operating limitations

section V

21.045

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LIST OF ILLUSTRATIONS

INTRODUCTION.

This section includes the engine and aircraft limitations that must be observed during normal operation. Particular notice must be taken of the instrument limit markings *(figure 5-1)*, which form a part of these limitations, and must be referred to because these limitations are not necessarily repeated in the text.

MINIMUM CREW REQUIREMENT (C-54 AIRCRAFT).

The minimum crew consists of a pilot, a copilot, and a crew engineer. Additional crew members, as required, will be added at the discretion of the commander.

MINIMUM CREW REQUIREMENT (R5D AIRCRAFT).

The minimum crew consists of a pilot and a copilot. Additional crew members, as required to accomplish special missions, will be added at the discretion of the commander.

ENGINE POWER INSTRUMENTS.

Refer to figure 5-1 for engine instrument limit markings.

ENGINE LIMITATIONS.

Refer to figure 5-1 for normal engine operating limits. Overspeed limits for the engines are: 3100 to 3300 rpm — engine must have complete inspection; over 3300 rpm — engine must be replaced. Note all conditions of overspeed on AFTO Form 781.

CAUTION

Under no conditions should 2550 rpm be exceeded during engine operation in HIGH blower.

MILITARY POWER.

Military power for an engine is the same as maximum power, except that it is limited to 30 minutes duration. An engine can actually be run continuously under overload conditions of power and speeds for much longer periods than those permitted by the ratings. However, the period of reliable operation is thereby reduced to an impractically short time. By imposing a time limit on maximum and military power ratings, the cumulative effect of the overloads is distributed evenly over the period between overhauls, and the useful life of the engine is accordingly lengthened. If the use of military power is required for any period longer than 30 minutes, a notation must be made in Form 781.

MAXIMUM POWER LIMITATIONS.

The maximum desired cylinder head temperature before the application of maximum power is 150 degrees centigrade. Maximum flight safety dictates the use of full authorized power for every takeoff. Maximum rpm is used so that the engine is putting its full capacity into operation. Maximum rpm also helps the propeller by compensating for the lack of forward speed with high rotational velocity. This crankshaft speed will be maintained until the aircraft has accelerated to a speed at which directional control can easily be maintained if one engine should fail suddenly, thus creating excessive drag. Normally, maximum power is seldom used for more than 1 minute. However, when conditions require, maximum power may be used for a period not to exceed 5 minutes, subject to limiting cylinder head and oil temperatures.

Note

With one magneto out, power not to exceed cruise settings may be maintained. All engine instruments should be closely monitored and normal limits not exceeded.

METO (NORMAL RATED) POWER.

METO (maximum except takeoff) power is the maximum continuous power that may be used in climb or cruise.

NORMAL FUEL GRADE OPERATING LIMITS.

The normal operating limits on grade 100/130 fuel are as follows. (Grade 115/145 fuel may be used when 100/130 is not available and operating limits remain the same.)

Power	*HP*	*RPM*	*MP (Inches Hg)*	*ALT*	*Blower*	*Mixture*
Maximum (5 minutes)	1450	2700	49.5 50.0	1000 S.L.	LOW	AUTO-RICH
METO	1200	2550	40.5 42.0	5300 S.L.	LOW	AUTO-RICH
METO	1100	2550	43.0 44.0	15,000 7000	HIGH	AUTO-RICH
Maximum Cruise	800	2230 2112	29.0 33.0	12,000 S.L.	LOW	AUTO-LEAN
Maximum Cruise	750	2150	31.1	19,000	HIGH	AUTO-LEAN

★ ★ ★ ★ ★

CARBURETOR AIR TEMPERATURE LIMITATIONS.

Low Blower: Maximum CAT (without preheat) +55°C

Low Blower: Maximum CAT (with preheat) .... +38°C

High Blower: Maximum CAT .... +15°C

AIRSPEED LIMITATIONS.

1. The maximum level flight and descent airspeed is 217 knots (250 mph) IAS.

2. The maximum dive speed is 290 knots (333 mph) IAS.

These limiting airspeeds are applicable at all altitudes. For effect of gross weight on speed limitation, refer to cruise speeds paragraph, this section.

3. Wing flaps:

Wing Flap Angle (degrees)	*Speed (Approximate IAS) (knots)*	*(mph)*
20	176	202
30	138	158
40	127	146

4. Landing light operation: Maximum speed with the landing lights extended is 127 knots (146 mph) IAS.

5. Landing gear extension: Maximum speed with the landing gear extended is 127 knots (146 mph) IAS.

PROHIBITED MANEUVERS.

The aircraft is restricted to normal flight maneuvers. No aerobatics are permitted.

CENTER OF GRAVITY LIMITATIONS.

Aft limit (landing gear down) ....33 per cent MAC

Aft limit (landing gear up) ....32 per cent MAC

Forward limit (landing gear down) ....16 per cent MAC

Forward limit (landing gear up) ....14 per cent MAC

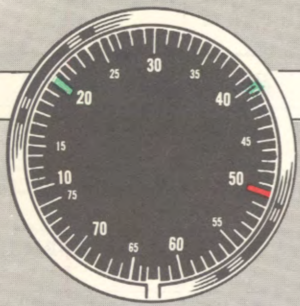
For information and method of calculating the cg of the aircraft, refer to the manual of Weight and Balance Data, *T.O. 1-1B-40.*

OPERATIONAL WEIGHT LIMITATIONS.

Weight, more than any other single factor, will determine the capability and performance of your aircraft. In designing aircraft, weight has always been a primary restrictive factor, as it has a direct effect on aircraft configuration, power, and range. Aircraft are designed with sufficient strength to accomplish a certain basic mission without undue allowance for overloading or improper weight distribution. Every effort is made to eliminate unnecessary weight; however, the weight penalty for making an aircraft foolproof is prohibitive. Weight limitations, therefore, are necessarily involved in the operation of the aircraft. If these limitations are exceeded, a loss in the performance of the aircraft is inevitable and structural failure is quite probable. When the aircraft is loaded beyond the established

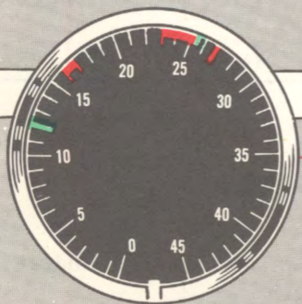
INSTRUMENT

FUEL GRADE 100/130



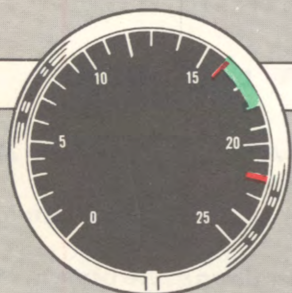
MANIFOLD PRESSURE

- (green) 20 IN. HG. MAXIMUM ENDURANCE
- (green) 40.5 IN. HG. MAXIMUM CONTINUOUS
- (red) 50 IN. HG. MAXIMUM



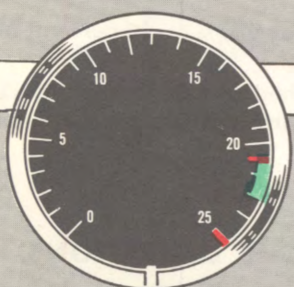
TACHOMETER

- (green) 1200 RPM MINIMUM FOR FLIGHT
- (red) 1601-1699 RPM DANGEROUS VIBRATION CHARACTERISTICS
- (red) 2301-2549 RPM POSSIBLE CRANKSHAFT FAILURE
- (green) 2550 RPM MAXIMUM CONTINUOUS
- (red) 2700 RPM MAXIMUM (5 MINUTES—TAKEOFF)



ENGINE FUEL PRESSURE

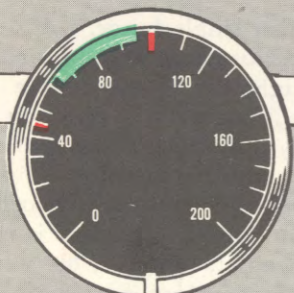
- (red) 16 PSI MINIMUM FOR FLIGHT
- (green) 16 TO 18 PSI NORMAL
- (red) 22 PSI MAXIMUM



ENGINE FUEL PRESSURE

(AIRCRAFT USING PD-12F-13 CARBURETOR)

- (red) 21 PSI MINIMUM FOR FLIGHT
- (green) 21-23 PSI NORMAL
- (red) 25 PSI MAXIMUM



ENGINE OIL PRESSURE

- (red) 45 PSI MINIMUM FOR FLIGHT
- (green) 65-95 PSI NORMAL
- (red) 100 PSI MAXIMUM

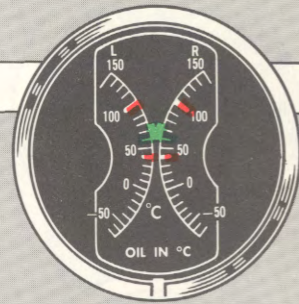
Figure 5-1 (Sheet 1 of 3)

MARKINGS

FUEL GRADE 100/130

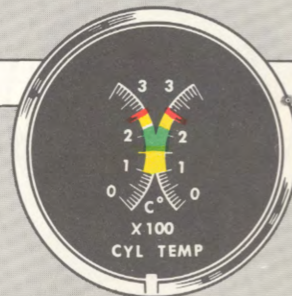
OIL TEMPERATURE INDICATOR

- 40°C MINIMUM FOR FLIGHT
- 60°C TO 75°C NORMAL
- 100°C MAXIMUM



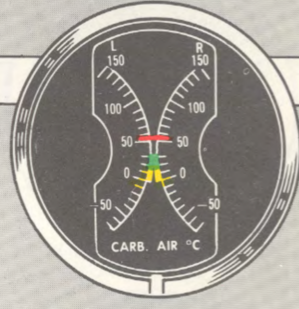
CYLINDER HEAD TEMPERATURE INDICATOR

- 100°C TO 150°C
- 150°C TO 232°C NORMAL
- 232°C TO 260°C
- 260°C MAXIMUM



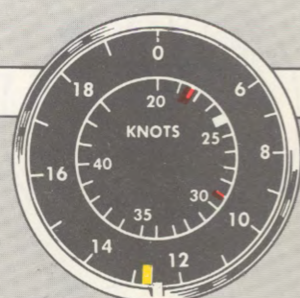
CARBURETOR AIR TEMPERATURE INDICATOR

- −10°C TO +15° POSSIBLE ICING
- +15°C TO +38°C NORMAL
- +38°C TO +55°C AREA TO BE AVOIDED
- +55°C MAXIMUM — DANGER OF DETONATION



AIRSPEED INDICATOR (KNOTS)

- 127 KNOTS LANDING GEAR AND MAXIMUM FLAPS
- 217 KNOTS MAXIMUM LEVEL FLIGHT AND DESCENT
- 290 KNOTS MAXIMUM DIVE



AIRSPEED INDICATOR (MPH)

- 144 MPH LANDING GEAR AND MAXIMUM FLAPS
- 250 MPH MAXIMUM LEVEL FLIGHT AND DESCENT
- 333 MPH MAXIMUM DIVE

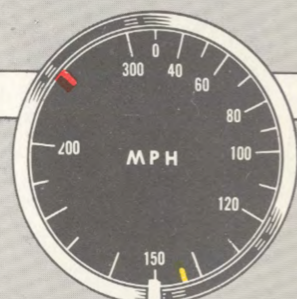
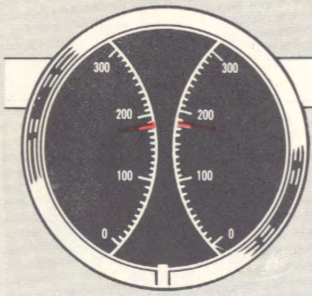


Figure 5-1 (Sheet 2 of 3)

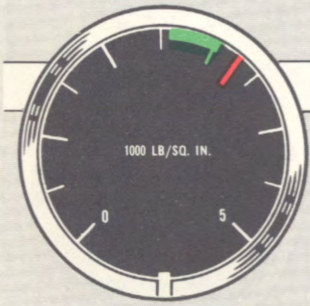
INSTRUMENT MARKINGS

FUEL GRADE 100/130



COCKPIT AND CABIN HEATER AIR TEMPERATURE INDICATOR

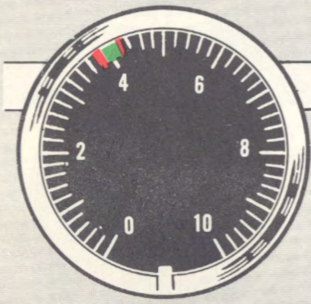
185°C MAXIMUM



HYDRAULIC PRESSURE

2600 PSI TO 3050 PSI NORMAL

3300 PSI MAXIMUM

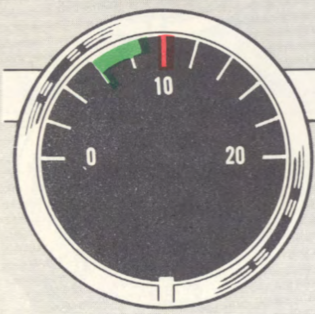


VACUUM PRESSURE

3.75 IN. HG. MINIMUM

3.75 TO 4.25 IN. HG. NORMAL

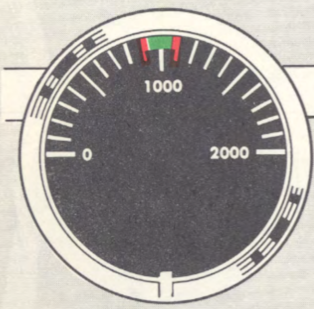
4.25 IN. HG. MAXIMUM



DE-ICING SYSTEM PRESSURE

6 PSI TO 8.5 PSI NORMAL

10 PSI MAXIMUM



EMERGENCY AIRBRAKE PRESSURE

950 PSI MINIMUM

950-1050 PSI NORMAL

1050 PSI MAXIMUM

X1-112

Figure 5-1 (Sheet 3 of 3)

limits, ceiling and range are decreased, control forces and stalling speeds become higher, and the rate of climb falls off rapidly as the maximum gross weight is exceeded. The takeoff and landing rolls increase appreciably with an increase in gross weight. Likewise, the brakes may become insufficient to brake the forward momentum of the aircraft, and the wings will become more vulnerable to airloads during maneuvers or flight through turbulent air. These resultant effects can reach serious proportions when the weight limitations of a specific aircraft are disregarded.

In cargo aircraft, the effect produced by weight is much greater than that encountered in aircraft of other types because the cargo itself adds a considerable amount to the weight at which the aircraft is operated. In order that cargo of various sizes may be accommodated, the cargo hold is of such proportions that space is not a restrictive factor; consequently, overloading is entirely possible. Weight limitations must be complied with if the aircraft is to be operated efficiently, economically, and safely. A consideration of the weight factors involved, particularly as they apply to this aircraft, appears in the succeeding paragraphs.

WEIGHT AND LOADS.

Due to the effect of gravity on the mass of your aircraft, the aircraft possesses weight. More exactly, this weight is a force which gravity exerts on the material used in the fabrication of the aircraft and which pulls the aircraft toward the earth. In any condition of static equilibrium, during straight and level flight or at rest on the ground, the aircraft is subjected to this pull of gravity, the strength of which is spoken of as 1 G. As fuel, cargo, crew members, and additional equipment are added in order that the aircraft may accomplish a specific mission, the weight of the aircraft correspondingly increases and the additional weight constitutes a force acting on the aircraft structure. The weight of the aircraft, or the force which gravity imposes on the aircraft, may also be considered as a load. On the ground, this load must be sustained by the landing gear; in flight, by the wings. There is a limit to the load which the landing gear is capable of supporting during taxi, takeoff, and landing operations; there is likewise a limit to the load which the wings can sustain in flight.

During maneuvering and flight through turbulent air, additional loads are imposed on the aircraft. These loads, caused by the acceleration of the aircraft are the result of forces which, in addition to that of gravity, act upon the total mass of the loaded aircraft. Both these forces tend to produce undesirable and potentially dangerous loads on the aircraft structure and its members. This is particularly true of the wings, which must sustain the aircraft in flight. When the weight of the aircraft is increased, the wings become more and more vulnerable to the loads imposed by sudden changes in air currents or manipulation of the controls. The ultimate strength of the aircraft structure is eventually exceeded by the combined forces of weight and airloads. When this condition occurs, structural failure results. The maximum weight which the aircraft can safely carry is dependent upon distribution of the weight throughout the aircraft and its capacity to sustain airloads in accelerated flight.

LOAD FACTORS.

A load factor is the ratio of the load imposed on the aircraft when accelerated in any direction as compared with the load imposed on the aircraft by gravity in any condition of static equilibrium. The load factor denotes the strength of the forces acting on the aircraft because of sudden changes in air currents and manipulation of the controls, and is expressed by the term, G, which is the gravitational force. By definition, then, all aircraft at rest on the ground or in straight and level flight possess a load factor of 1.0 G because the force acting upon the aircraft under either of these conditions is merely that of gravity. When the aircraft enters a region of turbulent air or the pilot elects to maneuver the aircraft, additional forces are imposed on the structure. The additional load on the wings resulting from these forces is expressed in relation to the gravitational force and referred to as 0.5 G, 2.0 G, 3.0 G, etc, which mean that the forces exerted on the wing structure and its members are ½, 2, or 3 times the force exerted by gravity. For example, if the normal weight of the aircraft is 50,000 pounds and the load factor at some given moment of accelerated flight is 3.0 G, the total force which the wings must sustain is 150,000 pounds or 3 times the normal weight of the aircraft in straight and level flight. See distribution of loads, this section.

CAUTION

The aircraft must have the load distributed so that the aircraft wings can safely withstand a load factor of at least 2.0 G's, or structural damage to the wings may result if the aircraft encounters a situation whereby more than 2.0 G's are imposed. Aircraft with combinations of payload and fuel which limit the load factor capability to 2.5 G's must be flown with caution, especially in turbulent air or during turns and pullouts.

MARGIN OF SAFETY.

The margin of safety is the range of forces which exist between two points, one of which is the load factor the aircraft is sustaining at any given moment, and the other the load factor at which structural damage will occur. If, for example, the aircraft is incapable of sustaining a load factor greater than 2.5 G and during flight through turbulent air is subjected to a force of 1.5 G, the margin of safety at this particular moment is 1.0 G. When fuel and cargo loads are increased, the margin of safety decreases. This increase in weight actually becomes a component of the forces acting on the aircraft, and, as such, lessens the capacity of the aircraft to sustain further loads due to accelerated flight. For this reason, it is advisable in loading aircraft to maintain a margin of safety which will never be exceeded during any period of flight.

WARNING

If the combined weight of cargo and fuel is such that the aircraft is incapable of sustaining a force of 2.5 G, turns and pullouts should be made with caution to minimize the resulting airloads.

EXPLANATION OF CHARTS.

The gross weight limitations charts *(figure 5-2)* are intended to present graphically the weight-carrying capabilities of the aircraft as defined by the various criteria which provide limits for safe and efficient operation. Through the use of these charts, the flight planner is aided in recognizing the weight limitations which will restrict operation in a specific mission and in determining what margin of safety may be established. A separate chart is provided for use with the C-54 G model.

Note

Although the charts indicate the limitations involved in the loading of the aircraft, the authority for operating the aircraft at a given gross weight remains the responsibility of the local authority.

GROSS WEIGHTS.

The data in the selected chart *(figure 5-2)* is based on an initial operating weight of the aircraft exclusive of fuel and cargo. The zero point of the chart at the junction of the fuel and cargo load axes represents an operating weight of 40,000 pounds. Because individual operating weights may vary, it will be necessary to adjust the chart for the specific aircraft involved. The operating weight plus the fuel and cargo as required in a mission can be shown by gross weight lines which slope at a 45 degree angle to the axis of the chart. These diagonal lines also indicate various structural and performance limitations. However, any gross weight line may be plotted to obtain a graphic representation of the limitations involved in the fuel-weight combination which a mission may require.

Note

The gross weight of the aircraft should never exceed that required for the mission, since unnecessary risk and wear of the equipment will otherwise result. Takeoff gross weights must also be considered in the light of available runways, surrounding terrain, altitude, atmospheric conditions, mission requirements, and the urgency of the mission.

DISTRIBUTION OF LOAD.

The maximum load that the aircraft can carry is dependent on the way that load is distributed throughout the aircraft. The weight of an aircraft in flight is supported by the wings, and therefore, the more load that is carried in the fuselage, the greater will be the bending moment on the wings. This means that an aircraft might safely carry 25,000 pounds if 12,000 pounds were carried in the fuselage and 13,000 pounds were in the wings. But the same 25,000 pounds might become an unsafe load if the weight distribution were 23,000 pounds in the fuselage and 2000 pounds in the wings, the unsafe condition resulting from the excessive bending moment imposed on the wings by the 23,000 pounds in the fuselage. When carrying cargo, load factors capabilities below 2.5 G's are not considered desirable because the cargo-distribution may be critical enough to overload the floor and/or the fuselage shell.

LONG-RANGE OR FUSELAGE FUEL LOAD.

When long-range or fuselage fuel tanks are installed in the cargo compartment to increase the range of the aircraft or to transport fuel, the total weight of this fuel and the tanks is computed as cargo load. In computing the fuselage fuel as cargo load, detailed chart work is eliminated, as are the individual calculations involved in adding the weight of the fuselage fuel to the fuel load and the weight of the fuselage tanks to the cargo load. Whenever fuselage fuel is carried, a reduction in the cargo load is necessary to compensate for the weight of the fuselage fuel and tanks.

WEIGHT LIMITATION CHART

C-54D, E, M AND R5D

This chart is based on the following sequence of fuel loading and usage:

Loading:

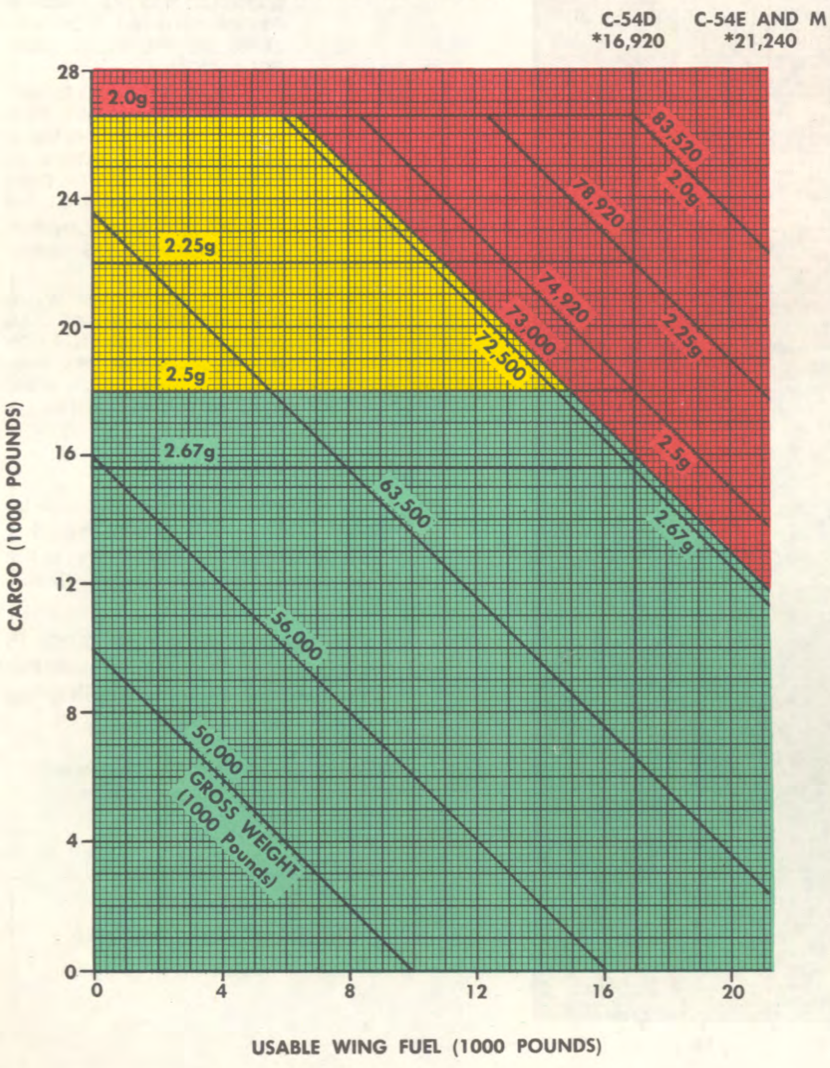
1. Fill main tanks equally.
2. Fill auxiliary tanks 1 and 4 equally.
3. Fill auxiliary tanks 2 and 3 equally (if installed).
4. Fill fuselage tanks equally (if installed).

Usage:

1. Taxi, takeoff, and climb with main tanks feeding respective engines.

After Climb

2. Fuselage tanks (if installed) feed respective sides.
3. Auxiliary tanks 2 and 3 (if installed) feed respective sides.
4. Auxiliary tanks 1 and 4 feed respective sides.
5. Main tanks feed respective engines.



LIMITATIONS BASED UPON A BASIC OPERATING WEIGHT OF 40,000 LB

MAXIMUM GROSS WEIGHT LIMITED BY PERFORMANCE

MODEL C-54D, E, M, AND R5D
R-2000-4 OR -9M2 ENGINES

94,300 LB	100 FT/MIN AT SEA LEVEL, STANDARD DAY, ONE ENGINE OUT, PROPELLER FEATHERED, REMAINING ENGINES OPERATING AT NORMAL RATED POWER, CLEAN CONFIGURATION
90,300 LB	500 FT/MIN AT SEA LEVEL, STANDARD DAY, ALL ENGINES OPERATING AT NORMAL RATED POWER, CLEAN CONFIGURATION
79,100 LB	100 FT/MIN AT SEA LEVEL, HOT DAY, ONE ENGINE OUT, PROPELLER FEATHERED, REMAINING ENGINES OPERATING AT NORMAL RATED POWER, GEAR UP, FLAPS SET FOR TAKE-OFF
63,500 LB	NORMAL MAXIMUM LANDING GROSS WEIGHT 9 FPS (STRUCTURAL DESIGN)
9,500 LB	NORMAL MAXIMUM WING FUEL AT LANDING. 395 GALLONS MAXIMUM IN EACH OUTER WING OR 395 GALLONS TOTAL IN OUTER WING AND OUTBOARD AUX. ON EITHER SIDE

Notes:

1. The information on this chart is to be used as a general guide. For other than standard conditions, refer to the performance data for weight limitations.
2. A structural limitation of 73,000 lb is imposed on the aircraft, since this is the critical weight on the landing gear for ground turning.

*Total wing fuel capacity at 6 lbs per gallon.

- RECOMMENDED (green)
- CAUTIONARY (yellow)
- NOT RECOMMENDED (red)

Figure 5-2 (Sheet 1 of 2)

WEIGHT LIMITATION CHART

(C-54G)

This chart is based on the following sequence of fuel loading and usage:

Loading:

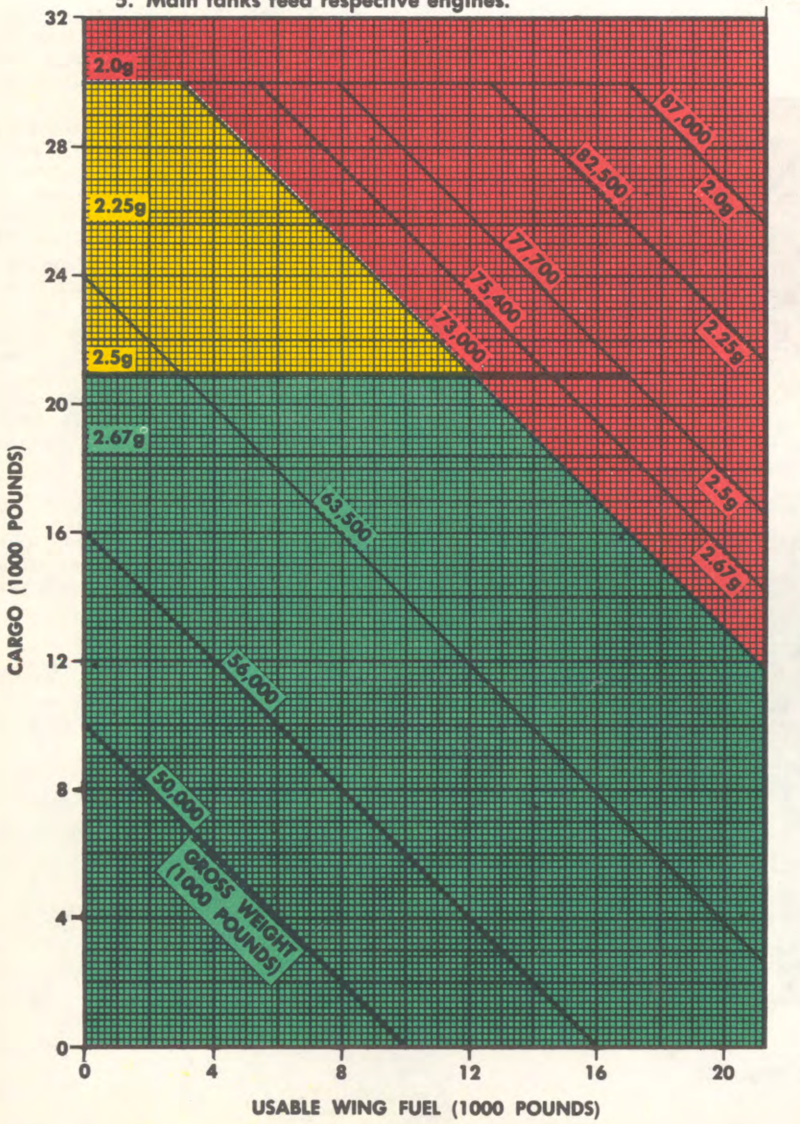
1. Fill main tanks equally.
2. Fill auxiliary tanks 1 and 4 equally.
3. Fill auxiliary tanks 2 and 3 equally (if installed).
4. Fill fuselage tanks equally (if installed).

Usage:

1. Taxi, takeoff, and climb with main tanks feeding respective engines.

After Climb

2. Fuselage tanks (if installed) feed respective sides.
3. Auxiliary tanks 2 and 3 (if installed) feed respective sides.
4. Auxiliary tanks 1 and 4 feed respective sides.
5. Main tanks feed respective engines.



LIMITATIONS BASED UPON A BASIC OPERATING WEIGHT OF 40,000 LB

MAXIMUM GROSS WEIGHT LIMITED BY PERFORMANCE

MODEL C-54G
R-2000-4 OR -9M2 ENGINES

94,300 LB	100 FT/MIN AT SEA LEVEL, STANDARD DAY, ONE ENGINE OUT, PROPELLER FEATHERED, REMAINING ENGINES OPERATING AT NORMAL RATED POWER, CLEAN CONFIGURATION
90,300 LB	500 FT/MIN AT SEA LEVEL, STANDARD DAY, ALL ENGINES OPERATING AT NORMAL RATED POWER, CLEAN CONFIGURATION
79,100 LB	100 FT/MIN AT SEA LEVEL, HOT DAY, ONE ENGINE OUT, PROPELLER FEATHERED, REMAINING ENGINES OPERATING AT NORMAL RATED POWER, GEAR UP, FLAPS SET FOR TAKE-OFF
63,500 LB	NORMAL MAXIMUM LANDING GROSS WEIGHT 9 FPS (STRUCTURAL DESIGN)
9,500 LB	NORMAL MAXIMUM WING FUEL AT LANDING. 395 GALLONS MAXIMUM IN EACH OUTER WING OR 395 GALLONS TOTAL IN OUTER WING AND OUTBOARD AUX. ON EITHER SIDE

Notes:

1. The information on this chart is to be used as a general guide. For other than standard conditions, refer to the performance data for weight limitations.
2. A structural limitation of 73,000 lb is imposed on the aircraft, since this is the critical weight on the landing gear for ground turning.

*Total wing fuel capacity at 6 lbs per gallon.

RECOMMENDED
CAUTIONARY
NOT RECOMMENDED

Figure 5-2 (Sheet 2 of 2)

CARGO LOAD.

In any mission, range and fuel consumption directly determine the fuel which must be carried, and indirectly the cargo which can be transported. With the necessary fuel for the mission established, cargo loading is variable within the limits established by the strength and performance of the aircraft. The payload, as carried in the cargo compartment, appears in thousands of pounds along the vertical axis of the chart. When fuselage fuel is utilized to increase the range of the aircraft, the combined weight of the fuel and tanks is computed as cargo load.

WING FLIGHT LOAD FACTORS.

Wing flight load factors of 2.0, 2.25, 2.5, and 2.67 are represented. The load factor 2.0 line represents an absolute minimum which should never be violated because of the dangerously small margin of safety; the load factors 2.25, 2.5, and 2.67 are included for comparative purposes. Notice that the effect of weight distribution is clearly illustrated by the shape of these lines. If the aircraft has a basic operating weight of 40,000 pounds, a load factor in excess of 2.0 may result in structural damage in each of the following instances:

At 66,600 pounds, when no load is carried in the wings.

At 71,600 pounds, when 5000 pounds of fuel are carried in the wings.

At 83,520 pounds, when 20,000 pounds of fuel (full wing fuel) are carried in the wings.

The airplane will safely withstand a load factor of 2.5 in each of the following instances:

At 58,000 pounds, when no load is carried in the wings.

At 67,000 pounds, when 9000 pounds of fuel are carried in the wings.

At 73,000 pounds, when 15,000 pounds of fuel or above are carried in the wings.

See cautionary loading area, this section.

WING FLIGHT LOAD FACTORS (G MODEL ONLY).

Wing flight load factors of 2.0, 2.25, 2.5, and 2.67 are represented. The load factor 2.0 line represents an absolute minimum which should never be violated because of the dangerously small margin of safety; the load factors 2.25, 2.5, and 2.67 are included for comparative purposes. Notice that the effect of weight distribution is clearly illustrated by the shape of these lines. If the aircraft has a basic operating weight of 40,000 pounds, a load factor in excess of 2.0 may result in structural damage in each of the following instances:

At 70,000 pounds, when no load is carried in the wings.

At 75,000 pounds, when 5000 pounds of fuel are carried in the wings.

At 87,000 pounds, when 21,240 pounds of fuel (full wing fuel) are carried in the wings.

The airplane will safely withstand a load factor of 2.5 in each of the following instances:

At 60,700 pounds, when no load is carried in the wings.

At 65,700 pounds, when 5000 pounds of fuel are carried in the wings.

At 73,000 pounds, when 12,300 pounds of fuel or above are carried in the wings.

See cautionary loading area, this section.

CRUISE SPEEDS.

Caution must also be exercised in selecting the cruise speeds for operation. Load factors result not only from maneuvers instituted by the pilot, but also by encountering atmospheric gusts. At any given speed and gross weight, the larger the gust the higher the load factor. Similarly, at any given gross weight and stated gust intensity, the higher the speed the larger the load factor. The aircraft is basically designed to be able to safely withstand the load factors resulting from a 30 FPS gust at 250 mph with 18,000 pounds of cargo. From the chart it can be seen that, as the cargo weight is increased, the load factor made good is decreased. If a 30 FPS gust is also to be made good, then the speed likewise must be decreased. With 26,600 pounds of cargo and low fuel weights, the cruise speed should be reduced to 158 mph to make good a 30 FPS gust; conversely, at 250 mph, only a 19 FPS gust can be made good in this latter condition.

CRUISE SPEEDS (G MODEL ONLY).

Caution must also be exercised in selecting the cruise speeds for operation. Load factors result not only from maneuvers instituted by the pilot, but also by encountering atmospheric gusts. At any given speed and gross weight, the larger the gust the higher the load factor. Similarly, at any given gross weight and stated gust intensity, the higher the speed the larger the load factor. The aircraft is basically designed to be able to safely withstand the load factors resulting from a 30 FPS gust at 250 mph with 20,700 pounds of cargo. From the chart, it can be seen that, as the cargo weight is increased, the load factor made good is decreased. If a 30 FPS gust is also to be made good, then the speed likewise must be decreased. With 30,000 pounds of cargo and low fuel weights, the cruise speed should be reduced to 158 mph to make good a 30 FPS gust; conversely, at 250 mph, only a 19 FPS gust can be made good in this latter condition.

LANDING GEAR LIMITATIONS.

The landing gear structure is designed for landing during routine operation at a gross weight of 63,500 pounds at a maximum contact sinking speed of 9 FPS limit *(figure 5-3)*. This is the maximum recommended landing weight for normal operation. The maximum recommended gross weight for normal landings based upon brake limitations is 68,800 pounds. At this gross weight, the brakes are good for approximately 100 stops. The landing gear strength for ground turning becomes critical at a gross weight of 73,000 pounds; however, in case of emergency, landings may be made above 73,000 pounds.

PERFORMANCE LIMITATIONS.

In the case of four-engine aircraft, it is generally inherent that structural rather than performance limitations restrict the weight which the aircraft can carry. Obviously, the gross weight must necessarily be limited by the ability of the aircraft to take off within available runway length and clear any obstacles. But the primary consideration is the ability of the aircraft to fly with partial power. One-engine-out performance is not generally a restrictive factor in the normal loading of the aircraft. Note the gross weight lines on the charts, particularly those which separate the loading areas. Each of these lines defines a specific limitation and several of the lines are performance limitations, but the gross weights are sufficiently high for normal operation. These performance limitations are based on the gross weight at which an adequate rate of climb can be maintained under various conditions of power, temperature, and configuration.

POWER LOSS AND PERFORMANCE.

The loss of one engine results in an asymmetric power condition and a decrease in the rate of climb. However, a 100 FPM rate of climb with three engines can be maintained with gross weights up to 94,300 pounds on a standard day at sea level. Power losses due to temperature, humidity, and engine deficiency exert a considerable influence on the rate of climb even when all the engines are operating. It is not difficult to visualize the effect which engine failure will produce on the rate of climb, but it is interesting to note the marked difference in aircraft performance resulting from a rise in temperature and a corresponding fall in air density. The gross weight difference to provide a 100 FPM rate of climb on a hot day as compared to a standard day at sea level is 15,200 pounds, resulting in a maximum gross weight of 79,100 pounds, in order to maintain a 100 FPM rate of climb at sea level on a hot day. (See weight limitation chart, this section.) For purpose of standardization, the temperature of a standard day is 15°C and that of a hot day, 38°C at sea level. Naturally, variations of temperature and altitude within this range will give similarly graduated values in brake horsepower and rate of climb. The effect of humidity and engine deficiency on brake horsepower, and ultimately the gross weight at which the aircraft may be operated, has not been included in the weight limitations chart because of the extreme number of variable conditions involved.

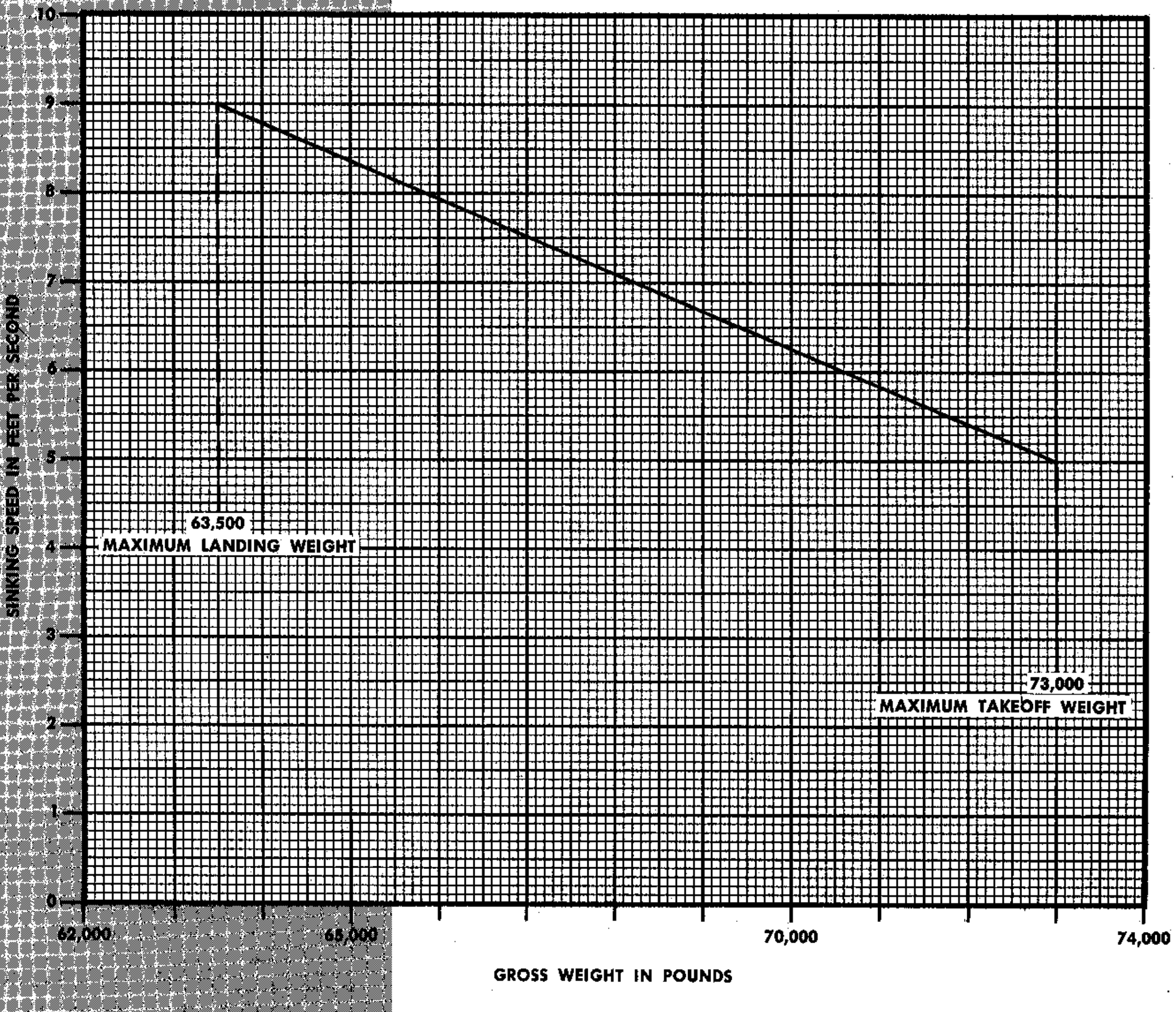
CONFIGURATION AND PERFORMANCE.

The configuration of the aircraft also imposes a penalty on performance. In other than clean configurations, the increase in drag produces a decrease in the rate of climb and requires a readjustment of the gross weight at which the aircraft may be operated. As with power losses, this condition is most critical at takeoff when of necessity the landing gear is extended, and the cowl flaps and oil cooler flaps are open. The drag created by a windmilling propeller and the extended landing gear during the takeoff roll is such that no attempt to take off should be made unless the critical engine failure airspeed for the gross weight of the aircraft has been attained or exceeded.

RECOMMENDED LOADING AREA.

The green area on the charts represents the loading conditions that present no particular problem in regard to strength or performance of the aircraft. Operation of the aircraft at weights outside this recommended loading area should be avoided unless the dictates of the mission require it. The green area is bounded by the 2.5 G wingload factor line and the landing gear limitation.

MAXIMUM SINKING SPEED CHART



X1-30

Figure 5-3

CAUTIONARY LOADING AREA.

The yellow area on the charts represents loadings of progressively increasing risk as the red area is approached. It should also be noted that as progress is made within the yellow area toward the red area that the range between the 1.0 G condition and the maximum safe load factor allowable (margin of safety) is reduced. For example, if the aircraft is carrying a combination of fuel and cargo which would allow it to safely withstand a 2.5 G load factor without structural damage, then the margin of safety for gusts and maneuvers is 1.5 G; on the other hand, if the fuel-cargo combination results in a maximum load factor capability of only 2.0 G, the margin of safety is then only 1.0 G or a reduction of 33⅓ percent from the former condition. Caution must be exercised when operating in the yellow area because one engine-out performance at these gross weights is marginal dependent on configuration, altitude and ambient air temperature.

LOADING NOT RECOMMENDED.

Note

Whenever flights are conducted at weights shown in the red area of the chart, entry of this fact in AFTO Form 781 is required.

The red area represents loadings which are not recommended because of loss of the margin of safety from the standpoint of both performance and structural limitations. Under conditions of extreme emergency when safety of flight is of secondary importance, the commanding officer will determine if the degree of risk warrants operation of the aircraft at gross weights appearing in the red zone.

USE OF WEIGHT LIMITATIONS CHART (D, E, M, AND R5D).

The sample problems shown below may be used to determine the exact position of a loaded aircraft on the Weight Limitations Chart *(figure 5-2)*.

PROBLEM:

Requiring 2000 gallons of fuel to reach a base, what is the maximum cargo that can be carried?

SOLUTION:

Presume that the aircraft weighs 45,000 pounds before the fuel and cargo are added. Enter the chart at a fuel weight of 12,000 pounds (2000 gal × 6 pounds per gal). By moving vertically up the chart to the maximum loading (limit of the yellow area), it is determined that a maximum cargo of 18,000 pounds may be carried. This limitation dictates that the gross weight of the aircraft cannot exceed 73,000 pounds. By adding the operating, fuel, and cargo weights, it is found that the aircraft would weigh 45,000 + 12,000 + 18,000 or 75,000 pounds, which exceeds the permissible limit by 2000 pounds (75,000 — 73,000 = 2000). This weight must be removed, and since the operating and fuel weights are not to be reduced, it becomes necessary to reduce the cargo weight to 18,000 — 2000, or 16,000 pounds. The additional operating weight of 5000 pounds (45,000 — 40,000 = 5000) is simply considered as added alternate cargo, which reduces the maximum cargo first determined. If, for instance, the aircraft weighed 38,000 pounds rather than the 45,000 pounds presumed above, the alternate cargo would be 40,000 — 38,000 or 2000 pounds and would allow a 2000 pound increase in the maximum cargo first determined.

PROBLEM:

Requiring a 17,000 pound cargo load, what is the maximum amount of fuel that can be carried?

SOLUTION:

Presume that the aircraft weighs 40,000 pounds before the fuel and cargo are added. Since the basic operating weight is 40,000 pounds, the chart can be entered at a cargo weight of 17,000 pounds and the maximum amount of fuel can be read directly from the chart. By moving horizontally across the chart to the maximum fuel load (limit of the green area), it is determined that the maximum fuel that can be carried is 16,000 pounds, or, 16,000 ÷ 6 = 2667 gallons.

USE OF WEIGHT LIMITATIONS CHART (G MODEL ONLY).

The sample problems shown below may be used to determine the exact position of a loaded aircraft on the Weight Limitation Chart *(figure 5-2)*.

PROBLEM:

Requiring 1333 gallons of fuel to reach a base, what is the maximum cargo that can be carried?

SOLUTION:

Presume that the aircraft weighs 45,000 pounds before the fuel and cargo are added. Enter the chart at a fuel weight of 8000 pounds (1333 gal × 6 pounds per gal). By moving vertically up the chart to the maximum loading (limit of the green area), it is determined that a maximum cargo of 20,800 pounds may be carried. This limitation dictates that the gross weight of the aircraft cannot exceed 73,000 pounds. By adding the operating, fuel, and cargo weights, it is found that the aircraft would weigh 45,000 + 8000 + 20,800 or 73,800 pounds, which exceeds the permissible limit by 800 pounds (73,800 — 73,000 = 800). This weight must be removed, and since the operating and fuel weights are not to be reduced, it becomes necessary to reduce the cargo weight to 20,800 — 800, or 20,000 pounds. The additional operating weight of 5000 pounds (45,000 — 40,000 = 5000) is simply considered as added alternate cargo, which reduces the maximum cargo first determined. If, for instance, the aircraft weighed 38,000 pounds rather than the 45,000 pounds presumed above, the alternate cargo would be 40,000 — 38,000 or a 2000 pound increase in the maximum cargo first determined.

PROBLEM:

Requiring a 20,000 pound cargo load, what is the maximum amount of fuel that can be carried?

SOLUTION:

Presume that the aircraft weighs 40,000 pounds before the fuel and cargo are added. Since the basic operating weight is 40,000 pounds, the chart can be entered at a cargo weight of 20,000 pounds and the maximum amount of fuel can be read directly from the chart. By moving horizontally across the chart to the maximum fuel load (limit of the green area), it is determined that the maximum fuel that can be carried is 13,000 pounds or 13,000 ÷ 6 = 2166 gallons.

flight characteristics section VI

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GENERAL FLIGHT CHARACTERISTICS.

The flight characteristics of the aircraft are entirely satisfactory. Extensive flight and service testing have proved the aircraft to be stable about all axes. Maneuvering and control of the aircraft does not require undue force by the pilot throughout the entire speed range of the aircraft. Little change in trim is required to maintain the desired aircraft attitude.

STALLS.

The stall warning is definite, appearing as a control buffet and structural shake, well in advance of the stall. Because of the severe amplitude of the buffet during the actual stall, it is recommended that complete stalls be avoided. It is well to remember that the stalling speed increases with the angle of bank *(see figure 6-1)*, and the buffeting speed decreases. Buffeting occurs at approximately 10 to 15 mph above stalling speed with the flaps up. With the flaps full down, buffeting occurs at approximately 5 mph above the speed for a complete stall. The extended landing gear has no appreciable effect on the stalling characteristics. Due to slipstream effect over the wing, power on stalling speeds is lower than zero thrust stalling speeds by approximately 5 to 10 mph at approach power, and 10 to 15 mph at take-off power. This difference is not taken into consideration in calculating performance speeds, so is available as an extra margin of safety.

RECOVERY FROM STALL.

In case the aircraft is inadvertently stalled, recovery should be made by allowing the nose to pitch down gently and applying power. When sufficient airspeed is regained, make a smooth recovery from a slightly nose-down attitude. Avoid abrupt pullout to prevent entering an accelerated stall.

SPINS.

Spins are a prohibited maneuver and must never be done intentionally. However, in case a spin is entered accidentally, use normal recovery procedure to regain level flight.

LEVEL FLIGHT AND DESCENT.

The maximum level flight and descent speed is outlined in Section V. This speed is the maximum speed at which the aircraft can fly continuously without damage to the structure, and should not be exceeded unless the urgency of the situation demands acceleration to maximum dive speed.

DIVING.

The maximum dive speed is outlined in Section V. The airspeed pointer should not be allowed to exceed the limit marking on the rim of the airspeed indicator *(figure 5-1)*, but if this should happen, avoid abrupt pullout during recovery to prevent structural damage.

BUFFETING.

Buffeting may result from various abnormal conditions affecting the wing surfaces (especially the leading edges), nacelle cowling, fuselage, or empennage. Some general conditions that can cause moderate to severe buffeting during normal operation are:

1. Damage to wing leading edge.
2. Loose, damaged, or missing cowling.
3. Excessive cowl flap openings.
4. Windmilling propeller.
5. Fuselage or empennage damage.

In the cruise configuration, buffeting from these causes is not usually confined to the wing alone. The empennage may be affected in proportion to the severity of the turbulence, due to the airflow into the region of the horizontal tail surfaces. Tail buffeting can occur from disturbances as far outboard as the outboard nacelles. Severe tail buffeting is usually accompanied by loss of elevator effectiveness and severe aircraft vibration. However, the vibration is not of a frequency or magnitude that will cause immediate failure of any primary structure essential to continued flight of the aircraft. The following procedures are recommended to improve the flying characteristics sufficiently to allow a safe landing to be made.

1. Try all speeds within the speed range in combination with flaps, as in step 2, until buffeting is sufficiently reduced.

   High power settings may be used to maintain the required airspeed as even emergency power has not been known to increase the severity of tail buffeting. Furthermore, any yawing tendency of the aircraft should be held to a minimum by utilization of evenly applied full rudder.

2. Lowering the wing flaps increases the downwash and raises the tail. In many cases this will result in a very effective reduction in buffeting. Usually 5 to 10 degrees or 10 to 20 percent of wing flaps is sufficient to eliminate all except extremely severe buffeting but more flap extension may be required. In some cases, this may even reduce the turbulent drag and improve

STALLING SPEEDS—POWER OFF

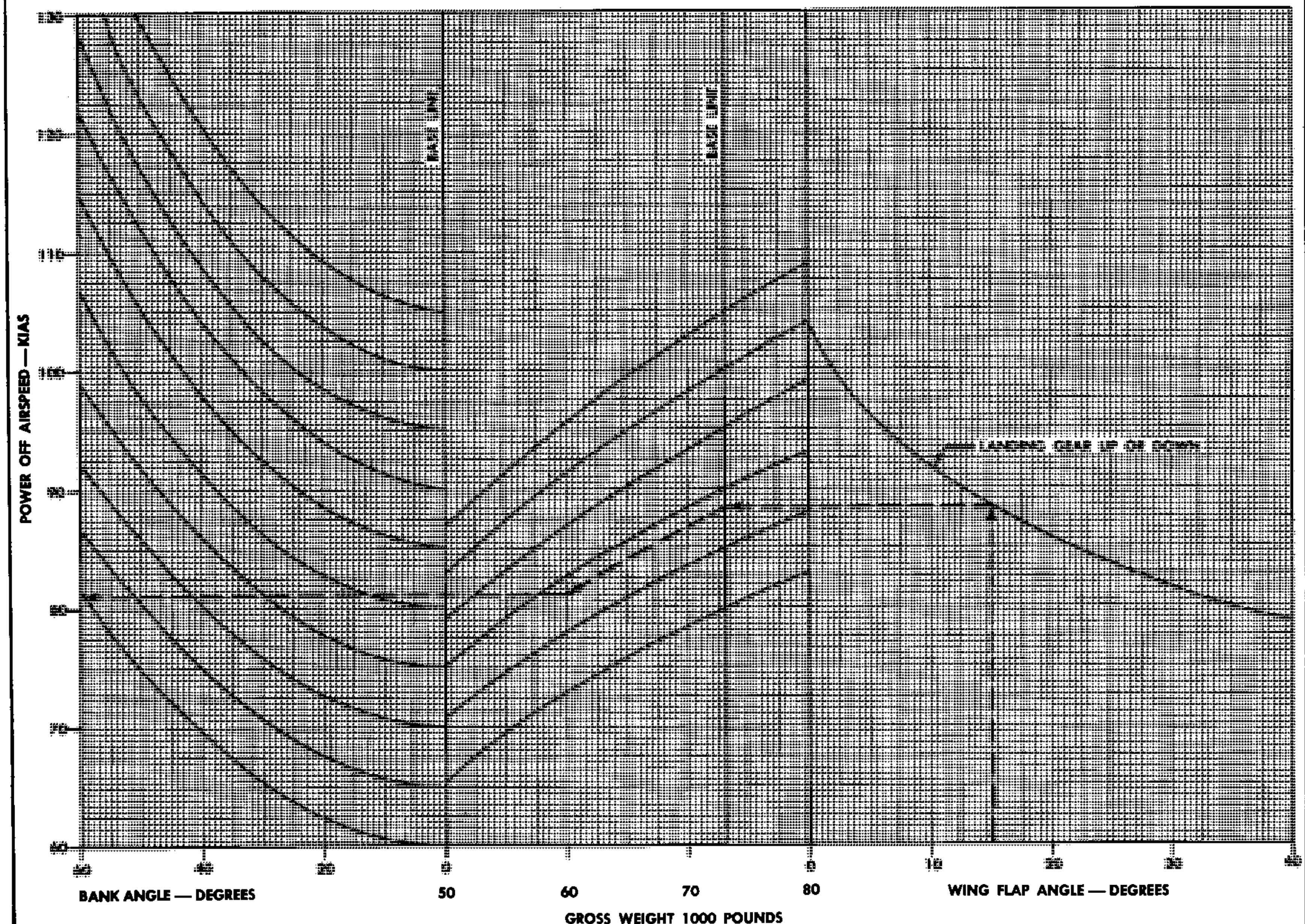

Figure 6-1

performance. With sufficient flap extension to eliminate buffeting, elevator control effectiveness will usually return to normal. If buffeting is not reduced with flap extension, the flaps should be retracted to minimize performance losses. In very severe cases where the extent of damage is not known, it is advisable before landing is attempted to check the controls in landing configuration to be sure that both elevator and aileron controls are adequate.

WARNING

If buffeting continues to increase and control of the aircraft becomes more difficult, an immediate decision should be made regarding the advisability of abandoning the aircraft.

system operation

section VII

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LIST OF ILLUSTRATIONS

ENGINE RATINGS.

Engine ratings are limits of operation within which the accepted degree of reliability and efficiency can be obtained. Outside of these limits, the pilot is relying on safety margins that have not been proven. The maximum power for takeoff for the R-2000-4 and -9M2 engines is 1450 bhp under standard day, sea level conditions. The METO (normal rated) power of 1200 bhp is the maximum power permissible for continuous operations under any normal flight condition. METO rpm (2550) is the maximum engine speed that may be used for continuous operation. Ratings for alternate climb and maximum cruise powers are established in percentages of METO power.

CAUTION

When maneuvering with low power or during descents with low power, it is important to cushion the high inertia loads on the master bearings which occur with high rpm and low manifold pressure. As a rule of thumb, each 100 rpm requires at least 1 inch Hg manifold pressure. Operation at high rpm and low manifold pressure should be kept to a minimum.

ENGINE SUPERCHARGER.

The rear crankcase section of the engine accommodates drive gears and clutches for the single-stage, two-speed, integral, engine-driven supercharger. The blower ratio clutch incorporates creeper gears that aid in preventing sludge accumulation. The creeper gears cause intermittent bleeding of pressure oil from the clutches to dissipate sludge formations which tend to cause clutches to stick. The formation and accumulation of sludge will vary with the operating conditions and the types of oil. Consequently it is advisable to shift the clutches prior to each takeoff and at periodic intervals during flight (approximately every 2 hours) to insure proper clutch operation. All engine ground operation, except during blower clutch check, should be made with the supercharger in the low position. All takeoffs should be made in low blower except under high altitude takeoff conditions when the power output is insufficient in low blower. The decision to use high blower for takeoff must be made as a result of a study of the engine power calibrations, not on the basis of the availability of manifold pressure. Approximately 6 inches Hg additional manifold pressure is needed in high blower at sea level to develop the same takeoff power obtained in normal low blower takeoffs, and the increase of brake horsepower required to drive the high blower creates an increased fuel consumption of about 10 gallons per hour per engine. The manifold pressure differential and fuel consumption decrease with altitude until critical blower altitude is reached.

SUPERCHARGER SHIFTING.

During climb, use of the low blower ratio should be maintained as long as possible. Shift to the high blower ratio when the critical blower altitude is reached. The critical altitude at METO power will occur at approximately 5300 feet and at alternate climb power at approximately 9100 feet. The shock which usually accompanies the blower shift is not harmful to the engines, but may be objectionable to the passengers. It may be minimized by reducing the pumping load on the superchargers through a momentary manifold pressure reduction to approximately 25 inches Hg while effecting the shift. No change in rpm is necessary.

Note

During cruising flight, blowers should be desludged every 2 hours. If operating in low blower, place mixture in AUTO-RICH, reduce the manifold pressure approximately 3 inches Hg, and shift to HIGH blower. If operating in high blower, it is not necessary to reduce manifold pressure before shifting to LOW blower. Adjust the manifold pressure to the required setting after supercharger shift. Prolonged operation in opposite blower is unnecessary. Desludging action occurs during shift. Remain in opposite blower only until instruments stabilize.

CARBURETOR ICING.

The carburetor air control must be maintained in COLD position at all times except when weather conditions are conducive to carburetor icing, and when CAT is below −10°C and poor fuel vaporization and distribution are indicated by engine roughness or loss of power (see operating limitations, Section V). Carburetor heat reduces the ram pressure of the inlet air, reducing engine critical altitude and requiring premature shift to high blower operation.

If manifold pressure and fuel flow drop unaccountably, carburetor icing may be the cause. Apply preheat to the carburetor for a short period. This will result in a further manifold pressure reduction, but if a subsequent slow rise is noted in manifold pressure, ice is present and is melting. In this event, continue applying carburetor heat until icing conditions no longer prevail. Manifold pressure and cylinder head temperatures should be watched closely during this period. When the ice has been cleared, return the carburetor temperature to the desired limits.

Use carburetor air preheat before carburetor icing becomes critical because, if the ice accretion is allowed to progress, the loss of engine power may make it impossible to generate sufficient heat to clear the engine. If the preheat capacity is sufficient and if remedial action is not delayed, screen or impact tube icing can be controlled.

If carburetor heat fails to remove the ice formation, use the carburetor alcohol anti-icing system until the malfunctioning engine is operating properly.

CARBURETOR SETTINGS.

Automatic-type carburetor settings are incorporated which provide an acceptable degree of metering with a minimum of crew attention. These settings will insure satisfactory acceleration, provide detonation protection and adequate cooling in climb and at METO power and takeoff power, and satisfactory fuel economy in cruise. Necessary manufacturing and maintenance tolerances prevent attaining the optimum adjustments. Metering variations from plus 6 to minus 9 percent in fuel air ratio from the mean of any carburetor setting may result from an adverse accumulation of known tolerances within the carburetor. Fuel flow values should be carefully monitored at all stages of flight and irregular indications reported immediately.

CARBURETOR AIR TEMPERATURE.

Because of the higher temperature rise through the supercharger when operating in high blower ratio, the temperature of the air entering the carburetor must be held to a lower limit than when operating in lower ratio in order to keep the supercharged temperatures below the detonation range. Temperature corrections for manifold pressure should be made on the basis of the deviation of the carburetor air temperature rather than the deviation of the outside air temperature from standard, because the density of the air charge is determined by the temperature in the induction system rather than that of the ambient air.

SPARK PLUG FOULING.

Spark plug fouling is a major cause of ignition trouble, which in turn is one of the most common engine maintenance and operating problems with military aircraft using 100/130 grade fuel having a relatively high lead content of up to 4.6 cc. Fouling is the result of an accumulation of deposits which cause misfiring or prevent firing across the spark plug electrodes. The most common types of fouling are lead fouling and carbon fouling, with lead fouling causing the majority of trouble. Cause, prevention, and elimination of spark plug fouling are all related to the chemistry and physics of the combustion cycle, which alternately is subject to wide variation under different ground and flight operating conditions. Prevention would seem to be the most economical method of solution.

LEAD FOULING AND CONTRIBUTING FACTORS.

Tetraethyl lead is the basic cause of lead fouling. Scavenger agents are provided to combine with the lead during combustion and remove it with the exhaust gases. However, under certain conditions of temperature and pressure, lead oxide or lead bromide compounds will condense on the spark plug insulator. In the presence of excess carbon as a reducing agent, these compounds may form metallic lead particles which can prevent ignition or firing. Additional factors which influence spark plug misfiring include the type of ignition system, spark plug characteristics and time element, general engine condition, operating requirements, and specific engine operating conditions. Spark plug fouling involves an accumulation of deposits through prolonged operation under a fixed set of conditions. Prevention and elimination of fouling depend upon taking action to vary these conditions, upset the chemistry of the fouling cycle, and restore normal ignition.

FOULING DURING GROUND OPERATION.

During ground operation, spark plug fouling may be caused by either carbon or lead. Lead fouling may be residual from a previous flight. Prolonged engine operation at idle speed will result in carbon fouling, particularly when the idle mixture is richer than best power; excess carbon from the rich mixture and burned engine oil form fouling deposits on the spark plugs. Such fouling will usually be indicated by excessive magneto drop during the power check at field barometric manifold pressure; however, engine malfunction during takeoff may be experienced in frequent cases where plug fouling has occurred but has not been apparent during engine checkout procedure.

Prevention of Fouling.

If possible, avoid prolonged or unnecessary ground operation. If engine shutdown is impractical, the engines should be run up to field barometric manifold pressure in AUTO-LEAN for 1 minute after each 10 minutes of ground running. The idle mixture should be adjusted to best power mixture at the idle speed commonly used for ground running, rather than at the minimum idle speed, since there is a tendency for the mixture to enrich with any increase in rpm, and excessively rich idling mixtures are the most common cause of carbon fouling. Frequent checks and proper adjustments of the idle mixture should be made to insure the setting is correct.

Cure of Fouling.

Preventive action is the best cure. The only practical cure of fouling may be spark plug change. The 1-minute runup to field barometric pressure in AUTO-LEAN may have a curative effect. Additional running for short periods of time with manifold pressure changes of 2 inches Hg is occasionally effective. Prolonged operation at or above field barometric manifold pressure must be avoided because of insufficient engine cooling.

TAKEOFF.

The rapid change in combustion temperatures and pressures and the high levels achieved under takeoff conditions are favorable to spark plug misfiring if there is any fouling from previous flight or ground running. The electrical resistance of residual deposits decreases rapidly as limiting temperatures are approached, so that the spark may short circuit along the insulator rather than firing the gap. If excess carbon is present, metallic lead may be formed by the reducing action of free carbon on lead oxides and lead bromides. The most common symptoms are backfiring and rough running.

Prevention of Fouling.

The best prevention of fouling during takeoff is proper ground running procedures. In addition, it is important to reduce cylinder head temperature to the recommended pre-takeoff cylinder head temperature level to take advantage of the increased brake horsepower, and decreased tendency for misfiring with relatively cool cylinder head temperature during takeoff. Smooth and steady application of power is preferable to rapid or jam acceleration. If backfiring or rough running occurs, reduce manifold pressure 2 to 5 inches or as required to restore smooth operation.

FOULING DURING CRUISE.

During cruise, lead fouling is usually generated rather than carbon fouling. Long-continued application of a given set of engine conditions typical of cruise flight contribute to lead fouling. An additional factor is operation with abnormally low CHT. Common symptoms are backfiring or afterfiring.

Prevention of Fouling.

Prevention of fouling is preferable to cure, and results may be accomplished by use of AUTO-RICH for 5 minutes at hourly intervals; a change of from 3 to 5 inches Hg, with a simultaneous increase on the inboard engines and decrease on the outboard engines to maintain airspeed; or a change of 100 to 300 rpm.

Cure of Fouling.

Cure of fouling may be effected by a complete change of power settings, including use of AUTO-RICH, a reduction of from 8 to 10 inches manifold pressure with a period of engine cooling, followed by gradual increase to cruise power settings in increments of 2 to 3 inches manifold pressure with several minutes of operation at each power level. Another method is to gradually increase power to METO power for several minutes. Spark plugs which are misfiring or completely fouled, may resume firing at lower power settings, so it is advisable to reduce power and then restore it, rather than attempt to attain METO power and thereby introduce the possibility of destructive backfiring during application of increased power.

IGNITION ANALYZER OPERATION (C-54 AIRCRAFT).

IGNITION ANALYSIS.

1. System power switch on the analyzer switch panel – ON.
2. Analyzer power switch on the engine analyzer – ON. The system power indicator light on the switch panel should illuminate.
3. Allow approximately 1 minute for the analyzer tubes to warm up. A bright dot should appear on the analyzer screen. Allow this dot to stabilize at one position on the screen, then adjust the position switches until the dot is in the center of the screen.
4. If the dot does not appear, adjust the horizontal and vertical position switches on the analyzer until the dot appears.

Note

To avoid burning a spot on the analyzer screen, the bright dot should not be held in one position on the screen for more than 2 minutes. When power is to be left on the analyzer for a longer period, select a pattern or shift the dot to the extreme side of the screen.

5. Analyzer magneto selector knob – Turn to LEFT 1 position.

Note

The analyzer magneto selector knob remains in the LEFT 1 position throughout the operating procedure; this is the only position of the selector knob used in the circuit.

6. Engine and magneto selector knob on switch panel — Rotate to the engine and magneto position desired.
7. Check for abnormalities in the patterns with the knob in the R and L positions. Cylinders which show abnormal patterns are determined by counting off from the first pattern and referring to the placard on the front of the analyzer switch panel. (See figure 7-1 for representative patterns.)
8. Use the horizontal position, vertical position, and horizontal gain control knobs to isolate and enlarge any abnormal pattern for more detailed study. Try to keep at least three patterns on the screen for comparison.
9. To check magneto synchronization of both sides of cylinder ignition, place the magneto selector knob at each of the R and L positions. The patterns for any one cylinder viewed on the screen should be superimposed.

VOLTAGE CONTROL OPERATION.

Use the voltage control knob on a ground check to determine the condition of spark plugs before noticeable failure occurs.

Operation of the voltage control switch is as follows:

1. Relay-resistor switch on the switch panel — ON for engine to be tested.

CAUTION

Guards for these switches should be down during flight to prevent inadvertent use of the voltage control, which could result in misfiring of cylinders, backfiring within the manifold section, or damage to the engine by fire.

2. Voltage control knob — Pull out and rotate from OFF in the increase direction, while viewing the pattern on the analyzer screen. Misfiring, and finally complete stoppage of the plug firing, should occur. (See figure 7-1 for representative patterns.)

Note

The voltage control knob will return to the inoperative position when released.

3. Note the value of the dial readings when misfiring and complete stoppage of firing occur. A low dial reading indicates that the ignition system is in good condition.

IGNITION ANALYZER OPERATION (R5D AIRCRAFT).

IGNITION ANALYSIS.

For ignition analysis, the ignition analyzer is operated as follows:

1. Intensity control knob — Rotate one-quarter turn in a clockwise direction.

Note

Allow at least 1 minute for the equipment to warm up and a pattern to appear on the face of the cathode ray tube. For protection of the tube face, the circuits are arranged so that no portion of the trace can appear unless the engines are in operation.

2. Rotate the intensity control knob until the pattern appears at a comfortable level of brightness (the arrow points in the direction of greater intensity). (See figure 7-1 for representative patterns.)

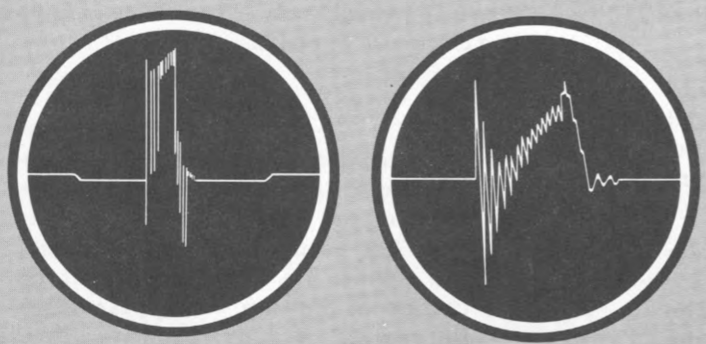
Note

If the intensity control knob is rotated too far in a clockwise direction, the pattern may bloom, that is, the pattern may become very large and then disappear. Rotating the knob in a counterclockwise direction will restore the pattern. This feature protects the tube from excessive intensity which might otherwise burn the phosphor.

3. Spread control knob — Adjust to display three ignition patterns on the tube face.
4. Engine selector switch — Rotate to the desired position.
5. Magneto selector switch — Rotate to the desired magneto primary. This selects left and right primaries in pairs and connects them to the display switch.
6. Display switch — Rotate to the desired magneto primary lead.
7. Parade dial — Turn until a pattern appears on the face of the screen. The dial is calibrated to the index line on the tube face
8. Analyze each cylinder pulse now being displayed, rotating the parade dial to observe individual pulses.
9. Repeat the above procedure until all cylinders on all engines are checked.

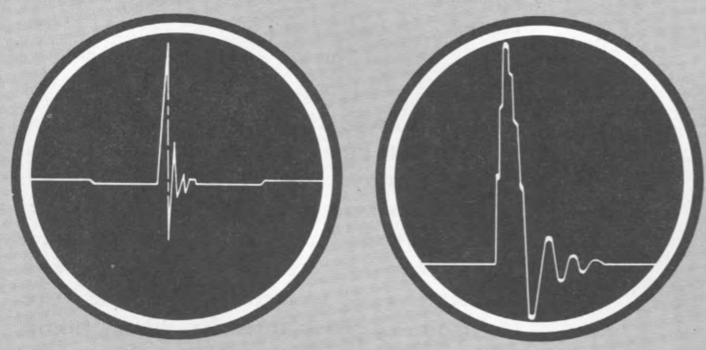
IGNITION ANALYZER

NORMAL	POSSIBLE SOURCES OF MALFUNCTION



C-54 R5D

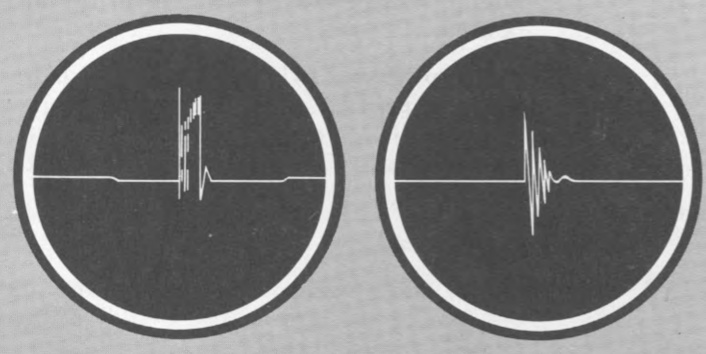
OPEN SECONDARY	POSSIBLE SOURCES OF MALFUNCTION



1. **Spark plug lead missing or not connected; extremely wide spark plug gap.**
2. **Open coil secondary or open high tension lead.**
3. **Damaged cigarette or missing cigarette spring.**

C-54 R5D

SHORTED SECONDARY	POSSIBLE SOURCES OF MALFUNCTION



1. **Badly fouled spark plug.**
2. **Short in high tension lead or coil secondary.**

C-54 R5D

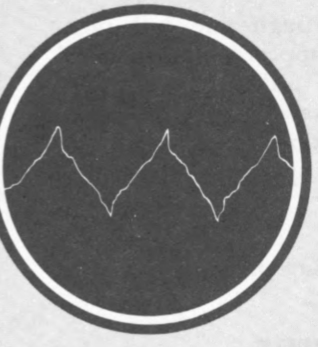
X1-31

Figure 7-1 (Sheet 1 of 2)

PATTERNS

POSSIBLE SOURCES OF MALFUNCTION	OPEN PRIMARY

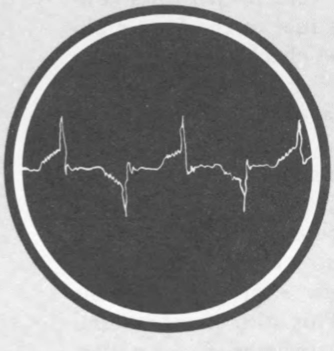
1. **Open lead from magneto winding to breaker points.**
2. **Breaker points not closing.**


C-54


R5D

POSSIBLE SOURCES OF MALFUNCTION	ARCING BREAKER POINTS

1. **Defective primary condenser.**
2. **Lead from breaker point to condenser disconnected.**
3. **Severely burned or oily breaker points.**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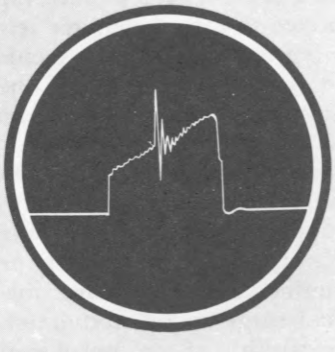
R5D

POSSIBLE SOURCES OF MALFUNCTION	HIGH VOLTAGE FIRING

1. **Wide spark plug gap.**
2. **Cigarette spring missing or not making contact.**
3. **Poor contact at distributor finger.**
4. **Contact spring in coil missing or not making contact.**


C-54

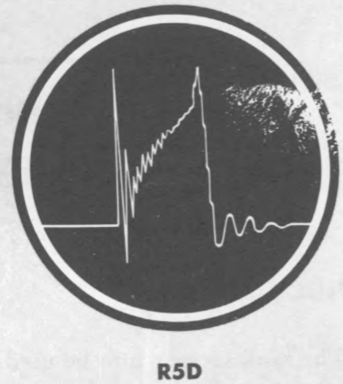
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Figure 7-1 (Sheet 2 of 2)

VIBRATION ANALYSIS.

1. Engine selector switch – Rotate to the desired position.
2. Magneto selector switch – Rotate to the VIB position.
3. Parade dial – Rotate through one full turn. Vibration patterns will appear on the face of the cathode ray tube in order of pattern sequence: (a) exhaust valve closing; (b) intake valve closing; (c) combustion; (d) exhaust valve opening; (e) intake valve opening; (f) scavenge or exhaust stroke.
4. Repeat the above procedure until all cylinders on all engines are checked.

FUEL SYSTEM MANAGEMENT (SIX-TANK SYSTEM).

Fuel flow is governed by the positioning of the fuel tank selector levers. Since vapor vent return lines connected to each carburetor return fuel to the four main wing tanks, fuel levels should be checked periodically to avoid overfilling when operating all engines on the auxiliary wing tanks or the fuselage tanks (if installed). When selecting a new fuel supply, the new supply should be selected before the old supply is depleted, in order to prevent fuel surge to the carburetor. If a fuel supply is completely depleted before selecting a new supply, retard the throttle or throttles of the affected engines before selecting the new supply to prevent fuel surge to the carburetor. This also prevents the possibility of an uncontrolled overspeed propeller, which can result from the sudden resumption of power following a momentary power loss. Figure 7-2 shows the fuel flow and the selector valve settings for various combinations of fuel system management.

WARNING

Fuel transfer in flight is prohibited.

FUEL LOADING.

The tank sequence to be used will be governed by the amount of fuel carried in the aircraft; therefore it will be necessary to fuel the aircraft in the following sequence:

1. 1980 gallons or less: the fuel will be equally distributed in main tanks No. 1, No. 2, No. 3, and No. 4.
2. All fuel in excess of 1980 gallons: Fill auxiliary tanks 1 and 4 equally; fill auxiliary tanks 2 and 3 equally (if installed).
3. If fuselage fuel tanks are installed, any additional fuel will be equally distributed between the LH and RH tanks.

FUEL USAGE.

The sequence for using the fuel supply during engine starts, takeoffs, and landing operations will be a straight line system of each main tank to its respective engine, i.e., MAIN TANK No. 1 to engine No. 1, MAIN TANK No. 2 to engine No. 2, MAIN TANK No. 3 to engine No. 3, and MAIN TANK No. 4 to engine No. 4. After takeoff and climb, the following fuel sequence will be used in accordance with the amount of fuel in the aircraft:

1. If fuselage fuel tanks are installed for long-range operation, follow steps a through c.
   a. LH fuselage tank through crossfeed to ALL ENGINES until 50 gallons remain. Make a final runout of the LH fuselage tank through one engine only, operating the other engines on their respective wing tanks.
   b. When only 10 gallons remain in LH fuselage tank, select the RH fuselage tank through crossfeed to ALL ENGINES until 50 gallons remain. Make a final runout on the RH fuselage tank through one engine only, operating the other engines on their respective wing tanks.
   c. When only 10 gallons remain in the RH fuselage tank, return the engine operating from the fuselage tank to its respective wing tank.

   Note

   If operating below 1000 feet altitude, do not operate more than two engines from any one fuselage fuel tank unless absolutely necessary.
2. LH AUX TANK to engines No. 1 and 2 or through crossfeed to ALL ENGINES until depleted. RH AUX TANK to engines No. 3 and 4, or through crossfeed to ALL ENGINES until depleted.

CAUTION

Never use both auxiliary tanks to supply fuel to all engines at the same time. This condition will result in fuel draining to the tank lowest in position or quantity.

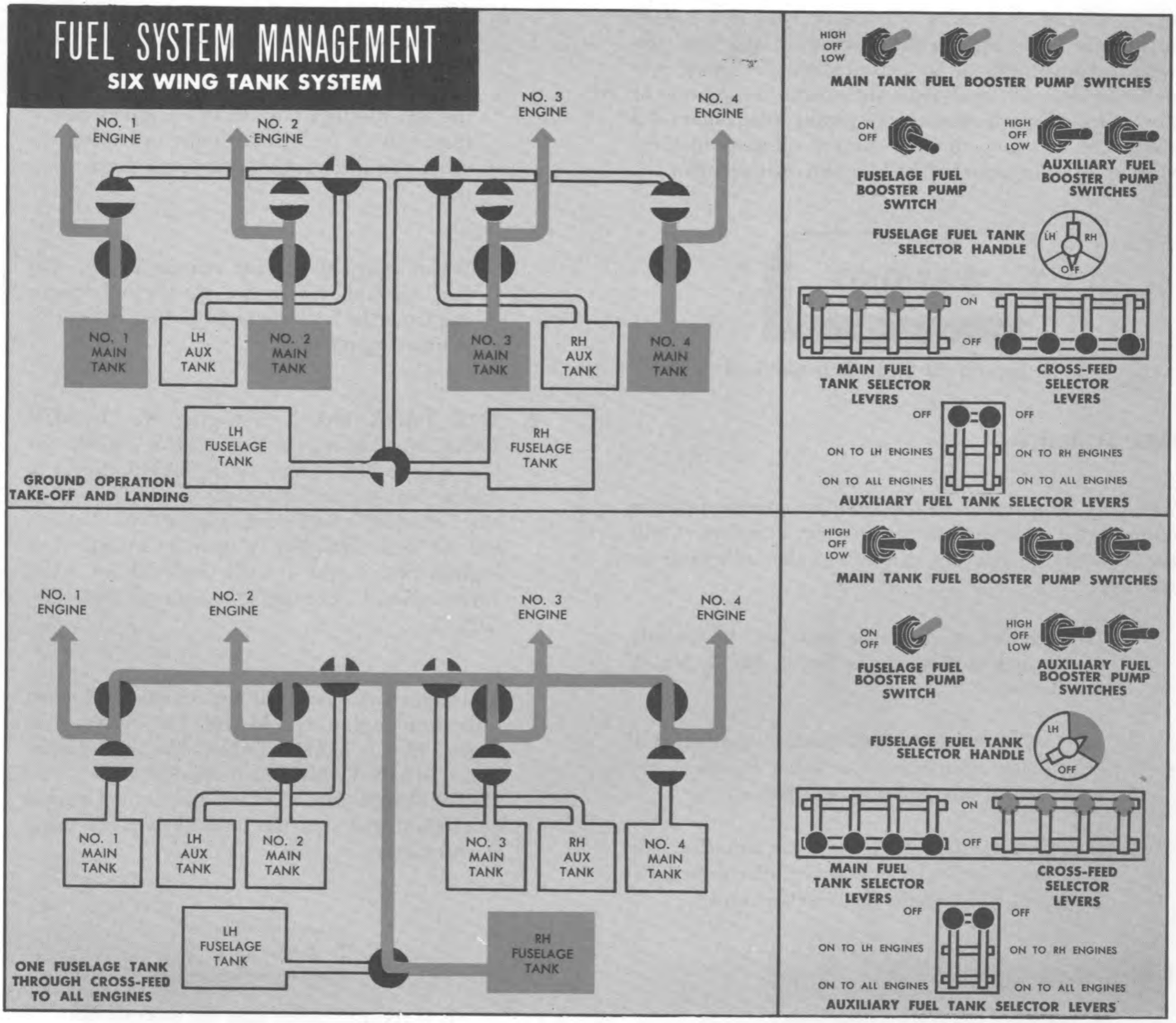

Figure 7-2

3. A straight line system of each main tank to its respective engine, i.e., MAIN TANK No. 1 to engine No. 1, MAIN TANK No. 2 to engine No. 2, MAIN TANK No. 3 to engine No. 3, MAIN TANK No. 4 to engine No. 4 (it must be remembered that the landing is made using these tanks).

CAUTION

It is recommended that the aircraft not be landed with total integral wing tank fuel of more than 9500 pounds and not more than 395 gallons in each outer wing or outer wing and outboard auxiliary tanks combined. This limitation is necessary in order that the wing may safely withstand the basic normal landing design requirements.

FUEL SYSTEM MANAGEMENT (EIGHT-TANK SYSTEM).

Fuel flow is governed by the positioning of the fuel tank selector levers. Since vapor vent return lines connected to each carburetor return fuel to the four main wing tanks, the fuel levels should be checked periodically to avoid overfilling while operating all engines on the auxiliary tanks or the fuselage tanks (if installed). When selecting a new fuel supply, the new supply should be selected before the old supply is depleted, in order to prevent fuel surge to the carburetor. If a fuel supply is completely depleted before selecting a new supply, retard the throttle or throttles of the affected engines before selecting the new supply to prevent fuel surge to the carburetor, and also prevent the possibility of an uncontrolled overspeed propeller, which can result from the sudden resumption of power following a momentary power loss. Figure 7-3 shows the fuel flow and the selector valve settings for various combinations of fuel system management.

WARNING

Fuel transfer in flight is prohibited.

FUEL LOADING.

The tank sequence to be used will be governed by the amount of fuel carried in the aircraft; therefore it will be necessary to fuel the aircraft in the following sequence:

1. 1980 gallons or less: the fuel will be equally distributed in main tanks No. 1, No. 2, No. 3, and No. 4.
2. All fuel in excess of 1980 gallons: the fuel will be equally distributed between the auxiliary tanks No. 1, No. 2, No. 3, and No. 4.
3. If special fuselage fuel tanks are installed, any additional fuel will be equally distributed between the LH and the RH fuselage tanks.

FUEL USAGE.

The sequence for using the fuel supply during engine starts, takeoffs, and landing operations will be a straight line system of each main tank to its respective engine, i.e., MAIN TANK No. 1 to engine No. 1, MAIN TANK No. 2 to engine No. 2, MAIN TANK No. 3 to engine No. 3, MAIN TANK No. 4 to engine No. 4. After takeoff and climb, the following sequence will be used in accordance with the amount of fuel in the aircraft:

1. If fuselage fuel tanks are installed for long-range operation, follow steps a through c.
   a. LH fuselage tank through crossfeed to ALL ENGINES until 50 gallons remain. Make a final runout of the LH fuselage tank to two engines on the same side of the aircraft only, operating other engines on their respective main wing tanks.
   b. When only 10 gallons remain in the LH fuselage tank, select the RH fuselage tank through crossfeed to ALL ENGINES until 50 gallons remain. Make a final runout on the RH fuselage tank to two engines on the same side of the aircraft only, operating the other engines on their respective main wing tanks.
   c. When only 10 gallons remain in the RH fuselage tank, return the two engines operating from the fuselage tank to their respective main wing tanks.
2. AUX TANK No. 1 to engine No. 1, AUX TANK No. 2 to engine No. 2, AUX TANK No. 3 to engine No. 3, and AUX TANK No. 4 to engine No. 4 until depleted; or AUX TANK No. 1 through crossfeed to engines No. 1 and 2, and AUX TANK No. 4 through crossfeed to engines No. 3 and 4 until depleted; or AUX TANK No. 1 through crossfeed to ALL ENGINES.
3. A straight line system of each main tank to its respective engine, i.e., MAIN TANK No. 1 to engine No. 1, MAIN TANK No. 2 to engine No. 2, MAIN TANK No. 3 to engine No. 3 and MAIN TANK No. 4 to engine No. 4 (it must be remembered that the landing is made using these tanks).

CAUTION

It is recommended that the aircraft not be landed with integral wing tank fuel of more than 9500 pounds and not more than 395 gallons in each outer wing or outer wing and outboard auxiliary tanks combined. This limitation is necessary in order that the wing may safely withstand the basic normal landing design requirements.

RECOMMENDED USE OF FUEL BOOSTER PUMPS.

It is recommended that the fuel booster pumps be operated in high boost under the following conditions:

1. For takeoffs and landings.
2. In case of engine-driven pump failure.

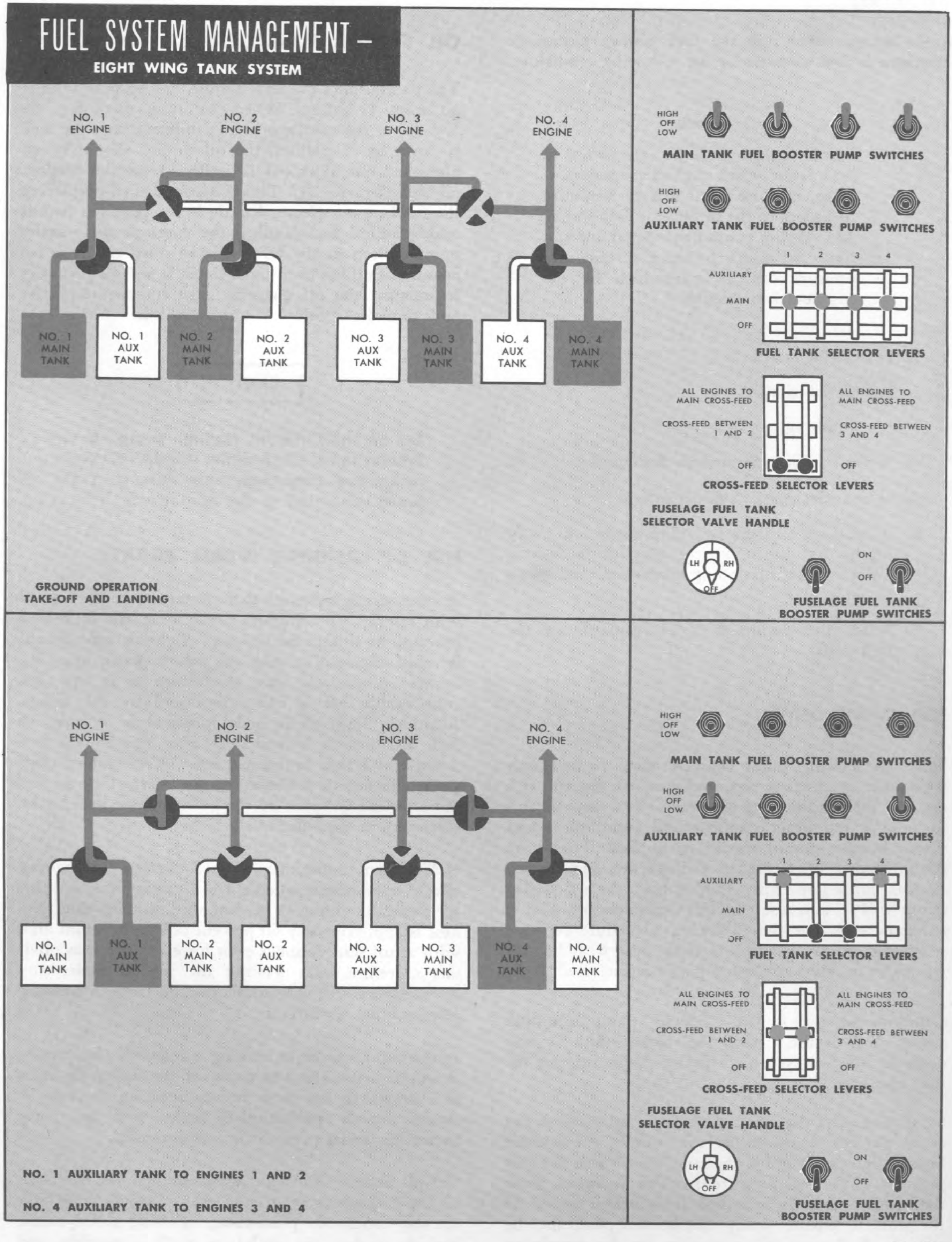
FUEL SYSTEM MANAGEMENT –
EIGHT WING TANK SYSTEM
NO. 1 ENGINE
NO. 2 ENGINE
NO. 3 ENGINE
NO. 4 ENGINE
NO. 1 MAIN TANK
NO. 1 AUX TANK
NO. 2 MAIN TANK
NO. 2 AUX TANK
NO. 3 AUX TANK
NO. 3 MAIN TANK
NO. 4 AUX TANK
NO. 4 MAIN TANK
GROUND OPERATION
TAKE-OFF AND LANDING
HIGH
OFF
LOW
MAIN TANK FUEL BOOSTER PUMP SWITCHES
HIGH
OFF
LOW
AUXILIARY TANK FUEL BOOSTER PUMP SWITCHES
1 2 3 4
AUXILIARY
MAIN
OFF
FUEL TANK SELECTOR LEVERS
ALL ENGINES TO MAIN CROSS-FEED
CROSS-FEED BETWEEN 1 AND 2
OFF
ALL ENGINES TO MAIN CROSS-FEED
CROSS-FEED BETWEEN 3 AND 4
OFF
CROSS-FEED SELECTOR LEVERS
FUSELAGE FUEL TANK SELECTOR VALVE HANDLE
LH
RH
OFF
ON
OFF
FUSELAGE FUEL TANK BOOSTER PUMP SWITCHES
NO. 1 ENGINE
NO. 2 ENGINE
NO. 3 ENGINE
NO. 4 ENGINE
NO. 1 MAIN TANK
NO. 1 AUX TANK
NO. 2 MAIN TANK
NO. 2 AUX TANK
NO. 3 AUX TANK
NO. 3 MAIN TANK
NO. 4 AUX TANK
NO. 4 MAIN TANK
NO. 1 AUXILIARY TANK TO ENGINES 1 AND 2
NO. 4 AUXILIARY TANK TO ENGINES 3 AND 4
HIGH
OFF
LOW
MAIN TANK FUEL BOOSTER PUMP SWITCHES
HIGH
OFF
LOW
AUXILIARY TANK FUEL BOOSTER PUMP SWITCHES
1 2 3 4
AUXILIARY
MAIN
OFF
FUEL TANK SELECTOR LEVERS
ALL ENGINES TO MAIN CROSS-FEED
CROSS-FEED BETWEEN 1 AND 2
OFF
ALL ENGINES TO MAIN CROSS-FEED
CROSS-FEED BETWEEN 3 AND 4
OFF
CROSS-FEED SELECTOR LEVERS
FUSELAGE FUEL TANK SELECTOR VALVE HANDLE
LH
RH
OFF
ON
OFF
FUSELAGE FUEL TANK BOOSTER PUMP SWITCHES
21,055

Figure 7-3

It is recommended that the fuel booster pumps be operated in low boost under the following conditions:

Note

Before operating the booster pumps in high boost, when engines are not operating, use low boost first to minimize fuel surge to the carburetor diaphragm. Always shut booster pumps off one at a time and watch to make certain that pressure can be maintained by the engine-driven pumps.

1. For engine starts.
2. For oil dilution.
3. For climbing.
4. When fuel flow or pressure fluctuates.
5. When selecting a new fuel supply.
6. If necessary to prime the cabin heater fuel pump supply line when heater operation is desired. (When heater fuel pump takes over, turn booster pump OFF.)
7. When fuel conditioning is required, see the following:

FUEL CONDITIONING.

Since the boiling point characteristics of fuel vary with each production run, and each run varies with age and the conditioning it receives, it is very difficult to predict the exact moment and condition under which booster pumps should be applied. The above recommended operating procedures are based upon critical conditions with 43.3°C fuel. As day-to-day flying will seldom result in 43.3° fuel conditions, it is recommended that the following procedure be used whenever the cruise altitude is reached with booster pumps on or when new tanks have been selected.

Conditioning the fuel by booster pump agitation covers most of the critical fuel conditions that may occur in the fuel system. Make the following test for fuel stability:

Some time after the aircraft has been stabilized at the cruise altitude, momentarily turn one of the selected booster pumps off and at the same time watch the fuel pressure. If the fuel pressure drops or fluctuates, leave the booster pump in operation for a longer period. If the pressure remains steady, that booster pump may be turned off. Repeat this procedure on the remaining booster pumps.

OIL SYSTEM MANAGEMENT.

The nacelle tank oil level should not be permitted to go below 11 gallons. When the oil quantity gage for any one of the nacelle oil tanks indicates that the tank is down to 11 gallons, the oil supply should be replenished not to exceed 17 gallons from the fuselage oil tank *(figure 1-21)*. This is accomplished by placing the fuselage oil selector handle in the required nacelle tank position and holding the fuselage oil transfer pump switch in the ON position until the required amount of oil has been transferred. It will be necessary to monitor the oil quantity gage for the respective tank to make certain it is not overfilled.

CAUTION

Do not hold the oil transfer pump circuit breaker in the ON position if it opens, except in extreme emergency, since this may cause pump motor failure due to overload.

USE OF LANDING WHEEL BRAKES.

It is absolutely necessary that aircraft brakes be treated with respect. To minimize brake wear, the following precautions should be observed. Extreme care should be used to avoid locking the wheels when applying brakes immediately after touchdown or at any time considerable lift is being produced by the wings. Relatively light brake pedal pressure is required to lock the wheels immediately after touchdown and when once locked in this manner will not unlock until pedal pressure is released. As the aircraft slows and more weight is borne by the gear, heavier pedal pressures may be used effectively.

It has been found that a rapid decrease in braking effectiveness occurs when a wheel commences to skid; for example with a 75 percent skid, braking effectiveness is approximately 60 percent of the optimum and, with a full skid becomes even lower. It becomes obvious therefore, that locking the wheels under any circumstance will only result in a decrease in braking efficiency for any aircraft.

In the event maximum braking is required after touchdown, lift should first be decreased by raising the flaps and dropping the nose before applying brakes. A single, smooth application of brakes with constantly increasing pedal pressure is recommended.

For all normal landings, advantage should be taken of the full available ground roll distance, wind and runway conditions permitting, utilizing aerodynamic braking to slow the aircraft as much as possible, and applying brakes only as necessary.

It is recommended that a minimum of 15 minutes elapse between landings when the landing gear remains extended in the slipstream, and a minimum of 30 minutes when the landing gear has been retracted, to allow for cooling if brakes have been used. After the brakes have been used excessively for an emergency stop and are in an overheated condition, the aircraft should not be taxied into a crowded parking area or the parking brakes set. To prevent brake fire and possible wheel assembly explosion, specified procedures for cooling brakes should be carried out, bearing in mind that peak brake and wheel temperatures usually occur 5 to 15 minutes after a maximum braking operation.