Industrial Manufacturing Traceability

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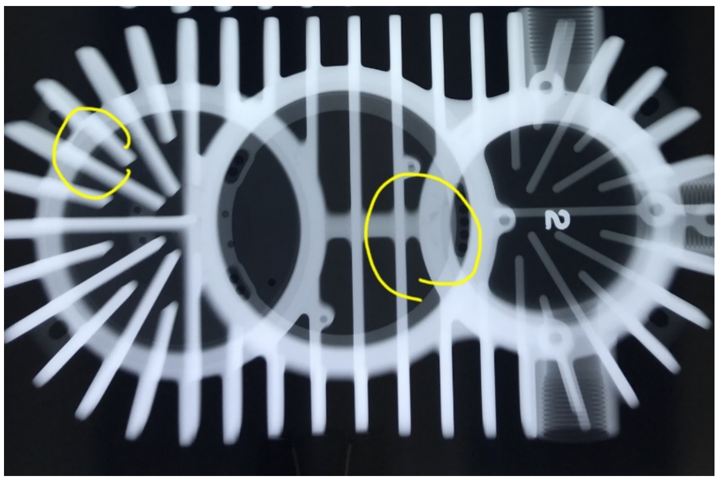

Image 1: XRay of an explosion proof light fixture

Image 2: Aluminum housing of an explosion proof light fixture

Important lessons in traceability in manufacturing supply chain - what to avoid, best practices and future blockchain and molecular tracing trends

Traceability is important. It's why manufacturing standards like ISO exist, so that customers can have assurance that accredited companies meet minimum quality standards. In a global economy where parts can come from suppliers located around the globe, traceability is more important than ever. The quality standards of one manufacturer in one country may be quite different from that of another manufacturer in another country. Without global standards, buying parts can be like spinning a roulette wheel. With the advent of conflict resources such as "blood diamond" and conflict minerals such as cassiterite (for tin), wolframite (for tungsten) or coltan (for tantalum) entering the marketplace, traceability becomes a necessity for political and ethical reasons as well. And with the growing importance of sustainability, new standards that measure ecological footprint, circular economy and sustainable growing and harvesting are already beginning to appear such as the Forest Stewardship Council's FSC certification for sustainably harvested timber or the cradle-to-cradle C2C certification. From illegal logging to pesticide laden food products, knowing what resources came from where, and how they were extracted is becoming an increasingly important supply chain management issue in an age of social and ecological upheaval. Nemalux specializes in manufacturing of industrial luminaires and has learned important lessons of traceability in the lighting industry. Manufacturers have to play a proactive, pre-emptive role in the quality assurance of their products or risk products falling out of specification, brand damage, expensive retrofit solutions and costly manufacturer product recalls.

In the early days of our company's entry into the global marketplace, a number of scenarios emerged that highlighted the need for traceability and spot checks to ensure that specified materials and material properties of components were being met. In the course of vetting new oversea vendors, our processes exposed a number of suppliers who misrepresented themselves. However, even amongst the honest vendors that are shortlisted, their manufacturing processes can suffer poor quality control issues, resulting in end products that do not meet their original specifications.

Technology is continuously evolving to meet the challenges of traceability. For example, Cogniscan, a leading Track, Trace and Control (TTC) solution provider in electronic manufacturing that has evolved a new solution to trace LEDs in PCB manufacturing. The problem stems from a unique trait of manufactured LEDs. Each reel of LEDs that comes from a manufacturer has a unique part number, but also has a unique BIN (Brightness Index Number). This production variation is both well known and unavoidable in current LED manufacturing processes. In many applications such as automotive, mixing reels with different BIN can create unacceptable lighting results. Cognisan has come up with a solution to track the BIN as well as part number of the reel loaded into an SMT Pick and Place machine. This traceability allows SMT plants to use only LEDs with consistent BIN in production.

It also pays to look outside one's immediate industry for inspiration and to spot industry trends that could be applicable. RFID tags are being increasingly embraced across many industries as a way to track material flow in supply chains. Chemical markers are being embedded in an increasing variety of products to enhance their traceability. Researchers at the Universidade de Brasilia are exploring adding lanthanide-doped $ZnAl_2O_4$ to act as an optical marker when added to lead-free ammunition to identify gunshot residue. Microbial and chemical markers are finding increasing usage in identification of sources and extent of waste water contamination of surface water. Recent studies by a research team headed by NH Tran from the National University of Singapore demonstrated that pharmaceutical care products (PPCPs) and artificial sweeteners (ASs) are promising markers for detecting sewer leakage. The Adelaide firm Double Helix Tracking Technologies helped the US government convict four defendants accused of illegal logging of Bigleaf maple wood from the Gifford Pinchot National Forest in the US. Prosecuted under the Lacey Act of the US wildlife protection law, Double Helix testified using their DNA profiling technique which matched the DNA of pieces of sawn wood with the DNA from stumps of trees from which they were cut. The likelihood of two trees having the same DNA profile is as low as one in 428 sextillion; there are only approximately 70 sextillion stars in the known universe.

On the information technology side, blockchains hold a huge potential for traceability. Frost & Sullivan predicts that by 2025, blockchain will penetrate retail, leasing, supply chain logistics and smart manufacturing a whopping 37.2 percent. A blockchain is essentially an incorruptible, distributed ledger updated and validated in realtime by each network participant. The incorruptibility emerges from the fact that a consensus algorithm is implemented across a vast network of decentralized computers, each one in possession of the same ledger. Once a transaction is encoded into the ledger, it is simultaneously updated on all computers. To try to change an entry on a ledger requires accessing every single computer to update the data, a virtually impossible task amongst so many unrelated actors. Blockchains thereby allow universal visibility, but no possibility for changing entries once entered. For consumers, this offers the potential to scan the code of the product you intend to buy and find out about its entire history. Companies such as IBM are employing blockchains for supply chain traceability in a number of areas – from auto industry to food safety to shipping containers. Shipping giant Maersk is eying blockchains for shipping because a shipping container can pass through as many 30 people and organizations with 200 interactions before arriving at its final destination port; each one is a point of potential counterfeiting. Counterfeit parts is a huge risk to OEM manufacturers and blockchains can ensure that OEM parts produced at a plant arrive at the final destination. Walmart is using blockchains for food safety while the World Wildlife Fund (WWF) is working with US-based ConsenSys, tech company TraSeable, and tuna fishing and processing company Sea Quest Fiji Ltd to implement a "bait to plate" pilot project that tracks tuna the moment it is caught to when it arrives on the consumer's plate. RFID, cheaper QR code or Near Field Communicator (NFC) tags are attached to the tuna as soon as it is caught. This tag is then used to trace the rest of the journey of the tuna until it arrives at the consumer's plate. All the information is entered into the ConseSys blockchain. Another company, Provenance has already completed a successful pilot project tracing Indonesian tuna to consumers in the UK. Provenance is applying its blockchain technology to cotton, fashion coffee and organically farmed food products. In another huge application area, Kodak launched its own blockchain recently to help photographers track and protect their images as intellectual property. We can take traceability lessons across these industries and apply them to our own.

But information ambiguity is only one of the three factors that can hinder traceability. Time pressures can strain a company's ability to track material flow. Supply chain permeation, or the insertion of un-verified or bad material into a manufacturing process can be difficult to pick up without extensive inspection and forensic accounting. Companies need to take an integrated approach, using the best traceability technologies, processes and a systematic plan for traceability.

Conclusion:

Non-existent compliance documentation of a critical casting for our luminaire fixture illustrates the value of traceability to assure quality control. At times, real world conditions place engineers in the challenging position of dealing with parts with no compliance documentation or traceability. In these circumstances, engineers have to make a judgment call, informed by delivery schedules, economics and capacity. With the supplier in question in the case study, there was considerable schedule pressure to continue with the supplier and try to bring them up to an acceptable standard for quality and documentation. To do so would also require continual internal testing on our part to verify processes are as represented and catch any deviations. On the vendors part, they were asked to maintain tight internal testing and monitoring of the casting process, open up for unannounced onsite inspections, and provide third party verified test reports for every batch of product shipped. Clearly there are a lot of external costs to compensate for a lack of traceability. The almost negligible time and costs to implement proper documentation and traceability procedures, of course standards such as ISO 900X are essential to keep potential issues at bay.

Unfortunately, at the end of this extended process, our original supplier was not able to meet our standards for consistency and quality and the relationship was terminated. On the other hand, our vendor management, QC, and supplier auditing process caught the issues before any questionable materials or products ever left our facility where they could pose a safety risk to our customers and the general public. Our processes and procedures identified the issue before it could become a greater issue, but the experience highlights the need to adhere to industry best practices regarding traceability, documentation control, and certificate of compliance/authenticity.

Selecting vendors that have established ISO compliant documentation and traceability processes in place, and relationships with ISO accredited test labs for compliance testing is a worthwhile strategy for controlling quality. Proper attention to the less glamorous aspects of material sourcing, traceability, and good documentation practices is a small price to pay to prevent the possibility of the intensive and expensive testing necessary when undocumented parts suddenly rear their ugly head. Spot checking and batch inspections will always be necessary, but with a good supply chain traceability system in place, they can be kept to a manageable level.

The rapidly advancing field of traceability technology, especially chemical, genetic, biological and blockchains can only help. These technologies can be of particular help if components or materials change hands several times between original manufacturer and end user. It’s relatively easy to implement good practices in internal operations and force direct supply chain vendors to follow suit, but policing the behavior of sub vendors and their suppliers in turn can become quite challenging. Providing certainty on material sourcing and origin when documentation is broken somewhere along the chain can greatly simplify supply chain management and requires constant management vigilance.

A Case Study:

A case study with die casting illustrates the real world complexities in our industry. Nemalux makes extensive use of aluminum die casting in producing the housings for our luminaires. These housings have unique industrial designs to maximize heat dissipation and manage heat, curved surfaces designed to minimize packaging debris collection or accumulation, and many details for ease of assembly, installation, or sealing purposes. The package design is critical to meet our more demanding industrial applications in marine, hazardous locations, and challenging outdoor environments.

With metal castings, quality issues can show up in simple ways such as a bad batch of material or can appear in more complex ways, such as when components preferentially diffuse out during a production run so that initial production parts have materially different composition than latter ones. In plastics, improper injection temperatures can degrade the components, and improper mold design can lead to bubbles, porosity, poor fill and warping of the finished part. An experienced vendor should be able to manage most of these issues and prevent them from occurring, but independent inspection and verification is required to verify their process is in control and capable of producing good components reliably.

For this case study, a vendor was not able to provide timely or cost effective certificate of analysis from an ISO accredited test laboratory fora critical safety component of one of our hazardous location luminaires. Without a traceable set of documents to confirm that the product met the required specifications, due diligence compelled us to initiate destructive testing of a set of samples to validate the physical properties and composition of the aluminum alloys was within our specification. As one set of tests revealed a certain flaw, it led to another test. After a series of consecutive tests, our engineering department was able to characterize the extent of the problem. While the cost of destructive testing isn’t cheap, the added time and substantial delay in the product development was an even greater expense. Three samples of two different components representing different production runs were submitted for tensile strength testing, and one sample of each component was also submitted for compositional analysis. Additionally, two fully assembled sample cases were also submitted for radiographic evaluation.

Composition Testing:

Test results for aluminum die castings exposed major issues with composition and physical properties. The chemical composition of two of the smaller components were discovered to be out of spec. Testing showed that the correct alloy was used in the larger component casting, but was slightly out of spec for one element, indicating inadequate control over composition. The test results for the smaller component revealed something far more serious, however; it was cast from a completely different alloy than specified. Alloy composition has a major influence on the physical and corrosion properties of a metal, where changes in elemental composition by fractions of a percent can lead to dramatic shifts in properties and material failure. Safety in hazardous locations can be compromised if incorrect materials are used, so further testing was required to track down the problem.

Tensile Testing:

Two physical properties were evaluated as representative of the strength and functionality of the components: Ultimate Tensile Strength (UTS) and yield strength. Both of these values are obtained from a destructive tensile test on a sample with precisely defined geometry. UTS is the stress (force divided by the sample cross section, measured in MPa or psi) an object can withstand at the moment of breakage or rupture. This is most relevant when parts could be subject to breakage, but is also a standard measurement that is easily compared against published standards. A more useful measurement in cases where deformation or bending of components would lead to a failure is material yield strength. Yield strength is the stress required to cause a plastic deformation of 0.2% - effectively the limit at which a material experiences a permanent change in shape.

In general, we expect that as-cast samples will have slightly lower strengths than the “informational” tensile strength values provided in alloy specification standards. This is due to casting fill and porosity differences between thin and thick sections in a casting. Material near the surface of a casting will have improved density, grain structure, and generally fewer casting defects resulting in higher physical strength compared to thick sections. The cast geometry and location in a casting that test samples are machined from can have a significant impact on the physical properties. As can be seen from the table of measurements for our test samples, there was a very wide % variation over the range of the samples tested for UTS. In one set of components the average UTS was 150 Mpa, 30% lower than the nominal value for the alloy. Some variation in test results between samples is expected, but the values our testing revealed an abnormally wide range, from 16600 psi to 31900 psi. The test result variation of the Yield Strength and UTS was far wider than expected. A wide variance in measured values can be caused by excessive variation in the test procedure or it can be representative of the actual range of strengths of the samples. In this case, an inspection of the cross sections that samples were machined from showed the cause to be variation in the casting quality. Excessive variation from part to part for strength, substantially lower strengths than expected, and out-of-spec composition proved that the supplier was not delivering what it had stated, and led us to the search for an alternate vendor since trust was irrevocably lost.

Radiographic Evaluation:

In an attempt to understand what factors may have contributed to the inconsistent component strengths and assess usability of the components for certification testing (knowing that we intended to move tools and find a new vendor to supply these components), we also submitted two complete case assemblies for non-destructive radiographic (X-Ray) analysis. In order to evaluate the relative quality of Aluminum and Magnesium die castings, the American Society for Testing and Materials (ASTM) standard 505E can be used to evaluate the prevalence and severity of porosity, cold fill, shrinkage cracks and inclusions or foreign material defects. A grade of 1 is the best, indicating a low number of defects, while grade 4 indicates more defects and higher severity. The radiographic tests revealed that the castings fell into a grade 3 category for both porosity and shrinkage cracks. We consider Grade 3 a marginally acceptable grade for these part designs, and an indication that the mold gating and vent design could be improved. Depending on the location of the porosity and shrinkage defects, the physical properties of the parts could be adequate or they could lead to catastrophic failure in service – engineering judgement is required to assess whether the defects form in a critical area or somewhere with no impact on safety or fitness for use. Radiographic images identified the location of the porosity, and the units were provisionally accepted while work was undertaken to improve the mold design to bring porosity and shrinkage cracking up to ASTM 505 Grade 2 or better.

This document serves as a proactive investigation into possible lighting related liability in hazardous locations. As technology moves forward with super high brightness LED's and fixtures, it's worthwhile to look into the safety standards for ignition of flammable gasses due to optical radiation.

A potential equipment hazard could be integrating enhanced technology LEDs with higher lumen output (but the same part number) the same fixture and the same power for the LED's with existing IEC, CSA or UL approvals may offer the benefit of enhanced brightness as the same LEDs are now brighter, but it may increase the potential of an explosion if the photometric power exceeds a certain threshold. This dynamic may go unnoticed by hazardous location luminaire manufacturers and their certifying body as technology changes so fast.

Furthermore, CSA and UL do not test to this specification for hazardous locations, but IEC has done complied a document recently.