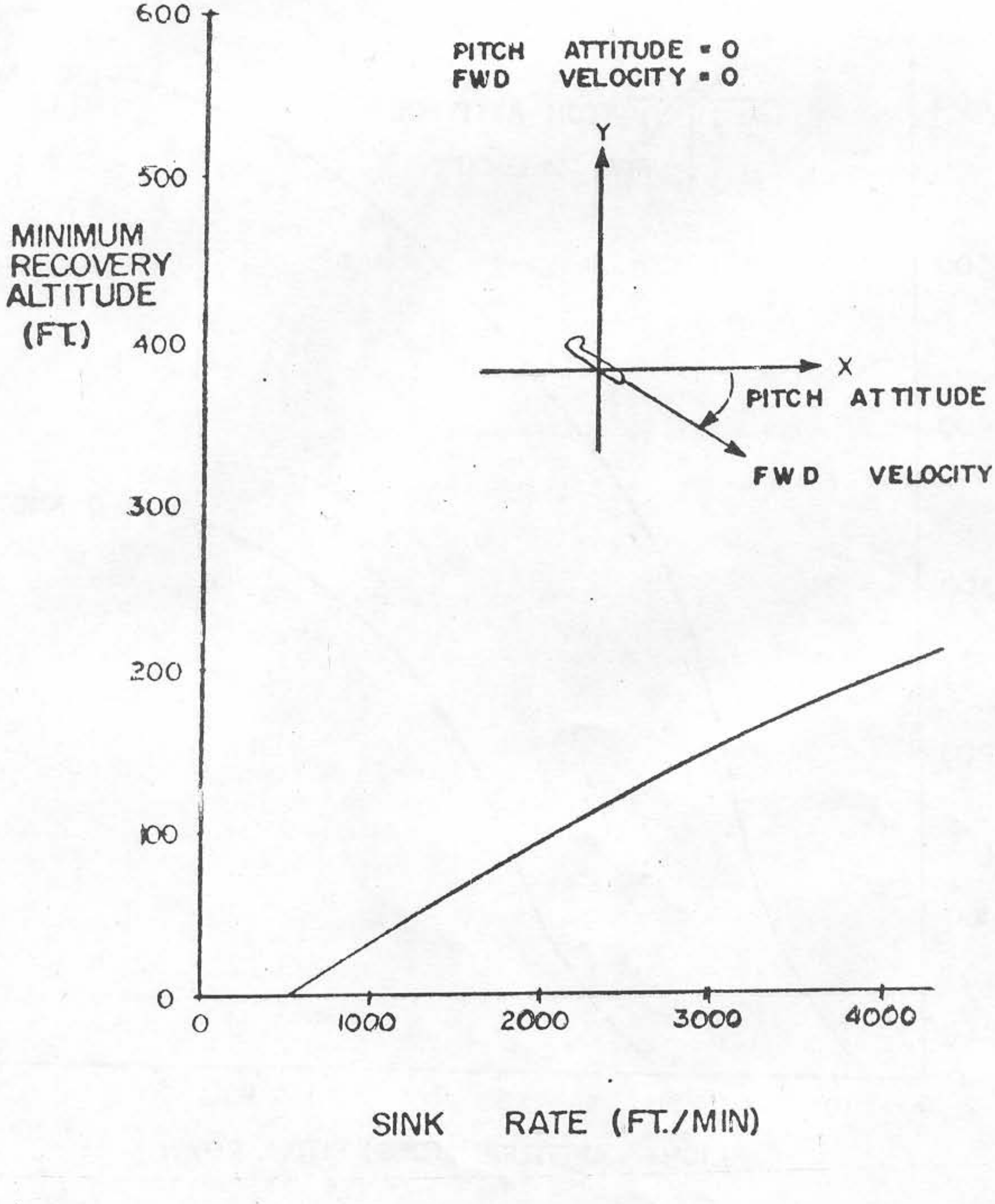


Figure 5-9 (Sheet 4 of 4)

SECTION VI - FLIGHT CHARACTERISTICS

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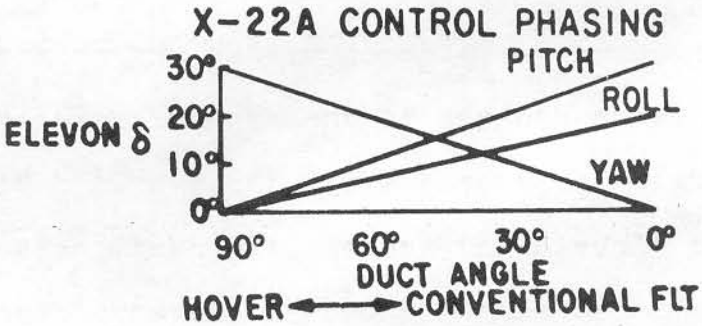
FLIGHT CONTROLS

Elevons

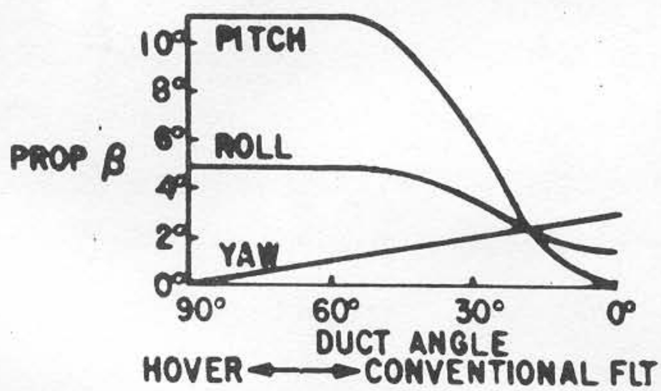
The control function and effectiveness of the elevons depends upon duct angle. In hovering flight the elevons provide yaw control by deflecting the airstream radially. During transition the elevon action is phased as a function of the duct angle from pure yaw at 90° to pure roll/pitch at 0° as depicted below.



In conventional flight the elevons provide roll and pitch control in the conventional manner. The handling characteristics are very good with slight adverse yaw which builds up as the turn develops making it necessary to hold rudder into the turn. The yaw spring is turned on during transition and conventional flight to provide a conventional rudder force gradient. For hovering flight the yaw spring should be disengaged which provides very good rudder forces for directional control.

Propeller Blade Angle

In this aircraft differential blade angle is a primary flight control. In hovering flight this provides pitch and roll control while in conventional flight it provides yaw control. Through transition the blade angle action is phased as a function of duct angle from that of pitch/roll at 90° to pure yaw at 0°.



Control Power

The combined elevon and propeller blade angle used for control is phased and scaled to provide essentially constant control moments through transition, with a minimum of undesirable control coupling.

Duct Rotation

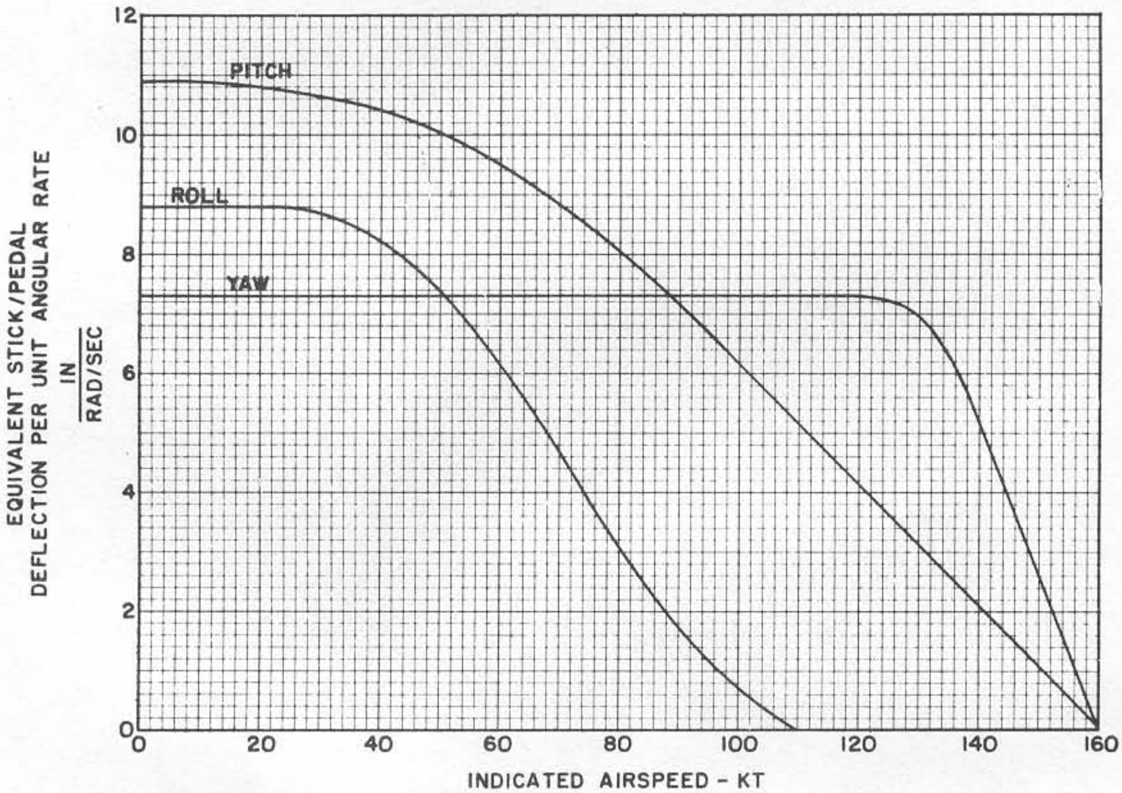
Duct rotation from 0 to 95° can be commanded by any one of five (5) switches; one on each collective pitch lever, one on each number 4 throttle and an emergency override switch on the center console.

Ducts rotate at a constant speed of 5°/sec. when any of the five (5) switches are engaged but slower rotation can be accomplished by momentarily beeping the switch to obtain the desired rate. Duct rotation can be accomplished anywhere within the transition envelope in either direction. At 5° prior to reaching a duct rotation stop the rate decreases to approximately 1.0°/sec. to decrease the shock upon reaching the stop. The duct rotation override switch on the center console can be used to rotate ducts in either direction independent of any other switch position. With this switch turned off ducts cannot be rotated.

The duct rotation lock switch opens the circuit to the hydraulic motors holding a constant pressure on the 0° stops. This prevents chattering against the stops at high speed. The switch is not active at duct angles above 5°.

STABILIZATION (STABILITY AUGMENTATION SYSTEM)

SAS is provided in hover, through transition, and in low speed conventional flight to improve aircraft stability and handling qualities. The authority of the rate damping provided in each axis is varied independently as a function of forward speed:



At speeds above 160 knots the system is completely phased out as aerodynamic damping provides adequate stability at higher airspeeds. The SAS is fully duplicated, and operation on one system results in reduced rate damping and authority, degrading the handling characteristics very little. The aircraft can also be flown in all flight conditions without undue difficulty with SAS-off. The most difficult flight conditions without SAS is in the final stages of a transition to hover, for this reason it is recommended that a 30° STOL landing be accomplished in the event SAS becomes inoperative.

FEEL AND TRIM

The hydro-electrical feel and trim system on the right hand stick provides good control force in pitch and roll through all flight conditions. The system changes the pitch stick force gradient as a function of speed up to 150 knots to maintain a good stick force/g relationship throughout the flight envelope. The feel and trim system is not duplicated.

The aircraft is controllable without feel and trim with only minor changes in control characteristics. With feel and trim off the stick has no force gradient and very low breakout. As long as flight operations are performed near the center of the transition envelope no difficulty should be encountered in making a landing with feel and trim, however to minimize exposure a 30° STOL landing is recommended.Takeoffs and landings have been demonstrated at 30° with $\frac{1}{2}$ SAS and feel and trim off, SAS off, and at hover with feel and trim off and $\frac{1}{2}$ SAS.

Roll and pitch force springs are available to provide a stick force gradient when feel and trim is switched off or above 150 knots. The forces provided by these springs are designed for high speed flight (above 150 knots) so they are not well suited for lower speed flight or hover.

The springs should be turned off prior to landing. Due to the possibility of encountering a feel and trim hardover failure at high speed it is required that feel and trim be turned off and feel springs be turned on at speeds above 150 knots.

The left hand stick has a similar hydroelectric feel servo system, the characteristics of which can be pre-selected with the VSS digitrol controls.

TAKEOFFS AND LANDINGS

Before takeoff the ducts are positioned between 75 to 90° depending upon the wind velocity. For each knot of headwind the ducts are prepositioned approximately one degree down from 90°. To liftoff, collective is increased while monitoring collective pitch angle and N_1. Depending upon weight and weather conditions, liftoff will occur at 20 to 25° of collective pitch at 90 to 95% N_1. While increasing power, stick position should be held central and small amounts of duct rotation used to arrest any longitudinal motion. At high power, prior to becoming airborne, the turbulence due to ground effect will be evident. Care should be exercised not to overcontrol pitch and roll in this condition by using only small control motions. At an altitude of ten to fifteen feet the aircraft will be clear of the ground effect and a steady hover easily established with very small control motions. Duct angle should be adjusted for a level fuselage attitude.

Vertical Landings

From a steady hover a descent to a vertical landing can easily be made with the ducts positioned for a slightly nose up attitude so that the main gear will contact the ground first. The collective is lowered to allow a vertical descent. As ground effect is encountered it will be necessary to reduce power to counter the positive ground cushion effect. Turbulence will also be encountered and the work load will increase in all axes to maintain a level steady attitude for ground contact. A positive rate of descent should be established clear of ground effect and allowed to continue until ground contact. This will minimize exposure to ground effect and provide a good positive landing. After touchdown the collective should be lowered firmly to minimum. As the nose wheel comes down a slight forward motion will devleop which is easily arrested with brakes.

Short Takeoffs

Even though a STO can be made at any duct angle between 75° and 0°, the normal STO configuration is 30°. This provides a good compromise between control mixing, ground run and power required.

After accomplishing a preflight takeoff check the collective is increased. Brakes can be held for the first 8-10° of collective travel if ground run is to be minimized. Acceleration is very rapid as N_1 speed reaches 85% and above. A normal rotation should be made at 50 knots. The aircraft will become airborne immediately and will accelerate to 80 knots if near maximum power is being used before reaching sufficient nose-up attitude to stop the acceleration. Power can then be reduced to approximately 85% N_1 for a 90-knot climbout. Handling characteristics are very good throughout the takeoff. The only trim change encountered is a slight rearward trim change during climbout.

The only correction that should be made for crosswind during the takeoff ground run is to maintain runway heading with the rudder. Roll stick should remain central until flying speed is achieved (50 to 60 knots). Any displacement of the roll stick into the wind will increase the weather cocking tendency and require additional rudder to maintain direction. In the extreme, this effect could be cumulative and result in loss of directional control due to roll stick displacement.

STO at other duct angles uses a similar technique with liftoff airspeeds appropriate to the duct angle.

Short Landings

Landings can be easily performed at any duct angle, however, the normal configuration for a STOL approach and landing is 30°. This provides a good compromise between control mixing, ground run, approach, and touchdown speeds. A normal traffic pattern is flown at 30°/90 knots after turning base leg. Care should be taken not to exceed a rate of descent of more than 800 ft/min. A speed of 85-90 knots is maintained over the fence. Roundout at 80 knots, and touchdown will occur at approximately 70 knots. During the roundout collective pitch must be lowered as otherwise decreasing airspeed will cause an increase in N_1 and a long float before touchdown. The touchdown point can be very accurately controlled with collective pitch. After the main wheels contact the runway drop the nosewheel by reducing collective. After all wheels are on the runway, minimum collective pitch produces very effective aerodynamic braking. Brakes should not be used at high speed as the light wheel loading will cause the wheels to skid and result in a possible blowout. Duct rotation toward 90° is very effective at slowing the aircraft immediately after reducing power.

To correct for crosswind the wing down method is satisfactory. It is essential that the aircraft be lined up with the direction of flight prior to touchdown. A crosswind creates no abnormal problems during approach or touchdown, however, trouble can develop during the runout. The large fin on the X-22 creates a strong weathercock tendency which must be offset with rudder and/or roll stick. At touchdown the roll stick will be into the wind which also creates a turning moment increasing the weathercock tendency. As speed decreased sufficient rudder may not be available to maintain heading. When full rudder travel is reached roll stick must be used by moving it out of wind to obtain directional control. This method provides adequate directional control during rollout, however, it is a reversal of standard fixed wing crosswind landing technique.

Conventional Takeoffs

A takeoff can be made with ducts set at 0°, however, the high speeds attained before liftoff and long ground roll makes it inadvisable.

Conventional Landings

A conventional landing should only be made when an in-flight problem makes it impossible or inadvisable to rotate ducts in the air.

A normal traffic pattern is flown at 120 knots with ducts unlocked. A long flat final approach is recommended. Slowing the speed to 110 knots over the fence, touchdown will occur at 100 knots. With minimum collective, deceleration is very slow and brakes should not be used until reaching taxi speed.

The only effective means of decelerating is by rotating ducts, even so, a ground roll of over 6,000 ft. may be required to stop the aircraft.

Feel and Trim-Off Landings

With the feel and trim system "off" the aircraft can be easily operated and landed at any duct angle with only minor degradation of handling characteristics. Without feel and trim the stick will have very light breakout forces and no force gradient. The rudder controls will not be effected. This is not an uncomfortable condition but may result in a slight pilot induced oscillation due to overcontrolling on first encounter.

Landing With SAS Off

The aircraft can be operated anywhere within the transition envelope on half SAS or SAS "off". At high speed (above 130 knots) SAS is nearly phased out so loss of SAS will have little or no effect. As speed is decreased and SAS gains increase the effect of a degraded system are greater. If it is necessary to land with no SAS, a 30° duct angle STOL approach and landing is recommended. This provides the best approach conditions while taking advantage of the natural stability characteristics. Hovering dynamics with no SAS is much different than with SAS. Under normal conditions the aircraft is controllable with half SAS with similar characteristics to full SAS as long as rates and attitudes changes are minimized. Under this condition a normal vertical landing can be made. With no SAS, controllability in ground effect is marginal and a vertical landing should not be attempted unless absolutely necessary. The ducts should be rotated slowly downward planning to make a STOL landing at 45 to 30° duct angle.

Hovering

Steady hovering flight out of ground effect is easily accomplished with only small control motions. Due to the high SAS gains in the hover, the aircraft is very stable and much easier to hover than helicopters under similar conditions. To maintain a level fuselage attitude into wind the ducts are lowered approximately one degree for each knot of wind velocity. Similarly, fuselage angle can be altered by varying duct angle. When hovering out of wind, one degree of bank attitude will be required to counteract each knot of lateral wind velocity.

The aircraft is relatively stiff in yaw making it necessary to make a positive rudder input to obtain a hovering turn. It is recommended that the yaw feel springs be disengaged while hovering to prevent the necessity to hold a rudder force. Adequate yaw rates are available to accomplish all hovering maneuvers. Spot turns require a slightly different technqiue than that used in helicopters. To minimize fuselage attitude change, duct rotation should be used during the turn in a wind. When hovering into wind the ducts will be positioned slightly forward. As the turn is initiated ducts should be rotated so as to be at 90° when the wind is off the wing. As the turn is continued to a downwind heading the ducts should be rotated on to the stops at 95° then fuselage attitude used as required to maintain position. For the second half of the turn the ducts are returned to arrive at the initial condition as the turn is completed.

Air taxiing forward is accomplished by rotating ducts downward to 60-75°. Care should be taken to avoid duct buzz. Aircraft control is very good and air taxi is quite easy. Rearward flight is accomplished by simply rotating ducts against the 95° stops and using fuselage attitude to adjust speed. With high winds it may not be necessary to rotate all the way to the duct stops, but any duct angle greater than that required for level fuselage hover can be used. Forward and aft translation can be accomplished by leaving the ducts fixed and using fuselage angle to adjust the thrust vector. However, this is ineffective for long translations due to the large fuselage attitudes required to obtain the desired velocity.

Lateral flight is easily performed with good control about all axes by merely lowering one wing to obtain the lateral velocity. Rudder control is required to offset weather cocking tendencies.

Hovering in ground effect (below 15 ft.) is characterized by high random acceleration about all axes and a slight reduction in power is required. This turbulent condition is very uncomfortable and accurate attitude control is difficult. The magnitude of the turbulence is a function of relative airspeed. The worse conditions occur at 5 to 10 knots of forward velocity. Maneuvering should not be attempted in ground effect and exposure should be kept to a minimum.

Transitions

Transitions from hover to forward flight or from forward flight to the hover are easily accomplished.

To transition into forward flight the ducts are rotated downward with the duct rotation switch on the collective while maintaining a level fuselage attitude with the stick. Continuous rotation can be performed by holding the switch down or slower rotation can be obtained by intermittent use. Collective pitch is used to control the flight path. Throughout the transition it is desirable to trim forward slightly but no difficulty is experienced in holding a forward force on the stick until reaching stable conditions.

During the last 20° of duct rotation it is necessary to counteract the loss of lift by pitching nose up 10 to 15° angle of attack. If this is not done a high rate of sink will develop.

When transitioning back to hover from conventional flight it is necessary to pitch down to prevent a climb from developing during the first 20° of duct rotation. The fuselage can then be held level and collective pitch used to control the flight path. The aircraft is very maneuverable throughout transition and it is possible to perform turns, climbs, or descents, while transitioning. It is necessary to maintain a proper airspeed/duct position schedule while transitioning but it is practically impossible to exceed the limitations without making very large pitch attitude changes.

At certain high duct angle/slow speed combinations duct buzz occurs. This is a high frequency (150 cps) vibration caused by the propellers passing through areas of airflow separation within the ducts. Even though this is not an unsafe condition it is uncomfortable and continued exposure could cause fatigue problems so high duct buzz areas should be avoided. The best method of decreasing duct buzz is to increase speed by rotating ducts downward or pitching nose down and increasing power.

CONVENTIONAL FLIGHT

In steady flight above 80 knots with duct angles between 30° and 0° the X-22 flies very much like any conventional aircraft in this weight category. The aircraft has very high control powers in pitch and roll and, therefore, is very responsive to control inputs. Since the aircraft exhibits near neutral static stability it is necessary to continually hold the aircraft level with control inputs.

When making a turn the requirement for rudder control is slow to develop but it is necessary to add rudder gradually during the turn to accomplish a coordinated turn.

The aircraft is very stable directionally. Rudder pedal centering is obtained with the feel springs which should be switched in during conventional flight. To trim in yaw the spring can be switched out momentarily to obtain a new center position.

Due to the collective pitch control method of regulating power the aircraft is very stable in airspeed. Even when making climbs or descents power output from the engines will change accordingly so as to cause only a minimum change of airspeed.

STALLS AND RAPID DESCENTS

Operation throughout the transition flight envelope is restricted to angles of attack less than 20° (indicated). Within this restriction no stall phenomena are evident providing airspeed is reduced slowly toward the transition envelope minimum value for any duct angle. Decreasing collective pitch below power required for level flight increases the operating angle of attack and decreases the propeller slipstream through the ducts and over the elevons. As power is reduced and rate of descent increases, a point is reached when slight airframe buffet will be felt and control power and damping of aircraft motions in pitch and roll are degraded. Increasing collective pitch and/or airspeed will reduce buffet and improve controllability. Collective pitch should not be reduced abruptly at low airspeeds or high angle of attack.

Onset of buffet at low airspeeds and high angles of attack will occur before power is reduced to zero, thereby precluding power off descents.

Section VII-SYSTEMS OPERATION
(not applicable)

Section VIII-CREW DUTIES
(not applicable)

Section IX-ALL WEATHER OPERATION
(information not available)

APPENDIX I - PERFORMANCE DATA

TABLE OF CONTENTS

INTRODUCTION

Performance charts in the appendix are based upon data derived from flight tests unless otherwise indicated. The performance is further based on nominal YT58-GE-8 engine data using JP-1 fuel.

POSITION ERROR CORRECTION

Figure A-1 presents position error corrections for airspeed and altitude, for both pitot static and low range airspeed systems.

ENGINE OPERATING LIMITS

Figure A-2 (sheet 1) presents engine operating limits at sea level and sheet 2 presents limitations at 10,000 feet.

TAKEOFF

Figure A-3 presents short takeoff performance.

The maximum gross weight for a rolling takeoff is 16,700 lbs. Takeoff in accordance with Figure A-3 will assure a rate of climb in excess of 500 feet per minute with 3 engines after liftoff. Figure A-4 presents the maximum gross weight for vertical takeoff, as a function of atmospheric temperature and pressure.

HOVERING

Figure A-5 presents the maximum gross weight for hovering (out of ground effects) with maximum power, as a function of altitude and atmospheric temperature.

CLIMB

Figure A-6 presents best rate of climb obtained when operating at the climb speed in Figure A-7.

CRUISE RANGE

Figure A-8 presents cruise range in nautical miles with and without fuel allowances for climb and descent from operating altitude.

ENDURANCE

Figure A-9 presents maximum endurance for various fuel loadings and Figure A-10 presents hover endurance.

LANDING DISTANCE

Landing distance information is not available from estimates and has not been demonstrated by flight tests.

DUCT ROTATION SCHEDULE

Figure A-11 presents the duct rotation schedule.

POSITION ERROR CORRECTIONS (AIRSPEED AND ALTITUDE)

NOSE BOOM & LORAS

DATE:FEB. 1968

MODEL: X-22A

DATA BASIS: FLIGHT TEST
& ESTIMATED

ENGINES: YT58-GE-8

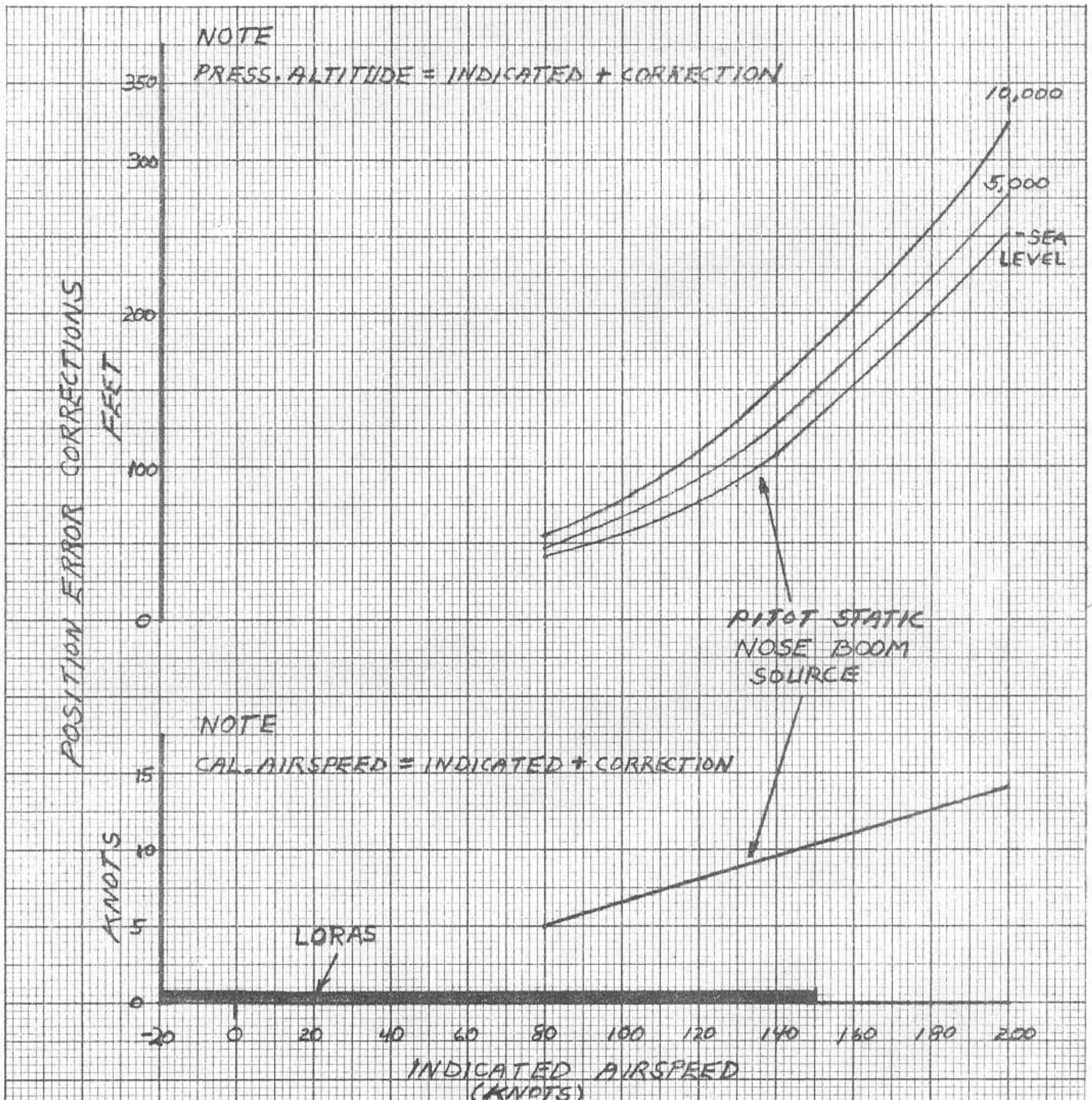


Figure A-1

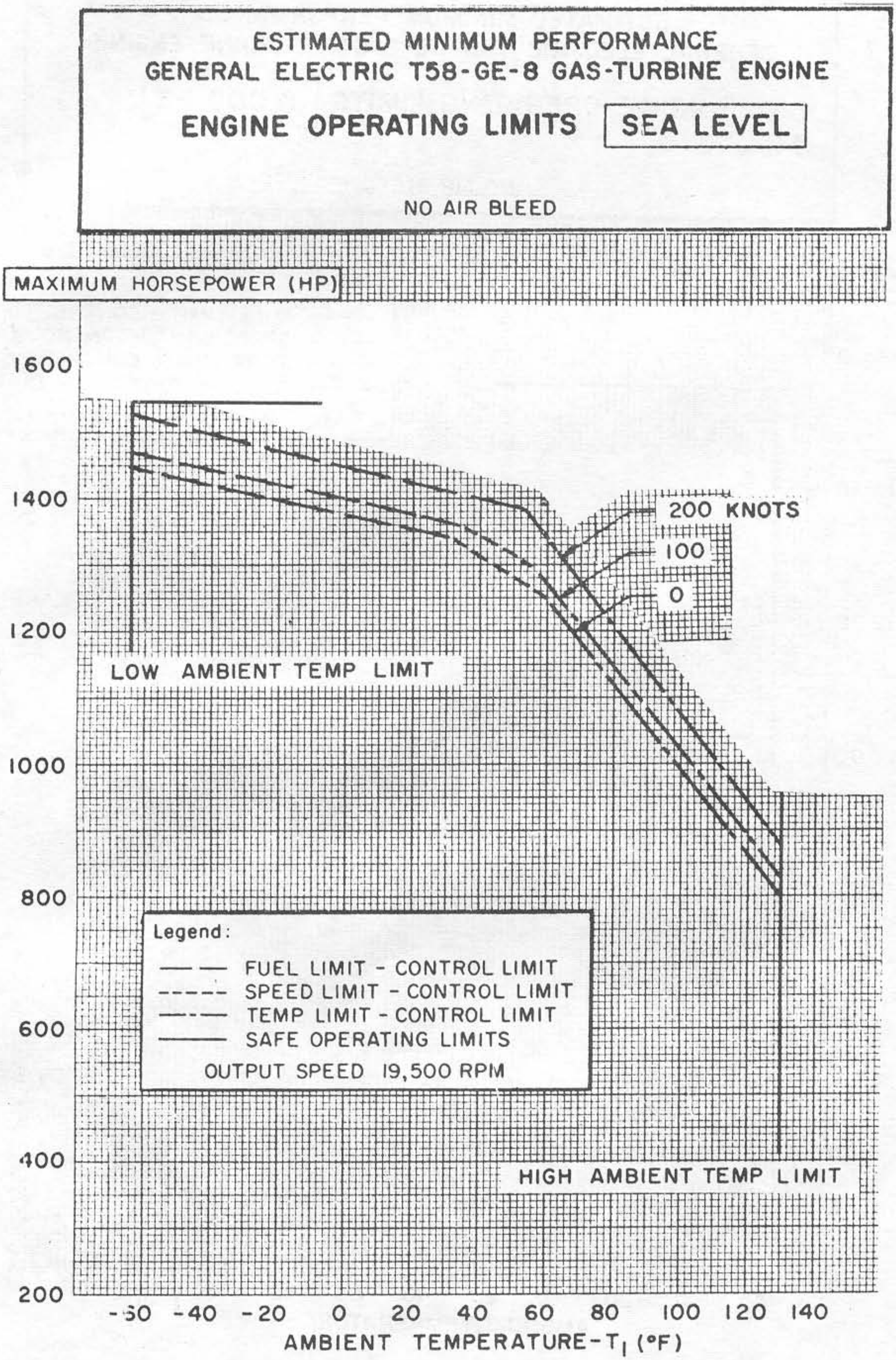


Figure A-2 (Sheet 1 of 2)

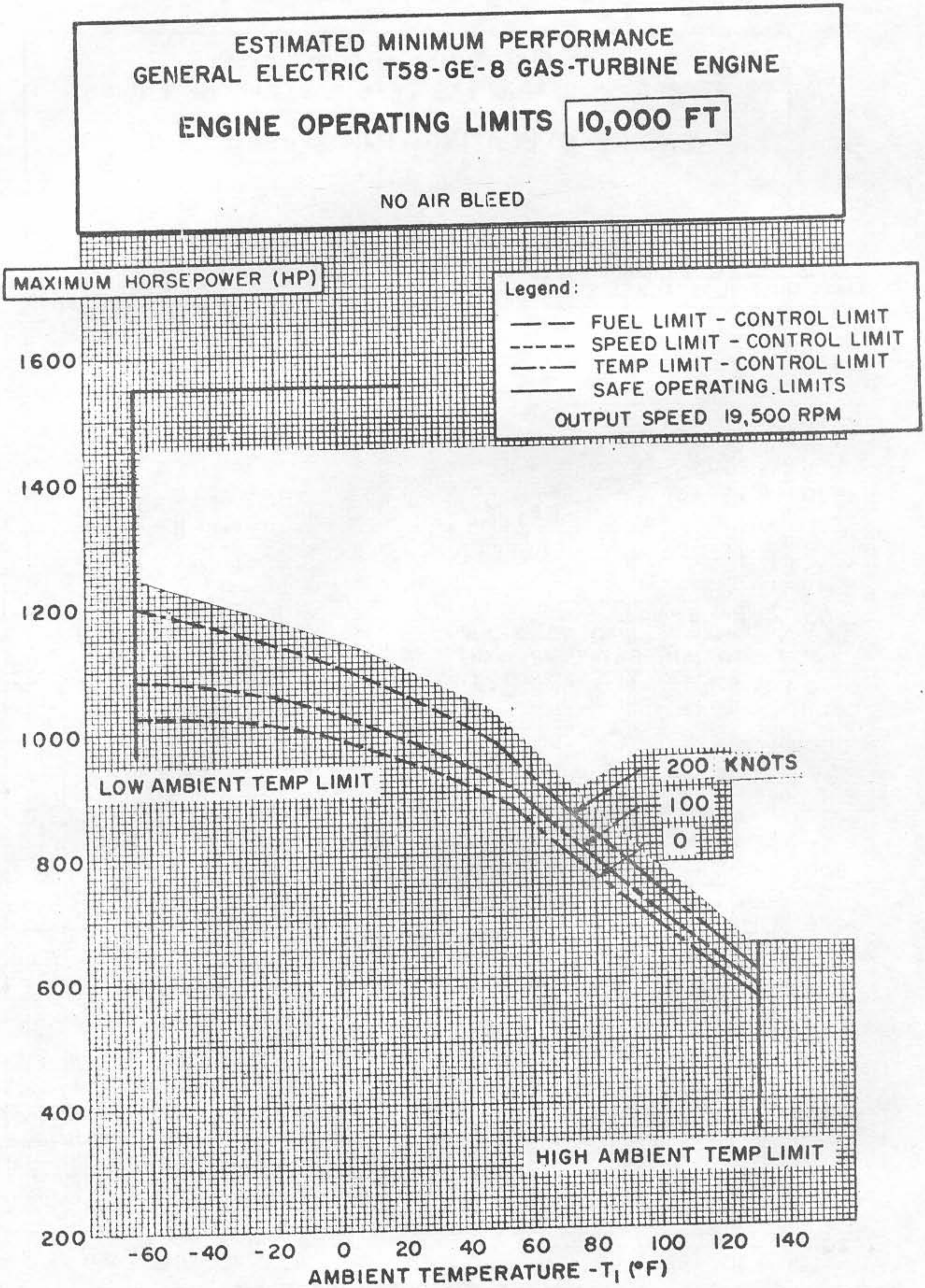


Figure A-2(Sheet 2 of 2)

SHORT TAKEOFF PERFORMANCE (4-ENGINE MRP)

DATE: FEB. 1968

MODEL: X-22A

DATA BASIS: ESTIMATED

ENGINES: YT58-GE-8

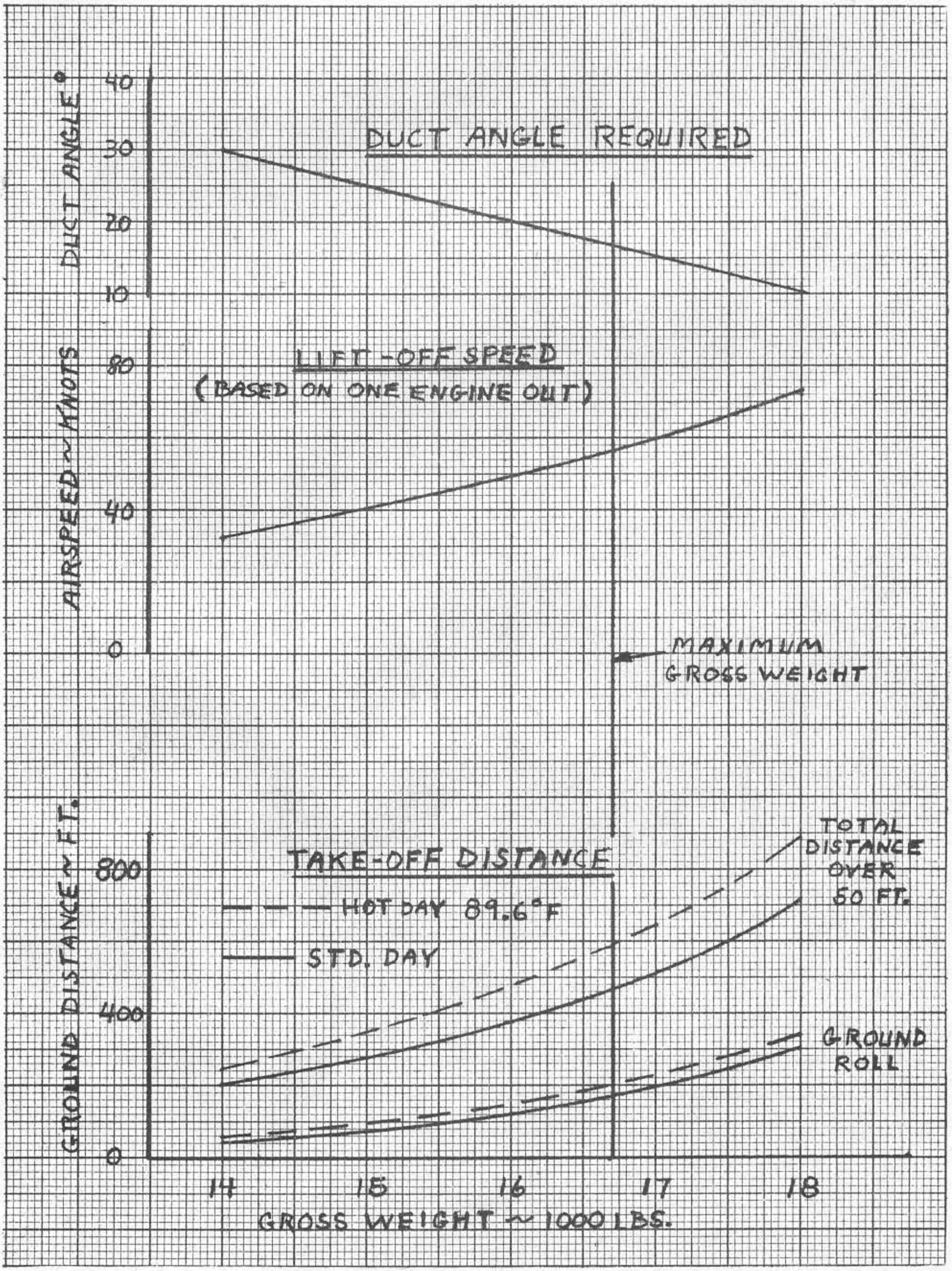


Figure A-3

MAXIMUM GROSS WEIGHT FOR VERTICAL TAKEOFF

DATE: OCT. 1968

MODEL: X-22A

DATA BASIS: FLIGHT TEST

ENGINES: YT58-GE-8

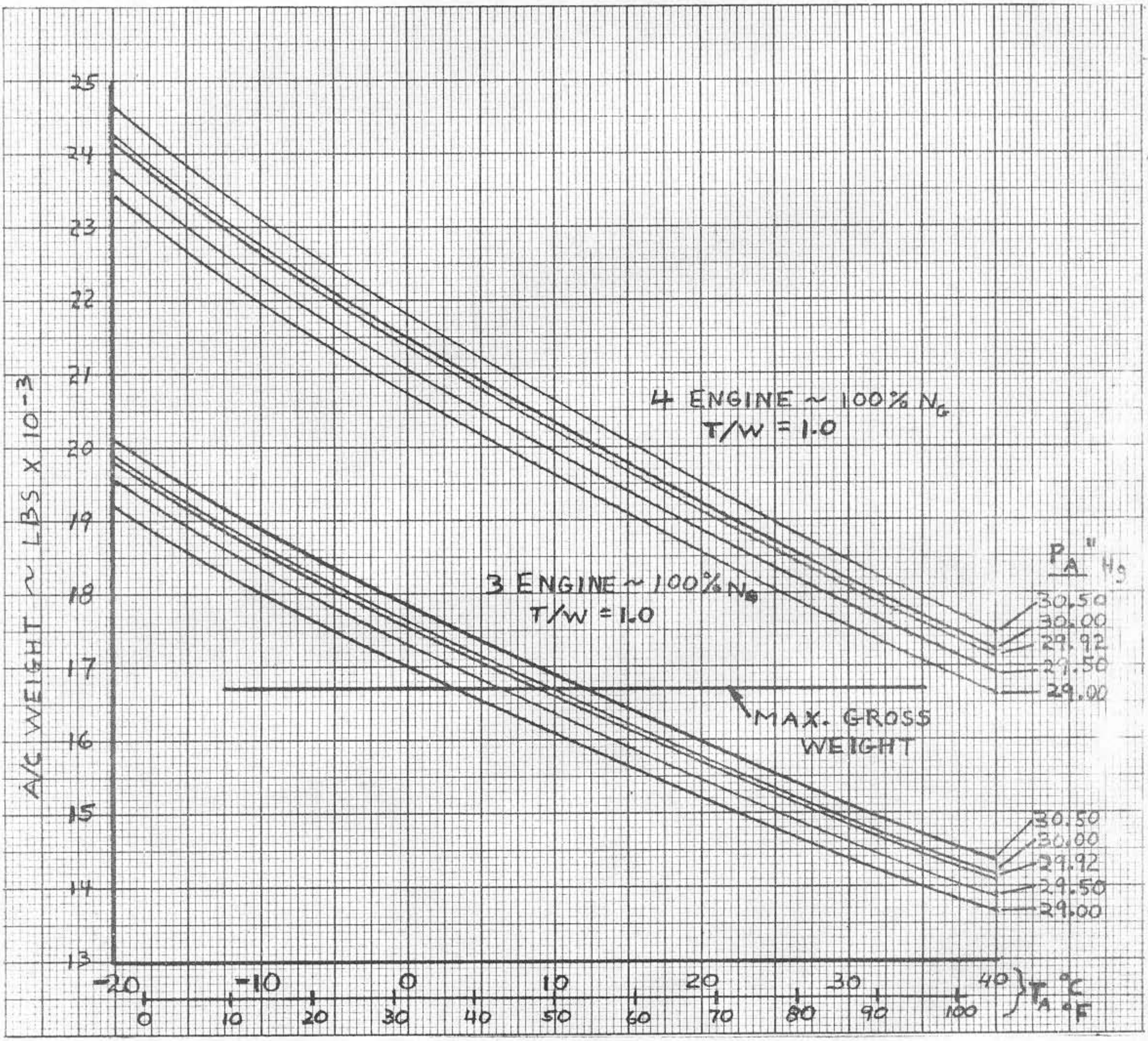


Figure A-4

MAXIMUM GROSS WEIGHT FOR HOVERING (OGE)
WITH MAXIMUM POWER

DATE:OCT.1968
DATA BASIS: FLIGHT TEST

MODEL: X-22A
ENGINES: YT58-GE-8

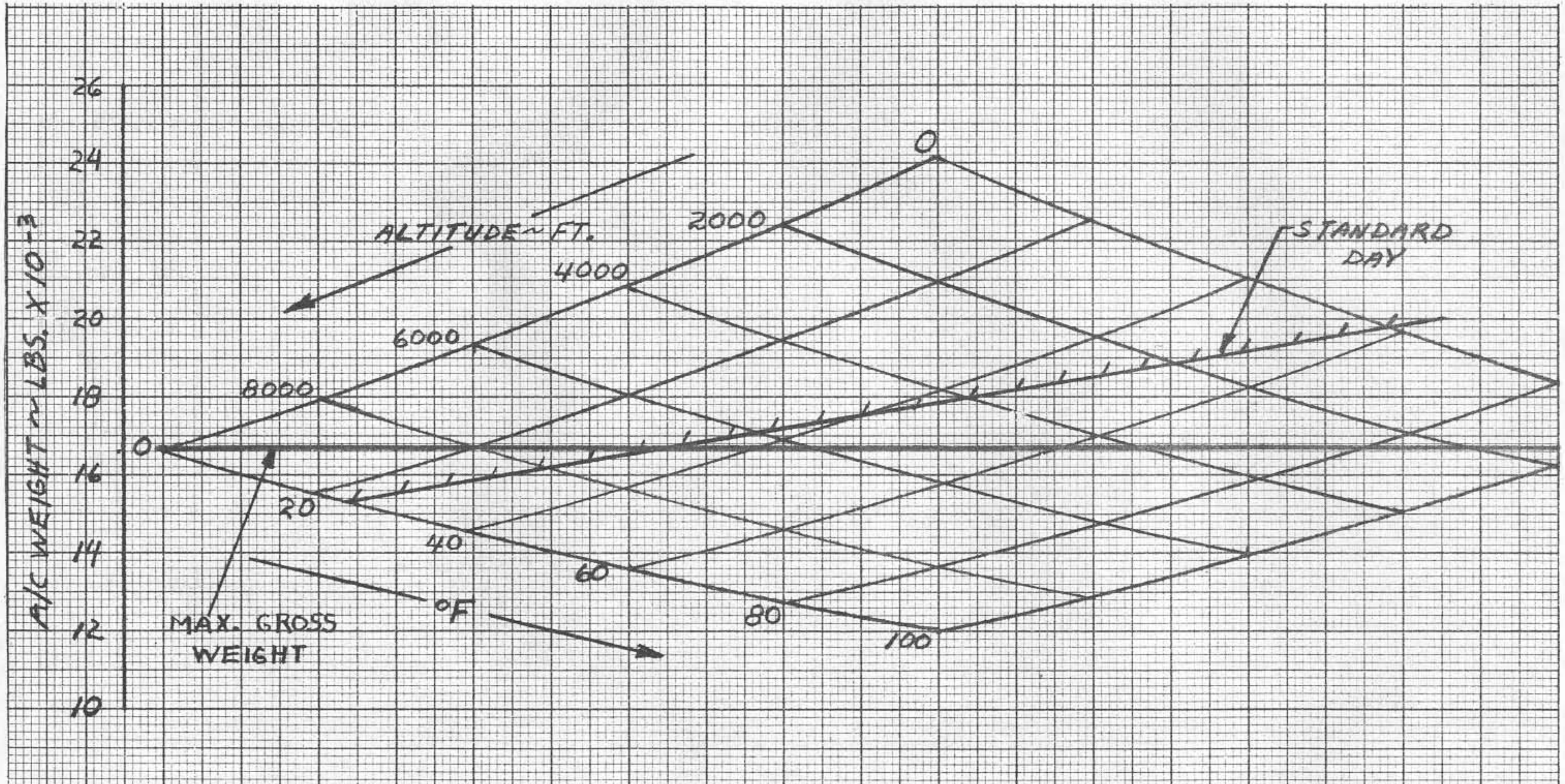


Figure A-5

RATE OF CLIMB

DATE: OCT. 1968

DATA BASIS: ESTIMATED

MODEL: X-22A

ENGINES: YT58-GE-8

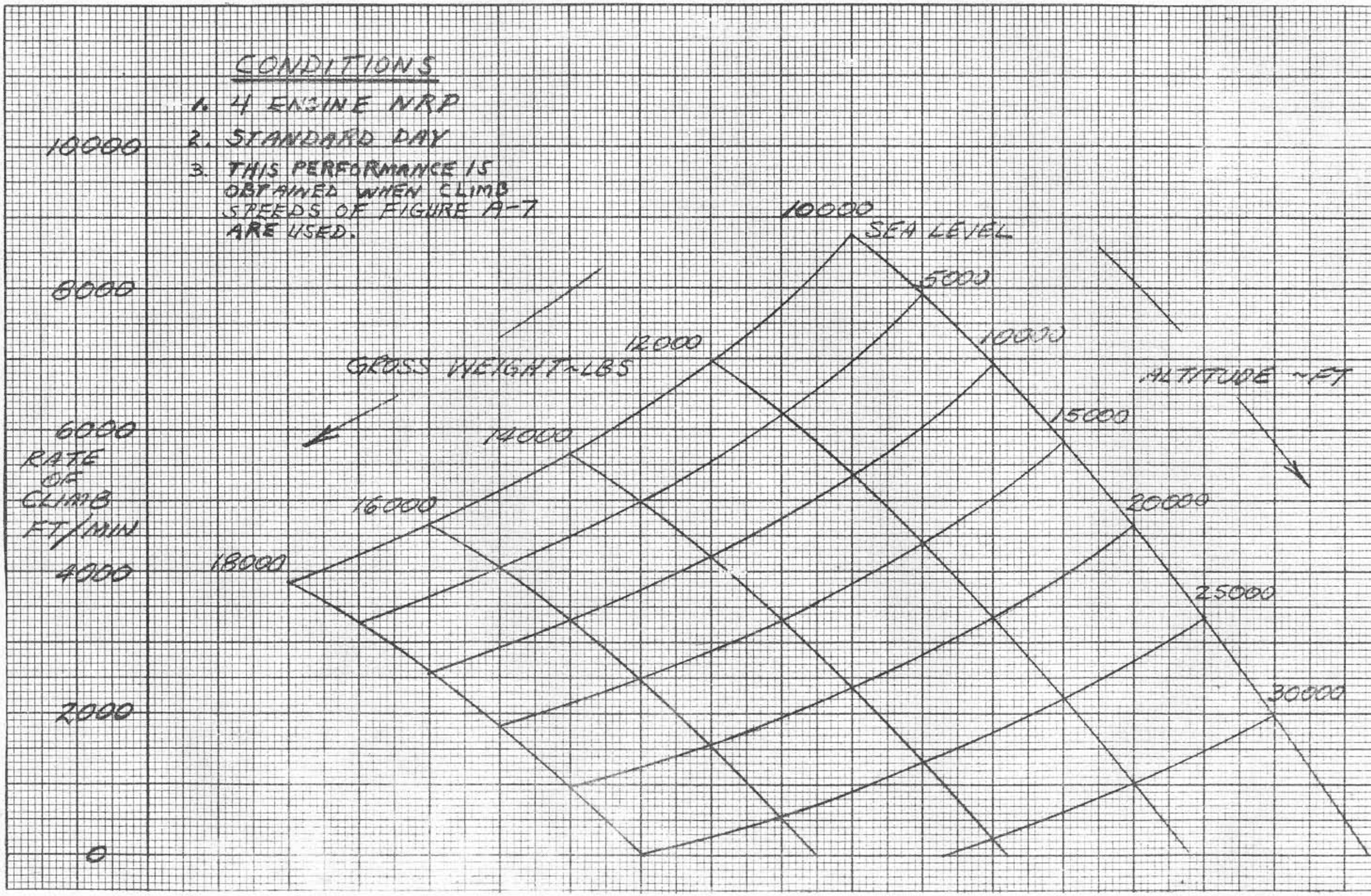


Figure A-6

CLIMB SPEED

DATE: OCT. 1968

DATA BASIS: FLIGHT TEST

MODEL: X22A

ENGINES: YT58-GE-8

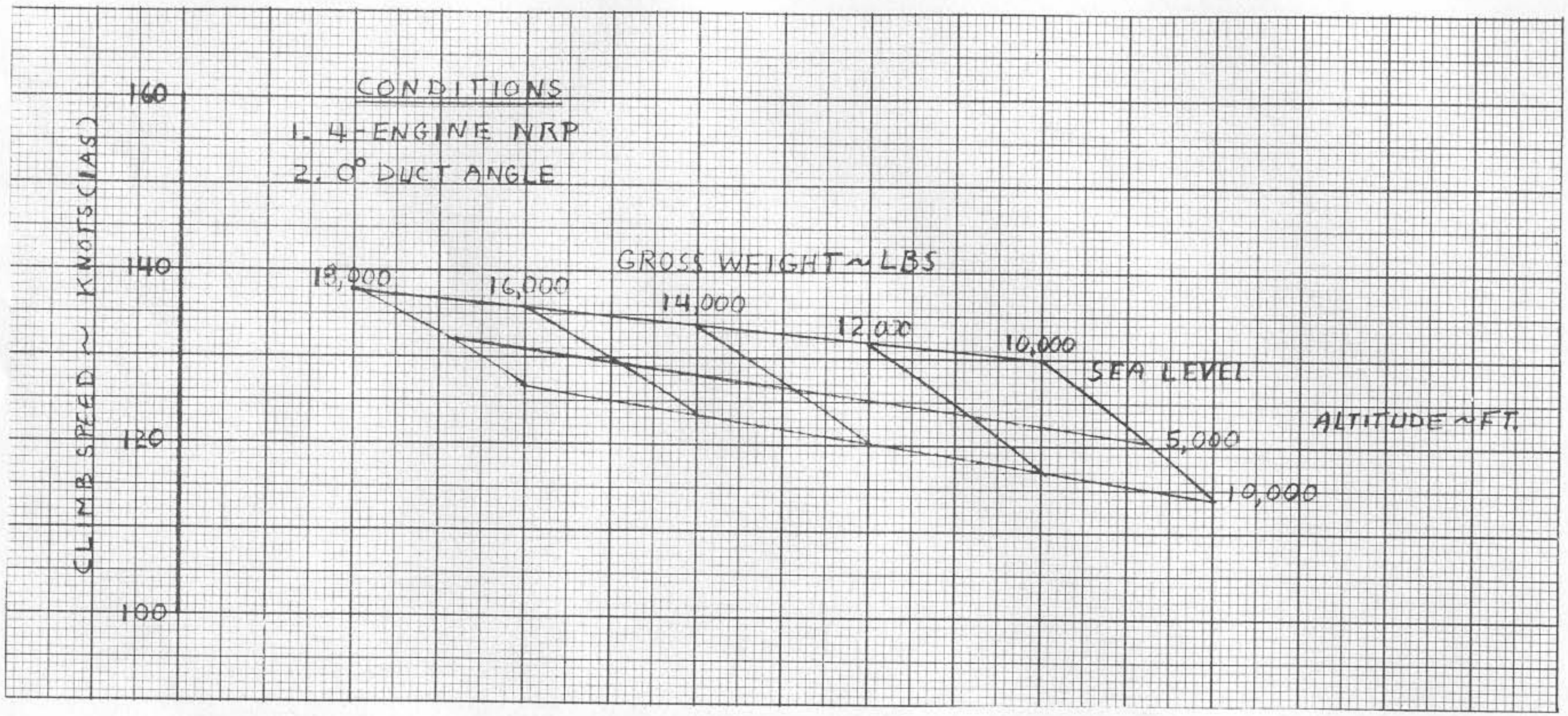


Figure A-7

CRUISE RANGE - STANDARD DAY

(4-ENGINES, 0° DUCT ANGLE)

DATE: FEBRUARY 1969
DATA BASIS: FLIGHT TEST

MODEL: X-22A
ENGINES: YT58-GE-8

Gross Weight (lb)	Pressure Altitude (ft)	IAS (knots)	TAS (knots)	Range - Naut. Miles (Without Climb) Fuel (lb)*							
				3200	2800	2400	2000	1600	1200	800	400
17,000	10,000	120	148	361	314	267	219	177	132	88	44
	5,000	130	150	314	274	234	194	154	115	76	38
	SL	141	150	280	244	208	172	137	102	68	34
16,000	10,000	120	148		321	274	227	181	135	90	45
	5,000	130	150		281	240	198	158	118	78	39
	SL	141	150		252	214	178	141	105	70	35
15,000	10,000	120	148				232	185	138	92	47
	5,000	130	150				204	163	121	80	40
	SL	141	150				184	146	109	72	36
				Range - Naut. Miles (With Climb)							
17,000	10,000	120	148	354	307	250	216	171	126	82	38
	5,000	130	150	313	273	232	192	152	113	74	36
	SL	141	150	280	244	208	172	137	102	68	34
16,000	10,000	120	148		314	267	221	175	129	83	39
	5,000	130	150		279	238	196	156	116	76	37
	SL	141	150		252	214	178	141	105	70	35
15,000	10,000	120	148				227	180	133	86	40
	5,000	130	150				202	161	119	78	38
	SL	141	150				184	146	109	72	36

* Fuel amount indicated is available for cruise. Takeoff and landing fuel is in excess of that shown (440 lb).

FIGURE A-8

MAXIMUM ENDURANCE - STANDARD DAY
(4-ENGINES, 0° DUCT ANGLE)

DATE: FEBRUARY 1969
DATA BASIS: ESTIMATED

MODEL: X-22A
ENGINES: YT58-GE-8

Gross Weight (lb)	Pressure Altitude (ft)	IAS (knots)	TAS (knots)	Endurance - Hours (Without Climb) Fuel (lb)* 3200	2800	2400	2000	1600	1200	800	400
17,000	10,000	101	125	2.8	2.4	2.1	1.7	1.3	1.0	0.7	0.3
	5,000	101	116	2.6	2.2	1.9	1.6	1.2	0.9	0.6	0.3
	SL	103	110	2.3	2.0	1.7	1.4	1.1	0.8	0.6	0.3
16,000	10,000	101	125		2.6	2.2	1.8	1.4	1.0	0.7	0.3
	5,000	101	116		2.4	2.0	1.6	1.3	1.0	0.6	0.3
	SL	103	110		2.1	1.8	1.5	1.2	0.9	0.6	0.3
15,000	10,000	101	125				1.9	1.5	1.1	0.7	0.4
	5,000	101	116				1.7	1.4	1.0	0.7	0.3
	SL	103	110				1.5	1.2	0.9	0.6	0.3
				Endurance - Hours (With Climb)							
17,000	10,000	101	125	2.6	2.3	1.9	1.6	1.2	0.9	0.6	0.3
	5,000	101	116	2.5	2.1	1.8	1.5	1.2	0.9	0.6	0.3
	SL	103	110	2.3	2.0	1.7	1.4	1.1	0.8	0.6	0.3
16,000	10,000	101	125		2.5	2.1	1.7	1.4	1.0	0.6	0.3
	5,000	101	116		2.3	2.0	1.6	1.3	1.0	0.6	0.3
	SL	103	110		2.1	1.8	1.5	1.2	0.9	0.6	0.3
15,000	10,000	101	125				1.8	1.4	1.1	0.7	0.3
	5,000	101	116				1.7	1.4	1.0	0.7	0.3
	SL	103	110				1.5	1.2	0.9	0.6	0.3

* Fuel amount indicated is available for cruise. Takeoff and landing fuel is in excess of that shown (440 lb).

FIGURE A-9

HOVER ENDURANCE - STANDARD DAY

(4-ENGINES)

DATE: FEBRUARY 1969
DATA BASIS: ESTIMATED

MODEL: X-22A
ENGINES: YT58-GE-8

Gross Weight (lb)	Pressure Altitude (ft)	Endurance (hours) Fuel (lb) 3200	2800	2400	2000	1600	1200	800	400
17,000	10,000		Gross weight above hover ceiling						
	5,000	1.3	1.1	1.0	0.8	0.6	0.5	0.3	0.1
	SL		1.1	1.0	0.8	0.6	0.5	0.3	0.2
16,000	10,000		Gross weight above hover ceiling						
	5,000		1.2	1.1	0.9	0.7	0.5	0.3	0.2
	SL		1.2	1.0	0.9	0.7	0.5	0.3	0.2
15,000	10,000				0.9	0.7	0.5	0.3	0.2
	5,000				0.9	0.7	0.5	0.3	0.2
	SL				0.9	0.7	0.5	0.3	0.2

FIGURE A-10

DUCT ROTATION SCHEDULE

DATE: MAR. 1968

MODEL: X22A

DATA BASIS: FLIGHT TEST

ENGINES: YT58-GE-8

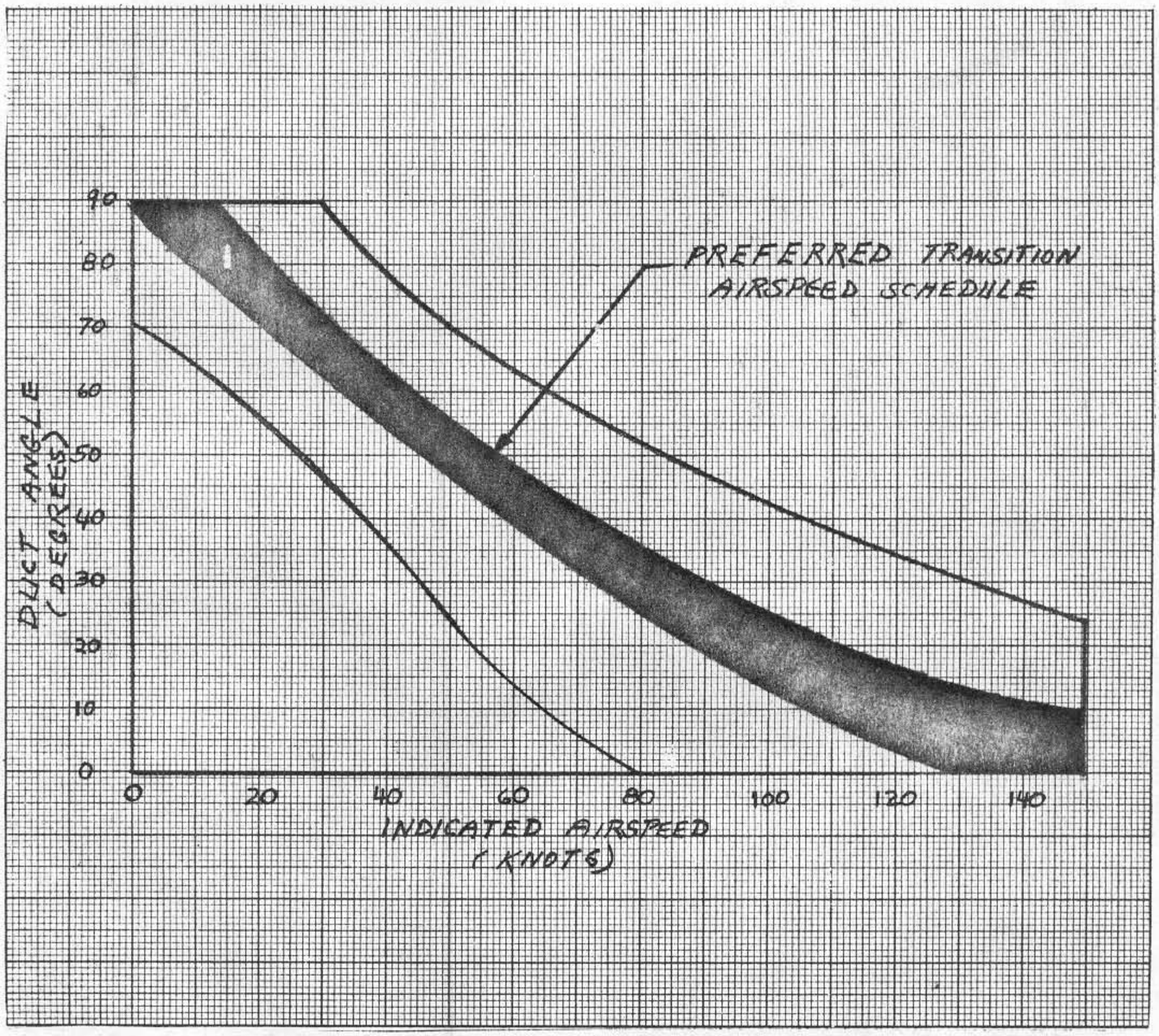


Figure A-11

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