Metal Crucible Tracking System at EGA Using Digital Technologies

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Abstract

Lack of visibility of the metal crucible along its journey is a common challenge in many of the aluminium smelters. Unavailability of metal crucibles disturbs the metal flow which might lead to pending activities. This challenge occurs due to the number of different stakeholders involved in the journey of the crucible and data being scattered and analyzed differently among them. The objective of the solution is to provide full transparency and visibility for all the stakeholders involved (Potroom, Potroom Services, Casthouse, Maintenance) as one single source of truth. This is done by collecting and capturing time and location of each crucible at all different processes along the journey from different machines and systems. A comprehensive dashboard was developed along with an auto generated report for all the different stakeholders to monitor the operation performance at each step in the journey. In addition, crucible tracking application was developed for the crucible transfer vehicle (CTV) operators to collect missing data and operate based on automated prioritized live work-order. The full visibility and transparency of the metal crucible journey allows to draw solid duration baselines for each process, therefore, introducing new KPIs for each process owner. In addition, providing the visibility to the CTV operators allows to shift from experienced-based to data-based operational decisions. The crucible tracking system helped to reduce pending metal tapping incidents, respond faster to debottleneck impediments, reduce cycle-time, reduce frozen crucible incidents, and reduce overweight crucibles.

Keywords: Industry 4.0, Aluminium smelter, Metal crucible tracking system, Metal crucible transfer vehicle, Metal flow.

1. Introduction

Pending tapping and unavailability of crucibles is a common challenge in many smelters around the world. There are many reasons why delays in tapping occurs, such as pot tending machine breakdown (PTM), unavailability of empty crucibles, furnace breakdown, emergency situations, etc. In some extreme cases, delayed tappings accumulate to a level where the line amperage is reduced to catch-up with the pending activities resulting in loss of production.

The lack of visibility in the metal crucible journey in the plant causes longer time to take the right actions to debottleneck the situation. The data along the journey is scattered, each team analyzes the data differently based on their perspective, making it hard to take a collective decision.

Having full visibility of all the crucibles in the plant enables all different teams to work collectively to overcome the different challenges along the crucible journey. Optimizing the crucible flow can reduce the turnaround time of the crucible by minimizing the idle durations in different processes along the journey. This will lead to deliver a hotter metal to casthouse, reduce the emission from the exposed tapped metal, and reduce the frequency of crucible cleaning. The transparency of the crucible movement allows the operators to move from experience-based to data-based operational decision.

This paper explains how the visibility of all the crucibles in the plant was obtained through the developed crucible tracking system and how this system helped improve the operation in EGA.

2. Operation Prior to the System

The job of the CTV operator is critical and challenging due to the number of stakeholders involved in the crucible journey from Potline, Casthouse (CH) to maintenance. During the shift change, the CTV operator is briefed by his/her colleagues about all the crucibles that he/she is responsible for. This is a manual process which might not be very accurate due to large number of crucibles and multiple operators working together. The operators communicate with each other using radio telecommunication, WhatsApp, text messages, and phone calls.

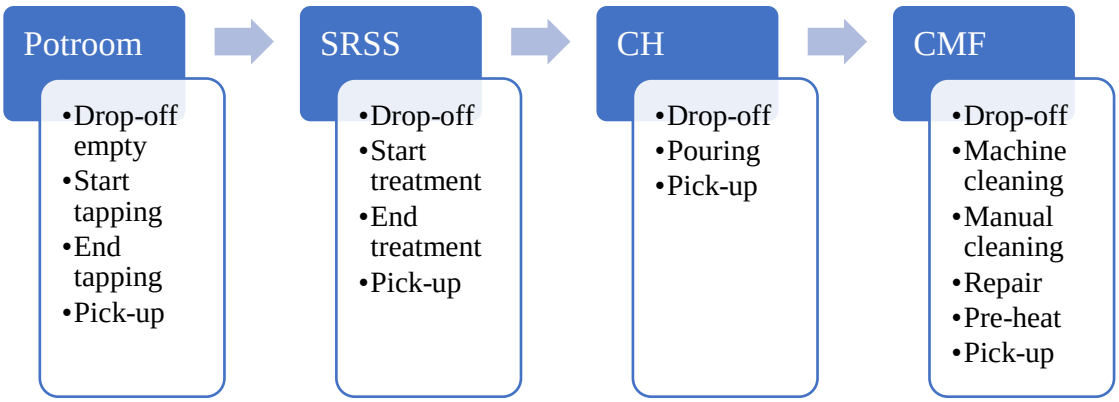


Figure 1. Diagram of the main processes along the metal crucible journey.

Starting with potlines, as shown in Figure 1, the CTV operator needs to ensure enough crucibles are available so the potline operator can perform metal tapping without any delay, as well as move the full crucibles to the next process as fast as possible to minimize the metal temperature drop and avoid frozen metal incidents. The CTV operator is fully dependent on his/her experience to predict the crucible status in the flow. If there is any long delay, potline supervisor communicates with services team to expedite the transfer of full metal crucible.

Next, the full crucible is transferred to sodium reduction and skimming station (SRSS) for treatment. After dropping, any other treated crucible is then moved to the assigned furnace in Casthouse. After the drop, the operator manually searches for any empty crucible in front of the furnaces to be used for the next tapping. This process is manual; therefore, the operator cannot perform first-in first-out (FIFO) to ensure hotter crucibles in the loop. As and when required, the

crucible is transferred to crucible maintenance facility (CMF) for cleaning and other maintenance work.

The entire journey of the crucible moving between potlines, SRSS, CH, and CMF is recorded manually on paper by the CTV operator. However, the duration since the crucible was ready until its actually picked-up is unknown in some processes and not spotlighted in others. This collected data is huge and not analyzed unless an investigation is required.

3. Solution Design

Crucible tracking solution consists of two different parts. First, a mobile application for CTV operators to provide visibility of all crucible statuses in all locations automatically and collecting new data of all the pick-ups and drop-offs. The second part is a one-stop dashboard for all supervisors providing transparency to see the live status, historical trends at each process in the crucible journey, as well as automated performance report.

To close the loop in the crucible journey, two different data sources were combined and used for the crucible tracking system. The existing scattered data from different areas and machineries, and the new collected data by the CTV operators from the application through a tablet in the vehicle.

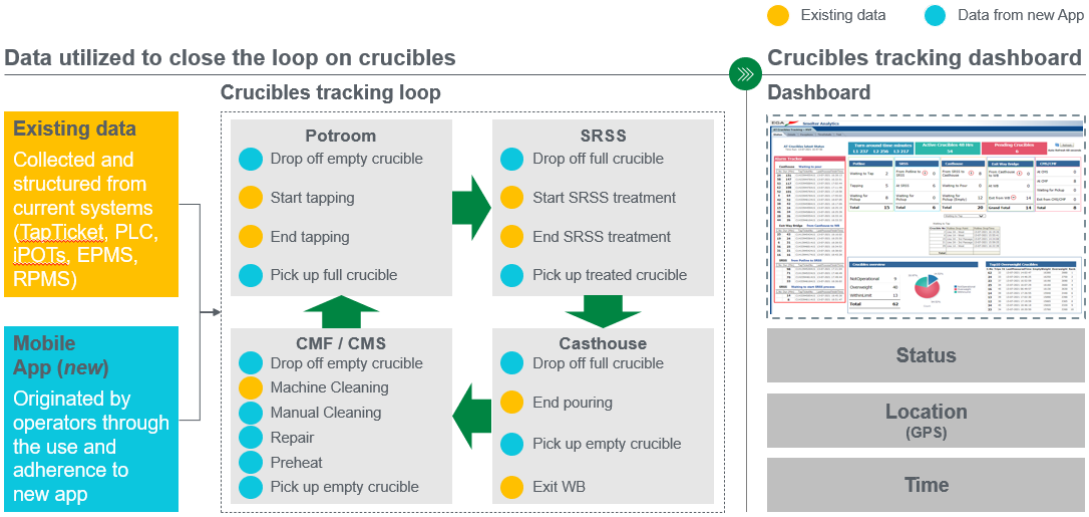


Figure 2. Data availability along the metal crucible journey after implementing the system.

As shown in the Figure 2, various data were available from different standalone systems. In the potline, tapping start and end data were collected from the pot control system tapping logic. In SRSS, the crucible arrival, treatment start, treatment end, and removal data are captured from PLC and additional tap-ticket scanners. In CH, a handheld device is used to indicate end of pouring into the furnace, as well as the weigh-bridge data. In crucible maintenance facility (CMF), the data from the cleaning machine was connected to our systems to automatically identify which crucible was cleaned.

Through the mobile application, the CTV operator registers all the pickups and drop-offs of different crucibles. Combining the collected data by the CTV operator with the existing data from various system allows to track the performance of the crucible journey at each process. The breakdown of the duration spent at each process along the journey of the crucible is obtained as shown in Figure 3.

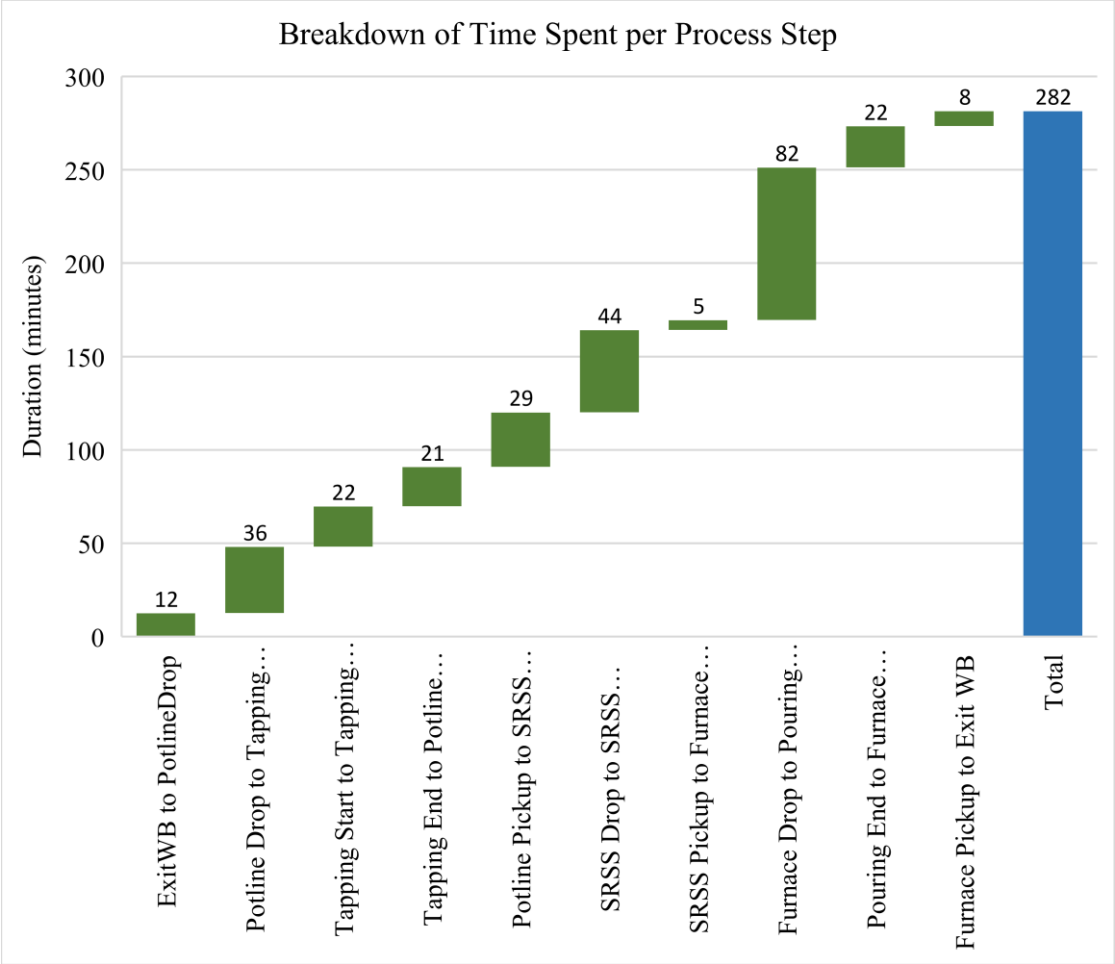


Figure 3. Breakdown of time spent in each process along the crucible journey.

For example, connecting end of tapping timestamp and the timestamp when the full crucible was picked up from the potline will allow to measure the duration of the full crucible in the potline waiting to be picked up. Similarly, the same was done in different locations of the crucible along the journey.

4. Operation with the System

4.1 Application

One of the main advantages of linking the data is it provides visibility to the CTV operator in the vehicle itself. A prioritized work-order list is developed in the mobile application showing real time status of all the crucibles in the operation through the tablet as shown in Figure 4.

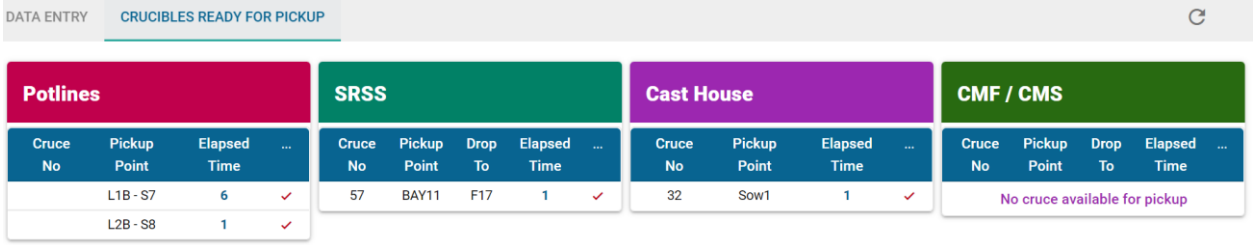


Figure 4. Prioritized work-order list for the CTV operators.

Work-order list supports the CTV operator to take decision and plan his/her trips in operation. It improves the productivity of the operator by planning the trips based on real-time status of all the crucibles he/she is responsible of. As shown in Figure 5, all operators have the visibility on how many tap-tickets are remaining in the current shift. This visibility enhances collaboration and teamwork among the operators to complete all the scheduled tapping in their shift.

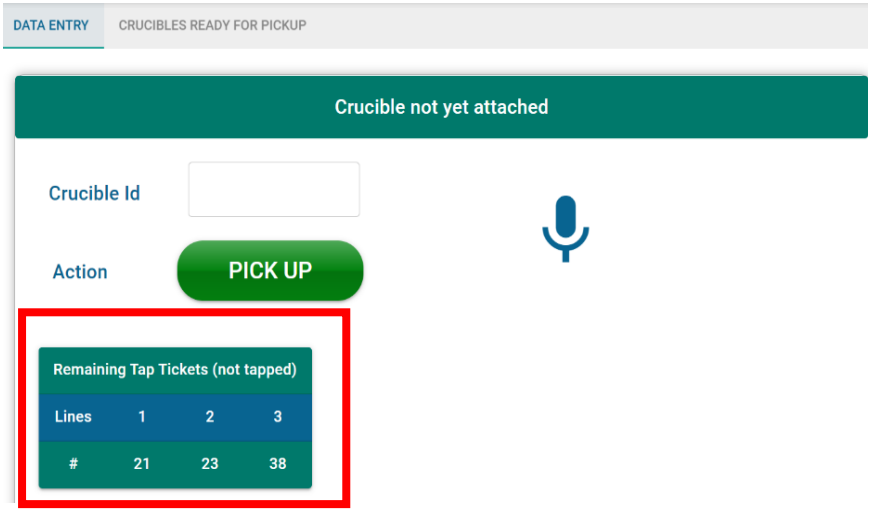


Figure 5. Screenshot from the application showing the number of remaining tap-tickets from the current shift.

Another visibility the application provides for the CTV operator is the automated count of the number of trips (tapping to pouring) completed since the last machine cleaning (Figure 6). This data is important for the operator to know when the crucible needs to be taken to crucible maintenance facility for cleaning. By adhering to the requirement, the number of overweight crucibles and necessity to manually clean the crucibles reduced.

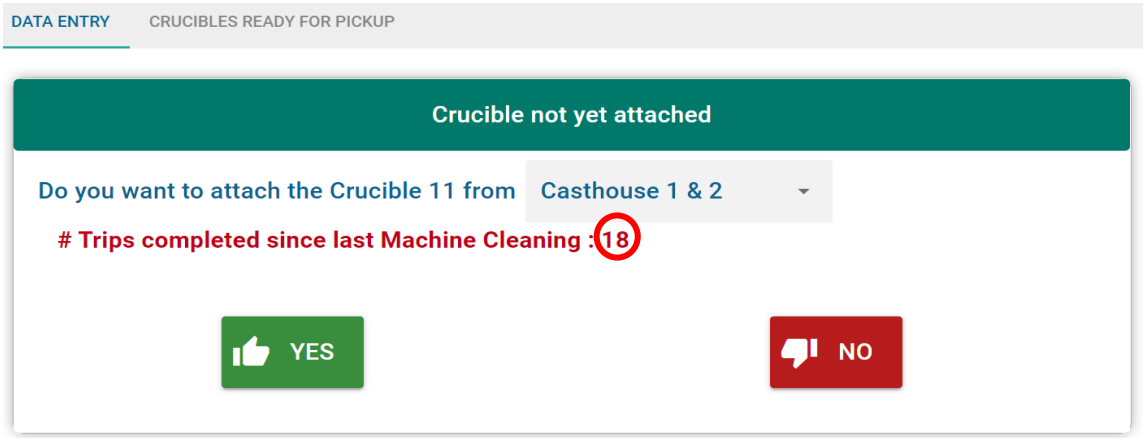
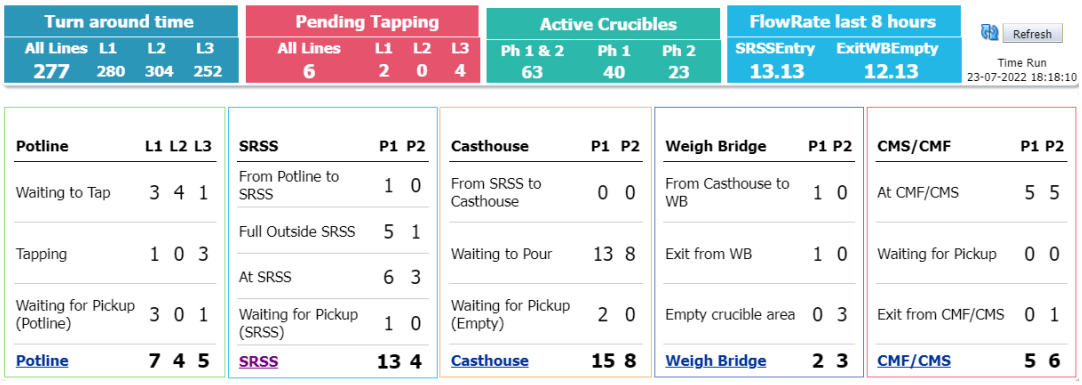


Figure 6. Screenshot from application displaying the number of trips completed since last machine cleaning for the selected crucible.

4.2 Dashboard

The second part of the solution is a one-stop dashboard that provides full visibility of the status of all the crucibles in the entire plant as shown in the Figure 7. The visibility allows the Potline services (PS) supervisor to take various decisions to improve the operation and debottleneck different challenges.



Turn around time			
All Lines	L1	L2	L3
277	280	304	252

Pending Tapping			
All Lines	L1	L2	L3
6	2	0	4

Active Crucibles		
Ph 1 & 2	Ph 1	Ph 2
63	40	23

FlowRate last 8 hours	
SRSSEntry	ExitWBEmpty
13.13	12.13

Refresh

Time Run
23-07-2022 18:18:10

Potline	L1	L2	L3
Waiting to Tap	3	4	1
Tapping	1	0	3
Waiting for Pickup (Potline)	3	0	1
Potline	**7**	**4**	**5**

SRSS	P1	P2
From Potline to SRSS	1	0
Full Outside SRSS	5	1
At SRSS	6	3
Waiting for Pickup (SRSS)	1	0
SRSS	**13**	**4**

Casthouse	P1	P2
From SRSS to Casthouse	0	0
Waiting to Pour	13	8
Waiting for Pickup (Empty)	2	0
Casthouse	**15**	**8**

Weigh Bridge	P1	P2
From Casthouse to WB	1	0
Exit from WB	1	0
Empty crucible area	0	3
Weigh Bridge	**2**	**3**

CMS/CMF	P1	P2
At CMF/CMS	5	5
Waiting for Pickup	0	0
Exit from CMF/CMS	0	1
CMF/CMS	**5**	**6**

Figure 7. Screenshot from the dashboard displaying the full visibility of all the crucibles in the plant.

For example, if the traffic is high in SRSS and number of full crucibles waiting to be treated is increasing, a collective decision with CH can be made to divert some of the crucibles to be cast without treatment for different grade of aluminium.

Additionally, the dashboard sends an automated daily report to the management reflecting on the performance of the crucible movement along the entire journey. The daily report contains the key performance indicators leading to either advanced or pending tapping.

5. Results and New Perspective

The visibility that the crucible tracking system provides allowed the management of both Potline and CH to look at the crucible journey from a new perspective. As shown in Figure 3, the new system provides a detailed breakdown of each process along the journey. This allows to introduce new measurable KPIs for each process to reduce the turnaround time of the crucible.

There are several steps in the crucible where the crucible is full with hot-metal while its idle waiting to be picked up. For example, Figure 8 shows the average duration of all full crucibles in the potline that were idle and waiting to be picked-up. Long idle duration causes the metal temperature to drop which will require the furnace to use more energy to raise the temperature again, as well as the need to clean the crucible more frequently.

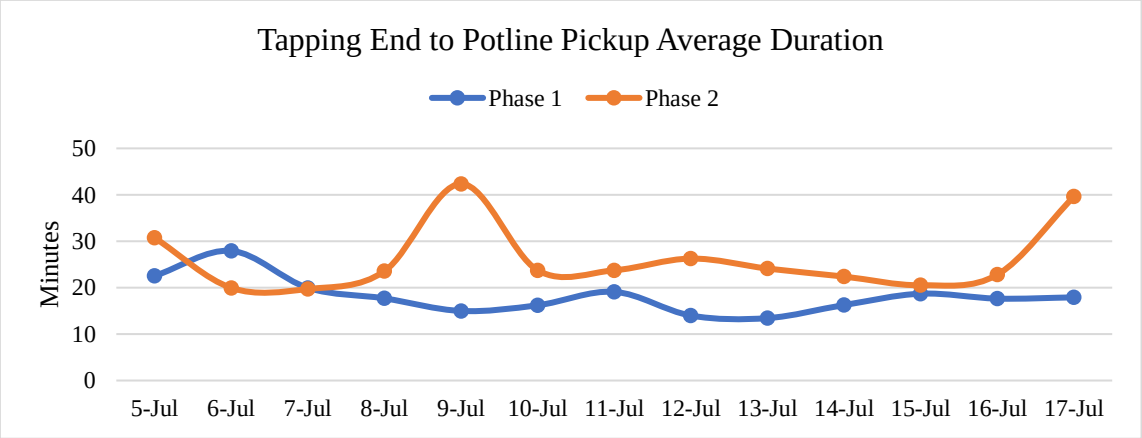


Figure 8. Average duration of all the full crucibles waiting to be picked-up from potline per day.

Due to the absence of data before implementing the system, we were unable to quantify how much the visibility to the CTV operator through the application resulted into reduction of idle/wasted time waiting to be picked up. However, the number of complaints due to delays in crucible operation reduced by 75 % after the system implementation (dropped from 35 to 8 complaints in the past 6 months). In addition, since the system was deployed (approximately 6 months), there have been no frozen crucible incidents recorded yet. Based on Potline and CH feedback, it was noticeable that the visibility the new system provided improved the operation significantly.

Another important insight the system visibility provided is the optimum number of metal crucibles required in the loop. Having fewer crucibles in the loop will lead to pending tapping. On the other hand, having excessive number of crucibles in the loop will lead to colder crucibles, therefore, increase in crucible cleaning frequency. In average, the number of overweight crucibles dropped by more than 85 % after implementing the system (from approximately 35 to 4 overweight/dirty crucibles). This had significant impact on overall work flow efficiency.

Potroom services team decided to allocate a physical location in the loop where the crucibles are dropped when they are not needed and sitting idle. Figure 9 shows the trend of how many crucibles were dropped in idle location and the average duration. The graph assists potroom services team to take an informative decision to either remove or add crucibles in the loop.

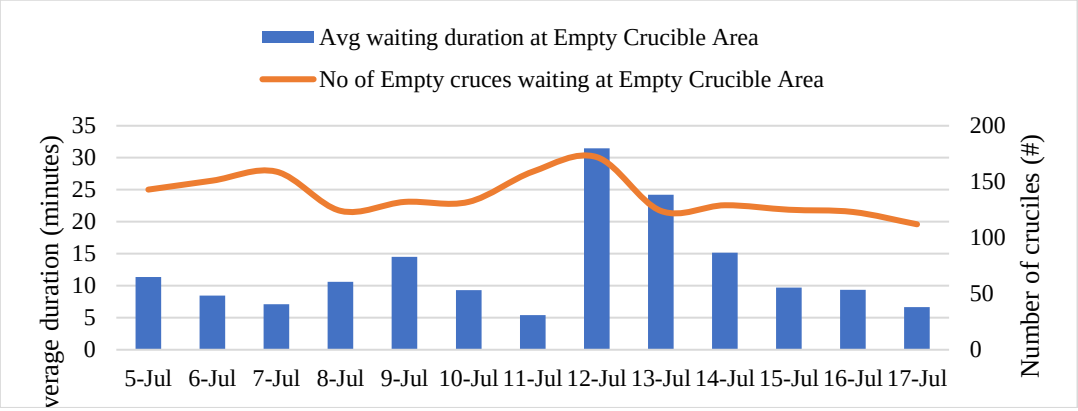


Figure 9. Number of empty crucibles and its average duration in idle position.

6. Conclusion

Full visibility and transparency of the entire crucible journey was achieved through the developed crucible tracking system. It consists of a mobile application for CTV operators and one-stop dashboard. Data from Potline, SRSS, CH, and Maintenance were combined to close the loop on the crucible journey. The mobile application was used to collect missing data and provide an automated prioritized work-order list for CTV operators. On the other hand, the developed dashboard was used to assist various teams to debottleneck the challenges. Detailed process breakdown of the entire crucible journey was obtained. This supports the operation to set new KPIs for each process in the loop to reduce the crucible turnaround time. After implementing the system there was a significant reduction in number of pending tappings, overweight crucibles, and frozen crucible incidents.