Emergency Generator Systems & APSA

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1

Objectives

- Review generator system types and how they are used
- Components of generator systems
- Identify common findings associated with these systems
- Key risks and observations about generator systems
- Tips on inspecting generator systems
- How to determine if gen base tanks are single or double walled

2

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

3

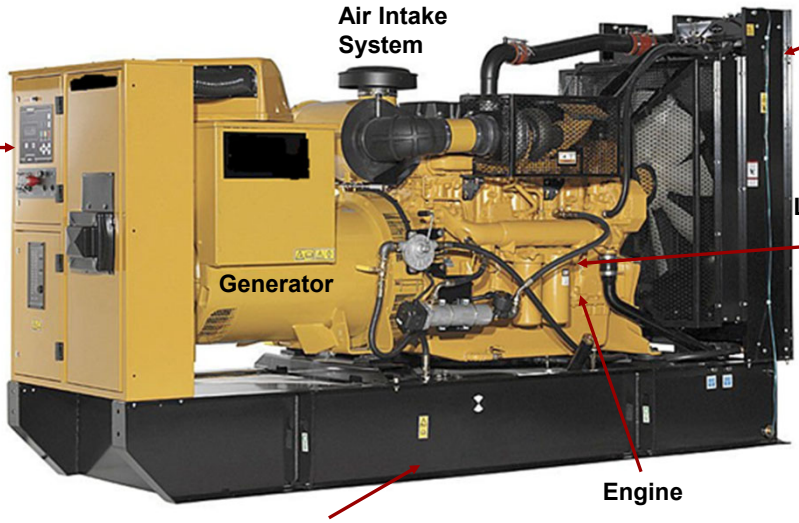
Types of Generator Systems

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

4

Generator Components



Not shown:
Batteries
Exhaust System
Enclosure
ATS
Others

5

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

6

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

7

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 installations will have complex systems with substantially large bulk fuel tanks to support critical equipment

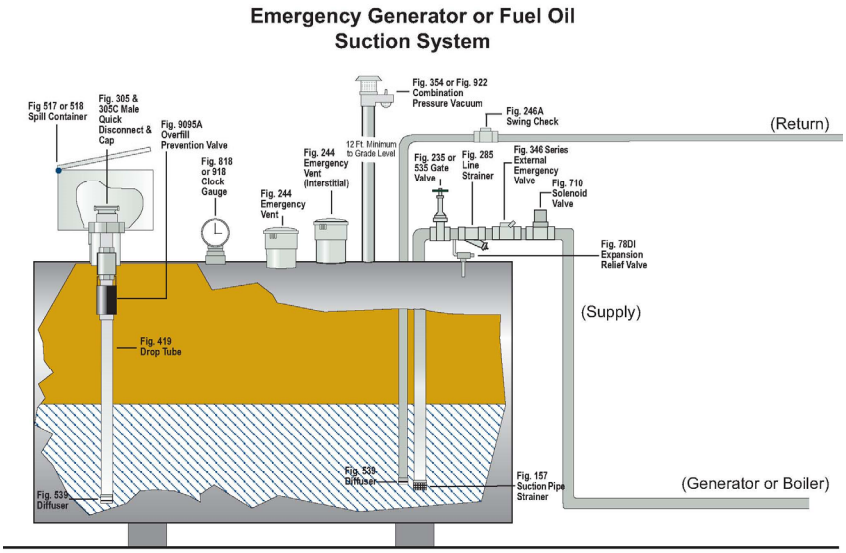
8

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.

9

Generator Tanks

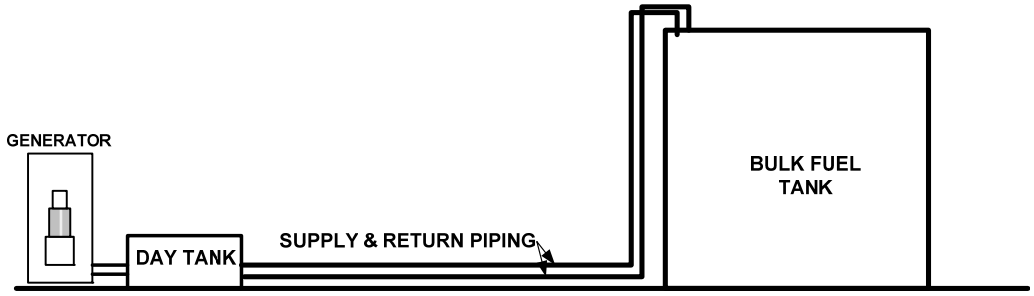


Source: Morrison Brothers Venting Guide

Tank system design for a separate tank supporting a generator system

10

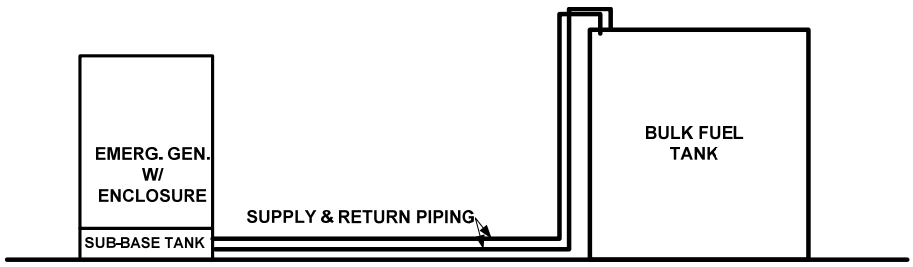
Emergency Generators



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

11

Emergency Generators



This example shows the base (or sub-base) tank) with integrated emergency generator package acting as the day tank. The larger bulk tank provides supplemental fuel as needed to support extended generator operation

12

Generator Day Tanks

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

13

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

14

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

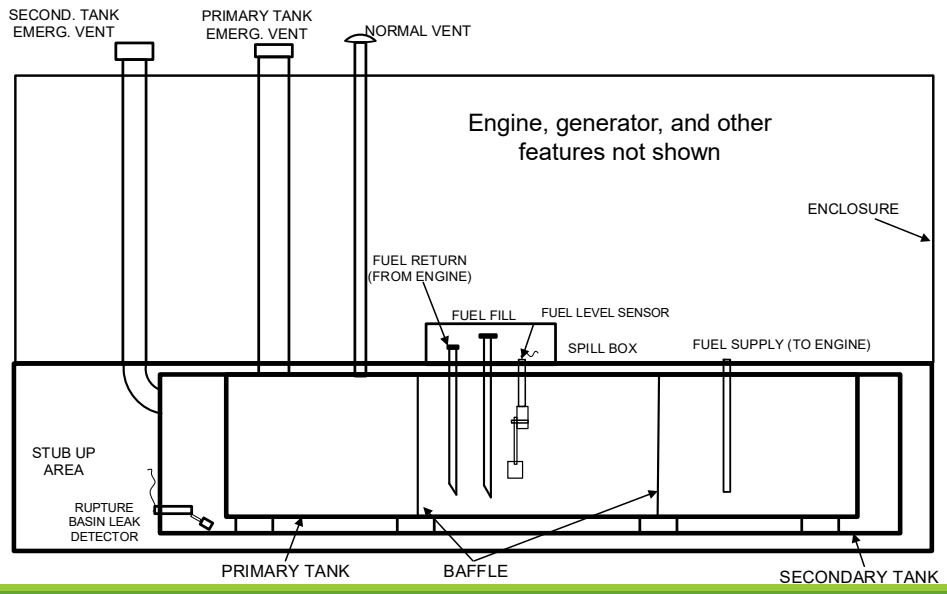
15

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

16

Emergency Generator Base Tank (typical)

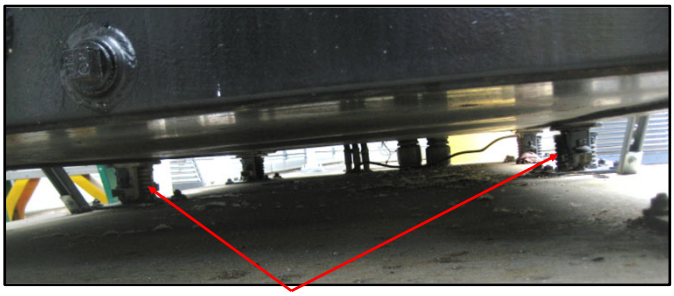


17

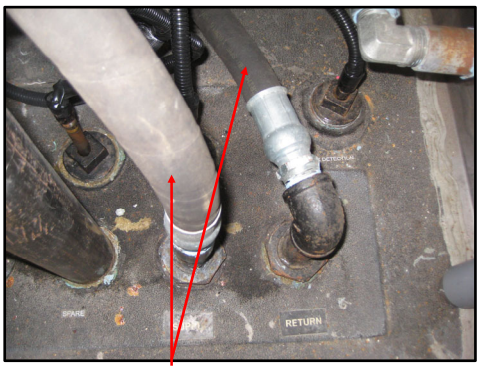
Generator Base Tank Features

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

18

Typical Emergency Generator Observations

- 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.

19

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

20

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

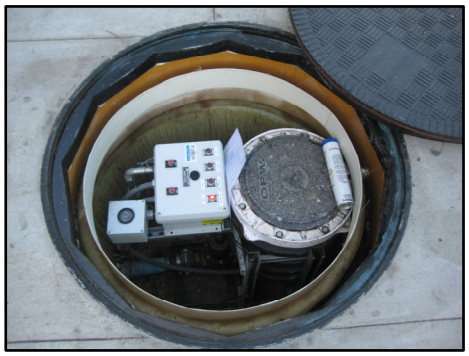
Remote fill for emergency generator located inside building-delivery driver can't see tank

21

Tank Fill Issues

Generators and day tanks are often located inside of buildings, with tanks in basements or underground parking areas

These require tank filling on the street level, some by gravity (instead of pumped fills)



Water can find its way into tank via this way, too

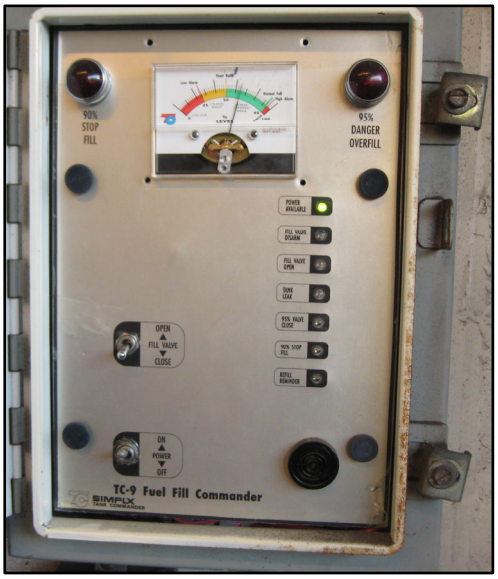
22

Tank Filling Issues

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

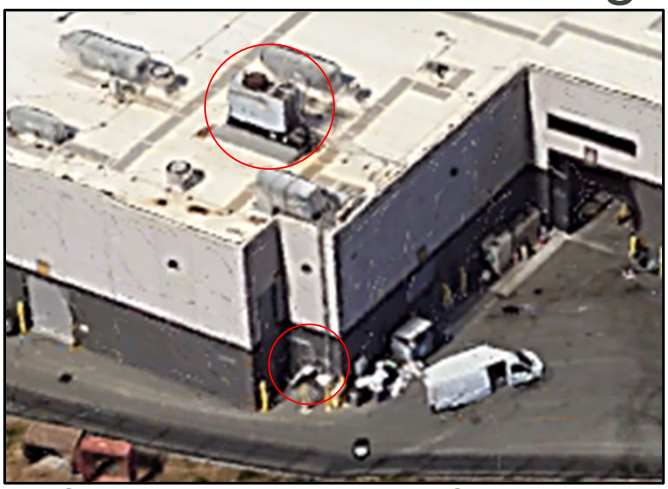
Human Factors: Written procedures need to be established and followed-Tank filling is rarely conducted, which can lead to errors

Overfill risks remain high, even on instrumented systems



23

Tank Filling Issues



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

24

Emergency generator system inspections

Care of emergency generator systems is important, for many reasons—first and foremost being able to respond in an emergency. Here are questions I normally ask during an inspection:

- Is owner/operator knowledgeable about operation of system, or is it largely outsourced? Normally the building engineer is the person to talk to about emergency systems
- Is the emergency generator being maintained to NFPA 110?—there are some specific requirements in that standard, especially for emergency systems (somewhat less for standby systems).
- Is the generator tank system inspected consistent with SP001 (monthly and annual) if SPCC Plan is required
- How is fuel quality managed? Are water checks of fuel in tank being performed? Is a fuel polishing program in place?

25

What do I look for on an emergency generator system during an inspection?

- If equipped with a rupture basin alarm, where is this alarm reported? (normally on panel inside enclosure, but may also be sent elsewhere too). Will the driver know if the tank is being overfilled?
- How often is the tank filled, and what safeguards are in place during fuel fills to avoid overfills?

Other notes:

- If equipped with separate bulk fuel tank, I normally focus on the bulk tank. Larger tanks have higher risks than day tanks--separate bulk tanks should have more safeguards, including overfill prevention
- The piping between the bulk fuel tank and day tank should be routinely checked, especially at threaded fittings

26

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

27

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

28

Control Panel

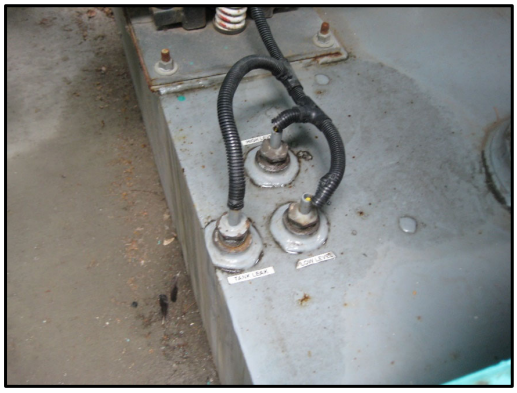
Ensure to check the control panel when inspecting; these are often hidden behind panels inside the enclosure

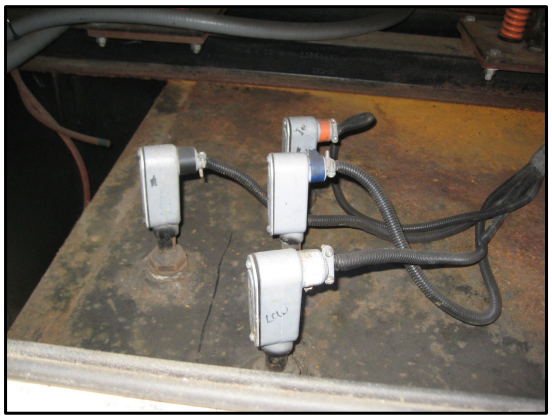
In some cases, alarms also may be “piggybacked” to signal a common alarm. In this case, the cause of the alarm will need to be isolated in order to troubleshoot & resolve the condition

29

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

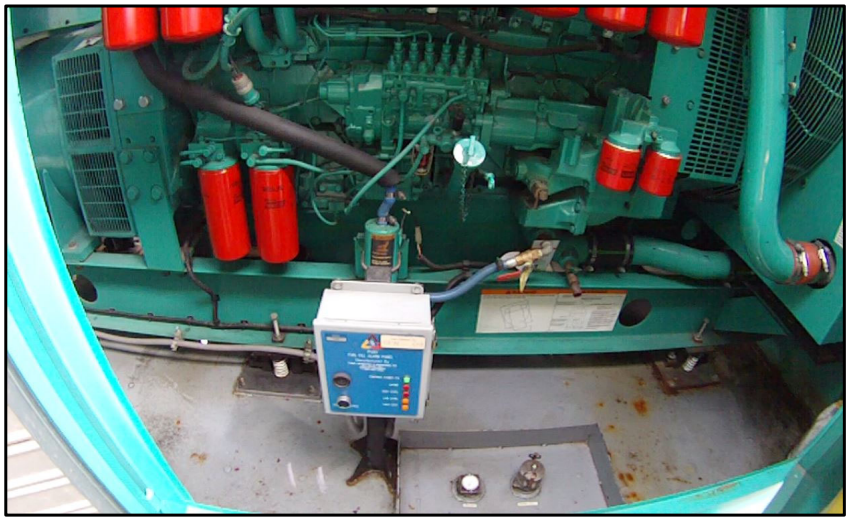




Interstitial leak sensor at left, with low, high, and high-high level sensors at right

30

Generator Base Tanks



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

31

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

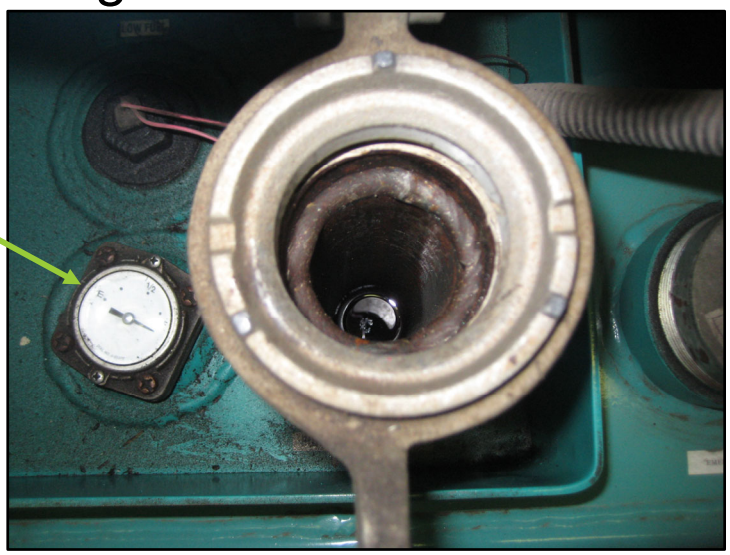
Common issues:

- 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

32

Common Findings-Tank Overfilled

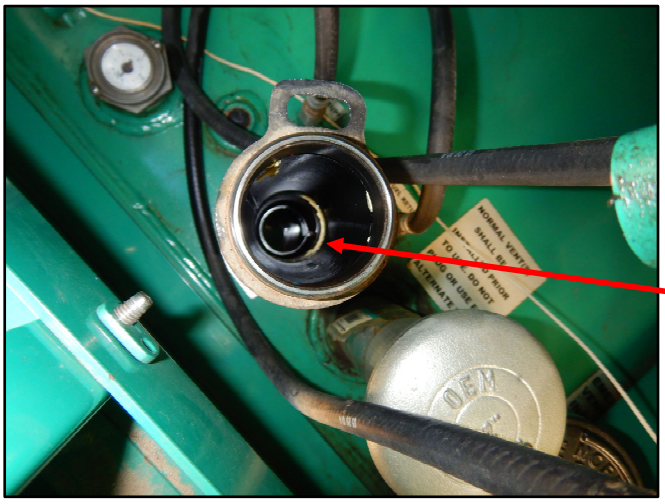
This gauge only reads ¼, ½, etc. Gauges like this are not precise enough to determine high level fill limit



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

33

Common Findings-Tank Overfilled



"Oops I Did it Again"

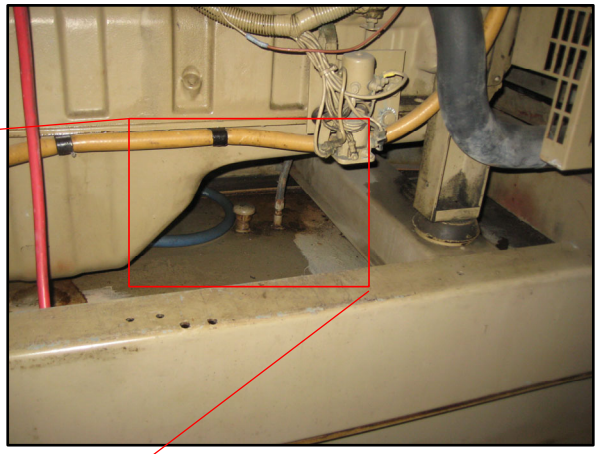
--signed Britney S.

The reflection seen in the fuel fill line is diesel. Fire Code restricts level of fuel filling in tanks to 90%. To prevent overfills, emergency generator tanks should have the high fuel level posted and require manual gauging instead of using the "primitive" fuel gauge.

34

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



35

Common Findings-Venting

Vent terminations inside of generator enclosure

36

Common Findings-Venting

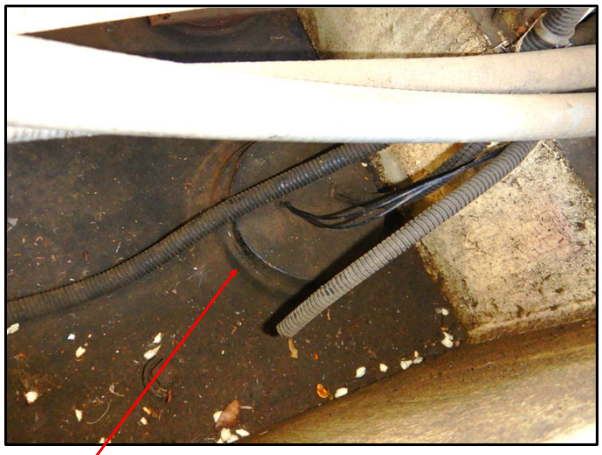
Emergency Vents not installed

Steel plug on emergency vent on day tank

Steel plug on emergency vent on generator base tank

37

Common Findings-Venting



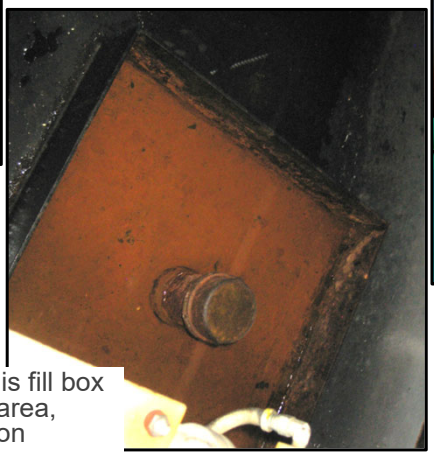
4-inch tank fitting on a base tank that should be location of emergency vent-but now used for sensors

Rated emergency vents not installed, nor properly terminating above grade outside of the enclosure

38

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

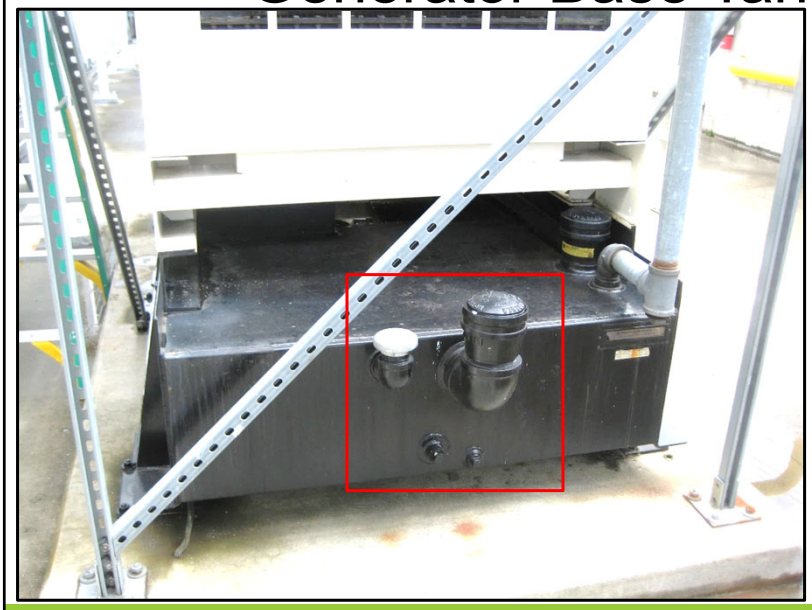
39

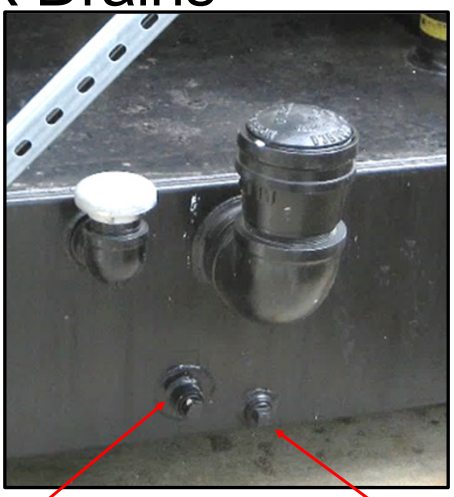
Generator Base Tank Drains

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

40

Generator Base Tank Drains



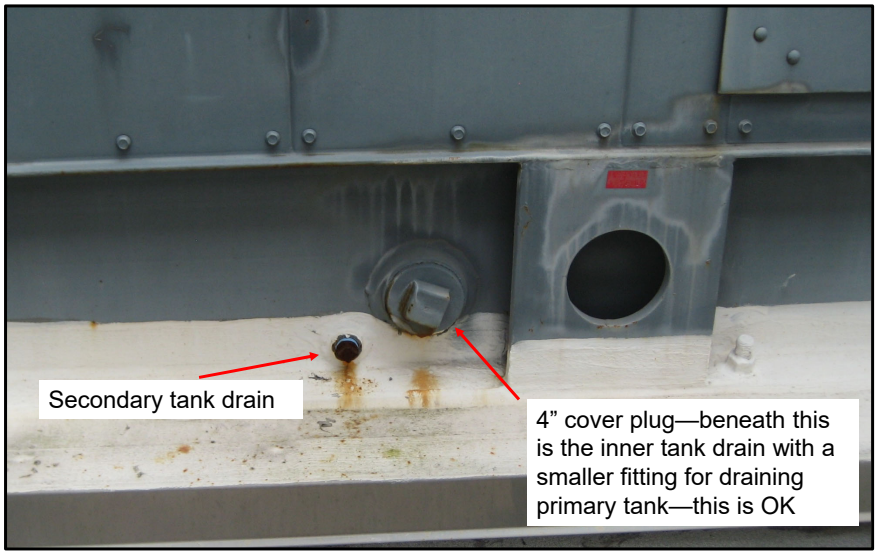


Primary tank drain

Secondary tank drain

41

Generator Base Tank Drains

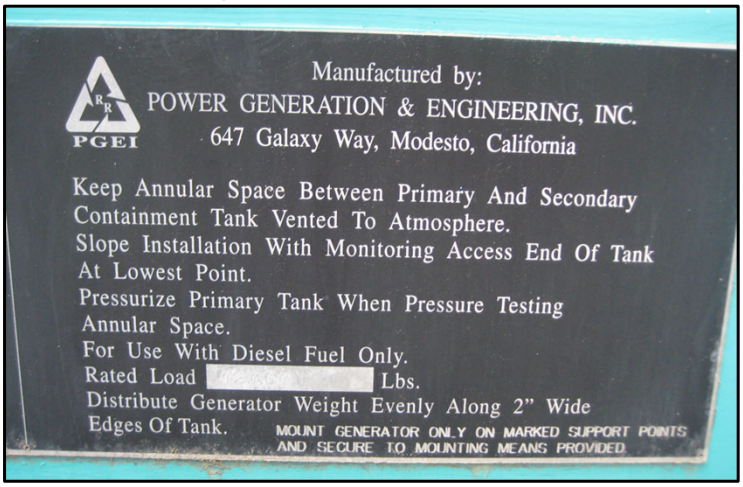


This tank, showing secondary tank drain at left and primary tank drain on right, has an internal tank drain line (w/plug) behind larger external shell plug—this design should be OK -- the 4” cover plug can be simply be removed to access the inner tank drain fitting that has its own plug.

42

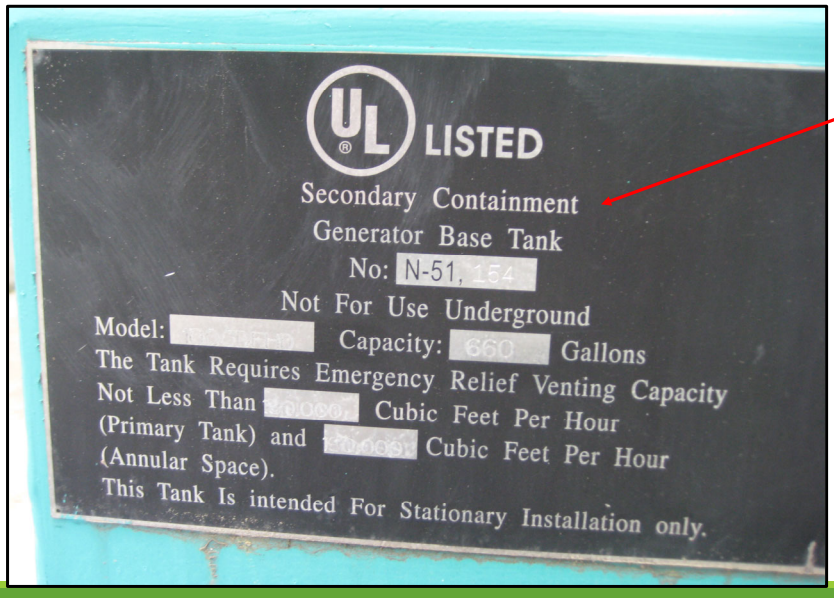
Is that base tank double walled?

Ways to determine if a generator base tank is double walled: Tank Placard describing annular space requirements



43

Is that base tank double walled?



UL listing stating Secondary Containment Generator Base Tank- also shows the primary and secondary tank emergency venting requirements

44

Is that base tank double walled?

Confirmation of two emergency vents

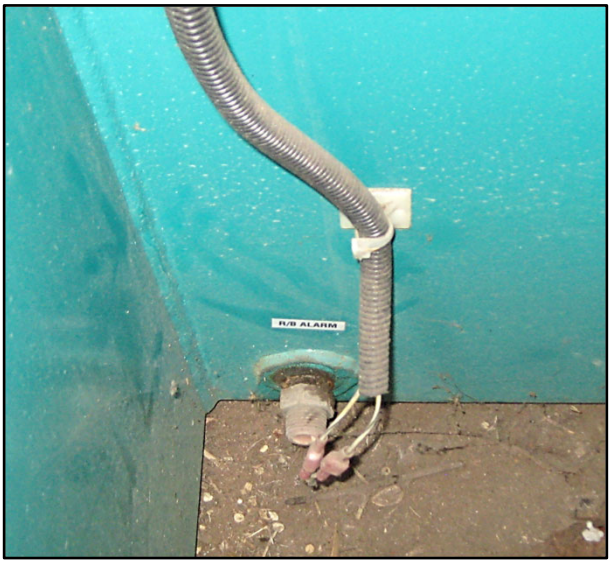
45

Is that base tank double walled?

Presence of “Rupture Basin Alarm” (if labeled)

46

Is that base tank double walled?



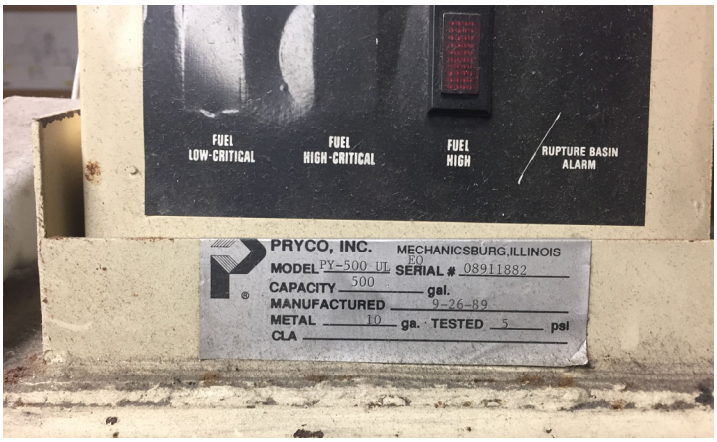
Evidence of a low voltage sensor wiring or label denoting "rupture basin alarm or sensor" (often "R/B alarm")

Often found at ends of tanks, commonly obscured by equipment

47

Is that tank double walled?

If able to identify tank manufacturer and unique serial number, call manufacturer



You'll need the manufacturer's serial number—the UL number is of no use

48

Is that tank double walled?

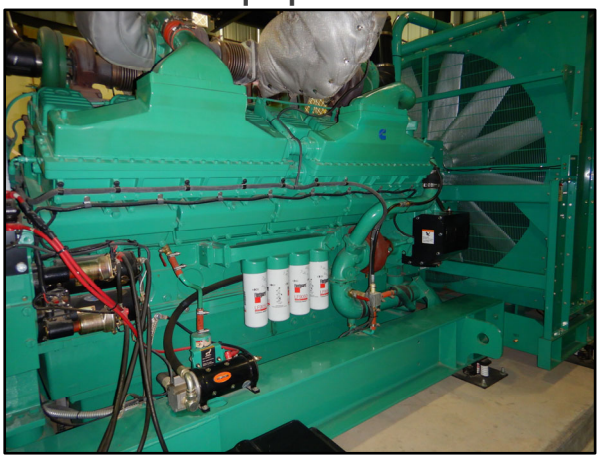
Hints on determining if tanks are truly double walled:

- Prior to visit, make sure the right staff are available who have the keys to the emergency generator enclosure.
- Open all enclosure doors during inspection-it's difficult to see inside as these systems are compact and full of various equipment
- Find the control panel and review carefully the inputs and alarms; look for "basin alarm", "leak alarm", or similar labels.
- Check all exterior locations for presence of drains—rupture basin drains are common but not always labeled. These will be at the lowest elevations on the base tank
- All vents (normal and emergency) will originate from the base tank in some way. Check the top of the tank to find the origination point.
- Not every emergency generator system has been properly installed. While non-compliant code conditions are often encountered, only a few impact tank integrity. Lack of emergency vents is one case that could impact tank integrity—tanks without adequate emergency relief venting are considered not suitable for continued service under STI's SP001 (10.2).

49

When are emergency generator engines themselves large enough to qualify as oil filled equipment?

- Some diesel engines may contain ≥55 gallons of crankcase oil—the engine would be oil filled operating equipment and need to be called out separately in SPCC plan.
- This is rare, except for generators typically greater than 1 MW (1000 KW). Engines this size are very large, usually 16 or more cylinders. Engines this size have high fuel demand rates (typically in hundreds of gallons per hour), and will have much larger separate fuel tanks connected to the day tank



This large generator engine held over 100 gallons of oil, making it oil filled operating equipment in the SPCC Plan

50

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

51

Questions

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52