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STARTING AND IGNITION SYSTEMS

TURBINE ENGINE STARTERS

To start a gas turbine engine:

- it is necessary to accelerate the compressor to provide sufficient air to support combustion in the combustion section, or burners

Once ignition and fuel has been introduced and the lite off has occurred:

- the starter must continue to assist the engine until the engine reaches a self sustaining speed

The torque supplied by the starter must be in excess of the:

- torque required to overcome compressor inertia and the friction loads of the engine's compressor

As soon as the starter has accelerated the compressor sufficiently to establish airflow through the engine:

- the ignition is turned on followed by the fuel.

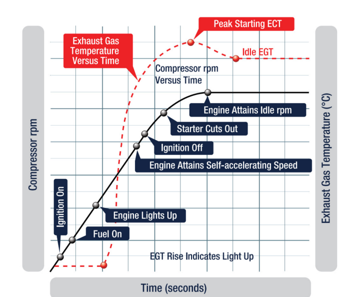

Figure 13-1. Typical gas turbine engine starting sequence.

The exact sequence of the starting procedure is important since there must be

- sufficient airflow through the engine to support combustion before the fuel air mixture is ignited.

At low engine cranking speeds:

- the fuel flow rate is not sufficient to enable the engine to accelerate

for this reason:

- the starter continues to crank the engine until after self accelerating speed has been attained

If assistance from the starter were cut off below the self accelerating speed:

- the engine would either fail to accelerate to idle speed
- might even decelerate because it could not produce sufficient energy to sustain rotation
- or to accelerate during the initial phase of the starting cycle.

The starter must continue to assist the engine considerably

- above the self accelerating speed to avoid a delay in the starting cycle

which would result in a:

- hot or hung false start or a combination of both

At the proper points in the sequence:

- the starter and ignition are automatically cut off.

The basic types of starters that are in current use for gas turbine engines are :

1, direct current (DC) electric motor

2, starter/generators

3, air turbine type of starters.

- Many types of turbine starters have included several different methods for turning the engine for starting.

An air impingement starting system, which is sometimes used on small engines: consists of

- jets of compressed air piped to the inside of the compressor turbine case
- so that the jet air blast is directed onto the compressor or turbine rotor blades, causing them to rotate.

Types of starters

1, CARTRIDGE PNEUMATIC STARTERS

A typical cartridge/pneumatic turbine engine starter may be :

- operated as an ordinary air turbine starter from a ground operated air supply or an engine cross bleed source

To accomplish a cartridge start:

- a cartridge is first placed in the breech cap

The breech is then :

- closed on the breech chamber by means of the breech handle and then rotated a partial turn to engage the lugs between the two breech sections

The cartridge is ignited by applying:

- voltage through the connector at the end of the breech handle

Upon ignition:

- the cartridge begins to generate gas.

The gas is forced out of the breech to the:

- hot gas nozzles that are directed toward the buckets on the turbine rotor, and rotation is produced via the ~~overboard exhaust collector~~

Before reaching the nozzle:

- the hot gas passes an outlet leading to the relief valve

This valve directs hot gas to the:

- turbine, bypassing the hot gas nozzle, as the pressure rises above the preset maximum

the pressure of the gas within the hot gas circuit is:

- maintained at the optimum level

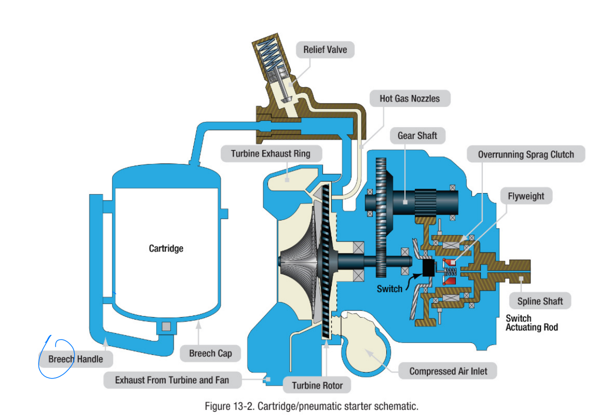

Figure 13-2. Cartridge/pneumatic starter schematic.

My statement:
A cartridge pneumatic starter is a system used to start a turbine engine. It can work in two ways:

1. Using air supply: It operates like a normal air turbine starter, using compressed air from the ground or another engine.

2. Using a cartridge: Hereâ€™s how the cartridge method works:

- A cartridge (like a small gas generator) is placed inside a part called the breech cap.
- The breech is closed and locked with a handle that you turn slightly to secure it.
- Voltage is applied through a connector on the handle to ignite the cartridge.

Once the cartridge ignites, it generates hot gas:

- The gas exits the breech and flows to nozzles aimed at the turbines buckets. These nozzles direct the gas to spin the turbine rotor, which helps start the engine.
- If the gas pressure becomes too high, a relief valve diverts some gas away to maintain the correct pressure. This keeps the system working safely and efficiently.

In simple terms, the cartridge burns to create gas, which spins the turbine to start the engine, with safety measures to control the gas pressure!

2, The fuel/air combustion starter

The fuel/air combustion starter was used to start gas turbine engines by using the:
- combustion energy of jet A fuel and compressed air

The starter consists of a:
- turbine driven power unit
- auxiliary fuel
- air
- ignition systems

Operation of this type starter is, in most installations:
- fully automatic

actuation of a single switch causes the starter to:
- fire and accelerate the engine from rest to starter cutoff speed

3, Hydraulic pumps and motors

Hydraulic pumps and motors have also been used for :
- some smaller engines.

Many of these systems are not often used on modern commercial aircraft because of the:
- high power demands required to turn the large turbofan engines during the starting cycle on transport aircraft

ELECTRIC STARTING SYSTEMS AND STARTER GENERATOR STARTING SYSTEMS

Electric starting systems for gas turbine aircraft are of two general types:
1, direct cranking electrical systems
2, starter generator systems

Direct cranking electric starting systems are used mostly on:
- small turbine engines, such as Auxiliary Power Units (APUs), and some small turboshaft engines.

Starter/generator starting systems are also similar to direct cranking electrical systems except that:
- after functioning as a starter, they contain a second series of windings that allow it to switch to a generator after the engine has reached a self sustaining speed.
- This saves weight and space on the engine

The starter/generator is permanently engaged with the:
- engine shaft through the necessary drive gears

while the direct cranking starter must employ some means of:
- disengaging the starter from the shaft after the engine has started

The starter/generator unit is basically a:
- shunt generator with an additional heavy series winding

This series winding is electrical ly connected to:
- produce a strong field and a resulting high torque for starting

Starter/generator units are desirable from an economical standpoint, since one unit performs the functions of both starter and generator.

the total weight of starting system components is:
- reduced and fewer spare parts are required

The starter generator internal circuit has four field windings:
1, series field (C field)
2, shunt field
3, a compensating field
4, an interpole or commutating winding.

During starting;

- the C field, compensating, and commutating windings are used

The unit is similar to a :

- direct cranking starter since all of the windings used during starting are in series with the source

While acting as a starter, the unit makes:

- no practical use of its shunt field

A source of 24 volts and 1 500 peak amperes:

- is usually required for starting

When operating as a generator:

- the shunt, compensating, and commutating windings are used.

The C field is used only for:

- starting purposes

The shunt field is connected:

- in the conventional voltage control circuit for the generator

Compensating and commutating or interpole windings provide:

- almost sparkless commutation from no load to full load.

starter generator with an undercurrent controller:

This unit controls the starter/generator when it is used as a :

- starter

Its purpose is to assure:

- positive action of the starter and to keep it operating until the engine is rotating fast enough to sustain combustion

The control block of the undercurrent controller contains:

- two relays:

One is the:

- motor relay that controls the input to the starter.

The other:

- the undercurrent relay: controls the operation of the motor relay.

The sequence of operation for the starting system is discussed in the following:

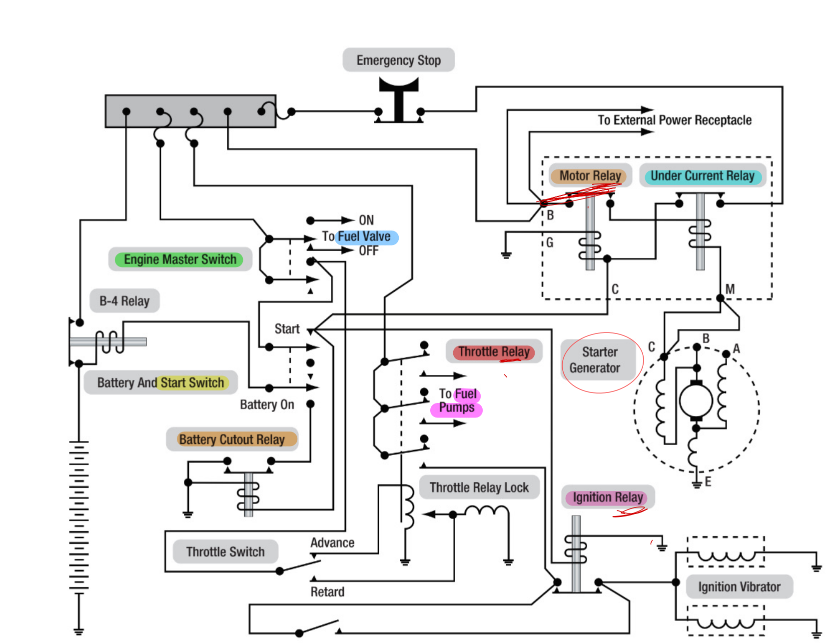

Figure 13-5. Starter generator circuit.

To start an engine equipped with an undercurrent relay:

- it is first necessary to close the engine master switch

This completes the circuit:

- from the aircraft's bus to the start switch, to the fuel valves, and to the throttle relay

Energizing the throttle relay:

- starts the fuel pumps,
- and completing the fuel valve circuit gives the necessary fuel pressure for starting the engine

As the battery and start switch is turned on, three relays close:

- the motor relay
- ignition relay
- battery cutout relay

The motor relay closes the circuit from the:

- power source to the starter motor.

The ignition relay closes the circuit to the:

- ignition units.

The battery cutout relay:

- disconnects the battery

Opening the battery circuit is necessary because:
- the heavy drain of the starter motor would damage the battery.

Closing the motor relay allows a:
- very high current to flow to the motor

Since this current flows through the coil of the undercurrent relay:
- it closes

Closing the undercurrent relay:
- completes a circuit from the positive bus to the motor relay coil, ignition relay coil, and battery cutout relay coil

The start switch is allowed to :
- return to its normal off position, and all units continue to operate.

As the motor builds up speed:
- the current draw of the motor begins to decrease.

As it decreases to less than 200 amp:
- the undercurrent relay opens

This action breaks the circuit from:
- the positive bus to the coils of the motor, ignition, and battery cutout relays

The deenergizing of these relay coils:
- halts the start operation

After these procedures are completed:
- the engine should be operating efficiently and ignition should be self sustaining.

If, however, the engine fails to reach sufficient speed to halt the starter operation:
- the stop switch may be used
- to break the circuit from the positive bus to the main contacts of the undercurrent relay

Troubleshooting a Starter Generator Starting System

Starter Generator Starting System Troubleshooting Procedures		
Probable Cause	**Isolation Procedure**	**Remedy**
Engine Does Not Rotate During Start Attempt		
• Low supply voltage to the starter	• Check voltage of the battery or external power source.	• Adjust voltage of the external power source or charge batteries.
• Power switch is defective	• Check switch for continuity.	• Replace switch.
• Ignition switch in throttle quadrant	• Check switch for continuity.	• Replace switch.
• Start-lockout relay is defective	• Check position of generator control switch.	• Place switch in OFF position.
• Battery series relay is defective	• With start circuit energized, check for 48 volts DC across series relay coil.	• Replace relay if no voltage is present.
• Starter relay is defective	• With start circuit energized, check for 48 volts DC across starter relay coil.	• Replace relay if no voltage is present.
• Defective starter	• With start circuit energized, check for proper voltage at the starter.	• Replace the starter if voltage is present.
• Start lock-in relay defective	• With start circuit energized, check for 28 volts DC across the relay coil.	• Replace relay if voltage is not present.
• Starter drive shaft in component drive gearbox is sheared	• Listen for sounds of starter rotation during an attempted start. If the starter rotates but the engine does not, the drive shaft is sheared.	• Replace the engine.
Engine Starts But Does Not Accelerate To Idle		
• Insufficient starter voltage	• Check starter terminal voltage.	• Use larger capacity ground power unit or charge batteries
Engine Fails To Start When Throttle Is Placed In Idle		
• Defective ignition system	• Turn on system and listen for spark-igniter operation.	• Clean or replace spark igniters, or replace exciters or leads to igniters.

Figure 13-6. Starter generator starting system troubleshooting procedures.

The procedures listed in Figure 13-6 are typical of those used to:

- repair malfunctions in a starter generator starting system similar to the system described in this section.

The appropriate manufacturer's instructions and approved maintenance directives should always be:

- consulted for the aircraft involved.

AIR TURBINE STARTERS

Air turbine starters are designed to provide:

- high starting torque from a small, lightweight source

The typical air turbine starter weighs from :

- one fourth to one half as much as an electric starter capable of starting the same engine.

It is capable of developing considerable:

- more torque than the electric starter.

The typical air turbine starter consists of an:

- axial flow turbine: that turns a drive coupling through a reduction gear train and a starter clutch mechanism

The air to operate an air turbine starter is supplied from either a:

- ground operated air cart
- the APU
- cross bleed start from an engine already operating

Only one source of around 30-50 pounds per square inch (psi):

- is used at a time to start the engines

The pressure in the ducts must be:

- high enough to provide for a complete start with a normal limit minimum of about 30 psi.

When starting engines with an air turbine starter:

- always check the duct pressure prior to the start attempt

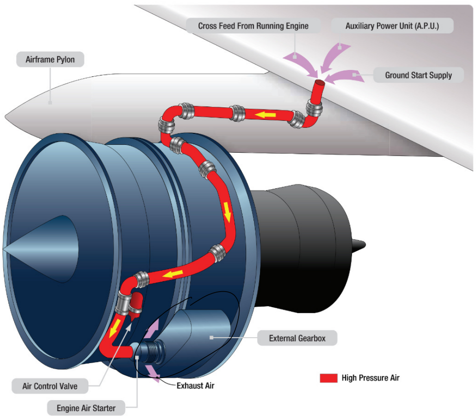

Figure 13-7. Air turbine starters are supplied by ground cart, APU, or another operating onboard engine.

Cutaway view of an air turbine starter

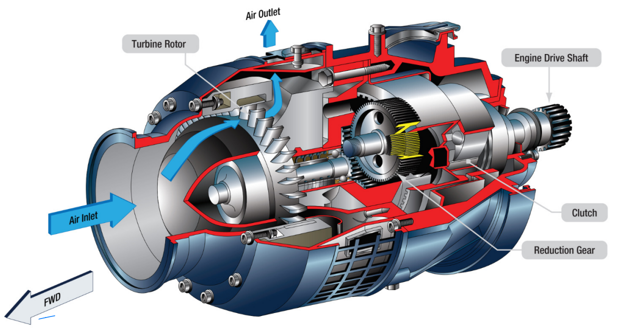

Figure 13-8. Cutaway view of an air turbine starter.

The starter is operated by:

- introducing air of sufficient volume and pressure into the starter inlet

The air passes into the starter turbine housing where it is:

- directed against the rotor blades by the nozzle vanes causing the turbine rotor to turn.

As the rotor turns:

- it drives the reduction gear train and clutch arrangement

which includes:

1, the rotor pinion

2, planet gears and carrier

3, sprag clutch assembly

4, output shaft assembly

5, drive coupling

The sprag clutch assembly:

- engages automatically as soon as the rotor starts to turn

but:

- disengages as soon as the drive coupling turns more rapidly than the rotor side.

When the starter reaches this overrun speed:

- the action of the sprag clutch allows the gear train to coast to a halt

The output shaft assembly and drive coupling continue to turn as long as the:

- engine is running

A rotor switch actuator, mounted in the turbine rotor hub, is set to :

- open the turbine switch when the starter reaches cutout speed.

Opening the turbine switch:

- interrupts an electrical signal to the start valve.

This closes the:

- valve and shuts off the air supply to the starter

The turbine housing contains the:

- rotor
- the rotor switch actuator
- the nozzle components that direct the inlet air against the rotor blades.

The turbine housing incorporates a-rotor containment ring designed :

- to dissipate the energy of blade fragments and direct their discharge at low energy through the exhaust duct
- in the event of rotor failure due to excessive turbine overspeed.

The transmission housing contains the:

- reduction gears
- the clutch components
- the drive coupling

transmission housing also provides a:

- reservoir for the lubricating oil

Normal maintenance for air turbine starters includes:

- checking the oil level
- inspecting the magnetic chip detector for metal particles
- checking for leaks

Oil can be added to the transmission housing sump through a:

- port in the starter

This port is closed by a:

- vent plug containing a ball valve that allows the sump to be vented to the atmosphere during normal flight.

The housing also incorporates a :

- sight plug in the transmission drain opening

A magnetic drain plug :

- attracts any ferrous particles that may be in the oil

The starter uses turbine oil:

- the same as the engine,

but:

- this oil does not circulate through the engine.

The ring gear housing

which is internal contains:

- rotor assembly

The switch housing contains the:

- turbine switch and bracket assembly

To facilitate starter installation and removal:

- a mounting adapter is bolted to the mounting pad on the engine

Quick detach clamps join the:

- starter to the mounting adapter and inlet duct

the starter is easily removed for:

- maintenance or overhaul

by:

- disconnecting the electrical line, loosening the clamps, and carefully disengaging the drive coupling from the engine starter drive as the starter is withdrawn.

The air path is directed through a: one of those 2 ways not both

1, combination pressure regulating and shutoff valves

2, a bleed valve that controls all duct pressure flowing to the starter inlet ducting.

This valve gauge is used to:

- check the oil quantity.

A magnetic drain regulates the:

- pressure of the operating air and shuts off the air supply to the engine when selected off.

Downstream from the bleed valve is the start valve, which is used to:

- control air flow into the starter.

The pressure regulating and shutoff valve consists of two subassemblies:
- pressure regulating valve
- pressure regulating valve control

The regulating valve assembly consists of a:
- valve housing containing a butterfly type valve.

The shaft of the butterfly valve is connected through a :
- cam arrangement to a servo piston

When the piston is actuated,:
- its motion on the cam causes rotation of the butterfly valve.

The slope of the cam track is designed to:
- provide small initial travel and high initial torque when the starter is actuated

The cam track slope also provides;
- more stable action by increasing the opening time of the valve.

The control assembly is mounted on the:
- regulating valve housing

consists of a
- control housing in which a solenoid is used to stop the action of the control crank in the off position.

The control crank links a pilot valve that:
- meters pressure to the servo piston

with the :
- bellows connected by an air line to the pressure sensing port on the starter.

Turning on the starter switch:
- energizes the regulating valve solenoid

The solenoid retracts and allows the control crank to :
- rotate to the open position

The control crank is rotated by the:
- control rod spring moving the control rod against the closed end of the bellows

Since the regulating valve is closed and downstream pressure is negligible:
- the bellows can be fully extended by the bellows spring.

As the control crank rotates to the open position:
- it causes the pilot valve rod to open the pilot valve,
- allowing upstream air, which is supplied through a suitable filter and a restriction in the housing,
- to flow into the servo piston chamber

The drain side of the pilot valve, which bleeds the servo chamber to the atmosphere, is now :
- closed by the pilot valve rod and the servo piston moves inboard.

This linear motion of the servo piston is translated to:
- rotary motion of the valve shaft by the rotating cam, thus opening the regulating valve

As the valve opens:
- downstream pressure increases

This pressure is bled back to the:
- bellows through the pressure sensing line and compresses the bellows

This action moves the:
- control rod,

thereby :
- turning the control crank,
- moving the pilot valve rod gradually away from the servo chamber to vent to the atmosphere

When downstream (regulated) pressure reaches a preset value the amount of air flowing into the servo through the restriction
- equals the amount of air being bled to the atmosphere through the servo bleed

The system is then in a state of:
- equilibrium

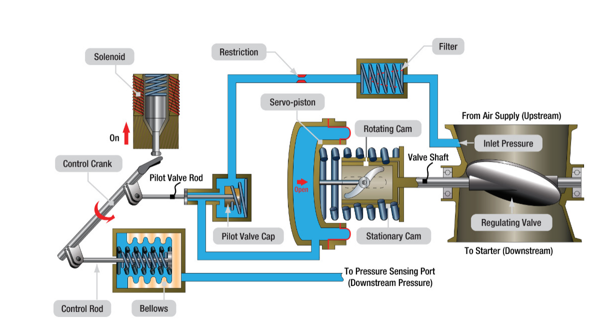

Figure 13-11. Pressure-regulating and shutoff valve in ON position.

When the bleed valve and the start valve are open:

- the regulated air passing through the inlet housing of the starter impinges on the turbine causing it to turn

As the turbine turns:

- the gear train is activated and the inboard clutch gear, which is threaded onto a helical screw,
- moves forward as it rotates its jaw teeth engage those of the outboard clutch gear to drive the output shaft of the starter

The clutch is an :

- overrunning type to facilitate positive engagement and minimize chatter

When starter cut-out speed is reached:

- the start valve is closed

When the air to the starter is terminated:

- the outboard clutch gear, driven by the engine, begins to turn faster than the inboard clutch gear
- the inboard clutch gear, actuated by the return spring,
- disengages the outboard clutch gear allowing the rotor to coast to a halt

The outboard clutch shaft continues to turn with the:

- engine

Air Turbine Troubleshooting Guide

Air Turbine Starter System Troubleshooting Procedures

Trouble	Probable Cause	Remedy
• Starter does not operate (no rotation).	• No air supply • Electrical open in cutout switch • Sheared starter drive coupling • Internal starter discrepancy	• Check air supply. • Check switch continuity. If no continuity, remove starter and adjust or replace switch. • Remove starter and replace drive coupling. • Remove and replace starter.
• Starter will not accelerate to normal cutoff speed.	• Low starter air supply • Starter cutout switch set improperly • Valve pressure regulated too low • Internal starter malfunction	• Check air source pressure. • Adjust rotor switch actuator. • Replace valve. • Remove and replace starter.
• Starter will not not cut off.	• Low air supply • Rotor switch actuator set too high • Starter cutout switch shorted	• Check air supply. • Adjust switch actuator assembly. • Replace switch and bracket assembly.
• External oil leakage.	• Oil level too high • Loose vent, oil filler, or magnetic plugs • Loose clamp band assembly	• Drain oil and re-service properly. • Tighten magnetic plug to proper torque. • Tighten vent and oil filler plugs as necessary and lock wire. Tighten clamp band assembly to higher torque.
• Starter runs, but engine does not turn over.	• Sheared drive coupling	• Remove starter and replace the drive coupling. If couplings persist in breaking in unusually short periods of time, remove and replace starter.
• Starter inlet will not line up with supply ducting.	• Improper installation of starter on engine, or improper indexing of turbine housing on starter r	• Check installation and/or indexing for conformance with manufacturer's installation instructions and the proper index position of the turbine housing specified for the aircraft.
• Metallic particles on magnetic drain plug.	• Small fuzzy particles indicate normal wear • Particles coarser than fuzzy (chips, slivers, etc.) indicate internal difficulty	• No remedial action required. • Remove and replace starter.
• Broken nozzle vanes.	• Large foreign particles in air supply	• Remove and replace starter and check air supply filter
• Oil leakage from vent plug assembly.	• Improper starter installation position	• Check installed position for levelness of oil plugs and correct as required in accordance with manufacturer's installation instructions.
• Oil leakage at drive coupling.	• Leaking rear seal assembly	• Remove and replace starter.

Figure 13-12. Air turbine starter system troubleshooting procedures.