EPA NSPS Emissions for STATIONARY GASEOUS GENERATORS

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INTRODUCTION

PURPOSE OF THE EPA NSPS GASEOUS EMISSIONS STANDARDS

The EPA issues New Source Performance Standards (NSPS) to define pollution control standards dictating the level of exhaust emissions that new sources are allowed to produce. NSPS issues codes of federal regulation for new or modified emission sources and addresses a wide range of industries and pollution sources.

The NSPS for Stationary Spark Ignition Internal Combustion Engines is defined in the Code of Federal Regulations (CFR) under 40 CFR Part 60 Subpart JJJJ. This regulation covers emergency and non-emergency applications and includes emission standards for both manufactures and owners/operators. The regulation includes compliance, monitoring and testing requirements. 40 CFR Part 60 Subpart JJJJ seeks to control nitrogen Oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC).

For the purposes of this white paper hydrocarbons (HC) will represent VOC, non-methane hydrocarbons (NMHC), or total hydrocarbons (THC) depending on the specific case. In all cases in this white paper, be sure to check the federal and local requirements to assure your application meets the emissions requirements. The regulations are living documents and are subject to change.

HISTORY OF EPA NSPS FOR STATIONARY GASEOUS GENSETS

The EPA first proposed 40 CFR Part 60 Subpart JJJJ in June 2006 with the final rule being published in June 2008. Prior to this, stationary spark ignition engines were regulated by state or local agencies. The federal, state, and local requirements for stationary gaseous gensets continue to evolve. To ensure a compliant solution, resources for federal, state, and local agencies should be reviewed early in the genset procurement process.

COMMON EMISSIONS TERMS

MANUFACTURER OF RECORD

The company that has requested the emissions certificate and is responsible for the steps required to maintain the certificate with the EPA.

EPA CERTIFIED

The EPA certificate provides proof that an engine or family of engines conforms to a specific EPA standard – 40 CFR part 60 Subpart JJJJ. The EPA defines a test cycle that must be followed for collection of key emission data. Gas engines are currently not required to be certified from a manufacturer of record under certain conditions. Kohler supplies EPA certified engine for gaseous stationary emergency generators to reduce burden on owners.

EPA COMPLIANT

The emissions compliant engine has performed and met all of the requirement for emissions test, however the data has not been submitted to the EPA and no certification has been provided.

Responsibility for the compliance of these engines may be on the end user. Emissions compliant engines may require additional testing and documentation to be maintained per EPA requirements.

HAZARDOUS AIR POLLUTANTS (HAP)

Are air pollutants that may cause cancer or other negative health effects. There are two classifications for HAPs that include major source and area source.

AREA SOURCE

An area source is defined as all sources that are under the major source limits.

MAJOR SOURCE

A major source for HAP emissions is defined as an industrial site that has the potential to emit an individual pollutant at a rate of 10 tons or more per year, or emits a total amount of pollutants of 25 tons or more per year.

ISO-8528 GENERATOR RATINGS

EMERGENCY STANDBY POWER

The emergency standby power (ESP) rating sets the maximum power of a generator set supplying power during periods when utility power (primary source) fails. The operation of ESP gensets is typically below 200 hours per year including power outages and genset maintenance and testing. The genset rating should be defined based on the typical average power output (load factor) according to the manufacturer's recommendation. It is important to note that a genset rated for ESP cannot exceed EPA regulated hours based upon usage type without risking EPA enforcement actions. As shown in Table 1 below, the EPA allows a different emissions compliance rating for ESP engines. Always refer to the EPA website for the latest requirements.

PRIME POWER

The prime power (PRP) rating defines the maximum power a genset is capable of providing continuously with a variable electric load applied and with no limit on the operational hours per year. As with the ESP rating, the genset rating should be defined based on the typical average power output (load factor) according to the manufacturer's recommendation. A 10% overload power can be provided to address transient load conditions that exceed the prime power rating. The 10% overload output should be limited to 1-hour or less over any 12-hour period.

CONTINUOUS POWER

The continuous power (COP) rating defines the maximum power a genset is capable of delivering with a constant electrical load applied with unlimited operational hours per year. This is often referred to as "base load" where there is only minor variation in electrical load.

LIMITED TIME RUNNING POWER

Limited time running power (LTP) sets the maximum power available for a genset operating up to 500 hours per year.

DATA CENTER POWER

The data center power (DCP) defines the maximum power a generator can provide with either a variable or constant load applied with no limits on annual run time.

APPLICATION CATEGORY

STATIONARY VS. MOBILE GENERATOR

The EPA regulates emissions based on product application and use. To meet the stationary requirement, the generator must not be mobile and must remain in the same location for at least 12 months. All other generators are non-road applications. Non-road gensets that are mobile, have lower emissions limits then stationary gensets.

STATIONARY EMERGENCY VS. STATIONARY NON-EMERGENCY GENERATORS

Stationary gensets in emergency stand-by applications have higher allowable emissions limits then other stationary applications. The higher limits are primarily based on the generator's limited allowable annual usage.

The ISO definition for an emergency stand-by generator is different than the EPA's definition. The EPA limits the operation of the generator to less than 100 hours per year of non-emergency operation. In some instances, this allowance can be modified though a petition process when local regulation requires utilization.

ENGINE TECHNOLOGIES

ENGINE CONTROL MODULE (ECM)

The engine control module communicates with sensors to facilitate the control and protection of the engine. Fuel, spark timing, and turbocharger boost pressure can be controlled by the ECM. Feedback from an oxygen sensor in the exhaust stream directs the engine to add or remove fuel and advance or retard timing.

This type of control is called closed loop control. Closed loop control provides the ability to increase power density, improve emissions performance, and increase engine efficient. Open loop control utilizes tables stored in the ECM to guild control with no direct feedback.

Closed loop systems will operate in open loop mode during initial startup operation to allow oxygen sensor to get to an operating temperature to provide accurate feedback.

To protect the engine and ensure efficient combustions, the ECM monitors the following critical sensors.

- Oil Pressure
- Coolant Temperature
- Knock Sensor
- Battery Voltage
- TMAP (Temperature and Manifold Absolute Pressure)
- HEGO/UEGO (Heated Exhaust Gas Oxygen/ Universal Exhaust Gas Oxygen)

THREE-WAY CATALYTIC CONVERTER

A three-way catalytic converter is utilized in some gensets to reduce exhaust emissions. The catalyst is installed in the exhaust stream after the turbo charger and before the silencer. As the exhaust flows through the catalyst, it reacts with the materials coating the surface of the catalyst. The following are the three primary pollutants that are targeted for reaction in the catalyst to limit their output.

- NO_X → $N_2 + O_2$
- $CO + O_2$ → CO_2
- HC → $CO_2 + H_20$

Closed loop control and a focused engine calibration can be directly linked to the catalyst design and efficiency. It is possible to add a three-way catalyst during site installation, but the most effective option is to have the catalyst design and engine calibration strategy linked by the genset manufacturer.

COMBUSTION CHAMBER DESIGN

The combustion chamber design is critical in achieving high power density while maintaining combustion stability. Thermal management of engines with high power density is key to a robust engine design.

Proper oil delivery to help cool pistons and coolant circulation in through the heads must be adjusted to ensure a long operational life.

The selection of material for pistons and valve seats are analyzed to ensure they will withstand the pressures and temperatures during full load applications.

TURBOCHARGERS

The turbo charger utilizes exhaust gas flow through a turbine to drive a compressor that pressurizes the air into the intake manifold. Turbochargers on natural gas and LP engines pressurize the gaseous fuel air mixture prior to the intake manifold.

Spark ignition engines do not always require a turbocharger. The turbocharger can increase the power density of the engine with some tradeoffs. The stability of the combustion process can suffer with the boosted intake pressures and more volatile LP fuel.

Knock sensors become more important with boosted engine. The higher intake pressures create higher combustion temperatures that may require additional consideration for combustion chamber design.

CHARGE AIR COOLING

The temperature of the gas/air mixture is elevated after passing through the compressor wheel of the turbocharger. The charge air cooler reduces the temperature and increases the density of the gas/air mixture being delivered to the engine intake manifold.

The higher density gas/air mixture allows increased power and improved combustion stability. The requirement for a charge air cooler is based on the targeted power density for a specific genset.

EMISSION CONTROL STRATEGIES

EMISSION CONTROL OF GASEOUS ENGINES

Natural gas and LP engines have different emissions output and control requirements than diesel engines. The combustion of natural gas and LP produces no appreciable particulate matter (PM) or heavy metal, so this is not tracked in the emissions analysis.

There are studies that show natural gas engines produce 40% less greenhouse gases during operation then the diesel alternative.

This is modeled as a 30% reduction in greenhouse gases when evaluating the full cycle from well extraction to the generation of power (Well to Wheel). Additional environment impacts include up to a 99% reduction in sulfur oxide and 80% lower nitrogen oxides (NOx).

RICH VS. LEAN BURN

Gas powered engines are defined in two categories – rich burn and lean burn. Rich burn engines run with an air-fuel ratio that is typically more balanced with a balanced air-fuel ratio.

Rich burn engines can use a three-way catalyst exhaust aftertreatment system primarily targeting NOx reduction while also reducing CO and NMHC. Rich burn engines are typically more responsive to block loading but have lower fuel efficiency. The ability to respond to larger block loads make the rich burn engine an ideal power source for emergency standby generators.

LEAN BURN

Lean burn engines run with an air-fuel ratio that has excess air. Lean burn engines are more fuel efficient and typically produce less NOx than a rich burn engine, however the excess O2 in the exhaust stream creates challenges to treat the NOx emitted. An oxygen catalyst can be applied to reduce CO and NMHC, however a selective catalytic converter (SCR) with DEF/urea injection must be used to reduce NOx. The increased fuel efficiency of the lean burn engine can provide an advantage in prime and continuous power applications.

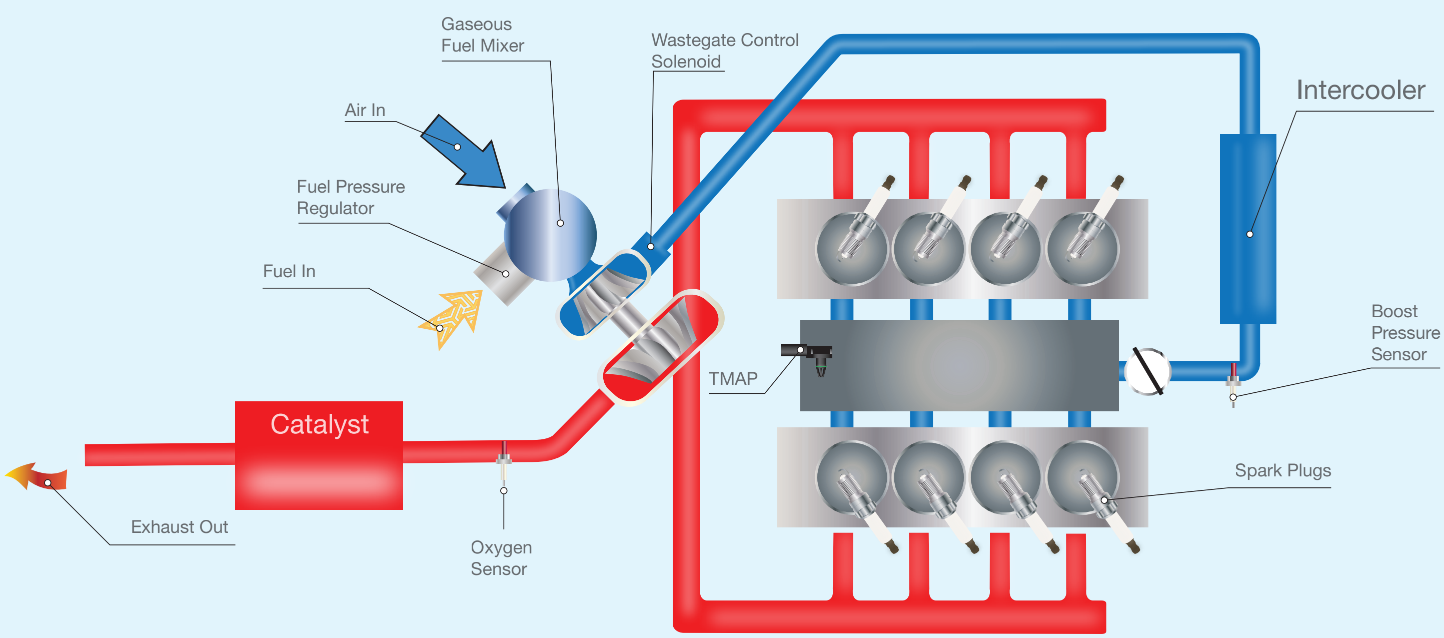
RICH BURN

Rich burn gas engines utilize a three-way catalyst to reduce NOx, CO, and HO as defined above. The universal exhaust gas oxygen sensor (HEGO/UEGO) is located in the exhaust stream after the turbocharger and before the catalyst. This sensor measures the exhaust gas content over a wide range of air-fuel ratios.

The temperature manifold absolute pressure sensor (TMAP) monitors the temperature and pressure of the air-fuel mixture coming into the engine. The feedback from this sensor also allows the ECM to optimize performance. The feedback to the engine ECM allows adjustment of fuel supply and spark timing to optimize the combustion process and power output. See *Figure 1*.

Figure 1

Kohler 6.2L Turbocharged Gaseous Engine



DIESEL ENGINE EMISSION CONTROL

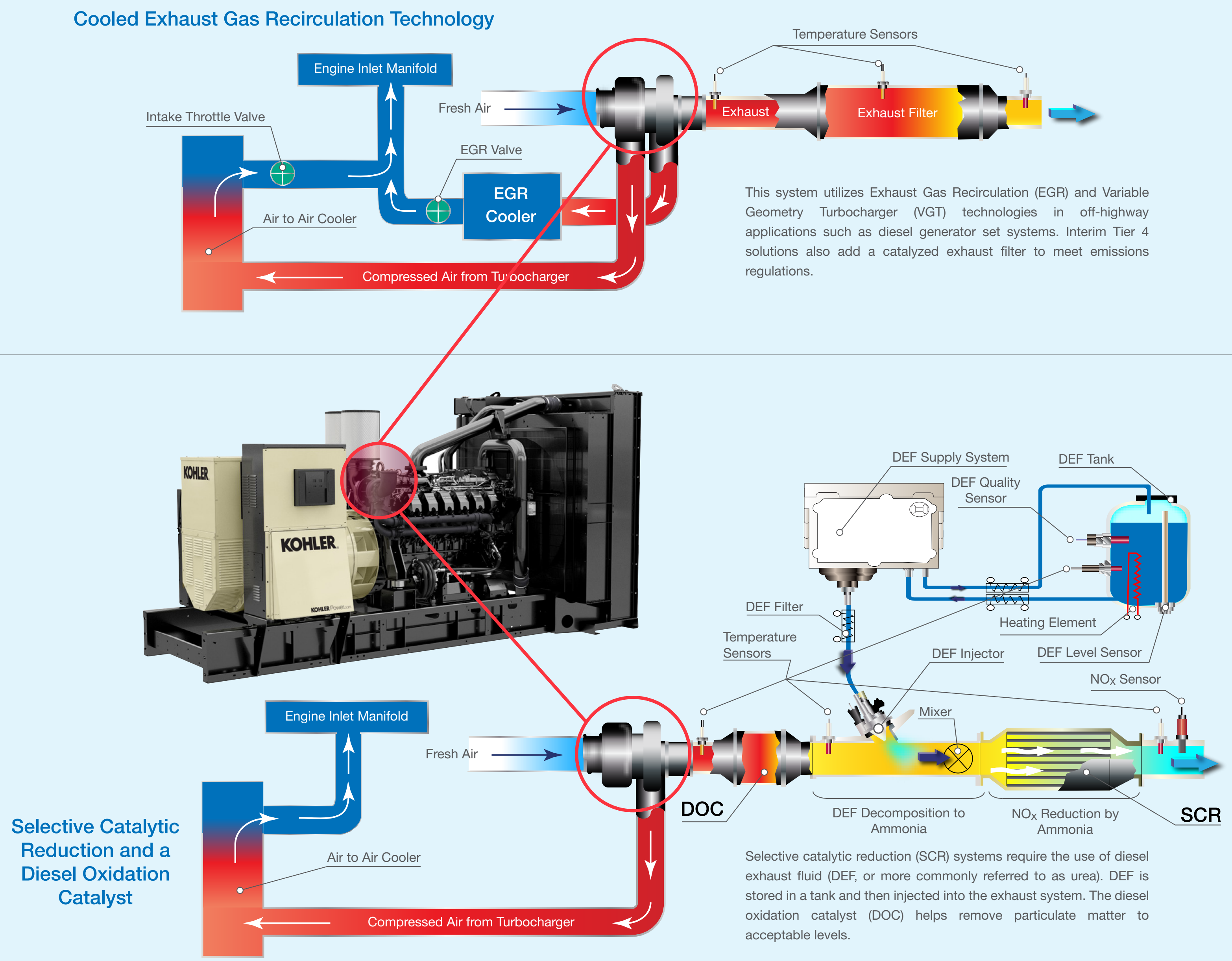
Diesel engines take a slightly different approach than gaseous fuel engines. The diesel engine has several options for controlling emissions.

The exhaust gas recirculation (EGR) method diverts exhaust gases to an EGR cooler and then back to the engine intake. The recirculation of exhaust into the intake of the engine limits the excess oxygen in the combustion chamber preventing NOx formation. EGR system often require a diesel particulate filter to remove higher levels of particulate matter.

Another common option for reducing diesel emissions is through selective catalytic reduction (SCR). Urea or diesel exhaust fluid (DEF) is injected into the exhaust stream and catalytic converter. The combination of DEF fluid coating on the surface of catalyst converts NOx into N2 and H2O. There are several combinations of emissions components that can be introduced to control NOx, PM, and CO. See *Figure 2*.

Figure 2

Diesel Engine Emission Technologies to Meet Tier 4 Emission Levels



This system utilizes Exhaust Gas Recirculation (EGR) and Variable Geometry Turbocharger (VGT) technologies in off-highway applications such as diesel generator set systems. Interim Tier 4 solutions also add a catalyzed exhaust filter to meet emissions regulations.

Selective catalytic reduction (SCR) systems require the use of diesel exhaust fluid (DEF, or more commonly referred to as urea). DEF is stored in a tank and then injected into the exhaust system. The diesel oxidation catalyst (DOC) helps remove particulate matter to acceptable levels.

COMPARISON OF EMISSION REGULATIONS

GASEOUS FUELED ENGINES

The emission control components defined above provide options to meet the increasingly stringent EPA emissions requirements. Gaseous fueled engines have lower emissions output without the addition of exhaust after treatment systems.

The lower baseline output has required fewer iterations of the EPA limits. Gaseous engines produce very low particulate matter (PM) and it is not a focus for EPA emissions certification.

The emissions regulation for stationary generator applications are divided into 2 different categories based on application and the number of operational hours per year. The emissions limits are further divided by fuel types and combustion strategy (rich burn/lean burn). Emergency standby application have higher allowable limits because the annual allowable run time is reduced.
See Tables 1 page-7 below and Table 2 bottom page-8.

DIESEL ENGINES

Diesel engine emission requirements have evolved over time based on the best available solutions available at the time.

Changes in the diesel fuel supply to ultra-low sulfur as well as changes to engine technologies and exhaust after treatment systems have created a path to greatly reduce diesel engine emissions

Table 1	Phase-In Program for Gaseous Stationary Emergency and Non-Emergency Engine EPA Regulations													
	Rich Burn		Lean Burn		NOx/CO/VOC (g/HP-hr)									
Application	NG	LP	NG	LP	HP	***kWe	2007	2008	2009	2010	2011	2012	2021	Document
Emergency	X		X	X	25-130	15-85			10.0*/38.7					**40CFR Part 60 Subpart JJJJ Table1
Emergency	X		X	X	130>	85>			2.0/4.0/1.0					40CFR Part 60 Subpart JJJJ Table1
Emergency		X			130>	85>			2.0*/3.3					40CFR Part 60 Subpart JJJJ 40 CFR 1048 1048.101 Table1
Non-Emergency		X			500>	330>	2.0*/3.3							40CFR Part 60 Subpart JJJJ 40 CFR 1048 1048.101 Table1
Non-Emergency	X		X	X	25-100	15-65		2.8*/4.8						40CFR Part 60 Subpart JJJJ Table1
Non-Emergency	X		X	X	100-500	65-330		2.0/4.0/1.0			1.0/2.0/0.7			40CFR Part 60 Subpart JJJJ Table1
Non-Emergency	X		X	X	500-1350	330-900		2.0/4.0/1.0		1.0/2.0/0.7				40CFR Part 60 Subpart JJJJ Table1

*NOx + HC - no VOC

** Transitioning to CFR 40 part 1054 in 2022

*** Assumes about 88% system efficiency

FEDERAL VS. STATE AND LOCAL STANDARDS

EPA EMISSIONS STANDARDS

The EPA defines the emissions standards and compliance requirements for the United States. Each state can have its own specific emissions standard that must meet or exceed the EPA's federal requirements.

STATE EMISSIONS STANDARDS

Within each state, there may be local agencies that mandate more stringent emission standards than the state and federal agencies.

The California Air Resources Board (CARB) works with 35 local air districts (AQMD/APCD) to regulate air quality and define emission regulation.

Many states and local agencies are following CARB's (AQMD/APCD) more stringent emissions regulations to better protect the air quality in their region. Many states follow CARB's emissions limits under Section 177 of the Federal Clean Air Act. As mentioned earlier, please refer to EPA, state and local agency resources for the latest emissions limits and integration requirements.

Table 2 Phase-In Program for Diesel Stationary Non-Emergency Engine EPA Regulations

<table>
<tr><th colspan="2">ENGINE GENERATOR</th><th colspan="10"></th></tr>
<tr><th>kWm</th><th>kWe</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th></tr>
<tr><td>8 -<19</td><td>10-15</td><td></td><td colspan="9">6.6/7.5/0.40</td></tr>
<tr><td>19 -<37</td><td>15-20</td><td></td><td colspan="5">5.5/7.5/0.30</td><td colspan="4">5.5/4.7/0.03</td></tr>
<tr><td>37 -<56</td><td>20-40</td><td></td><td colspan="5">5.0/7.5/0.30</td><td colspan="4">5.0/4.7/0.03</td></tr>
<tr><td>56 -<75</td><td>40-60</td><td></td><td colspan="4">5.0/4.7/0.40</td><td colspan="3">5.0/2.3/0.02</td><td colspan="2">5.0/0.19/0.40/0.02</td></tr>
<tr><td>75 -<130</td><td>80-100</td><td colspan="5">5.0/4.0/0.30</td><td colspan="3">5.0/2.3/0.02</td><td colspan="2">5.0/0.19/0.40/0.02</td></tr>
<tr><td>130 -<560</td><td>125-450</td><td colspan="4">3.5/4.0/0.20</td><td colspan="4">3.5/2.0/0.02</td><td colspan="2">3.5/0.19/0.40/0.02</td></tr>
<tr><td>560 -<900</td><td>500-800</td><td colspan="4">3.5/6.4/0.20</td><td colspan="4">3.5/0.40/0.67/0.10</td><td colspan="2">3.5/0.19/0.67/0.03</td></tr>
<tr><td>>900</td><td>900-2000</td><td colspan="4">3.5/6.4/0.20</td><td colspan="4">3.5/0.40/0.67/0.10</td><td colspan="2">3.5/0.19/0.67/0.03</td></tr>
<tr><td>>2200</td><td>>=2000</td><td colspan="4">11.4/1.3/9.2/0.54</td><td colspan="4">3.5/0.40/0.67/0.10</td><td colspan="2">3.5/0.19/0.67/0.03</td></tr>
</table>

CO/NMHC+NOx/PM (g/kW-hr)

CO/NMHC/NOx/PM (g/kW-hr)

TIER 1 Effective

TIER 2 Effective

TIER 3 Effective

TIER 4 Interim Effective

TIER 4 Effective

ADVANTAGES OF KOHLER'S GAS SERIES

KOHLER's gas series meet NFPA 110, Type 10 requirements with our 1800 rpm engines. The generators offer quiet operation to extend generator life and provide significant fuel savings.

Every KOHLER gas generator engine is EPA-certified, designed and calibrated to meet or exceed the latest spark-ignited emissions requirements.

KOHLER engines are specifically designed for generator applications and go through extensive testing with a proven design that is reliable and durable. Our engines have the highest potential horsepower for maximum efficiency. KOHLER engines are available in Natural gas, Propane and Dual fuel options with KOHLER's patent-pending dual fuel design.

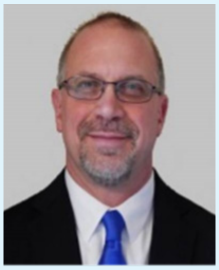
KOHLER's KG (KOHLER Gas) line of emergency standby generators 40-200kW is specifically designed for Industrial applications including commercial and municipal buildings, universities, apartments and more.

KOHLER's innovative design offers high-ambient cooling and PMG alternators to provide consistent, lasting reliability.

KOHLER offers a full line of enclosures that provide corrosion protection, advanced certifications such as IBC and Hurricane ratings.

KOHLER has been in the power business since 1920 with over 100 years of generator experience and is proven to be a superior brand in the industry.

ABOUT THE AUTHOR



Matthew Pomplun currently works as a Staff Engineer on the Industrial Solutions Team. Matt has a bachelor's degree in mechanical engineering and master's degree in engineering management, he has spent more than 7 years in the power generation industry. His career started in thermal systems design. His specialties include power train integration, thermal systems design, and mechanical systems.

A global force in power solutions since 1920, Kohler Co. is committed to reliable, intelligent products; purposeful engineering; and responsive after-sales support. Kohler Co. is among the world's largest manufacturers of industrial generators. The company has 100 years' experience in industrial power and benefits from global R&D, manufacturing, sales, service, and distribution integration.

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