INTRODUCTION

This section is intended to provide insight into the design of fuel oil pumping systems. It is intended to provide only introductory and generic information. For project specific or more detailed engineering support, contact your local PUMC sales office or representative.

This section deals primarily with light fuel oils such as Diesel and No. 2 fuel oil, although many of the topics covered are applicable to heavier oils. The design of a light fuel oil transfer system may be broken down into five steps:

1. Determination of required flow rate
2. Determination of maximum inlet suction
3. Determination of required discharge pressure
4. Design of fuel oil piping system
5. Selection of proper control strategy

All of these design tasks are interrelated to some extent, and they all depend on the nature of the application.

DETERMINATION OF REQUIRED FLOW RATE

The determination of required maximum pumping rate is dependent on the application and the overall piping system, but must be determined as the first step in the design of the entire fuel system. This section treats both day tank systems and burner loops systems, which are different enough to warrant separate discussion.

Day Tank and Diesel Generator Applications

Day tanks are used for any application where a small gravity head is desirable at the inlet to the generator or burner, and/or it is desirable to have a supply of fuel sufficient for some period of operation without the availability of the remote fuel transfer pumps. Day tanks are used with oil burners, for example, when burners are on the upper floors of a building and the main oil tank is underground. The fuel oil transfer set draws oil from the underground tank and pumps it to the day tank at the burner elevation. The burner mounted pump draws oil from the day tank and returns oil to the day tank. It would not be possible for the burner-mounted pumps in this example to draw oil directly from the underground tank because of the high lift. The use of a vented day tank also ensures that the pressure at the inlet to the burners will not become excessive.

Emergency diesel generators are supplied with day tanks to provide a period of operation without being dependent on the electric pumps in the transfer set to deliver fuel to the engines. In some cases, the injector bypass is piped back to the day tank. In other cases this oil is heated by the engine and must be cooled before it is returned to the day tank. Alternatively, the heated oil is returned to the main tank where it is diluted with cool oil. The recommendations of the engine manufacturer should always be followed with respect to fuel piping and cooling.

RULES OF THUMB

As a rule of thumb for sizing generator fuel oil systems, each 100 kW of generator capacity will consume about 7 gallons per hour. Any oil that is pumped to the engine but is not returned to the day tank would add to the generator capacity based requirement.

If all oil returned by the burner or engine is returned to the day tank, the fuel oil transfer system need only replace the fuel that is burned. The pumps will be sized based on the actual fuel consumption, the desired pump duty cycle, and some safety factor to allow for pump wear and unforeseen contingencies. For example, assume that a generator will consume 25 gallons per hour at full rated load and it is desired that the pumps run only 25 percent of the time. The transfer set should then be equipped with 120 gallon per hour pumps to provide a 20% safety factor on top of the 25% duty factor.

If oil returned by the burner or engine is returned to the main tank, the fuel oil transfer system must be sized to replace all of the oil directed to the engine (or burner) whether it is burned or not. The capacity of the day tank must be increased if the same period of operation must be maintained without depending on
the operation of the transfer set. If the amount of fuel returned to the main tank is considerable, the installation of an oil cooler in the engine return should be considered. The addition of a cooler will permit the return of oil to the day tank allowing the day tank volume and transfer set capacity to be smaller.

For multiple day tank systems piped as shown in Figure 1, the transfer set would be sized to meet the total requirements of the individual generators as outlined above. Of course, the transfer set would only have to be capable of supplying those pieces of equipment that might operate together in a worst case scenario. The level control system would assume the task of starting a pump and opening the appropriate solenoid valve when any day tank level dropped below the "pump start" setting of the level probe.

Stand-By Generator “Loop” Systems
It is also possible to design the system shown in Figure 1 with pumps that operate continuously. The pump control portion of the control system would provide for the starting of a back-up pump in the event that flow in the loop was lost. It might also alternate the operation of the pumps on a time-clock basis.

A back pressure regulating valve in the loop would provide a constant inlet pressure at the solenoid valves. The tank level control portion of the control system would open and close the appropriate solenoid valves to keep the fuel levels in the individual tanks between the desired limits. It would be good practice to provide a back-up solenoid valve at each tank. This valve would shut off fuel flow into the tank in the event that high level in the day tank or leakage into the rupture basin was detected.

Sometimes it is desirable to allow for the operation of multiple emergency generators without the installation of the day tanks. One strategy that has been applied is to pump the fuel oil to an oversized pipe header above the generators as shown in Figure 2. A vent pipe extends to a height equivalent to the gravity head that would exist if the return line was shut off. This vent also serves to allow air to enter the header to compensate for the withdrawal of fuel without replacement by the transfer set. The generators are then able to operate without depending on the operation of the transfer set for some time. Optionally, a vacuum breaker is added to prevent oil from being siphoned out of the header.

The larger the pipe size used for the header, the longer the period the generators can operate without power to the transfer set. In effect, the header becomes the day tank. The pressure switch and vent ensure that the pressure in the header does not rise above the safe working pressure of the engine’s fuel handling system.

Multiple Pumps
When two pumps are used to form a duplex pump set, each pump is selected to provide 100% capacity so that there is complete redundancy. When three or more pumps are used, there are more possible options. Very large pump sets often have three 50% pumps so that any two pumps will provide 100% of the maximum required flow. If the load is reduced, say in a boiler plant in spring or fall, one pump may be adequate and the electrical demand of the system will be reduced. Another strategy for triplex pump sets is to use two 100% pumps and one smaller unit for periods of low flow requirements.

In extremely critical applications, pump sets have been constructed with up to four 100% pumps. In this application, the control system must reliably sequence through the available pumps if a loss of flow is detected. Microprocessor-based or programmable logic controller based operating systems may be used to provide the degree of control sophistication and reliability required by such pumping systems.

Burner Loop Systems
Generally, the pump set runs continuously so that the entire piping system is continuously primed, and air is kept out of the burners. Any air entering the system is returned to the tank where it can settle out harmlessly.

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**Figure 2**
Emergency Generator “Loop System”

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**Notes on Header Systems:**
1. A back pressure regulating valve is added to keep the header full and to prevent oil syphoning out of the header.
2. The level switch is used for pump control. On pressurized header systems a pressure switch can replace the level switch.
3. A check valve prevents oil from flowing back down the fill line.
FUEL OIL HANDLING SYSTEM DESIGN

The pump set serves to pull oil from the main tank and supply oil to the burners when the burner pumps themselves may be inadequate. This would include cases where the burners are too high above the bottom of the tank or too far away to pull directly. In multiple burner installations, the use of a common fuel oil pump in conjunction with a burner loop system eliminates the need for each burner to be piped individually back to the main tank. To increase reliability, fuel oil pressure or flow switches may be incorporated into the system. Then, an impending loss of oil supply to the burners can be alarmed and corrected before a shutdown occurs. The use of a pump “lead/lag” control will fulfill the requirements if automatic back-up pump operation is specifically required.

In the case of a single oil burner, the selection of the required pumping rate is relatively simple. The pump set must be capable of supplying a greater oil flow into the loop than the maximum oil flow drawn out of the loop by the burner pump. Figure 3 shows a simplified system with a pump set supplying oil to a single burner. Note that the burner draws from the loop and any excess oil flowing through the loop simply bypasses the burner on its way back to the tank.

The important piece of information required for sizing the pumps is not the actual firing rate of the burner, but the pumping rate of the burner-mounted pump. It is relatively common for small burners (say 5 gallons per hour maximum firing rate) to have comparatively high pumping rates (up to 70 gallons per hour).

In this case, the pump set would be quite undersized if it was designed based on the traditional “rule of thumb” of twice the burner firing rate.

In the example presented in Figure 3, an undersized pump set would result in oil flowing backwards in the section of the loop between the supply and return connections on the burner. Any air leaking into the burner-mounted pump would be directed back to the burner supply rather than back to the tank where it would separate from the oil. Good practice dictates that the flow of oil in the loop should be continuous and one-directional from tank suction to tank return.

Figure 4 shows three burners connected to one loop system. In this case, the absolute minimum flow rate leaving the pump set would be equal to the firing rate of the first and second burners plus the pumping rate of the third burner.

Assume that each burner has a maximum firing rate of 100 gallons per hour, and a pumping rate of 250 gallons per hour. The required minimum pump set capacity would be 100+100+250 gallons per hour. With all burners operating at maximum rate, the flow up to the supply line of the first burner would be 450 gallons per hour. The first burner would pull its pumping rate of 250 gallons per hour from the loop, leaving 200 gph of oil to flow to the second burner. The first burner would burn 100 gph of the 250 gph drawn from the loop and return 150 gph to the loop. This would join with the 200 gph that had bypassed the burner. A total flow of 350 gph would be present just upstream of the supply connection for the second burner. Again, 250 gph would be drawn into the burner and 100 gph would flow past the burner. Of the 250 gph flowing into the burner, 100 gph would be burned and 150 gph would be returned to join the 200 gph that had by-passed the burner. A total of 250 gph would be available at the supply connection of the third burner. The entire 250 gph would enter the burner, there would be no flow bypassing the burner, and 150 gph would be returned to the tank from the third burner.

Of course the pump set, as designed, would have some reserve capacity because the pumps would be selected to have a design capacity exceeding the minimum requirement.

Notes on Series vs. Parallel Piped Systems:
1. Traditional series loops have lower flow rates and operate at very low pressures.
2. If oil is heated, heaters are smaller in series loops.
3. Parallel loops may operate at high pressure.
4. Parallel loops are used for pressure atomizing applications without burner-mounted pumps.

Figure 5
Burners Piped in Parallel
Figure 5 shows three burners piped in parallel. In this case, the minimum pump set capacity would be equal to the total pumping rate of the three burners. For the burners described above, the pump set would have a minimum capacity of 750 gph. Note: The series system requires a substantially lower pump set capacity than the parallel arrangement.

Actual Pump Capacity vs. Required Minimum Capacity
Once the theoretical minimum capacity of the pump set has been determined, the actual pump capacity must be chosen. An allowance should be made for pump wear especially with high discharge pressure and/or light fuel grade applications where slippage through a worn pump would pose more of a problem. A safety factor should also be applied to cover design approximations. The resultant number would then be compared to the available capacities of various pump and motor combinations. That combination with a capacity just greater than that determined above would be selected.

DETERMINATION OF MAXIMUM INLET SUCTION
While quality fuel oil pumps are often capable of “pulling” 20-inch (mercury) suction, it is good practice to keep the suction at the inlet to the pumps below 15 in. Hg. At higher vacuums (lower absolute pressures) the pumps can cavitate as a result of fuel vaporization and/or the expansion of any air that has been entrained in the fuel. The problem of entrained air will be dealt with later on in this section.

The pressure available to the inlets of the pumps then must be kept above 15 in. Hg. in absolute terms. This pressure consists of the available atmospheric pressure (30 in. Hg. At sea level on an average day) less the gravity head that must be overcome to get the oil to the pump inlet from the lowest point in the tank and less the friction losses in the pipe, valves and fittings between the tank and the pump. It is important, of course, to keep all the pressure drop figures in the same units of measure. In this article, inches of mercury are used throughout. Others may have different preferences.

Gravity Head
A multiplier may be developed to convert inches of oil to inches of mercury by dividing the specific gravity of the oil by the specific gravity of mercury (13.6). For fuel oil with a gravity of 0.85, a multiplier of 0.0625 would result. To lift this oil 12 feet, the available pump inlet pressure would be reduced by 9.0 inches of mercury ((12 feet) times (12 inches per foot) time (0.0625)).

In some cases, priming the system can require higher suctions (or present lower absolute inlet pressures) than normal operation. If the high point of the system is not at the pump inlet, it is imperative that provisions be made to fill the system at the high point. Check and foot valves should also be installed to keep the system primed.

For very large diameter tanks, or tanks buried deeply, it may not be possible to locate the pump set at grade without risking cavitation when the tank is nearly empty. In these instances, the pump set may be placed below grade in a pit. Precautions should be taken to prevent the pit from filling with oil or with ground water in the event of a leak. Drainage from the pit should be piped to a settling tank where oil and water can be separated and disposed of properly.

Line Losses
Once the flow rate of the pump set has been determined, the suction line may be sized to keep the friction or line losses in the piping to an acceptable level. Bear in mind that pump sizes and motor speeds are not available in continuous spectrum. Usually, the next larger pump and motor combination above the minimum flow requirement will be used. Also, it is good practice in estimating friction losses to use the flow rate produced by the pump set with the minimum expected back pressure at the pump discharge. With thin fluids, the pumps will produce a higher flow at low discharge pressures because slippage diminishes. If a pump is rated 300 GPH at 100 PSIG discharge pressure when pumping #2 fuel oil, it may pump 350 GPH or more with little back pressure. Using the 100 PSIG flow rating when the actual pressure would be only 25 PSIG or so would result in underestimating the suction line friction losses.

Total line losses are comprised of frictional losses in the foot valve, the pipe itself, in fittings such as elbows and tees, in valves and in the suction strainer. These losses may be estimated using line loss tables, or by using computer programs such as the “Oil System Sizing Program,” available from your local PUMC sales representative.

To use any of these methods, it is necessary to know the specific gravity of the fuel as well as the viscosity. Since both the specific gravity and the viscosity of petroleum oils are a function of temperature, it is necessary to correct the values referenced to standard temperatures to those under actual expected flowing temperatures.

Once the flow rates, specific gravity and viscosity are known the pressure drop of the piping system may be determined using appropriate charts or the referenced program.

Strainer Drop
The pressure drop through the suction strainer may be approximated by using the chart in this section, or using the Preferred “Oil System Sizing Program”. Note that the pressure drops that will be obtained will be for clean strainer baskets. As the strainer becomes clogged with foreign matter, the drop will increase. It is wise to use a 100% safety factor when estimating the strainer loss.

Often the main tank will be far enough away from the pump set such that the friction losses in the suction line are significantly larger than the loss through a strainer of the same pipe size. In these cases, it is common to use a suction strainer that is smaller than the suction piping.
Entrained Air
This is a significant problem when dealing with distillate fuels. The best design approach is to insure that all the fuel piping stays full of fuel at all times. This will involve keeping all returns to tanks submerged, putting back pressure regulating valves at the bottom of vertical runs rather than at the top whenever feasible, and guarding against any suction leaks. Air that has become entrained in distillate fuel takes quite a long time to settle out and can stay in a poorly designed system on a permanent basis. This will cause noisy operation and poor performance of pumps and regulators, short equipment life, and poor performance of the equipment being supplied with the air-filled fuel.

Provision for Tank Overflow and Tank Venting
These topics go hand in hand. Day tanks should always be equipped with overflow lines that will take excess fuel to a safe location in the event of a component failure. Remember that the vent line must be high enough so that the overflowing oil from the day tank does not just run out the vent. Conversely, an extremely high vent pipe could result in the development of a static pressure within the tank itself that exceeds the design rating. If the day tank is elevated sufficiently above the main tank, it may be necessary to provide an over flow holding tank. This tank would contain any oil spilling from an overfilled day tank or from the rupture basin of a leaking day tank. This fuel would be held until the situation was corrected, and a return to the main tank could be safely monitored.

Pump Set Control System Strategies
One of the most difficult tasks in designing a completely integrated fuel oil handling system is selecting the control strategy. The control system must integrate the operation of the pump motors, any automatic valves, warning devices, and operator interfaces such as switches and lights.

The purpose of this section is to review the important considerations involved, not to present a complete design manual for control systems. The selection of the most appropriate control strategy for any given fuel oil pumping system involves answering the following questions:

1. Will the pumps be in operation continuously or intermittently?
2. If the pumps are started automatically, what signal will be used to direct this?
3. Is automatic alternation of pump operation desirable?
4. Should the back-up pump be brought on line automatically if needed?
5. Are there automatic valves to be operated by the control system?
6. What conditions should result in the generation of an alarm signal?
7. What conditions should cause a shutdown of the system?

Piping System Design Considerations
In laying out the entire fuel piping system, key issues deserve specific attention. Namely... the possibility of entraining air in the fuel should be eliminated; loss of system prime should be prevented; re-establishment of prime should be quick and easy; back-flows and over-flows should be prevented; and tanks should be properly vented.

Summary of Suction Line Losses
The net positive pressure available to the inlet of the pump is determined by starting with atmospheric pressure, deducting the static lift from the bottom of the tank to the pump inlet, deducting the line losses at the actual flow rate and viscosity, and deducting the estimated loss through the suction strainer. The result should be comfortably less than 15 inches Hg.

With heated oil, it is important to use the worst case viscosity in any evaluations. This will be a function of the actual fuel purchased as well as the lowest temperature to which the piping will be exposed. For heavy oils and above ground piping, it may be necessary to provide heat tracing or impedance heating of the suction and return piping. In extreme cases, the piping can get so cool that the oil will not flow at all.

Pump Discharge Pressure Requirements
The pressure required at the discharge of the pump set will be the pressure required at the point of use plus the friction losses in the intervening piping, plus any additional gravity head that might need to be overcome. The same methods used for estimating the suction line friction losses and static head equivalents may be used.

In many cases, the gravity head to be overcome presents the largest single component of the pressure requirement. This is especially true when oil-consuming equipment is located near the top of a high-rise building while the pump set is in the basement.

The actual regulation of pressure is best accomplished at or near the point of use with the installation of a back pressure-regulating valve. Figure 1 illustrates the application of a back pressure-regulating valve to a multiple day tank system. This valve serves to maintain header pressure independent of the amount of returning oil. Pressure, air, and steam atomizing burners may require that relatively high pressures be provided by the pump set if there is no pump on the burner itself. It is important that the proper pressure be provided in the loop and that this pressure be closely regulated with a back pressure regulating valve or pressure regulating valve at the burner. The valve should be sized so that the pressure buildup (in the case of a back pressure valve) or droop (in the case of a pressure regulator) is small.

Day tank systems require that the pressure at the inlet of the level control solenoid valve be sufficient to insure the necessary flow. As an example, assume that a system is to operate with a “valve open duty cycle” of 25%. The pressure and valve Cv combination should be chosen to provide a flow through the solenoid valve of 4 times the design flow rate of fuel from the tank.

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pumping system? Unless these questions are answered, it is impossible to design a control system to optimize the performance, safety, and reliability of the fuel handling system. A brief discussion of each of these major topics follows.

Continuous vs. Intermittent Operation
If the pumps are to be run continuously, automatic start-stop signals are not required. In normal operation, one pump is manually started, and remains in operation until manually stopped. This does not eliminate the requirements for safety shutdown interlocks and automatic back-up pump operation.

Examples of such systems would include burner loop systems where the fuel oil is continuously circulated through the loop and past all the burners. The circulation is generally maintained regardless of burner operation. Similarly, some day tank level control systems rely on the opening and closing of multiple solenoid valves to keep the individual day tanks at the desired fuel levels. It might be desirable to keep oil circulating in a pressurized loop past all the day tanks to make certain that the suction piping cannot lose its prime during long idle periods.

Often, it is desirable to have the pumps start and stop based on some automatic signal. This should be done only when there is no danger of the suction piping losing its prime during off periods. Many day tank level control systems are designed so that the pumps only operate when one of the tanks requires the addition of fuel. This intermittent operation will minimize wear and tear on the pumps and motors, as well as reduce the average electric energy usage for the facility.

Automatic Start-Stop Signals
In some cases, the automatic pump start-stop signals are generated within the fuel handling system, and in other cases, they are generated externally. An example of an external start-stop signal is a set of contacts from an emergency generator management system. When a generator is required to operate, these contacts would close, and would be used to start the pump(s). This system could be used in a tankless loop system such as that depicted in Figure 2.

Day tank level control systems are examples of instances when pump start-stop signals are generated within the system. In most cases, level switches in the day tank are used to start and stop the pumps. By using separate switches for pump on and pump off, it is possible to minimize the on and off cycling of the pumps. When the level in the tank drops below the “pump on” setting, the pump will start. When the fuel level in the tank rises past the “pump on” switch, the pump continues to run. It does not shut off until the level reaches the setting of the “pump off” switch. A four switch assembly can be used to provide a high alarm level above the “pump off” switch and a low alarm level below the “pump on” switch.

Multiple day tank level control systems may be designed with a constantly pressurized header feeding the individual solenoid operated fill valves at each tank. The automatic signal to operate the pumps would come from a pressure switch (with dead band) at the top of the header. This system is similar to a domestic well water based system. An accumulator tank is used to provide an air cushion. Then the pumps will only have to start after a certain volume of fuel (the “draw-down”) has been drawn out of the accumulator tank.

Automatic Pump Alternation
When pumps are started and stopped remotely, it is desirable to alternate the operation of the pumps. This way, run time is spread equally between the available units. Also, if one unit should fail to operate, the pump that handled the “last call” for operation would be available as a back-up. If only one pump is run routinely, the back-up pump could freeze up, develop a leak, or be manually taken out of service and would not be available when required.

With duplex pump sets, a selector switch is used to select “Pump 1”, “Pump 2” or automatic “Alternation”. With more than two pumps, relay or microprocessor logic can be used to sequence the pumps whenever a start signal is received.

Back-Up Pump Operation
The back-up pump(s) may be brought on line either manually or automatically as required. Generally it is desirable for this to happen automatically, and this function is often handled by the same logic that alternates the operation of the lead pump. This logic is referred to as “lead/lag” logic, and the pump that is normally in operation is referred to as the “lead” pump. The pump that would normally be the back-up pump is called the “lag” pump. When there are more than two pumps, the lag pumps are referred to as “first lag”, “second lag”, etc. The “first lag” pump is the back-up pump that will start first if the lead pump does not function properly.

The signal to start the back-up pump generally comes from within the fuel system since it must respond to a failure of the primary pump. It is important to select a device that will reliably discriminate between the proper operation and a failure of the lead pump. If the oil is being circulated in a loop without any back pressure device, there might not be sufficient pressure at the pump discharge to indicate whether or not a pump is operating properly. If the pumps are being used to circulate oil within a loop, a flow switch might be used to detect loss of flow in the system. When the level in a tank is being controlled, the low level switch in the tank would indicate whether or not the lead pump is performing properly. For a system maintaining a header pressurized, a pressure sensor could be used to control the operation of a back-up pump.

When required, additional logic can be provided so that only one pump at a time is allowed to operate. When a lead pump failure is detected, the lead pump is de-energized and the first lag pump is then energized, and so on.
When the pumps have to be operated from emergency power, this sort of sequencing can be useful for minimizing the instantaneous total connected motor horsepower on the emergency circuit.

**Automatic Valves**
When one fuel oil pump set is used to maintain the level in multiple day tanks, automatic valves are required to isolate the tanks from one another. This assures that when the pumps operate, only those tanks that require fuel receive fuel. The control system is designed so that the level switch in the tank operates the fill valve. If the pumps were to run intermittently, the opening of any fill valve would trigger the starting of a pump. A second valve might be installed in the fill line to each tank, and controlled by the high level switch in the tank. If the main fill valve was to leak fuel into the tank, the back-up valve would then be closed preventing an overflow condition.

Another application of automatic valves in fuel oil handling systems is for main storage tank selection. Control logic can be provided to sense a nearly empty main tank, and to open the supply and return valves for the next tank in sequence. When these valves are proven open, the supply and return valves for the emptied tank close, isolating it from service.

**Alarm Signals**
A properly designed control system will provide sufficient information to the operating personnel to make intelligent decisions regarding the operation and maintenance of the fuel oil handling system. Some of the more common malfunction alarms are discussed here.

The control system should alert the operator if the “lag” pump is needed. Usually, a memory circuit is required so that this alarm does not clear itself when the “lag” pump starts. For example, if the “lag” pump is started because the pump set flow was interrupted, this flow would be re-established once the lag pump was operating. The memory circuit would keep the alarm light on until it was manually cleared so that the operators were made aware that a problem had occurred. Similarly, high level in a tank would correct itself as the fuel was used. A manual reset memory circuit would be used to retain the information that a high level condition had existed.

Other alarm conditions might include high discharge pressure (indication of a restriction in the piping system, or a valve inadvertently closed) or low discharge pressure. Flow through an overflow pipe might indicate a failure of the pump “off” and high level alarm circuitry, or a manual bypass valve left open or leaking. Build up of fuel in the day tank rupture basin would indicate a leak in the tank or connecting piping. By including a tank gauging system for the main storage tanks in the control system, the entire fuel system can be controlled from a central location and monitored for high and low levels, leaks and losses.

**Pump System Safety Shutdown**

Some of the alarm conditions listed above might be reason to shut down the fuel system. The detection of leaking tanks or piping is generally used as an automatic safety shutdown signal. When tank overflow must be collected in an “overflow catch basin” or tank, the system should be shut down when that tank or basin nears capacity. Depending on the nature of the installation, the detection of high level in a day tank might be cause to shut the system down. This is especially true when a pump set serves only one tank. Each system is unique, and the control strategy will be different from one job to another. The need for reliability, safety, and automatic operation must be evaluated on a job by job basis.

**CONCLUSION**
Many variables impact the design of a fuel pumping system and associated control logic. While the foregoing discussion is an attempt to highlight many of the major topics, it was not possible in this short article to touch on all of the unique problems and solutions that we have encountered in the past. Preferred Utilities Manufacturing Corp. has built thousands of custom designed fuel oil systems over the past half century and the variations continue. We stand ready to work with each customer to select the most appropriate fuel handling strategy for each job. If you have any questions, please do not hesitate to contact your nearest Preferred sales office or representative.

### Unit Conversion

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<table>
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<tr>
<td>1 ft of No. 2 oil</td>
<td>0.38 PSI</td>
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### RULES OF THUMB

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<th>Head</th>
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<tr>
<td>5 ft of No. 2 oil</td>
<td>2 PSI</td>
</tr>
<tr>
<td>7 ft of Water</td>
<td>3 PSI</td>
</tr>
</tbody>
</table>

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When the pumps have to be operated from emergency power, this sort of sequencing can be useful for minimizing the instantaneous total connected motor horsepower on the emergency circuit.

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When one fuel oil pump set is used to maintain the level in multiple day tanks, automatic valves are required to isolate the tanks from one another. This assures that when the pumps operate, only those tanks that require fuel receive fuel. The control system is designed so that the level switch in the tank operates the fill valve. If the pumps were to run intermittently, the opening of any fill valve would trigger the starting of a pump. A second valve might be installed in the fill line to each tank, and controlled by the high level switch in the tank. If the main fill valve was to leak fuel into the tank, the back-up valve would then be closed preventing an overflow condition.

Another application of automatic valves in fuel oil handling systems is for main storage tank selection. Control logic can be provided to sense a nearly empty main tank, and to open the supply and return valves for the next tank in sequence. When these valves are proven open, the supply and return valves for the emptied tank close, isolating it from service.

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A properly designed control system will provide sufficient information to the operating personnel to make intelligent decisions regarding the operation and maintenance of the fuel oil handling system. Some of the more common malfunction alarms are discussed here.

The control system should alert the operator if the “lag” pump is needed. Usually, a memory circuit is required so that this alarm does not clear itself when the “lag” pump starts. For example, if the “lag” pump is started because the pump set flow was interrupted, this flow would be re-established once the lag pump was operating. The memory circuit would keep the alarm light on until it was manually cleared so that the operators were made aware that a problem had occurred. Similarly, high level in a tank would correct itself as the fuel was used. A manual reset memory circuit would be used to retain the information that a high level condition had existed.

Other alarm conditions might include high discharge pressure (indication of a restriction in the piping system, or a valve inadvertently closed) or low discharge pressure. Flow through an overflow pipe might indicate a failure of the pump “off” and high level alarm circuitry, or a manual bypass valve left open or leaking. Build up of fuel in the day tank rupture basin would indicate a leak in the tank or connecting piping. By including a tank gauging system for the main storage tanks in the control system, the entire fuel system can be controlled from a central location and monitored for high and low levels, leaks and losses.

**Pump System Safety Shutdown**

Some of the alarm conditions listed above might be reason to shut down the fuel system. The detection of leaking tanks or piping is generally used as an automatic safety shutdown signal. When tank overflow must be collected in an “overflow catch basin” or tank, the system should be shut down when that tank or basin nears capacity. Depending on the nature of the installation, the detection of high level in a day tank might be cause to shut the system down. This is especially true when a pump set serves only one tank. Each system is unique, and the control strategy will be different from one job to another. The need for reliability, safety, and automatic operation must be evaluated on a job by job basis.

**CONCLUSION**
Many variables impact the design of a fuel pumping system and associated control logic. While the foregoing discussion is an attempt to highlight many of the major topics, it was not possible in this short article to touch on all of the unique problems and solutions that we have encountered in the past. Preferred Utilities Manufacturing Corp. has built thousands of custom designed fuel oil systems over the past half century and the variations continue. We stand ready to work with each customer to select the most appropriate fuel handling strategy for each job. If you have any questions, please do not hesitate to contact your nearest Preferred sales office or representative.

### Unit Conversion

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PSI</td>
<td>2.31 ft of water</td>
</tr>
<tr>
<td>1 PSI</td>
<td>2.60 ft of No. 2 oil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vacuum</th>
<th>Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; Hg</td>
<td>1.28 ft of No. 2 oil</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Head</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ft of No. 2 oil</td>
<td>0.78 PSI</td>
</tr>
<tr>
<td>1 ft of No. 2 oil</td>
<td>0.38 PSI</td>
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</table>

### RULES OF THUMB

<table>
<thead>
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<th>Head</th>
<th>Vacuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 ft of No. 2 oil</td>
<td>3 Inches Hg</td>
</tr>
<tr>
<td>5 ft of No. 2 oil</td>
<td>2 PSI</td>
</tr>
<tr>
<td>7 ft of Water</td>
<td>3 PSI</td>
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</tbody>
</table>