New Ways of Designing Large Refining Vessels And Steelmaking Plants For The LD Process

by R. F. Rinesch

As a result of the general trend in steelmaking development, larger and larger furnace units are being used in LD steel plants with tap weights running as high as 300 tons today. Particularly in the United States, such a changeover from the open hearth to the LD process is taking place on a large scale. It is, therefore, quite understandable that the steelmakers who have operated with large-volume open hearth furnaces so far, would now like to have large refining vessels for their LD process. Also for economic reasons, this idea is a logical one and therefore of the utmost importance, because today, not only the European steel industry, but also the American steel industry, is exposed to a great price pressure. When new steelmaking plants are built, everything must be done to enable them to produce steel more cheaply and more economically.

Although the experience gained with large LD vessels has yielded unobjectionable results from the metallurgical point of view, there are, nevertheless, certain limits related to manufacturing technique preventing any further increase in the size of the tilting refining vessels, as used at the present time.

The following statements cover a new design of refining vessels with tap weights exceeding 200 tons and a new type of steelmaking shop for the LD process.

Instead of tilting vessels, a multi-sectional stationary refining vessel with a tapping spout is used, so that tap weights of 500 tons or more become possible with the type of operation and the metallurgical advantages of the LD process being retained. Throughout the design and the construction of this new stationary refining vessel for the LD process, design characteristics and construction elements are used, which have been known to steelmakers and furnace builders for decades. This alone will insure great operating safety for this new type of refining plant. The new shape of the vessel changes the structure of the whole steelmaking shop, so that simultaneously a new type of steel plant is created, the capital costs of which, however, will be lower than those of the conventional LD steel plant.

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METALLURGICAL PROBLEMS INVOLVED IN LARGE TILTING LD VESSELS

Before going into details relating to the peculiar characteristics of the new stationary refining plant, I would like to point out certain difficulties preventing any further increase in size of the tilting LD vessels beyond a tap weight of 300 tons.

It is a well known fact that, just as in the open hearth furnace, a certain bath depth must not be exceeded in the LD vessel if irregular and incomplete refining is to be avoided. This maximum bath depth amounts to about 1.6-1.7 m. That is why the bath surface was increased as the size of the vessel became larger. It is true that the area of oxygen impingement, the so-called hot spot, became larger, but it did not grow as quickly as the bath surface did in proportion to the tap weight.

If an attempt were made to increase the tap weight to, say, 400 or even 600 tons, the bath depth would have to remain the same, whereas the bath surface would double in the extreme case. It is therefore easy to imagine that such an extremely unfavorable relationship between bath surface, bath depth and tap weight will make it, from the purely metallurgical point of view, more and more difficult to carry out the LD process, even if a multiple-jet lance is used.

TECHNICAL PROBLEMS INVOLVED IN LARGE TILTING LD VESSELS

Owing to the fact that the bath surface must be enlarged if the bath depth is to remain the same, the ratio of slenderness* of the vessel decreases and its hood becomes flatter and flatter. This causes difficulties affecting the refractory lining and the life of the vessel hood.

* Ratio between height and diameter of vessel.

As far as vessel design and the behavior of the vessels under rough conditions in steelmaking-shop operation are concerned, the following problems are involved in the present large tilting LD vessels. These problems interfere with any further increase in vessel capacity beyond 300 tons:[1]

a) Irregular temperature distribution in the vessel and the trunnion ring.

b) Local overheating or formation of zones of higher temperature caused by slag and steel slopping, by faster wear on certain areas of brick lining, and by steel and slag radiation affecting vessel shell during tapping.

c) A certain stress caused by temperature changes, because the absolute values of the various temperatures of the vessel and the trunnion ring change in the course of a campaign.

d) As a result of the above, deformation occurs in the vessel, and if the design has not been made with sufficient care, even cracking may occur.

e) Cracking occurs, particularly if thermal expansion is impossible or if it is prevented. That is what happens, for example, to vessels having their hoods flanged on to them (removable). In this case, the thermal expansion of the flanges differs from that of the vessel shell. As a result, there is cracking in the vessel shell or in the area of the welds.

f) In trunnion rings which are independent of the vessel, the shape and the design of the bracing elements play an important part. The trunnion ring has different temperatures, not only when viewed in its cross-section, but there is also a temperature gradient in the direction of the trunnions with respect to its circumference. The trunnion ring is supposed to fix the vessel, on the one hand, and to make possible the latter's quite considerable expansion, on the other, and it is pretty hard to meet both requirements.

g) In the case of a 300-ton vessel, for example, the total weight of the vessel including lining and tap weight amounts to about 1300 tons. The outside diameter is about 8.4 m, the height about 10.0 m. For this reason, very thick plate has to be used for the vessel and the trunnion ring; the plate thickness varies between 75 and 220 mm. It goes without saying that the selection of the right material and the welding technique to be applied is of special significance in this connection. Efforts to decrease the dead weight by using steels of greater strength, have not yielded any positive results. Experience has taught, time and again, that unalloyed, easily weldable fine-grained structural steels within the tensile-strength range of about 40 to 50 kp/mm², withstand best the stresses which occur in the construction of steel-making plants and in rough steel-making-shop operation. This experience must be taken into account, particularly when large vessels are built. These heavy weights which have to be moved require the existence of adequately dimensioned bearings and gears capable of withstanding axial pressure.

h) In order to lower capital cost, the vessels have been designed as interchangeable furnaces which, in view of the magnitudes and weights indicated above, have to be heavy and sturdy, thus raising additional technical problems. The advantages of the design of the furnaces as interchangeable vessels are offset by a number of certain drawbacks.

STATIONARY REFINING VESSELS

The essential feature is that in the case of tap weights beyond 200 tons, the reaction vessel is no longer designed as a tilting vessel, but as a stationary, multisectional vessel equipped with a tapping spout (Fig. 1). The reaction space remains the same as in a tilting LD vessel, the only difference being that the bottom is designed in a way similar to an open-hearth furnace.

It is a well known fact that in the LD process under normal operating conditions, the wear on the lining in the reaction area of the oxygen and on the surface attacked by the slag, is stronger than in the upper part. Thanks to the multisectional design of the new refining vessel, it is possible in the event of one section wearing out more quickly than the rest of the vessel, to reline just that section, while the other sections continue to be used.

Fig. 1 shows a refining vessel comprising three sections. Section 1 is the so-called bottom section, which receives the bath and is equipped with a tapping spout. Section 2 is the mid-section, which is placed on the bottom section, and Section 3 is the hood of the refining vessel.

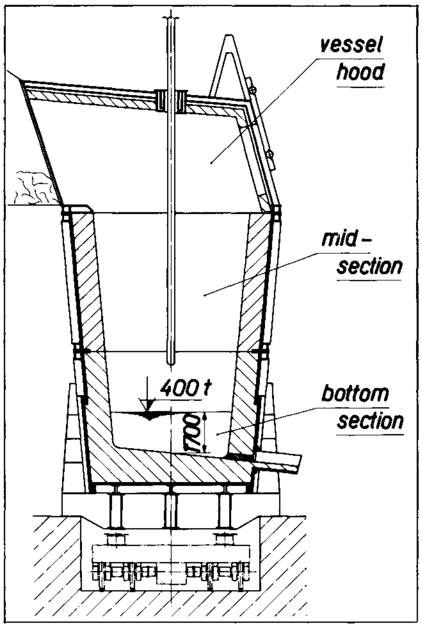

Fig. 1—Stationary refining vessel for the LD process consisting of three sections.

The bottom section and the mid-section form the reaction space. It will be helpful to give the bottom section and the mid-section a circular cross-section up to a tap weight of about 300 tons. For higher tap weights, elliptical, rectangular, or polygonal cross-sections should be chosen. The vessel hood will then have to be designed accordingly (Fig. 2).

As in the open-hearth furnace, the walls of the bottom and mid-section are slightly inclined toward the outside. For this reason the casing of these two fixed vessel sections could not possibly be simpler. It consists essentially of standardized rolled sections and plates. In contrast to tilting vessels, more of these elements are used in stationary refining vessels if they become larger, but the size of these elements does not increase substantially.

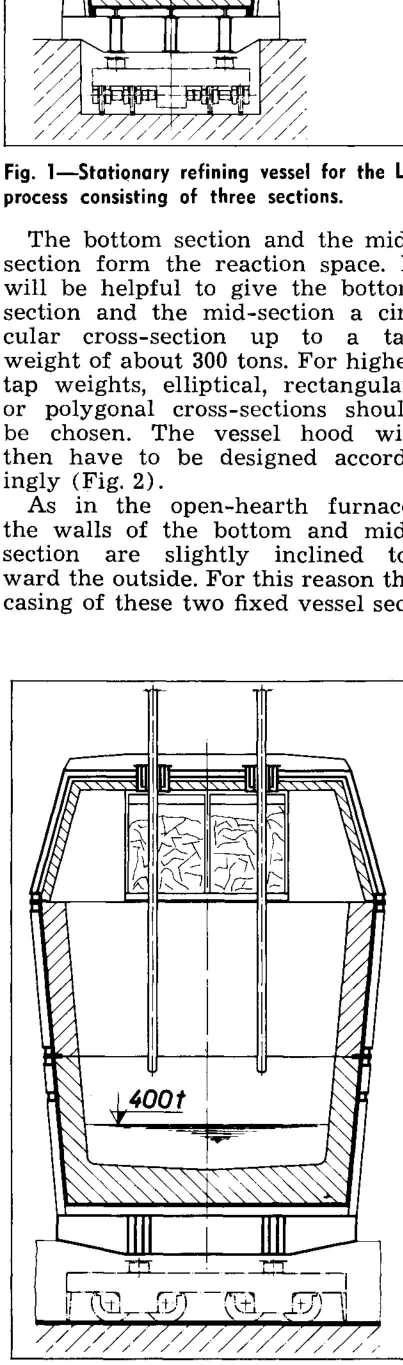

Fig. 2—Design of a stationary three-section refining vessel for the LD process (longitudinal section).

In tilting vessels, however, the number of structural parts remains the same as the tap weight increases, but their size increases if the stress becomes greater. Difficulties, therefore, arise already in shaping and welding during the manufacture of plate parts about 80 to 90 mm thick, as used for tilting vessels. The bearings for such vessels reach a capacity of about 900 tons at the present time. The gears, of which a maximum number of two can be mounted, already have diameters ranging from 4 to 5 m, weighing 30 to 40 tons. Changing them or repairing them is large-scale erection work. The breaking of a trunnion ring means a long shut-down of the whole steel-making plant.

The design of the refining vessel hood is also very simple. Through this vessel hood, the gases pass, the hot metal and the scrap are charged, and the refining lance is introduced. Any one of the known designs for furnace roofs and suspended roofs, as already available for hearth furnaces and regeneration chambers, and electric arc furnaces, can be used. While the bottom section and mid-section of the stationary refining vessel can be lined, for example, with tar-dolomite bricks, the hood of the new refining vessel can be lined instead with magnesite bricks and also with silica bricks.

During blowing, the stationary refining vessel rests on a simple support, which—in contrast to the trunnion rings and bearings in tilting vessels—cannot be damaged by concussion during charging, etc. For relining of the refining vessel or of individual parts of it, the parts can be moved to a relining area located at the side, and, in the meantime, the newly relined parts of a second vessel can be moved from a second relining area into blowing position, within a short time. Thanks to this arrangement, one single blowing area and one single waste-gas-cooling and dust-removing plant will do. In a steel plant with tilting vessels, however, two complete vessel plants and two complete waste-gas-cooling and dust-removing plants must be available, of which one only, however, will be in operation at a time.

In order to make relining work for the bottom section of the refining vessel easier, the casing has been designed in such a way that there is an opening in the area of the tapping spout or opposite it, permitting the use of break-out equipment for the removal of worn lining. Both during blowing and relining, the