WHAT'S OLD IS NEW, AGAIN: ELECTROSTATICS AND VARNISH, NOW WITH IOT

Written by IoT Diagnostics
May 2019

When it comes to equipment reliability, context is everything. Would you agree that the distance between people and the problems they face is measured by context? If you're hesitating, consider asking a fellow reliability engineer, maintenance technician, or operations director about a process or asset that has failed – you're going to hear a story, even down to characters (who or what's at fault), setting (timing, environment), and plot (what happened). These pieces of information create the context that helps us tie meaning to the issues we run into on the shop floor.

There is a familiar antagonist for machine downtime – poor fluid quality from poor fluid management. Rarely a happy ending, fluid left unprotected and undermanaged in the production process can create varnish, and the spiral continues: varnish infects our oil and our components and systems; these components and systems wear faster, and predictable uptime is replaced with fire-fighting failing assets and processes.

Methods of combatting varnish have been around for decades, all with varying degrees of success. While this paper will touch on some of these methods, including: changing oil, high velocity flushing/chemical flushing, agglomeration, and additives/one-shot treatments, the primary focus is to re-evaluate electrostatics as a trusted means of eliminating varnish – to discuss the emergence of electrostatics decades ago, it's dormancy, and now, it's re-emergence as a helpful tool. We will look to uncover this journey, and pose the question to whether the Industrial Internet of Things has proved to be a boon for this under-utilized technology, and ultimately, can varnish be better monitored and controlled with IoT-driven solutions that are entering the market?

VARNISH 101

Varnish is a generic term for an oil sourced contaminant – a degradation product of the oil. Over 50 different varnish chemistries have been identified with a wide range of colors, deposits, and effects on machinery.

Varnish is created by polymerized oxidation oil products through stress. This stress can be created by heat, extreme pressure, static discharge or water. The oxidation of the oil creates molecular strands of free-radicals. These free-radicals agglomerate together to create soluble varnish. This varnish is maintained and controlled by the antioxidants in the oil (Zinc, ZDDP's, Etc.). These antioxidants contain the free radicals and soluble varnish under normal conditions but once the oil is stressed the free radicals develop and create the varnish. Over time the free radicals will keep regenerating, producing more and more soluble varnish. Once the soluble varnish gets beyond the control of the antioxidants "beyond the point of saturation" then the oil becomes saturated. The soluble varnish becomes insoluble varnish -- soft varnish particles in the oil. At this point the antioxidants are tied up by the soluble varnish and have no controlling effect causing the insoluble varnish to increase in population.

Varnish can negatively impact your fluid in multiple ways:

1. **Heat Transfer:** Varnish can become an insulator on the heat transfer surfaces (heat exchangers) which will increase the oil temperature and accelerate insoluble varnish development. An 18 degree increase in the oil temperature can increase the varnish production by double. If the heat transfer surfaces are covered with varnish film, it will decrease the cooling system efficiency. See Figure 1 on scale/energy loss. It takes twice as much energy to cool the water due to poor thermal transfer.
2. **Energy loss:** You can have significant energy loss due to increase in amperage and power consumption. When the varnish starts to adhere to the pump, valve and cylinder surfaces the energy consumption increases due to the varnish creating friction on the equipment surface. This can impact production and decrease in product yield. Typically, if varnish is creating issues with pumps, valves and cylinders this will impact production due to the inability to run the machine at full capacity. This effect can also increase the temperature on this equipment as well and cause premature failure. When you can remove the varnish from the surfaces you are able to keep equipment cool, increase production, and decrease energy consumption.
3. **Friction:** When insoluble varnish develops, the particles layer themselves on the surfaces of the pumps, cylinders, valves and reservoir walls. This varnish layer is a sticky substance which does not hold the same lubrication characteristics of new oil. The sticky substance that layers itself on the surfaces creates resistance on the moving components inside pumps, valves, cylinders. The resistance created impacts the energy used on the machines equipment and will increase energy consumption, as more energy is needed to move the internal components. The varnish film will also affect nonmoving components such as heat exchanges. The varnish can layer itself on the heat exchange surfaces and create poor heat transfer and more energy cost to heat or cool the heat exchange fluid.
4. **Wear:** Varnish will accelerate the wear of internal components on the pumps, valves and cylinders. When the varnish layers itself on the surface it also attracts any hard or soft particles that are suspended in the fluid. The varnish film becomes like fly paper and the particles are then encapsulated in the varnish film as it layers itself on the surfaces. The somewhat sandy film can do significant damage to the moving components in the equipment. In addition to the contaminated film layer this will also increase the particles in the fluid due to wear from the sand like film. With ongoing wear, your equipment will become less efficient and could lead to catastrophic failures.

There are several ways to remove the insoluble varnish from the oil.

1. **Electrostatic**: These are systems that use a positive/negative charge in conjunction with a dielectric media to attract the non-polar particles (+/- charge). These non-polar particles are attracted or repelled depending on the particle charge. Insoluble varnish particles are non-polar particles and can be removed in this manner. Keep in mind that some of the contamination particulates that are in the oil are also non-polar and can be removed down to a .50 micron with this same process.

2. **Shearing:** This process uses a depth media ran at a higher velocity through the filter. This shears the oil, in turn, charging the oil. When the oil is charged, it agglomerates the varnish and particulate downstream of the depth media filter. The agglomerated varnish particles go through the hydraulic system back to the depth media filter where it is collected in the filter. The down side to this process is that if the filter is loaded and can no longer trap particles, or the filter has areas of bypass, or is in bypass, the particles continue to agglomerate to large particles which can create issues downstream in the hydraulic equipment. For example, if a hydraulic servo valve has the clearance of three micron or less, anything larger than three micron will get trapped in the spool chamber and eventually cause failure.

3. **High Velocity Flush:** This method uses varnish mitigation systems that are like the shearing equipment which agglomerates the insoluble varnish particle and collects them in the depth media filter. Depending on the application, chemical additives that address the insoluble varnish can be added as well during this process. Companies can typically perform this service in 24 hours per reservoir. The problem with this process is that it may not address the varnish that is on the surfaces of the pumps, valves, cylinders, reservoirs, and other hydraulic equipment in the system that the varnished oil contacts the surfaces. This method can strip some additives which have to be re-added to the system and come at an additional cost. This is a temporary solution and the varnish typically returns over time.

4. **New Oil:** This process is typically recommended by the oil suppliers. This is a very expensive solution and does not address all the varnish issues. It is also important to note that dumping the oil does not address the varnished surfaces.

UNDERSTANDING ELECTROSTATICS

Electrostatic technology has been around for almost 40 years. Electrostatics use the charge of the particle with the electrical field inside the collector to remove all 3 particle charge types (positive, negative, neutral). The electrical field (positive or negative) is generated across electrodes with dielectric media in between those electrodes. The particles are attracted or repelled into the dielectric media depending on the particle charge. The neutral particles are removed through dielectrophoretic which is caused by non-uniform electric field across the two electrodes. The non-uniform field is created by using the dielectric media with two parallel electrodes on opposing sides. The dielectric media takes the uniform electric field that is generated by the electrodes and makes it non-uniformed. This allows the neutral particles to be entrapped into the media with the positive and negative particles. Particle profiles from solids to deformables (gels) are captured across the electric field into the dielectric media. These particles can range from 100 um (micron) down to .50 um (micron). For additional information, reference the research articles of Akira Sasaki and Shinji Uchiyama.

FIELD USE OF ELECTROSTATICS, WITH AND WITHOUT IOT

Let’s revisit the opening question – is the Industrial Internet of Things the key to rediscovering the power of electrostatics for varnish elimination? Consider the context within these next use-cases.

Some years ago, a large midwestern surface company was in great need for fluid quality management. They were stuck in a myriad of failure modes, unplanned downtime, and was, at least, open to the suggestion that varnish could be a major culprit. It didn't take long to zero-in on the problem, both qualitatively and through color patch samples taken from the source. First, there was an admission that fluid quality management wasn't even on their radar and was nowhere to be found on the PM checklist – their motto was more "until death do us part" with their reliability program – run it into the ground and when it breaks, replace. Secondarily, a color patch sample taken from their fluid and sent to an independent lab was, jokingly, awarded "the worst fluid ever sampled" by the independent lab! Its color appeared to be a mix of dark-roast coffee and chocolate fudge; not good (See Figure 2). At the time of the sample, their ISO 4406 levels were at 23/20/13. With such a harsh reality check, they agreed to deploy an electrostatics system for mitigation. Within less than 30 days, the electrostatics system had reduced the ISO 4406 levels down to 9/8/7; below Servo quality fluid. The next color patch sample reflected and confirmed the success – their fluid had been cleaned and all varnish was virtually eliminated from the system. And yet, less than two years later, the same issues had returned, and the electrostatic system was nowhere to be found. What happened?

The answer is not definitive, but the dominating belief is that the electrostatics deployment lacked a data narrative. You see, this use-case was captured back in 2015-16, before the Internet of Things was readily available. The only "data" associated with the application included the color patch testing and lab results, the experiential change on-site, and a steno-pad notebook that penned the "trending" change of ISO 4406 levels, taken by-hand, at strategic periods through the deployment.

There are some potentially glaring issues with each of these "data points": often lab reports and paper slips are only briefly reviewed, if at all, and then quickly shoved in a pile, or a file, likely never to be consulted again. The incredible rate of varnish elimination via the electrostatics was reduced to hastily scripted penmanship on a single page inside a 200-page notebook. Notebooks are also easily discarded and difficult to showcase to a larger audience. Since all this data was collected at a moment in time, the ultimate challenge proved to be too much – the primary contact at the company moved on and took the radical change narrative with him. It was back to square one with a new cast of characters, with new problems to address.

Flash forward 18 months to 2017, where a similar issue was plaguing a global plastics injection molding company. It was shared that the number one issue at the company, discussed weekly on an international call, was asset failure and production performance issues. Once again, electrostatics technology was deployed, only this time, with IoT-connectivity, generating a digital footprint of performance (See Figure 3). Both the service contractor and the customer could watch the data to determine success. As they both watched the initial plummet of iso particle levels, the customer called the service company to celebrate the success. Yet, as you can see from the trend diagram in Figure 3, after a few days of running, the particle levels seemed to be reintroduced into the system. The customer called again, disappointed and frustrated in the poor performance, believing they were back to the drawing board. The service contractor capitalized on this opportunity to educate the customer and explain, using the shared trend chart, what was happening. They explained that with electrostatics, the first target is the insoluble varnish inside the fluid, which is showcased in the initial rapid drop in iso particles. After the insoluble varnish is removed, the electrostatics system then begins to target the varnish that has collected all along the substrates of the system, and therefore pulling these particles back into the fluid, causing a peak return to the higher iso particle levels. They encouraged the customer to standby and watch the change over the coming weeks. The project ended in success. And again, as the project concluded, a staffing change at the customer left the success in limbo, but with the digital data stored and still running, the new staff was able to get connected into the project faster and see the justifiable change in quality with completely undisputed, quantitative data.

In 2018, another maintenance director at a production plant in the Midwest was cycling through oil too quickly with a tightening budget and failing assets. A local service company working in another part of the plant was made aware of the issue and suggested that electrostatics may be able to "save" the next oil dump and replacement. The Director was skeptical to say the least. He'd tried about everything but decided to approve a run of electrostatics. Within 14 days, the fluid that he was about to replace went from 20-18-17 to 9-8-7 (See Figure 4 for latest snapshot of data) on iso particle levels. Not only did the local service company prove to be heroes and empowered them to do more business with this customer, the maintenance director now had a better data narrative to hold his oil suppliers more accountable, as well as his own PM program. He finally had a stable baseline to start from and adhere to with IoT-connected fluid.

IS THE INTERNET OF THINGS THE MISSING PIECE?

As a part of this article, we have explored the harsh effects of varnish on production assets and processes. There has also been a strong justification made that electrostatic technology is a proven and viable method for mitigation, among other tactics. The key takeaway then, is showcasing how impactful a steady stream of fluid data can be for the following reasons:

1. **Accountability for suppliers and service contractors:** Are the new fluid shipments at the highest quality upon delivery? Is your fluid service company providing, now measurable, improvements to your fluids? What about other components?
2. **Internal Accountability for PMs**: With a digital baseline and a steady flow of data, the timing, personnel, and practices of PMs can be massaged and dialed in for highest impact.
3. **Timeless preservation:** With data storage, significant events and best practices can be easily recalled under track & trace protocols, regardless of staffing changes, vacations, supplier changes, etc.
4. **Visible impact:** Attaching a digital data flow to technology like electrostatics proves the value beyond a written or spoken sales pitch, by showing rapid decrease in iso particle levels, and the process of attacking varnish attached to component surfaces.
5. **Mitigation comparisons:** With a connected fluid quality program, you can determine your best courses of mitigation by setting rate-of-change precedents. You can pit mitigation tactics against each other to determine the best fit for your needs.
6. **Remote monitoring and data distribution:** Fluid quality data can be easily shared among decision makers to increase speed and cost justification for projects.
7. **UPTIME:** The culmination of all the above values. Understanding your fluid's health minute-by-minute can be your first alert for critical issues that are likely first discovered within your fluid. This eliminates your downline issues with bearings, seals, etc.

We opened this paper discussing the importance of context in your maintenance and reliability practices. Now, in 2019, connected fluid quality is more readily available than ever before and an invaluable tool to create context inside your PM programs. If you need an impact project to justify IoT in your maintenance and reliability practice, consider connected electrostatics with a digital data stream showing measured performance improvements in your fluid. If possible, consider a cellularly connected electrostatics unit for rapid installation while you work with the local IT department during a pilot/trial phase for any future, scaled IoT deployments. Beyond a successful deployment of electrostatics, pay attention to the market, as varying IoT-Enabled fluid monitoring solutions are ready to keep your baselines healthy.

To get moving on eliminating varnish today, electrostatics with IoT just may be your old dog, now with some new tricks.

Consider units like the Estat™ to help eliminate varnish. https://www.iotdiag.com/estat/

Contact Mike Hoskins, Director of IoT Applications, for more information on varnish, electrostatics and connected fluid quality: mhoskins@iotdiag.com

About the Author:

IoT Diagnostics™
Connecting Prediction to Production

IoT Diagnostics
Cincinnati, Ohio
844-786-7631
info@iotdiag.com
www.iotdiag.com

IoT Diagnostics is part of an ISO 9001:2015 family of companies.

We believe that every industrial user around the globe deserves a chance at solving a problem before it happens. We're creating reliability with IoT.

EFFECT OF SCALE ON ENERGY REQUIREMENTS

Compiled from data from U. S. Bureau of Standards and University of Illinois

Scale Thickness	% More Energy Needed
1/32 inches	8.5
1/25	9.3
1/20	11.1
1/16	12.4
1/8	25.0
1/4	40.0
3/8	55.0
1/2	70.0

Figure 1 Above.

FIGURE 2. Above.

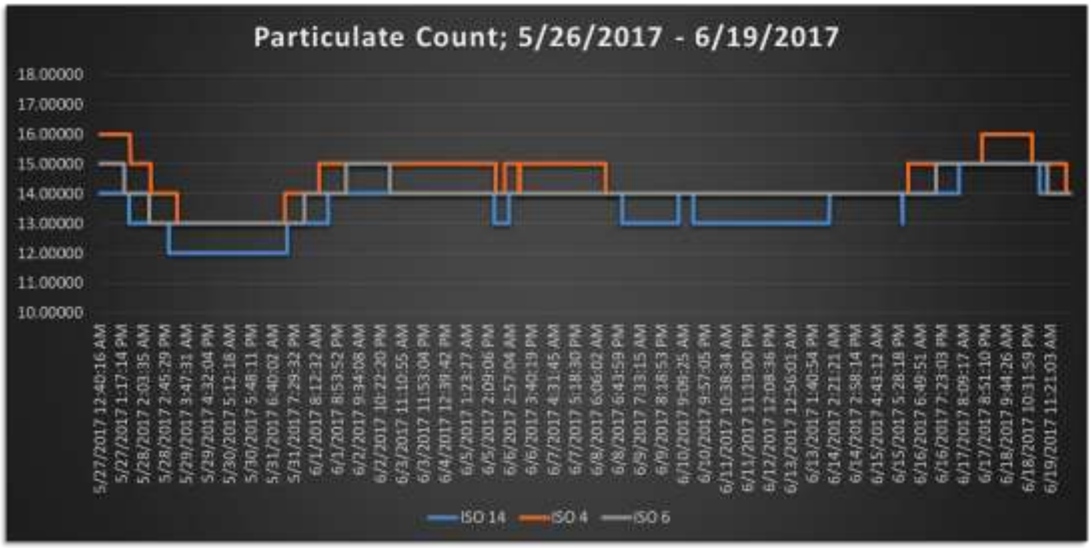

FIGURE 3 Above.

FIGURE 4 Above.