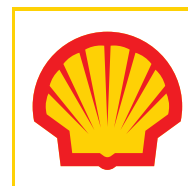


Shell Lubricants

## ARE SLUDGE AND VARNISH KILLING YOUR PRODUCTIVITY?

COULD THE LATEST OIL TECHNOLOGY GIVE YOU CLEANER, LONGER-LASTING AND MORE PRODUCTIVE HYDRAULIC SYSTEMS?

WHITE PAPER, FEBRUARY 2020





**OPERATORS ARE WORKING THEIR HYDRAULIC SYSTEMS HARDER FOR LONGER, WHICH EXERTS EXTRA STRESS ON HYDRAULIC OILS**

To remain competitive, operators are working their hydraulic systems harder for longer, which exerts extra stress on hydraulic oils, including higher operating pressures and temperatures. At the same time, mobile hydraulic systems are becoming more compact. Their smaller oil reservoirs restrict heat dispersion, which means higher peak oil temperatures. This increases the risk of oxidation and thus sludge and varnish formation. Smaller reservoirs also reduce the fluid residence time needed for the recovery or release of the contaminants that can cause hydraulic system failure.

Although most hydraulic oils sold today are zinc based, some equipment manufacturers still believe that hydraulic oils with zinc

technology can lead to increased sludge and varnish and the associated maintenance costs from plugged valves and filters and shorter oil life. These manufacturers use specific tests to differentiate oils with higher sludge formation. These tests include the Bosch Rexroth A2F10 piston pump test (JCMAS P 045);<sup>1</sup> the high-temperature Indiana stirring oxidation test (ISOT);<sup>2</sup> the 1,000-h turbine oil oxidation stability test (TOST);<sup>3</sup> the dry TOST;<sup>4</sup> and thermal stability and yellow metal protection tests. Until now, many zinc-based hydraulic oils have not performed well in these laboratory tests, especially in the Bosch Rexroth A2F10 piston pump test.

### CHOOSING THE RIGHT PRODUCT FOR THE RIGHT APPLICATION

Poor-quality hydraulic fluids are more susceptible to the problem of sludge and varnish, as they readily oxidise in the presence of yellow metals and water and air contamination. In addition, they contain additives that are not thermally stable and decompose at elevated temperatures. The best way to avoid this is to use a high-quality hydraulic fluid with excellent thermal and oxidation stability to help mitigate the risk of sludge and varnish build-up, and thus lower an operator’s total cost of ownership.

Zinc-based hydraulic oil formulations are used for their antiwear agent, antioxidant and system efficiency performance. Some equipment manufacturers believe that hydraulic oils with zinc technology can lead to increased sludge and varnish, which could result in additional maintenance costs from plugged filters, and shorter oil life.

Shell has used its lubricants expertise to formulate new low-sludge-forming, zinc-based technology that is now available in its latest hydraulic oil: Shell Tellus S4 VE. This low-sludge-forming technology combines outstanding wear and oxidation protection with excellent sludge and varnish control. Shell Tellus S4 VE outperforms leading zinc-free oils in sludge tests while exceeding the former Denison standard and the current Bosch Rexroth and Eaton wear test limits by three, four and five times respectively.<sup>5</sup>

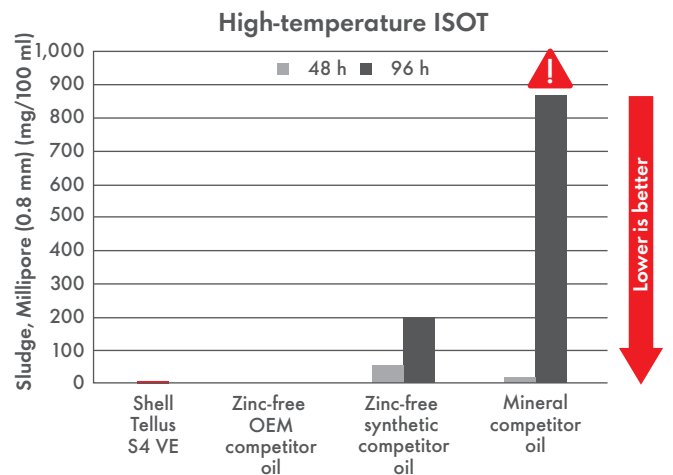
#### LESS SLUDGE

The new, zinc-based, technology oil passes sludge tests traditionally only met by zinc-free oils. In fact, it offers outstanding performance with 15 times less sludge formation compared with a leading zinc-free synthetic hydraulic oil in industry-standard tests (Figures 1 and 2).

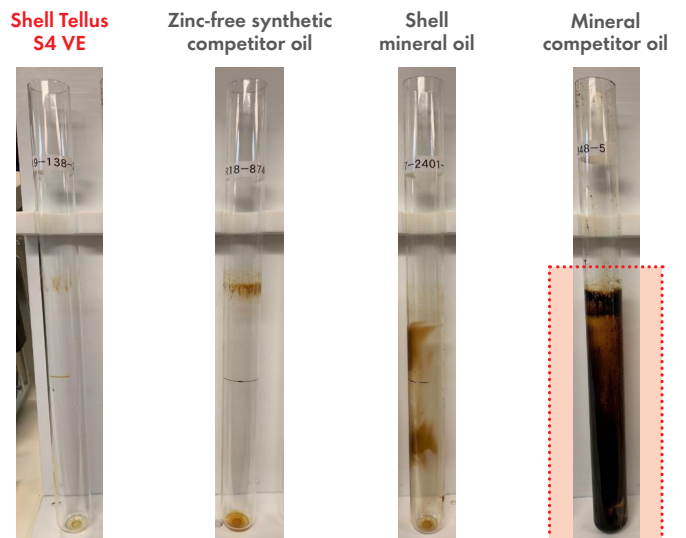
It is a similar story for varnish, which can lead to costly unplanned maintenance by causing system overheating, filter plugging, valve sticking, premature wear and pump failure. This latest formulation forms four times less deposits than a competitor’s mineral oil in Shell varnish formation tests (Figure 3).<sup>4</sup>

#### LONGER LIFE

Many modern hydraulic systems are designed for high-temperature operation. If an oil has poor thermal stability, it can break down under these conditions to form sludge, varnish and corrosive products that can lead to premature wear and increased maintenance frequency. In contrast, excellent thermal stability and corrosion protection can help to extend oil life, maintain good valve response, lower the likelihood of blocked valves and filters, and extend pump life.

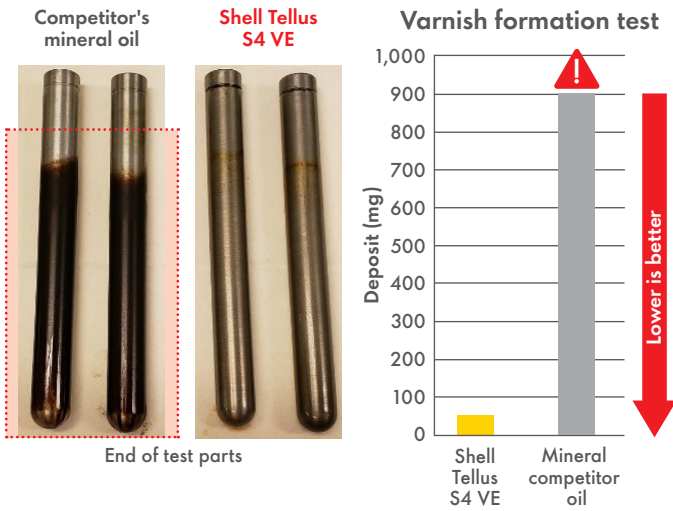


**FIGURE 1: Less sludge.** Zinc-based Shell Tellus S4 VE forms 15 times less sludge than zinc-free synthetic competitor’s oil in the 48- and 96-h, high-temperature ISOT (JIS K2514)<sup>2</sup>.

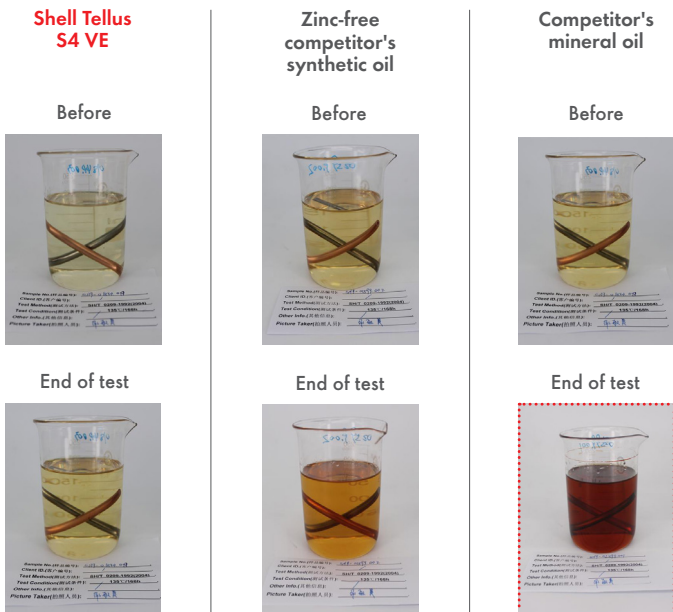


**FIGURE 2: Visibly clearer.** Shell Tellus S4 VE is noticeably clearer than a competitor’s zinc-free synthetic hydraulic oil following the dry TOST (ASTM D7873).<sup>4</sup> This test runs at severe temperatures (120°C) to help simulate typical hydraulic operating temperatures in the harshest summer conditions.

# THE NEW FORMULATION CAN HELP TO REDUCE THE TOTAL COST OF OWNERSHIP BY REDUCING SLUDGE FORMATION AND EXTENDING OIL AND EQUIPMENT LIFE.



**FIGURE 3: Less varnish.** Over 48 h, two 400-mL oil samples are kept at 195°C and have metal rods dipped in them for 3 sec and then taken out for 57 sec.<sup>6</sup> The steel rods are weighed before and after the test. This Shell test is designed to accelerate varnish formation. The rods in the Shell Tellus S4 VE had four times less varnish than those tested with a competitor’s mineral oil.



**FIGURE 4: Thermal stability.** In the Cincinnati Milacron thermal stability tests (ASTM D2070),<sup>7</sup> darkening of the oil is an indication of oxidation. By the end of this test, the new zinc-based technology oil was significantly lighter in colour than the competitors’ oils. In the test, oil is heated to 135°C for 168 h in the presence of steel and copper catalysts.

Superior thermal stability is visibly observed by comparing oils after the Cincinnati Milacron thermal stability tests<sup>7</sup> (Figure 4).

The new zinc-based technology oil also lasts more than 30% longer than zinc-free synthetic competitor’s oil in industry-standard oxidation tests<sup>6</sup> and has up to a 10,000-h TOST life, which is up to 8,500 h beyond typical equipment manufacturers’ requirements.<sup>3</sup> Although oxidation resistance does not equal oil-drain interval, it is a good indication of a hydraulic oil’s service life. Based on test results and field trials, the oil-drain intervals for the new zinc-based technology oil are expected to be up to 40,000 h for plastic injection moulding machines.<sup>8</sup>

The operational life for mobile equipment is based on the tough Bosch Rexroth A2F10 piston pump test (JCMAS P 045),<sup>1</sup> which evaluates the oxidation stability of hydraulic fluids for use in construction applications (Figure 5). Viscosity change, acid number increase and sludge build-up must each remain within the test limits after 500 h to pass. The new technology passed after 2,400 h, which would indicate an operational life longer than 9,600 h.

Actual oil-drain intervals will vary depending on the equipment used, the operating temperature and the maintenance practices.

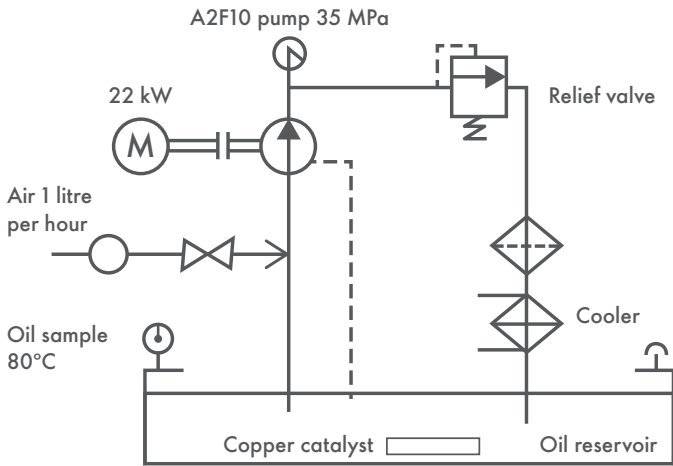
## DEMONSTRATED SAVINGS

The new formulation can help to reduce the total cost of ownership by reducing sludge formation and extending oil and equipment life. It can also increase hydraulic system productivity by up to 6% compared with a mineral oil.<sup>9</sup>

These total cost of ownership savings are not merely extrapolated from laboratory tests. In many examples, Shell technology teams have been able to help customers to identify and solve real-world hydraulic oil sludge and varnish issues.

In one example, an electrical appliance manufacturer based in Jiangsu Province, China, which owns 13 plastics injection moulding machines, was experiencing problems caused by blocked filters. The Shell technical team investigated and discovered an excess formation of sludge, which meant that the oxidation stability and filterability performance of the machines’ hydraulic fluid were ineffective. By switching to Shell Tellus S2 MX 46, the company no longer experienced blocked filters and was also able to extend the oil-drain interval from 8,000 to 24,000 h. As a result, it reported total annual savings greater than US \$125,000.<sup>10</sup>

This example is used because Shell Tellus S4 VE has yet to be in equipment long enough to share real-world savings. However, even bigger savings are likely for the zinc-based synthetic Shell Tellus S4 VE oil, made from GTL technology, as its results for oil life, sludge and varnish control are expected to be better compared with a mineral oil.



Pass-fail criteria of Bosch Rexroth A2F10 pump test

	UNIT	STANDARDS	
		JCMAS	OEM
		(500 h)	(1,000 h)
Change of $V_k$ 40	%	10 max.	10 max.
Change of acid number	mg KOH/g	2 max.	2 max.
Sludge (0.8- $\mu$ m millipore)	mg/100 mL	10 max.	10 max.

FIGURE 5: Bosch Rexroth A2F10 piston pump test [JCMAS P 045].<sup>1</sup>

### MORE CHOICE

Thanks to Shell’s new low-sludge-forming technology, customers now have a choice. They can use zinc-free oils or benefit from the latest low-sludge-forming, zinc-based technology. Indeed, the new myth-busting Shell Tellus S4 VE combines exceptional wear protection<sup>5</sup> with more than 15 times less sludge formation compared with a competitor’s zinc-free synthetic hydraulic oil (Figure 1).

Not all zinc fluids are the same. The performance of Shell Tellus S4 VE in key tests demonstrates its low sludge tendency, extended oil life, yellow metal protection and maintenance saving ability (Figure 4) as well as the all-important productivity improvement.<sup>5,9,10</sup>

Shell provides both zinc-based and zinc-free hydraulic oils. Contact your sales representative to discuss which oil is right for your equipment.

<sup>1</sup>Bosch Rexroth A2F10 piston pump test evaluates the oxidation stability of hydraulic fluid under high-pressure, dynamic conditions in situ. The test is part of JCMAS P 045. The oil temperature in the oil tank is 80°C and 1 L/h of air is supplied to the inlet pipe to cause cavitation in the pump. The JCMAS specification for change of viscosity and acid number and sludge is 500 h but the OEM requirement is 1,000 h.

<sup>2</sup>High-temperature Indiana stirring oxidation test (ISOT) JIS K2514. This test is typically a compressor oil test and favours zinc-free chemistry. However, it is a good indicator of sludge and varnish tendency. The test promotes the oxidation of the lubricant by blowing dry air in the presence of heat (165.5°C), and metal catalysts (copper and iron coils). After 48 and 96 test hours, the used oil samples were forced through a paper filter to examine the sludge build-up.

<sup>3</sup>The turbine oil oxidation stability test (TOST) (ASTM D943) measures the time an oil takes to reach a set acidity when heated in the presence of water, oxygen, copper and iron. Shell Tellus S4 VE was still within the limits when the test concluded after 10,000 h. The TOST is a measure of the hydraulic oil's oxidation stability in the presence of water, oxygen and copper and iron metals at an elevated temperature.

<sup>4</sup>Dry TOST test (ASTM D7873). This test is an indication of the sludge and varnish tendencies of a lubricant. The test measures the oxidative and thermal stability of the lubricant in the presence of heat (120°C) and metal catalysts (steel and copper coils) in the absence of water. Sludge levels are measured after a period of 1,008 hours. Measured using industry standard, Shell proprietary and internal competitor benchmarking tests.

<sup>5</sup>Shell Tellus S4 VE has 5 times lower wear compared with the Eaton Vickers pump test limit (Eaton E-FDGN-TB002-E). (Eaton Vickers 35VQ25 vane pump test ATS373.) Shell Tellus S4 VE has 3 times lower wear compared to the former Denison limit and current GB 11118.1 L-HV test limit. (Double pump test T6H20C, A-TP-30533.) Shell Tellus S4 VE has 4 times lower wear compared with the stringent Bosch Rexroth limit based on the pump piston weight loss. (Bosch Rexroth, RDE 90245 RFT-APU-CL Rig Test.)

<sup>6</sup>400 mL of each oil was kept at 195°C. Two samples per oil were used. Steel spindles were weighed and their masses were recorded. One steel spindle for each oil sample was reciprocally dipped into the oil for 3 s and brought out of the oil for 57 s. This procedure was carried out for 48 h. The spindles were left to dry and the spindle mass after the test was measured to determine the mass of sludge and varnish.

<sup>7</sup>Test Method Cincinnati Milacron, ASTM D2070-10. The Thermal Stability Test determines the ability of hydraulic oils to resist breakdown at high temperatures in the presence of copper and steel. A sample of the test lubricant and pre-weighed copper and steel test rods are placed in a beaker and heated at 135°C for 168 hours (1 week). At the end of this test period, the copper and steel rods are weighed and rated visually, and the oil is analysed for sludge and viscosity change.

<sup>8</sup>Based on Shell's technical experience with finished lubricants, additive chemistry and base oils, and field and laboratory testing. No guarantees. Follow your equipment manufacturer's recommended maintenance schedule and maintain cool, clean, dry conditions for the oil.

<sup>9</sup>Tests performed by the Milwaukee School of Engineering Fluid Power Institute run at 2,200 rpm with aeration using viscosity grade 46 fluids. Productivity relates to the volumetric efficiency of a formulation of Shell Tellus S4 VE when compared with a conventional, mineral oil fluid in standard hydraulic application under controlled conditions. The claim is based on test results in accordance with applicable industry standards and Shell protocols and methodology. Results may vary based on operating conditions and equipment.

<sup>10</sup>The savings indicated are specific to the calculation and site (an electrical appliance manufacturer based in Jiangsu Province, China, with 13 plastics injection moulding machines). These calculations may vary from site to site and from time to time, depending on, for example, the application, the operating conditions, the current product being used, the condition of the equipment and the maintenance practices.