7

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SYSTEMS OPERATION

TABLE OF CONTENTS

ENGINE

ENGINE TRIMMING

On many engines, engine trim adjustment can be accomplished only on a test stand or while the aircraft is on the ground. One of the features affecting operation of these aircraft is an engine trim device which is operated from the cockpit. The trimmer is normally used to maintain EGT within a recommended operating range in flight when at or near Military thrust or when the afterburner is operating. It modifies the turbine inlet temperature vs compressor inlet temperature scheduling characteristics of the main fuel control. Changes in engine trim are indicated by the EGT gage. Trimming has little direct effect on afterburner operation, but the trimmer is the only main engine control available to the pilot when a throttle is set in the afterburner range.

NORMAL EXHAUST GAS TRIM TEMPERATURE

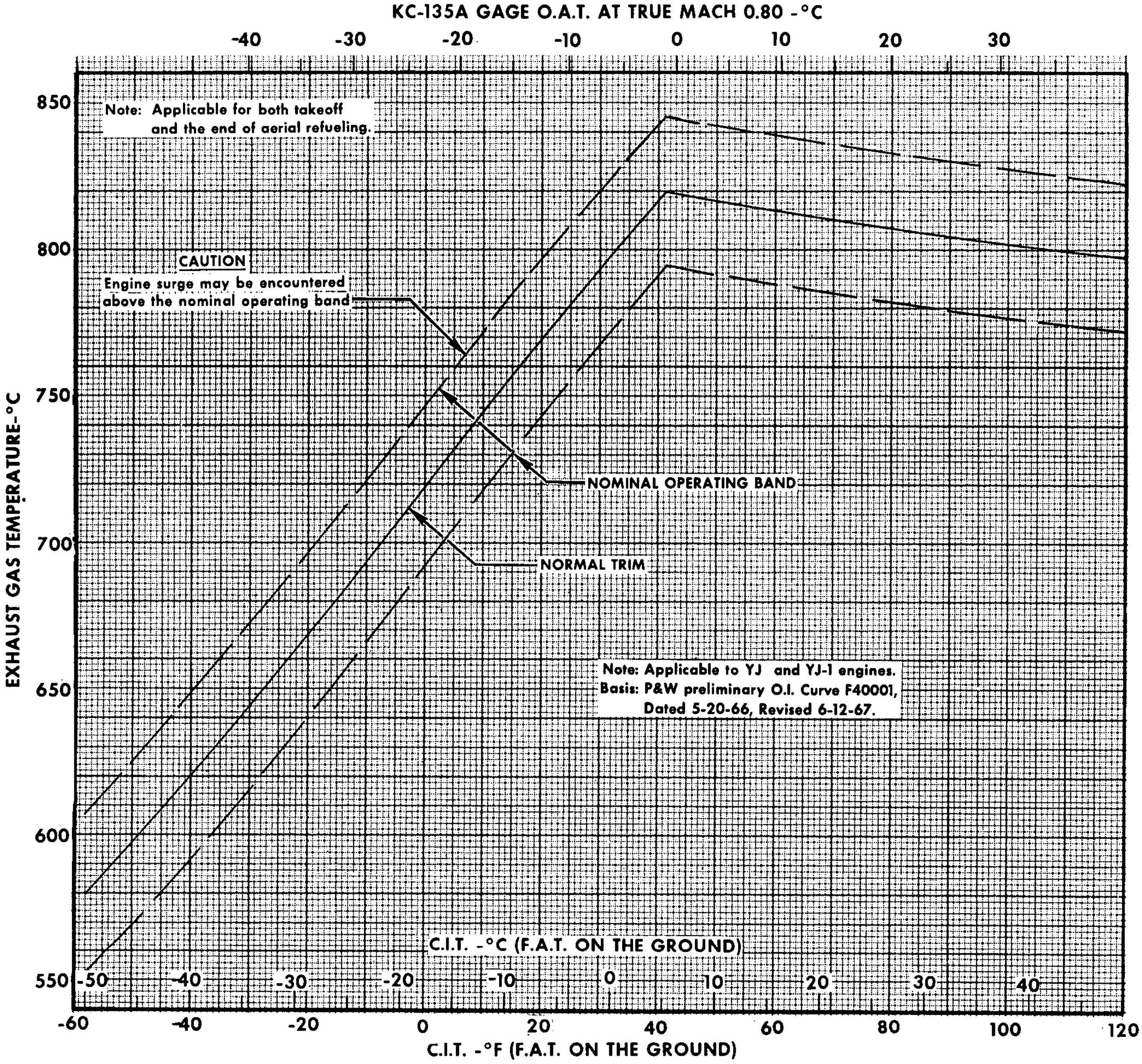

Figure 7-1

NORMAL TRIM OPERATION

The following describes the normal use of trim capability at the present time.

Prior to Takeoff

A trim run is usually made on the end of the runway prior to takeoff using the following procedure:

1. Wheels - Check chocked.
2. Throttles - MILITARY momentarily then IDLE.

   This serves to unload the trimmer and reduce hysteresis.
3. Throttles - MILITARY until EGT stabilizes.

4. EGT trim switches - As required per figure 7-1.

5. Throttle - IDLE rapidly.

   This throttle chop serves to check the proper sequence of bleed operation by the absence of compressor stall.

Climb and Cruise

Trim as necessary after takeoff and while accelerating to 60°C CIT to maintain EGT less than 845°C. EGT must be maintained below 805°C when above 60°C CIT. It is recommended that the EGT be maintained between 775°C and 805°C during cruise.

Subsonic Operation

The engine fuel control is scheduled to reduce turbine temperature rather rapidly as compressor inlet temperature falls below 5°C to preclude the possibility of engine stall. The EGT trim may be used in this operating regime to up trim the engine if required. It may be possible to increase the EGT more than 50°C but in most cases the increase will be less since the uptrim range is a function of the original trim setting.

WARNING

Uptrimming in the low temperature area can cause over temperature during subsequent aircraft acceleration or above 5°C CIT unless the EGT trim is reset to nominal schedule prior to acceleration.

Effect of Engine Thrust Variation with EGT

Figure 7-2 illustrates the typical variation of engine thrust with EGT at scheduled rpm, Mach 3.2 and 80,000 feet. For a given level of thrust, higher throttle settings and increased fuel flow are required as EGT is decreased. Full throttle ceilings in cruise and while turning are reduced; this occurs because combined burning efficiency of the engine and AB decreases with lowered EGT. The degradation in thrust for all throttle settings, at Mach 3.2 and 80,000 feet, is approximately 1.3 percent per 10°C of EGT decrease. Although only one flight condition is illustrated, the trend is the same for other flight conditions.

Effect of RPM Suppression on MAXIMUM THRUST

As EGT decreases, the engine nozzle opens to maintain scheduled rpm. At high Mach number and maximum power, low EGT may cause the nozzle to open fully and any further EGT decrease will result in rpm suppression below schedule. When this condition occurs the engine speed will suppress approximately 50 rpm for each 10°C of EGT decrease. The airflow through the engine decreases due to the suppressed rpm, leading to a higher inlet duct bypass requirement and opening of the forward bypass doors. At Mach 3.2 this results in a thrust degradation and drag increase of approximately 3.5 percent per 10°C of EGT decrease for each affected engine. If Mach number decreases as a result of the change in thrust and drag, the spikes schedule more forward and the forward bypass doors open further. Performance will deteriorate rapidly under these cumulative effects and it is recommended that cruise EGT be maintained between 775°C and 805°C to avoid the possibility of this situation occurring.

After Air Refueling

The KC-135 crew can advise the pilot of the proper engine trim to be set when the air-

TYPICAL THRUST VARIATION WITH EGT

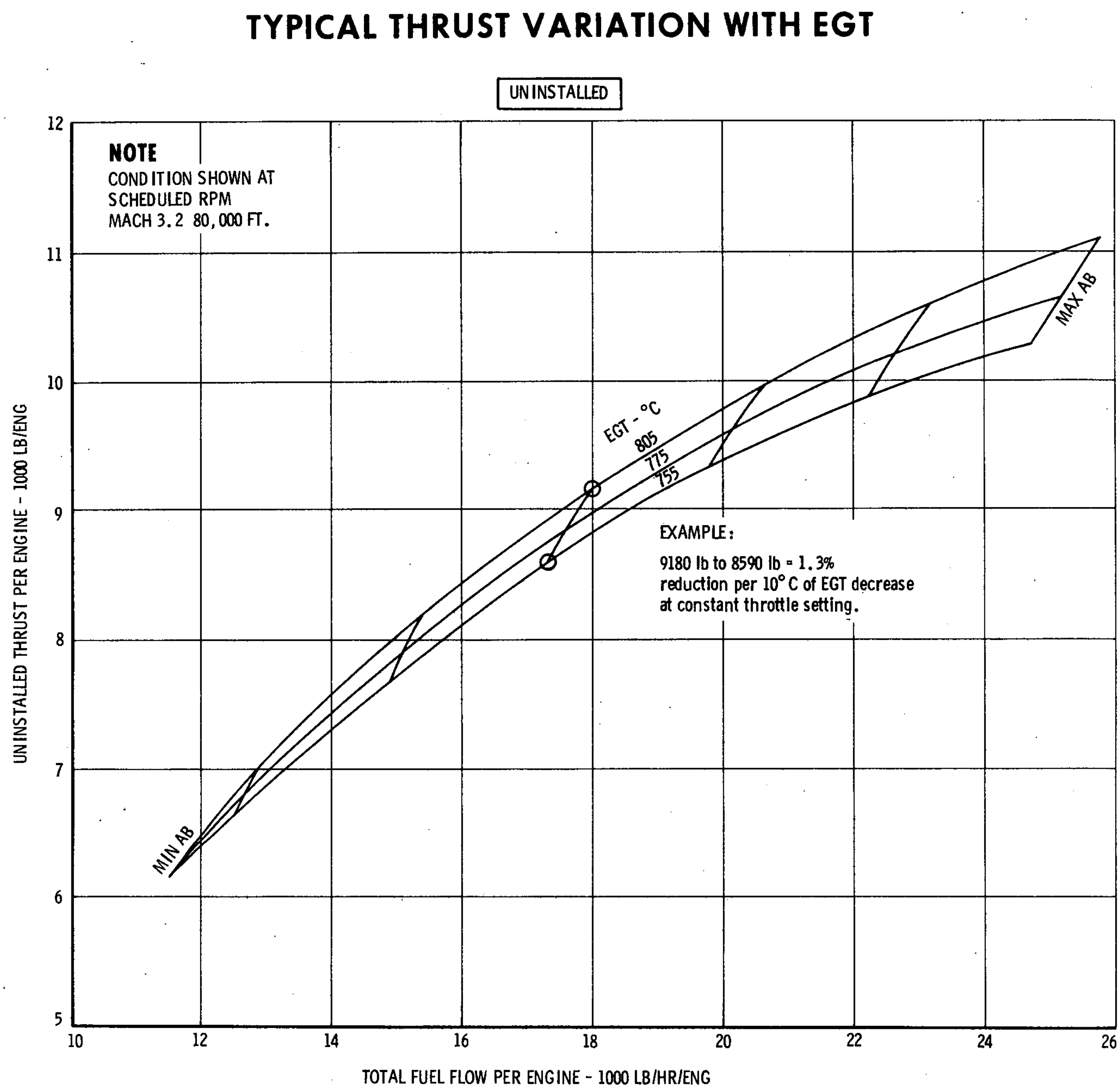

Figure 7-2

craft departs the tanker. Figure 7-1 provides engine exhaust gas temperature vs KC-135 indicated free air temperature.

NOTE

If an EGT increase between Military and maximum afterburning power exists the pilot should also be briefed on the amount of EGT increase.

TRIMMING WITH SURGE SENSITIVE ENGINES

Some engines have surged during ground operation while at turbine discharge temperatures (EGT's) specified for takeoff by the respective EGT trim curves. This tendency to surge, when it appears, is greater at lower ambient temperatures. Surge sensitive engines have not exhibited this problem in flight. Most of these engines can be identified prior to flight; however, engines with no previous surge history have developed into surgers after exposure to descents from high Mach numbers.

If an engine surges during pre takeoff trim, down trim to eliminate surge but do not trim lower than 60°C below the desired trim point for the ambient temperature.

NOTE

- Surging is a ground run problem only.
- Engine thrust is reduced about 210 pounds at sea level static for each 10°C of EGT down trim from the normal trim curve. After takeoff engines down trimmed for surge protection should be up trimmed to 775°C EGT when CIT reaches 0°C.

INLET OPERATION

SPIKE AND BYPASS CONTROL

1. When an inlet unstarts above approx. 2.0 Mn.
2. During normal scheduling as Mach decreases to 1.6 Mn, or with variations in angle of attack or yaw angle.
3. When descending past approximately 30,000 feet.

Spike is moved forward if the spike knob is not in AUTO:

1. If FWD position is selected.
2. If 1.4 position is selected.

Spike is moved forward under the following conditions:

1. The restart switch is actuated to ON.
2. If L or R hydraulic pressure to the spike actuator fails below Mach 1.6 and at higher Mach number unless the inlet is unstarted.
3. (On the left side) the number 2 inverter fails, the L SPIKE & DR ICS circuit breaker opens, or if the L SPIKE & DR LVDT circuit breaker opens.
4. (On the right side) the number 3 inverter fails, the R SPIKE & DR ICS circuit breaker opens, or the R SPIKE & DR LVDT circuit breaker opens.
5. The emergency spike forward switch is actuated to the forward position following confirmed loss of hydraulic pressure.

Forward bypass opens or moves toward open when the control knob is in AUTO under the following conditions:

RANGE OF CIP OPERATING PRESSURES

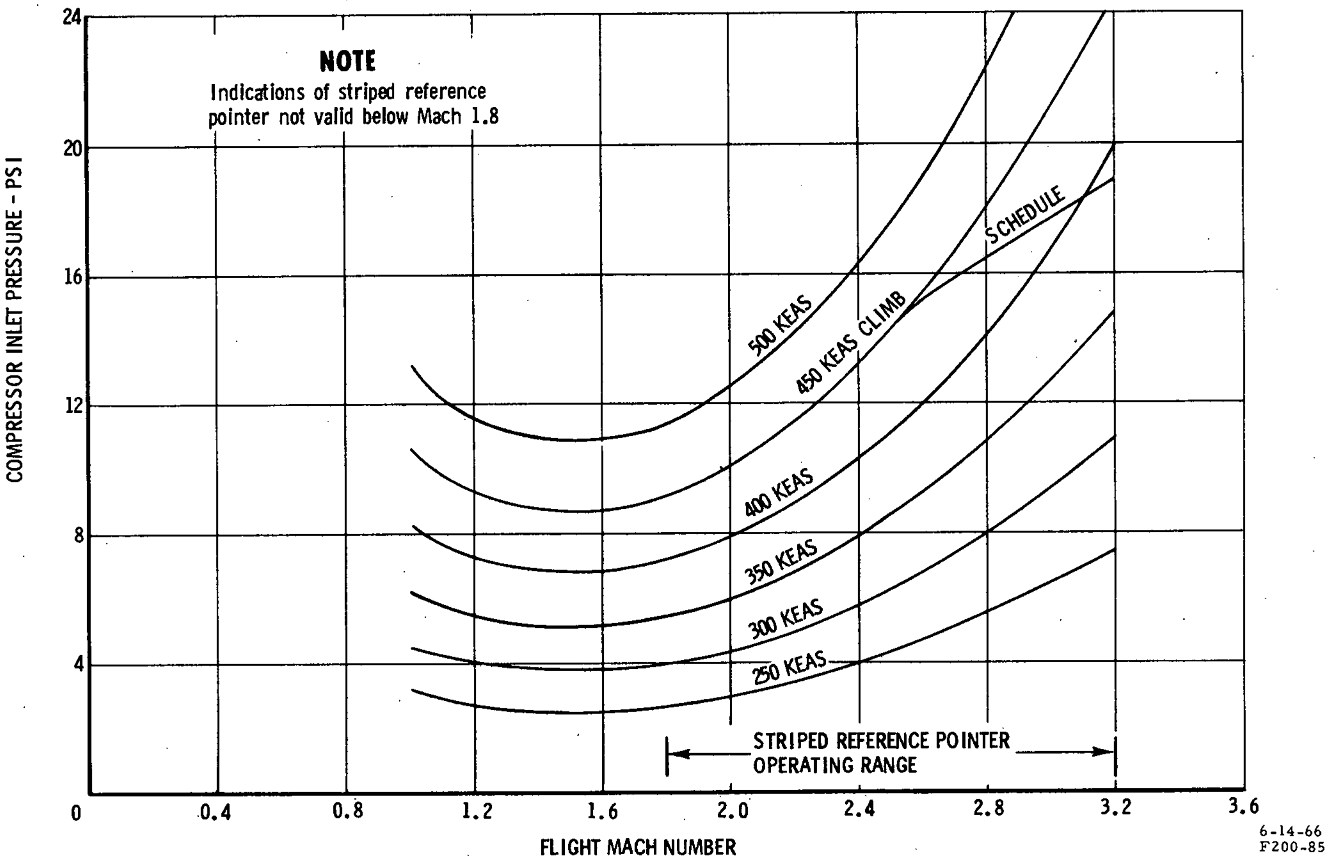

Figure 7-3

1. When an inlet unstarts above 2.0 Mn.
2. Per the automatic schedule.
3. During periods of rapid RPM decrease.
4. When manual spike is selected.

The forward bypass opens or moves toward open when the forward bypass control is not in AUTO under the following conditions:

1. As a lower number position or OPEN is selected.
2. As a function of the manual spike knob position selected, up to approximately one inch of door opening variation.
3. Restart switch is actuated to ON or forward bypass open.
4. The L or R hydraulic pressure to the door actuator fails.
5. (On the left side) the number 2 inverter fails, the L SPIKE & DR ICS circuit breaker opens.
6. (On the right side) the number 3 inverter fails, the R SPIKE & DR ICS circuit breaker opens, or the R SPIKE & DR LVDT circuit breaker opens.

7. The main landing gear doors are open.

The forward bypass is closed when the speed is below Mach 1.4, except when the main landing gear doors are open.

CIP INDICATIONS

The position of the third striped pointer on the CIP gage is controlled by an output signal from the air data computer from pressures sensed by the pitot static system. The indication is scheduled in accordance with automatically computed values of Mach number and KEAS so that the striped pointer shows a "normal" CIP (± 1.1 psia) (see figure 7-4) for the flight condition if over 250 KEAS and Mach 1.8. Values indicated while at lower speed conditions are not intended to be representative of normal inlet pressures. Above the minimum speed range a substantial difference between the "normal" and actual CIP pointer indicates improper inlet operation. Higher actual pressures than "normal" indicate possible unstart conditions. Lower than normal actual pressures indicates poor pressure recovery due to improper spike and/or bypass settings except when at abnormal angles of attack or in yaw conditions where inlet operation is automatically biased to produce less than normal recovery. The normal spread between CIP indications (L & R pointers) should not exceed 1 psi. The difference between either L or R pointer and the striped pointer should not exceed 1 psi. The striped pointer may be used as a guide for bypass door settings during manual operation of one or both inlets and it is preferable to keep the L and/or R pointer slightly below the "normal" indication to maintain a margin below unstart pressures. Continued automatic or manual inlet operation at pressures substantially below the "normal" indication can result in loss of aircraft range.

NOTE

As the total tolerance of the striped pointer can be as much as ± 1.1 psi at maximum Mach number, it is possible for a properly operating inlet to be above the "normal" indication.

FUEL SYSTEM OPERATION

NORMAL FUEL TANK SEQUENCING

The normal sequence of fuel usage with the aircraft fully fueled is completely automatic. After tank 1 fuel is used, this automatic sequencing maintains c. g. in the range from 25.5% to 26.9% MAC for optimum high speed cruise at altitude. Starting, taxi and takeoff are normally accomplished with the pumps in tanks 1, 2, and 6 feeding the engines. Tank 1 normally empties during climbout or shortly after supersonic speeds are reached, then tank 2 continues feeding the left engine and tank 6 the right engine. As tank 2 approaches empty a float switch starts the pumps in tank 3. When tank 2 becomes empty, a second float turns off the tank 2 pumps. Any residual fuel in the tank is pumped into tank 3 by the jet pump system. The float switch on tank 6 turns on the pump in tank 5 and the second (empty) float switch turns off the tank 6 pumps. As tank 3 approaches empty the two pumps in tank 4 feeding the left manifold are started and as tank 5 approaches empty the other two pumps in tank 4 feeding the right manifold are started. Aft transfer of fuel to tank 6 to control c. g. is accomplished automatically through the left manifold. Aft transfer occurs at any time when tank 6 pumps are on, space is available, tank 2 fuel is above the 2400-6000 pounds level as shown on figure 7-4 and both throttles are in the afterburner position. When aft transfer is in operation, tank 1 is feeding and tank 6 is nearly full the maxi-

GROSS WEIGHT VERSUS C.G.

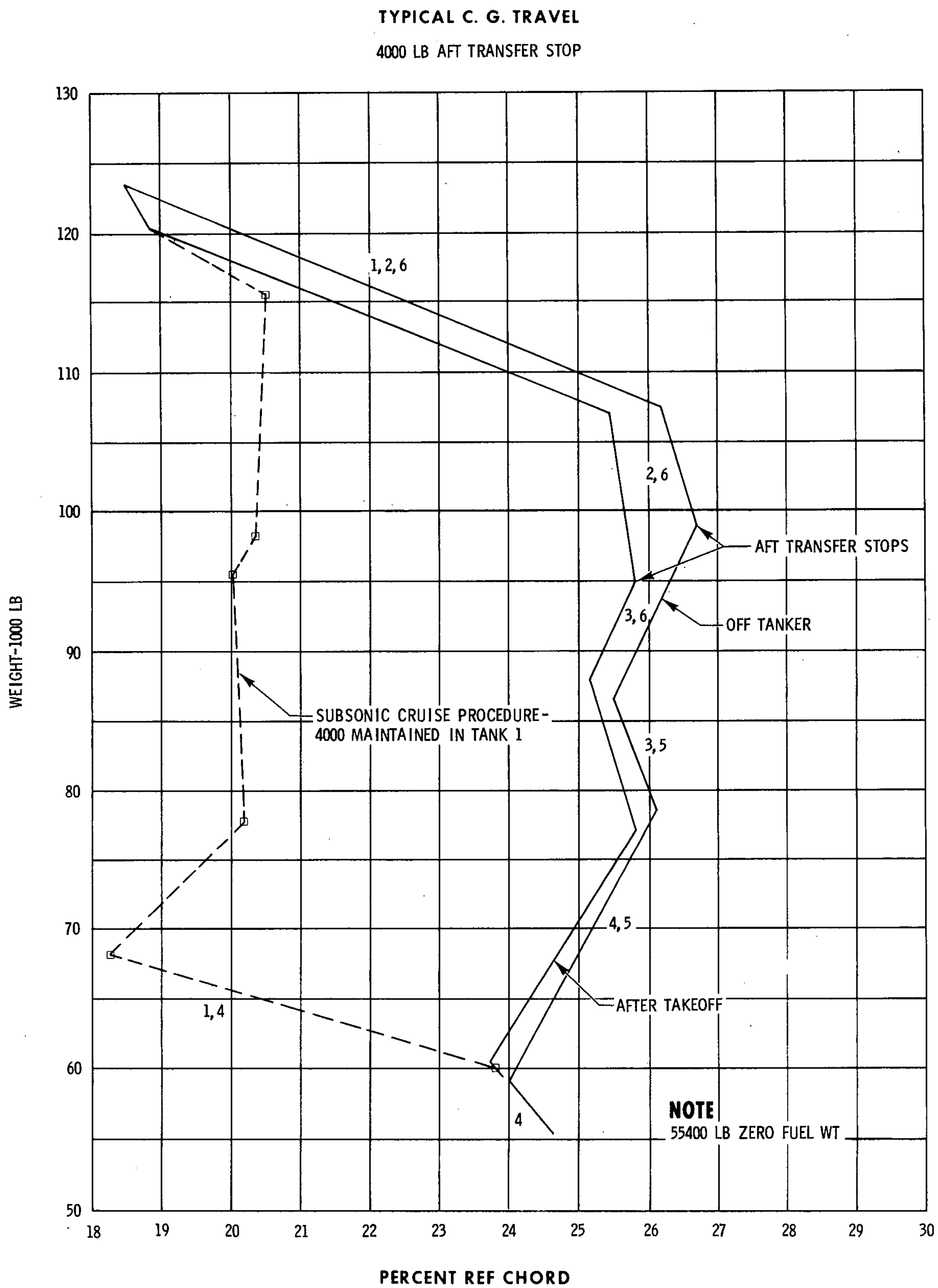

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Figure 7-4 (Sheet 1 of 3)

GROSS WEIGHT VERSUS C.G.

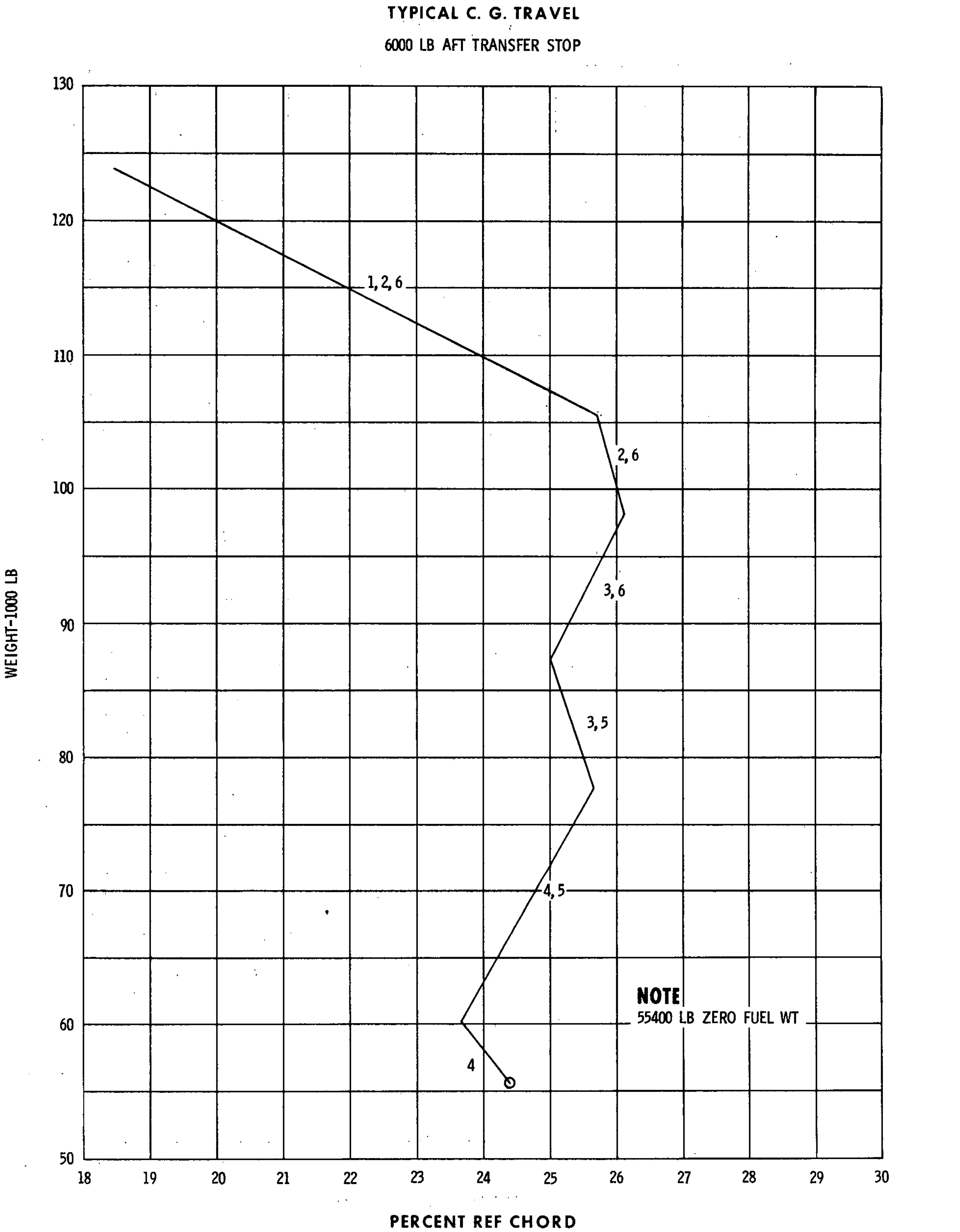

Figure 7-4 (Sheet 2 of 3)

GROSS WEIGHT VERSUS C.G.

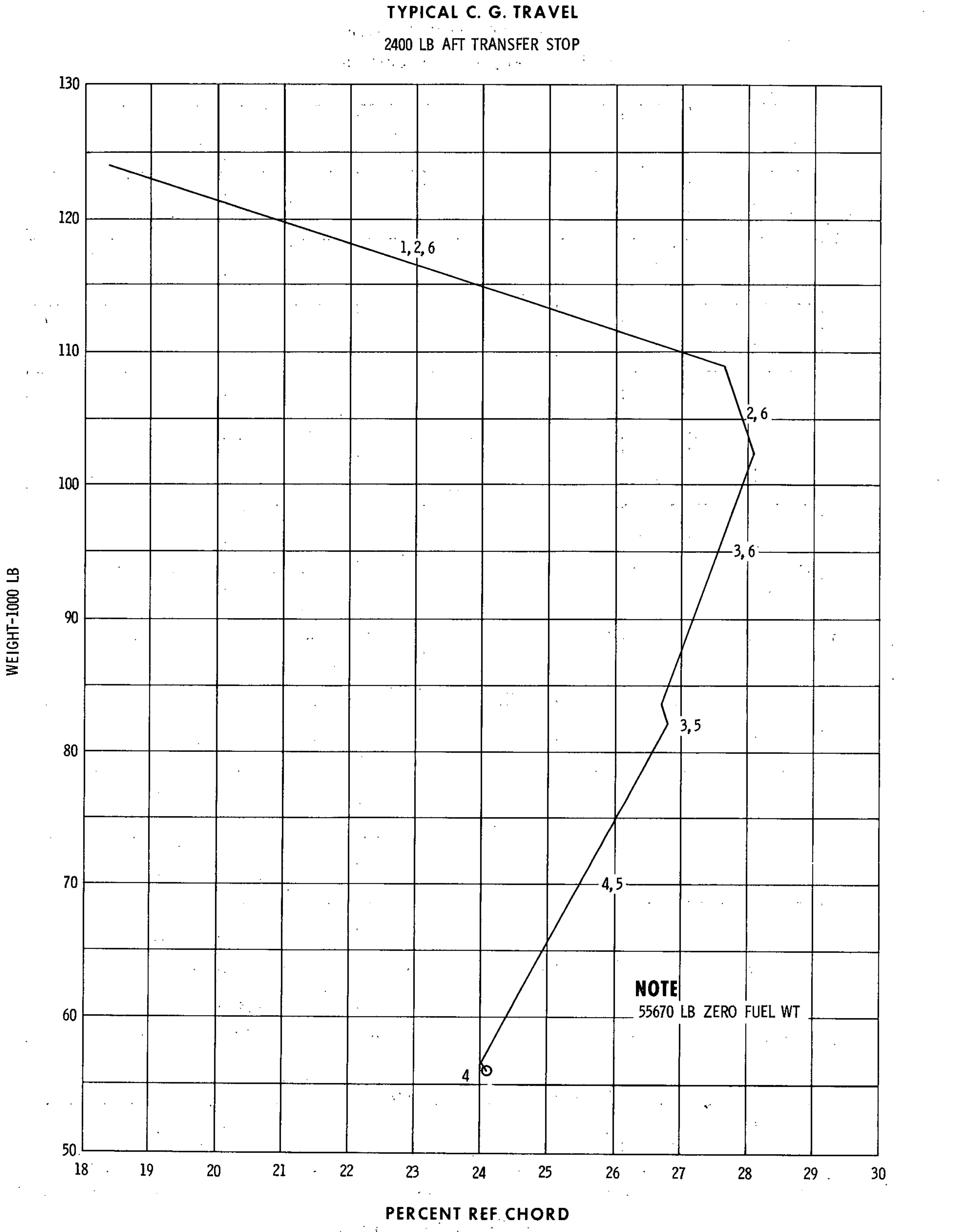

Figure 7-4 (Sheet 3 of 3)

mum aft transfer rate is approximately 250 lbs per minute. If space is available in tank 6 such as for a ground takeoff after a non-afterburning period, the transfer rate is approximately 320 lb per minute. These rates are based on the present .649 size orifice.

JET PUMP SYSTEM

A system of six jet pumps is installed. These transfer residual fuel from tanks which are almost empty to tanks whose boost pumps are operating. Jet pumps scavenge tanks 1, 2, 3, 5 and 6. Fuel from tank 1 is scavenged by the jet pump in tank 2. Boost pump 3-1 operates the jet pump which scavenge tank 2. Boost pump 4-4 operates the jet pump to scavenge tank 3. Boost pump 4-3 operates the jet pump to scavenge tank 5 and tank pumps 5-1 and 5-2 operate 2 jet pumps to scavenge tank 6. Jet pump usage is entirely automatic and requires no attention by the pilot. A tube from the boost pump outlet to the jet pump expands a bellows which opens a valve connecting a suction tube from the previous sequenced tank to the low pressure section of a venturi. When a boost pump is not running, the bellows in its associated jet pump contracts and closes the suction tube between the tanks.

TANK 4 ULLAGE SYSTEM

Through action of bypass and relief valves, excess cooling loop and engine fuel hydraulic system fuel not burned by the engine, or hot fuel not accepted by the fuel control, (smart valve) may be returned to tank 4. If tank 4 is close to being full, a dual float switch activates pump 4-1 to furnish tank 4 fuel to the fuel manifold and create an ullage space in tank 4. This same float switch also turns off pump 2-1. When pump 4-1 is running pump 2-1 can not run. A second back up float switch controls pump 4-2 and prevents pump 6-1 from operating when pump 4-2 is running. The operation of the tank 4 ullage system is automatic and the cockpit fuel pump lights will not indicate when tank pumps 4-1 and 4-2 are operating. However, the fuel quantity indicator may show a drop in tank 4 fuel.

NOTE

> The float switches are wired in series so that if one switch should stick closed pumps 4-1 and 4-2 will not keep running and so cause a premature depletion of tank 4 fuel.

FUEL TANK EMPTY LIGHT SEQUENCING

When tanks 1, 2 or 6 are empty the yellow EMPTY lights illuminate in the pushbutton switches. The empty lights for each tank will also illuminate for tank 3, 5 and 4 if normal sequence has been used. However, tanks 3, 5, and 4 do not always show an empty light if fuel has been used out of the normal sequence.

Tank 6 must be nearly empty before tank 5 empty light will illuminate. Tank 2 must be nearly empty before the tank 3 light will illuminate, and tank 5 must be nearly empty before the tank 4 empty light will illuminate. Tank 4 has a low warning light which operates independently of the tank empty light sequencing at the 5000 lb level. The individual tank quantities can also be checked if out of sequence fuel usage is suspected.

IN-FLIGHT REFUELING

In flight, all tanks can refuel simultaneously at invidivudal rates which vary from 550 ppm (tank 1) to approximately 1150 ppm (aft tank). The initial transfer rate if all tanks have space to accept fuel is approximately 5000 ppm with normal tanker nozzle pressure. The rate decreases as individual tanks are filled, becoming 1500 to 550 ppm as the last tanks are topped off. Engine fuel requirements during refueling increase as the tanks fill, ranging from approximately 270 to 400 ppm total.

FUEL MANAGEMENT PRIOR TO REFUELING

Up to 4000 pounds of fuel should be transferred to tank 1 prior to making a refueling contact. The transfer improves the unaugmented pitch stability of the aircraft by moving its center of gravity forward. With normal SAS operation, there is no marked change in handling characteristics.

In some cases a tanker rendezvous may be made after a high speed run with tank 4 full or almost full, and fuel remaining in tank 5. Normal forward transfer would empty tank 5 first. Tank 4 only forward transfer is more desirable in this case to make the maximum amount of space available in that tank for cool fuel from the tanker. This improves the fuel heat sink capability. This also speeds up the refueling operation. Hot fuel transferred from tank 4 is consumed from tank 1 when its pumps start. With both generators functioning normally, the air refueling procedure may be accomplished without any fuel management action except that failure to make a Tank 4 XFR Only before an air refueling will affect the temperature of the fuel in tank 4 after the air refueling is completed.

FUEL MANAGEMENT DURING REFUELING

During refueling, the engines are supplied by normal pump sequencing. Tank 4 pumps, or any other pumps, will remain on if they have been turned on by manual sequencing. With the forward transfer switch off, tank 1 pumps will continue to supply both manifolds as long as fuel remains in that tank. With the forward transfer switch on, tank 1 pumps are made inoperative unless tank 1 is selected manually or tank 4 reaches 800 lbs. If not selected manually, tank 4 will be shut off when tanks 3 and 5 receive fuel and the start tank 4 float switches in the bottom of those tanks are opened.

SUBSONIC CRUISE FUEL MANAGEMENT

The aircraft fuel system sequencing was designed to optimize the aircraft c.g. at normal cruise. The recommended c.g. for subsonic flight is between 19% and 25% as stated in Section V.

For subsonic cruise the following procedure will keep the CG within the recommended limits for subsonic flight.

At 57,000 lbs fuel remaining or after takeoff if initial load is less than 57,000 lbs, turn forward transfer switch ON. Leave forward transfer switch ON until before landing check or when starting acceleration if final portion of flight is supersonic.

FLIGHT CONTROL SYSTEM

Do not move the control stick during engine start. The inboard and outboard elevons may not deflect simultaneously or equally when powered by one hydraulic system if pressure is less than 1500 psi. This is due to unequal friction in the inboard and outboard sets of elevon actuators. A preloaded spring in the control pushrod mechanism can move from its detent position as a result of unequal elevon movement. Restoration of normal hydraulic pressure should cause the elevons to resume normal symmetry and restore the spring to its detented position. However, an inspection is required to ascertain that the spring has reset properly.

STABILITY AUGMENTATION SYSTEM

Pitch Axis Characteristics Due to Lagged Pitch Rate Switching

SAS Lagged Pitch Rate switching may cause transient load factors to develop when climbing or descending through 50,000 feet. This is a normal SAS characteristic which results from the design of the SAS pitch rate damping circuits.

Signals from the SAS pitch gyros always go to a straight-through circuit that varies the pitch rate gain (damping response rate) with pitot differential pressure. In addition to this path, the signals go through a lagged pitch rate circuit that changes the pitch rate gain when above 50,000 ft. altitude. In a descent, the lagged pitch rate term is switched out at 50,000 ft., but this does not instantly remove the existing command. The signal that existed prior to switching drops instantly to a level equal to 12/13 of its value for the higher altitude. The remainder of the signal decays exponetially to zero with a time constant of 13 seconds.

These two pitch rate gains are summed prior to introduction into the servo amplifiers. Therefore, as the aircraft descends toward 50,000 ft. in a turn, the SAS is supplying an input to the pitch transfer valves as a function of aircraft bank angle, Mach number, altitude, and pitch rate, causing the elevon surfaces to be deflected from the position commanded by stick position and trim setting as long as there is an aircraft pitch rate. The nose up pitch rate causes the SAS to oppose pilot control and/or trim action by interposing a down elevon deflection increment.

When the aircraft passes through 50,000 ft. altitude while descending, the lagged pitch rate term is switched out of the circuit, causing the pitch rate gain to reduce to that of the straight through circuit. Response to control stick positioning becomes more positive, SAS opposition to the pilot induced pitch rate is reduced, and the elevons are automatically repositioned to a new angle which is governed by the lesser SAS gain. The aircraft responds to this surface change by exhibiting a bump in the nose up pitch direction. Repositioning of the control stick and/or retrimming is necessary, with the amount of change being a function of pitch rate desired before and after the transition. The reverse action is prevalent if the aircraft is in an ascending turn.

During transitions through 50,000 ft. with no pitch rate, i. e., straight line climb or descent, the gain will switch at 50,000 feet with no resulting aircraft movement.

BRAKE SYSTEM OPERATION

To stop an airplane, the kinetic energy must be absorbed by aerodynamic drag, braking action and rolling friction. The variable relationship of these factors is modified by the landing or aborted takeoff roll distance, speed at the beginning of deceleration and weight. Rolling friction, although of considerable effect, is neglected in the following discussion. Aerodynamic braking is composed of drag effects of the airplanes surfaces and the drag chute. The most effective airplane surfaces are the wing and elevons.

Braking action is limited by three factors; braking friction available between the tires and the runway, methods of brake application and the kinetic energy limits of the brakes. Rated brake capability is shown in figure 5-8. Braking friction available depends on runway conditions, weight, and positive or negative aerodynamic lift conditions. Other considerations affecting stopping capability are tire hydroplaning effects, efficiency of anti-skid devices and pilot technique. Techniques must be varied depending on conditions existing at the time. Speed at start of deceleration will be dependent on touchdown speed during landings and time required to deploy the chute and apply brakes. Aborted takeoff speed will depend on the abort decision point and speed increase during the period for pilot reaction. Weight factors will differ depending on normal or emergency landings or aborted takeoffs. Stopping techniques and/or procedures must also be varied depending on deployment or non-deployment of drag chute, runway length, weather conditions and tire capability.

Drag chute failure procedures in Section III are mainly intended for landing weight conditions although the procedures are somewhat applicable to aborted takeoff weights also. The following braking technique discussion is mainly applicable to heavy weight aborted takeoffs.

Braking On Dry Runways - Anti-Skid On

Energize the brakes smoothly with moderate to heavy pressure with the nosewheel on the runway for dry runway conditions. It is unlikely that the anti-skid system will actuate on dry runways at weights over 120,000 pounds. At lighter weights, it is possible to cause momentary wheel spindown and, if this occurs, the center tires are more susceptible to blowout.

Pilot judgement regarding braking technique must be used after drag chute deployment. Brake pressure may be relaxed if a relatively low speed can be attained after a short run with ample distance remaining. However, if distance is critical or a long run would result, maximum use of brakes must be continued until the stop is assured. This requires hard and continuous brake pressure.

NOTE

> Hard braking may result in brake seizure after stopping, increasing time to clear the runway. If possible, keep the aircraft moving at slow speed until clear of the runway. Taxiing at low speed to clear a runway is permitted with all tires failed on a main gear. The massive tire bead tends to protect the wheels for a short distance at heavy weight.

Long runs at heavy weights may result in blown tires due to sidewall failures. Failure of one tire will usually overload the remaining tires on that side and probably cause successive failures. Therefore, sufficient brake pressure should be maintained during and after chute deployment to minimize stop distance. This reduces heat build-up in the tires which is characteristic of extended roll-outs at heavy weight. If tire failure is known or suspected, maintain enough brake pressure to prevent wheel spin-up and, possibly, wheel and/or tire disintegration at high rotational speeds.

NOTE

- With a dry runway, do not use up elevon as a method of increasing braking force because of the additional risk of tire fatigue failure. A faster stop is possible with the rolling stock intact.
- If tires blow with either wet or dry conditions, increased brake pressure on that side is required to maintain braking force with the remaining tires.
- Rated brake energy capacities and associated maximum braking speeds may be disregarded during aborted takeoffs. It is considered better to use the brakes at high speed, as tire failure may occur if the roll is extended by delayed braking.

Braking on Wet Runways

Energize the brakes smoothly with light to moderate pressure and the nosewheel on the runway for wet or slippery runway conditions. If the drag chute does not deploy, select NORMAL (or ALT STEER & BRAKE if the left engine has failed), and then shut down a failed engine, or shutdown the right engine if there has been no engine failure, in order to reduce thrust and increase braking effectiveness. Also use moderate up elevons so as to provide as much drag as posssible without lifting the nosewheel. The increased gear load may cause tire failure at heavy weight; however, tire failure may be acceptable since the tires will not necessarily disintegrate. Braking deceleration available is nearly the same for braked tire rolling and blown tire locked conditions with a wet surface. Locked wheel skids of up to 7000 feet have left the wheels undamaged during wet runway testing.

Unless hydroplaning is encountered, good nosewheel and rudder steering characteristics can be expected and have been demonstrated during stops on wet runways with and without the drag chute, with all main gear tires blown and wheels locked, and with one engine shut down.

Hydroplaning in various forms is a limiting factor with wet runway conditions and, although nosewheel and rudder steering remain effective, wheel braking force is nill until the tires can make contact with the runway. The aircraft tends to follow a trajectory and will drift with a crosswind. Except for the extended stop distance involved, skids across or into dry runway areas are the chief hazard of wet runway stops. The wheels tend to lock-up and cause blown tires while sliding on a wet surface. Dry areas tend to destroy the tires due to increased friction or wheel spin-up. This allows the wheels to make runway contact and may ultimately destroy the wheels and then the brake assemblies. Even so, the aircraft can probably survive on the landing gear struts so long as it remains on the main runway, or on a hard surface overrun where there is a smooth transition from runway to overrun.