Custom Oil Blend Helps Treatment Plant Use Caustic Sewage Gas for Energy

Lead Wastewater Treatment Plant Mechanic, Tom May (atop engine) inspects one of the six Waukesha lean-burn engines that provide power for the Pima County Wastewater Treatment Plant in Tucson, AZ. The engines run exclusively on sewage effluent gas.

Using sewage effluent gas to fuel engines and generators, operators of the Pima County Wastewater Treatment Plant in Tucson, AZ, save an average of $30,000 a month in outside energy costs, reduce environmental pollution by fueling with gases that otherwise would be flared off to the atmosphere, and reduce the use of non-renewable natural gas resources.

The Pima Plant handles 40 million gallons a day of raw sewage from the metropolitan Tucson area using an almost self-sufficient system. The plant fuels six huge Waukesha engines and generators with sewer gas produced by anaerobic digestion of solid wastes. It uses heat from the engines to keep the gas-producing bacteria happily munching away, cleaning up the raw sewage.

Corrosive gas a challenge

The greatest challenge for plant operators was that the caustic, corrosive sewage gas could easily destroy the engines, each costing $250,000 or more. The problem was solved by a specialty custom-blended lubricant from Phillips 66, made by Houston-based refiner ConocoPhillips Co. According to Tom May, the plant's lead mechanic, Phillips' Eclipse "W" 40 brand oil blend counteracts the extra stress that "sour" effluent gases put on the plant's six Waukesha lean-burn, gas-fired engines. "Impurities from sour digester gas collect in the crankcase, diluting the oil, depleting its base reserve and spreading contaminants throughout the engine," he says. "A lubricant for the digester gas-fueled engines must protect the engine by countering the effects of these corrosive impurities, preventing deposits on critical parts, and providing optimum lubrication over prolonged use."

May adds that the manufacturer recommends the oil in a digester gas-fueled engine be changed after 350 to 500 hours. "Using Eclipse oil and regular oil analysis," he says, "we've extended our oil service intervals to between 600 and 800 hours. When we change oil at 800 hours, we've run the engine to the equivalent of 44,000 miles," he adds. "So we're doing better than synthetic heavy-duty engine oils, which often stipulate recommended changers every 20,000 to 50,000 miles, even when fueled with extra-clean fuel."

Furthermore, before using Eclipse oil, the Pima County Plant had been replacing cylinder heads and rocker arm parts that were burned through from sour gas deposits every 6,000 to 10,000 hours. May says he expects the new oil to minimize piston replacement and keep all engine parts operating at peak efficiency.

"The aim is to extend the engine's life beyond 20,000 hours," he says.

Nearing self-sufficiency

The Waukesha engines used in the Pima plant are "lean burn" dual-fueled (natural

gas/digester gas) models, designed to meet EPA emissions standards even with sour gas fuels. They use less fuel and more air because the gas/air mixture is compressed with turbochargers, precooled with intercoolers and injected into the engine so it burns efficiently.

Two of the plant's six engines are 12-cylinder models that were converted from regular G to lean-burning GL models. Another is a six-cylinder lean-burn engine generator. All are turbocharged and intercooled, and use heat exchangers, instead of radiators, to convert waste heat from the exhaust to water heat that warms the plant's digesters.

Natural gas usually contains 900 to 905 British thermal units (BTUs) per cubic foot, while Pima's sour digester gas averages about 600 BTUs.

"That treated, compressed, sour-gas mixture fuels the engines that power our whole facility," says May. "We operate about 80% on generator power, so we don't have to buy power off the grid, further reducing our monthly energy costs. We're pretty close to being self-sufficient that way."

That energy-efficiency extends to other parts of the plant. Water heated by the engines' exhaust systems helps keep digester temperatures at the 96 F to 98 F preferred by the anaerobic bacteria. These engines usually run 24 hours a day, seven days a week. May estimates that if they were on wheels, they would be running at 55 miles an hour, and would cover more than 39,000 miles per month.

Oil must be balanced

May says the sour gas fuel creates the need for a delicate balance in the oil. "If you have a high-ash, high-TBN (total base number) oil in a sour gas fuel situation, the ash can actually become part of the problem in the pistons and can itself lead to detonation."

Without a high ash content, oil would quickly break down as impurities from the sulfur-rich (sour) gas build up inside the engine crankcase.

"Ash content becomes even more of an issue when you start heating up these engines with turbochargers and lean-burn configurations," says May. "All of that puts extra stress on the oil. You need to prevent engine deposits from the ash, but you still need the right amount of ash, plus the TBN balance and stability to handle that high-level sulfur."

At a 2,000-hour inspection, the structural integrity of the piston head at left was damaged by the high sulfuric acid content of sour gas. The piston head on the right shows normal combustion patterns with the use of Phillips 66 Eclipse "W" 40 engine oil. The oil is on target to help extend the Waukesha engine life beyond 20,000 hours.

A major challenge is the amount of sulfur in the digester fuel gas. "We are running about as high a sulfur level as is possible in the fuel," says May, who adds that Waukesha recommends less than 0.1 parts per million (ppm) of H2S and elemental sulfur in the fuel as close to zero as possible.

"But we have run as high as 0.3 parts per million sulfur and H2S in our fuel, because we can't control it, and all that corrosive material really puts a strain on the engine lubrication system."

Acid also a challenge

The Waukesha engine service bulletins are specific about the maximum total acid number (TAN) permitted in the lubricating oil, in relation to the total base number (TBN) of the oil. Because of the plant's use of digester gas as fuel, however, it needed specific TBN and TAN numbers not available with an off-the-shelf product.

"We needed at least an 8 to 10 TBN," says May, "and the Waukesha engine service bulletin specifies a starting maximum of 1.5 parts per million TAN in relation with the TBN. That ratio must be maintained between oil changes."

Because Pima's fuel contains hydrogen sulfide, over time the TBN falls and the TAN goes up, so the oil must start with an above-normal total base number to offset or neutralize the total acid number.

To obtain the proper ratio, ConocoPhillips blended the Phillips 66 product specifically for the plant. May wanted to assure the maintenance department that he had made the right decision in selecting Eclipse oil, so he began an oil-analysis program. For six months, he tested oil samples every 50 hours, then increased sampling intervals to 100-hour increments until he changed the oil. "This is the only way to make sure your oil is protecting your engines," he says.

May also conducts direct engine inspections, which involve checking the oil pan and wiping it down. "Because it's unfiltered, our gas can cause a lot of silicate deposits in the engine," he says. "Most of these we see are combustion byproducts which end up in the oil pan, so oil analysis will show high silicon levels of anywhere from 60 to 124 parts per million."

May adds that his crew has not seen excessive solids build-up since they starting using the Eclipse oil. The tops and insides of pistons that were changed during a 20,000-hour top overhaul showed only a lightly baked-on white caking of silicate. Without the use of the Eclipse oil, says May, "deposits would have built up on top and underneath the pistons. This would have caused compression drops and improper detonation."

This situation, known as "bad burn" can cause pistons to over-expand as they heat, scuffing the cylinder walls as the over-size piston and rings scrape away the cylinder interior. Deposits can also lead to power-robbing premature-ignition-system detonations which can begin to flame and cause premature detonation or poor engine timing.

A sign that the Eclipse oil does the job it was designed to do, says May, was that after the first 2,000 hours of using it, he didn't have to replace a corroded valve train - standard procedure before the switch.

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