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Generator Enclosure Spacing

Design Guidelines for Reliable Operation

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INTRODUCTION

Proper installation of electrical generator systems is essential for reliable operation. Most electrical generator systems utilize a unit-mounted radiator system with an air-moving fan to provide cooling and robust operation.

This white paper provides guidelines on best practices to ensure adequate cooling airflow associated with installations.

COOLING SYSTEM BASICS

INTERNAL COMBUSTION ENGINE (ICE)

Like ICE-powered automobiles, ICE electrical generator systems have radiators and exhaust systems that reject heat. The cooling system on an ICE electrical generator typically comprises a water-circuit radiator to cool the engine block and may also include radiators for oil cooling as well as charge air circuit cooling for the engine intake air.

The cooling system requires airflow supplied by a fan, which is either mechanically driven from the front of the generator's ICE or is electrically driven.

ADEQUATE COOLING REQUIRED

Cooling systems are designed to provide adequate cooling for full load operation at a specified ambient air temperature typically between 40C° (104F°) and 50C° (122F°). It is important to ensure that the ambient air capability is adequate for the site as operating above the rated ambient air capability may result in engine overheating, leading to a shutdown.

Generator sets must be properly installed to ensure that cooling air is not restricted or artificially heated by nearby heat sources or from recirculation. Fortunately, installation influences can be simulated using software called Computational Fluid Dynamics.

COMPUTATIONAL FLUID DYNAMICS (CFD)

PREDICTIVE SOFTWARE TOOL

CFD is a software tool used to predict fluid flow, including thermal influences. CFD can predict complex fluid flow fields, including the highly turbulent regions operating near radiator fans.

CFD is computationally intensive; however, with the increase of computational power during the last two decades, usage of CFD in the design and development phase has become more common. Kohler uses CFD for many aspects of electrical generator design such as alternator cooling, exhaust system, engine air intake, engine fuel system, and cooling systems design, including the fan blade as well as enclosure restriction.

In this white paper, CFD has been utilized to look at the influences of walls near generator enclosures as well as the influence of prevailing winds. The heat dissipated by the exhaust and the cooling system are injected into the airflow field and the temperature of the flow field is measured to quantify the amount of heat recirculation, which reduces the cooling capability of the electrical generator system.

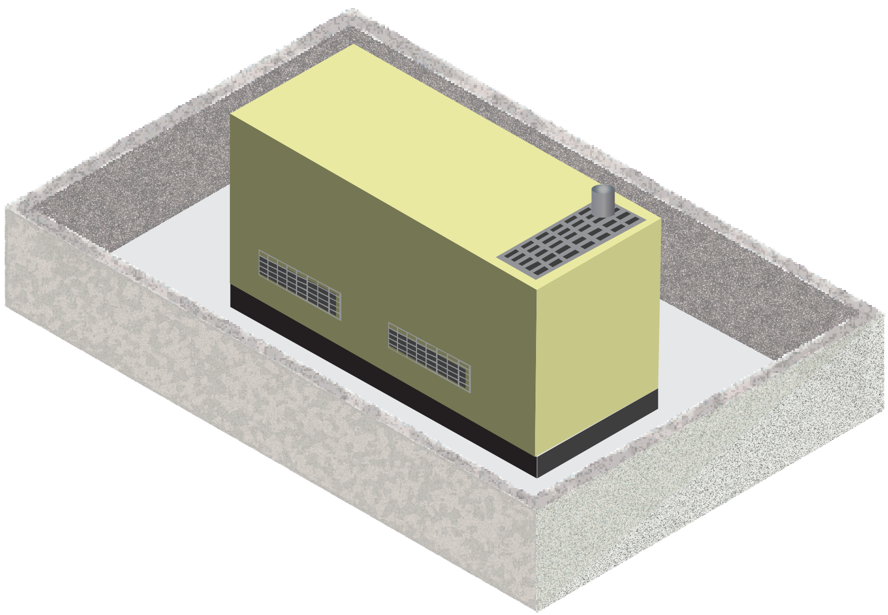
TEST CASE 1

VERTICAL DISCHARGE

The first test case is a 100-kW diesel generator set with side door intakes and a vertical discharge. The exhaust muffler is in the discharge plenum and has an outlet at the discharge opening directing upward.

The setup for this test case is shown in Figure 1. A half-height wall is shown. The height of the wall and distance of the wall from the generator was systematically varied for this test case to determine the influence.

Figure 1



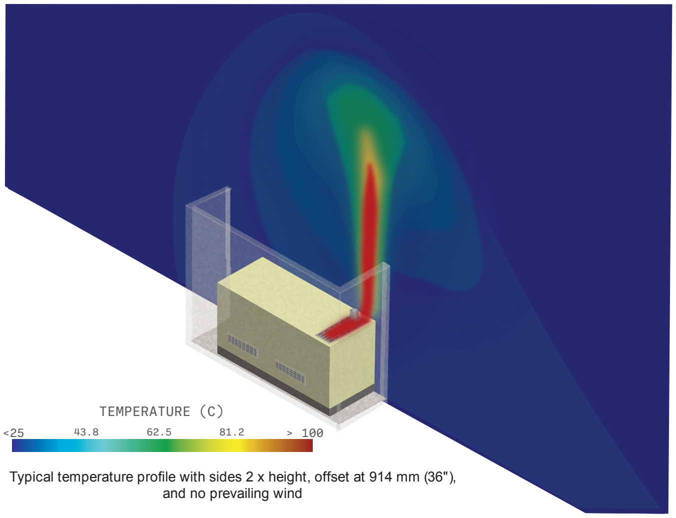
Setup for test case 1

VERTICAL DISCHARGE (CONT.)

In Figure 2, a typical temperature profile with the electrical generator operating at full load is shown. The wall height was twice the enclosure height, and the offset was 914 mm (36"). The entire flow field around the generator was solved. A slice of the temperature distribution is shown in the figure, with most of the air matching the ambient air temperature of 25C° (77F°). The heat rejection by the exhaust system is clearly visible in the plume, which is initiated at the exhaust outlet, and remains above 100C°, well above the enclosure.

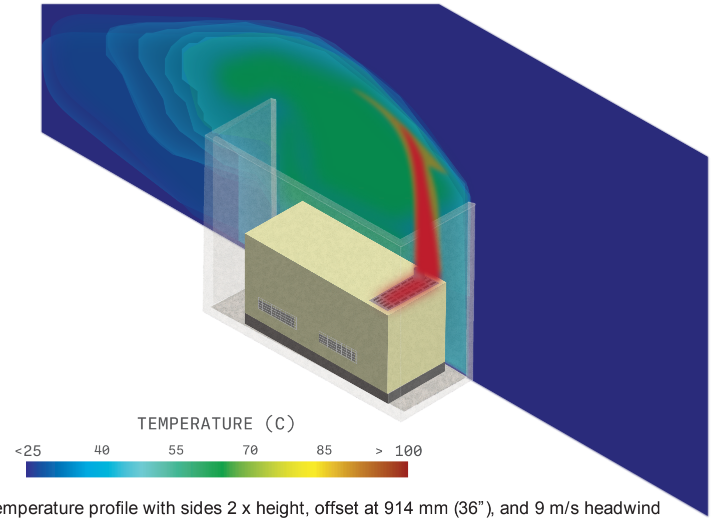
A headwind of 9 m/s was introduced for the results shown in Figure 3. The exhaust plume is pushed from its nearly vertical orientation and angles backward. In addition, the plume becomes wider resulting in higher temperatures directly above the generators. As this heated air is pushed backwards, the likelihood of recirculation increases. For this specific case, the recirculation is significant. The air entering the enclosure is 13C° hotter than the ambient air of 25C°. This effectively would reduce the cooling capacity by 13C°. If the cooling system was rated at 50C° capability, in this configuration, the rating would drop by 13C° to 37C°.

Figure 2



Typical temperature profile with sides 2 x height, offset at 914 mm (36"), and no prevailing wind

Figure 3

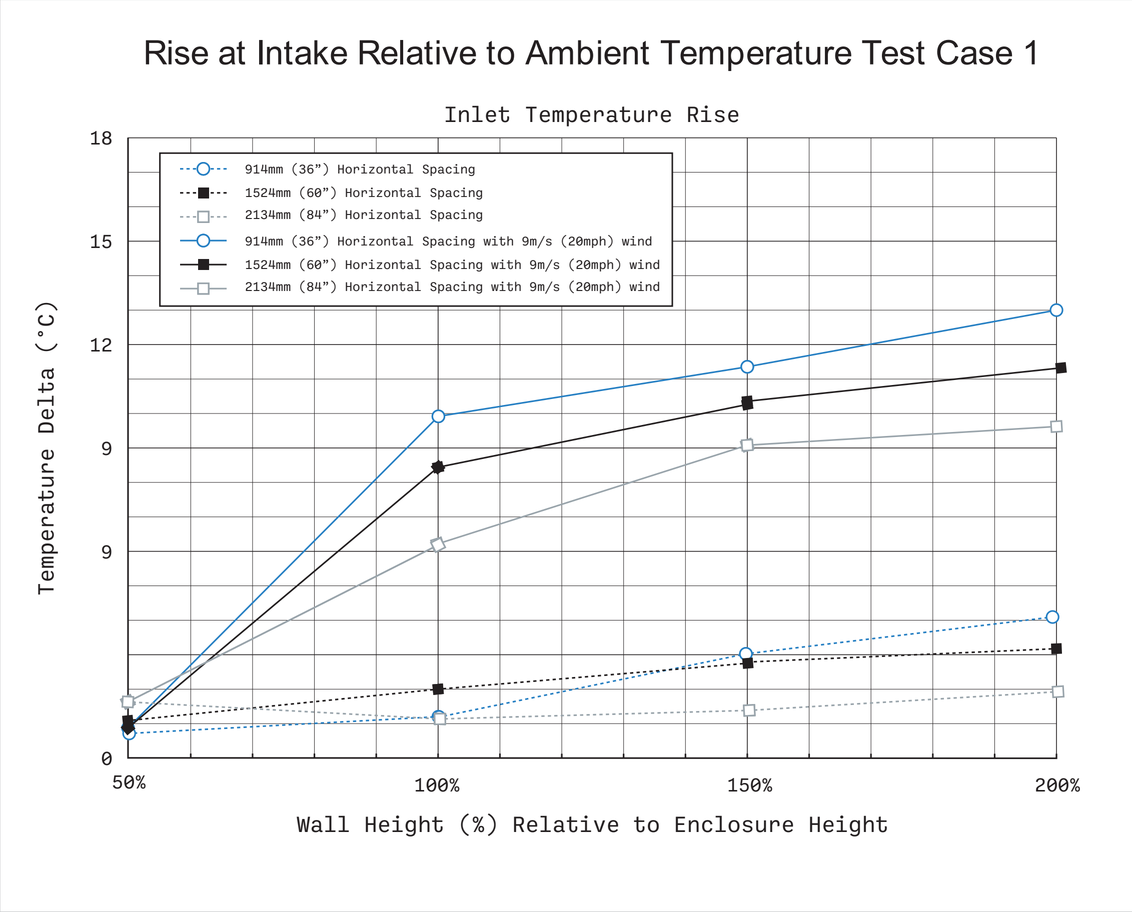


Temperature profile with sides 2 x height, offset at 914 mm (36”), and 9 m/s headwind

VERTICAL DISCHARGE (CONT.)

A parametric study of the wall height, wall distance, and influence of a headwind was performed. The results are shown in Figure 4. The headwind influence is significant and becomes more significant with taller surrounding walls. A reduction of 10C° cooling performance with the headwind is expected for a close-fitting (914 mm / 36") full-height surrounding wall. Without a headwind,, the recirculation of the heated air is significantly less at wall heights equal to or taller than the enclosure. If visual blocking walls are required for the installations, walls with louvers are recommended to minimize the potential for recirculation associated with headwinds.

Figure 4



TEST CASE 2

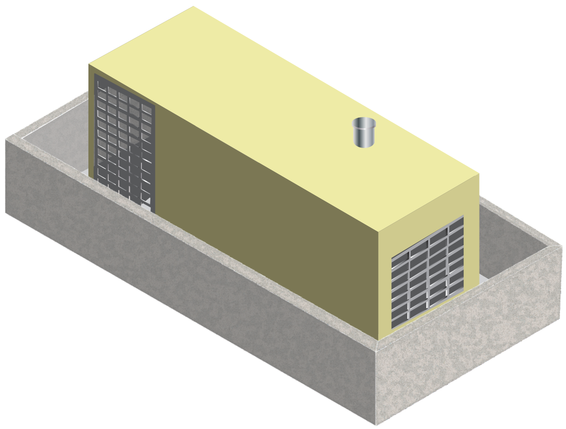
HORIZONTAL DISCHARGE

The generator set for test case, shown in Figure 5, is a 1250 kW with a horizontal discharge and the exhaust outlet out the top of the enclosure. The enclosure has side inlets toward the rear on each side.

Like case 1, a parametric study was performed focusing just on the wall dimensions.

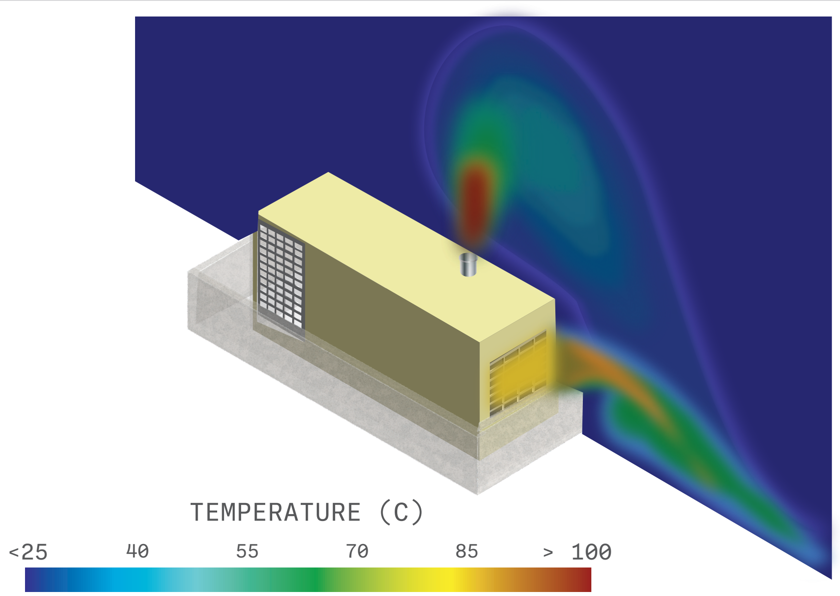
The temperature profile for the 50% wall height at 914 mm (36") spacing is shown in Figures 6 and 7.

Figure 5



Setup for test case 2

Figure 6



Temperature profile with sides 0.5 x height, offset at 914 mm (36"), and no prevailing wind.

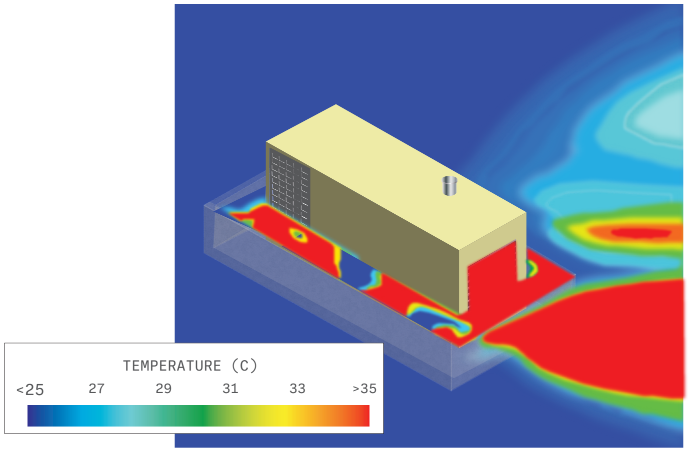
HORIZONTAL DISCHARGE (CONT.)

Figure 7 shows the mid-line vertical slice. The exhaust plume is easily identified. The heated air coming out the discharge is also visible wrapping around the half-height wall.

A horizontal slice of the temperature profile is shown in Figure 7. The color scale has been adjusted to provide better resolution. There is considerable recirculation of the heated air from the horizontal discharge into the intakes. The heated air coming out the discharge hits the half-height wall and is then pulled rearward into the intake. The air entering the enclosure intakes at this plane is greater than 35C°, which is more than 10C° above ambient.

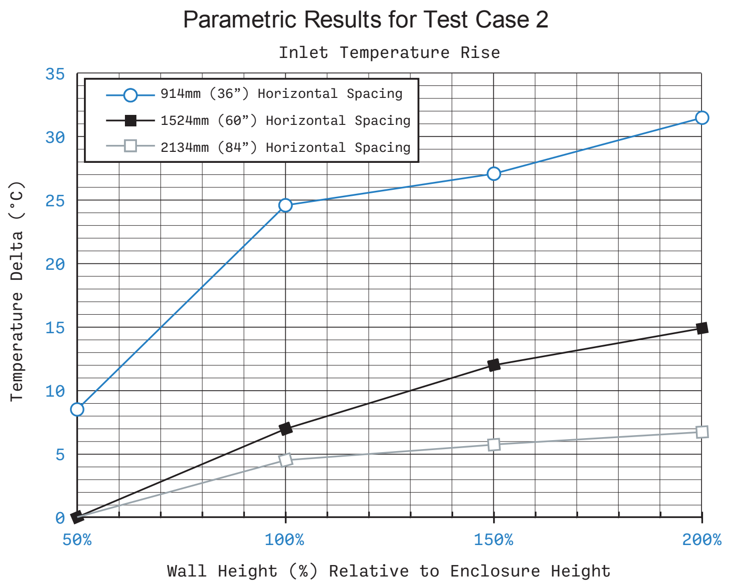
The parametric results for this case are shown in Figure 8. It is clear from the results that horizontal discharge enclosures are far more impacted by closely placed walls. Even at a wall distance of 2134 mm (84"), the full-height wall scenario yields a 5C° increase at the intake due to recirculation. The amount of recirculation at 914 mm (36") is substantial.

Figure 7



Temperature profile with sides 0.5 x height, offset at 914 mm (36"), and no prevailing wind.

Figure 8



TEST CASE 3

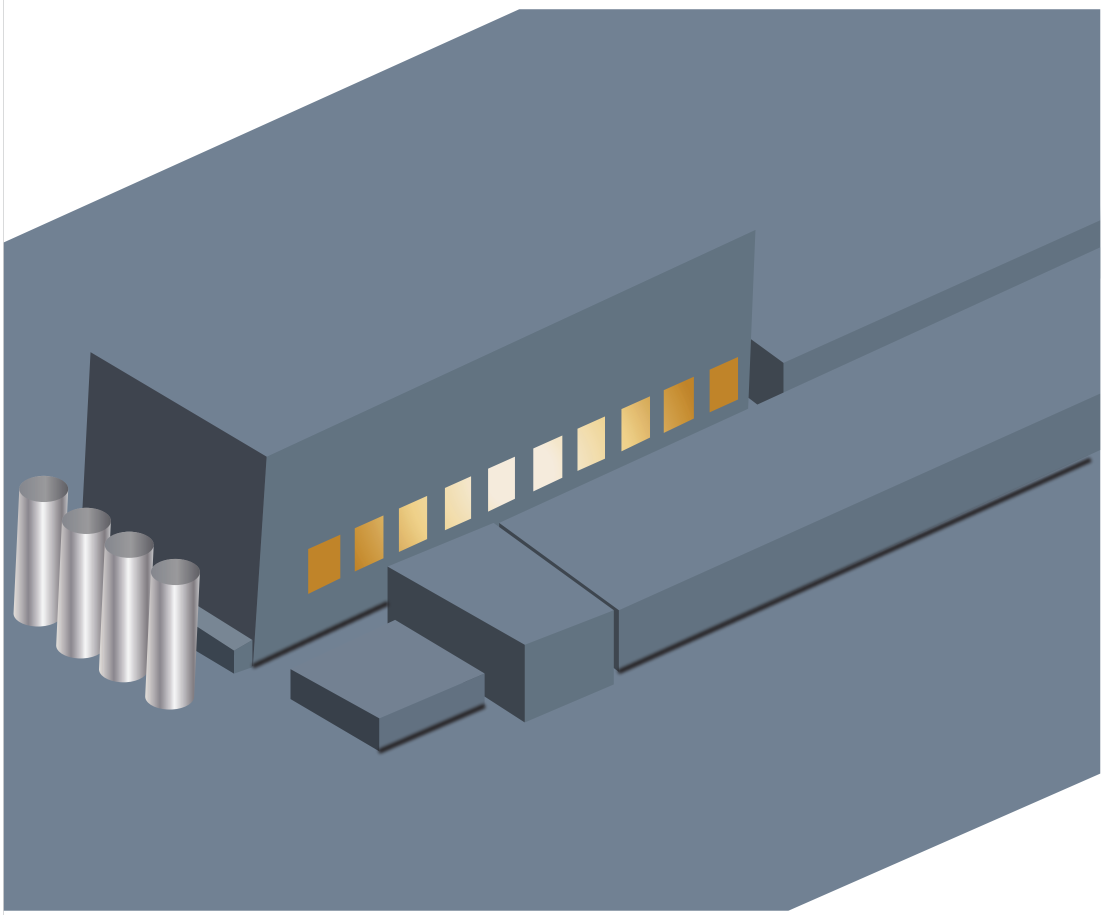
DATA CENTER BUILDING

In this test case, a customer wanted to ensure that the restriction presented by a nearby building would not impact cooling performance. CFD was utilized to predict the restriction seen by each cooling system fan. Since the intake and discharge were on opposite sides of the building, recirculation was not an issue; however, the proximity of the building and the amount of airflow required a simulation.

The data center and surrounding buildings are shown in Figure 9. There are ten generator sets installed on the second floor of the building and seven generator sets on the ground floor directly below. There is a building located directly across from the discharge openings. A CFD model was prepared to look at the restriction on the fans for the lower and upper generator sets.

Figure 9

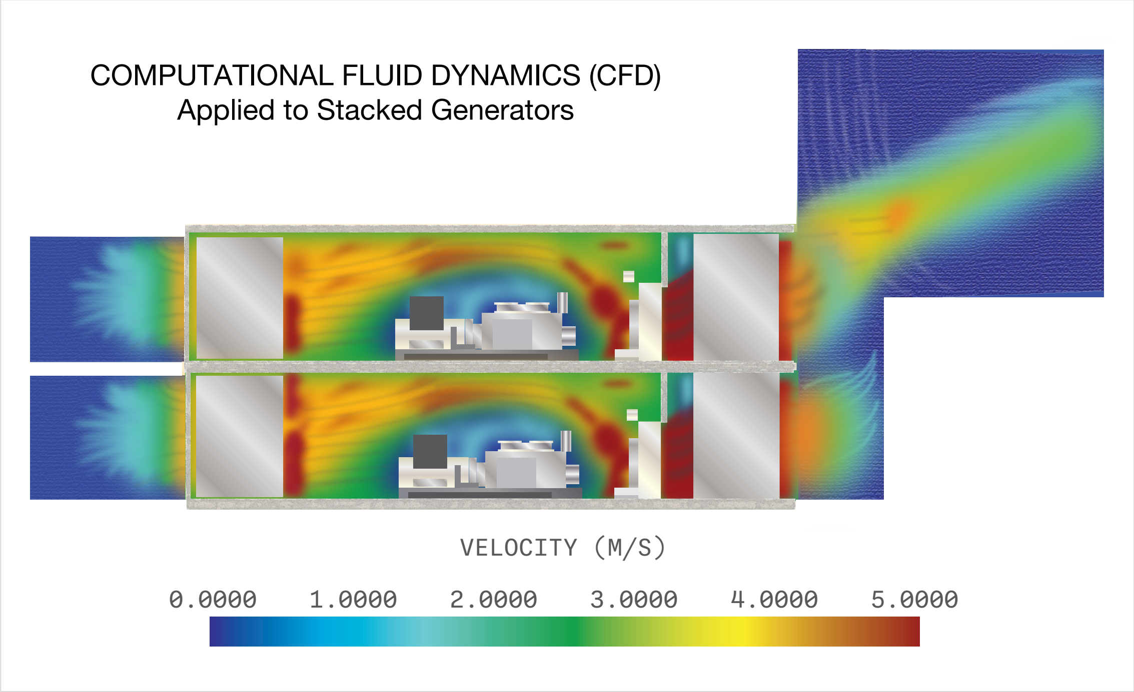
Data center building



DATA CENTER BUILDING (CONT.)

The resulting airflow pattern of one of the middle pair of stacked generators is shown in Figure 10. CFD was used to validate the entire restriction on the fan including not only the building wall impacts but also the intake and discharge louver and noise treatments. The added restriction was determined to be acceptable.

Figure 10



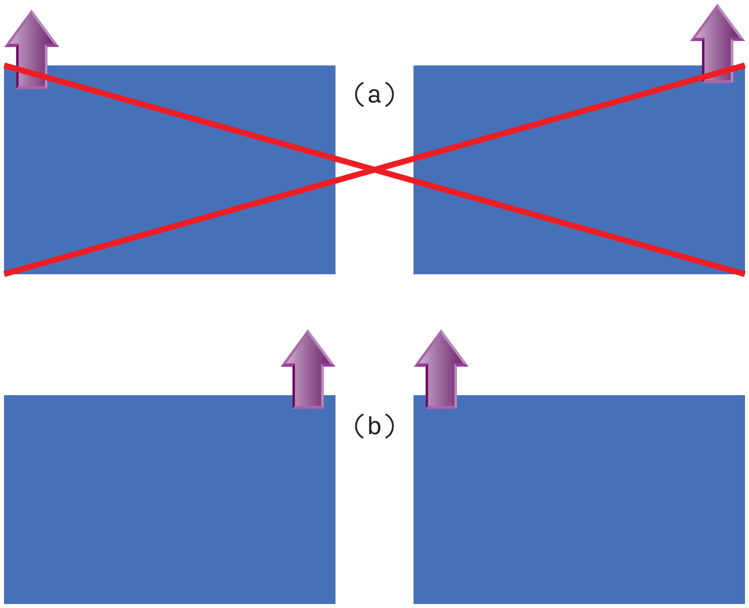
ADDITIONAL GUIDELINES

IMPACT OF INSTALLATION INFLUENCES

In this paper, some examples were shown to quantify the impact of installation influences. Many other installations have been modeled and the following sections provide simple, easy-to-use guidelines for multiple generator set installations as well as installing inside of a building.

For multiple generator set installations located outside of buildings and near each other, side-by-side installations with the same orientation of airflow is preferred. If the generators need to be installed in a line (end to end), this should only be considered for vertical discharge enclosures and the discharge plenums should be near each other. In-line installations oriented in the same direction run the risk of hot air from the first generator being ingested by the second generator. Please see Figure 11 for preferred orientations for vertical discharge enclosures that are mounted in end-to-end configuration.

Figure 11



End-to-end layout (b) for vertical discharge is acceptable, but layout (a) should be avoided due to the high potential of recirculation.

INDOOR INSTALLATIONS

For indoor installations, there are several key design practices that should be considered in the room design.

First, create as much separation between intake air entry and discharge air exit planes in the building. If possible, have these two airflow streams on different sides of the building to prevent recirculation.

Second, ensure proper sealing of the radiator to the discharge flow path to prevent recirculation.

Third, ensure that ICE exhaust is properly routed outside the building and does not discharge near the intake air path.

Finally, ensure restriction of the airflow does not exceed allowable limits for desired cooling performance. To aid the specifying engineer, Kohler publishes a table of cooling performance with respect to added airflow restriction for every generator set. A typical example is shown in Figure 12.

Figure 12

Generator Set Cooling System Data Sheet

	50˚C Ambient Temperature Cooling System							
KD3000 60 Hz (Standby Duty)	**Total external restriction on open unit[7]**	Pa (*in.H_2O*)	0 (0)	125 (0.5)	187 (0.75)	250 (1)	312 (1.25)	375 (1.5)
	Maximum allowable ambient temperature	˚C (˚F)	54 (129)	52 (126)	51 (124)	49 (120)	48 (118)	47 (117)
	Cooling system airflow	m^3/min (ft^3/min)	4038 (142600)	3823 (135000)	3696 (130500)	3576 (126300)	3453 (121900)	3330 (117600)

Example cooling system performance chart as a function of additional restriction

Additionally, KOHLER® Power Solutions Center sizing and specification software provides recommended room size and generator set installation dimensions.
https://kohlerpower.com/en/generators/industrial/sizing-program.

KOHLER ADVANTAGES

FACTORY-OFFERED ACCESSORIES

Kohler's factory-offered enclosure lineup offers vertical discharge cooling and exhaust air outlet options to minimize air recirculation for small-footprint installations. Through the use of CFD, Kohler is well-versed in examining complex and challenging installations.

ABOUT THE AUTHOR

Robert Danforth is the Director–Engineering, Simulation, and Advanced Development. He holds a bachelor of science degree in mechanical engineering from Rose-Hulman Institute of Technology and a master of science degree in mechanical engineering from Purdue University.

Robert has more than 25 years of cumulative experience in product development, performance simulation, and product testing. He joined Kohler in 2004 and is currently focused on mechanical and electrical simulation.

ABOUT KOHLER ENERGY

Kohler Energy, a global leader in energy resilience solutions, brings bold design and powerful impact to the energy systems that sustain people and communities everywhere around the world. It is an integral part of Kohler Co., with solutions across home energy, industrial energy systems, and power train technologies. Kohler Energy leverages the strength of its portfolio of businesses—Power Systems, Home Generators, Kohler Uninterruptible Power, Clarke Energy, Heila Technologies, Curtis Instruments, and Engines. With more than a century of industry leadership, Kohler Energy builds resilience and goes beyond functional, individual recovery to create better lives and communities. For more details, please visit KohlerEnergy.com.

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