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## ***Quality Improvement Plan Using Basic Quality Tools***

***Quality & Business Improvement (ACMA 4038)***

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Date: 24.01.2026

# TASK DESCRIPTION

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# 1 Introduction

The increasing adoption of advanced manufacturing technologies—particularly metal additive manufacturing (AM), metal injection moulding (MIM), and high-density sintering—has placed unprecedented emphasis on the quality and stability of atomised metal powders (Feng et al., 2023). These powders form the fundamental raw material for numerous high-precision applications across aerospace, medical, automotive, toolmaking, and energy sectors, where even small deviations in powder chemistry can translate into significant variation in product performance, corrosion resistance, mechanical properties, and overall reliability. In such contexts, robust chemistry control systems are not merely a technical preference; they are a critical enabler of process capability, product conformity, and safety (Cooke & Slotwinski, 2012).

At the core of the atomisation process lies a complex interplay of alloy composition, melt cleanliness, gas purity, oxygen pickup, and cross-contamination risk. Variations in trace elements—such as carbon, oxygen, nitrogen, sulphur, and residual metals—can compromise powder flowability, particle morphology, densification behaviour, and microstructure evolution during downstream thermal or mechanical processing. As a result, defects such as porosity, inclusions, cracking, poor layer adhesion (in AM processes), or reduced sintered density are often traceable back to insufficiently controlled powder chemistry (Cooke & Slotwinski, 2012). These issues directly influence scrap rates, rework, and process stability, driving up the cost of poor quality and undermining manufacturing throughput.

Maintaining chemical consistency in atomised powder production therefore demands the integration of rigorous quality tools, systematic root-cause analysis, and data-driven process monitoring. Key challenges typically include inconsistent deoxidation practices, variability in melt charge materials, furnace or tundish contamination, atomising-gas impurities, inaccurate spectrographic measurements, and poor handling or storage practices leading to oxidation or moisture adsorption. Left unmanaged, these sources of variation accumulate across batches and shifts, resulting in unpredictable alloy performance and difficulty achieving sustained process capability indices such as  $C_{pk} \geq 1.33$  for critical chemical elements.

Given these operational realities, this report focuses on a structured, data-driven improvement strategy for chemistry control within the atomised metal powder production process. The aim is to apply fundamental quality tools—such as Ishikawa diagrams, and control charts—to identify root causes, prioritise improvements, and strengthen the reliability of chemical composition and melt-process control. By doing so, the report supports key organisational objectives: reducing variation and defects, improving product quality, increasing productivity, and mitigating quality-related risks that could affect downstream customers (SixSigma.us, 2024)

Through a combination of root cause analysis, targeted countermeasures, and robust monitoring metrics, the following sections outline a prioritised improvement plan designed to enhance chemistry consistency, reduce batch-to-batch variation, and reinforce the company's capability to deliver stable, specification-compliant metal powders. This strategic approach reflects best practice in modern quality management and aligns with industry expectations for traceability, process stability, and continuous improvement in high-value manufacturing environments.

The study focuses on the reliability and repeatability of chemical elements within an alloy being developed within LSN Diffusion Ltd. From 2027 European legislation known as Euro 7 (EUR-Lex, 2024) will be introduced surrounding contamination control (Iron Particulates) for the use of domestic and commercial brake discs within Europe. All brake disc contact surfaces will have to carry a stainless-steel coating to remove the emission of oxidised iron particles to atmosphere. LSN has been producing these alloys in development phase for the past 24 months with the emphasis on final production specifications being finalised in mid to late 2026. Elements such as Nickel are tightly controlled by the specification supplied due to legal requirements surrounding the control of Nickel dust being delivered to atmosphere.

## 2 Problem Statement

During production trials within LSN several key elements which make up the alloy (F-BD18-BR6) have varied in and out of specification limits, in particular Nickel levels (Figure 1) have consistently been above specification limits leading to failed batches leading to remelted and blended with other batches to reduce the overall nickel content within the alloy. The alloy is the final product produced and sold within the organisation, so all quality concerns are costly to the business as non-conformance to material specifications can lead to reworked or scrap material and additional material needing to be produced again at a cost to the organisation. It must be noted that circa 70% of alloys produced at LSN contain Nickel.

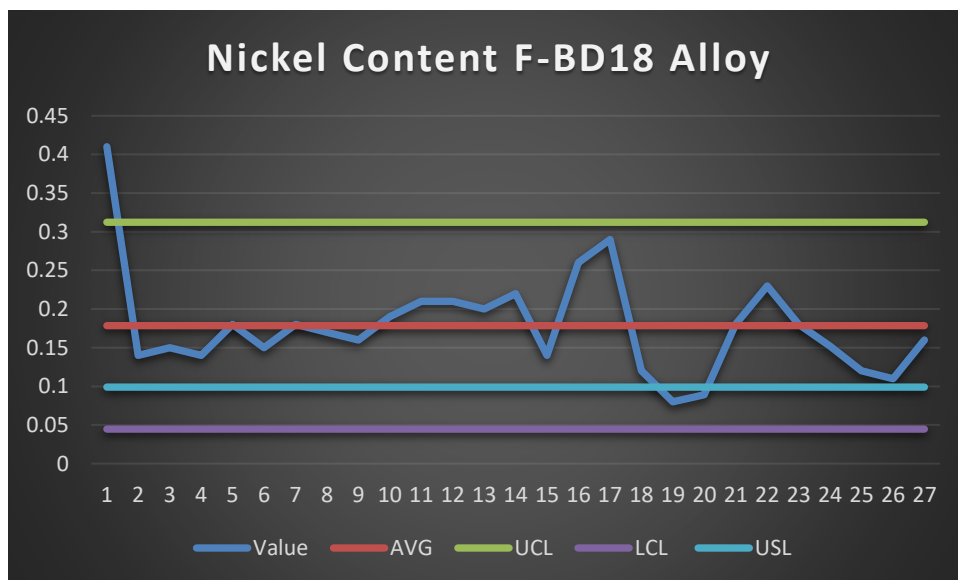


Figure 1 – SPC Data Nickel Content

### 3 Current Challenge / Issues

Melting of F-BD18-BR6 involves taking the elements in Figure 5 which make up the alloy to a temperature of 1700 degrees Celsius as alloying elements have different melt points some of the elements will be in solution before reaching the final melt temperature. The melt temperature is defined based on each element melting point which takes the element from solidus to liquidus. Due to the nature of this requirement lower melting temperature elements can burn off within the induction furnace as the melt pool reaches full liquid solution which allows the material to be processed. This requires the charge aims as shown in the specification to be tightly controlled to consider losses during production. The main issue facing LSN is the Nickel content in the final batches of atomised metal powder. The alloy is not charged with any known Nickel content in relation to raw material, but the alloy is still exhibiting high levels of pick up throughout the manufacturing process.

## 4 Manufacturing Route

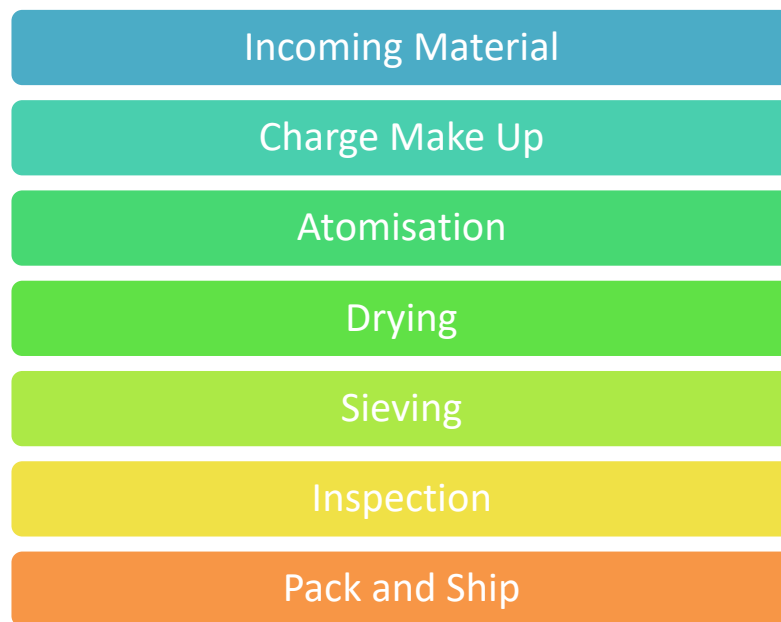


*Figure 2 – Process Flow LSN Manufacturing*

The manufacturing process within LSN involves the receipt of raw material to specific specification requirements. This material is then formulated into charges as per Figure 2, the material is then melted in an induction furnace to a liquidous state, the material is then atomised via nitrogen gas to convert the molten metal pool into sub 63um spherical metal powder particles. The material is then dried to allow processing into specific particle size distribution (PSD) grades via a sieving process and then submitted for inspection via the laboratory, once approved the material is packed to be shipped to customers.

## 5 Root Cause Investigation

An Ishikawa was carried out cross functionally within LSN to help determine the root cause of the failure mode. Kaizen Institute (2026) indicate that when carried out cross functionally the Ishikawa method is a strong tool for defining root causes of failures within the manufacturing sector. Figure 3 shows the areas identified within the manufacturing route and based on these points, reach finding was investigated for viability of contributing to the fault mode. Due to the cross-natured complexity of the issue the methodology was selected as opposed to a 5 why analysis based on the requirement of input from several stakeholders from different aspects of the business (Card, 2017)

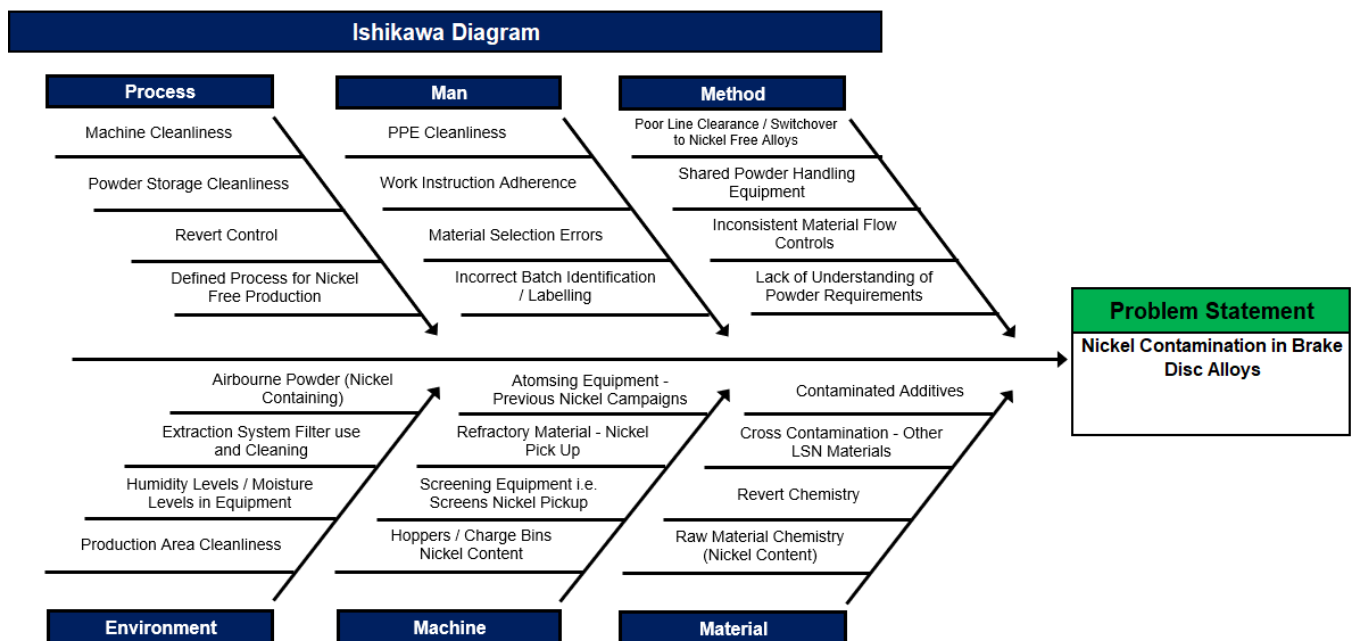


Figure 3 – Ishikawa Diagram – Corrective Action Identification

## 6 Corrective Actions / Improvement Plan

Based on the issues raised during the Ishikawa LSN Diffusion Highlighted the areas below as the main areas requiring improvement. It must be noted that as an SME LSN works within budget constraints so corrective actions are in line with the company budget. SMEs are more prone to restrictions leading to investment as opposed to large multi-national companies (Mulier, Schoors & Merlevede, 2016).

- Material Hopper Cleanliness
- Charge Material (Virgin) Nickel Content
- Screening Equipment (Nickel Pickup)
- Machine Clean-down / Changeovers of Alloys
- Standalone Processing Equipment – Defined Process

| Action No | Date Raised | Concern                                                                                              | Corrective Action                                                                         | Owner                        | Target Completion Date | Track Progress |    |    |     | Additional Comments                                                                                |
|-----------|-------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------|------------------------|----------------|----|----|-----|----------------------------------------------------------------------------------------------------|
|           |             |                                                                                                      |                                                                                           |                              |                        | 25             | 50 | 75 | 100 |                                                                                                    |
| 01)       | 20.07.2025  | Cross Contamination between material grades in powder/material hoppers.                              | Standalone material hoppers for F-BD18-BR6 grade material - Identified with blue markings | Paul White                   | 15.12.2025             |                |    |    |     | Implemented and operational identified on i2i ERP system                                           |
| 02)       | 20.07.2025  | Specification update to set charge aims at 0.00% for elements which could lead to chemistry failures | LAB / Technical staff to update MITP within i2i ERP system and ABS                        | Mark Phillips                | 29.08.2025             |                |    |    |     | Specifications updated and stored within ERP software                                              |
| 03)       | 20.07.2025  | Screening equipment cross compatibility with alloy code                                              | Source air classification unit from British Rema                                          | Paul White / Mitchell Watson | 18.02.2026             |                |    |    |     | Final sign off trials still ongoing as of March 2026                                               |
| 04)       | 20.07.2025  | Packing line contamination and length of cleandown procedure                                         | Build standalone line for packing of material                                             | Dominic Evans                | 15.12.2025             |                |    |    |     | Line now operational                                                                               |
| 05)       | 20.07.2025  | Measurement of effectiveness of planned changes                                                      | SPC data to be collected based on chemical analysis of powder batches post implementation | Ryan Owen / Todd Marshall    | 28.02.2026             |                |    |    |     | Initial results Ok - Significant production run required to stress test the procedures under load. |

Figure 4 – Action Plan – Corrective Actions

**Material Hopper Cleanliness** – All processed powder within LSN is moved around production and stored until packed in stainless steel hopper vessels which are used from the point the material is atomised until the product is moved to the packing line. As of the end of 2025 these powder hoppers had not been product specific and were cleaned in line with LSN working practices in between alloy changes etc. Due to the nature of the environment and product being produced remnants of different powder batches can remain in the hopper if not cleaned down properly.

**Corrective Action** – Considering the tight tolerance of the alloy in question to nickel content. Standalone material hoppers have been purchased and identified with blue identification numbers to highlight the

standalone use for only one material type (F-BD18-BR6). The powdered alloy for this reason will no longer be in contact with any other alloy family.

Nickel Content in Virgin Material – LSN utilise materials from several sources all of which are delivered against a purchase specification and are delivered with a certificate of authenticity (COA) which list the elements contained within each material group. These are then input in the Alloy Blending System (ABS) which allows the alloying elements to be combined to create a specific chemistry formulation which can be melted and atomised into the final powder product.

Corrective Action - After review tighter aims on elements including Nickel were added to the specification to control the levels to the lowest possible based on the raw materials available for use, the alloy code is now hard wired in relation to Nickel content and certain other elements to formulate charges at 0.00%, in turn this will automatically select raw materials that have had a certificate of analysis against them with a 0% reading in the designated elements.



# Product Specification

Date Modified:  
Created By: Mark Phillips  
Revision Number:

**Product Code:** F-BD18-BR6  
**Manufacture Method:** Dry Gas Atomised  
**Description:** HSLC FeCrMoNb 53-10µm

## Alloy Chemistry

**Alloy Code** F-BD18-  
**Comments**

**Base** Fe  
**Hardness** 0-0

| Chemical Symbol | Min  | Max   | Aim  | Result: |
|-----------------|------|-------|------|---------|
| B               | 0    | 0.005 | 0    |         |
| C               | 0    | 0.03  | 0    |         |
| Cr              | 21.5 | 23.5  | 22.5 |         |
| Mn              | 0.3  | 0.6   | 0.45 |         |
| Mo              | 4.0  | 5.0   | 4.5  |         |
| N               | 0    | 0.15  | 0    |         |
| Nb              | 1.3  | 1.8   | 1.5  |         |
| Ni              | 0    | 0.099 | 0    |         |
| Others          | 0    | 0.3   | 0    |         |
| Si              | 0.2  | 1.0   | 0.7  |         |

## Quality Testing Plan

|                  |                            |
|------------------|----------------------------|
| ICP              | ICP Chemical Analysis      |
| C & S analysis   | Eltra - CS800              |
| O2 & N2 Analysis | Eltra - ON900              |
| Sieve Analysis   | Powder Sizing - sieve      |
| SYNC (wet)       | Laser Diffraction          |
| Apparent Density | Apparent Density - gm/cm3  |
| Hall Cup Flow    | Hall Cup Flow - secs/50gms |

## PSD

**PSD Code** BR6  
**PSD Range** 53-10  
**Comments** Brake disc  
**Application** Brake disc

| PSD   | Min  | Max  | Method     | Result: |
|-------|------|------|------------|---------|
| >63   | 0    | 0    | Sieve      |         |
| >53   | -    | 1    | Sieve      |         |
| ----- | ---- | ---- | -----      |         |
| d90   | 42   | 50   | Sync (wet) |         |
| d50   | 25   | 32   | Sync (wet) |         |
| d10   | 12   | 20   | Sync (wet) |         |

## Physical Properties

|                          |      |                      |
|--------------------------|------|----------------------|
| <b>Apparent Density</b>  | ~4.0 | <input type="text"/> |
| <b>Hall Flow Seconds</b> | <20  | <input type="text"/> |
| <b>Welding Technique</b> | NA   | <input type="text"/> |
| <b>Hardness HRC</b>      | NA   | <input type="text"/> |

Figure 5 – LSN Specification F-BD18-BR6

Processing / Manufacturing Equipment Pickup – LSN is predominantly a nickel-based manufacturing plant with around 70% of all products produced and shipped to customer containing some percentage of nickel. This presents several challenges when producing alloys which are not allowed above 0.1-0.2% nickel in the overall final chemistry. The focus of the investigation was centered around the sizing of the product to customer specific Particle Size Distribution (PSD) bands. As shown in Fig.4 the PSD range on the given product is 53-10 microns in diameter. This has traditionally been sieved to size using the equipment shown in Figure 5 Virto high frequency sieving centre, or Figure 6 Locker gravity sieving centre. Both pieces of equipment operate based on metal powder being passed over specific product

sized sieves made from plastic mesh to remove oversized and undersize particles from the desired product to provide the desired PSD bands in this instance 53-10 microns. For this example, the sieve mesh diameter would be 55 microns for the top sieve and 11 microns for the bottom sieve to ensure the product falls within the specified tolerance. The inherent issue that LSN faces is that multiple different alloy codes made up of different chemistries must share this equipment involving deep cleans and inspection to minimise the risk of cross contamination. The sieves as shown in Figure 7 are prone to holding remnants of other alloys which can work loose when re-used and contaminate the next alloy being sieved over them, it is also not cost viable to use new screens for every alloy as due to the tolerance requirements set on each screen the manufacturer charges circa £250 per screen delivered to LSN.

Corrective Action – Based on the risks identified LSN made the decision to order standalone equipment to meet the requirements of the long-term requirements for delivery of this product. Stand-alone material specific hoppers identified with blue markings have been allocated to production Figure 9 shows the new hoppers which will only contain F-BD18-BR6 this therefore ensures only the chemistry related to the product will only ever contact the hopper.

A major investment was made in new sieve classification equipment, the equipment shown in Figure 10 was designed and installed in partnership with British Rema, as opposed to LSN's traditional system of powder sizing of sieve mesh the equipment uses air classification utilising cyclone technology to remove oversize and fine powders based on density and particle size. As the equipment is a standalone system which will only process this material and does not rely on any form of sieving system, the reduction in possible contamination failures is eliminated from this process. Other benefits in relation to yield improvement and operational costs also made the decision easier for LSN to make. Finally, a standalone packing line which only process this material was installed as per Figure 11 this reduces changeover times and removes the risk of alloy cross contamination.

The decision to invest in this new equipment was aimed at improving operational efficiency in relation to cleaning procedures, by having standalone equipment that can process more products with less interruptions for deep cleaning has allowed LSN stakeholders more time to process and improve manufacturing operations and increase operational efficiency.



Figure 6 – Virto Sieving System



Figure 7 – Locker Sieving System



Figure 8 – Mesh Sieve Screen



*Figure 9 – New Product Specific Hoppers*



*Figure 10 – British Rema Air Classification System*



*Figure 11 – Product Specific Packing Line*

## 7 Prioritisation and Measurement of Effectiveness of improvements

When scoring the viability of the planned changes the team could not agree 100% on any one factor being decisive in the elimination of the Nickel content, it was agreed cross functionally that to effectively eliminate risk that all actions were to be implemented, the item on which everyone agreed was the priority was the implementation of the British Rema air classification system, at circa £300,000 of investment this was a significant spend for an SME but the return on investment on yield alone was 8 months and then factoring in the cleanliness of the machine it was agreed to go ahead. The cost of new powder hoppers and the new packing line totaled circa £70,000 but based on the value of the contract and long-term prospects for growth the decision was made cross functionally to implement all suggested actions. The only physical barriers to introduction of these measures within LSN was the availability of cash flow to fund the purchases, the proposals were managed via internal CAPEX in consultation with the operations director – in this instance due to the requirements of the product and future prospects of product growth the decision was made to part finance the procurement of the equipment to ensure production and development of the alloy was not diversely effected.

The effectiveness of improvements will be monitored in physical data via statistical process control (SPC) based on the chemistry values taken via Inductively Coupled Plasma (ICP) or combustion analysis to obtain each elemental value of a given powder. The data will then be tracked and trends investigated if there is a risk of elements moving outside the agreed control and specification limits.

## 8 Conclusion

In conclusion quality tools when utilised correctly can deliver, defined, structured measures to help in the identification of the root cause of failure modes / issues and define a structure approach to resolving issues identified in a controlled manner (Pietsch, D. et al, 2024)

In this instance the use of an Ishikawa allowed a cross functional team to agree upon and implement robust corrective actions which appear to be resolving the issue of nickel contamination within an alloy family. The original issue was defined by data studied from SPC control charts indicating that LSN had to bring Nickel content under control to ensure supply of conforming product to its customer base. The lessons learnt can then be transferred onto future projects to ensure repeated mistakes are minimised and the overall efficiency of the manufacturing operation can be improved. In this instance by following a structure and evidence-based approach to fault identification and resolution LSN was able to bring the Nickel content under control Figure 12.

If more funding was available, incoming materials could be inspected in greater detail to look at trace elements of incoming material chemistry against certified values, in the future XRF technology could be investigated to provide this level of information without having a negative impact on material delivery due to real time data gathering.

The most important takeaway from this report is that correct APQP meetings and a more controlled manner of introduction to mainstream production could have reduced the chemistry variation from the start of production (Srinivasan *et al.*, 2026). This will be a key lesson to build into future projects.

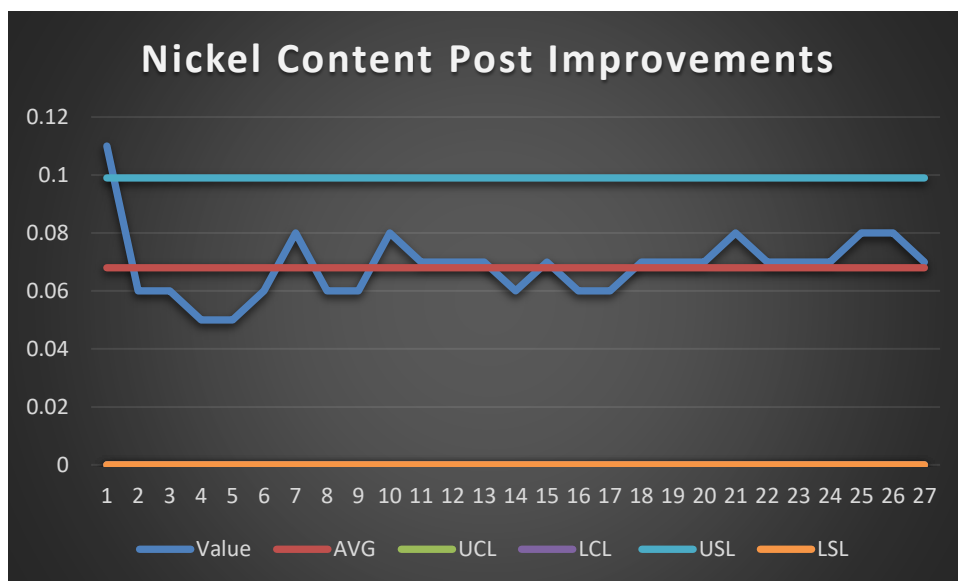


Figure 12 – Post Improvement Nickel Content

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