CHAPTER X

FINISHING, STRAIGHTENING AND WELDING

Castings frequently become warped to a certain extent, either from shrinkage in solidifying, or from bending when hot in the annealing furnaces, and then have to be straightened. As far as possible, this should be taken care of in the design of the pattern. For instance, if a projecting lug which should be at right angles with the casting is found to consistently take a position at an improper angle, it is far simpler to shift the lug on the pattern in the opposite direction, so that the lug on the finished casting shall be at the correct angle, rather than to bend the casting. Frequently, however, the bending of steel castings cannot be avoided, and the best way to do the work has to be considered. If the steel is sufficiently ductile, the part to be bent not too thick, and the degree of bend not too great, bending cold can be practised without harm to the casting. In too many shops this cold straightening is done with a drop of some kind, a practice that cannot be too heartily condemned. The effect of the suddenly applied blow is necessarily largely local, instead of being spread out along the casting, and frequently results in the cracking of the work. The crack may be visible, and spoil the piece; or even worse, it may be concealed and appear later in a broken casting whose failure results in loss of time, money, and even life. Even very tough alloy steels are frequently injured by this practice, and many failures of alloy steel castings have been traced to abuse in straightening. The hydraulic or power press, which enables the bending to be carried out slowly, is the proper instrument for bending castings and should be used to the absolute exclusion of bending by blows.

Bends in hard and comparatively brittle steels, or heavy bends, especially of thick sections, can be made only while the castings are hot. Experiments have shown that the lowest temperature that can be used for this purpose is about 600° C. Below this temperature ordinary cast steel is not sufficiently softened by heating to bend easily.

Should the casting have been heat treated by rapid cooling and

reheating, or by accelerated cooling, it is desirable not to heat it again above 720° C., since temperatures higher than 720° destroy the heat treatment, producing coarse ferrite and reducing the ductility of the steel. Such work has to be straightened at temperatures between 600 and 720°, and several heatings may be necessary to complete the job. Steel annealed in the ordinary manner by slow cooling, may be heated for straightening to any temperature below the annealing heat, without damaging the heat treatment. In case these higher temperatures are used for straightening, however, it is necessary to allow the castings to cool slowly after straightening, or heavy shrinkage stresses will be set up in the metal, neutralizing to a certain extent the benefit of the annealing.

In particular, the practice of heating only one part of a casting in a bed of coals or a small furnace, straightening it, and allowing it to cool freely in the air, is to be avoided as far as possible, because the stresses set up in the piece by the local heating and rapid cooling may be as heavy as those existing in the casting before it was annealed, and may well result in trouble when the casting is put to work. If a coal fire or small furnace must be used for local heating of castings, the least that can be done is to allow the steel to cool slowly at one side of the fire, or in the furnace, after it has been straightened. In the majority of cases, however, heating the whole casting is the best practice, and as far as possible should be resorted to.

Welding.—Blow holes, shrink holes (as for instance under sink heads), cracks, etc., which not many years ago would have made it necessary to scrap a casting, are to-day welded up by means of the oxyacetylene or other gas torch, or the electric arc. If the work is properly carried out, a welded casting is nearly as strong as one that was sound in the first place. There are, however, many precautions to be observed in the welding of steel, some of which must be mentioned here.

In filling up holes, it is absolutely essential to heat up the entire surface of the hole before any metal is run in. To do this, it is frequently necessary to enlarge the top of the hole to a considerable degree, in order to get at the lower portions. Too frequently, the hole is merely run full of metal, which does not weld to the casting except at the surface of the work, resulting in a job little better than can be done by pounding cold metal into the hole—a mere device to cover up bad work and get it past the customer's inspectors.

In welding cracks, it is almost always necessary to preheat the metal for some distance on each side of the weld, to avoid the pulling apart of the weld when it cools and contracts. In some cases it is sufficient to preheat the casting near the crack with the welding torch; but frequently the entire casting has to be put in a furnace and heated up.

The steel of the weld itself, and the casting adjacent to the weld, are hardened to a remarkable degree in cooling in the air. This is due probably to the high temperature to which the metal is heated by the flame or the arc, which results in a very rapid cooling through the critical range, the heat being absorbed from the hot portions both by the air and by the cold parts of the casting. Under these circumstances, an air cooling becomes the equivalent of a water quenching, hardening the weld so much that it cannot be machined. For this reason all castings that have to be machined on the welded face, and all castings in which large and important welds have been made, should be reannealed after welding. At first sight, it would appear easier to weld the castings before annealing. But the brittleness of the metal in the raw condition makes it impossible to weld cracks until after the casting has been treated, more especially in view of the heavy shrinkage stresses existing in the unannealed casting.

Hammering the weld as it cools is often of great assistance in cases where the weld tends to pull apart from contraction of the casting. By spreading the cooling metal with hammers, the shrinkage is largely neutralized, so that the weld holds.

CHAPTER XI

LABORATORIES

To-day, the steel foundryman who should attempt to run his shop without chemical analysis of his raw materials and product, would be in danger of incarceration as a lunatic. Yet it is but a few years since steel makers scoffed at the idea of employing a chemist. The very small foundry, of course, may not have its own chemical laboratory, and may analyze only occasional heats; nevertheless, chemical analysis is an essential in handling the shop.

"An ounce of prevention is worth a pound of cure," is a maxim that the steel foundryman may well keep in mind. In the conduct of the shop, systematic use of the chemical laboratory to keep record of the analysis of raw material used and steel made, from day to day, is worth a hundred "investigations" started after trouble has developed in the foundry, or in the machine shops of the customer. Whatever analysis of the steel is deemed necessary, should be made and recorded every day, and the records kept in such a manner that if trouble occurs there will be some information to go on, in searching for the cause of the difficulty. The first result of maintaining such a system will be that trouble will be easier to account for; the second, that trouble will be less frequent.

As a general rule, the chief chemist should not be the man who does the calculating for the melting shop. In the large shops, of course, this is seldom the case. But small Bessemer or crucible steel foundries frequently have but one man on the premises who is capable of doing this work, and that man the chemist. The human being may some day be born who will be capable of figuring a heat of steel, and gazing undismayed upon analytical results for that heat that show a composition that was not desired. But, allowing for the little weaknesses of human nature, it is best to have one man calculate the steel, and another analyze it.

Just as our fathers doubted the value of chemical analysis in steel making, so this generation questions the usefulness of microscopic examination and physical testing of their product, as a part of the shop routine. Some decry these methods altogether, others say they are of value solely as "post mortems." The author's experience in this line has been, that just as systematic records of analysis are of value not only in locating the causes of trouble, but in preventing it, so daily checking up of the work of the shop, particularly the annealing furnaces, by means of test bars, will keep the product uniformly excellent and lead to many improvements. When a certain amount of information, as for instance tensile test, bending test, microstructure and perhaps shock test and hardness, is obtained each day from test bars in every annealing heat, or a certain number of heats, it will not be long before enough data are accumulated to show the probable cause of the poor quality of a broken casting. Moreover, once this information is at hand, a poorly annealed heat can be recognized and held up before it gets out of the shop; and by investigation of one's best and poorest product, as well as that of competitors, much improvement will almost certainly result. The metallographist is rapidly winning his place in the steel business, and when the dust clears away, it will be found that his work is parallel with that of the chemist who is now no longer called on simply to conduct autopsies, but has his recognized place in regulating things so that autopsies shall not be needed.

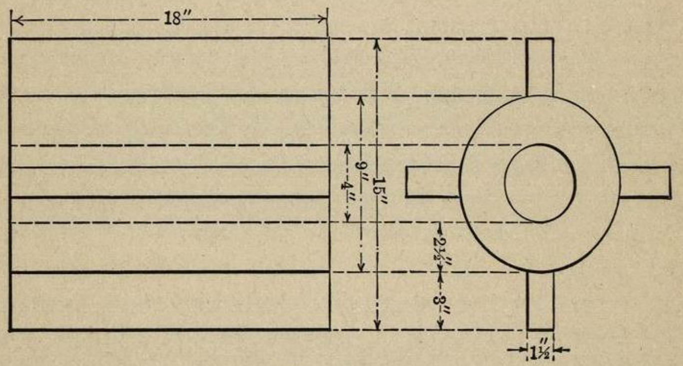

FIG. 37.—Test coupon casting.

It is the author's experience that test coupons upon ordinary steel castings should be attached to the casting along the full length of one of their long sides. A coupon attached to the casting by a narrow neck is not so reliable as a side attached one, even if cast on end and provided with a sink head of its own, unless its cross-section is made undesirably large. The same is true of coupons moulded and cast separately, with gate and sink head; to be truly reliable, they must be some 3 by 3 in., or better 4 by 4 in., in cross-section.

To obtain reliable coupons for experimental work the author has used with great satisfaction a casting in the shape of a hollow cylinder with a number of side attached, vertical coupons upon its outer face, like the spokes of a wheel. A sketch of this casting, which some one christened "the porcupine," is shown in Fig. 37. Each coupon gave two test bars 9 in. long. Four or eight coupons can be used.

CHAPTER XII

"BUILDING UP" IMPURITIES IN STEEL

In a number of places in this volume calculations are submitted showing the maximum increase in non-oxidizable impurities of the steel, that is to be expected after making a great number of heats, each of which contains a certain proportion of scrap from previous heats. These calculations are based upon the method worked out by Mr. A. H. Jameson, the gist of which is given here for reference. For the full text of this article see *Iron Age*, February 23, 1911, p. 480, and August 21, 1913, p. 406.

"It should be remembered that, through the melting and converting losses, we do condense in the steel any element which does not itself suffer loss in the melting or conversion. But this condensation takes the form of an increase in the percentage by gradually decreasing increments, and theoretically the increase goes on for an infinite number of operations. But it approaches a limit, even though it never reaches this limit, and if we plot a curve to show the increase in percentage by ordinates and the number of operations by abscissæ we find that at infinity the curve becomes a straight line."

"Practically we are interested in the limit only. We wish to know what will be the maximum content in the steel after a long run, and this we can determine readily."

"Let a = the percentage of steel scrap in the cupola charge.
$100 - a$ = the percentage of pig iron in the cupola charge.
b = percentage of loss in both melting and converting.
c = percentage of the element in question in the pig iron used.
x = the maximum percentage of the element in the steel after an infinite number of operations.

"When the limit is reached, and 'the curve becomes a straight line,' we shall find, of course, that after any operation our steel contains exactly the same percentage of the element in question that was in the steel scrap which was charged to the cupola furnace as stock for that blow, so that

$$x=\frac{(100-a)c+ax}{100-b}$$

and by resolving

$$x=\frac{(100-a)c}{100-(a+b)} \text{ or } \frac{100c-ac}{100-(a+b)}$$

"It will be noted that the foregoing formula and calculation are applicable to an element which, like copper, gains nothing from outside sources. Now, let us see what is the problem in the case of sulphur or phosphorus, which are increased by the amount absorbed from the fuel in the melting. Let d = the percentage of the element which is taken up by the metal in one melting operation; this can be determined readily by analysis of the stock before and after melting, and is a constant for a given fuel and burden. Then our original formula will become

$$x=\frac{(100-a)(c+d)+a(x+d)}{100-b}$$

and by resolving,

$$x=\frac{(100-a)\,c+100\,d}{100-(a+b)} \text{ or } \frac{100(c+d)-ac}{100-(a+b)}$$

Mr. Jameson's method is manifestly applicable to any method of melting in which the percentage of a non-oxidizable impurity is increased by melting losses, with or without "pick up" from the fuel; or, for that matter, to a case where by gain of weight in melting (owing for instance to ore additions), the percentage of the element is decreased, with or without a countervailing gain from "pick up." In this volume, the particular method of using these formulæ has been varied from place to place, for greater convenience. Thus, for instance, it is permissible to substitute for percentages of pig iron, scrap, etc., and percentages of metal obtained, the actual weights of material charged and of the metal obtained. In certain cases where a "pick up" occurs, the figuring has been done by multiplying the weight of each portion of the charge by the percentage of the element in question in that postion, adding the products, adding to this the weight of the whole heat multiplied by the percentage of "pick up" of the element in question, and dividing the sum total by the weight of the heat. That these variations in the method of using the equations are permissible, is clear at once. Thus the reasoning has been applied to all methods of steel making by the acid process, and to special mixtures of raw materials. The influence of the recarburizers, which often contain high percentages of phosphorus, has also been shown in a number of cases; and the method has been used to work backward from a known permissible maximum of impurity, to ascertain the percentage of impurity in the raw material that cannot be exceeded without producing steel above the desired maximum.