A. REYNOLDS.

MANUFACTURE OF STEEL.

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979,337.

Patented Dec. 20, 1910.

Fig. 1.

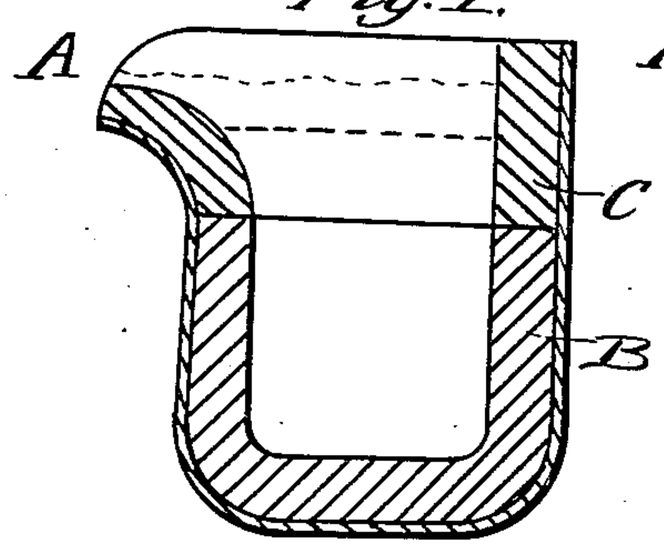


Fig. 2.

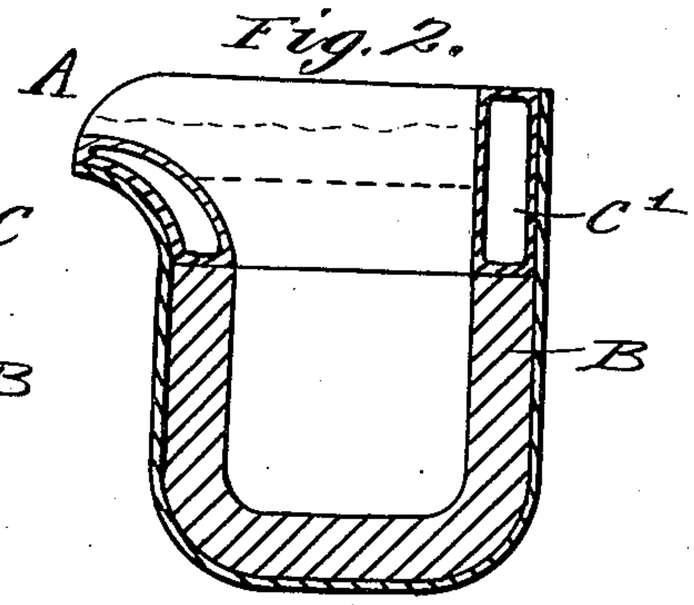


Fig. 3.

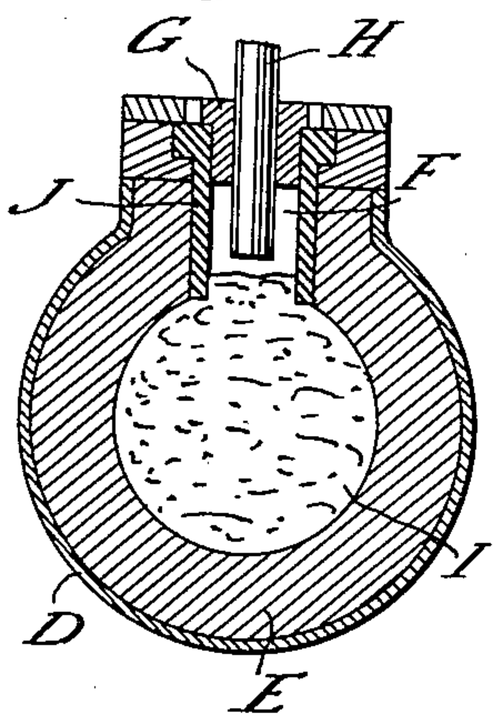
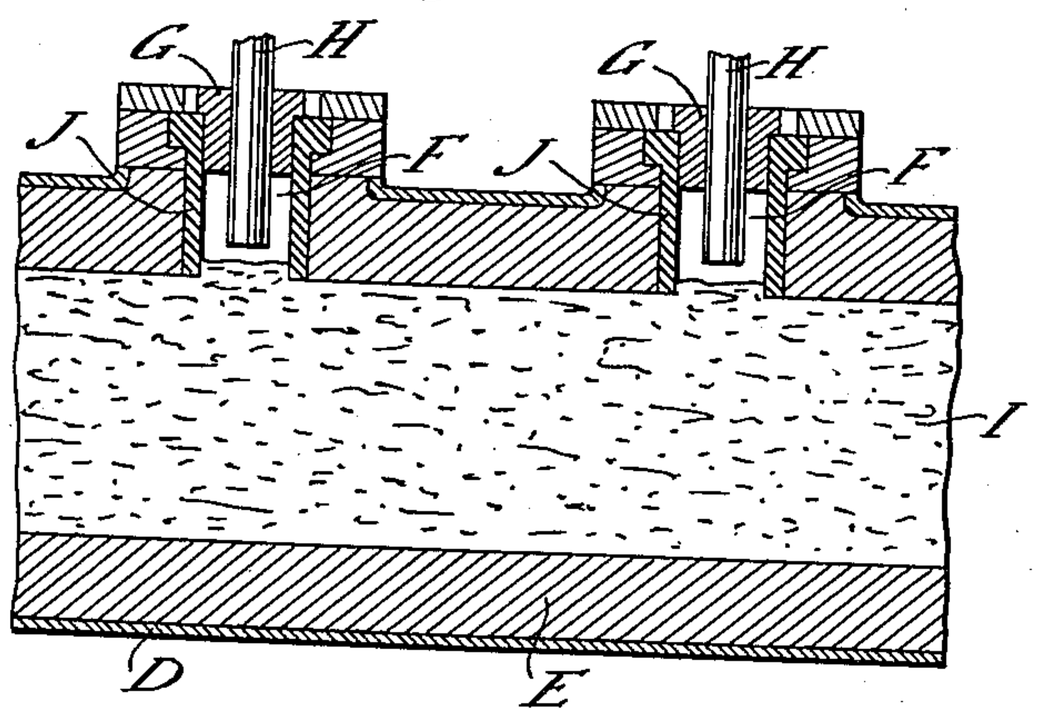


Fig. 4.



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MANUFACTURE OF STEEL.

979,337. Specification of Letters Patent. **Patented Dec. 20, 1910.**

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To all whom it may concern:

Be it known that I, ALLEYNE REYNOLDS, a subject of the King of Great Britain, residing at 11 Queen Victoria street, in the city of London, England, consulting metallurgical engineer, have invented certain new and useful Improvements in the Manufacture of Steel, of which the following is a specification.

My invention has for its object the economical production with certainty of steel ingots or castings of any desired analysis free from flaws. This I achieve by means of novel variations of known processes, employing suitable furnaces for each step of the process hereinafter described, in which I first produce a nearly pure iron free from foreign substances, and afterward, just previous to casting, alloy it with certain materials. For the overcoming of the oxidization unavoidable during casting, the extent of which may be ascertained by experience, I always add the necessary amount of highly exothermic acid and basic-flux-forming additions, in general silicon and manganese. The process in general may be most economically carried on as a so-called "continuous process" and I prefer this method, while I do not confine myself to it, and a description of my process as worked "continuously" will serve also to indicate its nature when worked "intermittently."

In the accompanying drawings: Figure 1 is a section of a ladle used in carrying out my process; Fig. 2 is a similar view of a modified construction of ladle; Fig. 3 is a transverse section; and Fig. 4 a part longitudinal section of an electrically heated cylindrical furnace suitable for use in my improved process.

In carrying out my process I employ three or it may be four sets of furnaces, the first of which is an oxidizing refining furnace, and need not be of special design. It may be either an "acid" or "basic" Bessemer converter or an open hearth furnace. In such a furnace I carry out the removal of impurities by oxidization in the usual manner until a bath of nearly pure iron is obtained in a sufficient degree of fluidity, owing to high temperature, and necessarily somewhat saturated with oxids of iron. I teem or tap these charges into ladles and for the purposes of the present description and by preference, this process is assumed to have been conducted in a basic open hearth furnace from phosphoric pig iron. The ladle which is fitted in the usual way with suitable tilting gear is provided with a spout A (Figs. 1 and 2) at a little lower level than the top of the ladle, and the lower part of which is lined in the ordinary way, with siliceous material or refractory clay bricks B. The upper part is lined with chromite or magnesite bricks C (Fig. 1) or a water-cooled steel ring C^1 (Fig. 2) or other material inert to the charge and clay. When the charge is run into this ladle, filling it, or rather over-filling it in most cases, the last portions of the charge and the slag overflow into a suitable receptacle provided for the purpose. Should any slag, however, remain, the ladle is slightly canted until it is all poured off, necessarily together with some little amount of iron, which may be afterward collected and returned to the furnace as scrap.

Owing to the construction of the ladle before described, there is no tendency to return by reduction phosphorus to the charge of iron. The charge from this ladle freed from slag is transferred for further treatment to a furnace, which in practice is electrically heated, and which I will designate the second or reduction refining furnace. The treatment in this furnace is devoted entirely to removing by reduction the "emulsified" or "dissolved" particles of oxid of iron contained in the charge. For this purpose slag actions are not required and are to be avoided. The furnace, therefore, requires to be of special form which is hereinafter described and which as before indicated, would usually be heated electrically. But the heat to be supplied need only be that required to compensate the loss of heat by radiation from the furnace itself and such small endothermic chemical reactions as it is required to bring about. Hence, with suitable design, only a very small amount of electrical energy is required to heat this furnace. An essential condition in the design of this furnace is, that consistent with the electrical heating requirements the surface of its interior in contact with the metal and of its exterior in contact with the atmosphere, shall be as small as possible in relation to the volume of the charge. To achieve this condition the cross section of this furnace is preferably that of a tube of suitable section constituted by an outer casing of metal lined with a suitable refractory material. At in-

tervals along these tubes are branches or uptakes of suitable size, according to the method of heating the furnace. These uptakes are closed by means of refractory plugs or portions of the electrical heating apparatus. I will now describe the process I propose to conduct in this furnace in order that the essential conditions of its construction may be better understood. As the process conducted in this furnace can be tentative I prefer, for the purposes of reliability, to remove the oxid of iron contained in the charge by treating it with carbon or a carbid of iron, the resulting carbon monoxid or carbonic acid being evolved in gaseous form and escaping by the uptakes above referred to, the closures applied to the uptakes being sufficiently loose to permit the escape of such gas. I accordingly charge into the furnace a small amount of carbon or of highly carbonaceous pig iron preferably previously melted in any suitable furnace. On pouring in the charge of iron containing oxid of iron, ebullition takes place and as soon as it has completely subsided, it is evidence either that the whole of the oxids of iron have been reduced, or the whole of the carbonaceous or other addition has been oxidized. A simple test proves whether or not the latter is the case. If the whole of the carbon or reducing agent is gone I tentatively add further small quantities of carbon or highly carbonaceous pig iron or other reducing agent until chemical action ceases and at least a minute trace of carbon or other reducing agent remains in the metal. The contents of the furnace will then consist of nearly pure iron, that is, iron combined with or alloyed with an extremely small percentage of carbon or other reducing agent, the extent of which can be absolutely and easily ascertained in a few minutes by analysis. I then add further charges of raw soft iron from the first or oxidizing refining furnace, and treat in similar manner until the second or reduction refining furnace is completely filled in its interior with charge just entering the necks of the uptakes before alluded to.

In what I will term the third furnace of which generally there are several, I melt and keep melted stocks of ferro-silicon, ferro-manganese and other additions which from time to time I may desire to alloy with the iron and of which I can conveniently pour off a portion into small ladles and weigh accurately. The analysis of these is easy to ascertain exactly and to maintain uniform. I also provide a fourth furnace of any suitable design, in which I melt a flux which will be a bi-basic silicate in general, most commonly silicate of lime and alumina, which is rendered still more fusible if possible by the addition of a substance such as silicate of soda or fluor-spar. I provide also a fairly large furnace, in which there is a stock supply of melted highly carbonaceous pig iron, of the kind commercially known as washed metal. I am now in a position to cast any quality of steel I may wish.

A sufficiently large ladle which may be of the ordinary form is placed in front of a second or reduction refining furnace and I commence to cast into the ladle therefrom purified dead melted iron. As soon as the bottom of the ladle is well covered with melted metal, I add a sufficient quantity of dead melted ferro-silicon and preferably also ferro-manganese taken from one of the third furnaces, to produce the given desired percentage of those elements and at all events sufficient to overcome the oxidization of the reduction refined metal from the second furnace during teeming, and during casting from the ladle to the mold.

The ladle in question is suspended from a crane on a weighing device which enables the weight entering it to be accurately known, or other suitable weighing devices are provided. In addition to the necessary quantities of ferro-silicon and ferro-manganese before indicated, I add quickly to the contents of the ladle from the third furnaces such quantities of other alloys as may be required and as soon as the required weight has been obtained I cease pouring in purified reduction refined iron. I then, or previously, if desired, run on some flux from the fourth furnace. A very few minutes' interval will suffice for the alloying of the metals to be perfect, but if desired, a cover-lid may be dropped over the ladle, and its contents electrically heated by means of any suitable device. The contents of the ladle may then be cast in the usual manner and a steel of a definite and known analysis can be with certainty and economy produced. It therefore only remains to describe the construction of the special type of furnace hereinbefore referred to which is required for dead melting without slag and to which the third or alloy stock furnaces may be similar. As shown in Figs. 3 and 4, this furnace is electrically heated by the arc method and consists of a tubular metal casing D of suitable construction which may be closed on itself to form a hollow ring and is lined with a suitable refractory material E and provided with uptakes F, which are closed almost hermetically by plugs G of refractory and electrically insulating material. The plugs G serve both as insulating bushes and as guides for the carbon electrodes H, which are arranged to be adjustable longitudinally in the usual manner for the purpose of establishing and maintaining an arc between the said carbons and the charge I, which usually completely fills the main portion of the furnace as shown. The electrodes H approximately fit the bushes G

and may be connected with a suitable source of current so that they are alternately positive and negative electrodes, the proportions of the furnace being so designed that the heat generated at the arcs is sufficient, by conduction through the metal downward and lengthwise of the furnace, to compensate for radiation losses and prevent local solidification of the metal. To protect the necks of the uptakes against intense local heating the uptakes may be lined with carbon sleeves J suitably supported from the mouth of the uptakes so that there can be no access of air to the furnace.

Whatever method of heating may be employed the construction of the furnace is such that it can be practically sealed during operation and the reduction refining process carried out under substantially slagless conditions, slag reactions being not only unnecessary but undesirable in this part of the process. The furnace may therefore be completely filled with a charge of melted iron free from slag. It will thus be seen that according to the present process the three stages into which the manufacture of steel may be separated, namely, (1) the production of a melted oxidized charge of iron, (2) the reduction refinement of the charge, and (3) the alloying of the charge are kept entirely apart, whereas in processes hitherto employed or proposed stages 2 and 3 have always been combined, and stages 1, 2 and 3 have often been combined. It is by separating stages 2 and 3 and conducting stage 2 under substantially slagless conditions that it becomes possible to obtain the desired result, namely the production of steel of a predetermined composition.

Having thus described the nature of my said invention and the best means I know of carrying the same into practical effect, I claim:—

1. The herein described process for the manufacture of steel of predetermined composition which consists in producing a melted charge of iron, transferring the charge free from slag into a suitable dead melting furnace, adding a reducing agent, teeming the dead melted iron into a ladle, and adding known proportions of dead melted ferro-silicon and ferro-manganese, substantially as described.

2. The herein described process for the manufacture of steel of predetermined composition which consists in producing a molten charge of iron containing small amounts of iron oxid, transferring the charge free from slag into a suitable dead melting furnace, adding a reducing agent slightly in excess of the amount necessary to reduce the iron oxid, teeming the resultant dead melted nearly pure iron into a ladle, and adding known proportions of dead melted ferro-silicon and ferro-manganese, substantially as described.

3. The herein described process for the manufacture of steel of predetermined composition which consists in producing a melted charge of iron containing small amounts of iron oxid, transferring the charge free from slag into a suitable dead melting furnace, adding a reducing agent slightly in excess of the amount necessary to reduce the iron oxid, teeming the resultant dead melted nearly pure iron into a ladle, adding known proportions of dead melted ferro-silicon, ferro-manganese and a quantity of suitable flux, substantially as described.

4. The herein described process for the manufacture of steel of predetermined composition consisting in producing a melted charge of iron containing iron oxid in a furnace, teeming and freeing said charge of slag, refining by reduction the slagless charge in a second furnace, teeming the refined charge and adding thereto melted alloys heated in separate furnaces, and casting the charge into a mold.

5. The herein described process for the manufacture of steel of predetermined composition consisting in producing a melted charge of iron containing iron oxid in a furnace, teeming and freeing said charge of slag, refining by reduction the slagless charge in a second furnace, teeming the refined charge and adding thereto melted alloys and a suitable flux heated in separate furnaces, and casting the charge into a mold.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

ALLEYNE REYNOLDS.

Witnesses:
JOSEPH MILLARD,
WALTER J. SKERTEN.