

***Generator Set
Installation Recommendations***

**WARNING:
CALIFORNIA PROPOSITION 65 WARNING:**

Engine exhaust from this product contains chemicals known to the state of California to cause cancer, birth defects and other reproductive harm.

**WARNING:
CALIFORNIA PROPOSITION 65 WARNING:**

Battery posts, terminals and related accessories are known to the state of California to cause cancer, birth defects and other reproductive harm.

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Installation Guidelines 30kW to 2000kW

Large generator sets have requirements that smaller generator sets do not. Vibration, noise, heat, air flow, fuel supply issues become more critical for very large power generation systems. The purpose of this document is to assist the consultant in the design and installation of this land based generator set. Closely following these recommendations will assure that the generator is properly installed and will provide many years of trouble free dependable service. These are general guidelines and if your installation requires some detail that is not described in this document, please contact your Baldor representative before you proceed.

Intended Use

This document describes techniques that should be followed to properly install Baldor 30kW to 2000kW Generators for stationary land based applications.

Important

Be sure you are completely familiar with all Safety Instructions detailed in product service manual. Do not proceed if you are unsure of any detail. Contact your Baldor Distributor, they are experienced and are happy to assist you and to answer your questions.

The procedures presented in this manual are suggestions and it is the responsibility of the Owner/Operator to arrange for these procedures to be performed by licensed contractors according to all applicable codes including local codes for your Municipality/City/County and State. In addition to these suggestions, before installing your generator you should obtain the most up to date copies of the following documents from the National Electrical Code and other authorities:

- National Electric Code, Articles 230, 250, 445, 517, 700.
- National Fire Protection Association
 - No. 30 – Storage, Handling and Use of Flammable Liquids.
 - No. 37 – Stationary Combustion Engines and Gas Turbines.
 - No. 99 – Essential Electrical Systems for Health Care Facilities.
 - No. 101 – Life Safety Code No. Systems.
 - No. 110 – 1985 Emergency and Standby Power Systems.
- NEMA MG1
- Local Codes applicable to Genset Installation. See your local building inspector.

NFPA (National Fire Protection Association) (617) 770-3000 (includes NEC)
1 Batterymarch Park, Quincy, MA 02169-7471 USA

NEMA (National Electrical Manufacturers Association) (703) 841-3200
1300 N. 17th Street, Suite 1847, Rosslyn, VA, 22209 USA

Site Planning

Room Size

Open frame generators must be protected from the environment while having good ventilation and cooling. Here are some considerations for planning a generator room or enclosure:

- Never use the Genset room for storage.
- The room must be large enough to contain the Genset and all the accessories, such as batteries and their charging system, transfer switch and other controls, and elements of the cooling and fuel systems.
- 2 feet minimum (preferably 4 feet), must be allowed on the two sides and the front of the engine for service access. Allow clearance between hot parts of the system (exhaust) and structural members of the building.
- On the generator end of the engine, allow a space equal to the length of the generator (generator length only, not the entire Genset).
- Certain safety and building codes may require the Genset room not to be used to house any other mechanical or electrical equipment.

Room Location Often a separate building located on the site away from the main building is the most simple and cost effective. Major considerations when housing the Genset in a separate building are:

- Maintain the building at a satisfactory temperature year round (to meet applicable codes).
- Assure the Genset is not located so far from the emergency loads that reliability is compromised.
- The floor's load carrying capacity must be checked and must exceed the weight of the Genset and its associated equipment.
- **Engine Cooling System**
A Genset with an engine mounted radiator is the least costly to install; however, the room must be located in a place where sufficient radiator cooling air can be brought into and exhausted from the room.
- **Exhaust System**
The exhaust system must minimize exhaust restriction. Exhaust restriction must be correct to ensure proper engine operation. Refer to product specifications for correct exhaust pressure (inches Hg). The exhaust system should be as short and have as few bends as possible. Engine exhaust must be directed away from occupied buildings, windows and doorways.
For aesthetic reasons, consider exhaust placement in relation to the building. Over a period of time, exhaust gas carbon deposits will tend to accumulate on any nearby wall or structure. Attention must also be given to exhaust noise in selecting placement of the exhaust system.
- **Room Air**
If the Genset is cooled with an engine mounted radiator, and sufficient air is brought into and exhausted from the room to satisfy the radiator cooling requirements and the combustion air requirements, the room will not overheat when the Genset is running. If a remote mounted radiator or a heat exchanger is used, and adequate air is circulated through the room to keep it at a reasonable temperature, there will be adequate air for combustion.
- **Fuel Tanks (Diesel Only)**
Locate the fuel storage tank as near the Genset as possible. This will minimize the cost of fuel system installation and will maximize fuel system reliability.
- **Controls and Transfer Switch**
Locate the control switch gear as close to the emergency loads and the Genset as practical. This will minimize the chances that a failure of the power line to the emergency load will go undetected. In locating the switchgear, accessibility for service and maintenance must be considered.

Room Location Continued

- **Genset Noise**

Internal combustion engines produce noise, so the room should be located away from occupied buildings. In addition the Genset room can be treated to reduce noise transmission. In locating the Genset room, both engine, fan and exhaust noise must be considered.

If noise within the Genset room, or noise transmitted to the surrounding parts of the building are a concern, then the room must be made large enough to allow for installation of noise attenuating walls and noise absorbing walls.

Light weight concrete blocks filled with sand or special “sound block” concrete blocks are commonly used. Noise attenuating, tight fitting windows and doors also help reduce noise transmission to the rest of the building.

A double-walled room should be considered. Vibration isolators under the Genset rails will also reduce the transmission of noise through the floor.

- **Code Requirements**

Building and safety codes deal with engine location. These requirements are concerned with fire rated walls, a location that minimizes the possibility of damage to the Genset and interruption of the emergency system due to storms, floods, fire, vandalism, etc.

Codes often deal with the need to maintain certain temperatures in the Genset room and with fuel system location. The most important codes in the USA are the National Fire Protection Association Code Numbers 99 and 110, but local codes must also be observed.

Utility Power During periods when the generator is not running, utility power must be provided to power critical components. Battery chargers, block heaters, space heaters and other devices must have power to maintain the generator set components and allow fast easy starting.

Foundation Design

WARNING: An open bottom stationary engine Generator Set must be installed over noncombustible materials and shall be located such that it prevents combustible materials from accumulating under the Generator Set.

Foundation Checklist

- A. Evaluate if a separate, isolated foundation is required for the application.
- B. Observe local codes on soil bearing capacity freezing and thawing.
- C. Design the separate foundation for the Genset and specify the appropriate concrete mix.
- D. Determine if the application requires vibration isolators and if so, order as a factory option.

The foundation must be strong enough to support the weight of the Genset and its associated equipment, must prevent any deflection of the Genset base and absorb vibration produced by the rotating and reciprocating masses.

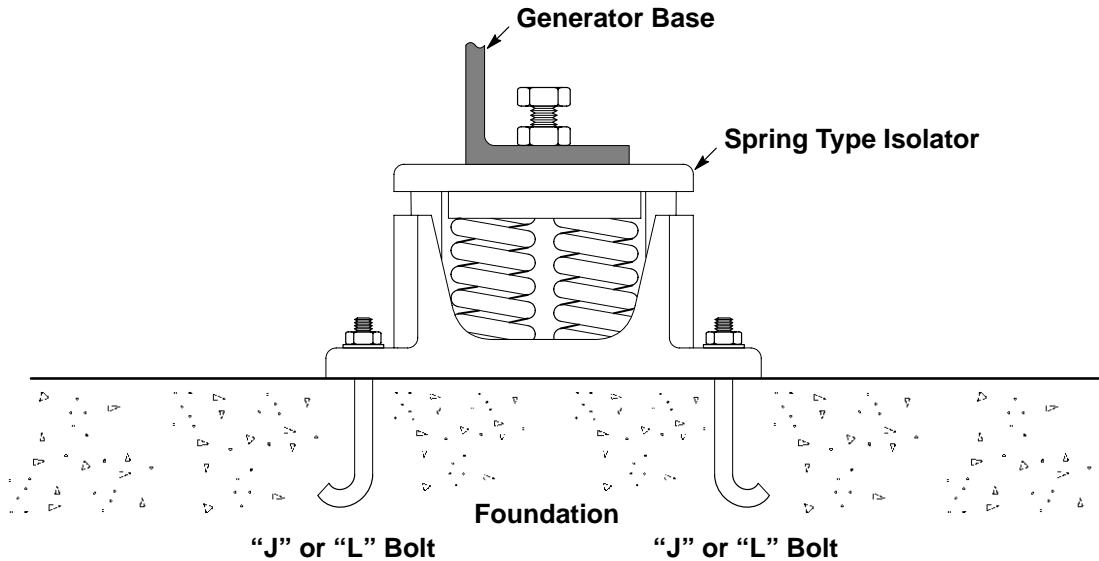
Setting The Genset On An Existing Concrete Floor Slab

- If an existing floor is used, the floor slab must be strong enough to carry 1.50 times the Genset wet weight (including coolant and oil) to accommodate dynamic loads.
- The actual mounting arrangement (ie., surface area in contact with the floor) will determine the compressive strength required.
- The Genset should be securely fastened to the floor slab with expansion anchors that fit the mounting holes shown on the Genset installation diagram.
- For installations not expected to be permanent, elastomer pad with non-slip surface placed between the base and the floor will also prevent movement.
- Any floor/slab surface should be as flat as possible to prevent sub-base deflection.

Vibration Isolators

- Vibration isolators are commonly used to mount the Genset to a concrete pad, Figure 2-1. The purpose of vibration isolators is to reduce the noise and vibration which would be transmitted from the Genset to the foundation or supporting structure.
- A simple and effective method of mounting and applying pad type isolators is to place non-skidding type isolation pads directly between the sub-base and floor. The number of pads required is determined by the rating of the pads and the Gensets weight.

Figure 2-1 Typical Installation of Spring Type Isolator



- Steel spring isolators are a very effective and commonly used. Steel spring isolators are typically 95–98% efficient (reduces the transmitted vibration 95–98%) while a pad type can be 75–88% efficient. Spring isolators also level the Genset sub-base in the event the foundation pad is not perfectly level. The base should be mounted to the foundation pad as shown in Figure 2-1 or as recommended by the isolator manufacturer.

A common practice is to pour a concrete pad directly on top of the floor slab and to mount the Genset on this pad. The purpose of the pad is for cleaning around the Genset and to provide a more level base. When using this method, floor strength must support the pad and the Genset. The pad should be at least 6in (150mm) thick and extend beyond the Genset in all directions 12in (300mm).

Weight of the Genset

The dry weight of the entire Genset is shown on the Generator Set Specification Sheet. The wet weight includes the fluids (coolant and oil).

Designing an Isolated Foundation

If the Genset cannot be mounted directly on a floor slab, or if it is desirable to isolate it from the floor slab, then a separate foundation slab must be designed.

A massive concrete foundation is not required. Outside dimensions of the foundation should exceed the outside Genset dimensions by 12in (300mm).

For single Genset installation, the foundation weight should be a minimum of 1.50 times the Genset wet weight.

For multiple Genset installation, the foundation weight should be a minimum of 2.0 times the Genset wet weight.

Figure 2-2 shows a method to calculate foundation thickness and the soil bearing load of the foundation and Generator Set. The soil load bearing capacity under the foundation must equal or exceed the load from the foundation and Genset. If it does not, then a footing must be added to spread the load over a larger area.

Caution: Check the local building codes for load bearing capacity requirements.

Caution: If the soil is subject to freezing and thawing, the foundation must be extended below the frost line. Check the local building codes.

Figure 2-2 Calculate Soil Bearing Load (SBL) Capacity

$$T = \frac{W_T}{145 \times L \times W}$$

Where:

T = Foundation depth in feet (m)
 W_T = Wet weight of Geneset in lbs (kg)
 145 = Density of concrete in lbs/ft³ (kg/m³)
 L = Foundation length in feet (m)
 W = Foundation width in feet (m)

The diagram shows a 3D perspective of a rectangular foundation. The vertical height is labeled 'T', the length is labeled 'L', and the width is labeled 'W'. The word 'Foundation' is written on the top surface.

$$SBL = \frac{TW}{W \times L}$$

Where:

SBL = Soil bearing load in lbs/ft² (kPa)
 TW = Total weight (foundation load)
 Geneset (wet) and all other
 equipment to be supported
 in lbs (kg)
 L = Foundation length in feet (m)
 W = Foundation width in feet (m)

Table 2-1 shows approximate load bearing capacities for various types of soil if the actual load bearing capacity of the soil under the foundation is not known.

Table 2-1 Approximate Load Bearing Capacities of Various Soil Types

Soil Type	Safe Bearing Capacity	
	lb per ft ²	kilo Pascals
Hard Rock – Granite etc.	50,000 – 200,000	2,395 – 9,576
Medium Rock – Shale etc.	20,000 – 30,000	958 – 1,436
Hardpan	16,000 – 20,000	766 – 958
Soft Rock	10,000 – 20,000	479 – 958
Compacted Sand and Gravel	10,000 – 12,000	479 – 575
Hard Clay	8,000 – 10,000	383 – 479
Gravel and Coarse Sand	8,000 – 10,000	383 – 479
Loose, Medium and Coarse Sand	8,000 – 10,000	383 – 479
Compacted Fine Sand	6,000 – 8,000	287 – 383
Medium Clay	4,000 – 8,000	192 – 383
Loose Fine Sand	2,000 – 4,000	96 – 192
Soft Clay	2,000	96

- Reinforce the foundation with No. 8 gauge steel wire mesh placed horizontally on 6in (150mm) centers. As an alternative, use No. 6 re-bars on 12in (300mm) centers horizontally. Minimum cover over the bars should be 3in (76mm).
- Suggested concrete mixture by volume is 1 part cement, 2 parts sand, and 3 parts aggregate. Maximum slump of 4in (100mm) and a 28-day compressive strength of 3000 psi (20,600 kPa).
- The size of the bolts holding the sub-base to the foundation should be sized to fit the mounting holes shown on the installation diagram.
- Three-inch (76mm) iron pipe sleeves should be placed around the bolts in the foundation to allow for any mislocation of the bolts after the foundation hardens. “J” or “L” type bolts are recommended for the foundation bolts.
- After the foundation is cured and the Geneset is located, the sleeves are filled with grout.

Exhaust System Exhaust Checklist

- A. Exhaust outlets are not located upwind or near any building air intakes.
- B. Flexible piping section is used at engine exhaust outlet.
- C. Exhaust piping material is adequate for expected service.
- D. Exhaust piping sizing is adequate to prevent back pressure.
- E. Exhaust piping components are insulated as necessary to prevent operator burns and reduce pipe radiant heat losses.
- F. Pipe sleeves or fire proof materials are used where exhaust pipe passes through building materials as per local and state codes.
- G. Exhaust pipe includes rain cap or is horizontal.

The purpose of the exhaust system is to safely discharge the engine combustion products into the atmosphere outside the building. A silencer should be installed in the exhaust system to reduce noise levels. Compliance with local noise codes is always required.

WARNING: Never allow the exhaust outlet to be positioned so that the exhaust gases are directed towards any openings or air entry routes (doors, windows, vents, etc...) of an occupied building. When discharging the hot exhaust gases out of the building do not direct them towards anything that could catch fire or explode.

For aesthetic reasons, consider exhaust placement in relation to the building. Over a period of time, exhaust gas carbon deposits will tend to accumulate on any nearby wall or structure. Attention must also be given to exhaust noise in selecting placement of the exhaust system.

Level Of Attenuation

In general, manufacturers offer three grades of silencers: industrial, residential, and critical. Check the attenuation curves for the silencer to assure the desired level of silencing is met.

Multi-Engine Installations

Caution: Do not connect multi-engine exhaust systems together. Each engine must have its own exhaust system for proper operation.

Exhaust gases from an operating engine will migrate back through a non-operating engine and cause a hydraulic lock. This may interfere with starting of the second engine. The migrating gases will also tend to turn the turbos which are not being provided lubrication if the engine is not running. Do not use check valves in the exhaust system because they can "stick".

Exhaust Manifold

There are two exhaust manifold types. Dry type which is standard and the optional water cooled. The dry type is simply exposed to the surrounding air and becomes very hot. Shields, insulating wraps, or other types of guards can be used to limit operator contact with the hot surfaces. This practice is common where engine room size is small, creating cramped conditions.

Water cooled exhaust manifolds are not available on all engine models. This type manifold has passages through which engine coolant is circulated to remove heat from the manifold surface. It also will help protect the operator from contact with the hot manifold surface. This will reduce the amount of heat that is radiated by the engine to the surrounding air by approximately 20%. In addition, this type manifold significantly increases the amount of heat the cooling system must dissipate. Marine and Mining Safety Administration (MSA) codes may require water cooled manifolds in all Genset installations. If you are in doubt on your particular application, consult your Baldor Distributor.

Note: If you are using a remote muffler a flexible coupling of 12" or more must be installed between the exhaust line and the manifold to absorb the engine's vibration. However, a short, solid section of pipe between 6" and 8" long should be placed between the connection of the manifold and the flexible coupling. This nipple will reduce the possibility of the hot gases burning up the flexible coupling.

Exhaust Gas Restriction

The maximum allowable back pressure, or system restriction, is stated in the product specifications data (inches Hg). If this back pressure is exceeded, the air–fuel ratio is reduced due to incomplete scavenging of the cylinders, fuel economy and power output is reduced, engine life is reduced and exhaust temperatures and smoke levels increase. Any restriction of the exhaust gas reduces horsepower. Take every precaution to reduce restriction. Proper design and installation will provide safe Genset operation.

It is essential that engine exhaust systems have the least possible restriction to exhaust gas flow. This can be calculated as shown in Figure 2-3.

Figure 2-3 Exhaust System Calculations

$$P \text{ (psi)} = \frac{L \times SL \times Q^2}{5,184 \times D^5}$$

Where:

P = Backpressure in psi (kPa)
 psi = 0.4912 x in Hg
 kPa = 0.1333 x in Hg
 L = Length of pipe in ft (m)
 Q = Exhaust gas flow ft³/min (m³/min)
 D = Inside diameter of pipe in (mm)
 S = Specific weight of gas lb/ft³ (kg/m³)

$$S \text{ (lb/ft}^3\text{)} = \frac{39.6}{\text{Exhaust Temperature} + 460^\circ\text{F}}$$

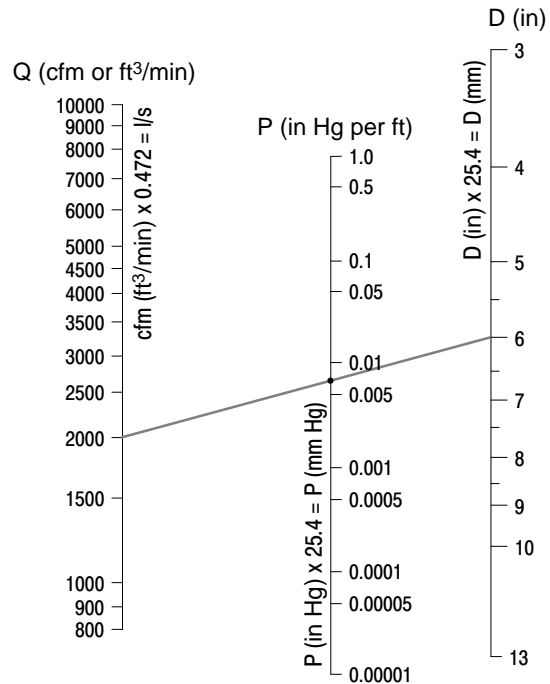
$$S \text{ (kg/m}^3\text{)} = \frac{352.05}{\text{Exhaust Temperature} + 273.16^\circ\text{C}}$$

To obtain equivalent length of straight pipe for each long radius 90° bend:

$$L \text{ (ft)} = 15 \times D \quad L \text{ (m)} = 15 \times D$$

$$L \text{ (in)} = \frac{15 \times D}{12} \quad L \text{ (mm)} = \frac{15 \times D}{1000}$$

Note: For 90° bends, radii of 1.5 times pipe diameter helps reduce resistance and backpressure.



Exhaust Piping

Caution: The weight of the exhaust system must never be imposed on the turbo-charger outlet. Damage to the turbo-charger and other components may result.

An exhaust system must withstand the vibration and thermal expansion that they are subjected to, yet supported well enough to remain independent of the engine.

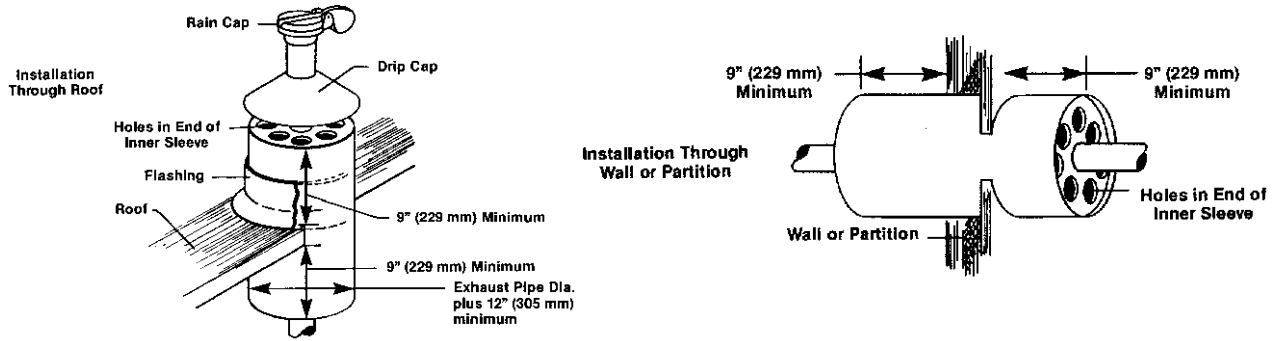
The most common method of providing flexibility is with the use of bellows type flexible piping. This piping component allows lateral and linear movement of the piping system without subjecting fixed components to excessive stress. A minimum of 12 inches of flexible connection must be provided at the engine exhaust manifold to allow for thermal expansion and vibration. If the engine is to be mounted on spring type vibration isolators, increase the length to 24 inches. This component can be specified to be provided by your Baldor distributor. Flexible pipe should never be used for pipe bends or to cure misalignment problems.

Exhaust piping systems may be supported by a wide variety of methods to long as the system remains flexible, and capable of withstanding thermal expansion.

The material most commonly used for straight runs and elbows in exhaust systems is Schedule 40 black iron. If hanging weight is a problem, other materials may be used. Galvanized piping should never be used in exhaust system. Where exhaust piping passes through combustible material, exhaust thimbles must be used. See Figure 2-4.

Note: Water is one of the by-products of combustion. This water must be kept from draining back into the engine. Slanting the horizontal section of the exhaust system piping downward slightly, away from the engine can do this. A water trap (tee extension with a drain cock) should also be used. The water trap should be located between the flex coupling and the muffler, but as close to the engine as possible on a horizontal section of the exhaust piping.

Figure 2-4 Exhaust Pipe Thimble Installation



Wind Barrier

(Noise Barrier shown in Figure 2-5)

Wind blowing against air exhaust or intake openings of the Genset room must be considered, especially where the radiator and fan are located on the engine. Wind blowing against an exhaust opening creates restriction to the fan. Wind blowing against intake openings can blow open gravity louvers causing low temperature and moisture problems in bad weather. A turning vane may be required to prevent exhaust air recirculation between the exhaust louvers and the barrier surface. This will route the exhaust upward into the atmosphere.

Rain Protection

Moisture entering the engine through an exhaust system can cause extensive damage. Exhaust outlets must have a rain cap or be horizontal to prevent such damage, see Figure 2-4.

Cooling System

Cooling System Checklist

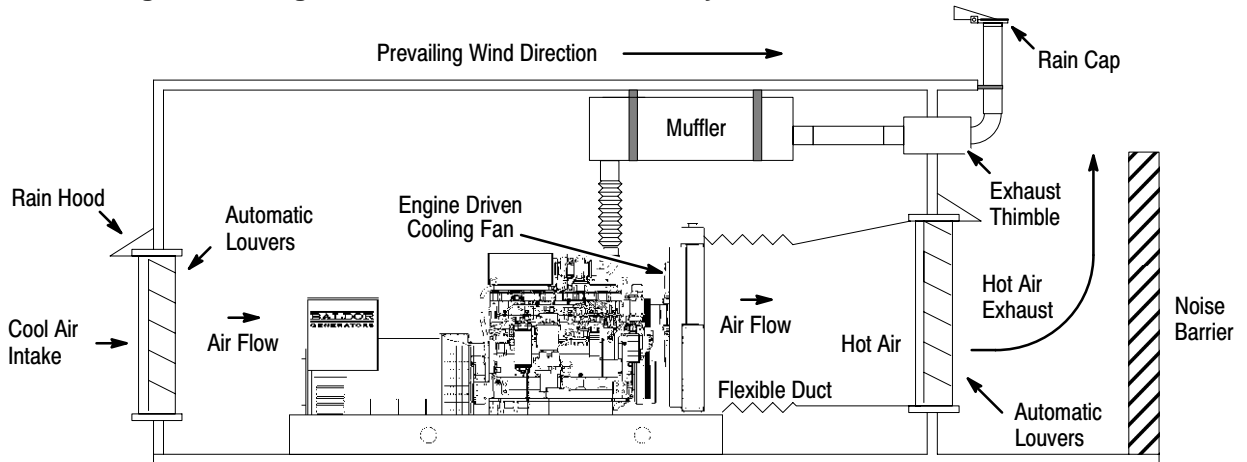
- A. Has noise been considered?
- B. Has system piping been properly sized?
- C. Has system been properly protected from freeze up and corrosion?
- D. Have standby equipment heaters been specified?
- E. Have all electrically driven devices been connected to load side of EPS connection points?
- F. Have system drain valves and air eliminators been installed?

The system consists of the cooling medium which is generally a solution of water and ethylene glycol, a method of rejecting engine produced heat, and a means to transport cooling medium between the engine and heat rejection system. The first determination is the type of cooling system to use – radiator cooling or heat exchanger cooling.

Engine Mounted Radiator Cooling

The most simple is the engine mounted radiator shown in Figure 2-5. The radiator, water circulating pump, fan and fan drive are mounted to the Generator Set base rails by the factory. This method of engine cooling is the most economical, but may require large ventilation vents and ducts. An added advantage of this arrangement is that the cooling air removes radiated heat from the engine, generator, and other equipment located in the emergency power system room. The only remaining design work with the engine mounted radiator is arranging a method of providing air to the room, and exhausting it from the radiator. See “Air Systems”.

Figure 2-5 Engine Mounted Radiator Cooled System With Wind/Noise Barrier



The ideal setup for cooling air would be to arrange the inlet or inlets such that relatively clean, cool, dry air is drawn across the electrical switchgear, generator, and engine. The air is then drawn into the radiator fan, and is blown through the radiator and exhausted by duct work outside the building. Air inlets must be sized to minimize air restriction and provide the quantity of air required by the radiator fan, engine combustion air, and any other air exhausts which might be used in the room. On engine mounted radiator cooled systems, the engine mounted fan will handle 0.25" of water column. This is combined intake and exhaust restriction.

The room air intakes must be located so as to minimize drawing exhaust fumes and other outside contaminants into the room. Be very cautious about the location of the engine exhausts in relation to room air intakes. Also, when locating the inlet and outlet, the consultant should consider prevailing winds and noise. Motor operated louvers or properly designed and sized gravity louvers should be used on the air intake and exhaust to minimize static pressure drop.

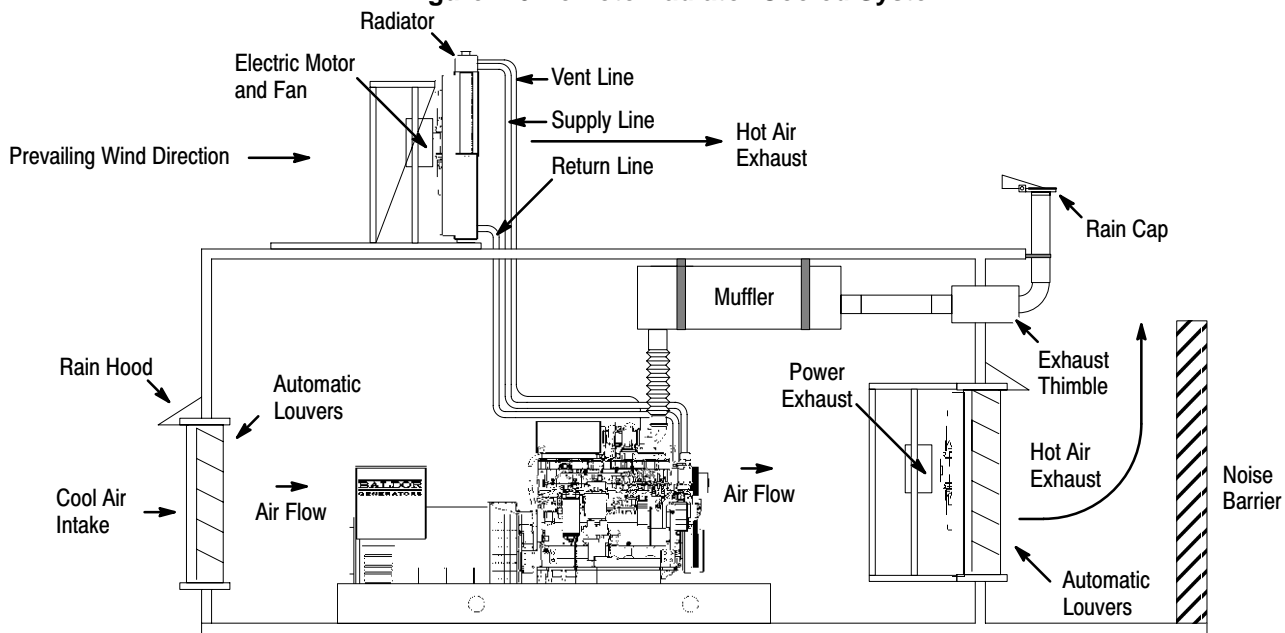
Caution: In cold climates, the high volume of outside air drawn into the Genset room can quickly reduce temperatures in the room to freezing. Any water piping or other equipment susceptible to freeze damage should be properly insulated or located elsewhere.

Remote Mounted Radiator Cooling

The radiator can be mounted remotely (not mounted directly at the engine). The remote/close system uses the same radiator type except it is mounted in another room or outside the building, but within close proximity to the Genset. See Figure 2-6.

The remote radiator may be mounted either vertically or horizontally. In general, the radiator will have an electric fan to provide cooling air and may be able to utilize the engine mounted coolant pump to provide coolant flow.

Figure 2-6 Remote Radiator Cooled System



The piping system friction and head loss between engine and radiator must be calculated and not exceed the capacity of the engine pump. If the maximum coolant friction head loss external to the engine is exceeded, a hot well system must be used. Before designing the piping system using an auxiliary pump and hot well, the consultant should look very closely at increasing the system's pipe size.

Electric motorized Power Exhaust louvers should be connected to the standby Genset and controlled to open whenever the Genset is running. Operable outlet louvers should be temperature actuated on remote radiator or heat exchanger cooled units. Louvers have resistance to air flow. Openings with louvers should be twice the area of an unobstructed opening to provide proper air flow. At times duct work is necessary to provide cooling air for the room. Duct work must be sized and installed according to SMACNA Standards.

The electric fan and auxiliary pump, if used, must be connected to the emergency power system. Radiator and cooling fan must be sized to provide the cooling capacity required at an acceptable sound level.

Remote radiator and heat exchanger cooled engine cooling systems will not have an engine driven fan. As a result, the consultant must provide a means of supplying air to the room, and exhausting it. The air movement must be provided by an electrically driven fan. This fan may be located in the air inlet or exhaust opening. If the fan is located on the exhaust side, care must be taken to not create a high negative pressure in the room and starve the engine of combustion air.

Heat Exchanger Cooling

In the heat exchanger system, engine coolant is circulated through the shell side of a heat exchanger, while city water, well water, or some other cooling medium, is circulated through the tube side. The primary consideration in this type cooling system is to remember that during certain types of disasters, these cooling mediums may not be available, especially city water. The system is relatively inexpensive to install and maintenance is low. Similar to Figure 2-6 except the heat exchanger mounts between the engine and hot air exhaust (no radiator).

The heat exchanger cooling system can be used with a cooling tower. These systems are complex, and consists of circulating pumps, heat exchanger for engine coolant, and cooling tower for heat rejection. The system design requires that several pieces of equipment be sized and installed. Overall, this system is more expensive than other methods of engine cooling.

Hot Well Installations

One final consideration on the water side is the Maximum Static Head. This is the maximum height allowable from the engine crank center line to the highest point in the coolant system. The maximum static head is specified on generator specification sheets. If this number must be exceeded, a hot well tank system must be used.

The design of hot well tanks and piping systems is somewhat complex. Your authorized Baldor Distributor has experience in the design and installation of hot well systems. Consult your Baldor Distributor if the static head of the coolant system in your Genset application exceeds this criteria and requires a hot well system.

Cooling System Design

Remote Radiator Cooling

Remote Radiator Airflow generally assumed there will be no external restrictions to airflow. If this is not true, restriction must be considered in sizing and selection of a cooling fan and drive motor. Typical examples of restrictions include landscaping, nearby buildings, air turbulence created by buildings or other structures, and sight or noise "screens". See Figure 2-6.

Remote Radiator Fan Motor. Remote radiator cooling systems require the use of an electrically driven fan. This fan must be connected to the emergency power source. Size of the motor is determined by the fan size and fan speed.

1. To specify a radiator to cool the coolant you will need to determine the amount of heat rejected to the coolant. This is listed on the Engine Data Sheet as Heat Rejected to Coolant in BTU/min. for engines using dry or water cooled type exhaust manifolds, as applicable.
2. Determine the minimum water flow required at the engine, and the maximum top tank temperature. Using this information, determine the heat rejection capacity required of the radiator. Radiator systems should be sized with approximately 15% greater capacity than the engine's maximum full load heat rejection to allow for overload and cooling system deterioration. Whether water flow is produced by an engine mounted or auxiliary pump, total piping system friction loss must be calculated. To do this, Genset location, remote radiator location and friction loss within the radiator, and piping system must be estimated.
3. Pressure drop through the radiator must be obtained from radiator manufacturer.
4. If total piping system pressure exceeds the allowable Maximum Coolant Friction Head External to the engine as listed on the Engine Data Sheet, the coolant piping size should be increased and/or a radiator with less restriction must be used.
5. Pressure drop in pipelines and friction of water tables may be found in most mechanical handbooks such as "Cameron Hydraulic Data" handbook.

Table 2-2

Fitting Size	Flow Restriction of Fittings Expressed as Equivalent of Straight Pipe (in inches)											
	1.5	2	2.5	3	4	5	6	8	10	12	14	16
90 Elbow	4.4	5.5	6.5	8	11	14	16	21	26	32	37	42
45 Elbow		2.5	3	3.8	5	6.3	7.5	10	13	15	17	19
Long Sweep Elbow	2.8	3.5	4.2	5.2	7	9	11	14	17	20	24	27
Close Return Bend		13	15	18	24	31	37	51	61	74	85	100
Tee–Straight Run		3.5	4.2	5.2	7	9	11	14	17	20	24	27
Tee–Side Inlet or Outlet	9.3	12	14	17	22	27	33	43	53	68	78	88
Globe Valve Open		55	67	82	110	140						
Angle Valve Open		27	33	41	53	70						
Gate Valve Fully Open		1.2	1.4	1.7	2.3	2.9	3.5	4.5	5.8	6.8	8	9
Gate Valve Half Open		27	33	41	53	70	100	130	160	200	230	260
Check Valve		19	23	32	43	53						

Other Considerations

General:

1. Deaeration of the coolant. This can be accomplished through the use of the system deaerators in very large systems, or simply ensuring the radiator top tank or surge tank is at the highest point in the piping system. Unvented piping systems can create air pockets which reduce coolant flow and can lead to engine overheating. Baldor furnished radiators are equipped with deaerating top tanks.
2. Flexible hoses must be installed at all engine connections and to the radiator to isolate vibration and allow for thermal expansion.
3. Drain valves must be installed at the lowest point of the cooling system to facilitate system cleaning and flushing.
4. Water treatment and antifreeze must be added to system coolant. Baldor recommends 50/50 ethylene glycol and coolant treatment for all engines.
5. Thermostatically controlled engine coolant heaters are required to be installed on all standby Gensets. These will increase starting reliability under cold conditions, and improve the start-up load handling ability.
6. According to the NFPA 110, priority level 1 equipment jacket water heaters shall maintain coolant at a minimum of 90 °F (32 °C). In outdoor installations where temperatures will be expected to drop below 32 °F (0 °C), a battery heater should be employed to keep the batteries at a minimum of 50 °F (10 °C), and will shut off at 90 °F (32 °C). All heaters will shut off when the engine is operating. Adequate antifreeze protection will be provided and ether starting aids will not be permitted.
7. The consultant should also consider oil sump heaters if conditions warrant.

Heat Exchanger Cooling:

1. If the engine is to be heat exchanger cooled, the system will require a reliable raw cooling water source and controls to regulate water flow during Genset operation.
2. The system will also need a reliable method of starting and stopping water flow automatically. The heat exchanger cooled system may be used with a cooling tower.
3. Baldor Gensets are available with heat exchangers factory mounted on the engine. If a heat exchanger cooled system is required, specify with order.
4. Shell and tube type heat exchangers are connected such that raw cooling water flows through the tube side of the heat exchanger, and engine coolant through the shell side. Tubes are more easily cleaned and the potential for fouling is much greater on the raw water side.
5. For economic reasons, the raw water flow can be regulated by varying the flow of raw cooling water through the heat exchanger. This control can be accomplished with a temperature actuated control valve. The thermostatic bulb for this control must be in the engine jacket water discharge line. The control valve should be a fully modulated type with a minimum flow setting. **NEVER attempt to regulate engine water flow.**
6. Water flow regulators are used only if raw water is from a city or well water source. Do not attempt to regulate flow if a cooling tower is used. Maintain at least 2 ft/second of water flow through the tube side of the heat exchanger.

7. Heat exchanger cooled systems using city or well water, and cooling, tower heat rejection, however, will not be protected on the tube side of the heat exchanger, nor interconnecting piping and cooling tower as engine coolant is not circulated through these components. These systems must be heat traced, and have sump heaters installed to protect the various components when the Genset is on standby.

It must also be noted that if an antifreeze solution is used in the shell side of the engine cooling system heat exchanger, local codes may restrict the discharge of the tube side cooling water after flowing through the heat exchanger.

Coolant Treatment:

1. Engine coolant should be treated with a Diesel Coolant Additive (DCA) to minimize corrosion of the engine and cooling system components. A 50/50 ethylene glycol antifreeze solution is recommended for all Genset engines. This will provide freeze protection and increase the boiling point of the engine coolant. A solution can be increased to 65% but freeze protection is reduced after 65%.
2. It is recommended that the consultant specify Baldor supplied DCA and water filters, and Baldor antifreeze.
3. When the proper solution concentration of antifreeze is used with radiators (engine mounted as well as remote mounted), and hot well systems, the system will be adequately protected from freeze-up.

Air Flow System Air System Checklist

- A. Air inlet faces the direction of prevailing winds.
- B. Air outlet does not face noise sensitive areas without noise attenuating devices.
- C. All heat loads have been taken into consideration in sizing air flow.
- D. Gravity louvers face inward for air intake and outward for discharge.
- E. Where electrically operated ventilation devices are used, power must be present under all operating situations. Be certain these devices are on the emergency circuit.

The room in which the Generator Set is to be installed must have adequate air flow through it to provide combustion air, and remove heat radiated from the engine, exhaust system and generator. See Figure 2-7 for air flow calculations.

Figure 2-7 Air Flow Calculations

$$\text{BTU/minute } V \text{ (cfm)} = \frac{Q_M}{0.0181 \times \Delta T_{F0}}$$

$$\text{Kilowatt•Hours } V \text{ (m}^3\text{/min)} = \frac{\text{kW} \cdot \text{hr}}{0.02015 \times \Delta T_{C0}}$$

$$\text{BTU/Hour } V \text{ (cfm)} = \frac{Q_H}{1.085 \times \Delta T_{F0}}$$

Where:

- V = Ventialting air flow ft³/min (m³/min)
- Q_M = Heat disipated by the engine, generator and other equipment BTU/min
- Q_H = Heat disipated by the engine, generator and other equipment BTU/hr
- kW•h = Heat disipated by the engine, generator and other equipment Kilowatt Hours
- ΔT = Premissible temperature rise in the room in °F or °C
- D = Inside diameter of pipe in (mm)
- S = Specific weight of gas lb/ft³ (kg/m³)

Notes:

- 1 These calculations assume room ambient of 100°F (38°C)
- 2 Increate V by 10% for each 2,500 ft (762m) above sea level
- 3 Increate V by 10% if uninsulated mufflers are inside room
4. Engine data sheet specifies "Radiated heat to ambient" in BTU/min. This value is dry type ad water cooled exhaust manifolds.
5. Generator efficiency is 88 to 95% for Gensets 50kW to 1200kW. 1kW loss = 56.88 BTU/min.

Fuel System (Diesel Only)

The fuel system must provide adequate and continuous quantities of clean fuel to the Generator Set. Bulk fuel is stored in large tanks, usually outside the building, and fuel is transferred to a smaller tank (day tank) located near the engine.

Day Tank

The quantity of the fuel to be stored by the day tank may be regulated by local or state agencies, and should be given consideration. If not, NFPA and the NEC require that enough fuel be stored to operate the Genset for a minimum of 2 hours depending on the type of facility. For practicality, the day tank should be sized to operate the Genset for two to four hours minimum depending on how critical the availability of standby power is to your client. Engine fuel consumption can be calculated based on Net Generator Output by using the engine performance curve.

High fuel level in the day tank should never be higher than the engine injector level unless the engine is equipped with factory installed check valves. If this condition is encountered, consult your Baldor Distributor. Lateral distance and the number of pipe fittings from the day tank to the engine injector pup should be minimized.

Baldor engines use a fuel bypass type injector. The unused fuel is bypassed and drained away from the engine. This fuel should be returned to the day tank and not the bulk tank. If fuel is returned to the bulk tank, be sure to size the day tank based on fuel flow to the fuel pump and not fuel consumption.

Fuel System Placement

The first decision to be made in this section is where to place the bulk storage tank, the day tank, and how to route the interconnecting piping. Routing of the piping should be as direct as possible, and with few bends as possible. The bulk storage tank placement should receive careful consideration. For aesthetic reasons, the tank should be in an area that will not detract from the building. For practicality, the tank should be located as close as possible to the Genset.

To provide the quickest starting time, and to meet the 10 second starting code requirement imposed by the National Fire Protection Association (NFPA) 110, it is suggested that a "day tank" be used. This tank should be mounted adjacent to the engine. The quantity of the fuel to be stored may be regulated by local or state agencies, and should be given consideration. The U.S. National Electric Code, Article 700 calls for on-site fuel supplies to be capable of operating the Genset at full demand load for at least two hours. Consult NFPA 37 for additional information on fuel storage methods and quantities. NFPA 110 Level 1 lists Genset fuel quantities required by class of installation.

Pipe sizes must be determined and installed so as to not exceed injector pump inlet and injector return line restriction listed on the Engine Data Sheets. The head loss in the pipe system may be calculated. The graph and friction of viscous fluids tables may be found in most mechanical handbooks such as "Cameron Hydraulic Data" handbooks. Refer to product specifications for lift limits and fuel flow data.

Bulk Tank

Large capacity bulk storage tanks allow delivery of fuel in quantity, and minimize dirt and condensation contamination. Bulk tanks should be kept full to minimize condensation. Bulk tanks may be located above or below ground. For an above ground tank, consider insulating the tank to minimize condensation. Whether the tank is to be above or below ground, the consultant must keep EPA and NFPA, as well as the owner's insurance underwriters requirements in mind.

The bulk tank should be sized to provide several days of standby power. The quantity of the fuel to be stored must be determined based on the length of expected power outages, availability of fuel deliveries, and how critical the availability of long term standby power is to your client. Engine fuel consumption can be calculated based on Net Generator Output by using the engine performance curve.

High fuel level in the main bulk tank may be above the engine injector level if a day tank is used, and a solenoid valve controlled by a float switch in the day tank is installed in the line to the day tank. The solenoid valve should be operated electrically from battery voltage and have a means for a manual bypass. The manual bypass should be of a "deadman" type to prevent day tank overflow. For safety, a manual shutoff valve should also be installed ahead of the solenoid valve, but should remain open under normal circumstances.

Lateral distances and the number of pipe fittings from the bulk tank to the day tank should be minimized. Piping sizes must be determined and installed so as to not exceed fuel lift pump head as listed on the day tank manufacturer's data sheet. The head loss in the piping system may be calculated using head loss calculation procedures. The consultant should never plan to use any line size smaller than 1 inch nominal between the bulk tank and day tank.

General Considerations

In the design and layout of the fuel piping from the bulk tank to the day tank, it is advisable to either run the piping underground or insulate the line to minimize jelling problems during cold weather. In cold climates, provisions for heat tracing or preheating the fuel in outside enclosures may be necessary. Exposed fuel lines inside the Genset building should meet fire resistance qualifications.

Do not use flexible non-metallic piping unless it meets these requirements. Galvanized, zinc bearing alloy, solid copper, or brass should never be used for fuel piping or storage tanks. These materials can catalyze fuel decomposition and cause fuel filters to plug prematurely. Black steel is recommended.

Fuel tanks should be epoxy resin coated to minimize metal contact and corrosion. Provision should be made in the design of the bulk and day tanks to allow access for checking stored fuel, the addition of additives, and full filtration of stored fuel every 6 to 12 months. If at all possible, the bulk tank(s) should have gravity fill. Every two years, the owner should have the fuel checked and changed out as necessary to remove water, scale, and bacteria.

Fuel Type and Grade

The recommended fuel grade for standby Genset operation is No. 2-D as specified in ASTM D 975. No. 1-D may be used, or a blend of 1-D and 2-D if climatic conditions warrant. The use of common bulk storage tank for a diesel standby Genset and No. 2 burning boilers is generally not recommended. If it is being considered, a careful review of fuel type, expected operating temperatures, and code requirements is necessary.

The Cetane rating of No. 2 boiler oil is usually lower than that required by a diesel engine to provide quick starts. This will reduce Genset start up reliability, especially in cold weather.

NFPA 110 does not allow the fuel supply for standby Gensets to be shared by other equipment on Level 1 type installations. The use of other fuels, including Jet-A and JP-4, in the operation of Gensets is not recommended, as they will result in loss of engine power, and reduction in the life of fuel system components.

Multi Engine Considerations

In a multi-engine installations, fuel piping should not be manifold connections to each engine. Provide a day tank and fuel pump system for each Genset. Also, each day tank should be supplied from the bulk tank individually. If it is desired to operate more than one Genset from a common day tank, please consult your Baldor Distributor.

Other Fuel System Considerations & Recommendations

1. Specify that a flexible section be used at all fuel system connections at the engine.
2. Tanks must be provided with drain connections or a means to allow condensate and other impurities to be removed periodically from the bottom of tanks.
3. Never allow unions to be installed at the high point in the fuel piping system as they allow air to enter the system.
4. Low fuel level alarm for main and day tanks.
5. Critical low fuel alarm and engine shutdown on day tank.
6. Fuel heater with thermostat in day tank should be used if temperatures around the day tank will be less than 20 °F (-7 °C).
7. High fuel level alarm on day tank.

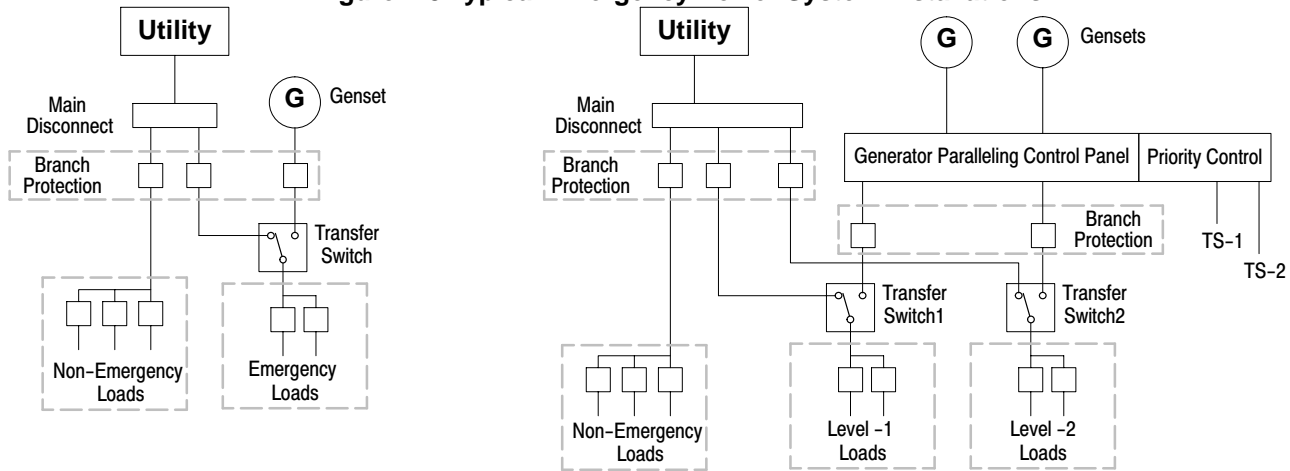
Transfer Switch

Transfer Switch Checklist

- A. Locate transfer switch in a clean, dry place, near the emergency load.
- B. Provide a circuit breaker between the Genset and the transfer switch.
- C. Put a flexible connection between the conduit and Genset.
- D. Observe applicable codes in wiring-in the transfer switch and Genset.

The transfer switch connects the Genset to the emergency power system. The emergency power system may include several Gensets and several transfer switches. Typically, the Genset is wired to the emergency power system through a transfer switch as shown in Figure 2-8.

Figure 2-8 Typical Emergency Power System Installations



Multiple Gensets can be arranged either in parallel or separately connected to dedicated emergency loads. Figure 2-8 also shows a typical arrangement of two Gensets in parallel with transfer switches for loads that have different levels of priority. A typical multiple Genset installation is shown for NFPA 110 Level 1 and Level 2 emergency power circuits and a priority control to select the appropriate transfer switch.

Wattmeters should be installed on each Genset so load sharing can be checked. The control system should include an automatic paralleling control. Paralleling identical Gensets is not difficult, but paralleling dissimilar sets can cause load sharing problems. When designing an installation that includes the paralleling of dissimilar generators, contract your nearby Baldor Distributor.

Transfer Switch Location

The transfer switch location is important and key considerations are:

1. Locate the transfer switch as close to the emergency load as practical to avoid interruptions of the emergency power system due to natural or man-made disasters, or to equipment failures. Consider several small transfer switches instead of one large one to increase reliability.
2. Locate the transfer switch in a clean, dry, well ventilated location, away from excessive heat. When the ambient air is above 104 °F (40 °C), fuses and circuit breakers must be derated. Allow adequate working space around the transfer switch.
3. A circuit breaker (or fuses) should be installed in the line between the generator and the transfer switch. Baldor Gensets are available with properly sized circuit breaker built into the generator control. The circuit breaker can be separately mounted. In the case of very large circuit breakers, a separate floor mounted circuit breaker is easier to wire up than a wall mounted breaker.
4. Install power and control wires in separate solid conduit with flexible sections at the Genset. The flexible sections prevent vibration from damaging the conduit. All power conduits from the Genset must contain all three phases.
5. Never install control wires in the same conduit as power conductors.
6. Conduit, wire, circuit protective device sizes, insulation etc. must conform to applicable local and national codes and regulations.
7. Be certain to seal around conduits that penetrate the walls of the Genset room to reduce the amount of noise that is transmitted to the surrounding areas of the building and maintain site fire code rating.

Battery Starting System

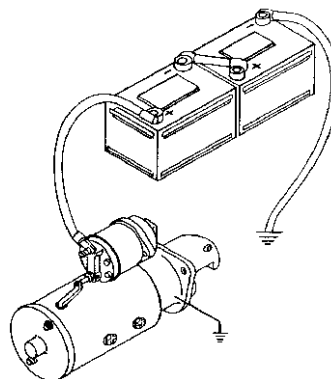
This section describes the battery starting system (nominal 12 volt rating of the battery supply) for the engine, battery charger, and precautions to take if the ambient temperature is expected to be below 70 °F (20°C).

WARNING: If batteries are not mounted in the battery rack supplied with the Genset, protect batteries from vibration and do not locate them near a source of flame or spark. A battery presents a risk of fire and explosion because they generate hydrogen gas. Hydrogen gas is extremely explosive. Never jump start a battery, smoke in the area around the battery or cause any spark to occur in the area around the battery.

Battery Location

Locate batteries as close as possible to the Genset to minimize starting circuit resistance, see Figure 2-9. High starting circuit resistance substantially reduces starting cranking ability. The Genset data sheet lists the maximum allowable cranking system resistance. Mount batteries on a level rack away from dirt and liquids. Allow space for servicing (checking water level and level of charge). Baldor Gensets can be ordered with battery racks already installed. Cold ambient temperature at the battery location substantially reduces the battery output.

Figure 2-9 Battery Starting System

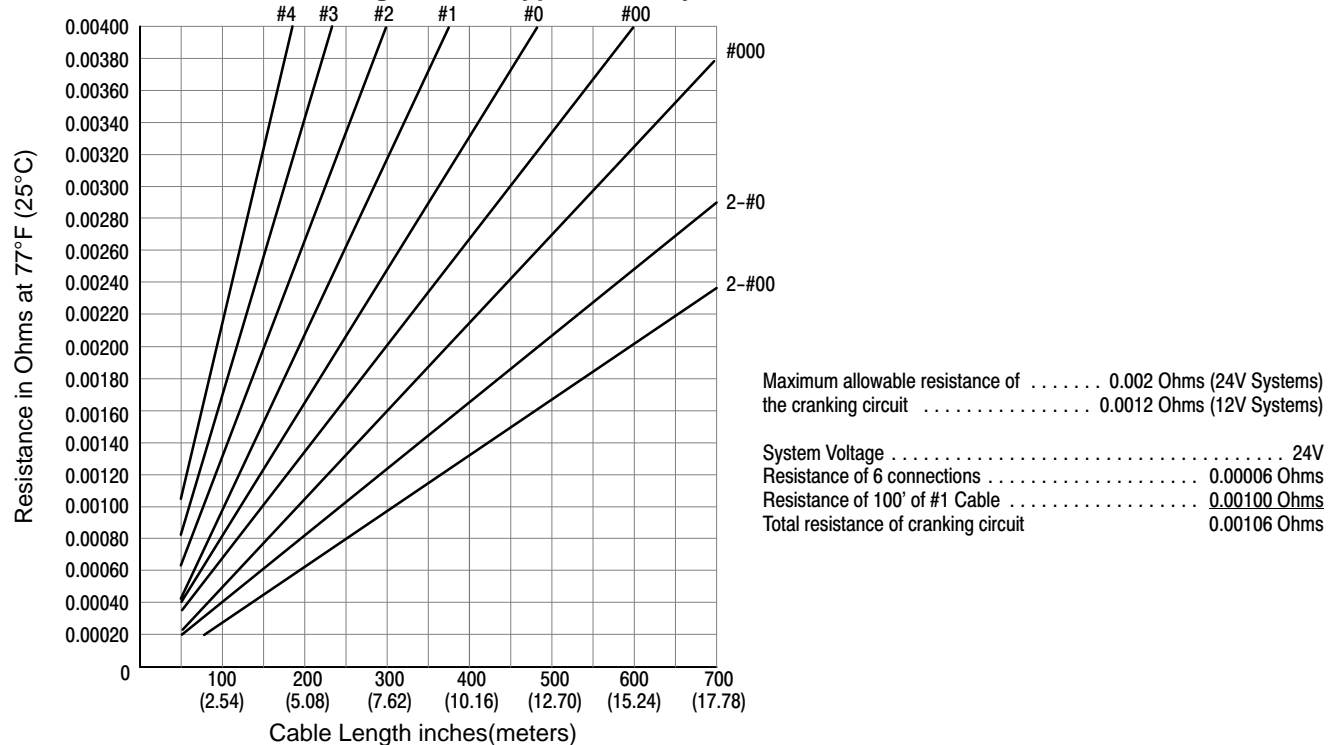


Battery Size The ability to start the engine depends upon battery capacity, ambient temperature and coolant and oil temperatures. The Engine/Generator Set Data Sheet lists minimum recommended battery capacity at various ambient temperatures. The recommended battery capacities are listed in the Electric Systems section of the Engine Data Sheet, cold cranking amps (CCA) at 0 °F (-18 °C). Battery capacities decrease as ambient temperatures decrease so it is important to specify batteries with the appropriate CCA rating at a temperature no higher than the minimum ambient temperature for the application. Baldor requires thermostatically controlled coolant heaters on all after cooled standby Gensets. After cooling is called out on the Engine Data Sheet under General Engine Data section as “aspiration”. Oil pan immersion heaters are recommended for standby Gensets housed outside where ambient temperatures may drop below 0 °F (-18 °C). Coolant heaters and oil pan immersion heaters are available from Baldor as factory installed options.

Battery Charger An engine mounted alternator to charge the batteries during operation is an available option. Standby Gensets require a solid state battery charger that is connected to utility power so the battery is charged continuously while the Genset is not running. The battery charger should be connected to the emergency circuit. The batteries on prime power Gensets are charged by the engine mounted alternator, if equipped. Harmonic wave forms from solid state battery charges and belt driven alternators can cause the electronic governor on the engine to act erratically. To avoid this, the output of the battery charger or the belt driven alternator must be connected directly to the battery or to the battery terminals on the starter. Make control connections to the Genset control using a conduit with a flexible section at the Genset to avoid damage due to Genset vibrations.

Battery Cables The wire size (wire gauge) of the cables connecting the starter to the batteries must be large enough to ensure the resistance of the cranking circuit is less than the “Maximum Allowable Resistance of the Cranking Circuit” as shown on the Engine-Generator Set Data Sheet. The total cranking circuit resistance includes the resistance of the cables from the starting motor to the battery and the resistance of all relays, solenoids, switches, and connections. The resistance of various sizes of cables is shown in Figure 2-10. For purposes of calculating cranking circuit resistance to select cable size, the resistance of each connection can be taken as .00001 ohms and the resistance of each relay, solenoid, and switch can be taken as .0002 ohms. Figure 2-10 illustrates an example of a typical cranking circuit resistance calculation.

Figure 2-10 Typical Battery Cable Calculations



Formulas

Single Phase – Electric

Single Phase Power Factor is typically 1.0
1 kW = 1 kilo Watt = 1,000 Watts

$$\text{Watts} = \text{Volts} \times \text{Amps} \times \text{Power Factor}$$

$$\text{Amps} = \frac{\text{Watts}}{\text{Volts} \times \text{Power Factor}}$$

Three Phase – Electric

Three Phase Power Factor is typically 0.8
1 kW = 1 kilo Watt = 1,000 Watts

$$\text{Watts} = (\text{Volts} \times \text{Amps} \times \text{Power Factor}) \times 1.732$$

$$\text{Amps} = \frac{\text{Watts}}{\text{Volts} \times \text{Power Factor} \times 1.732}$$

Length

inches x 25.40 = mm
feet x 0.305 = m
yard x 0.914 = m

mm x 0.03937 = inches
m x 3.280 = feet
m x 1.094 = yard

Area

inches² x 6.451 = cm²
feet² x 0.0929 = m²

cm² x 0.394 = inches²
m² x 10.764 = feet²

Pressure

pounds/ft² x 0.006944 = pounds/in²
psi x 6.8948 = kPa
psi = 0.4912 inches Hg

pounds/in² x 144 = pounds/ft²
kPa x 0.1450 = psi
kPa = 0.1333 x inches Hg

Temperature

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.55555$$

$$^{\circ}\text{F} = (^{\circ}\text{C} \times 1.8) + 32$$

Torque

oz-in x 0.007062 = Nm
lb-in x 0.11296 = Nm
lb-ft x 1.356 = Nm

Nm x 141.6029 = oz-in
Nm x 8.8495 = lb-in
Nm x 0.7376 = lb-ft

Velocity

ft/sec x 0.3048 = m/sec
miles/hr x 1.6093 = km/hr
miles/hr x 0.44704 = m/sec

m/sec x 3.2808 = ft/sec
km/hr x 0.6214 = miles/hr
m/sec x 3.2808 = ft/sec
m/sec x 2.2369 = miles/hr

Volume

inches³ x 16.388 = mm³
feet³ x 0.0283 = m³
gallons x 3.785 = liter
gallons x 0.13337 = ft³

cm³ x 0.06102 = inches³
m³ x 35.315 = feet³
liter x 0.2642 = gallon

Miscellaneous

Watt x 0.00134 = hp
BTU/hr x 0.293 = Watts
BTU/hr x 0.0003929 = hp

Watts x 3.4122 = BTU/hr
hp x 2545.177 = BTU/hr

Baldor District Offices

UNITED STATES

ARIZONA

PHOENIX
4211 S 43RD PLACE
PHOENIX, AZ 85004
PHONE: 602-470-0407
FAX: 602-470-0464

CALIFORNIA

LOS ANGELES
6480 FLOTILLA
COMMERCE, CA 90040
PHONE: 323-724-6771
FAX: 323-721-5859

HAYWARD
21056 FORBES STREET
HAYWARD, CA 94545
PHONE: 510-785-9900
FAX: 510-785-9910

COLORADO

DENVER
2520 W BARBERRY PLACE
DENVER, CO 80204
PHONE: 303-623-0127
FAX: 303-595-3772

CONNECTICUT

WALLINGFORD
65 SOUTH TURNPIKE ROAD
WALLINGFORD, CT 06492
PHONE: 203-269-1354
FAX: 203-269-5485

FLORIDA

TAMPA/PUERTO RICO/
VIRGIN ISLANDS
3906 EAST 11TH AVENUE
TAMPA, FL 33605
PHONE: 813-248-5078
FAX: 813-247-2984

GEORGIA

ATLANTA
62 TECHNOLOGY DR.
ALPHARETTA, GA 30005
PHONE: 770-772-7000
FAX: 770-772-7200

ILLINOIS

CHICAGO
1601 FRONTENAC ROAD
NAPERVILLE, IL 60563
PHONE: 630-848-5100
FAX: 630-848-5110

INDIANA

INDIANAPOLIS
5525 W. MINNESOTA STREET
INDIANAPOLIS, IN 46241
PHONE: 317-246-5100
FAX: 317-246-5110
800-428-4141

IOWA

DES MOINES
1800 DIXON STREET, SUITE C
DES MOINES, IA 50316
PHONE: 515-263-6929
FAX: 515-263-6515

MARYLAND

BALTIMORE
6660 SANTA BARBARA RD.
SUITE 22-24
ELKRIDGE, MD 21075
PHONE: 410-579-2135
FAX: 410-579-2677

MASSACHUSETTS

BOSTON
6 PULLMAN STREET
WORCESTER, MA 01606
PHONE: 508-854-0708
FAX: 508-854-0291

MICHIGAN

DETROIT
33782 STERLING PONDS BLVD.
STERLING HEIGHTS, MI 48312
PHONE: 586-978-9800

FAX: 586-978-9969

MICHIGAN Continued

GAND RAPIDS
668 3 MILE ROAD NW
GRAND RAPIDS, MI 49504
PHONE: 616-785-1784
FAX: 616-785-1788

MINNESOTA

MINNEAPOLIS
21080 134TH AVE. NORTH
ROGERS, MN 55374
PHONE: 763-428-3633
FAX: 763-428-4551

MISSOURI

ST LOUIS
422 INDUSTRIAL DRIVE
MARYLAND HEIGHTS, MO 63043
PHONE: 314-298-1800
FAX: 314-298-7660

KANSAS CITY

915 N W PLATTE VALLEY DR
RIVERSIDE, MO 64150
PHONE: 816-587-0272
FAX: 816-587-3735

NEW YORK

AUBURN
ONE ELLIS DRIVE
AUBURN, NY 13021
PHONE: 315-255-3403
FAX: 315-253-9923

NORTH CAROLINA

GREENSBORO
1220 ROTHERWOOD ROAD
GREENSBORO, NC 27406
P O BOX 16500
GREENSBORO, NC 27416
PHONE: 336-272-6104
FAX: 336-273-6628

OHIO

CINCINNATI
2929 CRESCENTVILLE ROAD
WEST CHESTER, OH 45069
PHONE: 513-771-2600
FAX: 513-772-2219

CLEVELAND

8929 FREEWAY DRIVE
MACEDONIA, OH 44056
PHONE: 330-468-4777
FAX: 330-468-4778

OKLAHOMA

TULSA
2 EAST DAWES
BIXBY, OK 74008
PHONE: 918-366-9320
FAX: 918-366-9338

OREGON

PORTLAND
20393 SW AVERY COURT
TUALATIN, OR 97062
PHONE: 503-691-9010
FAX: 503-691-9012

PENNSYLVANIA

PHILADELPHIA
1035 THOMAS BUSCH
MEMORIAL HIGHWAY
PENNSAUKEN, NJ 08110
PHONE: 856-661-1442
FAX: 856-663-6363

PITTSBURGH

616H BEATTY ROAD
MONROEVILLE, PA 15146
PHONE: 412-380-7244
FAX: 412-380-7250

TENNESSEE

MEMPHIS
4000 WINCHESTER ROAD
MEMPHIS, TN 38118
PHONE: 901-365-2020
FAX: 901-365-3914

TEXAS

HOUSTON
4647 PINE TIMBERS
SUITE # 135
HOUSTON, TX 77041
PHONE: 713-895-7062
FAX: 713-690-4540

DALLAS

3040 QUEBEC
DALLAS, TX 75247
PHONE: 214-634-7271
FAX: 214-634-8874

UTAH

SALT LAKE CITY
2230 SOUTH MAIN STREET
SALT LAKE CITY, UT 84115
PHONE: 801-832-0127
FAX: 801-832-8911

WISCONSIN

MILWAUKEE
2725 SOUTH 163RD STREET
NEW BERLIN, WI 53151
PHONE: 262-784-5940
FAX: 262-784-1215

INTERNATIONAL SALES

FORT SMITH, AR
P.O. BOX 2400
FORT SMITH, AR 72902
PHONE: 479-646-4711
FAX: 479-648-5895

CANADA

EDMONTON, ALBERTA
4053-92 STREET
EDMONTON, ALBERTA T6E 6R8
PHONE: 780-434-4900
FAX: 780-438-2600

OAKVILLE, ONTARIO

2750 COVENTRY ROAD
OAKVILLE, ONTARIO L6H 6R1
PHONE: 905-829-3301
FAX: 905-829-3302

MONTREAL, QUEBEC

1844 WILLIAM STREET
MONTREAL, QUEBEC H3J 1R5
PHONE: 514-933-2711
FAX: 514-933-8639

VANCOUVER,

BRITISH COLUMBIA
1538 KEBET WAY
PORT COQUITLAM, BC V3C 5M5
PHONE 604-421-2822
FAX: 604-421-3113

WINNIPEG, MANITOBA

54 PRINCESS STREET
WINNIPEG, MANITOBA R3B 1K2
PHONE: 204-942-5205
FAX: 204-956-4251

AUSTRALIA

UNIT 3, 6 STANTON ROAD
SEVEN HILLS, NSW 2147,
AUSTRALIA
PHONE: (61) (2) 9674 5455
FAX: (61) (2) 9674 2495

UNIT 8, 5 KELLETTS ROAD

ROWVILLE, VICTORIA, 3178
AUSTRALIA
PHONE: (61) (3) 9753 4355
FAX: (61) (3) 9753 4366

BALDOR CENTROAMERICA

RESIDENCIAL PINARES DE SUIZA
POL. 15 #44, NVA. SAN SALVADOR
EL SALVADOR, CENTRO AMERICA
PHONE: (503) 288-1519
FAX: (503) 288-1518

BALDOR SUDAMERICA

CALLE F, EL CANGREJO
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