Contents

Challenges

“Massive structural beams that functioned as a sort of bridge to hold up the 47-story skyscraper known as 7 World Trade Center were compromised in a disastrous blaze fed by diesel fuel, leading to the building's collapse on Sept. 11. (NY Times 02MARCH02)

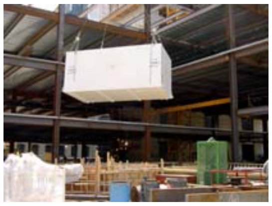
The dramatic events of that day have brought renewed attention to safety in buildings. The use of diesel fuel in buildings for emergency power and boiler operations is a critical component of building safety. Sound mechanical engineering design and advanced control technologies can be applied to significantly improve current practices.

The design of emergency power diesel fuel systems for high rise technical facilities is particularly challenging. These challenges are being presented with increased frequency as buildings in urban areas become more technical with a greater need for reliable power sources. Buildings of this type would include hospitals, research facilities, emergency service operations, financial operations, telecom facilities, and corporate facilities with significant computing.

The challenges stem from the highly constrained system layouts which result in separate locations for important fuel system functions. Fuel storage is typically in the basement, fuel delivery areas are at grade, and emergency generators may be on the building roof. Diesel fuel must be safely transferred through the building with fail-safe containment and overfill protection. Information on system status must be shared at the points of use and integrated with the Building Management System (BMS).

Fuel system challenges are discussed for each major functional element.

Bulk Fuel Storage



Bulk fuel storage tanks are typically located inside buildings in the lowest level. While local code requirements vary, the highest standard for the bulk fuel tank is a fire rated secondary containment tank. These tank are available as horizontal cylindrical or rectangular units, with the rectangular units used inside buildings for space efficiency.

Room Construction: Rooms for fuel oil storage typically require fire-rated wall construction as a separation from other building areas. Curbing is required to provide secondary containment for the piping connections to the tank and to prevent vapor passage beneath doors. Room ventilation to the exterior is separated from other building ventilation systems.

Clearance Issues: Tanks in buildings are often complicated by a lack of adequate clear space between the tank and the ceiling. The clearance constraint requires special consideration for suction pipe, fill drop pipes, and level transmitters. These problems are addressed by using segmental piping for the suction and drop pipes, and by using new flexible level transmitters.

Tank Venting: Venting of bulk tanks can be an important cost issue depending on requirements for piping tank vents to the building exterior. In the simplest case, the tank normal vent, usually 2” or 3” diameter pipe, will be extended to the building exterior and terminated 12 feet above grade. In the extreme case: (a) local codes may require exterior termination of the tank emergency vent and possibly the containment tank emergency vent, usually each 4”-12” diameter, and (b) architectural considerations may require the vent piping to be carried within the building to a termination on the roof.

Tank Sizing. It is important to correctly calculate the bulk tank capacity. The number of generators times their maximum hourly consumption times the required duration of operation gives the basic capacity requirement. Allowance should be made for (a) the 10% above the high level limit of the tank which cannot be filled beyond 90%, (b) the 5-10% low level in the tank which cannot be accessed by the pumps and which may include undesirable moisture or dirt, and (c) a working allowance for exercising the generators periodically.

Other Sizing Considerations: Tank capacities are often increased above the emergency power requirements for (a) combined boiler backup fuel storage, and (b) use of the generator for peak shaving or contract interruptible power.

Remote Filling of Bulk Tanks

Filling of bulk tanks in buildings is typically “blind”, in that the tank cannot be observed by delivery personnel during the fill operation. Tank spills and overfills during delivery operations are the major causes of releases from aboveground tanks. System designs should include safety characteristics to overcome these difficulties.

Fill Hardware: Fill point spill containers for delivery hose connections should have a camlock type hose connection, shutoff valve, check valve, and approximately 15 gallons of spill containment capacity. Some users like a drain valve or hand pump to transfer spilled fuel from the container to the bulk tank. Others prefer the delivery driver to cleanup any spilled product with absorbent and remove t from the site.

Offloading Pumps: Facilities may want to provide an offloading pump to enable them to receive fuel from supplier trucks lacking on – board transfer pumps. These pumps are mounted with the spill container equipment. Controls for the pump should disable the pump operation on high level. Controls may include a pump jog feature that allows intermittent pump operation near high level to clear delivery hoses.

Architectural: Exterior tank fill points are often include architectural considerations. The delivery connections, spill containers, and controls may be located within a lockable flush mounted polished stainless steel enclosure.

Overfill Valves: The bulk tank should be equipped with an overfill prevention valve to close at 90 % of tank fill level. The overfill valve is commonly a float valve mounted in the tank that closes at 90% tank fill level. These valves should be rated for pressurized delivery. Automated valves are also used. These would include solenoid valves, actuated ball valves, and actuated butterfly valves. The automated valves should be controlled by a level sensor independent of the tank level gauge transmitter.

Fill Controls: Tank fill controls should provide adequate information for fuel delivery personnel at the fill point. This information should include: (a) green(OK) / yellow (Warning) / red (Stop) status lights, (b) an audible and visual high alarm and acknowledge switch, and (c) optionally a display of the actual tank volume in gallons and % fill. The controls may also include pump on / off controls where offloading pumps are provided by the facility.

Multiple Tanks: Filling multiple tanks inside buildings complicates the fill operation. Automated valves in the tank fill pipes are normally closed. Delivery personnel select the tank to be filled. The controls should (a) disable the tank inlet valve in the closed position if the tank is at high level, and (b) allow the selection of only one tank at a time. Actuated ball or butterfly valves are preferable to solenoid valves for this application since they can be monitored for actual valve position.

Fuel Transfer Pumps

Pump Type and Capacity: Submersible pumps are a reliable option where required system pressures are less than 30 PSI and adequate clearance above the tanks exists to allow installation. Suction pumps are used in all other applications. Pumps should be sized for a 50% - 75% duty cycle when all generators are operating at full load. Pump motor HP should be sized to accommodate the pressure and flow requirements. Pumps of 1 HP capacity and greater should be 3 phase. A primary and secondary pump should be provided for all applications. Typically a pump set can feed multiple generator tanks, however some local authorities do not allow this arrangement.

Pump Power: Pump controls should provide for motor starting and overload protection. Pump motor starter coils should operate from the pump line voltage. This allows for the pumps to be operated in manual mode, even if the pump control unit is disabled. Power disconnect switches for pump motors should be located within line of sight for maintenance safety.

Pump Controls: Dual pumps are provided for redundancy with pressure or flow switches to prove pump operation. When the pump controls receive a pump on signal from the generator tank level control, the primary pump is activated. The secondary pump is activated if the flow / pressure switch is not activated, or alternatively if a low alarm signal is received from the generator tank. Primary and secondary pumps are automatically selected on alternate pump starts. Pump controls may disable the pumps based on inputs from(a) emergency stops, (b) leak sensors, or (c) fire alarm systems. It is important that emergency stop controls be located at remote points of use.

Fuel Valves

Shutoff Valves. Code compliant shutoff valves should be carbon steel valves, not brass or other soft metals.

Suction Pump Foot Valves: Suction pumps should be examined to determine that they operate within the range of their suction capability. In general suction piping should be at least the size of the pump inlet and should slope continuously back to the bulk tank to avoid air pockets.
Most fuel tanks will have top only openings for safety reasons. This can be a problem in high flow applications where the pump is mounted at the floor and must draw fuel through an inverted-U suction pipe. Foot valves should be used where suction piping is less than optimal to maintain pump prime. Valves should be double poppet design and installation should include an extractor fitting to assist inspection and maintenance. Where foot valves are installed, pump and pipe pressure relief paths should be examined since pump discharge relief is commonly piped to the pump suction piping.

Anti-siphon Valves. Where piping is routed below the top of the tank, anti-siphon protection should be provided. Spring loaded anti-siphon valves balance the static siphon head and require a positive suction from the pump to open and allow flow. These valves must be selected to avoid excessive suction side requirements for the fuel transfer pumps. Normally closed solenoid valves are used as anti-siphon valves. They are mounted in the fuel supply lines and are activated open when the transfer pump is energized.

Pressure Relief and Backpressure Valves. Safety relief valves are designed to relive excessive pressure in piping systems. The most common overpressure condition is created by thermal expansion of fuel in a pipe section blocked on each end by a closed valve. The safety relief valve discharge should be piped to the tank. Safety relief valves should be set above the normal operating pressure, since they are not designed for continuous normal flow.
Backpressure valves are regulators designed to maintain a normal operating pressure in the pipe system, at a level below the normal discharge pressure of the pipe. The valve should discharge directly to the tank.

Fire Safety Valves. Fire safety valves are designed to automatically close when a high temperature condition is sensed. The valves are typically installed at the pipe entry into a building or a room where fire conditions could exist. The valves are normally closed valves held in an open position by a fusible link that fails at 165 degrees F casing the valve to close. The best valves of this type are fire rated carbon steel valves that are FM approved for the application.

Fuel Piping inside Buildings

Fuel piping inside building should be designed to be highly resistant against leaks, damage, or failure under fire conditions. Fuel piping inside buildings should be schedule 40 carbon steel seamless pipe. Pipe and fittings should be welded except at tank or special valve connections. Copper pipe and plastic piping is not acceptable because of low resistance to fire conditions.

Single Wall Pipe. Piping within fuel storage rooms should be single wall as long as the room is fire rated and includes a containment curb. This arrangement provides protection for the large numbers of pipe joints and fittings at the tank and pump sets. Vent piping is also typically single walled.

Double Wall Pipe. Piping outside of special rooms (except vent piping) should be double contained within a minimum schedule 10 steel containment pipe with welded connections. Plastic or fiberglass containment pipe is typically not acceptable for applications within buildings because of low resistant to fire and potential off gassing issues. Containment pipe should be designed with (a) centralizers to adequately support the inner pipe, (b) expansion / contraction control details, (c) support details for vertical sections, and (d) leak detection access points.

Fire Rated Pipe. Local code requirements may also require that the piping be fire rated or protected within a fire rated enclosure. This is typically accomplished by (a) routing the piping through a concrete or masonry chase, (b) enclosing the pipe within a gypsum board framed enclosure, or (c) providing fire proof pipe insulation.

Return Flow Pipe. Fuel return piping should be sized typically as a minimum one size larger than the fuel supply pipe. However return flow conditions should be closely analyzed because the supply pipe operates under pump pressure and the return pipe is typically gravity flow.

Generator Day Tanks

Generator day tanks are limited capacity tanks located adjacent to the generator set. The day tank provides a reservoir of fuel at atmospheric pressure to minimize the requirements on the generator engine fuel pump. Building codes typically restrict the capacity of day tanks within buildings especially above the lowest floor.

Generator Tanks. Generator day tanks should be furnished by the fuel system supplier to assure a single source of responsibility of system function and integration. The day tanks should have carbon steel valves, redundant inlet solenoid valves, and manual solenoid bypass valves. Where pumps are provided with the day tanks the pumps should be high quality iron body pumps. The generator day tank should include a full containment basin. The day tank includes an electronic level control panel that integrates with the fuel system. An independent critical low level switch should be provided for generator shutdown.

Limited Capacity Issues. The limits on generator day tank capacity complicate the fuel system design based on two primary issues: (1) the small quantity of fuel makes the reliability of fuel supply critically important – there is no time to respond to system problems, and (b) heat buildup in the day tanks can impact the operating characteristics of the generator. Large engines require cool fuel to cool the engine fuel system components. Also the energy value of the fuel decreases slightly with increased temperature.

Header Systems. One response to the limited allowable day tank capacity is to use an enlarged pipe as a header serving multiple day tanks. The generators suction fuel from the header and return excess flow to it. Fuel supply is continuously circulated through the header with excess flow returned back to the bulk storage tank. The circulation maintains fuel temperatures at acceptable levels. The fuel transfer pumps operate based on a generator start and stop signal from the generator control panel. Critical to the design are (a) providing fully redundant fuel supply components and controls to accommodate the lack of manual response time, and (b) assuring a low pressure system less than 3 PSI to operate within the acceptable range of the generator engine.

Day Tank Return Flow. Generator day tanks in buildings and on roofs should be provided with gravity overflow pipes to the bulk tank for failsafe overfill protection. Return flow pumps may be allowed by some codes, however for this application a fail safe method of protection is justified.

Return Flow to Multiple Tanks. Where multiple tanks are used the return flow must be directed to the selected supply tank. This is best accomplished by a three way valve where one of the return flow paths is always open. An overflow pipe connecting the bulk tanks is a backup for valve or control failure. Emergency vent openings should be raised above the level of the overflow pipe.

Fuel Temperature Issues

Fuel in generator day tanks increases in temperature because of heat gain in the generator fuel return. The generator consumes 1 / 3 and returns 2 / 3 of its suction flow. The fuel heats up as it passes through the engine fuel rail. The fuel temperature is important because the fuel is used to cool engine generator fuel system components. It is recommended that fuel temperatures be maintained below 115 degrees F.

Day Tank Cooling Issues. Fuel cooling is typically not an issue where (a) the generator is equipped with a return fuel cooling radiator, and (b) the day tank capacity is a minimum 2 times the hourly generator fuel consumption rate. A smaller generator day tank can cause problems with fuel overheating. Some designs allow for pump out of the day tanks on a high temperature condition. This method is not recommended because the increased system complexity increases the potential for failure. The preferred method is to direct the generator return flow to the bulk tank through a gravity return pipe. The fuel supply system must be increased in capacity to 3 times the initial flow, since the generator consumes 1 / 3 and returns 2 / 3 of its suction flow.

Boiler Fuel Supply

Diesel fuel is often provided as a backup fuel supply to natural gas for boilers. The boiler fuel supply can be integrated to a large extent with the emergency power fuel supply.

Common Bulk Tanks. Where common bulk tanks are used the refill level alarms should be set to maintain the minimum capacity required for emergency power generators.

Boiler Day Tank Systems. Where a boiler day tank is used, the fuel system is very similar in design to an emergency power system.

Continuous Circulation System. More commonly boilers are fed from a continuous circulation fuel supply. The fuel system is started manually or automatically by a boiler on condition and fuel transfer pumps operate continuously to provide fuel to the boilers. A back pressure regulator connects the boiler supply header pipe to the boiler return header pipe. The back pressure regulator is adjusted to maintain a steady fuel supply pressure to the boilers, and also establishes a low pressure return header condition. Excess fuel flow from the boiler is piped to the return pipe header and flows back to the bulk tank.

Independent Fuel Transfer. Fuel pumps and piping for boilers are typically independent of those used for emergency power where continuous circulation systems are used for the boilers.

Electrical and Control

Electrical Distribution. Fuel distribution equipment should be fed from emergency power circuits. Where more than 6 circuits are required in a given area, a separate distribution panel should be provided for the fuel system. This will minimize the risk of inadvertent disabling of fuel system equipment during maintenance of other equipment.

Separate and diverse power sources should be provided for each pump motor in a duplex pump set. The pump motor starters should use a coil voltage the same as the pump line voltage. This arrangement will allow for manual activation of at least one pump, and manual operation of generator day tank fill valves, to provide fuel to generator engines.

Typical operating voltages are as follows:

120 VAC, 1 Phase	Control Panels
208 VAC, 1 Phase	Submersible pumps, pump motors less than 1 HP, heat tracing
480 VAC, 3 Phase	Pumps 1 HP and greater, Tank heaters

Fuel System Component Integration. Interfaces between control panels should be hard wired, for example between the day tank level control and the duplex pump control. A separate monitoring data network should connect all fuel system control modules. The data network allows system status information to be shared at the various points of use. The data network also allows for complete fuel system information to be integrated into the building management system.

Remote Information Displays. The fuel system information needs to be displayed (a) at the tank and pump area, (b) at the tank fill location, (c) at the generator area, (d) at the boiler room, and (e) in a central communication / control room. The information displayed should include: (a) bulk tank volumes, (b) bulk tank level alarm status, (c) pump status, (d) generator tank level status, (e) leak detection alarms, (f) equipment not in auto.

Control Wiring. Conduit and wiring for fuel system controls should be the responsibility of the fuel system contractor. This provides for a single source of responsibility for system function. 120 VAC control, 24 VDC control, Intrinsically safe, and data wiring should all be in independent conduits and separated from power circuits. Control and data cables should meet the specifications of the equipment manufacturers.

BMS Integration. The fuel system controls should have a Modbus (or other open protocol) output of all system parameters for integration into the BMS system. The fuel system contractor should provide graphic screens for the fuel system to the BMS contractor to assure that all relevant information is displayed in a logical format. The BMS contractor provides wiring from the Modbus device to the BMS system, and all mapping of data points within the BMS system.