Chapter Five

GENERAL INFORMATION RELATING TO OPERATION, SERVICING AND MAINTENANCE

Contents

THIS CHAPTER is 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.

THIS GROUP OF CHAPTERS (chapter 5 to 20 inclusive) is for the Aircraft Engineer responsible for ground operation and day to day servicing and maintenance of the engine. This group includes chapters which describe the procedure for installing and removing the engine (i.e., how to change a " time expired " or faulty engine for one that is serviceable), the recommended operating procedure (i.e., how to start, ground run, and stop the engine), the method of tracing running defects, the periodic maintenance required, instructions for carrying out all maintenance operations which can be done without completely overhauling the engine, and the method of protecting the engine against corrosion when it is not in use. A complete list of the chapters contained in this group is given on the marker card which precedes this page. Throughout this group of chapters, it is assumed that the reader is acquainted with the engine and that the general description contained in chapters 1 to 4 has been read, or will be referred to as necessary.

The majority of the operations described in these chapters can be carried out whilst the engine is in position in the aircraft, but operations have not been excluded merely because they can be done only with the engine removed from the airframe. Where a workshop stand, in which the engine can be turned over, is not available, it is assumed that the engine will be placed on a transport stand in order to work on it out of the airframe, and it is assumed that, in this instance, in an emergency, the engine can be suspended from a crane—being, if necessary, held steady by additional personnel—in order to gain access to components on its underside. Instructions for removing the engine from the airframe and for its subsequent re-installation are contained in chapters 6 and 7; instructions for assembling the engine to the workshop, or erecting, stand are contained in chapter 23, page 3.

Chapter 10, which contains the engine manufacturer's recommendations for flight operation of the engine, is, primarily, intended to provide ground personnel with a description of the principles obtaining in the operation and control of the engine in flight. For specific details of flight operation in any particular aircraft, pilots should refer to the specific instructions issued in connection with individual aircraft by the aircraft manufacturer and to the relevant Flight Manual ; so far as engine operation is concerned, these instructions should be based on the recommendations contained in chapter 10.

To assist the reader to locate the required information quickly, and to simplify amendment action, the servicing and maintenance information has been divided between seven chapters, each of which deals with a clearly-defined system or group of components.

Chapters 13 to 19 describe all the dismantling or removal which is necessary to carry out the periodic examinations specified in the Maintenance Schedule ; the method of cleaning, examination or adjustment ; wherever possible, the extent of permissible and non-permissible wear or damage ; and the subsequent reassembly or refitting. They contain also instructions for repair by replacement, that is for removing and refitting those accessories, components, or parts which can be removed and refitted without the facilities of a complete repair depot. Wherever new parts must be fitted at each reassembly, such as tab-washers, etc., the part number is quoted to assist the operator to ensure that these essential renewals are available before operations are commenced.

Rectification or repair of worn or damaged parts is described in chapters 28 to 32.

To avoid needless repetition, general information which is applicable to a number of chapters within the group is contained in the following pages.

For instructions relating to airframe components such as cowlings, etc., reference must be made to the relevant aircraft handbook, the engine handbook being confined to parts and components which are listed in the engine Spare Parts Catalogue.

PERMISSIBLE WORN DIMENSIONS, CLEARANCES, AND DAMAGE

The extent of permissible wear or damage, and the permissible repairs, described in chapters 22 to 38, which deal with overhaul and reconditioning, are intended, primarily, for use when the component has been dismantled for complete overhaul with the object of reconditioning it for a new overhaul life. The similar information contained in the servicing and maintenance group of chapters (5 to 20) is intended to cover the rectification necessary to enable the engine to run until the next inspection period.

Where a dimension in the Table of Fits and Clearances (chapter 38) is qualified as being for "engines in service," or where a different value is quoted in chapters 5 to 20, that dimension or value is applicable at routine inspection during servicing or maintenance, and is intended only to permit the engine to run until the next inspection period. It will be appreciated that, in order to avoid unnecessary rejections of engines in service, a little more latitude is permissible during maintenance between overhauls than would be good practice during complete overhaul.

METAL IN FILTERS

When metal has been found in a filter any report should state the nature of the metal and the quantity.

PRECAUTIONS

Whenever the engine is not running, blanking boards must be kept on the air-intakes and on the propelling nozzle, except when their removal is essential in order to perform some particular servicing operation, and they must always be refitted immediately such operations have been completed.

To obviate any risk of the engine being started unintentionally, before commencing any servicing operations, ensure that the L.P. fuel cock lever, the H.P. fuel cock lever, and the master or safety switches are in the OFF position. After any servicing operation for which it is necessary to move any of the controls to the ON position, ensure that they are returned to the OFF position.

Scrupulous cleanliness, the proper use of the correct tools, and punctilious attention to detail is vital in every stage of these servicing operations. Anything loose left near the air-intakes may wreck the engine, and a particle of grit may ruin the fuel system components.

GROUND RUNNING PRECAUTIONS

Dust covers must be kept on the air-intakes and propelling nozzle whenever the engine is not running, and they should not be removed until immediately before starting. If a take-off is not contemplated, the air-intake covers should be replaced by wire-mesh debris guards. To prevent the aircraft taking off with these wire-mesh guards in position they should be connected to the chocks by a length of light cable or cord.

The following precautions should be observed during any period of ground running. Failure to observe these precautions can result both in injuries to personnel and damage to aircraft.

All personnel should be warned of the danger of approaching close to a turbo-jet aircraft whilst ground running is in progress, as headgear, paper, or other articles within approximately five yards of the front of the engine are liable to be drawn into the air-intakes. It is possible to approach a running engine from an angle at which the noise is comparatively inaudible, due to the sound being directional and of high frequency. This danger particularly concerns motor transport drivers as the noise from their vehicles can make it difficult for them to determine whether an engine is running.

Before starting the engine ensure that:—

(1) No personnel are within five yards, *4,57 metres*, of the air-intakes.

(2) The ground immediately in front of the aircraft is free from scraps of paper, small stones, and other light articles liable to be drawn into the air-intakes.

(3) The aircraft is positioned so that the jet is not directed towards any building, vehicle or other aircraft within a distance of 50 yards, *45,72 metres*; no inflammable material, however stored or contained, should be within 25 yards, *22,86 metres*. This is necessary as the heat of the exhaust 'wake' and the stones which it carries up from the ground may cause damage.

(4) The aircraft is headed as nearly as possible into wind to prevent hot gases re-entering the air-intakes, thereby causing overheating.

(5) The aircraft is standing on concrete. Where a concrete surface is not available, ground running should be carried out with the aircraft

standing on grass. The use of tarmacadam surfaces should be avoided.

(6) Wire-mesh debris guards are fitted to the air-intakes. These are to be removed immediately prior to taxying for take-off.

If during ground running, personnel or motor transport vehicles are seen to be approaching in a manner likely to cause them to pass close to the front of the aircraft, the engine should be throttled back immediately.

When running-up engines installed in Venom aircraft, to ensure that the elevator is not damaged by heat, it is advisable to hold the control column hard back to keep the elevator clear of the exhaust stream. The "smothering blanket" which forms part of the aircraft ground equipment should be fitted over the tail plane.

IDENTIFICATION OF COMPONENTS

Before a component is removed, ensure that it is marked to indicate its position on the engine. It is essential that each component should be so marked before removal unless its design ensures refitment in the correct position. Components which can be turned through 90 or 180 degrees, must also be marked to ensure that they are refitted the original way round and in their original relative position to other parts of the same assembly. It is sound practice, unless the operator is thoroughly used to this particular type of engine, to make written notes of the location of, or to label, all small parts such as shims, packing pieces, etc., so that each part can be refitted with absolute certainty in its original position during reassembly.

Temporary marking of components

During servicing and maintenance, it may be necessary to apply temporary marking to identify a component; or to mark a suspected area, such as a crack in a component, either with a view to determining its rate of increase or to indicate the area where a more thorough examination is considered necessary—possibly by a more experienced operator. Such marking must not be carried out by using lead pencils, wax crayons, or similar media. Use chalk, soapstone, or some similar substance which will not leave any carbon deposit; soapstone, or steatite, is a coarse, massive, or granular variety of talc which is greasy to the touch. On components which are subjected to high operating temperatures, particularly the hot components of turbine engines, failures have occurred due to the carbon deposit from lead pencils, wax crayons, grease pencils, and similar marking media, causing carburisation and subsequent hardening or embrittlement of the area immediately surrounding the carbon deposit, when subjected to intense heat.

SPLIT PINS, LOCKING WASHERS, JOINT WASHERS, SHIMS

All parts which must not be reused, such as split pins, locking washers, joint washers, etc., must be discarded as they are removed, so that there is no risk of their becoming mixed with new items and used again. Copper and aluminium sealing washers should be thoroughly examined to decide whether they are suitable for further use. Shims and packing pieces should be secured to their respective components so that, upon reassembly, time is not wasted in checking components to ascertain the correct shim or packing thicknesss.

SEPARATING COMPONENTS

When components are difficult to remove or separate because of jointing compound between them, or close fitting dowels or studs, tapping with a mallet around the periphery of the component should be sufficient to 'break' the joint. In no circumstances should any form of wedge be inserted between the mating faces in an endeavour to part them.

BLANKING OPENINGS

During the removal of parts or components, all openings, unions, etc., should be blanked off immediately they are exposed to prevent the entry of dirt, loose nuts, small tools, etc. In the absence of proper blanking plates, caps, or plugs, cavities should be blanked off with improvised plates of metal or plywood, and pipes and similar openings with rubber caps. Fabric in the form of cotton waste, rags, etc., must never be used for these purposes as small particles might enter the oilways or the fuel system with disastrous results.

JOINTING COMPOUND

Where jointing compound has been employed, all traces of the previous coating must be removed and the mating surfaces thoroughly cleaned before reassembly. Having ensured that the joint faces are perfectly clean and that there are no burrs, nicks, or other damage which might prevent the components seating properly or an oil-tight joint being obtained, smear each joint face with a thin even film of flexible Hermetite 1326B or Wellseal jointing compound.

ANTI-SEIZE COMPOUND ON SCREW THREADS

To reduce the risk of seizure, all screw threads which are subjected to high temperature should be coated with an anti-seize compound. Because of the critical torque loading which must be applied when tightening the nuts and bolts which secure the turbine disc to the hub shaft, the threads of these nuts and bolts must be lubricated with either Ragosine L.M. grease (British specification D.T.D. 900/4424) or anti-scuffing paste to British specification D.T.D.900/4284. For all other screw threads which are subjected to heat, anti-seize grease to British specification D.T.D.392 is recommended, but any other reputable graphite anti-seize grease may be used as an alternative.

Screw threads which are not subjected to heat should either be coated with Ragosine L.M. paste. or a mixture of engine oil and anti-seize grease ZX-13.

SPLINED OR SERRATED DRIVES

Especially when changing an essential, or engine-driven aircraft, accessory, on an engine which has a number of flying hours to its credit, thoroughly examine the splines, or serrations, within the drive in the engine, on the accessory's spindle, and, where applicable, at each end of any coupling, drive, or quill shaft. There should not be any appreciable evidence of wear, in the form of 'stepping' on the flanks of the splines, or serrations. In all cases of doubt, reference should be made to the Table of Fits and Clearances contained in chapter 38.

On all occasions when fitting splined, or serrated, drives to the engine, the splines, or serrations, should be lubricated with Shell grease Rhodina No. 2 or a grease such as British Specification D.T.D.825 ; if, however, this is not available, some other form of lubricant may be used—engine oil, grease, etc.—on no account should these drives be assembled dry.

RIGID PIPES WITH BELLED ENDS

Sharp edges at the end of the conical seat of unions can cause deep grooves in the belled end of rigid pipes and this may result in complete fracture of the pipe at that point. Before fitting any rigid pipe, therefore, each union should be examined to ensure that there is neither a sharp edge nor a burr which might damage the pipe when the union nut is tightened. Any burrs found should be carefully removed, and if a sharp edge is discovered it should be radiused very slightly.

Similarly, examine the belled end of each pipe looking for signs of a circumferential ridge in the belled mouth. If a ridge is found, it should be removed by the use of a small hand scraper, and the belling lightly polished with metal polish ; finally, wash away all traces of abrasive. After polishing, visually examine the pipes for signs of cracks. Cracks in any form are not acceptable and defective pipes must be replaced by new pipes.

FLEXIBLE PIPES

All flexible pipes should be inspected during routine engine inspections, and great care should be taken at all times when handling these pipes. It is strongly recommended that, before being fitted to an engine, new or replacement pipes should be flushed through, and, if they have been in store for a period of six months or more, pressure tested. Detailed instructions for fitting, inspecting, and testing flexible pipes are contained in chapter 51.

Additional information relating to pipes is contained in Civil Aircraft Inspection Procedures ML/3-1 (Flexible Pipes) and ML/3-2 (Rigid Pipes) issued by The Air Registration Board.

BUNDY PIPES, TIGHTENING OF UNION NUTS

The Bundy pipes fitted to the Ghost 48 Mk. 1 and to the Ghost 48 Mk. 2 are:—

Ghost 48 Mk. 1

Diffuser bolt to A-F.R.C., Part No. 97434, mod. 469 pre-mod. 1139.

Diffuser bolt to expansion chamber, Part No. 97435, mod. 469 pre-mod. 1139.

No. 10 diffuser bolt to centre casing, Part No. 46883, pre-mod. 1095.

Centre casing to rear bearing, Part No. 46884, pre-mod. 1095.

Ghost 48 Mk. 2

Front support cone to rear bearing, Part No. 97375, pre-mod. 1095.

Mod. 1139 replaces the two separate pipes connecting the A-F.R.C. to No. 8 expansion chamber by a single rigid pipe direct from the A-F.R.C. to No. 9 expansion chamber. Mod. 1095 replaces the flexible, Bundy, and Tungum pipes, which carry the lubricating oil to the rear bearing, by stainless steel pipes. For full details of these modifications, reference should be made to the relevant Modification News Sheets.

When tightening Bundy type union nuts, the nut must be tightened sufficiently to deform the olive so that slight but positive necking of the pipe is produced ; Bundy pipes may be recognised by their characteristic bright silvery (tinned) finish. Excessive tightening must, however, be studiously avoided as for each re-assembly the nut will require just a little extra movement to ensure a leak-free connection, and it is the sum of these extra movements, plus the initial distortion, which dictates the life of the pipe assembly. The slight necking of the pipe is necessary to ensure that, when it is fitted, it is mechanically locked ; friction pressure of the olive on the pipe, although probably leak free, is not sufficient. For the foregoing reasons, whenever a pipe which is to be refitted, is disturbed, it is most important to ensure that the olive remains in the same position on the pipe ; any lateral movement of the olive on the pipe will destroy the initial seal.

When fitting a new assembly: check that the pipe enters the coupling squarely, and bottoms in the coupling ; hold the pipe in position and screw up the union nut finger-tight ; finally, tighten the union nuts as follows:—

Bundy pipe	*Thread*	*Tighten*
$\frac{5}{16}$ inch	$\frac{1}{4}$ in. B.S.P.	Hand-tight plus one complete turn.
$\frac{1}{4}$ inch	$\frac{1}{4}$ in. B.S.P. or $\frac{7}{16}$ in. by 26 T.P.I.	Hand-tight plus one complete turn plus one-sixth (60 deg.) of a turn.

When refitting a used assembly: check that the pipe enters the coupling squarely, and that the olive seats positively in the coupling ; hold the pipe in position and screw up the union nut finger-tight ; finally, tighten **hand-tight plus one sixth (60 deg.) of a turn** regardless of the pipe size. A radial pencil line on the nut end will provide a good datum for correct tightening.

These instructions must be followed carefully, and it must be clearly understood that no attempt must be made to continue tightening these nuts until appreciable resistance is felt. The check for sufficient tightening, having complied with the foregoing instructions, is freedom from leaks on ground run. If, to correct slight leakage, it is necessary to tighten a union nut further, this must be done to the least possible extent which will cure the leak ; tighten the nut a few degrees at a time only. If excessive 'necking' of the pipe, or excessive distortion of the olive, has occurred, a new pipe assembly should be fitted.

TURBO STARTER

Always treat the turbo starter as though it contained live cartridges. If it is necessary to carry out adjustments to the engine or to work on the starter or its selecting and firing mechanism, all live cartridges must be removed from the breeches, as described in chapter 9, before such work is commenced. In the event of a live cartridge having been selected but which has not been fired, a period of at least 15 seconds must elapse before attempting to unload the breeches. If a cartridge fails to fire, a fresh cartridge must not be selected and fired for a period of 15 seconds, during which time all personnel must keep clear of the engine.

Cartridges must not be loaded singly after a second attempt to start, but in pairs, and then only when the breech temperature has dropped to about 45 deg. C. When a 'heated' cartridge is removed during servicing, it must be loaded into a starter only in company with an expended cartridge, thus reducing accidental firing of 'heated' cartridges.

The cartridges deteriorate if exposed to extremes of temperature and should not, therefore, be allowed to soak in the starter breeches after flight. When the engine is stopped there is no induced airflow to cool the engine bay and a temperature of 60 to 70 deg. C. will obtain in about 30 minutes. Each time this process is allowed to occur, the burning rate of the charge increases and will ultimately become an explosive charge. A cartridge in this condition is dangerous for handling and storage, and if used in the starter will blow the safety disc when fired. Therefore, under normal and tropical conditions, the breeches should be unloaded immediately the aircraft has landed. When operating under freezing conditions, however, the turbo-starter breeches should be unloaded, cleaned, and reloaded immediately the engine is shut-down (whilst it is warm). This is particularly important after short ground runs as the moisture which results from firing a cartridge freezes in the breeches and make cartridge removal and breech cleaning almost impossible. In flight the continued operation of the engine (heat) dries out this moisture and less trouble is experienced than after short ground runs.

The cartridges should be kept clean and free from grease or oil, and should be carried in the special satchel provided. Spent cartridges must not be left in the starter breeches for more than eight hours.

AT THE COMPLETION OF ANY SERVICING

At the completion of any servicing operation, ensure that no loose parts, tools, or rags are left lying about the engine or cowling ; particularly examine the air-intakes and ducts leading to the impeller. At the completion of any servicing operations, especially after any operations involving a disturbance of the fuel pipes, the subsequent ground-run must be made with the cowling open so that a thorough examination may be made for fuel leaks. Finally, ensure that all cowling panels and inspection doors are correctly fitted and securely attached, referring, if necessary, to the aircraft handbook for any special instructions.

DISMANTLING AND ASSEMBLY STAND

Certain servicing and maintenance operations are performed with the engine out of the aircraft and mounted on the dismantling and assembly stand. Pre-tool-mod. 655, as far as possible, work on the engine, whilst it is mounted on this stand, should be accomplished without entering the confines of the rectangular base ; unless the weight of the engine is taken fully on independent supports. Due to mishandling of the manual brake and locking device, instances have occurred of engines swinging round out of control, with the consequent risk of serious injury to operators. Mod. 655 introduces a self-locking device on the turning gear, in place of the original manually operated brake and locking device ; where this modification has been embodied, the recommendation to take the weight of the engine on independent supports, no longer applies.

GENERAL OPERATION

BASIS OF CONTROL

The thrust developed by any turbo-jet engine depends upon the volume of gas expelled through the propelling nozzle. This depends upon the quantity of air entering the engine and, therefore, on the speed at which the impeller rotates, i.e., engine r.p.m. The engine r.p.m. depends on the power developed in the turbine, and this is governed by the amount of fuel being burnt in the combustion system. Thus, a change in the rate of the fuel flow to the burners causes an increase, or a decrease, in the rate of air expansion and produces a sympathetic change in engine r.p.m. From this brief explanation it will be seen that by regulating the fuel flow, the thrust produced by the engine can be controlled.

STARTING

To start the engine it is necessary to employ an auxiliary source of power to rotate the main shaft and to ignite the fuel. A two-shot, cartridge, turbo-starter, which is mounted on the top wheelcase, is employed to rotate the engine, and high energy, electric ignition equipment to ignite the fuel. As conditions for successful starting are critical, the starting cycle is controlled automatically. The controls are set and the starter push button is pressed manually, and when the engine has attained the correct speed and the fuel pumps are delivering fuel to the burners, surface-discharge igniter plugs in No. 3 and 10 combustion chambers ignite the fuel issuing from the burners ; the flame spreads to the remaining combustion chambers through the interconnectors. The Ghost 48 Mk. 2 employs high energy torch igniters in place of the simple igniter plugs fitted to the Ghost 48 Mk. 1. The engine then accelerates under its own power until the normal idling speed is reached. When relighting in flight, since the impeller will be rotating already, it is necesary only to set the controls and ignite the fuel.

MANUAL CONTROLS

Engine r.p.m. is controlled by a throttle lever which moves in a quadrant marked SHUT–THROTTLE–OPEN, situated in the cockpit. This lever is linked to the engine throttle valve. To permit the small fuel flow required for idling to be adjusted easily, on the ground, a tapered needle valve is provided on the engine. This can be screwed in, or out, to regulate the fuel flow through a by-pass orifice which connects the upstream and downstream sides of the throttle valve orifice.

Ghost 48 Mk. 1. The throttle valve takes the form of a graduated needle in the control valve assembly, and provides a variable orifice through which the fuel delivered by the engine-driven fuel pumps is metered to the burners.

Ghost 48 Mk. 2. The throttle valve takes the form of a rack and pinion operated, profiled plunger, which regulates the flow of high pressure fuel through an orifice in the circulating pump and valve group unit.

To stop the engine positively, both when shutting down normally, and in an emergency, a high pressure fuel cock lever, which is marked OPEN (forward position) and SHUT (aft position), is provided in the cockpit adjacent to the throttle lever.

Ghost 48 Mk. 1. The H.P. cock lever is connected through suitable linkage to the fuel cut-off valve in the control valve assembly, between the throttle valve and the outlet, which shuts off the high pressure fuel supply to the burners. Where Mod. 470 has been embodied, two flats are machined on the cut-off valve to form a taper which is symmetrical about the centre line of the valve. In an emergency, in the event of failure of the normal throttle control, this taper enables the H.P. fuel cut-off valve to be used as a coarse throttle.

Ghost 48 Mk. 2. The H.P. cock lever is connected through suitable linkage to two high pressure shut-off valves in the valve group unit on the engine. When the lever is pulled back to the SHUT position, the two shut-off valves are moved to the off position causing the fuel delivery from the fuel supply pump to be diverted back to the inlet side of that pump, and opening both burner manifolds to the inlet side of the circulating pump so that that pump can withdraw all liquid fuel from the burner manifolds and associated pipe lines and return it to the main aircraft fuel tank. As a result of this, there is no external dumping of liquid fuel when the engine is stopped.

A low pressure fuel cock lever, which is marked FUEL OFF (down and aft) and FUEL ON (forward and up) controls the flow of fuel from the aircraft tank. Normally, this lever should not be used to stop the engine as the engine-driven fuel pumps rely on the circulation of fuel for their lubrication.

Ghost 48 Mk. 1 only. A servo isolating valve is fitted to the front fuel pump and provides a safeguard in the event of failure of either fuel pump, or of the barometric pressure control, the air-fuel ratio control, or the servo connecting pipes. The control is operated by moving the fuel pump isolating solenoid switch in the cockpit, to the ON position. To ensure protection against failure during take-off the switch must be placed in the ON position prior to take-off and returned to the OFF position as soon as the aircraft has attained its correct climbing speed and a safe height. Except in the event of a fuel system failure, the fuel pump isolating valve switch must not be moved to the ON position whilst the aircraft is in flight, as this may cause a rich extinction. At altitudes above 20/25000 feet, *6096/7620 metres,* the throttle must be closed *before* the switch is moved to the ON position. Failure to comply with this latter instruction will almost certainly result in a rich extinction.

The fuel tank booster pump is controlled by an ON–OFF switch. A fuel pressure warning light, operated by a pressure switch on the engine low pressure fuel filter outlet, lights when the booster pump delivery pressure falls below a specified minimum.

Venom aircraft, Pre-mod. 201, are fitted with Rotax starting equipment. A Venner time switch with a dial marked IGNITION–OFF–ON, is fitted on the left-hand instrument panel. Turning the switch in a clockwise direction, from OFF to ON winds a clockwork mechanism in the switch and supplies current to the high energy condenser units mounted on the engine. Immediately the switch is released, the clockwork mechanism commences to return the dial pointer from the fully ON position to the OFF position and after a period of about 20 seconds, cuts off the supply of current to the high energy units. A cartridge selector and a starter push-button are mounted as a unit below the instrument panel. The cartridge selector can only be rotated in a clockwise direction and should be advanced to OFF after each cartridge has been fired. The starter push-button will not operate unless the ignition time switch is ON and, when pressed, it remains in for 15/20 seconds after a cartridge has been fired to avoid a second cartridge being fired too soon after a misfire.

Where Venom Mod. 201 is embodied, the Rotax starting equipment is replaced by Teddington equipment. The Teddington switch has only one control, the firing button, operation of which supplies current to the ignition system and selects and fires the appropriate cartridge. This switch is mounted on the right-hand instrument panel below the fuel contents gauge. This push-button also remains in for 29 seconds after being pressed so that a second cartridge cannot be fired prematurely after a misfire. On aircraft where the Venner time switch is retained, the switch remains on the left-hand instrument panel but is only used for testing the ignition equipment on the ground, or for relighting in flight. On later aircraft this time switch is replaced by a push-button mounted on the H.P. cock lever.

In all cases an engine starter master switch is fitted on the electrical switch panel to control the supply of current to the starting system and, except when Venom Mod. 290 is embodied, the relighting system. This switch must be ON for starting and, except when Venom Mod. 290 which renders the relighting circuit independent of the master switch, has been embodied, should be left on for the duration of flight in case the necessity for relighting occurs.

On early aircraft the Venner time switch is used for relighting in flight and for testing the ignition equipment on the ground. As stated already, rotation of this time switch to the ON position gives approximately 20 seconds operation of the ignition equipment. Later aircraft with modified starter control equipment are provided with push-button operation instead of the Venner time switch. This push-button is mounted on the H.P. cock lever and facilitates relighting in flight as the H.P. cock lever and the ignition control can be operated at the same time, using one hand only.

AUTOMATIC CONTROLS

To minimise the risk of the engine being damaged as a result of incorrect manipulation of the manual controls, the fuel system includes units which automatically adjust the fuel supply to the burners as required by changes of throttle setting, and which automatically compensate for variations in barometric pressure, altitude and forward speed.

Ghost 48 Mk. 1. Automatic adjustment of the fuel supply is effected by the barometric pressure control and the air-fuel ratio control in conjunction with the servo mechanism in the fuel pumps. Overspeeding of the engine is prevented by a governor mechanism which is integral with each fuel pump.

Ghost 48 Mk. 2. Automatic adjustment of the fuel supply is effected by the flow control unit and the air-fuel ratio control unit in conjunction with the servo by-pass valve mechanism in the fuel supply pump. Overspeeding of the engine is prevented by a governor mechanism which is integral with the fuel supply pump.

In both marks, the air-fuel ratio control is, essentially, an over-riding control to maintain the correct ratio of fuel to air during acceleration when the throttle opening is increased.

ENGINE INSTRUMENTS

To enable engine behaviour to be observed, provision is made on the engine for the following instruments to be fitted in the aircraft cockpit:—

(1) Tachometer, or engine speed indicator, which indicates engine main shaft r.p.m.

(2) Jet pipe temperature gauge, which indicates the temperature of the exhaust gas, as registered by a thermocouple projecting one inch into the gas stream, at the top of the exhaust cone, 3½ inches forward of the centre line of the bolts which fasten the propelling nozzle to the exhaust cone.

(3) Oil temperature gauge which indicates the temperature of the oil in the high pressure oil filter.

(4) Rear bearing temperature gauge which indicates the temperature of the rear bearing outer race.

(5) Fuel pressure warning light which lights should the fuel pressure on the outlet side of the low pressure fuel filter fall below the safe minimum.

Normally, no rear bearing temperature gauge is fitted in the cockpit and, therefore, when it is required to observe this temperature, a suitable temperature recording instrument must be connected, using the correct compensating leads, to the thermocouple which is provided on the engine.

Connections are provided on the engine for an oil pressure gauge (*Ghost 48 Mk. 1,* from union situated at the bottom of the port side of the top wheelcase; *Ghost 48 Mk. 2,* from union adjacent to the air compressor drive housing towards the starboard side of the top wheelcase) and for checking the fuel pressure at sundry points in the fuel system. Neither an oil pressure gauge, nor a fuel or burner pressure gauge is fitted in the cockpit and when it is required to observe any of these pressures, as for instance when attempting to trace a running defect, suitable slave instruments must be connected to the appropriate points on the engine; the necessary instructions being given in chapter 9 and 11.

HANDLING

Engine control centres around the intelligent use of the throttle and correct interpretation of the tachometer and jet pipe temperature gauge readings. The throttle is the only manual control over engine power, the r.p.m. and jet temperature indicate the extent to which the engine is being stressed; engine speed also provides an indication of the thrust being developed. The remaining engine controls and instruments are of secondary importance only.

The Operating Limitations specified are those for which the engine has been approved for civil use; any infringement of these limitations may lead to defects which will render the engine unserviceable before the normal period between overhauls has been completed. These limitations represent the maximum conditions which may be used in flight and are not necessarily those which will be used for normal routine operation. Greater reliability and longer engine life will be obtained by operating at ratings lower than the limiting maxima. The engine must be operated on the fuels and oils specified at the beginning of this handbook.

The thrust of a turbo-jet engine is almost directly proportional to the total quantity of fuel being burn. Excess power for acceleration is provided by over-fuelling, which temporarily increases the temperature and energy of the gases entering the turbine. Some increase in jet pipe temperature is inevitable during acceleration but violent acceleration may involve temperatures which will reduce the serviceable life of the engine, and must, therefore, be avoided.

If the throttle is opened suddenly at some intermediate engine r.p.m. the temperatures throughout the combustion system will rise rapidly before the maximum governed speed is reached and the fuel flow is automatically regulated to its proper value. Protection against excessive over-fuelling during acceleration is afforded by the air-fuel ratio control unit which limits the fuel flow to the burners during acceleration in proportion to the air mass flow.

A turbo-jet engine will accelerate more readily in its upper r.p.m. range than in the lower, and it is particularly desirable to move the throttle lever slowly and gently when accelerating from idling r.p.m. Conversely, except at extreme altitude, excessive temperatures will not normally be induced by accelerating fairly briskly from, say, maximum continuous r.p.m. to take-off r.p.m. This is recognised in the Operating Limitations which quote two minimum speeds, Ground Idling, and Approach Idling (minimum). Acceleration from the approach minimum r.p.m. to take-off r,p,m, should take at least five seconds but acceleration from Ground Idling to maximum r.p.m. should be much more leisurely and take at least ten seconds.

Although the air-fuel ratio control unit minimises the dangers of high turbine temperatures due to over-fuelling during acceleration or in the event of sudden throttle movement affecting the ratio of air to fuel to the extent that 'blow out' or roughness occurs, there are other objections to excessively rapid movement of the throttle lever. Sudden changes of temperature may involve distortion and stresses which would not occur if the variations were more gradually applied. This consideration applies particularly to such parts as the flame tubes, discharge nozzle, and nozzle blade assemblies. Improved service can be obtained from these components when temperature changes are reasonably regulated. The quenching process on shutting down from high duty to idling speed is, in this sense, just as important as the heating process during acceleration. For this reason it is recommended that the engine is always allowed to idle for about half a minute before being stopped.

These limitations must be observed except in the event of extreme operational necessity. Movement of the throttle lever should be smooth and progressive both when opening up and when shutting down the engine. Under steady operating conditions, the temperature appropriate to the particular flying condition given in the Operating Limitations should not be exceeded, but if as the result of a sudden change of altitude or too rapid opening of the throttle the temperature is taken too high, it should return to normal as soon as conditions are again stable. The jet pipe temperature must, therefore, be observed frequently and too vigorous use of the throttle avoided, particularly at altitude where the response is more sensitive than at sea level. If for any reason maximum power cannot be used without exceeding the jet pipe 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.

Ghost 48 Mk. 1. Careful opening of the throttle is essential whenever the fuel pump isolating switch is ON as, with the switch in this position, the air-fuel ratio control is rendered inoperative.

It is advisable to run the engine on the ground with the aircraft headed into wind whenever the aircraft is stationary. If the aircraft is headed out of wind a mixture of hot exhaust gas and air may be drawn into the air-intakes and cause high jet pipe temperatures and overheating. The aircraft may be taxied normally but care must be taken to open the throttle gently and evenly, otherwise the jet pipe temperature may rise above the maximum permissible.

Before stopping the engine it should always be allowed to idle for about half a minute to permit temperature conditions to stabilize. The L.P. fuel cock should not be moved to the OFF position until the engine has stopped as the engine-driven fuel pumps rely on the circulation of fuel for their lubrication. The tank booster pump need not remain switched ON whilst the engine is running down but must be switched ON if the engine is to be run at large throttle openings; serious damage can be caused to the fuel pumps if full duty running is carried out with the tank booster pump switched OFF.

Ghost 48 Mk. 1 only. To avoid a hot start, due to the pressure head from the main fuel tanks causing fuel to flow through the drain pipe between the L.P. fuel filter and the fuel flow distributor, and thence past the distributor piston to the burners and into the combustion chambers, the L.P. fuel cock must be turned OFF after every engine run. This is essential even if the engine is to be re-started after a short interval only, as even if the inside of the combustion chambers is only slightly wetted with fuel a hot start will result. A glance at the fuel system diagram in chapter 3 will show that neither closing the throttle nor the H.P. fuel cut-off valve will prevent this seepage of fuel into the engine. Mod. 1074 introduced a non-return valve to minimise this seepage of fuel into the engine.

SNOW OR ICE

Experience shows that, even in Canada, snow or ice seldom accumulates in or around the air-intakes, due to the fitment of the air-intake covers whenever the engine is not running. In very severe conditions further precautions are usually taken by stretching a tarpaulin over the leading edge of the main plane and thus completely covering the air-intake apertures. If, however, snow or ice has accumulated in the air-intakes, it must be removed before flight, and this must not be done by any method which may involve pieces of rag, or wood splinters, etc., being drawn into the engine when it is started.