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GFA Basic Sailplane Engineering - ENGINES

MOSP PART 3: AIRW-M06

Airworthiness

UNCONTROLLED WHEN PRINTED

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DEDICATION

This document is dedicated by the authors to and in memory of John Viney.

John was our Friend, Mentor and Mainstay in the development of this document and the ensuing training courses that followed, each of which brought revisions as we gained experience in teaching the subject matter. John was there from the beginning and for all the ensuing courses and further course development.

We express our gratitude for his input and wealth of knowledge.

PREFACE

This document has been created as a guide to students undertaking motor glider engine training. It describes the basic principles of engines and systems with a view to broadening the reader's knowledge and understanding, and with this understanding be better equipped to conduct the maintenance of motor glider engines and systems.

At all times the maintenance and inspections must be conducted with reference and adherence to the approved, most current, relevant manual or reference material.

The lectures, discussion and practical exercises will encompass the 'how to' aspects of the different maintenance practices.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 AMENDMENTS TO THIS MANUAL

It is GFA policy to amend this manual from time to time to ensure that the latest knowledge and experience is available to all inspectors.

Amendments will be done by reissuing the entire affected section. These will be notified in the Soaring Australia magazine and on the GFA webpage. Amendments may be downloaded from the webpage or obtained from the GFA Secretariat. It is the responsibility of each glider inspector to ensure he or she is working from the latest version of this manual.

1.2 PRIORITY OF PROCEDURES

These standards and procedures are to be followed when the manufacturer's manuals are lacking on the subject. The information contained herein is also intended to provide additional information and knowledge to assist inspectors in performing the required tasks in an efficient manner. To achieve this the priority of procedures set down in MOSP Part 3 must be followed.

1.3 DEFINITIONS

Throughout this manual every attempt has been made to be consistent with respect to common terms and abbreviations; however, over time the usage of some terms has changed and inspectors should attempt to assess the context of any abbreviations as to their meanings.

In this manual the terms 'glider', 'powered sailplane, touring motor glider and 'sailplane' are used as follows:

Glider	An aircraft without an engine.
Powered Sailplane	An aircraft capable of soaring flight which has an engine. This may or may not be approved for self-launching
Touring Motor Glider	An aircraft capable of soaring flight and is fitted with an engine designed for self-launching and sustained engine on operation with fuel capacity for long range flight
Sailplane	A generic term covering both gliders and powered sailplanes.

Table 1 Definitions of Sailplanes

Note that there are more detailed technical definitions which are used during certification but the above definitions are sufficient for this manual. Exact definitions may be found in the MOSP Part 3 Airworthiness.

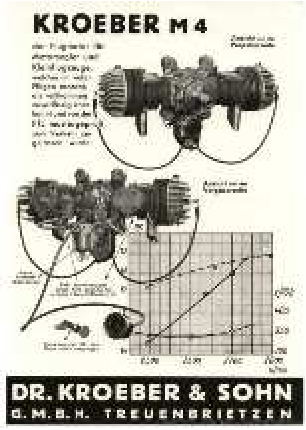
1.4 WHAT IS A MOTOR GLIDER

The FAI defines a motor glider as a fixed-wing aerodyne equipped with a means of propulsion, capable of sustained soaring flight without thrust from the means of propulsion.

1.5 THE FIRST MOTOR GLIDERS

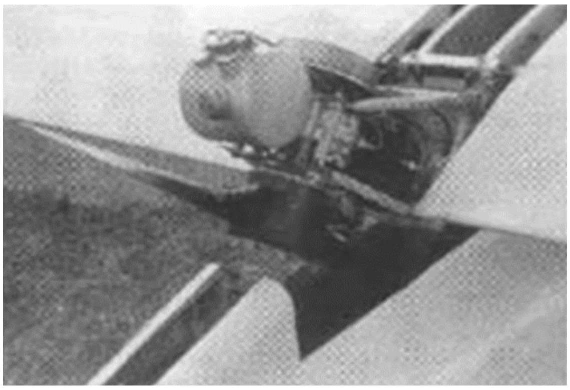
1.5.1 GRUNAU BABY II

The first production motor glider was built by Edmund Schneider in Grunau in 1938, when a Grunau Baby II was fitted with a 13.2 kW Kröber M4 motor. This aircraft was capable of self-launch and approximately 25 were built.



1.5.2 CARDEN-BAYNES AUXILIARY

This first self-launching glider with retractable motor and propeller was incorporated into the Carden-Baynes Auxiliary that first flew on 8 August 1935. The engine was a 250 cc single-cylinder, air-cooled two-stroke Villiers motorcycle engine mounted with the propeller just behind the trailing edge. An unusual and possibly unique feature of the Auxiliary was that it had a secondary throttle on the port wing tip, so that the pilot could easily taxi the aircraft whilst supporting the wing!



The propeller was indexed to stop in a vertical position and its lower tip moved forward on retraction into a slot in the bulkhead, whilst the other blade pressed on a lever that caused hinged fairing doors, previously held open with springs, to close over it. With the engine retracted, the rear of the pylon was as smoothly faired as on any conventional sailplane.

1.6 MOTOR GLIDERS TODAY

1.6.1 CLASSIFICATION OF MOTOR GLIDERS

There do not appear to be any official classifications for motor gliders but the descriptors frequently used are:

a. A touring motor glider is usually a purpose designed airframe with a front mounted reciprocating engine and a fixed or full feathering propeller. They can take off and cruise like an airplane or soar with power off, like a glider. Their large wingspans but higher drag than conventional sailplanes, means they have a moderate gliding performance which is not as good as that of unpowered gliders. Examples are: Grob G109 and Super Dimona.

b. Self-launching motor gliders have sufficient thrust and initial climb rate to take off without assistance. They are usually based on a conventional glider design. They may be launched in a similar manner to a conventional glider by winch or aero-tow. Examples are: Pik20E, DG500M, ASH 26E Nimbus 4DM.

c. Sustainer motor gliders must be launched like an unpowered glider, but can climb slowly to extend a flight once the engine is deployed and started. They often operate in a “saw-tooth” mode of: climb under power – glide – climb under power – glide etc. Examples are: ASG29, Discus 2T, Ventus T.

1.6.2 ENGINE SOLUTIONS

There are numerous types and makes of engines fitted in motor gliders. They can broadly be split into 4 categories:

a. Reciprocating 2-stroke and 4-stroke engines are the most common engines currently in motor gliders. There are purpose built aero-engines and also engines designed for another purpose and modified for use in aircraft. They may be nose mounted or aft mounted. The Stemme S10 motor glider is unique in having an aft mounted engine with a nose mount propeller.

b. Wankel Rotary engine. The prevalent rotary in gliders is the Austro. This version of the Wankel was originally designed for a Norton Motor Cycle but was modified for the UAV market by Austro (a division of Diamond aircraft) but later again modified for aircraft use.

c. Gas turbine. Small gas turbine engines such as the AMT Olympus and the M&D Flugzeugbau have appeared on a number of glider designs in Australia. They are a Turbo Jet engine. The AMT has been applied to airframes in the experimental category while the M&D Flugzeugbau comes factory fitted to Jonker sailplanes as an option.

d. Electric. The continuing development of lightweight brushless DC motors and high-power lightweight batteries is allowing exciting developments of electric powered self-launching and sustainer motor gliders. Designs have included nose and retractable mast configurations. While importation of these new types has been small it is thus only a matter of time until we see these in our skies in higher numbers.

1.6.3 PROPELLER SOLUTIONS

As a motor glider only uses its propulsion for a fraction of the flight time, it is highly desirable not to leave the propeller in the air flow causing high levels of drag. Several solutions have evolved:

a. Variable pitch propellers. Touring motor gliders frequently use this solution whereby the propeller blade angle of attack is minimized (feathered) when in gliding mode. There is minimal drag in this configuration.

b. The retractable mast mounted propeller. This has become the normal configuration for self-launching and sustainer motor gliders. The 2 bladed propeller is mounted on the top of a mast that rotates up and forward out of the fuselage, usually aft of the cockpit and wing carry-through structure. The fuselage has engine bay doors that open and close automatically, similar to landing gear doors. The engine may be near the top or bottom of the mast. Newer designs have the engine fixed in the fuselage to reduce noise and drag when in engine on mode, typically coupled to the propeller via a transmission belt reduction/transmission drive.

c. Nose, forward folding. Example pictured below: AMS – Karat.

Figure 1-1 AMS - Karat

d. Nose, rearward folding. At least one propulsion design has a nose propeller with blades that fold back, the FES system. Pictures below:

Figure 1-2 FES System

e. Nose, radially folding. The Stemme S10 is currently unique in that when not in use, the propeller folds radially and the nose cone slides back, leaving a clean nose. The engine is behind the cockpit. Pictures below:

Figure 1-3 Stemme S10 with retractable propeller

f. Powerplant from a Schleicher ASH 26E self-launching motor glider, mounted on a test stand for maintenance at Alexander Schleicher in Poppenhausen, Germany. The engine remains in the fuselage and the propeller pilon retracts into the fuselage.

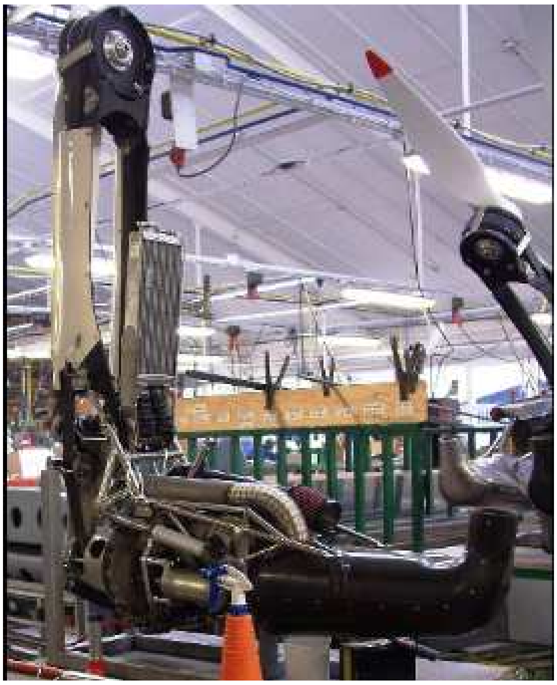


Figure 1-4 Austro

1.7 MOTOR GLIDER ENGINES ON AUSTRALIAN REGISTER

There are a number of different types of engines in use in Australia

a.	Rotax	2 strokes air cooled and liquid cooled
b.	Rotax	4 strokes liquid cooled
c.	Rotax	4 strokes liquid cooled and turbocharged
d.	Solo Kleinmotoren	2 strokes air cooled and liquid cooled
e.	Limbach	4 stroke air cooled
f.	Limbach	4 stroke liquid cooled with fuel injection and electronic ignition
g.	Limbach	4 stroke liquid cooled, turbo charged with fuel injection and electronic dual ignition
h.	Grob Werk	4 Stroke air cooled
i.	Konig	2 stroke air cooled radial.
j.	Walter Mikron IIIAE	4 stroke air cooled in line 4-cylinder heads down like a Gypsy engine and used in the Blanik L13 Vivat
k.	Stark Stammo	4 stroke air cooled
l.	Sauer	4 stroke air cooled
m.	Hirth	2 stroke air cooled
n.	M&D Flugzeugbau	Gas Turbojet
o.	AMT	Gas Turbojet

2. RATING SYSTEM AND RESPONSIBILITIES

2.1 AUTHORITY

Previously the airworthiness system of qualification of an Inspector was known as a 1109 rating.

In GFA over time where the origin of that reference was mostly forgotten although it was continually used until quite recently. It originated as a CAR under what at the time was known as the DCA or “Department of Civil Aviation” and we are talking in the 50’s or earlier.

The GFA has now adopted the term of MA for Maintenance Authority which is the term that CASA uses throughout the GA and Airline industry. It also makes a lot more sense than calling it by a CAR number that disappeared many decades ago.

The GFA, by way of an Instrument of Authority granted by CASA, controls the maintenance standards for gliders registered in Australia. The GFA is the ONLY path for Airworthiness compliance for an Australian Registered glider. There are 2 HK36 Super Dimona’s operated in Australia that are the ECO model and while for all intents and purposes they qualify as a Motor Glider, they are registered under GA and thus are maintained under the CASA regime by LAME’s and operated as GA aircraft. Engine OFF or soaring operations are not permitted. They are owned and operated by ARA for atmospheric research and they are a long way from what we do.

These are the only 2 exceptions.

The control and education system under the GFA starts with the CAD (Chair of the Airworthiness Department) and the Airworthiness Panel, which is made up of all the RTOA’s (Regional Technical Officers Airworthiness) from each region. Each State Association has at least 1 RTOA, and he/she is responsible for carrying out surveillance of standards of the clubs in the respective Association. Each club has an Airworthiness Officer. The MA holder is the last link in the chain.

The ‘Maintenance Authority’ (MA) is issued by the CAD or relevant RTOA, based on training, experience and when competency is achieved. The MA is issued with ratings for types and work the individual is qualified to undertake.

The MA has 2 sections. Section 1 is all the ratings for airframes and Section 2 is for engines and systems. The ratings issued in section 2 vary by engine type, system and level of expertise. On issuing the ratings, the issuer may apply restrictions to limit the activities of the MA holder where experience is low and specific to type.

The ratings in order of competency are:

a. DI examiner motor gliders.

b. Periodical and scheduled maintenance (100-hourly or annual etc.)

c. Replacement of components.

d. Magneto servicing.

e. Top overhaul.

f. Major overhaul.

Additionally, the propeller types and type of work authorised for the same are also defined.

Retraction systems etc.

There are many variations and other items that can be included by the CTO or RTOA, where it fits within the scope of what GFA is allowed by CASA, and the relevant experience of the individual.

The responsibility of the MA holder when working on and clearing an engine and or system for flight is high and must be taken very seriously. Once work is done, it is there until either a following procedure replaces it, or the aircraft finishes its service life. The responsibility does not go away with time. Whoever flies the aircraft assumes the MA holder has done the work correctly and the aircraft is safe. The possibility of a dangerous occurrence is enhanced when a motor is added to a glider. In addition to engine failures, the systems can kill. The dangers of fire and carbon monoxide poisoning are real and should be in the mind of the MA holder in every activity they conduct on an aircraft.

Because the Maintenance Authority is issued by the GFA, ratings may be withdrawn by the GFA in response to negligent or unacceptable work.

Motor glider systems are becoming more and more complex in their design. With that comes increased opportunity for human error, and for components to fail.

2.2 CERTIFICATION

Gliders commercially operated in Australia must be Australian type certified or alternatively, the type or model imported must be eligible and issued with an Australian Type Acceptance Certificate. The above is the primary requirement for the issue of a Standard category Certificate of Airworthiness. To be eligible for type acceptance, the type must be manufactured and certified in a 'recognised' state-of-design (SOD). The state-of-design is the term for a country that is a signatory to the Chicago convention (1944), better known as the International Civil Aviation Organisation (ICAO). Recognised 'State-of-Designs' that manufacture and certify aircraft eligible for Australian type acceptance are Germany, Netherlands, France, Great Britain, Canada, United States of America, New Zealand and EASA. All gliders that are manufactured and type certified in the above countries are eligible for Australian automatic type acceptance under Regulation 21.029A.

Those gliders from State-of-Designs not listed above that require an Australian Standard Certificate of Airworthiness must be issued an Australian Type Certificate. The manufacturer of the type or model would require CASA to perform an audit and type validation. If acceptable, this would result in the issuance of the Australian type certificate.

Currently type certified gliders must meet a recognised airworthiness design. Australia has CASR 21.22 for gliders. The FAA standard is the FAR 22 and EASA the CS 22 airworthiness design standard, (previously known as JAR 22). Most sailplanes imported are type certified to the EASA CS 22. The Type Certificate Data Sheets (TCDS) will state the category for the type being one or a more in the Normal, Utility and Aerobatic category. CS 22 for gliders is not as arduous as the CS 23 design standards used for general aviation and other design standards such as for transport category aircraft. Thus, some engines designed under CS22, for example 'sustainer' and 'self launch' two stroke engines, cannot be considered as reliable as those used in GA. This is reflected in the GFA MOSP where it states that a motor glider should always operate within gliding range of a safe landing site.

In the event that the glider does not meet the standards of CS 22, it may be possible to operate on a Special Certificate of Airworthiness or an Experimental Certificate.

Compliant Light Sports Aircraft (LSA) must meet the ASTM standard or equivalent. See AC 21.42 Appendix A for accepted design standards. Compliant LSA are eligible for a Special Certificate of Airworthiness for the LSA and can be used for the purpose of flight training, glider towing (if manufacture approved) and private operations. The manufacturer of the LSA and Kit-Built LSA are responsible for the continuing airworthiness of the type. They must be maintained to the manufacturer's maintenance schedule and require a GFA logbook statement detailing their continued airworthiness maintenance requirements. The manufacturer responsible for their continued airworthiness must issue safety directions when any unsafe condition arises. An AD will generally not be issued for LSA though any certified equipment fitted will be subject to State-of-Design airworthiness directives. Note that CASA can issue Airworthiness Directives for LSA but that would be very rare.

Kit-Built LSA and non-compliant LSA are eligible for an experimental certificate but can only be used for private operations. For further information on LSA, refer AC21.41 and AC21.42.

Other gliders that do not meet an airworthiness standard, or for other reasons are not eligible for a Standard or Special Certificate of Airworthiness but are deemed safe when operating to any imposed operating condition, are eligible for an experimental certificate. The experimental certificate permits operations for specific purposes (refer CASR 21.191 and CAR262AP. Experimental also may include gliders that are certified in a non-recognised country and do not have or do not meet Australian type certification or requirements. The GFA has the ability to issue experimental certificates for Research and Development, Showing Compliance with the Regulations, Air Racing, Operating an Amateur-built Aircraft, Kit- Built LSA and Non-compliant LSA purposes.

GFA MOSP3, BSE, ADPM, RO Handbook and the Form 2 guidelines offer members good information relating to the above requirements for the issue of a range of Standard and Special Certificate of Airworthiness. CASAs applicable Advisory Circulars available on the CASA website are additionally excellent references.

2.3 AIRWORTHINESS STANDARDS

The inspection, repair and maintenance work undertaken by glider inspectors must be of a suitably high standard. To ensure appropriate standards are being achieved, a system of audits and inspections is undertaken by an RTO/Airworthiness or delegate that provides an independent review of work practices and procedures.

Occasionally, poor standards of work or record keeping are identified. Unacceptably poor standards cannot be tolerated, and ratings may be suspended or withdrawn.

Annual Inspectors are able to be involved in the training of pilots for Daily Inspection. Annual Inspectors are not able to examine a Daily Inspector candidate unless they hold a Daily Inspector Examiner rating. The Annual Inspector must hold a MA for the engine type being examined.

MA holders are responsible for ‘standards’ and workmanship by any ‘external’ organisation which may work on a motor glider engine, e.g. starter motor, alternator, carburettor etc.

It is recommended that the MA Inspector ‘oversee’ any work undertaken on components as it is the Inspector’s responsibility to ‘sign off’ the work. This is not necessary where the work is undertaken by a manufacturer’s representative (e.g. propellers, magnetos) and a release note is provided.

3. INSPECTIONS AND MAINTENANCE

3.1 GFA SYSTEM OF MAINTENANCE

All aircraft need to be/ have to be maintained to a System of Maintenance (SOM)/ maintenance program, to keep them legal and safe. However, to give recreational aircraft owners some freedom, the Australian Regulations allow some flexibility which is different to foreign regs. Also, some aircraft do not have a good or suitable SOM so GFA provides Guidance and a minimum SOM. The GFA Form 2 and Appendices are part of this. Please read RO Handbook Section 3.8 Maintenance Requirements for a layman's description and MOSP 3 Chapter 9 for the GFA rules/ procedures that have to be followed.

An Aircraft Maintenance System needs to be defined as 'one size does not fit all' and the RH has some flexibility to decide how he wants his aircraft maintained. A Maintenance System needs to define:

a. What must be done;

b. When it must be done;

c. How it must be done; and

d. Who is allowed to certify that it was done correctly.

Follow MOSP 3 as the source of procedures, but GFA SOM needs to evolve and it is being updated so it will change. But the general intent for engines is:

e. The default GFA SOM requires at least an annual inspection itemized in the Form 2 for the airframe and Appendix A, B, C, D etc for the engine. The RO must ensure at least this is done and must submit a Form 2c return when the Maintenance Release is issued. This is to certify that the required maintenance over the last year was performed and to supply some basic data for GFA records.

f. If the engine does more than the specified number of hours then more frequent servicing is recommended. This must be done as decided by the RH, but does not require that a return is submitted to GFA for the engine.

g. The Manufacturer's guidelines as given in the Maintenance Manual (MM), Service Bulletins or equivalent are good advice on what, when and how maintenance must be done. However, they are usually not mandatory for recreational aircraft in Australia so the RH may change what is done on his aircraft. Eg he may elect to change oil at 25 hours rather than 50 because he operates in hot conditions or he wants to be more careful. He would be increasing risk to extend the recommended oil change or inspection to a longer period.

h. If an applicable AD exists then that has to be done. And ALS and CMR as defined in MOSP 3 must be done (but these are very rare for gliders).

i. MOSP 3 requires the glider engine is inspected at least annually to the Appendix A, B, C, or D checklists. So, if it has had this at 100 hours or 50 hours during the year, another engine annual is not required. But the return must be submitted saying the required maintenance was done. And the next hours or time-based inspection must be done when it is due, ie a 100 hourly or an annual, whichever comes first.

j. An engine is best maintained to the recommended hour schedule or at least annually. If you want to vary from the Manufacturer's schedule or the GFA SoM then the RH must fill in a Logbook Statement and have it approved by GFA and stuck in the logbook to make it clear what is to be done. This includes What, When, and/ or How. A 100 hourly for a small engine is a long time between checks and not recommended as the only maintenance.

k. Most RH will follow the default MM schedule, have the Appendix A, B, C, or D checklists completed annually and submit the Form 2c return annually. They do not have to redo the maintenance to tick off the Appendices - the inspector is just certifying this was done within the year at the required intervals.

l. At the manufacturer's specified TBO they may elect to obtain approval under MOSP 3 Section 3.2.2 Service Life to operate the engine and propeller 'On Condition'.

3.2 PERIODIC INSPECTIONS

Scheduled maintenance of engines and systems is preventative maintenance performed to ensure that the motor glider is in a sound condition. Provided it can still pass a daily inspection it will remain airworthy for the duration to the next scheduled maintenance. Motor glider airframes, engines and associated systems will almost always have a regime of scheduled maintenance and inspection specified by the aircraft or engine manufacturer. When doing an annual or scheduled engine maintenance item it is advisable that this schedule be considered by the inspector while following the GFA schedule and F2. By schedule we mean what and when. How is usually in the manuals or BSE Engines.

The following inspections/ maintenance occur on GFA motor gliders:

Daily Inspection – the last chance to find a fault – and the most important

a. Periodic maintenance like oil, filter, sparkplug changes. Generally, to the manufacturers schedule and checklist. Often 20, 25, 50 and 100 hourlies.

b. Annual Inspection

When performing Annual Inspections, the inspector should use the appropriate GFA Form 2 engine appendix as the basic checklist, giving consideration to any additional inspection requirements from the manufacturers' manuals. However, you don't have to repeat what has already been done at the 100 hourly – just confirm the minimum checks have been done. It does not have to be onerous.

Inspectors should also ensure that all ADs have been complied with by checking the logbook entries. The type specific and general Schedules of Airworthiness Directives which is received with the Form 2 kit should be used as a checklist of applicable ADs. Further requirements may be set by service bulletins from the manufacturer of the engine, aircraft or any associated systems. ADs may also be applicable on the State of Design website.

Certain documentation is required to complete an annual inspection engine appendix

c. Logbook. To check maintenance history and record the results of the current maintenance.

d. Previous Maintenance Release.

e. Certificate of Registration. If the certificate of registration is not correct then Airworthiness Directives will not be received.

f. Manufacturer's manuals. To provide technical data and information, such as Spark Plug Gap, ignition timing etc.

g. All applicable Airworthiness Directives.

h. A Form 2 kit with the engine supplement from the GFA Secretariat. Just print the one for your engine and ignore the others.

3.2.1 LEVEL OF INSPECTION

The level of inspection required varies with a number of factors. These factors include:

a. The usage in the previous period - high hours, low hours.

b. Storage conditions - wet trailer, dry hangar.

c. Inspector's familiarity with the particular aircraft. Did you work on this aircraft last year and what work was done then?

d. The last periodic maintenance performed

If an inspector has never seen a particular motor glider before, the level of inspection will obviously be more in depth than if the inspector has worked on a particular motor glider over the past few years and knows, for example, that the fuel hoses were replaced last year and noted in the logbook and so a visual inspection will be adequate this year.

3.2.2 SCHEDULED MAINTENANCE

The schedule of maintenance and inspection is normally related to the hours in service use, but occasionally a period of time (e.g. 6-monthly inspection). Different components may have different start dates in service and different intervals between scheduled maintenance e.g. propeller and engine. The maintenance and inspection requirements may be different at each interval (e.g. a minor inspection at 50-hours but a major inspection at 100-hours intervals).

Annex A near the end of this document shows an example checklist of scheduled maintenance and inspection, in this case for a H36 Dimona, which is typical of a touring motor glider. The last 3 columns indicate what is required at 50, 100 and 500hr scheduled maintenance intervals.

The Annual Inspection (Form 2) under the GFA and the appropriate appendix, is the minimum required maintenance schedule used for all GFA aircraft (except LSA aircraft must only follow the manufacturer's SoM and no other option is permitted).

All work <u>must</u> be carried out in accordance with the GFA MOSP Part 3. The relevant manufacturer's manual should be used as an advisory reference - it is good advice but not mandatory.

The GFA system relies on inspectors following the specific requirements for each aircraft and engine type, as the field is very broad. Consideration must also be given to the currency and validity of manuals for engines, propellers etc. In the case of the H36 Dimona, these have been updated since production of the aircraft manual. The approved documentation from the original manufacturer overrides the aircraft manual where it is a more recent publication. Care must be taken to check that the updates apply to the specific model, as changes in production happen over time. Again, this is not mandatory but advisable. Component life must be followed where other Australian approved data is not available.

The term 'approved' documentation refers to the requirement for approval of the original issue and further changes by the controlling body in the country of manufacture. The controlling body in this case was the LBA, now EASA.

The GFA maintenance schedule appendix is a check list and should be used as such. Obviously, it does not instruct the inspector on how to do every task. There is always the assumption that the inspector has been adequately trained for the task at hand. Additionally, they should find the approved data on how to do the work and have it on hand.

3.3 THE FIRST INSPECTION

When a motor glider first enters Australia, it is required to undergo an inspection. This is regardless of if it being new or used. All aircraft new and old are inspected for compliance to Australian regulations and checked for defects. This is known as the inspection for the initial issue of a C of A. This might seem overkill in the case of new aircraft but history shows the reverse. There are multiple cases of complicated situations involving new aircraft.

Imagine a brand new aircraft rolls out of the container and taken in it's trailer to an AMO for it's initial inspection. This is the first of type in Australia when it arrives and also a sustainer is fitted. It comes out of the trailer with a flat tyre that refuses to stay up when pumped up.

It arrived with 5 ADs issued by EASA while it was on the water all of which had to be conducted at the owners expense and required some parts from the OEM.

To rub salt into the wound it came with a ready to go previously arranged fuel leak at a fitting just after the boost pump. The AMO needed extra pages for the defect reports at the back of the Form 2. He listed 21 defects in the report to the GFA. The OEM gave the AMO poor service for years after as they were really annoyed that EASA had taken them to task over the GFA complaints. It was 3 months before all the parts arrived and it could be put into the air. The owner paid for a new inner tube for his main wheel.

In the case of used aircraft there are just as many reasons to be cautious if not more. The above is frequently the case so do not trust any engine installation.

3.4 SERVICE LIFE

It is common for the manufacturer to specify a ‘life’ for some items. This is generally expressed in hours or years and includes engines, propeller and airframes. As an example, below is a list for the H36 Dimona:

Component	Life time
Engine	The recommended TBO of the Limbach engine is 850 hours. Extended TBO will be published by service bulletins of the manufacturer.
Propeller	The recommended TBO for the propeller assembly is 600 hours or every 4 years, whichever comes first. Extended TBO will be published by service bulletins of the manufacturer.
Magnetos	The Slick magneto model 4230 and Bendix magneto model 54RN21 have a TBO of 1000 hours. At 500 hours they must be inspected.
Rudder cables	The rudder cables can be controlled during normal inspection intervals. Should excessive wear be found, the cables should be replaced. When no wear is discovered, the cables are to replace every 5 years or 1000 hours, whichever comes first.
Tail wheel steering cables	1000 hours of operation or 10 years
Air brake control cable	1000 hours of operation or 10 years
Silent blocks of engine mount	3000 hours of operation
Engine tension-cables and turnbuckles	3000 hours of operation
Electric fuel pump, part no. 4412	1500 hours of operation
Electronic fuel pump part no. 8812:	3000 hours of operation
Fuel shut-off valve, type Truma 8L	3000 hours of operation or 5 years
Fuel tank made of FRP	3000 hours of operation
Rod end bearings, fastening screws, and brackets of main landing gear attachment	3000 hours of operation
Outer rod end bearings of elevator attachment:	3000 hours
Flexible fuel and hydraulic lines of airframe / cell	8 years
Flexible fuel and oil lines of engine compartment	5 years

As mentioned before, there may at times be a later ‘approved document’ that changes these times, and this is the case for the engine, propeller and magneto, in this case where the TBO has changed. There is little scope for deviation from these limits, however CASA does allow the GFA to extend the engine TBO using ‘on condition’ rules. And the prop may also be operated beyond the time TBO according to MOSP 3. There is a list of requirements to follow and approval must be gained from the GFA Airworthiness office in that case.

CASA will not entertain the idea of either they or the GFA allowing an airframe to operate beyond its life by the issue of an Experimental Certificate of Airworthiness.

The ‘lifed’ items must be recorded in the logbook in the section pertaining to that subject with the date and airframe/engine time due. Additionally, when changed, the new expiry time for the item must be recorded. Use the Lifed Components section in the Logbook.

Where there is a reasonable possibility of an item’s life expiring between annual inspections, it must be recorded in the front section of the Maintenance Release under maintenance to be performed, with either a date or hours due.

Periodical maintenance, such as a 50-hourly inspection, must also be recorded in this section.

In the case of using used parts they must have a chronicle of history and time in service. For instance, a damaged aircraft with 2500 hours flying time is damaged and is then fitted with a replacement tailplane from another wreck that is in serviceable condition. This is not unusual but if the tailplane has 5900 hours that then transfers to the present aircraft. The aircraft is thus as old as its oldest component so 5900 hours. You have essentially aged the aircraft by a further 3400 hours and it will then need its first survey in 100 hours from that time.

The same applies to an engine. Where the item does not have a life or is able to be overhauled then it is not a problem but remember the service life of any used component must be observed just as it is during major overhaul.

3.4.1 SCHEDULE of MAINTENANCE CHECKLISTS

GFA Form AIRW F002 (Appendix A, B, C, D etc) contains checklists that provide a systematic approach to engine and engine system inspection. Use the one to suit the engine type. These are generic and some flexibility is required to fit them to the aircraft and engine. The detail of the inspection will involve considerably more than a cursory look. They include a 'GFA Powered Sailplane Engine Run Sheet' to record annual data for records of the engine operating condition.

When the manufacturer of a glider, engine or component recommends or requires an Inspection, either on a time of use or calendar basis, that inspection must be completed unless the RH elects another SOM. At the glider annual, to issue a new Maintenance Release (MR), the AIRW F002 Appendix A, B, C, or D or the more detailed manufacturer's checklist must be completed.

The 'GFA Powered Sailplane Engine Run Sheet' is required to be completed for at least 3 maintenance cycles before approval for operation 'On Condition' (annually or 100 hourly) to provide the basis to approve operation 'On Condition'.

4. SAFETY – PERSONNEL, GLIDERS & WORKSHOP

During work on any sailplane, the safety of all personnel, including those in the work team and any onlookers, the sailplane (and all components), and the workshop (and its contents), must be given the appropriate consideration and care.

Some of the safety considerations necessary to prevent injury to personnel include:

a. Personnel

i. Electrical items (power tools, extension leads, lead lights etc.) must be maintained in good condition and regularly checked.

ii. Lifting devices and supports. Manual handling injuries can be prevented – ensure a lifting aid, or team-lifting practices are used.

iii. Personnel should be warned not to lift any heavy items when alone.

iv. Lighting should provide plenty of light for the tasks to be performed.

v. Trip hazards should be eliminated.

vi. Safety Personal Protective Equipment (PPE); gloves, goggles, aprons etc should be used when necessary.

vii. Develop and use a tool control system to prevent tools and other foreign items being left inside the glider structure.

viii. Never run a glider engine while the fuselage is in a fuselage stand. Never!

b. Sailplane

i. Wing stands, fuselage stands and the like should be well constructed and be stable.

ii. Storage – all components removed from the glider should be stored in a safe location (ie don't store the canopy under a wing, if it falls, the canopy will be adversely affected) and be adequately labelled.

iii. Fuel and oil should be stored in clean, clearly marked, air-tight containers, away from ignition sources.

iv. Tool control – inadequate 'tool control' is vividly demonstrated by the state of the torch in the following picture. The torch was 'lost' during work on the motor glider – only to be 'found' some time later, still in the engine bay.

Figure 4-1 Poorly controlled torch.

c. Workshop

i. Electrical safety – as above. It is recommended that there be an earth-leakage circuit breaker in the power supply for personnel and equipment protection. This is also covered under state legislation. Apart from working in your home workshop it is extremely unlikely the state law will allow a workshop with club members working in it not to meet that requirement.

ii. Fire Safety - Consider a rule whereby there is no welding, cutting, grinding etc near the sailplane.

iii. Have suitable fire extinguishers on-hand in case of fire:

1. BCF, Dry Powder or CO2 for electrical fires.

2. Foam for fuel or chemical fires

3. Pressurised water for wood and paper fires.

iv. Chemical safety – consider the storage of solvents, cleaning agents etc in a separate area well away from the glider.

1. Store motor glider fuel in approved, clean fuel storage containers.

2. Store engine oil in approved containers which are clearly labelled.

v. Storage - glider components

1. Ideally, clean and inspect all components as they are removed, before storing serviceable components in suitably labelled, clear plastic bags.

2. After cleaning and inspecting canopies, store them in a suitable location, under clear plastic – everyone can see it is a canopy.

3. Provide a supply of labels for attachment to parts etc to indicate problems, outstanding checks etc.

vi. Tools - condition

1. Pay particular attention to tools – ensure they are regularly maintained (chisels, hammers, etc) and stored clean and ready for use.

2. An arrangement such as a Shadow Board is a good method to be used for tool control.

vii. Smoking – should not be permitted in the workshop.

viii. Keep the workshop clean and tidy.

ix. Provide a well-lit space for the storage and use of reference material (flight / maintenance manuals, ADs, etc)

5. AIRWORTHINESS DIRECTIVES AND AIRWORTHINESS NOTICES

Up-to-date airworthiness information is critical to the ongoing airworthiness of an aircraft. A system is in place to help provide the Registered Operator (RO) of an aircraft (which includes gliders and motor gliders), with airworthiness information. BSE and the Aircraft Manuals are the main advisory documents and source of approved data. The TCDS is the origin of most critical data. But ADs over-ride these for critical corrective actions.

An AD, if relevant, must be complied with in the time-frame stipulated, while an AN, is advisory.

Refer to MOSP 3 Chapter 15 to 17 and the Registered Operator Handbook for a simple description. The RO must check for new ADs which may be published by GFA and CASA or overseas by the State of Design, all mandatory. Compliance with the ADs and ANs must be recorded in the aircraft logbook. Recurring AD items must be listed in the aircraft's Maintenance Release.

ADs and ANs are issued in two forms:

a. General - these are applicable in all circumstances.

b. Specific - for a certain aircraft type, model, etc or component, ie Tost release, Rotax engine, etc.

Compliance with an AD may be required before further flight or by a certain date, which will be stated in the AD.

An AD may be generated by the aircraft or component manufacturer, the regulator in the country of origin, the regulator in Australia (GFA or CASA).

Compliance with an AN is optional.

Some ADs and ANs require once-off attention (ie inspection, test etc), while others require ongoing attention. This requirement is identified in the document.

A listing of current ADs and ANs is provided on the GFA website in the Airworthiness Section. Any AD, which requires immediate attention will be forwarded to the Registered Owner.

Copies of the relevant ADs and ANs will be provided to the Registered Owner with each Form 2 pack.

Compliance with the ADs and ANs should be recorded in the aircraft logbook. Recurring AD items should be listed in the aircraft Maintenance Release.

5. MAINTENANCE RELEASE AND LOGBOOK

5.1 MOTOR GLIDER MAINTENANCE RELEASE

The Maintenance Release of any glider is a vital part of the airworthiness history. This individually numbered document provides for the ongoing recording of progressive total airframe hours, total number of landings, a list of scheduled maintenance, the recording of minor and major defects, a record of daily inspections and blank Defect Report Forms.

The Maintenance Release (MR) (GFA Form 1) for a motor glider contains some subtle changes from the standard glider MR. These are:

a. The individual number of the MR booklet is preceded by the letter ‘P’, ie P0745

b. A blue coloured appendix added for the recording of engine/propeller hours etc.

The additional items to be recorded daily for a motor glider include:

c. Completion of any scheduled maintenance items, engine, oil/filter changes, 50hr, 100hrs etc

d. Engine hours. Total for the day and a running total.

e. Propeller hours. Total for the day and a running total. (may be different from the engine in the event of a propeller or engine change.

f. Oil quantity uplifted (ie added to the engine)

g. Write in the next scheduled maintenance after completion of an item.

5.2 FORM 2 MOTOR GLIDER SUPPLEMENT

A motor glider Form 2 (Annual Inspection) involves an inspection of the engine and the engine systems in the same way the glider hull involves an inspection of the parts (wings, fuselage, tailplane, etc) and all of the associated systems.

The inspection results are recorded on the Powered Sailplane Inspection Report APPENDIX which comes in several versions for different engine types. Currently there is A, B, C and D which can be accessed via the GFA website

5.2.1 SCHEDULE MAINTENANCE CHECKLISTS

GFA Form AIRW F002(A) contains a checklist that provides a systematic approach to engine and engine system inspection. The detail of the inspection will involve considerably more than a cursory look.

Where the manufacturer of a glider, engine or component requires an Annual Inspection, that inspection should be completed in conjunction with the AIR F002(A) (i.e. both are to be completed).

5.2.2 SPECIFIC CHECKS

Some checks specified in the checklist will require special tools, which may be available from clubs or State Associations. These tests may include:

a. Compression check. A standard ‘compression tester’ is suitable, or a differential pressure test set.

b. Electrical bonding of the fuel tank to the airframe ground. A device to test ‘continuity’ is required, i.e. multi-meter or similar.

c. Magneto timing. Requires a magneto timer.

d. A check of the revolution counter requires a test revolution counter.

e. Spark plug removal will require a torque wrench to reinstall the plugs, unless your arm is ‘calibrated’ to the required tightening tension.

5.2.3 MOTOR GLIDER LOGBOOK

An inspector must strive to record the complete history of the glider in the Logbook. This will ensure that over time, people will be able to consult the logbook to determine why, what, how and when repairs were made.

A motor glider requires the recording of some extra information beyond a sailplane as follows:

a. Completion of scheduled maintenance.

b. Update of engine hours

c. Update of propeller hours – may be different from the engine.

d. Oil uplifts.

e. AD compliance (engine, propeller and associated systems)

6. BBL AND WHAT IT COVERS

The Broad-based Liability (BBL) Insurance is not specifically an engine course or airworthiness subject, so it will not be discussed in any detail in this document.

It is however important that glider inspectors are aware of the existence of the BBL policy.

7. HUMAN FACTORS IN MAINTENANCE

Maintenance is a vital aspect in every form of aviation, from flying model aircraft to supersonic fighter aircraft and the Space Shuttle – and includes sailplanes.

In the distant past, the most complex task in the 'transport' arena was the shoeing of a horse. If a failure occurred, there was almost no impact, let alone any significant or serious injury.

Today, the consequences maybe considerably more serious eg the failure of a component or system on-board an A380 airliner may have far more reaching affects in the air and on the ground.

Significant improvements have been achieved in the safety of systems and procedures, particularly where human involvement is concerned. These improvements have largely been achieved by automation, but maintenance activity is difficult to automate.

7.1 GLIDER MAINTENANCE

Maintenance work and outcomes, whether they are good or bad, continue to rely significantly on human hands, minds and inputs. Humans continue to remain awfully fallible.

Research, practice and experience in the field of human endeavour have not yet been able to resolve the two significant and recognised threats in maintenance practices:

a. That an actual or potential failure will not be recognised and corrected (either partly or fully) before a real failure, i.e., an oversight. Example: A crack in a bolt is not identified and the bolt is not replaced.

b. The maintenance task itself will introduce a failure or increase risk of failure, which may not have occurred if it weren't for the maintenance activity. Example: A good part in a sound system is wrongly reassembled after an inspection.

7.2 HISTORICAL EVENTS

There have been many significant events in the not too distant past where 'Human Error' during maintenance has had a devastating effect on people and facilities. These include:

a. Flixborough, UK, where an explosion and fire in a cyclo-hexane facility in 1974 resulted from an uncontrolled (poorly designed and constructed) pipework modification.

b. Bhopal, India, where a methyl-iso-cyanate release in 1984 killed thousands of people, and disabled many more.

c. Piper Alpha, North Sea, where uncontrolled maintenance practice and activity in July 1988, resulted in 167 deaths.

d. Space Shuttle 'Challenger'. Poor maintenance practices (regarding booster O-rings) resulted in the death of 7 crew members on 28 January 1986.

Human "Maintenance Error" (ME) incidents are not generally random events committed by some wayward and/or careless individuals. These events are also committed by very good, competent individuals working in excellent organisations using the most up-to-date systems, procedures and practices. In short, the very best people can, and do make the very worst mistakes.

There are many 'factors' associated with failures which occur during maintenance activity. In order to address these failures, it is necessary to understand and appreciate some of the underlying causes and influences, which include.

e. The individual: What are the pressures, stresses, make-up, training and disposition which influence (consciously or otherwise) the individual person's actions and attitudes?

f. The team: What influences and actions do the combined personal involved have on the team? Is adequate time allowed for the tasks to be performed?

g. The task: Are the tasks considered boring, repetitive, or so difficult as to be bordering on impossible? (e.g. overhauling an LS-7 nose release).

h. The workplace: Is the workplace bright, well-lit and airy, with adequate storage and workspace facilities, and with good (at least adequate) tools, spare parts, and access to reference material?

i. The organisation: Does the organisation support the individuals responsible for the maintenance, with good communications practices, up-to-date reference materials and procedures, and is it willing to listen to concerns and upgrade practices and procedures?

In the gliding and sport aviation environment, generally these issues may be less of an issue due to the 'voluntary' nature of the work tasks. However, failures consistent with the mainstream, are possible and do occur.

Two frequently repeated (routine) maintenance practices are the:

j. Removal, cleaning, inspecting and replacement of components.

k. Dis-assembly and re-assembly of components.

Consider the removal of cowls. The first step (1) is the removal of fasteners, perhaps in the cowls of the engine in a Falke motor glider. When the work is completed, it is necessary to replace the fasteners (2). How often do we find fasteners missing, wrongly installed (cross threaded!) etc. or hear of cowls coming adrift in flight.

This involves the dismantling of a component, e.g. an operating magneto - inspection, measurement and testing as necessary, replacement of parts or components prior to reassembly.

How often do we hear of the component failing to operate correctly when returned to service?

It is often easier to undertake item (1) above, than item (2). But still many mistakes are made with both items.

As an example, consider this situation: A bolt with 8x nuts, labelled from 1 to 8 sequentially, screwed onto the same bolt. The required task is to:

l. Remove the 8x nuts.

m. Clean the bolt and the 8x nuts

n. Replace the nuts in the <u>original sequential order</u>.

There is only one sequence for taking the nuts off the bolt. However, re-assembly could see the order the nuts are screwed back onto the bolt being different to before they were unscrewed. Mathematically the number of permutations of the order the nuts could be replaced is: 8x7x6x5x4x3x2x1=40,320 So there are 40,319 ways of getting it wrong and only one way of getting it right! The task therefore requires thought, planning, checking, etc.

7.3 THE BIG BOYS

Boeing Aircraft, the manufacturer of some of the bigger aircraft in civil aviation, has published details of their ME experiences:

The top 7 causes of in-flight engine shut-down (IFSD) at Boeing were:

a. Incomplete installation (33%)

b. Equipment damaged on installation (14.5%)

c. Improper installation (11%)

d. Equipment not installed (at all) or missing (11%)

e. Foreign object damage (FOD) (6.5%) – tools

f. Improper fault isolation, inspection, testing (6%)

g. Equipment not activated or deactivated (4%)

This accounts for 86% of all reported incidents.

In gliding, we must acknowledge the ‘human weakness’ of fallibility. There is no harm likely to occur because you ask someone to check your work.

7.4 INSPECTORS PROBLEMS

As well as the technical problems associated with engine and systems maintenance, the inspector must deal with a number of organisational problems which can affect the quality of the work.

7.4.1 CLUB STRUCTURE

In modern accident investigation increasing emphasis is being placed on the overall responsibility of the organisation to provide a working environment which is conducive to safety. If an inspector fails to tighten a bolt because he or she is under pressure to have the aircraft finished then a club officer who has set an unreasonable work schedule or failed to provide adequate facilities for the job must bear some of the blame for any accident.

7.4.2 LACK OF TECHNICAL INFORMATION

Inspectors are often faced with inadequate manufacturers’ manuals when inspecting engines and systems especially for older types. This manual is intended to fill in the gaps; however sometimes an inspector will encounter a problem which is not covered by any manuals and which they have not experienced before.

Inspectors who cannot solve a problem on their own should seek the advice of a more experienced inspector. If the problem still cannot be solved the inspector should contact their RTO/A or the CTO. Inspectors should never “guess” the solution to a problem.

7.4.3 WORKLOAD

Overloaded inspectors are more likely to make mistakes. Inspectors should make a point of having as many helpers as are necessary (but not so many that the inspector loses track of what they are doing). This has a double advantage as there is someone to help lift heavy objects and you may be training someone who can ease the workload in the future.

Teaching potential new inspectors and spreading airworthiness knowledge are very important. Inspectors who lock themselves away deny themselves the chance of a second opinion.

Club management must also bear some responsibility for the workload of its inspectors.

7.4.4 FINANCE

Airworthiness standards cannot be compromised for any reason. An inspector cannot stand up in court and say “we couldn’t afford to put a new one in so I let it go”. If the money is not available and the problem is serious enough the glider is not airworthy.

7.4.5 PERSONALITY

As well as dealing with the technical aspects of inspecting and servicing motor gliders engines and systems inspectors must deal with helpers and “experts”. When working with helpers it is important to keep a close eye on their work. After all it is the inspector’s final signature that says a motor glider is safe to fly.

The word of unknown experts must be treated with caution. If help is required seek out a recognised source of information and be prepared to ask a disruptive person to leave the workshop.

8. THE 2-STROKE RECIPROCATING ENGINE

8.1 INTRODUCTION TO THE 2-STROKE ENGINE

The 2-stroke engine is the simplest concept. Like the rotary engine it has no overhead valves, camshaft or complicated valve operating mechanism. Valve function is achieved by ports in the bore & crankcase which are covered or uncovered by the piston crown & skirt. In some designs a thin steel reed valve controls the inlet of the air/fuel mixture to the crankcase, and in others a rotary disc attached to the crankshaft achieves this purpose.

Each of the engine cycles described below consist of 4 specific cycles – being induction, compression, ignition and exhaust cycles, which occur within the engine at different times and different places, i.e. a 4-stroke engine cycle and a gas turbine engine have these 4 cycles occurring at the same time in different places within the engine, with the Turbine compression, ignition, power and exhaust cycles occurring at different places within the engine - but continuously.

Unlike the 4-stroke which needs to perform two revolutions for every combustion (or power) stroke the 2-stroke engine produces a combustion (or power) stroke every rotation, so with very few parts, it gives a very good power to weight ratio.

However, there are two significant drawbacks to the 2-stroke design:

a. Considerably higher fuel consumption than the 4-stroke.

b. Higher emissions due to the quantity of unburnt fuel which passes through the engine during the cycle, and the combustion of the lubrication oil in the fuel.

There is not normally an oil pump or sump, the engine is instead lubricated by mixing the lubricating oil into the fuel prior to tank filling. The fuel & oil mixture then lubricates the internal parts as it travels through the crankcase & into the cylinder. In some designs oil is supplied from a separate tank and a small metering pump injects it via a port in inlet duct or the carburettor. This has some advantages, as less oil is needed and straight petrol can be used, thus emissions are lower, although this system is not usually seen in motor gliders with 2-strokes. On fuel injected 2-strokes and rotary engines, oil injection is necessary for internal parts of the engine, as there is no lubrication available via the fuel.

8.2 MAIN COMPONENTS OF 2-STROKE ENGINES

The main components of the 2-stroke engine are:

a. Crankshaft.

b. Connecting rod (often called a “con” rod).

c. Piston.

d. Piston rings.

e. Crankcase.

f. Cylinder.

g. Cylinder head.

8.2.1 CRANKSHAFT

The crankshaft is generally steel, as is the connecting rod. The piston rings are usually cast iron, while the rest of the components are alloy and the wall of the cylinder is plated with either hard chrome, nickel or nickosil.

8.2.2 CONNECTING ROD

The connecting rod 'big end' bearing is a needle roller, while the gudgeon (piston pin) bearing is usually bronze but may be a needle roller bearing. The crankshaft main bearings are either needle roller, or more commonly, white metal.

8.2.3 PISTON

In some engines the piston may have a profiled crown to assist with scavenging. The ring grooves are normally fitted with small pins which prevent the piston rings from rotating in the bore. This is important as the ends of the piston rings must be kept in the continuous part of the bore. Should a piston ring end meet with an inlet port, the ring would be broken.

8.2.4 CRANKSHAFT

The crankshaft has a seal at each end in the crankcase which sits outboard of the bearing. This seal is critical for crankcase compression as it stops emission of fuel air mixture from the crankcase. It also of course keeps the outside air dust out. It is usually a common lipped spring energised shaft seal. The lips face inward to hold crankcase compression. If the seal condition is poor, it may let air and dust into the bearing and crankcase during induction. This causes the bearing to run dry and this will cause catastrophic failure of the bearing and possibly a broken crankshaft. It has been known to happen many times in 2-stroke self-launchers.

8.3 INDUCTION PRINCIPLES

There are 2 principles for transfer of Induction in a 2-stroke:

a. Loop scavenged and

b. Cross scavenged.

Cross scavenged needs a reed valve, or uses part of the crankshaft counterweight section to act as a rotary valve to block escape of the fuel air mixture during crankcase compression.

With the loop scavenged principle, the piston is used to control escape of the air fuel mixture during crankcase compression.

The following images show the principles of both:

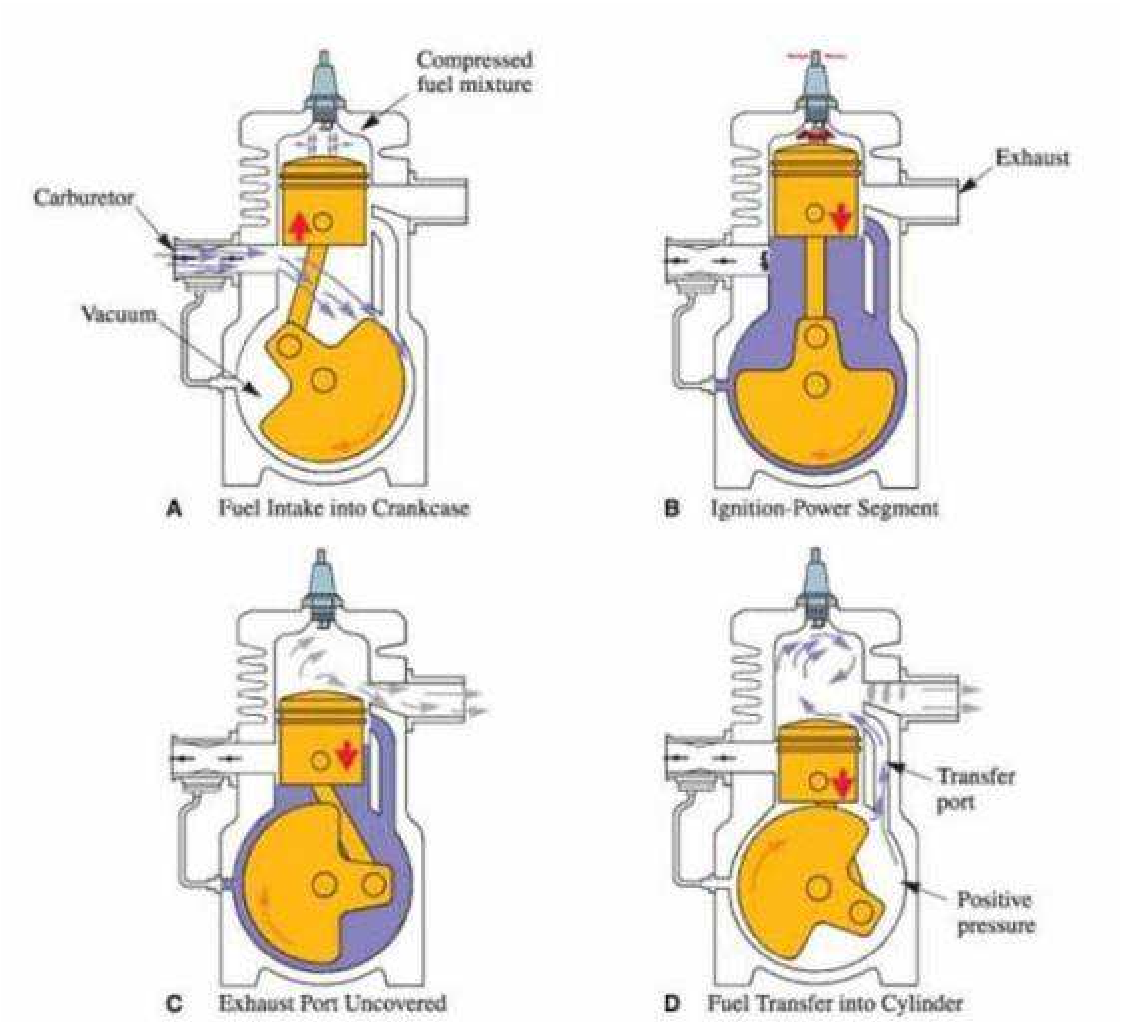


Figure 8-1 LOOP SCAVENGED

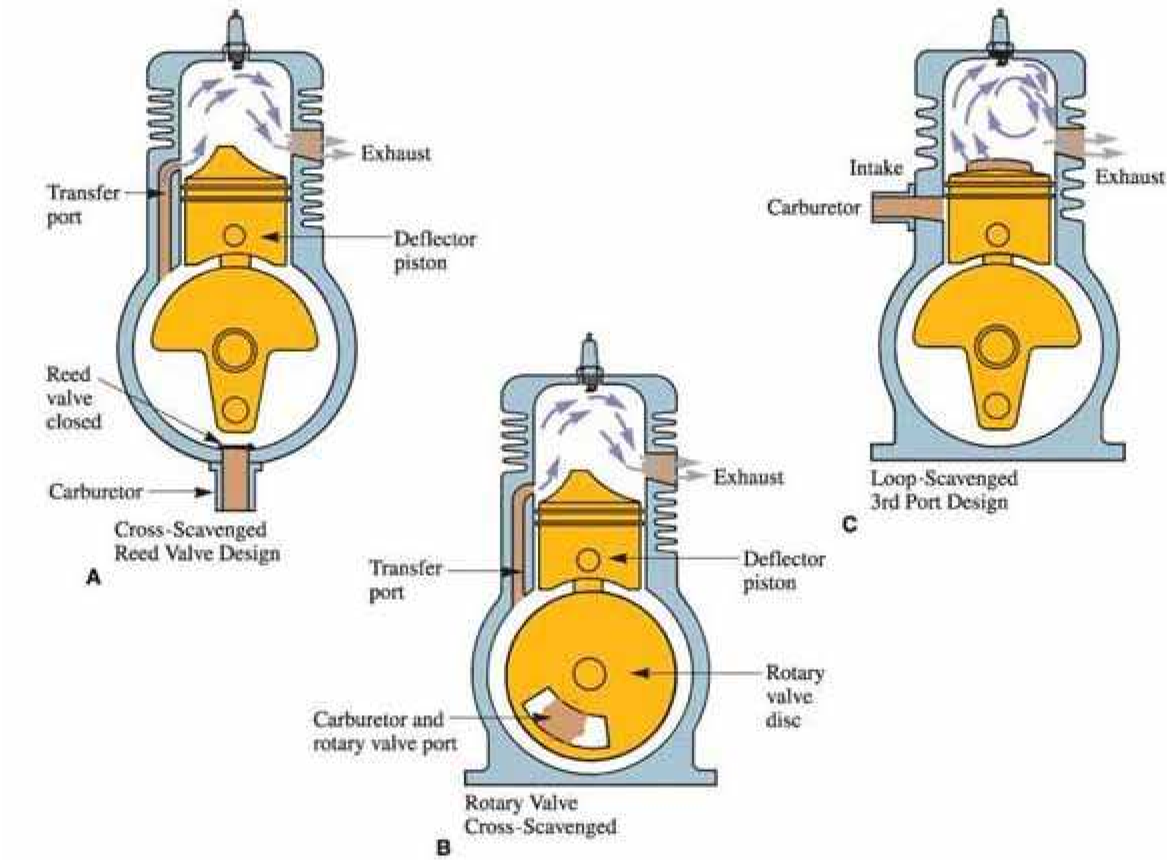


Figure 8-2 CROSS SCAVANGED

As a 2-stroke warms up, the crankcase also gets warm, and this in turn warms the intake gasses resulting in a high density altitude and loss of performance. Unlike the 4-stroke and rotary engines which have a pumped lube system where warm oil is desirable before using high power settings, the 2-stroke engine is lubricated as soon as it is started, as the lubrication is in the fuel mixture. Warm up is not required in a 2-stroke and it performs best when cold. Smooth running will occur with an increase in RPM, enabling take off as soon as it is running in order to get the best performance (and thus a safety advantage) in the early stages of climb.

The 2-stroke engine suffers higher performance drops from exhaust back pressure which results in the manufacturer making efforts to reduce back pressure while also trying to address noise pollution problems. Mufflers (exhaust silencers) are a generator of back pressure and a balancing act between the two considerations is taken during development. A straight out exhaust or stack gives the best performance all round but is not good for aerodrome neighbours.

To overcome this short fall, one common method is the use of a ‘tuned’ exhaust. This is an expansion chamber shaped in such a way as to use the dynamics of pressure pulses to assist in drawing extra air fuel mixture into the cylinder and even the chamber itself, and then pushing it back in before the exhaust port closes. This essentially acts as positive induction like a turbocharger but on a small scale. As the dynamics involved are affected by RPM (the frequency and speed of the pulse), there is an area of RPM range where it works at its peak. This is known as the ‘sweet spot’ to most 2 stroke motorcycle enthusiasts. In the case of a self-launching glider, the principles remain the same and the manufacturer will have worked out what RPM is giving the best performance, and matched the pitch of the propeller blade to make use of the RPM range with the best performance, at the optimal climb speed.

The following images show how a ‘tuned’ exhaust works:

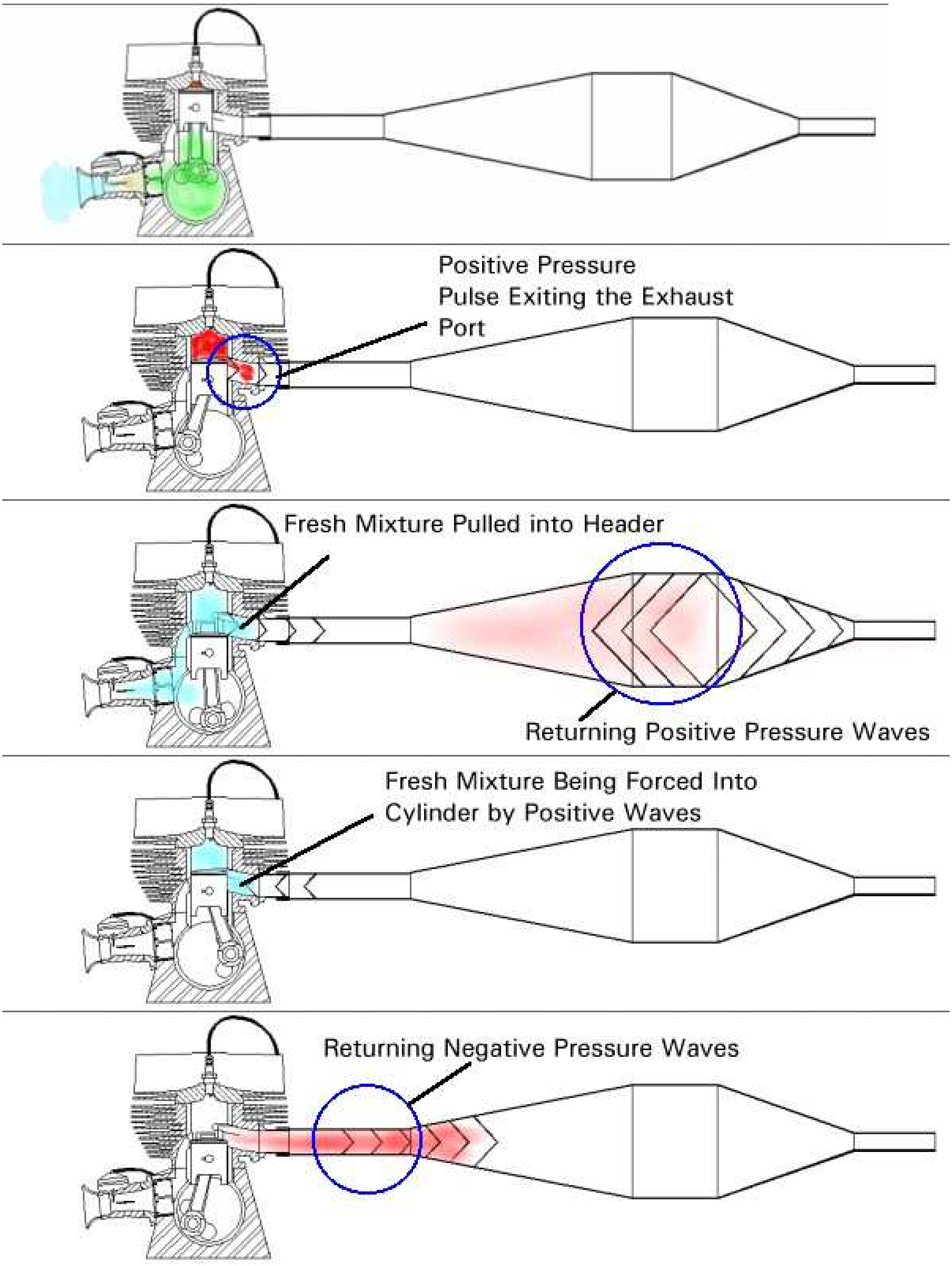


Figure 8-3 Tuned Exhaust

9. THE 4-STROKE RECIPROCATING ENGINE

9.1.1 INTRODUCTION TO THE 4-STROKE ENGINE

The 4-stroke engine is more complex than the rotary or 2-stroke engine.

It has exhaust and inlet valves along with all the associated drive equipment, so it has many moving parts along with the crankshaft, connecting rods and pistons. It therefore is more demanding in maintenance than the others. With the additional components comes increased weight and as the 4-stroke produces one combustion (power) stroke for every 2 rotations of the crankshaft, the power to weight ratio is not as good as for the 2-stroke or rotary engines. The 4-stroke is however more fuel efficient and generally has better reliability than the 2-stroke, despite all the additional parts, and usually has a longer Time Between Overhauls (TBO).

4-strokes generally achieve torque in a lower RPM range than either the rotary or 2-stroke, resulting in many installations not requiring speed reduction units for efficient propeller operation.

9.2 CONSTRUCTION OF THE 4-STROKE ENGINE

All 4-stroke engines used in motor gliders utilise overhead valves operated by pushrods, so we will not address side valve or overhead cam designs, (except for the pictures below!).

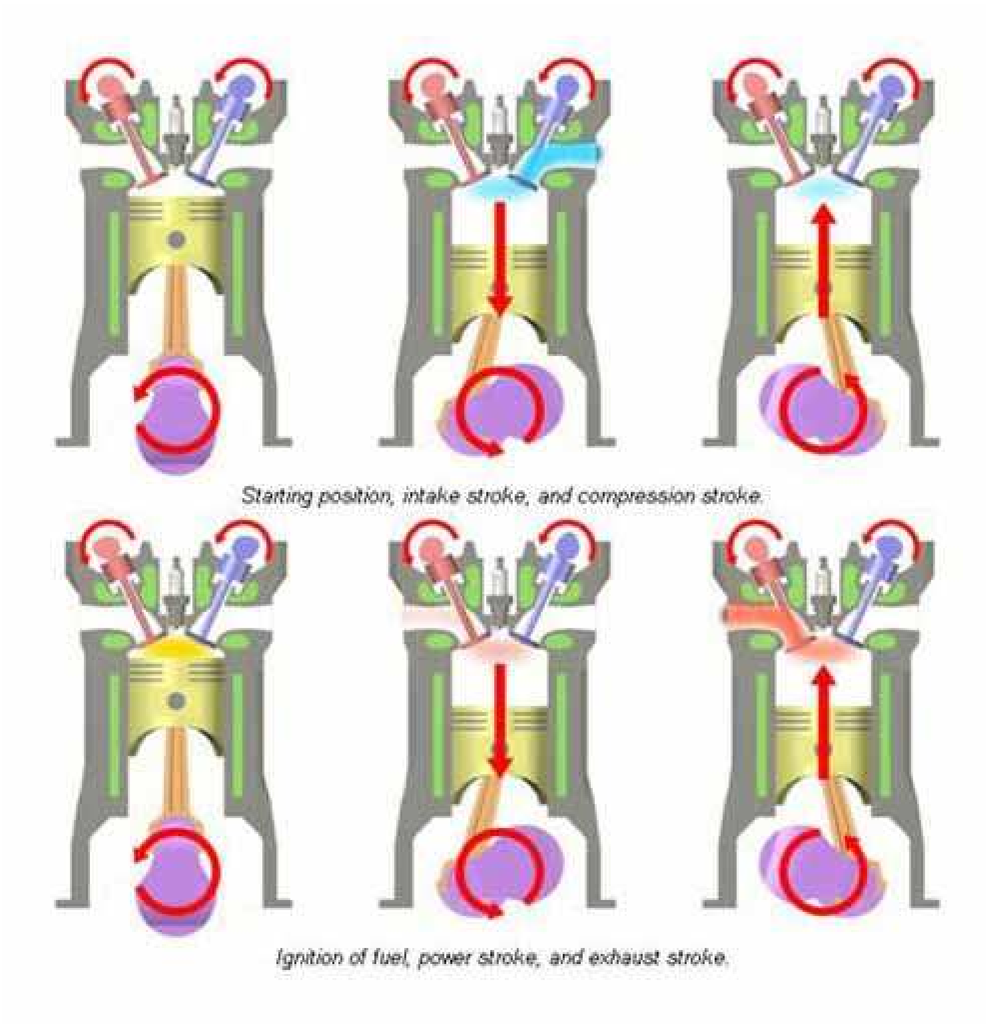


Figure 9-1 The 4-Stroke Engine Cycle.

The inlet and exhaust valves in a 4-stroke engine are driven by a camshaft via push rods and rocker arms. Clearance is set between the rocker arms and the valve stems to ensure that the valve is closed when intended, and also to allow for thermal expansion of the valve stem at normal operating temperature.

The camshaft is driven by gears from the crankshaft at a 2:1 ratio.

All items in the engine are lubricated by oil delivered from the oil pump, which is typically driven from the camshaft. Oil galleries in the crankcase carry the oil from the pump to pressure feed the crankshaft main and connecting rod bearings, camshaft, and tappets via internal drillings. Low pressure oil is fed to the rocker shafts and rockers via the tappets and hollow pushrods. Valve stems & guides are lubricated by splash from the rockers. Cylinder bores, pistons, rings, gudgeon pins & timing gears are lubricated by oil ‘slinging’ out of the crankshaft and cam bearings. Some connecting rods have a longitudinal drilling from the big end to the small end to lubricate the gudgeon pin. On some engines a small jet sprays oil into the meshing area of the timing gears. Engine oil pressure may also be supplied to a hydraulically operated propeller speed governor mechanism.

Oil pressure is controlled by a relief valve. The reservoir for the oil is either the sump (lower part or cover of the crankcase) or a separate tank, with the latter style known as a ‘dry sump’ system. The dry sump principle produces some efficiency gains due to the reduced ‘windage drag’, because it keeps the majority of the oil away from the crankshaft and connecting rods, but it does require a second oil pump for ‘scavenging’ the crankcase and generally, results in more weight. Some ‘wet sump’ engines employ a baffle which closely cowls the underside of the rotating components to minimise this drag. This is known as a ‘windage tray’ and stops the rotating components coming into contact with the oil. The Rotax 4 stroke fitted with the dry sump and reservoir uses crankcase breathing pressure to drive the oil into the reservoir so there is no need for a scavenge pump. In the case of the turbocharged version there is a scavenge pump needed to take the spent oil from the turbocharger and deliver it to the reservoir.

Below is the oil circuit for a Limbach engine (wet sump):

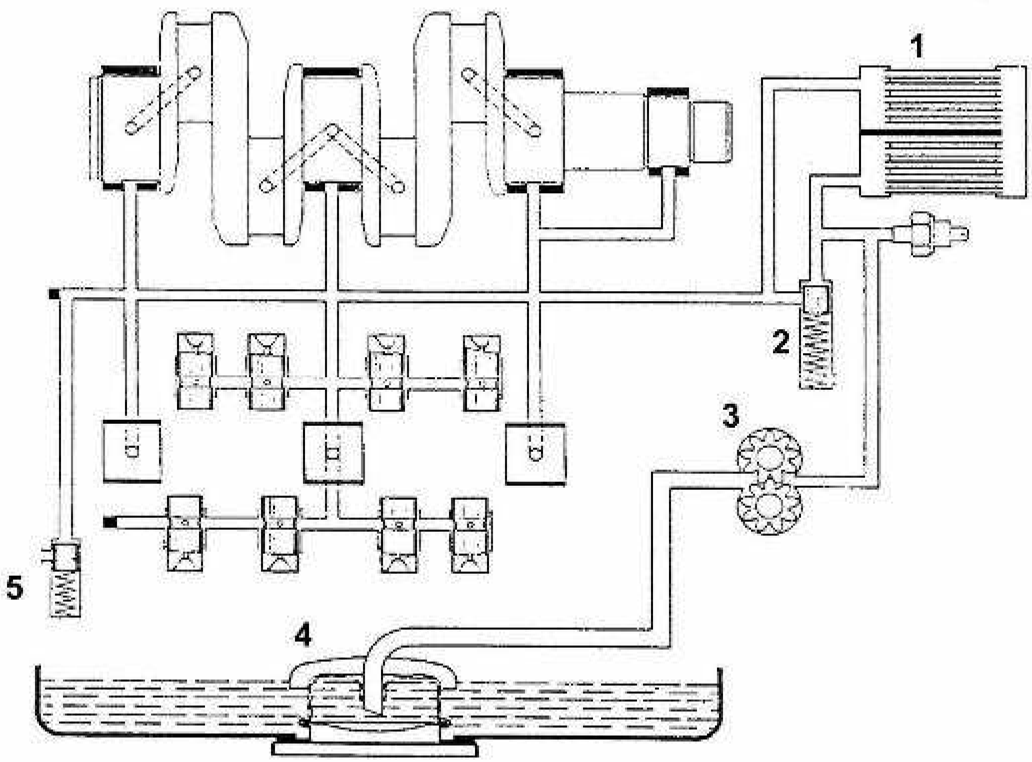


Figure 9-2 Wet Sump

The pistons are sealed to the cylinder barrel using piston rings. The top 2 rings are called compression rings and are designed to form a seal keeping the gasses above the piston. They are however, not a perfect seal. The lower ring is called the oil ring. It is comprised of several components, enabling it to seal the oil below the piston and also distribute a thin film of oil on the cylinder wall as it strokes to keep it lubricated.

The compression rings are generally made of chilled cast iron. Single piece oil rings are also cast iron while segmented oil rings are stainless steel. Pistons are aluminium alloy with steel gudgeon pins and the connecting rods are of high grade forged steel.

Barrels are either cast iron or aluminium alloy, with the cylinder wall chrome or nickel plated.

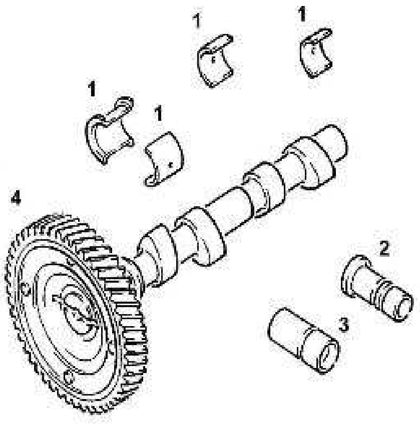
Cylinder heads are aluminium alloy and the crankcase may be aluminium or magnesium alloy. The crankshaft may be cast iron or forged steel. Big end and main bearing shells may be white-metal or multi-layer white-metal/copper/lead.

The camshaft and followers are hardened steel. The bearing shells are generally white-metal.

Below is a diagram of the camshaft assembly:

The three split bearings (1) support the camshaft (4) in the crankcase. The bearings (1) are made from steel and have shells coated with white metal. The bearing number 1 takes the camshaft thrust. A helical gear on the crankshaft drives the camshaft.

The valves are operated by the cam followers (2 and 3). Each cam operates the valves of two opposed cylinders in turn.



The camshaft assembly consists of:

Item	Description	Item	Description
1	Camshaft bearings	2	Cam follower (L1700/L2000)
3	Cam follower (L2400)	4	Camshaft

Figure 9-3 Crankshaft

The cam followers supply oil to the hollow push rods which carry the oil to the rocker assembly for distribution (top end lubrication).

Following is a diagram of a typical head assembly which also shows the push rods and their cover tubes.

The cylinder head and rocker assembly consists of the following components

Item	Description	Item	Description	Item	Description
1	Rocker-box cover (L2400)	2	Waisted stud (L2400)	3	Washer (L2400)
4	Cap nut (M8) (L2400)	5	Gasket (not L2400)	6	Rocker-box cover (not L2400)
7	Clip (not L2400)	8	Rocker shaft	9	Seal
10	Support	11	Spring washer	12	Nut
13	Spacer (if required)	14	Rocker arm	15	Adjusting screw
16	Locknut	17	Face washer	18	Spring washer
19	Thrust washer	20	Circlip	21	Collets
22	Valve-spring cap	23	Valve spring	24	Washer
25	Nut	26	Locknut	27	Waisted stud
28	Oil seal	29	Pushrod	30	Pushrod tube
31	Oil seal	32	Stud	33	Valve
34	Stud	35	Cylinder head		

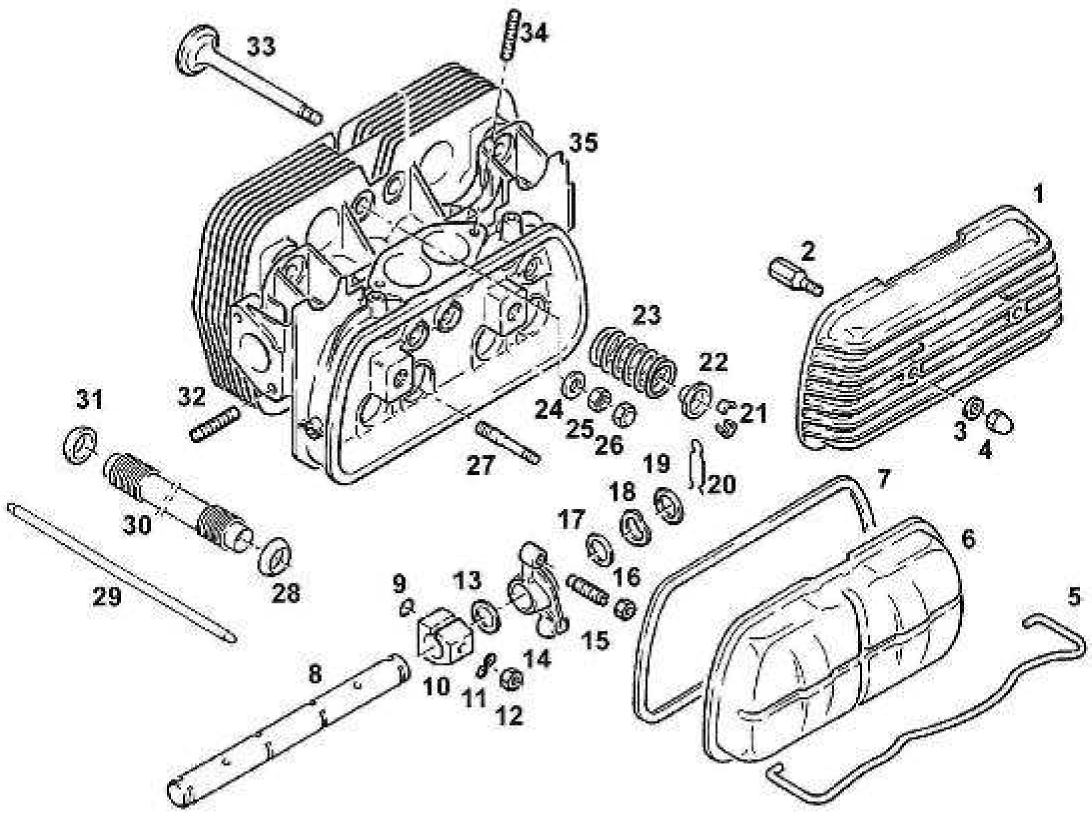


Figure 9-4 Cylinder Head

The compression in the cylinders of an engine must be correct to permit the engine to develop full power. The condition of an engine can be determined by compression testing. Testing must be carried out at specific intervals, or when doubt exists as to the delivery of the full potential of the engine. If there is an obvious decrease in power, carry out a check to assess the adequate sealing of the combustion chambers and cylinders. A simple initial check is the “pulling through” of the propeller method, which is best done by a qualified engine mechanic familiar with the engine to be tested.

The oil ring (6) shows it has a spring energiser to assist in sealing the ring against the cylinder wall.

All the rings usually have the 'gap' dispersed evenly around the circumference of the piston to enhance sealing.

This diagram shows a crankshaft assembly with alternative end assemblies for a variety of engine models. These include different propeller flange and flywheel options. Item 15 is the gear that engages with the camshaft in the camshaft diagram.

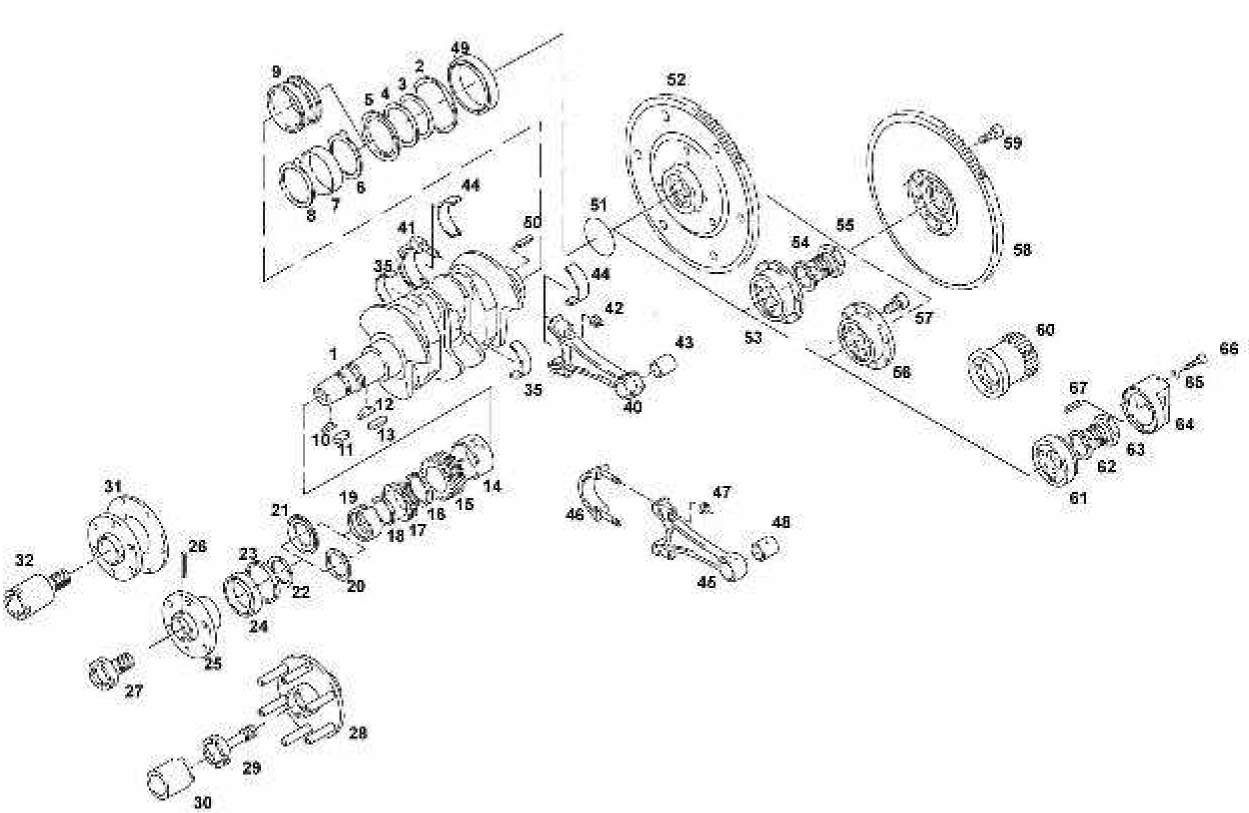


Figure 9-5 Crankshaft

There are other systems related to mechanical fuel pump etc. but this section is to explain the principal of the 4-stroke engine generically. Always refer to the engine's manual for specific details.

9.3 COMPRESSION TESTING

There are two common methods used to test the compression performance of an engine's cylinders:

a. Using a 'compression tester'. This is the most common test. It measures the engine's ability to <u>generate</u> cylinder pressure'

b. Differential pressure test. Technically this is not a compression test; it is a leak-down test which tells you about the engines ability to <u>hold</u> pressure. This is commonly used for GA piston engines, often seen as readings such as "80/79".

Another way to think of it is that with a compression test you are seeing how much pressure the engine creates, and with a differential (leak-down) test you are seeing how much pressure it loses.

It is always important to have the engine at operating temperature when doing any type of pressure tests. Rings, pistons, head gaskets, cylinder walls, etc. all expand by different amounts at different temperatures. To help minimise the effect of this on testing, you always want the engine at operating temperature.

Either of these methods is acceptable. The manufacturer will likely give guidance in the engine manual as to which test to use. Whichever test is used, the results must be viewed with respect to the manufacturer's specifications.

Recording the compression when the engine is new or overhauled gives a good record of a starting point for further reference in assessing the ongoing condition of the engine.

9.3.1 USING A COMPRESSION TESTER

This is basically a pressure gauge which measures the maximum pressure observed in a cylinder when the engine is cranked over. Due care must still be taken when working near the rotating propeller. Keep onlookers well clear!

The test should be done on a warm engine that has just run and thus the cylinder walls have been lubed. Loosen the plugs slightly for the engine run to avoid stripping the spark plug hole thread when removing from a warm engine.

A hose is screwed into the spark plug hole with a pressure gauge fitted to the end of the hose and the test is performed while the engine is being cranked by the starter motor, with all other spark plugs removed and full open throttle and with no choke resulting in a peak pressure reading. This is achieved by a non return valve stopping the pressure from flowing back into the cylinder between compression strokes. This may take 4 or more compression strokes to achive max pressure depending on the length of the hose. A trigger is pressed to open the return valve and eliminate pressure to allow removal. Repeat for each cylinder. This figure is then compared to a factory specified value and readings should be within a certain percentage of the specification figure if the engine is in good condition. If a low figure is detected, injection of a little engine oil and a re-test, will show whether leakage is from the piston rings or other sources. A higher than normal pressure indicates the presence of excessive carbon deposits in the combustion chamber.

In the following figure, a LAME has used 3x compression testers to enable a quicker test procedure as multiple readings can be taken in one cranking with all cylinders at similar hot/warm temperatures.

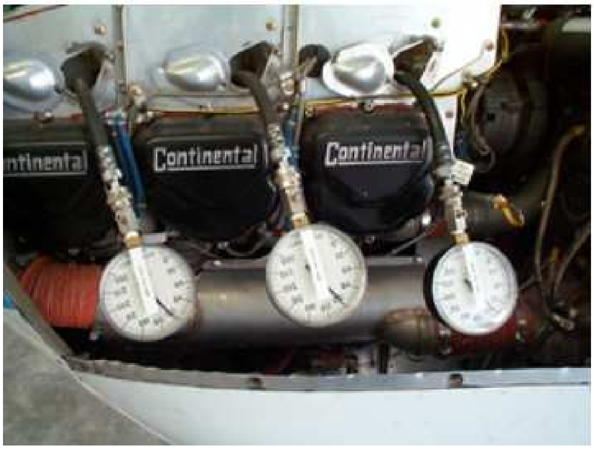


Figure 9-6 Compression testing

The norm is to use one tester and repeat the process moving around the engine - cranking and measuring the compression pressure of each cylinder in turn

With the progression of time, this ‘pressure’ is monitored for a trend in cylinder maximum pressure.

It is worth noting that an engine will develop higher cylinder pressure when it is running compared with when you are just cranking it over for the compression test. This is due to several things, including:

a. When the engine is running, the higher speeds of the pistons don't allow as much time for pressure to bleed past the rings.

b. While the engine is running, a lot of oil is coating the cylinder walls, which helps seal the rings.

c. When the engine is running, pressure changes due to "scavenging"; a process caused by the valve timing overlap at the end of the intake stroke.

d. Higher temperatures in the cylinder will create higher pressures when running

9.3.2 DIFFERENTIAL PRESSURE TEST

This requires a “differential test gauge set” and a compressed air supply.

This method presents an elevated safety risk due to the introduction of compressed air into the cylinder. Considerable care is required when conducting this test to avoid possible damage to the propeller or injury to personnel.

The procedure requires the piston of the individual cylinder under test to be positioned and held at Top-Dead-Centre (TDC) on the compression stroke. When a piston is at TDC, both valves of that cylinder are closed. If they weren't, pressurised air would leak out through the opened valve and into the intake or exhaust...which would be perfectly normal for an open valve.

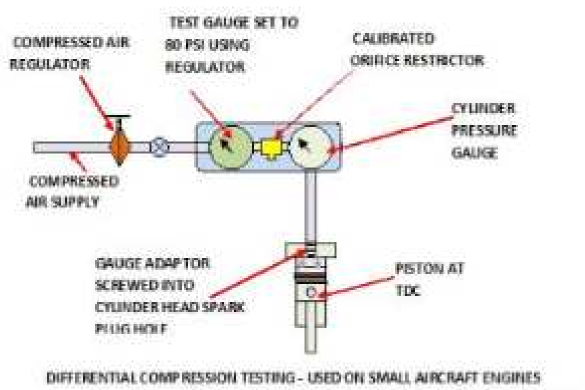


Figure 9-7 Differential Pressure Testing

The pressure gauge set is connected to one cylinder at a time. With the propeller secured, compressed air supply is applied through the gauge set to the cylinder. One gauge indicates the air supply pressure applied less the small leakage via the orifice. This is usually regulated to 80 psi (by tradition). The other gauge indicates the pressure in the cylinder. If the cylinder had no leakage of air then both gauges would read the same.

There will inevitably be some leakage from the cylinder so the cylinder gauge will usually show a lower pressure than the supply gauge.

Leakage causes and the means of audible detection, are:

a. Through badly seated inlet valves (noise in the air intake / inlet manifold)

b. Past the piston rings (noise from crankcase vent / breather),

c. Through badly seated exhaust valves (noise in exhaust system).

The pressure recorded for each cylinder is recorded and expressed as “80/XX”. As this is a ratio, it can also be expressed as a percentage of pressure retention. The greater the ‘differential’ between the numbers, the greater the loss of pressure and the more significant the leakage problem.

There is no standard regarding the size of the restriction orifice for non-aviation use and that is what leads to differences in readings between leak-down testers generally available from different manufacturers. Comparisons will only be of value if identical test equipment & pressures are used each time. Trending of this information over time will identify the problem, or indicate the rate of fair wear and tear. Even looking at sets from Aircraft Spruce it is difficult to know what the size and shape of the orifice is in each unit. The internal diameter, length and shape of the bore edge in the orifice affect the readings substantially.

Additionally, it can be difficult to determine whether leakage is from the rings or valves, and it cannot detect any increase in compression ratio due to carbon build-up in the combustion chamber.

Listening with your ear near the exhaust, inlet manifold (carburettor) or crankcase oil filler can help pinpoint leakage.

In the case of a Limbach, Sauer, Grob, Stark Stamo etc. aero engines, the differential pressure test (leak-down test) will require the propeller to be securely supported or held with the piston at TDC for each cylinder in turn.

DANGER WARNING

There is a serious risk of personal injury or damage to the propeller if the support or hold fails to maintain the crankshaft at TDC.

Unless the piston is maintained at exactly TDC, the high air pressure applied to the cylinder during testing will push the piston to BDC thus rapidly spinning the crank through approximately 180 degrees and the propeller through an angle dependant on the gearing ratio.

Leak testing of Rotax 912 & 914 engines is much safer as they have provision for a locking pin to be installed in a port in the crankcase. This positively locks the crankshaft in either of the two TDC positions, thus preventing inadvertent rotation during leak down testing. However it only locks at one position allowing the testing of only 2 cylinders.

CAUTION

Don't forget to remove the propeller locking pin when the test is finished!!

With any engine, hold the propeller at the tip and carefully guide it to the very centre of TDC as the pressure is increased. Ensure no one is within striking distance including your self and let the prop go if you lose control. Do not attempt this unless you have had practical training by an experienced instructor. There are inherent risks.

Enquiries with Limbach Flugmotoren as to the acceptable pressure for this test, resulted in advice that they could not answer the question as they did not use this test method. Limbach specify the use of the more commonly known and used 'compression tester'. However, the differential pressure test results are still of value, especially when compared with further tests done over time.

9.4 Valve Seat Regression

This is a common problem on Volkswagen derivative engines and seems to be helped by maintaining lower CHT and using an upper cylinder lubricant. The valve impacts into the head and causes the tappet clearance to reduce. In the end it is so worn that the tappet clearance cannot be adjusted and the valve train starts clashing.

Limbach supply a special tool to measure it with the heads in place. Otherwise keep note of tappets needing frequent adjustment and correct the cause before it progresses to far. It can be slowed significantly. If the tappet runs out of adjustment the heads will need to be replaced. They are probably best not repaired in the case of an aero engine as this introduces higher risk of extreme failures in flight.

9.5 Tappet Adjustment

Tappet adjustment should be checked and adjusted frequently in older style engines. Some like Rotax have hydraulic tappets that adjust themselves. These need initial setup with shims and may appear loose when the engine is stopped. However, with oil pressure they automatically take out the slack. These do wear (the valve lifter surface) and sometimes require replacement.

If adjustable the tappet is adjusted to the specified feeler gauge thickness using a screwdriver and spanner. Make sure the feeler gauge is just filling the gap without catching or being loose. And the lock nut is firmly tightened – no secondary lock.

10. THE WANKEL ROTARY ENGINE

10.1 INTRODUCTION TO THE ROTARY ENGINE

The Wankel rotary engine is used in some self-launching gliders such as the ASH26E and the ASK21MI. In those aircraft it is fixed in the fuselage engine compartment with a retracting pylon for the propeller.

The rotary engine develops very good power for its weight, but fuel consumption is much higher than a 4-stroke reciprocating engine of similar power output.

The following image is a comparison indicative of this. This 300HP Mistral engine weighs 190kg and the 200HP model weighs 132kg. It is a Swiss design and designed and built specifically for aircraft use. As the rotary engine is a high revving engine, it needs speed reduction for practical use with a propeller. The Mistral design uses a planetary gear box for this reason and this is easily identified behind the propeller flange.

300 HP Mistral 3 rotor. **260 HP Lycoming 6 cylinder.**

10.2 DESIGN AND CONSTRUCTION OF THE ROTARY ENGINE

The rotary engine has only 2 moving parts for a single rotor version. These are the rotor and the eccentric shaft or E-shaft. The E-shaft is so called as it has an eccentric lobe onto which the rotor is directly mounted, unlike the crankshaft used in reciprocating 4-stroke and 2-stroke engines which have offset journals set between flanges. It looks like a crank handle, for example on a sail winding winch, hence the name.

The rotor shape approximates an equilateral triangle with slightly bowed out sides. Half way along each side there is a small depressed area which forms the combustion chamber. As the rotor revolves, the tips describe a path which exactly matches the shape of the specially profiled housing. This shape is known as a trochoid.

The photo below shows the construction:

Figure 10-1 Rotary Engine

The outline of the eccentric lobe can be seen inside the minor diameter of the rotor gear. The rotor path is controlled by the engagement of the rotor gear to the centre gear fixed to the end housing, on centre with the E-shaft main journal.

The rotor is sealed to the housing and end housing with spring loaded seals made of high temperature materials. On the peaks of the rotor can be seen the apex seals, so named as they sit at the apex of the rotor profile. They include the corner seal to accommodate transition to the side seals, which can be seen to follow closely near the edge of the rotor profile.

Figure 10-2 Apex Seal Design

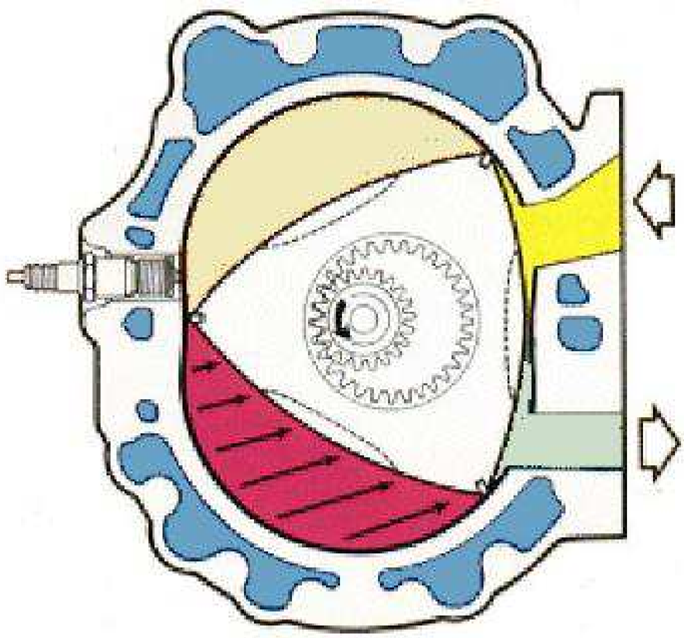
At any time in the cycle of one rotation of the rotor, the engine is inducting fuel mixture, compressing and firing, and exhausting simultaneously.

So, in one rotation of the rotor there are 3 ignitions. In one rotation of the rotor, the E-shaft rotates 3 times, thus 1 firing per revolution of the shaft. This results in a smooth running engine. It is also well balanced.

In the image below the porting is through the rotor housing, with the intake at the upper left and the exhaust at the lower left of the end housing.

Lubrication of the E-shaft for the main journals and the eccentric journal is by oil from a pump, as per a 4-stroke engine. The oil also cools the rotor. The housing is liquid cooled. Both an oil cooler and a radiator for the liquid cooling are needed to control the temperatures.

The cycle is shown in the 2 following diagrams:



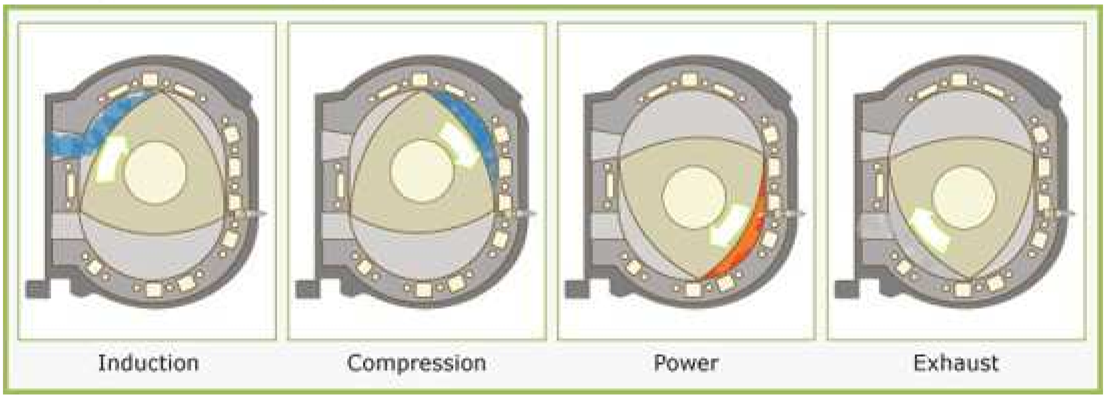
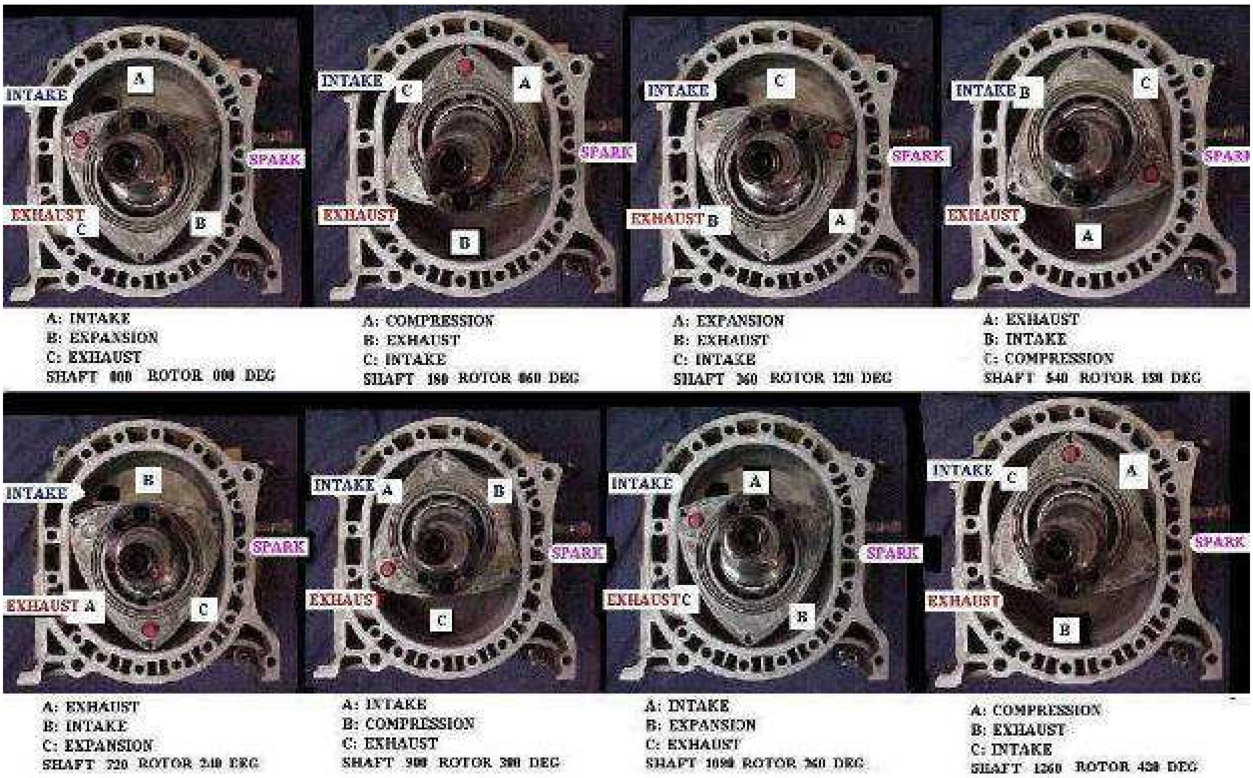


Figure 10-3 Rotary Cycle



While the E-Shaft and rotor gears are pressure lubricated by an oil pump, the apex seals must also be lubricated. This is achieved by injecting a metered amount of oil into the inlet port. While most of the oil fed into the E-bearings and gears is returned to the oil tank via a scavenge pump, the oil injected into the inlet port is of course lost to the combustion process.

In a Mazda engine the oil in the sump is used to lubricate both areas and thus sump oil level must be maintained, but there is a good volume of it in the sump.

The rotor housing is alloy and the inner face is a cast iron insert which is placed into the mould when the housing is cast, creating a bond with the alloy, Thus the apex seals run on cast iron. The lining insert is typically polished to 0.4 um (4 micron) finish. The end housings are generally made of cast iron but some engines do use alloy with iron inserts or nickel plating, but both these methods are not common. The rotor is alloy with a steel insert to carry the gear and bearing.

There are two forms of porting for induction and exhaust. Mazda have predominately used side porting where the gasses are passed through the end housing. In that instance the side seals run over the porting. The other form also commonly used is P-porting or peripheral porting. This is harder on the apex seals as the porting is through the trochoid, but it does provide a significantly higher performance.

Having no valves, the rotary is considered a low maintenance engine. Oil changes, spark plugs and the fan drive belt being the main regular maintenance items.

The Austro engine differs markedly from the Mazda, Mistral & NSU rotary in the following ways:

a. Combination of liquid cooled housing and air cooled rotor

b. Belt driven cooling fan with its importance to engine survival

c. Safety sensors in the oil system

d. DI considerations peculiar to the engine/installation

e. Fire protection because of installation considerations.

f. Lubrication is a total loss process. The initial lubricant oil is misted into the rotor cooling air flow to lubricate the core of the rotor, drive gears and main bearings. Any recovered oil is then injected into the fuel/air intake system just below the fuel injector manifold. Lubricant is burned totally during the exhausting process.

CAUTION

For this reason, it is very important that the oil tank is checked for sufficient contents before every flight.

g. Later production variants of the Austro engine have an oil recovery system in the exhaust which has dramatically reduced losses but there are still some.

h. The rotor housing is alloy and the inner surface of the housing is a cast iron insert which is placed into the mould before injection casting which locks it in place so they become one part.

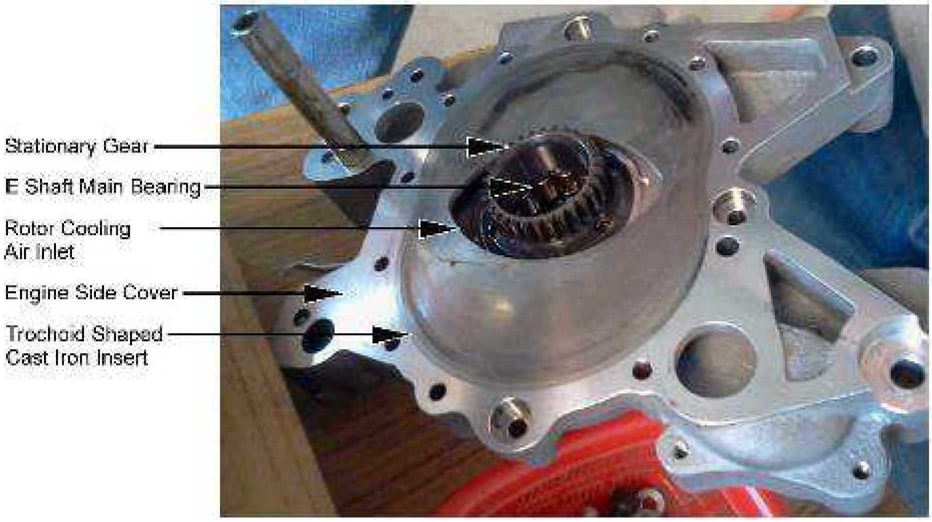
i. Side housings are alloy with a cast iron insert using the same principles as the trochoid insert previously described.

j. The side housings have ports for the passage of cooling air oil mist through the rotor. They are shaped so that the side seals do not expose these ports to the outer rotor area.

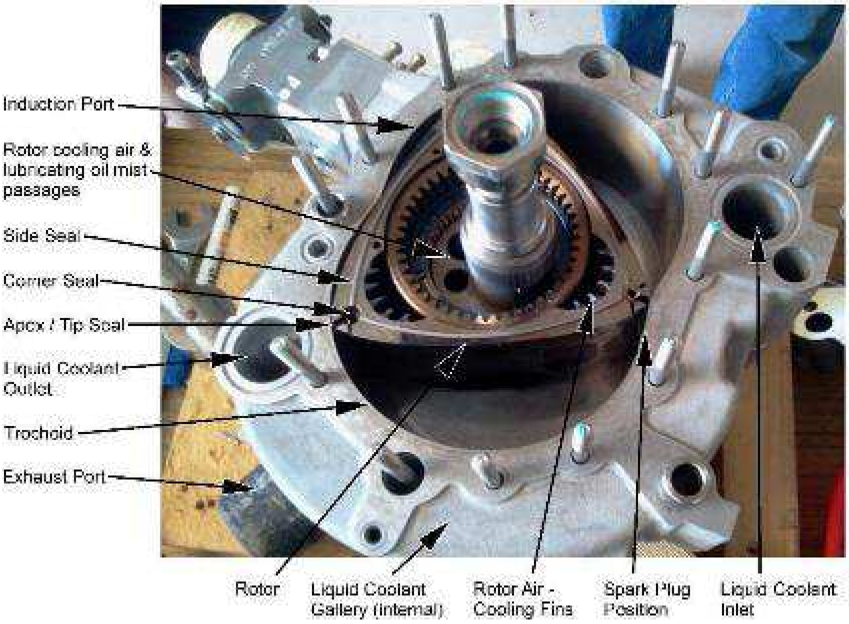
k. Due to the lubrication method, the E-shaft main and rotor bearings are roller bearings, not traditional plated steel shells.

l. The engine is P-ported.

The following image shows the side housing of the Austro engine:



The following image shows the core of the Austro engine.



11. THE GAS TURBINE ENGINE

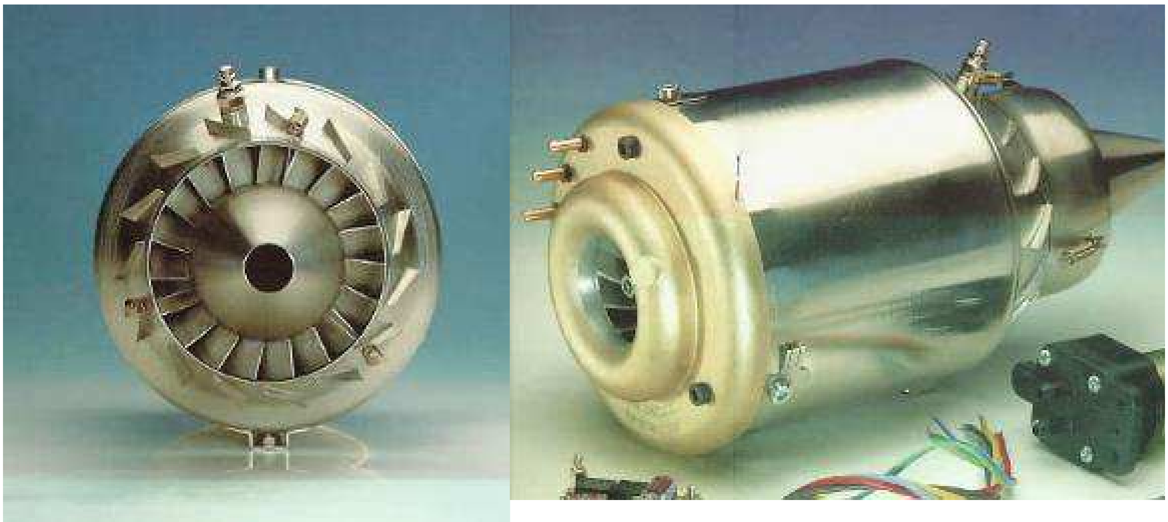
11.1 INTRODUCTION TO GAS TURBINE ENGINES

Small gas turbine engines are now appearing on gliders in Australia. Some are homebuilt others are manufacturer installed.

These small engines, which range in 'power' from around 180 – 700 Newton thrust each, offer some advantages over other traditional engines, including a significant engine weight reduction.

Advantages	Disadvantages
Small size. High power to weight ratio. Simplicity Very low mass rotating assembly, spools up and down quickly, cools quickly.	High rotational speed (100,000 RPM +) at full power. Hot temperatures, exhaust gas at 700^{0}C. Very fine tolerances – need for absolute cleanliness. Risk of un-contained break-up. Relatively long time to start and spool up to maximum power

Some of the small turbine engines, developed and built by various international manufacturers, were initially designed for model aircraft and Unmanned Aerial Vehicles (UAV's). The UAV market has significantly increased the demand and scope for these engines in recent times. Some engines (MD-TJ 42) were designed specifically for gliders.



There is now a considerable operating history associated with small turbine engines (AMT have been manufacturing since 1992). While this history has facilitated improvements, technology is resulting in the enhancement of performance of the micro-turbines – an engine with physical dimensions that yesterday produced 180 newtons of thrust, today produces around 800 Newtons (or 80 kg of thrust) with very similar physical dimensions.

Turbine engines are also now being made available by the commercial sailplane manufacturers.

11.2 GAS TURBINE CYCLE

The turbine engine cycle is called the 'Brayton' cycle after George Brayton. The Brayton cycle is a 4 stage process – Induction, Compression, Ignition and Exhaust, but all occur continuously at the same time at different locations in the engine.

The engine is started mostly by an electric starter, which drives the (air) compressor up to a modest speed to begin air compression.

In the start cycle, which is mostly an automatic function controlled by the Engine Control Unit (ECU), atmospheric air enters the engine through the air inlet, where the inlet air temperature (T1) is measured. The air passes through the compressor, where it is pressurised to around 40 – 50psi (depending upon the compression ratio of the compressor, typically around 3:1 to 4:1).

For starting some turbine engines burn Propane gas (AMT Jets) while others use the normal Kerosene fuel. During the Start Cycle, turbine rotor speed is measured, and given the right conditions RPM), Fuel is introduced and the glow-plugs are fired to ignite the fuel/air mixture. Once ignition has occurred a major increase in air flow volume occurs and the engine accelerates to Idle Speed (around 30,000 RPM). During this period, the ECU introduces the normal fuel and shuts down the Propane. The start sequence – from pressing the START button to the runup to idle speed - is largely controlled by the ECU.

The compressed air then passes into the combustion chamber. The air temperature (T2) is measured at the compressor outlet. Fuel (kerosene/Jet A1) is injected prior to the mixture being burnt. The burning of the mixture in the combustor significantly increases the temperature of the stream, which is measured at the exit from the combustion chamber (T3). The increase in temperature significantly increases the volume of air/combustion products (at a constant pressure). This stream now passes through the compressor turbine, which in turn drives the compressor to compress the inlet air stream, before exiting the engine through the exhaust nozzle.

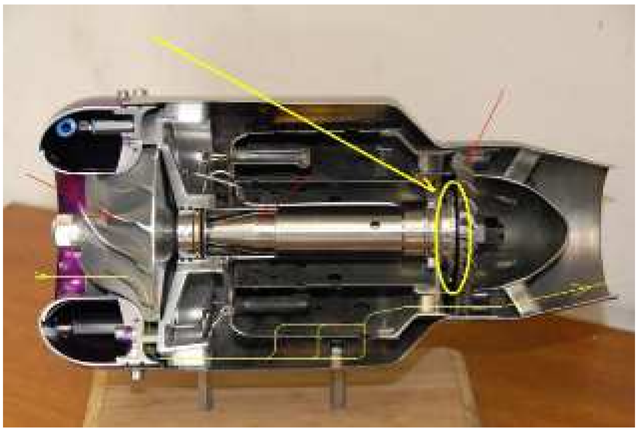
Once the engine is running and the starter is disengaged, fuel flow may be increased using the throttle (Thrust) lever. The Max T4 temperature (EGT) is determined by the designer (based upon metal qualities, etc) and is <u>never to be exceeded</u>. It is a common feature in gas turbines of all sizes to 'control' T4 temperature at a level below the published maximum EGT, i.e. adjust the fuel flow to control the T4 temperature. This is called 'temperature topping' and is achieved through parameters set in the Engine Control Unit (ECU).

Because of the rotational speed of the engines, ingestion of foreign bodies into the engine is to be avoided at all times. When working near a running jet engine, be aware of hats, sun-glasses, Canopy Covers etc which may be readily 'sucked' into an engine.

The diagram below is a representation of a simple gas turbine engine:

11.3 GAS TURBINE ENGINE DESIGN

A typical turbine engine is the 'Olympus HP' ES, manufactured by Advanced Micro Turbines (AMT) in the Netherlands.



It is constructed with a single radial compressor and an axial flow turbine which is able to develop a thrust of 230 Newtons (23 kg force) at 108,000 RPM. The combustion chamber is an annular type, fitted with a low pressure fuel system. The front and rear engine bearings are lubricated and cooled by the fuel system, so there is no separate lubrication system or oil reservoir. The lubricating oil is mixed with the fuel (as with a 2-stroke engine). The engine burns standard Jet-A1 fuel, at a rate of around 1 litre/minute at full power.

This engine is able to 'spool up' or 'spool down' from idle at 40,000 RPM, to full power at 108,000 RPM in around 3 seconds.

This turbine engine is fully controlled by a small micro-processor ECU, which automatically regulates the maximum performance within programmed limits. The ECU also manages the start and shutdown sequences to protect the engine.

Some Interesting operating data:

		AMT	MT-TJ42
a.	Engine case diameter, mm	130	150
b.	Engine length, mm	374(electric start)	400 (Electric start)
c.	Airborne weight, Grams	3795 (including ECU)	3300
d.	Thrust @ max RPM, Newtons	230 Newton (108,000)	42Kgf
e.	Pressure ratio	4:1	3.8 : 1
f.	Mass flow @ max RPM	450 g/sec (0.99 Lbs/Sec)	NA
g.	Max RPM	112,000	97,000
h.	Idle RPM	Around 36,000 RPM	30,000
i.	EGT (Degrees C)	700^0C	500^0
j.	EGT, max design, C	750^0	790^0
k.	Fuel burn @ max RPM	640 gr/min	1000 gr/min

11.3.1 TURBINE MAINTENANCE

The maintenance involvement for these small engines is very low, mainly due to the operating conditions of the engine and the fine tolerances and balance. Apart from inspection and minor cleaning, the manufacturer recommends the engine be returned to the factory for major maintenance/overhaul.

Preventative maintenance typically comprises:

a. After each 1 hour of operation, visually check the outer casing for colour change.

b. Check mounting brackets for cracks.

c. Visually inspect inlet area and compressor wheel for damage.

d. Check fuel pump and fuel system connections for leaks.

e. Check fuel tank for leaks.

f. Check turbine and compressor wheels not dragging/rubbing.

g. Check / clean fuel filters. Replace filters after every 50 – 60 litres of fuel.

h. Check Bearings. Monitor noise, If bearing noise has increased and bearings are lubricated by the fuel (as in AMT Olympus) and then check/replace fuel filter. Uneven or rough running, bearings require replacement, return engine to the factory.

11.3.2 ENGINE DATA AND RECORDS

The manufacturers recommend detailed operating records are maintained. A blank log-sheet is usually provided in the engine's Operating or Maintenance Manual.

Some engines, such as the AMT, have the facility to down load running history and other data from the ECU to a PC as a record and for analysis.

The data to be recorded usually includes engine start details such as; engine Serial No, date, max EGT during 'start' cycle, Run time, etc.

The max EGT during the start cycle is important as it is possible to exceed the published maximum EGT during start-up (eg AMT Olympus engine, 750^{0}C) and cause permanent damage to the turbine. Each start results in the engine passing through the Stoichiometric Range, where the fuel/air mixture is ideal for total combustion of the fuel, which is when the maximum combustion temperature occurs.

11.3.3 TYPICAL MANUFACTURER'S WARNINGS

Because of the serious hazards present, manufacturers place warnings at critical points. Examples include:

a. 'Treat engines as a precision instrument'

b. 'Due to high precision tolerances in the fuel pump gear-wheels, fuel must be absolutely clean and pure'

c. 'Fuel must be pre-mixed with 4.5% Turbine Oil'

d. 'Have an extinguisher on-hand when starting'

e. 'Use hearing protection to avoid hearing damage'

f. 'Observe fire precautions when refuelling'

g. 'Inlet Danger Zone = 1 metre in front of the engine'

h. 'Exhaust Danger Zone = 12 metres behind the engine'

i. 'Side Danger Zone = 15 metres either side of engine'

11.4 THE FUTURE

Because of the high power to weight ratio, simplicity and power developed, these small gas turbine engines are likely to play an increasing role in motor glider applications.

Currently the size and power of these small gas turbine engines are suited best as sustainers. In the quest for enough power for self-launching capability, the following images show an AS W20A fitted with 3x AMT Olympus gas turbines which provide ample thrust for self launching.

Some of the commercial glider builders are now providing jet engines and systems for their gliders.

Jonkers JS1 with Jet sustainer.

12. ELECTRICAL PROPULSION

12.1 INTRODUCTION TO ELECTRIC PROPULSION

Electrical propulsion is an emerging technology, with numerous experimental aircraft flying worldwide but no production aircraft flying in Australia at the time of writing this manual.

Theoretically, electrical propulsion has the following advantages:

a. Powerful electric motors can be smaller and lighter than combustion engine.

b. Virtually silent propulsion without loud exhaust noise, no ear plugs needed!

c. Very clean - no smell of gas in cockpit, no oil film from exhaust on the tail and no 2-stroke oil to mix.

d. Very reliable - no fuel pumps, no filters, no spark plugs, and no carburettor icing.

e. Instant restarts - no warm-up needed.

f. Virtually vibration free!

g. The only movable parts are the propeller and the motor's bearing and rotor.

h. Almost no maintenance of motor, no lubrication issues, no moving parts to wear out

i. Full torque from zero to max rpm (BLDC).

j. No loss of motor performance at higher altitude, equal performance day to day.

k. Easy to operate - just flip a switch and open the "throttle".

l. Lower carbon footprint, especially with solar charging (might be on top of your trailer).

The development of high power light weight bushless DC motors and high efficency battaries has caused the rapid emergence of recreational and professional ‘drones” since 2010.

Examples of electric motor gliders are:

Figure 12-1 Ventus 2Cxa with FES motor and rear folding propellor

Figure 12-2 Alatus ME. With Electravia electric propulsion system

Figure 12-3 DG1001TE.

12.2 BRUSHLESS DC MOTORS

Brushless DC electric motor (BLDC motors, BL motors), also known as electronically commutated motors (ECMs, EC motors), are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform.

A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system.

Brushless motors offer several advantages over brushed DC motors, including high torque to weight ratio, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

As an example, the FES motor designed specially for gliders is shown below:

Figure 12-4 FES Motors

The manufacturer states the basic specification is:

a. Out runner BLDC brushless synchronous permanent magnet motor with electronically controlled commutation system 3-phase

b. 20kW continuous power at 118V

c. Up to 23kW power for shorter time

d. Rotor rink diameter 180mm

e. Length 100mm

f. Weight of motor only 7.3 kg

g. Efficiency up to 95%.

The brushless DC motor controllers that create the AC signal will normally generate heat that needs to be disappated and allowed for in the design.

13. ENGINE FIREWALL

The 'firewall' is, as the name indicates, a 'wall' to provide a degree of protection to the pilot/crew for a short time in the event of an engine fire.

13.1 ENGINE BAY FIRES

An engine fire may occur for a variety of reasons:

a. Ignition of a fuel or oil leak.

b. Ignition of a component in the engine bay.

Ignition sources include;

c. Exhaust system.

d. Electrical system (chaffed wiring / shorting/battery)

e. Friction (a drive belt rubbing)

f. Oil or fuel leaking on an exhaust.

In the event of fire the properly trained pilot will follow that training and the procedures in the flight manual for the given aircraft. It is the MA rated Inspector's task to ensure the systems in place from the manufacturer are in working order and functioning as intended, including the firewall.

This started as an oil fire due to an oil leak and progressed to an extensive amount of damage and near fatality.

We know the fire wall did its job for just long enough as the pilot still has feet. He was seconds from a serious situation when he ditched the aircraft in a Lake. He had opened the canopy in flight and side slipped to keep the flames away from himself. He was close to serious burn injuries. The dangers of fire cannot be stressed enough and are a significant risk in the maintenance of engines and systems.

In recent years there have been 2 other in-flight fires in motor gliders and all 3 likely started due to maintenance faults. There have been dozens of fuel leaks that could have caused a fire!

Often the actual cause cannot be positively identified let alone the ignition point or what fuel was involved because an aircraft burns completely. Recent fires could have been caused by a LiPo battery, an electrical short, a gas leak from an LPG turbine start, or even the jet engines themselves, broken plastic fittings, recent fuel hose maintenance, leaking oil onto a hot exhaust, a leaking exhaust jetting hot fumes onto nearby flammables such as fuel or oil hoses - we can only speculate and guard against this happening. Often fire resistant sleeving has saved the day. The risks of inadequate or substandard maintenance is apparent and yet time and time again this happens whether by carelessness, lack of due diligence or purely someone missed something.

At every level down to the DI person each of us must be diligent in all manner of our activities. If a wing runner spots a fuel leak from the belly and the pilot says “that’s normal don’t worry about it”, it is time for the wing runner to put the wing on the ground and get someone of higher authority for support in the event the pilot won’t accept the wing runner’s decision. This has happened. The actions of the pilot who observed and took action may well have saved a couple of lives. Because he took action, the multiple problems evident here were resolved.

13.2 FIREWALL CONSTRUCTION

The firewall is constructed of material such as aluminium or thin metal sheet, generally located on a bulkhead between the engine bay and the cockpit or aft fuselage, to provide some protection to the crew for a relatively short period of time. It should also stop fuel and fumes entering the cockpit. It cannot stop the ingress of fire for long, but will buy time for the pilot to take action as described above.

It is generally necessary to provide access through the firewall and into the cockpit to allow wiring, engine controls etc to pass. The number and size of any holes through the firewall must be limited in both size and number in order to provide the maximum protection possible.

No gaps or unsealed holes are acceptable in a firewall. Holes around wiring, throttle / choke cables, rev counter drive cables etc. should be tightly 'sealed' to prevent flame, combustion products or heat getting into the cockpit in the event of a fire. This includes noxious gasses from the combusting materials but also carbon monoxide in normal operations. Penetration seals also stop abrasion of wires, hoses and cables which may also provide a risk of ignition or fuel for a fire.

13.3 FIREWALL MATERIALS & CONSTRUCTION.

Under CS22, the materials commonly used in glider firewalls are.

a. Thin aluminium sheet.

b. Aluminium foil.

c. Thin stainless steel sheet.

d. Fire retarding paint products. FF-88 - available from Aircraft Spruce

e. Contego Fire Barrier paint. ($US26.00/can).

Some suggested firewall sealants are:

f. 3M Fire Barrier 2000

g. High temperature silicone for small areas.

h. Fire resistant rubber grommets

i. Fire resistant rubber sheet (from GA suppliers)

j. Oil resistant "silicone 735"

k. Fire resistant foam.

13.4 FIREWALL ISSUES

Common firewall issues are unsealed holes and openings. The use of purpose made bulkhead fittings are a good idea and provides a reliable means of sealing the hole through the firewall.

A recent fatal accident probably became fatal because there was no firewall - there was no panel between the engine bay and cockpit. It is believed that from the time the pilot knew he had a problem until the aircraft ceased controlled flight was about 1 minute. A firewall would have reduced air through-flow fanning the fire and reduced copious fumes entered the cockpit giving the pilot the vital few seconds to land.

14. LIQUID FUELS

In modern aviation engines, a variety of fuels are used, including:

a. Avgas 100LL. (Aviation Gasoline 100 Octane Low Lead). The most common fuel used in general aviation piston engines.

b. Avtur. (Aviation Turbine). Usually Jet A-1 which is based on kerosene. Used in practically all turbine engines.

c. Auto fuel. Standard petrol used in cars. Sometimes referred to as Mogas (Motor Gasoline). Available as unleaded and premium grades. Used by a small number of G.A. aircraft piston engines. Commonly used in Motor Glider engines which don't need lead and much cheaper than Avgas. Limbach prefers you use 98 unleaded but under EASA must ensure it can run on Avgas as that is what is mostly available at airfield FBO's.

d. Two-stroke. AvGas or Mogas of a range of fuel qualities, with oil and sometimes or additives.

The fuels used have differing qualities and handling requirements. There are many features of the fuels we use which are the same or similar.

14.1 SAFETY – FUEL HANDLING

The fuels used to power motor glider engines will all readily combust and produce extremely high temperatures. With due consideration, preparation and care, fuel incidents and accidents can be avoided.

DANGER WARNING
Always use extreme caution when handling any fuel.

14.2 FUEL QUALITIES

The various fuel types used in motor glider engines have varying qualities, including:

a. Colour

b. Boiling Point

c. Flash Point

d. Specific Gravity

e. Octane rating

14.2.1 COLOUR

While colour may not appear important, it is often important that the correct fuel is put into the aircraft fuel system. Knowing the colour of the correct fuel is therefore important, this may be the only indicator you have.

a. Avgas 100LL Blue

b. Auto fuel No colour

c. Avtur Straw-coloured

14.2.2 BOILING POINT

The 'Boiling Point' is a significant factor in how fuel is stored, both in storage prior to loading into the motor glider and while it is in the motor glider fuel tank.

Auto fuel and Avgas are commonly known as ‘petrol’. They have a relatively low Boiling Point. These fuels are very likely to reach their Boiling Point in a hangar on a hot summer day. In a vented fuel tank, such as in the motor glider, the fuel will commence to boil – with the lighter factions (components) being evaporated off first – purely a function of temperature.

In terms of fuel quality, it is therefore vital that fuel be stored in a cool environment. Caution is required for fuel stored on-board the motor glider, as this will lose the lighter fractions of the mixture. This may cause symptoms such as; difficulty starting, rough running and poor engine performance.

Be aware of the ‘sticky’ residue left when fuel evaporates, particularly from unleaded fuel. This may detrimentally impact the effective operation of the carburettor, eg stuck needles, blocked jets, etc.

14.2.3 FLASH POINT

The ‘Flash Point’ of a mixture is the temperature at which the product will vaporise to maintain an ignitable mixture in air. This temperature is important in terms of starting an engine. Fuel which has been allowed to ‘weather’ or ‘boil-off’ in storage will get progressively more difficult to ignite – remembering it is the heat of a spark plug which must initiate ignition of the mixture.

Flash Point of some fuels:

Product	Flash Pt (C)	Auto-Ignition (C)
70% Ethanol	16.6	363
Petrol	-43	280
Diesel	62	210
Jet A1	60	210
Kerosene	38 – 72	220
Canola Oil	327	
Bio-Diesel	130	

14.2.4 SPECIFIC GRAVITY

The various fuel types have a ‘Specific Gravity’ (SG) (and density), which is important in determining the weight of the fuel load. As fuel weathers or ‘boils off’, the SG and density increase (per unit volume).

The normal fuels used in motor gliders are all ‘lighter’ than water, so will float on-top of any water.

14.2.5 OCTANE RATING

It is important to use fuel with the engine manufacturers’ recommended “Octane” rating. Using a fuel with a lower rating will almost certainly result in detonation.

The “Octane” rating is a measure of how much compression may be applied to the fuel before it spontaneously ignites. The lower the “Octane” number, the less compression required to ignite the mixture.

The octane rating is derived from the chemical make-up of the fuel which is determined in the refining process. Fuel, as a refined product, consists of a blend of various molecules which are initially separated and then blended. Some of these form “hydrocarbon chains”, with other molecules, including hydrogen, to form the fuels and oil we know.

Molecule	Hydrogen Atoms	Carbon Atoms
Methane	1	(C1)
Ethane	2	(C2)
Propane	3	(C3) BBQ/Auto gas
Butane	4	(C4) BBQ/Auto gas
Pentane	5	C5
Hexane	6	C6
Heptane	7	C7
Octane	8	C8

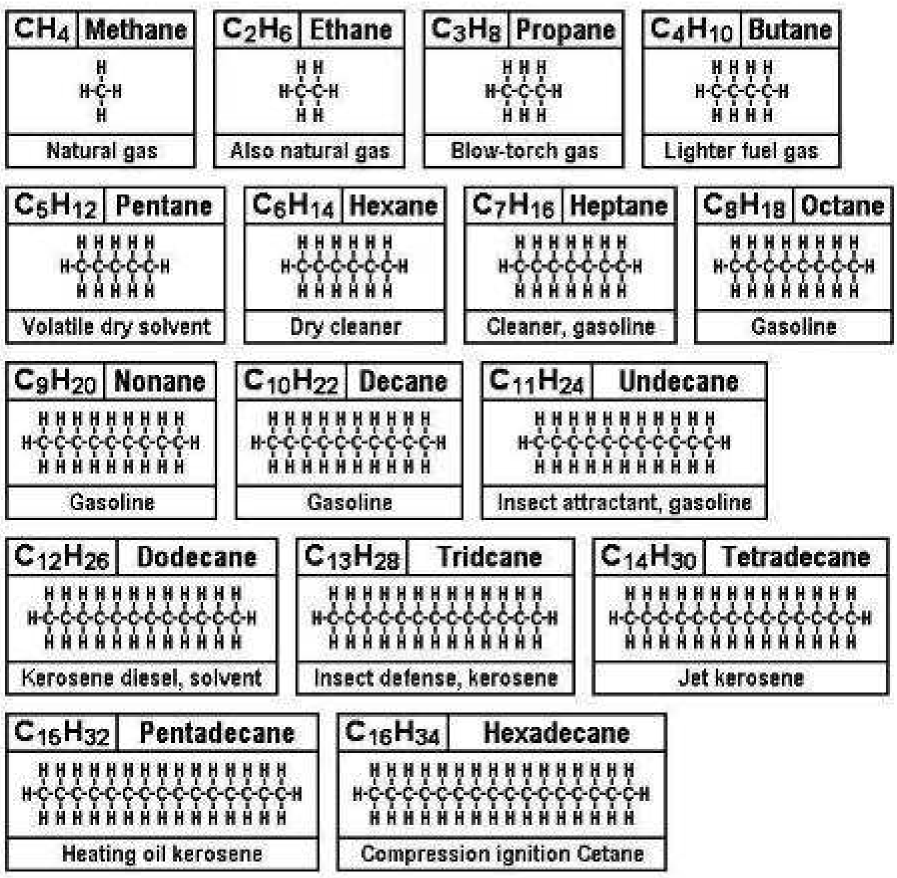
Heptane (C7) has very poor compression qualities, while Octane (C8) has very good compression qualities.

We are no doubt familiar with 87 Octane fuel (or others of a higher Octane rating). The “87” indicates the fuel contains 87% Octane and 13% Heptane (or a combination of other components giving the same performance.

The refined fuel is “blended” to provide a fuel with a recognised “Octane” rating. This fuel will ignite spontaneously at a given compression level and should only be used in engines which do not exceed this ratio.

It was found that adding lead, in the form of Tetra-ethyl Lead, significantly improved the Octane rating of the fuel above published Octane/Heptane combination rating of the fuel, however the environmental impacts of the lead were not sustainable. Hence the transition to low lead and unleaded petrol over the last 30 years.

A list of hydrocarbons, showing the link between carbon and hydrogen follows:



14.3 SIGNIFICANT FEATURES OF FUEL TYPES

14.3.1 AUTO FUEL

Auto fuel includes unleaded and premium grades. Often referred to as petrol or Mogas:

a. Very volatile, evaporates quickly at ambient temperature, the higher the temperature, the higher the evaporation rate.

b. Great care required when handling – in a confined area, an explosion risk exists.

c. Relatively low 'flash point'.

d. Upper cylinder lubricant may be required in some engines

e. Unleaded may leave a sticky residue as it evaporates.

14.3.2 AVGAS 100LL

As for auto fuel and:

Upper cylinder lubricant may be required in some engines.

14.3.3 TWO-STROKE

2-stroke can have a wide range of fuel qualities and oil additions. The oil may be mineral or synthetic.

It is important that the correct fuel and oil type of the required quality are used, and in the correct mix ratios. The engine manufacturer will have specified this in the engine's operating manual.

14.3.4 AVTUR

In Australia, Avtur is usually Jet A-1 (kerosene based) which has the following characteristics:

a. Much higher 'flash point' than Avgas.

b. Stable to much higher temperatures.

c. Subject to fungus growth in storage.

14.4 FUEL STORAGE & HANDLING

Perhaps the most significant impact on "Octane rating" of fuel is the age and storage conditions in which our "fuel" is stored. This relates to fuel storage following refining all the way through to the storage arrangements in our hangars and aircraft.

There is very little "pressured" fuel storage anywhere in the land . Fuel tanks are vented:

a. Most fuel used in Australia is now imported from Singapore, in ships with vented (non-pressurised) tanks.

b. Our motor gliders have "vented" fuel tanks.

c. The local service station has "vented" fuel tanks.

Aircraft owners and pilots should have fuel quality as the top priority. The "lightest" (and most volatile) components in the fuel will evaporate out of the fuel first in a vented storage vessel. The longer it is stored and the higher the ambient temperature the more the volatiles will evaporate reducing the Octane Rating. This is worth noting in motor gliders which spend a lot of time not flying. It is better to keep the fuel quantity low and top up with fresh fuel when next flying. If detonation has occurred and Octane rating is the suspect, it is best to drain the tank and start again.

Storing fuel in a tightly sealed container, such as a quality jerrycan, is essential to maintain the octane rating during storage.

Fuel companies in Australia provide access to the MSDS on their websites and with the above knowledge of fuel blends you can make your own choice of brands. However, note the blend will be adjusted seasonally.

It is vital that engine fuel be:

d. Stored in clean, approved fuel storage containers. Beware of old jerrycans which may contain debris. The use of a filter is recommended when filling from jerrycans.

e. Because most motor gliders use very small volumes of fuel, fuel should not be stored in large quantities. Stored fuel should be used on the basis of the oldest fuel first.

f. All equipment used for refuelling must be scrupulously clean.

g. The ideal containers and equipment are made of a conductive material (metal) and inter-connected by an 'earth wire' (to neutralise any electrical charge). Do believe that static electricity can initiate fuel combustion, particularly petrol.

h. Remain aware of the potential for the quality of the fuel 'left in the tank' to be of suspect quality.

i. Check fuel in aircraft and storage regularly for water.

To check Avgas for water:

j. Take a reasonable volume sample from the fuel drain. (A small sample might be all water).

k. Hold up to light or against a white background and look at colour of fuel.

l. Fuel floats on water.

m. Look for the wrong colour and/or a distinct layer boundary.

n. Look for debris in the bottom of the sampler.

Note. It is not advisable to put the sample back into the tank and should be disposed of in an environmentally friendly manner.

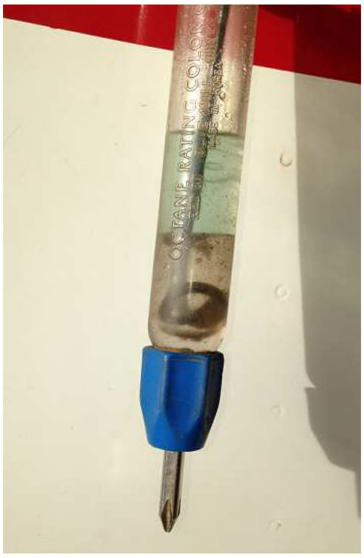


Figure 14-1 Water found in a Pawnee tug after it had stood out overnight in rain.

14.5 FUEL SAFETY DATA SHEETS

The fuel companies are required to produce a Material Safety Data Sheet (MSDS), which describes all of the qualities, hazards and emergency procedures associated with the various fuels.

For the fuel you use, seek a copy of the MSDS and study the document.

14.6 COMBUSTION

The various fuels have different combustion characteristics and burning qualities, including:

a. A lean mixture burns hotter than a rich mixture.

b. A mixture which is lean may burn hot enough to damage pistons.

c. A mixture which is too lean will result in a reduction of power.

A great example of the fuel burning characteristics of fuel is the start cycle of a gas turbine, where the EGT of the turbine will rise rapidly after ignition to a peak [where mixture is stoichiometric – just the right amount of air for the fuel (which may be above the red-line EGT temperature in some conditions, i.e. high ambient temperatures), before stabilising at a lower temperature as the mixture settles down.

Incomplete combustion will result if there is insufficient to oxygen for the amount of fuel or excessive fuel for the available oxygen. It is important that there is complete combustion to avoid:

d. Spark plug fouling.

e. Carbon build up in the cylinder.

All fuel combustion produces water as a combustion product.

14.7 ETHANOL ADDITION TO FUEL

Ethanol blend fuels, such as E10 and E85 are now readily available in Australia.

Most new, and many older engines operate effectively with up to around 10% ethanol blended fuel, i.e. E10 for fuels which satisfy the Australian Fuel Quality Standards. E85 (85% ethanol) is increasingly available in Australia.

To avoid operational issues, it is recommended that the engine manufacturer be consulted regarding the suitability of their engines to burn ethanol blend fuels and to what level of ethanol content. It is also appropriate to ensure that the engines are maintained in accordance with the manufacturer’s requirements using genuine replacement parts. Few engines are able to cope with this level of ethanol.

The use of ethanol, at levels above the manufacturer’s recommendations, may result in problems associated with fuel system materials compatibility (hoses, O-rings, seals, etc).

Ethanol consists of additional oxygen molecules within its chemical structure. This can impact the fuel /air ratio in older engines with carburettors causing vapour lock issues or hot restarting difficulties.

Ethanol attacks both metallic and rubber based fuel lines and other fuel system components. Ethanol is also hygroscopic (i.e it has an affinity to water) which may result in accelerated corrosion of fuel tanks and lines. Rust from any corrosion may block fuel filters and fuel lines.

In fuel injected engines, ethanol blended fuels may result in premature deterioration of injector seals, delivery pipes and hoses, fuel pumps and pressure regulators. Electronic fuel injection systems may experience difficulty to fully compensate for the ‘lean-out effect’ of ethanol blended petrol, resulting in flat-spots during acceleration and difficulty starting.

14.8 FUEL ISSUES

Common fuels issues encountered are:

a. Quality

b. Water – keep it out of the system, generally keep fuel tanks full..

c. Grade, colour

d. Fuel “freshness”

e. Quantity determination and indication.

15. FUEL SYSTEMS

15.1 INTRODUCTION

It is vital, in terms of the safe flight of a motor glider that the fuel system continues to function correctly. With its many components, including tank(s), lines/hoses, filters, pump(s) and carburettor, it is important that each of these continue to function normally.

Another section of this manual highlights the need to ensure good quality, clean fuel is always used.

15.2 FUEL SAFETY

Don’t accept fuel leaks from the fuel system. Correct these before any flying.

There is NO such thing as a normal fuel leak. There are plenty of examples of fire in Motor Gliders where a leak has not been detected or even accepted. There is no such thing as an acceptable fuel leakage rate. We have had some fatalities and very close calls but our best defence is absolute diligence from the inspector to the DI and the pilot and proper emergency training. These are all paramount to safe operation.

Use only good quality, fresh fuel for the sake of your engine and its ongoing service. Stale fuel can destroy an engine. Additives are known to separate in some circumstances. This can cause detonation and even severe damage in a 2 stroke.

15.3 SYSTEM COMPONENTS

The major components of a motor glider fuel system are:

a. Fuel tank

b. Fuel lines and hoses

c. Fuel isolation valve (may be called a fuel shut-off valve)

d. Fuel filter(s)

e. Fuel pump and/or Boost pump

f. Carburettor

g. Drain point (usually at the lowest point of the system). There may be multiple drains.

15.3.1 FUEL TANK

Every effort should be made to ensure the fuel tank is kept clean. This requires that only clean fuel is added to the tank and that the fuel cap is always securely on the tank. Any refuelling equipment must also be thoroughly clean.

It is important that the fuel tank have a visible means of displaying the tank contents, such as a fuel gauge, level indicator (sight glass) or calibrated dip stick.

15.3.2 FUEL LINES AND HOSES

Fuel lines and hoses must be maintained. This may entail the regular changing of flexible fuel hoses in accordance with the manufacturer’s (of the sailplane, engine or hose) requirements, or requirements of the country of origin regulator, GFA or CASA.

Fire sleeve on fuel lines must be in good order.

15.3.3 FUEL ISOLATION VALVE

A fuel shut-off valve must be installed on the tank side of the fire-wall, visible to the pilot and within easy reach. This valve may be a “lifed” component.

15.3.4 FUEL FILTER(S)

Filters are installed in the fuel system to capture any debris which may find its way into the fuel system.

Filters may be:

a. In-line (small cylindrical devices inside a pipe or hose),

b. Small plastic devices in fuel lines; or

c. Gauze or other filter medium at the entry point of fuel pumps.

Filters must be maintained in accordance with the manufacturer's recommendations at periodic maintenance intervals, or more regularly if contaminated fuel is found.

15.3.5 FUEL PUMP(S)

Motor gliders may have an engine driven mechanical fuel pump. Most also have an electrically driven auxiliary fuel (or boost) pump.

It is important that the fuel pump(s) are maintained in accordance with the manufacturer's recommendations to ensure ongoing, uninterrupted engine operation.

An electric boost pump is able to be used to pressurise the fuel system and check for fuel leaks.

15.3.6 CARBURETTOR

The carburettor is discussed in a separate section of this manual.

15.4 FUEL SYSTEM ISSUES

Common fuels system issues encountered are:

a. Water contamination of fuel

b. Debris clogging fuel lines and filters

c. Carburettor icing

d. Fuel leaks e.g. hoses split, clamps loose

e. Fuel tank vent(s). e.g. a blocked venting cap may cause fuel starvation

f. Fuel freshness.

g. Leaking fuel drains e.g. washer spilt, weak valve return spring, debris preventing closure

16. FUEL INJECTION SYSTEMS

16.1 THE EVOLUTION OF FUEL INJECTION

Very early in the evolution of the internal combustion engine it was realised that optimum atomization and accurate control of the air/fuel ratio over the full operating range of the engine was extremely difficult, if not impossible using a carburettor. Multi-cylinder engines also suffer from uneven mixture distribution because the cylinders furthest from the carburettor(s) invariably run leaner while those closest tend to run richer. Efforts to overcome these shortcomings led to multiple carburettor installations; some engines using as many as one per cylinder, very sophisticated carburettors with multi stage jets, carburettors with up to four separate venturis, tuned inlet systems and a host of other 'compensating' devices. Despite all the modifications and variations, the carburettor has always remained a 'compromise' device.

Aviation brought an additional set of problems. It now became essential to have some form of variable mixture control to cope with changing altitude and carburettor icing became a serious issue, but perhaps the largest problem was control of the fuel level in the fuel bowl during manoeuvring, especially when reduced or negative 'G' loads occurred. Low G causes the fuel level to become excessively high resulting in an over rich mixture or 'flooding' which can cause engine stoppage. Of course, aerobatics pushed conventional carburettors well beyond their limits and to counter these problems very complex and expensive fuel systems and carburettors had to be developed, but the problems were never completely overcome.

Fuel injection actually dates back to the late 1800's and had the potential to address all the shortcomings of the carburettor, but it was expensive and its use was confined primarily to diesel engines. Early systems used a high pressure pump to provide a constant supply of fuel to an accumulator from where it was piped to the injectors which were actuated by mechanical means. WW II saw the introduction of the multi-piston injection pump and hydraulically operated injectors, with the Bosch system developed for the Daimler Benz 600 series aero engines. Claudel Hobson in UK followed with an 'injection carburettor' and Bendix produced a system for the B-29's Wright 3350 engines.

The advent of the jet engine ended aviation-based development of petrol injection, and it was not till the mid 1950's that petrol injection started to be seen seriously in automotive engines. Again, Bosch led the way closely followed by Chevrolet and Chrysler, although the latter was notoriously unreliable. By the 1960's petrol injection was starting to be seen in the more exotic marques and in high performance vehicles. These systems utilised a piston type distributor pump producing up to 5000 psi, and injectors operated hydraulically by the pulse of the high pressure fuel. Acceptance by the auto industry was slow because of the very high cost, due mainly to the extremely precise (0.00001') tolerances required in the injection pump and injectors. Also, the output pressure varied depending on engine speed, and the only sensors available to control air flow, fuel flow, timing and mixture strength were mechanical and crude at best.

It was the advent of the microchip, and the development of an effective Electronic Control Unit (ECU) that brought petrol injection within economic reach of the automotive world in the mid 1970's. With microprocessor control it became possible to monitor all the parameters necessary to provide the optimum fuel mixture under all engine operating conditions, and make adjustments in milliseconds. These systems utilise a rotary pump and a pressure regulator to supply constant fuel pressure of around 30-60 psi to solenoid operated injectors via a manifold, or fuel rail. Inputs to the ECU include engine temperature, inlet air temperature, air mass, throttle opening, engine rpm, ignition timing, detonation sensors and exhaust oxygen sensors. These inputs allowed the ECU to control the air / fuel ratio, timing and duration of the injection and ignition timing with extreme accuracy and at very high speed. The systems can also compensate for fuel quality by means of a 'knock sensor' to detect the onset of detonation, and cold starting can be achieved without the need for auxiliary devices such as a choke. The precise control also results in significantly improved fuel consumption and perhaps more importantly, huge reductions in harmful exhaust emissions.

16.2 TYPES OF FUEL INJECTION IN USE TODAY

There are two main types of electronic petrol injection in common use today but both utilise similar components:

a. Single Point Injection. This system has a single solenoid type injector which feeds the fuel into the manifold, usually just downstream of the butterfly valve. This system cannot provide really accurate fuel distribution to multi cylinder engines so is no longer popular but there are still quite a few around.

b. Multi point Injection. By far the system in widest use today. Each cylinder is supplied by its own injector which is generally fitted into the manifold or cylinder head so that it discharges into the inlet port upstream of the inlet valve and is generally timed to discharge while the inlet valve is open, although on some engines fuel is injected into several ports at once, before the inlet valves open. This is known as Indirect Injection. Indirect injection in diesel engines is slightly different as the injector discharges into a pre-combustion chamber downstream of the inlet valve

Some engines, particularly diesels, have the injector mounted in the cylinder head so that it discharges directly into the combustion chamber. This is called Direct Injection.

New on the scene in modern common rail systems is the piezoelectric injector. This injector type can operate at pressures well beyond the capabilities of the solenoid or electromagnetic injector, and are used in common rail diesels where pressures of 20,000 to 30,000 psi are normal. Not yet in wide use in petrol systems, but as pressures increase we will see them soon. These injectors are capable of unbelievably fast reaction times (microseconds) and can produce up to ten separate pulses during each injection. Multiple-pulse injection results in ‘softening’ of the power stroke, more complete combustion over a larger arc of crank rotation, quieter operation and significantly cleaner combustion.

Electronic injection is replacing mechanical systems on aero engines and at least three manufacturers of powered sailplane engines are already using electronic petrol injection. Petrol injection on 2-stroke engines is gaining favour and gives huge improvements in economy and drastically reduced emissions. Some injected 2-strokes use oil in the fuel whereas others use straight petrol. Lubricating oil is injected with the air via a separate metering pump.

Servicing electronic injection systems requires special care and knowledge and no work should be undertaken unless the service personnel are thoroughly familiar with the system. Modern common rail systems can contain pressures of up to 30,000 psi and voltages to injectors of up to 400 volts at 20 amps! Further, dangerous pressures can remain in the system long after the engine has been stopped. Additionally, capacitors in the ECU may hold dangerous voltages for some time after the engine is shut down.

Always consult the relevant service manuals, bulletins and safety instructions before undertaking any work on any component of an electronic fuel injection system.

17. LUBRICATION

The various engines installed in the glider fleet all have a requirement for reliable engine lubrication for ongoing engine operation and engine life.

The failure of almost any part of the lubrication system is likely to result in major engine damage unless rectified quickly.

There is little a pilot can do to the lubrication system once the engine is running, or worse if flying, other than to shut the engine down.

17.1 LUBRICATION REQUIREMENTS

There are various lubrication requirements and systems installed in the motor glider fleet, including:

a. Lube oil mixed in a specified ratio with fuel (petrol or avgas), as in a 2-stroke engine.

b. Lube oil injected into the fuel/air stream at the carburettor, as in some 2-stroke engines.

c. Lube oil mixed in a specified ratio with fuel (Avtur), as used in ~~a~~ small turbine engines.

d. Lube oil circulated through a specifically designed system of pump, pipes, galleries, filters and coolers, as in most 4-stroke engines.

e. Lube oil which is ‘flung’, ‘splash’ or ‘spray’ fed to internal engine components for lubrication purposes, as in most 4-stroke engines.

Most lubricating oils used in motor glider engines today are standard automobile engine lubricants. This situation results from the fact that motor glider engines are the result of automobile technology. In both the automobile and aviation arena, the engine designer specifies the lubrication qualities required for an engine.

17.2 PURPOSE OF LUBRICATION

Lubrication is required in an engine for a number of reasons:

a. To reduce the friction between moving components in an engine to reduce the amount of heat generated.

b. To carry the heat generated by the friction away from the engine. In this case, the heat picked up by the oil is subsequently removed through an oil cooler, where air is directed over the outside of finned tubes containing the oil.

c. To cushion moving parts against shock.

d. To help piston rings ‘seal’ against the cylinder.

e. To protect internal parts from corrosion.

f. To clean the engine by carrying the combustion products out of the engine. These products are subsequently removed from the oil stream by being passed through an oil filter and in the absence of a filter, settle in the sump due to the emulsifiers in the oil.

g. Lube oil may be supplied to the drive gear of components, e.g. magnetos.

17.3 LUBRICATING OIL

No single oil is able to satisfy all the lubrication demands for an engine and associated systems. The engine manufacturer does not build an engine then try to find a suitable lubricant. The qualities of the lubricant are identified and the requirements are built into the engine as oil gallery dimensions, oil pressure requirements, oil cooler dimensions, oil filter specifications, etc.

There are many and varied lubricating oils available, all with various specifications and qualities. It is normal that the component manufacturer, be it the engine, gearbox etc, will specify the oil quality and specification to be used in each application, knowing the oil and the requirements.

The nominated specification is made by the manufacturer for specific reasons, and oils of other specification or quality may not satisfy the specific engine requirements. Therefore, it is strongly recommended that manufacturer's lubrication specification for an engine be recognised and complied with.

Some lubricating oil specifications and qualities include:

a. Viscosity – too 'thin', oil may not carry combustion products to the filter or lubricate the engine.

b. Viscosity is generally specified as an SAE number, ie SAE 30, SAE 40 etc. (See below)

c. Temperature range – consider winter versus summer operations.

d. Oil change period, expressed as engine hours or calendar period. Do not extend these as it may result in engine damage. Oil is much cheaper than engine damage!

17.4 OIL VISCOSITY

Oil viscosity is measured with a viscometer and is expressed in numbers in accordance with the Society of Automotive Engineers (SAE), ie SAE 30. The viscosity is a measurement of the oils resistance to flow – the thicker the oil, the slower it will flow.

Standard SAE numbered oils are measured at 100^0C. Where a "W" number is shown, this indicates the viscosity at a colder temperature. It therefore provides information about how the oil will perform when an engine is first started (and where lubrication is equally important to reduce or avoid wear). Examples:

a. SAE 10W-30 oil has the same viscosity as SAE 30 oil at 100^0C but performs as SAE 10 oil at 200C.

b. SAE 5W-30 oil performs like SAE 5 at 250C (i.e. when cold) but like SAE 30 oil at 1000C.

The viscosity characteristics are changed using 'pour point depressants' or 'viscosity modifiers'. There are pros and cons with the use of the additives.

All 'multi-purpose' oils have modifiers added. A drawback from using viscosity modifiers results from the modifiers breaking-down in high shear stress or high temperature situations, resulting in sludging.

As the additives are depleted through breakdown, the oil has different 'thinning' characteristics – and is un-likely to sustain the initial lubricating qualities. Multi-purpose oils - such as 20W – 50 and 10W-40 - are such oils. Synthetic motor oils do not generally contain 'thinning additives'.

Again, the engine manufacturer's recommendations should be closely followed.

17.5 SPECIFIED LUBRICATING OILS

In any modern automobile engine, it is likely that a 'multi-grade' oil is recommended. What is a multi-grade oil and why is it recommended?

Oil grades:

a. Mineral oil is sourced from the ground ie oil wells and refined.

b. Synthetic oil is manufactured from oil (sourced from the ground) but with chemicals added in a petro-chemical facility.

c. A 'single grade oil' is an oil, generally a mineral oil, that does not contain any viscosity modifying additives.

d. A 'multi-grade' oil is one that is made up of additives or a blend of oils and additives which change the viscosity profile of the final oil.

As indicated above, a multi-grade oil may be produced from a mineral or synthetic oil base or a mixture of both. Avgas fuelled, air cooled engines using only synthetic based ‘multi-grade’ oils have problems handling the lead by-products of combustion.

Oils with a 100% mineral oil base also display problems handling combustion products, particularly in Avgas fuelled air cooled aircraft engines.

A blend of mineral and synthetic oil to formulate a multi-grade oil is considered best for Avgas fuelled, air-cooled aircraft engines.

For automotive derivative engines, the engine manufacturer’s recommendations should be heeded.

The engine designer determines the lubrication requirements long before the engine sits in the mounts.

A multi-grade oil based on a mineral oil is likely to contain a high level of ‘viscosity index modifiers’, which may result in high temperature oxidation and high shear breakdown issues.

A multi-grade oil produced from a mixture of a synthetic and mineral oil base results in an oil which is very viscous at low temperature while at high temperature has the quality to provide superior engine protection.

Another aspect of the oil specification is the possible impact on other system parts, such as gaskets and O-rings. The wrong oil may damage these.

17.6 2-STROKE LUBRICATING OIL SYSTEMS

The fuel/oil mixture for a two-stroke engine should be in strict accordance with the manufacturer’s instructions, both in terms of the oil quality and specification and quantity (ratio of fuel/oil).

A mineral oil used in 2-strokes burns readily and over time fouls spark plugs and piston rings. Synthetic 2-stroke oil does not burn as readily as mineral oil and has the advantage reducing fouling. The offshoot of this is that as it does not burn as readily less is need to lubricate the engine and thus the ratio changes. The engine manufacturer will generally specify the ratios for both types. The ratio change from mineral to synthetic is usually half the mix for synthetic.

It is further recommended that fuel be kept ‘fresh’ by storage in an air-tight container, preferably in relatively small volumes.

17.7 4-STROKE LUBRICATING OIL SYSTEMS

The major components of lubrication system on a 4-stroke engine are:

a. Sump or oil reservoir. Provides a space for the storage of a relatively small volume of oil. The engine driven oil pump, or its pick-up, may be located in the sump.

b. Dipstick or oil sight glass. The dipstick or sight glass provides a method to determine the volume of oil in the sump. Normally the measure is taken when the engine is shutdown with the glider on a level surface. Always keep the dipstick and the dipstick opening clean.

c. Oil drain plug. Provides the means to drain the oil from the engine. It is generally recommended that the oil be slightly warmed up before draining to aid the flow of oil from the sump. Precautions need to be taken to avoid burn injuries.

d. Oil filler. Allows the filling of the sump. Always keep the oil filler and filler cap clean and free of dirt and dust.

e. Engine driven oil pump.

f. Oil pressure gauge.

    i. The oil pressure gauge provides a cockpit indication of the oil pressure to the pilot. This should be regularly monitored while the engine is running.

   ii. It is recommended that the oil pressure gauge have a green arc (for normal operating pressure), a yellow arc (for caution) and a red line (for minimum/maximum oil pressure).

   iii. An oil pressure (low) alarm may be fitted.

g. Oil pressure relief valve. Prevents over-pressure of the lube system, particularly where a gear-type positive displacement pump is used. The use of a ‘relief valve’ to regulate oil pressure is common.

h. Oil filter.

   i. The oil filter is designed to remove combustion products, sludge and introduced dirt etc from the oil stream. The filter specifications are normally described by the manufacturer.

   ii. Particular care is required when installing the oil filter. Many have an O-ring seal, which requires a good quality O-ring, appropriately cleaned and lubricated before installation. There are many examples of damaged engines caused by the failure or wrong installation of the O-ring.

i. Oil cooler.

   i. The oil cooler generally consists of a bank of finned tubes. The hot lube oil passes within the tubes, while cooling air passes through the fins on the outside of the tubes.

   ii. Care is required not to impede the flow of cooling air, which is generally provided as a result of the forward movement of the glider.

j. Oil temperature gauge.

   i. The oil temperature gauge provides a cockpit indication of the oil temperature to the pilot. This should be regularly monitored while the engine is running.

   ii. It is recommended that the oil temperature gauge have a green arc (for normal oil temperatures), a yellow arc (for caution) and a red line (for maximum oil temperature).

k. Propeller drive gearbox. Where a gearbox is incorporated in the prop drive system, the gearbox manufacturer is likely to stipulate the lubrication oil requirements, including oil change periods. The gearbox is likely to require a ‘gear oil’, which is generally a thicker oil. It is vital that the relatively small volume of oil in the gear-box be maintained.

l. Propeller lubrication

   i. On some variable pitch propellers, grease is used to lubricate components, with the greases retained within a seal. Prop lubrication, because of the impact on prop performance and balance, is generally not in the domain of an 1109 Inspector.

   ii. The propeller’s manual must be consulted to determine the servicing that can be undertaken.

18. IGNITION SYSTEMS

The vital aspects of any engine are; the fuel, air, ignition and exhaust arrangements. When an engine won't run, it is usually because one of the vital aspects is missing or poorly represented. This section addresses ignition.

The ignition system is exactly that - it ignites the fuel/air mixture in the combustion chamber of the engine (diesel engines excluded). It is the only time in aviation we want to start a fire in an aircraft!

In motor gliders there are two common systems in use; magneto and electronic.

The distributor ignition system, as is used in cars, powered by the battery, has never been favoured by the aviation industry. A magneto is similar in some ways but generates its own power and so is independent of wiring, battery and generation problems. It is thus much more reliable.

18.1 MAGNETO IGNITION

The main advantage of the magneto is that it is, in effect, a generator and it is simple. It produces the electrical power required for the ignition 'spark', so the system is totally independent of the rest of the aircraft electrical system.

The main disadvantage of the magneto is that it has only two timing positions. It is not variable; being retarded for starting and advanced for running. It also does not produce high voltage when compared to a modern electronic system. The magneto also has some specific maintenance requirements.

As it is the most common system see a special section at the end of this section.

18.2 ELECTRONIC IGNITION

The main advantages of an electronic ignition system are that there are no mechanical points, the timing is 'mapped' (variable timing), there is a relatively high spark voltage and there is a 'set and forget maintenance' regime because there is no mechanical wear.

The main disadvantage is that it requires an external electrical power supply, so, in the case of a touring motor glider, a second power supply is required for redundancy in the case where both ignition systems are electronic. Some systems, such as in a Rotax engine, have a hybrid magneto/electronic ignition system.

The Limbach DFI range of engines and the Jabiru 4- and 6-cylinder engines use pure electronic ignition with no inbuilt power generation and rely on the aircraft supply. These engines are currently used in some motor gliders in Australia. Redundancy for the lack of inbuilt power supply is done by way of a reserve battery system that the main system cannot draw from but in the case of the Limbach will keep the charge up too. There is also the UL Power engine which is the same system as Limbach and will no doubt reach our shores in the near future in a glider. It is already common here in LSA and ultralight aircraft.

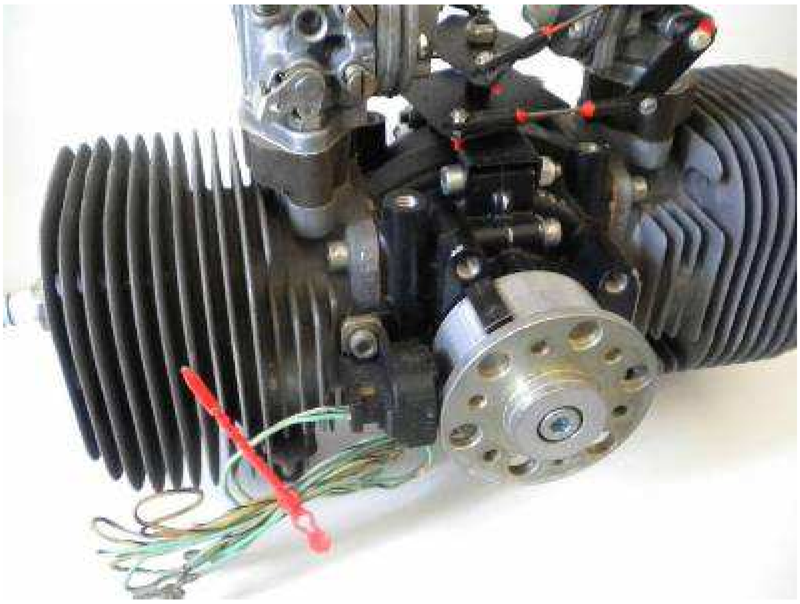
Electronic ignition systems use a cranking sensor as a trigger for timing. The trigger is an electric pulse that is used by the Ignition Control Module (ICM) to determine the base timing point in relation to the crankshaft. This is generally an electronic chip (Hall Effect magnetic sensor) or a small coil, excited by a small magnet fitted to a component on the crankshaft as it goes past the coil or sensor, which is stationary.

The ICM recognises that point and RPM on the basis of time between pulses. From this it then drives the system to a programmed 'map'. The ICM is able to work multiple cylinders, thus the opportunity for multi-firing points from the one trigger.

There is nothing to service in the ICM, it being a sealed solid state device. The ICM drives coils that supply the spark plug.

In automotive applications it remains common to use coils with spark plug leads from both sides of the coil driving spark plugs on two cylinders with opposing cycles in the 4-stroke application.

In motor gliders, for redundancy, they are often grounded on one side, thus having a coil for each spark plug. For dual ignition, there may be leads on both sides, with 2 coils serving 2 cylinders with 2 plugs each - for redundancy.



A capacitor (often referred to as a condenser) is a part of all ignition systems. It works with the coil and resistance, as a tuned IRC (inductance-resistance-capacitance) circuit, to produce the spark as the points open. They also help suppress noise in radios as a secondary function and so may occasionally also be called suppressors.

In the case of an aircraft, we are concerned with VHF radio interference which is far more sensitive due to the frequency range and relatively low signal strength.

The high tension leads and spark plugs are a source of 'noise' (interference) for the radio where it interferes with the reception. This is usually overcome by shielding the high tension leads (spark plug leads) with a wire braid sheath on the outside of the insulation. This is sometimes covered by another layer of plastic/rubber making it less obvious. The shield is 'grounded' at the magneto or coil end, and in some cases also at the spark plug where the plug is shielded by a closed metal case. There may also be a resistor in the spark plug, often termed a suppressor to suppress noise.

Below is an aviation style shielded spark plug and shielded lead, which grounds to the plug body.

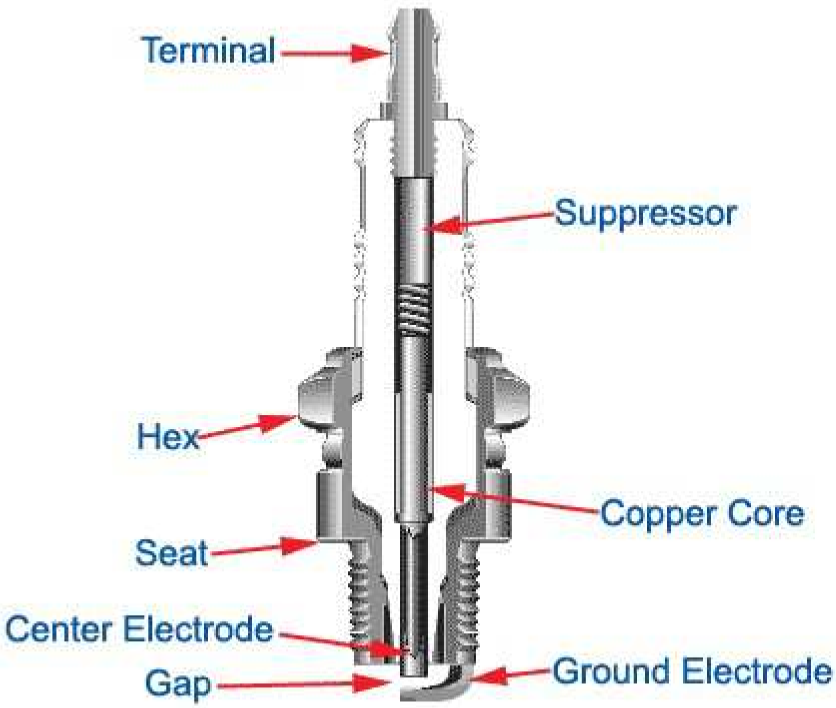
Below is an ICM and coil for an L275. This is a single ignition, no redundancy, with one coil for both cylinders.

Below is a Slick 4330 magneto with shielded leads grounded at the magneto end only. It also shows a modern style plug common in sport aircraft. On the left is the drive and impulse unit. On the right is the distributor cap. Underneath is the vent plug which can be replaced with a rev counter pickup.

18.3 SPARK PLUGS

The ignition system provides timed high voltage current to the spark plugs where the high voltage jumps between the centre electrode and the ground electrode, creating a spark. The distance between the two electrodes is known as the 'gap'.

Spark plugs are a very important component, simple but critical to the engine. They will be specified by the engine manufacturer and the correct plug must be used (as with all certified aircraft components).



Some little understood items:

a. The manufacturer will specify a replacement interval to avoid failure or reduction in performance. Plugs do wear at the gap and can fail, so carry spares and replace as specified for reliability.

b. A plug has a characteristic called the heat range. This is matched to the operating temperature of the engine so it self-cleans, but conversely so it does not burn out in hotter engines. The correct heat range plug must be used.

c. Plugs have different threads, length, tapered or straight diameter. These must all be correct for the type of engine.

Note: In the Limbach engines, the heads were designed for a slightly shorter plug than the available aviation plugs, which project into the cylinder head. The cylinder end thread gets covered in carbon, which tends to strip~~s~~ or damages the aluminium head threads, resulting in the plug stripping the head thread when you remove it. This can be fixed with helicoils but is an avoidable nuisance. Make sure the plugs have two washers instead of one in the case of the Limbach or where the plug thread protrudes into the combustion chamber.

d. Special plugs have various electrodes and gap designs, ie shape and materials to gain slight improvements.

18.4 TIMING

The spark is timed to ignite the mixture at the appropriate point in rotation of the crankshaft or, in the case of a Rotary engine, the rotor. Once ignition of the mixture starts, it takes a small amount of time to propagate across the chamber and, as it is desirable to have burnt all the mixture in the arc of rotation giving the best effort for energy, the timing of this event is important. The manufacturer of the engine conducts research to determine the optimum timing. This is RPM dependant; as RPM increases the ignition needs to start earlier in order to have ignited all the mixture before the piston or rotor progresses past the optimum point. Thus they ‘map’ advancing the ignition with RPM.

The ignition timing is described as BTDC (Before Top Dead Centre). Top Dead Centre refers to the piston being at the top of stroke position in compression. This still applies to the Rotary but in that event is the rotational point where the rotor is at the highest compression point in its path. The higher the RPM, the more degrees BTDC the timing must be set and this is referred to as 'advanced'. Reducing the number of degrees BTDC is called 'retarding'.

In the case of twin ignition systems; having 2 spark plugs speeds propagation and thus the timing map changes. In the case of some engines such as the Limbach, the timing point remains the same for the primary ignition. The second ignition is set to a lower advanced position or less degrees BTDC. Dual ignition is of course for redundancy and reasonable or normal performance will remain on one ignition.

In the case of the rotary engine, it has always had 2 spark plugs from the beginning and of course in all the Mazda cars built. This was not for redundancy but because of the wide combustion area of the rotary. This is due to the shape and configuration of the chamber between the rotor and housing. It needs both the spark plugs to achieve efficient combustion and losing a plug dramatically reduces performance. However it does not stop the engine, so can still be considered a redundant system to an extent as the engine will still run. Large bore engines suffer the same problem, for example the 260 HP engine in a Piper Pawnee which has a capacity of 1.5 litres per cylinder. If running on only one ignition, it does affect performance.

The physical point that is used as the reference to set the system indicated with a 'timing mark' on a component fitted to the crankshaft or E-shaft (rotary). This will be the prop flange or similar style of item.

18.4.1 SETTING THE TIMING

Setting the timing is a common maintenance procedure that needs to be done correctly. The engine manual will specify how to set the timing. Essentially it is the same on all engines:

a. There is a timing mark on the crankshaft to show at what point the spark should occur.

b. Most magnetos need a special timing device rather than just a light or strobe light as used for autos.

c. The device is connected to the magneto while part of it is loosened and then turned until the points open at the correct timing mark. This may mean working around the impulse or starting delay circuit as per the manual.

18.5 MAGNETOS

18.5.1 MAGNETO OPERATING PRINCIPLES

Magnetos are meant to be self-contained ignition units that will work without batteries, alternators and any other part of the aircraft electronics. Even the off switch tends to fail ON. However, some variations require external power at least at start up. Also the Slick and the Bendix are self-contained units whereas the Rotax is a distributed system with bits all around the engine. Most pop-up motors have a magneto system built into the flywheel assembly – similar electrically but different in layout. Most are very robust and self-sustaining.

Usually two units or systems are used with a dual ignition for redundancy and if only one is in place there is increased risk of total failure in flight or start-up; therefore, as discussed above and by Slick, extra care is required to compensate. Dual ignition is not just redundancy in plugs but also all parts of the ignition system. It is one of the design aspects of aircraft engines that make them more reliable. These days electronic ignitions are reliable but the old magneto is pretty reliable and is independent of all other failures in the glider that may stop the engine.

The magnetos are directly coupled to the engine and turn synchronised to the engine. They therefore generate a spark in sync and must be timed to spark at the correct time. The magneto rotor shaft turns permanent magnets that induce a magnetic field in the primary and secondary coils within the unit that in turn produce high tension current. The points, coils and condenser are a tuned circuit that stores energy and releases it to produce the spark at the correct timing. This is distributed to the correct plug by a distributor mechanism in the unit via the ignition leads.

There are two coils in the ignition spark circuit; actually, there are three coils. Two Spark coils and One Magneto coil on the armature.

To produce a spark, the points are initially closed. A strong Magnet passes rapidly past the Magneto Coil as the engine rotates. This induces a current in the Magneto coil which is in series with the Spark coils. A current is now flowing through all the coils. A magnetic field is built up (Induced) in the spark coils.

Notice; The magnet field induces a current in the Magneto coil and the current induces a magnetic field in the spark coils.

Changing Magnetic Field = Current.

Current = Changing Magnet Field.

At the proper moment, the points open. The spark happens when the current Stops flowing! The current instantly stops. (Almost instantly!)

The magnetic field in the Coils almost instantly collapses. The collapsing magnetic field induces a reverse current in the spark coils. The faster the field collapses the higher the current and voltage it produces. The spark plug is open an open gap, so the current is nil. Therefore the voltage is going to be extreme. (Ohms Law). The voltage reaches 10's of thousands of volts very quickly (microseconds) and arcs across the spark plug gap.

Meanwhile, back the Points, the points are open and the current in the magneto coil is also collapsing and inducing a reverse current in the Magneto coil. This voltage is also going to try to induce a spark, and the points are the target. There is a capacitor across the points that initially charges when the points first open. This allows the current to continue to flow as it charges, giving the points enough time to open far enough apart before the voltage builds too high causing a spark. Very quickly the capacitor is charged and can no longer protect the points.

This is where the Dampening Box comes in. It is a Diode and a (Dampening) Resistor. Remember that the collapsing field induces a REVERSE current in the coils. The Diode's polarity is connected to only conduct with the reverse current. As the reverse current attempts to build in the magneto coil, The diode conducts this current through the Resistor in the Dampening Box, The Current is significant so the voltage will be small. (Ohm Law again) This Dampens out the Spark across the Points. The spark circuit has a lot more going on than meets the eye. Inquiring minds might want to Google "FlyBack Diode"

Rotax 9-Series engines have a coil working each pair of plugs (to avoid a distributor) and so fires two plugs at each cycle, one at the firing cycle and one on the non-firing cycle. Thus the plugs and ignition fire twice as often, i.e. every cycle whereas a Slick fires every other cycle. The Rotax 9-Series engine magneto is therefore a self-sustaining electronic magneto system with no moving parts to wear.

Rotax 9-Series engines have two plugs per cylinder and two redundant ‘magneto systems’. Thus each system fires either a top or bottom plug per cylinder and so either system or a coil etc can fail and the engine should continue to run. i.e. it has a redundant system. Whereas if any plug or lead fails in a single system, one cylinder stops working and if any part of the magneto fails the engine stops.

Note that redundancy can mask failure and make it difficult to detect or to resolve. This is the reason for a magneto check on dual ignition engines. It will show you if there is a fault. You must fix this or get special authority to fly with a failure evident.

More importantly for gliders some failures make starting more difficult. For a normal aeroplane this is a nuisance but if you are in a glider flying engine off and then it fails to start for a retrieve, it can lead to a crash. It shouldn't if the pilot is properly trained and has planned correctly but it still happens. So we need to make sure of starting. The part that gives trouble is usually the impulse unit. It could be other things like a cracked coil or a condenser (capacitor) etc but there is little you can do about these other than check them and hope they fail while on the ground.

The impulse unit is a mechanical device within a Slick and Bendix Magneto that improves the spark at low RPM and retards the timing to enable starting. If the engine has spark but has become hard to start, then suspect the Impulse Unit (IU). See the manual for more details. A Stemme operates the IU much more than other aircraft and so typically wear it out in 250hrs or less whereas other aircraft last to over 1,000hrs. If the engine is started often per hour of operation then the IU will also wear more and may stop operating properly. The reason for failure is wear, which makes it kick out early and so it stops working before the engine starts and does not retard the spark to enable the slow engine to accelerate.

An engine like a Rotax with a dual ignition pickup system does not have an IU. But a pickup or the ECU could fail and so result in the same problem – not common.

Dual ignition systems have an advantage of redundancy. But you must test 'mag drop' to see if one system is faulty and being masked by the other.

Most ignition systems turn off the engine by grounding the 'P-lead'. The exception being full electronic systems relying on the aircraft power supply. If the switch or wiring fails it does not ground the magneto and cannot turn it off. This leads to the well-known risk of the engine firing during maintenance when we think it is off. So be absolutely sure this works and then be careful to take no chances with the prop that you hope is dead. Take out the plugs or at least remove leads if at all possible, all of them, before getting in line with the prop.

Remember pop-up motors, while being apparently simpler, have ignition systems, usually a form of magneto, and you must figure it out and most importantly service them as required. They are really just as complicated and need as much care as a touring motor glider.

Usually in small motors, the magneto is built into or around the flywheel. Inside or outside will be a coil which generates current and there will be points or a pickup to trigger the spark. They can have an engine control module for electronic ignition like the Limbach L275 shown above and will have a coil and condenser to generate the high voltage current. It will have a lead to kill the spark to turn the engine off. Really the same system but they all have variations and look different.

The magneto on aircraft engines is vital and therefore needs to be reliable. It is designed as an independent source of energy for the spark to ignite the fuel/air mixture in the engine. In GA aircraft it does this job superbly but possibly at the sacrifice of easy starting.

What would you rather have; an engine that starts well but fails in flight, or a spark that never fails once it has started? For GA this is obvious, but not so clear for gliders, where we like to turn our motors off. So we need a reliable spark but it must also start reliably, and this takes some extra care.

Slick and Bendix magnetos have been well designed to work reliably for the life of the engine and not require much maintenance. This goes a little wrong in motor gliders like the Stemme, where it overworks the magneto at start-up and it can wear it out early. May be also in other gliders as we start often and have short run times. This problem is caused by the impulse unit, on which we will focus later.

There are many variations of magnetos on glider engines, but they tend to follow the same principles. This chapter has been written around the Slick magneto, as this is best known to the author. Other types are Bendix – which are not common in gliders but are sometimes found in older models, and the custom built Rotax 912/ 914 or pop-up motor variations. The Rotax is built into the alternator assembly, with external pickups, ECU (Electronic control unit) or ICU, and coils. This may be somewhat more risky than a self-contained unit like a Slick but they have stood the test of time and are partly electronic, so they probably offer better starting and don't usually give trouble except for bad contacts. They have electronic pickups and no wearing parts rather than points as found in the Slick. They use a dual pickup to delay the spark for start-up. Pop-up motors of all types usually have a similar magneto integrated into the flywheel and could be points or pickup and electronic control.

The usual Slick magneto in gliders with Limbach and other VW derivative engines is the 4330 series.

Figure 18-1 Slick 4330 Magneto

This is an impulse coupled 4-cylinder magneto. Other types are pressurized (we don't need and don't consider) and dual points delayed type or 6-cylinder types which are unusual in gliders. There is a very detailed, thorough manual for Slick magnetos; 'L-1363D, 4300/6300 Series Magneto Maintenance and Overhaul Manual' available from Unison for the total maintenance of Slicks. It is a good manual and is essential to overhaul them. Understand it and follow it diligently.

The Rotax engine manuals cover the Rotax magneto system in detail and it is essential to have access to them. Other engines will detail their systems and must be obtained and understood.

A copy of all current ADs, ANs and Service Bulletins must be available.

18.5.2 THE INSIDES OF A SLICK 4330

Note: A Bendix will be similar to a Slick, ie self contained, self generating, electro-mechanical with a single source of spark, distributed to the plugs. But a Rotax has some similar components spread around the engine but is electronic and non-mechanical.

The impulse unit dissembled showing the spring and housing on the left, the pawl unit in the middle, and the shaft of the magneto on the right. It is the pivot pin of the pawl that wears and causes the rotational speed limit to change. They are expensive and hard to get but Slick/ Champion is adamant that you do not attempt repair of any parts.

Looking inside under the distributor cap. You see the red coil, the points top left, and the rotor shaft under the points. The distributor centre rotates on the coil tab in the middle transferring the high tension current. Common failures are wearing of the points and cracking of the orange insulation (caused by sparking without plugs to provide a current path).

Inside the distributor cap showing the gear driving the distributor, and the capacitor on the left. There is a carbon pin in the middle between the 2 screws that picks up the high voltage current to the distributor.

The solder joint for the wire on the condenser has a dob of silicon on it to reduce fatigue of the wire at that point. They do still fail and need checking.

The distributor assembly. Wear and cracking could occur but seems uncommon. Turning the engine over with the timing pin in place can strip a gear or damage the distributor electrode. But cases of teeth stripping are well documented and gears should both be replaced every 500 hours. As should points and capacitors as listed but by the manufacturer.

The permanent magnet armature rotor and bearing cap removed. Spring spacer washer.

You must replace bearings at the overhaul time to avoid potential failure.

The magneto is mainly reliable in GA aircraft because there are two independent units. Gliders commonly have only one. If it fails, and it is more likely to fail at startup, then the engine dies. Therefore in gliders where we restart in the air we need higher reliability and the manufacturers recommend they are serviced twice as often to compensate.

18.5.3 SOURCES OF DATA

Rotax supplies all manuals and issues ADs through the normal channels.

Unison/Champion, the manufacturer of Slick magnetos and supplier of parts, has a web site to provide all data but you must be a subscriber to get the current manual:

a. http://www.unisonindustries.com/ or

b. https://www.championaerospacepubs.com/default_setup.asp for publications.

The latest manual is CAS5B_L-1363G.pdf (Aug 2018). Champion Aerospace LLC has taken over Slick/ Unison.

It is a confusing task to sort through and comply with all the service bulletins.

You need to do this using:

https://www.championaerospacepubs.com/preLoginView.asp?areaSelect=PreLoginSlick

This lists all bulletins and allows you to get them (without a subscription) to make sure you have the latest copy. There is at least one stating motor gliders as an issue and many suggesting magnetos have historically not been maintained to schedule; thus increasing risk. Many are concerned with high wear of some ignition points.

Bendix magnetos are manufactured and distributed by Teledyne. They seem to be less current than Slick on documentation but similarly an overhaul manual (L-205-10 for the S-20 series magnetos is available on the internet dated August 1975 and appears to be the latest). And Service Bulletins are available on the internet. All this needs to be obtained and studied if you have a Bendix to service. These are rare in gliders and so will not be detailed further but it appears the data is available if required and they are very similar to the more common Slick.

The hardest part about maintaining magnetos is making sure you comply with all the documentation and finding and understanding the subtle differences. So spend the time if you are going to maintain them and make sure you get it right. Get trained and get a rating.

18.6 OVERHAUL OF MAGNETOS

18.6.1 SCHEDULE SLICK 4300 OVERHAUL

Slick 4300 series magnetos used in gliders are usually in a single magneto, non-redundant system. Unison intended certified applications be double magnetos. Therefore for single magneto aircraft they have halved the service interval to 250hrs to compensate for the increased risk. Most gliders will therefore require magneto service at 250hrs even if normally that magneto has a 500hr service interval. This may have been applied after engine or aircraft production and will apply to all Slick magnetos, regardless of what the old manuals say.

Rotax and all other engines will specify the service and overhaul schedules.

A service is essentially a check and lube with setting of point and/ or timing. Whereas an overhaul would be mandatory replacement of parts identified by the manufacturer as having a service life.

Generally, it is accepted that servicing as follows is within our abilities and worth the effort:

a. A 100hr or annual service is little more than a clean and timing check.

b. A 250hr or 500hr service now requires replacement of components previously not required until engine overhaul.

However, an overhaul required at 1000hrs or TBO of the engine is classified as a major overhaul. It requires too many special tools, and it is hard to get the parts. It is considered better to just replace the magneto as they are not that expensive. But you can do this if qualified and have the correct tools and data.

18.6.2 BENDIX OVERHAUL

The overhaul manual mentioned above and available on the internet provides the service requirements and data. The Active Service Bulletin list Form X-09-06 dated 22 Sept 2006 appears to be the latest list of SBs that must be obtained and considered. Be careful and become certain of your interpretation of requirements. It appears wear inspections are required at 100hr engine service, and a more complex inspection at 500hr intervals, refer SB643B and later requirements. Overhaul is required at engine TBO or early overhaul with replacement of listed components. And also at 4/5 year intervals!

18.6.3 OTHER MAGNETOS OVERHAUL

As seen above, Slick and Bendix magnetos wear like the engine and require inspections, setting and overhaul at similar service intervals. Find out what is required for any engine you work on.

18.7 PRE-IGNITION & DETONATION

In normal operation, all internal combustion engines, including those used in motor gliders, produce quite high internal pressures and temperatures. It is important that the engine, its components and systems are so designed that they can safely withstand these loads in order to reliably perform their expected function.

An engine which is performing badly may be exposed to temperatures and pressures far in excess of those for which the engine was designed resulting in reduced performance, destructive damage, or in the worst case, engine failure.

18.7.1 NORMAL COMBUSTION

Normally, the fuel/air mixture in the cylinder is compressed before being ignited by the spark-plug, then burns at a relatively even rate across the combustion chamber and cylinder until all the fuel is burnt. The air/fuel mixture flame propagation rate is quite rapid, from 100 to about 200 feet per second, but it does not simply explode. Explosion propagation rates are measured in thousands of feet per second. As the mixture burns, the pressure in the cylinder (rapidly and) progressively increases as a result of the compression and combustion, to reach a peak (ideally) at around 140^0 After Top Dead Centre (ATDC).

There are a raft of factors which may result in reduced engine performance or efficiency, rough running or difficulty starting, including fuel quality, mixture “tuning” and ignition timing.

Two common forms of abnormal combustion which can cause poor performance, and engine damage, are detonation and pre-ignition.

18.7.2 PRE-IGNITION

Pre-ignition, as the name suggests, occurs when the fuel/air mixture is ignited during the compression stroke before the intended timed ignition provided by the spark-plug.

This can occur quite early in the compression stroke, indeed the nearer to Bottom Dead Centre (BDC) the easier the air/fuel mixture is to ignite. Sources of ignition include glowing carbon deposits in the combustion chamber or on the piston crown, glowing edge of a poorly fitting head gasket, or an overheated head of an exhaust valve but most commonly, overheated spark plug electrodes. It usually occurs in only one or two cylinders of a multi cylinder engine.

Pre-ignition causes severe local overheating as the abnormal combustion disrupts the thin film of residual gases which help shield the cylinder wall and piston crown from the extreme heat. It is this extreme heat that does the damage, typically resulting in eroded combustion chambers and piston crowns, distorted cylinder barrels and piston seizures, even holes melted through the piston crown. Pre-ignition is extremely destructive and does not produce any tell-tale “engine knock” or other audible noise. Severe cases can result in destruction of the engine within a few revolutions, generally accompanied by a lot of whitish exhaust smoke and then, no noise at all!

A more common form of pre-Ignition is known as “Running On” and occurs at engine shut down. With the throttle at idle and the ignition switched off the engine continues to run, generally only on one or two cylinders, and usually only for a few revolutions. Frequently the mixture will ignite early enough in the compression stroke for the piston to be pushed back downwards before reaching TDC, reversing the engine’s direction of rotation, whereupon it will usually come to a halt. This form of pre-ignition, whilst annoying, is not destructive.

Pre-ignition can also occur in a stopped engine, especially if it is hot. Turning the engine by hand with the ignition off can result in a cylinder “firing” unexpectedly, with the consequent serious risk of injury.

DANGER WARNING

Always treat a propeller as LIVE.

Sources & further information:

a. The High Speed Internal Combustion Engine. (Sir Harry Ricardo)

b. Engine Basics, Pre Ignition & Detonation (Allen W Cline)

c. Pre Ignition & Detonation (George Missbach Jr)

18.7.3 DETONATION

Detonation occurs when a small amount of unburnt air/fuel mixture is pushed away from the main flame front and explodes spontaneously. Chemical changes brought about by the increase in heat & compression of the burning air/fuel mixture result in the formation of highly explosive compounds. These can “detonate” causing an extremely powerful pressure wave which penetrates through the rest of the burning mixture resulting in a “hammer blow” shock causing the engine to ring as if hit with a metal hammer and the well-known engine knock or pinging noise. The shockwave can also destroy the laminar film of residual gases on the cylinder wall and piston crown which help shield these components from the normal combustion process. This of course leads to overheating and loss of power. Detonation always occurs on the power stroke after the spark has ignited the charge and after the piston has passed TDC.

In naturally aspirated engines producing one-half horsepower or less per cubic inch, detonation is not normally destructive, and can usually be tolerated for short periods.

High performance engines producing in excess of 1 horsepower per cubic inch and supercharged engines are much more at risk from detonation, and if it is permitted to occur in these engines, even for a short period, it can cause severe overheating, damage to piston ring lands, and can even result in hammered out bearings and bent connecting rods.

Perhaps the most insidious result of prolonged detonation is “detonation induced pre-ignition” (no, this is not doublespeak!). This occurs when the excessive temperature generated by detonation causes something in the combustion chamber/cylinder (usually the spark plug electrodes) to become hot enough to ignite the mixture early on the compression stroke.

18.7.4 CAUSES OF DETONATION

Detonation results from one or a combination of the following factors:

a. “Lugging” the engine, i.e. Wide Open Throttle in coarse pitch at low RPM.

b. Fuel octane rating too low for the engine’s design (compression ratio).

c. Fuel/air mixture too lean.

d. Magneto or spark timing too far advanced.

e. Cylinder and/or cylinder head temperature too high.

f. Boost pressure too high resulting in an abnormally high air/fuel mixture charge.

g. Compression ratio too high due to incorrect overhaul procedures.

h. Video clip: Detonation & Pre-Ignition in aero engines. (3mins 24sec). www.youtube.com/watch?v=ZWKRw0HmBLE

i. Video clip: Difference in sound of Deflagration vs Detonation. (49sec) www.youtube.com/watch?v=D-dLjHJuFWQ

18.8 CONCLUSION

This chapter has not gone into detail regarding every magneto found on motor gliders, there simply are too many different systems to detail here. This chapter has tried to give an overview of magnetos so that you understand what has to be done and you can find the data to service the engine you are dealing with.

Most of the time you don’t have to do much for the magneto, perhaps occasionally clean it, set the points and timing. Check the components for signs of failure and replace them in time. An overhaul will be required probably at TBO or major engine overhaul.

Ignition systems can be confusing and temperamental. They are vital to keep your engine running and to start it. Get experience and knowledge and then a rating. When in doubt, ask someone who knows for help.

19. CARBURETTOR

19.1 INTRODUCTON TO CARBURETTORS

It is necessary to mix the right amount of fuel and air for combustion in the engine. The fuel/air mixture is determined by the engine manufacturer. There are two basic methods used to get the correct amount of fuel and air into the engine – a carburettor or a fuel Injection system.

This chapter will deal with carburettors in detail. While there are very few fuel injection systems used in sailplanes at this time, it will be covered as a separate item.

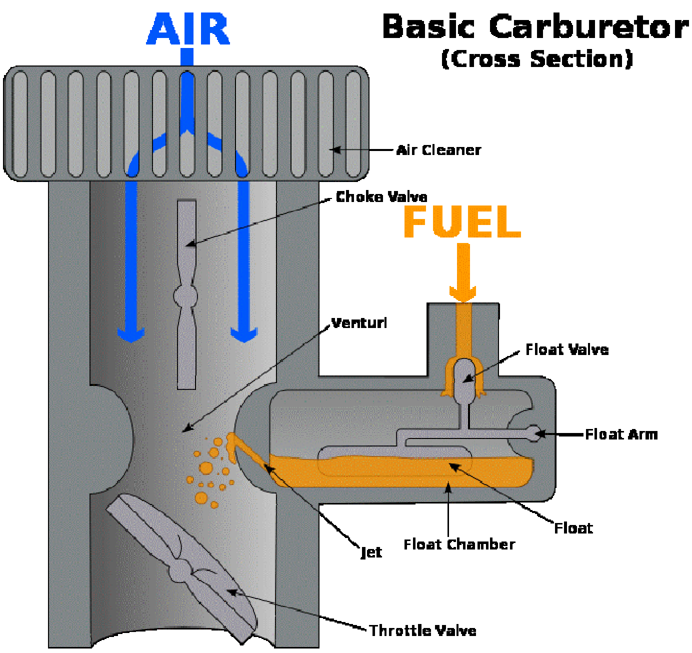
A carburettor basically consists of an open pipe through which the air passes into the inlet manifold of the engine. The pipe is in the form of a venturi: it narrows in section and then widens again, causing the airflow to increase in velocity in the narrowest point.

Below the venturi is a butterfly valve called the throttle valve. It is a pivoted disc that can be turned end-on to the airflow so as to offer minimum restriction to the flow, and at the other extreme it can rotate to almost completely block the flow of air. This valve controls the flow of air through the carburettor throat and thus the quantity of air/fuel mixture the system will deliver, thereby regulating engine power and speed. The throttle is connected, usually through a cable or a mechanical linkage of rods and joints, to the throttle lever/plunger in the cockpit.

Fuel is introduced into the air stream through small holes at the narrowest part of the venturi and at other places where pressure will be lowered when not running on full throttle. Fuel flow is adjusted by means of precisely calibrated orifices, referred to as jets, in the fuel path and may include an adjusting needle to set idle mixture. This is the idle circuit.

As the throttle is progressively opened, the manifold vacuum is lessened since there is less restriction on the airflow, reducing the flow through the idle and off-idle circuits. This is where the venturi shape of the carburettor throat comes into play, due to Bernoulli's principle (i.e., as the velocity increases, pressure falls). The venturi raises the air velocity, and this high speed and thus low pressure flow, sucks fuel into the airstream through a nozzle or nozzles located in the centre of the venturi.

As the throttle is closed, the airflow through the venturi drops until the lowered pressure is insufficient to maintain this fuel flow, and the idle circuit takes over again, as described above.

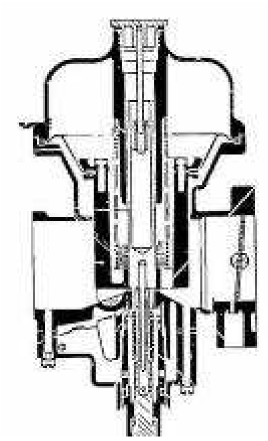


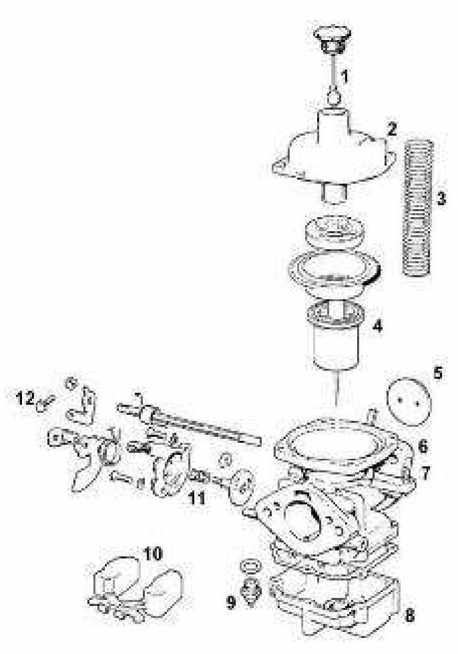
For cold starting, the carburettor is fitted with a device to enrich the fuel mixture. There are two main methods used to achieve this:

a. Fitting a butterfly valve or similar restricting device at the inlet to the carburettor. This is called a choke and it works by restricting the amount of air available to the carburettor, thus increasing the depression in the venturi causing additional fuel to be drawn through the main jets.

b. Fitting a fuel enrichment valve to the carburettor body. When operated this device opens a port between the fuel bowl and venturi allowing additional fuel to be drawn into the venturi. Unlike the choke butterfly, the fuel enrichment valve does not restrict the amount of air available to the carburettor during its operation.

In touring motor gliders with 4-stroke engines such as Sauer, Limbach, Stark Stamo and Rotax, constant depression type carburettors are normally used. The main manufacturers are; Bing Stromberg and Solex.





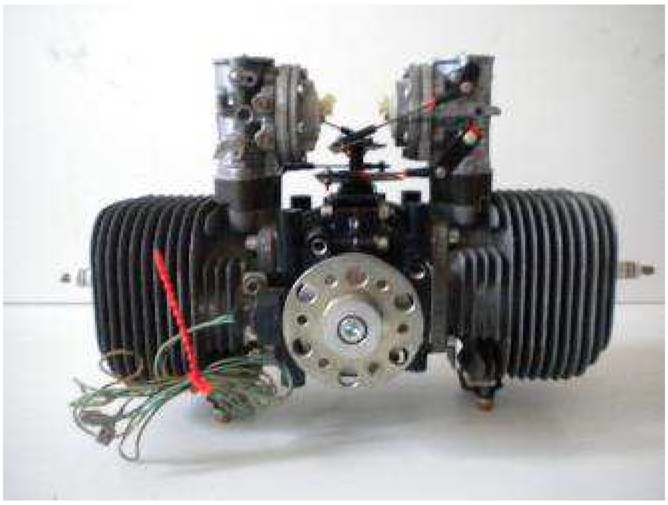
These carburettors don't perform well at extreme angles as they use the standard fuel bowl with needle and seat arrangement. Fortunately, touring motor gliders do not normally operate at extreme attitudes & provided banked turns are flown with minimum slip & skid the fuel level in the carburettor will not be adversely affected. A major advantage of the constant depression carburettor design is that it is altitude compensating.

The butterfly valve is positioned between the intake manifold and the jet/air valve piston. As the butterfly valve is opened, the piston is exposed to low manifold pressure on the butterfly side. There is a transfer port at the bottom of the piston on this side and this exposes the diaphragm to the manifold pressure on the top side resulting in the piston being lifted against the spring pressure until pressure equilibrium occurs. The lower side of the diaphragm is vented to the intake side and thus atmospheric pressure. As altitude increases and atmospheric pressure drops so does the pressure on the lower side of the diaphragm, thus drawing it back down to a lower equilibrium position to lean the mixture via the tapered needle on the bottom of the piston which slides in the jet to vary the jet size, and thus mixture.

The conventional choke by butterfly will not work on this style so a bypass valve is used instead. This valve opens a Jet on the manifold side of the piston to the fuel bowl allowing extra fuel to enter.

2-stroke engines & some rotary engines in motor gliders commonly use a diaphragm carburettor. This type of carburettor differs from those previously described in that it has no fuel bowl and incorporates an internal fuel pump. This carburettor will work at any attitude, including upside down, because of these features.

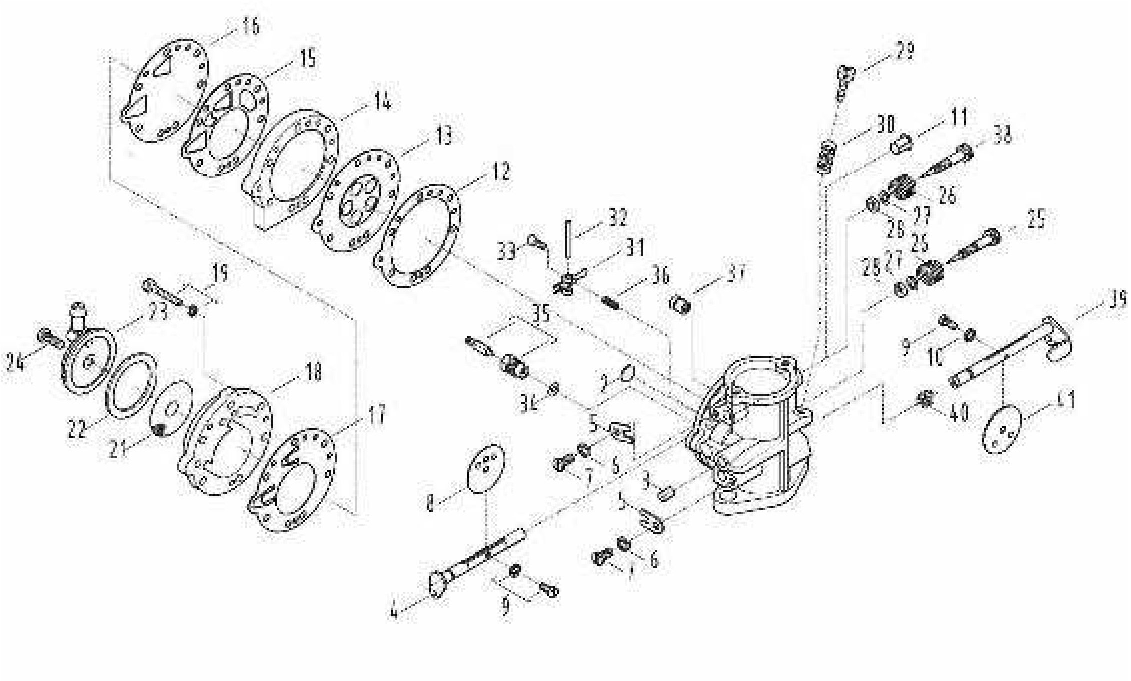
The Integral fuel pump is shown here on the side of the carburettors with the white covers facing each other.



The diaphragm pump operates by crankcase pressure. There are 2 diaphragms with one operating as the pump and the other operating a needle valve in a seat to allow flow of fuel to the jets from the intermediate chamber during intake.

The pump diaphragm (17) as mentioned is driven by crankcase pressure. Thus when the piston is on the down stroke and crankcase compression occurs it drives the Diaphragm to pump fuel into the chamber (14). When the piston travels up on the compression stroke the crankcase pressure drops for intake and the diaphragm relaxes allowing intake of fuel through the check valve.

The other diaphragm (16) drives a needle into a seat (35) so when crankcase compression occurs it closes the valve as the pump diaphragm fills the chamber. In the compression stroke when the crankcase pressure drops for induction the diaphragm relaxes so the needle lifts off the seat allowing the fuel to flow to the jet where the venturi effect does the rest.



This carburettor design is commonly seen on small plant such as chain saws and whipper snippers.

The engine manufacturer does a lot of testing on a flow bench and dynometer to make sure the selected carburettor is fitted with the appropriate needles and jets to suit the engine type.

A lean mixture results in a high CHT. Excessively lean results in burnt exhaust valves and damage to pistons. In extreme cases, in a 2-stroke engine it will burn a hole in the piston and in a 4-stroke engine also damage pistons. A rich mixture will result in colder CHT to an extent. However too rich mixture results in fouled plugs and reduced performance as well as poor economy. The manufacturer via its manual provides the details to get the best from your engine and an engineer who strays from those guidelines does so at their own peril.

19.2 CARBURETTOR ICING

Carburettor icing does not only occur when the weather is cold, it is possible for it to occur in summer, when you least expect it. There are two forms of carburettor icing; impact icing and induction icing.

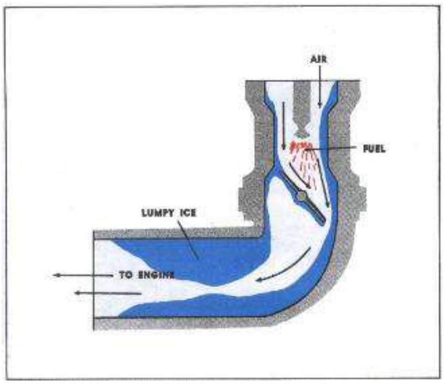
Impact icing results when an airframe is at or below freezing temperature and is impacted by airborne moisture resulting in a build-up of ice. This ice may build-up in the engine induction system (ie air inlet, air filter), restricting airflow causing a power loss. This is seldom experienced on a glider, mainly because we tend to fly away from rain.

Induction or ‘venturi’ icing restricts the flow of air into the carburettor. The venturi (or throat narrowing) in a carburettor causes the air velocity to speed up and reduce the static pressure, which causes fuel to be drawn into the airstream. The reduction in pressure also results in a reduction in the temperature of the stream. The temperature reduction is increased due to the effect of vapourising (or evaporating) the fuel drawn into the airstream. If the conditions are right (Relative Humidity, Air Temperature [0 – 15C], Dewpoint [within 10^{0}C of dewpoint] and Air Pressure) ice will form in the induction system and result in a progressive loss of power when ambient air temperature is well above freezing. It must be noted that the water vapour is carried by the induction air and not by the fuel.

The fuel quality may also influence induction icing, fuels with a higher proportion of ‘light ends’ or a higher latent heat of vaporisation (alcohol fuels) will tend to increase induction icing. In short, Mogas is generally more susceptible to induction icing than Avgas.

Induction icing is less likely to occur at full throttle but is more likely to occur when the venturi butterfly valve is only partially open, resulting in a greater differential pressure. There are no additives that can be added to fuel to eliminate carburettor Icing.

How do you identify Induction icing? Induction icing will result in a progressive decline in engine power output. This will be seen a reduction in RPM. Pilots should not simply increase power in an attempt to restore the power output – they should think about induction icing. Opening the throttle on an icing-up system may ultimately result in a significant power loss. If the engine is fitted with carburettor heat, apply it early and remember it takes time to melt the ice.



Induction icing is less of a problem with fuel injected systems.

19.3 THROTTLE LINKAGE FAILURE.

In the event of a throttle linkage failure (this should not occur if the engine DI is undertaken thoroughly), most motor glider carburettor systems have a spring on the throttle butterfly spindle to drive the butterfly wide open (ie to the full power position). This is a 'fail-safe' arrangement to avoid a total loss of power in the event of the throttle-linkage failure.

20. ELECTRICAL SYSTEMS

20.1 ELECTRICAL SYSTEMS INTRODUCTION

A motor glider often presents the opportunity to power an on-board electrical system by running an alternator or generator capable of directly powering various devices and to maintain a charge in the battery.

Powered systems not seen on a normal glider include lighting (navigation lights, strobes etc) and transponders.

It is important that the on-board electrical system devices, wiring and protection systems be maintained to a high standard.

20.2 ELECTRICAL CONCEPTS

The first thing to be aware of is the distinction between AC (alternating current) and DC (direct current).

When assessing electrical systems, it is helpful to have a basic understanding of the concepts involved.

Term	Definition
Voltage	Provides the electrical pressure that drives the flow of current around the circuit, and is measured in either volts AC or volts DC as appropriate.
Current	Describes the rate of flow of electricity in a circuit and is measured in amperes. Current that flows continually in one direction is Direct Current or DC. Current which changes direction is known as Alternating Current or AC.
Resistance	Is the degree to which materials allow or resist the flow of electrical current. Materials such as rubber and plastic have a very high resistance and are hence used as insulators. Most metals have low resistance, and copper is the most widely used material for electrical conductors. Resistance is measured in ohms.
Power	Is a measure of the rate at which electricity is supplied. Power is expressed as watts and is calculated as voltage multiplied by current. For example, 2 amps at 12 volts is 24 watts.
Energy	Is a measure, of how much electricity is supplied or consumed and it is calculated as watts multiplied by time. If 12 watts flows for one hour 12 watt hours have been consumed. If 1000 watts flows for one hour, that is one kilowatt-hour.

AC current changes direction or ‘alternates’. The rate at which it does this is known as the frequency. Where the AC is generated by a rotating machine, the AC frequency is related to the rotational speed of the alternator. In Australia, mains grid supplied electricity is 240V AC at 50 Hertz (Hz), that is, 50 cycles per second.

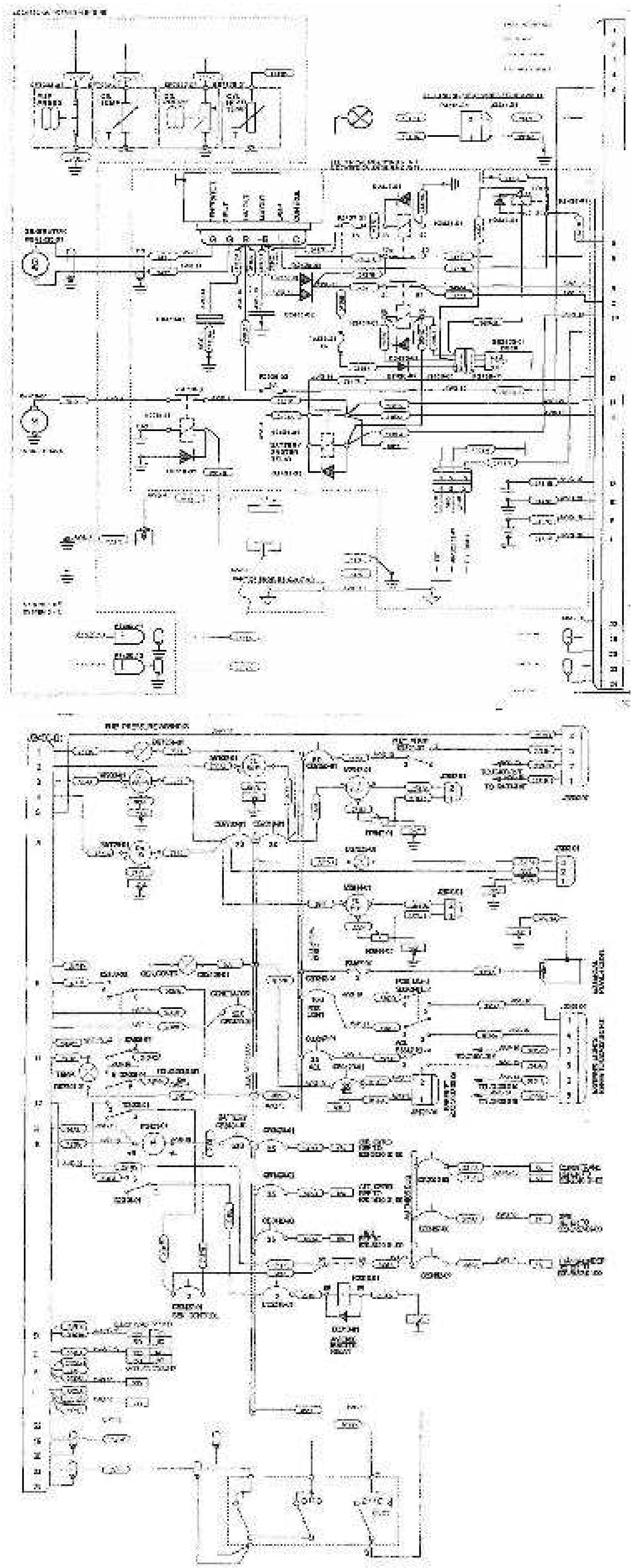
Most voltages in a motor glider will be DC that is supplied by the battery or has been rectified (ie converted) from AC supplied by the alternator to charge the battery.

AC voltages are grouped into low frequency (LF) and high frequency (HF). LF is in the range hearable frequencies 10 to 10,000 Hz. LF can be measured with the multi-meter. This might be the AC supplied from the alternator (if the diodes are not inside the alternator), loudspeaker signals, charging coils for the ignition system (CDI capacitor discharge ignition on 2-strokes Rotax and Solo)

HF is above LF, but usually above 1 MHz. HF is used in the radio, transponders, FLARM and ELTs. HF is hard to measure with a simple multi-meter and usually diagnosing and resolving HF problems is reserved for experts.

20.3 SYSTEM DRAWINGS

A schematic drawing is often provided of the electrical system installed in the motor glider. The drawing identifies the electrical system components, including generator/alternator, battery, protection system and wire size (gauge). Two examples follow:



20.4 CONTROL SYSTEMS

Electric systems are sometimes categorised as power system and control systems. Control systems use electrical inputs to determine outputs. For example, the engine controller for a ILEC Nimbus 4DM self-launch glider requires the following affirmative signals for the engine to start:

a. Mast in end position

b. Fuel valve open

c. Propeller arrest disengaged

d. Ignition on

The inputs may be derived from switches or other sensors such as temperature, proximity (eg magnetic sensing relays).

20.5 ELECTRICAL WIRING

It is recommended that all wiring in any glider use Tefzel aircraft grade electrical wire of a gauge appropriate to the planned system load. Tefzel wire is insulated with an insulation material which does not produce poisonous smoke in the event of electrical system overload or fire.

Electrical wiring in a motor glider is subject to “stresses” not experienced in a standard glider. The additional stresses are the result of vibration (caused by the engine) or chafing, where the wiring passes through the firewall or bulkheads etc or around short radius bends.

In a motor glider, the wiring must be suitably supported and restrained, with adequate protections (grommets, etc) where the wiring passes through the firewall etc.

20.6 SYSTEM PROTECTION

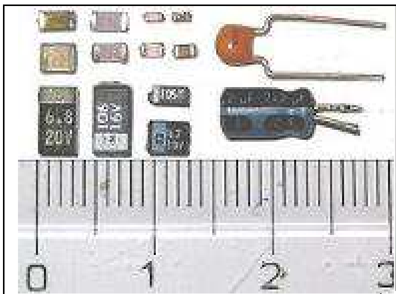
The electrical system must be protected by devices such as fuses or circuit breakers. These are carefully rated at a capacity that will prevent overloading of the equipment and wiring, such as may occur in a short-circuit situation.

Particular attention is directed at the alternator or generator, where, in the event of a fire, these may continue to provide electric current while the engine is running.

20.7 ELECTRICAL COMPONENTS

20.7.1 CAPACITOR

A capacitor is a passive two-terminal electrical component used to store energy in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric (insulator); for example, one common construction consists of metal foils separated by a thin layer of insulating film. Capacitors are widely used as parts of electrical circuits in many common electrical devices.

		
Miniature low-voltage capacitors	Electrolytic capacitors of different voltages and capacitance	Typical solid-body, resin-dipped Tantalum capacitors

Polyester film capacitors are frequently used as coupling capacitors.

High-energy capacitor


Catastrophic failure of a capacitor

Figure 20-1 Capacitors

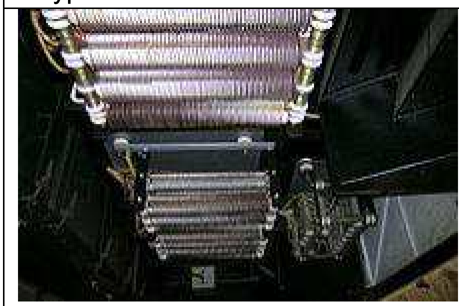
20.7.2 RESISTOR

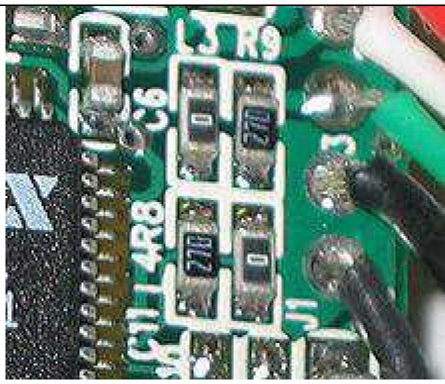
A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. The level of resistance and its tolerance (how close to the nominated value of resistance) are indicated by the colour bands. It is also important to consider the current carrying capability of the resistor – current in excess of a resistors capacity will cause it to "blow" like a fuse. Blown resistors can sometimes, but not always, be identified visually as they look burnt.

A variable resistor is adjustable across a resistance range. It comprises an arc or length of resistive material or wound wire with terminals at each end and a moveable wiper with a 3rd terminal. As the wiper is moved across the body of the device, the resistance increases between the wiper terminal and one end terminal and decreases between the wiper and the other end also. This is also known as a potentiometer, rheostat or trimpot.


A typical axial-lead resistor


Partially exposed Tesla TR-212 1 kΩ carbon film resistor


High-power wire wound resistors

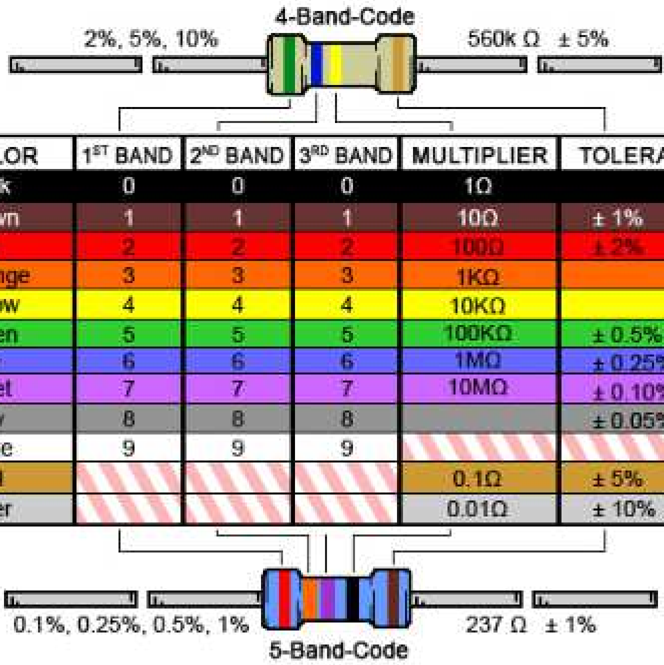

Surface-mount resistors

Typical single-turn potentiometer

PCB mount trimmer potentiometers, or "trimpots"

Figure 20-2 Resitors

Decoding resistor markings

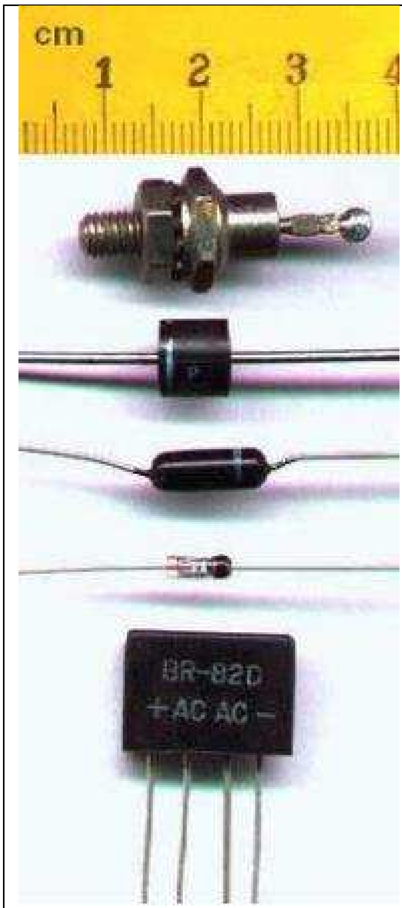


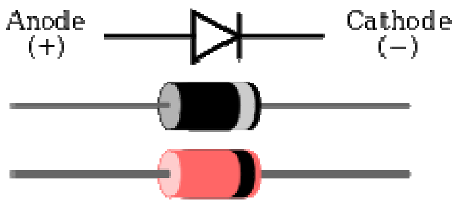
COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

Figure 20-3 Resistor Colour Chart

20.7.3 DIODE

In electronics, a diode is a two-terminal electronic component with an asymmetric transfer characteristic, with low (ideally zero) resistance to current flow in one direction, and high (ideally infinite) resistance in the other.





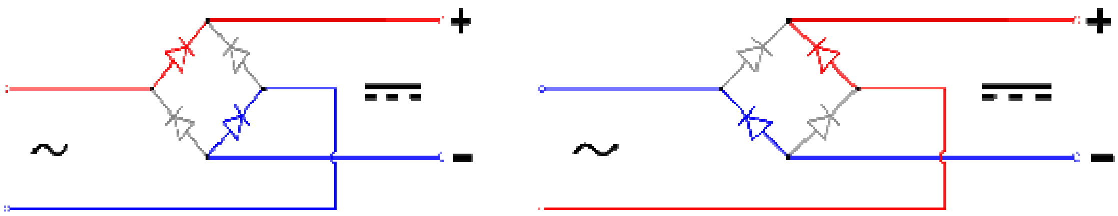
Typical diode packages in same alignment as diode symbol. The thin bar depicts the cathode.

Figure 20-4 Diodes

20.7.4 DIODE BRIDGE RECTIFER

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an Alternating Current (AC) input into a Direct Current (DC) output, it is known as a bridge rectifier.

A single-phase diode bridge rectifier consists of four diodes which provide a one-way path for the current depending on which half of the AC input cycle.

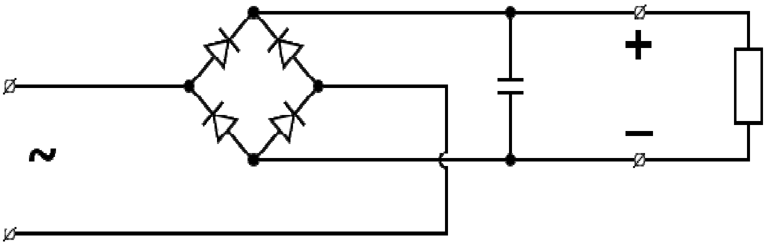


First half of AC cycle

Second half of AC cycle

Figure 20-5 Bridge Rectifier

For many applications, a capacitor is added to smooth the output which otherwise would be a pulsed DC.



20.7.5 INDUCTORS

An inductor (also known as a choke, coil, or reactor) is a passive two-terminal electrical component that stores energy in its magnetic field. For comparison, a capacitor stores energy in an electric field, and a resistor does not store energy but rather dissipates energy as heat.

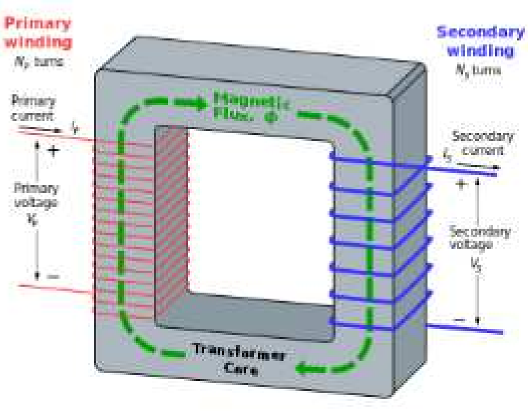
American-style symbol

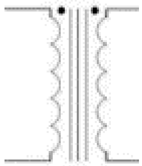
IEC-style inductor

Figure 20-6 Inductors

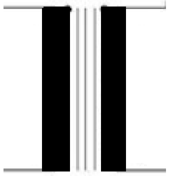
20.7.6 TRANSFORMER

A transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding. This varying magnetic flux induces a varying Electro-Motive Force (EMF) or voltage in the secondary winding.





American-style symbol

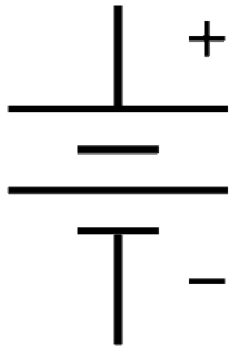


IEC-style inductor

Figure 20-7 Transformer

20.7.7 BATTERY

There are two types of batteries: primary batteries (disposable batteries), which are designed to be used once and discarded, and secondary batteries (rechargeable batteries), which are designed to be recharged and used multiple times. Batteries come in many sizes, from miniature cells used to power hearing aids and wristwatches to battery banks the size of rooms that provide standby power for telephone exchanges and computer data centres.



Symbol

Leaking battery

Figure 20-8 Batteries

20.7.8 RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

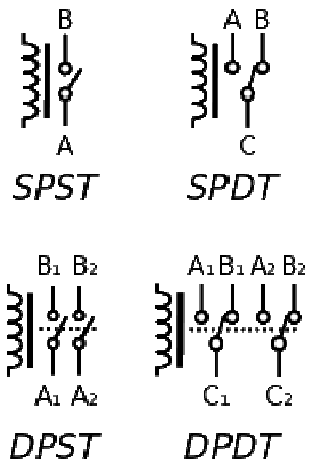
In the examples below:

SPST = Single Pole Single Throw (switches one input on/off)

SPDT = Single Pole Double Throw (switches one input C between two outputs A or B)

DPST – Double Pole Single Throw

DPDT = Double Pole Double Throw



Symbols

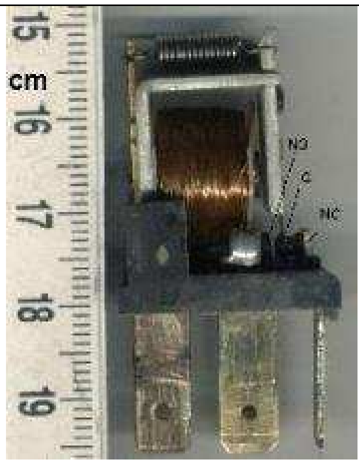


Figure 20-9 Relays

20.7.9 TRANSISTOR

A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal.

Figure 20-10 Transistor

20.8 FAULT FINDING

Most electrical problems in motor gliders, especially self-launchers, are caused by vibration. 30mm of heat-shrink, a zip-tie, a drop of silicone or spiral hose might solve the problem.

Fault finding electrical circuits can be very frustrating! It takes patience, persistence and logical thinking. The basic tools are a multi-meter (often just used as a continuity tester) and the system schematic.

When a schematic is not available, as when additional equipment has been added but not documented, then tracing wires and constructing your own schematic may be necessary.

The following steps should help to solve problem, such as the engine will not start:

ELECTRICAL FAULT-FINDING PROCESS
STEP 1: ASSESS THE SITUATION Familiarise yourself with the operational surroundings. What happened to cause the fault? Talk to the pilot! The operator can tell you exactly what happened when the engine stopped, explain to you how the engine works if you are not familiar with it and maybe also tell you what normally goes wrong. These guys are your best friends at a breakdown! They can point you to the spot that was worked on the last time.
STEP 2: WHAT HAPPENED TO CAUSE THE FAULT? Check for any visible damage to the glider. This sort of damage may have caused a limit switch to shift etc. If you have a fault indication, you are almost there. Check each limit-switch for operation and repair the faulty unit. If you have found the problem and repaired it and move to step 5. If not, continue on to step 3 of fault finding
STEP 3: FAULT TRACING Understand the system, what's supposed to do. Study the schematic and system logic diagram if available. Consider is there a sequence for starting of equipment i.e. is there a specific oil pressure level that needs to be reached before the engine can be started. Are there any other interlocks on the engine etc? Understand the logic! Check all signals that are required for usual operation. The voltage should be measured at the controller. Depending on the logic you will measure either virtually 0V or a voltage close to the battery voltage. An end-switch that switches to

ground (negative or inverted logic) will indicate 0V if activated and a voltage close to 12 if deactivated. Always check the actuator activated and deactivated.

If you don't get a change it can have various reasons. The lead from the switch to the controller can be broken or have a short circuit. The switch can be defect. The switch can be misplaced. The actuator for the switch can be missing, misplaced or too weak (e.g. a magnet for a reed contact).

Keep on working your way through the circuit until you find the fault. Even when you think you have found a fault it is advisable to continue through to the end of the circuit as there may be more than one fault.

This method of fault finding works well even if you do not have a circuit diagram. What you need to do is physically trace the wire from one connection to the next.

Assuming you have now found the fault, proceed to next step, else keep looking for the fault!

STEP 4: FIX

Repair the fault.

STEP 5: TEST & RESTORE NORMAILITY

Close all covers you may have removed. Tidy up your work area. Get all your tools back into your tool box. Inform the operator you are going to test the engine. Ensure it is safe to do so. Get the operator to start the engine and check it is operating correctly

STEP 6: LONG TERM FIX

Analyse the cause of the breakdown to see if there is any way that it can be prevented in future. It is not enough to merely find the fault, fix it and then walk away from the glider only to have the same fault again. If an improvement wouldn't mean a design change then go for it. If you feel that others will be affected by the same problem and that it is a design problem then inform the CTO and the manufacturer about the problem. If a design change is necessary they might come with a solution.

20.9 USEFUL LINKS

FAA AC.43-13-1B Chapter 11

http://www.faa.gov/documentLibrary/media/Advisory_Circular/Chapter_11.pdf

AIRCRAFT WIRING AND BONDING AC021c99

http://www.casa.gov.au/wcmswr/_assets/main/rules/1998casr/021/021c99.pdf

MIRCROAIR - Typical Aircraft Electrical Systems

http://www.microair.com.au/admin/uploads/Typicalaircraftelectricalsystems.pdf

Top 10 Aircraft Wiring Mistakes

http://www.verticalpower.com/docs/Top_10_Wiring_Mistakes.pdf

21. ALTERNATORS

The alternator generates alternating current which is converted to direct current by a rectifier for recharging the battery and powering electrical loads while the engine is in use.

Figure 21-1 Limbach L2000EB1A Alternator

The alternator consists of a spinning set of electrical windings called a rotor, a stationary set of windings called a stator, a rectifier assembly, a set of brushes to maintain electrical contact with the rotor, and a pulley. All of these parts except the pulley are contained in aluminium housing. Alternators may use compact, electronic voltage regulators housed inside the alternator or the voltage regulator may be fitted to the firewall as is typical of the Grob and Falke aircraft.

The housing is usually made up of two pieces of die-cast aluminium. Aluminium is used because it is a nonmagnetic, lightweight material that provides good heat dissipation. Bearings supporting the rotor assembly are mounted in the front and rear housing. The front bearing is usually pressed into the front housing or onto the rotor shaft. It is usually a factory-lubricated ball bearing. The rear bearing is usually installed with a light press fit in the rear housing.

Stator Assembly. The stator is clamped between the front and the rear housing. A number of steel stampings are riveted together to form its frame. Three windings around the stator frame are arranged in layers in each of the slots on the frame. At the other end, they are connected into the rectification assembly.

Rotor Assembly. The rotor assembly consists of a rotor shaft, a winding around an iron core, two pole pieces, and slip rings. The rotor is pressed into the core. Six-fingered, malleable, iron pole pieces are pressed onto the shaft against each end of the winding core. They are placed so that the fingers mesh but do not touch. When direct current is passed through the field coil winding, the fingers become alternately north and south poles. A slip ring assembly is pressed on to the rear end of the rotor shaft and connected to the two ends of the field winding.

Two brushes are held against the slip rings by springs, usually mounted in plastic brush holders that support the brushes and prevent brush sticking.

The brushes ride on the slip rings and are connected through a switch to the battery. Generally in a motor glider the switch is either the master battery switch or a relay. When the switch is closed, current from the battery passes through the brushes and the slip ring to the field winding. The flow of electrical energy through the field winding, called field current, creates the magnetic field for the rotor.

Leaving the master on leaves the field active and thus drawing current resulting in a flat battery at DI the next day.

Current is generated in the stator coils which are connected to the rectifier.

Rectifier Assembly. The rectifier assembly consists of diodes mounted either in the rear housing or in a separate small housing called a rectifier bridge.

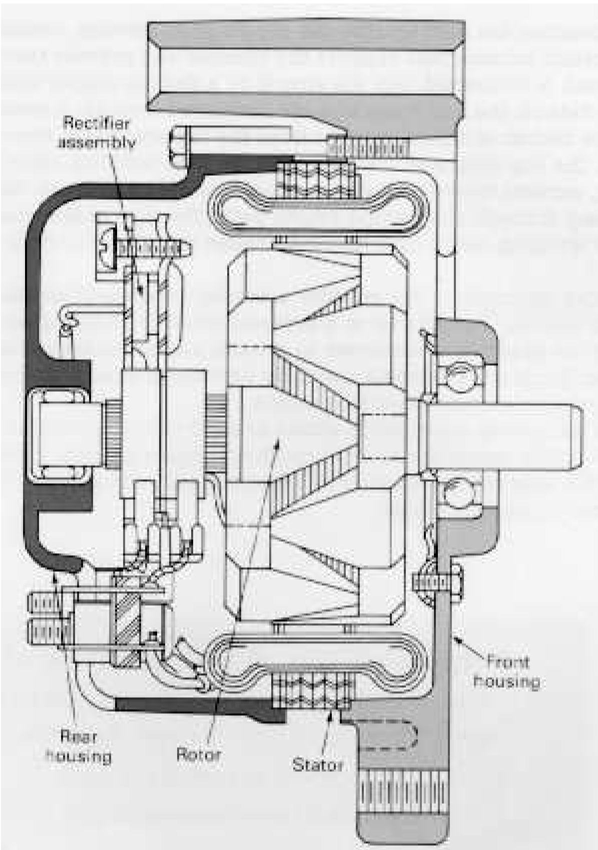
Figure 21-2 L2000EB1A alternator with rectifier diodes showing

In the image above the diodes have been cooked due to an electrical fault. The Stator windings went to ground and thus were also destroyed by heat.

A fan and pulley assembly is either pressed onto the rotor shaft or held with a nut. The pulley drives the rotor through an engine accessory drive belt. The fan behind the alternator pulley pulls air in through vents at the rear of the alternator to cool the diodes and windings.

The Time Between Overhaul (TBO) of the alternator is generally, if in reasonable condition requires new brushes and bearings and re machining of the slip rings. The slip rings must run true and have clean surfaces for longevity of the brushes and sound conductance.

The TBO is assumed the same as the engine TBO unless otherwise specified in the engine or aircraft manual.



22. STARTER MOTORS

22.1 STARTER MOTOR INTRODUCTION

The starter motor is an electric motor with a solenoid switch. The switch is similar to a relay and may be bolted to the side of the starter motor or, in the case of aircraft like the Falke and Sperber, it is bolted to the firewall.

When low-current power from the battery is applied, usually by pressing the starter button, the solenoid closes high-current contacts for the starter motor power. In the case of a solenoid fitted to the starter, it also drives the pinion gear to engage with the ring gear.

In the case of a solenoid fitted to the firewall, the pinion is driven out by acceleration due to the drive shaft and gear connection being a helix.

Figure 22-1 Limbach L2000EB1 Starter Motor with Solenoid attached

A direct-current (DC) motor is a device for converting DC electrical energy to rotating mechanical energy.

All starter motors have several basic common characteristics. These include:

a. The frame and its stationary components

b. The fixed magnetic field.

c. An armature - which is the rotating shaft and its associated parts (many coils of wire are wound on a cylindrical shaft);

d. Auxiliary equipment such as a brush/commutator assembly

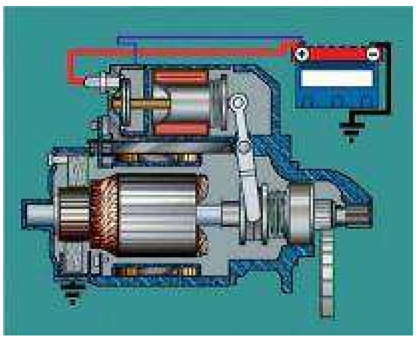
e. A solenoid switch assembly.

The typical amount of current required to ‘crank’ a Limbach engine is approx. 80 – 100 amps. Current requirements differ between engines due to capacity and type (4- or 2-stroke and rotary) and engine condition.

22.2 ELECTRIC MOTOR PRINCIPLE

When electric current flows in a conductor it gives rise to a magnetic field. This current carrying conductor experiences a force which makes it move when it is placed between the poles of a powerful magnet.

The conductor moves because the magnetic field of the permanent magnet reacts with the magnetic field produced by the current in the conductor.



22.3 COMMUTATION

When current flows in a conductor, an electromagnetic field is generated around it. If the conductor is placed so that it cuts across a stationary magnetic field, the conductor will be forced out of the stationary field. This happens because the lines of force of the stationary field are distorted by the electro-magnetic field around the conductor and try to return to a straight-line condition to each other.

A conductor loop which can freely rotate within the magnetic field is the most efficient design. In this position, when current flows through the loop the stationary magnetic field is distorted and the lines of force try to straighten. This forces one side of the loop up and the other side of the loop down. The motor effect causes the loop to rotate until it is at ninety degrees to the magnetic field. To continue rotation, the direction of current flow in the conductor must be reversed at this static neutral point. A commutator is used for this purpose.

An example commutator consists of two semi-circular segments which are connected to the two ends of the loop and are insulated from each other. Carbon impregnated brushes provide a sliding connection to the commutator to complete the circuit and allow current to flow through the loop. Rotation commences with both sides of the conductor loop cutting the stationary field. When the loop passes the point where the field is no longer being cut, the momentum of rotation carries the loop and the commutator segments over so that the brushes maintain current flow in the same direction in each side of the loop relative to the stationary field.

A starter motor armature has a large number of conductor loops and so has many segments on the commutator.

22.4 STARTER MOTOR CONSTRUCTION

A basic starter motor consists of:

a. Field coils

b. Armature

c. Commutator

d. Brushes

e. A drive pinion with an over-running clutch

f. A drive pinion engagement solenoid and shift fork

The armature is the revolving component of the direct current motor (shown on the right in the above picture).

The armature shaft is supported at each end by bushes pressed into end frames which locate the armature centrally in the outer casing or yoke of the motor.

The commutator serves as a sliding electrical connection between the motor windings and the brushes and is mounted on one end of the armature shaft. The commutator has many segments that are insulated from each other. As the windings rotate away from the pole shoe (piece), the commutator segments change the electrical connection between the brushes and the windings.

This action reverses the magnetic field around the windings. The constant changing electrical connection at the windings keeps the motor spinning.

The commutator end frame carries the copper-impregnated carbon brushes which conduct current through the armature when it is being rotated in operation. The brushes are mounted in brush holders and are kept in contact with the commutator by tensioned spiral springs.

Half of the brushes are connected directly to the end-frame and via the ground return of the engine frame to the battery negative terminal. The other half are insulated from the end-frame and are connected to the positive battery terminal via the main starter solenoid input terminal.

Time between overhaul (TBO) of the starter motor generally if in reasonable condition requires new brushes and bearings and re machining of the commutator. The commutator must run true and have clean surfaces for longevity of the brushes and sound conductance.

The TBO is assumed the same as the engine TBO unless otherwise specified in the engine or Aircraft Manual.

23. MOTOR GLIDER BATTERIES

There is a wide range of batteries currently used in the Australian glider fleet. These are required to power instrument and avionics systems, and in the motor glider, the engine systems which include starting, extend and retract systems and instrumentation.

A significant advantage of touring motor glider electrical systems is the ability to recharge or maintain battery capacity with an alternator or generator, driven when the engine is operating. Self-launching gliders commonly require external battery charging.

Battery type ‘preference’ would appear to be a function of individual or club experience – hence the wide variety of battery types, sizes and electrical systems. Battery technology is one which in recent times is constantly, and rapidly, improving. - if you have the best technology today, it is likely to be outdated tomorrow.

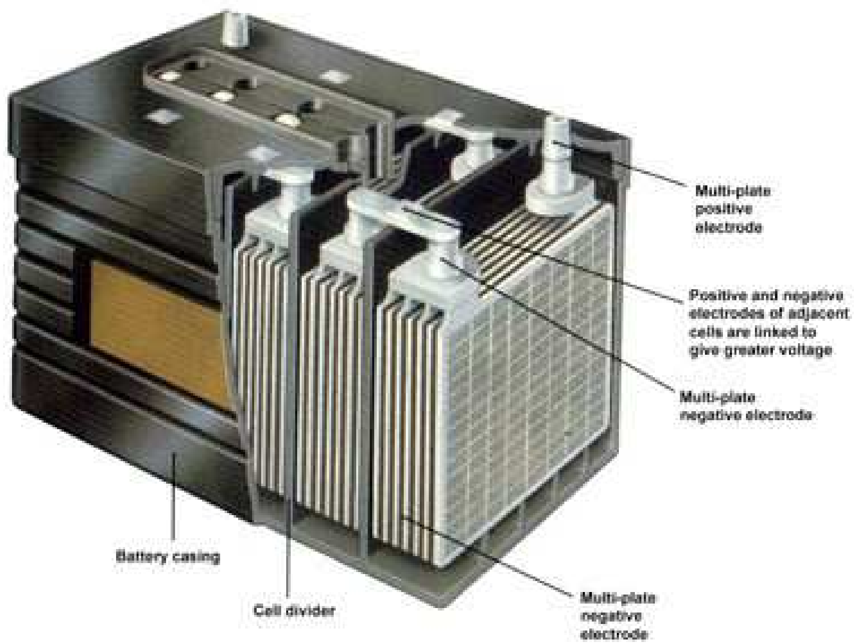
At the same time that battery technology is being enhanced, the power consumption requirements of the individual systems and equipment we seek to drive is reducing due to more efficient devices. This is contributing to longer run-times and apparent improvement in battery performance. Transponders are a good example; once there was no way a transponder could be powered for any reasonable time, now they easily last even for the longest flights.

As battery users, we continually seek a battery that has an in-exhaustible supply of energy, in a small, cheap, safe, portable and clean package.

23.1 BATTERY TERMINOLOGY

There are many terms used to describe the various attributes of batteries. The following is a brief summary of these:

Type	Details	Application
Primary Batteries	Non-rechargeable	Watches, electronic keys, remote controls, toys.
Secondary Batteries	Rechargeables	Toys
Specific Energy	Capacity (Wh/kg)	
Specific Power	Power delivery (W/kg).	
Cycle-life	Number of recharge cycles.	



23.1.1 FACTORS CONSIDERED IN BATTERY MANUFACTURE

Specific Energy	Size
Load capability	Durability
Service life	Manufacturing cost
Shelf life	Price
Safety	Re-charge cycles.

23.1.2 BATTERY TYPES

Battery technology continues to advance – at an ever increasing rate.

There are now many battery types, models and manufacturers in use in the national glider fleet, including:

a. Lead based variants – require recharging to replace lost power, disposal issues with lead.

    i. Sealed Lead-Acid. (Odyssey, Panasonic, etc)

    ii. Lead-Acid (Odyssey, etc).

b. Nickel variants - require recharging to replace lost power.

    i. Nickel-Cadmium - Environmental issues with disposal, Memory effect,

    ii. Nickel-Metal Hydride – Environmentally acceptable disposal in landfill,

c. Lithium variants – require specific recharging systems to replace lost power, Environmentally acceptable disposal in landfill, more costly and safety issues, which include poor thermal stability when fully charged and prone to thermal run-away. Cold temperatures reduce battery performance while elevated storage / idle time temperatures shorten service life.

    i. Lithium-Cobalt - Thermal run-away issues.

    ii. Lithium Ion –

        1. Generally lower specific energy,

        2. Higher price

        3. Requires an approved protection circuit,

        4. Thermal run-away issues.

    iii. Lithium Metal Hydride

    iv. Lithium Iron Phosphate (LiFePO4) – found to be the best general use battery, with a high current rating, a (relatively) long cycle life with good thermal stability and enhanced safety features and a good tolerance to abuse.

23.2 BATTERY SAFETY

One of the greatest single potential for serious problem to a pilot is the battery. These are generally located in a position where the pilot is unable to readily access them during flight. The pilot must depend on the master switch or the battery protection system in the event of a fault developing.

Problems may arise due to overload of a circuit or wiring caused by a short circuit or damage (abrasion, rodent attack etc).

To protect the glider, its crew and systems, a fuse or circuit breaker, located as close to the terminals of the battery as possible is required. The battery terminals must be well insulated, so that any shorting at the terminal cannot occur (at least easily).

There is a serious risk of personal injury when changing a battery. While unpowered gliders generally use low capacity batteries motor gliders use larger units to supply substantial current for engine starting. While the voltage is considered as low, the available cranking amps is high. Thus, for safety, care must be taken not to short the terminals during change out. Watches are known hazard as are spanners. The heat generated through a short with a steel watch band will quickly cause a serious burn. Care in the use of spanners etc is needed and always remove the earth before the positive and vice versa on reinstalling to reduce the risk.

Much has been said/written about battery technology. In recent times, major problems have been experienced with Lithium-ion batteries, which have suffered internal shorting during recharging resulting in thermal run-away.

The GFA have developed a Technical Airworthiness Revision - MTAR 1/2017 - which addresses approved battery types, their installation, operation, protection systems, etc.

23.3 BATTERY MAINTENANCE

The modern Sealed Lead-Acid (SLA) battery, and other batteries used in the glider fleet, require little maintenance other than regular recharging.

23.3.1 RECHARGING

Battery performance and service life may be severely affected if incorrectly recharged. A single battery charger is unlikely to be able to service all the various battery chemistries. An ideal Lithium Ion battery charger is unlikely to provide a satisfactory recharge of a SLA battery or vice versa.

Each discharge/recharge cycle wears the battery down a bit. Heat is a major enemy of most batteries.

Issues include;

a. Incorrect charging

   i. voltage, too low or too high

   ii. charge rate, too low or too high.

   iii. 'Float' charge too high or too low.

   iv. incorrect charge program for the battery (need to consider flooded, Gel, AGM batteries)

b. Batteries stored not fully charged.

c. Memory effect

It is important to closely follow the battery manufacturer's recommendations for battery maintenance, including the battery recharge procedure.

Lithium-Ion batteries must have the inbuilt safety system and use an approved Li-ion battery charger.

23.3.2 CHARGING LEAD ACID (LA) BATTERIES, INCLUDING SLA'S

Recommended these be charged in 3 stages:

a. Constant current to 70% of capacity (over 5 – 8 hours).

b. Topping (lower) charge to 100% of capacity (over 7 – 10 hours)

c. Apply intermittent 'float' charge to maintain capacity.

The 'topping charge' is important in order to avoid the battery losing the ability to accept the full charge (full capacity).

LA batteries should be recharged immediately after each use to prevent sulphation.

23.4 PROTECTION SYSTEMS

A relatively large amount of energy is stored in a battery and has the potential to cause harm to equipment and people. Electrical installations should have a protection system, designed to protect the electrical system and the connected devices against short-circuit or over-load situations and the battery(s) themselves.

Protective devices include fuses and/or circuit breakers. It is recommended a 'master' fuse, able to withstand the 'normal' system load, be located as close to the battery terminals as possible. It is also recommended that these battery terminals (if more than one battery), be appropriately insulated to prevent the possibility of a short-circuit before the protection device. A dead-short across battery terminals may produce significant heat.

Fuses or circuit breakers must be 'graded'. This means the highest capacity fuse/circuit breaker at the battery terminal and the lowest capacity fuse/circuit breaker near the actual device (radio, glide computer, etc)

23.5 SECURITY

Battery security is also important – in the event of an accident, the battery may become a missile. The battery must be restrained such that it will not move in the event of an accident. For further information on G Load requirements of batteries refer to BSE. Additionally, if a batteries security is in poor condition and failure occurs in flight, there is the risk of the battery being shorted across the terminals.

23.6 DISPOSAL

It is increasingly important that batteries be disposed of responsibly. Many battery dealers will now accept old batteries for disposal, at no cost, when the new battery is purchased.

Many discarded batteries still contain a charge, thus present a fire / or short circuiting hazard.

23.7 BATTERY ISSUES

In the wider aviation community, cheap imitation Li-ion batteries have been identified, which do not have the inbuilt protection systems of the genuine article.

There is an increasing demand for information / approval to convert existing glider electrical systems to Lithium Iron Phosphate batteries because of the increasing improvements in battery performance accompanied with a significant reduction in battery weight,

Formally the only gliders approved for LiFePO4 Battery use are;

a. Those where the Lithium based batteries are installed by the manufacturer. It is important that these systems are carefully maintained in accordance with the Glider Maintenance Manual.

b. Those gliders which comply rigidly to the GFA MOSP Technical Airworthiness Revision (MTAR 1/2017).

CASA have also produced an article about travelling with Lithium (Li) batteries, the document is as valid for travelling with batteries as it is for installation and use of batteries in a glider:

https://www.casa.gov.au/standard-page/travelling-safely-batteries?WCMS%3ASTANDARD%3A%3Apc=PC_100484

The GFA has formerly directed that other than listed above no other LI Battery or chemistry may be used in a GFA registered aircraft and with good reason.

LI Polymer are considered unstable and inherently dangerous in flight in the event of a thermo chemical incident.

The risks are not worth it on any personal judgement or performance consideration.

24. ENGINE COOLING

The various engines types have differing 'cooling' systems and cooling requirements. Engine cooling is a vital part of the ongoing engine operation. An unrecognised failure of/in the cooling system is likely to cause significant damage to an engine.

24.1 LIQUID COOLING

Some engines have a liquid filled (coolant) cooling system. The components in such a system include:

a. Radiator, which may include a 'storage' reservoir and finned air-cooling heat exchange tubes.

b. Separate 'storage' reservoir.

c. Filler cap.

d. A circulation pump.

e. Interconnecting hoses.

The coolant is generally water with a rich mixture of an anti-freeze. This is typically an automotive coolant/ anti-freeze. While the anti-freeze will contain an agent to prevent corrosion, it is best to use only de-mineralised water in the system to reduce the risk of corrosion further. Periodical changing of the coolant is paramount to longevity of the system and the minimum period will be noted in the manual for the aircraft and/or engine. To operate efficiently the fins of the cooler/radiator must be kept free of debris such as dust or locusts.

It is recommended that de-mineralised water be used in coolant systems.

24.2 AIR COOLED

Some engines have finned cylinder barrels which allow air, the flow of which is specifically directed over or around the engine and through the cooling fins, to carry the generated heat away from the engine.

An air-cooled system is generally dependent on the engine cowling and baffles, which may comprise:

a. Some rigid (ie aluminium sheet)

b. Some flexible (orange rubber like sheeting) and/or

c. Dense felt

These direct the airflow over, around and away from the engine. The 'airflow path' is generally the result of significant testing by the manufacturer. When maintaining the motor glider, it is important to maintain the air flow path and ensure there is no restriction in the inlet to or exit from that path. Remember we are in a much hotter country and even though they should be designed for hotter conditions, our engines will be stressed more.

Maintaining the baffles and seals ensures no air escapes from the intake side of the baffles thus maintain performance of the system. Probably more important is the outlet side which if restricted will dramatically reduce cooling efficiency. Due to heat transfer the volume of air is greater going out than in.

On most motor gliders, the propeller spinner also plays a significant part in the flow of air for engine cooling. The loss of the spinner may result in a sudden reduction in airflow and cooling performance.

Figure 24-1 Motor Falke Cooling Baffles

24.3 OIL COOLING

Many 4-stroke and rotary engines have a pumped system to circulate lubricating oil through galleries etc to lubricate components and in the case of a rotary the rotor. The oil carries heat away from the engine to an oil cooler, which generally consists of finned tubes across which airflow passes to cool the oil. The above engine (Motor Falke) uses induction system oil cooling. While the oil needs to be warm to operate at its optimum and to burn off acids and moisture and to convert the lead in Avgas to get rid of it, too high a temperature breaks down the additives in the oil reducing its performance and burns it onto components.

Some engines will use a combination of cooling systems such as a 4-stroke Rotax and some Limbach models where the cylinder heads are liquid cooled and the barrels are air cooled.

24.4 COWL FLAPS

Some motor gliders are fitted with ‘cowl flaps’, which are designed to increase the air-flow across the engine during periods of high power settings (take-off and climb) and are able to be closed (partly or fully) during cruise and descent to maintain engine temperatures.

There is a defined operating procedure for cowl flaps (refer to the motor glider’s Flight Manual). The wrong operation of the cowl flaps may result in significant over-heating of the engine and possible damage, particularly at high power settings with (relatively) slower airspeed.

A ‘hot’ engine may be indicated by:

a. High cylinder head temperature.

b. ‘High temperature’ smell.

24.5 ENGINE INSTRUMENTATION – ENGINE COOLING

Depending on the type (and age) of the motor glider, there are various instruments installed to indicate to the pilot the status of engine cooling. Some modern motor gliders for example have a ‘low coolant level’ warning light in the cockpit.

Instrumentation may include:

a. Oil temperature gauge. (Green arc, Yellow arc, Red line)

b. High oil temperature warning light.

c. High coolant temperature warning light.

d. Cylinder head temperature gauge.

A note of warning, particularly for hot countries: Most engines use a thermocouple (TC) based CHT gauge which measure the temperature difference between a reference TC and one bolted on the sparkplug. The reference TC is in the readout in the cockpit. The gauge assumes it is at 15C and so if your cockpit instruments are at 50C in the sun your CHT will read 35C low. For example, your engine is cooked at 250C, it is reading 215C so you throttle back - but in reality, it is too late, it is cooked!

Secondly, CHT gauges can go out of calibration. Get an accurate gauge, check calibrate it in boiling water and then use it to very precisely check your CHTs. Infra-red gauges are nice - but imprecise.

Modern CHT gauges can be compensated for ambient temperature and so can read correctly. Know your gauge and placard it for corrections.

Be aware that our clever alloy engines are very susceptible to terminal overheating damage. The Alloy softens at 200 to 250C and so deforms permanently. The Limbach factory advised that at CHTs over 200C, the engine is accumulating heat damage. Be very wary!

Be careful with changing thermocouple wiring. They work by dissimilar metals and by very minute voltage and currents. You must use the correct components, wire, junctions and procedures. If unsure calibrate them carefully. Remember that EGTs have different TCs and wire to CHTs.

24.6 COOLING SYSTEMS MAINTENANCE

Maintenance of the cooling system includes:

a. Check engine operates within green zones, not too hot or too cold.

b. Check the Engine Management System (EMS) is giving the correct indicators. Some ‘simplified’ engines use complex and essential EMS. If the lights or gauges don’t work the engine could be damaged.

c. Check system is clean and unobstructed.

d. Check for signs of overheating, blowing gas discolouration and even loose cylinder head nuts.

e. Check colour of exhaust and plugs to check mixture.

f. Check cowling is tight and working well. No cracks or gaps.

g. Check hoses are in good condition and within life. Check fire sleeving is properly installed.

h. Check calibration of CHT and oil temperature gauges.

i. Oil cooler, ensure finned tubes are clean, consider flushing, and pressure testing.

j. Check placards relative to cooling.

k. If there is a history of overheating, work out how to fix this before it costs you a lot. This is very difficult and may take perseverance. Remember a “mod” is a modification and needs to be correctly done if it is not a repair. Change one thing at a time so you know what works. Document in your logbook so the next person knows what has been done.

l. Document and submit defect reports so others are aware of the issues.

24.7 ENGINE COOLING ISSUES

Engine cooling issues include:

a. Cooling baffles missing or leaking

b. Cowl flaps, incorrect operation.

c. Oil leaks

d. Valve seat regression is increased when the heads run too hot.

25. EXHAUST SYSTEMS

25.1 EXHAUST SYSTEM INTRODUCTION

The engine exhaust system is as vital to the efficient operation of an engine as are the pistons.

The exhaust system is designed to safely and effectively discharge the hot combustion products from each cylinder during the engine cycle while not creating excessive back-pressure on the 'system' for efficient operation and to reduce engine noise.

The exhaust systems on our motor gliders (& cars, motor bikes etc) operate in an extremely hostile environment, subject to high temperatures, low temperatures, high moisture content gases - water is a combustion product - and high vibration.

An exhaust system generally consists of individual pipes from each cylinder to an exhaust manifold into a muffler and a common discharge pipe.

Exhaust systems are prone to corrosion ('wet' exhaust gases), leaks at joints and cracking at welded connections (both from stress and differential expansion).

25.2 EXHAUST SYTEM HAZARDS

Exhaust systems present a danger in every motor glider:

a. Hot exhaust gases.

b. Carbon monoxide – a combustion product that is an insidious killer. A Carbon Mon-oxide indicator is required in the cockpit.

c. Cold exhaust gas leaks should not be under estimated for their lethal seriousness, with the potential to incapacitate a pilot.

d. Many exhaust system 'fix ups' present problems - dodgy welding is common – and most often are not an acceptable remedy or repair.

The safety aspects of a faulty exhaust system should not be overlooked.

Many 'temporary fixes' often become a long term (years) fix- like the one in the following picture:

Changing the bandage at a Form 2 is clearly not an accepted practice - adding wire to support the bandage when there is little pipe left.

Cracks and holes, shown in the following picture were ignored at the Annual Inspection – this picture was taken of a motor glider exhaust system fresh out of a Form 2

25.3 FIREWALL SECURITY

The security of the firewall is also an exhaust system issue.

The following picture shows an example of unacceptable and dangerous practice; the cabin heat valve has been "repaired" with a zip-lock bag and tape utilised to stop the ingress of exhaust gases into the cabin heat system!

Regardless of the condition of the exhaust system, it is vital that the integrity of firewall sealing always be maintained.

25.4 EXHAUST SYSTEM ISSUES

Common exhaust issues include:

a. Exhaust leaks.

b. Carbon monoxide

c. Muffler bandage.

d. Exhaust system repairs.

NOTES:

To prevent seizure of pipes, nuts and bolts in exhaust systems use Loctite Anti-Seize Stick, Silver Grade.

26. PROPELLERS AND THEIR SYSTEMS

26.1 INTRODUCTION TO PROPELLERS AND THEIR SYSTEMS

The range of propeller types in use on motor gliders is very broad and includes fixed, folding, variable pitch, constant speed variable pitch, from 2 blades to 5 and in combinations of the above. In the case of the Stemme S10VT for example a folding variable pitch unit is fitted.

Propellers are commonly constructed from; timber, FRP, CRP, plastic, alloy and combinations of the above as well.

Maintenance options available to an 1109 holder are limited and will be defined in the associated manual for each type.

26.2 PROPELLER PRINCIPLE

The aerodynamics of the propeller are basically the same as an aircraft wing and the propeller could be described as a rotary wing.

Like the aspect ratio of a glider wing, and using the same principles, the larger the tip diameter of the propeller the more efficient it is. As always in design there come compromises for a practical size. Ground clearance and clearance to the fuselage are obvious ones along with the RPM range of the engine. A larger slower speed propeller is more efficient than a smaller one at higher RPM.

The speed of the propeller is limited by structural limitations resulting from centrifugal force and the tip speed of the blade. The tip speed of a blade is quite high. For instance, a Hoffman HOV 62" prop as fitted to a Dimona in climb at 3200 RPM has a tip velocity of Mach 0.74. At high Mach numbers the propeller rapidly loses efficiency and much past 0.75 or 0.8 is losing energy to excessive drag. Mach 0.9 and higher results in a "barking prop" which is telling you it is running too fast. Close to Mach 1.0 and damage is imminent (if the blades are still attached).

With high tip speed also comes more centrifugal force trying to separate the blades. The manufacturer will give a max RPM value and inspection requirements at specified over-speed values past that limit. Should a propeller over-speed event occur the risk of damage or blade separation is a clear and present danger. Any reported over-speed events or suspicious damage should be taken seriously and always err on the side of caution. It is better to send a prop in for inspection by a qualified workshop and wear the cost rather than the unthinkable ramifications.

Blade separation is dangerous at any time and in the air will inevitably finish with the aircraft being destroyed. If it happens on the ground there is still a real risk to personnel within range of the aircraft and in the event of a retractable type the flight crew is also at high risk.

In a front engine glider, to lose a blade means you lose the engine and it all happens in a split second: the pilot won't even know about it until after the engine has departed the airframe. Removing say 80kg from the front of a glider results in a massive rearward change of C of G that will in all probability render the aircraft incapable of controlled flight.

If you were to try and lift a helicopter by the rotor blades mid-section they would break. The blades are long and slender and the highest load is from centrifugal force and this is designed for. The centrifugal force keeps the blades straight and enables the rotor to be able to lift the aircraft and support g loads. Looking at a stationary rotor blade, sag is evident from the weight of the blades. As soon as they start spinning they straighten out and don't bend up much once it takes flight.

The same applies to the propeller. It is not designed to be pulled by the blades when stationary. Thus, it is not allowed to pull an aircraft by the blades at the tips or even mid-way out the blade.

Propellers and engines have resonant features and matching the propeller to the engine requires knowledge and testing that is beyond our scope.

In many engines where the propeller is directly connected to crankshaft and turns at crankshaft speed, the position of the blades relative to the pistons is important thus the propeller must be 'timed' when fitted. This is usually 90 degrees to the con rod angle, i.e. No 1 piston at TDC with blades vertical.

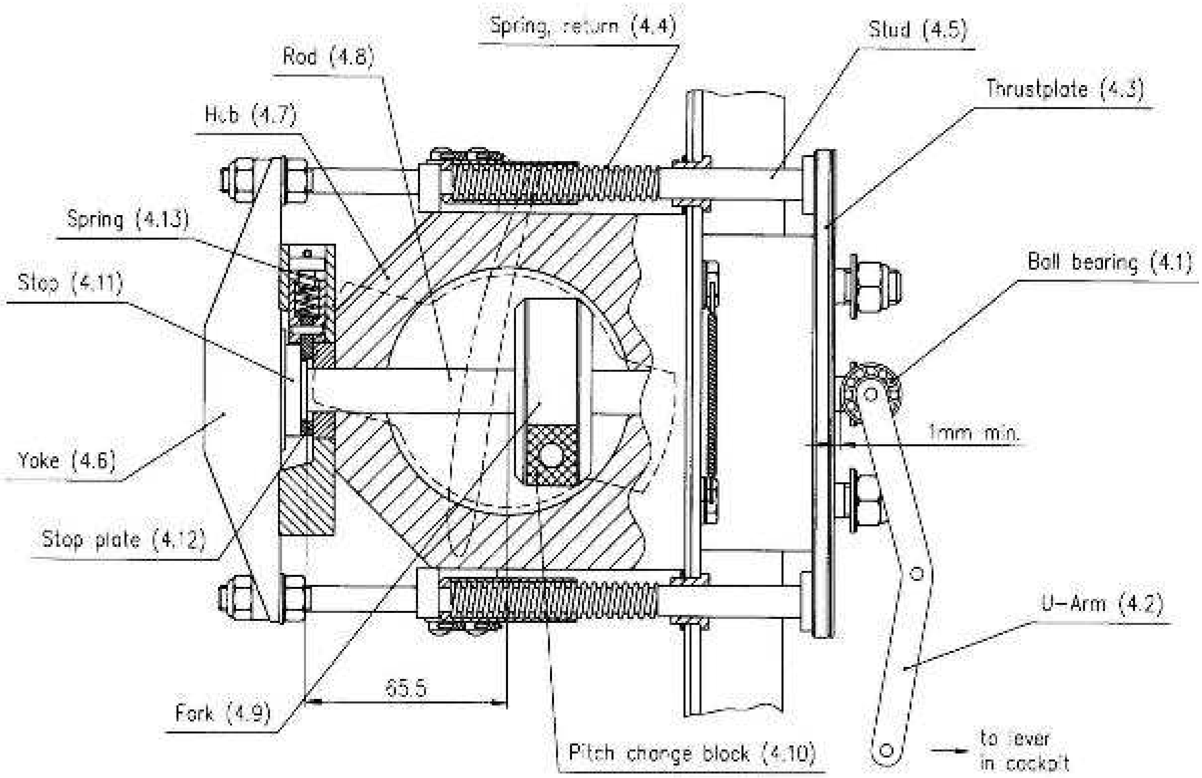
The engine manufacturer will have certified the propeller options for the engine type. Using a different propeller than specified requires a qualified engineer (CAR 21) and approval.

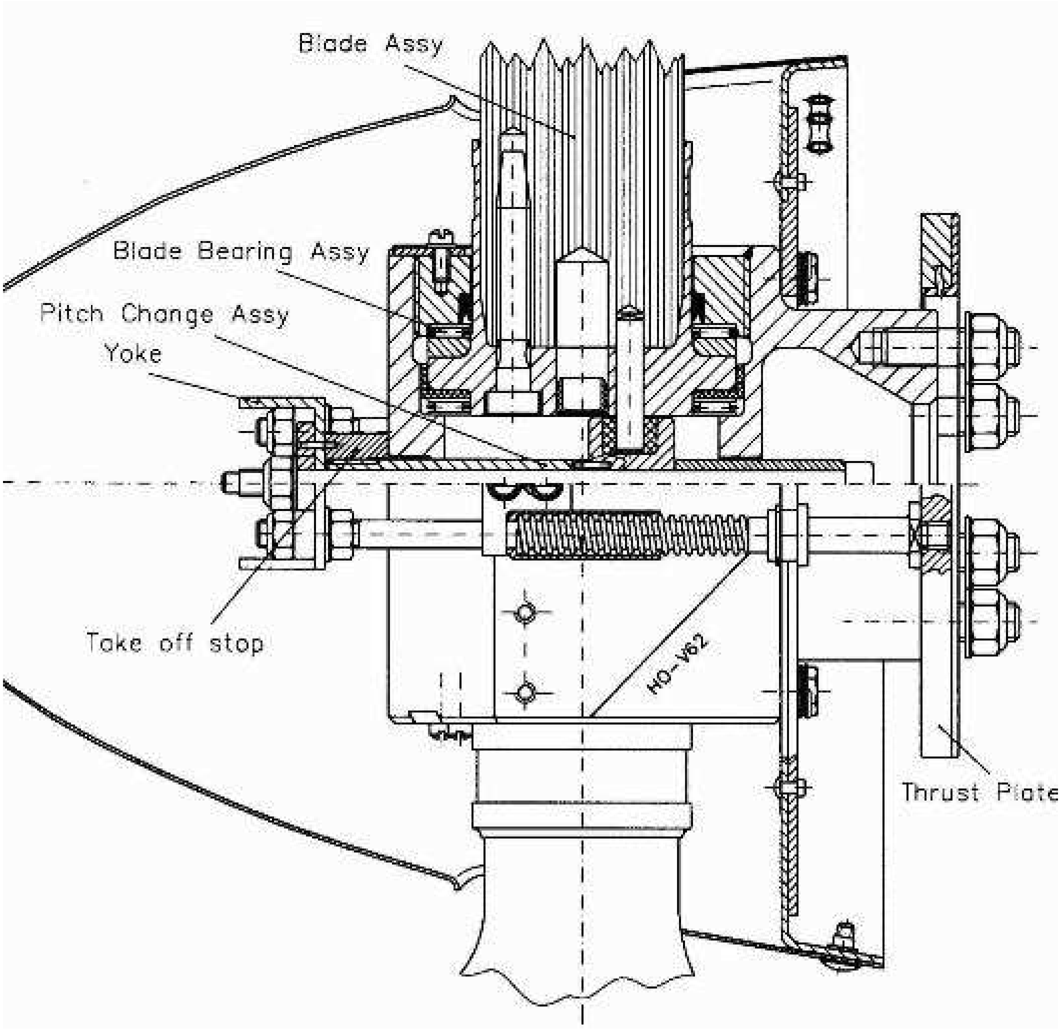
26.3 PROPELLOR PITCH AND FOLDING SYSTEMS

Folding and variable pitch propellers require regular maintenance and checks. There is no general approach as each type has its own individual requirements and again will be defined in the manual. Checking bearing clearance and lubrication is the common requirement.

The variable and constant speed props used in motor gliders all work with the same principle of driving the pitch change in the hub. The drawings below show that system. The stub end of the blade has an eccentric pin which is driven by a fork fitted to a shaft which runs through the centre of the hub and moving the shaft and thus the yoke forward and back along the thrust line sets the pitch.

In the following images this is done mechanically by driving a thrust plate via a set of roller bearings that run on it during pitch change and is moved by means of a lever. The MT propeller may be driven by an electric linear actuator or hydraulic piston.





In the case of the hydraulic piston, pressure is supplied by a valve which is driven by a governor thus providing constant speed control. The oil pressure is derived from the engine's lubrication system. The governor is driven by gear connection to the main shaft and in the case of the Rotax this is on the reduction gear box.

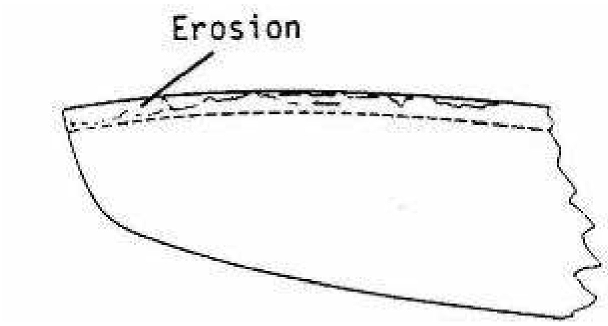
With the electric propeller, the motor is controlled electronically and again delivers constant speed. Thus, the electronic control system acts as the governor.

26.4 PROPELLER CONSTRUCTION

Propeller blades are generally built with a twist or wash out in them. This is to address the issue of the changing of angle of attack with diameter.

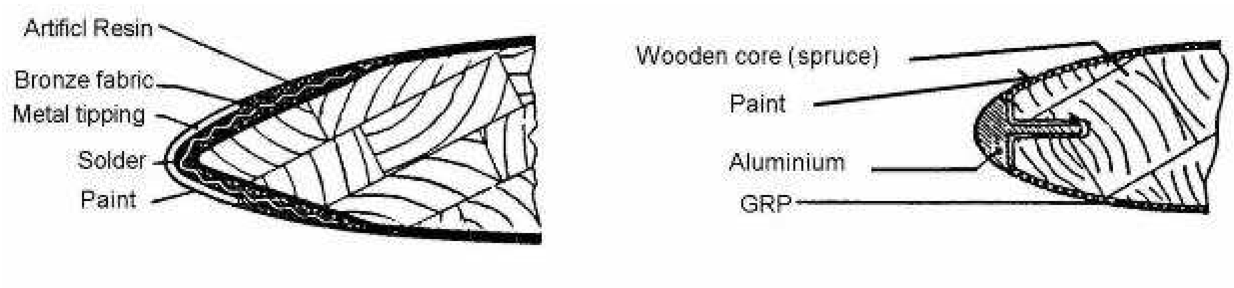
The outer half of the blade generally does most of the work.

The high speed the blades travel results in wear and tear (erosion) from dust, rain and stones etc. Some minor repair work is allowed by most manufacturers and those details will be defined in the propeller's manual. The following drawing from the Hoffmann manual shows what to look for:



In the case of front mounted propellers, the use of a leading edge protection in the form of an alloy or bronze cap is commonly used to reduce erosion ~~bit~~ but it will wear and stones will dent it.

The images below show typical construction of a wooden composite prop. Laminations of spruce are aligned to stiffen the blade for twist and take the operating loads as well as preventing warping which would change the profile of the blade. In the composite design the FRP layer is used to provide further protection of the structure and stop the ingress of moisture.



FRP and CRP blades are generally hollow core or foam core while the alloy and plastic blades (generally only seen on sustainer installations) are solid.

26.5 PROPELLER STRIKE

Any propeller strike regardless of the material and construction of the blades, level of damage done or the conditions of the strike is serious.

The actions required after a propeller strike are defined in the manual and must be adhered to. There is no alternative regardless of any opinions offered.

The propeller shown below had damage found at DI which could not be accounted for. The propeller was overhauled and the engine had a bulk strip. Inspection of the crankshaft at bulk strip revealed it was cracked. This is an example of how damage can exist when you don’t expect it. The engine had done 40 hours since overhaul.

Hoffmann propeller from a G109 fitted with a Limbach L2000EB1. This propeller had severe damage to both blade tips. The engine had 20 hours since new and no damage was found at bulk strip.

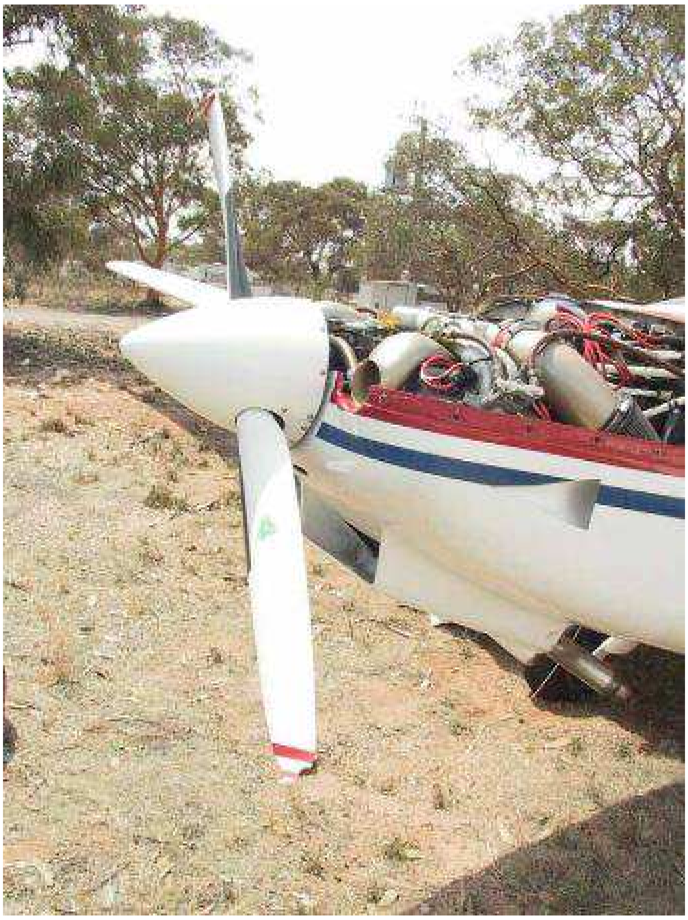


Figure 26-1 G109 with Limbach L2400DFI 100HP and MT Electric Propeller.

26.6 PROPELLER ISSUES

Typical propeller issues include:

a. Stones

b. Rain

c. Damage, repair

d. Parking

e. Blade attachment

f. Balance

g. Wooden props – seasonal variation.

h. Torque

27. REDUCTION UNITS AND DRIVE TRAINS

In a motor glider, where a propeller is not directly connected to the crankshaft or the RPM range of the engine requires a prop speed reduction, a drive train or transmission is required to transmit the engine power to the propeller. Typically, this will be in the form of either a toothed transmission belt running on a pulley installed on the prop shaft and the crankshaft, or a gear box for propeller speed reduction or a combination of the above.

27.1 BELT DRIVE/REDUCTION

With a tooth belt drive the propeller is driven by a toothed rubber drive belt, not dissimilar to timing belts found in cars. This is commonly found in retractable 2-stroke engines. The belt may be quite long where the engine remains inside the fuselage and only the propeller and pylon are exposed to the airflow.

The pylon may also carry a radiator and likely a propeller braking/stop device.

It is important that the belt is adjusted to the correct tension. This is usually achieved by changing the distance between the centres of the shafts. The method of adjustment is defined in the Maintenance Manual. Because belts do break after time, manufacturers generally put a life on the belts (a number of starts, or hours of operation).

Belts are generally made of rubber with fiberglass or Kevlar reinforcement. The toothed belts engage in toothed pulleys for transmission of torque.

No lubrication is required or recommended, as this may affect the life of the belt material.

To monitor the operation of a drive belt, the following actions are necessary:

a. Thoroughly check the condition of the belt at each DI.

b. Replace the belt at the specified time intervals set by the manufacturer. (Ensure the change interval is listed in the scheduled maintenance section of the Maintenance Release.)

c. Ensure the tension of the drive belt is correct (in accordance with the procedure specified in the Maintenance Manual).

27.2 DRIVE SHAFTS

Currently, there is only one type of motor glider in Australia using a drive shaft – the Stemme S10 series.

In this motor glider, the engine is mounted in the fuselage behind the cockpit and wheel bay. The propeller is mounted at front of the aircraft, with the propeller retractable into the nose-cone. The transmission from the engine to the propeller at the front of the aircraft is by a drive shaft made of Carbon Reinforced Plastic (CRP).

Figure 27-1 Stemme CRP Drive shaft.

Components of a power transmission system are:

a. Centrifugal clutch - between engine and drive shaft.

b. A force transmitting clutch actuated by direction-of- turn and rotating speed. Since the centrifugal clutch transmits torque by friction, it is also an overload protection.

c. The drive shaft is manufactured in carbon fibre reinforced composite material for weight and strength.

d. A flexible coupling is installed on the front and rear end of the shaft allowing for angular and torsional elasticity.

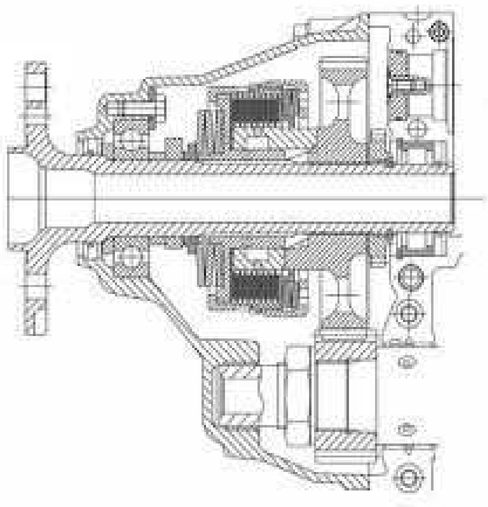
e. A belt reduction drive is installed between the Shaft and the Propeller.

The CRP drive shaft and the rubber clutches require inspection on a regular basis. It is vital that there is no damage to the carbon fibre driveshaft. These components can be removed completely from the Stemme for inspection.

Complete maintenance requirements for this system are extensive and include the propeller which is often variable pitch. The maintenance and inspection requirements are clearly outlined in the Stemme Manual.

27.3 GEAR BOX TRANSMISSION

A gear box propeller speed reduction system is commonly used with the Rotax range of engines, where the gearbox is integral with the engine.

Rotax 914 engine showing speed reduction unit on the output shaft.	
Rotax 914 Gearbox.	

The Rotax gearbox is lubricated with oil from the engine lubrication system. The gears have a long life and maintenance is not demanding. This unit also has a Dog Clutch included in the drive.

The gearbox consists of a drive gear fitted to the crankshaft and a driven gear fitted to the prop shaft. A Dog clutch segment that engages in the driven gear and rides on the prop shaft with 3 conical washers (springs), bearings and a nut to set the tension on the conical washers.

Checking the tension setting of the clutch is part of the scheduled maintenance program. Adjustment requires the partial disassembly of the gearbox. The Dog clutch is used to protect the engine from shock loading.

27.4 DRIVE TRAIN ISSUES

Drive train issues include:

a. Dog clutch.

b. Drive belt maintenance.

c. Over-filling gearboxes.

28. INSTRUMENTS

Engine instruments come under the 1109 engine rating as they are specific to the engine system. Instruments range from basic in a 2-stoke retractable engine glider, to more extensive in touring motor gliders.

In the basic range commonly, used gauges are:

a. Cylinder Head Temperature (CHT)

b. Tachometer (tacho). This measures engine revolutions per minute.

c. An engine hour meter. This activates when the engine electrical system is switched on.

In the case modern touring motor gliders, the variation in requirements is more extensive and commonly seen instruments are:

d. Tachometer (electronic or mechanical, often has an hour meter built in)

e. Oil pressure gauge.

f. Manifold pressure gauge.

g. Oil temperature gauge.

h. Cylinder Head Temperature (CHT) gauge.

i. Coolant temperature gauge.

j. Exhaust Gas Temperature (EGT) gauge.

k. Voltmeter.

l. Ammeter.

28.1 TACHOMETERS

The mechanical tachometer generally has a built-in hour meter. The advantage of the mechanical tacho is that the hour meter isn't really measuring time, it is counting rotations of the crankshaft. The manufacturer selects a tacho to suite the engine type. For instance, if the engine's cruise power is at 2800 RPM, then the tacho selected will show 1 hour after 1 hour running. If at full power it will count an hour in less time and if at idle will count slowly so not much time is recorded when at low power settings.

The mechanical tacho is driven by a cable which in turn is driven by the engines rotation. The point the cable drive emanates from is commonly the camshaft.

The electric hour meter counts hour for hour and commonly records in decimals of an hour, not minutes.

The tacho in a 2-stroke is generally electronic and driven from the ignition system.

Mechanical tacho gauge as fitted in a G109	
Mechanical tacho cable gear takeoff drive	
Electric “Hobbs” hour meter	

28.2 CHT AND EGT TEMPERATURE GAUGES

The Cylinder Head Temperature (CHT) gauge in the case of an air cooled engine is generally not electronic. Commonly it is a sensitive voltmeter which registers a temperature value based on the voltage supplied from the thermocouple. The thermocouple is a bi-metallic device, usually fitted under the spark plug of the hottest running cylinder head. It produces current when heated and the higher the temperature the greater the current. It is not connected to the aircraft electrical system but is a standalone device.

The Exhaust Gas Temperature (EGT) gauge works on the same principle. The thermocouple is in the form of a probe that is fitted into an exhaust pipe close to the exhaust port of the cylinder head. It may be directly into the pipe held by a clamp or screwed into a threaded port welded to the pipe.

There are electronic versions of both these temperature gauge systems but they are not common in motor gliders.

CHT Gauge	
Thermocouple	
Falcon 8mm Threaded EGT Probe	
Clamped EGT Probe	

28.3 OIL TEMPERATURE AND PRESSURE GAUGES

Oil temperature and oil pressure gauges are commonly electric. Mechanical gauges have not been fitted to motor gliders in recent times and now rarely seen other than in older touring motor gliders with nose mounted engines.

With electrical gauges, each receives a signal from its own ‘sender’ (sometimes called a sensor) fitted into the engine. The senders use a single wire to give a resistance to ground signal to the gauge.

It is common for the pressure sender to have a second terminal which is a switch used for a light or alarm to indicate a loss of pressure. It is sometimes used to switch the field off in the alternator to avoid flattening the battery when the master switch is left on. It may also be used to switch on an electric hour meter.

Oil Temperature Gauge	
Oil Temperature Sender	
Oil Pressure Gauge	
Oil Pressure Sender (electric)	

28.4 MANIFOLD PRESSURE GAUGE

This instrument is common in GA aircraft with variable pitch propellers but rather rare in motor gliders. A manifold pressure gauge displays a measure (in inches of mercury or “in hg”) of the air pressure in the induction system, just before the air/fuel mixture enters into the cylinders. It is one of the best methods to determine just how much power is being developed by the engine as the more air and fuel drawn or pumped into the cylinders, the more power the engine can develop.

In normally aspirated engines (ie non turbo-charged), the manifold pressure gauge has a range of anywhere between 10 – 40 in. hg (inches of mercury). In a turbocharged engine, where air is forced into the engine, the manifold pressure is allowed to go as high as the engine manufacturer allows.

The manifold pressure measurement is commonly mechanical with a fine tube running from the instrument to the manifold port. There are electronic instruments available but not generally used in motor gliders.

Manifold pressure gauge for a typical 4-stroke normally aspirated engine. A Lycoming 180HP engine commonly cruises at 23"HG/2400rpm.	

28.5 MAINTENANCE OF INSTRUMENTS

For the engine ground engineer, with these instruments there is basically nothing that can be maintained or repaired, it is a case of checking and calibration. With electrical senders, it is of course worthwhile checking the electrical circuits.

If a mechanical tacho has a problem it is likely worth sending it to an aircraft instrument fitter but for all the other instruments it is unlikely to be worth repair and thus replacement is usually the best action.

Devices are available for checking/calibrating the instruments. The tacho is a good example where small electronic units using laser technology will deliver the RPM reading from the laser being applied to a spinning propeller from a safe distance.

29. MEASUREMENT TOOLS – USE AND CARE

The measurement of components, including clearances and tolerances is a significant feature of motor glider engine maintenance and repair, which requires:

a. Good quality measurement equipment.

b. A good understanding of fits, tolerances, etc

c. Practice at using the various measurement devices to ensure an accurate and consistent result.

29.1 MEASUREMENT EQUIPMENT

Typical measurement equipment includes:

a. Tape measure - metric, 8m tape measure.

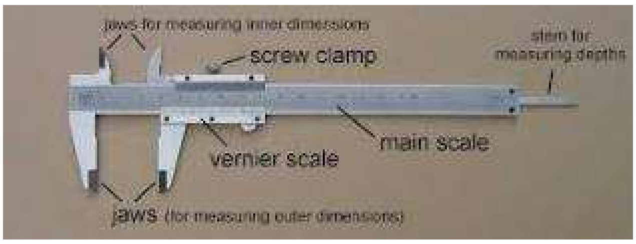
b. Steel ruler(s)

  i. 150mm steel rule.

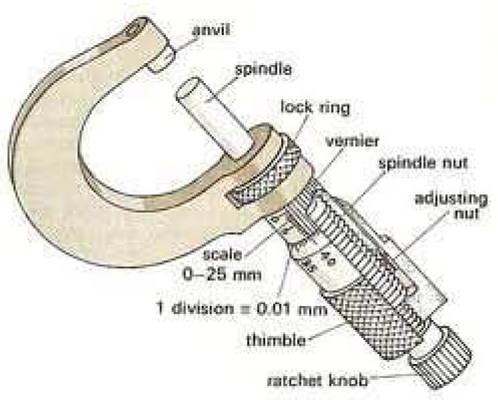
  ii. 300mm steel rule

c. Feeler gauge - set of good quality ‘feeler gauges’, 1 metric, 1 imperial scale.

d. Good quality Vernier Caliper.



e. Good quality external Micrometer



Above a 0-25mm and a 25mm-50mm Micrometer. Note the checking staff for the 25-50mm Micrometer

Tension Wrench

Good quality internal Micrometer

Dial Indicator and Finger/Test style Dial Indicator

Ball Gauge

Telescopic Gauge

29.2 Care of Micrometers

Micrometers are sensitive devices and need care for the best results and accuracy. They do not cope well with being dropped and a solid impact can ruin the accuracy and may not be recoverable. They are best kept in a timber or plastic box preferably padded and stored in a dry environment. Always leave a small gap between the anvil and spindle when storing. Avoid using them over metal surfaces and preferably work over a timber bench for that reason. After use wipe clean and apply a thin layer of light oil to avoid corrosion. Special attention to the Anvil and Spindle in this process is needed.

Unscrewing the Spindle completely and oiling the thread is occasionally needed.

A common abuse of a Micrometer is to use it as a G Clamp. A Tradesman would threaten death to anyone who did this to his Micrometer. Over tightening the device in use is detrimental to the ongoing accuracy.

Adjusting the calibration of Micrometers and the spindle thread clearance is done with 'C' spanners which are usually supplied with the unit at purchase. This can be done by a well trained Fitter/Machinist or if you don't know one take it to a Metrology Workshop.

29.3 Using a Micrometer.

How to read a Micrometer, See:

http://www.linnbenton.edu/auto/day/mike/read.html

Before measuring, check the zero point of the Micrometer. The faces of the Anvil and Spindle must be cleaned to achieve accuracy and this is best done by first winding the Spindle down onto the anvil with a piece of paper between the faces and then slide the paper out.

This is done in the case of a 0-1' or 0-25mm Micrometer by winding the thimble down until the spindle bears against the anvil. Tension is set by the ratchet nob on top of the thimble. The thimble should now show zero on the scale. Small errors are easily allowed for when measuring but when they are too great the Micrometer needs adjusting to calibrate the zero point. In the case of 25-50mm and 1-2' Micrometers or larger the Calibration of the Zero point is checked using a 'staff' as shown in 'external Micrometer' Photo above using the same principle as for the 0-25MM described.

Internal Micrometers can be checked with an External Micrometer (allow for any detected error in the external unit) using the comparator principle however normal workshop practice is to ignore the reading on the inside Micrometer and instead use the external unit for the final measurement on the internal Micrometers set length. Both devices need a gentle touch 'feel' for the best accuracy and this is done by adjusting the device to pass lightly through the shortest path around the outside or through the inside of the dimension being measured.

Practical demonstration and practice is the only way to learn this skill.

29.4 Care of Vernier Calipers.

The care of Vernier Calipers is similar to that of Micrometers. There is NO adjustment except for the clearance of the slide which is easily done with an instrument screwdriver. The blades of the caliper are very susceptible to damage and especially the internal blades which are very fine at the point. Dropping on a hard surface will readily destroy the fine points.

Dropping it on the Stem will also affect accuracy but in the depth mode.

While there is no thread like the spindle of the Micrometer the Slide does need occasional oiling.

29.5 Using the Vernier Caliper.

Before measuring check the zero point of the device. Clean the external blades and close. Then check the reading on the vernier scale. Hold the blades up to light and check that the external blades are in contact across their length and are square. Check the tips of the internal blades to make sure they align properly. For checking depth measurement accuracy place the calliper on end on a precision ground surface and slide the vernier body down and lock in place with the locking screw. Read the scale to ensure it is zero.

The principles as per the Micrometer for the shortest path still apply in the case of the caliper however it is an easy device to use.

29.6 Care of Feeler Gauges.

Feeler Gauges are simply strips of shim in varying thicknesses in a set enabling sliding the shim blades out and using one or more to achieve the required thickness by applying the basic 'binary' principle.

They are best kept in a container for protection and lightly oiled when not in use.

Common problems are corrosion when poorly stored and crush damage from bad application and even folding crease damage. All of these will affect the accuracy of the measurement being taken.

29.7 Using Feeler Gauges.

These are the simplest device of all described here. However, as they are a set dimension and are not adjustable they rely totally on 'feel'.

Most commonly used for checking valve clearance and ignition point clearance.

When measuring a thickness which requires multiple blades always use the least number of blades and try to use blades of approximately the same thickness. Example: need to measure 27 thou; 25 +2 thou would work, but 13 +14 thou would be preferable. This gives a more rigid gauge which will enhance the 'feel'.

29.8 Care of a Torque/Tension Wrench.

Lubrication of a tension or torque wrench is dependent on the type of unit but basically the usual moving parts principle applies. Storage as per any measuring device. They are usually pretty robust and can take a bit of hammering but do need calibration, especially for some of our applications. This requires the help of a testing centre and not in the scope of the operator. A basic check can be done by comparison to another accurate unit but in any event needs specialist treatment if there is any doubt.

29.9 Using a Torque/Tension Wrench.

These are pretty simple devices to use. However, it is important to be familiar with the particular unit and thus its scale, setting, unit of measure and operating direction function. It is better to test on a bolt in a vice first to ensure you have things set correctly rather than strip a thread because you had the ratchet set the wrong way around.

29.10 Care of a Dial Indicator.

The dial indicator is a sensitive device. Excessive load on the needle will cause damage. The spindle can be easily bent so respect of the setup and loads is required. The most common damage seen in Dial Indicators is from being dropped. Generally, dropping them is terminal and they are not a cheap item.

Calibration checking can be done by setting them up rigidly over a ground plate and sliding feeler gauges between the spindle and the plate.

Storage is best in a padded box and a dry environment.

29.11 Using a Dial Indicator.

The Indicator will only give good readings if it is securely mounted. Any flex in the mounting will give inaccuracy. It is commonly used in Aircraft Engine work for checking Propeller Flange run out, Propeller Swash Plate run out and setting Crankshaft End Float along with Checking Crankshaft run out with the latter two being typically done at Overhaul.

29.12 Care of Telescopic and Ball Gauge.

Both of these devices are fairly robust and generally come in a plastic pouch.

They are both used for measuring bores by setting to the size of the bore and then measuring the Gauge with a Micrometer so effectively a comparator. Therefore as they are for a comparator there is no calibration. However, the surface finish of the contact points on both is important to get an accurate measurement both when setting in the bore and measuring with a Micrometer.

29.13 Using a Telescopic Gauge.

The telescopic gauge is placed in the bore and set at an angle to the long axis. The locking screw is then nipped up by the thimble and the Gauge rotated through an arc where the Bore then drives the telescopic slides down to the bore size. These are not particularly accurate as a comparator as the ‘feel’ is set by the tension of the locking screw. This may deliver a variation to the set length of the gauge prior to measuring with a Micrometer. The Advantage of this gauge compared to an Inside Micrometer is that it will get into smaller diameter bores and is far cheaper than a Micrometer.

29.14 Using a Ball Gauge.

The Ball Gauge is used primarily in very small holes. The ‘Feel’ is set by the size adjustment via the thimble on top and is done while rocking the ball through an arc in the bore. Thus, it is quite accurate as a comparator.

Most of the devices described in this chapter rely on a practical skill that is not common to many who have not worked in a mechanical type trade. Hands on demonstration is the only way to effectively pass on this skill to the reader as the ‘feel’ etc. is paramount to achieve accurate results and it really is a matter of holding your tongue right.

With respect to Imperial and Metric dimensional checking it is likely that you may not have the appropriate version of instrument and it costs a lot to double up. However, conversion is easy.

1’ = 25.4mm

30. SUGGESTED TOOL LIST - MOTOR GLIDERS

30.1 SUGGESTED TOOLS & GEAR

- Engineers Hammer
- Quality Metric Ring Spanners.
- Quality Metric Open-ended Spanners.
- Quality Metric Socket set.
- Fine files
- Good Torch & Penlight torch
- Inspection Mirror
- Magnet
- Wire Brush
- Parts Cleaning Brush
- Screw driver set
- Set Instrument Screw drivers
- Allen Key set
- Pin Punch Set
- Brass Punch
- Digital Camera
- Centre Punch
- Pliers – Standard,
- Pliers – Long-nose.
- Pliers, Circlip
- Pliers, Side-cutting.
- Pliers, Crimping
- Wire Stripper
- Strong Magnifying Glass
- Steel Ruler

30.2 SPECIALTY TOOLS

Torque Wrench

Feeler Gauges

Micrometer

Vernier

Magneto Timer

Multi-meter

Test Leads (electrical fault finding).

Safety Tie Wire Pliers

Mixture Adjusting Tool

Spark-plug Spanners

Stanley Knife

Oil Filter Wrench

Hot-air Gun

Soldering Iron or Station.

30.3 SOME RECOMMENDED ITEMS

Cardboard labels (with string to attach).

Permanent Marker pens.

Note book, pens, pencils.

Zip-lock Bags & marker pens

Oil Filter spanner.

Zip Tie selection

30.4 CONSUMABLES

Safety Tie-wire

Heat Shrink

Resin Cored Solder

Thread-lock (Loctite)

Thread Sealant

Thread Tape

Clean Rags.

31. VIBRATION

Vibration is a natural result of generating power and spinning a weight.

The Engine Manufacturer generally has a tight tolerance for balancing the engine which includes matching the Weight of the pistons and Connecting rods in sets. They also have stringent tolerances for the dynamic balancing of the crankshaft.

All of this goes a long way to achieving a smooth running engine however nothing is perfect. While the propeller is statically balanced it also is not perfect and putting the 2 units together can negate errors or enhance them. The relationship of the Propeller mount to the axial position of the Crankshaft also has relevance. Add to this the Cycle of any engine resulting in small changes in Propeller and Crankshaft RPM and Vibration is an inevitable fact. While steps can be taken to reduce vibration, it is inevitable and the results are broad and result in maintenance activities not generally required in an unpowered Glider.

With a Propeller spinning at 2800RPM (typical cruising RPM for a Touring Motor Glider) it will induce pulsing loads on every part of the airframe at 41 Hz. A 2 Stroke Engine at 6000 RPM will induce pulses at 100 Hz. Of course, the intensity of the load will vary and also will be less in a well balanced system but these cycle rates are conducive of Fatigue.

The closest components and structural elements to the Engine and propeller suffer the most and the common result is fatigue cracks occurring in the Cooling Baffles which are usually alloy. Wiring Harnesses suffer as well and a common problem with 2-stroke retractable is failure of the wire entering the ignition coil. A small dob of Silastic at that point goes a long way to slowing that fatigue point failure. In the Slick Magneto there is a blob of Silicone on the wire where it enters the Capacitor for the same reason. Safety tying of fasteners is critical in Motor Gliders. If anything is going to come loose, it will on a Motor Glider due to vibration. It is a constant battle for the Ground Engineer so in all facets of maintenance look for problems from vibration in every system to catch it early.

When repairing or replacing Cooling Baffles eliminate stress riser as much as possible. De- burr Screw and Rivet holes after drilling. Any slits cut need a hole drilled at the end. Cracks need to be hole-stopped before repairing with a riveted patch. Edges of the sheet should be filed and polished with emery to a smooth edge to remove stress risers.

Regardless of the above steps taken to minimise vibration damage most engines will still have certain rpm ranges in which the natural frequency of the crankshaft, propeller, transmission or other crucial components cannot be fully overcome, and it is inadvisable to intentionally operate the engine within these rpm ranges for other than transitional periods. The engine handbook will make note of any such operating limits. Continued operation within these ranges can lead to catastrophic engine or propeller failure and is a fruitful source of transmission belt failure.

Many air cooled two strokes have small rubber ‘spacers’ inserted between the cooling fins to damp out damaging vibrations in the fins which can occur at specific rpm ranges. These spacers must be kept in place. Loss or removal of these spacers will probably result in cooling fin breakage.

Figure 31-1 Badly cracked Baffle on a PIK 20E

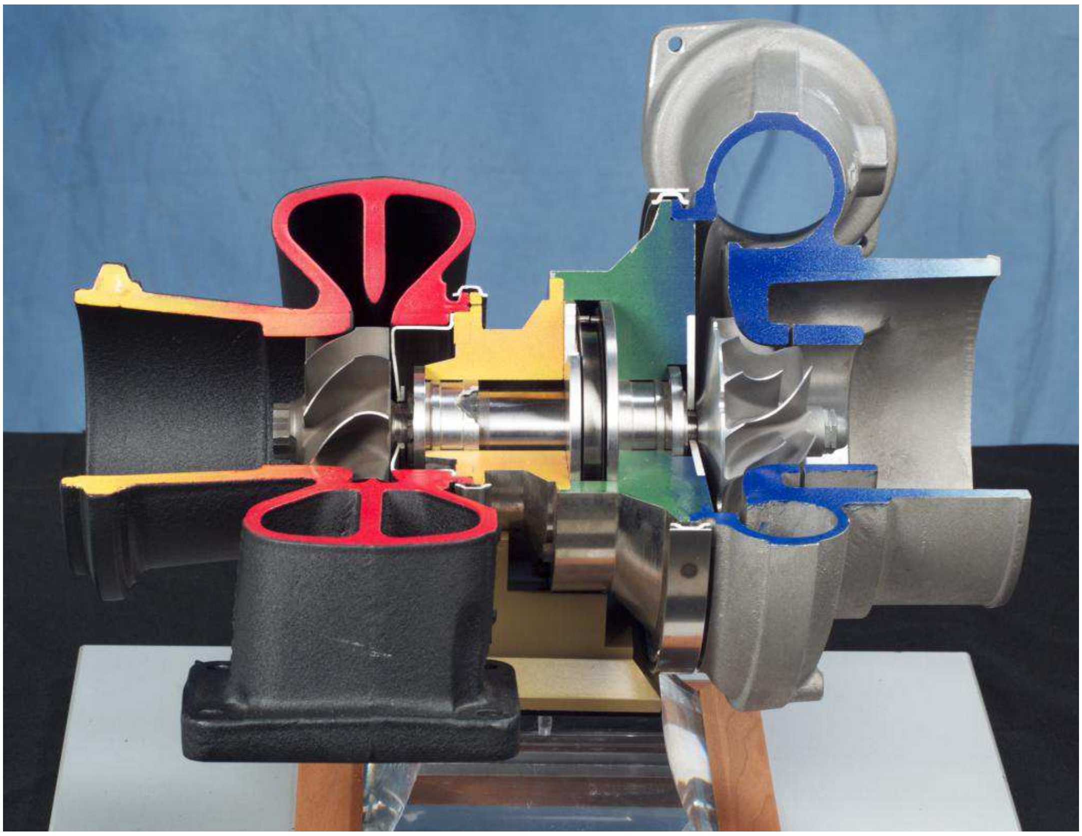
Figure 31-2 Intake Manifold for a Limbach L2000EB1AC Cracked at a weld and in the material where it mounts on the Cylinder Head.

32. TURBOCHARGER PRINCIPALS AND SYSTEM

32.1 INTRODUCTION

The Turbocharger is not dissimilar to a Jet Engine. It has a hot section which houses the Turbine and a cold section housing the Compressor. The Turbine drives the compressor and in an aero engine application the Compressor feeds the engine induction. It can be turned into a simple Jet (though not a very good one) by taking the engine induction out of the arrangement and feeding the Compressor into the Turbine.

The Displacement (Capacity) of an engine is considered at 1 atmosphere, but supplying a pressure higher than 1 atmosphere effectively results in larger displacement from the same engine and thus giving more power.

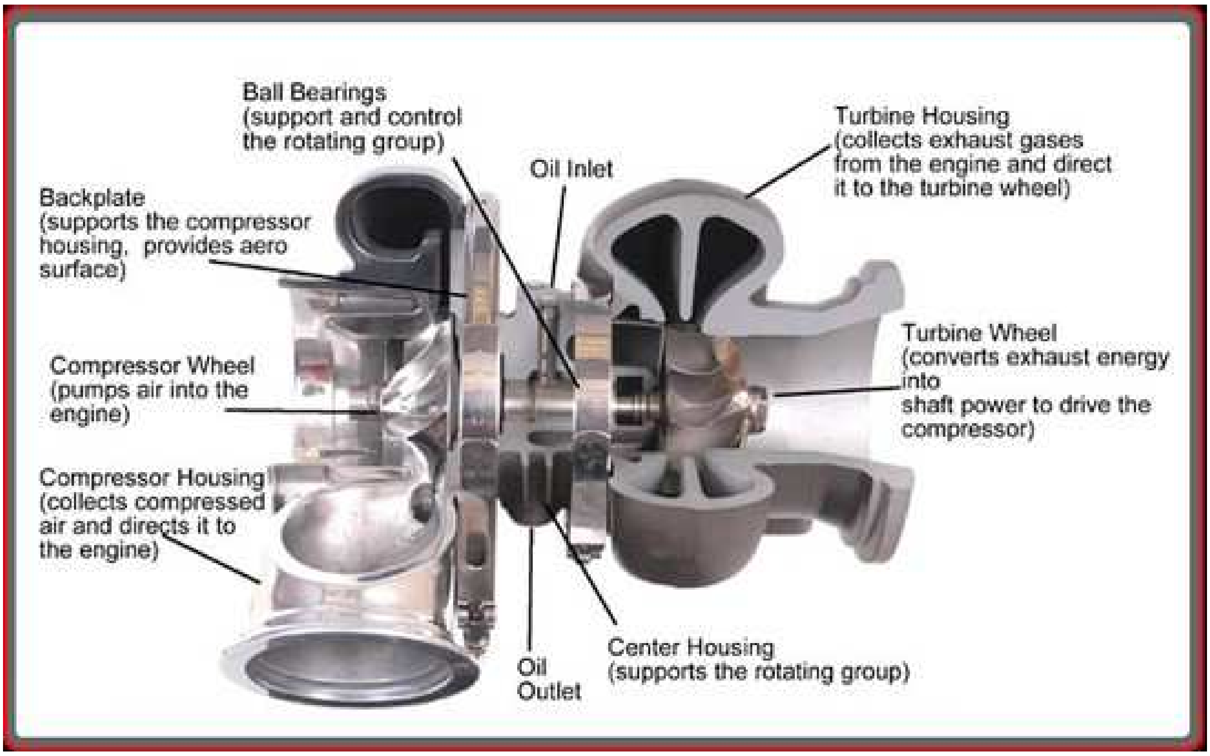


32.2 PRINCIPLE.

The Compressor and turbine rotors are connected by a shaft running on bearings in the body of the unit between the hot and cold sections. The bearings are fed by engine oil for lubrication and cooling. Seals on the outer side of the bearings hold the oil in the chamber.

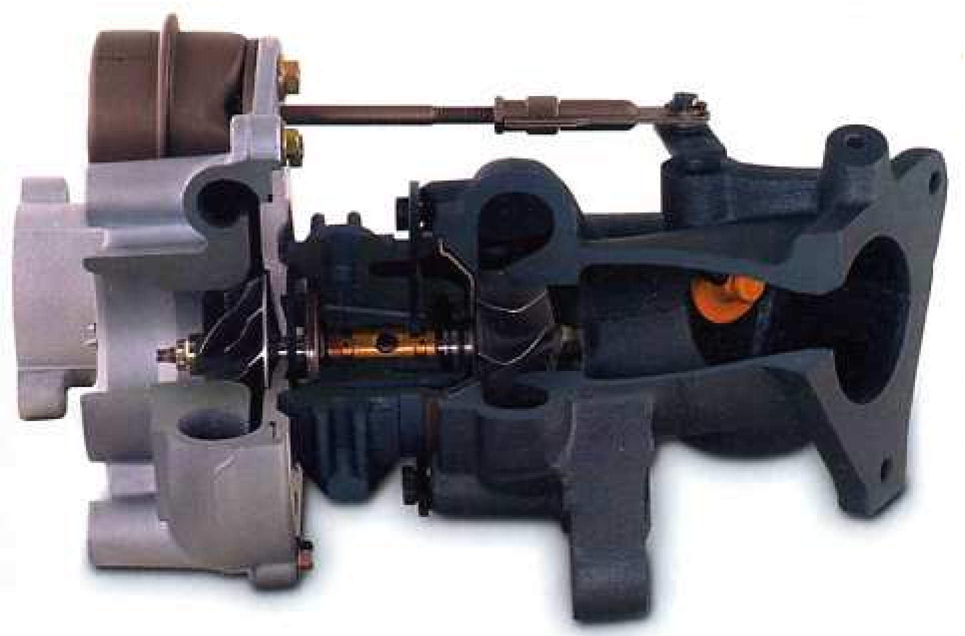
With exhaust gas flowing through the Turbine it then spins at high speed driving the Compressor Rotor which then pressurises the Intake Manifold. This is a closed loop self-generating system and thus the more power the more exhaust gas so the more manifold pressure until an equilibrium is obtained. The positive Manifold pressure is known as Boost.

In an aircraft, to achieve good performance of the engine at higher altitude, a larger turbocharger than needed at sea level is used. This of course means that excessive boost will be generated at lower altitudes so a control is needed. This control is in the form of a valve which can be opened to regulate the boost pressure. The appropriately named Waste Gate is a valve which allows exhaust gas to exit directly through the exhaust system bypassing the Turbine. This then lowers the turbine rpm and reduces the Boost as required.



32.3 SYSTEMS

There are two common systems of waste gate control. A purely mechanical system uses a diaphragm or piston driven by boost pressure to operate a lever driving the waste Gate. Alternatively, the waste gate can be spring loaded closed so the pressure is controlled by the setting of the spring tension applied. Both methods are designed to supply a fixed boost pressure and are generally NOT altitude compensating.



32.4 TURBOCHARGER WITH MECHANICALLY CONTROLLED WASTE GATE

There is currently only one type of Turbocharged Engine operating in Motor Gliders in Australia and that is the Rotax Engine. The Waist Gate System in the Rotax is Electronic. The Waist Gate is operated by an Electric Servo Motor. The Servo Motor is controlled by the ECM (Engine Control System) which uses sensitive pressure transducers (sensors) to measure both Manifold and Static Atmospheric Pressure. With these the ECM considers Altitude Density and can set the Waste Gate to give the same absolute manifold pressure at 10,000 feet as you would get at Sea Level. This method of waste gate control is altitude compensating, thus the engine can produce virtually the same power at altitude as at sea level

Absolute pressure is actual pressure, not relative (to atmosphere).

33. ENGINE RETRACTION SYSTEMS.

33.1 WHERE IT STARTED

In 1935, an occasional or auxiliary motor that could be retracted was suggested by Sir John Carden, an English tank and vehicle designer.

The first motorglider to be built was a variant of the British Abbott-Baynes Scud III, called a Carden-Baynes Auxiliary.

Carden had selected a 250 cc single-cylinder, air-cooled two-stroke Villiers motorcycle engine. He encouraged Villiers to persuade this engine to run inverted, in order to put the propeller line to the top of the mounting and thus minimise air resistance. This proved satisfactory, and many hours of testing with the cowling in place and at full throttle showed there were no overheating problems. A small fuel tank was fixed above the crankcase, at the top of the engine. Carden also designed the engine mounting that enabled the engine and its propeller to be swung out of its housing and into action. The engine was hung to the top of the pylon bulkhead, just ahead of the trailing edge, on a diagonally cross-braced pair of tubes from the hinge to the crankcase and with V-tubes to the cylinder head.

In use the engine and propeller were vertical, the latter having a small diameter to clear the lips of the open top of the fuselage. The engine was held in position by a diagonal longitudinal member attached to a nut on a screw thread which could be rotated with a crank in the cockpit. As the lower end of this member moved forward, the engine rotated into the horizontal position, its fairing closing the fuselage opening. The propeller was indexed to stop in a vertical position and its lower tip moved forward on retraction into a slot in the bulkhead, whilst the other blade pressed on a lever that caused hinged fairing doors, previously held open with springs, to close over it. With the engine retracted, the rear of the pylon was as smoothly faired as on any conventional sailplane.

One other unusual and possibly unique feature of the Auxiliary was that it had a secondary throttle on the port wing tip, so that the pilot could easily taxi the aircraft whilst supporting the wing.[1]

[1] Wikipedia

33.2 RETRACTABLE ENGINES TODAY

These days many new gliders straight from the factory have engines or the ability to add an engine.

Most retractable engine sailplanes flying today were initially designed as sailplanes. In the case of a self-launcher, or sustainer engined sailplane, the power plant was added to an existing sailplane airframe. This requires fuselage modifications including installation of engine mounting hard points, a fuel tank, a retraction system, a more robust electrical system and an engine/pylon control system.

The types of engines are typically 2-stroke, rotary, jet or (increasingly) electric. Some engines will self-launch and some are sustainers. Details of these engine types are discussed elsewhere. This section deals with the retraction mechanism.

Most retractable engine systems are driven electrically but some of the older gliders such as the SF27M have mechanical extension and retraction.

33.3 PARTS OF THE RETRACTION SYSTEM

The aim of these designs is to get the propeller (or jet) into the airflow to provide propulsion when it is needed and out of sight when it is not - to add no penalty (except additional weight) to the performance as a glider.

33.4 DRIVE SYSTEM

Generally, a drive system is needed to rotate the propeller into the airflow, doors to cover the propeller when it is not in use, and a method of arresting the forward motion of the engine

The SF27M mechanism operates via a handle which rotates about 3 ½ turns. The engine is driven up and down by a chain, similar to a bike chain.

Figure 33-1 SF27M Engine extended

Figure 33-2 Chain drive of the SF27M connected to the mechanical handle

Modern electric extension/retraction systems often use a spindle drive.

It is important for the limit switches to be set properly - so the engine management system knows when the engine is safely up to start. If the engine is not where it should be, the propeller may not have adequate clearance, or other parts of the engine may be damaged by conflicting items.

In the Nimbus 4DM, the limit switches are standard mechanical micro switches.

Figure 33-3 Nimbus 4DM Spindle Drive

The instructions for setting up the limit switches in the Nimbus are shown below.

Nimbus-4DM MAINTENANCE MANUAL

5.7 Adjusting pylon limit switches and engine doors

Configuration "pylon extended":

- Extend pylon until arresting wire is taut, then
- retract it by about 10 to 15 mm (0.4 - 0.6 in.) measured at the arresting cable.
- Loosen limit switch mount and move micro limit switch such that the green signal "pylon extended" comes on.
- Tighten limit switch mount.

  Note: Power on, the thrust of the propeller will pull the arresting wire taut, while the spindle drive is softly supported by rubber vibration isolators.

Configuration "pylon retracted":

- Disconnect actuating rod from doors of engine compartment.
- Retract pylon until it rests firmly on the bulkhead inside the engine compartment.
- Detach rubber boot from fire wall and move micro limit switch such (with limit switch mount loosened) that the green signal "pylon retracted" comes on.
- Tighten limit switch mount and re-attach rubber boot.
- Re-connect actuating rod to engine doors.

33.5 ARRESTING WIRE

An Arresting wire is usually fitted to prevent or arrest the engine forward movement.

33.6 ENGINE BAY DOORS.

These are operated automatically as the engine extends and retracts.

Figure 33-4 The arresting wire and engine doors can be seen.

33.7 EXCEPTIONS

A special case of a retraction system is the Stemme Motorglider.

The 4-stroke engine is embedded in the tail-boom, back behind the pilot. The propeller is driven by a carbon drive shaft. The propeller blades fold like blades on a pocket knife and the nose cone is manually retracted to cover them for soaring flight.

Now you see it…..

……….…now you don't.

34. HIERARCHY – REFERENCE MATERIAL

34.1 INTRODUCTION

The reference material associated with the operation, maintenance and repair of sailplanes, including Motor Gliders, must be ***approved*** and ***be current***. These Notes describe the hierarchy of approval for reference material associated with the operation and maintenance of motor gliders, with a particular emphasis on the engine and engine components.

34.2 HIERARCHY OF INFORMATION

In the order of applicability, the following is a hierarchical list of applicability;

a. Sailplane or Component Manufacturer - for airframe, Control Systems, etc - Type Certificate, Flight Ops Manual, Maintenance and Repair Manual

b. Engine Manufacturer – for Engine, Engine Controls and auxiliary systems.

c. Regulator, Country of Origin, ie EASA

d. Regulator, Country of Operation, ie GFA.

e. Regulator, Country of Origin, ie CASA.

34.3 MAINTENANCE INFORMATION

For a modern sailplane, Maintenance information is likely to be found in the Maintenance Manual and, to a lesser degree, in the Flight Manual. The sailplane manufacturer may include specific instructions associated with various components as supplements to the Maintenance Manual.

All this information is likely to be ‘controlled’ under a *Document Control System*, whereby it is necessary to ensure the most current document is being accessed.

For older sailplanes, a *Document Control System* may not exist (or have existed) and the most current information is likely to be the original ***Maintenance Manual*** and GFA AD’s.

35. NUTS, BOLTS & HARDWARE NOTES

Refer to BSE for basic information on hardware for gliders. Note in engines:

a. NO NYLOC NUTS IN HOT AREAS OR ON HOT COMPONENTS.

b. RUBBER MOUNTS ON ENGINE

c. COPPER NUTS IN EXHAUST SYSTEMS

36. GLOSSARY OF ABBREVIATIONS AND TERMS

AC	Alternating Current
CTO	Chief Technical Officer (Airworthiness)
DC	Direct current
DI	Daily Inspection.
EASA	European Aviation Safety Agency
ERSA	En-Route Supplement, Australia, an Airservices document listing full information, including layout diagrams, on all licensed (and some unlicensed) aerodromes.
FAI	Federation Aeronautique Internationale.
GFA	Gliding Federation of Australia.
GFA Operations Manual	This manual comprises a copy of: 1. CAO 95.4, the Order under which GFA exercises specified exemptions from the CARs and CASRs; 2. the GFA Operational Regulations, those GFA procedures which are required to be approved by CASA; and 3. MOSP 2 - Operations, a document approved by the GFA Board specifying the normal operational procedures of the GFA. The GFA Operational Regulations are numbered from Sections 1 to 7 (plus Appendices) and the Manual of Standard Procedures follows from Section 8 onwards. When using this Manual for guidance, it may be necessary to refer to both sections and possibly to the CAO.
HF	High Frequency.
HPa	Hectopascals, the unit of pressure set on an altimeter sub-scale.
JAR-22	Joint Airworthiness Requirements, Section 22 (Gliders).
IAS	Indicated Air Speed.
Km	Kilometre.
Mode C	Another operating mode of a transponder, in which altitude-encoded information is added to the unique code already being transmitted.
MOSP	Manual of Standard Procedures (this document).
MR	Maintenance Release.
NM	Nautical Mile.
NOTAM	Notice to Air Men, a document issued by Airservices to provide operational information to pilots which supersedes that available in other publications.
QFE	Altimeter setting in which the altimeter will read zero with the glider on the ground.
QNH	Altimeter setting in which the altimeter will read the field's elevation above sea level with the glider on the ground.
REPCON	ATSB Confidential Reporting Scheme.
RM Plan	Risk Management Plan which provides a structured way of identifying and analysing potential risks, and devising and implementing responses appropriate to their impact.
RM/O	Regional Manager, Operations.
RPM	Revolutions Per Minute
RTO/A	Regional Technical Officer, Airworthiness.
SDS	Safety Data Sheet
TAS	True Air Speed.
TBO	Time Between Overalls
TDC	Top Dead Centre
UHF	Ultra High frequency.
V	Volts
VFR	Visual Flight Rules.
VHF	Very High Frequency.

37. ANNEX A: EXAMPLE MAINTENANCE SCHEDULE

The following is an example maintenance schedule for airframe and engine:

A.1.1

	INSPECTION CHECKLIST FOR 50-100-500 HOUR INSPECTIONS:	50	100	500
	A. Powerplant:			
1	Start engine and run until temperatures are in green range. Shut down engine.	X	X	X
2	Remove engine outlet air grill and clean	X	X	X
3	Inspect grill and engine cowling for security and damage.	X	X	X
4	Remove wiring from spark plug tips and remove spark plugs	X	X	X
5	Perform compression test on all 4 cylinders (differential press. check). Nr. 1: .... Nr. 2 .... Nr. 3: .... Nr. 4:	X	X	X
6	Remove sump plug and drain engine oil	X	X	X
7	Check oil screen for metal particles, wash oil screen in solvent bath and dry.	X	X	X
8	Oil temperature, oil pressure fittings, check for security and oil seepage	X	X	X
9	Clean oil cooler and check for security and leaks.	X	X	X
10	Replace sump plug, re-fill engine with 2.5 ltr. oil	X	X	X
11	Clean engine (solvent or degreaser)	X	X	X
12	Check valve clearance (cold), replace cylinder head valve gaskets.	X	X	X
13	Remove air filter and clean by compressed air. Blow air from inner surface to outer surface	X	X	
14	Replace air filter element with new element			X
15	Check fuel lines from carburettor, fuel pump and fuel filter for security and damage.	X	X	X
16	Replace fuel filter element with new element	X	X	X
17	Replace float needle in carburettor			X
18	Clean filter in engine driven fuel pump		X	X
19	Drain fuel, remove finger filter and check for dirt and condition. Look also Pos. 11 and 14 (Fuselage)			X
20	Check carburettor membranes		X	X
21	Check flapper valve play in carburettor throat. If play exceeds 0.8 mm. repair by bushing or replace.			X
22	Check oil level in carburettor dome. Add original 'Zenith lube oil' if necessary.	X	X	X
23	Check carburettor, choke, heater and air bowden flex cables for ease of movement. Lubricate if necessary with light oil	X	X	X
24	Check engine mounting bolts and Silent blocks for security, safety and damage.	X	X	X
25	Check V-wire brace beneath engine for security. If cables are loose, re-tighten.		X	X
26	Check Generator belt for security and condition. Replaced frayed belt.	X	X	X
27	Check ignition timing (Refer to Limbach handbook)		X	X
28	Inspect magneto points. Replace if worn.			X
29	Check ignition harness for security, abrasion and porosity. Replace cracked or damaged harness.	X	X	X
30	Electrical and connectors and. battery, check for security, damage and corrosion.	X	X	X
31	Clean spark plugs and reset gap (0.4 mm). Replace plugs after 200 Engine hours.	X	X	X
32	Check exhaust system for blow by, cracks and security.	X	X	X
33	Remove heater shroud and check for cracks, hot spots, corrosion and damage	X	X	X
34	Check engine case for oil seepage or cracks		X	X
35	Check engine breather for blockage. If blocked, remove and clean.	X	X	X
36	Check cylinder air baffles for security and condition.	X	X	X
37	Check firewall for security and, where bulkhead fittings pass thru, for sealing.	X	X	X
38	Check combining hose between carburettors for security and porosity.	X	X	X
39	Check battery for damage and security. Check water/acid level. If low add distilled water.	X	X	X

**** WARNING : This checklist is an example only. Not for operational use ****

	INSPECTION CHECKLIST FOR 50-100-500 HOUR INSPECTIONS:	50	100	500
	B. Propeller:	X	X	X
1	Remove propeller spinner and check for condition.	X	X	X
2	Inspect the four thrust rods for condition, grease rods and mating surface of plate with Calypsol H 442 or equivalent grease.	X	X	X
3	Check propeller blades for installation and security. Check function of pitch change system.	X	X	X
4	Check pitch stops for ease of function.	X	X	X
5	Check pitch change lever for security and function.	X	X	X
6	Check prop flange bolts with torque wrench. Prop flange nuts should not turn with 45 Nm force.	X	X	X
7	Check propeller blade cuff for cracks. If cracks are longer than 0.1 mm wide, notify manufacturer.	X	X	X
8	Check propeller blade paint and leading edge shield for cracks 90* to blade length. If such cracks exist, notify manufacturer.	X	X	X
9	Check leading edge shield for 900 cracks, security and condition. Such damage, including de-bonding or separation should be reported immediately to manufacturer.		X	X
	C. Cockpit area:	X	X	X
1	Check cockpit canopy for security and damage, frame and latching unit for function.	X	X	X
2	Check seat belts for security and damage. Check mounting/attaching bolts for security.	X	X	X
3	Check trim unit for damage and function.	X	X	X
4	Check rudder pedals for security, free movement and function. Should the occasion arise, lubricate.	X	X	X
5	Check control stick for freedom of movement and function. Check 0-position in reference to ailerons.	X	X	X
6	Check airbrake lever for function and positioning. Check wheel brakes for function when airbrake lever is in full up.1	X	X	X
7	Check that installed replaceable fuses have the proper Amp. rating.	X	X	X
8	Check instrument markings for legibility.	X	X	X
9	Check all control knobs and handles for security and proper colour coding.	X	X	X
10	ck all switches, circuit breakers, instruments and fuel shut-off valve for security and function.	X	X	X
11	ck seat adjustment unit for condition and security.	X	X	X
12	ck safety on main bolts for security	X	X	X
13	ck main bolts for smoothness of operation. Should bolts bind, check for burrs and lubricate.	X	X	X
	D. Fuselage:	X	X	X
1	Check exterior skin of aircraft for security and damage.	X	X	X
2	Check ailerons for function and security.	X	X	X
3	Check aileron outboard controls (thru plastic window) for function and security.	X	X	X
4	Check airbrakes for proper seat and safeties.	X	X	X
5	Remove horizontal stabilizer assy. and check mounting fittings for security and corrosion. Check rod end bearings for cracks	X	X	X
6	Check elevator attachments for function and security	X	X	X
7	Check elevator drive for function, security and corrosion.	X	X	X
8	Check rudder mounts and cables for function and security.			
9	Check tail wheel for function and security. Check tire for tread wear and proper inflation.	X	X	X
10	Remove rudder and lubricate hinge bushings. Drain static pitot system from water.			X
11	Remove baggage compartment floor. Check: Rudder cables, rudder cable drive Aileron bellcranks Airbrake drive. Check all above for function, security and corrosion.		X	X

A.1.2

**** WARNING : This checklist is an example only. Not for operational use ****

12	Remove baggage compartment panel on aft bulkhead. Inspect the following: Control cables Turnbuckles and springs in tail wheel steering Check all above for function, security and corrosion.		X	X
13	Check brake fluid reservoir for security and proper fluid level	X	X	X
14	Check fuel lines and tank assy. for security and leaks.		X	X
15	Check static ground wires and outboard installed electrical units, i.e. Lights for function and security.		X	X
16	Check pitot static, TEK nozzle and antenna units for condition and security.	X	X	X
17	Check moisture drain holes and vents for stoppages	X	X	X
18	Check placards and markings.	X	X	X
19	Remove wings and check airbrake drive-lubricate	X	X	X
20	Check aileron drive in butt rib-wing/fuselage for function-lubricate	X	X	X
21	Lubricate remaining points in lube diagram.	X	X	X
22	Re-install wings.	X	X	X
	E. Landing Gear	X	X	X
1	Check landing gear for cracks, un-bonding or deformity	X	X	X
2	Check landing gear mounting bracket for proper seating	X	X	X
3	Check brake pucks for condition and wear.	X	X	X
4	Check tires for condition, check tire tread for cuts, abrasion and porosity.	X	X	X
5	Check tire pressure.	X	X	X
6	Check wheels, especially rim bead for cracks or damage	X	X	X
7	Check brake lines for security and condition	X	X	X
8	Check brake lines for security and condition	X	X	X
	F. General	X	X	X
1	Check manufacturers service bulletins for compliance as required.	X	X	X
2	Check ad notes for compliance.	X	X	X
3	Perform test flight for completion of inspection.	X	X	X

NOTES

Motor glider X-XX, Reg. Nr. ___________ has had a 50/100/500 hour inspection performed in accordance with this checklist.

Total time airframe:

Total time engine:

Date __________________ Mechanic's signature ______________________

**** WARNING : This checklist is an example only. Not for operational use ****