

THE ROLE OF DIRECT REDUCED IRON IN STEELMAKING

There are certain general principles associated with the use of direct reduced iron (DRI) in the various steelmaking processes. These principles relate specifically to those operating strategies that recognize not only the economics but also the protection of the equipment and personnel involved. The ability of each steelmaking facility to take full advantage of the unique characteristics of DRI largely depend upon the shop layout/equipment and the availability of certain raw materials needed to meet product specifications in a timely manner.

The following comments summarize Bethlehem Steel's experience with DRI. This special material has been used in most of their steelmaking shops and is a vital part of the overall drive to upgrade cost and productivity performance.

- Although several Bethlehem shops have had experience with the Midrex DRI pellets, virtually all their experience involves the FIOR DRI briquetted material.
- Bethlehem has consumed several hundred thousand tons of DRI without encountering a single hazardous furnace operating condition.
- At the electric furnace facilities at Steelton and Johnstown, DRI is used as a scrap substitute on grades of steel where control of certain residual elements is critical to product quality and yield. Steelton batch charges the FIOR briquettes along with the regular scrap requirement while Johnstown (the newest shop) injects the FIOR material through the furnace roof during the furnace meltdown period.
- Bethlehem's Burns Harbor BOF shop (three furnaces at 270 tons per heat) has been the major consumer of FIOR briquettes. Here the DRI is used primarily as a thermal trim agent in the charge calculation program in an effort to extend the hot metal availability.
- The ideal BOF charge consists of scrap, hot metal, and slagmaking fluxes. Originally, a thermal balance was achieved by adjusting the scrap weight after the hot metal for that heat had been analyzed and weighed. As the production pace increased, there

frequently was not enough time to trim the scrap weight. It was not unusual to be charging the hot metal into the BOF while the chemical lab was still running the actual hot metal analysis. In order to establish a thermal balance for that heat of steel, it became necessary to use a calculated amount of iron ore pellets that were fed into the BOF, along with the flux materials, during the initial stage of the blow. Since iron ore has about four to five times the cooling effect of scrap, the ore requirement was generally not that large.

- The convenience of using iron ore instead of scrap as the final thermal trim for the BOF charge unfortunately carries with it the penalty of higher hot metal charge percentages. This means lower process yields, higher flux costs, and the potential for poorer process control. On a typical .06% carbon heat, the charge would consist of 70% hot metal and 30% scrap. However, if iron ore was used as a thermal trim in an amount equal to 1% of the charge, the balance of the BOF charge would have to contain 74% hot metal, and 25% scrap. Thus, the convenient use of 1% ore on the charge requires 4% more hot metal and brings into play a host of cost and operating penalties.
- In the U.S.A., about half the BOF shops use an iron ore trim practice and a significant number of shops use raw limestone chips in a similar practice. Even during periods of sharply reduced operations, many shops often do not have time to adjust scrap weights and still must resort to ore trimming because their actual operating hours have been reduced to control labor and other related costs.
- By totally substituting DRI for iron ore in the BOF process, the penalties associated with the iron ore thermal trim practice can essentially be eliminated. With this change in strategy, FIOR briquettes are treated as high quality scrap that can easily be handled, belt-conveyed, and stored in the overhead bins normally reserved for the storage of iron ore pellets. Any additional scrap trim weights required after the hot metal has been charged, can be made up in the form of FIOR DRI without the need for extra hot metal.
- The practice whereby the DRI is added to the BOF is vital to gaining the full economic advantage of this unique materia

After ignition of the charge occurs, the DRI, along with the flux requirements, is gradiently released into the BOF. The initial rate of release of material is usually slow to avoid smothering the rather fragile flame at the onset. Once the blow has been firmly established, the DRI and the fluxes are fed into the furnace as rapidly as conditions permit. With experience, the rate of DRI additions can be matched to ^(the speed with which) the furnace bath can absorb the briquetted material. Ultimately, this experience can be translated into a pre-programmed feed rate.

- In contrast with the generally wild -often uncontrolled- bath reactions that usually accompany large additions of iron ore trims, the DRI practice tends to result in furnace reactions that are mild and controlled. Additions of FIOR approaching 25 tons in total have been made without any unusual furnace activity.
- Under no circumstances should any form of DRI be charged directly onto the BOF bottom prior to the regular scrap and hot metal charge. In fact, any small uniformly-sized ferrous material such as scrap derived from a slag separation operation or scrap shredders when charged directly onto a BOF bottom can create a potentially dangerous condition for the shop and its personnel. With this type of material, the top surfaces tend to melt very rapidly, forming a protective coating over the balance of the charge. During the hot metal addition or during the subsequent oxygen blow, the liquid melt eventually penetrates the partially-fused covering over the small pieces of scrap. This sudden release of unmelted scrap and energy can be catastrophic, expelling slag and steel from the furnace and creating a serious hazard for furnace personnel and equipment.
- If DRI material would be charged directly onto the furnace bottom, the high residual heat of the BOF interior would encourage rapid reoxidation of the FIOR briquettes and this source of oxygen plus the film of reoxidized material on each briquette would combine very rapidly with the high carbon hot metal. This type of reaction can also be extremely dangerous. Furthermore, any entrapped moisture in the DRI could produce hydrogen, another highly volatile combustible gas in the process.
- In the absence of overhead storage bin capacity, the DRI portion

could be spread over the box containing the regular scrap charge, thus diminishing the hazard of premature reoxidation of the briquettes. However, this practice where DRI is being used as a scrap substitute is generally not economically sound unless there are unusual conditions such as an extreme shortage of scrap. If the DRI material is being used because of concern with undesirable residual elements, the diluent effect of the high hot metal charge should be adequate protection.

- On those heats where a temperature test taken after completion of the primary oxygen blow indicates that some form of bath coolant is required, the necessary reduction in bath temperature can be accomplished in several ways: additions of iron ore pellets or limestone chips or simply rocking the furnace back and forth. All of these practices have their shortcomings. The ore additions tend to become entrapped in the slag, creating a severe foaming condition wherein the slag often billows up and over the furnace mouth and occasionally into the components of the lower section of the gas collection hood. This type of reaction blocks up the additive chute and can jam the movable skirt that is an integral part of the limited combustion furnace design. At the Burns Harbor plant, considerable furnace delay time was required to clear slag from their lower hood area on the furnace equipped with the Baumco limited combustion system.
- Another disadvantage of the iron ore cooling practice is the loss of Fe units to the slag; this loss can exceed 50% of the ore addition.
- Using raw limestone chips as a coolant can stiffen the slag to such a point that a phosphorus reversion can occur on borderline slag conditions. This type of addition can fuse into large floaters that can block the taphole during the tapping operation.
- Rocking the furnace to cool the BOF bath is a favorite diversion of furnace crews but unfortunately this action exerts the maximum amount of mechanical torque on the furnace rotation gear system and can lead to premature failure and excessive maintenance.
- The use of DRI briquettes as a bath coolant after the primary blow represents the most desirable operating strategy. The larger higher density briquette allows the DRI to penetrate the slag covering and react directly with the molten steel bath. Usually, the amount of coolant required with the FIOR briquette practice

- is about one-half that needed with the ore pellet additions, thus improving process yields and decreasing the coolant time period.
- The markedly lower level of bath reactivity with the DRI coolant practice also assists the environmental control operation in that excessive fume generated during the off-blow period is difficult to condition and clean.
 - The more consistent level of bath reactions that results when FIOR briquettes are fed directly into the BOF during the main oxygen blow provides a more predictable reaction trajectory that is vital to optimizing process control.
 - FIOR briquettes must be handled like ferro-manganese in the belt-conveying operation. Care must be taken not to overload the belt with the relatively high density material. Belt scrapers and transfer points must be adjusted and properly guarded for the heavier briquette. The overhead storage bins should be checked to be certain they are adequate to support the DRI. These DRI storage bins must also be vented to prevent any concentration of gases that may result from reoxidation of the material.
 - A particular advantage of the FIOR briquette practice in those BOF shops exposed to low temperatures in the winter months is the elimination of freeze-ups normally encountered in the iron ore pellet storage bins. This situation poses a constant serious problem during the winter months often requiring desperate measures just to keep operating.
 - The use of FIOR briquettes in Burns Harbor's BOF shop has proven to be an extremely effective operating strategy. This practice has reduced the hot metal charge requirement by 2%, thus providing enough hot metal to produce at least one additional BOF heat per day. The process yield has improved by 1 to 2% due to the lower hot metal charge, less slopping during the oxygen blow (elimination of iron ore from the charge), and fewer Fe units lost to the slag during cooling. Flux requirements have been reduced due to the lower metal charge percentage. In addition, productivity improvements have been derived from the additional hot metal availability, fewer cutbacks in oxygen blow rate (more consistent bath reactions) and less delay time required to clear slag accumulation in the lower hood section.