

SEPTEMBER 2016 VOL. 22 ISSUE 9

LUBES'N'GREASES

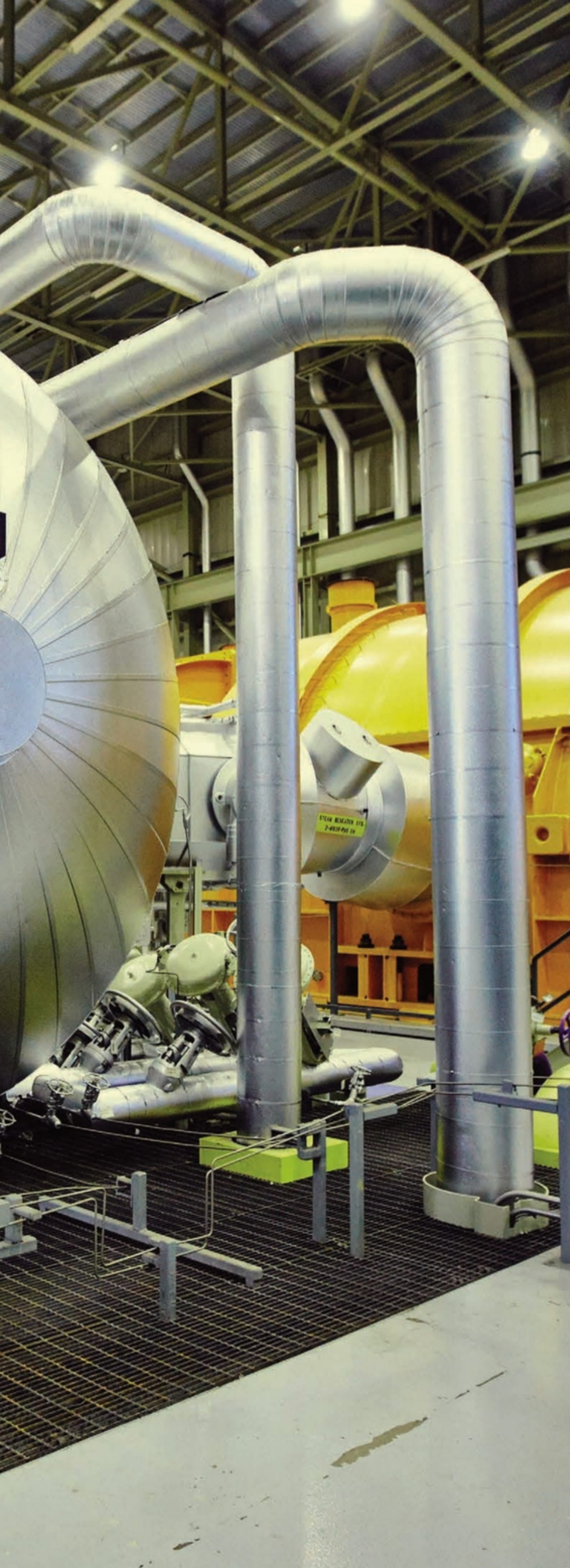
**Grease That's
to Dye For**

**Focus on Direct
Injection**

The Nuclear Option

A large, silver, spherical turbine ball is the central focus of the image. It is positioned in a vast industrial space, likely a turbine hall, with a complex network of pipes and structural beams visible in the background. The ball is supported by a metal frame and sits on a dark, gridded floor. The lighting is bright, highlighting the metallic surface of the ball and the industrial environment.

Darlington Nuclear Generating Station's turbine ball is about six football fields long and 12 stories high.



When a supplier stops producing the lubricant a company has relied upon, choosing a replacement oil presents both a challenge and an opportunity. One nuclear power company conducted a series of tests to define the right lubricant for its steam turbines when the incumbent oil was discontinued. “The lesson learned from our point of view,” Ontario Power Generation’s Khalid Malik told an industry gathering, “is that all Group II oils are not the same.”

Ontario Power is wholly owned by the Ontario government and runs two nuclear power stations outside Toronto, plus hydro, oil and gas-fueled plants throughout the province. The Pickering Nuclear Power Station — one of the largest nuclear facilities in the world — was built in 1971 with six working reactors and generates 3,100 megawatts. Darlington nuclear station’s four units, which opened in the early 1990s, produce 3,512 megawatts, about 20 percent of Ontario’s electric power needs.

Both stations house CANada Deuterium Uranium reactors. Instead of enriched uranium, a hydrogen isotope called deuterium or heavy water enables CANDU reactors to use natural uranium as the fuel source. The fuel rods in such reactors are inserted horizontally, and can be replaced individually while the system is still running, increasing uptime. The heavy water heats regular water in a boiler to create steam to power the station’s turbines, Malik explained in May at the Society of Tribologists & Lubrication Engineers’ annual meeting in Las Vegas.

Steam turbine oil lubricates most of the moving components within the two power generating stations, including governors and pumps, and most importantly it serves the massive, low-speed turbines responsible for spinning the generator shafts that create electricity. With some station turbines reaching temperatures above 100 degrees Celsius, the two plants require a combined 175,000 liters of lubricating oil. This oil is expected to last from 10 to 12 years, though oxidation sometimes forces shorter drain intervals.

Points for Group I

Historically, the aromatics in API Group I based turbine oils were thought to stand up well in a radiation environment, resulting in better performance, reported Malik, who is senior technical officer for nuclear engineering. And although the turbines at CANDU stations are located on the conventional side of the plant where radiation levels are low, Group I oils were used for decades at OPG.

Jilted by its favorite Group I turbine oil, could Ontario Power find exactly the right Group II product for long-term happiness?

BY CAITLIN JACOBS

By the early 2000s, Group II turbine oils were becoming more widely available for power stations, but Ontario Power noted that these were said to have poor solvency and varnish issues that inhibited performance in U.S. nuclear plants. The Electric Power Research Institute (EPRI) also began hearing from other power plant operators on this topic around the same time.

In addition to the technical challenges, close regulatory oversight means any modifications made to nuclear power plants require mountains of documentation. “Canadian Nuclear Safety Commission requirements are more or less the same as the [U.S.] Nuclear Regulatory Commission,” said Malik. “Huge paperwork and practical justifications are required before a change can be implemented.”

Ontario Hydro times, Malik recalled that the company was a pioneer in development of turbine oil standards in the early 1980s. Collaborating with the CANDU Owners Group, a consortium of nuclear plant operators, Ontario Power now conducts a range of research projects. “Our lubrication research work, in my opinion, sometimes exceeds EPRI study project requirements on the same subjects,” he boasted.

While the incumbent Group I oil seemed to have good demulsibility — the ability to shed harmful water — plant operators observed rust and other damage that comes from water in the lubricant. Varnish and deposits had also been a problem, though Malik revealed that operators were able to adjust some of their procedures to mitigate water uptake and deposit formation. “It is very difficult

generation systems, Ontario Power evaluated the physical and chemical properties of eight candidate products in a series of experiments conducted between May and September 2015. Anticipating the need for a higher quality base oil — and seeing how Group I capacity is fading — the team chose to test a slate of mostly API Group II oils. These included one Group II+ stock, Malik told *Lubes’n’Greases*, though he did not disclose how the Group II+ fared versus the others. The incumbent Group I oil was included for comparison, along with a blend of the incumbent and another brand’s Group II product.

“We also tested a Group I from another supplier, and they assured us that they can continue to supply” until Ontario Power changes over to its final oil selection, said Malik. Candidate oil suppliers included Chevron, Esso, ExxonMobil, Lubrication Engineers, Petro-Canada and Shell.

With treat rates of less than 1 percent, additive packages tend to have less influence on turbine oil performance than they have on other types of lubricants. “In my opinion, base oil quality impacted a lot, in comparison with additive pack performance,” said Malik after the conference. “Certainly, well-formulated oils with proper additives have made the difference” in the final results.

Each candidate oil was subjected to an artificial aging process to promote accelerated oxidation. Ten-liter samples were mixed with a copper and iron catalyst in an open glass container, then heated to 130 C and exposed to a continuous dry air flow of 1.5 liters per minute. Magnetic mixing circulated the samples.

The oils were tested at three stages: as new oils, during the aging process, and after aging for six weeks. All tests were performed by Kinectrics research laboratory in Toronto using standard ASTM methods.

First, fresh oils were tested to determine viscosity index, kinematic viscosity at 40 and 100 C, flash and pour points, water content, and foaming and air-release characteristics. Other tests included a rust test, copper corrosion at



Located 70 km from Toronto, Darlington supplies one-fifth of Ontario's electricity needs.

(Photos: OPG)

to modify turbines,” he pointed out. With a \$12.8 billion major system refurbishment now scheduled for its Darlington plant, Ontario Power sees the facility as a prime candidate for a new turbine oil. As each reactor is overhauled over the next 10 years, its associated turbines, steam generators and auxiliary systems will be disassembled and replaced or rebuilt, one by one, until all four trains are complete.

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Which Way Next?

To determine what types of oils can stand up to the demands of its power

This was not the first time Ontario Power had undertaken such a task. Operating as one of the largest utility providers in North America during its

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100 C for three hours, rotating pressure vessel oxidation test (RPVOT), turbine oxidation stability test (TOST) for acid and sludge, pressure differential scanning calorimetry test for oxidation, and a pentane insolubles test, which indicates varnish potential.

As they were aging, the oils were tested at one day, two days, three days, one week, and at the end of every week thereafter. These staggered tests determined acid number, K.V. at 40 C, color, foaming tendency, air release and water separation properties. Additional tests included membrane-patch colorimetry for varnish potential, RPVOT and linear sweep voltammetry test, also for oxidation.

Making the Cut

After 1,008 hours of artificial aging, the laboratory again conducted the same tests that were run on the new oils, with the exception of the TOST test. At the STLE gathering, Malik highlighted some of the results from this before-and-after process.

- In particle count tests, the oils showed no notable differentiation when measuring for ISO-4 particle size. In tests for ISO-6 particles, one of the Group II oils broke away from the pack and maintained a lower count for longer, but showed comparable particle totals to the other oils by 1,000 hours. At ISO-14, far more differentiation appeared: The Group I oils and the Group I/II mix showed a count around 21, while the Group II oils' counts were spread between 12 and 20.

- The Group I oils and the mix showed the greatest change in membrane-patch colorimetry tests, which measures insoluble degradation products in an oil sample, producing results between 78 and 81 delta-E (a gauge of color differentiation). Results for the Group II oils were far more varied at 1,000 hours, with readings between 13 and 69 dE. All oils began at 10 dE or below, and most labs consider any result above 40 dE to be critical.

- RPVOT tests also showed a split

between Group I and Group II oils, with more variation among the Group II products. The Group I oils lasted about 150 minutes, while the mix persisted for 300 minutes. The Group II oils varied from around 1,950 minutes to 2,600 minutes, with the exception of one Group II candidate that produced the worst results of all of the oil samples.

- The total acid number for all of the oil samples showed far less variation. The Group I oils had slightly higher numbers than the Group II samples, which were all very close after 1,000 hours of testing. However, the same Group II product that performed most poorly in the RPVOT tests had a strikingly higher TAN — about 2.4 — than the other oils after just 672 hours.

Tallying the Results

Ontario Power used a weighted scorecard to align each candidate oil's test results with the company's needs and priorities. For tests conducted on the new oils, TAN, sludge, air release and differential scanning calorimetry results were given the most weight. RPVOT and TAN were given highest priority for tests conducted during the aging process, and air release was favored in the post-aging tests.

The heaviest weighting overall was given to the oils' initial properties.

The most striking takeaway from the experiments, Malik summarized, is that Group II oils can vary widely. "Some performed very well; some didn't perform to our expectations," he recalled.

With the weighted scores tallied, one of the Group II oils demonstrated the most consistently high performance in all three stages of testing. The oil was tested in two ISO viscosity grades (32 and 46), and both performed exceptionally well.

Most important, Ontario Power was able to develop a performance-based, written specification for a Group II based turbine oil, to help choose the best lubricants for its power plants' design and the company's processes.

"Now we know exactly what we want," Malik concluded. ■



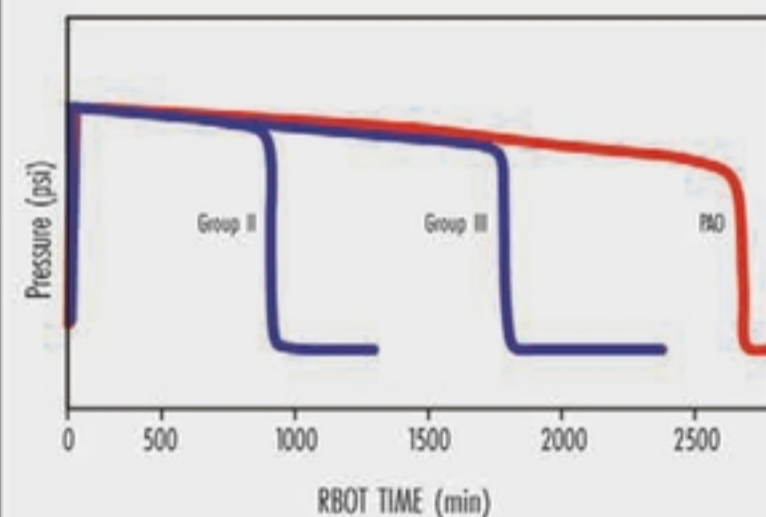
Khalid Malik



with Ken Hope, Ph.D.

Q: One of the key benefits I'm seeking is the extended drain interval, how can Synfluid® PAOs help?

A: Long lasting lubricants keep equipment running and minimize waste. The key to long drain intervals is oxidative stability. The chart below shows rotating pressure vessel oxidation test results between Synfluid® PAOs and some mineral oils.



As you can see from the chart, a lot more time passes for the PAO-based lubricants before it becomes oxidatively unstable, and starts to break down. PAOs also tend to resist viscosity increase upon oxidation. These combined benefits provide the properties required for severe service applications and extended drain intervals.

Give us a call and we will be happy to discuss unlocking the benefits of Synfluid® PAOs in your application.

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