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[54] STAINLESS STEEL MELTING PRACTICE 9 Claims, No Drawings

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ABSTRACT: Melting a charge comprising alloys of iron and chromium in an electric arc furnace to achieve metal of maximum cleanliness with minimum oxide inclusions but of high-carbon content, and then ridding the metal of carbon in a vacuum furnace by way of readily reducible oxides and low pressure.

STAINLESS STEEL MELTING PRACTICE

As a matter of introduction, my invention relates to the production of stainless steel.

One of the objects of the invention is the production of stainless steel of the chromium grades, as well as the chromium-nickel grades, employing such combination of raw materials as to enjoy the maximum use of available furnace capacity with minimum slag volumes, minimum furnace operating temperatures, and minimum attack of furnace refractories.

Another object is the provision of a stainless steel melting process requiring a minimum consumption of electric power and minimum time of complete melting cycle.

A further object is the provision of such a process wherein clean, high-quality stainless steel is had, and wherein losses of chromium and other oxidizable ingredients into the slag are obviated and wherein the requirement for irrecoverable alloying additions, such as ferrosilicon is minimized.

Other objects of my invention in part will be readily apparent from the description which follows and in part more especially pointed out hereinafter.

The invention accordingly consists in the several operating steps and in the relation of each of the same to one or more of the others as described herein, the scope of the application of which is indicated in the claims at the end of this specification.

BACKGROUND OF THE INVENTION

In order to gain a better understanding of my invention, it may be noted at this point that the stainless steels generally are viewed as alloy steels containing chromium from about 10% on up to about 35% or more, with or without other alloying ingredients. Carbon commonly is present, this on the order of some 0.03% to 0.10% for certain grades, and up to some 1.0% or more for others. And, too, in some grades nickel is present either in such a large amount, say 7% to 35% or more, to assure an austenitic steel, or in lesser amount for other purposes. Manganese and silicon in small amounts customarily are present, and so, too, the ingredients phosphorus, sulfur and nitrogen. Where desired, one or more of copper, aluminum, molybdenum, titanium and columbium may be present for special purposes. The number of different grades of stainless steel in this art is legion. But, as noted above, chromium is an essential element in all grades.

Much of the stainless steel available to the trade today is melted in the induction furnace, this by melting down low-carbon steel scrap and/or stainless steel scrap and adding to the resultant melt a low-carbon ferrochrome. The prealloy contains some 66% to 72% chromium, with a carbon content not exceeding 2.00%, usually some 0.06% to 0.50% depending upon the carbon content permitted in the steel to be produced, and remainder iron.

But as long ago as 35 or 40 years, there was developed a process wherein there was employed available stainless steel scrap, along with the less expensive high-carbon ferrochrome, a prealloy containing some 66% to 70% chromium, 4% to 6% carbon, and remainder iron. This is the process described in the Field U.S. Pat. No. 1,925,182, of Sept. 5, 1933. In the process of that patent the stainless steel scrap and high-carbon ferrochrome are melted down in the presence of a strong oxidizing agent, notably iron oxide or roll scale. High melting temperatures, that is, temperatures of about 3400° F., are employed in order to preferentially oxidize the carbon present as compared to the chromium, although substantial quantities of chromium nevertheless are oxidized and migrate into the slag. Unfortunately, the high-operating temperatures not only cause some fuming of the metal but they accelerate the attack on the furnace refractories, this frequently taking the form of severe localized erosion.

Recovery of the metallic values from the slag is had by way of a ferrosilicon reducing agent, this at significant cost and prolongation of furnace operating time, especially because of the large volume of slag and its depth, this commonly amounting to as much as 12 inches. In that regard, the chromium oxides formed in the melting operation add to the volume of slag

and thereby limit the furnace capacity for metal. And of course available furnace capacity is further limited by the large quantities of lime added along with the reducing agent during the chromium-recovery period.

Further prolonged furnace operation is necessitated by reason of stratification effects. These produce differing levels of chromium and/or silicon which first must be resolved to give a bath of uniform composition in order to permit an accurate sampling of the metal. The time required for achieving a uniform composition and for sampling, chemical analysis and frequently resampling, further prolongs the overall furnace time; three samples are taken at 5-minute intervals and analyses are made, this taking 15 minutes. When the results are not uniform, further samplings and further analyses are made at a further expenditure of time.

As a further source of chromium in the stainless steel melting processes of the prior art there may be employed chrome ore. The melting process in which stainless steel scrap and chrome ore are employed forms the subject of the Arness U.S. Pat. No. 1,954,400 of Apr. 10, 1934. And here again, the useable furnace capacity directly suffers in direct proportion to the slag volumes encountered.

A melting process enjoying even further economies in raw materials, that is, the use of a low grade chrome ore, is that described in the Feild U.S. Pat. No. 2,430,117 of Nov. 4, 1947. This process results in even greater volumes of slag and even greater consumption of electric power. It may be efficaciously practiced only in regions of low power rates.

In the process of the above patent there is first had an impure grade of stainless steel of high-carbon content, this by melting in the conventional ferroalloy furnace a charge comprising a low-grade chrome ore and a carbonaceous reducing agent. The resulting steel contains some 10% to 35% chromium, with carbon up to 2%, and the remainder iron and impurities. The impure steel is then processed in a second furnace wherein carbon is eliminated by means of an addition of iron oxide and the use of high-furnace temperatures, there being some concomitant loss of chromium through oxidation, the chromium oxides thus formed migrating into the slag overlying the metal. The chromium so lost, of course, is recovered as in the Feild and Arness processes noted above, by way of a ferrosilicon addition to the slag. In this process, as in the others, there is a costly and inefficient feature: eliminating carbon at the expense of concurrently eliminating chromium and then recovering that chromium by way of further expense in ferrosilicon and furnace time.

Within recent years significant savings in time have been had by speeding up the oxidizing stage employed in the processes noted, that is, in the stage immediately subsequent to melt-down. Instead of relying entirely upon the recent oxygen content of the ingredients of the charge, that is, the chrome ore and/or iron oxide or roll scale additions, the carbon content of the melt is substantially eliminated through an oxygen blow. Gaseous oxygen is introduced into the melt under a pressure of 120 pounds per square inch and at the rate of out 500 cubic feet per minute. An initial carbon content on the order of 1% is brought to a figure of 0.08% in about 15 minutes' time. Fore a further lowering of carbon, the time required is greatly increased, this amounting to about 20 minutes to bring the carbon from 0.08% to 0.03%. Here again, however, with the elimination of carbon a substantial amount of chromium is oxidized from the bath, this migrating into the slag, from which it is recovered only with the use of large quantities of ferrosilicon or other reducing agent.

The several melting processes noted, although enjoying maximum utilization of the less costly chromium-containing raw materials high-carbon ferrochrome and/or chrome ore, require prolonged furnace operation, this commonly amounting to some 8 or 9 hours, and amounting to some 6 or 8 hours where an oxygen blow is employed. Additionally, in these prior practices there is consumed a maximum of costly electric power and, because of the necessary high-operating temperatures, occasion fuming of the bath and pollution of the at-

mosphere. As well, the high-operating temperatures entail substantial attack of furnace refractories, all with the resultant lowering of refractory life, and even more importantly, the inclination toward the production of dirty metal, that is, metal fraught with oxide inclusions. Such metal is cleaned up only at further cost and prolongation of furnace time.

Additionally, in the processes noted, precise knowledge of the chemical composition of the charge is not possible because of its heterogeneous nature. And where substantial quantities of stainless steel scrap are employed furnace melting becomes difficult because of the loose character of the charge; the furnace electrodes must first burn through the loose mass of scrap and other materials of the charge to form a pool of metal for effective further melting. Where substantial quantities of chrome ore are employed there is no assurance that all ore charged in the furnace becomes immediately available; and indeterminable quantity may fuse to the furnace bottom. An the removal of sulfur, something of a problem because of the imprecise knowledge of the sulfur content of the various grades of stainless steel scrap employed in the charge, is further complicated by the unknown composition of the slag and the erosion had of furnace refractories.

An object of the present of the present invention, therefore, is to overcome certain of the shortcomings of prior practices and produce clean, high-quality stainless steel to precise chemical analysis while effecting a savings in furnace time, in furnace refractories, in electric power, and in ferrosilicon or other reducing agent, while at the same time achieving maximum utilization of furnace capacity with minimum encumbrance of furnace slag, and effecting virtually complete recovery of chromium and other oxidizable elements involve.

SUMMARY OF THE INVENTION

Referring now more particularly to the practice of my invention, I find that in the highly industrialized eastern part of the U.S., where electric power is at a premium, and so, too, the cost of labor, stainless steel melting processes which are advantageously employed in other parts of the U.S. are found unduly costly. I refer to the processes of the Feild U.S. Pat. No. 2,430,117 and the Arness U.S. Pat. No. 1,954,400, as well as improvements thereon. In the practice of these processes, and others, there are encountered substantial slag volumes which preclude maximum utilization of furnace capacity and slow the metallurgical reactions involved.

I find that great savings are had in electric power, and maximum utilization made of furnace capacity, with minimum time of complete cycle of melting furnace operation by employing as a source of chromium stainless steel scrap and/or high-carbon ferrochrome and/or ferrochrome silicon. The several ingredients conveniently are melted in an electric arc furnace, that is, the known Heroult furnace having carbonaceous electrodes, with suitable basic lining. Preferably, the furnace is lined with magnesite to a height significantly above the slag line. Where desired, however, there may be employed the less expensive material chromite.

In accordance with the practice of my invention, the electric arc furnace is charged with stainless steel scrap and/or other alloy of iron and chromium, such as high-carbon ferrochrome and/or ferrochrome-silicon. Where high-carbon ferrochrome is employed, there additionally is employed low-carbon steel scrap in order to provide sufficient iron; where substantial amounts of ferrochrome-silicon are employed there may be added chrome ore, this to take advantage of the silicon available for ore reduction. The ore is directly charged into the bath instead of being placed around the banks of the furnace as in certain prior practices. And along with the charge of iron and chromium there additionally is a charge of lime in amounts sufficient to provide a protective slag during the melting operation, this generally being such as to provide a slag layer of only some 1 or 2 inches in depth. Slag fluidity is assured by an addition of fluorspar, small amounts of ferrosilicon additionally being employed near the end of the melting

period as desired. The protective slag not only prevents loss of heat during the melting operation but also serves to effect desulfurization of the bath of metal, all as more particularly noted hereinafter.

Melting ordinarily is had at a temperature of about 2,900° F., yielding a bath of the desired high-chromium content, a chromium content of about that desired in the finished steel, but having a carbon content greatly in excess of that finally desired. If find that the metal at the end of the melting operation is clean and significantly free of oxide inclusions, especially the chromium oxide inclusions commonly found at the end of the melting periods in the processes of the prior art. The sulfur content is at desired low-value. The weight of metal tapped is at a maximum because I find that in my process the slag volumes encountered are at a minimum.

Much of the slag is withdrawn from the bath or melt and the furnace tapped into a suitable ladle for transfer to a vacuum induction furnace. Preferably there is employed a furnace located within a compartment which is exhausted of its atmosphere, this being commonly referred to as a degasser. The molten metal is streamed in to the vacuum furnace rather slowly, the molten stream breaking into droplets, thereby providing a maximum of metal surface. I employ a strong oxidizing agent, or decarburizer, to effect removal of the objectionably large amounts of carbon present in the molten metal; the amount of oxidizing agent required is determined by making a carbon analysis immediately before teeming into the vacuum furnace. While a portion of this oxidizing agent may be added to the metal as it is streamed into the vacuum furnace, I find best results are had where most of the oxidizer is added to the metal in the furnace. In either instance there is had an intimate mixing of metal and deoxidizing agent, this being aided by the stirring had with the induction furnace operation. I achieve best results with nickel oxide, this of course being employed in the production of the chromium-nickel stainless steels. For the straight-chromium grades, that is, the grades which desirably are essentially free of nickel, I find best results are had with mill scale, this being a combination of the oxides of iron and chromium. Where desired, there may be employed iron oxide, although for certain grades, as for example the copper-bearing grades of stainless steel, excellent results are had with copper oxide. In other grades there may be employed the oxides of cobalt, molybdenum, chromium, manganese, silicon, or titanium, the kind and quantity of oxide added of course depending upon the particular composition and analysis of the metal sought.

The vacuum furnace preferably is lined with alumina having sufficient silica present to serve as a binder. The alumina lining is well calculated to withstand the temperatures encountered. At the same time any alumina picked up the metal is not retained as an objectionable inclusion, but rather rises to the surface and is readily eliminated.

During the treatment in the vacuum furnace the carbon present in the metal combines with the oxygen content of the oxidizing agent employed forming carbon monoxide, a gas. This comes out of the metal in the form of minute bubbles, where upon reaching the surface of the metal, the gas is exhausted into the atmosphere. During streaming the pressure in the vacuum furnace ranges from atmospheric pressure on down to several millimeters of mercury. While this pressure rises to about 50 millimeters or more during much of the degassing operation, following the conclusion of streaming the pressure drops back to several millimeters, or even less. The temperature of the metal in the vacuum vacuum is maintained at about 2,900° F., or perhaps 2,950° F. During this period there are made additions for composition adjustment and/or auxiliary deoxidation as desired.

Where instead of nickel oxide there is employed iron oxide, chromium oxide, manganese oxide, silica, or others as indicated above, even higher degrees of vacuum are desired, pressure as low as 1 millimeter or less being desired to effect carbon elimination within a minimum period of time.

When the carbon content of the steel has been brought to the desired low value and desired chemical composition is had, the degassing or vacuum treatment is at an end. The vacuum is broken and the furnace tapped into a suitable ladle for teeming. Where desired the ladle, and even the ingot molds, may be maintained within the degasser, in which event the vacuum is not broken until the metal is streamed into the ladle or teemed into the ingot molds, as the case may be, all as more particularly noted hereinafter. Final deoxidation of the metal conveniently is had by adding aluminum to the ladle in teeming.

The tapped metal is clean, sound and of desired high-chromium content and low carbon content. A maximum weight of metal is had in minimum total melting and degassing time, with minimum consumption of electric power and maximum utilization of furnace capacity, all as more particularly pointed to above. Wear of refractories is minimized. And a certain flexibility nevertheless is enjoyed in the selection of raw materials.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As more particularly illustrative of the practice of my invention, in the production of a heat of chromium-nickel stainless steel Type 304 (carbon 0.08% max., manganese 2.00% max., phosphorus 0.045% max., sulfur 0.03% max., silicon 1.00% max., chromium 18.00/20.00%, nickel 8.00/12.00%, and remainder iron) I employ a 20-ton Heroult electric arc furnace with a chromite brick hearth extending well up above the intended slag line. The upper sidewalls and roof are lined with alumina-silica brick in accordance with standard practice.

I charge the furnace with 12,800 pounds of mild steel scrap, 8,000 lbs. of 3% nickel scrap and 3,000 pounds of 18-8 chromium-nickel stainless steel scrap (about 18% chromium, about 8% nickel, 0.08% max. carbon, the remainder iron). Additionally, there is charged 9,000 pounds of high-carbon ferrochromium (66/70% chromium, 4/6% carbon, and remainder iron), together with 3,200 pounds of ferronickel (52% nickel and remainder iron). The total metal content of the charge amounts to 36,000 pounds. And along with the charge there is included 1,700 pounds of lime and 800 pounds of fluorspar.

The charge is melted down under the heat of the electric arc, the molten metal reaching a temperature of some 2,900° F. The slag overlying the metal has a depth of about 2 inches. It is fluid and well protects the metal from oxidation during the melting period. Moreover, the slag effects desulfurization without necessity of other special additions. At the end of melt-down the molten metal analyzes 1.54/1.55% carbon, 0.35% manganese, 0.018% phosphorus, 0.011% sulfur, less than 0.05% silicon, 18.53% chromium, 6.32% nickel, and remainder iron.

In the illustrative practice noted, the molten bath is subjected to a series of four oxygen blows, each at the rate of about 500 cubic feet per minute and at a pressure of about 120 pounds per square inch for about 8 minutes' time. The carbon content during the blowing drops radically. There, however, is some loss of chromium through oxidation, with resultant stiffening of the slag. There is then added some 300 pounds of fluorspar and 310 pounds of ferrosilicon of the 75% silicon grade. A substantial part of the slag is then withdrawn and the oxygen blow continued with further loss of carbon. At the end of the blowing operation the carbon content of the molten metal amounts to 0.110/0.114%. Just prior to the final blow the metal analyzes 0.19% manganese, 0.01% phosphorus, 0.011% sulfur, less than 0.05% silicon, 16.62% chromium, 6.75% nickel, and remainder iron.

The chromium analysis of the bath suggests a significant loss of chromium into the slag, a chromium content of 16.62% as against a chromium content of 18.53% in the initial bath. High-carbon ferrochromium in the amount of 235 pounds is then charged into the bath, this effecting a substantial recovery of the chromium content of the slag, but at the same time adding some carbon to the bath. Upon assimilation of the

high-carbon ferrochromium, the heat analyzes 0.250% carbon, 0.017% phosphorus, 0.011% sulfur, less than 0.05% silicon, 17.48% chromium, 6.51% nickel, and remainder iron. The analysis shows a substantial recovery of the lost chromium.

With the substantial chromium recovery the metal is ready for transfer to the vacuum furnace. And in this regard the temperature of the bath is brought to about 3,000° F., some lime is added to stiffen the slag, and the heat is tapped beneath the slag into a suitable ladle for transfer to the vacuum furnace or degasser. It is found that bringing the bath to the 3,000° F. temperature immediately before tapping, adequate compensation is had for the chilling effect of the ladle. Conveniently, lime is thrown on top of the metal in the ladle in order to prevent a in the ladle in of heat and, to some extent, protect the metal oxidation. oxidation

The molten metal is streamed into the vacuum induction furnace under a pressure of one atmosphere. The vacuum pumps are then turned on. Nickel oxide of commercial purity is added from time to time, this on total amount of about 520 pounds. With the nickel oxide addition there is an oxidation of carbon, this forming carbon monoxide which is exhausted into the atmosphere. During this practice the temperature of the metal is on the order of 2,900° F. And the furnace pressure ranges from about 50 millimeters down to about 2.5 millimeter of mercury. The carbon-oxygen reaction is facilitated by a stirring action had in the induction furnace operation.

At the end of the decarburization period, the metal analyzes 0.022% carbon, 0.11% manganese, 16.93% chromium, 7.64% nickel, and remainder iron. The composition of the steel is then adjusted, this through the additions of low-carbon ferrochromium and pig nickel.

Conveniently, in preparing the heat for tapping, some 300 or 400 pounds of 50% ferrosilicon are added, and carbon, metal is brought to a temperature about 2,950° F. The furnace is tapped into a suitable ladle for teeming. Here again, the increase in the temperature of the metal allows for heat losses and drop of temperature as the metal is tapped into the ladle. Upon breaching the vacuum and teeming, there are had 20 ingots of 13 inches square section, weighing 31,500 pounds. The skull and butt metal comes to another 1,400 pounds. Chemical analysis of the steel reveals an average composition of 0.052% carbon, 0.74% manganese, 0.026% phosphorus, 0.021% sulfur, 0.51% silicon, 18.28% chromium, 8.74% nickel, and remainder iron. The metal is found to be sound, clean, and significantly free of oxide inclusions.

As further illustration of the practice of my invention, as in the production of a heat of stainless steel Type 304, I charge the electric arc furnace with 9,300 pounds of mild steel scrap, 26,700 pounds of 18-8 chromium-nickel stainless steel scrap, 2,800 pounds of high-carbon ferrochromium, and 1,200 pounds of low-carbon ferrochromium (66/72% chromium, 0.05% carbon, and remainder iron). The total weight of metal amounts to 40,000 pounds. With the charge there are added some 1,700 pounds of lime and 900 pounds of fluorspar.

Here again, the charge is melted down under the heat of the electric furnace, the molten metal reaching a temperature of some 2,900° F. With completion of melt-down, the metal analyzes 0.483% carbon, 0.71% manganese, 0.015% phosphorus, 0.006% sulfur, 0.17% silicon, 18.23% chromium, 5.67% nickel, and remainder iron. Small amounts of ferrosilicon are added in batches, one of about 100 pounds and another of about 140 pounds, both of a 75% silicon grade. At this stage the metal analyzes 0.460% carbon, 0.66% manganese, 0.013% phosphorus, 0.005% sulfur, 0.05% silicon, 17.80% chromium, 5.68% nickel, and remainder iron. With a final check on the carbon, chromium and nickel contents, the metal here analyzing 0.459% carbon, 17.89% chromium, 5.62% nickel, and remainder iron, the heat is readied for tapping into a suitable ladle, as before.

The molten steel from the ladle is streamed into the vacuum induction furnace under one-atmosphere pressure, and the vacuum pumps then turned on. Because of the significantly higher carbon content than before (0.459% carbon as com-

pared to 0.250% carbon in the prior illustrative heat), a substantially larger quantity of nickel oxide is charged into the vacuum furnace, this in separate batches. The total quantity of nickel oxide amounts to 1,040 pounds.

During the treatment in the vacuum furnace the pressures range from some 20 millimeters down to 0.6 millimeters of mercury. The carbon content of the metal falls rapidly as a result of the reaction with the nickel oxide and the stirring action had in the bath. At the end of the decarburization period, the carbon content amounts to 0.042%. The heat is then adjusted for composition through additions of low-carbon ferrochromium and pig nickel and tapped into a suitable ladle for teeming. There are had 37,780 pounds of ingots analyzing 0.042% carbon, 0.82% manganese, 0.028% phosphorus, 0.025% sulfur, 0.62% silicon, 18.38% chromium, 8.45% nickel, and remainder iron. Here the skull and butt scrap amount to 660 pounds, giving a total weight of 38,440 pounds.

In comparing the two illustrative examples of the practice of my invention, it will immediately be seen that in the latter there is employed a maximum quantity of 18-8 chromium nickel stainless steel scrap with a minimum of high-carbon ferrochromium, whereas in the former there is employed a minimum amount of this scrap with a maximum of high-carbon ferrochromium. Moreover, it will be seen that in the latter example the oxidizing blow is eliminated in favor of the use of ferrosilicon. While in this latter example the carbon content at melt-down amounts to something less than 0.5% and this carbon is eliminated in the vacuum furnace rather than in the arc furnace, in the practice of the former the carbon at melt-down amounts to about 1.5% and by far the greater portion of this is eliminated in the arc furnace. Considerable flexibility, therefore, is enjoyed in the practice of my invention, the particular combination of arc furnace practice and vacuum furnace practice depending upon the availability and relative costs of raw materials and, of course, the melting specification to be met.

As a further illustrative example of the practice of my invention, as in the production of a high-sulfur heat of stainless steel Type 303 (carbon 0.15% max., manganese 2.00% max., phosphorus 0.20% max., sulfur 0.15% min., silicon 1.00% max., chromium 17.00/19.00 %, nickel 8.00/10.00%, and remainder iron), there is charged into the electric arc furnace mild steel scrap, 18-8 chromium-nickel stainless steel scrap, high-carbon ferrochromium, low-carbon ferrochromium, lime and fluorspar, as in the second illustrative example given above. Along with this charge there is added some 3.85 pounds of iron pyrites (FeS_2) containing 53.5% sulfur and remainder iron.

Upon completion of melt-down in the electric arc furnace and recovery of the small amount of chromium lost into the slag as a result of the oxidation encountered in the melting operation, the heat is tapped into a ladle for transfer to the vacuum furnace. The metal analyzes 0.05% carbon, 0.67% manganese, 0.014% phosphorus, 0.039% sulphur, 0.10% silicon, 18.31% chromium, 6.04% nickel, and remainder iron. The metal is streamed from the ladle into the vacuum induction furnace under one-atmosphere pressure. the vacuum pumps are activated and nickel oxide in the amount of 1,170 pounds added, this to effect decarburization. Here again, the temperature of the metal is maintained about 2,900° F. throughout the degassing process, the furnace pressures ranging from some 80 millimeters down to 1.6 millimeters of mercury. Adjustments in chromium, nickel, manganese, silicon, and sulfur contents are conveniently made through additions of low-carbon ferrochromium, pig nickel, ferromanganese ferrosilicon and iron pyrites. Upon checking the analysis, the heat is tapped into a ladle for teeming. The vacuum is broken, the ladle removed, the ingots are teemed. Here again, the metal is found to be sound, clean, and significantly free of oxide inclusions. There are had 37,720 pounds of ingots analyzing 0.079% carbon, 1.33% manganese, 0.019% phosphorus, 0.18% sulfur, 0.70% silicon, 17.86% chromium, 9.26% nickel, and remainder iron. Here the skull and butt

scrap comes to 500 pounds, giving a total weight of metal of some 38,220 pounds.

In this third example of the practice of my invention it will be noted that, as in the second example given above, the elimination of carbon is effected in the vacuum furnace at substantial temperatures and at low pressures. During the melting in the arc furnace there is had a minimum of oxidation, with the result that minimum slag volumes are encountered. The furnace capacity available to metal, therefore, is directly increased. In this regard it is noted that while the first example gave total metal in the amount of 32,900 pounds, the two latter examples gave total weights of 38,440 and 38,220 pounds.

In conclusion, it will be seen that I provide in my invention a stainless steel melting process in which there are achieved the many advantages pointed to above. There is produced a maximum weight of metal for the available furnace capacity and this in minimum length of time and with a minimum number of sampling for chemical analysis. The elapsed time for melting in the Heroult furnace, from the steps of charging, melting, tapping and readying the furnace for a further heat, amounts to about 2½ hours. And for treatment in the vacuum induction furnace the total time involved comes to about 1 hour. These time relationships are such that the vacuum furnace is well calculated to handle the production of two operating Heroult furnaces.

In my process there is encountered a minimum of slag volume, a maximum enjoyment of furnace capacity, and surprising operating efficiency. The requirement for the expensive ferrosilicon reducing agent of the prior art is virtually eliminated. Moreover, as a result of the lowered temperatures required there is gained a maximum of refractory life and a minimum requirement of electric power.

Inasmuch as many possible embodiments may be made of my invention, and many changes may be made in the embodiments hereinbefore set forth, it will be understood that all matter described herein is to be interpreted as illustrative, and not by way of limitation.

I claim:

1. In the production of stainless steel containing about 10% to 35% or more chromium and of low-carbon content the art which comprises melting in an electric arc furnace a charge comprising at least one of the following two ingredients stainless steel scrap and high-carbon ferrochromium, to give a bath of undesirably high-carbon content but desirably low chromium oxide content; and treating the resulting melt in a vacuum induction furnace in the presence of the reducible oxide at temperatures of at least about 2,900° F. and at pressures brought to a value, not exceeding several millimeters of mercury to eliminate carbon in the presence of chromium.

2. In the production of stainless steel containing about 10% to 35% to more chromium and of low-carbon content the art which comprises melting in an electric arc furnace a charge comprising at least one of the following two ingredients stainless steel scrap and high-carbon ferrochromium, yielding a melt of desirably high chromium and low chromium oxide contents but undesirably high-carbon content; and thereafter treating the melt in a vacuum induction furnace with one or more of the oxides of nickel, cobalt, molybdenum, chromium, copper, iron, manganese, silicon and titanium at temperatures of at least about 2,900° F. and under pressures brought to a value not exceeding several millimeters of mercury to eliminate carbon.

3. A process according to claim 1 in which the melt of undesirably high-carbon content is treated with a reducible oxide under pressures brought to a value not exceeding several millimeters of mercury and temperatures of at least about 2,950° F.

4. In the production of stainless steel containing about 10% to 35% or more chromium and with nickel up to 35% or more the art which comprises melting a charge comprising iron and chromium in an electric arc furnace to form a melt of substantial chromium and desirably low chromium oxide content but

undesirably high-carbon content at temperatures not exceeding about 3,000° F.; and thereafter a vacuum the melt, in a vacuum induction furnace with nickel oxide at temperatures of at least about 2,950° F. and pressures brought to a value not exceeding several millimeters of mercury to eliminate carbon in the presence of chromium.

5. In the production of a chromium-nickel stainless steel containing about 10% to 35% or more chromium and with nickel up to 35% or more the art which comprises melting in an electric arc furnace a charge comprising at least one of the following two ingredients stainless steel scrap and high-carbon ferrochromium, forming a melt of undesirably high-carbon content but desirably low chromium oxide content at temperatures not exceeding about 3,000° F.; maintaining the melt under a slag of lime and ferrosilicon at such temperatures to eliminate sulphur; and thereafter ridding the melt of carbon by treating the same, in a vacuum induction furnace, with nickel oxide under conditions of high-temperature and under pressure brought to a value not exceeding 1 millimeter of mercury.

6. In the production of stainless steel containing about 10% to 35% or more chromium the art which comprises melting in an electric arc furnace having carbon electrodes a charge comprising stainless steel scrap and high-carbon ferrochromium, yielding a melt of substantial chromium content but desirably low chromium oxide content and undesirably high-carbon content at temperatures not exceeding about 3,000° F.; and thereafter treating the melt, in a vacuum induction furnace, with iron oxide at temperatures of about 2,900° F. to about 3,000° F. and under conditions of pressure brought to a value not exceeding several millimeters of mercury to rid the

same of carbon.

7. In the production of stainless steel containing about 10% to 35% or more chromium the art which comprises melting a charge comprising stainless steel scrap in an electric arc furnace at moderate melting temperature, giving a melt of undesirably high carbon content but desirably low chromium oxide content; and thereafter treating the melt, in a vacuum induction furnace, with a reducible oxide at temperatures of about 2,950° F. to about 3,000° F. and pressures brought to a value not exceeding several millimeters of mercury.

8. In the production of stainless steel containing about 10% to 35% or more chromium and with nickel up to 35% or more the art which comprises melting, in an electric arc furnace a charge comprising stainless steel scrap and high-carbon ferrochromium, yielding metal of substantial chromium content but desirably low chromium oxide content and undesirably high-carbon content; and treating the same, in a vacuum induction furnace with nickel oxide at temperatures of at least about 2,950° F. and pressures brought to a value not exceeding 1 millimeter of mercury to rid the metal of carbon.

9. In the production of stainless steel containing about 10% to 35% or more chromium the art which comprises melting in an electric arc furnace a charge comprising iron and chromium, yielding metal of undesirably high-carbon content, but desirably low chromium oxide content; and treating the metal, in a vacuum induction furnace, with iron oxide at temperatures of at least about 2,950° F. and pressures brought to a value not exceeding 1 millimeter of mercury to rid the same of carbon.

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