BRITISH MODEL FLYING ASSOCIATION

Code of Practice for the Operation of Gas Turbines and Gas Turbine Powered Model Aircraft.

Available free of charge from the BMFA

Issue 4 (Draft 04 - Provisional) Jan 2023

Introduction

Code of Practice for the Operation of Gas Turbines and Gas Turbine Powered Model Aircraft.

Definitions

Persons complying with the requirements of the Code must be aware that throughout the Code there are certain words which have specific meanings, defined as follows:-

must - Indicates an absolute obligation to comply. There are no circumstances under which the requirement could be relaxed.

should / strongly recommended - Indicates an obligation to comply so far as is practicable but allows a relaxation of the requirement under exceptional circumstances. There has to be a very good reason why the requirement is not complied with.

may / highly recommended - Indicates a preferred course of action, based on collective experience. Non-compliance is not expected to result in an unsafe situation.

Preface

Gas turbine engines and model aircraft powered by them share many of the safety issues of conventional model power-plants and aircraft. Those embarking upon the construction of a gas turbine or model aircraft powered by such an engine should first make themselves familiar with conventional model aircraft power-plant safety issues, as detailed in (for example) the BMFA members handbook. Specific safety issues relating to gas turbine aircraft in particular are as follows: -

a. Danger of burns or damage caused by hot exhaust gases.

b. Danger of fire, after a crash, ignited by hot components and made more serious by the relatively high fuel loads commonly carried.

c. Danger of fire caused by overheating as a result of poor start-up procedures or engine failure.

e. Dangers relating to the relatively large size, power and wing loading of many (but not all) turbine powered aircraft. These dangers are of course shared with many other large, powerful models.

f. Problems of ground handling relating to the relatively high idle thrust of some engines.

γ. Risk of injury caused by engine parts, which may be ejected at high velocity in event of an engine failure.

h. Risk of hearing damage to persons in either close proximity to operating engines or present for prolonged time periods.

i. Risk of the ingestion of body extremities (fingers, long hair) and loose clothing though the engine intake when a gas turbine is running.

To prevent or minimise risk from all of these possibilities there are five approaches.

i. Ensure that operators and remote pilots have a high level of skill, knowledge, and experience to enable them to avoid dangerous situations.

ii. Ensure that failures and incidents happen as infrequently as possible by paying detailed attention to reliability issues and by careful, systematic design procedures, operational procedures and maintenance.

iii. Provide fail safe and cut-off mechanisms whenever practicable to ensure that most failures follow a “low risk” path.

iv. Pay attention to where and when aircraft are flown (or engines are operated) to ensure the safety of people, property and the environment.

v. Ensure anyone in close proximity to a running gas turbine wears appropriate clothing and safety protection equipment - e.g. tight fitting garments and ear defenders.

The total safety approach is a compromise between each of these factors, although (iv) remains the most critical.

Additional guidance on the safety issues specific to particular gas turbine arrangements are included in Appendix 2

Issue 1, Jan 2008 - Original Text with amended B.2.2.2 to clarify failsafe operation

Issue 2, May 2009 - Replace references to “event organiser” with “Flight Line Controller”. Appendix 1 (Flight Line Layout) added.

Issue 3, May 2010 - 2009 Text with minor amendments

Issue 4, Jan 2023 - Updated in line with current best practice and changes to CAA requirements. Review undertaken by RC Power Technical Committee, Gas Turbine Builders Association and Jet Modellers Association.

Code of Practice for the Operation of Gas Turbines and Gas Turbine Powered Model Aircraft.

The guidance given in this document has been distilled from the Gas Turbine Builders Association (GTBA) ‘Code of Practice for the Safe Operation of Model Gas Turbines’ and the Jet Modellers Association (JMA) ‘Flying Event Safety Rules’. It is presented to provide a document relevant to the needs of individuals and groups (such as model flying clubs), who may not be associated with the GTBA nor JMA, who are the recognised specialist bodies for Gas Turbine operation within the BMFA..

GTBA members by association are required to abide by the guidance set out in the GTBA ‘Code of Practice for the Safe Operation of Model Gas Turbines’. JMA members similarly are required to abide by the guidance set out in the JMA ‘Flying Event Safety Rules’ and any specific arrangements associated with the site in use.

Article reference numbers in this document are cross-referenced in Appendix 3 to the respective GTBA and JMA documents from which these articles have been derived. Topics are presented here in a logical order for the achievement of safe and competent operation of gas turbines and gas turbine powered model aircraft.

Individuals or groups flying gas turbine model aircraft are encouraged to adopt the terminology, principles and flying site layouts (where practical), set out in this document, in order to become familiar with those guidelines, so that, should an individual or group progress to participation in Events, Displays and/or Competitions, they will be more readily familiar with the requirements relevant to such events.

At club level any roles such as Flight Line Controller, as mentioned in this document, should be undertaken by the club's Safety Officer or another designated club official, acting under club rules.

On any particular occasion, when none of these individuals are present, it is acceptable for the remote pilot to take on these responsibilities provided that:

a) He has the consent of all other club members present.

b) He acts in accordance with these guidelines and with any rules or standard practices that have previously been laid down by the relevant club officials.

For example, given a particular wind direction, the remote pilot might choose a suitable start-up area and taxi point from a small number of options that have previously been defined by the club safety officer.

Builders of homebuilt gas turbines or engine control units (ECU) are strongly recommended to refer to the GTBA Code of Practice for the Safe Operation of Model Gas Turbines, which can be seen at :

http://www.gtba.co.uk/

Organisers of model jet flying events are strongly recommended to seek the advice of the Jet Modellers Association. Contact details can be found at:

https://jmajets.bmfa.uk/

Individuals keen to learn more about the safe design, construction and operation of model gas turbine engines are highly recommended to join the GTBA. Joining information can also be found at http://www.gtba.co.uk/ and then click on the ‘Apply for Membership’ tab.

Individuals interested in further developing their flying skills of gas turbine powered model aircraft are highly recommended to join the JMA. Joining information and event details can be found at http://jmajets.bmfa.uk

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A. Gas Turbine Operators / Remote Pilots Responsibilities

A.1 Manufacturer's or designer's operating instructions must be followed at all times.

A.2 Inexperienced gas turbine operators should, wherever possible, seek the assistance of an experienced gas turbine operator before running a gas turbine. **If in doubt - seek help**.

A.3 In order that the operator / remote pilot shall gain experience with the start-up procedure and the running characteristics of the engine, initial runs of any gas turbine must be carried out on a test stand. The operator / remote pilot must not attempt any operation of the engine in public until such experience has been gained.

A.4 Operators and Remote Pilots in the UK must comply with the requirements of the Civil Aviation Authority publication CAP 722F “Model Aircraft Operations Policy and Guidance”.

British Model Flying Association and British Drone Flyers members may alternatively comply with the CAA issued Article 16 Authorisation “A guide to model aircraft & drone flying” but in so doing must also abide by the requirements set out in the current issue of the BMFA Members Handbook.

NOTE:- you cannot operate under both CAP 722F and Article 16 Authorisation in any one flight.

A.5 Persons supervising gas turbine flying activities should be experienced to a standard of, or equivalent to the BMFA Power Achievement Scheme 'B' Certificate.

Gas turbine operation requires that operators / remote pilots must be aware of the flying characteristics that arise from the application of gas turbine power. Paying particular attention to: -

- The delay in response to opening and closing the throttle.
- The high airspeeds that can result from the high velocity thrust generated by a gas turbine engine. Note, this thrust does not decrease with increasing model aircraft airspeed which is common on propeller driven models.
- The high thrust at engine idle speed, which makes for difficulties in slowing the aircraft down for landing.

A.6 The Remote Pilot of an aircraft is that person who is operating the radio control transmitter whilst an aircraft is being prepared for or undertaking flight.

A.7 The ultimate responsibility for the safe operation of a model aircraft rests with the Remote Pilot.

A.8 All Remote Pilots are expected to be competent in the operation of their aircraft. If an Event Organiser, Flight Line Controller and/or Flight Line Safety Officer determines that a Remote Pilot is not competent, it is expected that the pilot will not be allowed to continue with the flight.

A.9 Any Pilot determined to be suffering from the effects of Alcohol or Drug abuse must not be allowed to fly.

A10 All turbine powered models must be of sound construction throughout the airframe, as should the power plant and ancillary equipment within. It is highly recommended that “Best Practice” be employed at all stages of any build and installation.

B. Gas Turbine Protection and Control

B.1 Start up and static running

Where engines are being run statically, on a test bench or during start up procedures in a model aircraft, boat or vehicle, a manual fuel shutoff mechanism must be provided. This mechanism may take any suitable form, such as a fuel valve or electrical switch to cut power to the pump, but must be independent of the normal throttle control. Gas turbine manufacturers instructions should be followed in detail and the fuel shut off mechanism located as advised accordingly. Where no manufacturers guidance exists it is advised that where a fuel valve is used in a liquid fuel system, it should be located in the low-pressure part of the fuel line, between the tank and the pump. In a self-pressurised (gaseous fuelled engine) system it should be located as close as possible to the engine to ensure a rapid shutdown.

B.2 Operation under remote control,

The following paragraphs apply only to engines that are operated remotely, such that the manual control referred to in B.1 above is inaccessible.

B.2.1 Shutdown mechanisms.

The engine control function must include an independent fuel shut off device in addition to that operated by the throttle channel. I.e. a shut off device in addition to the servo operating the valve in gaseous fuelled engines, or the pump speed controller in liquid fuelled engines.

The fuel shut off device could be a solenoid valve or a servo operated valve in the fuel line, in which case the considerations in regard of positioning given in B.1 above should apply.

Alternatively a relay, servo operated switch or additional transistor in the pump circuit may be used. Electronic Engine Control Units (ECUs), that include outputs controlling fuel solenoid valves, should meet this requirement.

B.2.2 Failsafe operation

"Failsafe" device refers to any equipment or facility associated with the radio control system that is activated by the loss of radio signal or interference to the signal. It is common for a failsafe state to become operational after a short delay (1-2 seconds) The shut down delay is specifically intended to overcome possible transient signal disruption.

B.2.2.1 Flying Gas turbine powered models must incorporate a radio failsafe which is capable of preventing the aircraft from leaving the area in which it is being flown. This can be achieved in a number of ways to be determined by the Remote Pilot dependant of the type of aircraft, local conditions and flying site rules. In any case the minimum requirement of the failsafe function will be to reduce the engine speed to its preset idle position. For aircraft such as gliders or other models with low wing loading where sustained flight is likely even at idle, it is strongly advised that additional measures are taken such as deployment of airbrakes or similar.

B.2.2.2 Due to the high fuel load and the fact that gas turbine engines have a continuously lit flame in the combustion chamber when operating, there is a risk of fire in the event that a model aircraft crashes. Therefore: -.

If the engine is set to idle on initial failsafe then consideration should be given to it remaining at that preset for some considerable time. The Remote Pilot should consider the consequences of this and determine if a second stage of failsafe preset is required which will stop the engine completely after a short time if signal loss is maintained (1 to 2 seconds).

It is not unusual for preset failsafe requirements to differ across flying sites and is often related to local conditions at different times of year (dry crops or grass for example). It is important that the Remote Pilot has the knowledge to change the failsafe preset to satisfy the requirements of the site and the briefing of the relevant Safety Officer or Flight Line controller who may specify a different failsafe state or time delay.

Correct failsafe operation is an obligation for the Operator / Remote Pilot of all turbine powered craft. The Remote Pilot must also satisfy himself that any flight can safely be made. A full list of considerations is given in the BMFA safety Codes for general flying.

B.2.2.3 The failsafe mechanism must be correctly programmed and tested to ensure correct operation. This is particularly important where additional power management systems are utilised as it is often required to teach these units the failsafe preset in addition to any radio receiver. Where both fuel cut-off mechanisms are operated by a single control unit, e.g. an ECU, then this unit should be configured so that an internal failure will activate at least one of the shut off mechanisms.

B.2.2.4 It is the responsibility of the Remote Pilot to demonstrate these functions upon request if required. Responsibility for correct operation of failsafes cannot be delegated to an unassociated individual such as a club safety officer or flight line controller.

B.2.2.5 The Remote Pilot should check the settings and operation of failsafe devices prior to each flying session, as well as after any changes made to the remote control system (e.g. re-binding), to confirm compliance with these rules.

B.2.3 Emergency Shutdown

Radio transmitters used for the control of gas turbine powered models should incorporate a control that will instantly shut the engine down when operated. This control should be easily accessible. Consideration should be given to an operational kill switch which is independent of the transmitter throttle control and also the implications of inadvertent operation of said switch. It may be desirable to install a fence or guard around or over the switch, to prevent inadvertent activation which may potentially lead to a dangerous situation arising.

C. Fuel Systems

C.1 Where possible fuel tank(s) should be located in a separate compartment from the engine. The tank(s) must be protected from the heat of the engine.

C.2 The fuel tank(s) and fuel system components must be adequately secured and protected to minimise the risk of movement or rupture in the event of a crash.

C.3 Flexible fuel tanks, including plasma bags, should only be used where it is impractical to use any alternative form of fuel tank. If such tanks are used, they shall be placed in a separate compartment, or protective ‘shell’, the construction of which shall not compromise the integrity of the tank, and be leak-proof and be fitted with a drain to route any spilled fuel overboard.

C.4 Fuel lines, connectors and associated equipment must be tested to show the ability to withstand the pressure imposed without leakage or failure when the engine is operating at maximum safe speed. A drainage hole should be made in every part of the model where fuel could collect as a result of a leak.

C.5 Fuel lines and associated equipment must be of a suitable quality material and where appropriate tested to determine suitability for the intended service and the environmental conditions of the installation. For example, silicon tubing must not be used for fuel lines, because it rapidly degrades when in contact with kerosene (jet fuel).

C.6 Separate feed lines for starting gas and liquid fuel should be used to avoid the dangers of migration of the starter gas back into the liquid fuel system.

C.7 The fuel tanks of liquid fuelled engines should not be subjected to any form of high pressure pressurisation. Low pressure pressurisation is permitted, in systems of a suitable pressure rating, up to a maximum of 5 psi (0.35 bar) for the purpose of aiding fuel movement between tanks and to the fuel pump(s).

C.8 Tanks for gaseous fuel are pressure vessels and must be certified as such.

C.9 All tanks and fuel lines should be regularly checked for deterioration and renewed where necessary, paying particular attention to the possibility of hardening of flexible pipes and seals in the vicinity of joints that are subjected to high pressures.

C.10 Only clean, filtered fuel should be used and measures taken to prevent contamination of fuel systems. It is strongly recommended that fuel be filtered when filling the storage vessel. Filters should also fitted between the storage vessel and model's tank, as well as between the model's tank and the engine.

C.11 The lubricating oil content of the fuel must be as specified by the designer or manufacturer.

C.12 An appropriate lubricating oil suitable for use in gas turbines should be used. Special oils, designed for full size gas turbine operation, may contain hazardous chemicals such as organophosphates. Given suitable precautions to avoid skin contact and the breathing of vapours these oils can be used safely. However, non-toxic alternatives such as Mobil DTE Light are available and used successfully in model gas turbines. Many operators may prefer to use these non-toxic oils because of their environmentally friendlier properties. If you are in any doubt as to the suitability of these oils for your particular engine, you are advised to consult the designer or manufacturer.

D. Gas Turbine Installation

D.1 Engines must be securely mounted and attached in a manner to ensure that they remain so for all operating regimes.

D.2 All components, such as pipes, lines, wires and control cables etc, anywhere in the vicinity of the engine intake must be adequately secured to prevent ingestion.

D.3 Model gas turbine engines induce a significant volume of air when operating and can be considered likened to a vacuum cleaner, sucking in any loose objects in the vicinity. Gas turbine engines should therefore be protected from Foreign Object Damage (FOD) by suitable screens or by virtue of the position of the air intake(s).

D.4 Pipes, lines, wires, control cables etc., should be routed away from the hot parts of the engine or be suitable for the temperatures arising.

D.5 Until experience has been gained in operating gas turbines, engines powering aircraft or other vehicles should be mounted externally so as to be easily observed, or alternatively familiarisation can be obtained by useful test bed operation where emergency states can be practised.

D.6 For internal turbine installations, adequate heat protection from the hot exhaust gases and radiated heat from the engine must be provided.

D.7 The idle thrust of a gas turbine can be very high. If the model does not remain stationary with the engine at idle, positive measures must be taken to restrain it. Note that the behaviour of the aircraft may vary depending upon the nature of the runway surface.

E. Fire Safety

E.1 Remote Pilots operating gas turbines must provide an appropriate and serviceable fire extinguisher and nominate a competent Fire Person (see below) for the entire duration of the preparations to fly, the take-off, the flight and landing, to stand by and use this extinguisher in the event of fire. The nominated Fire Person must assume responsibility, under the direction of the Remote Pilot, for extinguishing any fires that may arise.

E.2 **Fire Person (in respect of Gas Turbine operations).**

E.2.1 The Fire Person is that person nominated by the Remote Pilot to undertake the responsibility of dealing with any fire that may occur during the preparation and flying of the Remote Pilot's aircraft.

E.2.2 The Fire Person must be familiar with the location on and around the aircraft of all equipment and substances that would represent a hazard in the event of a fire and be competent to deal with such hazards.

E.2.3 The Fire Person must, whilst on duty, have ready access to an appropriate and serviceable fire extinguisher and be competent to operate it effectively.

E.2.4 A Fire Person can only be assigned to one aircraft at any one time.

E.2.5 The Fire Person's duties will have priority over all other tasks and he/she will maintain an overview of all activities while the gas turbine is being operated.

E.3 Gas turbines must not be run if the surrounding environment presents a fire risk, unless adequate precautions are taken to negate the risk.

E.4 Smoking or other sources of ignition are prohibited within a radius of 50 metres of decanting, venting or fuelling of flammable gases. Signs designating the fuelling areas should be displayed if a gas-fuelled engine is being operated in public.

E.5 Any venting of liquefied gas must be conducted in a safe manner, in particular venting must not be undertaken within a radius of 50 metres, and never upwind, of any other gas turbine which is running.

E.6 All fuels must be contained in appropriate vessels clearly marked with a description of the contents.

E.7 Fuelling of aircraft should only be carried out by competent persons nominated by the Remote Pilot.

E.8 An appropriate and serviceable Fire Extinguisher must be available for all fuelling operations. Whilst CO2 extinguishers are generally acceptable for a small model fire during start up or following a wet start, Foam is more useful for a fuel spill or external fire.

E.9 The Remote Pilot or the nominated competent person must ensure that the fuelling equipment is fit for the intended purpose before fuelling takes place.

E.10 During refuelling, the engines(s) must be shut down.

E.11 It is strongly recommended that a manually operated shut-off device is fitted in the fuel supply line to the engine(s), as detailed in section B.1 above, to prevent inadvertent fuel flow to the engine(s) during refuelling.

E.12 Engine Fires constitute a major hazard and awareness of potential causes must be fully understood, they include:-

- Residual fuel in the engine leading to a "wet start" (characterised by significant volumes of flame discharged from the exhaust).

- Incorrect starting procedure.
- Turbine rubbing.
- Excess lubrication oil introduced during the priming of the lubrication system.
- Debris partially blocking the air intake, reducing compressor performance.
- Blocked fuel jets.
- Expansion of fuel into the engine after shut-down of the fuel pump.
- Tail-pipes pointing into wind at start-up.

F. Test Running

F.1 Any test bed should be adequately restrained and operated in a controlled area and must ensure that the engine and ancilliary equipment is securely fixed in such a manner that ingestion to the running engine is not possible.

F.2 The test area must be adequately ventilated and consideration given to the ever present fire risk.

F.3 During protracted ground running adequate eye and ear protection should be worn.

F.4 A gas turbine engine must be shut down immediately if any mechanical abnormalities indicated at any time by vibration, unusual or excessive noise, excessive temperature, overspeed or any other unexpected phenomena. The cause must be investigated and corrected, before the engine is re-started.

F.5 During ground running, particularly in built-up areas, due regard must be given to preventing noise nuisance.

G. Operations in Public

G.1 An engine must only be run in public after the operator / remote pilot is fully familiar and competent with its operation. Private club sites are excluded from this rule, provided the remaining rules in this section are followed strictly.

G.2 All engine running must be conducted at a safe distance from uninvolved people and property, with the jet pipe always facing away from them. When wind direction requires that tailpipes are directed towards people or property then the distance from the tailpipe to people or property must be increased to the point where jet blast and temperature effects are of no consequence.

G.3 No person must be allowed to stand close to an operating engine in the rotational plane of the compressor or turbine, (see Appendix 2 for additional guidance relating to all arrangements of gas turbine engine).

G.4 Particular attention must be paid to site husbandry and cleanliness to reduce the risk of foreign object damage to the gas turbine by ingestion and to prevent any loose articles being picked up and carried away in the jet efflux.

H Maintenance

H.1 Engine maintenance must be regularly performed. The frequency and detail of checks and actions will depend upon engine installation, usage and any manufacturer's instructions. Maintenance may vary from simple external inspections prior to flight to major services undertaken by the engine manufacturers service engineers or experienced home builder.

Flying Site Organisation

I.1 General

Most flying clubs will have a pre-existing flying site layout that is adapted to local conditions. Provided that this layout complies with BMFA guidelines it should be suitable for jet operations.

In other cases it may be necessary to revise the site organisation to allow gas turbine operations or declare the site unsuitable.

The BMFA Members Handbook is now available on-line at https://handbook.bmfa.uk and contains all of the information to be considered when flying turbine powered aircraft. In addition to the general guidance for Flying Site organisation please study Annex A – Public Displays and Annex B - Technical

Appendix 1

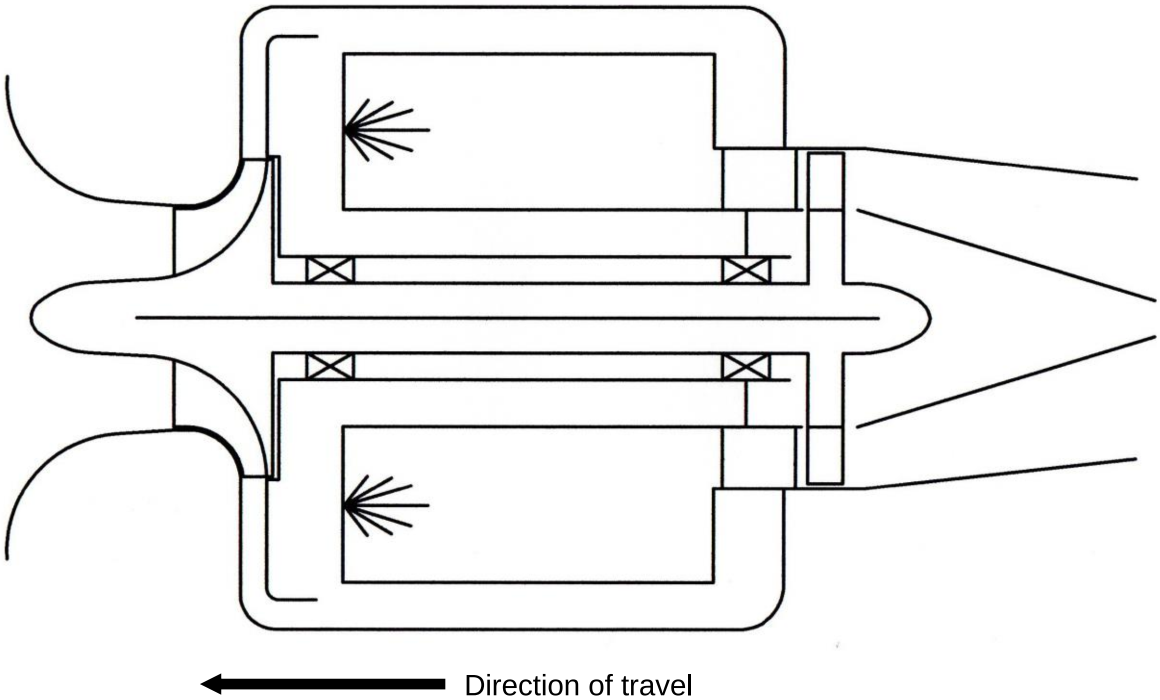
Common Gas Turbine Engine Arrangements and Associated Risks

Turbojet engines

This is the most common model gas turbine arrangement, with a centrifugal compressor at the front and an axial flow or radial inflow turbine at the back and a vaporising combustor between the two wheels. The primary fuel source can be either kerosene or, less commonly, liquid propane.

At full power, there is a considerable suction force at the intake, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust from the nozzle at the rear of the engine can reach over 600 deg C at a velocity close to 1000 mph. Although the gas heat and velocity diminish with increasing distance from the engine, no one must be allowed to stand in the direct path of the jet blast.



Due to the very high rpm of the rotating shaft, there is a risk of the compressor and/or turbine bursting under the huge centrifugal forces exerted on these two components. There is also a risk that the lubrication flow to the bearings could be interrupted by contaminants in the fuel system, causing the bearings to fail with little or no warning, this can also lead to compressor and/or turbine wheel failure. Such failures also present a significant risk of fire. Therefore, no one must be allowed to stand beside or behind this type of engine when it is operating.

The engine case and exhaust nozzle, of all gas turbines, get very hot, when running normally, leading to a risk of black metal burns if touched. Sufficient cooling time must be allowed before handling, or allowing anyone to touch a gas turbine engine after shut down.

Turboprop engines

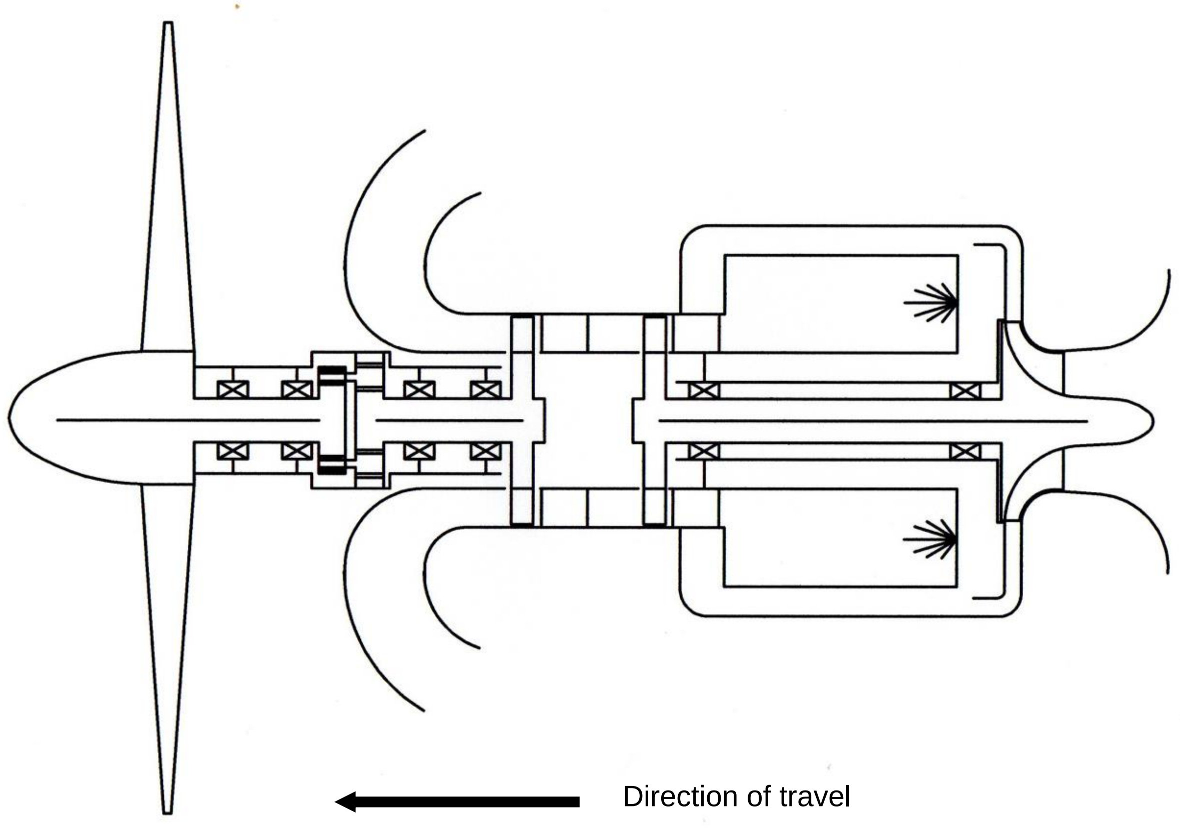
Turboprop engines comprise of a turbojet, referred to as a gas generator. In place of the turbojet's thrust nozzle there is an enclosed duct in which a second turbine, referred to as a Free Power Turbine, is located. The free power turbine converts the hot, high velocity gas, produced by the gas generator, into shaft power.

The most common arrangement for model turboprops is the back to back design, where the free power turbine, which drives the propeller through a gearbox, is located immediately behind the primary turbine of the gas generator (turbojet). In this arrangement, the gas generator is back to front, in terms of direction of travel (as shown in the diagram below).

At full power, there is a considerable suction force at the gas generator intake, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust, typically from two nozzles, one on each side of the engine, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet.

Considerable care must be taken when installing this arrangement of engine, as it is necessary to avoid the hot exhaust gases from being ingested by the intake.



In addition to the risk of compressor and turbine burst, there is also a risk of injury from the propeller. Therefore, no one must be allowed to stand beside or in front of this type of engine when it is operating.

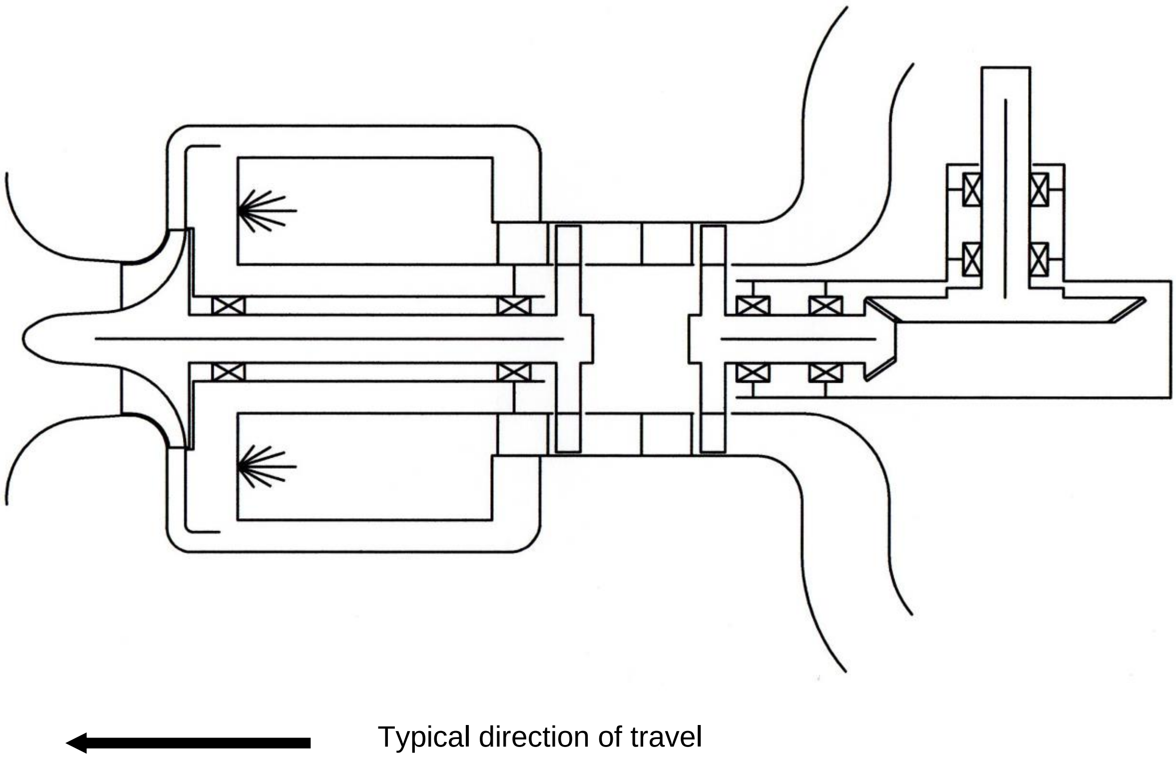
Because the free power turbine is not mechanically linked to the gas generator shaft, turboprops must never be run without a propeller, due to the risk of bursting the free power turbine. Operators must follow the designer's or manufacturer's instructions, when choosing the diameter and pitch of the propeller to use with the engine, to avoid the free power turbine being over sped and damaged.

Turboshaft engines - (Helicopters)

Turboshaft engines, intended for use in helicopters, comprise of a turbojet, referred to as a gas generator. Like the turboprop, in place of the turbojet's thrust nozzle there is an enclosed duct in which the free power turbine is located.

The most common arrangement for model helicopter turboshafts is the same back to back design as described in the turboprop section. However, the free power turbine connects to a 90 deg gearbox, the output of which drives the helicopter rotor head.

For clarity, the diagram below shows the exhaust and the output shaft to be on the same plane. However, in practice, the exhaust and output shaft are typically arranged at a 90 deg angle to each other.



Typical direction of travel

At full power, there is a considerable suction force at the gas generator intake, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust, typically from two nozzles, one on each side of the engine, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet.

In addition to the risk of injury from the helicopter rotors, there is a risk of compressor and turbine burst. Therefore, no one must be allowed to stand beside or behind this type of engine when it is operating.

Because the free power turbine is not mechanically linked to the gas generator shaft, turboshaft engines must never be run without a load on the output shaft, due to the risk of bursting the free power turbine. Operators must follow the designer's or manufacturer's instructions, when choosing the diameter and head gearing of the helicopter rotor, to avoid the free power turbine being over sped and damaged.

Turboshaft engines - (Other Application)

In addition to helicopters, turboshaft engines can be used to drive almost anything. Other examples of turboshaft applications include electric power generators, direct drive to land based vehicles, such as cars, trucks and trains. Also waterborne vessels, such as powerboats. The list of applications is wide and varied.

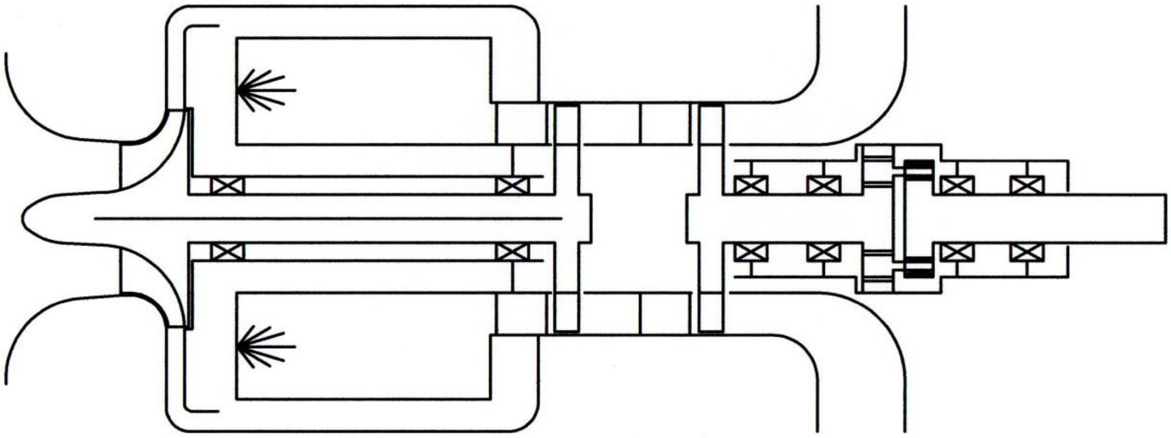
As described in the above turboprop and helicopter turboshaft sections, the arrangement is the same, comprising of a turbojet (gas generator). Like the turboprop, in place of the turbojet's thrust nozzle is an enclosed duct, in which the free power turbine is located.

The most common arrangement for model turboshafts is the same back to back design as described previously. However, the output shaft can be used to drive any suitable load.

At full power, there is a considerable suction force at the gas generator intake, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust, which, in a static application, could be a single upright stack, or, in a mobile application, one or more exhaust ports suitably located on the vehicle, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet.

Considerable care must be taken when installing this arrangement of engine, as it is necessary to avoid the hot exhaust gases being ingested by the intake.



No typical direction of travel

In addition to the risk of compressor and turbine burst, the operator must be aware of the risks associated with the application in which the engine is to be used. However, as a standalone machine, no one must be allowed to stand beside or down stream of the exhaust path of this type of engine when it is operating.

Because the free power turbine is not mechanically linked to the gas generator shaft, turboshafts must never be run without a load being applied to the output shaft, due to the risk of the bursting the free power turbine. Operators must follow the designer's or manufacturer's instructions, when choosing the load to be applied to this type of engine, to avoid the free power turbine being over sped and damaged.

Turbofan engines (back to back puller)

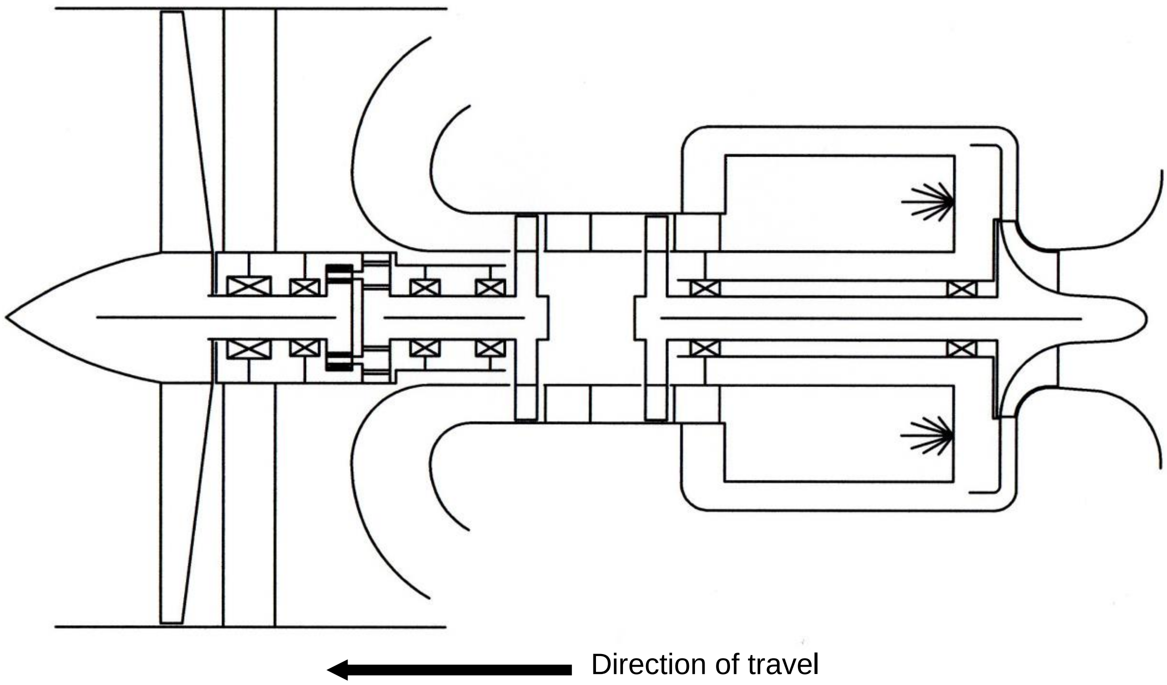
Like turboshaft engines, turbofans comprise of a gas generator (turbojet) with an enclosed duct in which a second (free power) turbine, is located. The free power turbine converts the hot, high velocity gas from the gas generator into shaft power.

There are three alternative arrangements for model turbofans. The one shown here is the back to back puller design, where the free power turbine, which drives the fan through a gearbox, is located immediately behind the primary turbine of the gas generator. In this arrangement, the gas generator is back to front.

At full power, there is a considerable suction force at the gas generator intake, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust, typically from two nozzles, one on each side of the engine, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet.

Considerable care must be taken when installing this arrangement of engine, as it is necessary to avoid the hot exhaust gases being ingested by the intake.



In addition to the risk of compressor and turbine burst, there is also a risk of injury from the fan. Therefore, no one must be allowed to stand beside or in front of this type of engine when it is operating.

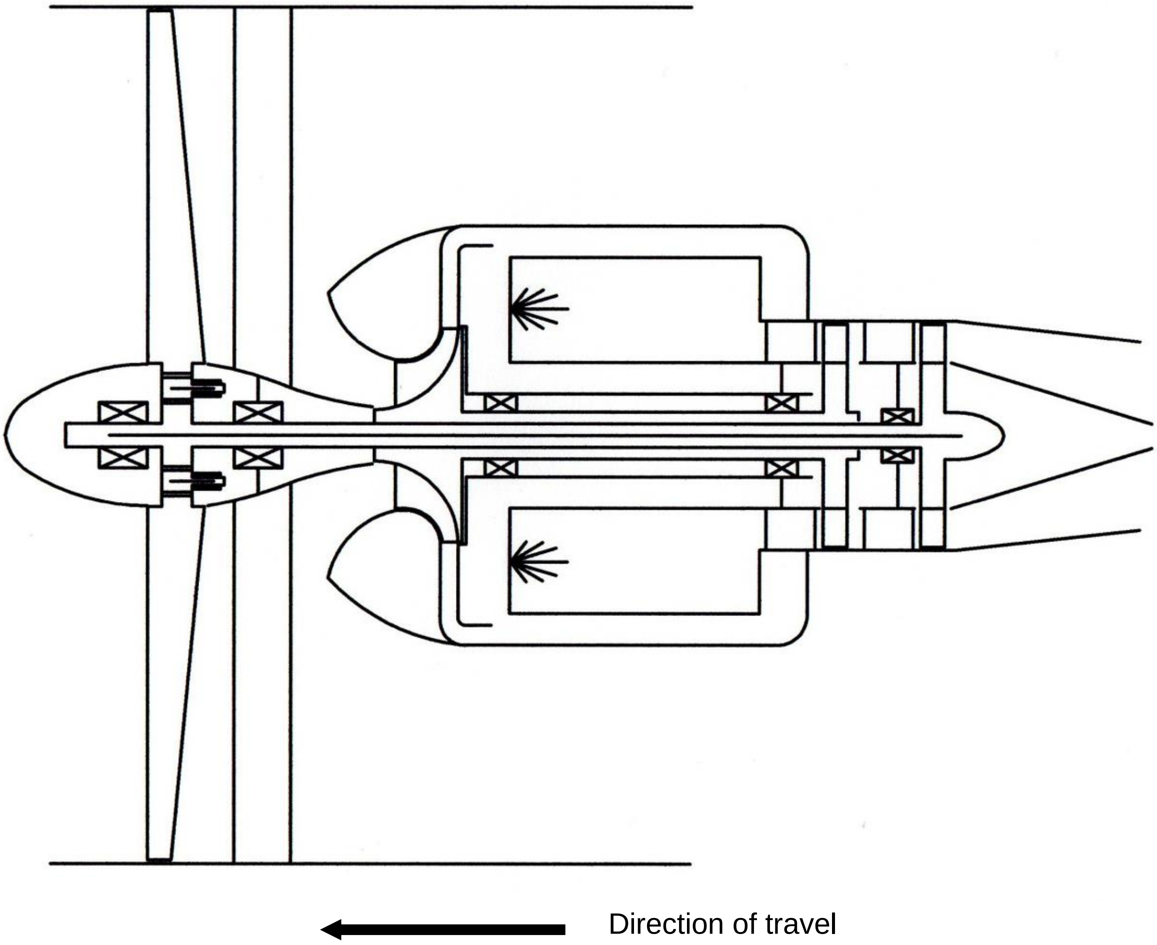
Because the free power turbine is not mechanically linked to the gas generator shaft, turbofans must never be run without the fan in place, due to the risk of the bursting the free power turbine. Operators must follow the designer's or manufacturer's instructions, when choosing the diameter and pitch of the fan, to avoid the free power turbine being over sped and damaged.

Turbofan engines (concentric shaft)

The second alternative arrangement for model turbofans, the free power turbine shaft passes concentrically through the centre of the gas generator shaft. The free power turbine drives the fan through a gearbox, which in this case is located in front of the gas generator intake (as shown in the diagram below).

The gas generator intake is located immediately behind the fan, enhancing the gas generator compression ratio.

The jet exhaust, typically from a single thrust nozzle, similar to that on the turbojet, is located at the back of the engine and the cold air stream, from the fan, passes around the hot jet exhaust.



Direction of travel

In addition to the risk of compressor and turbine burst, there is also a risk of injury from the fan. Therefore, no one must be allowed to stand beside, behind or in front of this type of engine when it is operating.

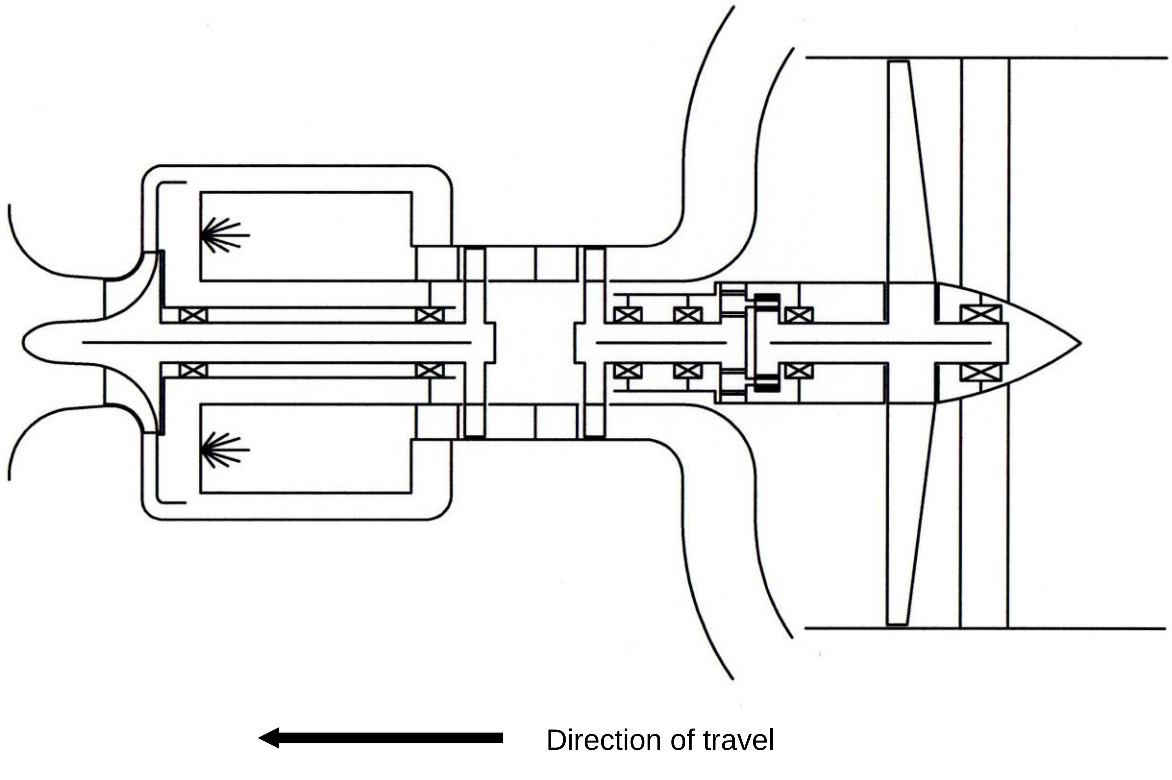
Because the free power turbine is not mechanically linked to the gas generator shaft, turbofans must never be run without a fan in place, due to the risk of the bursting the free power turbine. Operators must follow the designer's or manufacturer's instructions, when choosing the diameter and pitch of the fan, to avoid the free power turbine being over sped and damaged.

Turbofan engines (Pusher)

The third alternative arrangement, is the back to back pusher design, where the free power turbine that drives the fan, through a gearbox, is located immediately behind the primary turbine of the gas generator. In this arrangement, the gas generator is at the front, facing the direction of travel (as shown in the diagram below).

At full power, there is a considerable suction force at the gas generator intake, not only from the compressor but also the fan, which can result in ingestion of loose items and clothing, leading to server injury.

The jet exhaust, typically from two nozzles, one on each side of the engine, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet but must be ducted around the outside of the fan shroud.



Direction of travel

In addition to the risk of compressor and turbine burst, there is also a risk of injury from the fan. Therefore, no one must be allowed to stand beside or behind this type of engine when it is operating.

Because the free power turbine is not mechanically linked to the gas generator shaft, turbofans must never be run without a fan in place, due to the risk of the bursting the free power turbine. Operators must follow the designer’s or manufacturer’s instructions, when choosing the diameter and pitch of the fan, to avoid the free power turbine being over sped and damaged.

BRITISH MODEL FLYING ASSOCIATION

SMAE Ltd

Chacksfield House, 31 St Andrews Road, Leicester, LE2 8RE

Telephone - 0116 2440028 Fax - 0116 2440645

E-Mail - admin@bmfa.org Website - http://www.bmfa.org