

Extending the Runtime of Stand-by Diesel Generators Using Natural Gas

Stand-by Diesel Generators

- Allow for brief periods of continuous operation
- Limited by size of diesel fuel storage tanks
- Designed for intermittent power losses

Stand-by Diesel Generators

- Utility diminished during extended power failures
 - Duration of outage can exceed capacity of fuel storage tank

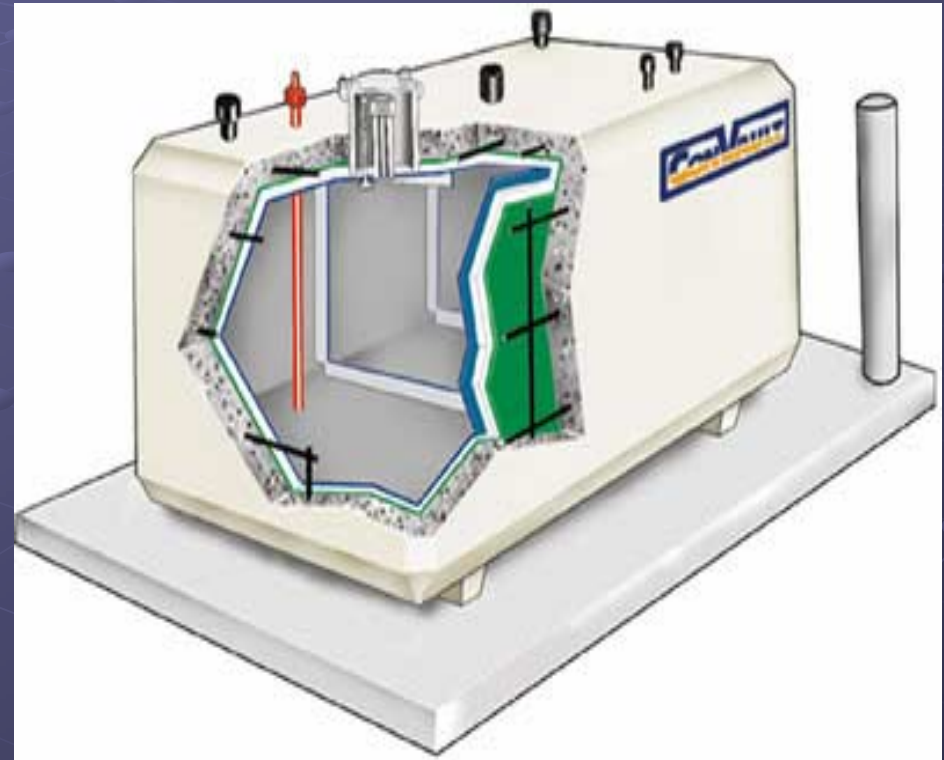


Fuel Storage Limitations

- Cost of additional storage
- Space availability
- Diesel fuel maintenance
- Permitting/code restrictions
- Environmental liabilities

Fuel Storage Tanks

- Large tanks needed to increase runtime beyond typical 24 to 48 hours
- Complex spill-containment and monitoring systems
- Increased cost and space requirements



Fuel Storage Maintenance

- Long term storage issues
- Low fuel turnover
- Diesel can become contaminated
 - Water
 - Algae
 - Other biological contaminants

Fuel Storage Maintenance

- Larger capacity systems need more intensive programs
- Cost of re-conditioning or replacing fuel can be significant
- Contaminated fuel may damage engine

Permitting Issues

- Restrict location
- Deny permit for storage above a maximum limit
 - Fire safety concerns
 - Possible contamination of ground-water and/or nearby lakes, rivers, shorelines, etc.

Liability Issues

- Liability for environmental contamination resulting from an accidental spill
 - More fuel = more liability
- Minimize onsite storage capacity to decrease liability exposure

Runtime vs. Fuel Storage

- Example: Generic 500 kilowatt diesel generator with a 500 gallon fuel storage tank
- Fuel rates at 50%, 75% & 100% load
- Fuel rapidly exhausted at and above 50% load

500 kWe Generator 500 Gallons of Diesel Storage

Load %	Kilowatts	Diesel Consumption	Run Time
50%	250 kWe	23.7 gph	21.0 hrs
75%	375 kWe	28.5 gph	17.5 hrs
100%	500 kWe	37.5 gph	13.3 hrs

Runtime vs. Fuel Storage

- Larger generators typically have larger quantities of fuel stored onsite
- Additional capacity offset by higher rates of consumption
- Example: 1500 kilowatt generator with a 2000 gallon diesel storage tank

1500 kWe Generator 2000 Gallons of Diesel Fuel

Load %	Kilowatts	Diesel Consumption	Run Time
50%	750 kWe	58.1 gph	34.0 hrs
75%	1125 kWe	82.1 gph	24.0 hrs
100%	1500 kWe	104.8 gph	19.0 hrs

Fuel Delivery Issues

- Damaged roads and infra-structure
(natural disasters)
- Short Supply
- Fuel delivery priorities
- Stranding of diesel fuel at supply
depots

Fuel Delivery Issues

- Delivery delayed for hours or days after a natural disaster



- Prevents refueling of storage tanks in time to prevent loss of emergency power

Fuel Delivery Issues

● Deliveries often resume on a priority basis:

- Local, state and federal agencies
- Hospitals
- Other critical facilities

Fuel Delivery Issues

- Longer outages can result in interruption of deliveries:
 - Limited run time of stand-by generators at fuel depots
 - Delivery companies unable to pump fuel into trucks

Options for Extending Runtime

- Decrease generator load
 - Shed non-critical load
- Reduced rate of consumption
- Increase total runtime
- Remaining critical loads
 - Rapid drawdown during extended emergency

Options for Extending Runtime

- Augment onsite diesel supply with a secondary fuel that :
 - does not require storage or delivery
 - can be readily used for combustion in the generator's diesel engine

Natural Gas

- Widely available
- Transmission and distribution independent of grid
- Infrastructure resistant to natural disasters
- “Unlimited” supply

Dual Fuel

Using Natural Gas with Diesel Engines

- Not commonly used in stand-by power applications
- Available for decades
- Diesel fuel / natural gas mixture
 - Over 90% natural gas
 - Enough diesel fuel for ignition only
- 100% diesel fuel when needed

Dual Fuel Engines



Dual Fuel

Using Natural Gas with Diesel Engines

- Typically not used for emergency stand-by service
 - High acquisition cost
 - Limited production
- Prime power and marine sector success

The Bi-Fuel Option

- Initially used for prime power and peak shaving applications
- Now being used in the stand-by market
- Maximize generator runtime
- OEM's offer kits

The Bi-Fuel Option

- Pipeline supplied natural gas
- No engine modification
- No reduction of power output
- 50% to 75% less diesel consumed
- Generator can operate on 100% diesel if required

Installation and Operation

- Installation of low pressure gas line close to generator
- “Gas Train” reduces pressure
- Air/gas mixer supplies natural gas to engine
 - Installed upstream of turbocharger air-inlet

Installation and Operation

- Air/gas mixture distributed to cylinders via engine air intake system
- Compressed by piston, mixture is ignited when diesel injector is activated
- Lean condition of mixture prevents pre-ignition

Installation and Operation

- Gas flow controlled according to engine/generator load level
- Gas controlled either mechanically or electronically
- Control of diesel injection for both diesel and bi-fuel modes handled by OEM speed control governor

Typical Bi-Fuel Components

- Gas filter
- Gas pressure regulator
- Electrically-operated gas shutoff valve
- Control Panel
- Engine sensors

Typical Bi-Fuel Components

- Gas train sensors
- Wiring harnesses
- Air/gas mixer(s)
- Manual shutoff valve
- Gas power valve / flow control valve

Typical Bi-Fuel Components

● Control panel monitors:

- Manifold air pressure and temperature
- Exhaust gas temperature
- Intake vacuum
- Gas supply pressure
- Engine vibration

Typical Bi-Fuel Components

- Dedicated sensors monitoring required parameters
 - Determine when to activate or deactivate bi-fuel operation
 - Depends on engine load level, gas supply pressure and/or engine performance levels

Generator Performance with Bi-Fuel

- On par with OEM specs
- Operating parameters within OEM published limits
 - Automatically switches to 100% diesel in case of out-of-limit condition
 - Fuel mode switch has little or no impact on output or stability

Generator Performance with Bi-Fuel

● Meets or exceeds 100% diesel levels for:

- Stability
- Power output
- Transient load response
- Block load acceptance

Extending Generator Runtime with Natural Gas

- Use of natural gas allows generator to consume diesel at a significantly lower rate
- 50% to 75% of diesel can be replaced with natural gas
 - Each gallon of diesel fuel displaced requires 130 standard cubic feet of natural gas

500 kWe Generator Using 70% Natural Gas w/ 500 Gal. Diesel Storage, Unlimited Gas Supply

Load %	Kilowatts	Diesel Consumption	Run Time
50%	250 kWe	7.10 gph	70.4 hrs
75%	375 kWe	8.55 gph	58.5 hrs
100%	500 kWe	11.25 gph	44.4 hrs

Extended Runtime vs. Load %

+ 50 hours @ 50% load

+ 41 hours @ 75% load

+ 31 hours @ 100% load

1500 kWe Generator Using 70% Natural Gas w/ 2000 Gal. Diesel Storage, Unlimited Gas Supply

Load %	Kilowatts	Diesel Consumption	Run Time
50%	750 kWe	17.43 gph	114.7 hrs
75%	1125 kWe	24.63 gph	81.2 hrs
100%	1500 kWe	31.44 gph	63.6 hrs

Extended Runtime vs. Load %

- + 81 hours @ 50% load
- + 57 hours @ 75% load
- + 45 hours @ 100% load

Limitations

- Dual fuel engines are purpose-built to operate on very small quantities of diesel
- Conventional diesel engines require more conservative pilot fuel levels in order to maintain performance and ensure long-term durability

Limitations

● Limiting variables include:

- Lubricity and cooling effect of diesel fuel
- Air-gas mixture must stay below LEL for safety
- Engine load/knock limits
 - Diesel injection timing is not adjustable
 - “Ignition” timing is fixed
 - Gas composition can be a factor

Conclusion

- Power failures can persist for days
- Emergency power can be lost...
 - due to insufficient onsite diesel fuel storage
 - and/or the inability to replenish an exhausted supply
- Natural gas can be safely and reliably used to extend the runtime of existing diesel generators through the use of mature bi-fuel retrofit technologies



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