Gas Turbine Builders Association
Appendix 1
Guidance Notes for compliance with the
GTBA Code of Practice - Issue No.10 – 3rd April 2022

The following notes are given to assist in meeting the requirements of The Code and represent a minimum standard.

Each note in Appendix 1 is preceded with the number of the relevant Article from the Code. The reference number is preceded with the letter "A" to distinguish the Note from the actual Article).

Appendix 2, on page 9, provides guidance on hazardous materials that may be used in model gas turbines.

Appendix 3, starting on page 10, provides an overview of the risks relating to different gas turbine engine arrangements.

A1.1 Testing.

Before any engine is run in public it must be shown that it is capable of sustaining the stresses arising from forces generated in the engine. These forces will include:-

- Centrifugal forces arising from the high rotational speeds of the compressor and turbine.
- Gyroscopic forces on the rotor assembly arising from changes in direction of motion of the engine.
- Bending forces on the rotor shaft as the critical speed is approached.

As an absolute minimum an engine must demonstrate that it can survive, without damage, three consecutive runs each of 10 minutes duration at continuous maximum rated power.

A1.2 Certification of Material Specification

It is recommended that materials intended for highly stressed components be obtained complete with a certificate confirming the material specification and any process, such as casting, heat treatment and use of advanced manufacturing methods such as additive or subtractive machining, to which the material has been subjected.

A2.2 Over-speed protection

The engine and its systems should be designed and constructed such that the rotational speed cannot exceed the maximum safe limit. This may be achieved by the following:-

A2.2.1 The fuel system is permanently restricted to limit the fuel flow to a safe value.

A2.2.2 Fuel pump motor battery voltage is limited by the number of cells in the battery such that the pump output will not exceed the engine's maximum safe demand if the electronic control fails and continuously applies full battery voltage to the pump motor.

A2.2.3 The fuel system incorporates a pressure relief valve set to limit the fuel pressure so that fuel flow cannot exceed the maximum safe value. The relief system must contain the fuel and return it to the suction side of the pump or to the tank.

A2.3 Under-speed protection.

Engine fires can result from the engine losing speed, as a result of mechanical problems, to a level such that the consequential exhaust temperatures will have risen too high. Also, because of the reduced airflow arising from the loss of rotational speed, combustion chamber performance will deteriorate and fuel will begin to burn outside of the combustion chamber. Under these circumstances the fuel must be shut off to avoid a fire. The operator of a remotely controlled engine may not, under certain conditions, detect the under-speed condition and may therefore not react in time to prevent a fire.

Hence, consideration should be given to a control system whereby an engine under-speed condition causes the fuel to be shut off.

A pressure switch sensing the compressor diffuser discharge pressure and arranged to be open circuit whenever the pressure falls below the engines minimum safe operating pressure will provide suitable protection if connected in series with the pump motor. A manual switch with mechanical spring bias to the open circuit condition, connected in parallel with the pressure switch, would be required to override to pressure switch during engine starting. Current ECU and FADEC systems typically incorporate under-speed monitoring and will shutdown the engine in such an event.

A2.4 Over-temperature protection.

Over-temperature protection by discrete temperature control should not be considered a substitute for inherent over-temperature prevention. Provided a current ECU and FADEC systems is employed, these typically incorporate exhaust gas temperature monitoring and are able to reliably control the fuel speed pump to avoid exceeding temperature limits. At the engine test and development stage there will be benefits in incorporating some form of active temperature monitoring and control, if an ECU or FADEC is not used, whereby the fuel flow is reduced whenever the exhaust gas temperature exceeds acceptable limits.

A2.6 & A2.7 Remote Control and Emergency Fuel Shutoff Systems and Failsafe set-up

There should be some means of remotely isolating the fuel supply in an emergency. If the engine is being operated under radio control the isolating valve should be operated by a servo assigned to a separate control channel independent of the throttle. This servo channel should also be arranged to close the valve if the radio link fails, (necessitating a radio system with failsafe facilities). There may be an advantage in having a short time delay before closing the valve on radio failure to prevent unnecessary stopping of the engine during very short term interruptions in the radio signal.

The servo and valve must be linked so that the valve can only be moved to the closed position by the servo. Once closed the valve must not be able to be opened by the servo. The valve should only be able to be opened manually and should remain closed except when the engine is about to be started.

In the event of the operator initiating a shutdown, or the radio entering the failsafe mode, the valve would shut off the fuel, stopping the engine. The servo must not be allowed to open the valve by operator command or if the radio signal is regained, as the pump could once more deliver fuel. This, at the least, would saturate the model with unburned fuel, but worse, could result in a fire. It is therefore also recommended that a means be incorporated to prevent the fuel pump from delivering any more fuel until the valve is manually reset.

A suitable linkage between servo and valve would be arranged to have "slack" or lost motion equal to the amount of motion needed to move the valve from the open to the closed position. Thus the servo would only be able to close the valve. A switch could also be incorporated in the arrangement to isolate the fuel pump. Both of which could only then be reset by hand after the servo had been returned to the "open" position.

Under no circumstances should the failsafe of a PCM receiver fitted to a turbine powered model be left in the default mode. Depending on the make of equipment in use this may result in the throttle either remaining at the last known throttle setting or going to half power. It must instead be programmed to cut the engine altogether, by setting the throttle to the minimum and operating the fuel shutoff valve.

Please note that, depending on the configuration of receiver, switch and battery, the failsafe programming may be lost when the battery is disconnected. The setting should therefore be checked before each engine start. When switching from a PPM receiver to a PCM one it is important to note that, although your ECU or speed controller may cut the engine if the PPM receiver loses signal, the PCM failsafe will mask this function.

In exceptional circumstances, an operator may choose, at his/her own discretion, to extend the maximum recommended delay before engine shutdown on loss of radio link. For example, model aircraft with a very high wing loading, e.g. a scale model of an F-104 Starfighter, where the model is wholly reliant on the propulsive force of the engine to maintain aerodynamic lift and would be uncontrollable without power, particularly in the event that the radio link were to be subsequently re-established. Ultimately the remote operator of a model must determine the distance the model is able to travel per second, without radio link, and the most likely duration beyond which the model would be in an unrecoverable attitude, even in the event of the radio link being re-established. This should determine the absolute maximum period prior to automated engine shutdown on failsafe. Remote model operators must also make a full risk assessment of the local area, including fire risk to, for example but not limited to, woodland, crops and livestock, and adjust failsafe settings, including engine shutdown delay, accordingly.

For model aircraft specifically, both CAP 722F and Article 16 Authorisation prohibit the use of autonomous flight control systems. However, in the event of loss of radio link, automatic activation of failsafe flight settings, including engine shutdown as well as the deployment of flaps, airbrakes, undercarriage and flight stabilisation systems, are accepted in order to keep the model within the vicinity of the remote pilot and to reduce the risk of a high energy impact. Model aircraft fitted with automated ‘Return and Land at Point of Take-off’, that can only be activated on loss of radio link, may also be employed and the operator may choose not to set the engine to automatically shutdown on loss of radio link.

Ultimate responsibility however remains with the remote pilot, who must carefully consider what the response of the aircraft would be in a failsafe scenario, taking into full consideration, the location in which the flight is to take place, the idiosyncrasies of the model and all other means of ensuring that the flight shall be made safely.

A3.4 Pressure testing of fuel systems.

An acceptable test would be to block the system at the entry point to the engine and run the fuel pump motor directly connected to a freshly fully charged battery with the electronic speed control system disconnected. This test will apply the maximum available voltage to the pump motor and represents the worst case of short circuit failure of the electronic control. The number of cells used and their nominal capacity should be recorded and means taken to ensure that these values are not exceeded. For example the battery compartment cover could carry a notice stating the maximum number of cells, the nominal battery voltage and the cells' nominal capacity.

Limiting the maximum permissible voltage or number of cells used in the fuel system power supply will also contribute to preventing the gas turbine from being operated above its maximum permissible speed.

A3.5 & A4.8 Fuel and Oil Systems Materials

Materials containing the fuel and oil must be suitable for these duties. It is essential to determine the long-term effects of exposure to fuels and oils. Some flexible plastic materials become brittle after exposure to typical gas turbine liquid fuels. Such embrittlement could lead to leaks or fractures in the fuel system. It is a simple matter of soaking a sample of the material in the fuel or oil for a prolonged period and then to test the material for flexibility and dimensional stability.

Fuel and oil lines can also be exposed to elevated temperatures in the vicinity of the engine so the convenience of flexible plastic tubing may have to be sacrificed and metal tube used in the final connection to the engine.

Gas fuelled engines present an additional problem in that the gas will be stored in the fuel tank initially in a liquefied state. The fuel system materials must be suitable for the very low temperatures created by evaporation of the fuel to the gaseous state while on route to the combustion chamber. This problem could also apply to the gas starting system of liquid fuelled engines.

A3.6 Starting System Fuel Lines

Liquid fuelled engines which are started on gas present a potential hazard if the starter gas system is integrated with the main (liquid) fuel system. Such integrated systems allow the risk of starter gas invading the liquid fuel tank where it would present a greater hazard than that expected of liquid fuel.

It has also been found that fuel manifolds intended for liquid fuel can become overheated and damaged if subjected to prolonged exposure to gaseous fuels. This arises because the manifold would normally be cooled by the liquid fuel.

Care should also be taken to avoid gas and liquid fuel injectors being too closely positioned in vaporizer tubes, as the pressure at higher rpms can result in liquid fuel being forced back down the gas line, into the gas canister. This normally results in the gas canister being wasted, as the resultant mix stops the gas vaporizing properly.

A3.7 Pressurising fuel tanks

For liquid fuelled engines it is recommended that the fuel pressure is raised and controlled by a motorised pump that draws the fuel from a tank, which should not be significantly pressurised. There are systems under development which have eliminated the motorised pump and in its place use pressurisation of the fuel tank. When such systems have been safely developed guidelines will be provided.

A3.10 & A4.6 Filtration and Cleanliness.

A totally clean zone should be maintained, for both fuel and oil, by the following means:

a) Most importantly start with clinically clean fuel tanks, pump and pipe work and filter all fuel stocks - even fresh paraffin can be very dirty.
b) Fit a filter to the discharge of the storage container, this should make the tank a clean zone.
c) Fit a filter on the fuel tank overflow pipe, as the air coming in to replace the fuel is probably dirtier than the fuel in the storage container.
d) A filter can, optionally, be fitted between tank and fuel pump but it must be cleaned regularly and it can be a significant source of leakage. Filters in the line between pump and turbine are subject to higher pressures increasing the possibility of a leak.
e) Plastic bodied fuel pumps are not recommended as they can shed plastic particles, which will block the vaporiser/fuel jets.

The same principles apply to the oil system:

a) Filter the oil when filling the tank.
b) Fit a filter in the oil tank pressurisation pipe, as the air from the engine could be dirty.
c) Fit a filter in the air path to the bearings. Very fine bronze or stainless steel gauze will keep out the larger particles; do not use too fine a filter, as the air flow may be impeded.

A4.5 Lubricating Oil Flow Rates.

The very high speeds to which small gas turbine shaft bearings are subjected impose quite severe requirements on the lubrication system. In general, the oil flow will have to be restricted to very low rates. Excessive oil flow will actually result in early failure of the bearings, arising from hydraulic effects causing rolling elements to lock-up and skid with consequent high wear rates.

Oil flow rates should be set to the designer's or manufacturer's recommendations and are usually measured with the engine running at full power.

Flow rates of the order of 0.3 millilitres/minute for separate lubricant systems or 2 millilitres/minute for mixed fuel /lubrication systems are typical for engines in the 54-66mm rotor diameter range. Excess oil flow will also result in randomly occurring flaring in the exhaust stream, sometimes accompanied by a "fluffing" sound, as the excess oil is ignited.

A4.10 Confirmation of Oil Flow

Means should be provided to confirm the flow of lubricating oil to the bearings. A transparent section of line will allow oil flow to be seen as the system primes but flow will not be obvious when air has been purged from the line. Also flow rates, when correctly set, may be so small that it is difficult to register a fall in the level of oil in a separate lubrication reservoir, however it may be possible to determine the difference in the oil level before and after a run. Alternative means of actively monitoring the flow in mixed fuel/lubrication system need to be considered.

A5.3 Foreign Object Damage

Foreign matter sucked into an engine presents a particular hazard. The result is known throughout the aviation world as FOD (Foreign Object Damage). Any loose articles in the hull, body work or fuselage of a model will almost certainly be "discovered" by the engine and, with the same degree of certainty, will result in FOD. Additionally, particles thrown up, for instance by aircraft landing gear, can be sucked into the engine. The probability of this is especially high on aircraft where the nose leg is located forward of the air intake or where the gear bays are not sealed off to the inside of the fuselage. Water thrown up by aircraft as they taxi, takes off or land through puddles on the runway, which equally applies to model boats and land vehicles, can also result in FOD.

A5.6 Protection from High Temperatures

Some systems will inevitably be exposed to high temperatures. Where this occurs the materials must be suitable for high temperature use or suitable thermal insulation used to provide protection. For example exhaust gas temperature thermo-couple probes should be of Inconel sheathed mineral insulated construction and of sufficient length to place the connecting wires away from the exhaust heat.

Exhaust ducts will have to both withstand the temperature of the exhaust gases and protect the surrounding structure from the radiant and conducted heat from the duct itself. It will not be sufficient to install a heat resistant metal duct without also providing some insulation on the outside of the ductwork. The necessary insulation can take the form of conventional heat-resistant insulation such as lightweight ceramic fibre or could be provided by a cooling flow of air. In the air-cooled solution consideration must be given to protection against loss of the air flow.

Heat reflective materials can also be very useful in protecting the structure from exhaust heat.

There may be some benefit in treating wooden structures with flame retarding agents which can be obtained in aerosol spray cans. The effect of such agents on the strength of the structure and on surface finishes should be determined on test pieces.

A6.1.1 Dealing with Fire.

(In respect of dealing with a fire in a model aircraft powered by a gas turbine.)

A6.1.1.a Training.

All persons assigned to fire-fighting **must** familiarise themselves with the use of the particular fire extinguisher to be employed by careful study of the extinguisher manufacturer's written instructions and procedures.

The fire-fighters should also be instructed by the operator of the gas turbine as to the most effective ways of dealing with a fire. For instance, the fire-fighters should be made aware of any specific access points on the model through which to direct extinguishant.

The operator of the gas turbine must retain authority over the fire-fighters to prevent the unnecessary discharge of fire extinguishers, for example during a "wet-start" which the operator is able to bring under control.

A6.1.1.b Risks to Fire-fighters.

All potential fire-fighters must be made aware of the specific hazards associated with any particular model. For instance if the fuel involved is a gas contained under pressure there is a risk of the pressure vessel exploding in a fire. Only in the very early stages of such a fire would it be safe to approach and attempt to fight the fire.

Fires involving liquid hydrocarbon fuels which are not normally contained under pressure present a lesser risk but fire-fighters must allow for the circumstance of the fuel vaporising in the heat of the fire, causing the container to become pressurised and subsequently exploding.

A6.1.1.c Foam extinguishers.

Foam extinguishers are **not recommended** for model gas turbine fire-fighting because of the mess and potential damage resulting from their use. *(In the UK. the containers of foam extinguishers are currently cream in colour).*

A6.1.1.d **Dry Powder extinguishers.**

Dry Powder extinguishers are **not recommended** for model gas turbine fire-fighting because of the mess and potential damage resulting from their use. *(In the UK. the containers of Dry Powder extinguishers are currently blue in colour).*

A6.1.1.e **Halon or BCF extinguishers.**

Halon or BCF extinguishers, whilst suitable for model aircraft, were banned in December 2003 due to their significant adverse environmental impact. *(In the UK. the containers of Halon or BCF extinguishers were green in colour).*

A6.1.1.f **Carbon Dioxide (CO2) extinguishers.**

CO2 extinguishers containing at least 2.5 kg of extinguishant **are recommended** for model gas turbine fire-fighting. *(In the UK. the containers of CO2 extinguishers are predominately black in colour).*

A6.1.1.g **Colour coding of fire extinguishers.**

Regulations have changed requiring that all fire extinguishers be coloured red. However, they will still carry a coloured band or label on the upper body, identifying the extinguishant contained. The above identifying colours therefore still apply but will, as older cylinders are replaced, become an identifying banner rather than the dominant cylinder body colour.

A6.1.1.h **NEVER USE A WATER JET on a liquid fuel fire**.

A6.1.1.i **On-board extinguishers.**

In the event of a crash of a gas turbine powered model, it is extremely likely that the crash site will be some distance from the location of the fire-crew. Also it is possible for a fire to develop while a model is moving / airborne and the model stopping / landing some distance from the fire-crew. Therefore consideration should be given to arranging for the model to carry its own automatic fire-fighting system, particularly if there is any fire risk to the environment.

Automatic systems are available, one such system comprises a lightweight plastic tube containing liquefied extinguishant gas. In a fire the plastic tube melts and bursts, releasing the extinguishant. The system is most effective where the fire and the extinguishant are contained within an enclosed space. A model with a gas turbine installed internally with the usual air intake and jet exhaust is likely to be suitable for protection by this system. Tubes are typically 500 mm long by 8 mm diameter and weigh 30 grammes.

A6.1.2 Grass and Vegetation Damage and Fire

All vegetation (grass / hedges / plants) will be damaged by hot exhaust gas streams but this may not be immediately apparent. If damage has occurred it will be apparent by the dying back of the affected area a few days after the exposure to the hot gases. It is in everybody's interest that this damage is prevented. A fire-blanket lying behind the gas turbine will provide good protection for the grass. A localised grass fire can be dealt with by smothering with such a glass fibre fire blanket. Take every precaution to avoid allowing gas turbine hot exhaust gas streams to affect any form of vegetation.

It is good practice to employ an external extension duct to provide protection from the hot jet exhaust during starting.

A fire extinguisher should always be taken by the assigned fire-fighter to a model being retrieved.

A6.1.3 Control of Sources of Ignition

Decanting, venting or fuelling of flammable gases must be prohibited within a radius of 50 metres from operating gas turbines or other sources of ignition. In still-air conditions it may be necessary to increase significantly the radius of the protected area because of the heavier than air nature of gaseous fuels which could collect in significant quantities.

A6.1.5 Transport and Storage of Liquid Fuel

Always comply with the instructions displayed at the point of sale. A typical notice contains the instruction:- "Always store and carry petrol or diesel fuels in a properly designed and labelled metal or plastic container which can be securely closed."

The same notice, but in respect of petrol, also warns that it is illegal to store more than 13 litres (3 gallons) of petrol without the consent of the Local Petroleum Licensing Authority. It does not warn that such storage is illegal in the case of diesel fuel.

A6.1.6.1 & A6.1.6.7 Residual Fuel

Loss of control of engines on start-up can be caused by fuel having accumulated in the engine prior to the start. Sealed fuel systems will deliver significant quantities of fuel, because of expansion, if a model is allowed to stand in the sun for a time after refuelling. It is a sensible precaution to tip an engine on end before starting to empty out residual fuel.

On shutting down an engine it is good practice to reverse the fuel pump to remove all fuel in the line between the pump and the engine. Also check that there are no flames still burning within the engine.

A6.2.1 Check Lists

A check list should comprise, but not necessarily be limited to, the following:-

Check prior to running that:-

- The shaft is free turning and the engine emits no unusual noises. (Check by blowing into the air intake or a brief application of the starter motor).
- Oil levels are correct.
- Residual fuel is drained off. (Tip engine to whatever attitude necessary to release all trapped fuel).
- Engine and all associated fittings are secure.
- Serviceable fire extinguisher and trained operator are in position.
- Starter gas supply is of adequate pressure.
- Starter batteries are adequately charged.
- Loose foreign objects are removed. (FOD Check)

Following the appropriate starting sequence, when the engine is stopped perform the following:-

- Isolate the fuel supply.
- Listen for unusual noises during the run-down.
- Ensure that all flames are extinguished.

A6.2.6 Engine protection

Engines under development should always be monitored by speed and temperature sensors to prevent maximum safe values being exceeded. Maximum allowable speed should be approached with caution and a means of shutting off the fuel quickly in an emergency must be provided. Electronic protection systems, which will automatically intervene and reduce the fuel flow when maximum parameters are about to be exceeded, can be very useful, particularly during development testing. However, operator should be aware that electronic sensors can fail, so engine development should be directed at removing sole reliance upon electronic protection systems.

A6.3.3 Danger from the Rotational Plane

If a compressor or turbine of a running engine were to fail and the case of the engine was unable to contain the debris, such debris would be ejected in the plane of rotation of the failed component, i.e. sideways. Therefore no person should be allowed close to the side of a running engine. As the rear of the engine is also a prohibited area because of the heat of the exhaust the only safe area is in front of the engine. (*Also see the additional notes on the risk zones around various typical gas turbine arrangements in Appendix 3, starting on page 10 below.*)

When more than one engine is being operated in close proximity, operators should liase with each other to arrange that all engines point in the same direction (away from any spectators) and all lie on one line which is at right angles to their rotational axes. All operators should then remain in front of the line of engines.

A7 Maintenance and Service History

By logging all running and maintenance, a detailed history of an engines performance and serviceability will be produced. This will provide valuable information in respect of maintenance intervals. Degradation in performance will be more easily detected and it may prevent the engine being operated in an unsafe state.

A9 Radio Controlled Model Aircraft Pilots Qualifications

A crash involving a gas turbine powered aircraft can have serious consequences because of the risk of fire. Also gas turbine powered aircraft can be capable of high speeds because the thrust does not decrease much with increasing airspeed, unlike those equipped with propellers. These factors combined with other idiosyncrasies, such as throttle lag and high thrust at minimum power, serve to place demands upon an operators competency that may be much higher than those met with propeller equipped aircraft.

Appendix 2
Hazardous Materials

Hydrocarbon Fuels and Oils

There are health hazards associated with fuels and oils and suppliers are bound by law to make health and safety information available to users of such products. It is recommended that copies of the Material Safety Data Sheets are obtained; these can be obtained, for instance, from the garage supplying the products. The data sheets will give information in respect of the acute and chronic health hazards together with first aid and emergency action. To emphasise the importance of obtaining such information the following is an extract from a diesel fuel data sheet in respect of the chronic health hazard:-

"Skin contact over prolonged and repeated periods can lead to defatting of the skin, dermatitis, erythema, oil acne and oil folliculitis. Where occupational and personal hygiene practices have been of a poor standard, warty growths have occurred and these can become cancerous."

Viton Synthetic Rubber

Viton rubber is a fluoroelastomer and if heated beyond 400oC does not burn but decomposes with the formation of HYDROFLUORIC ACID. This acid is extremely corrosive and is almost IMPOSSIBLE to REMOVE once it has contaminated the skin. Any person required to inspect and/or replace any overheated gaskets or seals made from this material should not permit, under any circumstance, contact with the bare skin. VERY NASTY BURNS may occur, which under extreme circumstances could lead to the need for AMPUTATION.

High temperature oil resistant Viton o-rings are capable of operating in temperatures down to -15oC and up to +200oC. The much safer Nitrile o-rings are capable of withstanding temperatures from -40oC to +110oC for long periods with excursions to 135oC . It is strongly advised that Viton 0-rings are not used for any purpose in gas turbine engine construction.

Turbine Oils containing Organophosphates

Special lubricating oils, designed for full size aviation gas turbine operation, may contain hazardous chemicals such as organophosphates. These additives are included specifically to enable a wide range of operating environment from sea level to high altitude, where low pressure and low temperatures are normal. Commercial gas turbines typically employ fully sealed lubricating systems, preventing vapour from these lubricating oils being released into the atmosphere. Given suitable precautions to avoid skin contact and the breathing of the vapours, these oils may be used. However, non-toxic alternatives such as Mobil DTE Light and similar terrestrial based gas turbine lubricating oils are available and have been used very successfully in model gas turbines. Many operators may prefer to use these lubricating 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.

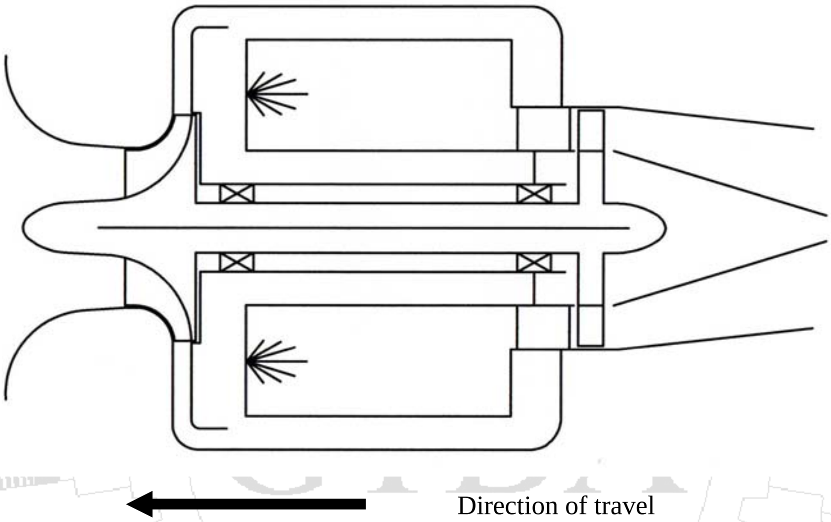
Appendix 3
Common Gas Turbine Engine Arrangements and Associated Risks

Turbojet Engines

This is the most common model gas turbine arrangement, with a centrifugal compressor at the front, an axial flow or radial inflow turbine at the back and a vaporising combustor between the two wheels. Fuel 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 severe injury.

The jet exhaust from the thrust 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 enormous 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 or lubrication system, causing the bearings to fail with little or no warning. This can also lead to subsequent 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 thrust 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 it has been shutdown.

Turboprop Engines

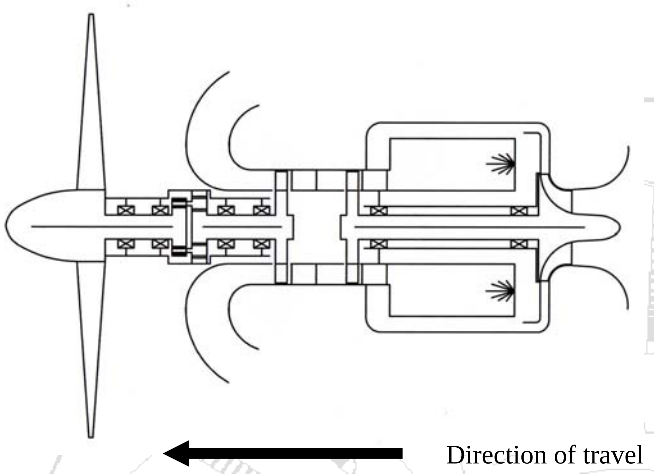
Turboprop engines comprise of a turbojet (see above), referred to as a gas generator. In place of the turbojet's thrust nozzle, there is an enclosed duct in which a second turbine, referred to as a Free Power Turbine, is located. The free power turbine converts the hot, high velocity gas, produced by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

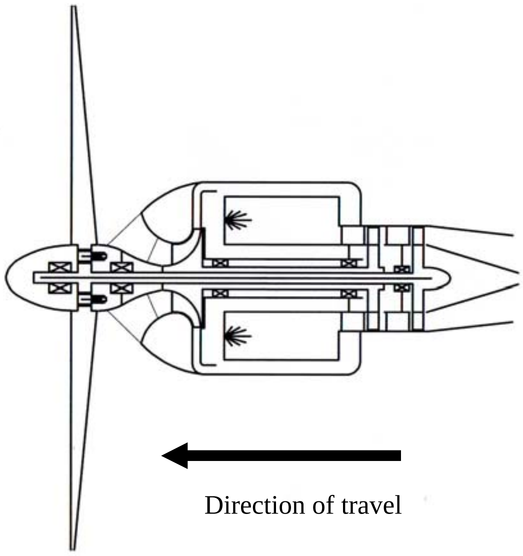
The most common arrangement for model turboprops is referred to as a back to back configuration, where the free power turbine and gearbox, which drives the propeller, is located immediately behind the primary turbine of the gas generator (turbojet). In this arrangement, the gas generator is back to front,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

A less common and more complex arrangement is the concentric shaft arrangement, where the gas generator is arranged in the direction of travel, with the shaft driving the propeller passing through the centre of the gas generator shaft, as show below right.

In both arrangements, at full power, there is a considerable suction force both at the gas generator intake in addition to the propeller suction / wash. Combined, these can result in ingestion of loose items and clothing, leading to severe injury.

The jet exhaust, usually from two nozzles, one on each side of the engine, in the case of the back to back arrangement and typically a single nozzle at the rear of the concentric arrangement, discharge the exhaust gas at a lower temperature and velocity, compared to a turbojet but still hot enough to cause burns.





Considerable care must be taken when installing the back to back arrangement of engine, as it is necessary to avoid the hot exhaust gases from being re-ingested by the intake. Re-ingestion will result in the engine overheating with an associated risk of fire. No such risk affects the concentric arrangement but means must be found of safely ducting the hot gasses from the exhaust, if the engine is mounted in an enclosed fuselage.

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

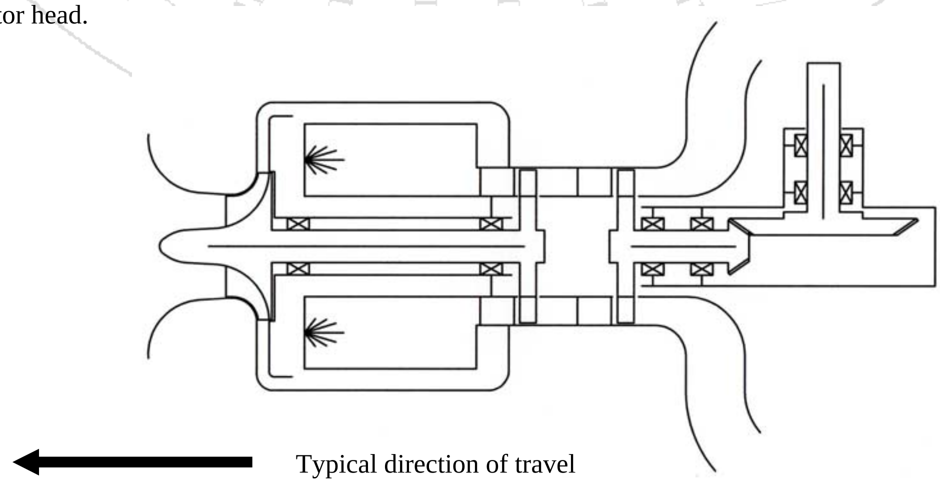
Because the free power turbine is not mechanically linked to the gas generator shaft, turboprops must never be run without a propeller, due to the risk of bursting the free power turbine.

To avoid the free power turbine being over sped and damaged, operators must follow the designer’s or manufacturer’s instructions when choosing the diameter and pitch of the propeller to use with the engine.

Turboshaft Engines - (Helicopters)

Turboshaft engines, intended for use in helicopters, comprise of a turbojet, referred to as a gas generator as mentioned above. 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 configuration as described in the turboprop section above. However, the free power turbine connects to a 90 deg gearbox, the output of which drives the helicopter rotor head.



For clarity, the diagram above shows the exhaust and the output shaft being on the same plane. However, in practice, the exhaust and output shaft are typically arranged 90 degs to each other.

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 severe injury.

As with the turboprops, 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 still hot enough to cause burns.

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 of land based vehicles, such as cars, trucks and trains and tanks. Also waterborne vessels, such as powerboats and hydroplanes. The list of applications is wide and varied.

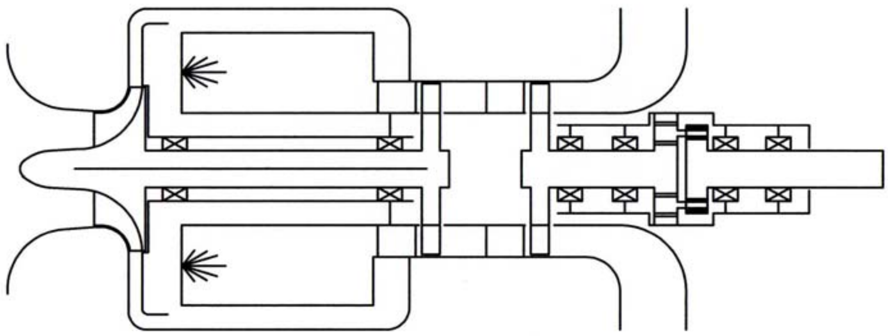
As described in the above turboprop and helicopter turboshaft sections, the arrangement is the same, comprising of a turbojet (gas generator). As detailed, in place of the turbojet's thrust nozzle is a duct, in which the free power turbine is located.

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 severe injury.

The 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 but still hot enough to cause burns.

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 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.

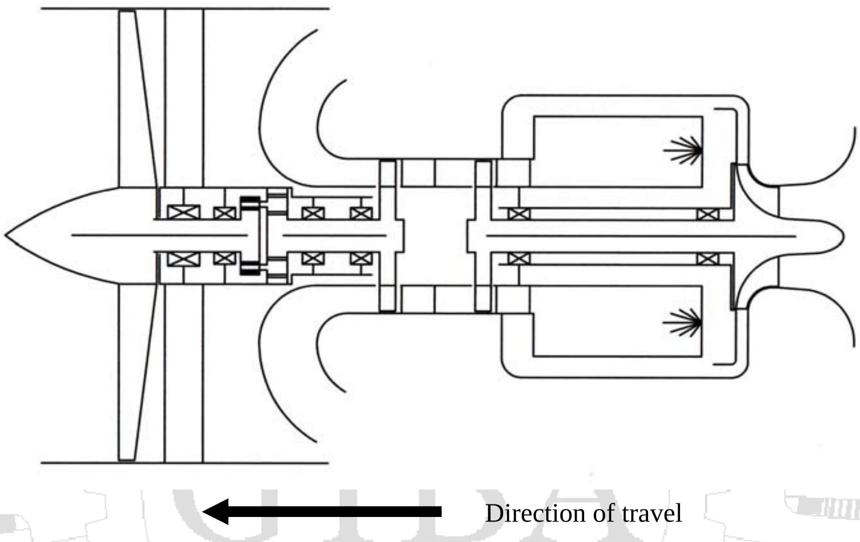
Turbofan Engines (Back to Back, Puller)

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 of model turbofan. The one shown below 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 severe 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 still hot enough to cause burns.



Considerable care must be taken when installing this arrangement of engine, as it is necessary to avoid the hot exhaust gases being re-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 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, Puller)

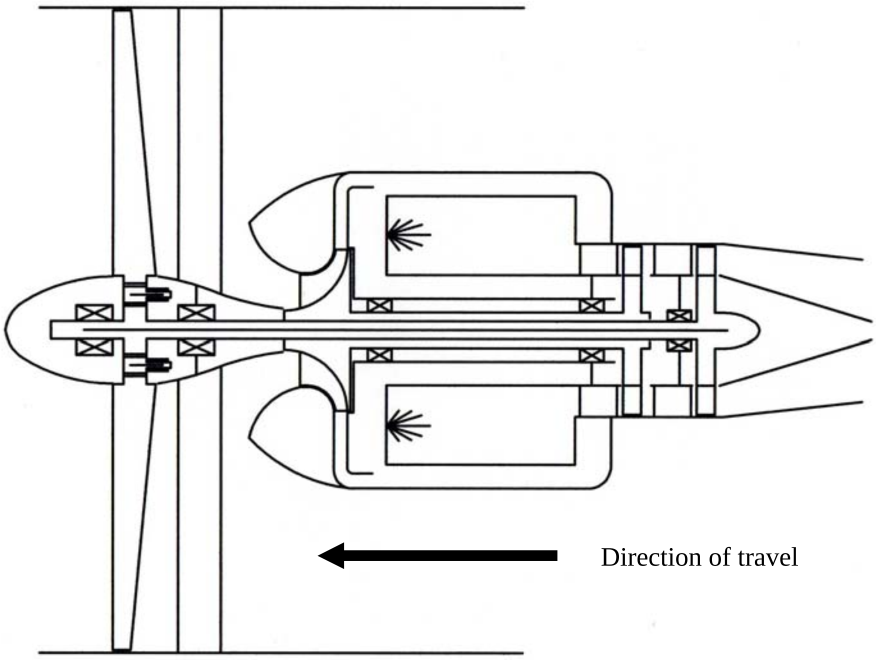
In this second alternative arrangement of model turbofan, the free power turbine shaft passes concentrically through the centre of the gas generator shaft. The free power turbine drives the fan through a gearbox, which in this case is located in front of the gas generator intake (as shown in the diagram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

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

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

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 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.

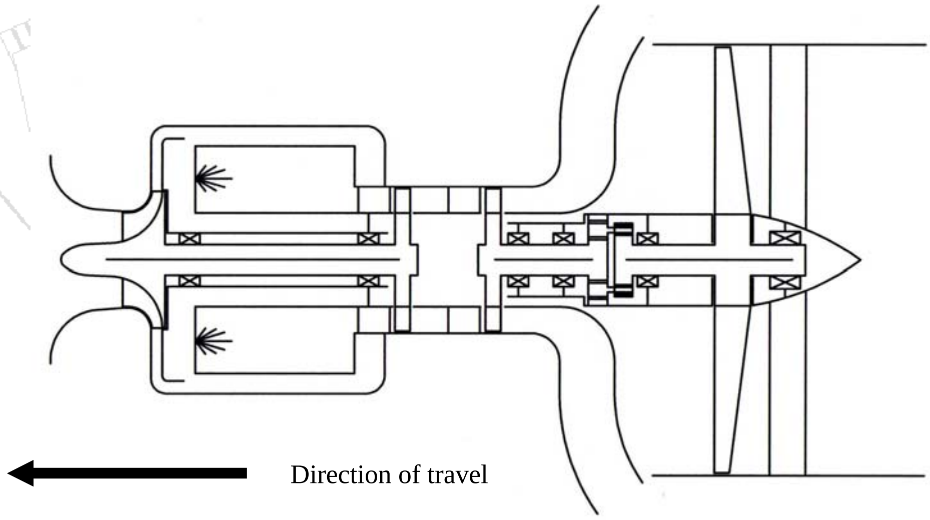


Turbofan Engines (Pusher)

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 severe injury.

The 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 still hot enough to cause burns. It is also essential that the exhaust be ducted around the outside of the fan shroud.



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 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.