Inspecting Complex Emergency Systems

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Objectives

- Quick review of emergency system operations and how they are used
- Review sub-base (belly) tank configurations-and key items to check
- Review day tank-bulk tank configurations
- Review what are complex emergency systems and where to find these- and items to check during inspections

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Emergency Generator System Basics

- Emergency generators are very common—more so than you might think. This building we're in today undoubtedly has an emergency generator system.
- About 90% use diesel fuel, although natural gas and propane are occasionally used.
- Emergency generator systems require air permits, as diesel engines are significant emitters of nitrogen oxides (NOx) and diesel exhaust particulates. Emergency generator run hours are restricted, permitted to run for long periods only under true emergency conditions.
- Certain facilities require substantial backup generation in event of power loss. These facilities will have separate bulk tanks and day tanks. Same for large buildings, data centers—nearly any location with critical applications that need to be available in power outages. Hospitals, nuclear power plants, and others have specific requirements for longer duration operations in emergencies—normally fuel supplies for these facilities are high.

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Types of Generator Systems

- The US Generator sales market was $4.68 Billion in 2020 and expected to grow to over $6.9 Billion by 2028
- Market drivers: Need for constant and reliable power supply
- Increasingly common in California and throughout US to face grid and weather-related problems in providing consistent utility power service
- Continuous Load Operation: generators used when suitable power is not available from grid-common in mining operations, oil and gas industry
- Standby Load Operation: generators used to provide backup to continue operations of key facility equipment and systems when usual power supply is lost. Some generators operate in peak shaving load mode
- Emergency Load Operation: generators used to provide backup power to provide essential services, as required under building and fire codes

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Types of Generator Systems

Several Types of Emergency Systems Exist (NFPA 70/NEC)

- **Emergency Power System**-independent reserve source of electric energy…Automatically provide illumination of power essential for safety to human life.
- May include power for fire detection/alarm systems, elevators, fire pumps, communication systems, and industrial processes where loss of power would produce serious life safety or health hazards
- **Standby Power System**-independent reserve source of electrical energy… to provide electric power so user's facilities may continue in operation
  - Legally Required Systems
  - Optional Standby Systems

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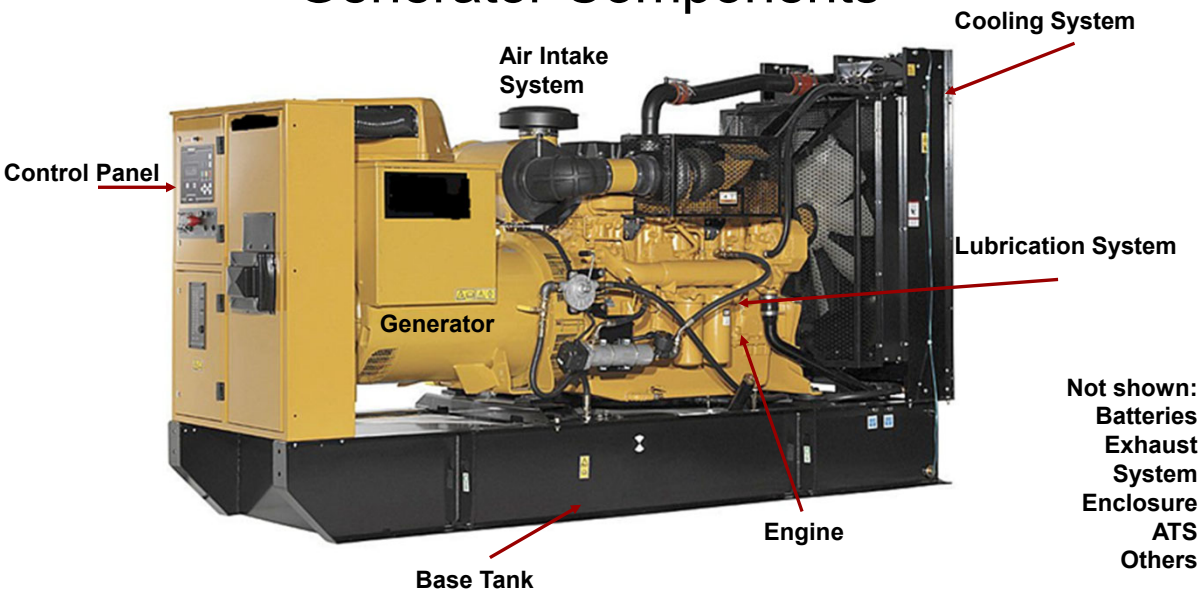
Generator Components



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Generator System Components

Engine: Also called the prime mover--comprised of pistons, engine blocks, fuel injectors, crankshafts, valves, etc. to convert chemical energy, such as diesel, into mechanical power. The size of the engine determines the power output

Generator: Converts the energy from the engine into electrical power by electromagnetic induction; electrical coils and a moving rotor, using the mechanical energy provided by the engine

Lubrication System: Needed for engine operation, just like your car

Cooling System: Needed for engine cooling; most use radiator, antifreeze, fans. May also include separate cooling system for fuel cooling, such as heat exchangers

Exhaust System: Include a muffler for noise suppression; need to terminate outside of building, with special considerations for wall penetrations

Control Panel: Used to control and monitor various components on the engine, generator, and other equipment

Fuel Tank: On fully enclosed emergency generator systems, the generator base tank lies beneath the engine and other equipment to provide a ready source of fuel. In other systems, a small day tank is used to provide the immediate source of fuel, and connected via piping to a separate bulk tank

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Generator System Components

Air Intake System: Louvers and in some cases dampers, used to bring fresh air into the system; may be more sophisticated for certain systems

Batteries: used in engine starting. Will typically include battery charger as well. A common way that generators don't start is battery failures.

Enclosure: The exterior of most emergency generators are enclosed for protecting the equipment from the environment, and to provide security from vandalism. These also include sound attenuating features to reduce the noise from the engine operation, derived from internal combustion engine noise, from rotating/moving parts noise, and air flow noise from combustion inlet draw and cooling fan tips

Transfer Switch: Used to switch the power from the utility by deactivating circuit breakers from the utility power and transferring the power source to the emergency generator

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Generator Systems

- Unlike motor vehicle fueling tank systems, generators (and boilers) use a looped system that has a return line for sending heated unused diesel back to the tank
- This is necessary as the design of the diesel engine requires high pressure for atomization of the fuel for combustion—so about 6 gallons of every 7 gallons fuel drawn by the engine is returned to the tank
- Returned fuel to the tank is typically hot--Since heated fuel affects engine combustion, designers have to make provisions to limit hot fuel from entering engine—this directly affects engine performance.

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Generator Layouts

- Vary in Size and Configuration—based on the facility needs, including required generator run times and electrical load needed
- Rule of thumb for fuel tank sizing for generators: 7 gal/hr per 100kw at full load
- Most use a bulk fuel tank and a smaller day tank. Some stand alone systems use only a sub-base (belly) tank; these will have limited run times
- Some installations will have complex systems with substantially large bulk fuel tanks to support critical equipment

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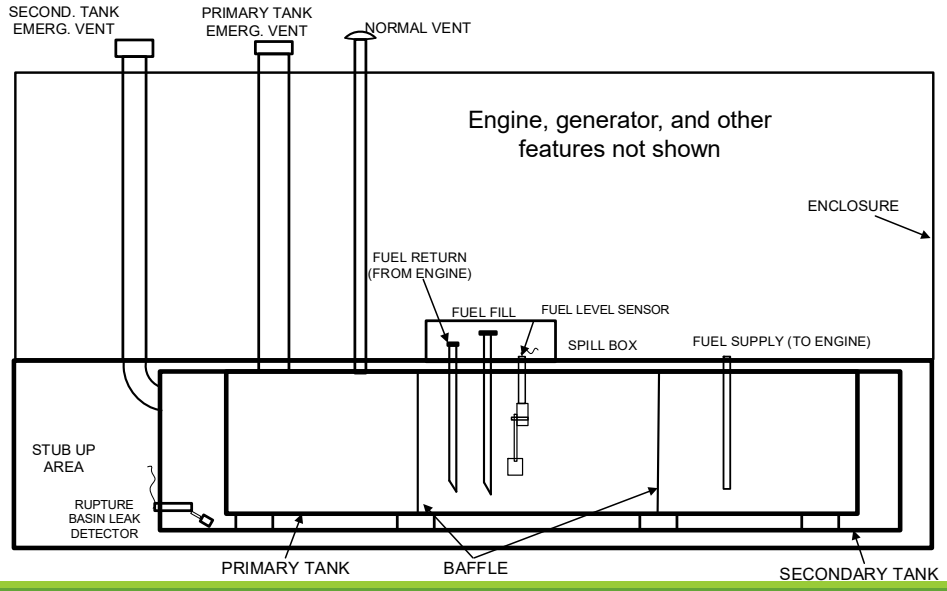
Emergency Generator Base Tank (typical)



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Emergency Generator Base Tanks

- Emergency generator base tank systems are relatively low risk, at least compared to motor vehicle fueling—these are small tanks usually
- Rarely have need for SP001 Formal External Inspections—virtually all base tanks are below 5000 gallons
- Nearly all recent emergency generator base tanks are double walled (provided with rupture basin)—but confirming this can sometimes be difficult

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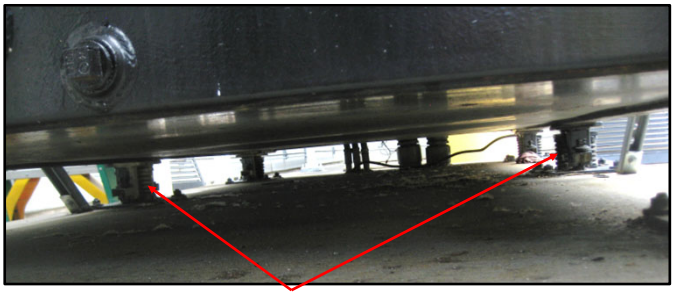
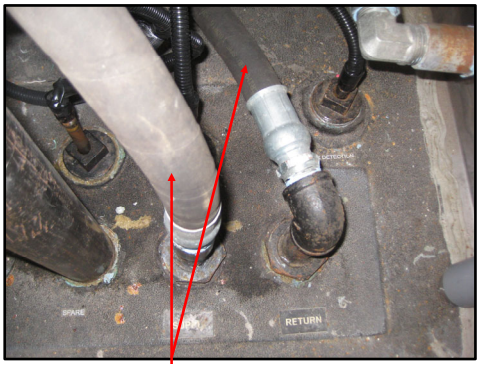
Generator Base Tank Features

Vibration Considerations:

Vibration from engine operation is substantial--Normally spring absorbers are used to limit tank and equipment vibration damage from operating the engine. This also reduces vibration from transmitting into other parts of the building. This vibration also affects piping, which is why hard-walled flexible pipe (instead of rigid pipe) is used on the connection from the base tank to the engine.



Spring Absorbers beneath base tank



Flexible pipe for supply and return lines

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Generator Base Tank Observations

- Overfill prevention valves on generator base tanks are rare, due to limited space and height of base tank
- Secondary containment shell commonly known as ‘rupture basin’—or sometimes just “basin”
- Since fuels rarely turn over (due to limited operating, primarily only for testing), fuel degrades and water can be found in fuel
- Its common to find emergency generator base tanks to have substandard venting—either terminations that don’t discharge outside the enclosure, or even some e-venting systems not properly installed. This is more of a Fire Code violation, unless no emergency venting exists at all…
- Access to the control panel needed to understand more about what’s on these systems—which ranges from relatively simple to complex

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Control Panel

Typical functions/outputs:

Electrical: voltmeter, frequency meter, ammeter

Engine Parameters: Working hours counter, oil pressure, coolant temp, fuel level, engine speed

Alarms & Faults: oil pressure, coolant temp, failure to start, overspeed, alternator min/max, battery voltage min max, emergency stop, fuel level, rupture basin alarm

Testing the alarm panel by engaging the lamp test should be a part of routine inspections. While this confirms electrical continuity with the sensor, it won't fully check that the sensor is actually working

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Control Panel

Ensure to check the control panel when inspecting; these are often hidden behind panels inside the enclosure

In some cases, alarms also may be "piggybacked" to signal a common alarm. In this case, the cause of the alarm will need to be isolated in order to troubleshoot & resolve the condition

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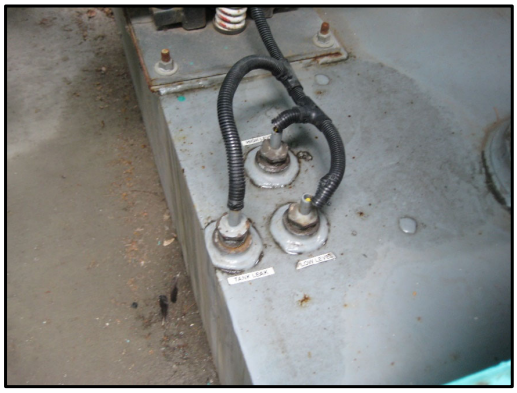
Generator Base Tanks

Generator tanks use low voltage wiring controls that include a low, high, and high-high level system indication, along with other control and indication equipment



Interstitial leak sensor at left, with low, high, and high-high level sensors at right

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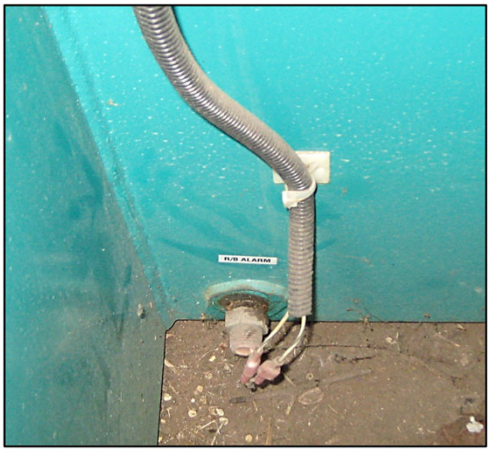
Generator Base Tanks

Most emergency generator base tanks are double walled designs with a common single top. The rupture basin drain sensor may be located on the end of the tank in difficult to access locations.



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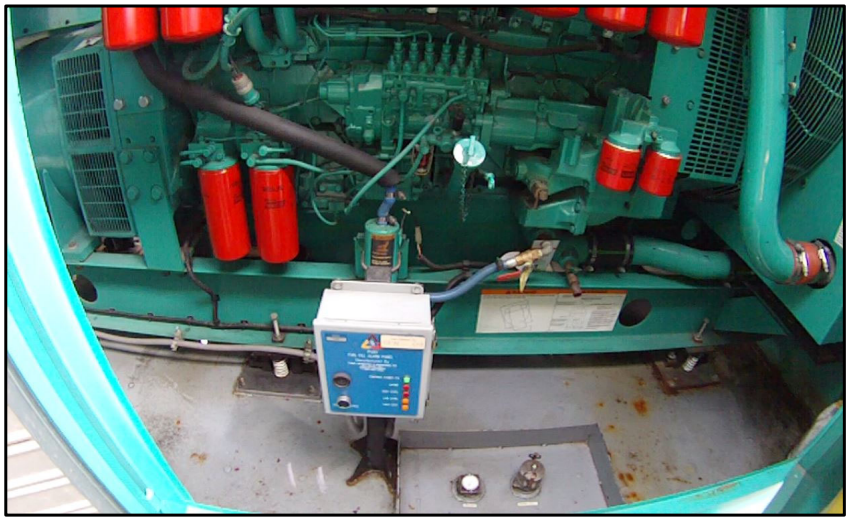
Generator Base Tanks



Some emergency generator systems have separate tank overfill alarms installed to warn of impending high fuel level during tank filling

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Common Findings-Why?

Emergency generator systems have a lot of moving parts, including engine operations. Usually far more focus in maintaining these is on ensuring generator will operate, than on tank issues

Common issues:

- Overfills or lack of defined program to limit overfilling
- Lack of emergency vents, or not terminated outside of enclosure or building
- Corrosion on flat surfaces on tank inside of enclosure due to standing rainwater
- Occasionally some generator base tanks designs have a primary tank drain penetrating through secondary, defeating the value of the double wall configuration. This is not particularly common, but does affect the containment status if encountered

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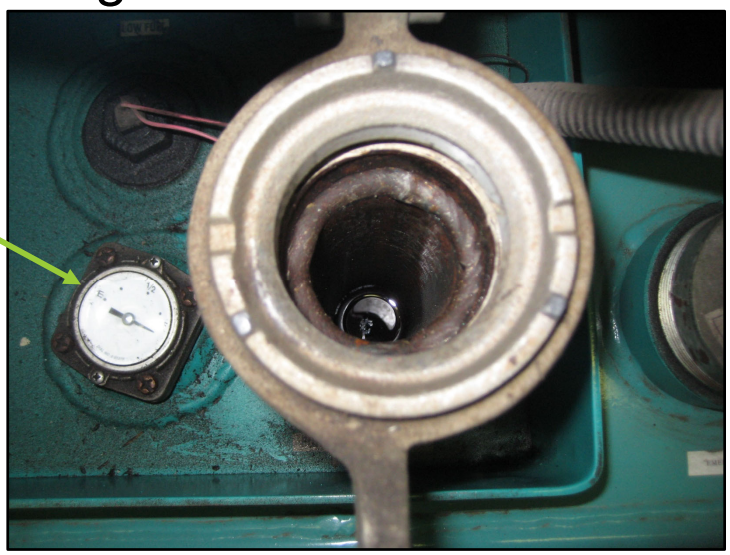
Common Findings-Tank Overfilled

This gauge only reads ¼, ½, etc. Gauges like this are not precise enough to determine high level fill limit



This tank has been filled all the way to the top of the tank-remember the coefficient of expansion of petroleum is about 0.5% for each 10 degree rise in fuel temperature

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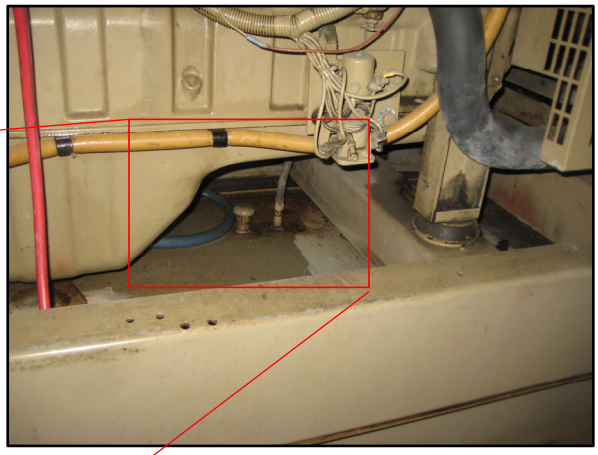
Common Findings-Tank Overfilled

This vent shows evidence of overfilling as a result of the owner filling the tank completely full. When the tank heats up, there's no place for the fuel to go but out the vent



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Common Findings-Venting

Emergency Vents not installed

Steel plug on emergency vent on day tank

Steel plug on emergency vent on generator base tank

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Common Findings-Corrosion

Corrosion of tank top surface and enclosure sides from standing water

Rainwater filled this fill box spill containment area, promoting corrosion

Tank top corrosion evaluated by UT inside the containment for generator

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Generator Base Tank Drains

Some (not all) base tanks have tank drains (for draining fuel), as well as having a rupture basin drain (for draining secondary). This would require external containment

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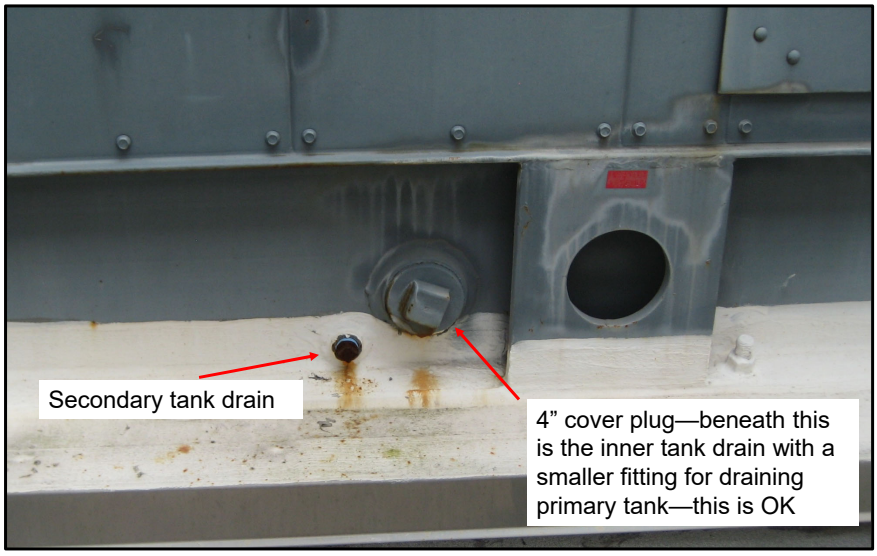
Generator Base Tank Drains



This tank, showing secondary tank drain at left and primary tank drain on right, has an internal tank drain line (w/plug) behind larger external shell plug—this design should be OK -- the 4” cover plug can be simply be removed to access the inner tank drain fitting that has its own plug.

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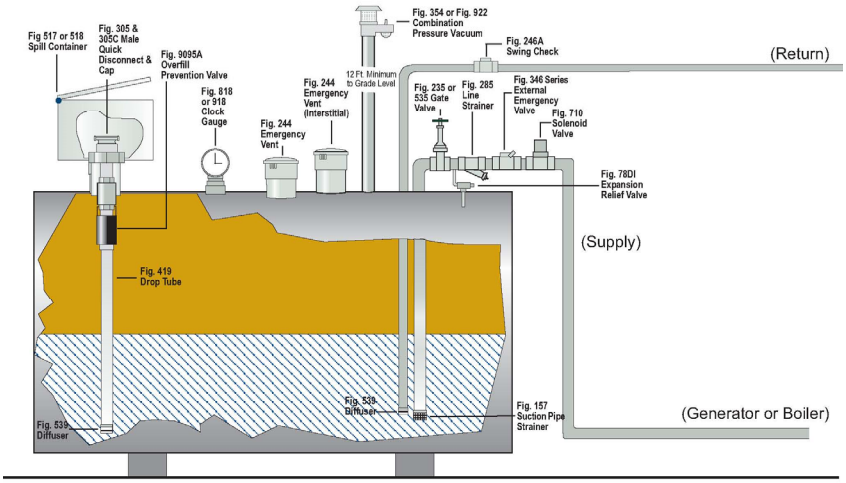
Generator Tanks

Emergency Generator or Fuel Oil Suction System



Source: Morrison Brothers Venting Guide

Tank system design for a separate tank supporting a generator system

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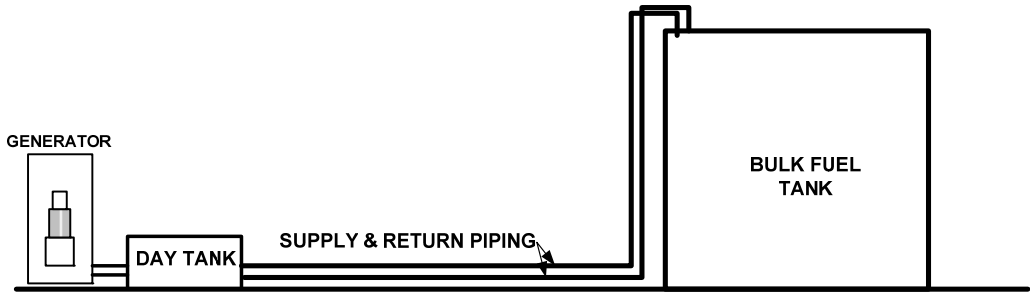
Emergency Generators



Day tank, also known as an auxiliary or service tank, is designed to provide a ready source of fuel for the generator. Required to be located close to the generator

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Day Tank-Bulk Tank Systems

In some cases, the emergency generator will be installed as a stand-alone system, not associated with a sub-base tank. These are fed by a day tank located nearby, and typically use a separate bulk tank to refill the day tanks

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Generator Day Tanks

Single walled day tank equipped with external secondary containment provided by bermed system

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Generator Day Tanks

Some day tanks located indoors use a single walled tank with a tub-type secondary containment basin, known in this industry as “rupture basin”.

Other types are completely double walled

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Generator Day Tanks

Typical day tank level switch activations are:
90% High Level
85% Fill Stop Level
75% Fill Start Level
50% Low Level
15% Critical Low Level

Day Tanks typically use multi-point level switches to call for fuel from bulk tanks, typically low, high, and high-high. These are normally located close to the engine

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Complex Emergency Systems

- Complex emergency systems typically refer to a sophisticated arrangement of backup power generators to provide electrical service to critical infrastructure or large facilities in event of power loss. These often include multiple generators, a bulk storage tank or tanks, that feed downstream day tanks that serve emergency generator systems, and/or supply fuel to other equipment, such as fire pump systems.
- These systems can be substantial in both tank sizes and in complexity of piping and pumping systems. It's not uncommon for these systems to have extensive piping runs that traverse many building levels and substantial distances.
- These systems almost universally provide essential services for the supported buildings and provide life safety and ongoing operations support in the event power is lost, often for extended run times, typically over 24 hours—but can range up to even longer.

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Complex Systems-Where are They?

Hospitals: These facilities are required to have 96 hours of fuel to be able to operate for extended periods. Due to large fuel supply needs, some of these will use USTs

Banking & Finance: Depending upon the needs of the supported operations, some financial centers require extended outage protection, such as those involved in trading operations or for processing transactions in realtime.

Sites with Critical Needs: These range from special use facilities (like emergency public safety buildings), high-rise buildings, laboratories, factories and commercial businesses, and others. The loss of power for these facilities has both health and financial impacts that can be devastating if not addressed.

Data Centers: Depending upon the size of the data center, the backup generators can range from single standalone generators (typically 1-3MW), have multiple standalone generators in enclosures, or have generator engines located inside the main building and be serviced by exterior bulk tanks and piping.

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Data Center Emergency Systems

Some data centers use multiple gensets served by sub-base tanks instead of a common bulk fuel tank type system. Others use the day tank-bulk tank design

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Complex Systems-How they Differ

Not like motor vehicle fueling: These systems are more complicated than tanks used in motor vehicle fueling.

- Some have extensive piping runs and pumping systems, typically incorporating duplexed system pumps. These systems require substantial care and maintenance due to the critical nature of these operations.
- With the exception of multiple gensets provided by their own belly tanks (sometimes found at data center applications), many systems use a main fuel tank or tanks of substantial size.
- Depending upon the application, expect to see a variety of pumps, filters, valves, monitoring equipment, complicated piping systems, and a host of other related features required to make these complex systems work.
- At well run facilities, the building engineers and technicians are well-versed in the operations and maintenance tasks associated with the generator operations.

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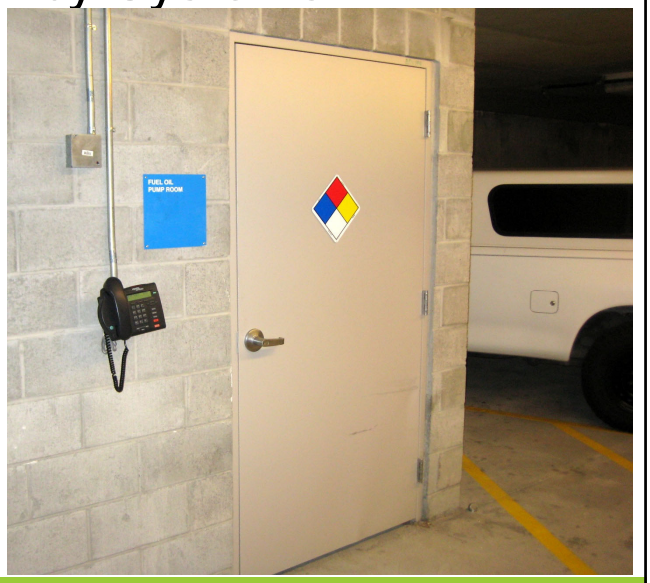
Complex Emergency Systems

High-rise buildings are commonly served by complex emergency systems, and these typically will have the main fuel tank located in a basement or lower parking level, usually in a fuel oil room of specialized construction, particularly in newer buildings. These are typically TIUGAs.

Generally, these tanks will be moderately sized, typically 6,000 gallons or less—although that can vary by installation and vintage



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Complex Emergency Systems

Other facilities use a combination of a bulk fuel tank with day tanks located near the generators; in some cases, the bulk fuel tank may also feed fire pump diesel tanks

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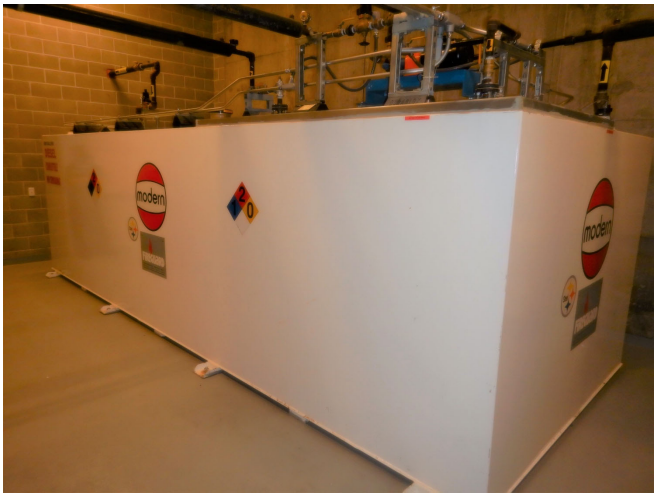
Complex Emergency Systems

Virtually all newer installations inside buildings—and even tanks located outdoors—will use UL 2085 tank designs to reduce the fire risk and to provide designers additional flexibility



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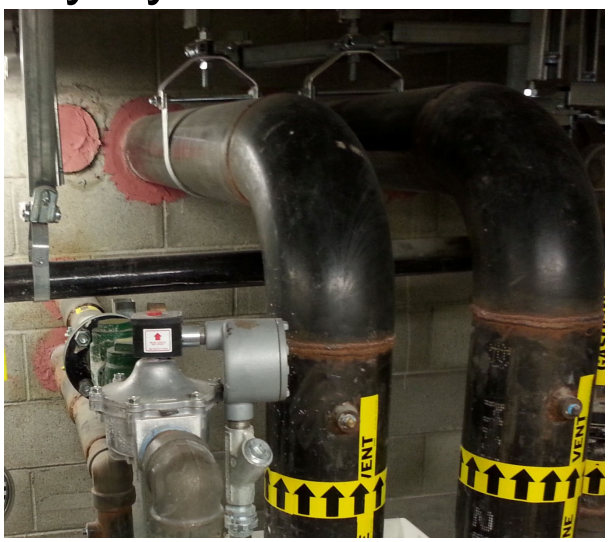
Complex Emergency Systems

Tanks located inside fire rooms are required under current codes to have firestop materials at all penetrations through the walls to prevent smoke transfer into adjoining portions of the building.



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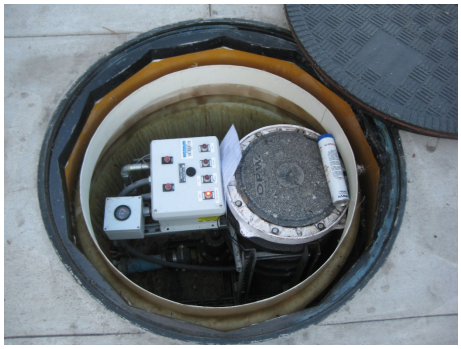
Complex Emergency Systems

Because the Fire Code prohibits fueling from other than street level, these sites will use remote fill systems that present special challenges, particularly in preventing overfills

Some designs use traditional spill buckets (like those seen on USTs) for at grade fills—these spill buckets sometimes suffer water infiltration problems



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Complex Emergency Systems

Some designs fill from street level using remote fill boxes enclosed inside of service doors designed for this purpose. This reduces the chances of water infiltration via at grade spill buckets

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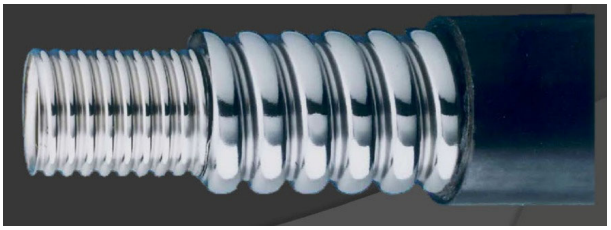
Complex Emergency Systems

In many cases, piping is provided with secondary containment, sometimes provided by integrated designs (such as Omegaflex or Brugg); in other cases it may be double walled steel, or fiberglass over steel



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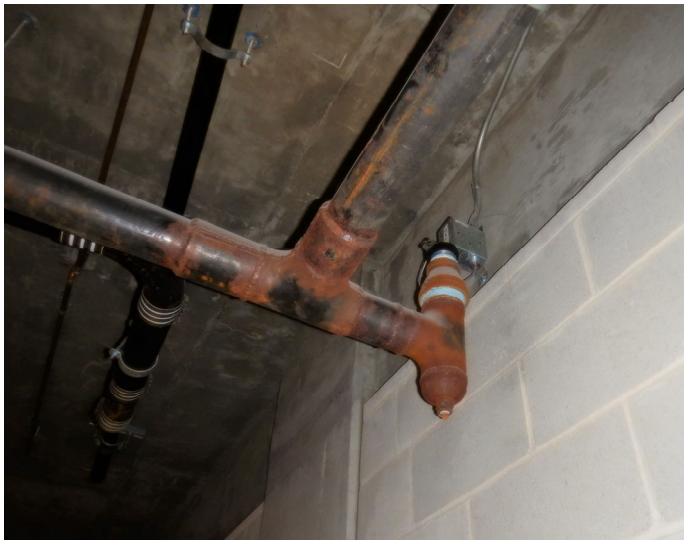
Complex Emergency Systems

Low point sensors are commonly installed in key locations to monitor for leakage for the primary into the secondary piping



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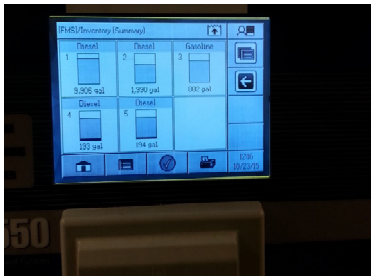
Complex Emergency Systems

Electronic monitoring systems are common in complex emergency systems, and are sometimes connected to building management systems for monitoring by building engineers



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Complex Generator Systems

Fuel polishing systems are used on these systems to maintain fuel quality—most emergency generators run very infrequently, leading to fuel degradation

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Complex Emergency Systems

- Because of the significant head differences between the tank located in the lower portion of the building and the generator sets (often on the higher levels) most of these use pressure systems, not suction systems, to supply fuel.
- For sites with bulk tanks that support day tanks, it is not uncommon to see duplexed pumps for redundancy, especially in critical applications
- Other equipment that may also be seen on complex systems: actuator valves, flowmeters, pressure gauges, controls, other ancillary equipment

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Risks & Special Concerns

Improperly designed or poorly maintained generator systems can result in substantial releases if not designed with fail-safe designs on day tank high-high level controls to prevent overfilling the day tank during generator operation. Note that these are operational failures, not tank failures

Fuel Spill, San Jose October 2010: 1300 gallons of diesel entered into roof drain system, then released to sewer system

Fuel Spill, Berkeley, December 2011: 1700 gallon diesel spill, Strawberry Creek, extended to Berkeley Marina

Fuel Spill, North Natomas Area, Sacramento November 2022: Reported diesel generator overflow event; wildlife, fish impacted in Tanzanite Community Park Pond

APSA Inspector Question: If the day tank high level controls failed and overflowed the day tank, where will the spill eventually go?

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Risks & Special Concerns

In addition to failures of level controls, fuel fills are emergency systems are typically very infrequently-tasks not performed often lead to errors

Tanks in basements are filled from street level, resulting in a blind fill

Tanks on roofs directly filled from street level also result in blind fills

Filling tanks at street level is a requirement of the Fire Code

Remote fill for emergency generator located inside building-delivery driver can't see tank

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Tank Filling Issues

Blind fills, where the tank isn't visible to the fuel delivery driver, pose special risks. Normally additional safeguards are installed

Human Factors: Written procedures need to be established and followed-Tank filling is rarely conducted, which can lead to errors

APSA Inspector Question: Does the facility have a written procedure for tank filling if remote fills are conducted?

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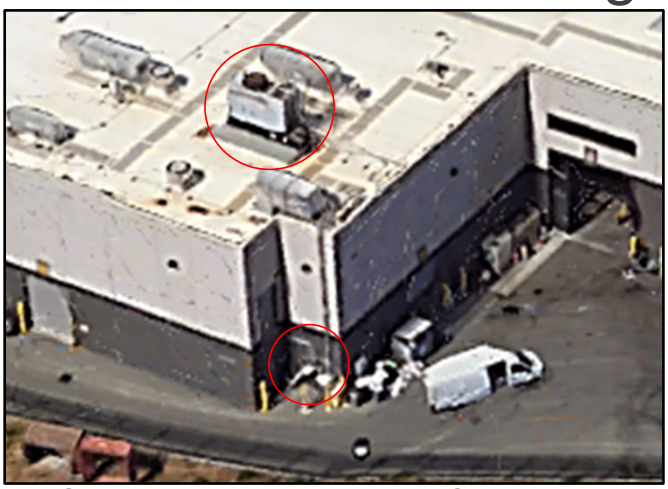
Tank Filling Issues



Rooftop generators require fuel to be pumped up multiple floors: results in blind fill, and residual fuel remaining in fill line

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APSA Inspector Questions for Complex Systems

Complex facilities are staffed with qualified building engineers, so these are different than motor vehicle fueling sites. Normally staff are aware of the critical nature of the backup systems and should have established procedures for this equipment.

APSA Inspector questions to consider for complex systems:

- For sites with larger bulk tanks (>5000 gallons), review the STI Formal Inspection reports, if previously conducted. Confirm that recommendations and actions to be taken have been addressed. If these have not been addressed, ask the facility why.
- For sites with electronic monitors, ask when the last monitoring certification was performed. Although monitoring certification is not required under APSA/SPCC explicitly like in USTs, the SPCC Plan should discuss regular testing of level sensors, which includes leak sensors
- Ask if fuel testing is performed on the bulk tank, or at least if the STI monthly checks for the presence of water are being conducted. Well run facilities will typically conduct fuel testing on an annual basis, or at least periodically. Certain facilities (such as those regulated under NFPA 110 as emergency power systems) are required to conduct annual fuel testing.

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Emerging Trends

- CA Health and Safety Code 1418.22 mandated by AB 2511--based in partial response to Hurricane Irma in Florida in 2017, where 12 nursing home residents perished inside facility where temperatures reached 99^{o} F
- Became effective Jan 1, 2023, required all skilled nursing facilities to provide alternate source of power to maintain safe temperature for residents, maintain availability of life saving equipment, and maintain availability of oxygen-generating devices for 96 hours (4 days)
- Required compliance by Jan 1, 2024—but few facilities meet this requirement
- Natural gas not allowed for fuel; 96-hour requirement is substantial. Although other solutions possible (solar, battery storage, others) most will be diesel backup generators
- Permitting done through Department of Health Care Access and Information (HCAI); subjects these facilities to Office of Statewide Hospital Planning and Development (OSHPD) requirements—these are substantial and complex, including special seismic certification (SSC) for generators, batteries, and certain other equipment
- Will take years to get facilities into compliance.

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Emergency Systems-Resources

Fire Code

- NFPA 110 Standard for Emergency and Standby Power Systems

Recommended Practices

- PEI/RP1400-14 Recommended Practices for the Design and Installation of Fueling Systems for Emergency Generators, Stationary Diesel Engines and Oil Burner Systems

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Questions

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