SECTION VII—SYSTEMS OPERATION

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ENGINE OPERATION.

CARBURETOR ICING.

Whenever there is visible moisture in the air, such as rain, snow, sleet, clouds, supercooled precipitation, etc., the flight crew should be alert for indications of carburetor icing which can be detected by close attention to fuel flow and BMEP. With the fuel-injection engine, the occurrence of throat ice or refrigeration ice is very rare. Furthermore, precipitation particles of large density are removed by inertia separation at the induction scoop entrance. Icing in this installation, therefore, is the result of very fine particles of ice in the impact tube system of the carburetor, and is most likely to occur when visible moisture is present and the free air temperature is below 10°C. The most likely causes of engine instability during precipitation conditions are the following:

1. Ice crystals or water droplets entering the impact tube system and physically restricting the passages. This results in excessive leanness and usually causes a sudden and radical power loss.

2. Ice crystals or fine snow becoming lodged in the automatic mixture control unit needle aperture. This also results in excessive leanness and usually causes a sudden and radical power loss. This particular condition is most critical at higher altitudes and at very low free-air temperatures when carburetor heat is being used.

3. Accumulation of moisture in passage or bleeds (with heat on) and subsequent freezing and blocking of bleeds after removal of heat.

4. Accumulation of ice on various parts of the master control.

Power losses can also occur because of the following:

a. Richness due to mixture control bleed restriction (the occurrence of this is relatively rare). This condition usually results in a more gradual loss of power than occurs with the above conditions.

b. Leanness or richness due to water in the air passages.

A power loss due to a manifold pressure loss, which is usually gradual, is probably caused by a reduction of airflow because of surface icing, either in the air scoop or carburetor. This condition may be encountered in freezing rain, heavy snow, ice, or when an extremely cold aircraft is exposed to moisture conditions during descent. The prevention and correction of this type of icing is the same as for the icing conditions previously described. The following procedures have been shown to be effective under all normal conditions where ice is likely to be encountered at altitudes below 20,000 feet and at temperatures between 10° and –25°C. At altitudes above 20,000 feet, extremely high carburetor air temperatures may cause excessive leaning of the mixture and result in engine instability. If such a condition occurs, the mixture should be entriched or carburetor heat reduced. It also may be necessary to use alcohol more frequently. At ambient temperatures below –25°C, the amount of visible moisture in the air is extremely small and is not likely to cause icing trouble; however, the temperature inside of clouds may be considerably different from the temperature outside the clouds. Therefore, it should be anticipated that icing conditions will be prevalent when entering a condition of visible moisture and preventive measures should be taken.

Air-Side Icing.

The application of carburetor heat and alternate fuel source is not permissible during takeoff. The use of alternate air scoop position is permissible during takeoff if conditions warrant it (refer to Appendix). Carburetor heat may be used before takeoff to ensure that any ice accumulation has been dislodged, but the switch must be in the COLD position and the carburetor temperature normal before takeoff. The alternate fuel source switch must also be in the NORMAL position before takeoff. After the first power reduction is made, carburetor heat may be applied to maintain a minimum temperature of 20° to 30°C. Temperature stratification at the carburetor deck when using carburetor heat causes the carburetor air temperature gage to read 30°C when the actual average air intake temperature at the carburetor is 38°C. Therefore, it is recommended that the carburetor air temperature not exceed 30°C, as read on the carburetor air temperature gage. Anticipation of impending icing conditions is of primary importance in avoiding fuel metering disturbances. Visible moisture in the air with free-air temperature below 10°C may be an indication of impending fuel flow disturbance. Intermittent fluctuations of fuel flow and BMEP, or gradual decrease or increase in fuel flow under these conditions, usually indicate a fuel metering disturbance which may be followed by a loss of power.

Operate the engines in the ram air configuration, unless severe icing is anticipated or structural icing is encountered. Maintain 85°C oil inlet temperature and position ram air doors to the alternate position. Apply carburetor heat and/or alcohol as necessary.

NOTE

> The engine should be returned to the ram air position as soon as ice is melted from the front of the ram air doors. (This should be accomplished one engine at a time.)

CAUTION

> Throttle butterfly icing is critical, especially during partical throttle operation. If throttle cannot be moved during icing condition, attempt to free it with alcohol. If it still cannot be moved, apply carburetor heat until throttle is freed.

NOTE

> If fuel flow indicates that the mixture is excessively rich, which has happened on very rare occasions, manually lean with the mixture control to maintain smooth operation, then apply carburetor heat to remedy.

The first step in preventing a fuel metering disturbance caused by carburetor ice is to use the alternate air source. Maximum effectiveness of the undercowl air source in preventing moisture from entering the induction system is dependent upon opening the cowl flaps from the normal cruise setting. A possible explanation of this is that by opening the cowl flaps the airflow velocity through the cowling is increased, and therefore moisture particles are more likely to continue straight through the cowling instead of following the air into the undercowl opening. Cowl flap openings beyond faired (30 percent) position are not recommended because openings beyond this position may reduce the available carburetor heat. While it is recommended that the alternate air source be used to combat induction system ice, there are some conditions where it may be desirable to apply heat with the door in the ram position. If icing conditions are anticipated, or if any atmospheric condition is encountered which could cause a radical metering disturbance, apply the following procedures:

1. Mixture levers – AUTO RICH.
2. Alternate air switches – ALTERNATE.
3. Cowl flaps – OPEN 20-30 percent.
4. Manual spark switch – As required.
5. Carburetor heat switches – Raise temperature to maximum 30°C for low blower and 22°C for high blower.

NOTE

> In event of BMEP or fuel flow loss during icing conditions, position carburetor heat switch to FULL HOT. If engine power is restored, regulate carburetor heat control so as not to exceed limits stated above.

6. Reset cruise power, and monitor fuel flow and BMEP for evidence for instability.
7. Continue to monitor all instruments to detect indications of icing.

8. Leave carburetor heat on for approximately 5 minutes after passing through icing conditions to ensure that ice is melted, then remove heat slowly in small increments, one engine at a time.

9. Reset cruise power and mixture.

When a metering disturbance or manifold pressure loss (caused by atmospheric conditions) occurs suddenly and unexpectedly, apply the same procedure as outlined above with special attention to "resetting power and fuel flows" and:

1. Carburetor alcohol – As required to stabilize power (3 to 5 seconds maximum).

If the foregoing procedures are not effective in relieving the metering difficulties, apply the following procedures on one engine at a time:

1. Mixture levers – AUTO RICH.

2. Throttle levers – Reduce manifold pressure to 25 in. Hg.

3. Alternate fuel switch – EMERGENCY.

4. Reset power – Advance throttle to desired BMEP, Manually lean mixture to best power and readjust throttle to maintain desired BMEP.

5. Carburetor heat switch – Adjust, on one engine at a time. to maintain temperature within limits. (Refer to Section V for limitations.)

6. Return to normal metering and power adjustment as soon as deemed advisable, doing so on one engine at a time.

If it is absolutely necessary to continue operation in level flight with the alternate fuel source, lean mixture and simultaneously open throttle to maintain constant BMEP until manifold pressure is 3 in. Hg above value noted at best power. If aircraft altitude is changed, the mixture will have to be reset. When using the alternate fuel source, the following cautions should be observed:

CAUTION

- Monitor fuel flow and power indications closely to detect changing conditions. Power changes may require resetting the mixture control.
- The alternate fuel source does not depend upon airflow; therefore, fuel flow, BMEP, and manifold pressure should be monitored carefully. The alternate fuel source should not be used without the prescribed amount of carburetor heat because a dangerous buildup of ice can occur without the usual fuel flow effects. Increasing throttle requirements to maintain manifold pressure usually indicates ice buildup, and increased carburetor heat should always be used under these conditions to ensure airflow to the engine.
- In the event of total loss of metering differential pressure, the alternate fuel source will supply sufficient fuel flow to allow power settings up to and including maximum cruise power.

Deactivating the Alternate Fuel Source.

1. Mixture lever – AUTO LEAN and simultaneously move alternate fuel source switch to NORMAL.

NOTE

Monitor fuel flow when deactivating the carburetor alternate fuel system.

2. Leave carburetor heat on for approximately 5 minutes after passing through icing conditions to ensure that ice is melted, then remove heat slowly in small increments, one engine at a time.

3. Reset cruise power and mixture.

During Descent.

It is possible that conditions conducive to carburetor icing will be aggravated by lower power, lean mixture, and part-throttle operation, especially during long steep descents. If trouble is encountered under these circumstances, the icing condition should be controlled by use of alternate air or carburetor heat.

The use of carburetor heat has been effective under all normal conditions where ice is likely to be encountered at altitudes below 20,000 feet and at temperatures between +10°C.

At ambient temperatures below −25°C the amount of visible moisture in the air is extremely small and is not likely to cause induction system icing trouble; however, the temperature inside of clouds may be considerably different from that outside. Therefore, it should be anticipated that icing conditions will prevail when entering a condition of visible moisture, and preventive measures should be taken.

Generally speaking, it may be better not to change an established configuration while in icing conditions as long as no difficulties are encountered, whether or not any anti-icing technique is used. In any event, do not switch to RAM air until it is determined that ice has not accumulated on the scoop door while in ALTERNATE. Air supply may be restricted and result in a power loss.

Fuel-Side Icing.

Because of the similarity of induction-side and fuel-side icing indications, and the possible damaging consequences of improper use of the fuel-side alcohol deicing system, it is recommended that the following factors be evaluated before operating this system:

1. Determine that extremely cold ambient temperatures are being encountered. (Tests and operational experience indicate that fuel-side icing difficulties should not be encountered at ambient temperatures above approximately −12°C.)

2. To ascertain that the metering disturbance is not of the induction-side type, and to prevent it, attempt to alleviate disturbance by applying normal induction system deicing measures before operating the fuel-side alcohol deicing system.

3. A 2 to 3 psi drop in engine fuel pressure is a definite and predictable characteristic of an iced bypass-type master control inlet screen. Positive identification of this symptom, associated with persistent metering disturbances, is by far the most reliable indication of carburetor fuel-side icing.

It cannot be emphasized too strongly that improper or untimely use of the fuel-side deicing system can result in engine operational difficulties as severe as carburetor icing itself. Therefore, the following CAUTIONS must be observed and strictly adhered to:

CAUTION

- Do not actuate system until factors listed above have been analyzed.
- Do not actuate carburetor deicing system when engine is operating in lean mixture. Severe combustion instability may result.
- Do not actuate system with mixture control in IDLE CUT-OFF or with engine stopped, since this may cause damage to diaphragms in certain fuel system components.
- Do not inject fuel-side alcohol for periods in excess of 15 seconds. Tests have shown that longer bursts are no more effective, are wasteful of the alcohol supply, and are capable of imposing marginal fuel-air ratios.

If it is definitely ascertained that fuel-side icing is being encountered, the following deicing procedure may be used, one engine at a time if more than one engine is affected.

1. Mixture lever – AUTO RICH.

2. Manual spark control – As required.

3. Alcohol injection switch – Hold to FUEL INLET SCREEN position for 10 seconds (do not exceed 15 seconds). Proper operation will be indicated by a drop in fuel flow of approximately 200 lb/hr. A resumption of normal fuel pressure is an indication that ice has been removed successfully.

If the above procedure does not remedy the suspected carburetor fuel-side icing problem, the mixture control lever may be moved back and forth several times between AUTO RICH and AUTO LEAN to impose maximum control pressures on the master control diaphragm. This will assist the alcohol in freeing an iced regulator poppet.

NOTE

The carburetor fuel-side alcohol injection system is designed to function as a restoring, rather than a preventive, device. By proper fuel system maintenance and operation, the likelihood of experiencing fuel-side icing is slight.

Although it has not been flight tested under actual icing conditions, the fuel-side deicing system has been demonstrated on a full-scale fuel system mockup to be capable of clearing the carburetor of major accumulations of ice under severe icing conditions for periods of 1 to 2 hours. Indiscriminate or excessive injection of alcohol through this system will deplete the available alcohol supply, which should be reserved for induction system and propeller deicing. (Engine damage is also possible through careless use.)

MANUAL LEANING.

General.

One thing is noticeable and that is the difference in manifold pressure between AUTO RICH and 10% drop. This difference provides the only means of determining whether the mixture has been set properly.

In AUTO RICH the manifold pressure required to obtain 177 BMEP is 37 in. At 10% BMEP drop mixture, the manifold pressure required to obtain 177 BMEP is about 40 in. There is about a 3-inch manifold pressure spread between AUTO RICH and 10% drop. In low blower, the manifold pressure spread is about 2 inches; therefore, in order to check yourself and in order to check that the engine is operating properly, note the manifold pressure in AUTO RICH when you first start to set power and mixture. At this time, record the manifold pressure in AUTO RICH and take a complete set of AUTO RICH readings before setting the mixture at 10% BMEP drop. Set the mixture in accordance with the procedure given at 10% BMEP drop. Note the MAP in AUTO RICH and the MAP at 10% drop. In high blower there should be about a 3 in. spread; in low blower, about 2 in.

This manifold pressure spread can vary according to several factors, but primarily the fuel flow that is obtained in AUTO RICH. Note that if the AUTO RICH fuel flow instead of being 1170 were about 1000 (if the carburetor were metering lean), the manifold pressure spread instead of being 3 in. would be about 3-1/2 in. Correspondingly, if the AUTO RICH fuel flow were very rich (about 1400 lb), the manifold pressure spread would be about 2-1/2 in. The same applies to low blower operation around the 2 in. limit. Therefore, these 3 in. and 2 in. numbers are not limits, but rather approximate guides to help you determine that the mixture has been set properly and to help you double-check yourself and the engine.

This type of check protects not only against improperly set mixtures, but also against certain types of engine malfunction. For example, assume that the fuel injection line to one cylinder is leaking. With the mixture control in AUTO RICH the cylinder, in spite of the leak, might receive enough fuel to fire, and the MAP fuel flow – BMEP relationships would be normal. However, when leaning is started, the cylinder may begin to fire intermittently or drop out altogether when the fuel-air ratio to that cylinder becomes excessively lean due to the leak plus the leaning. Engine symptoms which may accompany this condition are roughness at the manual – lean point, excessive MAP spread, and high fuel flow.

The symptoms that are observed will depend upon how far the engine has been leaned when the affected cylinder begins firing intermittently or drops out. When the cylinder drops out early in the leaning, the MAP rise necessary to regain power is less than normal because for a fixed rpm 17 cylinders require less MAP to produce a given power at Best Power than 18 cylinders at 10% lean. Since the engine is running near Best Power, the fuel flow will be high.

If the cylinder drops out late in the leaning, the MAP rise is usually excessive because the 17 cylinders would then be operating close to a 10% lean fuel – air ratio. Under these conditions a proportionate increase in both air flow and fuel flow would be required for 17 cylinders to produce the same power as 18.

NOTE

- If the cruise power is above 1550 bhp in low ratio, or above 1450 bhp in high ratio and the position of the mixture control, after manual leaning, is richer than the AUTO LEAN detent, place the mixture control in AUTO LEAN. This condition should be investigated as it may indicate an engine discrepancy requiring maintenance correction.
- At powers below those stated above, the power enrichment valve is closed and the position of mixture control is of no consequence.
- If investigation discloses that this condition is encountered only in low blower and the power drop is not greater than 15%, operation may be contained in AUTO LEAN without further maintenance providing the specified CHT spread limits are not exceeded.

Manual leaning to a 10% in low blower and 15% in high blower BMEP drop from best power is recommended for all cruise operation at maximum cruise power and below. This procedure will place the mixture in the best economy range and is desirable since it results in a direct saving in fuel. It has the additional advantage of cooling the engine by means of lower combustion and exhaust temperature due to the excess air which absorbs some of the heat of combustion resulting in optimum cylinder, turbine, nozzle box, and exhaust system durability. The use of mixtures leaner than 10% BMEP drop in low blower and 15% in high blower should be avoided also since any abnormal distribution of fuel or air to the cylinders can result in serious cylinder-to-cylinder power differences which are aggravated by extremely lean operation.

If engine condition does not permit stable operation when leaned to 10% BMEP drop, it is recommended that AUTO RICH be used until the engine condition can be corrected. (Stability is defined as no visual roughness of the engine, no indication of power fluctuation in excess of 5 BMEP, or both.)

NOTE

Determine if the master control is metering lean by returning the mixture lever to the AUTO RICH position and operate the primer intermittently. If there is a BMEP increase the master control is metering lean. Subsequent operation should be in AUTO RICH until the discrepancy is corrected. Lean mixtures can be detrimental to engine life during high power operation.

1. Throttle levers – Reset to desired BMEP.

2. Lean manually with the mixture lever for 10 percent BMEP drop in low blower and a 15 percent BMEP drop in high blower.

3. Throttle levers – Reset to desired BMEP.

NOTE

If the cruise engine speed is above 2200 rpm and the position of the mixture control after leaning is forward of the AUTO LEAN detent, place the mixture control in AUTO LEAN detent and observe the percent power drop. If more than 15 percent power drop or instability occurs, return the mixture to AUTO RICH until the discrepancy can be corrected. If not more than 15 percent power drop occurs, the engine is stable and CHT spread limits are not exceeded, operate the engine in this manner. At 2200 rpm and below, the position of the mixture control after leaning is of no consequence.

This procedure has the advantage of cooling the engine by means of lower combustion and exhaust temperature due to the excess air which absorbs some of the heat of combustion, resulting in optimum cylinder, tubing, nozzle box, and exhaust system durability. When low blower 10 percent lean critical altitudes cannot be maintained and carburetor heat is required, it is prefereable to use low blower and lean to 7 percent mixture than to use high blower at 10 percent lean. (The 7 percent mixtures can only be used in low blower.) If momentary applications of high power are required, use RICH mixture and increase rpm as necessary. This will provide cooler combustion temperatures with less cowl flap drag and lower overall fuel consumption.

An occasional need to maintain cruise power in low blower at altitudes above the 10 percent lean critical altitude is recognized. On such occasions, it is permissible to use the same procedure, leaning to 7 percent BMEP drop provided rpm is 2500. The critical altitude increase is approximately 700 feet and the fuel consumption increase approximately 2 percent.

The use of mixtures richer than 7 percent BMEP drop at cruise power in level flight should be avoided since this results in temperatures which have an adverse effect on the engine durability.

If engine condition does not permit stable operation when leaned to 10 percent BMEP drop in low blower, it is recommended that AUTO RICH be used until the engine condition can be corrected. In high blower, mixtures 15 percent through 10 percent BMEP drop (no less than 10 percent) are permissible in an effort to achieve stable operation. Stability is defined as no visible roughness and no power indication fluctuation in excess of 5 BMEP.

NOTE

BMEP gage fluctuation without engine roughness can be an engine discrepancy and should be investigated.

Under normal conditions when operating with either an AUTO RICH or a 10 percent BMEP drop mixture, it is recommended that all engines be operated within a maximum of 2 inches MAP of each other. Appropriate corrections should be made.

4. Recheck manual lean mixture setting whenever there is a 50 BHP change or following any change in cruise altitude greater than 2000 feet.

MANUAL SPARK CONTROL OPERATION.

The manual spark control provides the flight engineer with a positive control of engine ignition timing. The spark control switch shall be placed in the RETARD position for starting, ground operation, takeoff, climb, approach, landing, and whenever the engines are operating above a certain rpm. (Refer to Section V for limitations concerning use of the manual spark.)

CAUTION

The manual spark control must be in the RETARD position for takeoff and for all engine operation above 2500 rpm in low blower or above 2400 rpm in high blower. Operation above these rpm with advanced spark may result in engine damage, particularly with AUTO LEAN mixture.

Spark Advance With Ignition Analyzer Operative.

1. Establish stabilized cruise power with mixture in AUTO RICH.

2. Select BOTH position for No. 1 engine on engine analyzer selector switch.

3. Place spark control master switch in ADVANCE and the spark control switch for the No. 1 engine in RETARD.

4. Move No. 1 engine spark control switch to NORMAL and note that analyzer pattern shifts to the left.

5. Repeat on other engines.

NOTE

If one pattern fails to shift to the left, that spark advance relay is inoperative. Select LEFT on analyzer selector switch and check. If pattern shifts, the right relay is inoperative.

Spark Advance Check With Ignition Analyzer Inoperative.

Proper operation of the manual spark advance relays when ignition analyzer is inoperative may be checked as follows:

1. Establish a cruising power (lean mixture) in stabilized flight and clear air.

2. Move the spark control master switch to the ADVANCE position.

NOTE

There should be a definite increase in BMEP when the spark is advanced. If no increase occurs, the spark advance relays are not operating.

ENGINE OIL-IN, OIL-OUT TEMPERATURES.

The oil-out temperature indicator is useful in the detection of incipient master rod bearing failures. It should be realized that the normal spread between oil-in and oil-out temperatures will be affected by a number of factors, among which are oil-in temperature, engine power, ambient temperature, and possibly oil tank quantity. The important fact is not the stable temperature spread, but rather a rapid and uncontrollable change in this relationship.

The following information should be evaluated and adhered to on all oil temperature indications other than normal:

a. A rapid rise in oil-out and oil-in temperature, with a widening of the normal spread between these temperatures, is indicative of internal engine failure.

b. Narrowing of the spread between oil-in and oil-out temperature during a rise of both is indicative of oil cooler malfunction.

c. A sudden rise to maximum of either temperature with no change in the other is indicative of a fault in the temperature indicating system.

Engine Supercharger Shift.

If a climb to high cruising altitudes is made and an engine supercharger shift is required to maintain adequate climb power, shift to HIGH ratio position in the following manner:

1. Reduce manifold pressure to 20 in. Hg, or less.

2. Reduce engine speed to 1600 rpm.

3. Shift supercharger lever to HIGH position. (Make all shifts as smoothly and as rapidly as possible.)

4. After manifold pressure increases, indicating shift has been made, reset throttles and rpm to obtain the required climb power.

NOTE

Shift to HIGH position during normal climb power at the altitude at which the BMEP drops to approximately 210.

ABNORMAL BMEP INDICATION.

If the overhaul modifications to the torque cell support brackets have been made, the possibility of a propeller decoupling in the event of a torque cell failure is greatly reduced. However, these modifications do not relieve the flight crew of their responsibility to troubleshoot and evaluate a malfunctioning or abnormal BMEP indication.

1. In the event of a complete loss of BMEP, the pilot should use his own good judgment prior to making the decision to feather.

2. Sudden changes in BMEP from normal indication to zero, either clockwise or counterclockwise are not cause for immediate feathering. Stand by, however, to retard throttle quickly; turn on automatic feather test switch for affected engine; turn on master automatic feather switch and stand by for automatic feathering of affected engine. If the feathering button is energized, retard throttle quickly and continue feathering procedure; if feathering button is not energized within 2 to 3 seconds, turn automatic feather switches off. Observe closely for any other signs of malfunction and continue mission. Make a runup after next landing for analysis of trouble. Record all engine instrument indications for the benefit of maintenance personnel.

3. A BMEP drop to zero, preceded by unaccountable, progressive, BMEP spread will justify immediate feathering. Attempt to account for the BMEP spread by setting the affected engine and its symmetrical engine at identical rpm, MAP, and best-power mixture. Note BMEP spread. Check analyzer patterns for indication of a nonproductive cylinder. Check for power recovery turbine failure as follows: During daytime flight, visually inspect turbines for unusual discharge of smoke from or around exhaust flight hood. During night flight, visually inspect turbines for heavy discharge of orange sparks. If BMEP spread cannot be accounted for, feather propeller when spread exceeds 20 BMEP. An engine that operates to 20 BMEP below the other engines at the same throttle setting, should be watched carefully for any signs of increase in torque deviation, or other indications of engine malfunction.

An engine that apparently malfunctions in this manner should be referred to maintenance for inspection and correction. In all instances of low BMEP indications, possible instrument error should also be investigated prior to any extensive torquemeter system malfunction investigation.

4. An indicated BMEP rise to off-scale is an occasional flight occurrence. This is not to be considered as a cause for feathering. Continue mission, maintaining identical rpm, MAP, and fuel flow with its symmetrical engine. Monitor cylinder head temperatures closely and adjust mixture accordingly.

5. In all instances, suitable correction should be allowed for instrument calibration correction and cabin supercharger and alternator power demands. .

SPARK PLUG FOULING – CAUSE, PREVENTION, AND CURE.

Fouling of spark plugs is a principal cause of ignition trouble, which in turn is one of the most common engine maintenance and operating problems with aircraft engines using 115/145 or 100/130 grade fuel. These grades of fuel may contain a relatively high lead content. Such fouling might be defined as 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 the principal troublemaker. Cause, prevention and cure of spark plug fouling are all linked to the chemistry and physics of the combustion cycle, which in turn are subject to wide variation under different ground and flight engine-operating conditions. A logical treatment of the problem involves separate discussions of each aspect of typical engine operation, including ground running, takeoff, climb, cruise, and descent, and following the typical sequence of operation in the flight manual. Prevention appears to be the most profitable line of attack on the problem.

Important Factors.

Tetraethyl lead is the most important basic cause of lead fouling. Scavenger agents, such as bromine in the tetraethyl lead, are provided to combine with the lead during combustion, removing it with the exhaust gases. However, under certain conditions of temperature and pressure, the lead will precipitate on the spark plug insulator as lead oxide or lead bromide compounds. In the presence of excess carbon as a reducing agent, these compounds may form metallic lead particles. Such deposits can ultimately prevent ignition or firing. Obviously, the best solution is to remove or reduce the lead compounds presently contaminating the fuels. Other pertinent factors influencing plug misfiring include the type of ignition system, spark plug characteristics, and time used. General engine conditioning (including the care and handling of spark plugs), the operating requirements and characteristics of the particular engine installation, and the specific engine operating conditions.

In general, spark plug fouling involves a buildup of deposits through prolonged operation under a fixed set of conditions. Prevention and remedy for plug fouling, therefore, depend on taking action to vary these conditions, upset the chemistry of the fouling cycle, and restore good ignition.

SPARK PLUG ANTI-FOULING PROCEDURE.

The following procedure is recommended to prevent spark plug fouling during extended periods of operation in idle range on the ground.

a. Set the throttle at 800 to 1200 rpm with the mixture control set at AUTO RICH.

b. Momentarily energize the primer. If either an rpm drop or less than a 25-rpm rise is observed, manually lean to a 25-rpm drop.

SPARK PLUG CLEANOUT PROCEDURE.

150 BMEP Operation.

In order to prevent excessive buildup of carbon deposits on the spark plugs during prolonged ground operation, the following procedure is recommended as a supplement to the procedure outlined above:

1. Cowl flaps – OPEN.
2. Mixture levers – AUTO RICH.
3. Propeller switches – Full INC RPM.
4. Throttle levers – As required for 150 BMEP.

NOTE

Do not use alcohol.

Operate the engines at this power setting for 1 minute after each 15 minutes of ground operation. Cylinder head temperatures should be maintained below 200°C, if possible, so as not to exceed takeoff temperature.

Progressive Power Cleanout Procedure.

If the foregoing spark cleanout procedure fails to satisfactorily clean the affected spark plugs, the flight engineer will proceed as follows:

1. Mixture levers – AUTO RICH.
2. Propeller switches – Full INC RPM.
3. Throttle lever – 1600 rpm.

From the 1600-rpm position, gradually increase power in 200-rpm increments. At each 200-rpm increment, allow power instruments to stabilize. Check for fouled plugs with ignition analyzer. When fouled plugs are detected, power should be reduced to the point where the plug commences firing (determined by the analyzer pattern). Allow the plug to fire for 15 seconds; then increase power to the next 200-rpm increment.

NOTE

This progressive power cleanout procedure is based on the fact that a plug must be firing in order to clean lead and carbon deposits. Spark plugs will often fire properly at low power settings, yet will break down at higher settings. A decrease in power, slightly below the break-down point, will allow the plug to fire and clear deposits. For progressive power cleanout procedures, CHT should be maintained below 260°C.

Fouled Plug Procedure.

Ground Procedure. When the analyzer indicates two fouled plugs in the same cylinder, the following procedure will be used in an attempt to recover the cylinder:

1. Set engine at barometric manifold pressure with mixture in AUTO RICH.
2. Apply steady prime.
3. Advance throttle gradually to 2600 rpm.
4. Observe affected cylinder spark plugs on analyzer as power is advanced.
5. When any activity is noted on either pattern, release primer immediately and reduce power to barometric manifold pressure.
6. Recheck all spark plugs on affected engine at 150 BMEP.

NOTE

If one minute of operation at 2600 rpm with steady prime does not restore cylinder, shut down affected engine and return for maintenance.

In-Flight Procedure. Whenever spark plug fouling patterns are observed on the ignition analyzer during extended low power cruise, the following will be accomplished:

1. Move mixture to AUTO RICH position. Advance power slowly (1 in. Hg manifold pressure per 5 seconds) to 1540 BHP. This power setting will produce a core nose temperature of sufficient amplitude to effect satisfactory cleanout. As soon as analyzer pattern indicates optimum plug firing, return to cruise power and manually lean affected engine. (To obtain 1540 BHP advance rpm slowly to 2200. Increase MAP slowly until limit BMEP for particular altitude is reached.)

ENGINE MALFUNCTION ANALYSIS.

When a spread of over 100 rpm on symmetrical engines is encountered at field barometric pressure, the following procedures will be initiated to determine the cause:

a. Determine that all engines are fully warmed up and all pressures and temperatures are normal.

b. Turn the aircraft as necessary to head into the wind and repeat barometric check.

NOTE

Use corrected MAP, as obtained from static readings on MAP gages, before starting engines.

c. Perform standard magneto check noting rpm, BMEP, and fuel flow. A drop of 100 rpm while operating on one magneto is permissible, provided no engine roughness is encountered. If magneto check is unsatisfactory, a cross-reference with the pilot's tachometer and the ignition analyzer will be made.

d. If ignition system is satisfactory, a cruise power performance check will be made as follows:

(1) Mixture levers – AUTO RICH.

(2) Propeller switches – Full INC. RPM.

(3) Manual spark switches – Advance.

(4) Throttle levers – Advance to 2200 rpm for symmetrical engines.

(5) Propeller switches – Reduce rpm to 2100.

(6) Throttle levers – Advance to obtain 169 BMEP.

(7) Mixture levers – Manually lean to best power, reset throttles to 169 BMEP, and compare manifold pressures.

NOTE

If the BMEP increase between AUTO RICH and best power is more than 3 BMEP, the master control is metering rich. If the engine will develop minimum acceptable BMEP at maximum power, the master control is acceptable for flight. If no increase occurs place the mixture lever in AUTO RICH, engage the engine primer intermittently and if any increase of BMEP occurs, the master control is metering too lean. If master control is metering too lean, corrective action is s required.

(8) Mixture levers – Continue leaning to 152 BMEP.

(9) Throttle levers – Advance to obtain 169 BMEP.

NOTE

Under normal conditions with either best power or at 10 percent lean, all engines should be within 2 in. Hg MAP or 5 BMEP. If these limits are exceeded, make specific performance checks. Suitable allowances must be made in above checks for accessory power variations.

(10) Check for engine instability.

If the above checks reveal no engine malfunction, but indicate a probable incorrect propeller blade pitch setting, make maximum power check with brakes set. If correct rpm, MAP, and BMEP are obtained the engine may be considered acceptable for flight.

NOTE

Once the propeller is off the low pitch stop, the propeller governor will maintain proper blade pitch.

SPECIFIC PERFORMANCE CHECKS.

Fuel System Checks.

1. Primer check for fuel injection troubles (flight).

a. Note the exact fuel flow, MAP, and BMEP at 10 percent manual lean mixture on engine to be checked.

b. While still operating at 10 percent manual lean mixture, add prime fuel flow to engine to be checked, and hold.

c. Manually lean mixture back to the original 10 percent lean fuel flow reading of the engine to be checked.

d. Note new BMEP reading.

e. If this reading is higher than the engine's original reading, there is trouble with the fuel injection system causing imperfect distribution either cylinder to cylinder, or row to row.

f. While holding steady prime, return mixture to AUTO RICH, then release primer.

g. Reset cruising mixture and make appropriate entry in Form 781.

NOTE

The primer on a fuel-injection engine is a valuable tool with which to troubleshoot the engine for fuel injection troubles. With it, fuel is injected directly into the induction system at a rate of 160 to 200 pounds per hour. This fuel goes directly into the induction system, and by manual leaning to the original fuel flow, the engine is running partially on fuel injection and partially on carburetion. Malfunctioning fuel injection system components, or leaks, can therefore be detected by its use. Partial fuel injection line leaks can be detected by the use of inflight primer check. However, it can be readily seen that a leak of sufficient magnitude to cause a cylinder to be inoperative throughout the mixture range cannot be brought back in by the inflight primer check.

2. Primer check (ground run).

a. Obtain a minimum of 150°C CHT.

b. Run engine at 1200 rpm with propeller control set to full increase rpm and mixture control AUTO RICH.

c. Hold steady prime on engine, and place mixture control in IDLE CUT-OFF.

d. Adjust throttle slowly until highest rpm and lowest MAP are reached.

e. Check and note exact rpm and fuel flow at this setting.

f. Move mixture control to AUTO LEAN and release the primer.

g. Obtain the same fuel flow at noted in step (e) with the mixture control.

h. Check rpm. If it is within 25 rpm of that noted in step (e) the fuel-injection system is functioning properly. If more than a 25-rpm deviation occurs this is an indication of a malfunction, such as a fuel injection line or seal leak, poor synchronization, or fuel pump diaphragm leak.

Because the engine may be operated on the ground as a full carburetion engine, fuel injection line leaks of a magnitude which cannot be detected with the inflight check can be detected.

Cylinder Head Temperature Comparison — Fuel Air Distribution

1. Improper fuel-air distribution between the front and rear row cylinder can adversely affect combustion chamber component service life. The following procedure, using row to row cylinder head temperatures as a guide, may be used to check the distribution characteristics of the direct injection engine.

2. Set the following conditions:

a. Low Blower

2400 RPM
180 BMEP
10% lean mixture
Advance spark
Ram air source
15% cowl flap angle
175 knots airspeed (minimum)
Pressure altitude 6,000 to 10,000 feet

b. High Blower

2400 RPM
175 BMEP
10% lean mixture
Advance spark
Ram air source
15% cowl flap angle
175 knots airspeed (minimum)
Pressure altitude 14,000 to 18,000 feet

3. Exercise care to obtain stabilized CHT readings at stabilized airspeed heading and altitude. The following constitute limits of allowable CHT spreads:

	Low Blower	High Blower
Rear Row Hot	25°C	30°C
Front Row Hot	15°C	10°C

4. At the above 10 percent lean conditions, the CHT spread normally experienced is approximately 10°C rear row hot in lower blower and 15°C rear row hot in high blower. The CHT spread in auto-rich mixtures will normally be small and can be either front or rear row hot. As a result, a small crossover in the hot indicated CHT is common when leaning from auto-rich to 10 percent lean.

5. If cylinder head temperature spreads appear to be out of limits, apply the applicable condition outlined in paragraph b. If CHT spread is excessive open the cowl flaps to 30 percent. If the rear CHT now cools off, the CHT spread limits are not exceeded; no discrepancy is indicated. If limits are exceeded with cowl flaps set at 30 percent, reset cowl flaps to 15 percent. CHT MAP and fuel flow data should be obtained and plotted for auto-rich, best power, 10 and 15 percent lean. This information should then be turned over to the appropriate maintenance personnel for investigation and corrective action when aircraft returns to its main base.

6. This check is normally accomplished at 10 percent lean mixture; however, if the rear row CHT does not cool off somewhat when leaning from best power to 10 percent lean, accomplish the check at 15 percent lean. The same spread limits apply. If the rear row CHT still does not cool

NORMAL IGNITION PATTERN EXPLANATION

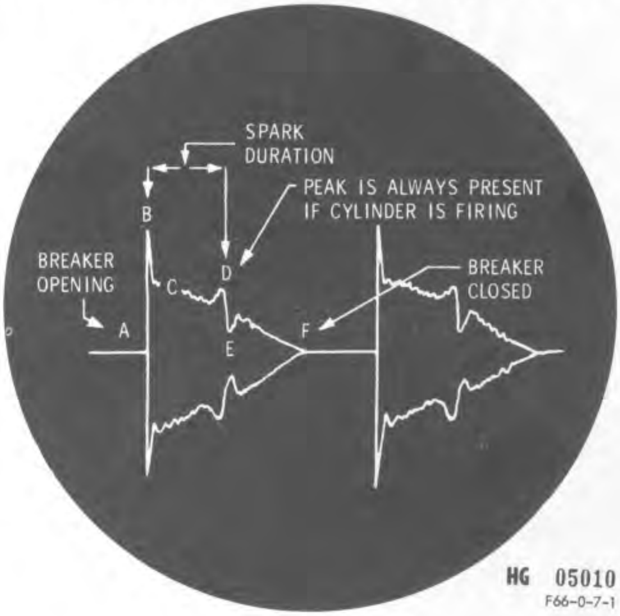


Figure 7-1

off, a discrepancy is indicated and should be investigated upon return to home base. If rear row CHT now cools off, the CHT spread limits are not exceeded and no discrepancy is indicated.

7. If the normal low blower flight altitude is lower than 6000 feet, this check may be performed at lower altitudes provided that rechecks are performed at the same altitude after maintenance has been performed to correct the discrepancy.

Magneto Output Check.

Warm up the engine until the cylinder heat is 125°C or more with throttle closed, the engine should idle at approximately 700 rpm. Move the mixture control into IDLE CUT-OFF; then, when the engine slows down to 300 rpm, move the mixture control back to AUTO RICH. The engine should return smoothly to 700 rpm. Make this check with the ignition switch on right (R) and then on left (L). The engine should be capable of performing this test on either side of the ignition switch, if the magnetos and breaker points are in good condition. This test should not be made until the engine is warm and temperatures are stabilized.

IGNITION ANALYZER.

The ignition analyzer operates on the principle that the voltages in the magneto primary vary with the condition of the ignition circuits. Since these voltages change in value very rapidly, a cathode ray tube is used to show the variations. The vertical displacement of the electron beam is proportionate to the voltage in the magneto primary. The electron beam is moved horizontally across the tube in a set time relationship with the degrees of crankshaft rotation so that a graph can be seen of the voltage changes "plotted," with respect to crankshaft rotation. When a normally operating ignition system fires a fuel-air charge in a normally operating cylinder, a normal pattern occurs. Normal operation implies normal cylinder head temperature, compression ratio, mixture, ignition circuit, and spark plug gap, because all these factors affect the total resistance characteristics of the ignition system. A malfunctioning ignition system or abnormal cylinder conditions will affect the pattern, and therefore certain engine and ignition malfunctions can be detected by analyzing the ignition patterns.

Normal Patterns.

Figure 7-1 shows a normal ignition analyzer pattern. The letter headings in the discussion following correspond to the letter positions on figure 7-1.

A. Breaker Point Opening Time. At this time a rapidly rising voltage is induced in the magneto coil. The primary current flows to the distributor and the primary side of the high tension coil. A high tension voltage is thereby induced in the secondary winding of sufficient value to break down the spark plug gap. This voltage is represented by the first excursion line A to B.

B. Spark Plug Firing Time. At the instant of spark plug firing, the gap between the electrodes becomes ionized, lowering the resistance and requiring less voltage. This voltage decrease is represented by line B to C.

C to D. Spark Activity Period. This is best described as the thermal time delay necessary for the flame front to propagate. With the plug gap ionized, the voltage requirements are lowered and the activity traced is the continued spark plug firing.

D. Combustion Indication Hook. This portion of the pattern is associated with the combustion phenomena. The height and position of the combustion hook at D are determined by combustion mixtures and cylinder condition. A stable or stationary hook indicates good combustion characteristics.

E. End of Spark Plug Firing Time (Hook). The line D to E represents the time the spark is dispelled. The remainder of the energy is then dissipated through the capacitance in the harness leads, etc., represented by the sloping line E to F.

F. Breaker Point Closing Time. The duration of point opening or point dwell is the horizontal distance between points A and F. The breaker point closing event is not visible on all cylinders due to pattern overlap resulting from distributor cam compensation.

The letter headings in the discussion following correspond to the letter positions of figure 7-2.

A. Lead Line. The appearance of the lead line is affected as follows:

a. Residual voltage in primary circuit determines slope.

b. Distribution brush arcing causes hash on line (see figure 7-3, sheet 8).

c. Flux reversal in magneto generator causes every other pattern to have crossover.

Position on the scope is affected by position control.

B. Breaker Point Opening. Breaker point arcing causes a step to appear (see figure 7-3, sheets 4 through 8). The position of the breaker point opening is affected by:

a. Breaker point bounce (see figure 7-3, sheet 8).

b. Breaker point timing.

c. Synchronizing generator timing.

d. Cam and/or cam compensation.

e. Drive train variations (see figure 7-3, sheet 4).

f. Aborted primary interruptions (see figure 7-3, sheet 4).

C. Spark Plug Firing Time. The initial amplitude of the pattern at spark plug firing time is affected by the following factors:

a. Spark plug gap (see figure 7-3, sheet 6).

b. Secondary circuit open or short (see figure 7-3, sheets 6 and 7).

c. Primary circuit open or short (either intermittent or steady) (see figure 7-3, sheets 5 through 7).

d. Magneto generator or distributor timing (see figure 7-3, sheets 4 through 10).

e. Strength of magnets in magneto generator (see figure 7-3, sheet 1).

f. Amount of pressure in cylinder.

D. Spark Activity. The appearance of the pattern during spark activity is affected by:

a. Amount of turbulence in cylinder.

b. Distributor brush arcing (see figure 7-3, sheet 8).

c. High tension lead contact spring bounce (see figure 7-3, sheet 8).

d. Rate of energy dissipation (determines slope of the pattern).

EFFECT OF IGNITION MALFUNCTION ON NORMAL PATTERN

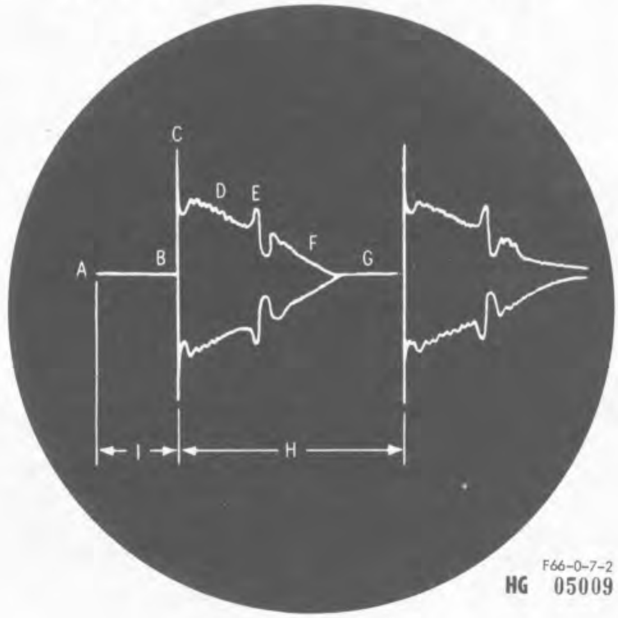


Figure 7-2

E. Point Where Spark Goes Out (Hook).

a. Unstable dancing hook indicates lean mixture operation (see figure 7-3, sheet 3).

b. Unstable high amplitude hook intermittently displaced to left of normal position indicates no combustion (see figure 7-3, sheet 10).

F. Tail End. The appearance of the pattern between the points where the spark goes out and the breaker point closes is affected by:

a. Distributor brush arcing (see figure 7-3, sheet 8).

b. Rate of energy dissipation in the primary circuit.

G. Breaker Point Close. The position of the breaker point close is affected by:

a. Breaker point dwell.

b. Breaker point bounce (see figure 7-3, sheet 8).

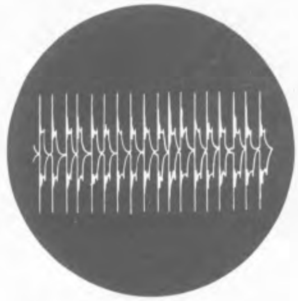
H. Distance Between Two Patterns. The distance between two patterns is determined by the number of crankshaft degrees between two consecutive firing impulses (cam compensation causes this to vary from cylinder to cylinder).

I. Distance Between First Pattern and Initiation of Trace. The distance between the first pattern and the

IGNITION ANALYZER PATTERNS

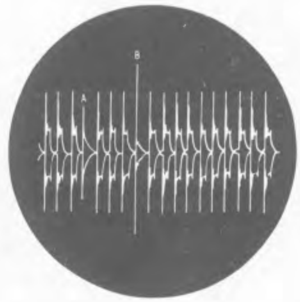
NORMAL PATTERN—SLOW SWEEP

THE PICTURE OBSERVED ON SLOW SWEEP PRESENTS THE PATTERN OF 18 PLUGS FIRED BY ONE DISTRIBUTOR IN ONE COMPLETE ENGINE CYCLE, OR 720 CRANKSHAFT DEGREES. THE NORMAL POLARITY REVERSAL OF CONSECUTIVE FIRING OF ONE MAGNETO IS INDICATED BY PATTERNS APPEARING ALTERNATELY ABOVE AND BELOW THE TRACE LINE. IT WILL BE NOTED THAT BECAUSE OF THE MAGNETO ARRANGEMENT FOR THIS ENGINE, SUCCESSIVE FIRINGS OF THE SAME SPARK PLUG ARE ALTERNATELY POSITIVE AND NEGATIVE.



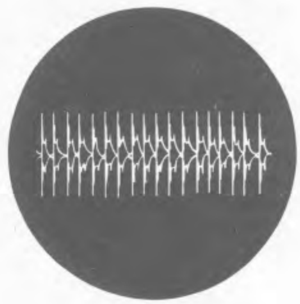
MALFUNCTION PATTERN—SLOW SWEEP

MALFUNCTION PATTERNS SUCH AS AN OPEN SECONDARY (B) (HIGH TENSION) CIRCUIT CAN BE IDENTIFIED AS MUCH HIGHER THAN NORMAL PATTERN, A SHORTED HIGH TENSION CIRCUIT (SHORTED SECONDARY) (A) APPEARS AS A PATTERN SLIGHTLY LOWER IN HEIGHT THAN A NORMAL PATTERN WITH COMPLETE LACK OF COMBUSTION HOOK CHARACTERISTICS. AN OPEN SECONDARY, A SHORTED SECONDARY, AND SIXTEEN NORMAL PATTERNS ARE SHOWN.



MALFUNCTION PATTERN—SLOW SWEEP
LOW MAGNETO VOLTAGE OUTPUT

GENERAL OVERALL LOW AMPLITUDE OF NORMAL IGNITION PATTERNS INDICATE LOW MAGNETO VOLTAGE OUTPUT. IF ALTERNATE CYLINDERS INDICATE LOW AMPLITUDE IT CAN BE ATTRIBUTED TO THE MAGNETS. PROBABLE CAUSES: 1. WEAK MAGNETO MAGNETS. 2. DAMAGED COIL WINDINGS. 3. IMPROPER SETTING OF E GAP TIMING.



MALFUNCTION PATTERN—SLOW SWEEP
WEAK MAGNET IN MAGNETO OR UNBALANCED ISOLATING RESISTOR VALUES

EVERY OTHER PATTERN HAS A DECREASED AMPLITUDE DUE TO: 1. A WEAK MAGNET IN THE MAGNETO GENERATOR, THIS WILL BE NOTICEABLE ON BOTH THE LEFT AND THE RIGHT MAGNETO. 2. UNBALANCED ISOLATING RESISTOR VALUES, THIS WILL BE NOTICEABLE ON EITHER LEFT OR RIGHT DISTRIBUTOR.

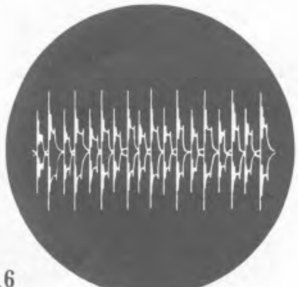


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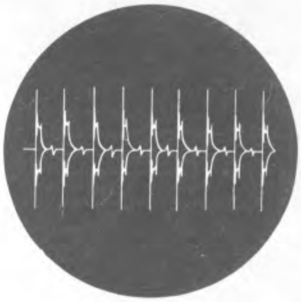
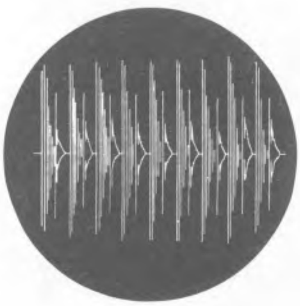
Figure 7-3 (Sheet 1 of 10)

IGNITION ANALYZER PATTERNS



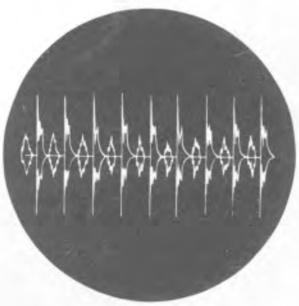
MALFUNCTION PATTERN—SLOW SWEEP
SHORTED PRIMARY CIRCUIT (MAGNETO TO DISTRIBUTOR)

A COMPLETELY SHORTED PRIMARY CIRCUIT IN GROUNDING SYSTEM OR BETWEEN THE MAGNETO AND THE DISTRIBUTOR WILL BE SEEN. NINE VERY SMALL PIPS WHICH ARE INDUCTIVE PICK-UP FROM THE OTHER (UNAFFECTED) DISTRIBUTOR ARE SOMETIMES VISIBLE. ALL SPARK PLUGS FIRED BY THE AFFECTED DISTRIBUTOR WILL DISPLAY THIS PATTERN. THE NINE ADDITIONAL PATTERNS APPEARING AT THE LEFT ARE FROM THE OTHER (UNAFFECTED) DISTRIBUTOR AND ARE VISIBLE BECAUSE OF THE ANALYZER TIE-IN TO THE MAGNETO GROUNDING SYSTEM (P LEAD). PROBABLE CAUSES:
1. BREAKER POINTS NOT OPENING. 2. GROUNDED PRIMARY COIL OR CONDENSER.
3. GROUND BETWEEN MAGNETO GENERATOR AND THE DISTRIBUTOR.



MALFUNCTION PATTERN—SLOW SWEEP
OPEN PRIMARY (DISTRIBUTOR BRUSH)

EVERY OTHER PATTERN HAS A VERY HIGH AMPLITUDE AND A COIL-SPRING EFFECT. PROBABLE CAUSES: 1. BROKEN DISTRIBUTOR BRUSH. 2. BROKEN DISTRIBUTOR BRUSH SPRING. 3. OPEN BETWEEN BREAKER POINTS AND THE SEGMENT PLATE.



MALFUNCTION PATTERN—SLOW SWEEP
OPEN PRIMARY CIRCUIT (MAGNETO TO DISTRIBUTOR)

THIS PATTERN CAN BEST BE DESCRIBED AS NINE PIPS SUPERIMPOSED ON A DISTORTED SINE WAVE. THE PIPS OCCUR AT APPROXIMATELY THE BREAKER POINT CLOSING POINTS OF THE AFFECTED DISTRIBUTOR. THE SINE WAVE VOLTAGE VARIATION IS THE NORMAL VOLTAGE VARIATION INDUCED IN THE PRIMARY COIL BY THE MAGNET ROTOR. THE NINE NORMAL PATTERNS ARE FOR THE UNAFFECTED POINTS, BUT ARE GENERALLY DISTORTED BECAUSE OF THE MALFUNCTION PRESENT ON THE ONE MAGNETO. PROBABLE CAUSES: BROKEN DISTRIBUTOR BRUSH OR BRUSH SPRING, OR ANY OPEN IN THE PRIMARY CIRCUIT BETWEEN THE BREAKER POINTS AND THE SEGMENT PLATE.

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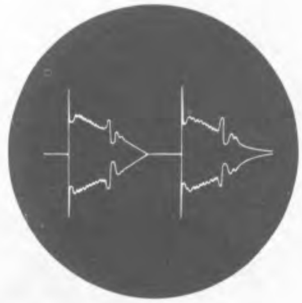
F66-0-7-3 (2)

Figure 7-3 (Sheet 2 of 10)

IGNITION ANALYZER PATTERNS

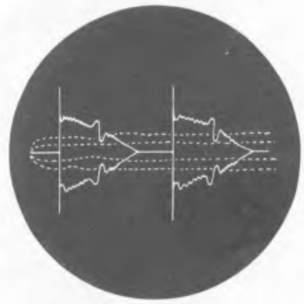
NORMAL PATTERN—FAST SWEEP

THE TWO PATTERNS THAT APPEAR IN FAST SWEEP ARE FOR THE CYLINDER SELECTED BY THE CYCLE SWITCH AND FOR THE NEXT CYLINDER FIRED BY THE SELECTED DISTRIBUTOR. THE PATTERN AT THE LEFT END IS THE CYLINDER SELECTED BY THE CYCLE SWITCH. BOTH PATTERNS APPEAR ABOVE AND BELOW THE TRACE LINE AS SUCCESSIVE FIRINGS OF THE SAME SPARK PLUG.



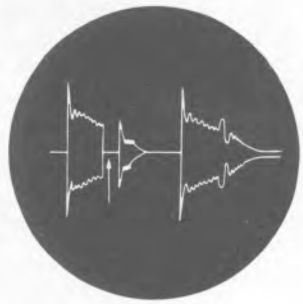
NORMAL PATTERN—FAST SWEEP
HORIZONTAL TRACE LINES

A PHENOMENON QUITE OFTEN NOTICED ESPECIALLY AT NIGHT ARE WAVY TRACE LINES RUNNING HORIZONTALLY THE FULL LENGTH OF THE SCOPE WHICH ARE REPRESENTED BY DOTTED LINES IN THE SKETCH. THESE LINES WILL BE MORE NOTICEABLE AT NIGHT TIME OR WHEN THE ANALYZER INTENSITY IS ADJUSTED TOO HIGH. THESE LINES WILL ALWAYS BE PRESENT BUT AT TIMES THEY ARE NOT AS NOTICEABLE AS AT OTHER TIMES. THEY ARE CAUSED BY FREE ELECTRONS BEING THROWN OFF FROM THE ENDS OF THE SECOND PATTERN THAT IS SOMETIMES EVIDENT AT THE LEFT SIDE OF THE SCREEN AND BEING TRIGGERED ACROSS THE SCREEN BY THE SYNCHRONIZING GENERATOR IMPULSES.



NORMAL PATTERN—FAST SWEEP
BOOSTER POINT FEED BACK

THIS PATTERN WILL BE NOTICED ON AUTOMATIC SPARK ADVANCE DISTRIBUTORS. CAUSE: THE GROUNDED CONDITION MARKED BY THE ARROW IS THE MOMENTARY PERIOD WHEN THE BOOSTER BREAKER POINTS ARE CLOSED DURING THE SAME PERIOD THE PRIMARY BREAKER POINTS THAT ARE FIRING THE SPARK PLUG ARE OPENED. THIS CONDITION CAUSES A MOMENTARY GROUND OF VARIOUS TIME DURATIONS. THE ACTIVITY FOLLOWING THIS CONDITION WILL TAKE MANY WAVEFORM VARIATIONS. THIS IS AN ACCEPTABLE CONDITION AND DOES NOT AFFECT ENGINE OPERATIONS.



NORMAL PATTERN—FAST SWEEP
LEAN MIXTURE

THE COMBUSTION HOOK DANCES BACK AND FORTH AS INDICATED BY THE ARROWS. THE HOOK ALSO INCREASES AND DECREASES IN HEIGHT FROM NORMAL. PROBABLE CAUSE: NORMAL INSTABILITY OF COMBUSTION WHEN OPERATING WITH EXTREMELY LEAN MIXTURES. NOTE: IF LOCALIZED TO ONE CYLINDER OR TO ONE ROW OF CYLINDERS, IT MIGHT INDICATE FUEL DISTRIBUTION FAULTS.

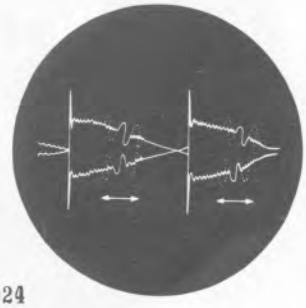


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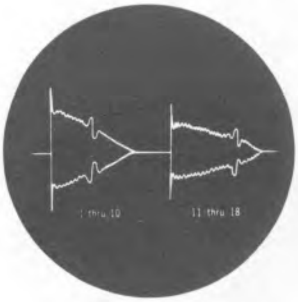
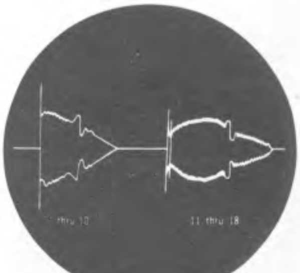
Figure 7-3 (Sheet 3 of 10)

IGNITION ANALYZER PATTERNS



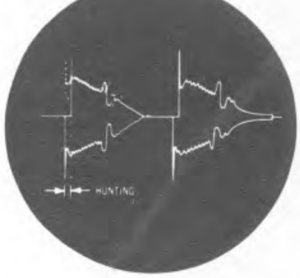
NORMAL PATTERN—FAST SWEEP
IGNITION ADVANCED

CYLINDERS WHICH ARE COMPENSATED TO FIRE EARLY (11 THROUGH 18) WILL HAVE LOWER INITIAL AMPLITUDE AND LONGER, FLATTENED ACTIVITY PERIOD DUE TO POINTS OPENING FROM 0^0 UP TO 4^0 BEFORE DESIGN E-GAP IN RETARD AND FROM 5^0 UP TO 9^0 BEFORE E-GAP IN ADVANCE. CYLINDERS WHICH ARE UNCOMPENSATED OR COMPENSATED TO FIRE LATE (CYLS. 1 THROUGH 10) WILL BE OBSERVED TO HAVE NORMAL AMPLITUDE DUE TO POINTS OPENING AT DESIGN E-GAP UP TO 4^0 LATE IN RETARD AND ONLY FROM 1^0 UP TO 5^0 EARLY IN ADVANCE. THE DIFFERENCE IN PATTERNS IS MORE PRONOUNCED IN THE ADVANCED CONDITION.



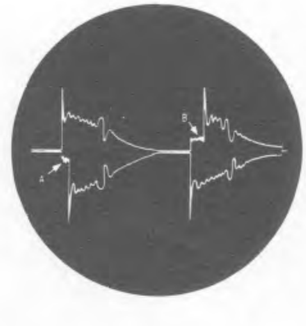
NORMAL PATTERN—FAST SWEEP
IGNITION ADVANCED

THIS IS AN EXAGGERATED CONDITION OF THE PATTERN ABOVE. IT SHOWS UP MORE FREQUENTLY ON CYLINDERS 11 THRU 18 WITH 14 BEING THE MOST OUTSTANDING. CAUSE: MAGNETO GENERATOR TIMED LATE WITH RESPECT TO BREAKER POINTS.



NORMAL PATTERN—FAST SWEEP
DRIVE TRAIN VARIATIONS

THIS CONDITION WILL BE RECOGNIZED BY A HORIZONTAL JITTER OR HUNTING BETWEEN THE POSITIVE AND NEGATIVE VOLTAGE RISES OF THE SAME PATTERN. THIS PATTERN IS THE RESULT OF ANGULAR HUNTING OF THE DISTRIBUTOR DRIVE TRAIN WITH RESPECT TO THE SYNCHRONIZING GENERATOR DRIVE. THIS IS CONSIDERED A NORMAL CHARACTERISTIC WHICH WILL BE FOUND TO VARY WITH THE INDIVIDUAL ENGINE.



NORMAL PATTERN—FAST SWEEP
BREAKER ARC

THIS CONDITION WILL BE RECOGNIZED BY INTERMITTENT ARCING OF A SHORT DURATION, SKIPPING ABOUT AT RANDOM FROM ONE PATTERN TO ANOTHER EVERY FEW SECONDS. THIS ARCING SEEMS TO HAVE NO PREFERENCE TO POSITIVE OR NEGATIVE IMPULSES OR POSITION (NOTE A AND B ABOVE). THE WRIGHT AERONAUTICAL DIVISION CONSIDERS THIS RANDOM ARCING OF SHORT DURATION TO BE AN ACCEPTABLE CONDITION AND SHOULD NOT BE CONSIDERED AS DETRIMENTAL TO ENGINE OPERATION UNTIL THE PHENOMENON BECOMES STEADY ON THE AFFECTED PAIR OR PAIRS OF BREAKER POINTS (SEE SHEET 7 NO. 2 PATTERN).

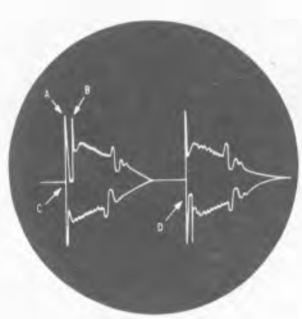
HG 05018
F66-0-7-3 (4)

Figure 7-3 (Sheet 4 of 10)

IGNITION ANALYZER PATTERNS

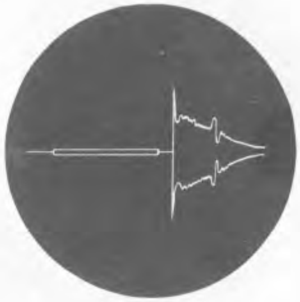
NORMAL PATTERN—FAST SWEEP
ABORTED PRIMARY INTERRUPTION

THE ABOVE REPRESENTED PATTERNS RESULT FROM ANY CAUSE WHICH INTERFERES WITH CLEAN AND SMOOTH INTERRUPTION OF THE PRIMARY CURRENT. OF THE THREE MOST COMMON CAUSES OF THIS CONDITION, ONE IS NORMAL AND THE OTHER TWO HARMFUL. THESE PATTERNS MAY BE RECOGNIZED BY THE RISE OF AN INITIAL EXCURSION (A) WHICH PRECEDES THE ACTUAL EXCURSION (B). THIS INITIAL OR FALSE PEAK MAY RETURN TO THE BASE LINE AS SHOWN AT (C) OR MAY IN SOME CASES BE BRIDGED TO THE ACTUAL EXCURSION BY A HORIZONTAL LINE WHICH IS SOMETIMES JAGGED IN APPEARANCE (D). PROBABLE CAUSES: 1. NORMAL—DRIVE TRAIN VARIATIONS (SEE SHEET 4 NO. 3 PATTERN). 2. HARMFUL—SPARK ADVANCE RELAY CHATTER (SEE SHEET 9 NO. 3 PATTERN). MAY BE SEEN INTERMITTENTLY ON ANY PATTERN AT ANY SPEED. USUALLY MOST PREVALENT AT HIGH RPM. OPERATE THE SPARK ADVANCE RELAY. IF TROUBLE DISAPPEARS RELAY PROBABLY DEFECTIVE. 3. HARMFUL—BREAKER CAM FOLLOWER BOUNCE (SEE SHEET 8 NO. 3 PATTERN). MOST OFTEN SEEN AT HIGH RPM. USUALLY CONFINED TO CERTAIN CAM LOBES (INDIVIDUAL CYLINDER PATTERN ONLY). NORMALLY DOES NOT SKIP AROUND. CAUSED BY IMPROPERLY ASSEMBLED BREAKER ASSEMBLY.



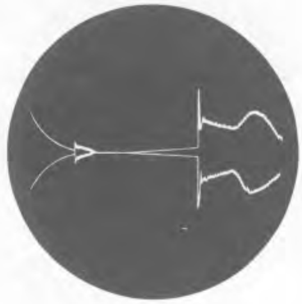
MALFUNCTION PATTERN—FAST SWEEP
SHORTED PRIMARY (DISTRIBUTOR TO COIL)

A SHORTED PRIMARY CIRCUIT BETWEEN THE DISTRIBUTOR AND CYLINDER MOUNTED COIL PRODUCES NO PATTERN FOR THE CYCLE SWITCH SELECTED SPARK PLUG POSITION; ONLY A SPLIT HORIZONTAL TRACE LINE WILL APPEAR. THE PATTERN WILL BE SEEN ONLY ON THE SELECTED CYLINDER POSITION, BUT THE PATTERN FOR THE NEXT CYLINDER TO BE FIRED BY THE SELECTED DISTRIBUTOR WILL GENERALLY BE DISTORTED BECAUSE OF THE REACTION OF THIS MALFUNCTION ON THE SYSTEM. PROBABLE CAUSES: A GROUND IN THE PRIMARY LEAD FROM THE DISTRIBUTOR TO THE CYLINDER MOUNTED COIL OR A SHORT IN THE PRIMARY WINDING OF THIS COIL.



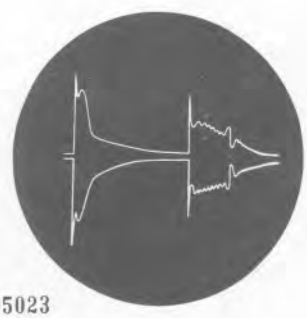
MALFUNCTION PATTERN—FAST SWEEP
OPEN PRIMARY (MAGNETO GENERATOR TO BREAKER POINTS)

EVERY OTHER PATTERN IS DIMINUTIVE WITH PATTERNS OF THE OTHER COIL HAVING A SUPER-IMPOSED HUMP IN THEM. PROBABLE CAUSES: 1. OPEN COIL IN MAGNETO GENERATOR. 2. A BROKEN SPRING IN THE DISTRIBUTOR HAT. 3. ANY OPEN BETWEEN THE MAGNETO AND BREAKER POINTS. 4. BROKEN DISTRIBUTOR BRUSH.



MALFUNCTION PATTERN—FAST SWEEP
FOULED PLUG—SECONDARY CIRCUIT BREAKDOWN

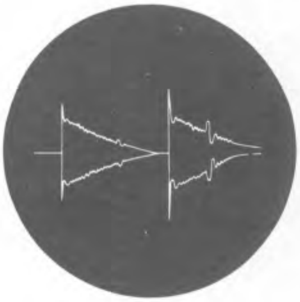
THE MOST CHARACTERISTIC DIFFERENCE NOTICED ABOUT THIS PATTERN, IS ITS CUPID'S BOW APPEARANCE. THE INITIAL PEAK VOLTAGE AMPLITUDE IS SLIGHTLY HIGHER THAN NORMAL. THIS EXCURSION HOWEVER, INSTEAD OF ABRUPTLY DROPPING AS IN A NORMAL PATTERN, INDICATES A SLIGHT OSCILLATION AND SLOPES DOWNWARD TO A POINT NEAR THE BASELINE, THEN SUDDENLY PROGRESSES TO THE RIGHT IN A LONG SLOPING TAIL UNTIL BREAKER POINT CLOSING. THERE IS NO INDICATION OF A HOOK. PROBABLE CAUSES: 1. LEADED, CARBON FOULED, OR OIL FOULED SPARK PLUG. 2. CRACKED PLUG CERAMIC. 3. DIRTY OR CRACKED CIGARETTE, OR ANY BREAKDOWN OF THE SECONDARY CIRCUIT. (MOST FREQUENTLY SEEN AT HIGH POWER SETTING WHEN BREAKDOWN IS MORE LIKELY TO OCCUR.) MOST LIKELY TO OCCUR AFTER EXTENDED GROUND RUNS. IN MOST CASES, SPARK PLUG CLEAN-OUT PROCEDURE WILL BRING THE PLUG BACK IN.



HG 05023
F66-0-7-3 (5)

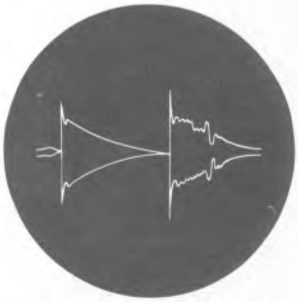
Figure 7-3 (Sheet 5 of 10)

IGNITION ANALYZER PATTERNS



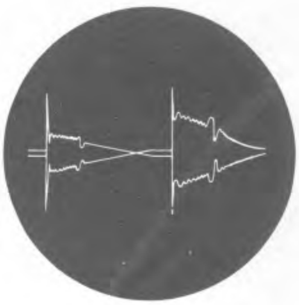
MALFUNCTION PATTERN—FASTSWEEP LOW RESISTANCE SECONDARY

THE INITIAL PEAK VOLTAGE AMPLITUDES ARE LESS THAN NORMAL. THERE MAY BE SOME OSCILLATION IN THE SLOPING PORTION, BUT THEY WILL BE SMALL IN AMPLITUDE AND OF A VERY MILD NATURE. THE SMALL OSCILLATION AT THE END OF THE PATTERN INDICATES THAT A SMALL OR INTERMITTENT SPARK EXISTS DURING THE BREAKER POINT OPENING PERIOD. THE ACTIVE PORTION OF THE PATTERN TENDS TO BECOME LONGER HORIZONTALLY THAN THE NORMAL PATTERNS. PROBABLE CAUSES: 1. NARROW SPARK PLUG GAP. 2. PLUG FOULING (LEAD CARBON OIL). 3. LOSS OF COMPRESSION. 4. SHORTED SECONDARY CIRCUIT. NOTE: IF THIS PATTERN APPEARS ON BOTH PLUGS OF ONE CYLINDER IT MAY MEAN A MECHANICAL FAILURE.



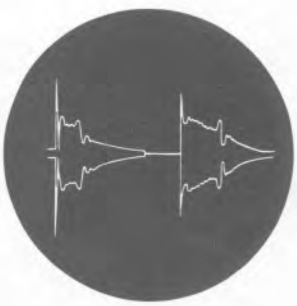
MALFUNCTION PATTERN—FAST SWEEP SHORTED SECONDARY

THE INITIAL PEAK VOLTAGE AMPLITUDE IS LESS THAN NORMAL. THIS EXCURSION DROPS SLIGHTLY THEN IMMEDIATELY EXTENDS IN A LONG SLOPE TO THE ZERO BASE LINE. THE LONG SLOPING LINE APPEARS STEADY AND WITHOUT OSCILLATION, SINCE THE CIRCUIT IS NOT DISSIPATING ENERGY IN THE PRESENCE OF COMBUSTION IONIZATION. PROBABLE CAUSES: 1. NARROW SPARK PLUG GAP. 2. PLUG FOULING (LEAD CARBON OIL). 3. LOSS OF COMPRESSION. 4. SHORTED SECONDARY CIRCUIT. 5. PEENED SPARK PLUG ELECTRODES. NOTE: IF THIS PATTERN APPEARS ON BOTH PLUGS OF ONE CYLINDER IT MAY MEAN A MECHANICAL FAILURE.



MALFUNCTION PATTERN—FAST SWEEP TWO DISTRIBUTOR SEGMENTS SHORTED TOGETHER

THE ACTIVITY PORTION OF THIS PATTERN IS EXTREMELY SMALL BECAUSE THE RATE OF ENERGY DISSIPATION IS DOUBLED BY THE TWO PARALLEL PATHS. THIS PATTERN WILL APPEAR ON TWO ALTERNATE FIRING IMPULSES SUCH AS 1 AND 5, 12 AND 16, ETC. PROBABLE CAUSE: TWO DISTRIBUTOR SEGMENTS SHORTED TOGETHER (CARBON DUST).



MALFUNCTION PATTERN—FAST SWEEP HIGH RESISTANCE SECONDARY CIRCUIT (FIRST STAGE)

THE INITIAL HIGH PEAK VOLTAGE IS HIGHER THAN NORMAL AND THIS FIRST EXCURSION RETURNS NEARER TO THE TRACE LINE. THE NEXT PORTION OF THE PATTERN, UP TO THE ABRUPT NEGATIVE SLOPE, IS QUITE NARROW AND APPEARS SQUARED OFF. THE REMAINDER OF THE PATTERN APPEARS QUITE NORMAL. PROBABLE CAUSES: 1. MISSING CIGARETTE SPRING. 2. HIGH RESISTANCE WITHIN THE PLUG. 3. LARGE SPARK PLUG GAP. 4. DIRTY SPARK PLUG CONTACT BUTTON. 5. ANY GAP IN THE SECONDARY CIRCUIT.

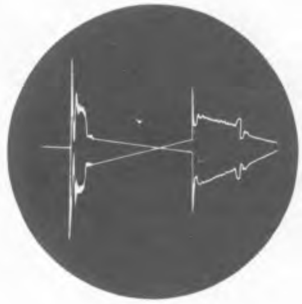
HG 05019
F66-0-7-3-(6)

Figure 7-3 (Sheet 6 of 10)

IGNITION ANALYZER PATTERNS

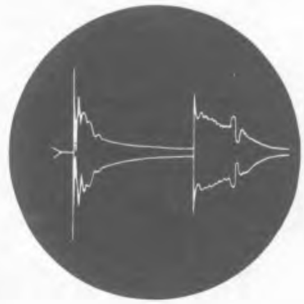
MALFUNCTION PATTERN—FAST SWEEP
HIGH RESISTANCE SECONDARY CIRCUIT (SECOND STAGE)

THE INITIAL HIGH PEAK VOLTAGE IS HIGHER THAN NORMAL AND THE FIRST EXCURSION RETURNS NEARER TO THE TRACE LINE. THE NEXT PORTION OF THE PATTERN REPRESENTS A VERY SHORT ACTIVITY PERIOD, IS QUITE NARROW AND APPEARS SQUARED OFF. BOTH AMPLITUDE AND ACTIVITY PERIODS ARE VERY STABLE. PROBABLE CAUSES: 1. MISSING CIGARETTE SPRING. 2. HIGH RESISTANCE WITHIN THE PLUG. 3. LARGE SPARK PLUG GAP. 4. DIRTY SPARK PLUG CONTACT BUTTON. 5. ANY GAP IN THE SECONDARY CIRCUIT.



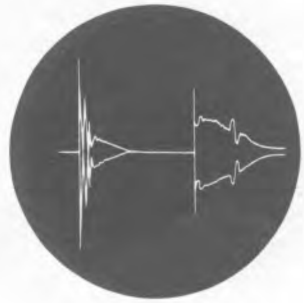
MALFUNCTION PATTERN—FAST SWEEP
HIGH RESISTANCE SECONDARY CIRCUIT (THIRD STAGE)

THE INITIAL HIGH PEAK VOLTAGE IS HIGHER THAN NORMAL AND THIS FIRST EXCURSION RETURNS TO A POINT AT THE BASE LINE AND SOMETIMES BEYOND IT. THE NEXT PORTION OF THE PATTERN IS EXTREMELY NARROW, FOLLOWED BY THE ABRUPT NEGATIVE SLOPE, SMALL OSCILLATION AND NORMAL SLOPING TAIL. PROBABLE CAUSES:
1. MISSING CIGARETTE SPRING. 2. HIGH RESISTANCE WITHIN THE PLUG.
3. LARGE SPARK PLUG GAP. 4. DIRTY SPARK PLUG CONTACT BUTTON. 5. ANY GAP IN THE SECONDARY CIRCUIT.



MALFUNCTION PATTERN—FAST SWEEP
OPEN SECONDARY CIRCUIT

THE INITIAL HIGH PEAK VOLTAGE IS HIGHER THAN NORMAL AND THIS FIRST EXCURSION RETURNS TO A POINT AT THE BASE LINE AND SOMEWHAT BEYOND IT. THE NEXT PORTION OF THE PATTERN IS EXTREMELY NARROW, FOLLOWED BY THE ABRUPT NEGATIVE SLOPE, SMALL OSCILLATION AND NORMAL SLOPING TAIL. PROBABLE CAUSES:
1. ABNORMALLY LARGE PLUG GAP. 2. AN OPEN WITHIN THE SPARK PLUG. 3. DISCONNECTED HIGH TENSION LEAD. 4. ANY OPEN IN THE HIGH TENSION CIRCUIT.
NOTE: WHEN HIGH TENSION LEAD IS DISCONNECTED AND THE EXPOSED TERMINAL IS CLOSE ENOUGH TO A CONNECTOR FOR A SPARK TO JUMP BETWEEN THE TWO, PATTERN WILL APPEAR MORE NORMAL OR WILL BE INTERMITTENT.



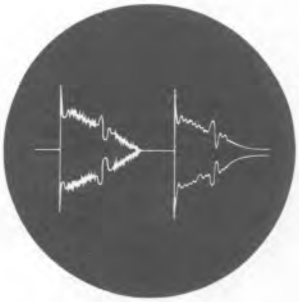
MALFUNCTION PATTERN—FAST SWEEP
OPEN PRIMARY (DISTRIBUTOR TO COIL)

THIS PATTERN PRODUCES A VERY HIGH INITIAL PEAK VOLTAGE. THIS PEAK IS HIGHER THAN ANY OTHER PATTERN, EXTENDING BEYOND THE LIMITS OF THE SCREEN. THIS EXCURSION IS FOLLOWED BY OSCILLATIONS OF LOW FREQUENCY, CENTERED ON THE BASE LINE AND EXTENDING IN A LONG LINE PARALLEL WITH THE HORIZONTAL TRACE UNTIL BREAKER POINTS CLOSE. PROBABLE CAUSE: AN OPEN IN THE LEAD FROM THE DISTRIBUTOR TO THE CYLINDER MOUNTED COIL OR IN THE PRIMARY WINDING OF THIS COIL.

HG 05025
F66-0-7-3 (7)

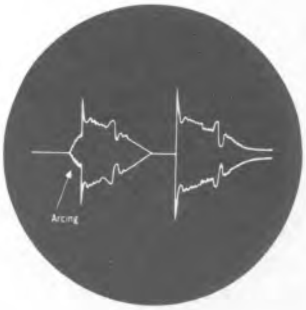
Figure 7-3 (Sheet 7 of 10)

IGNITION ANALYZER PATTERNS



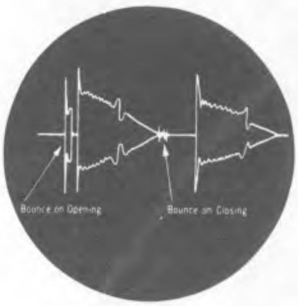
MALFUNCTION PATTERN—FAST SWEEP
ARCING DISTRIBUTOR BRUSH

THE PATTERN APPEARS NORMAL EXCEPT FOR THE PRESENCE OF SMALL JAGGED VARIATIONS APPEARING THROUGHOUT THE PATTERN FROM THE FIRST EXCURSION TO BREAKER POINT CLOSING. EARLY BRUSH ARCING APPEARS ON ONLY ONE OR A FEW POSITIONS. SEVERITY MAY VARY, BUT THE CONDITION IS ESPECIALLY NOTICEABLE AT ALTITUDE. THE MOST FREQUENT OCCURRENCE IS ON THE OUTER SEGMENT RING OR OUTER SLIP RING. PROBABLE CAUSES: 1. BURNED OR DIRTY DISTRIBUTOR SEGMENTS. 2. CONCAVE SEGMENT SURFACE CAUSING BRUSH TO HOP. 3. WEAK BRUSH SPRING. 4. FEATHERED SEGMENT EDGE. 5. EXCESSIVE DISTRIBUTOR VIBRATION MAY CAUSE THE BRUSHES TO ARC.



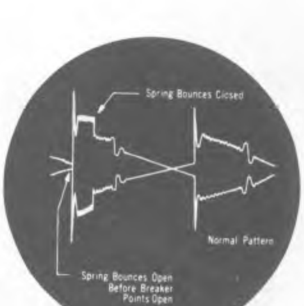
MALFUNCTION PATTERN—FAST SWEEP
ARCING BREAKER POINTS

AN EARLY STAGE OF ARCING BREAKER POINTS APPEARS AS A BRIGHT SPOT JUST AFTER BREAKER POINT OPENING INDICATED BY ARROW; A MORE SEVERE CONDITION IS ILLUSTRATED. THE ARC IS MAINTAINED UNTIL THE POINTS HAVE OPENED SUFFICIENTLY TO EXTINGUISH THE ARC, AT WHICH TIME PRIMARY COIL CURRENT FLOW CEASES, INDUCING A SURGE OF ENERGY INTO THE HIGH TENSION COIL. THE ACTIVITY IN THE HIGH TENSION COIL THEN BECOMES VISIBLE ON THE INDICATOR. SINCE A LARGE PERCENTAGE OF THE PRIMARY COIL ENERGY WAS DISSIPATED DURING ARCING, THE AMPLITUDE OF THE PATTERN IS NOT AS LARGE AS NORMAL. THE OSCILLATION AND DANCING HOOK INDICATES THAT THE SPARK PLUGS ARE BEING FIRED. ALL SPARK PLUGS FIRED BY THE AFFECTED BREAKER POINTS DISPLAY THIS PATTERN. PROBABLE CAUSES: 1. OIL ON BREAKER POINTS. 2. DEFECTIVE PRIMARY CONDENSER. 3. FOREIGN MATTER ON POINTS.



MALFUNCTION PATTERN—FAST SWEEP
BREAKER POINT BOUNCE

THIS PATTERN RESEMBLES THAT FOR MAGNETO BREAKER POINT MISTIMING. THE MARKED DIFFERENCE, HOWEVER, IS THE SHORT TRACE LINE SEPARATING THE TWO INITIAL HIGH AMPLITUDE OSCILLATIONS AND THE APPEARANCE OF THE PATTERN WITH THE CONDITION SWITCH SET FOR ONLY A SINGLE MAGNETO POSITION. BREAKER POINT BOUNCE MAY OCCUR BOTH BEFORE THE NORMAL BREAKER POINT OPENING AND AFTER THE NORMAL BREAKER POINT CLOSING. PROBABLE CAUSES: A WEAK BREAKER POINT SPRING OR DAMAGED CAM WITH ROUGH SPOTS ON IT. A WEAK SPRING SHOULD CAUSE BOUNCE ON ALL SPARK PLUG POSITIONS OF THE AFFECTED MAGNETO WHILE FOR A DAMAGED CAM THE BOUNCE SHOULD OCCUR ON ONLY ONE SPARK PLUG POSITION. NOTE: OCCASIONAL BOUNCE NOT SERIOUS UNLESS SPARK DISCHARGE AFFECTED.



MALFUNCTION PATTERN—FAST SWEEP
HIGH TENSION LEAD SPRING BOUNCE

JUMP IN AMPLITUDE OF PATTERN APPEARS WHEN SPRING BOUNCES OPEN CAUSING A SERIES GAP IN SECONDARY CIRCUIT. CAUSE: TOO SHORT OR TOO WEAK CIGARETTE SPRING ON HIGH TENSION LEAD. NOTE: IF THIS TYPE OF PATTERN APPEARS ON SEVERAL OR MORE CYLINDERS, IT MAY BE DUE TO IGNITION MISTIMING.

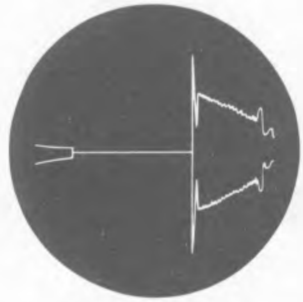
HG 05020
F66-0-7-3 (8)

Figure 7-3 (Sheet 8 of 10)

IGNITION ANALYZER PATTERNS

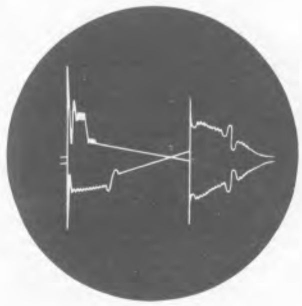
MALFUNCTION PATTERN– FAST SWEEP
OPEN MAGNETO GROUNDING CIRCUIT

EVERY OTHER PATTERN IS MISSING WITH THE NEXT ALTERNATE PATTERNS APPEARING MUCH HIGHER THAN NORMAL. CAUSE: AN OPEN GROUNDING LEAD BETWEEN THE MAGNETO AND THE MAG. SWITCH OR POSSIBLY AN OPEN ISOLATING RESISTOR IN THE ANALYZER IGNITION CIRCUIT.



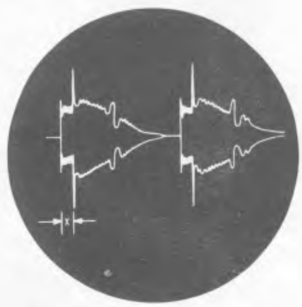
MALFUNCTION PATTERN–FAST SWEEP
RECTIFIER EFFECT OF UNEVEN SPARK PLUG EROSION

HALF OF THE PATTERN APPEARS AS A HIGH RESISTANCE SECONDARY WHILE THE OTHER HALF APPEARS TO BE NORMAL. PROBABLE CAUSE: THIS PATTERN IS CAUSED BY THE RECTIFIER EFFECT OF A SPARK PLUG WHICH HAS ITS CENTER ELECTRODE ERODED INTO A ROUND END AND ITS GROUND ELECTRODES ERODED TO A SHARP POINT. SINCE IT IS HARDER FOR A SPARK TO LEAVE A ROUND OBJECT THAN IT IS A SHARP OBJECT, IT TAKES MORE VOLTAGE TO PUSH THE ARC ACROSS FROM THE CENTER ELECTRODE THAN IT DOES IN THE OPPOSITE DIRECTION.



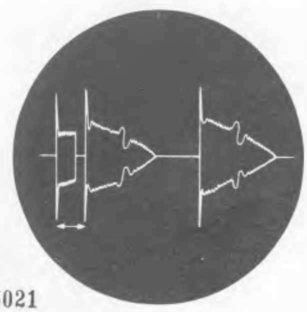
MALFUNCTION PATTERN–FAST SWEEP
BREAKER POINT NON SYNCHRONIZATION

NOTE: THIS CHECK IS MADE WITH THE CONDITION SWITCH SET ON BOTH. THE DISTANCE X CAN BE MEASURED TO DETERMINE THE NUMBER OF DEGREES OF UNSYNCHRONIZATION. IF ALL CYLINDERS SHOW APPROXIMATELY THE SAME AMOUNT OF UNSYNCHRONIZATION, THE TROUBLE LIES IN DISTRIBUTOR TO ENGINE TIMING. IF HOWEVER, ONLY THE ODD OR ONLY THE EVEN CYLINDERS SHOW UNSYNCHRONIZATION THEN THE INTERNAL DIST. TIMING IS AT FAULT. IF AN UNSYNCHRONIZATION OF 5^{0} (5/32") APPEARS FOR ONLY THE ADVANCE OR RETARD POSITION, THE ADVANCE MECHANISM OF ONE DISTRIBUTOR IS MALFUNCTIONING.



MALFUNCTION PATTERN–FAST SWEEP
DISTRIBUTOR ADVANCE RELAY CHATTERING (MANUAL ADVANCE ONLY)

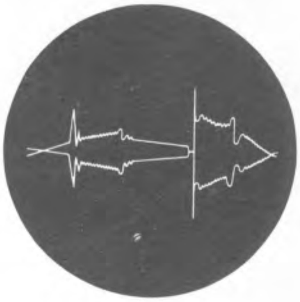
PATTERN SHIFTS BACK AND FORTH AND APPEARS TO BE FIRING AT BOTH ADVANCED AND RETARDED POSITION. IT MAY OCCUR ON ONE, TWO OR ANY NUMBER OF CYLINDERS, DEPENDING UPON VIBRATION CHARACTERISTICS OF THE ENGINE AT SOME PARTICULAR ENGINE POWER SETTING. PROBABLE CAUSE: BY THE POINTS OF THE ADVANCE RELAY CHATTERING AND MAKING INTERMITTENT CONTACT AND THUS INTERMITTENTLY REGROUNDING THE RETARD POINTS. NOTE: EASILY MISTAKEN FOR BREAKER POINT BOUNCE.



HG 05021
F66-0-7-3 (9)

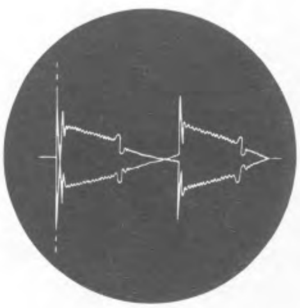
Figure 7-3 (Sheet 9 of 10)

IGNITION ANALYZER PATTERNS



MALFUNCTION PATTERN—FAST SWEEP
LATE DISTRIBUTOR FINGER TIMING

THIS MALFUNCTION APPEARS AS A LOW AMPLITUDE PATTERN WITH A SLANTED INITIAL RISE SOMETIMES LOOPING LIKE AN OPEN PRIMARY. ACTIVITY PERIOD BUILDS UP IN AMPLITUDE AS IT PROGRESSES. APPEARS ON CYLINDERS 13 AND 14 FIRST, SINCE THEY ARE COMPENSATED THE EARLIEST. PROBABLE CAUSES: DISTRIBUTOR INTERNAL MISTIMING, DAMAGED DISTRIBUTOR CAP POSITIONING PIN LOCATING SLOT.



MALFUNCTION PATTERN—FAST SWEEP
CHIPPED DISTRIBUTOR SEGMENT

THE PATTERN PRESENTATION IS CAUSED BY THE MOMENTARY "OPEN PRIMARY" WHEN THE BRUSH BOUNCES, AT THE SAME TIME THE POINTS OPEN. THEN THE BRUSH RETURNS TO THE SEGMENT, REESTABLISHING THE CIRCUIT, AND A NORMAL SECONDARY DISCHARGE OCCURS. IN THE ADVANCED STATE OF PITTING, THERE IS FREQUENTLY A NEARLY COMPLETE "OPEN PRIMARY" PATTERN, APPARENTLY SUPERIMPOSED ON A NORMAL PATTERN, AS THE CONDITION VARIES FROM CYCLE TO CYCLE. PROBABLE CAUSES: LATE FINGER TIMING CAUSES ARCING AT LEADING EDGE OF SEGMENTS LEADING TO PITTING OF THOSE SEGMENTS.

MALFUNCTION PATTERN—FAST SWEEP
NO COMBUSTION (IGNITION WITHOUT COMBUSTION)

THIS PATTERN HAS A SAWTOOTH APPEARANCE. THE AMPLITUDE OF THE SAWTEETH WILL INCREASE WITH INCREASING RPM. THE SAWTEETH MAY APPEAR MAINLY IN THE VICINITY OF THE 2ND HIGH FREQUENCY OSCILLATION POSITION IN THE PATTERN. PROBABLE CAUSE: FAULTY FUEL NOZZLE, FAULTY INJECTION PUMP, A LEAK IN A FUEL LINE, OR ANY MALFUNCTION CAUSING LOSS OF FUEL MIXTURES AND RESULTING IN NO COMBUSTION.

HG 05022
F66-0-7-3 (10)

Figure 7-3 (Sheet 10 of 10)

initiation of the trace is determined by the following factors:

a. Synchronizing generator timing.

b. Distributor timing.

c. Manual spark advance position.

d. Cam and/or cam compensation.

NOTE

Due to the open dwell used in this system (22 magneto degrees of 44 crankshaft degrees) the breaker point closing event is rarely visible, because No. 2 points will have opened prior to the closing of the No. 1 points. Split tail patterns are normal and are related to this effect.

Any change of total circuit resistance, which includes spark plug gap resistance, will affect the voltage requirements of the system. If the resistance is high, the voltage required will be high; if the resistance is low, the voltage required will be low. Extreme conditions will be indicated by patterns for open and short circuit conditions.

Synchronizing Generator Timing Check in Flight – Ignition Pattern Method. The following procedure represents a simple means of checking synchronizing generator timing to the correct cylinder in flight or during ground runup. It depends upon the fact that the interval between ignition of successive cylinders varies because of magneto cam compensation. For each engine-magneto combination the distance between patterns will be a maximum for No. 14 cylinder (approximately 1-1/2 inches) and a minimum for No. 5 cylinder (approximately 1-1/16 inches).

Procedure:

1. Set condition switch to desired engine on left or right distributor.

2. Set selector switch to No. 14 cylinder with push-pull button in FAST SWEEP.

3. Measure distance (it should be approximately 1-1/2 inches).

4. Set selector switch to No. 5 cylinder.

5. Measure distance (it should be approximately 1-1/16 inches).

With a little practice the operator should be able to determine in a very short time if the synchronizing generator is timed with reference to the correct cylinder.

OPERATING PROCEDURE.

NOTE

It is recommended that an ignition analysis be made during taxiing and during ground runup magneto check. A troubleshooting check with the ignition analyzer should be made during the climb to cruising altitude, and at least once an hour during cruising flight.

1. Turn on the amplifier power supply and allow it and the cathode ray tube to warm up.

2. Set the index on the inner dial of the condition switch to the L index (near the number 1) beneath the general caption IGNITION on the fixed ring.

3. Set the index labeled IGN on the inner dial of the cycle switch against the number 1 on the fixed ring. This setting, supplementing that of the condition switch, will present the pattern of No. 1 cylinder left magneto of No. 1 engine on the indicator, followed by the pattern of No. 12 cylinder, next in firing order.

NOTE

With the push-pull knob in the pulled-out position, in the above condition, the indicator will portray all the ignition patterns associated with the left magneto beginning with No. 1 cylinder. When the spark plug is fired on the negative pulse of the magneto, the major portion of the pattern will appear below the zero line, and when fired on the positive pulse, the major portion will appear above the zero line. This condition is apparent at low rpm only.

4. Push in the push-pull knob and set the index of the condition switch to B, near the numeral beneath the general caption IGNITION. Maintain IGN against 1 on the cycle switch. The pattern on the indicator will portray the functioning of both magnetos and both spark plugs for cylinders 1 and 12. This setting is used for checking magneto synchronization.

5. For study of the individual ignition patterns or all of the ignition patterns of engines 2, 3, or 4, the same settings of the cycle switch as for engine 1 are used, but the condition switch must be switched to L, B, and R adjacent to the numerals 2, 3, and 4, respectively.

6. For an engine speed synchronization check, set the dial index of the condition switch against the index 2 under the caption SYN on the fixed ring. This setting establishes

the electrical connection for the comparison of speed of engine 2 to that of engine 1. The push-pull knob should be in the pushed-in position. To compare the speeds of engines 3 and 4 to engine 1, set the dial index on the condition switch to 3 and 4 within the captioned SYN segment of the outer ring.

NOTE

When using the analyzer to synchronize the engine speed with a tachometer generator inoperative, a false on-speed condition can occur. Under certain rpm spreads (approximately 200 rpm) it may be noted that the analyzer indicates synchronization of a selected engine with No. 1 engine. This is a false condition and can be recognized by the distortion, or splitting of the patterns on the scope. Reference should be made to other basic instruments (i.e. fuel flow, MAP, BMEP) to aid in synchronization of affected engine. When making the engine synchronization check, the position of the cycle switch is of no importance.

ENGINE OIL TANK REPLENISHING.

NORMAL INFLIGHT ENGINE OIL TANK REPLENISHING PROCEDURE.

Operational procedures for adding oil to the engine oil tanks are as follows:

NOTE

During interior flight station check, the reserve oil transfer circuit breaker should be pushed in and the reserve oil tank heater switches turned ON.

1. Reserve oil tank selector switch – RIGHT or LEFT, as desired.

NOTE

The oil tank manifold line heater is protected by the left auxiliary oil tank heater circuit. In order to have heat available to the oil manifold tank line, use right tank first.

2. Rotate engine tank selector switch to tank requiring replenishing.

NOTE

In the event of hydraulic transfer pump failure, place pump selector switch to AUX (ELECT) position.

3. Place pump selector switch to NORMAL (HYD) position.

4. Press the start transfer button and check pump transferring light.

NOTE

- When the engine tank maximum quantity limit has been reached, the transferring operation will automatically stop, the pump transferring light will go out, and the pump evacuating light will glow for 60 seconds, indicating that the pump has reversed to evacuate the lines. If the engine tank is to be replenished but not filled to the maximum limit, press the stop transfer button when the fluid quantity reaches the desired amount.
- The minimum oil quantity remaining in the engine oil tanks necessary to maintain 65 pound oil pressure at 2600 rpm is shown on chart below:

Sea Level	15,000 feet	20,000 feet
7.3 gallons	7.6 gallons	10 gallons

Normally engine oil tank quantity is maintained above 150 pounds.

MANUAL ENGINE OIL TANK REPLENISHING PROCEDURE.

A manual reserve oil transfer procedure is provided for operation of the system in the event of electrical power failure. The sequence of steps is as follows:

CAUTION

Open the reserve oil system circuit breaker on the station 260 upper switch panel before operating the manual controls.

1. Rotate engine oil tank selector to END position, then return to OFF position.

2. Select engine oil tank by rotating the handle from OFF to the desired engine tank position. Do not rotate handle backward while selecting engine tank.

3. Rotate auxiliary oil tank handle to OPEN position.

4. Set hydraulic pump transfer handle to PUMP position. Time pump operation to determine quantity of oil to be transferred. Transfer rate is approximately 3 gallons per minute.

5. After the desired quantity of oil has been transferred, set pump transfer handle to EVACUATE position and allow pump to operate for approximately 60 seconds.

6. Return hydraulic pump transfer handle to OFF position.

7. Rotate auxiliary oil tank handle to CLOSED position, then return to NEUTRAL.

8. Rotate engine oil tank selector handle to END position, then return to OFF.

NOTE

For each engine oil tank replenished, the above procedure is to be followed.

9. When not in use, the handles must be in the following positions:

a. Engine oil tank selector – OFF.

b. Hydraulic pump transfer – OFF.

c. Auxiliary oil tank shutoff – NEUTRAL.

FUEL SYSTEM.

FUEL SYSTEM MANAGEMENT.

For normal long-range operation, all takeoffs are to be made with tanks 1, 2, 3, and 4 supplying fuel to their respective engines. All landings are to be made on tanks 1, 2A, 3A, and 4, Use of the Recommended Operational Fuel Loading chart (figure 7-4) for normal operation results in optimum fuel distribution. Minimum wing stresses result when this loading schedule is used in conjunction with the recommended fuel usage procedure. Minimum fuel load restrictions shown in Section V should be observed if deviations from the normal loading usage procedure are necessary. Improper fuel distribution due to unusual loading or usage procedures can, under some circumstances, result in the inability of the wing to withstand design load factors. See figure 7-4 for the proper fuel consumption sequence for various fuel quantities when the recommended operational fuel loading is followed. Use the tables by entering the column corresponding to gallons of fuel on board the aircraft at takeoff and completing the fuel usage procedures in numerical sequence as shown on the left side of the table. The various routes of fuel flow from the fuel tanks to the engines are also shown on the samples (figure 7-6).

Refueling.

During refueling operations, the following precautionary measures must be taken:

1. Ensure the aircraft is connected to ground.

2. Assign a crewmember to prevent smoking in the aircraft or in the vicinity until refueling is completed.

3. Loading ramps or stairways must be in position at the entrances and the doors must be kept open.

4. During daytime refueling, the cart battery and the ship battery switches must be turned OFF.

5. During night refueling, the ship battery switch may be left on to provide cabin lighting. The exterior lights switch may either be turned OFF or left in the STEADY position, if required by the airport. All radio equipment, inverters, motors, and similar electrical equipment must be off. No switches are to be operated after refueling starts.

6. The auxiliary ground power source must be shut down and moved clear of the aircraft unless it is explosion-proof.

Auxiliary Fuel Pump Operation.

Each fuel tank contains an electrically operated, submerged, fuel booster pump, which supplies relatively vapor-free fuel under pressure to the engine-driven fuel pumps so that engine operation is not affected by vapor or trapped air. The HIGH position is used during takeoff and landing, to supply fuel under pressure in the event of engine-driven fuel pump failures, or where the LOW position cannot maintain sufficient pressure. The LOW position is used during climb, cruise, and descent.

Crossfeed Operation.

When going to crossfeed operation, it is recommended that the fuel booster pump of the tank to supply the fuel be turned to HIGH. After crossfeed operation has been established, the fuel booster pump of this tank will be returned to the LOW position, provided fuel pressure is maintained within limits.

CAUTION

Do not place the switches for tanks 6R and 6L in HIGH position except during fuel dumping. In the event of a float valve malfunction in tanks 1 and 4, the HIGH position will deliver pressure to tanks 1 and 4 in excess of their design limitations.

NOTE

During crossfeed when fuel in tank being emptied reaches 1000 pounds, boost pump should be turned on HIGH and backup tank fuel pump turned on LOW.

No more than two crossfeed valves should be open at one time to prevent power loss on all engines due to ruptured fuel line.

FUEL LEAKS.

Inspecting and Recording Leaks.

Careful inspection in a well-lighted area is of prime importance. It is particularly important to inspect carefully for seeps and leaks in confined areas, such as forward of the front spar, aft of the rear spar, and in the nacelles. Care and judgment will ensure that old stains and leaks that have been fixed, are not recorded. If there is doubt of whether a stain actually indicates the presence of a leak, the stain should be wiped off and the area observed for a time to see if fuel reappears.

CAUTION

Leaks in certain areas can be potential fire hazards. Give special attention to areas in the vicinity of the nacelles, wing-to-fuselage fillets, and navigation lights in the wing-tip tanks. Also watch places where vapor from fuel leaks may be trapped, such as in the nacelles, liferaft compartments or wing-to-fuselage fillets where the heaters are situated.

Types of Leaks.

1. Stain: The mildest kind of leak is the stain. This is a discoloration around fasteners or seams caused by very slow fuel seepage which dries as it meets the open air. A stain should be wiped off, and if it does not reappear within 1 hour, it should merely be recorded and periodically inspected.

2. Seep: A seep is a heavy stain which, when wiped off with a rag, reappears within 1 hour. This type of leak should be inspected frequently for increased activity.

3. Heavy Seep: Seepage that increases to the point where it reappears immediately after being wiped off is defined as a heavy seep.

4. Dripping Leak: This is a continuous fuel leak which wets a limited area and then drips off the aircraft.

5. Running Leak: This is a continuous running of fuel caused by a definite break in the sealant and the source is usually easy to locate.

Types of Leaks and Recommended Action.

The following table may be used as a guide to determine the remedial action required when any type of leak occurs in various locations in the wing.

FUEL LEAK LOCATION	ACTION REQUIRED				
	Stain	Seep	Heavy Seep	Dripping Leak	Running Leak
Open areas, upper and lower surfaces	A	A	B	D	D
Face of forward beam (except inside nacelles)	A	B	B	D	D
Face of rear beam (except inside nacelles)	A	B	B	D	D
Inside nacelles, including beam faces, but excluding corrugations in top of wheel well	A	B	B	D	D
Between WS 450.5 and 480	A	B	B	D	D
Internal leakage between tanks	A	A	A	D	D
Under deicer boots on wing outer section leading edge	C	C	C	D	D
Corrugations in top of wheel well	A	B	B	D	D
Center section cell drain tubes	–	–	–	E-1	D
Corrugation drain outlet tubes	–	–	–	E-1	D

Continued –

RECOMMENDED OPERATIONAL FUEL LOADING

For Normal Operation With Tip Tanks Installed

FUEL DENSITY: 6.0 LB/US GAL

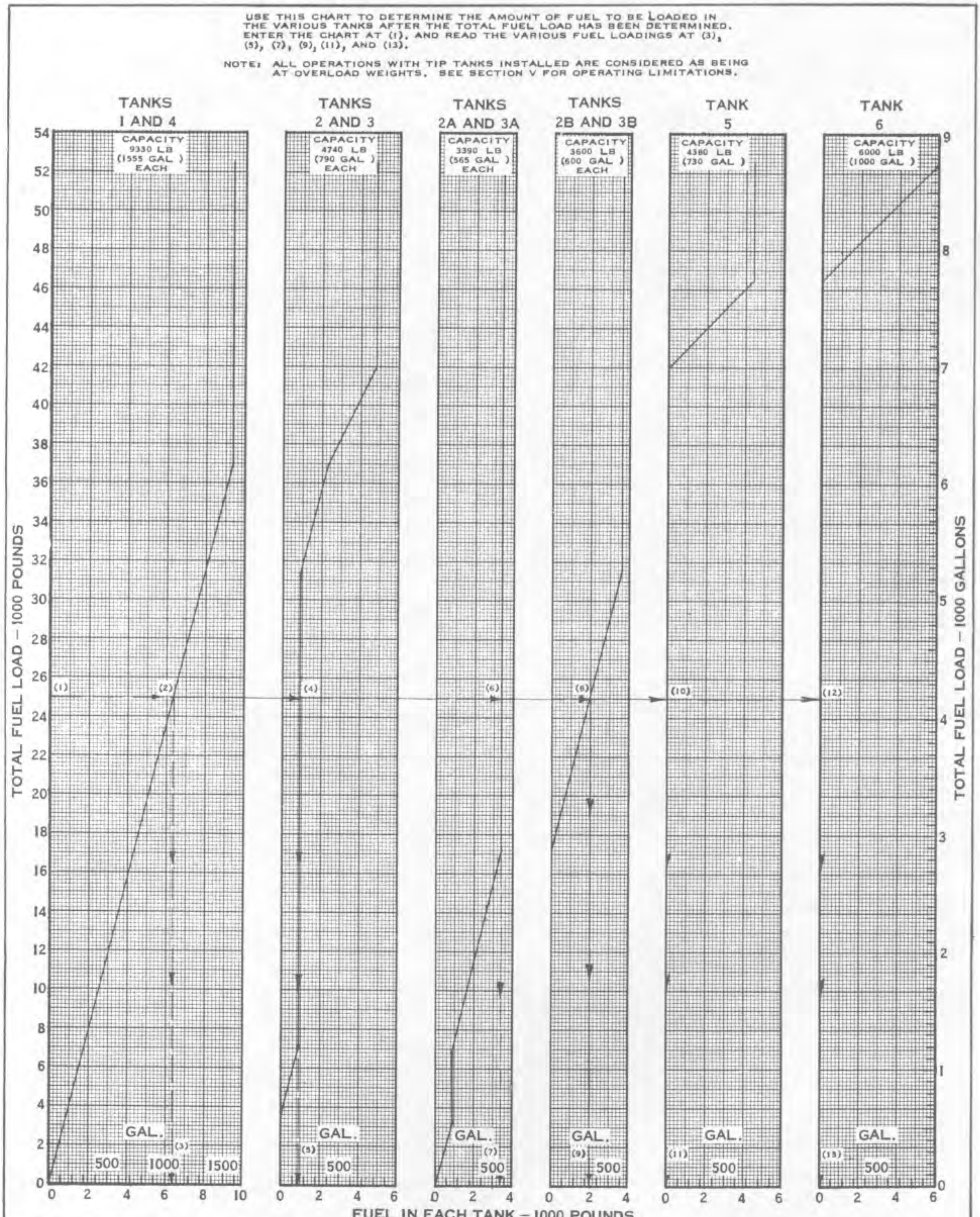


Figure 7-4 (Sheet 1 of 2)

RECOMMENDED FUEL LOADING TABLE

WING TIP TANKS ON

FUEL DENSITY: 6.0 LB/US GAL

TOTAL FUEL GALLONS	QUANTITY PER TANK — GALLONS					
	2B & 3B	2A & 3A	1 & 4	2 & 3	5	6
2000	0	350	500	150	0	0
2200	0	400	550	150	0	0
2400	0	450	600	150	0	0
2600	0	500	650	150	0	0
2800	0	550	700	150	0	0
2860	0	565*	715	150	0	0
3000	35	565*	750	150	0	0
3200	85	565*	800	150	0	0
3400	135	565*	850	150	0	0
3600	185	565*	900	150	0	0
3800	235	565*	950	150	0	0
4000	285	565*	1000	150	0	0
4200	335	565*	1050	150	0	0
4400	385	565*	1100	150	0	0
4600	435	565*	1150	150	0	0
4800	485	565*	1200	150	0	0
5000	535	565*	1250	150	0	0
5200	585	565*	1300	150	0	0
5260	600*	565*	1315	150	0	0
5400	600*	565*	1350	185	0	0
5600	600*	565*	1400	235	0	0
5800	600*	565*	1450	285	0	0
6000	600*	565*	1500	335	0	0
6200	600*	565*	1550	385	0	0
6220	600*	565*	1555*	390	0	0
6400	600*	565*	1555*	480	0	0
6600	600*	565*	1555*	580	0	0
6800	600*	565*	1555*	680	0	0
7000	600*	565*	1555*	780	0	0
7020	600*	565*	1555*	790*	0	0
7200	600*	565*	1555*	790*	180	0
7400	600*	565*	1555*	790*	380	0
7600	600*	565*	1555*	790*	580	0
7750	600*	565*	1555*	790*	730*	0
7800	600*	565*	1555*	790*	730*	50
8000	600*	565*	1555*	790*	730*	250
8200	600*	565*	1555*	790*	730*	450
8400	600*	565*	1555*	790*	730*	650
8600	600*	565*	1555*	790*	730*	850
8750	600*	565*	1555*	790*	730*	1000*

* Tanks full.

Figure 7-4 (Sheet 2 of 2)

FUEL DENSITY VS. FUEL TEMPERATURE

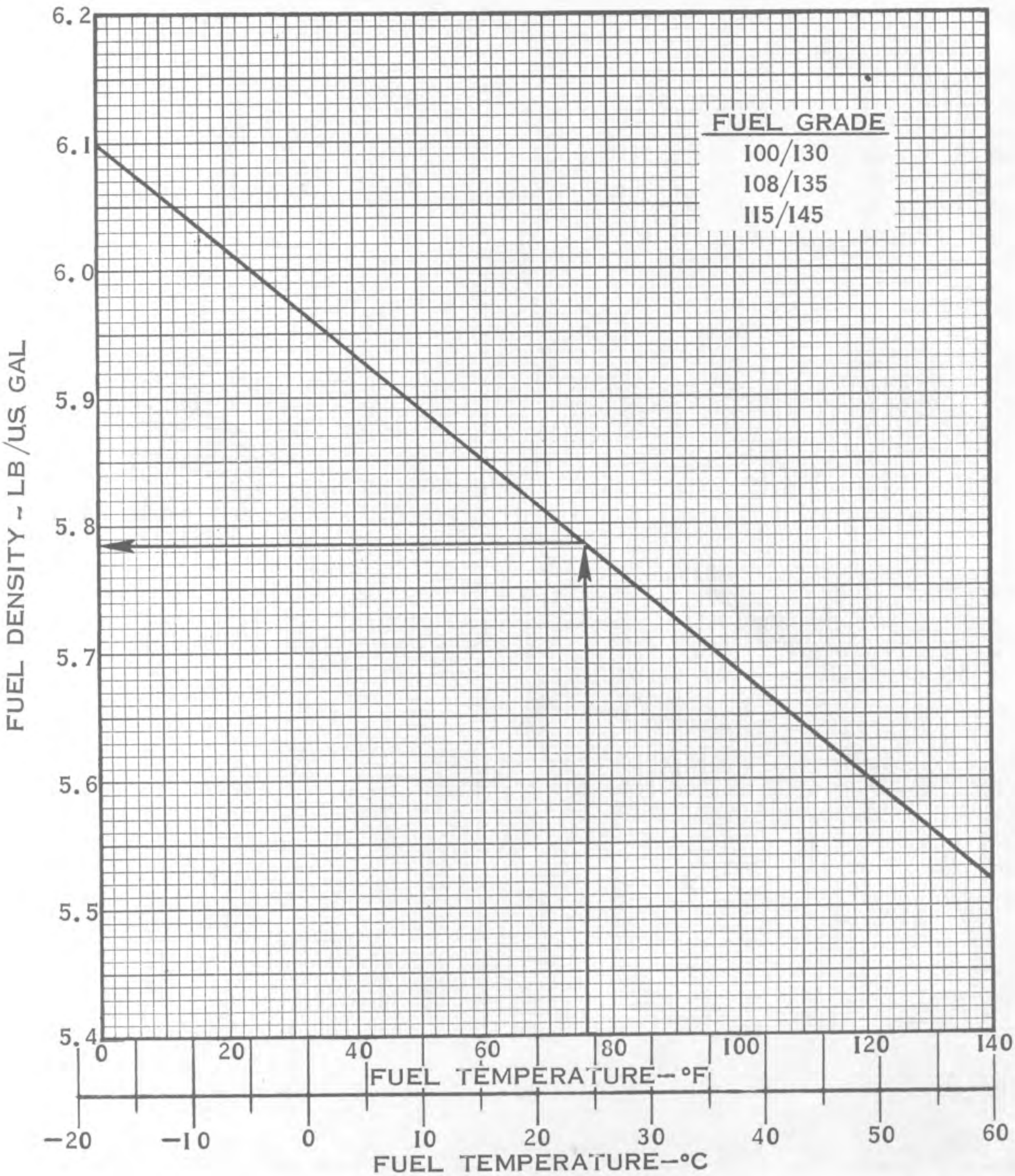


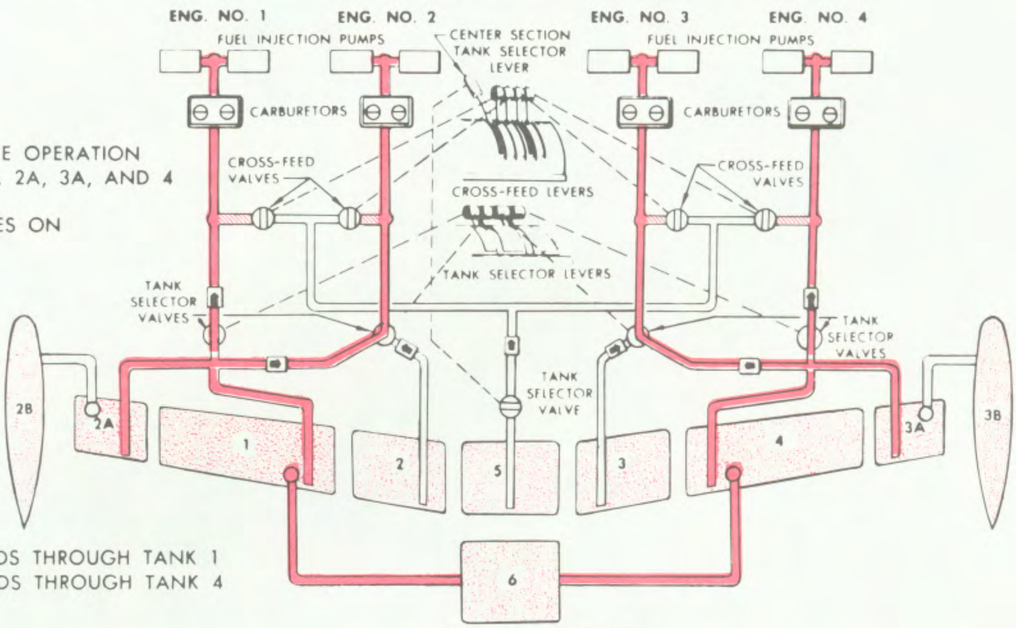
Figure 7-5

FUEL SYSTEM MANAGEMENT-TIP TANKS ON

TIP TANKS ON

SEQUENCE — INITIAL FUEL IN GAL: 8750 TO 8480	8480	8480 TO 7750	7750 TO 7020	7020 TO 6220	6220 TO 5260	5260 TO 2860	2860 TO 1200		ENGINE 1 — FUEL TANK	ENGINE 2 — FUEL TANK	ENGINE 3 — FUEL TANK	ENGINE 4 — FUEL TANK	FUEL USAGE PROCEDURES
1	1	1	1	1	1	1	1	TAKE OFF AND CLIMB	1	2	3	4	TAKE OFF AND CLIMB, USING NOT MORE THAN 150 GAL / TANK
2								EMPTY FUSELAGE TANKS	6[1]	5	5	6[2]	UNTIL TANK 5 IS EMPTY
	2								6	5	5	6	UNTIL TANKS 5 & 6 ARE EMPTY
		2							6	5	5	6	UNTIL TANK 6 IS EMPTY
3									6	2	3	6	UNTIL TANK 6 IS EMPTY
		3	2						5	2	3	5	UNTIL TANK 5 IS EMPTY
4	3	4	3	2				CROSS FEED	2	2	3	4	UNTIL TANK 1 = TANKS 2 + 2A + 2B
5	4	5	4	3					1	2	3	3	UNTIL TANK 4 = TANKS 3 + 3A + 3B
6	5	6	5	4	2			CRUISE	1	2	3	4	UNTIL TANKS 2 & 3 ARE EMPTY
7	6	7	6	5	3	2			1	2B	3B	4	UNTIL TANKS 2B & 3B ARE EMPTY
8	7	8	7	6	4	3	2	END FLIGHT AND LAND	1	2A	3A	4	REMAINDER OF FLIGHT AND LANDING

The cross-feed operation is shown immediately after fuel in tank 5 is exhausted, which is the most critical time from structural considerations. However, it may be done at any operationally desirable time after the fuel in tank 5 has been used, provided it is complete by the time that tanks 2 and 3 become empty.
This fuel management procedure affords optimum utilization of wing strength.



TANK-TO-ENGINE OPERATION FROM TANKS 1, 2A, 3A, AND 4

BOOST SWITCHES ON 1, 2A, 3A, & 4

[1] TANK 6 FEEDS THROUGH TANK 1
[2] TANK 6 FEEDS THROUGH TANK 4

FUEL FLOW

STATIC FUEL

HOW TO USE TABLE:

(a) ENTER THE INITIAL FUEL COLUMN AT LEFT AND TOP CORRESPONDING TO FUEL LOAD AND READ DOWN TO NO. 1.
(b) READ THE PROCEDURE AT THE RIGHT OF NO. 1 (FUEL TANK) AND ADJUST THE FUEL FEED AS SHOWN.
(c) CONTINUE FEED UNTIL INSTRUCTIONS OF THE FUEL USAGE COLUMN ARE COMPLETED.
(d) RETURN TO ORIGINALLY SELECTED VERTICAL COLUMN AND COMPLETE FUEL USAGE PROCEDURE IN NUMERICAL SEQUENCE AS SHOWN.

F66-0-7-6

Figure 7-6 (Sheet 1 of 2)

OPERATIONAL FUEL SYSTEM MANAGEMENT ECM EQUIPMENT INSTALLED IN "M" COMPT.

NOTE

- During crossfeed when fuel in tank being emptied reaches 1,000 lbs., boost pump should be turned on high and back-up tank fuel pump turned on low.
- No more than two crossfeed valves should be open at one time to prevent power loss on all engines due to ruptured fuel line.
- When landing is planned for 3,600 lbs., or less, tanks 2B, 2, 3, 3B, 5 and 6 must be emptied to have sufficient fuel in tanks 1, 2A, 3A and 4.
- These procedures are recommended to insure proper wing loading throughout flight.

	Fuel Tank 1	Fuel Tank 2	Fuel Tank 3	Fuel Tank 4	EC-121R Fuel Usage Procedures
Takeoff and Climb	1	2	3	4	Takeoff and climb, using not more than 150 Gal/Tank.
	6	5	5	6	Unit tanks 5 and 6 are 300 lbs.
Cruise Crossfeed	6	5	5	6	Unit tanks 5 and 6 are 300 lbs.
	6	2	3	4	Until tank 1 = tanks 2 + 2A + 2B
	1	2	3	3	Until tank 4 = tanks 3 + 3A + 3B
	1	2	3	4	Until tanks 2 and 3 are 1,000 lbs.
	1	2	2	4	Until tank 2 is 300 lbs.
	1	3	3	4	Until tank 3 is 300 lbs.
	1	2B	3B	4	Until tanks 2B and 3B are 200 lbs.
End Flight and Land	1	2A	3A	4	Remainder of Flight and Landing.

OPERATIONAL FUEL SYSTEM MANAGEMENT NO ECM INSTALLED IN "M" COMPT. FUEL IN TANK NO. 6 FOR BALLAST

NOTE

- During crossfeed when fuel in tank being emptied reaches 1,000 lbs., boost pump should be turned on high and back-up tank fuel pump turned on low.
- No more than two crossfeed valves should be open at one time to prevent power loss on all engines due to ruptured fuel line.
- When landing is planned for 3,600 lbs., or less, tanks 2B, 2, 3, 3B, 5 and 6 must be emptied, to have sufficient fuel in tanks 1, 2A, 3A, and 4. Weight and/or crew will have to be moved aft to "L", "M", or "N" compt for landing CG to be within forward limits with boost "on" or "off".
- These procedures are recommended to insure proper wing loading throughout flight.

	Fuel Tank 1	Fuel Tank 2	Fuel Tank 3	Fuel Tank 4	EC-121R Fuel Usage Procedures
Takeoff and Climb	1	2	3	4	Takeoff and climb, using not more than 150 Gal/Tank.
	5	2	3	5	Until tank 5 is 300 lbs.
Cruise Crossfeed	5	2	3	5	Until tank 5 is 300 lbs.
	6	2	3	6	Until tank 6 is 3,000 lbs.
	2	2	3	4	Until tank 1 = tanks 2 + 2A + 2B
	1	2	3	3	Until tank 4 = tanks 3 + 3A + 3B
	1	2	3	4	Until tanks 2 and 3 are 1,000 lbs.
	1	2	2	4	Until tank 2 is 300 lbs.
	1	3	3	4	Until tank 3 is 300 lbs.
	1	2B	3B	4	Until tanks 2B and 3B are 200 lbs.
End Flight and Land	1	2A	3A	4	Remainder of Flight and Landing.

Figure 7-6 (Sheet 2 of 2)

FUEL LEAK LOCATION	ACTION REQUIRED				
	Stain	Seep	Heavy Seep	Dripping Leak	Running Leak
Corrugation drain at WS 80	–	–	–	E-3	D
Cabin heater solenoid and filter drains	–	–	–	E-2	D
Fuel sump (remote control) drains	–	–	–	E-2	D
Fuel booster pump drains	–	–	–	E-3	D
Fuel dump valves, heater areas, fuel pressure lines and fittings	D	D	D	D	D
Wing-tip tank surfaces	A	B	B	D	D
Inside wing-to-fuselage fillets	D	D	D	D	D

Legend:

A. Clean surface; inspect frequently to ensure that leakage does not increase.

B. Make temporary repair as described in paragraph 2-78, Structural Repair Manual, and repair at next scheduled inspection period or when aircraft is grounded for other maintenance.

C. Repairs to fuel leaks under deicer boots can only be made by peeling back that portion of the boot covering the affected area. Good judgment must be used to determine whether leakage is of sufficient magnitude to require immediate repair. Replace deicer boot according to instructions in Maintenance Manual.

D. Make a permanent repair as described in the Structural Repair Manual.

E. Maximum leakage is permitted as indicated below. Determine leak source and repair at next scheduled inspection, or when aircraft is grounded for other maintenance.

1. 50 drops per minute.
2. 25 drops per minute.
3. 10 drops per minute

NOTE

If leaks are in excess of above limits, refer to maintenance manual.

FILLING MAIN OR EMERGENCY HYDRAULIC RESERVOIR IN FLIGHT

Emergency hydraulic fluid may be used to replenish either the main hydraulic reservoir or the emergency extension and brake reservoir by the following method:

1. Attach the emergency fluid hose to the capped line.
2. Set hydraulic reservoir selector to reservoir to be replenished.
3. Operate hydraulic reservoir filler wobble pump handle.

NOTE

If fluid fails to flow, the pump requires bleeding. Proceed as follows:

a. Pump bleed valve – OPEN.

b. Disperse air in the pump by operating handle until fluid flows from the bleed port.

c. Pump bleed valve – CLOSED.

USE OF LANDING WHEEL BRAKES.

In order that brakes can be used as little and as lightly as possible, take full advantage of the length of the runway utilizing aerodynamic braking to stop the airplane. To minimize brake wear, the precautions discussed in the following paragraphs shall be observed insofar as is practicable.

BRAKE OPERATION AT TOUCHDOWN.

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

MINIMUM ROLL LANDINGS.

If maximum wheel braking is required, lift should be decreased as much as possible by lowering the nose gear and raising the flaps before applying brakes. This procedure will improve braking action since the load on the tires will be increased, thus increasing the friction force between the tires and the runway. Reverse pitch propellers should be used whenever possible in lieu of wheel braking.

OPTIMUM BRAKING ACTION.

After touchdown when the nosewheel has contacted the runway, a single smooth application of the brakes with constantly increasing pedal pressure will result in optimum braking. This procedure will provide the shortest stopping distance possible from braking action.

BRAKE COOLING.

During a series of successive landings, a minimum of 15 minutes should elapse between landings where the landing gear remains in the slipstream, and a minimum of 30 minutes between landings with the landing gear retracted, to allow adequate cooling time between brake applications. This time restriction is not applicable to touch-and-go type landings when no brake application is involved. The brakes should not be dragged while taxiing, and should be used as little as possible for turning the aircraft on the ground. At the first indication of brake malfunction, or if brakes are suspected to be in an overheated condition after excessive use, the aircraft should be maneuvered off the active runway and stopped. The aircraft should not be taxied into a crowded parking area and the parking brakes should not be set. Overheated wheels and brakes must be cooled before the aircraft is subsequently towed or taxied. Peak temperatures in the wheel and brake assembly are not attained until some time after a maximum braking operation is completed (the time may vary from 5 to 60 minutes). In extreme cases heat buildup can cause the wheel and tire to fail with explosive force or be destroyed by fire if proper cooling is not effected. Taxiing at low speeds to obtain air cooling of overheated brakes will not reduce temperatures adequately and can actually cause additional heat buildup; therefore this procedure is not recommended.

NOTE

> The time required to reach peak temperatures is dependent upon various factors, such as the severity of the maximum braking operation and wheel and brake assembly installation in different aircraft.

SYNCHRONIZER OPERATION.

With the stepmotor electric-head system, the governor speed setting is controlled by the operation of a commutator switch which energizes the multiple-field stepmotor in the head, and changes the adjustment of the speeder spring by a gear train and track. These commutating switches are driven by three-phase differential motors which are driven by the airplane engines. The output of the propeller synchronizer generator on the master engine is fed into the fields of each of the three differential motors, and the output of each of the propeller synchronizer slave generators, is fed into the armature of a corresponding differential motor. Thus, the frequency of the voltage from each of the "slave" generators is continually compared with that of the master propeller synchronizer generator, through the medium of the differential motor and its associated commutator switch. This rotation produces a change in the setting of the governor speeder spring, through operation of the stepmotor head, and direction of change is such that speed of the slave engine (as characterized by the frequency of the propeller synchronizer generator output) is altered until synchronism with master engine results. A mechanical device on the connection between each differential motor and commutator switch limits the synchronization within three percent of the master engine speed. However, a decrease in speed or even failure of the master engine cannot drag the speed of the slave engine down more than three percent.

Individual adjustment of governor speed setting is obtained through the use of double-throw toggle switches at the flight engineer's lower switch panel. Operation of each toggle switch disconnects the differential motor commutator switch from the stepmotor head, and substitutes commutator switches driven by the non-reversible dc motor. Reversal of the stepmotor rotation by the toggle switch results from the reversal of two of the three leads to the stepmotor. The dc motor drives four commutator switches, one for each stepmotor head. Any toggle switch, by relay action, connects its head to its commutator switch and starts the motor so that any number of heads may be adjusted simultaneously. The toggle switches override both the synchronizer and the master lever control. Master lever control of all units simultaneously is achieved through the adjustment of a cable control to the synchronizer box. The master control consists of an off-seeking, reversible followup element which is driven through a clutch by the reversible dc motor and commutator switch combination. Movement of the master element toward INCREASE or DECREASE speed position, energizes the motor which will drive the followup element in the proper direction so that the mechanism will resume the OFF position. At the same time, relays disconnect all stepmotor heads from the differential motor commutator switches and connect them to the commutator switch driven by the reversible motor energizing all four governor head stepmotors to adjust the speed setting in the direction of and proportional to the master element movement. Synchronization is momentarily cut out during the brief initial movement and followup period. When the master control is advanced to takeoff rpm position, all governors are set to their positive high-speed stops regardless of their initial settings and the synchronizing features are cut out so failure of the master engine on takeoff would have no effect upon the slave engine. When the resynchronize push-button is pressed and released it will allow each slave engine stepmotor head to move 3 percent of the speed of the slave governor toward synchronization with the master engine. It may be necessary to press the push-button several times to get synchronization, if any engine is operating outside the 3 percent range. It is usually more convenient to approach synchronization by means of the individual toggle switches on each engine before using the resynchronize button.