Oct. 23, 1962 R. SPOLDERS ET AL 3,060,015

STEEL PURIFICATION

Filed March 22, 1960

5 Sheets-Sheet 1

Fig. 1

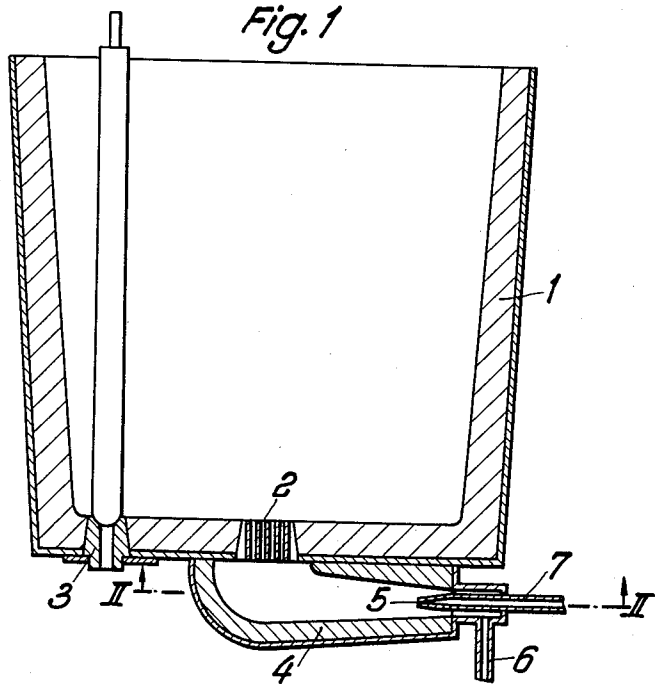
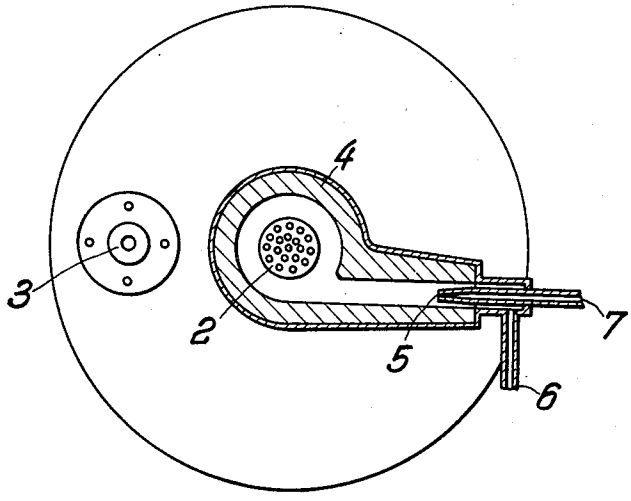


Fig. 2



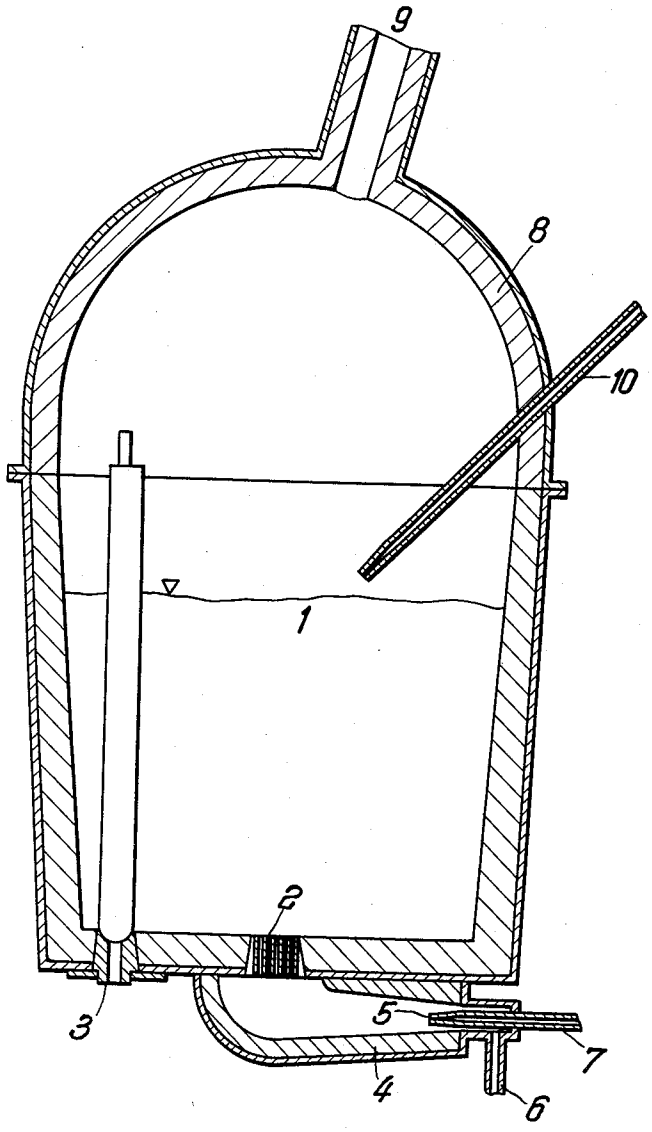
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STEEL PURIFICATION

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Fig. 3



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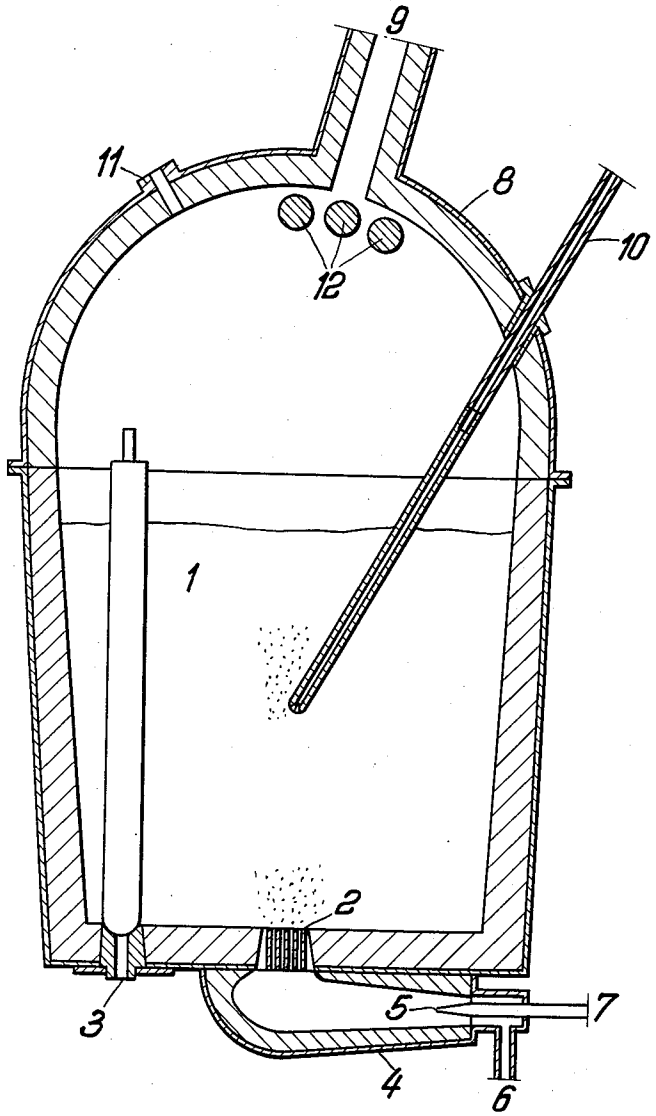
Oct. 23, 1962 R. SPOLDERS ET AL 3,060,015

STEEL PURIFICATION

Filed March 22, 1960

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Fig. 4



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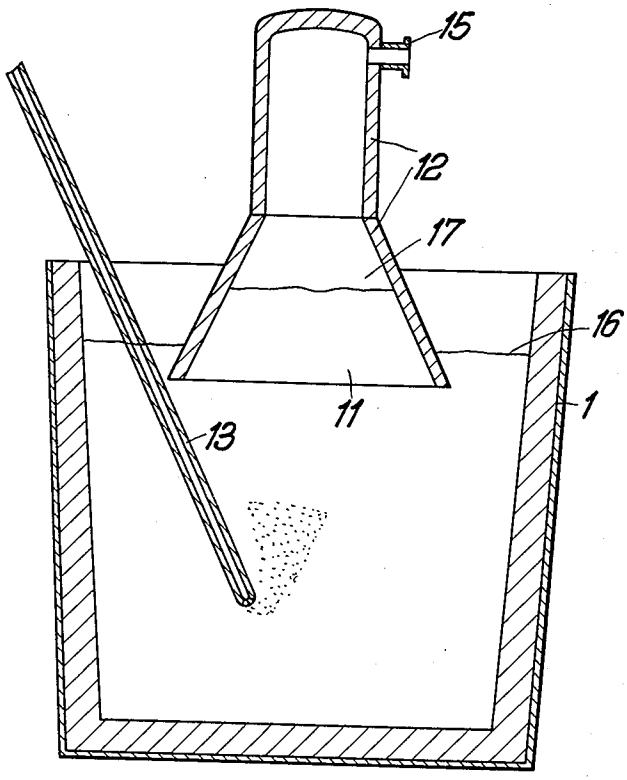
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STEEL PURIFICATION

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Fig. 5



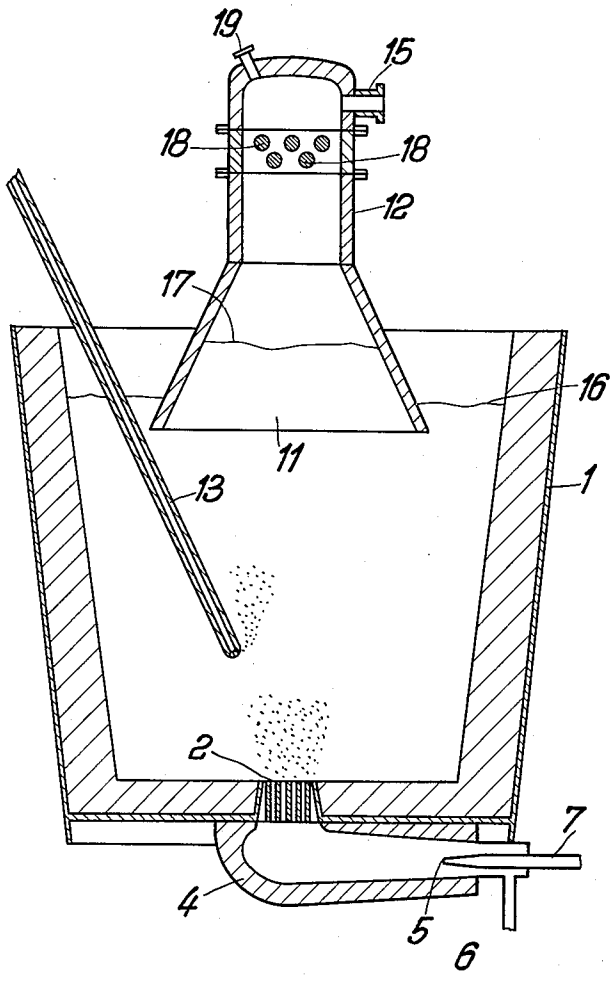
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STEEL PURIFICATION

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Fig. 6



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3,060,015

STEEL PURIFICATION

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Filed Mar. 22, 1960, Ser. No. 16,754
10 Claims. (Cl. 75—60)

The present invention relates to steel purification and, more particularly, it relates to a method and apparatus for purifying molten steel by means of gases.

The present application is a continuation-in-part of our co-pending application Serial Number 717,756, filed February 26, 1958, now abandoned, and entitled "Method and Apparatus for Purifying Steel."

It is well known that steel, as it comes from the furnace or converter, contains considerable quantities of occlusions including gases which exert a harmful effect and the passage of which through the bath of molten steel is rendered difficult or prevented due to the ferrostatic pressure of the molten steel.

It has been attempted to facilitate the passage of undesirable gases through and out of the molten steel by passing argon through the body of molten steel. The argon while not reacting with the steel serves to flush out undesirable gases. However, the large quantities of argon required for this purpose are frequently not available and, in any event, make this process uneconomical.

It is therefore an object of the present invention to provide an effective and economical method and apparatus for the removal of undesirable matter from molten metal.

It is another object of the present invention to provide a method whereby particularly hydrogen can be removed from molten steel in an economical and simple manner.

It is a further object of the present invention to provide an apparatus which is particularly suitable for the treatment of molten metal therein.

Other objects and advantages of the present invention will become apparent from a further reading of the description and of the appended claims.

With the above and other objects in view, the present invention contemplates in a method of purifying steel, the step of passing a gas selected from the group consisting of carbon monoxide and carbon dioxide through the molten steel.

According to a preferred embodiment of the present invention, the same includes in a method of purifying molten steel, the steps of introducing a body of molten steel into a vacuum chamber, and blowing a finely subdivided, preheated gaseous mixture comprising at least one gas selected from the group consisting of carbon monoxide and carbon dioxide, and at least one gaseous substance selected from the group consisting of halogens and halogen compounds through the body of molten steel while maintaining a vacuum in the vacuum chamber.

According to another preferred embodiment, the method of the present invention includes the steps of blowing a first oxidizing gas into the bottom portion of a mass of molten steel, and blowing through a lance into the mass of molten steel at a point upwardly spaced from the bottom portion thereof a second gas having a composition different from the composition of the first gas.

It is also within the scope of the present invention to reverse the location of introducing oxidizing and reducing gases or to introduce at one location a gas having either an oxidizing or a reducing effect and at the other location a gas which will cause neither oxidization nor reduction in the molten steel.

The present invention also contemplates in a device for the purification of molten steel, in combination, container means for holding a body of molten steel, the container means having a bottom, withdrawal means for withdrawing molten steel from the container means through the bottom thereof, gas distributing means in the lower portion of the container means, and blowing means for blowing a gas through the gas distributing means into the container means.

According to another embodiment, the device of the present invention comprises a container including side walls and a bottom and being adapted to hold molten metal up to a predetermined level, gas distributing means in the bottom of the container communicating with the interior of the same, first blowing means for blowing a gas through the gas distributing means into the container, second blowing means including a lance extending into the container means and terminating at a point upwardly spaced from the bottom, hood means located in part above the container and including a downwardly flaring lower end portion extending into the container below the predetermined level spaced from the side walls and bottom thereof, and means for producing a partial vacuum within the hood means communicating with the latter at a point above the side walls of the container.

Surprisingly, it has been found according to the present invention that a molten steel bath can be purged easily of a large proportion of undesirable gases by blowing through the molten steel either carbon dioxide or carbon monoxide or a mixture of these two gases. It may be assumed that the following reactions occur when carbon dioxide is blown through the molten steel:

(1) $Fe—CO_2 \rightarrow FeO—CO$
(2) $FeO—C \rightarrow Fe—CO$
(3) $CO_2—C \rightarrow 2CO—38{,}369$ kcal./kmol.

It is believed that the above assumption will facilitate the understanding of the present invention, however, the present invention is not based on or dependent on the accuracy of the reaction described above.

It has been found that frequently best results are obtained by using a quantity of 5 cubic meters of carbon dioxide calculated at atmospheric pressure per 1 metric ton of molten steel. When using 5 cubic meters of carbon dioxide for 1 metric ton of molten steel the decarbonization will amount to 0.1 kilogram per ton of steel.

When carbon monoxide is blown through the molten steel, decarbonization of the same does not take place but only a flushing or purging effect.

Due to the fact that the reaction of carbon dioxide within the molten steel is an endothermic reaction and since heat is also withdrawn by the blowing process itself, it has been found advantageous to preheat the gases, be it carbon dioxide or carbon monoxide or a mixture of the same, in per se known manner prior to introduction of the gases into the molten steel. In many cases it has been found particularly advantageous to burn carbon monoxide with oxygen so as to transform all or part of the carbon monoxide into carbon dioxide and to introduce the thus-formed hot reaction gas into the steel bath.

This latter method also affords the opportunity to introduce the gas into the steel bath at optimum temperature. The carbon monoxide used for this purpose may be for instance produced in a coke generator operated with oxygen and carbon dioxide, such as is described in the copending patent application Serial No. 682,256, or the carbon monoxide may also be formed by decomposition of synthetic gas, or in any other suitable manner.

It has been found particularly advantageous according to the present invention to combine the gas treatment of the molten steel bath with a vacuum treatment of the same. Heat consumption in a vacuum chamber used for this purpose is considerable and it is therefore desirable to preheat the gas which is to be blown through the molten steel in the vacuum chamber. A further economy with respect to the heating of the vacuum chamber can be

achieved by introducing within the chamber into the area adjacent to the upper surface of the liquid steel body a quantity of oxygen sufficient to burn carbon monoxide emanating at the surface of the molten steel so that the thereby formed combustion heat can be utilized for the heating of the vacuum chamber. Per ton of molten steel about 10 cubic meters of carbon monoxide calculated at atmospheric pressure will become available and consequently the heat provided by oxidation of carbon monoxide near the surface of the molten steel bath will amount per ton of molten steel to about the following:

(4) $CO—\frac{1}{2}O_2 \rightarrow CO_2—3020$ kcal./Nm.^{3}

(5) Q (heat) $=10 \times 3020 = 30{,}200$ kcal.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is an elevational view in cross section of an embodiment of the device of the present invention;

FIG. 2 is a cross section through the device illustrated in FIG. 1 taken along the line II—II;

FIG. 3 is an elevational view in cross section of another embodiment of the device of the present invention;

FIG. 4 is an elevational view in cross section of yet another embodiment of the device according to the present invention;

FIG. 5 is an elevational view in cross section of a further embodiment of the device according to the present invention; and

FIG. 6 is an elevational view in cross section of a still another embodiment of the device according to the invention.

Referring now to the drawings, and particularly to FIGS. 1–3, container **1** adapted to receive molten steel is shown carrying in its bottom portion removable tuyere block **2** and laterally spaced therefrom stopper nozzle **3**. Underneath container **1**, a blast box **4** of circular horizontal cross section is shown towards which burner **5** extends in a direction tangential to the inner circular wall of blast box **4**. Oxygen is introduced into burner **5** through conduit **6**, and carbon monoxide through conduit portion **7**. Within the blast box **4** combustion of the carbon monoxide to carbon dioxide takes place. Thus, blast box **4** fulfills the function of a combustion chamber. Blast box **4** may also be additionally provided with a conduit for introducing carbon dioxide into the same. However, it is also possible to introduce carbon dioxide jointly with either the oxygen or the carbon monoxide, or to use an excess of carbon monoxide relative to the quantity of oxygen. The individual nozzles of the tuyere block preferably have a diameter of about 1 mm. in order to prevent liquid steel after completion of the introduction of gas to pass through the nozzles into the combustion chamber or blast box. If the diameter of the nozzle is chosen sufficiently small, steel will penetrate into the same only for a short distance and will then solidify. The tuyere block is then to be removed after each treatment of a batch of molten steel and after the treated steel has been drawn off.

As will be explained in detail below, it is particularly advantageous to admix a gaseous halogen or halogen compound to the carbon monoxide or carbon dioxide gas prior to blowing the same through the molten steel. For introduction of a halogen or a vaporized halogen compound, it is sometimes advantageous to provide an additional conduit communicating with blast box **4**. Evaporation or gasification of suitable halogen compounds is known per se and can be achieved without difficulties.

As illustrated in FIG. 3, a hood **8** is superposed over container **1** so as to form a vacuum chamber. It is of course necessary that hood **8** and container **1** are air-tightly connected. Conduit **9** leads to a suitable vacuum pump provided with a cooling device, and lance **10** serves for introducing oxygen into the vicinity of the upper level of molten steel within container **1**, i.e., into the area where carbon monoxide emanates from the molten steel. Thereby it is achieved that the carbon monoxide is oxidized to carbon dioxide, freeing a considerable amount of heat and thus improving the heat economy of the entire process.

A preferred embodiment of the present invention will be best understood in connection with FIG. 4 of the drawing. The purification of the steel bath is carried out according to FIG. 4 under vacuum and with introduction of two different gases which are introduced vertically spaced from each other. This can be accomplished in a modification of the apparatus illustrated in FIG. 1, and including the following features:

A cover **8** is superposed upon container **1** closing the same. Cover **8** is formed with conduit **9** communicating with a means for producing a partial vacuum. Lance **10** extends into the container and terminates therein at a point upwardly spaced from the gas distributing means **2** located in the bottom of container **1**.

Reference numeral **11** indicates a sight glass and reference numeral **12** a conventional arrangement for preventing splashing molten steel from entering into conduit **9** leading to the vacuum pump or the like.

With an apparatus such as illustrated in FIG. 4 and described above, it is possible to introduce at least two gases of different composition into the molten metal while simultaneously maintaining a partial vacuum in the apparatus. Introduction of the two gases is carried out at or in the vicinity of the bottom of the container and at a level which is substantially higher than the container bottom. In many cases, it has been found to be particularly advantageous to introduce into the molten steel through the bottom of the container an oxidizing gas, and through the lance at the higher level a deoxidizing or neutral gas. On the other hand, particularly in the case of unkilled steel, a reducing gas such as hydrogen gas may be introduced through the bottom of the container and a substantially neutral gas such as argon or carbon monoxide through the lance at the higher level. The neutral gas which is introduced through a lance may also consist fully or in part of vaporized or gasified halogens or halogen compounds.

After treatment by introduction of an oxidizing gas has been completed, it is sometimes desirable to introduce through the bottom distributing plate **2** a reducing gas without introducing a second gas through the lance during this last stage of the process.

The apparatus illustrated in FIGS. 5 and 6 is particularly well suited for providing a partial vacuum without requiring tight closing of the entire container top.

According to the embodiments of FIGS. 5 and 6, a hood is partially lowered into the container so that the lowermost preferably outwardly flaring portion of the hood will be situated below the upper level of molten metal in the container. This allows a convenient and flexible arrangement of the lance, as well as gas introduction and gas withdrawal towards the vacuum producing means, without requiring the placing of an air-tight cover member on the top of the container.

As shown in FIGS. 5 and 6, the lower portion of hood **12** extends downwardly below level **16** of the molten metal in container **4**. Due to the downwardly flaring configuration of lower portion **11** of hood **12**, gas losses will not occur to any appreciable extent. Gas will be withdrawn from the molten metal towards the partial vacuum maintained in hood **12**. Due to the partial vacuum therein, the upper level **17** of molten metal within hood **12** will be higher than the upper level **16** of molten metal outside hood **12**. Hood **12** is removably kept in the indicated position by conventional means not shown in the

drawing. Conduit **15** connects the interior of hood **12** with vacuum-producing means such as a vacuum pump (not shown). Gas is introduced into the molten metal within the container by means of lance **13**.

The embodiment illustrated in FIG. 6 differs from what is shown in FIG. 5 by additionally providing means for introducing gas through the bottom of the container, similar to those shown in FIG. 1; by including in hood **12** an arrangement **18** for preventing splashing metal from reaching vacuum conduit **15**, and by arranging sight glass **17** in the upper portion of hood **12**. Tuyere block **2** is replaceable and may be removed after hood **12** has been raised, the container has been tilted and the molten metal has been poured. In combustion chamber **4**, a mixture of a combustible gas such as carbon monoxide (which is introduced through nozzle **7**) and oxygen (introduced through conduit **6**) may be burnt and the thus formed hot combustion gas introduced into the container through distributor **2**. In this manner, very hot carbon dioxide gas penetrates from the bottom of the container through the molten steel and passes into flaring hood portion **11**, so that separate heating means for the steel bath will not be required. Additionally, a similar or different gas may be introduced through lance **13**. It is of course possible to introduce a great variety of gases through lance **13** and tuyere block **2** depending on the specific requirements of the melt.

As stated above, it is particularly advantageous to introduce jointly with the purging gas consisting of carbon monoxide or carbon dioxide or a mixture of carbon monoxide and carbon dioxide, a halogen or vaporized halogen compounds into the molten metal bath. Thereby, it is achieved that due to the intermediary reactions between the halogen and the hydrogen gas contained in the steel bath, the gaseous hydrogen is removed from the steel bath to a very considerable extent. For practical purposes, chlorine and fluorine are preferred as halogens for the present process, particularly in view of the higher costs of bromine and iodine.

A great number of halogen compounds can be advantageously used in accordance with the present invention. Particularly good results are obtained by using aluminum chloride or aluminum fluoride as the halogen compound and it has also been found that carbon tetrachloride is particularly effective since it is relatively easy to saturate the purging gas with any desired dosage of carbon tetrachloride and consequently optimum concentration of the carbon tetrachloride for any given operating conditions can easily be maintained. However, other halogenized hydrocarbons such as hexachlorobenzene have also been advantageously used. All of these halogen-supplying gases or vaporized substances can be used either alone or as a mixture of several of the same.

The following examples are given as illustrative of the process of the present invention, the invention however not being limited to the specific details of the examples.

Example I

Steel type	CK–15.
Standard analysis:	
C	0.14–0.17.
Si	0.15–0.30.
Mn	0.35–0.45.
P	Up to 0.045.
S	Up to 0.045.
Batch analysis:	
C	0.16.
Si	0.21.
Mn	0.40.
P	0.025.
S	0.031.
Temperatures:	
Prior to treatment	1600° C.
After treatment	1570° C.
Treating gas, CO_2	2.5 m.³/t. of steel.

Treating time	12 minutes.
Gas pressure	2.2–2.4 atmospheres, excess pressure.
Hydrogen content:	
Prior to treatment	8.1 cm.³/100 g. steel.
After treatment	4.8 cm.³/100 g. steel.

Example II

Steel type	St 37 m. Si.
Standard analysis:	
C	0.10–0.14.
Si	0.15–0.30.
Mn	0.40–0.50.
P	Up to 0.035
S	Up to 0.035
Batch analysis:	
C	0.13.
Si	0.20.
Mn	0.48.
P	0.026.
S	0.035.
Temperatures:	
Prior to treatment	1620° C.
After treatment	1590° C.
Treating gas, CO	4.0 m.³/t. steel.
Treating time	12 minutes.
Gas pressure	2.2–2.4 atmospheres, excess pressure.
Hydrogen content:	
Prior to treatment	8.0 cm.³/100 g. steel.
After treatment	4.8 cm.³/100 g. steel.

Example III

Steel type	SII shipbuilding plate.
Standard analysis:	
C	0.14–0.17.
Si	0.15–0.30.
Mn	0.50–0.60.
P	Up to 0.045.
S	Up to 0.045.
Batch analysis:	
C	0.17.
Si	0.22.
Mn	0.51.
P	0.038.
S	0.028.
Temperatures:	
Prior to treatment	1610° C.
After treatment	1585° C.
Treating gas	CO_2–CCl_4.
Gas consumption:	
CO_2	2.54 m.³/t. of steel.
CCl_4	0.043 l./t. of steel.
Treating time	12 minutes.
Gas pressure	2.2–2.4 atmospheres, excess pressure.
Hydrogen content:	
Prior to treatment	8.3 cm.³/100 g. steel.
After treatment	3.8 cm.³/100 g. steel.

In all examples, gas volumes are given at atmospheric pressure.

The purification obtained according to the present invention can be clearly seen by comparing the hydrogen content of the steel prior and after treatment. Hydrogen content in all cases was determined on steel samples taken from the treating vessel. Furthermore, the viscosity of the treated steel was lower thus facilitating casting of the same.

This was true with the steel as before mentioned with an oxide content of 0.04% and hydrogen content of 7–8 cm.³/100 g. steel. After blowing of 180 m.³ CO with 2% Cl the temperature was changed from 1600° C. to

1590° C., the oxide content was 0.015–0.02% and hydrogen content 3.5 cm.^{3}/100 g. steel.

The degree of vacuum applicable in the process of the invention may be varied within wide ranges. Although it is possible to apply a vacuum, e.g. of 50–0.1 mm. Hg and less, it may be preferred to apply a vacuum not far from atmospheric pressure (50–400 mm. Hg under atmospheric pressure), i.e. the pressure within the vessel may be between about 700–300 mm. Hg.

The amount of halogen, e.g. chlorine, may range from about 2 to 5% of the gas or gas mixture applied. When using halogen compounds the amounts of said compounds may be calculated so that the amount of halogen, e.g. chlorine, contained in said compounds would constitute about 2–5% of the gas or gas mixture. This is true also when 2 or more halogen or halogen compounds or mixtures of halogen and halogen compound are used.

Besides, the proportions of CO and CO_2 may be varied as desirable for the special conditions. It is preferred to burn off a part of CO to CO_2 to raise the temperature of the gas mixture. So e.g. a mixture with about 50% CO and 50% CO_2 with an addition of vaporized aluminum chloride (7 kg.) was very effective. A similar mixture was prepared with 45% CO and 55% CO_2 with an addition of carbon tetrachloride (6 kg.).

Introduction of suitably preheated gas will prevent any appreciable drop of the temperature of the steel bath during the above described purification process.

Example IV

Molten steel, treated and finished in conventional manner in an electric furnace, was introduced into container **1** of the apparatus shown in FIG. 4. Container **1** had a capacity of 30 tons and the composition of the steel was as follows:

	Percent
C	0.35
Si	0.27
Mn	0.59
S	0.017
P	0.009

After introducing the steel into container **1**, the container was closed by superposing thereon cover **8** holding lance **10** so that the free end of lance **10** was located about in the center of the bath of molten steel. In combustion chamber **4**, a hot gas consisting of 90% carbon dioxide and 10% carbon monoxide was produced by combustion of carbon monoxide with oxygen. Production of this gas was so arranged that a total quantity of about 25 liters of hot gas were introduced into container for each ton of molten steel. Through the lance hydrogen gas was blown into the molten steel in an amount of 15 liters per ton of steel. Pressure reduction was carried out so that after about three minutes a residual pressure of 2 mm. mercury was reached and this residual pressure was then maintained during the entire treating period which lasted a total of fifteen minutes.

Thereafter, atmospheric pressure was restored, cover **8** and lance **10** were removed and it was found that the above-described two-gas vacuum-treatment had resulted in a reduction of the oxygen content of the steel by about 50%, the hydrogen content by about 45% and occlusions by about 55%. The bath temperature prior to treatment was 1620° C. and was found to be 1595° C. upon completion of treatment.

Example V

The general method and apparatus as described in Example IV were used, however, with the modification that the steel was not killed during tapping from the electric furnace, so that the silicon content was only 0.07%. In this case, 25 liters of hydrogen per ton of steel were introduced through tuyere block **2**, as well as 10 liters of carbon monoxide per ton of steel through lance **10**. Degree of vacuum and length of treatment were the same as described in Example IV.

Initial steel bath temperature was 1615° C. and the temperature upon completion of treatment was 1595° C. It was found that the oxygen content of the steel had been reduced by about 65%, the hydrogen content by about 45% and the amount of occlusions by about 65%.

In Examples IV and V, determination of the oxygen content was carried out by the hot extraction method, determination of the hydrogen content by the tin fusing method and determination of the occlusions by separation of the residue.

Example VI

The method of the present invention was carried out in an apparatus as illustrated in FIG. 5.

Liquid steel was treated and finished in an open hearth furnace in conventional manner. Eighty tons of the molten steel were introduced into container **1** of FIG. 5. The steel composition was as follows:

	Percent
C	0.30
Si	0.27
Mn	0.50
S	0.034
P	0.021

The major part of the slag was removed from the molten steel and thereafter flaring portion **11** of hood **12** was lowered into the steel bath so as to penetrate through the residual slag and further to a depth of about 5 cm. into the steel bath. Thereafter, pressure within hood **12** was reduced so that after about 3 minutes a residual pressure of 2 mm. mercury was reached. Simultaneously, argon was introduced through lance **13** in a quantity of 30 liters per ton of steel. Lance **13** was made of ceramic material and the introduction of argon was evenly distributed over the entire treating period of about 16 minutes. The lance was placed in such position within container **1** that the free lower end of the lance was located about 30 cm. above the bottom of container **1**.

After completion of the treatment, lance and hood were removed and the molten steel was cast into ingots.

Analysis of the thus treated steel in accordance with the methods described in connection with Example V, showed that the above treatment had reduced the oxygen content of the steel by about 25%, hydrogen content by about 30% and occlusions by about 30%. The initial bath temperature was 1620° C. and the temperature upon completion of treatment was 1590° C.

Example VII

A process somewhat similar to what has been described in Example VI was carried out in the apparatus illustrated in FIG. 6.

Through tuyere block **2**, a combustion gas consisting of 40% carbon monoxide and 60% carbon dioxide was introduced in a quantity of 28 liters per ton of steel. The temperature of the combustion gas entering container **1** was about 1450° C. Simultaneously, through lance **13**, 15 liters of argon per ton of steel were introduced into the molten mass. Treatment was carried out for 12 minutes at a residual pressure of 2 mm. mercury as described in Example VI.

Steel bath temperature prior to treatment was 1610° C. and upon completion of treatment 1600° C.

It was found, by using the analytical methods described in Example V, that the oxygen content of the steel had been reduced by about 35%, the hydrogen content by about 40% and occlusions by about 40%.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of devices for the gas treatment of molten metal differing from the types described above.

While the invention has been illustrated and described

as embodied in a device for the purification of molten steel, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

2. In a method of purifying molten steel, the steps of reacting a mixture of carbon dioxide gas and carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature upwardly in the form of finely subdivided gas bubbles into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

3. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature into a bath of molten steel maintained in a vacuum chamber under a partial vacuum so as to obtain purification of the said molten steel while maintaining said partial vacuum in said chamber, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

4. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature into a bath of molten steel so as to obtain purification of the same, the high temperature

of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof, at least a portion of the thus introduced carbon dioxide gas being reduced in contact with said steel bath to carbon monoxide gas, said carbon monoxide gas emanating from the upper surface of said body of molten steel; and contacting said carbon monoxide gas emanating from said upper surface with oxygen gas so as to cause combustion of said carbon monoxide gas above and adjacent to said upper surface of said bath of molten steel so as to heat at least said upper surface of said steel bath due to the exothermic nature of said combustion.

5. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with a gaseous substance selected from the group consisting of halogens and halogen compounds into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

6. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with gaseous aluminum chloride into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

7. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with gaseous aluminum fluoride into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

8. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with at least one halogenized hydrocarbon into a bath of molten steel so as to obtain purification of the same, the high tempera-

ture of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

9. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with gaseous carbon tetrachloride into a bath of molten steel so as to obtain purification of the same, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

10. In a method of purifying molten steel, the steps of reacting carbon monoxide gas with oxygen gas so as to form a hot combustion gas having due to the reaction heat caused by the exothermic nature of the reaction a temperature substantially higher than the initial temperature of the reacting gases and consisting at least partly of carbon dioxide gas; and immediately upon formation of said hot combustion gas blowing the same at said substantially higher temperature together with a gaseous substance selected from the group consisting of halogens and halogen compounds upwardly through a bath of molten steel maintained in a vacuum chamber under a partial vacuum so as to obtain purification of the said molten steel while maintaining said partial vacuum in said chamber, the high temperature of the thus introduced hot combustion gas due to said reaction heat caused by the exothermic nature of the reaction avoiding any substantial cooling effect of the introduced gas on said bath of molten steel during said purification thereof.

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