



## ENERGY SAVING AND WASTEWATER PROCESSING EQUIPMENT OPTIMIZATION USING INORGANIC FULLERENE-LIKE TUNGSTEN DISULFIDE

Patented IF-WS<sub>2</sub><sup>®</sup> nanoparticle-based concentrate reduces wear, heat, friction and overall energy use of mechanical aerators.

Wastewater treatment facilities are vital to protecting human health and reducing our impact on the environment. However, effectively disposing waste and preparing effluent for post-treatment places a significant burden on our nation's infrastructure. An estimated 2 percent of total U.S. electricity goes towards moving and treating wastewater.

At the plant level, sludge handling is a perfect example of the enormous energy wastewater treatment facility operators can expend on just one process. Each year, publicly owned treatment works generate 8 million tons of sludge, and aerators — an important sludge-processing component — can account for up to 60 percent of the energy used in wastewater treatment systems. Not surprisingly, wastewater plant managers are constantly investing in equipment upgrades and maintenance with a focus on improving energy efficiency.

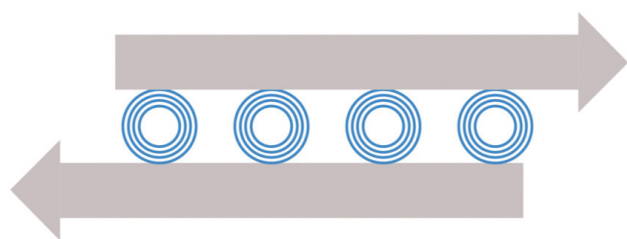
## IF-WS<sub>2</sub> NANOTECHNOLOGY IMPROVES ENERGY EFFICIENCY AND MANY OTHER PERFORMANCE CRITERIA

All machines, including mechanical aerators, need lubricants that are not only lubricious but can also withstand wear, heat and friction. These conditions must be controlled in order to decrease energy waste. Novel nanosized particles of inorganic fullerene-like tungsten disulfide (IF-WS<sub>2</sub>) are now used to create cutting-edge industrial lubricant concentrates. The IF-WS<sub>2</sub>-based products are especially formulated to reduce energy consumption, lessen wear and friction, lower operating temperatures and protect equipment from pressure and shock.

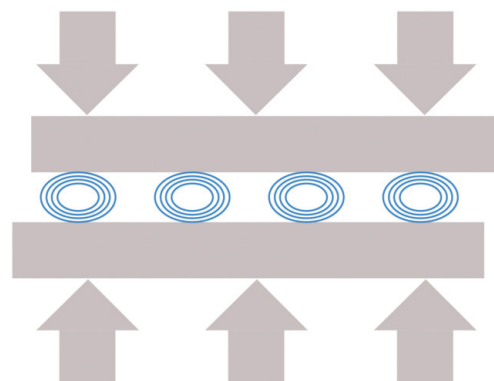
IF-WS<sub>2</sub> formulated concentrates outperform conventional additives in a wide range of features and benefits. NanoGuard IC-3101X — developed for use in all industrial gearboxes — may bring unmatched tribological benefits to mechanical aerators in wastewater treatment facilities.

NanoGuard IC-3101X turns standard lubricants into super-performing ones. It may improve the performance of lubricants by lowering friction coefficient to 0.03, reducing wear from 25 to 37 percent and temperatures up to 27 percent. Lowering friction contributes to 5 to 8 percent energy savings, and extends maintenance intervals by a factor of 2.5. For example, after introducing NanoGuard IC-3101X, one set of mechanical aerators saved over 226 MW of electricity, and another site with industrial gearboxes has saved over 1,100 MW on two machines per annum.

### BENEFITS OF IF-WS<sub>2</sub> NANOPARTICLES' SPHERICAL STRUCTURES



The nanoparticles' spherical geometry creates a ball bearing effect.



The spherical, hollow cage structure also gives nanoparticles the elasticity to withstand dynamic and static loads.

NanoGuard IC-3101X is easy to apply. To start saving energy and optimizing ROI, just add the required dose into the gearbox directly. One municipal wastewater treatment plant manager, whose \$6,000 investment in six months has saved him \$40,000 in electric bills, said that he “never thought that saving energy could be that easy — simply by servicing my gearboxes.”

IF-WS<sub>2</sub> is the result of work by Dr. Reshef Tenne of the Weizmann Institute of Science in growing fullerene-like WS<sub>2</sub> nanoparticles and nanotubes. The award-winning research led to the discovery, synthesis and characterization of novel closed inorganic nanostructures with numerous potential commercial applications including as industrial lubricants. Today, Nanotech Industrial Solutions (NIS) produces the IF-WS<sub>2</sub> IC-3101X industrial gear concentrate — which proudly carries Bluesea Technologies' NanoGuard brand name — for use in industries such as wastewater treatment, paper and pulp, milling, mining, quarries, steel production, transportation and others.

## SUMMARY OF NANO GUARD IF-WS<sub>2</sub> IC-3101X FEATURES AND BENEFITS

NanoGuard IC-3101X is formulated to reduce energy consumption by protecting gear compartments against wear, friction and extreme pressure. This IF-WS<sub>2</sub> formulated product is based on nanoparticles that create a protective tribofilm, which refurbishes surfaces. For end-users, this translates to unmatched performance and the following benefits:

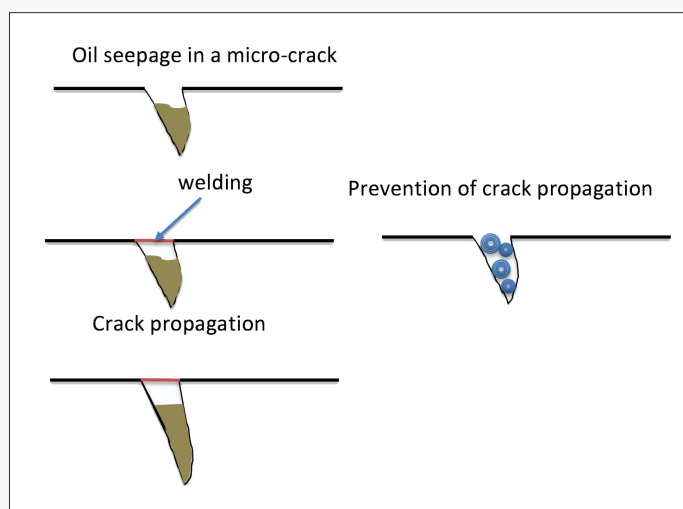
- **Energy reduction.** As a result of the dry lube effect, aerators can achieve energy reductions from 5 to 8 percent, and consistent average reductions of 5 percent have been reported across a large roster of aerators.
- **Wear reduction.** IF-WS<sub>2</sub>'s surface protecting properties have been shown to decrease wear by 20 to 37 percent. Less wear means longer equipment life, maintenance cycles and cost of ownership.
- **Shock absorbance.** Reduced metal to metal contact gives NanoGuard concentrates better resistance to mechanical shock, minimizing noise from gearboxes and other mechanical components.
- **Temperature reduction.** NanoGuard IF-WS<sub>2</sub> IC-3101X can reduce operating temperatures by up to 27.5 percent.
- **Low coefficient of friction.** IC-3101X offers a low coefficient of friction of 0.003.
- **Extended equipment life and less downtime.** Less friction and wear lowers the risk of costly downtime or equipment malfunctions. Service requirements can be reduced by up to 2.5 times.

Additional features and characteristics of IC-3101X include:

- Reduced seepage of oils into cracks, minimizing hydraulic pressure and crack growth.
- Reduced vibration and mechanical noise.
- High performance at a low treat rate.
- Improved operational costs.
- Suitable for use with all synthetic, semi-synthetic and industrial lubricants.

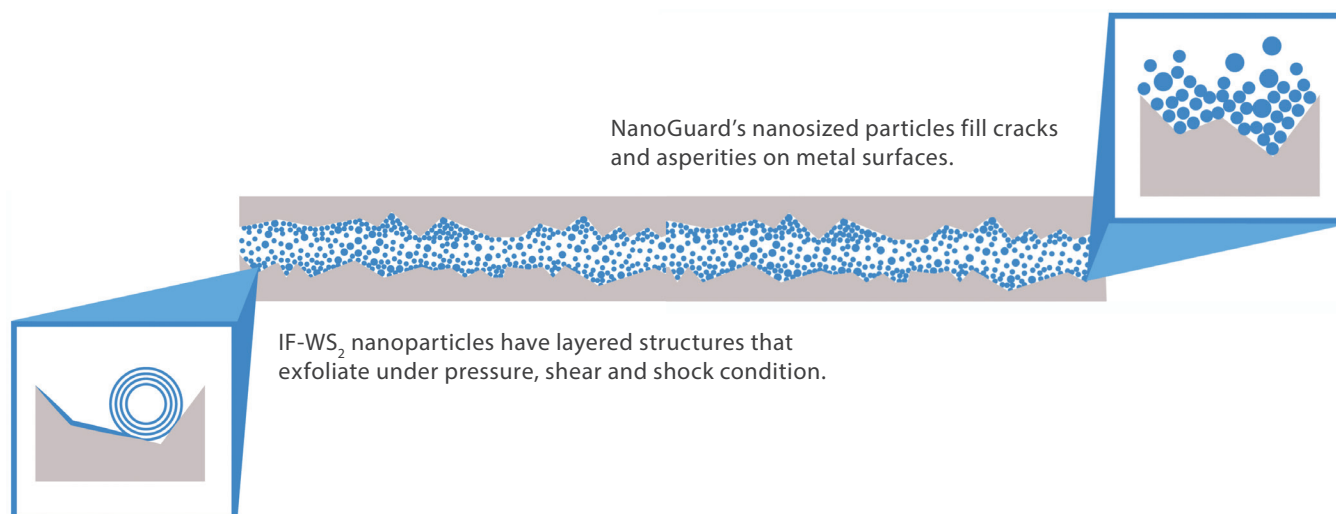
Implementing NanoGuard IC-3101X concentrate into your plant's gear equipment is simple:

- Record amp measurements before application.
- Measure the appropriate dose. (Please note: recommended initial dose is 8 percent.)
- Apply directly into the lubricant reservoir.
- Turn on your equipment.
- For recording post-application amp measurements, run the equipment for at least one hour.



The nanoparticles can reduce oil seepage into the crack and prevent crack propagation.

## IF-WS<sub>2</sub> NANOPARTICLES' SURFACE-SMOOTHING EFFECTS

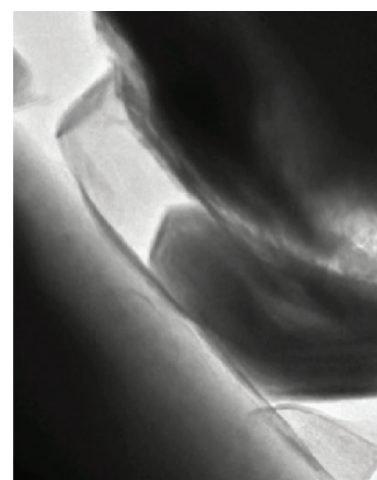


## SPHERICAL MORPHOLOGY ADDS CONTINUOUS SURFACE RECONDITIONING PROPERTIES TO LUBRICANTS

Legacy additives such as friction and viscosity modifiers or anti-wear additives, while helpful, only provide partial benefits when used in mechanical equipment. They exhibit limited operating temperatures and moderate performance under extreme pressure. Traditional products might be sufficient for conventional engines, but they offer questionable efficacy for demanding industrial applications where high loads, shock, pressure and temperature are standard.

A closer look at the IF-WS<sub>2</sub> morphology reveals why NanoGuard IC-3101X performs very well under harsh conditions. Multilayered, inorganic fullerene-like tungsten disulfide submicron particles — in sizes from 120 to 280 nanometers — act as nanosized bearings that produce a rolling effect to reduce friction between surfaces. The unique structure gives IF-WS<sub>2</sub> particles the high elasticity needed to resist hydrostatic forces and inhibit surface deformation. Under pressure and wear, their onion-like layers undergo an exfoliation process. As the spherical layers are released, they form a tribofilm that fills up asperities, cracks and irregularities, thereby reconditioning metal surfaces while preventing micropitting, spalling, crack propagation and growth.

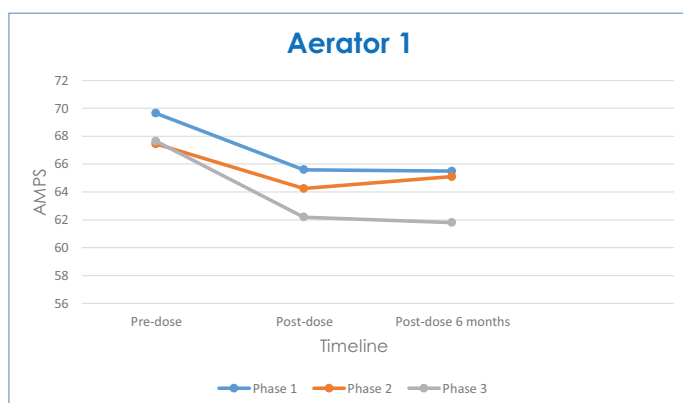
The nanoparticles' spherical morphology and layered structure promote surface reconditioning and differentiate IF-WS<sub>2</sub> concentrates from traditional additives whose chemistry provide moderate performance. Those common additives consist of particles with platelet-type structures whose large and irregular geometries do not allow for effective rolling friction or shock absorption. They can also be compromised by high wear in high-speed applications and therefore have limited utilization.



Exfoliation of IF-WS<sub>2</sub> particles reduces friction.

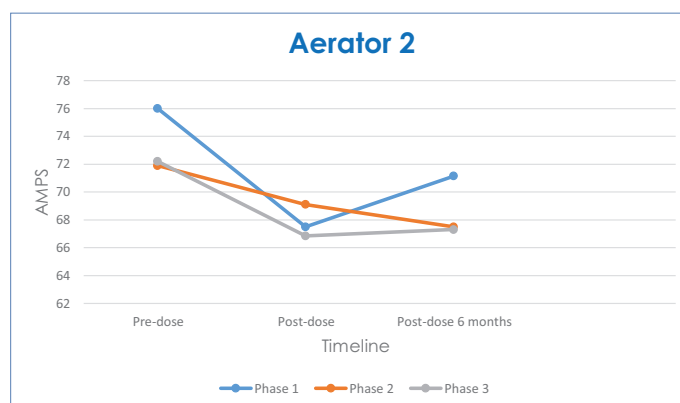


## AMP DRAW REDUCTIONS OVER TIME



TIMELINE	PHASE 1	PHASE 2	PHASE 3
PRE-DOSE 11-14-2018	69.65	67.45	67.65
POST-DOSE 11-14-2018	65.60	64.25	62.20
FOLLOW-UP 05-02-2019	65.50	65.10	61.80

**AVERAGE AMP SAVINGS POST-USE: 6.2%**



TIMELINE	PHASE 1	PHASE 2	PHASE 3
PRE-DOSE 11-14-2018	76.00	71.90	72.50
POST-DOSE 11-14-2018	67.50	69.10	66.85
FOLLOW-UP 05-02-2019	71.15	66.85	67.30

**AVERAGE AMP SAVINGS POST-USE: 7.7%**

## MECHANICAL AERATOR APPLICATION RESULTS FROM A WASTEWATER FACILITY

Imagine how much energy an average aerator uses. Some estimates say that aerators account for up to 50 percent of total energy consumption in a modern wastewater plant, and keeping energy costs in line is a challenge. Recently, one Bluesea Technologies customer began using IC-3101X in the gearboxes driving their mechanical aerators. Almost immediately, amp draw data indicated significant energy savings.

The tables and graphs above provide a snapshot of the performance of two aerators using IC-3101X. The tables show amp pre-dose and post-dose measurements as well as follow-up readings for three power phases. The two aerators achieved amp reductions in all three phases resulting from treatment using IC-3101X — including a Phase 1 reduction of 8.5 amps for Aerator 2 — with average amp savings of 6.2 percent for Aerator 1 and 7.7 percent for Aerator 2. Six months after the initial application, the aerators' amp draw figures were still similar to the initial amp reductions, demonstrating IC-3101X's long-term effectiveness when used in wastewater processing equipment.

According to Bluesea Technologies, wastewater treatment facilities may save between 5 and 8 percent of their total energy use, although a 10 percent reduction is also possible.

## RECONDITIONING TEST PERFORMANCE

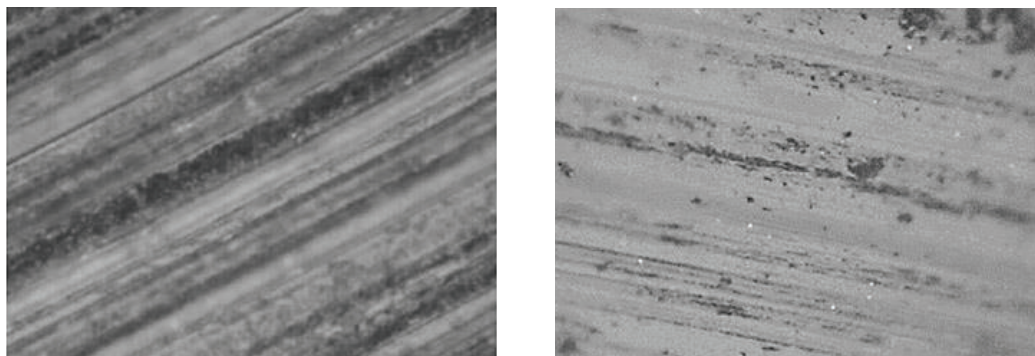
The IC-3101X concentrate has undergone third-party testing to verify the productiveness of IF-WS<sub>2</sub> particles as lubricant enhancement. The auto-reconditioning tests were conducted using a four steel-ball test bench and gear-lubricated testbed to gauge IF-WS<sub>2</sub>'s performance in reconditioning the metal surface of gears. The Auger electron energy spectrum images from the tests show a damaged surface (below, left) and the results from applying IF-WS<sub>2</sub> nanoparticles to the same damaged surface (below, right). The tribofilm that is released under extreme pressure forms a protective layer over the abrasive surface, demonstrating that the IF-WS<sub>2</sub> particles repaired the interior elementary distribution of the abrasive surface. The following conclusions were drawn after the auto-reconditioning tests:

- IF-WS<sub>2</sub>'s refurbishing properties enhance gear performance. IF-WS<sub>2</sub> forms a protective layer on metals, reducing friction, thus lowering temperatures.
- IF-WS<sub>2</sub> offers a low coefficient of friction. The tests revealed a testbed surface so smooth that slippage easily occurs between layers.
- IF-WS<sub>2</sub> extends the lifetime of oil and equipment up to 2.5 times while maintaining consistently high performance.
- IF-WS<sub>2</sub> particles have low chemical reactivity, low toxicity and high metal bonding capacity.

Tests have also been carried out on two gear systems working in the same environment at a cement plant. When added to the conventional oil, IF-WS<sub>2</sub> IC-3101X demonstrated:

- Much lower wear, in patch tests, versus gears using only conventional oil.
- Less pronounced acid formation and base oil degradation.

In both of the tests and environments described above, NanoGuard IC-3101X proved the ability to recondition and smooth surfaces.



These Auger electron energy spectrum images show a damaged surface (left) and a surface dosed with NanoGuard IF-WS<sub>2</sub> IC-3101X (right). IC-3101X has formed a protective film on the metal surface, resulting in reconditioning of the surface.

## APPLICATION RESULTS: FINAL DRIVES IN MINING INDUSTRY

NanoGuard IF-WS<sub>2</sub> IC-3101X can be applied wherever oil and grease are used, making this additive an attractive option for a variety of applications across several industries, including wastewater treatment plants. A recent analysis of a final drive application in the mining industry demonstrates reduction in iron after applying NanoGuard IF-WS<sub>2</sub> IC-3101X.

The excessive presence of iron in the sample indicates significant component wear and could lead to premature failure of a geared mechanism:

Each point on the graph shows the amount of iron buildup for a given sample.

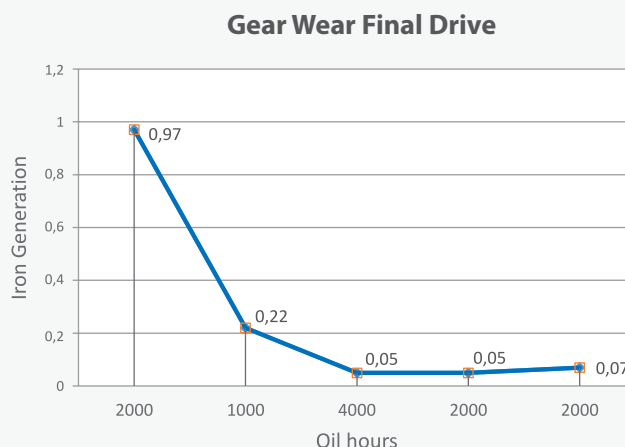
**Sample 1.** The 0.97g measurement of iron generated per hour becomes 38 kg of iron over a 40,000-hour final drive life, which is enough to cause premature failure. The oil is changed (same brand and grade) and NanoGuard IC-3101X is added.

**Sample 2** was taken 1,000 oil hours later. The oil generated 0.22g of iron — a 78 percent reduction in iron generated per oil hour. This wear rate over a 40,000-hour component life represents 9 kg of iron generation.

**Samples 3 and 4** were taken at 4,000 hours and a further 2,000 hours, for a total of 6,000 hours at an iron generation rate of 0.05g per oil hour. Iron generated over the 6,000 hours was 300g or equivalent to 2 kg over a 40,000-hour component life, indicating a 77 percent reduction from the previous period where there was no NanoGuard IC-3101X in the oil.

**Sample 5** was taken 2,000 hours after an oil change with un-dosed oil. It shows increasing iron presence.

This field trial is a clear demonstration of NanoGuard IC-3101X's superior anti-wear properties thanks to a unique inorganic fullerene-like tungsten disulfide formulation.



## ENERGY SAVINGS AND IMPROVED PERFORMANCE FOR DEMANDING PROCESSING APPLICATIONS

Reliable equipment is essential to improving energy efficiency at wastewater treatment facilities; plant managers seek alternatives to conventional lubricants and additives in an attempt to optimize machine performance. IF-WS<sub>2</sub> inorganic fullerene-like tungsten disulfide nanoparticles, when introduced to lubricants, respond to pressure by producing a protective film that reduces wear, heat and friction while refurbishing surfaces. All of the above translates into substantial energy savings.

IF-WS<sub>2</sub> nanotechnology has shown proven results in both independent laboratory tests and real life applications. NanoGuard IC-3101X delivers remarkable benefits when added to oils and greases in demanding processing applications like mechanical aerators. The energy savings made possible by uninterrupted and reliable operations means wastewater treatment plant managers can achieve shorter downtimes, higher productivity and ample overall cost reduction.

For more information about NanoGuard IF-WS<sub>2</sub> IC-3101X concentrate for industrial applications, visit <https://superlube.energy>.