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FUEL SYSTEMS

GENERAL REQUIREMENTS

The fuel system must be possible to :
- increase or decrease the power at will to obtain the thrust required for any operating condition

In turbine powered aircraft, this control is provided by:
- varying the flow of fuel to the combustion chambers

The quantity of fuel suppl ied must be:
- adjusted automatical ly to correct for changes in ambient temperature or pressure

If the quantity of fuel becomes excessive in relation to mass airflow through the engine:
- the limiting temperature of the turbine blades can be exceeded,

or
- it will produce compressor stall and a condition referred to as rich blowout

This occurs when:
- the amount of oxygen in the air supply is insufficient to support combustion and when the mixture is cooled below the combustion temperature by the excess fuel

The other extreme is :
- lean flame out

occurs if the :
- fuel quantity is reduced proportionally below the air quantity

The engine must operate through acceleration and deceleration:
- without any fuel control related problems.

The fuel system must deliver fuel to the combustion chambers with:
- the right quantity
- right condition for satisfactory combustion

The fuel nozzles form part of the fuel system its job to :
- atomize or vaporize the fuel so that it ignites and burns efficiently.

The fuel system must also supply fuel so that the engine can be easily :
- started on the ground and in the air
- This means that the fuel must be injected into the combustion chambers in a combustible condition during engine starting, and that combustion must be sustained while the engine is accelerating to its normal idling speed

Another critical condition to which the fuel system must respond occurs during a

- rapid acceleration

When the engine is accelerated, energy must be furnished to the :

- turbine in excess of that necessary to maintain a constant rpm.

However, if the fuel flow increases too rapidly,

- an over rich mixture can be produced
- with the possibility of a rich blowout or compressor stall

Turbofan, turbojet, turboshaft, and Turboprop engines are equipped with a :

- fuel control unit which automatically satisfies the requirements of the engine

TURBINE ENGINE FUEL METERING SYSTEMS

Gas turbine engine fuel controls can be divided into three basic groups:
1, Hydromechanical.
2, Hydromechanical/Electronic.
3, Full Authority Digital Engine (or Electronics) Control (FADEC).

Introduction to TURBINE ENGINE FUEL METERING SYSTEMS

The hydromechanical/electronic fuel control is a :
- hybrid of the two types of fuel control, but can function solely as a hydromechanical control

In the dual mode:
- inputs and outputs are electronic, and fuel flow is set by servo motors.

The third type, FADEC:
- uses electronic sensors for its inputs and controls fuel flow with electronic outputs.

The FADEC type control gives the electronic controller (computer):
- complete control

The computing section of the FADEC system depends completely on:
- sensor inputs to the electronic engine control (EEC) to meter the fuel flow.

The fuel metering device meters the fuel using only:
- outputs from the EEC

Most turbine fuel controls are quickly going to the:
- FADEC type of control.

This electronically controlled fuel control is:
- very accurate in scheduling fuel by sensing many of the engine parameters.

Regardless of the type, all fuel controls accomplish :
- the same function.

That function is to :
- schedule the fuel flow to match the power required by the pilot

TURBINE ENGINE FUEL METERING SYSTEMS

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1, HYDROMECHANICAL FUEL CONTROLS (my students)

Hydromechanical fuel controls are
- systems used in engines to regulate fuel flow.

They rely entirely on
- mechanical components, without any help from electronics,
- and are driven by the engine's own moving parts to sense factors like speed, pressure, and temperature.

The hydromechanical fuel controls have two main jobs:
1. Computing: They figure out how much fuel the engine needs.
2. Metering: They deliver the right amount of fuel using cams and valves.

However, they are not very precise, and their operation is quite complex.

Over time, electronic fuel controls have become
- more popular because they can handle more data with better accuracy.

Early versions of electronic systems combined the two technologies using
- the hydromechanical system for the main job
- and the electronic system to fine-tune the fuel flow. In case the electronics failed, the hydromechanical part acted as a backup.

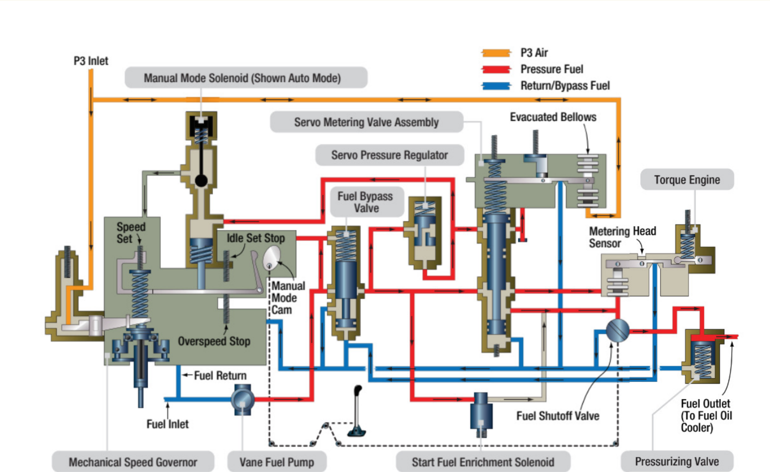

Figure 11-1. Fuel control assembly schematic hydromechanical/electronic.

2, HYDROMECHANICAL/ELECTRONIC FUEL CONTROLS

this type of system used a :

- remotely located EEC to adjust the fuel flow.

The basic function of the engine fuel system is to:

- Pressurize the fuel,
- Meter fuel flow, and
- Deliver atomized fuel to the combustion section of the engine.

Hydromechanical Fuel Control Assembly:

- Contains a fuel shutoff section and a fuel metering section.
- Often mounted on the vane fuel pump assembly.

Provides:

- Power lever connection.
- Fuel shutoff function.
- Mechanical overspeed protection for the gas generator spool during normal (automatic mode) operation.

Modes of Operation:

1. Automatic Mode:

- The EEC (Electronic Engine Control) manages fuel metering.
- Handles thrust setting, speed governing, acceleration, and deceleration through the fuel control assembly.

2. Manual Mode:

- The hydromechanical control takes over.

Allows engine operation at reduced power if:

- Electrical/EFCU failure occurs, or
- Pilot chooses to switch modes.

The total engine fuel and control system consists of the following components and provides the functions as indicated:

1, The vane fuel pump assembly:

- is a fixed displacement fuel pump that provides high pressure fuel to the engine fuel control system

Figure 11-2. Fuel pump and filter.

The total engine fuel and control system consists of the following components and provides the functions as indicated:

1, The vane fuel pump assembly:

- is a fixed displacement fuel pump that provides high pressure fuel to the engine fuel control system

2, The filter bypass valve:

- fuel pump allows fuel to bypass the fuel filter when the pressure drop across the fuel filter is excessive

3, The hydromechanical fuel control assembly:

- provides the fuel metering function of the EFCU

3.1, The pressurizing valve also provides a :

- positive leak tight fuel shutoff to the engine fuel nozzles when the manual valve is closed

4, The flow divider and drain valve assembly:

- proportions fuel to the engine primary and secondary fuel nozzles.

It drains the:

- nozzles and manifolds at engine shutdown.

It also incorporates an :

- integral solenoid for modifying the fuel flow for cold starting conditions.

During an engine start, the flow divider directs:

- all flow through the primary nozzles

After start, as the engine fuel demand increases, the flow divider valve opens to allow the:

- secondary nozzles to function

5, The fuel manifold assembly is a :

- matched set consisting of both primary and secondary manifolds and the fuel nozzle assemblies

- These are the components that are used in a HYDROMECHANICAL/ELECTRONIC FUEL CONTROLS

3, FADEC FUEL CONTROL SYSTEMS

A full authority digital electronic control (FADEC) has been developed to:
- control fuel flow on most new turbine engine models.

A true FADEC system has no:
- hydromechanical fuel control backup system

The system uses:
- electronic sensors that feed engine parameter information into the EEC

The EEC gathers the needed information to:
- determine the amount of fuel flow and transmits it to a fuel metering valve

The fuel metering valve simply reacts to the:
- commands from the EEC.

The EEC is the computing section of the:
- fuel delivery system and the metering valve meters the fuel flow.

FADEC for Propulsive Engines

Many large high bypass turbofan engines use the FADEC type of fuel control system

The EEC is the primary component of the:
- FADEC engine fuel control system.

The EEC is a computer that controls the:
- operation of the engine

if one Fails the other work

convection: is a way of Coling the EEC

The EEC housing contains two electronic channels:
- two separate computers
- that are physically separated internally and are naturally cooled by convection

The EEC is generally placed in an area of the engine nacelle that is cool during:
- engine operation.

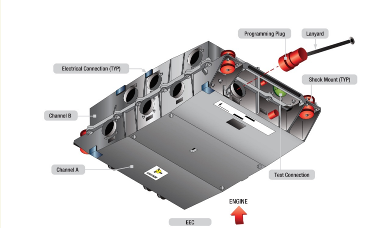

Figure 11-5. EEC and programming plug.

The EEC computer uses data it receives from many engine sensors and airplane systems to:

- control the engine operation

It receives electronic signals from the:

- flight deck to set engine power or thrust

The throttle lever angle resolver supplies the EEC with a:

- signal in proportion to the thrust lever position

Power for the EEC comes from the:

- aircraft electrical system or the permanent magnet alternator (PMA)

When the engine is running:

- the (PMA) supplies power to the EEC directly

The EEC is a two channel computer that :

- controls every aspect of engine operation

Each channel, which is an :

- independent computer, can completely control the operation of the engine

The EEC can control the engine thrust in two modes:

- which can be selected by use of a mode selection switch

Mode 1 , In the normal mode:

- engine thrust is set through engine pressure ratio (EPR)

Mode 2, in the alternate mode:

- used when the normal mode does not work
- thrust is set by N1. (RPM)

When the fuel control switch is moved from run to cutoff:

- the EEC resets

During this reset:

- all fault data is recorded in the nonvolatile memory

The EEC controls the :

- metering valve in the fuel metering unit to supply fuel flow for combustion.

The fuel metering unit (FMU), is mounted on the:

- front face of the gearbox
- is attached to the front of the fuel pump.

The EEC also sends a signal to the
- minimum pressure and shutoff valve in the fuel metering unit to start or stop fuel flow.

The EEC receives position feedback for several engine components by using :
- rotary differential transformer,
- linear variable differential transformer,
- and thermocouples

These sensors feed engine parameter information from several systems back to the:
- EEC

Each channel of the EEC has:
- seven elect r ica l connections, three on each side and one on the bottom

Both channels share the inputs of the:
- two connections on the top of the EEC

These are the :
- programming plug and test connector

The programming plug selects the proper:
- software in the EEC for the thrust rating of the engine

FUEL SYSTEM LAYOUT AND COMPONENTS

ENGINE DRIVEN FUEL PUMPS

Main fuel pumps deliver a:
- continuous supply of fuel at the proper pressure and at all times during operation of the aircraft engine.

The engine driven fuel pump must be capable of:
- delivering the maximum needed flow at appropriate pressure to obtain satisfactory nozzle spray and accurate fuel regulation

These engine driven fuel pumps may be divided into two distinct system categories:
1, Constant displacement : Positive displacement
2, Non-constant displacement: non positive displacement

Their use depends on where in the engine fuel system they are used.

Non-constant displacement: non positive displacement ;

Generally, a nonpositive displacement (centrifugal pump) is used at the:
- inlet of the engine driven pump

to provide:
- positive flow to the second stage of the pump.

The output of a centrifugal pump can be:
- varied as needed
- is sometimes referred to as a boost stage of the engine driven pump.

Constant displacement : Positive displacement;

The second or main stage of the engine driven fuel pump for turbine engines is generally a :
- positive displacement type of pump.

The term "positive displacement" means:
- that the gear supplies a fixed quantity of fuel to the engine for every revolution of the pump gears

relief valve is incorporated in the :
- discharge port of the pump

This valve opens at a predetermined pressure and is capable of :
- bypassing the total fuel flow

This allows fuel in excess of that required for engine operation at the time to be recirculated.

FUEL HEATER

Gas turbine engine fuel systems are very susceptible to :
- the formation of ice in the fuel filters

When the fuel in the aircraft fuel tanks cools to 0°C or below:
- residual water in the fuel tends to freeze, forming ice crystals

When these ice crystals in the fuel become trapped in the filter:
- they block fuel flow to the engine
- which causes a very serious problem

To prevent this problem, the fuel is kept at a:
- temperature above freezing

Warmer fuel also can improve:
- combustion, so some means of regulating the fuel temperature is needed

One method of regulating fuel temperature is to
- use a fuel heater which operates as a heat exchanger to warm the fuel

The heater can use :
- engine bleed air

or
- engine lubricating oil as a source of heat

The bleed air type is called an :
- air to liquid exchanger

the oil type is known as a :
- liquid to liquid heat exchanger

The function of a fuel heater is to :
- protect the engine fuel system from ice formation.

Fuel deicing systems are designed to be used
- intermittently.

The control of the system may be:
- manual, by a switch in the cockpit,

or
- automatic, using a thermostatic sensing element in the fuel heater to open or close the air or oil shutoff valve

In a FADEC system, the computer controls:
- the fuel temperature by sensing the fuel temperature and heating it as needed

FUEL FILTERS

A low pressure filter is installed between the
- supply tanks and the engine fuel system

to protect the :
- engine driven fuel pump and various control devices

An additional high pressure fuel filter is installed between the :
- fuel pump and the fuel control

to protect the fuel control from :
- contaminants that could come from the low pressure pump

The three most common types of filters in use are:
1, the micro filter
2, the wafer screen filter
3, the plain screen mesh filter

The micron filter has the
- greatest filtering action of any present day filter type and, as the name implies, is rated in microns
- (A micron is one thousandth of 1 millimeter.)

The minute openings make this type of filter susceptible to:
- clogging

therefore,
- a bypass valve is a necessary safety factor

FUEL SPRAY NOZZLES AND MANIFOLDS

The fuel nozzles inject fuel into the combustion area in a:
- highly atomized, precisely patterned spray so that burning is completed evenly, in the shortest possible time, and in the smallest possible space

It is very important that the
- fuel be evenly distributed
- and well centered in the flame area within the liners.

This is to preclude the formation of any hot spots in the combustion chambers and to prevent:
- the flame burning through the liner

Fuel nozzle types vary considerably between engines

although for the most part fuel is sprayed into the combustion area under :
- pressure through small orifices in the nozzles.

The two types of fuel nozzles generally used are the
- the simplex configurations
- the duplex configurations

the simplex nozzle requires only a :
- single manifold for proper fuel delivery

The duplex nozzle usually requires a
- dual manifold
- a pressurizing valve or flow divider for dividing primary and secondary (main) fuel flow

The fuel nozzles can be constructed to be installed in various ways. The two methods used quite frequently are:

1, External mounting:
- wherein a mounting pad is provided for attachment of the nozzles to the case or the inlet air elbow, with the nozzle near the dome

2, Internal mounting:
- at the liner dome, in which the chamber cover must be removed for replacement or maintenance of the nozzle

The nozzles used in a specific engine should be :
- matched so that they flow equal amounts of fuel

The fuel nozzle must present a :
- fine spray with the correct pattern and optimum atomization

Simplex Fuel Nozzle:

The simplex fuel nozzle was the first nozzle type used in turbine engines and was replaced in most installations with the duplex nozzle which gave a:

- better atomization at starting and idling speeds.

simplex nozzles consists of a:

- nozzle tip
- an insert
- a strainer made up of fine mesh screen and
- a support.

Figure 11-16. Simplex airblast nozzle cutaway.

Duplex Fuel Nozzle

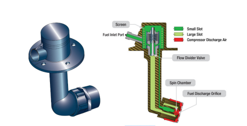

Figure 11-18. Duplex fuel nozzle.

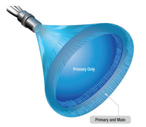

Figure 11-17. Duplex nozzle spray pattern.

The duplex fuel nozzle is :

- widely used in present day gas turbine engines

its use requires a

- flow divider

but at the same time it offers a

- desirable spray pattern for combustion over a wide range of operating pressures.

Airblast Nozzles

Airblast nozzles are used to provide :

- improved mixing of the fuel and airflow to provide an optimum spray for combustion.

Squirrel vanes are used to

- mix the air and fuel at the nozzle opening.

By using a proportion of the primary combustion airflow in the fuel spray:

- locally rich fuel concentrations can be reduced

This type of fuel nozzle can be :

- either simplex or duplex, depending upon the engine.

This nozzle type can operate at

- lower working pressures than other nozzles which allows for lighter pumps.

This airblast nozzle also helps in

- reducing the tendency of the nozzle to carbon up which can disturb the flow pattern.

Flow Dividers

This is only used in duplex nozzle

Figure 11-19. Flow divider.

A flow divider creates
- primary and secondary fuel supplies

that are discharged through
- separate manifolds, providing two separate fuel flows.

FUEL PRESSURIZING AND DUMP VALVES

The fuel pressurizing valve is usually required on engines incorporating duplex fuel nozzles to:
- divide the flow into primary and secondary manifolds

Fuel pressurizing valves usually:
- trap fuel forward of the manifold, giving a positive cutoff

This cutoff prevents fuel from:
- dribbling into the manifold and through the fuel nozzles
- limiting afterfires and carbonization of the fuel nozzles

Carbonization occurs because
- combustion chamber temperatures are lowered and the fuel is not completely burned.

A flow divider performs essentially the same function as a
- pressurizing valve

It is used, as the name implies, to
- divide flow to the duplex fuel nozzles.

It is not unusual for
- units performing identical functions to have different nomenclature between engine manufacturers.

COMBUSTION DRAIN VALVES

The drain valves are units used for
- draining fuel from the various components of the engine
- where accumulated fuel is most likely to present operating problems

The possibility of combustion chamber accumulation with the resultant :
- fire hazard is one problem.

A residual problem is the deposit of lead and/or gum, after evaporation, in such places as
- fuel manifolds
- fuel nozzles.

In some instances, the fuel manifolds are drained by an individual unit known as a
- drip or dump valve.

This type of valve may operate by
- pressure differential

or it may be
- solenoid operated.

The combustion chamber drain valve drains fuel that:
- accumulates in the combustion chamber after each shutdown
- fuel that may have accumulated during a false start.

If the combustion chambers are the can type, fuel drains by gravity down through the flame tubes or interconnecter tubes until it gathers in the lower chambers which are fitted with drain lines to the drain valve. If the combustion chamber is of the basket or annular type, the fuel merely drains through the air holes in the liner and accumulates in a trap in the bottom of the chamber housing which is connected to the drain line.

After the fuel accumulates in the bottom of the combustion chamber or drain lines:
- the drain valve allows the fuel to be drained whenever pressure within the manifold or the burner(s) has been reduced to near atmospheric pressure.

A small spring holds the valve
- off its seat until pressure in the combustion chamber during operation overcomes the spring and closes the valve

The valve is closed during:
- engine operation.

It is imperative that this valve be in

- good working condition to drain accumulated fuel after each shutdown.

Otherwise:

- a hot start during the next starting attempt or an afterfire after shutdown is likely to occur.

FUEL QUANTITY INDICATING UNITS

A fuel counter or indicator mounted on the

- instrument panel

is electrically connected to a:

- flowmeter installed in the fuel line to the engine

The fuel counter, or totalizer, is used to:

- keep record of fuel use.

When the aircraft is serviced with fuel, the counter is manually set to the total number of

- pounds of fuel in all tanks.

As fuel passes through the measuring element of the flowmeter:

- it sends electrical impulses to the fuel counter.

These impulses actuate the fuel counter mechanism so that the

- number of pounds passing to the engine is subtracted from the original reading.

Thus, the fuel counter continually shows the :

- total quantity of fuel, in pounds, remaining in the aircraft.

There are certain conditions that cause the fuel counter indication to be inaccurate

Any jettisoned fuel is indicated on the fuel counter as:

- fuel still available for use

Any fuel that leaks from a tank or a fuel line upstream of the flowmeter is :

- not counted