Chapter Ten

FLIGHT OPERATION

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Approved flight operation instructions are given in the relevant aircraft Flight Manual. This chapter contains the engine manufacturer's recommendations for flight operation of the engine, and is intended, primarily, for the information of ground personnel; pilots must refer to the specific instructions issued in connection with individual aircraft. These instructions are applicable to both the Ghost 48 Mk. 1 and 48 Mk. 2; where information is applicable to one mark of engine only, this is indicated in the text.

The Operating Limitations must be observed strictly at all times. At all engine speeds, a frequent check should be made to ensure that the jet temperature and r.p.m. are within the limits; so that, if necessary, suitable remedial action can be taken as quickly as possible. These limitations represent the maximum conditions which may be used in flight and are not necessarily those which should be used for normal routine operation; greater reliability and longer engine life will be obtained by operating at ratings lower than the limiting maxima.

During flight, the maximum permissible jet temperature and r.p.m. may not be attained concurrently, and it is essential that the engine be throttled back, as necessary, so that neither limit is exceeded. Day-to-day changes in the ambient temperature and barometric pressure affect the engine and these day-to-day changes, coupled with errors in the engine speed and jet temperature indicating equipment, and variations in the specific gravity of the fuel, cause the apparent variations in engine behaviour on different days, and between engines installed in different aircraft.

Chapter 5 describes the precautions which must be observed whilst on the ground, and, under the heading 'General Operation' on page 5, gives brief details of typical controls and instruments, and the general handling procedure; from reference to the latter information, it will be understood that coarse movement of the throttle, which will produce excessive temperatures in the engine during acceleration, must be avoided.

PERFORMANCE

When the engine is being flown in an aircraft having a forward-facing air-intake, it can be said, broadly, that the energy of the air entering the compressor is increased by an amount equivalent to the kinetic energy of the free air stream relative to the aircraft. This effect may be regarded as a pre-compressor feeding the main compressor; its efficiency depending upon the design of the aircraft air-intake ducting. The pressure rise resulting from this 'ram' effect increases all pressures throughout the engine and, therefore, also increases the expansion ratio between the turbine entry and the final discharge to atmosphere. Thus the energy of the efflux per unit of mass discharge is increased. In addition, the higher pressure ahead of the engine results in an increased air mass flow which is dependent upon the characteristics of the engine and its capacity to handle this greater flow efficiently. The curves shown in Fig. 1 are based on results obtained during flight trials of Ghost engines installed in various types of aircraft, and illustrate the variation in thrust with forward speed and the increased thrust, due to 'ram' effect, at forward speeds above about 300 m.p.h. (260 knots) at sea level and 200 m.p.h. (174 knots) at altitude.

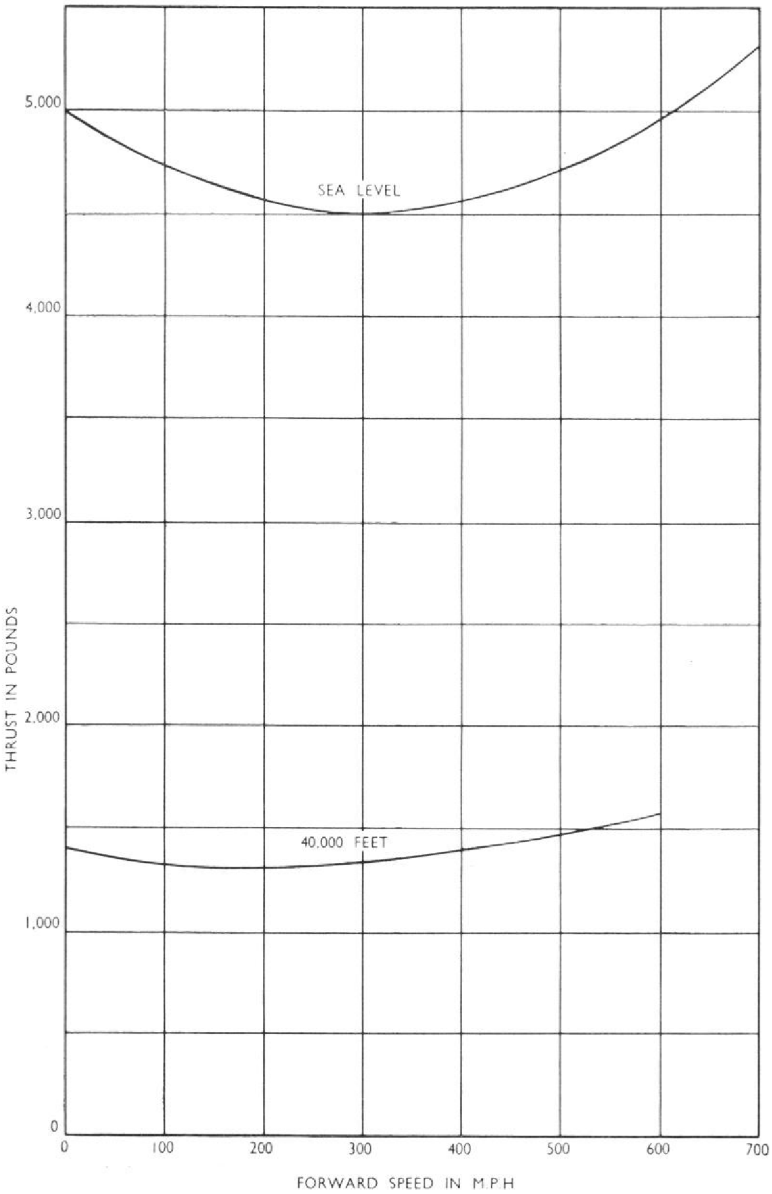

Fig. 1. Typical curves illustrating the manner in which the thrust increases progressively with forward speed—at speeds above about 300 m.p.h. at sea level and 200 m.p.h. at altitude—as a result of pre-compression or 'ram' effect; these curves are based on results measured during flight trials of Ghost engines installed in various types of aircraft. International Standard Atmospheric conditions.

Fig. 2 is a typical curve illustrating the way in which thrust and specific fuel consumption vary with engine r.p.m., assuming zero forward speed and sea level International Standard Atmospheric conditions, i.e. test bench conditions. Fig. 3 indicates the manner in which thrust and specific fuel consumption vary at altitude with forward speed and various engine r.p.m.

These three curves must be regarded as typical examples for explanatory purposes only, as the actual thrust and fuel consumption will depend upon the efficiency of the aircraft/engine combination as a whole. The type test performance rating and calibration of the engine are tabulated in the Leading Particulars at the beginning of this handbook.

EFFECT OF COLD WEATHER ON PERFORMANCE

Reports of loss of r.p.m. under cold weather conditions have, in some instances, resulted in accessories, such as the barometric pressure control, flow control unit, air-fuel ratio control, tachometer and other items, being changed unnecessarily.

In a turbo-jet engine, the power of the turbine is primarily absorbed in driving the compressor; the residual energy of the gases, after passing through the turbine, being used to propel the aircraft. As the atmospheric temperature falls, the

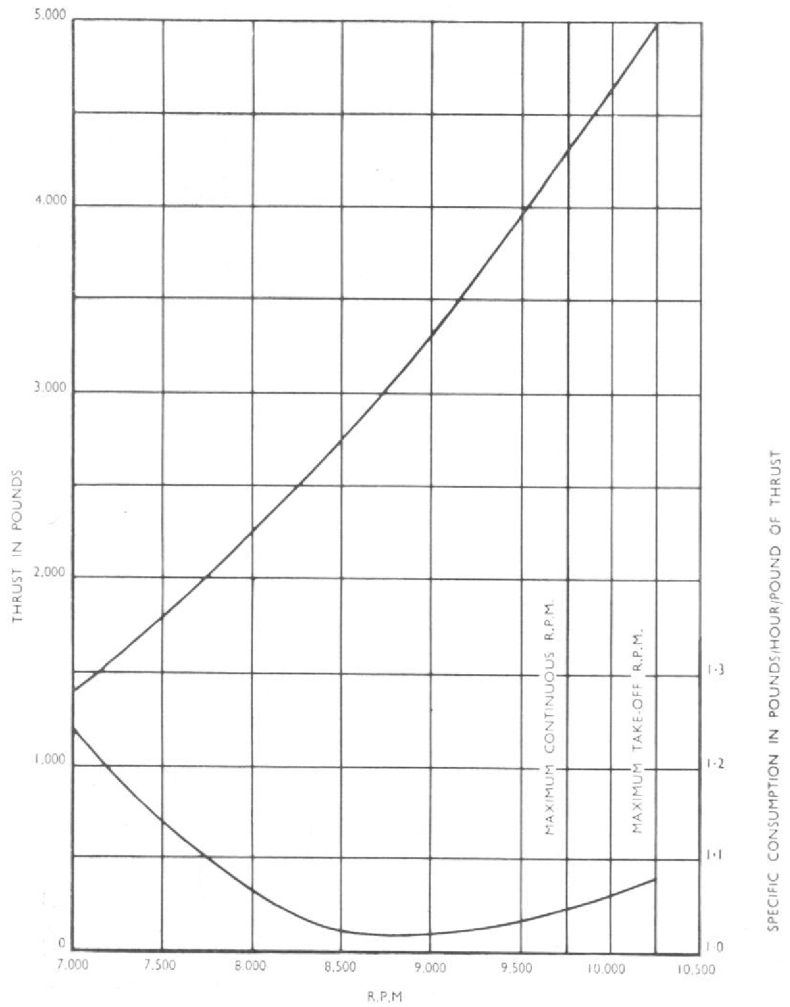

Fig. 2. Typical curve illustrating the way in which thrust (the upper of the two curves) and specific fuel consumption (lower curve) vary with engine r.p.m. assuming zero forward speed and sea level International Standard Atmospheric conditions—i.e. test bench conditions.

density of the air inhaled at the air-intake increases and the power required to drive the compressor at a given r.p.m. rises proportionately. Similarly, as the forward speed increases, there is an increase in the density at the air-intake due to the 'ram' effect, and an increased rate of air flow through the engine. This also increases the power required to drive the compressor at a given speed of rotation.

Thus, a decrease in air temperature and an increase in forward speed both require increased turbine power to maintain compressor revolutions. This extra power can be obtained only by an increase in the rate of fuel flow. Obviously, there comes a time when, due to low ambient temperature or high aircraft performance or a combination of both these factors, there is a limit in the fuel flow available caused by limitations of pump capacity or in the setting of the automatic control mechanisms. When this limiting condition is reached, there is a fall of r.p.m. from the maximum obtained under normal conditions. This loss of r.p.m. provided that it is neither excessive nor accompanied by high jet temperature, does not indicate any imperfection in the operation of the engine; in fact, thrust, being proportional to fuel flow, will be greater than the normal thrust on a standard day. True air speed will be practically unaffected. From this, it will be appreciated that loss of r.p.m. is most likely to occur when the demands on fuel flow are a maximum, i.e., conditions of full throttle at low altitude, high speed flight, and low atmospheric temperature.

STARTING, GROUND CHECKING, AND STOPPING

The correct procedure for starting the engine, for checking it by ground running, and for stopping the engine is detailed in chapter 9.

TAXYING

The precautions detailed in chapter 5 should be observed whilst the aircraft is on the ground.

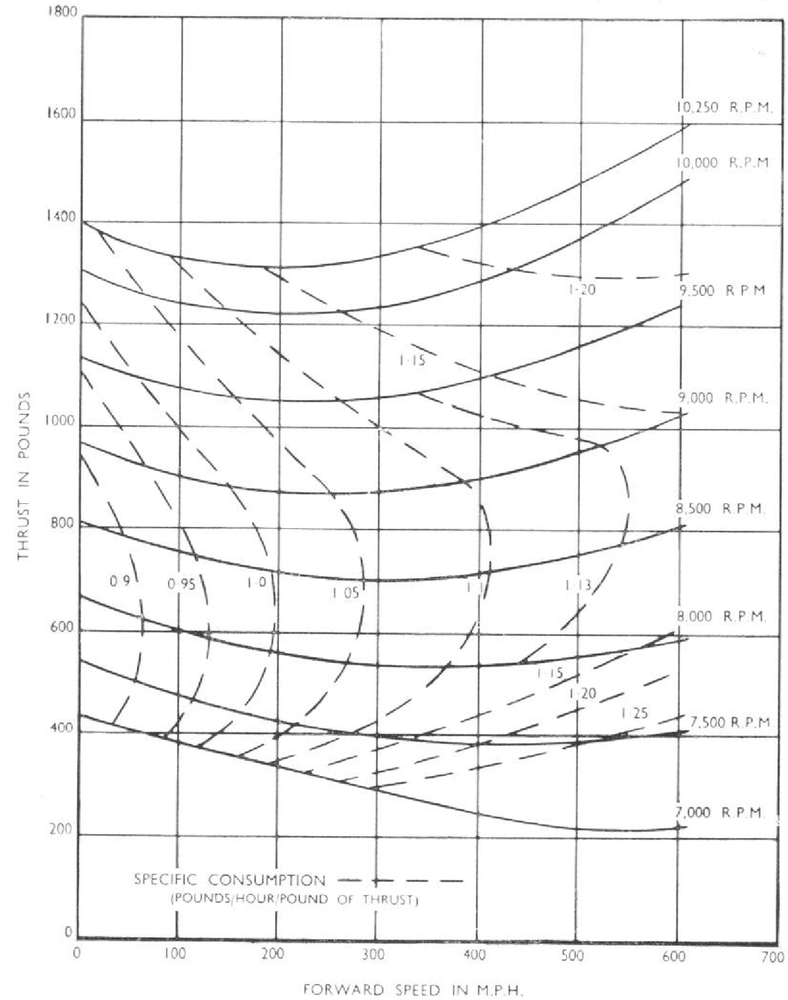

Fig. 3. Typical curve illustrating the way in which thrust and specific fuel consumption vary with forward speed at various engine r.p.m. at 40000 feet; International Standard Atmospheric conditions.

The aircraft may be taxied normally, but care must be taken to open the throttle gently and evenly, otherwise the jet temperature may rise above the maximum permissible. Every effort should be made to prevent the engine being run with the aircraft headed out of wind, otherwise a mixture of hot exhaust gas and air may be drawn into the air-intake and cause high jet temperatures and over-heating. For this reason, also, it is undesirable to remain, or follow, close behind another jet-engined aircraft.

TAKE-OFF

Head the aircraft in the direction of take-off and, with the aircraft wheel brakes applied, open the throttle smoothly until the take-off r.p.m. has been attained.

Ghost 48 Mk. 1 only. When take-off r.p.m. has been reached, move the fuel pump isolating switch to the ON position; the r.p.m. should increase to the setting of the higher governor. The correct functioning of the fuel pump isolating valve will have been checked during the normal ground running but if the pilot desires to recheck this he should proceed as described in chapter 9.

Make a quick check to ensure that the r.p.m. is correct and that the jet and oil temperatures are within the limits.

Ghost 48 Mk. 2. If a cold engine is opened up to full throttle, the maximum r.p.m. attainable may be less than the normal take-off r.p.m. This is due to the fuel system components being below their normal operating temperature, and is acceptable provided that the engine speed is not less than 10150 r.p.m.

If everything is satisfactory, release the wheel brakes and take-off.

Ghost 48 Mk. 1. When taking-off with the fuel pump isolating switch in the ON position, the maximum engine speed may hunt between approximately 9900 and 10400 r.p.m. Although this may be unpleasant it is not dangerous and the hunting can be overcome by throttling back to 10000 r.p.m., which will take the overspeed governor mechanism out of action.

During take-off in high ambient temperatures, governor creep can be accepted up to 100 r.p.m. above the normal maximum provided that the maximum jet temperature is never exceeded. Any tendency for the engine to exceed either this r.p.m. or the maximum jet temperature must be controlled by closing the throttle as necessary.

CLIMB

As the efficiency of this method of propulsion improves with forward speed and the maximum rate of climb is only obtainable at high air-speeds, no attempt should be made to climb more steeply than at the recommended indicated air speed for the aircraft.

If for any reason maximum power cannot be used without exceeding the jet temperature limit, the r.p.m. should be reduced or the forward speed increased or both adjusted accordingly. Except when accelerating, a sudden rise in temperature is a definite indication of trouble and the engine should be throttled back at once.

As soon as the aircraft has attained its correct climbing speed and a safe height, reduce engine speed to the permitted maximum continuous r.p.m. In any case, at 25000 feet and above, the r.p.m. must be reduced as indicated in the Operating Limitations.

Ghost 48 Mk. 1 only. **Before closing the throttle** to reduce r.p.m., return the fuel pump isolating switch to the OFF position.

When the engine is being used for military purposes, in order to complete a climb at maximum power, it will, normally, be necessary to reduce engine speed throughout the climb to maintain the jet temperature within the permissible maximum. The extent to which the throttle must be closed and the altitude at which this must be commenced will be influenced by many factors, including the ambient temperature, barometric pressure, r.p.m. indicator accuracy, and aircraft climbing speed.

When climbing, the r.p.m. limitations, given in the Operating Limitations, page xiii, must be observed strictly ; the throttle being manipulated as necessary. For this engine, engine speed has been adopted as the means of engine control, instead of jet temperature, for the following reasons : the r.p.m. indicator is more easily read by the pilot ; and, due to variations which are known to occur between engines and installations, the positive reduction of engine speed is a more reliable method of ensuring that the maximum mean turbine temperature is not exceeded than relying on the readings from a single thermocouple in the exhaust. To ensure that the r.p.m. indicator in the cockpit can be read sufficiently accurately for this purpose, a correction card is provided, immediately above the r.p.m. indicator, to show the indicated r.p.m. which corresponds to a true engine speed of 10100 and 10250 r.p.m. respectively.

LEVEL FLIGHT

In level flight, the mass flow through the engine increases with forward speed and there is, therefore, a tendency for the engine temperatures to be lower than when climbing at the same altitude and engine speed. For this reason it is not necessary to close the throttle to the same extent to maintain the jet temperature within the limits as when climbing.

MAXIMUM R.P.M.

It is important that the duration, r.p.m., and temperatures specified in the Operating Limitations are not exceeded during periods at maximum take-off r.p.m. At 35000 feet and above, in level flight, the reduced r.p.m. indicated in the Operating Limitations must not be exceeded.

Ghost 48 Mk. 1. The overspeed governor mechanism is adjusted to give maximum r.p.m. under standard sea level conditions and will only maintain this precise r.p.m. with the corresponding fuel flow and pressure conditions. At full throttle during a high speed level flight at low altitude, below about 5000 feet, the engine fuel requirement will increase with the increased air flow through the engine due to the forward speed, but the preset governor mechanism will tend to restrict the fuel flow and a lower governed speed will result. The extent to which the governed speed will be reduced is influenced by the forward speed, the ambient temperature, and the barometric pressure. Normally, the maximum observed engine speed should not be less than 10000 r.p.m. At high altitude, however, with the corresponding reduction in the fuel flow and pressure at full throttle, the governor 'rate' acts in the opposite sense so that the engine tends to run at a higher governed speed. To minimise this effect, the B.P.C. is set to give a slightly excessive fall in the fuel pressure at altitude so that the combined effect is to maintain, approximately, the correct governed speed in level flight at altitude.

Ghost 48 Mk. 2, pre-mod. 1175. At altitude, the special r.p.m. limitations, contained in the Operating Limitations, must be observed strictly. If not controlled, the governed speed of the engine rises with altitude and at 40000 feet may rise as high as 10450-10500 r.p.m. To avoid the operating limitations being exceeded the pilot must control the engine speed by manipulation of the throttle, particularly during a climb or acceleration at altitude.

CRUISING

To reduce the stresses on the engine as much as possible when cruising, the r.p.m. and jet temperature must be kept within the limits specified in the Operating Limitations for the maximum continuous condition.

IDLING AT HIGH ALTITUDE

When idling at high altitude, the jet temperature should not be allowed to fall below 200 deg. C. If necessary, the throttle should be opened slightly to increase the temperature.

GLIDING, LANDING, AND STOPPING

When gliding with the throttle shut, the jet temperature should be watched and the throttle opened slightly, to increase the temperature if it falls too low.

To minimise the risk of damage to the engine if it is necessary to accelerate rapidly in the event of a baulked landing, when approaching to land the engine should not be throttled back to a speed below the 'minimum r.p.m. for approach' specified in the Operating Limitations.

Ghost 48 Mk. 1 only. In the event of a baulked landing, or as soon as it is apparent that a second circuit is necessary, it is desirable to move the fuel pump isolating switch to the ON position as a safeguard against the possibility of a fuel system failure at a critical moment. When a safe height is attained, return the fuel pump isolating switch to the OFF position. If an attempt is made to land with the fuel pump isolating switch in the ON position, the idling speed, even with the throttle hard back in the slow-running position, may be as high as 5000 r.p.m. This will involve a longer landing run, and it may be necessary to move the H.P. fuel cock lever to the SHUT position at touch-down in order to stop the engine.

After taxying in, it is advisable to turn the aircraft into wind, and then reduce engine speed to idling r.p.m. and continue running for about 30 seconds to stabilize the temperature conditions. The correct procedure for stopping the engine is detailed in chapter 9. Do not move the L.P. fuel cock lever to the OFF position until the engine has stopped, as the engine-driven fuel pumps rely on the circulation of fuel through the pumps for their lubrication. It is not necessary for the fuel tank booster pump to remain switched ON whilst the engine is running-down. Finally, ensure that the air-intake and propelling nozzle covers are replaced.

FUEL SYSTEM IRREGULARITIES, OR FAILURE IN FLIGHT

Ghost 48 Mk. 1. If the engine speed fails to rise when the throttle is opened whilst flying at above about 20000 feet, a descent should be made and the trouble should then rectify itself. If this defect is encountered below 20000 feet, the throttle should be SHUT and the fuel pump isolating switch moved to the ON position and remain ON for the remainder of the flight; the aircraft should be landed as soon as practicable. It must be remembered that, as under these conditions the altitude and acceleration control units are inoperative, the r.p.m. and the rate of acceleration must be regulated by careful manipulation of the throttle—also, the idling speed on landing will be higher than normal and will involve a longer landing run.

Ghost 48 Mk. 1. Cessation of combustion at high altitudes, following aerobatics or comparatively rapid acceleration or deceleration of the engine, indicates a 'blow out' rather than a fuel system failure. In such instances, the engine may be relit as described in the next column.

Ghost 48 Mk. 1. Cessation of combustion during normal flight, where the flight conditions do not suggest a 'blow out' of the foregoing type, may indicate a fuel system failure. Failure of either fuel pump, the B.P.C., air-fuel ratio control, or the servo pipes in flight will normally be indicated by an unexpected and progressive decrease in r.p.m. Should this occur the throttle should be SHUT and the fuel pump isolating switch should be moved to the ON position immediately. It cannot be too strongly emphasised that, at altitudes above 20-25000 feet the throttle must be closed **before** moving the fuel pump isolating switch to the ON position; failure to comply with this instruction will, almost certainly, result in a rich extinction. In addition, ensure that neither the H.P. fuel cock nor the L.P. fuel cock levers have been inadvertently moved to the OFF position, and that there is still some fuel in the tanks. In such instances, the engine may be relit as described but the isolating switch should remain ON for the remainder of the flight.

Ghost 48, Mk. 2. If, particularly at altitude, the engine responds so slowly to manipulation of the throttle lever that it is difficult to select the required speed, or if it is impossible to obtain the maximum permitted r.p.m. (as opposed to the tendency to overspeed, referred to under the heading 'maximum r.p.m.') a descent should be made and the trouble should then rectify itself.

Ghost 48 Mk. 2. If the booster pump fails at altitude, the engine may run erratically.

RELIGHTING IN FLIGHT

Relighting may be achieved up to 40000 ft. (35000 ft. Ghost 53 Mk. 1) but below 30000 ft. relighting is more positive. The indicated air speed is not unduly critical but a very hot relight results at low air speeds and, therefore, it is recommended that the I.A.S. should be above 180 knots (but not above 250 knots in the case of the Ghost 48 Mk. 2, and 53 Mk. 1).

As stated on the facing page, in sub-para 3, in the case of the Ghost 48 Mk. 2, which has a Dowty fuel system, the main shaft windmilling speed should not exceed 1800 r.p.m. and the altitude and/or forward speed should be selected so that this r.p.m. is not exceeded; as will be understood from the brief description contained in chapter 4, at normal running r.p.m. the action of the isolating valve in the valve group unit closes the torch igniter valve and shuts-off the supply of fuel to the torch igniter jet assemblies. Therefore if the main shaft r.p.m. is too high the torch igniters are not available to initiate combustion; which then relies solely on the action of the high energy igniter plugs.

The most likely cause of failure to relight in flight is insufficient voltage at the high energy ignition units as a result of partially discharged aircraft batteries. It is to reduce this likelihood that the switching OFF of all non-essential electrical loading has been recommended; if discharged batteries are thought to be the cause of failure to relight in flight, all auxiliary electrical loads should be turned OFF before attempting a further relight. *In the case of the Ghost 48 Mk. 2,* the fuel tank booster pump must not be one of the services which are switched off. *In the case of the Ghost 53 Mk. 1* the flight instruments' inverter must be ON before any attempt is made to open the throttle fully. The recommended relighting in flight drill, for each Mark of Ghost is tabulated on the facing page.

Ghost 48 Mk. 1

If combustion ceases at any time, and the cause is *known* to be other than mechanical failure, a relight may be attempted immediately, whilst engine speed is decreasing. Close the throttle and, keeping the H.P. fuel cock open, press the relighting button (EARLY VENOM AIRCRAFT, refer also to sub-para. 6); the button should be pressed for not longer than 15-20 seconds. If, after this period, the engine has not restarted, shut the H.P. fuel cock and proceed as described below. In all other instances, the H.P. fuel cock lever must be moved to the SHUT position immediately combustion ceases.

If the engine fails to re-start after applying the immediate action described above, provided that mechanical failure is not suspected, proceed as instructed in sub-para. (a) or (b) as appropriate.

(a) When combustion ceases at high altitudes, following aerobatics or comparatively rapid acceleration or deceleration of the engine, the recommended sequence of operations for relighting in flight is as summarised in sub-para. 1 to 7 inclusive. Such cessation of combustion is indicative of a 'blow out' as distinct from a fuel system failure

(b) When combustion ceases during normal flight where the flight conditions do not suggest a 'blow out' of the foregoing type, SHUT the throttle fully and move the fuel pump isolating switch to the ON position before attempting to relight. In such instances, the instruction, to open the throttle, contained in sub-para. 5 must be ignored, and, if the failure occurs at altitudes above 30000 feet, a descent to this altitude is recommended before attempting to relight; as, with the isolating switch ON, at altitudes above 30000 feet, the rapid acceleration to the idling speed normal for the altitude may cause excessive temperatures, or a rich extinction, before idling speed is attained. The isolating switch should remain ON for the remainder of the flight and it must be remembered that, as under these conditions the altitude and acceleration control units are in-operative, the r.p.m. and the rate of acceleration must be regulated by careful manipulation of the throttle—also, the idling speed on landing will be higher than normal and will involve a longer landing run.

(1) SHUT the H.P. fuel cock and allow any excess fuel to drain out of the exhaust system—if possible allow at least one minute.

(2) If possible, reduce altitude to below 30000 feet.

(3) It is recommended that the indicated air speed should not be less than 180 knots.

(4) **IN EARLY VENOM AIRCRAFT ONLY.** Ensure that the starter master switch is in the ON position and that the cartridge selector switch is in the OFF position.

(5) Set the throttle lever one-quarter open, except when the isolating switch is ON (in which case the throttle must be SHUT).

(6) Press the relighting button, which is incorporated in the H.P. fuel cock lever, to energize the igniters, and re-open the H.P. fuel cock **AS QUICKLY AS POSSIBLE.**

IN EARLY VENOM AIRCRAFT ONLY. Wind up the Venner time switch, in a clockwise direction, and release it, simultaneously returning the H.P. fuel cock to the OPEN position **AS QUICKLY AS POSSIBLE.**

Whilst attempting to relight, to give every assurance of a satisfactory current supply to the high energy ignition units, switch OFF all non-essential electrical loading such as R.T. etc.

The engine should now relight.

(7) Immediately a rise in r.p.m. or jet temperature is observed, SHUT the throttle; the engine should then accelerate to the normal slow running speed for the altitude.

It is possible that the two igniter combustion chambers (No. 3 and 10) may relight satisfactorily without causing any perceptible indication on the cockpit instruments and that combustion will not spread to the other eight combustion chambers until the throttle is SHUT. Therefore, if the engine has not relit normally within 5 or 6 seconds of reopening the H.P. fuel cock, SHUT the throttle to encourage flame propagation to the remaining combustion chambers.

In the event of the engine failing to relight within 30 seconds of reopening the H.P. fuel cock, or (early Venom aircraft only) by the time the Venner time switch has unwound, SHUT the H.P. fuel cock. Allow approximately one minute (about 2500 ft. loss of altitude) to permit excess fuel to drain from the engine and then repeat the relighting procedure.

Ghost 48 Mk. 2

If combustion ceases at any time, and the cause is *known* to be other than mechanical failure, a relight may be attempted immediately, whilst engine speed is decreasing. Close the throttle and, keeping the H.P. fuel cock open, press the relighting button; the button should be pressed for not longer than 15-20 seconds. If, after this period, the engine has not restarted, shut the H.P. fuel cock and proceed as described below. In all other instances, the H.P. fuel cock lever must be moved to the SHUT position immediately combustion ceases.

If the engine fails to re-start after applying the immediate action described above, provided that mechanical failure is not suspected, the recommended sequence of operations for relighting in flight is as summarized in sub-para. 1 to 6 inclusive.

(1) SHUT the H.P. fuel cock and allow any excess fuel to drain out of the exhaust system—if possible allow at least one minute.

(2) If possible, reduce altitude to below 30000 feet.

(3) It is recommended that the indicated air speed should be between 180 and 250 knots and that the windmilling speed of the engine main shaft should not exceed 1800 r.p.m.; at 250 knots at altitude the stabilized windmilling speed may be above this r.p.m. and in such instances the altitude and/or forward speed should be selected to obtain the desired main shaft r.p.m.

(4) Not applicable.

(5) Ensure that the throttle lever is in the fully SHUT position.

(6) Press the relighting button, which is incorporated in the H.P. fuel cock lever, to energize the igniters, and re-open the H.P. fuel cock **AS QUICKLY AS POSSIBLE.**

Whilst attempting to relight, to give every assurance of a satisfactory current supply to the high energy ignition units, switch OFF all non-essential electrical loading such as R.T. etc. The fuel tank booster pump must not be one of the services switched off.

The engine should now relight.

(7) Not applicable.

In the event of the engine failing to relight within 30 seconds of reopening the H.P. fuel cock, SHUT the H.P. fuel cock. Allow approximately one minute (about 2500 ft. loss of altitude) to permit excess fuel to drain from the engine and then repeat the relighting procedure.

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FIRE OR OTHER EMERGENCY

Should fire become apparent in the engine bay, either during ground running or in flight, or in the event of an emergency such as a forced landing or engine failure during take-off, the following action should be taken immediately.

(1) Move the L.P. fuel cock lever to OFF.

(2) Move the H.P. fuel cock lever to SHUT.

(3) Switch OFF the fuel tank booster pump, and SHUT the throttle fully.

(4) *Fire in flight.* Reduce air speed as far as possible before operating the fire extinguisher.

These operations should be carried out as nearly simultaneously as possible. In flight, since the aircraft fire extinguishing equipment is sufficient to deal with one outbreak of fire only, **no** attempt should be made to relight after successfully extinguishing a fire.

Except that the fire extinguishing equipment will not be operated, the same procedure should be carried out in the event of failure to relight in flight after obtaining favourable conditions, or if extreme roughness and vibration, which may be the result of major mechanical failure, occurs.

The normal stopping procedure of shutting the H.P. fuel cock **before** the L.P. fuel cock, is intentionally reversed to cut-off the fuel supply at its source as quickly as possible, and thus minimise the leakage into and around a damaged engine.

Ghost 48 Mk. 1. Where the engine-driven fuel pumps have been run dry as a result of applying the foregoing instructions, or as a result of inadvertently running out of fuel, closing the L.P. fuel cock, or selecting an empty fuel tank, the pumps can be considered fit for further service provided that the 'dry running' period does not exceed 3 minutes at any one time; this is applicable regardless of the engine speed and the moment when the fuel supply is cut-off, and there is no restriction on the number of times the pumps may be run dry provided that the pumps are adequately primed between each occasion.


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