



POWER GENERATION

AFTERTREATMENT THERMODYNAMICS – IMPACT ON EMISSION REDUCTION

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A quick review of thermodynamics when designing systems for exhaust gas aftertreatment (EGAT) can have a long-lasting impact on total emissions reduction and site air permit testing.

It all adds up

Even the smallest reduction in emissions can make a significant contribution to the overall environmental impact of a site -- especially if that site is a data center operating several megawatts of backup power systems. Choosing the right system to meet your environmental targets begins with carefully evaluating how the entire system is designed.



A Rolls-Royce
solution

The most common type of backup power for mission critical facilities comes from diesel generator sets. Because these gensets are used in standby power generation, many of their operating hours are from required maintenance and readiness tests, not actual operation. Historically, these unit checks are run monthly or weekly, however there has been a recent shift for backup generators to be optimized to run once every three months or even less. Thus, these systems typically run only for a few hours every year.

During testing, manufacturers require the units to reach a stable temperature and be loaded to at least 30% capacity to minimize the effects of low load operation. Getting to that stable temperature takes some systems longer than others depending on their installation. There is also an ever-increasing pressure to reduce emissions, which has resulted in the addition of exhaust gas aftertreatment (EGAT) systems, but to have an EGAT system reduce the emissions, it takes heat and heat takes time.

Sizing aftertreatment systems requires the design to consider worst-case situation(s). Generally speaking, this would be full load operation for diesel backup systems, as in this condition they have the highest mass of exhaust flow. This sets the volume of catalytic elements required to achieve the desired emission reduction.

As we know from thermodynamics, it takes time for a mass of X to warm up to temp of Y. As a rule of thumb, the catalysts within aftertreatment systems generally need to achieve 250°C or warmer to ensure there is a proper environment for the chemical reactions to happen for peak performance. These catalysts are also a huge heat sink, resulting in significant time for them to reach the desired operating temperature. When these systems are sitting in standby mode, the EGAT system is at the same temperature as the ambient environment. Typical engine exhaust temperatures at full load can easily exceed 500°C, and in these conditions the EGAT system can warm up much quicker. However, as mentioned earlier, backup generators more often operate at 30% load where exhaust temperatures are much lower, and the mass flow of the exhaust is much lower as well. Therefore, it will take longer for the EGAT system to reach operating temperatures to achieve emissions reduction.

It takes specific considerations to find the optimal design between the engine and the EGAT system to optimize the behavior of the thermodynamics of the entire system without applying advanced controls that could impact reliability. Therefore, Rolls-Royce and its partners have developed a system that truly optimizes the entire system by looking at the specific make up of what metals are used in the EGAT housing, catalysts characteristics and composition, plus the layout of the entire system to optimize thermodynamic principles. To compare this design process to our day-to-day life, this is like designing energy efficient houses.

It is common to thermally insulate the exhaust piping and reactor, not only for safety purposes, but also to reduce thermal loss. One way to improve the thermal characteristics of the system is via its general design. Traditional reactors were designed in a linear fashion where the exhaust first enters the diesel particulate filter (DPF) followed by a long mixing pipe where diesel exhaust fluid (DEF) is injected before it goes into the selective catalytic reduction (SCR) section. There is a growing trend for exhaust after treatment systems to be designed as a one-box design where everything is tightly packed, and the thermal energy is trapped/shared between these critically sensitive components.

In addition to insulation, the selection of the materials used also plays a very critical role. One example of material selection plays into the metallurgy. Exhaust components are typically made from high carbon steel or stainless steel. The thermal conductivity coefficient of carbon steel is higher than that of stainless steel. This means that carbon steel requires more heat energy from the exhaust flow to heat itself up. Therefore, the parasitic energy consumption in carbon steel is higher than that of the stainless steel construction.

When an EGAT system is initially started, it does not reduce NOx emissions until the system reaches its minimum injection temperature threshold. This becomes a critical topic for some facilities that are trying to stay under a major source permit and need to keep emissions limited. As mentioned earlier, if most of the operation is at 30% load where exhaust temps are already low, it will take longer for the aftertreatment system to get up to temperature. This can result in a challenge for the site air permit, as this could play into a significant portion of the total emissions. On the other hand, if a quick heat up time is achievable, via the system design, the emissions during the warmup time are minimized, resulting in benefits for the site air permit. Therefore, this becomes our goal.

The critical parameter with an aftertreatment system is NOx emission reduction. This starts by first decomposing DEF into ammonia. The ammonia then mixes with the exhaust, in the presence of a catalyst, resulting in a chemical reaction. It is important to note, heat is needed to achieve this reaction – beginning at a 200°C catalyst temperature but ideally at 250°C. (Emphasis must be noted this is catalyst temperature and not exhaust temperature). Decomposing DEF to Ammonia requires higher temperatures of 200-300. At full load, Rolls-Royce has tested its systems and has seen typical behavior where the aftertreatment system is injecting DEF and reducing NOx within 3 minutes of starting the unit and going to full load. Rolls-Royce has also done tests showing that at 30% load the system is injecting DEF and reducing emissions within 8 minutes after starting the unit. Even when operating at 10% load, the unit was able to inject DEF and reduce NOx emissions within 30 minutes after starting.

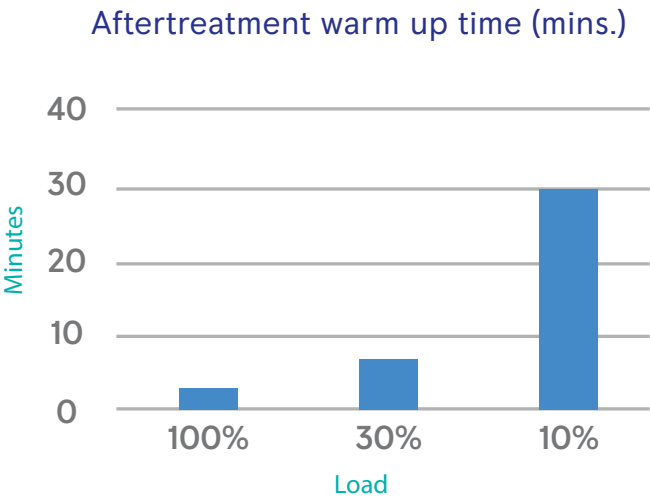


Figure 1 - 2-3MW Gensets heat up time without external heating

Conclusion

In conclusion, the design of the aftertreatment system for diesel backup power generator set applications optimize the system for emissions reduction. The way the system is laid out and the materials used in its makeup are essential design considerations for minimizing heat up time and maximizing emission reduction. In addition, maximizing the interface between the engine and aftertreatment can provide additional benefits. The solution that Rolls-Royce and its partners have developed maximizes these design characteristics to offer a solution that shortens the heat up time of the aftertreatment system, allowing for additional benefits for the owner/operator when filling out site permits.

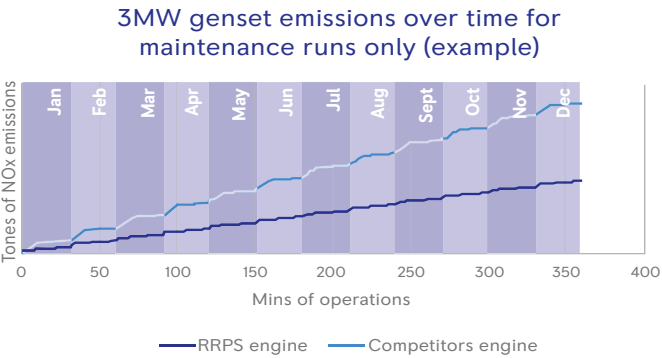


Figure 2 - 3000kWe Genset SCR+DPF after treatment system at full load

Under its Power Systems division, Rolls-Royce provides world-class **mtu** power solutions and complete lifecycle support for applications from marine to military to power generation. The **mtu** power generation portfolio includes diesel and gas-based engines and systems, dynamic UPS, battery energy storage, smart controls and digital services to connect and optimize complete power systems.

From Cold Start to reduction in less than 3 mins

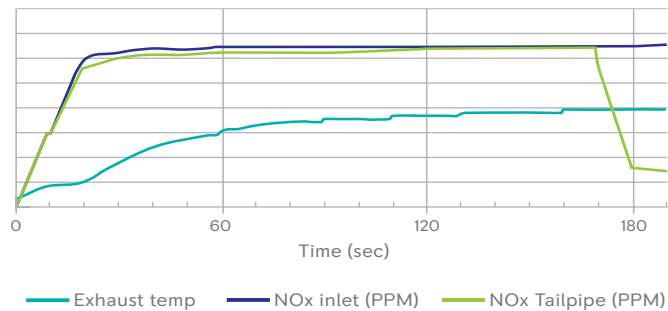


Figure 3: 3000kWe Genset aftertreatment reduction perform at full load

With more than 15 years serving hyperscale data center customers, we have become a leader in mission critical emergency power systems. Our installed base for data centers alone is 10GW and growing. Our highly-efficient gas systems have been proven all over the world with over 4,000 installations and 4GW installed. Together with our partners, we are providing solutions to meet the power demands of today and tomorrow.