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PRODUCTION OF ALLOY STEEL

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In the co-pending application No. 292,127 filed July 1, 1963, there is described a process of making alloy steel from crude iron and alloying agents, preferably high alloy scrap, using an oxygen top blowing process which takes place in two phases. In the first phase an intermediate product with a phosphorus content of less than 0.025% is produced under a highly basic first slag rich in iron oxide, that is to say a slag with a basicity (CaO/SiO_2) of more than 3. After removal of the slag and addition of alloying elements the second phase of the process is carried out. In this phase the blowing of the liquid intermediate product is carried out under a second slag (about 1 to 4% of slag-forming constituents) with a basicity of about 2. The process can be ended when the desired carbon content is reached.

This invention is concerned with a further development of this process, and aims at improving the economy of the process by the use of cheap charge material—for example, of the steelworks own return scrap. Further aims of the invention are to improve the reliability of the analytical composition of steels produced and to produce high alloy steels, that is steels having a content of more than 5% of alloy elements, for example stainless steels, more economically than hitherto.

According to the invention, stainless steel is made from liquid crude iron and solid alloy carriers and the liquid part of the charge which forms between 20% and 75% by weight of the total charge is first charged into the blowing crucible and is blown in a first blowing phase beneath a highly basic slag, which is rich in ferric oxide to yield an intermediate product having a phosphorus content of less than 0.025%. The slag is then removed and a main part of the solid alloy carriers, which are relatively non-oxidising (e.g. nickel or molybdenum alloys) when compared to the alloy of another part of the carriers are added to the crucible together with chemical heat carriers such as ferro-silicon if required, after which the blowing is continued in the second phase until the solids are liquified and preferably until the required carbon content is reached and then the other part of the solid alloy carriers which are relatively oxidising (e.g. chromium alloys, preferably ferro-chromium) and contain silicon and carbon, are added and blowing is continued in a third blowing phase beneath a new basic slag having a CaO/SiO_2 ratio of at least 2.5 or a $(\text{CaO} + \text{MgO})/\text{SiO}_2$ ratio of at least 1.5, until the carbon and silicon introduced with the oxidising part of the alloy carrier have been removed. After this the slag is treated with reducing agents to reduce the slagged alloy constituents and finally, after removal of the reduced slag, the remainder of the alloy carriers of high quality are added to the crucible.

In the first phase of the process that is the dephosphorisation phase, blowing is performed to start with at a normal blowing energy corresponding to a lance interval of approximately 90 to 140 cm. and a blast pressure of 6 to 10 atm. g. The blowing is subsequently continued during the second half of this phase with application of low blowing energy corresponding to a lance interval from 200 to 350 cm. and a blast pressure from 3 to 8 atm. g. The basicity of the slag in the first phase (CaO/SiO_2) should be more than 3.

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After removing the first slag, the relatively non-oxidising alloys such as nickel and molybdenum, preferably in the form of high alloy scrap, are added to the melt up to 30% by weight of the total quantity of alloy carriers. Depending upon the constitution of the liquid charge (pig-iron or hot air cupola furnace iron), chemical heat carriers may also be added to the melt. The latter are however necessary only in exceptional cases. The manganese content of the melt is also preferably increased before the start of the second blowing phase by the introduction of relatively non-oxidising manganese carriers.

In order to loosen the silicon contained in the solid alloy carriers and in the heat-surrendering additives (FeSi or the like), fresh slag formers may be added to the charge before starting the second blowing phase. The metallurgical functions of the second slag are slight, so that the quantity of slag may be kept small. Having regard to technological considerations (quiet blowing and the prevention of depositions on the lance and on the dome of the crucible) the quantity of these slag formers should be approximately 1 to 4%, and the basicity of the slag should not fall below 2.

The second blowing phase is performed with a normal lance interval and oxygen pressure—for example, with a lance interval of 90 to 140 cm. and a pressure of 6 to 10 atm. g. It continues at least until the metallic charge is thoroughly liquefied, and preferably until the carbon content desired in the finished steel is attained.

After completion of the second blowing phase, the readily oxidising alloy carriers, more particularly the chromium alloys, are added to the melt. In principle, any type of chromium alloy may be used. Ferro-chromium alloys containing at least 5% silicon and 5% carbon are preferred. The chromium contained in such a material is far cheaper than in normal ferro-chromium, and the necessary heat carriers in the form of silicon and carbon are also inserted into the melt at no cost. The latter elements are effective during the entire third blowing phase which follows. The chromium content of the melt at the end of the second blowing phase is adjusted to be in accordance with the chromium and carbon contents desired in the finished steel and so that the chromium content is higher by 1 to 3% (absolute) than the chromium content in the finished steel. It is advantageous simultaneously to adjust the manganese content of the charge to the upper limit of the finished steel.

Before the third blowing phase, new basic slag formers are added to the charge thus prepared. Their quantity depends upon the SiO_2 produced during the third blowing phase. The basicity (CaO/SiO_2) of the slag produced should not fall below the value 2.5. For steels which must be blown to extremely low carbon contents, it is appropriate, in preparing the crucible to replace a portion of the lime by dolomite; in this case, the slag ratio $(\text{CaO} + \text{MgO})/\text{SiO}_2$ may be lowered to the value 1.5.

During the third blowing phase which now starts it is preferable to keep the lance interval somewhat below normal or else to use a lance which generates a more compact oxygen jet than is otherwise customary. The choice of the quantity of oxygen to be blown per unit of time is dependent upon the lump size and composition of the ferro-chromium added. The latter dissolves continuously. By an appropriate control of the oxygen supply, it should be ensured that the active oxygen is only equal in quantity to that required for the combustion of the carbon and silicon liberated. The blowing is performed to a carbon content which is below the carbon content prescribed for the finished steel.

After completing the blowing, the crucible is tilted. In this position, reducing agents in the form of for example Al, Si or CaSi, are applied to the slag present on the charge in order to reduce oxidised chromium and man-

ganese. The proportion of reducing agents depends upon the level of the preceding addition of chromium, and upon the carbon content of the bath. It may be determined empirically for each individual case. The addition of the reducing agent may also be performed through a chute or the like with the vessel upright or obliquely positioned. After adding the reducing agents, oxygen is preferably blown onto the bath for approximately 1 minute with a reduced lance interval and a reduced oxygen supply, in order to accelerate the progress of the slag reduction by mechanical turbulence. The reduction process is usually complete after 5 to 10 minutes.

After the slag has been reduced, the crucible is tilted back into the horizontal position, a sample is taken, and a portion of the slag is removed by vigorous letting off. Not later than 5 minutes after the sampling, the crucible is positioned obliquely and 10 to 40% according to the temperature of return scrap, of the same or of a similar quality to the steel to be manufactured is added. Owing to the poor thermal conductivity of the high alloy steels, the heat losses in the stationary bath are low, as the thermal content of the melt is fully sufficient to dissolve the added scrap. Neither the iron content nor the alloy content of the scrap suffers losses during its dissolution.

After adding the scrap, the crucible is restored into the horizontal position and the residue of the slag is removed. The further treatment is governed by the quality of steel desired.

It is advantageous to add to the charge, in order to make a fining slag, slag formers—e.g., in the form of lime and ingot iron, which can be heated with gas burners or oil burners.

In manufacturing steels which are required to conform to high specifications—for example, in the manufacture of stainless steel for cutlery, turbines and high-polishing plate, a preferred example of the invention consists in the treatment of the fining slag with reducing agents. In this case a white disintegrating slag is produced which causes a diffusion deoxidation and a vigorous disulphurisation. Furthermore, the steel may also be deoxidised with aluminum or silicon in a conventional manner. By treating the melt with the reduction slag, the sulphur content of the steel is also reduced to approximately 0.004%. Finally, in this stage of the method before tapping, corrective additions of alloy media and/or of silicon may be made.

We claim:

1. A process for the production of stainless steel from crude iron and solid alloy carrier consisting at least in part of chromium, nickel and molybdenum by oxygen top blowing, said process including the steps of charging liquid crude iron, which forms between 20% and 75% by weight of the total charge, into a blowing crucible, said crude iron being selected from the group consisting of pig iron and hot air cupola furnace iron, blowing said liquid crude iron in a first blowing phase beneath a highly basic slag, which is rich in ferric oxide, to yield an intermediate product having a phosphorus content of less than 0.025%, removing said slag, adding a main portion of solid alloy carrier bearing nickel and molybdenum together with a heat carrier to said crucible, continuing blowing said charge in a second phase until said main portion of solid alloy carriers is liquefied, and a predetermined carbon content is reached adding another portion of alloy carrier bearing chromium, silicon and carbon, continuing blowing in a third blowing phase beneath a new basic slag having a CaO/SiO_2 ratio of at least 2.5 until the carbon and silicon introduced with said other portion of alloy carrier have been removed, treating said

new basic slag with reducing agents to reduce the slag alloy constituents and adding the remainder of said alloy carrier to said crucible.

2. A process as claimed in claim 1, in which said heat carrier is ferro-silicon.

3. A process as claimed in claim 1, in which said chromium bearing alloy carrier is ferro-chromium having a minimum content of 5% silicon and 5% carbon.

4. A process as claimed in claim 1, in which said portions of alloy carrier are scrap from the previous manufacture of steel, the same as that which is produced by this process.

5. A process as claimed in claim 1, further comprising the step of adding a manganese carrier to said crucible with said main portion of alloy carrier bearing nickel and molybdenum to raise the manganese content of the melt in said crucible.

6. A process as claimed in claim 1, in which at the start of said first blowing phase the oxygen has a normal blowing energy corresponding to a lance distance of between about 90 and about 140 centimetres and a pressure of about 6–10 atmospheres and during the latter part of this phase, said blowing energy is reduced to one corresponding to a lance distance of between about 200 and about 350 centimetres and a pressure of about 3–8 atmospheres.

7. A process as claimed in claim 1, in which said second blowing phase is carried out beneath a minimum quantity of slag and with 1–4% of slag formers, said slag having a basicity of 2.

8. A process as claimed in claim 1, in which said third blowing phase is carried out with low blowing energy corresponding to a pressure of about 3–8 atmospheres.

9. A process as claimed in claim 1, further comprising the step of blowing said slag treated with said reducing agents for between $\frac{1}{2}$ and 3 minutes to stir it and accelerate the reaction of the reducing agents and the slag after the addition of said reducing agents.

10. A process as claimed in claim 9, in which said reducing agents are selected from the group consisting of aluminum, silicon and calcium-silicon.

11. A process as claimed in claim 1, further comprising the step of adding a lime and fluxing medium to said crucible to produce a fining slag after the addition of the remainder of said alloy carrier.

12. A process as claimed in claim 11, in which the melt in said crucible is heated with burners to assist in producing said fining slag.

13. A process as claimed in claim 11, further comprising the step of treating said fining slag with reducing agents to produce a white disintegration slag.

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