Combustion Gas Turbine Fuel Pumps

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The modern combustion gas turbine is one of the most reliable machines in use and a workhorse of the electric power generating industry. They can be on-site and running in a relatively short period

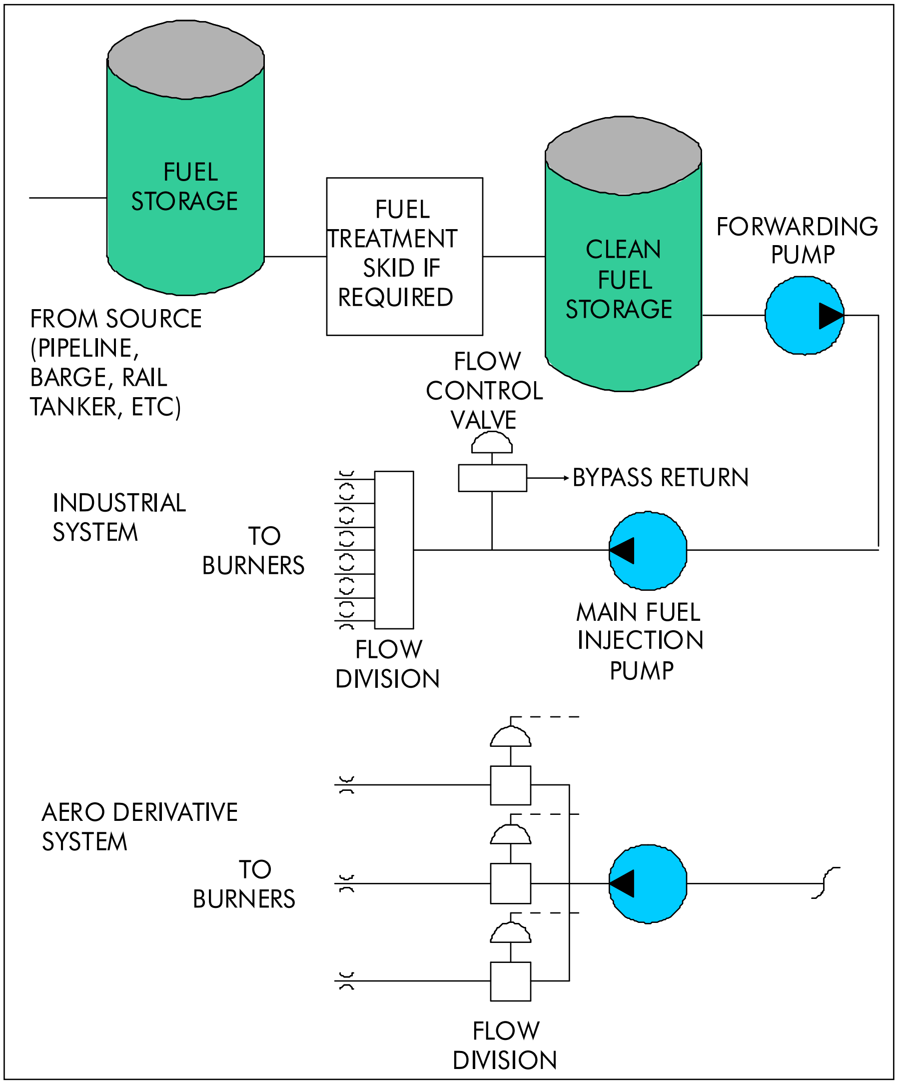

Figure 1 – Liquid fuel system schematic

providing quick additional power capability when needed. The fuel system is a very key part of a combustion gas turbine power plant or system, figure 1.

The most common fuels for these machines are natural gas and distillate fuel oil. Many industrial machines are delivered suitable to burn either gaseous fuel or liquid fuels. Thus, a liquid fuel system is frequently a part of the installation. Even if natural gas is the primary fuel, liquid fuel as a backup is very common to provide for interruptions in gas supplies. Some fuels are relatively inexpensive if they are an excess product from a refinery. Naphtha is currently a very popular gas turbine fuel in India due to government regulation. Typical rotary positive displacement main fuel pump performance is illustrated in figure 2. As can be seen, pump efficiency is quite good. Flow performance is also fairly flat over a wide pressure range.

FUELS

Common liquid fuels for combustion gas turbines include:

Naphtha	Natural Gas Liquids
Methanol	Various Jet Fuels
Kerosene	Natural Gasoline
Crude Oil	Distillate (no. 2 Fuel)
Gas Oil	Residual (Bunker) Fuel Oil

Many of these fuels require special treatment and/or handling to be both safe to use and to minimize excessive erosion or corrosion to the hot gas parts of the machine. For example, naphtha is an extremely volatile liquid and some purchasers of pumps for

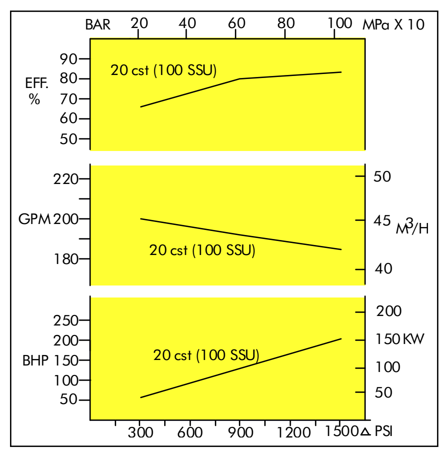

Figure 2 – Medium size main fuel pump performance at 3500 rpm pump speed

this fuel specify a barrier system for the pump shaft seals. Figure 3 shows a twin screw naphtha fuel injection pump that includes a lube oil barrier system to insure that any shaft seal leakage is lube oil into the fuel. Such leakage can be readily detected so that an orderly shutdown can be initiated to investigate a possible seal leak. Figure 4 is a simplified schematic of the barrier system. The instrumentation is not shown for clarity.

FUEL TREATMENT

Some crude oils and virtually all residual fuel oils will require heating both to reduce viscosity for efficient handling and to insure that a maximum viscosity, usually less than 20 centistokes (100 SSU), for the burner nozzles is achieved. Low pressure fuel treatment skids provide the necessary fuel conditioning components in a package ready for site installation. A normal residual oil may require heating in the range of 225 to 250°F (107 to 121°C) or higher. These fuels will typically require pretreatment to remove solid contaminants and may have additives introduced that provide some corrosion inhibiting performance when the fuel is burned. A water wash to remove objectionable salts may be needed where water soluble salts are dissolved in water and the water is then removed, normally by centrifuge. In addition, gas turbines using crude or residual fuels are normally started as well as shut down while burning a light clean fuel, usually distillate fuel oil. This leaves the injection fuel system, including the pump, flow division mechanism and nozzles, clean for the next restart. Otherwise, crude oils or residual fuel oils may solidify and/or leave deposits that will inhibit a successful restart.

When the main fuel is a heated fuel and the start up/shut down fuel is unheated, consideration should be given to the thermal shock that will be imposed on the main fuel injection pump and downstream fuel system components when its suction flow is switched from an ambient temperature fuel to one of elevated temperature. These pumps and other fuel system components typically have very close internal clearances and drastic or sudden temperature swings should be minimized.

BLACK START

Gas turbines are frequently supplied in "black start" configurations, that is, equipped to be started and brought on-line with no external source of power. Among other issues in such a configuration is that of supplying fuel oil at sufficient flow and pressure to initiate turbine combustion mode. This is normally accomplished by having the fuel injection pump driven from an accessory gear (attached pump) that, in turn, is driven by the gas turbine. The gas turbine is rotated using a diesel engine, itself a black start configuration. The attached main fuel pump is sized to deliver the minimum light-off flow at maximum light-off pressure at minimum light-off speed. Once combustion begins, the turbine is self sustaining and brought to normal running speed with the diesel being clutched out of the accessory gear and stopped. At normal turbine speed, the fuel pump will deliver slightly in excess of the maximum required flow rate due to being sized for the low speed light-off condition.

FUEL RECIRCULATION

Note that it is common practice that the main fuel injection pump control valve and bypass relief valve flow be returned the inlet side of the pump. When burn rates are low and bypass pressures are low (no or low load running), there are usually no problems as the power input to the pump is also low. When the pump power draw is high, such as sub-

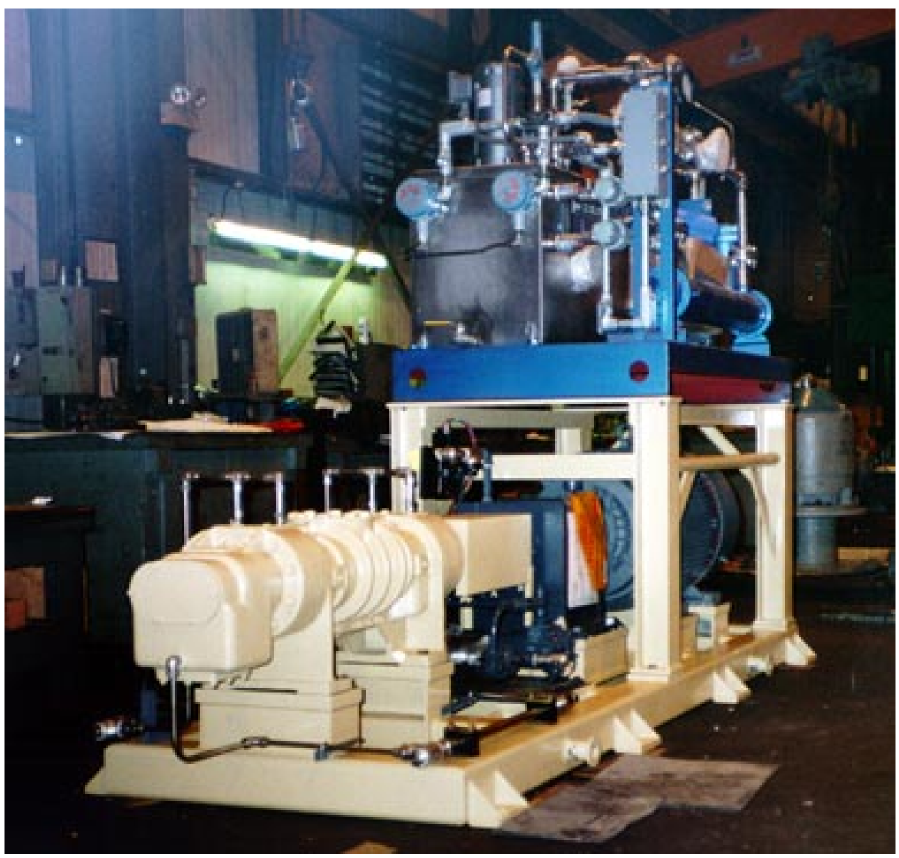

Figure 3 – Twin screw naphtha main gas turbine fuel pump

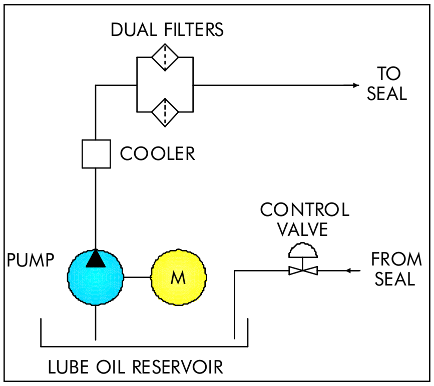

Figure 4 – Simplified fuel pump seal barrier system

stantial to full load on the turbine, any bypassed flow will be converted to temperature rise within the bypassed fuel. Continuous high flow bypass to the pump inlet can overheat the fuel resulting in pump damage. This condition can exist especially if something causes the main pump relief valve to bypass back to the main pump inlet such as a failed downstream flow divider. The preferred bypass return location is upstream of the fuel treatment/forwarding pumps or, back to fuel storage tanks if the distance is not excessive. In either of these preferred return locations, a larger volume of fuel can dissipate the heat gain before the temperature rise becomes excessive. If the fuel is continuously heated as part of its preparatory treatment, the optimum return location is upstream of the heaters which will reduce the heater load and improve operating efficiency. If recirculation is directed to the main fuel pump inlet, then pump liquid suction temperature should be instrumented for alarm or shutdown if an excessive temperature is reached.

MAIN FUEL PUMPS

Most power generation gas turbines use industrial grade, heavy duty main fuel pumps, typically twin screw or three screw (see figure 5) designs. Such pumps are not flight qualified having far too low a power to weight ratio. Aero derivative gas turbines will sometimes use their equivalent flight qualified main fuel pumps which are most ordinarily of the gear pump design. Multistaged, industrial gear pumps, figure 6, are now also available for use on these machines. Both the gear type and three screw type pumps will use 2-pole electric motor direct drive speeds of 2900 rpm (50 Hz) or 3500 rpm (60 Hz) or 4-pole 1450 rpm (50Hz) or 1750 rpm (60Hz). The largest sizes as well as the twin screw pumps will use 4-pole electric motor speeds. Specific pump configurations will depend to varying degrees on the fuel type, operating temperature, fuel viscosity range, required pressure rise and flow rate. Main fuel pumps have been supplied for pressures just above 2000 psi.

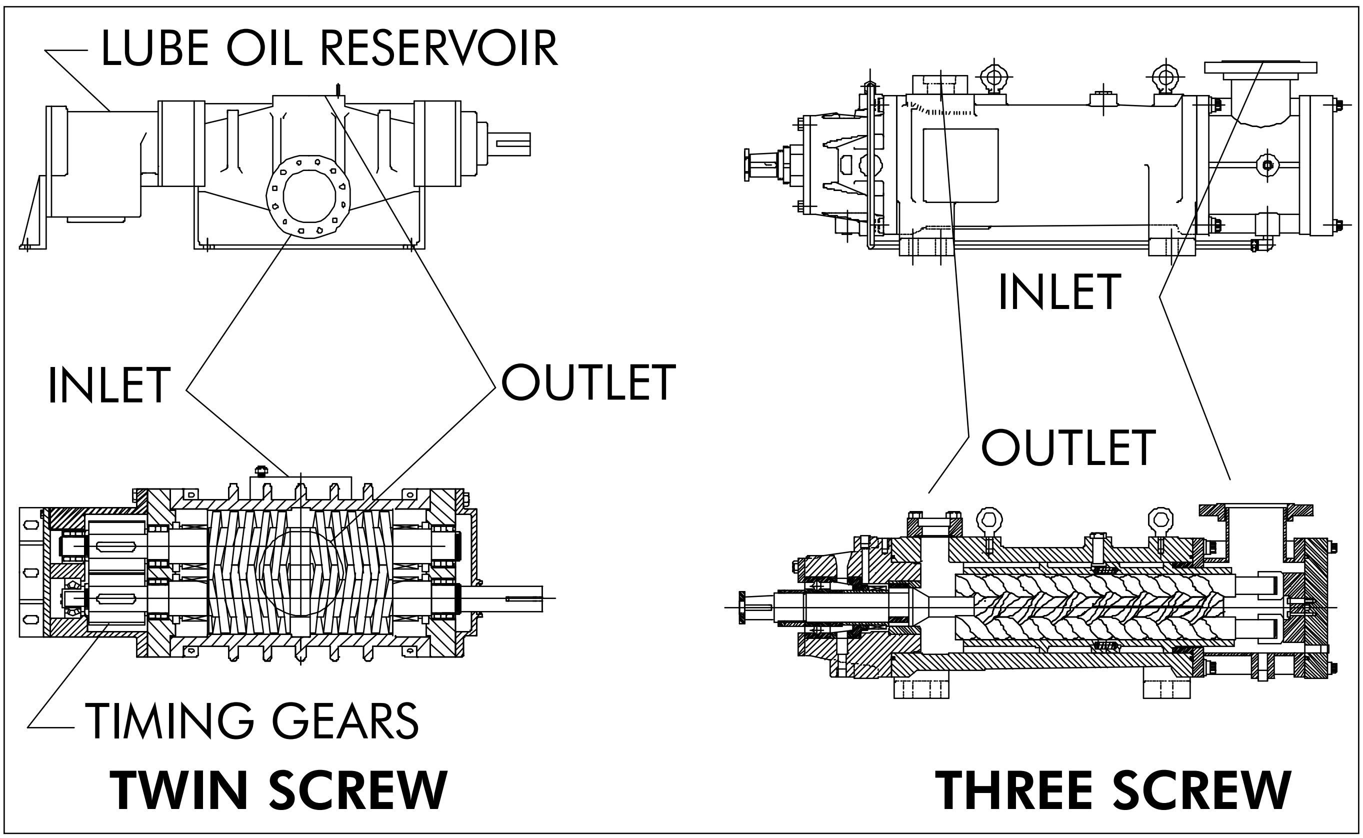

Figure 5 – Screw pump designs for gas turbine fuel injection

FLOW SIZING

Required pump flow rate will depend on a number of variables including turbine power rating, site conditions, turbine thermal efficiency, and the heating value of the liquid fuel to be used. The net heating value for distillate fuel is in the order of 128,000 BTU per gallon. At this heating value, a 100% thermally efficient combustion gas turbine will therefore need 0.445 gallons per minute (1.68 liters per minute) per megawatt exclusive of control flow allowances. With a thermal efficiency of 30% and a control flow allowance of +15%, a 100 megawatt machine will need a pump rated to deliver about 170 gpm (645 l/m). At a fuel pressure rise across the pump of 1200 psi (83 Bar), a typical requirement, the fuel pump will require a 150 hp (112 Kw) driver and could be expected to operate at around 80% efficiency. For standardized fuel system designs, pumps would be sized to provide the required fuel flow for the maximum possible turbine power rating while pumping the lowest net heating value fuel for which the system is suitable.

Trends in numbers of main fuel pumps continue to evolve. The most reliable systems will have two 100% capacity main fuel pumps, one acting as standby for the other. This arrangement can be found in power plants whose primary or only fuel is liquid and full load continuous operation is the norm. The use of three 50% capacity pumps will provide both backup pump availability as well as being able to run partial flow for partial load applications. Where liquid fuel is a backup fuel only and/or interrupted service is not catastrophic, a single 100% capacity fuel pump is the most common arrangement. Black start systems having the main fuel pump driven from the accessory gear could also have a 100% backup motor driven standby pump if desirable.

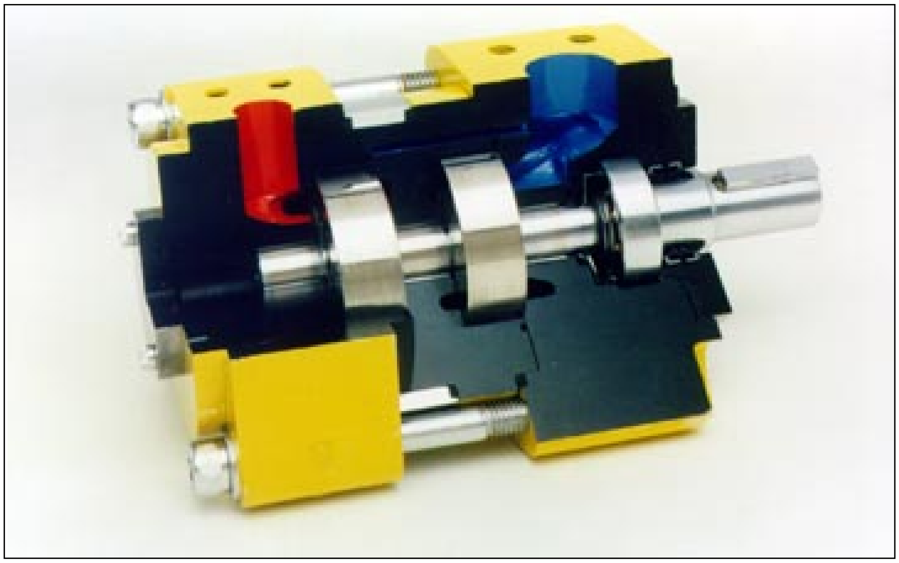

Figure 6 – Multistage gear type high pressure fuel injection pump

Nearly all installations will include fuel unloading pumps to deliver fuel to storage tanks. Additionally, there are usually fuel forwarding pumps that deliver fuel to the main injection pumps or the fuel treatment skid if such treatment is necessary. The fuel treatment skids frequently have forwarding pumps as well. Most of these ancillary pumps will be for low pressure operation and of the centrifugal or screw type designs depending on the economics and specifiers' preferences. For heavier, higher viscosity fuels such as Bunker fuel or crude oil, these pumps are almost always twin or three screw designs. Pumps will often be paired for main and standby service to insure uninterrupted operation.

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