THE MAKING OF SOUND STEEL INGOTS.*

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THE metallurgist of to-day bears almost the same relation to steel as a doctor does to his patient. Where formerly a simple examination and a small number of tests completed a diagnosis, to-day the physician investigates the physical life history of the patient, together with some matters in the physical life of his parents and grandparents. The metallurgist also is not now content with the condition of the steel as revealed by mechanical and physical test, but wants to be informed as to its life history during manufacture, and as to the quality of pig iron from which it was made and the conditions prevailing during the conversion and during the the manufacture of the pig iron itself.

It is comparatively easy to tell by the usual tests whether the structure and composition of steel attain a given standard or quality, but certain dangerous defects, which may be inherent in the metal, will often escape the customary inspection, and may be difficult to discover even by such extraordinary investigations as sulphur-prints, microscopic examination, hardness tests, shock tests, etc., unless these are carried on at such an extensive scale as to destroy the steel for service. Defects of this character are generally classified under the head of unsoundness, and the chief ones may be described as follows:—

1. Presence of blow-holes;
2. Presence of combined and occluded oxides;
3. Presence of an unwelded shrinkage cavity; and
4. Excessive segregation.

The most effective means of preventing these elements of unsoundness is the exercise of great care and watchfulness during the manufacture of the steel, and also during the manufacture of the iron from which the steel was made, because it now seems to be removed practically beyond controversy that certain unfavorable conditions during the smelting of iron ores in blast furnaces will produce a grade of pig iron which, during the ordinary process of manufacture, will be converted into an unsatisfactory grade of steel. It is not our purpose to discuss this matter at length in this paper, but the literature on cast iron during the years 1913 and 1914 will afford ample proof of the accuracy of this statement. Fortunately, careful and expert inspection of the manufacturing process, and suitable testing of the product, are sufficient to prevent steel of this undesirable quality going into service.

Expert care and inspection during the manufacture and rolling of steel is also the best safeguard for preventing unsound metal from any of the other causes mentioned above going into the service of the consumer. Steel that is dangerously filled with blow-holes, or which is badly segregated, will give some indications of this condition during the ingot-forming or rolling stages. The presence of a residual unwelded shrinkage cavity can usually be prevented by proper inspection during cropping, although this is not an infallible safeguard. Oxide inclosures result from improper conditions of manufacture during the conversion of ingot-forming stages, such as: too late addition of ore to the open-hearth furnace; improper composition of the final open-hearth slag; insufficient fluidity of metal; wildness; excessive or improper addition of deoxidizers in the melt, etc.

The subject of prevention of oxide inclusion has received a good deal of attention from several eminent investigators during the past two years, and a number of remedies have been suggested. The most effective means which has been extensively applied during manufacture is the addition to the liquid bath of steel of properly proportioned quantities of titanium alloy.

Segregation does not occur to a dangerous extent when the phosphorus and sulphur are reduced to reasonable limits, provided the steel is properly deoxidized before teeming; is not wild in the moulds, and is poured in ingots not exceeding 5 to 10 tons each in weight. The larger the ingot, the smaller should be the proportion of sulphur and phosphorus in the steel, and ingots of very massive sections should not be used, unless the central core is to be drilled out and discarded, as is the case in the manufacture of large guns, for example.

The presence of blow-holes is not dangerous in low-carbon steels, except in certain situations, the causes for which are now well understood and can be eliminated. In medium and high carbon steel, the presence of blow-holes will always be indicated by the action of the liquid metal in the moulds, and suitable care in manufacture forbids such material going further in the manufacturing process. The careful steel-maker sends it at once to the scrap pile.

The prevention or elimination of the shrinkage cavity in steel ingots and castings without prohibitive expense, or equally prohibitive complication in manufacture, has taxed to the utmost the ingenuity of metallurgists, and many hundreds of thousands of dollars have been spent in experiments and investigations of numerous schemes and inventions. For many years the compression of the ingot during the process of solidification, in order to reduce the size of its outer envelope and thus compensate for the shrinkage taking place during solidification, has been practised at steel works where steel of the highest quality is made. The expense of this compression process, consisting of interest on investment, complication in the process of manufacture, and cost of operation, is not wholly compensated for by the lesser proportions of the ingot which has to be converted into scrap. The compression during solidification is also claimed to improve the strength of the metal, and this claim, although not granted by all metallurgists, has some practical evidence in its favor.

An English and an American investigator have used the compression process for elimination of the pipe in a way which aims to eliminate interference with the manufacturing process and interest on the investment, by taking the steel ingot before it has completely solidified and reducing its section in an ordinary pair of blooming rolls; then returning it to the heating furnace until entirely solidified, and subsequently completing the rolling operation in the usual way. Other recent investigators have aimed to accomplish a reduction in the cost of treating the steel by substituting some other method for the compression process, but none of these newer inventions secures the elimination of the shrinkage cavity, but only its reduction to a smaller size or a greater concentration at the top of the ingot, with consequent smaller proportion of cropped-off metal being necessitated.

Sir Robert Hadfield burns charcoal on top of the steel ingots in a special mould with a sand top, so as to delay the cooling of this portion of the metal and consequently draw the shrinkage cavity to that point.

*From a paper read before the Mining and Metallurgical Section of the Franklin Institute.