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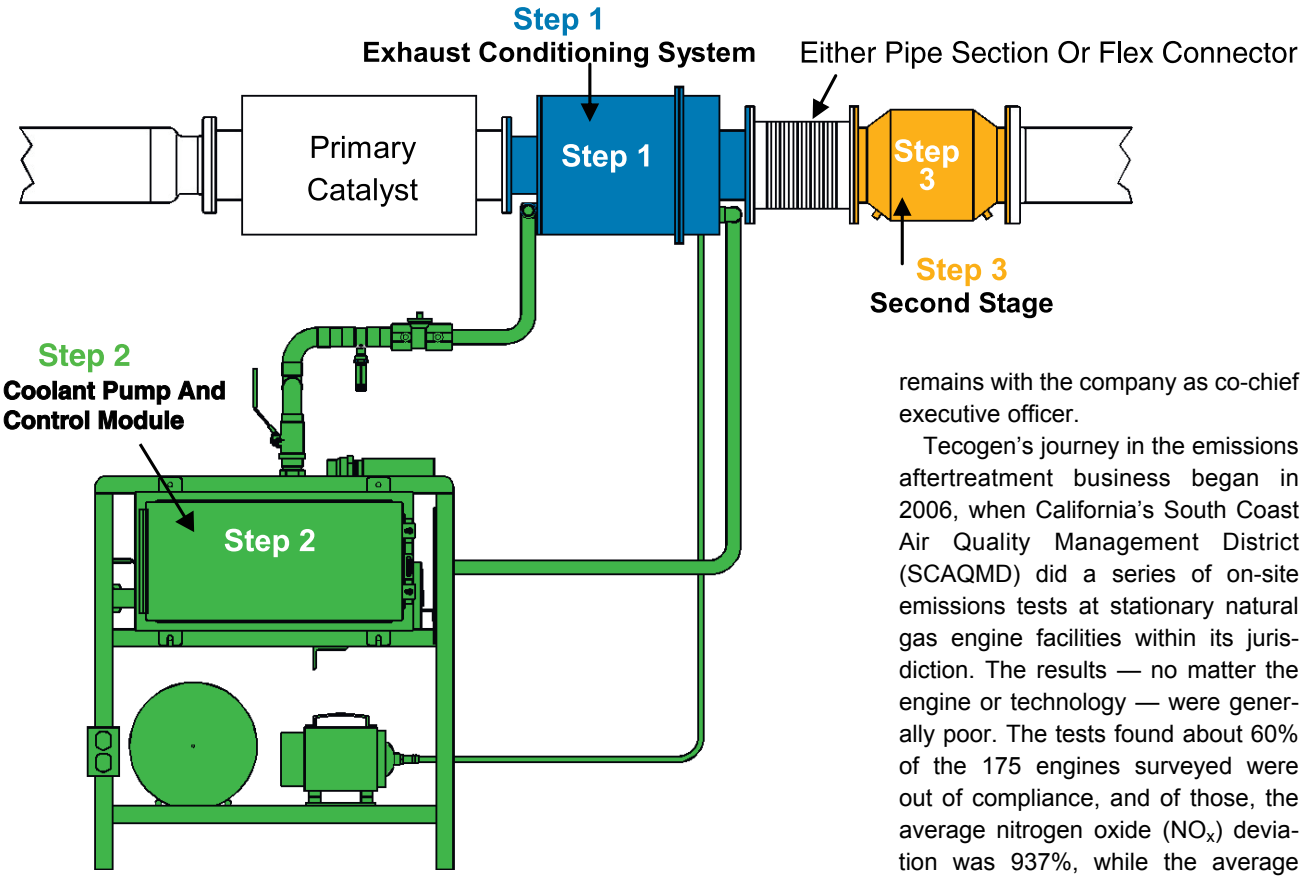
Tecogen natural gas engine retrofit kit designed to meet strict requirements for both NO_x and CO



The basic design of Tecogen's Ultra Emissions System.

BY JACK BURKE

For Tecogen, a manufacturer of natural gas-fueled, engine-driven combined heat and power (CHP) products, necessity truly was the mother of invention.

Faced with a regulatory environment in California that threatened its core business, the Waltham, Mass.-based company set out to engineer an emissions aftertreatment system that would keep its products in compliance, said Bob Panora, chief operations officer (COO) for Tecogen.

"The reason we felt a need to pursue this is that we had no place to go," Panora said. "We were natural gas engine folks — we're not fuel cell folks, we're not turbine folks. And if we can't get our engines to be compliant, well, we knew these regulations weren't going to just stay in L.A. They're going to go elsewhere, and they certainly have migrated to the East Coast — Massachusetts, Rhode Island, New Hampshire."

Tecogen began life as a research division of Thermo Electron Corp. (now Thermo Fischer Scientific). The division was charged with developing cogeneration technology and released its first major product — a 60 kW cogenerator — in 1982. By 2000, Tecogen was sold to a group of private investors, including Thermo Electron's founders, George and John Hatsopoulos. The company, which has 80 employees, went public in 2013, and John Hatsopoulos remains with the company as co-chief executive officer.

Tecogen's journey in the emissions aftertreatment business began in 2006, when California's South Coast Air Quality Management District (SCAQMD) did a series of on-site emissions tests at stationary natural gas engine facilities within its jurisdiction. The results — no matter the engine or technology — were generally poor. The tests found about 60% of the 175 engines surveyed were out of compliance, and of those, the average nitrogen oxide (NO_x) deviation was 937%, while the average carbon monoxide (CO) deviation was 1780% — "really shocking numbers," Panora said.

"What they'd discovered was the shortcoming of pipeline-fueled natural gas engines: that using rich-burn catalyst technology was really dicey," Panora said. "If you're running a three-way catalyst — which everybody does — you're trying to find a very precise air-fuel ratio where you simultaneously get rid of NO_x compounds and get rid of your CO and hydrocarbons. It turns out you can't — you sort of have to pick your poison. You can get low NO_x but not low CO at the same time. Or you can get low CO and high NO_x, but getting them both together is extremely difficult, especially with low-pressure gas systems."

SCAQMD kept testing, and systems kept failing, Panora said. In

Tecogen's Ultra Emissions System, shown here during testing, is a patented turnkey retrofit kit that the Massachusetts-based company has begun to market.

2008, SCAQMD implemented more aggressive emissions rules based on California Air Resources Board (CARB) standards for distributed generation electricity sources. As the new standards came into the market, Panora said engine-based CHP basically stopped in Southern California.

That's when Southern California Gas Company (SoCalGas) and the California Energy Commission approached Tecogen and asked the company to find a way to make natural gas engines for CHP comply with the new emissions standards and become commercially viable again.

"We didn't think we had a real strong chance of being successful," Panora said. "You always hope, but I didn't see a path in the beginning."

At first, Tecogen tried to fine-tune the air-fuel ratio control on the engines to hit the precise balance between the necessary NO_x and CO output. But the engines used in CHP have very harsh duty cycles — they run full speed, all day long — and the company couldn't maintain the balance just right, Panora said.

"Maybe you could do it for a month, maybe for two months, but eventually you were going to have a problem," he said.

Converting the engines to lean burn and adding selective catalytic reduction (SCR) technology was deemed too cost-prohibitive, Panora said.

"We're really talking about the smaller engines, under 1 MW, where you have constraints on costs and can't afford an SCR, which would have to be a pretty expensive one to get to those emissions values," he said.

So Tecogen decided to look at the chemistry of emissions instead of simply the mechanical controls of the engine. They broke the catalyst process into two steps and tried running each step at a different temperature. Panora said that by controlling the temperature in the first stage, the system could achieve very low NO_x.

"Having eliminated the NO_x in stage one, the second stage process needed to be configured to oxidize the remaining pollutants — carbon monoxide and various hydrocarbons — into harmless carbon dioxide with a very high efficiency and without adverse consequences.

"The first step in the second stage process is obvious — inject a small stream of air to promote oxidation of these remaining compounds. The insight we had was how to control the chemistry in the second stage catalyst such that unwanted reactions were eliminated — the primary one being the reconstitution of the O_2 and N_2 from the air back into NO_x, bringing you right back where you started from," he said. "But when we injected a little air between the first and second stages and altered the process conditions, the good reaction proceeds, the bad ones do not, such that you can get very low NO_x and very low CO even with commonplace controls."

That's the heart of the Ultra Emissions System, a turnkey retrofit kit patented by Tecogen that's now being deployed commercially, Panora said. The Ultra Emissions product is designed to deliver simple, cost-effective solutions for select rich-burn natural gas engines to meet stringent emissions standards. The system is designed to work without changes to the engine or controls and

The Ultra Emissions System is designed for installation on rich-burn natural gas engines to meet stringent emissions standards, Tecogen said. This system was part of a pilot project at the Eastern Municipal Water District in Perris, Calif. It was installed on a 15 L Caterpillar natural gas engine used to move stored water.

Tecogen said the company's Ultra Emissions System is available in a range of configurations for various engines and site needs. In a pilot project for the Eastern Municipal Water District in Perris, Calif., the second stage of the Ultra Emissions System can be seen here, and the final segment of the exhaust was placed on the roof.

is completely self-adjusting and self-contained, Panora said.

"All you need is a basic engine that does reasonably well with emissions, and we can take the levels from BACT (best available control technology) to much lower levels on a sustainable basis," Panora said. "That takes the scariness out of emissions compliance. Why didn't I think of this 30 years ago?"

Panora said that typical exhaust temperature is 1100° to 1200°F. In a cogeneration application, the exhaust stream is already conditioned, so only the specialized second stage catalyst and small air pump to enable oxidation is necessary, he said.

"If it's a water-pumping engine, then you have to have a heat exchanger to properly condition the exhaust," Panora said. "We've designed it so you set whatever temperature you want within limits, and regardless of engine output, you maintain that temperature."

On a gen-set, a radiator upgrade might be necessary to enable cooling the exhaust, or a second, smaller radiator could be added for that purpose, which is how Tecogen has assembled the system, Panora said.

"It's pretty straightforward — there are no laser beams or chemicals to inject, nothing like that," he said. "It's pretty much just separating a three-way catalytic reaction into two separate and distinct reactions."

Tecogen was contracted to upfit a conventional 130 kW Generac generator with the Ultra Emissions System. The project was underwritten by an industrial customer requiring a group of emergency standby generators on its property in Southern California to perform at extremely low pollution limits for extended hours. Panora said standby generators are normally exempt from the strict limits required for cogeneration and other heavy use generators but only if the annual use can be limited to 200 hours. The projected use by this customer exceeded that limit.

The testing phase of the project, which included a wide variety of loads and simulated load swings, was successfully completed at Tecogen's Waltham laboratory. Under all test conditions, the unit maintained compliance to the SCAQMD District Rule 1110.2, which applies to engine equipment in Southern California. The company is now proceeding with SCAQMD permit applications for this test generator and the others on the property. During the permit process, the other units will require individual Tecogen aftertreatment kits.

"We were very pleased with the project results," Panora said. "We achieved very low emissions with the unit, similar to a fuel cell, which we expected. We were able to quickly complete the job because the engine, which was unfamiliar to us, required no adjustment whatsoever. A simple, effective aftertreatment kit that can alter the emissions output from an ordinary standby generator, without any engine modification, such that it could be permitted for regular daily use, would have great potential for use in demand response programs and other strategies to curb facility peak electricity demand."

Panora said he believes this unit would be the first natural gas standby generator re-permitted for nonemergency use in SCAQMD territory since the requirements of Rule 1110.2 were revised more than six years ago.

"It worked great," Panora said. "All we had to do was add it to the engine and not go in and be invasive with the gen-set controls — didn't have to touch that. From an engine warranty point of view, it's like adding a muffler, so there's no argument about that."

Now Tecogen is seeking markets for the Ultra Emissions System.

"Outside of our own CHP products, we are still navigating where to go with this technology," Panora said. "And obviously doing ones and twosies is not long-term the best way to do it, but we don't want to push our way through the door and try to sell it before we've really found out who wants it and what is the best place for it to be. We are still exploring possible opportunities in search for the best market fits."

One possible application for the Ultra Emissions System is in peak demand gen-sets that run 500 to 1000 hours a year.

"A very inexpensive gen-set can run very short amounts of time and really shave peak demand, demand response, and really get around some quirks in electric tariffs for people who have a lot of solar, for example," Panora said. **dp**