# Production of P0303 Grade Sows at Mahan Aluminium

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## Abstract

Globally, customers consistently demand high purity grade metal and Mahan Aluminium, a unit of Hindalco Industries Limited, part of Aditya Birla Group (ABG), took up this challenge as an opportunity for new product development by initiating production of P0303 premium grade metal ingots/sows. Mahan is consistently producing high purity grade metal beyond the regular grades and established itself as a preferred choice of world's leading customers of primary aluminium. Mahan Aluminium metal is also categorized as equivalent to "Good Western Metal" by some of our customers. For production of high purity metal, the chemical composition is a major quality attribute that controls product quality and adds extra value to aluminium produced. Mahan products have reformed the views of global customers for Indian aluminium by continuous quality improvements in all products. Our new initiative "Make in India" for manufacturing of aerospace and defense products encouraged us to foray into this premium segment. With continuous product quality upgrades, we have an opportunity to enter this segment and be a partner in nation building.

The methodology adopted for achieving this goal consists of understanding customer requirements, analysis of factors affecting hot metal purity, brainstorming, and raw material selection and blending to produce high purity metal. Further new process improvements, such as introduction of magnetic separator, usage of fresh tapped bath with alumina were carried out to obtain desired purity in metal for P0303. Dedicated pots to produce P0303 grade metal, shuttle planning, process improvements, monitoring and feedback enabled us to consistently produce P0303. This new product has enhanced our product portfolio and meets our client's expectations while showing the world that Mahan has the capability to produce high premium grade metal on a consistent basis.

Production of Premium Grade Aluminium P0303 is an extraordinary feat achieved by Mahan Aluminium in metal purity and customer centricity.

**Keywords:** Mahan Aluminium, Aluminium purity, Premium grade P0303 aluminium, Hot metal purity.

## 1. Introduction

Mahan Aluminium is an integrated aluminium smelting complex which uses globally proven smelter technology AP36 from Pechiney, France, while its integrated carbon plant uses technology from Solios, and the captive power plant uses Bharat Heavy Electricals Ltd (BHEL) technology for each of its 6 x 150 MW units. Both, smelter and captive power plant commenced operation in April 2013 and reached full capacity in August 2015. The plant was commissioned in a record time of 27 months, a benchmark time for Greenfield project execution in India. Mahan Aluminium is an ISO 9001, 14001, 45001 and 50001 certified company and its primary products are London Metal Exchange (LME) registered. Within a short time, Mahan has established itself as the preferred choice of the world's leading customers of primary aluminium. Over 60 per cent

of total production is exported to various countries such as USA, Japan, Korea, Mexico, Israel and others.

Customers consistently demand high purity metal and Mahan Aluminium, a unit of Hindalco Industries Limited, took this challenge to produce high purity metal beyond the regular grades and established itself as a quality conscious unit. Delivering high quality grade metal has been the primary goal of Mahan Aluminium smelter, which has a direct impact on the customers and at large the face value of the organization. The production of Grade P0404 metal has been reported [1]. Production of Premium Grade P0303 is a bigger challenge. The P0303 metal grade comprises elemental impurities such as silica < 0.03 % and iron < 0.03 %. The source of Si and Fe in metal is primarily from raw materials like alumina, anode, anode cover mix, $AlF_3$, etc.

Mahan metal is categorized as equivalent to "Good Western Metal" by some of our major customers. For production of high purity metal to meet customer's demand, the chemical composition is the major attribute that controls the product quality and adds extra value to the aluminium production. Raw materials, cell process and regular operational works play important role in the production of high metal grade. To achieve this high metal grade production, a cross-functional team was formed, and they worked in coordination with various departments. Mahan products have reformed the views of global customers for Indian Aluminium by continuous quality improvements in all products. Our new initiative "Make in India" for manufacturing of aerospace and defense products encouraged us to foray into this premium segment. These segments are currently dominated by western and Middle East smelters. With continuous product quality upgrades, we have an opportunity to enter this segment and be a partner-in-nation building.

Figure 1 shows that, while Mahan was continuously producing high purity metal, it kept on adding new grade products in its portfolio.

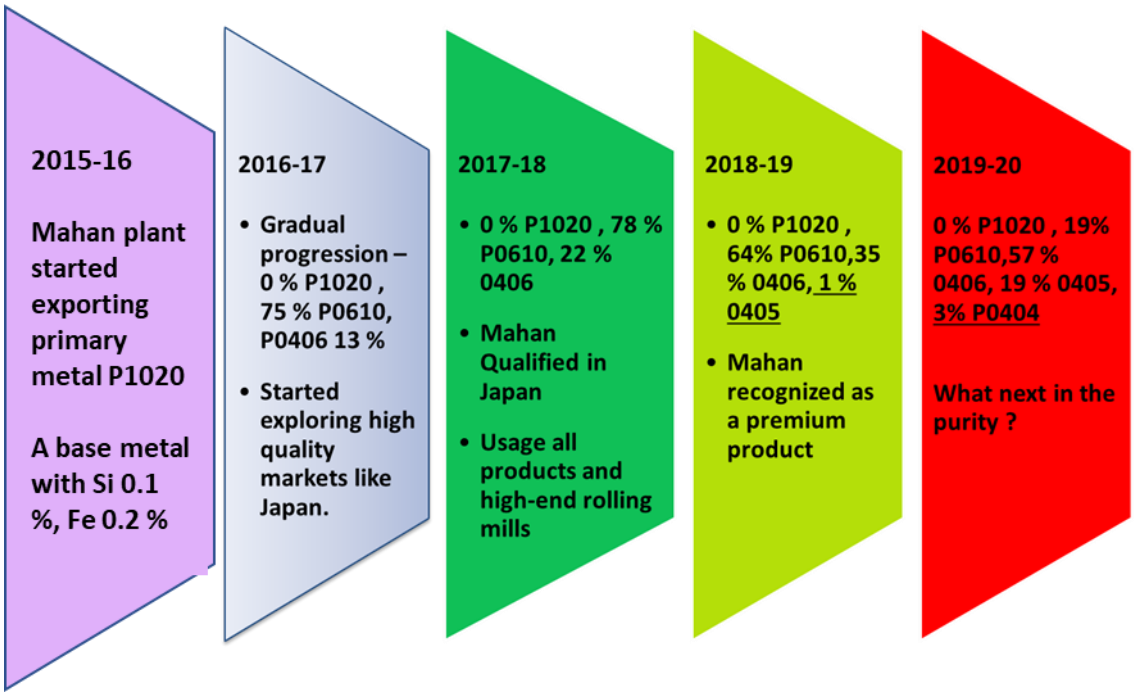


**Figure 1. Evolution of metal purity at Mahan Aluminium.**

Demands from customers were coming through marketing on capability to produce P0303. Since this metal grade is used in aerospace and defense equipment, this gave us an opportunity to enter

into premium market and take Hindalco Mahan into new horizons as no other plant in India was producing P0303 premium grade metal and so Mahan took up this challenge to enter into league of premium metal producers.

**Table 1. Chemical composition of different metal grades.**

| **Nomenclature** | |
|---|---|
| P0303 | Al- above 99.85 %, Si- 0.03 % max and Fe 0.03 % max |
| P0404 | Al- above 99.85 %, Si- 0.04 % max and Fe 0.04 % max |
| P0405 | Al- above 99.85 %, Si- 0.04 % max and Fe 0.05 % max |
| P0406 | Al- above 99.85 %, Si- 0.05 % max and Fe 0.06 % max |
| P0610 | Al- above 99.85 %, Si- 0.06 % max and Fe 0.10 % max |
| P1020 | Al- above 99.70 %, Si- 0.10 % max and Fe 0.20 % max |

## 2. Challenges

The following challenges were faced while improving metal purity:

- Alumina received from two different suppliers, namely, Utkal and Muri:
  - Two different suppliers means different chemical compositions of alumina and managing these two different chemical compositions posed a major challenge.
- Multiple grades of coke:
  - Mahan is getting two types of coke, namely, high sulfur (high vanadium) and low sulfur (low vanadium) from different suppliers in an 80:20 ratio.
- Pot relining:
  - Relining of second-generation pots began in April 2017, which also impacts metal purity of the potline. As newly started pots were having very high silicon which needs to be diluted by blending with other high purity metal.
- Historical Trends of Fe/Si:
  - Historical trends of iron and silicon in metal was not suitable for production of P0303 purity metal.
- Dilution of high Fe metal:
  - High Fe metal needs to be diluted by high purity metal to meet the required metal purity standards.
- Equipment availability:
  - Breakdowns in potroom, cast house cranes or sow casting line affects P0303 metal production.

## 3. Execution Methodology

Mahan realized that a proper methodology must be adopted for production of P0303 on a consistent basis, which is briefly described below:

- Understanding customer and their requirements:
  - P0303 grade is mainly used in aerospace and defense applications, where minor elements like Na, V, etc., impact the process.
- Gap analysis and scope of improvement with respect to customer's requirements.
- Analysis of factors affecting hot metal purity, raw material quality assessment of coke, alumina, and hot metal.
- Raw material selection and blending to produce high purity anodes.
- Brainstorming.
- Dedicated pots to produce P0303 grade metal.
- Shuttle planning.

- Strategy development and process improvements at anode, hot metal and casting stages.
- Process capability, process improvements, monitoring and feedback.
- Qualification and sustenance.

## 4. Actions Initiated at Various Levels

The following sections briefly describe different initiatives undertaken on different fronts in order to improve metal purity.

### 4.1 Alumina Handling System and Bath Recycling System

- Silo categorization to produce metal based on Utkal and Muri alumina:
    - A silo categorization of two different types of alumina received was implemented. Both Utkal and Muri alumina specifications were studied, and dedicated groups of pots were defined based on age and other parameters for focused quality metal production.
- Special magnetic separator installed in enriched alumina hyper-dense phase system (HDPS) feeding line to pots: Enriched alumina had higher iron impurities than fresh alumina. With magnetic separator these iron impurities, found in form of minute iron particles, were removed from the enriched alumina, Figure 2. This ensured reduction in iron content of enriched alumina going into the pot.
- Erection of new structure for fresh alumina feeding into pots – for production of P0303 grade metal. Fresh alumina charging permanent feeding line setup completed:
    - Alumina was picking up iron impurities during transportation from unloading of rakes to feeding in pots and during enrichment process.
    - Hence fresh alumina feeding was planned in few selected pots.
    - Fully automatized mechanical setup done for feeding fresh alumina from GTC-1 with help of bulkers to 1–45 pots of B-Room.
    - Fresh alumina bulkers are unloaded directly in GTC-1 (Room-B) and this fresh alumina now can be directly fed into the pots.
- Detailed process mapping of each output parameter was formulated:
    - A team of process control engineers along with few technicians were designated to monitor and control raw material quality. Amidst many power troubles and few power outages, said process control team-maintained pot thermal balance, and improved the pot process to sustain and continuously improve the quality of metal produced [2].
- Focused anode covering quality and bath height:
    - Changes were made in the bath tapping logic of ALPSYS to control proper bath heights and increased its follow-up after bath tapping. Implemented auditing systems for checking anode covering quality and reporting of abnormalities as soon as possible [5]. In depth checks were performed for those pots to reduce the quality of metal and identified issues were rectified as soon as possible.
- Optimized anode cover-mix quality:
    - Anode cover-mix quality was improved by mixing tapped bath and fresh alumina together for better quality control.
- Raw material quality control:
    - A methodology was developed to monitor all incoming raw materials and in-process checks for pot line such as alumina, anode cover mix and tap hole closing material on a daily basis.
- Dedicated pots for P0303 metal production:
    - 21 pots dedicated for P0303 production. Consistent metal purity (low Fe, Si, V and Na) for continuous production of P0303.

- Bath height optimization. Bath tapping logic and bath height setpoint revised. Bath height measurement done every 16 h as opposed to the regular 32 h schedule to minimize any adverse impact of bath heights on metal quality. Note that metal quality checks, on the other hand, were done on regular 32 h cycle.

**Magnetic separator**

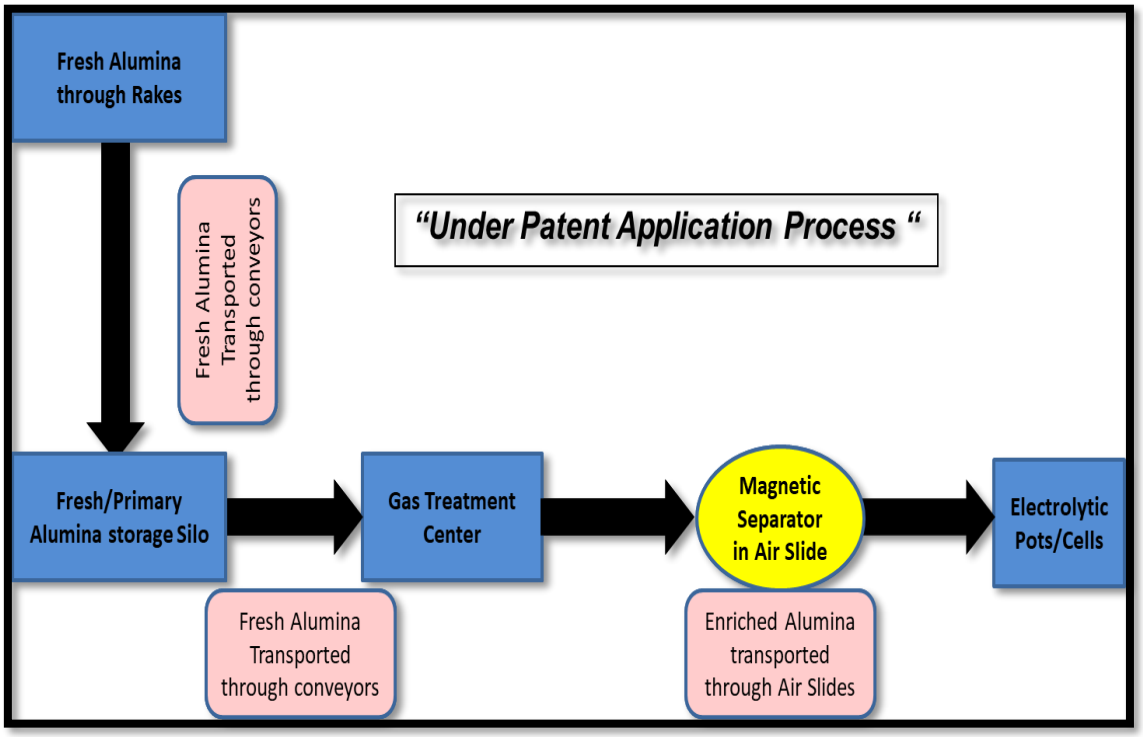


**Figure 2- Showing the installation of magnetic separator (top) in HDPS Line to remove iron**

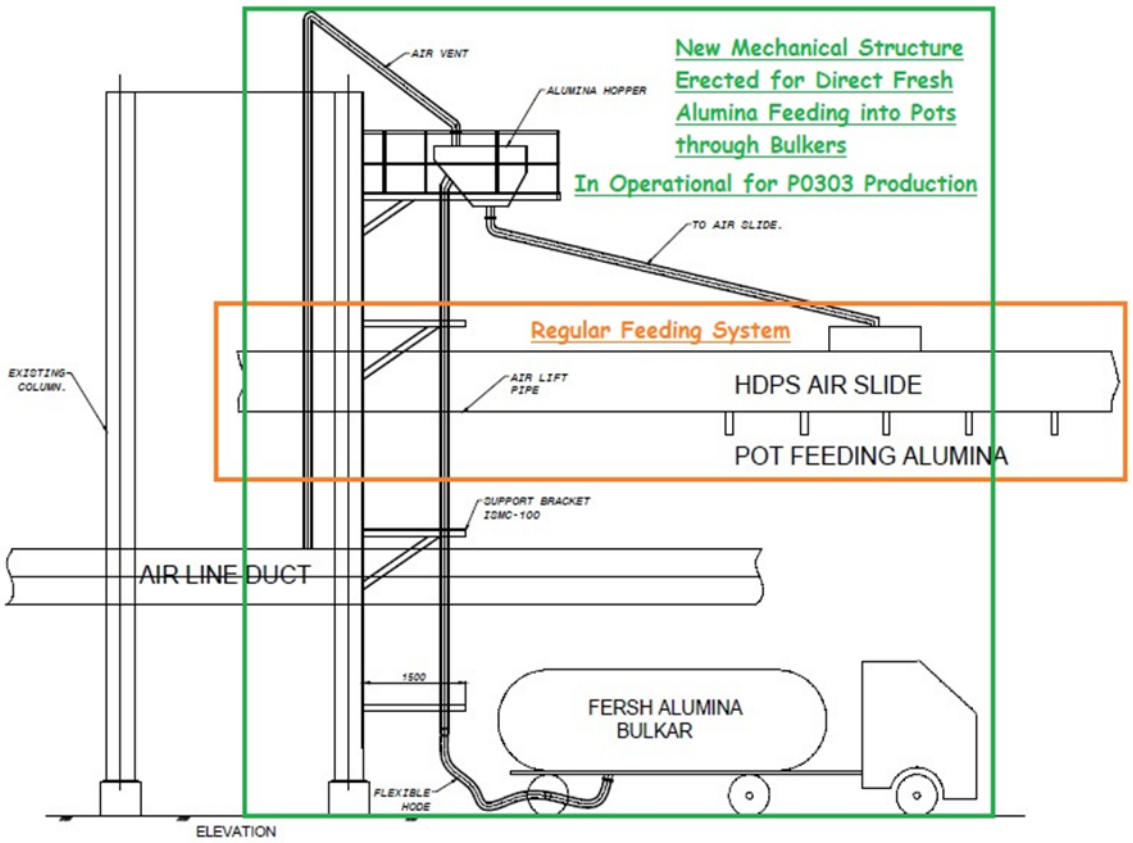


**Figure 3-Schematic representation showing additional arrangement done to fed fresh alumina into a group of Pots for P0303**

### 4.2 Carbon

- Multiple checks were imposed on incoming raw material and in process materials to avoid any adulteration [3].
- Modifications in operational procedures were made in the carbon plant, such as various check points that were imposed on incoming raw material to avoid any kind of contamination. Periodic scheduled inspections were made to ensure the availability of magnetic separators. Changes in process systems for handling and monitoring the quality of raw materials like coke, butt and green scrap were made. Changes in design and structures were made for improved quality of butt cleaning to reduce iron, silicon and sodium in anodes. Furthermore, silo categorization for low and high sulfur calcined petroleum coke to reduce vanadium in baked anodes and finally in cold metal via blending [3].
- Recipe change for anode production
    - Selection and blending of raw materials (low sulfur coke) for production of high purity anodes [6]: Usage of low sulfur coke to reduce Fe, V in anodes. The recipe is shown in Table 2.

As per predicted scenarios (based on previous data), with 100 % Numaligarh calcined petroleum coke and 10 % anode butt, suited for the production of high-quality anodes. These anodes contain lower Fe (approx. 100 ppm), Si (approx. 120 ppm) and V (almost 130 ppm) which helps to produce P0303 quality metal.

**Table 2. Recipe blending table for prediction of elemental impurities in baked anodes.**

| Prediction of Fe, Si, Na and V in metal with respect to different calcined petroleum coke and anode butt recipes | Normal (20.5 %) anode butt | | | | With 10% anode butt | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Fe | Si | Na | V | Fe | Si | Na | V | |
| 20 % low sulfur calcined petroleum coke* blending | 549 | 317 | 261 | 233 | 510 | 325 | 238 | 257 | Fe and V not qualified for P0303 |
| 100 % Brahmaputra high sulfur calcined petroleum coke** | 546 | 312 | 258 | 104 | 507 | 319 | 235 | 101 | Fe and V not qualified for P0303 |
| 50 % Numaligarh low sulfur calcined petroleum coke* + 50 % Brahmaputra high sulfur calcined petroleum coke** | 527 | 256 | 252 | 91 | 485 | 253 | 228 | 86 | Fe and V not qualified for P0303 |
| 100 % Numaligarh low sulfur calcined petroleum coke* | 509 | 199 | 246 | 84 | 464 | 187 | 220 | 78 | Fe and V qualified for P0303 and lowest impurities in anode to produce premium metal grade |

*Low sulfur coke: 90 ppm vanadium and 1 % sulfur.
**High sulfur coke: 350 ppm vanadium and 2-3 % sulfur.

### 4.3 Cast House

- Focused metal planning and furnace categorization.
- Cast house team diligently studied the quality of metal produced in ingot and sow and designed a blending strategy to achieve the desired quality of metal. Furthermore, an appropriate metal tapping plan was devised, as shown in Figure 4.
- Shuttle planning:
    - Planning and making of shuttles with Fe (295 ppm), Si (295 ppm and below) for P0303 production [4].
- Use of statistical tools, Critical to Quality and Critical to Process Parameters were identified:
    - Quality control team at cast house identified Critical to Quality and Critical to Process with use of statistical tools. Cast house team blended raw materials and liquid metal to get the correct mix of cost and quality.

### 4.4 Process Improvements

- Critical parameters identified for P0303 production in carbon, pot room and cast house. Process modified to accommodate dedicated pots in Potroom B, special anode production in carbon and shuttle planning, metal allocation and equipment allocation in cast house.

### 4.5 Monitoring and Feedback

- Analysis of P0303 pots and failed P0303 casts. Monthly meeting with pot room team on metal quality and delivery. Improvement project started by the carbon plant for special anode for P0303 production – refer to Figures 5 and 6.

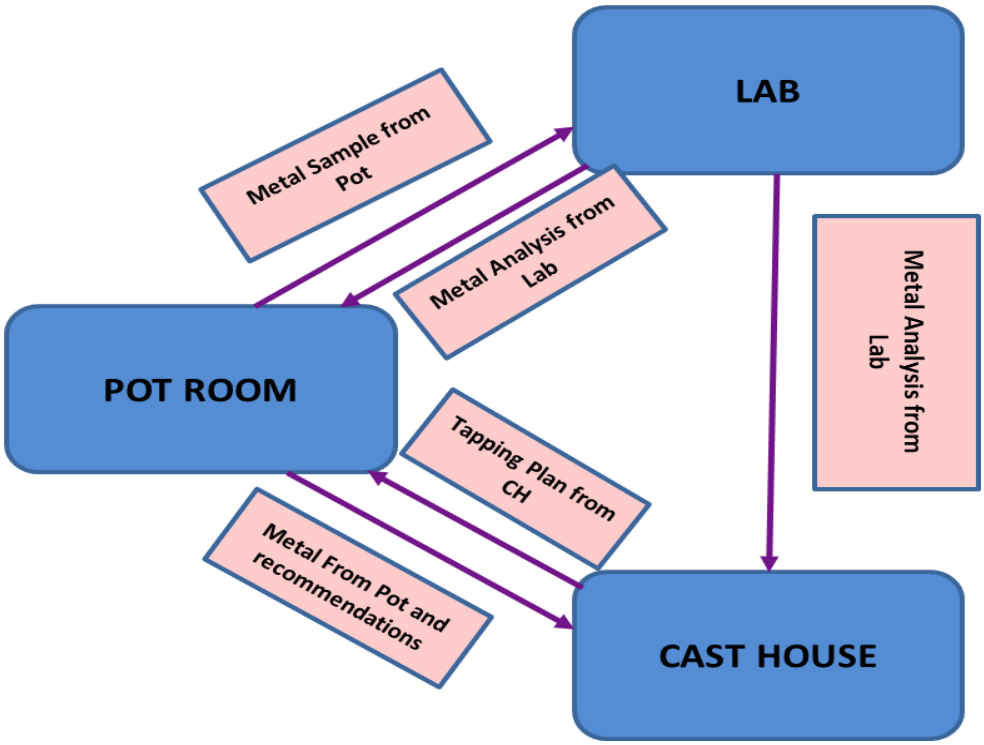


**Figure 4. Process flow diagram for metal tracking and reporting system.**

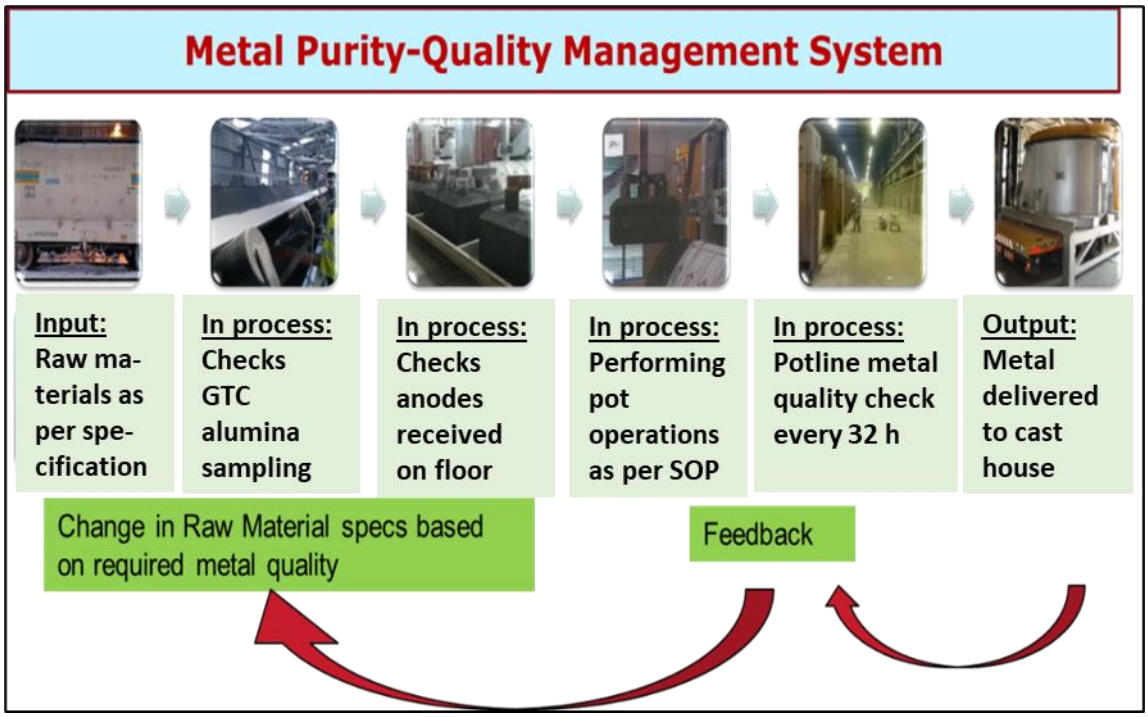


**Figure 5. Quality management system. SOP = Standard Operating Practice.**

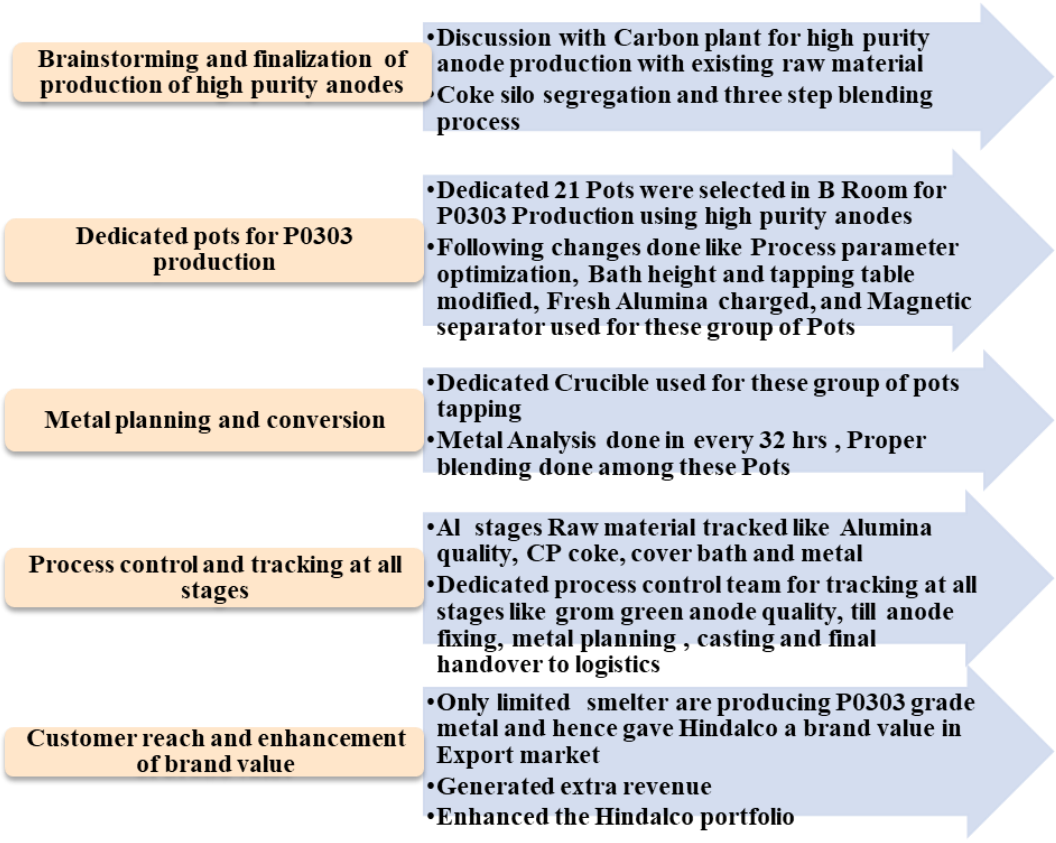


**Figure 6. Approach used.**

## 5. Current Status and Deliverables

The above improvements resulted into a consistent production of P0303 premium grade, as shown in Figure 7, showing consistent production of P0303 premium grade metal from January-2020

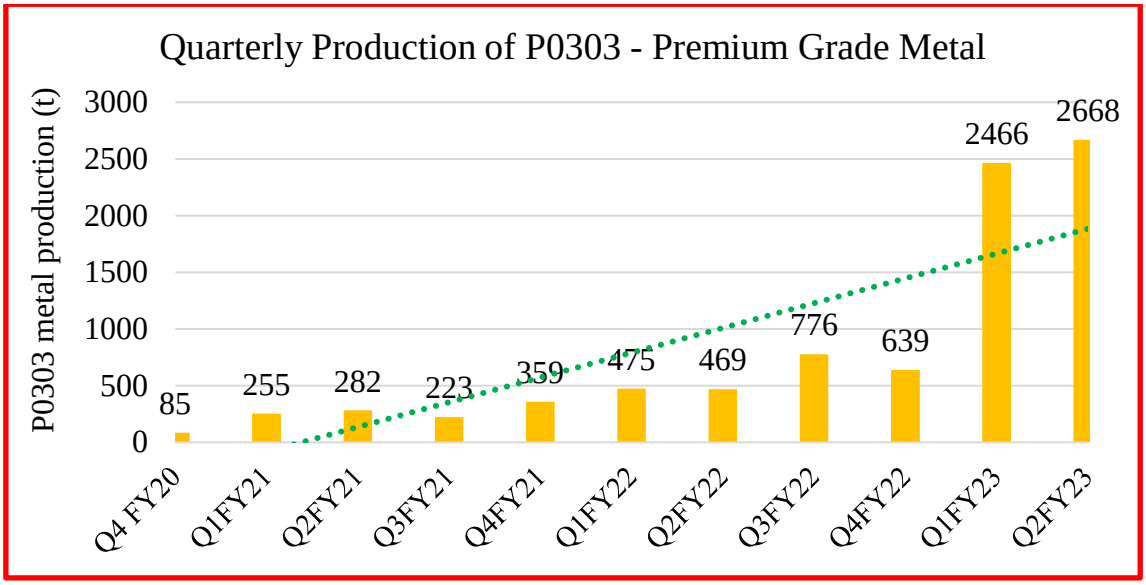


**Figure 7. P0303 quarterly production. Q4FY20 = Quarter 4, full year 2020.**

## 6. Financial Benefits

The financial benefits of continuing P0303 metal production are shown in Table 3.

**Table 3. Financial benefits.**

| P0303 Production (t) | Premium Obtained (USD) | Actual Gain (USD) |
|---|---|---|
| **8697** | **$ 180 per tonne of metal** | **USD 1 564 560** |
| **Cost Incurred** | ***$2560*** | |

## 7. Non-Financial Benefits

- Patent application submitted by Corporate Legal Team for the method of P0303 production. (In-tangible asset).
- Acquired new customers and delighted existing customers.
- Product portfolio enhancement.
- Deeper penetration of Hindalco brand in exports market.
- Mahan has entered in the league of premium metal producers in the world.
- Developed first time in India as an import substitute.
- Supporting "Make in India" initiative by enabling aerospace and defense manufacturing (Supplied 10 t to Indian Space Research Organisation (ISRO)).

## 8. Conclusion

This paper shows that high purity aluminium can be produced consistently by optimizing the raw materials, stringent process control, using innovative approach and seamless coordination among all sections of the aluminium smelter. As marketing demand is increasing for high purity aluminium, it will give extra advantage with extra premium.

## 9. Acknowledgements

We would like to extend our sincere gratitude to the following leaders of Mahan Aluminium: Mr. Senthil Nath (Unit-Head) and Mr. K. K. Pandey (Head Reduction) who were spearheading this project and made it successful.

## 10. References

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