OPERATIONAL ASSISTANCE AND PROCESS SUPPORT: HOW TO SECURE KNOW-HOW AND EXPERIENCE REGARDING SPECIAL SITUATIONS IN BLAST FURNACE IRONMAKING*

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Abstract

The highly dynamic economic climate of recent years has tightened the operating envelope for steel producers world-wide. Steel producers continue to experience immense pressure to respond quickly to changing circumstances and the focus has shifted towards efficiency improvement and maximizing flexibility in operations. The ability to safely stop, restart and ramp-up production facilities has become essential. Establishing this level of flexibility, without sacrificing efficiency, requires sound process control, fit-for-purpose process management practices and solid know-how and experience regarding special situations in blast furnace ironmaking operations.
The same business environment that demands this increased flexibility has made it increasingly difficult for steel producers to sustain sufficient knowledge about these situations. While many experienced, senior operational staff have retired, a new generation of ironmaking specialists has acquired its hands-on experience over more recent decades, during which these process situations have been much less frequent than before. Over the past 10-15 years, the requirement in the industry for external operational support during e.g. blast furnace blow–downs, salamander tapping and restarts after planned and especially unplanned stops, has become increasingly frequent. This article presents a number of these cases from a process management perspective as well as with regard to project organization and optimized cooperation between internal and external teams of experts.

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1 OPERATING ENVIRONMENT OF BLAST FURNACE IRONMAKING IN THE 21ST CENTURY

Ironmaking operations have stabilized as a result of improved process know-how, better instrumentation and increased automation. This has led to a reduced number of critical events and production anomalies. Similarly, the sharp decline in the number of blast furnaces per production site and again this higher degree of process automation have led to a fall in the number of operational personnel in casthouses and control rooms. The know-how essential for coping with (escalating) process upsets is eroding, while the risk of exposure to events of this kind is rising.

Throughout its modern history, the global steel industry has been confronted with repeated crises, repeated shifts in demand, septs in consolidation, etc. Each of which phenomena has had its consequences for steel producers around the world. The long term sum of these consequences has been a traditionally narrowing margin per tonne of steel – keeping the industry balanced near the edge of being able sustain operations for the long term, intermitted by short periods of high demand and earnings.

Against this backdrop of financially tightening circumstances, the steel industry is left with no choice but to push operations towards their limits. Especially in blast furnace ironmaking – a continuous process that is relatively difficult to control – unexpected process fluctuations or mishaps may be insured against at the premium of e.g. slightly elevated coke rates or slight safety margins in raw material specifications. Eliminating some of these safety margins is a necessary “quick win” in cost savings and as such, in sustainable operations for the long term. The added operational risk of eliminating these safety margins can remain limited if and only if some of them are kept in place and if the condition of the plant equipment and external factors (e.g. logistics) allow. Pushing both the process and the plant equipment to their limits will escalate these risks to potentially unacceptable levels – yet this is a natural driver for plant management in the increasingly competitive economic operating environment of the plant. The boundaries of this cost optimization – or in fact the ultimate limits of the *process related* operating environment – are for the blast furnace operators and process technologists to be identified and monitored. Regardless of whether management and operations will be capable of steering the process away from escalating upsets and their consequences, the ability to spot the early signs is a first requirement.

Today, many blast furnace operators have grown used to continuous, relatively problem-free operation, in part as a consequence of the improved process know-how, better instrumentation and increased automation mentioned earlier. As more and more operators and technical experts with decades of experience go into retirement, steel producers are running an increasing risk of early signs of process upsets remaining unnoticed. Expert systems so far have no proven capability of predicting and mitigating all such events and cannot be relied on entirely in this respect.

As the blast furnace ironmaking community well knows, “a chill is only eight hours away,” and now that the luxury of having good quality raw materials at acceptable price levels is a thing of the past, the industry needs to manage ironmaking operations based on sustainable approaches for securing the know-how for de–escalating and recovering from process anomalies such as the chill condition shown in Figure 1.

Figure 1. Serious furnace chill.

2 "CRITICAL EVENTS" IN BLAST FURNACE IRONMAKING

With stabilizing ironmaking operations and decreasing numbers of blast furnaces per site, operational staff has faced serious upsets far less frequently than in earlier times. Yet with equipment and process being pushed to their limits and typical blast furnace sizes having increased, the associated risk has increased.
Whereas a few decades ago, it would not be uncommon for a multi-furnace site to experience an serious upset resulting in an unprepared stop or even process chill on an approximate annual basis, the typical frequency of such events has declined to typically a single chill per furnace campaign and up to three unprepared stops per ten years.

Examples of root causes for unscheduled stops or chills are inability to drain liquids from the furnace in the event of problems in the casthouse/trough and runner system or escalating consequences of (extreme) water leakages (example shown in Figure 2) within the furnace as a consequence of for example poor maintenance. Mechanical failures in conveyor belts and other equipment, along with electrical faults may also contribute.

Figure 2. Water from taphole, clear indication of leaking staves.

Modern steel plant management, grown accustomed to untroubled operation over recent years and having deployed operational policies accordingly, is not always aware of the real impact, costs and consequences of long unscheduled stops. This may slightly shift the balance in the (natural) tension between plant management exerting pressure to achieve maximum performance and efficiency on the one side and process operators pushing for increased safety margins towards the acceptance of slightly elevated risk. Long and unscheduled blast furnace downtime is not publicized widely, but is and will remain a reality.

Costs associated directly to lost production vary, but can run to the hundreds of thousands of euros per day. Consequences of the critical event that cause the unprepared stop go beyond cost quantification given the health and safety risks that they introduce. These consequences may be, but are not limited to:

- Gas explosions caused by e.g. explosive gas mixtures in the furnace or the release of hot top gas such as in the case of furnace slips
  - Damage to furnace equipment and surrounding area
  - Catastrophic damages
- Unexpected hot liquid flows (examples shown in Figures 3 and 4)
  - Burn–out of tuyeres
  - Taphole or hearth break–out
  - Runner overflow
  - Bad separation of hot metal and slag
  - Gas/liquid blow–out from the taphole
  - Liquid splashes

Figure 3. Taphole Blow-out.

Figure 4. Slag from tuyeres.

Once a process upset has escalated to a critical event, putting the blast furnace process into an unprepared stop, plant management and operating staff are facing major challenges, the first of which is the simple fact that the period of escalating process conditions – typically up to around two weeks – has asked a lot of all of those involved. All have to work in an exceptional and demanding working environment covering 24/7 for two to three weeks continuously at typically double the workload of normal operation while usually being tired and having lost focus.
Anomalous process events are by their nature unpredictable and no two such events are the same. Since how these events play out will depend to some extent on local and furnace-specific conditions, there is no fundamental substitute for having this specialized know-how on site, with hands-on experience of the operations of the specific blast furnace concerned. Given the erosion of this expertise as described above, it is highly unlikely for a steel producer to have this expertise available locally.

Larger scale, multi-site steel producers may have a viable opportunity to secure this know-how. Among multi-site companies, there has been a trend of centralizing their dwindling expertise on hand to deal with critical events that have become an increasingly rare phenomenon. While these expert teams or knowledge groups appear to offer a solid solution, they may also struggle to accrue as well as sustain their level of know-how, e.g. owing to the associated requirement for experts to change their working environment or the fading hands-on experience. Bringing in external experts gives the organization access to vast experience in a multitude of operational circumstances, but has the apparent downside of increased external costs. Flying in support from these (internal off-site or external) centers of expertise after problems have reached an advanced stage has the definite drawback of increased response time with the risk of further escalation of the situation e.g. through further wasting of valuable unconsumed coke inside the furnace.

Another challenge is the availability and condition of equipment and machinery required during the process of getting the furnace restarted safely. This operation requires e.g. lancing equipment for introducing heat into the furnace and creating a connection between taphole and tuyere levels and machinery for cleaning out the casthouse, clearing the troughs and runners and cleaning the dry pit. This machinery and equipment need to be in a technical state allowing for heavy use over the full two to three week period – a precondition that may be jeopardized by lacking maintenance e.g. after prior use. Ideally, most equipment and machinery is even redundant.

3 RESTARTING AFTER UNPREPARED STOPS

Whichever the nature of the critical event, the common denominator connecting them is the fact that the ironmaking process had to be stopped without preparation – sometimes even ending in a chill. The burden is left with insufficient fuel because there was no time to add substantial amounts of coke to the burden and/or fuel was wasted during the last hours before stopping the process.

When starting up again after an unprepared stop, answers are needed to a range of questions:

1) Are sufficient experienced technical staff and operators on hand 24/7 for safe and efficient startup? The challenge regarding the lack of qualified personnel is a major bottleneck in a process that could take days or even weeks to start up again from a chilled hearth. Staffing schedules should be assessed and – where required - external experts (either intercompany or from third parties) should be flown in, the overall schedule accommodating for their response and travel times;
2) What burden composition to start with and what process settings?
3) Where and how to start up – which tap hole(s) are suitable, how many tuyeres to start with, how much blast (production of liquid), when to start casting?
4) Dry pit capacity, safe dry pit cleaning and runner layout and availability are further issues.
5) Identifying and mitigation of all safety risks during this period for personnel and equipment.

The problems to be expected and addressed before startup include connection loss between tuyeres and taphole, high blast pressure, hanging and slipping of burden, asymmetrical burden descent, “dark” tuyeres, slag in blowpipes, scabs behind tuyeres, high top temperatures, clogging of runners, too-long inter-cast time, burning and tipping tuyeres, low and high Silicon percentage and low liquid temperatures.

After startup, another set of crucial decisions is needed: when and how to open tuyeres, when to open a second taphole, when and how to adjust burden content? Process upsets in the initial phase and the parameters needing special attention are other factors.

Figure 5. Test firing of lancing equipment.

Equipment should be tested thoroughly, including e.g. test firing of (oxyfuel) lances (see Figure 5). If the availability and condition of the required equipment and machinery turns out to be prohibitive, alternatives should be sought elsewhere on site and options for quick reconditioning of equipment considered. Equipment in “plug and play” condition may be sourced or rented externally but lead time should be clearly tracked.

During the preparation for the restart, all parties involved are pressed for time given the need to minimize production loss. Completing these preparations conscientiously, covering all required checks, contributes to a smoother and quicker restart. As a case study, the two figures below illustrate the difference between a well-prepared restart after an unscheduled stop and a restart with mediocre preparation. Both furnaces were similar in size.

In the first case, a restart schedule targeting all tuyeres open and having the furnace on full blast after 56 hours was drafted. The restart was well-prepared and could be completed smoothly and within the envisaged timeframe as shown in Figure 6.

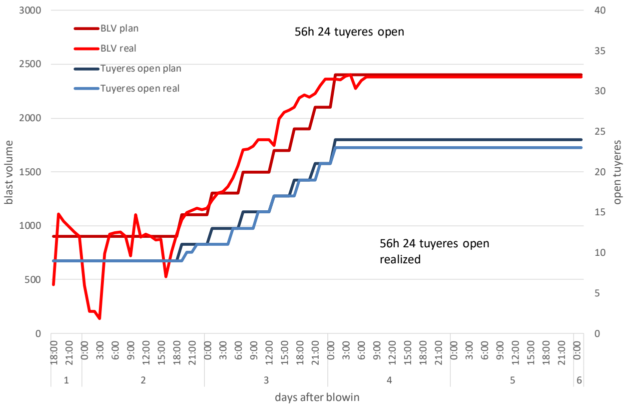

Figure 6. Restart after good preparation.

In the second case, preparation checklists weren’t followed and the people involved badly aligned. The targeted full restart within 77 hours was not met with several occasions where the blast volume had to be reduced and there were repeated time frames between the opening of additional tuyeres that were much longer than agreed. Progress of this restart is illustrated in Figure 7 on the next page.

Figure 7. Restart after sub-par preparation.

This restart was completed with a 65 hour delay, equating to an additional damage of over one million euros in lost production.

Further reading on the restarting of (chilled) blast furnaces after unprepared stops is provided by Van Stein Callenfels et al[(1)].

4 NEXT STEPS IN REDUCING THE LIKELIHOOD OF CRITICAL EVENTS

Since during recent decades, ironmaking operations have stabilized yet critical events leading to unprepared stops and process chills have not disappeared entirely, blast furnace operators and plant managers need for means of at least reducing their likelihood and frequency.

In “planning for the unexpected”, a major step forward is taken based on an improved, fundamental understanding of these events in combination with clearly stipulated mitigation plans for each condition. Operational staff needs to be trained to recognize anomalous events as early as possible and develop skills for doing a quick but reliable root cause analysis. That training needs to encompass not only what to do when faced with a specific set of circumstances, but also why it needs to be done. An understanding of the nature of the anomaly and its specific circumstances will prove an indispensable asset in de-escalating the event and responding to unexpected process behaviour during de-escalation and recovery.

An effective method of deploying this know-how is through programs based on a “train the trainer” approach. A first group of experts participates in an intensified training program (off-site if required), after which they move on to train their colleagues at their own production site or unit.

On top of a first know-how and know-why driven step, plant management and operational staff should develop and agree on a set of early warnings and connected countermeasures. The early warnings should be clearly defined in terms of process behaviour and process parameters. Countermeasures could be defined in terms of actual thermal process modifications such as fuel rate, moisture, oxygen and hot blast temperature, but also as a clear specification of within what bandwidth process operators are authorized to modify the process without prior consent of senior management. In all cases, countermeasures should include schedules stipulating who should be informed or consulted by whom and at what frequency.

The objective of this practice is to reduce the risk of further escalation of the upset during the time spent on lengthy discussions and analyses between operators and management – a commonly found non-technical root cause for furnace chills on top of the original root cause that initiated the upset.

In mature industries, the empowerment of operational staff through elevated know-how and added degrees of freedom in managing the process – especially with predefined boundary conditions in the context of process upsets – has proven to offer strongly increased operational stability and quicker and more effective response to unusual conditions. In addition, this fosters a working culture in which efficiency improvement and maximum performance become the prime focus for all operating staff.

External parties can support greatly in all steps indicated above, particularly since this opens the door for different perspectives and benchmarking against practices employed elsewhere. For the de-escalation of actual process upsets, the lead time that comes associated with employing external expertise remains a factor – but this effect may be somewhat reduced by working under framework agreements predefining terms of cooperation and support.

5 CONCLUSIONS

- Stabilized process conditions have reduced the frequency of critical events in blast furnace ironmaking, leading to lacking availability of expertise regarding these events
- Following a critical event it is essential for management to analyze the root causes and to implement the training needed to avoid recurrence.
- Restarts should be well-prepared and experienced and skilled operators and process specialists should be made available 24/7 for casthouse operations, liquid management, tuyere floor handling and process evaluation and adjustment.
- Procedures for out-of-the-ordinary process conditions must be developed, stipulating quickly cascading communication and decision patterns in connection with specified process conditions.
- Staff need to be trained to develop for maximum know-how and empowered for quick response to process upsets.

REFERENCES

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