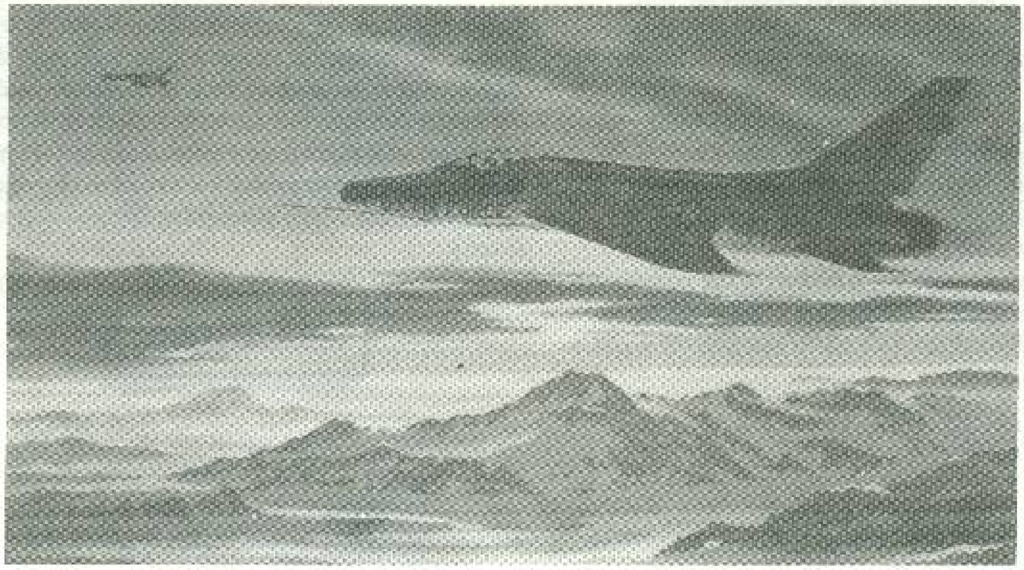
SYSTEMS OPERATION

section VII



F-100D-1-0-83

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THRUST-RPM RELATIONSHIP.

The J57 engine has a split ("two-spool"), 16-stage, axial-flow compressor. The compressor section consists of a nine-stage, low-speed, low-pressure rotor unit and a seven-stage, high-speed, high-pressure rotor unit. The rotor assemblies are mechanically independent and, therefore, do not rotate at the same rpm. The tachometer, however, shows the rpm of the high-pressure compressor rotor only. A tachometer reading of 100% rpm for the J57 engine, unlike that for other jet engines, is not intended to show proper thrust output. In fact, on these engines, 100% rpm is considerably above the rpm at which rated thrust is obtained. During the factory calibration run of the engine, high-pressure rotor rpm for Military Rated Thrust is determined for an outside temperature of 60°F, and this speed is stamped on the engine fire-wall speed data plate. This original trim speed varies from engine to engine 93.5% rpm to 96.5% rpm. However, as engine operating time increases, some loss of performance results, and the engine speed may be increased progressively above the original trim speed by adjustments (retrimming) to restore Military Rated Thrust. It is apparent, then, that each engine must be treated individually with respect to the rpm at which Military Thrust is obtained. Because of the maximum speed variations between engines, the large variation between engine speed and thrust (1% change in rpm changes thrust about 5%), and the inherent inaccuracies of tachometers, the engine is trimmed and power-checked according to turbine discharge pressure, which does not vary as much with thrust as does rpm. The ratio of turbine discharge pressure to pitot pressure is shown by the engine pressure ratio gage. This gage gives a more accurate indicator of takeoff thrust than the tachometer or exhaust temperature gage. The desired pressure ratio gage reading at Military Thrust depends upon outside air temperature; therefore, the gage must be adjusted just before takeoff, to compensate for temperature. (Refer to Engine Pressure Ratio Gage in section I.) When the engine preflight check is made, the engine is unstabilized. During this transient period, thrust may be higher than the stabilized rated thrust. The pressure ratio gage pointer will also indicate thrust "overshoot" by exceeding the position of the index marker on the gage. This engine thrust "overshoot" is acceptable for takeoff if the pointer falls within the limits listed under Engine Limitations in section V. Takeoff should not be made if the pointer is not within the allowable limits.

MAXIMUM CONTINUOUS THRUST OPERATION.

Some pilots have misinterpreted the maximum continuous exhaust temperature limits as the maximum continuous engine thrust operation limits. This procedure will often result in using thrust that is above the continuous rating. The maximum continuous exhaust temperature limit was not intended to be used as a means of setting up continuous thrust, but only as a cross-check.

Operation at Maximum Continuous Thrust requires a reduced thrust setting of about 3% rpm below that noted for Military Thrust. After selecting the Maximum Continuous Thrust setting, using the tachometer, cross-check with the exhaust temperature gage to be sure it remains within limits of 580°C below 30,000 feet and 610°C above 30,000 feet. For review, Maximum Continuous Thrust is first a thrust reduction of about 3% rpm below the indicated Military Thrust and secondly, observance of exhaust temperature limits.

Disregarding this method of setting up the Maximum Continuous Thrust will shorten the service life of the engine and cause unnecessary fuel consumption.

AIR TEMPERATURE VS THRUST.

Air density, and therefore engine performance, of all air-breathing jet engines is affected by inlet air pressure and temperature. When inlet air density is increased by either a lower air temperature or a higher ram pressure, the engine, at a constant rpm, "pumps" an increased quantity of fuel and air (by weight), resulting in an increase in thrust.

ENGINE STARTER CARTRIDGE MALFUNCTIONS.

Tactical Commanders may waive the 5-minute waiting period. Reducing the 5-minute time limit should be done only after it is determined that no smoke is emitting from the starter exhaust, the starter breech cover is not hot to the bare hand, and there is no evidence of pressure inside the chamber. (Chamber pressure is evidenced by encountering undue resistance when attempting to remove the breech cover.)

WARNING

The cartridge screen end must not be pointed toward airplane equipment or personnel during removal, and should be treated as a potential hangfire and fire hazard for a period of 10 minutes after removal.

HANGFIRE.

A hangfire is recognized by the time interval (as much as 5 minutes) between pressing the start button and the generation of the full pressure of the cartridge propellant and is caused by an abnormal firing of the cartridge. A hangfire usually is indicated by black smoke coming from the starter exhaust port and ineffective operation of the starter. There usually will be a gradual increase in chamber pressure to a normal or almost normal level which results in the acceleration of the starter. However, a start will be improbable.

MISFIRE.

A misfire occurs if the cartridge fails to ignite. It usually is caused by either a faulty cartridge or an electrical malfunction. If the starter holding relay is at fault, pushing the starter and ignition stop button will sometimes cause the relay to make momentary contact and fire the cartridge. If the cartridge does fire at this time, the starter and ignition button must be pressed again so engine ignition will occur when the throttle is moved outboard to IDLE. The malfunction should be corrected as soon as possible. Also, the misfire could be caused by having the external air connected.

WARNING

Protective equipment, such as asbestos gloves and a face shield, must be worn for removing the cartridge after a misfire or hangfire. Electrical power must be disconnected from the airplane and the power-on cartridge warning light must be off before the cartridge is removed.

OIL PRESSURE.

When oil pressure is normal (between 40 and 55 psi), adequate oil flow for lubrication and for cooling is indicated. When oil pressure falls below or fluctuates to below 40 psi, oil flow may not be adequate for cooling, and bearing temperatures can rise. High bearing temperatures can lead to relatively rapid bearing failures. For this reason, power must be reduced when low oil pressures are noted. Power reduction reduces bearing loads, particularly in thrust bearings; reduces internal friction in the bearing when rpm is reduced; and reduces heat transfer into the bearing from the engine. Power reduction thus will permit normal bearing operation for a longer time under adverse conditions compared with high power operation. After a complete loss of lubricating oil, it is possible that the engine may continue to run for 10 to 30 minutes, provided the throttle was retarded upon the first indication of oil pressure difficulty. Bearing failure caused by oil starvation is generally characterized by a slight vibration which rapidly increases and very quickly results in an engine seizure. In some types of turbojet engines, high oil pressures indicate oil system potential failures. However, this is not likely in the case of the J57 engine. If oil pressure fluctuates above 55 psi at any power setting or exceeds 55 psi at high power settings and does not return to the normal range, a malfunction of the oil system or of the oil pressure gaging system is indicated and should be corrected before future flights. A temporary rise in oil pressure to a maximum of 60 psi is tolerable and will not harm the engine, provided there is no substantial oil pressure fluctuation, and provided the stabilized pressure returns to the normal range.

NOTE

Oil pressure will have a tendency to follow the throttle. This condition is normal provided pressure stabilizes between minimum and maximum limits.

COMPRESSOR BLEED SYSTEM.

During acceleration and deceleration of engine speed, one or more stages of the compressor may reach the stalling point. Engine operation becomes unstable when stall occurs, with surging flow and fluctuating compressor discharge pressures. The stall condition is partially relieved by bleeding part of the low-pressure compressor discharge air overboard at low engine speeds. A duct carries the bleed air from the discharge area of the low-pressure compressor to an exhaust port on the fuselage skin. Operation of the compressor bleed system is completely automatic, and no manual override is provided. Opening and closing of the bleed valve is automatically controlled by a governor that senses engine inlet temperature and pressure and the speed of the low-pressure compressor rotor. (The system does not use electrical controls.) A slide valve in the governor ports air from the high-pressure compressor to the bleed valve actuator. The actuator opens or closes the butterfly-type bleed valve, exhausting the low-pressure bleed air overboard. The governor control is adjusted to open and close the bleed valve according to the low-pressure compressor speed and engine inlet temperature-pressure schedule.

COMPRESSOR STALL.

An undesirable but inherent characteristic of most air compressors, including those of the axial-flow multistage turbojet design, is that airflow instability may occur as a result of adverse compressor inlet or exit conditions. This characteristic is more pronounced in high-performance compressors of the type used in the J57 engine. This unstable condition has been referred to as surge, pulsation, chugging, "choo-choo," or explosions, but is usually described as compressor stall in a turbojet engine because it results from separation of airflow from the surfaces of the compressor blades just as separation of airflow from a wing surface results in an airplane stall. Compressor stalls may vary in severity, and may occur momentarily or be cyclic. J57 engine compressor stalls may occur during certain adverse operating conditions, or because of an engine accessory malfunction.

CAUTION

> Severe compressor stalls in this airplane are usually the result of improper and abnormal operation, and must be recorded on Form 781 because of possible engine case damage or malfunction of the engine fuel control unit.

During night flight, flame may be seen coming out of the engine bleed-air door on the side of the fuselage, or out ot the intake duct when a severe compressor stall is experienced. A discussion of compressor stalls sometimes encountered as a result of adverse conditions during normal operation follows:

1. Low airspeed maneuvering may induce stalls because of distortion of intake duct airflow. However, stalls will not usually occur under these conditions unless throttle movement is also used. During spins, continuous mild stalls will probably be encountered with a steady increase in exhaust temperature because of severe engine airflow distortion.

2. During high-altitude, low-airspeed flight conditions, the engine compressor is operating closer to the stall region because low-density air has a greater tendency to separate from the compressor blades. Consequently, engine acceleration stalls may be induced at high altitude with low airspeeds. The engine is expected to be stall-free above .8 Mach at high altitude.

3. On the ground, mild acceleration stalls will usually be experienced just above idle (60 to 70% rpm). This type of stall is considered acceptable, provided the engine accelerates from IDLE to Military Thrust within 15 seconds.

4. During high-altitude air starts (above 30,000 feet) using the normal fuel control system, mild compressor stalls may occur as the engine accelerates to idle. If persistent stalls occur, they can be eliminated by descending to increase airspeed.

5. Erratic throttle movements can induce compressor stalls. An example of this is when the throttle is retarded and then advanced while the engine is still decelerating.

6. The emergency fuel control system does not provide automatic fuel scheduling to meet engine acceleration requirements. Consequently, compressor stalls may be experienced whenever rapid throttle movements are made using the emergency fuel system.

If the stall condition was not induced by adverse operating conditions or erratic throttle movement, a severe stall or a series of severe stalls is usually the result of one of the following malfunctions:

1. Excessive fuel scheduling by the fuel control unit can cause stalls during engine acceleration.

2. Unsatisfactory operation of the intercompressor bleed valve may result in stalls during engine acceleration or deceleration or steady-state fixed-throttle stalls.

3. Failure of the fuel control to reduce engine rpm with colder inlet air temperatures or engine operation at thrust settings above rated thrust can cause steady-state fixed-throttle stalls. Generally, this type of stall occurs only at high altitude.

4. If the exhaust nozzle is slow acting or will not open, an extremely violent compressor stall will occur when afterburner is selected.

The following procedure is recommended for recovering from severe compressor stalls:

1. Retard throttle and correct any unusual attitude of the airplane.

2. Then slowly advance throttle to the desired thrust setting.

3. If stall persists, reduce altitude and increase airspeed.

4. If stall occurs upon afterburner selection, shut down afterburner immediately.

Exhaust temperature should be monitored during compressor stalls and any overtemperature condition recorded in Form 781. An engine surge, unlike that associated with a compressor stall, may occur during low-altitude high-speed flight. This is usually the result of the normal automatic operation of the burner pressure limiter in the engine fuel control unit. The limiter automatically reduces fuel flow, when required, to prevent burner pressure from exceeding the maximum safe value. This surge is not harmful and can be eliminated by a slight reduction of the airspeed or rpm. Under extreme cold-weather conditions, limiter action can occur just after takeoff and before initial climb. At outside air temperatures of 60°F and above, the limiter operates at about .8 to .85 Mach at sea level.

FLAME-OUT.

Flame-out can result from rapid throttle movement and is most likely to occur at extremely high altitudes. Acceleration flame-out, like compressor stall, occurs when more fuel is injected into the combustion chambers than the engine can use for acceleration at the existing rpm. But, unlike the compressor stall condition, this mixture is so excessively rich that it cannot burn, so the flame goes out. Flame-out, which can also occur during rapid engine deceleration, will result when the amount of fuel injected into the combustion chambers is reduced to too low a level to sustain combustion at the existing rpm. Acceleration flame-out can be avoided by accelerating engine rpm at a slower rate. Since flame-out conditions are more severe during compressor stall, the throttle should not be "chopped" to eliminate stall, as flame-out will result. Flame-outs are indicated by loss in thrust, drop in exhaust temperature and rpm, and airplane deceleration.

NEGATIVE-G FLAME-OUT.

The inverted-flight tank in the right cell of the intermediate tank traps about 1.6 gallons of fuel to permit limited negative-G operation. If the limitations of the fuel system are exceeded by negative-G, fuel starvation leading to possible flame-out can occur in a relatively short time. There are two conditions that can cause engine flame-out during negative-G operation. In the first of these, flame-out can occur when the fuel supply of the inverted-flight tank is exhausted. Fuel is then not available until positive-G flight is resumed. The second negative-G condition that can cause flame-out occurs any time the suction-feed capabilities of the engine are exceeded. Negative-G operation uncovers the inlets of the tank-mounted fuel booster pumps so that fuel is supplied to the engine from the inverted-flight tank by suction feed. Depending on fuel condition, suction feed cannot sustain engine operation long enough to empty the inverted-flight tank (because of cavitation of the engine-driven fuel pump) above 45,000 feet at Maximum Thrust or at Military Thrust. Thus, negative-G operation is time-limited (by the capacity of the inverted-flight tank) and altitude-limited (by the suction-feed limitations of the engine).

NOTE

> The time limits of negative-G operation at Military and Maximum Thrust, based on the capacity of the inverted-flight tank and the required fuel flows, are given in section V.

The suction-feed characteristics depend on fuel temperature, fuel pressure, pump performance, etc. These factors, in turn, are influenced by flight duration, speed, and outside air temperature. The altitude limits on suction-feed operation are based on a fuel temperature of 110°F. If fuel temperature is lower, suction-feed might be sustained to higher altitudes.

NOTE

> There are no inverted-flight fuel system restrictions as long as positive-G is maintained.

AFTERBURNER IGNITION.

The engine afterburner ignition system incorporates a recirculating fuel afterburner igniter which ensures more positive light-ups at all altitudes. Continuous circulation of fuel through the igniter when the afterburner is not in operation cools the igniter casting, lessening the possibility of fuel vaporization, cooking, and resultant igniter valve seizure. The continuously circulating fuel also ensures a full igniter fuel charge when afterburner is selected.

Normally, afterburner fuel ignition occurs just after the nozzle opens. However, if afterburner power is selected and terminated repeatedly over a short period of time, fuel ignition may occur before or during exhaust nozzle opening resulting in a "jolting" hard light-up. Under this condition chances of a hard light-up may be lessened by slightly retarding the throttle when afterburner selection is made.

Afterburner ignitions that are attempted following Military Thrust climbs are sometimes unsuccessful on the first attempt.

TURBINE NOISE DURING SHUTDOWN.

The light scraping or squealing noise sometimes heard during engine shutdown results from interference between the rotating and stationary parts of the engine that have dissimilar cooling rates. The scraping is undesirable and may damage parts. To minimize scraping, it is necessary to operate the engine at reduced power (below 85% rpm) for at least 5 minutes before shutdown after any high-power operation (either ground or flight).

NOTE

> After flight, operation during approach and taxi can be included as reduced-power time.

If, despite this precaution, heavy scraping still occurs on shutdown, no attempt to restart the engine should be made until the turbine temperature has dropped enough to provide adequate clearance between the affected parts, since a starting attempt might result in destruction of the starter. If a start must be made when interference is suspected, a check should be made to find out if the engine begins to turn as soon as air is supplied to the starter. This is done by listening and by taking tachometer readings. If the engine does not begin turning when air is supplied to the starter, the starter and ignition stop button must be pressed immediately to stop the starting cycle.

SMOKE FROM TAIL PIPE DURING SHUTDOWN.

During engine shutdown, oil or fuel fumes may be noticed coming from the tail pipe or inlet duct, depending on ground wind conditions. These fumes show the presence of fuel or oil in the hot section of the engine. Boiling fuel, shown by the appearance of white vapor, will not damage the engine, but is a hazard to personnel, since the vapor may ignite with explosive violence if allowed to collect within the engine or fuselage. Therefore, all personnel should keep clear of the tail pipe for at least 3 minutes after engine shutdown and at all times when fuel vapors or smoke comes from the tail pipe. The appearance of black smoke from the tail pipe, after shutdown, shows burning oil or fuel which will damage the engine. Vapor or smoke should be eliminated by motoring the engine. (Refer to Clearing Engine in section II.)

OPERATION ON ALTERNATE OR EMERGENCY FUEL.

Alternate fuel is defined as fuel which may be substituted for the recommended fuel with possible restriction to airplane performance. Alternate fuel does not cause permanent damage to the engine or fuel systems; however, its use may require engine retrim.

NOTE

> Aviation gasoline and JP-4 fuel mixed in any proportion are suitable for continuous operation from an engine performance standpoint. However, the use of aviation gasoline must be restricted to emergency evacuation or one-time ferry-type missions to minimize undesirable lead deposits in the engines and to avoid damage to the engine-driven fuel pump due to the poor lubricating properties of aviation gasoline.

Use of approved kerosene-type alternate fuel does not adversely affect engine performance. Generally, the full takeoff rating is more readily available with the denser kerosene-type fuel, while airplane range performance will be at least as good or slightly better than with JP-4 fuel. With cold fuel, ground starts and restarts at high altitude may be slower and less consistent with the denser fuel such as JP-5. With JP-5 fuel, hard starts in cold temperatures are due to negligible fuel vapor pressure (0 psi).

Only during use of aviation gasoline (AVGAS) will it generally be necessary to retrim engines to obtain the full takeoff rating. It is recommended that, if a landing is made at a base having only aviation gasoline available and no facilities for engine retrimming, only enough fuel be loaded to accomplish a one-time flight to a base where JP-4 fuel is available. The engine operating limitations under Engine Limitations in section V also apply to alternate and emergency fuels.

Gasoline and JP-4 fuel mixtures that contain less than 10 percent gasoline in all fueled tanks have no climb rate limitations. When fuel mixtures containing more than 10 percent gasoline are used, do not exceed 5000 feet per minute rate of climb above 1500 feet altitude when fuel temperature is above 80°F. The fuel tank and vent system is not designed to handle high vapor pressure fuel. As a result, excessive fuel venting will occur, coupled with the build-up of high internal tank pressures which may cause damage to the fuel system.

After 5 or 6 hours of flight, the wing fuel temperature, regardless of fuel temperature when loaded, may be assumed to be equal to the free air temperature. T.O. 42B-1-14 prohibits airplane operation at temperatures below the freezing point of -51°F while using JP-5 fuel. However, to ensure proper engine operation, it is recommended that engine operation be restricted to no lower temperature than 5°F above the freeze point of the fuel being used. Operation at temperatures colder than these recommended limits may cause fuel screen and filter clogging by ice particles as well as fuel pump cavitation and resultant flame-out. (See figure 7-1.)

JP-4 fuel is the only fuel which presently contains an anti-icing additive to prevent fuel filter icing due to moisture in the fuel.

The F-100 fuel flow indicator measures volume-per-hour indication. The use of the higher density fuel results in a fuel flow indication that is somewhat lower than the actual flow; however, speed and range are not affected. Conversely, lower density fuel (AVGAS) presents a fuel flow indication that is somewhat higher than the actual flow; however, in this case, speed is not affected, but range is reduced by a factor of approximately 7 percent because of the lower heating value of the fuel on a volume basis. The fuel quantity gage system will read approximately one percent higher when aviation gasoline is used. Fuel quantity gage system error is negligible when other alternate grade fuels are used.

CAUTION

When operating on alternate or emergency fuel, check Military Power setting, and have engine trimmed if necessary.

- Refer to T.O. 1F-100C(I)-1-1 for fuel specific weight differences.

FUEL SYSTEM MANAGEMENT.

INTERNAL FUEL SEQUENCING.

Sequencing of internal fuel is entirely automatic. Normal fuel sequencing is indicated by the following forward tank/total quantity gage readings:

FUEL TRANSFER SEQUENCE
(BASED ON FUEL FLOW OF 4000 POUNDS OR LESS)

	FWD GAGE READS (LB)	TOTAL GAGE SHOULD READ (LB)
Full internal fuel load	2913	7730
Drop tanks start feeding when	2877	7693
Aft cell starts feeding when	2637	7453
Intermediate tanks start feeding when	1828	5944
Wing scavenge pumps start when	1535	4259

NOTE

When total fuel reading is 1500 pounds or less, and fuel flow is 4000 pounds per hour or less, the forward gage should not indicate more than 200 pounds less than the total gage.

DROP TANK FUEL SEQUENCING.

To maintain the most favorable CG conditions and adequate lateral control when drop tanks are installed, the fuel from the drop tanks must be used in the sequence described under Drop Tank Fuel Sequencing Limitations in section V. However, some fuel may be transferred from nonselected drop tanks because of any one or combination of the following circumstances which could pressurize the nonselected drop tanks:

1. Climbing from a low altitude to a high altitude.

2. Pausing at a "full" position when rotating the drop tank fuel selector switch to the next desired position. Fuel will be used from the nonselected drop tanks until the pressure within these tanks has been dissipated.

3. Ram air entering the dive vent port on the drop tanks. (This is considered negligible.)

Pressurizing of the drop tanks can also be caused by certain mechanical or electrical failures or malfunctions.

1. Loss of tertiary bus power, by any means, will de-energize all the drop tank shutoff valves. The valves open

FUEL GRADE PROPERTIES AND LIMITS

USE	FUEL TYPE	GRADE	NATO SYMBOL	US MILITARY SPECIFICATION	FREEZE POINT (°F)	LIMITS
RECOMMENDED FUEL	WIDE CUT GASOLINE	JP-4	F-40	MIL-J-5624	-76	
ALTERNATE FUEL	WIDE CUT GASOLINE	COM JET B	NONE	ASTM	-56	1, 2
	KEROSENE	JP-5	F-44	MIL-J-5624	-51	1
		COM JET A-1	NONE	ASTM	-54	1, 2
		COM JET A	NONE	ASTM	-36	1, 2
			F-34	NONE	-58	1
EMERGENCY FUEL	AVIATION GASOLINE (AVGAS) PLUS 3% GRADE 1100 OIL	80/87	F-12	MIL-G-5572	-76	3
		91/96	F-15	MIL-G-5572	-76	3
		100/130	F-18	MIL-G-5572	-76	3
		115/145	F-22	MIL-G-5572	-76	3

1 Avoid flying at altitudes where OAT is below the freeze point of the fuel. See limits Section V

2 Before using commercial fuel, obtain freeze point from vendor or airline supplying the fuel; then follow limit 1. If there is any indication of improper fuel handling procedures, or that cleanness is not up to standard, a fuel sample should be taken in a glass container and observed for fogginess, presence of water, or rust.

3 Follow climb restrictions given in "Alternate and Emergency Fuel Limitations" in Section V.

Figure 7-1

and all drop tanks are pressurized, causing simultaneous feeding from all drop tanks.

2. Failure of a drop tank shutoff valve causes this drop tank to also feed when other drop tanks are selected.

3. If the stop in the drop tank fuel selector switch has been removed, lost, or indexed wrong, the selector switch can be moved past the inboard tank position, which opens all of the drop tank shutoff valves, pressurizing all the drop tanks.

FUEL TRANSFER.

WARNING

Prolonged use of afterburner at any altitude, and high non-afterburner thrust settings at low altitude, can result in fuel consumption rates that exceed fuel transfer capabilities. The forward fuselage tank gage should be monitored frequently and high thrust settings discontinued if rapid forward tank depletion is noted.

Fuel is transferred to the forward fuselage tank from all other internal fuel tanks and the drop tanks. Internal fuel is transferred by means of gravity flow, by electrically driven transfer pumps in the aft and intermediate tanks, and by scavenge pumps in the integral wing tanks. Normal transfer of fuel is in this order: drop tanks (if carried), aft tank, intermediate tank, and finally the wing tanks. Transfer of fuel is automatically controlled by float-operated fuel transfer control valves mounted at different levels in the forward tank. The transfer pumps run continuously, but fuel is not transferred until the fuel transfer control valves open as the fuel level drops below each one. For example, when the forward tank fuel level drops about 35 pounds from full, the drop tank fuel starts transferring. At about 275 pounds from full, the aft tank fuel starts transferring. When the fuel level in the forward tank is about 1185 pounds from full, the intermediate tank transfers its fuel. After the intermediate tank is empty, fuel flows by gravity from the wing tanks until the forward tank has only about 1535 pounds of fuel remaining. At this time, the wing tank scavenge pumps are started by float switches to complete the transfer of the wing tank fuel not transferred by gravity. During all of the transfer operation, if the fuel transfer rate exceeds the consumption rate, the transfer of fuel stops when the fuel level raises the floats in the fuel transfer control valve. If fuel transfer rate is slower than the consumption rate, the transfer pump transfers fuel until the transferring tank is empty. A simplified fuel transfer diagram is shown in figure 7-2.

FUEL QUANTITY GAGES.

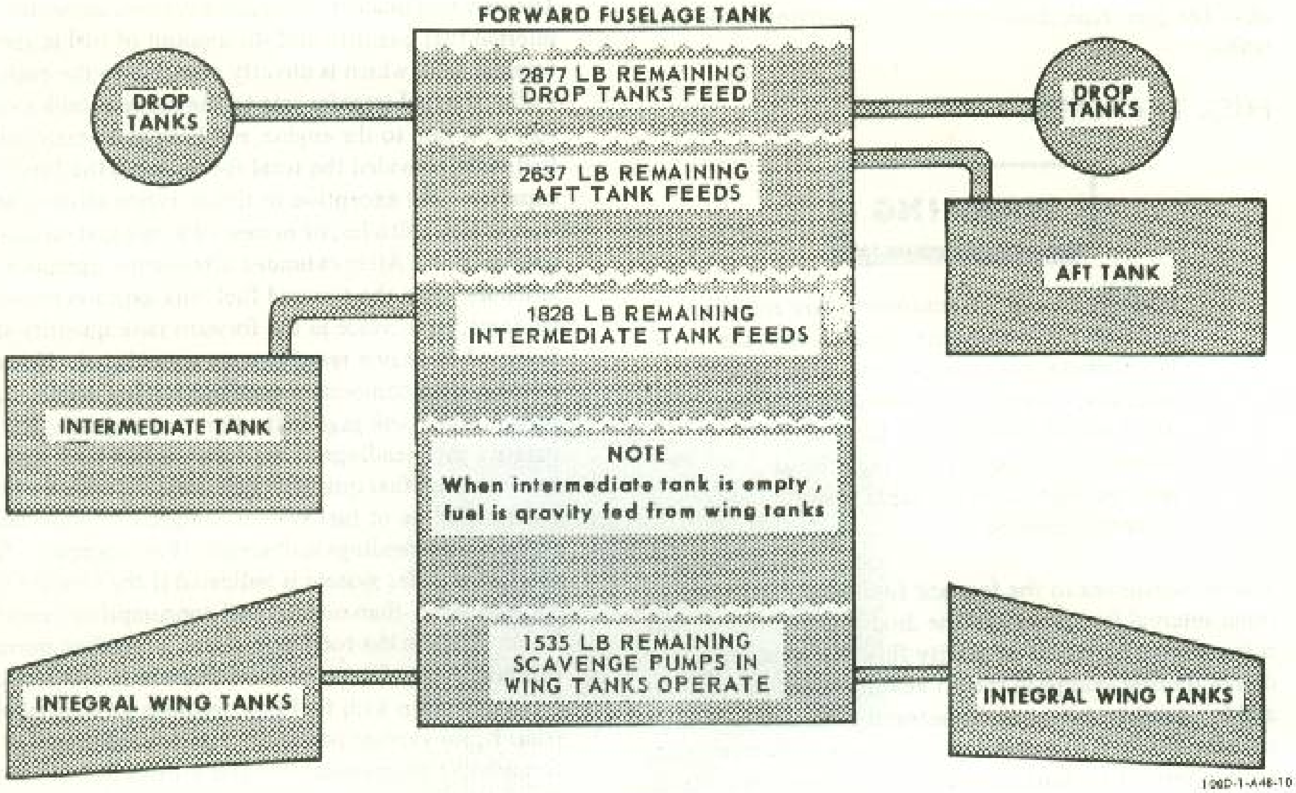
The two fuel quantity indicating systems show the total internal fuel quantity and the amount of fuel in the forward fuselage tank which is directly available to the engine. Normally, the fuel transfer rate to the forward tank exceeds the fuel flow rate to the engine, resulting in a nearly full forward fuel tank, provided the total fuel exceeds the forward tank capacity. The exception to this is during afterburner operation at low altitudes, or in case of a fuel system component malfunction. After extended afterburner operation at low altitudes when the forward fuel tank gage has shown a decrease, an increase in the forward tank quantity should occur when engine requirements are reduced. However, if a fuel system component malfunction has occurred, the forward fuel tank gage indication may not rise. The comparative gage readings of the forward fuel tank gage and the total internal fuel quantity gage may, if correctly interpreted, indicate failure of fuel system components when deviation from normal readings is observed. For example, a failure of the fuel transfer system is indicated if the forward tank gage shows a faster-than-normal fuel consumption (nonafterburning) while the total gage shows a less-than-normal consumption rate. (Refer to Fuel Transfer in this section.) Familiarization with fuel gage readings for normal missions (that is, for average power settings, altitudes, and properly functioning equipment) will give greater flexibility and utility to the airplane, because the limitations of the fuel system are then reduced to the amount of fuel remaining in the forward fuel tank. When the two fuel quantity gages have the same reading, it is an indication that all remaining fuel has transferred to the forward tank, and the forward tank reading indicates the total fuel remaining. Therefore, if all fuel remaining is in the forward tank, the only fuel quantity limitation is that set by the practical minimum landing fuel reserves which may be established by the using organization.

HEAT EXCHANGER COOLING AIRFLOW CIRCUITS.

PRIMARY HEAT EXCHANGER.

Cooling air for the primary heat exchanger is normally obtained from the engine air inlet duct. It passes through

FUEL TRANSFER



FUEL IS FED TO THE FORWARD FUSELAGE TANK FROM DROP TANKS AND FROM ALL OTHER INTERNAL FUEL TANKS AT LEVEL INDICATED.

Figure 7-2

the primary heat exchanger and is then ducted overboard. The amount of cooling airflow available depends on the pressure differential between the engine inlet duct and the overboard discharge. The greater the pressure differential, the greater the available cooling airflow. During normal level flight, the pressure in the inlet duct is higher than the pressure at the overboard discharge, and the cooling air from the duct goes through the primary heat exchanger and out the overboard discharge. This is known as positive flow. During ground operation and some flight conditions, the pressure in the engine air inlet duct is less than the pressure at the overboard discharge. This causes a reverse (negative) airflow through the primary heat exchanger. However, to prevent negative flow, the source of the cooling air for the primary heat exchanger automatically changes from the engine air inlet duct to the equipment compartment, whenever the inlet duct pressure is less than overboard discharge pressure. The air is then drawn from the forward electronics equipment compartment, through the primary heat exchanger, and discharged overboard. Also, a jet pump, using air from the engine air bleed manifold, produces a positive airflow through the primary heat exchanger. This produces a low-pressure condition at the heat exchanger discharge duct which draws cooling air through the primary heat exchanger. The jet pump operates constantly during engine operation.

SECONDARY HEAT EXCHANGER.

Cooling air for the secondary heat exchanger is not dependent upon the pressure differential between the engine air inlet duct and that outside the duct. Therefore, positive flow is not required for operation. (See figure 7-3.) Air for this heat exchanger is drawn from the intake duct by two fans within the heat exchanger and exhausted back into the duct. These fans are driven by a cockpit cooling turbine and an electronic equipment cooling turbine. Air from the engine compressor, after passing through the primary and secondary heat exchangers, drives these two turbines before going to their respective systems. (See figure 4-1.)

FLIGHT CONTROL SYSTEM EMERGENCY HYDRAULIC PUMP.

The ram-air turbine-driven emergency hydraulic pump in the No. 2 flight control hydraulic system supplies pressure to this system in case of engine or engine-driven pump failure. The emergency pump is designed to maintain adequate system pressure with either a frozen or a windmilling engine at altitudes from sea level to the service ceiling of the airplane and airspeeds down to about 150 knots IAS (160 knots with engine at idle). The turbine and the emergency pump (which is mounted on the turbine hub) are in the upper part of the fuselage, aft of the cockpit. When the emergency pump is selected, utility hydraulic system pressure opens the ram-air inlet doors in the engine air intake duct, below the turbine, and the ram-air exhaust door in the upper fuselage fairing, above the turbine. In case the utility system pressure is depleted, the ram-air turbine door emergency accumulator provides pressure to open the ram-air inlet doors and the ram-air exhaust door. The ram air from the intake duct rotates the turbine and is exhausted overboard. (See figure 7-3.) Rotation of the turbine drives the emergency pump, which builds up and maintains pressure in the No. 2 flight control hydraulic system. A governor is used to control the speed of the turbine so that the speed of the pump remains within design limits. When the pump is engaged and the turbine is suddenly exposed to high-velocity ram air, the governor automatically increases the pitch of the turbine blades to decrease turbine rpm, thus preventing the turbine and pump from overspeeding. As the speed of the incoming ram air decreases, the rpm of the turbine decreases and the pitch of the turbine blades is decreased. This lower pitch setting causes an increase in turbine rpm, to maintain the proper pump output. The changes in turbine blade pitch continue as long as the system is engaged, to compensate for variations in ram-air flow. When the airplane is flown at low airspeeds using high engine rpm, airflow through the turbine may reach a null (no airflow) or completely reverse direction. (As airflow approaches the null point, hydraulic power from the ram-air turbine-driven emergency pump is proportionately lowered until a zero output is reached at the null point.)

NOTE

> This region of insufficient airflow to drive the ram-air turbine fast enough to maintain system hydraulic pressure should not be referred to as "null flow." Null flow means no airflow.

The turbine cannot be damaged by reverse airflow. During reverse airflow conditions, pump output is not available. If the ram-air turbine-driven emergency pump is used when the engine is operating, it is necessary to vary the throttle setting to avoid a reduction of pump output.

The ram-air turbine-driven pump is an emergency system which does not provide normal maneuvering capability, but is considered adequate for a proficient pilot, flying under near-normal conditions of visibility and turbulence, with adequate runways to permit a well-planned approach. Under other circumstances, the pilot's judgment must prevail.

NULL FLOW.

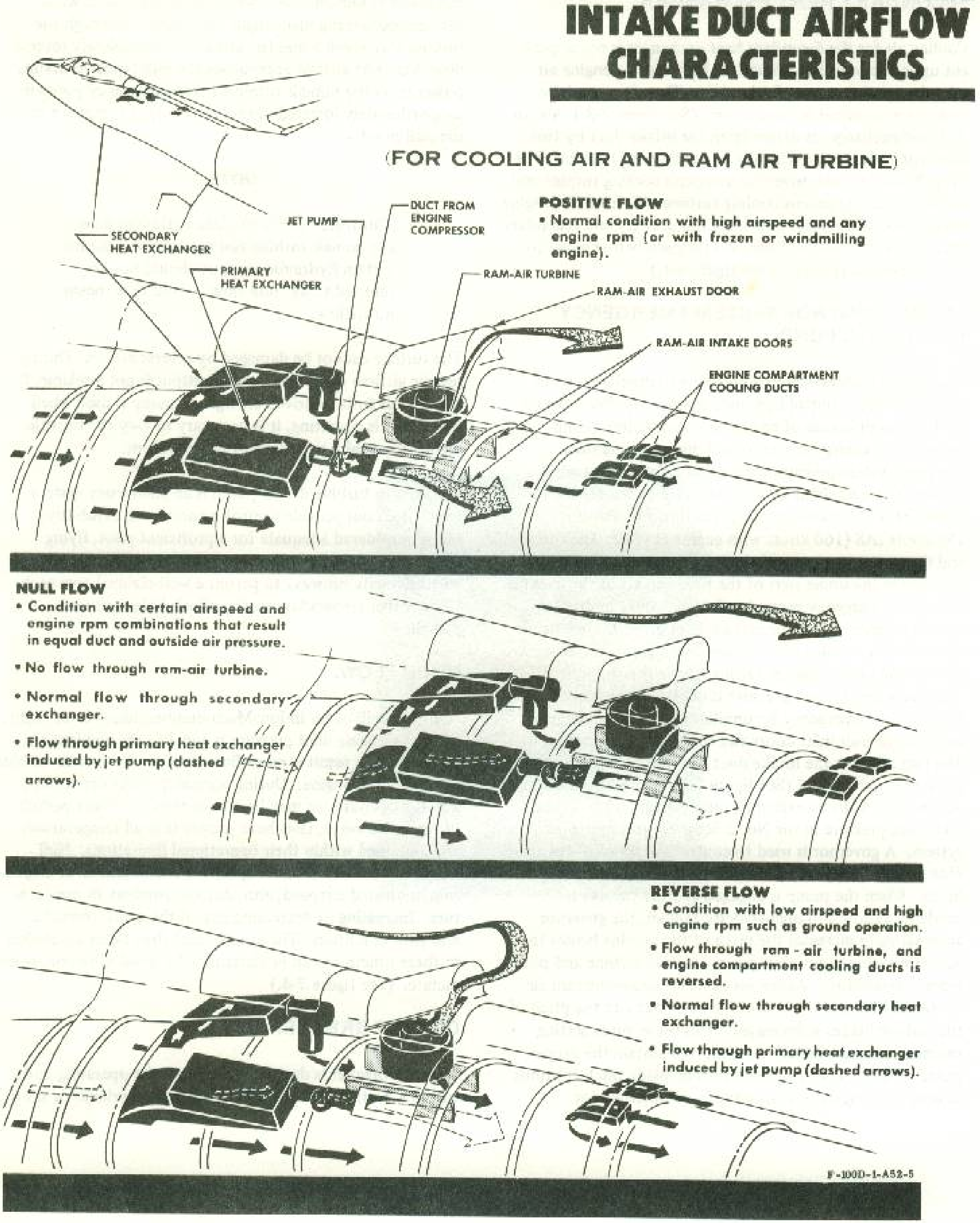
Null flow will occur in low-Mach-number, high-power flight, when the engine duct pressure is equal to the ambient air pressure. The result is no airflow through the ram-air turbine or around the engine. During normal in-flight operations, null flow conditions may be encountered for short periods of time. However, tests have proved that all temperatures are contained within their operational limitations. Null flow will occur only under specified combinations of engine rpm, indicated airspeed, altitude, and ambient air temperature. Increasing or decreasing any of these will correct a null flow condition. The specific null flow point in relation to these functions can be determined if mission requirements dictate. (See figure 7-4.)

CIRCUIT-BREAKER USE.

A circuit breaker is designed to protect the operating units within a particular electrical circuit from overloads or short

INTAKE DUCT AIRFLOW CHARACTERISTICS

(FOR COOLING AIR AND RAM AIR TURBINE)



POSITIVE FLOW

- Normal condition with high airspeed and any engine rpm (or with frozen or windmilling engine).

NULL FLOW

- Condition with certain airspeed and engine rpm combinations that result in equal duct and outside air pressure.
- No flow through ram-air turbine.
- Normal flow through secondary exchanger.
- Flow through primary heat exchanger induced by jet pump (dashed arrows).

REVERSE FLOW

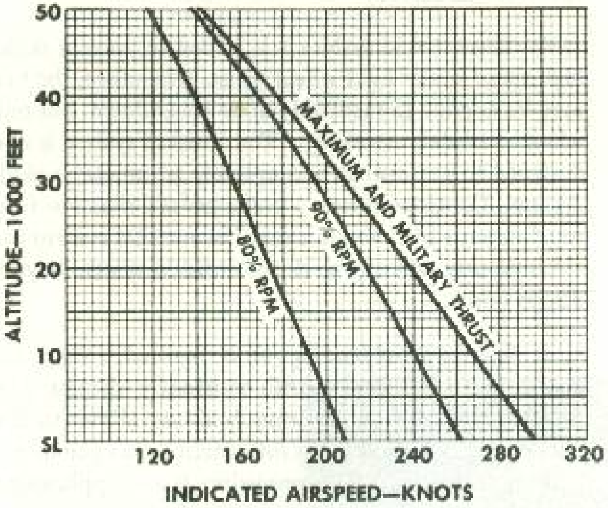
- Condition with low airspeed and high engine rpm such as ground operation.
- Flow through ram - air turbine, and engine compartment cooling ducts is reversed.
- Normal flow through secondary heat exchanger.
- Flow through primary heat exchanger induced by jet pump (dashed arrows).

Figure 7-3

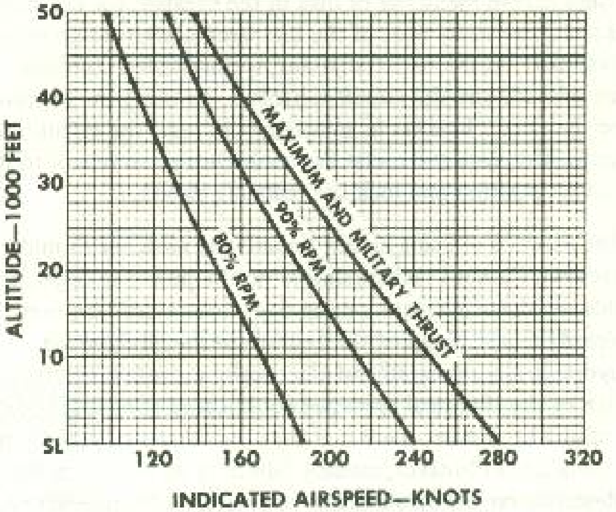
NULL FLOW CONDITIONS

J57 ENGINE

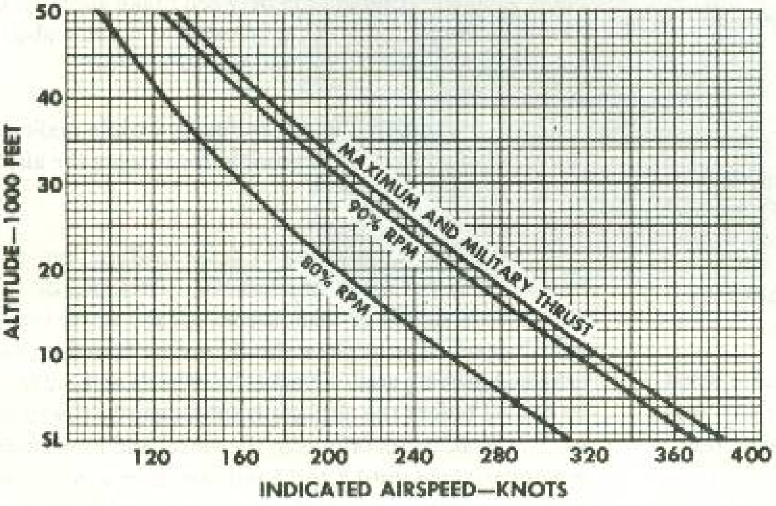
AIR FORCE STANDARD DAY



AIR FORCE SUMMER DAY



AIR FORCE WINTER DAY



AMBIENT TEMPERATURE VARIATION WITH ALTITUDE

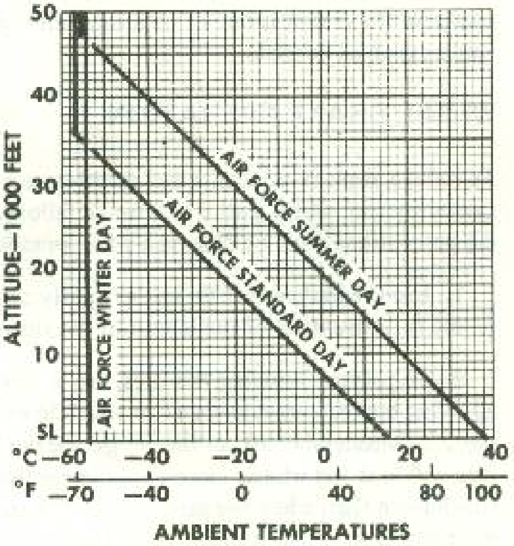


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Figure 7-4

circuits, and is capable of automatically breaking the circuit under specified conditions of current flow. The length of time a circuit is subjected to an overload before the breaker trips to open the circuit depends on the amount of overload, and the rate (fast or slow) of overload build-up. Trip-free circuit breakers are used on this airplane. After being tripped by an overload in the circuit, the trip-free circuit breaker cannot be reset immediately. Because of its internal construction, this type of circuit breaker, when tripped, needs a cooling period before it can be reset. A small, normally curved metal bar or disk in the breaker, for example, is straightened by heat of the increased current drain of an overload. As the bar straightens, spring-loaded contacts are released and the circuit is broken. Pressing the button on the circuit breaker in an attempt to reset the circuit is ineffective until the metal bar cools enough to return to its normal position and lock the contacts closed.

The practice of using circuit breakers as switches should be avoided. Circuit breakers should not be pulled in flight, as this could easily create a more dangerous condition than already exists. Many of the systems in the airplane are hydraulically operated and electrically actuated. Interruption of the electrical sequence could cause complete system malfunction. Also, there is always the danger of pulling the wrong circuit breaker, causing failure of another system. Resetting circuit breakers can be entirely safe, provided circuit-breaker operation and the individual circuit involved are thoroughly understood. It is necessary to analyze the condition which caused the breaker to trip, and then determine whether the unit is one of continuous operation, or if motor-operated, if it is reversible, and the position of the control switch in the cockpit. If a circuit breaker cannot be reset and the circuit is one of major systems, prepare to land as soon as possible.

WHEEL BRAKE OPERATION.

To reduce airplane accidents and maintenance problems caused by tire, wheel, and wheel brake failure, the following precautions must be observed when practical:

1. Use the brakes as little and as lightly as possible by taking full advantage of the length of the runway.

2. To prevent skidding the tires, use extreme care when applying brakes immediately after touchdown, or any time there is considerable lift on the wings. Heavy brake pressure will lock the wheels more easily immediately after touchdown than when the same pressure is applied after the full weight of the airplane is on the tires. As long as brake pressure is maintained, a wheel once locked in this manner immediately after touchdown will not become unlocked as load increases. Brakes can stop the wheels from turning, but stopping the airplane depends on the frictional force between the tires and the runway. As the load on the tires increases, the frictional force increases giving better braking action. During a skid, the frictional force is reduced thus requiring more distance to stop.

3. If maximum wheel braking is required, lift should be decreased as much as possible by lowering the nose gear and raising the flaps before applying brakes. This procedure improves braking action since the load on the tires will be increased thus increasing the frictional force between the tires and the runway.

4. The antiskid system is intended to prevent skidding at high speed under light wheel loads. Therefore, the brakes may be applied immediately after touchdown, but only when absolutely necessary. The antiskid system is not designed to perform as a completely automatic braking system. Continuous heavy brake pedal deflection from touchdown which would cause the antiskid system to cycle continuously will overwork the antiskid system beyond design limits.

5. When a short landing roll is required, a single smooth application of the brakes with constantly increasing pedal pressure will result in optimum braking. (Refer to Braking Technique in section II for information on optimum braking technique.) This procedure is also applicable when operating on emergency braking systems.

6. During a series of successive landings, a minimum of 15 minutes should elapse between landings where the landing gear remains in the slip stream, and a minimum of 30 minutes with the gear retracted between landings, to allow adequate cooling time between brake applications. This time restriction is not applicable to touch-and-go landings when no brake application is involved.

7. The brakes should not be dragged while taxiing, and should be used as little as possible for turning the airplane on the ground.

8. At the first indication of brake malfunction, or if brakes are suspected to be overheated after excessive use, the airplane should be maneuvered off the active runway and stopped. The airplane should not be taxied into a crowded parking area. Overheated wheels and brakes must be cooled before the airplane is subsequently towed or taxied. Peak temperatures in the wheel and brake assembly are not attained until 5 to 15 minutes after a maximum braking operation is completed. In extreme cases, heat build-up can cause the wheel and tire to fail with explosive force or be destroyed by fire if proper cooling is not effected. Taxiing at low speeds to obtain air cooling of overheated brakes will not reduce temperatures adequately and can actually cause additional heat build-up.