Chapter 13

Tundish Operations

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13.1 Introduction

The tundish represents the inextricable link between the batch steelmaking and the continuous casting process. In its initial stages of development, the tundish was regarded as nothing more than a reservoir to hold sufficient liquid steel to provide a constant head over the mold, and to permit a ladle exchange to occur without interruption of sequence casting. This all-important coupler in the process of continuously casting high-quality steel has only over the past 15 years truly become recognized as a critical metallurgical reactor. As such, it is a vessel in which a series of operations occurs that requires chemical, thermal, and physical control. The quality of the liquid product delivered from the tundish to the mold thus depends highly on the degree and control of interaction of slag, gas and refractory phases with the steel melt.

At the 71st ISS Steelmaking Conference in 1988, Alexander McLean of the University of Toronto delivered the Howe Memorial Lecture, in which he provided a benchmark review of the tundish.[1] As part of his presentation, McLean assessed the roles of this vessel as a critical link in the steelmaking chain of quality, as a continuous refiner and as a transmitter of metallurgical signals. Although more than a decade has passed since this presentation, the basics of sound tundish operations are all contained within the paper: the crux of the process remains that an uncontrolled tundish becomes a contaminator rather than a refiner. It is undeniable that the tundish is as much a part of clean steel practices as the ladle before it and the mold subsequent to it. If the quality built into the steel in the primary and secondary refining operations is lost in the tundish, the ability to produce a quality product that meets the intended application depends wholly on recovery in the mold. This is a far more arduous task, considering the limited time that the steel resides in the confines of the mold, which provides a finite capability to cleanse the steel in the last stage prior to complete solidification.

Many steelmakers have studied their tundishes in order to maximize the benefits of the residence time available for the flotation and assimilation of reaction products from the molten steel into the slag phase. These can be products of deoxidation, reoxidation, precipitation, emulsification and/or entrainment of refractory components into the melt, and thus encompass both indigenous and exogenous inclusions. Based on a sound choice of vessel design, the operation of a tundish needs to be geared to

- promote inclusion flotation by maximizing residence time;

- ensure inclusion assimilation by a captive and noncorrosive slag;
- prevent thermal and chemical losses from the melt;
- minimize short-circuiting and dead zones; and
- offer the steelmaker an optimal design for quality and yield.

Elimination of contamination by air and/or refractory phases and technologies to support clean steel practices is part and parcel of sound tundish operations. It is in light of these issues that tundish operations shall be examined here. Design criteria, modeling, tundish flow controls, slags, temperature control and cleanliness improvements will be reviewed, as will be the effect of non-steady-state operations. Once a tundish design has been finalized for a specific application, steelmakers are in the position to maximize quality improvements when this vessel is regarded and operated as a continuous refiner. The operator needs to be cognizant that deviations from established clean steel practices can have disastrous results.

With an emphasis on higher productivity rates driven by increased casting speeds, greater machine availability and improved product yield, larger and deeper tundishes have become the norm in the industry. This has provided a beneficial effect on steel cleanliness, as inclusion separation is generally facilitated in a taller and more volumetric vessel, especially if care is taken that inclusions are not physically entrained to unnecessarily deep levels. A recent AISI review of 33 North American slab caster operations showed that the average single strand slab caster tundish holds 42.5 (short) tons, while the tundish working volume for two-strand slab casters averaged 47.9 tons.[2] Tundish volumes ranged from a low of 28 tons to a maximum of 72 tons for the casters surveyed.

The pursuit of greater tundish operating depths not only added to metal residence time, but also provided the additional benefit of reducing the potential for vortexing of tundish slags, especially during transient conditions such as ladle exchanges. This is true irrespective of the type of tundish-to-mold metering devices used, which can be simple metering orifices, stopper rod control, multi-plate slide gate mechanisms or the more recently introduced precision control valves. In order to utilize the tundish as a refining vessel, then, the following criteria must be satisfied:

- elimination of sources of molten steel contamination, e.g., refractory erosion, reoxidation, ladle slag carryover and tundish slag emulsification;
- promotion of inclusion flotation and separation from the melt by means of flow-modifying devices (FMDs), filters and engineered slags; and
- introduction of technologies such as thermal control, slag-free transfer and optimized metal delivery systems to the mold.

These criteria form an excellent framework in which the tundish can be considered as a refining unit. Although much of the work in tundish metallurgy has been performed on high-volume plain carbon steel slab casters, the philosophies and solutions span across to tundishes of smaller-volume producers, such as billet and bloom casters, near-net-shape producers, and, of course, the specialty steel industry itself.

It is not possible to provide a discourse on tundish operations that incorporates potential questions and solutions to all tundish metallurgy issues. (For instance, design issues in horizontal continuous casting tundishes will not be covered here; the interested reader is referred to a review article by Heard.[3]) Rather, the authors designed this section to serve as a road map to tundish technologies for steelmaking novices and experts alike. This information should provide a springboard to design site-specific solutions that must be cost-justified on an individual basis. The following selections are offered:

- Tundish Fundamentals: Design and Operation
- Water Modeling: An Effective First Approach

