Implementation of a New Measuring Device for Cathode Current Distribution

Matthias Dechent[1] and Richard Meier[2]
1. Process Engineer Potrooms
2. Reduction Manager
TRIMET Aluminium SE, Hamburg, Germany
Corresponding author: matthias.dechent@trimet.de

Abstract

The cathode current distribution (CCD) is giving essential information about the condition of a critical pot. In order to measure the cathode current distribution at the Hamburg smelter with a clamp tool, it is necessary for the operator to get underneath the pot. Risk of a tap-out during the measurement of iron pots is high. With the introduction of top down measurements, the operator safety was highly increased. Further improvement was made with the introduction of a measuring tool and a corresponding tablet device in 2012. The visualization of individual cathode current measurements of critical pots is used in day-to-day work of operators. The ease-of-use has increased the number of measurements per month, which is helping to gather more data preventing tap-outs. Due to faster identification of critical collector bars, less iron is dissolved and the overall metal quality increased.

Keywords: Electrolysis cells, operations, critical pots, cathode current distribution measurement.

1. Introduction

Using cathode current measurements for evaluation of critical cathode collector bar is a standard operation practice for pots with increasing age and iron levels at the Hamburg Smelter operated by TRIMET. By cutting a cathode collector bar of a faulty cathode, the life cycle can be extended [1]. Using a Halmar (now called Dynamp) Clamp-on Portable (COP) ammeter for collector bar currents measurements is a known practice [2].

The Hamburg smelter was restarted in 2007 after being shut down in 2005 by the former owner [3]. The smelter is equipped with 270 Reynolds P19 pots in two potlines with retrofitted siderisers. The pot has 18 anodes and 28 cathode collector bars. The nominal line current is 180 kA. During 2012, the Hamburg smelter had a crisis due to various factors. For the restart in 2007, 145 pots were reused; the others had to be relined with any material available on the market. During the economic crisis beginning with the end of 2008, 50 % of the pots were shut down again due to a reduced overall production. All of those were restarted in 2010. With some pots being restarted at least once, 102 pots were cut out of operation from 3 January 2012 to 28 December 2012 (see Figure 1).

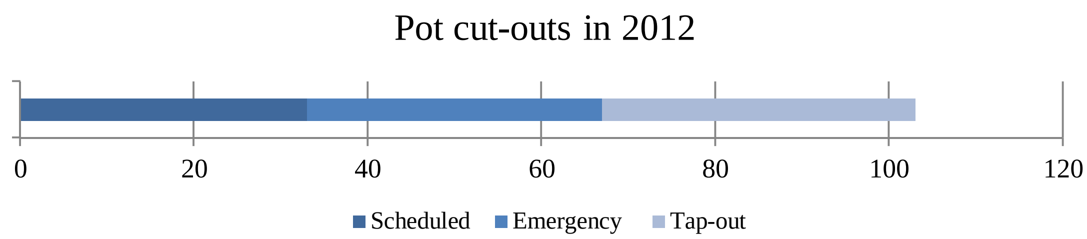

Figure 1. Pot cut-outs 2012, sorted by reason for cut-out.

A mere 33 were scheduled for a cut-out, the remaining either had to be shut down due to a tap-out or a emergency cut-out to prevent the tap-out. Pots were kept in operation as long as possible in order to supply metal to the cast house. One of the emergency cut-outs was pot 334 with a temperature of 1126 °C, 6.33 % Fe and with 12 of 28 collector bars disconnected.

2. Development of a New Tool

Until then, all measurements of cathode current distributions had to be done from underneath the pot with a Halmar COP portable ammeter. This is a major safety risk, especially with critical pots. As an additional risk, in Potline 2 the return busbar system is close to the other busbars. The complete basement of Potline 2 is therefore an electrical room, which may only be entered by electrically trained personnel. This led to the development of the top-down measurement with hall sensors. The schematic of the tool can be seen in Figure 2. The tool uses four Hall sensors, which are placed on both sides of the collector bar. The Hall sensors measure the magnetic field generated by the current in the collector bar. The current is calculated from the magnetic field. Measuring the magnetic field is more reliable than measuring voltage drop for a top-down measurement, as the collector bars can be covered in alumina or anode cover material. his would influence the measurement of the voltage drop drastically because a good contact with the electrical probes is difficult to make through the material.

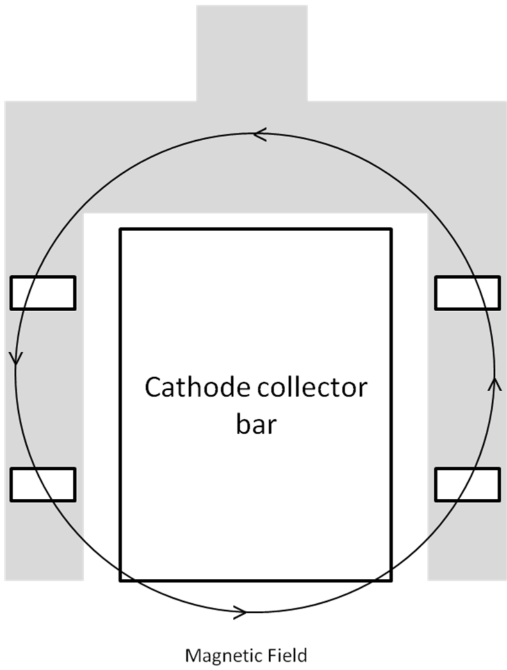

Figure 2. Schematic of measuring tool with 4 hall sensors. Rectangles on the side are Hall sensors.

With the first generation of this tool, the operators could measure the CCD from the top right next to the deckplate. One operator was holding the measurement fork, while a second operator was writing down the measured values. Afterwards the data was transferred to the level 2 database system.

The next generation measurement tool is using a tablet device and a Bluetooth connection to transfer the values via a database interface directly to the supervisory systems. The measuring schedule is generated from the database; the operator can select the individual pots and compare the measured values with the last measurement for an immediate overview and verification. If the values have changed more than a certain threshold, the operator is alarmed and contacts the shift supervisor.

3. CCD Data Analysis

With the new ease of CCD measurements, the amount of measurements has increased. The schedule for measurements is currently as follows:

- As part of start-up procedure,
- Every three months,
- Daily, if one or more collector bars are disconnected,
- Every 8 hours, if Fe content is higher than 0.5 %.

Sampling of the metal quality is done twice a week for normal pots and every shift for an iron pot with more than 0.5 % Fe. This has increased the control over pots immensely, as the distinction for an anode-related or cathode-related increase of iron content is more easily determined. An increase of iron-content (above 0.8 % Fe) and significant shifts in the CCD indicate, that one or more cathodes are damaged. The decision on whether to cut a collector bar or not is done by the acting shift supervisor.

3.1. Impact of Correct Disconnected Collector Bar

From 17 to 30 July 2017, Pot 178 was under special observation, as the metal sample on 17 July showed an increase in iron content from 0.43 % to 0.65 %. Within 48 hours, the iron content increased to 1.30 %. The pot was already under daily observation, as two collector bars were disconnected. Figure 4 shows the increased current flow of collector bar 16 (blue line). This increase was most likely due to a crack in the cathode block and therefore metal infiltration to the steel collector bar. As aluminium has a lower electrical resistance than the cathode block, the current increased. The iron content of the pot increased, as the aluminium dissolved the collector bar. After 48 hours, collector bar 16 was identified as the faulty collector bar. Subsequently, the collector bar was disconnected. The iron content decreased after the bar was disconnected (see Figure 3).

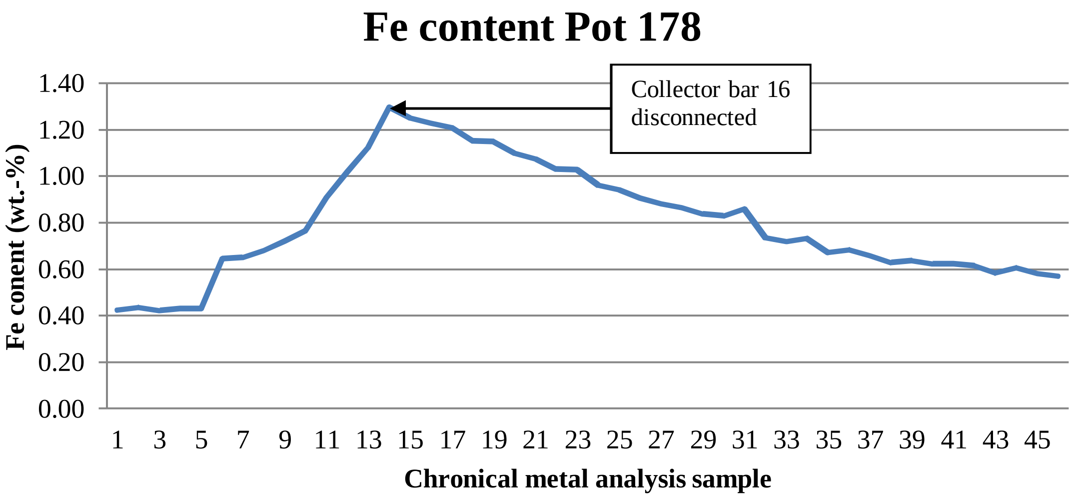

Figure 3. Fe content of pot 178, 46 measurements.

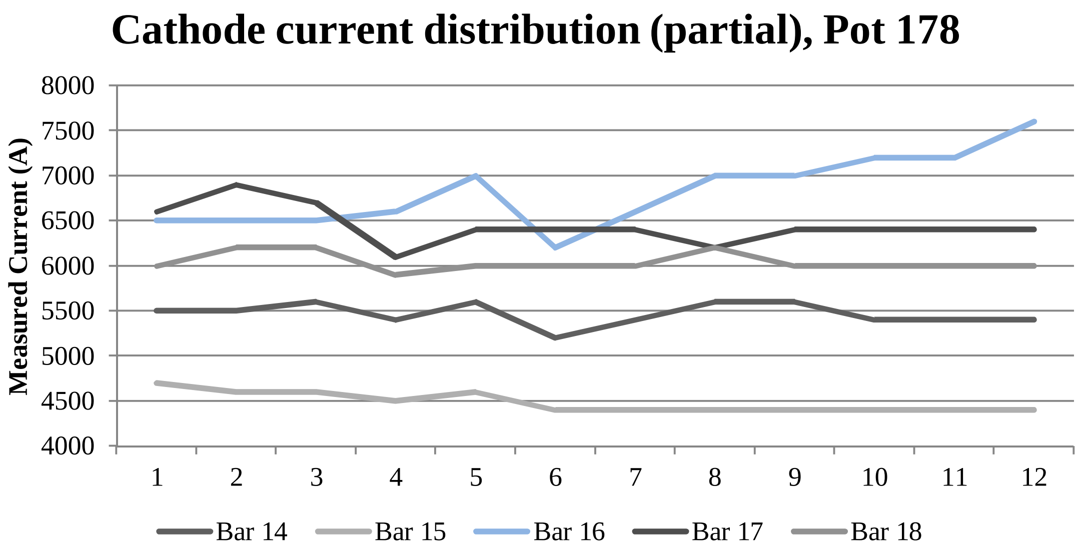

Figure 4. Cathode current distribution for pot 178, 12 measurements.

With 28 collector bars and 180 kA line current, the average current per collector bar is approximately 6425 A. Collector bar 14 and 15 are on the tap-end side of the pot. The current flow in the last cathode on both suction and tap side is always smaller, as there is freeze on them to some extent. The decreased current of collector bar 16 at measurement 6 is due to an anode change above the collector bar. The effect can also be seen at collector bar 15 and 14, with less impact.

Disconnecting collector bar 16 was the right choice and has possibly prevented a pot failure due to a tap-out at that position.

3.2. Cathode Current Distribution for Pots with Faulty Relining

Pot 261 was taken into operation on January 16th, 2017 and has been a critical pot ever since. Figure 5 shows the current distribution 2 days after the start-up with very different currents of the upstream (15 - 28) and downstream (1 – 14) side of the pot. Figure 6 shows the boxplot of 319 measurements. Six months after the start-up (see Figure 7), collector bars 9, 10, 11, 12 and 14 had been disconnected.

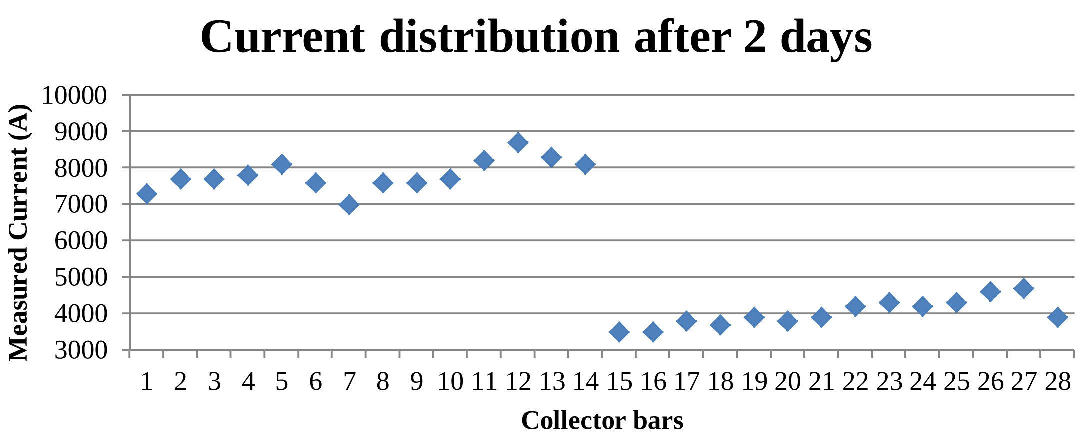

Figure 5. Cathode current distribution, pot 261, after 2 days.

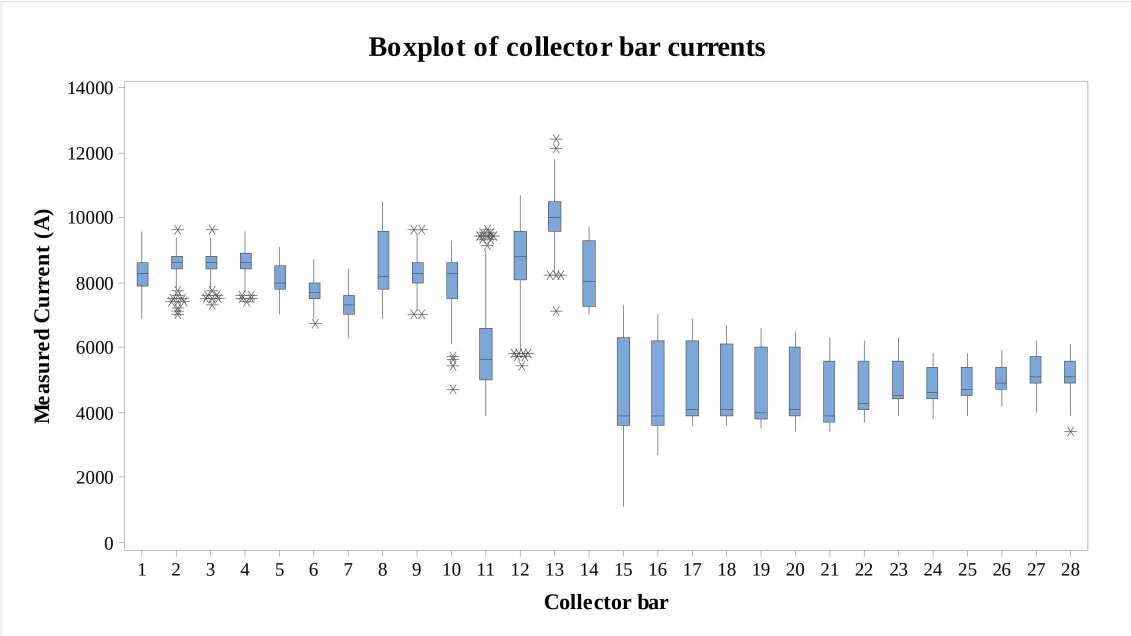

Figure 6. Boxplot of collector bar currents.

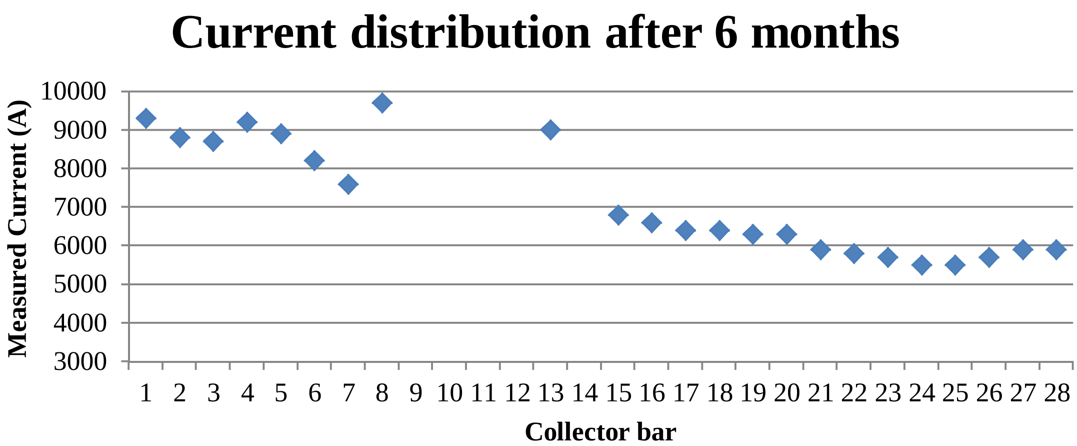

Figure 7. Cathode current distribution, Pot 261, after 6 months.

Hadi Fanisalek [4] proposed the disconnection and reconnection of all collector bars as a possibility to correct the current distribution of an upset pot. However, this would require welding of 28 collector bars in the potrooms, which is only possible during line shutdown and had not been done before. Whether this would be a feasible option for Pot 261seems to be questionable.

3.3. Cathode Current Distribution for Pots with Center Cracks

When looking at the data from a pot with a centreline crack through all cathodes, the CCD shows no indications for an individual cathode bar failure. Changes of current distributions are likely due to anode change. Pot 122 was started on 8 July 2011 and shut down on 7 April 2017 at pot age of 2100 days. During the last months, the iron content of the pot steadily increased until 15 March 2017, when collector bar 16 was disconnected and the iron level decreased, only before it increased again at a rapid rate (see Figure 8).

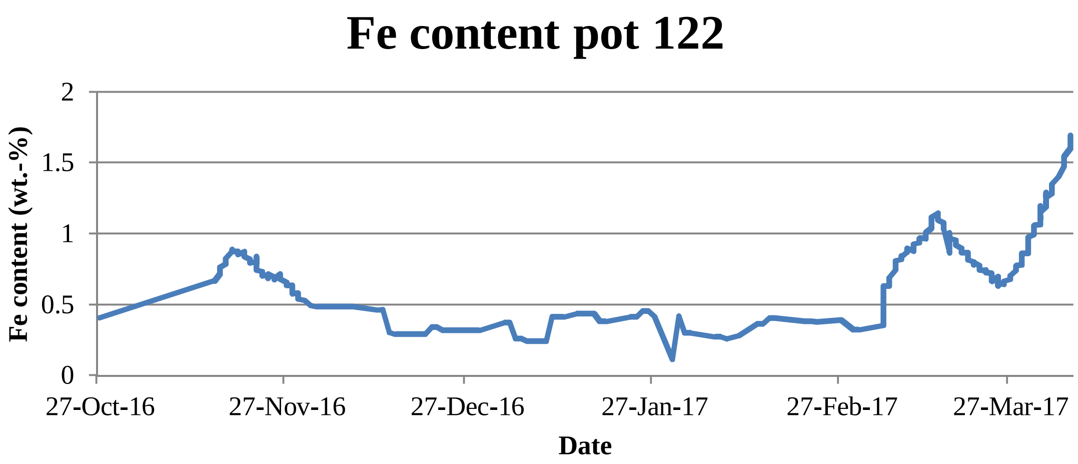

Figure 8. Fe Content of metal samples in wt.-%, pot 122.

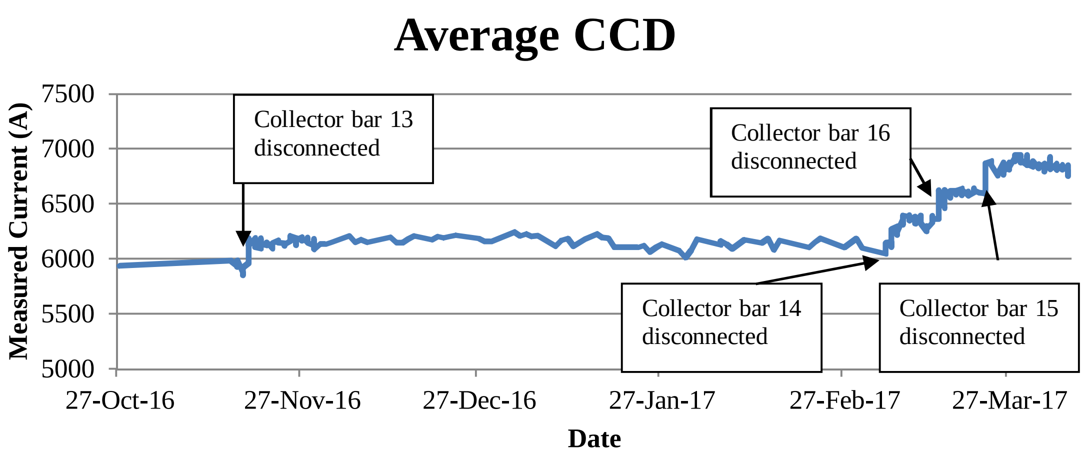

Figure 9. Average current in collector bars, Pot 122.

During the pot autopsy, it was confirmed that the pot had a centreline crack in all 14 cathodes due to cathode heave from a reaction of the refractories. Additionally, the cathodes at the tap hole were heavily eroded. This corresponds well with the disconnected bars 13 to 16. However, the collector bars at the tap hole were not the only influence on the iron content, as the evolution after 27 March shows.

4. Summary and Outlook

The successful implementation of a top-down measurement for cathode current distributions allows the identification of faulty cathodes and cathode collector bars due to more and faster measurements compared to the use of the Halmar COP ammeter. By identifying certain patterns of CCD, the potroom management can identify and anticipate certain pot failure modes by evaluating the cathodic current distribution.

With today’s results and robustness of the measurements, the next steps are the implementation of a continuous measurement of individual collector bar currents. This will lead to a better understanding of current distributions during pot start up and stable processes, but also help with critical pots. The first step could be a mobile setup for critical pots as a kind of “crash-cart” setup.

5. References

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