July 6, 1954 C. A. HARTMAN 2,683,032

BASIC LINED CUPOLA

Filed Feb. 14, 1951 3 Sheets-Sheet 1

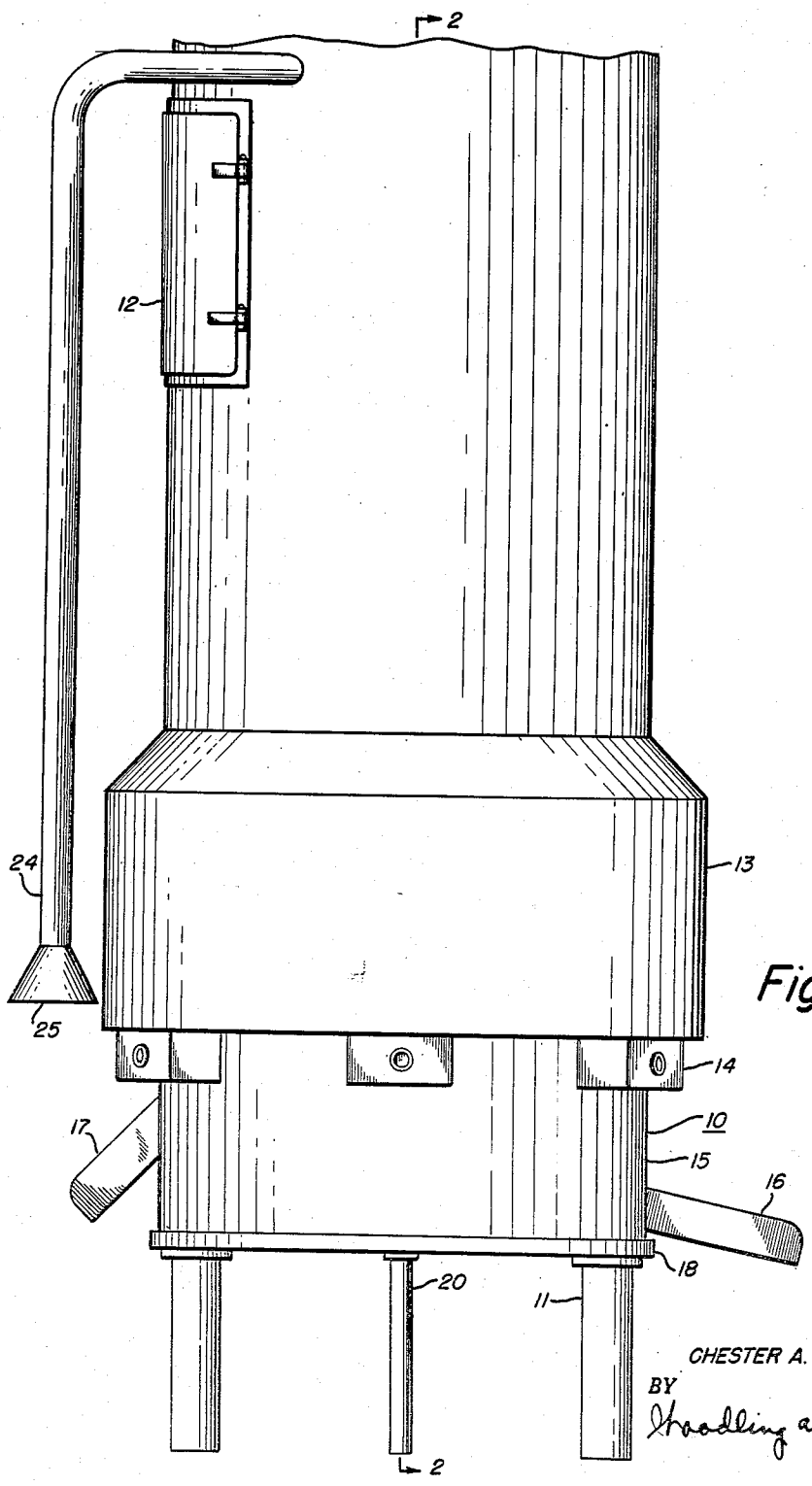


Fig. 1

INVENTOR.
CHESTER A. HARTMAN
BY
Woodling and Krost
attys.

July 6, 1954 C. A. HARTMAN 2,683,032

BASIC LINED CUPOLA

Filed Feb. 14, 1951 3 Sheets-Sheet 2

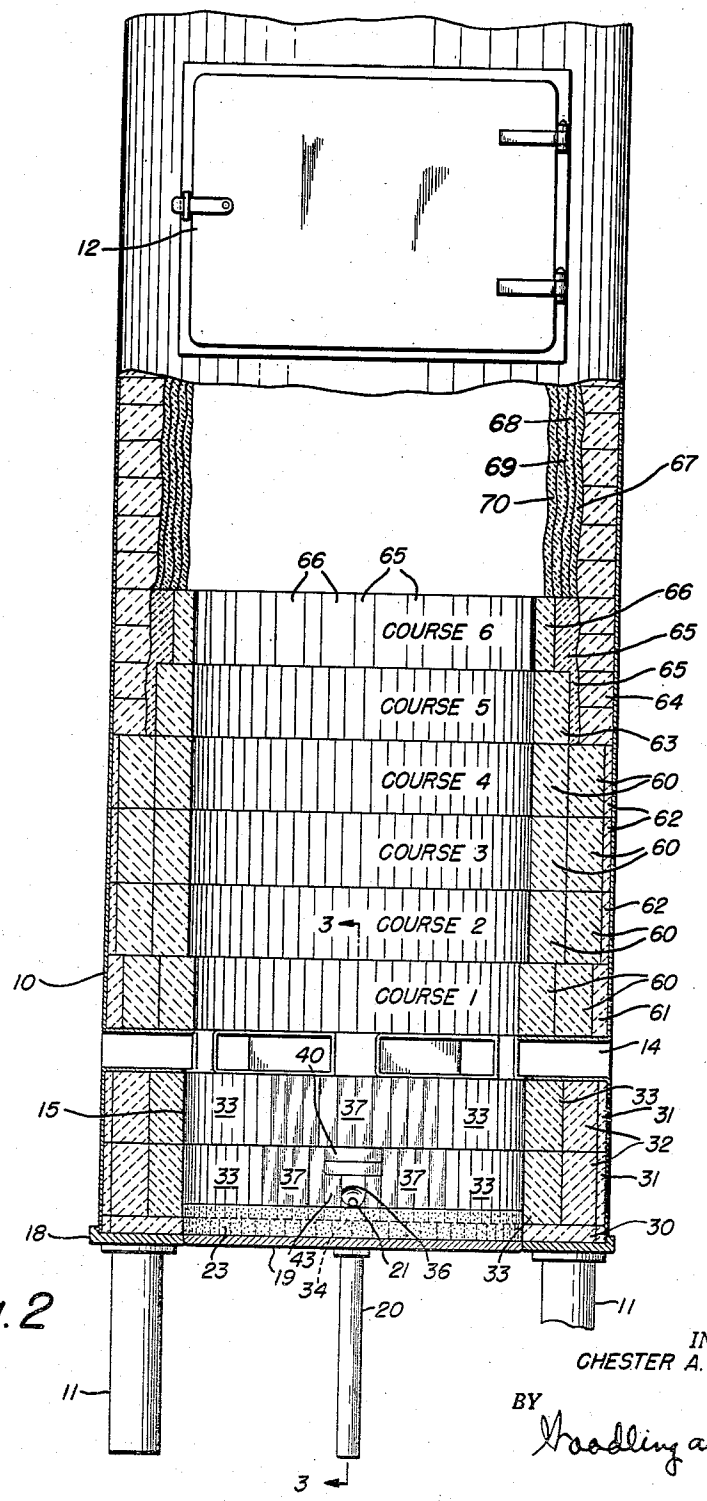


Fig. 2

INVENTOR.
CHESTER A. HARTMAN

BY Hoadley and Frost
attys.

July 6, 1954 C. A. HARTMAN 2,683,032

BASIC LINED CUPOLA

Filed Feb. 14, 1951 3 Sheets-Sheet 3

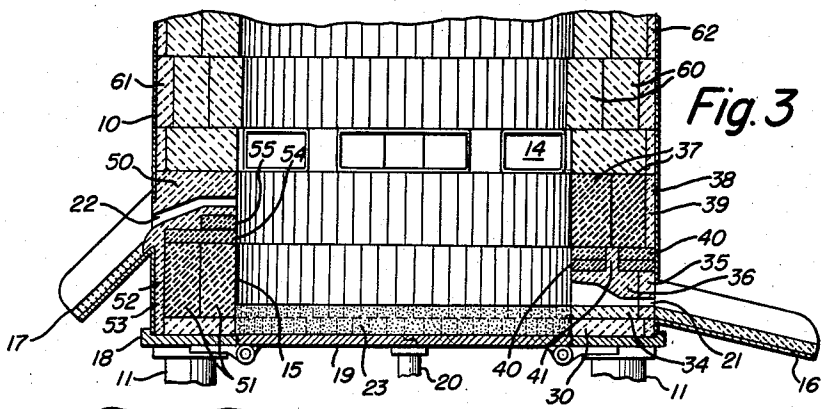


Fig. 3

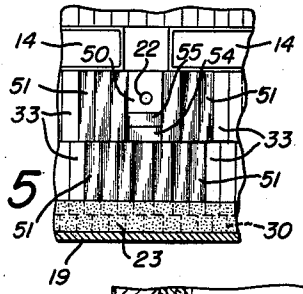


Fig. 5

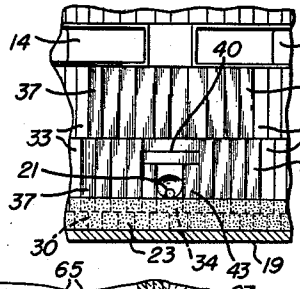


Fig. 4

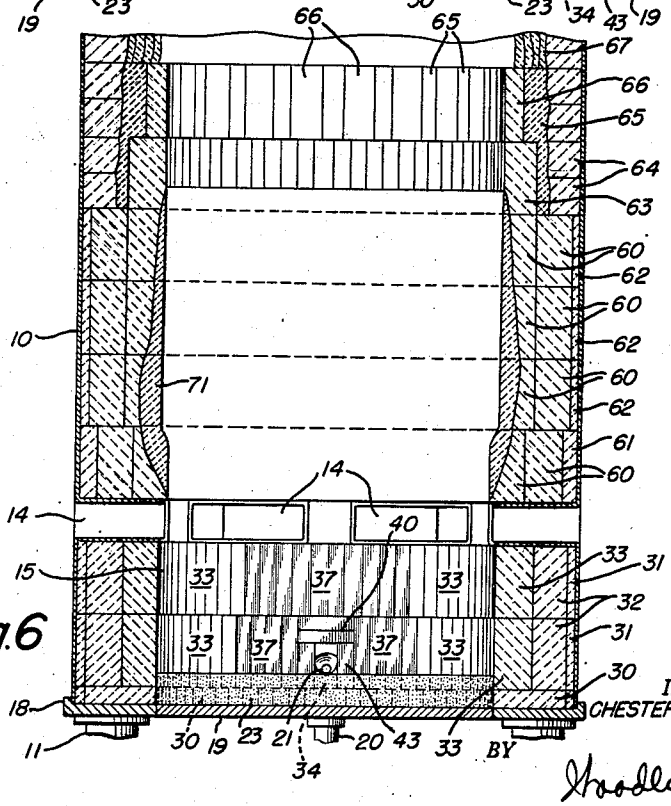


Fig. 6

INVENTOR.
CHESTER A. HARTMAN

Hoodling and Kost
attys.

Patented July 6, 1954

2,683,032

UNITED STATES PATENT OFFICE

2,683,032

BASIC LINED CUPOLA

Chester A. Hartman, Cleveland Heights, Ohio, assignor to Meehanite Metal Corporation, a corporation of Tennessee

Application February 14, 1951, Serial No. 210,950

2 Claims. (Cl. 266—43)

1

This invention relates to cupolas for the melting of a charge of ferrous materials and more particularly to cupolas having a basic lining of particular construction and designed for operation under conditions which have now been established for practical foundry operation to yield a consistent and reproducable molten complex having special characteristics, different from acid cupola melted iron. The invention also permits the use of modifications in the materials charged into the cupola which are not practicable in acid refractory lined cupolas to provide iron of comparable physical characteristics and mechanical properties.

Many attempts have been made to develop and operate a basic lined cupola for melting cast iron but in all cases such attempts have been finally abandoned as impracticable or deferred to such time when all the details could be formulated and demonstrated so that such melting unit could receive acceptance as a practical foundry method of melting a ferrous charge to produce cast iron.

It was further necessary to demonstrate the characteristics of the resultant molten complex in terms of its physical characteristics as well as in terms of mechanical properties and the degree or consistency of reproducability of the iron as an engineering material of construction.

Problems which have arisen and which have deterred previous attempts at invention have included the selection of materials and method of lining a basic cupola in order that a full heat might be run without early shut-down dependent on such ever-recurrent problems as:

1. Disintegration and failure of the cupola lining, particularly in the melting zone.

2. Erosion, burnout, decomposition and stopping-up of the slag hole in the early stages of the heat.

3. Erosion and slagging or decomposition of the breast and of the tap hole so that it was not possible to periodically close the tap hole by botting up or to unbott at predetermined intervals to take consecutive taps from the heat at defined rates dependent on the maintenance of a tap hole of defined and predetermined dimensions.

4. Prevention of bridging which holds up the progress of the charge and prevents it moving smoothly down the cupola from the charging door. This problem involves well known difficulties such as metal dilution, unsatisfactory changes in metal temperature, changes in blast pressure and blast distribution and in rate of melting and unpredictable metal characteristics as tapped from the cupola spout.

2

Since the problems encountered in the operation of an acid lined cupola have long been examined, analyzed and defined, it is natural that such past attempts to develop the basic lined cupola were soon abandoned or left in a state of hopefulness that some one would eventually provide the details of construction and modus operandi of effectively using a basic lined unit, as well as defining the effect of modifications covering the invention, on the physical and mechanical characteristics of the resultant iron taken from the tap hole and made into a casting in the conventional foundry method.

The cost of developing this invention and the well known seemingly economic disadvantages of the basic lined cupola have also materially contributed, along with the several operational factors already outlined, to the failure or refusal of foundry management to prosecute the prolonged investigations necessary before any possible invention could approach practicability in terms of foundry operation and utilization.

A further deterrent was undoubtedly associated with the uncertainty of the importance or usefulness of such melting unit in the economic production of basic cast iron in association with the known characteristics of this iron in terms of an engineering casting in competition with the excellent properties obtainable from acid cupola iron and with the thoroughly established and well known operating features of this latter melting unit.

I have discovered that by the application and integration of many factors, hereafter disclosed, in construction and operation, a basic lined cupola can be satisfactorily and economically operated in competition with an acid lined cupola and that superior metal characteristics, as compared with those of acid cupola melted iron, can be assured and produced according to defined property specifications.

It is an object of the present invention to provide a basic lined cupola for melting a ferrous charge to produce basic melted cast iron.

It is a further object of this invention to provide a cupola for melting cast iron in which the high temperature zone consists of a shell of basic refractory material.

It is also an object of this invention to provide details of the special construction of the breast and tap hole which makes the utilization of the basic cupola principle practicable.

It is also a further object of the invention to provide details of the special construction of the tap hole which makes the utilization of the basic cupola unit practicable.

It is a further object of this invention to provide a refractory lining for a cupola having both basic and neutral refractory materials.

It is a further object of the invention to disclose the special slagging conditions and operation of the basic cupola which are desirable and necessary to provide consistent production of cast iron of predetermined physical properties as well as the necessity of conditions to prevent bridging and the several concomitant problems encountered in a prolonged heat.

It is also an object to provide in a basic lined cupola for sulphur reduction and control. The basic lining permits fluxing of oxides and sulphides in the melt with a highly basic slag something that cannot be accomplished in an acid-lined cupola.

It is a further object of the present invention to provide a basic lined cupola which permits fluxing of oxides and sulphides in the melt with a highly basic slag, something that cannot be accomplished in an acid-lined cupola.

It is also an object of this invention to disclose the materials, nature of materials and method of patching a basic cupola so that day-to-day operating difficulties may be eliminated.

Other objects and a fuller understanding of the invention may be had from the following description and claims, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a side elevational view of a cupola which may be lined with basic and neutral refractory materials;

Figure 2 is a cross-sectional view taken along the line 2—2 of Figure 1 with the wind box removed for purposes of clarity;

Figure 3 is a cross-sectional view of the lower portion of the cupola, taken along the line 3—3 of Figure 2;

Figure 4 is a fragmentary view looking at the inside of the well of the cupola and showing the tap hole;

Figure 5 is a fragmentary view looking at the inside of the well of the cupola and showing the slag hole; and

Figure 6 is a fragmentary view of the bottom of the cupola as shown in Figure 2 but shows the condition of the inner lining after it has been slightly burned out and repatched.

The difference between acid and basic cupola linings lies in the nature of the materials used.

Acid lining materials are those which contain silica as the base material. Silica brick and fire brick are typical examples of materials that are acid in their chemical reactions. The basic materials are those which contain lime, magnesia, or other compounds of calcium and magnesium oxides such as dolomite, magnesite or other refractory materials that are basic in their chemical reactions.

In the preferred embodiment of my invention which is disclosed and claimed herein, several types of basic and neutral bricks and patching material are used to line the inside of the cupola. To facilitate the description, these basic and neutral bricks and patching materials and their composition will be set forth first. This will be followed by a detailed description of the actual construction and method of lining the cupola.

Basic refractories comprise the products made from magnesia base materials, and I find that magnesite or dolomite, which are particular forms of magnesia base materials are satisfactory for my basic lining. As a group, basic materials

in contrast to alumina, alumina-silica, and silica groups, exhibit much greater refractoriness and better resistance to chemical attack of slags and metallic oxides. Magnesite is particularly suited for resistance to attack by iron oxide but it tends to shrink and spall at high temperatures. While chromium ore shows poor iron oxide resistance, it does not shrink as does magnesite. The two materials can be mixed to form refractory products combining the best characteristics of each component. Chromium ore is regarded as being neutral in that it is neither strongly basic nor acid in its reaction.

Four major types of bricks are produced from these ores.

1. Magnesite—magnesite used alone.
2. Chromium—chromium ore used alone.
3. Magnesite-chromium—a mixture in which magnesite predominates.
4. Chromium-magnesite—a mixture in which chromium predominates.

Magnesite bricks, being one form of a magnesia base material, are made from a rock composed essentially of the mineral magnesite which theoretically contain 47.6% MgO (magnesia) and 52.4% CO_2 (carbon dioxide). The rock is calcined at a temperature sufficiently high enough to drive off the CO_2 and to form a dense sintered product in which the MgO is in such condition that it will not continue to react chemically with the moisture or CO_2 in the atmosphere at ordinary temperatures.

Magnesite bricks are made from the dead burned mixture tempered with 5. to 8.% of a water containing 15% of glutrin.

Bricks made from this material have a softening point above 3335° F., and up to 3900° F. depending on composition and method of manufacture. Magnesite brick are basic in their chemical reactions which makes them suitable for melting furnace linings in which highly basic slags are to be carried.

In most refractories, the conductivity increases as the temperature becomes higher, but in those containing magnesia the reverse is true. The conductivity decreases as the temperature rises. This characteristic is the probable reason for hot iron and clean drops in that the brick seem to absorb and hold the heat better as the conductivity is reduced. Excessive blast and combustion of gases through the slag hole will have a tendency to heat the brick to above their softening points due to the above characteristics. Rapid slag erosion takes place when this occurs.

Chromium bricks are made from a chromium ore known as chromite. It is composed of chromic oxide and iron oxide. Theoretically, chromite has a composition of Cr_2O_3:FeO. However, it is seldom found as such. The ores vary in Cr_2O_3 content from 35 to 60%. Magnesia replaces the iron oxide in some instances forming Cr_2O_3:MgO compounds. The chromium bricks which I prefer to use are of the Cr_2O_3:FeO type.

The ground chromite is mixed with binders of lime and clay after which it is calcined and sintered for the manufacture of brick. The melting point of the chromium ore is about 3900° F. This is lowered to some extent by the bonding materials used in the mixture. Chromite refractories are neutral in their chemical reactions and therefore possess good resistance properties to either acid or basic slag attack.

The patching and mortar materials which I

prefer to use comprise essentially the following materials:

1. Magnesia base air setting mortar (basic)
2. Dolomite, stabilized (basic)
3. Chromium base air setting mortar (neutral)
4. Bauxite (essentially neutral)

The magnesia base air setting mortar is preferably made from the mineral magnesite, treated in a similar manner to the preparation of this material in the manufacture of brick. The dead burned materials are mixed with suitable bonding materials the nature of which renders them applicable for purposes of cupola patching and mortar use.

The dolomite material (stabilized) is made from a high magnesite dolomite rock containing approximately 7% of an iron, aluminum, chromium oxide compound (Fe_2O_3, Cr_2O_3, Al_2O_3). The average magnesia lime and silica content of the mixture runs about:

44% MgO
33% CaO
6% SiO_2
7% Fe_2O_3, Al_2O_3, Cr_2O_3
10% bonding materials (air setting) such as clay

The dolomite material is burned and ground to a maximum grain size of $\frac{3}{16}$ inch. It withstands high temperatures having a refractory value above 3300° F. The material is fairly plastic when tempered with water and adheres to the cupola walls as a basic patching material.

The chromium base air setting mortar is preferably made from chromium ore. The material is sintered, mixed with binders such as clay and ground to a fine powder. When mixed with water it produces an air setting high temperature bonding mortar of exceptional merit. Because of its chemically neutral character, it forms joints which are extremely resistant to chemical corrosion of cupola slags.

Bauxite is a high alumina rock usually consisting of rounded concretionary grains imbedded in an armorphous clay-like mass; and believed to consist essentially of a mixture in various proportions of alumina trihydrate ($Al_2O_3:3H_2O$) and alumina hydrate ($Al_2O_3:H_2O$).

For making the patching material more plastic in the green state, I preferably use molasses as a binder.

In Figure 1, I show a cupola to which my basic and neutral lining materials may be applied. The cupola comprises in general an outer metal casing or shell 10 supported on suitable legs 11. The cupola may be charged through a door 12 in the side wall of the upper portion thereof. The enlarged intermediate portion 13 comprises the wind box having tuyères 14 through which air may be introduced into the melting zone which is the hottest part of the cupola. Below the melting zone and the wind box is the hearth or well 15 into which the melted iron drops down before being tapped out through a tap hole 21 and into a cupola spout 16. On the side opposite from the cupola spout 16, is a slag spout 17 which is located a short distance below the tuyères. The bottom of the hearth or well 15 is provided with sand which extends substantially up to the level of the bottom edge of the tap hole 21. As shown in Figure 2, the bottom comprises an outer support ring 18 in the middle of which are drop doors 19 supported by a support member 20. The molten metal is drawn from the hearth or well 15 through a tap hole 21 communicating with the cupola spout 16. The slag in the well 15 is drawn off through a slag hole 22 communicating with the slag spout 17. The fumes from the slag spout 17 may be collected in a fume hood 25 connected by a duct 24 to the upper portion of the cupola.

The locations inside the cupola in which the basic and neutral materials are used are shown in Figures 2 to 6.

Starting at the bottom of the cupola and working up to the charging door 12, the lining is preferably installed in this order:

1. The first course in the well comprises an annular ring of straight fire brick 30, preferably nine inches long, laid on their broad side on top of the supporting ring 18.

2. On top of the fire brick 30 and disposed vertically next adjacent to the casing or shell 10, are two courses, respectively, 9 inch split and 9 inch arch, back-up bricks 31 and 32 comprising the outer part of the well of the cupola. These bricks are made of clay.

3. The well is faced with two vertically disposed courses of magnesite arch bricks 33, nine inches long and 4½ inches thick, except at the tap hole 21 and breast, and around the slag hole 22 as shown in Figures 2, 3, 4 and 5. With the scale used in the drawing, the inside diameter of the lined well is approximately 42 inches. However, it is to be understood that my invention may be applied to a cupola of any diameter.

4. A brick 34 preferably made of magnesia or chromium base material is placed broad side down on top of the row of fire brick 30 in front of the tap hole 21, see Figures 3 and 4.

5. The actual tap hole 21 extends through a 2 inch thick brick 35 preferably constructed of magnesia or chromium base material disposed in front of the cupola spout 16. The diameter of the actual tap hole in the brick 35 is preferably one inch.

6. The tap hole block 35 on the inside of cupola is faced and shaped with preferably dolomite or any of the other patching materials indicated by the reference character 36 as shown in Figure 3. The dolomite is shaped to provide an enlarged tap hole as it meets with the inside wall of the well. The enlarged tap hole in the dolomite 36 may be referred to as the feed hole portion and the small hole through the brick 34 may be referred to as the tap hole portion.

7. The breast section on top of and on the sides of the tap hole consists of a double row of vertically disposed chromium bricks 37 two courses high. The space 38 between the chromium bricks 37 and the cupola shell or casing 10 is preferably rammed with dolomite as indicated by the reference character 39. In Figure 4 which shows a front inside view of the tap hole, there are ten chromium bricks 37 in the top course in the well above the tap hole. These bricks 37 are shaded in the drawing. The rest of the bricks on the top course, except those around the slag hole, are the magnesite bricks 33 and are not shaded. There are eight full height chromium bricks 37 in the bottom course in the well, four being on each side of the tap hole. Next adjacent the tap hole are two foreshortened chromium bricks 43, with two stretcher bricks 40 bridging same. The space 41 between the stretcher bricks 40 over the tap hole is filled with dolomite 41, see Figure 3. The rest of the brick in the lower course in the well are magnesite and are not shaded. The chromium bricks 40 and 43 may be regarded as a support structure for the dolomite 36 through which the feed hole portion

extends. These chromium bricks also function to resist erosion.

8. The slag hole proper is preferably made with dolomite or any of the other patching material indicated by the reference character **50** preferably rammed with a pneumatically operated gun. The brick work around the slag hole section in the well consists of a double row, two courses high of chromium bricks **51**. The space **52** between the chromium bricks **51** and the shell **10** of the cupola is rammed preferably with dolomite **53**, or any of the other patching or mortar material, see Figure 3. In Figure 5 which shows a front inside view of the slag hole, there are seven chromium bricks **51** in the bottom course in the well below the slag hole. These bricks are shaded in the drawing. The rest of the brick on the bottom course, except those around the tap hole are the magnesite bricks **33** and are not shaded. There are six full height chromium bricks **51** in the top course in the well, three being on each side of the slag hole, with two bricks **54** and **55** being below the slag hole. These chromium bricks **51**, **54** and **55** are shaded in Figure 5. The slag hole is formed in the dolomite **50** by any suitable means, such, for example, by ramming dolomite around a 1¾ inch pattern, which is subsequently removed. Thus the section surrounding the slag hole is of a chromium brick construction and the chromium bricks **51**, **54** and **55** may be regarded as supporting elements for the dolomite through which the slag hole **22** extends. These chromium bricks also function to resist erosion. With the **42** inch diameter well, the inside layer of bricks constituting the shell for the molten metal has approximately 54 bricks for each course, assuming that the tap and slag hole construction were made of full height bricks. Of this number for each actual course, there are approximately 16 chromium base bricks and 38 magnesia base bricks. It is preferable that the number of chromium base bricks for each course in the well should not be less than an effective area of eight bricks and should not exceed an effective area of 27 bricks. Thus the percentage of chromium base bricks to magnesia base bricks for each course in the well ranges from approximately 15 to 50 percent.

Basic slags solidify quickly on exposure to the atmosphere. For this reason it is advisable to construct the slag hole as shown in Figures 3 and 5 to insure drainage of slag out of the hole between slag taps. Since basic slags are usually very hot and liquid there is no difficulty in keeping the hole open during slag tapping operations. Slag hole freeze-ups can be opened with a ¾ inch pointed rod if attended to promptly, otherwise it is advisable to use an oxygen lance to avoid damaging of the hole. Slag holes will usually last for three 25 ton heats under careful slagging operations. The first slag tap is not made until the metal holding capacity of the well falls below 1000 pounds or multiple thereof depending on the well capacity of the cupola. The slag hole is left open for the remainder of the heat after the first slag tap.

9. The brick work in the melting zone above the tuyères **14** consists of a double row, four courses high of magnesite arch bricks **60**, see Figure 2. The first course above the tuyères is backed by 2 inch splits, fire clay bricks **61**. The second, third and fourth above the tuyères are backed with 1 inch splits, fire clay bricks **62**. The bricks **60** are vertically disposed and are 9 inches high and 4½ inches thick.

10. The fifth course above the tuyères consists of a single row of magnesite arch bricks **63**, 9 inches high and 4½ inches thick. This course is backed by deteriorated fire clay block brick **64**, which is preferably old lining. The space **65** between the back up bricks **64** and the magnesite bricks **63** is preferably rammed with dolomite **65** or any of the other patching material.

11. The sixth course above the tuyères, being considered the top course of the melting of combustion zone, consists of 9 inch x 4½ inch x 2½ inch magnesite straight bricks **66**. These brick are laid on end with the face side (4½ inches wide) facing the inside of the cupola. The bricks are spaced about 2 inches apart. The space between the straight bricks **66** on the face, and between these bricks and the clay backing bricks **64** is preferably rammed with the dolomite **65** or any of the other patching material.

12. The old clay bricks **64** next to the shell in the charging zone are first faced or coated with about ¾ inch of bauxite material by means of a gun. This initial lining **67** of the charging zone is preferably coated and built up with three additional coats **68**, **69** and **70** as indicated in Figure 2 of bauxite base patching material. Each coat or layer may be applied three consecutive heats of the cupola. The lining is built up in this manner.

If chromium brick are used in the lining above the tuyères the iron shows a chromium pick up ranging up to .23% Cr. For this reason it is advisable to use these bricks with discretion. The number of chromium bricks required for successful basic cupola operation can be confined to the breast of the tap hole in the well and at the slag hole. Magnesite brick resist erosion just slightly below that of chromium brick in other locations of the cupola and are otherwise satisfactory in their performance when used for this purpose.

Double lining thickness is essential to economic cupola operation since any penetration of highly basic slags between the joints and into the backing brick would react rapidly with any silica brick or other acid materials with which it comes in contact. The back-up bricks between the shell and the outer magnesite brick should be of an insulating type or the space between the shell and the first row of brick can be filled in with an asbestos sheeting or other type of insulating material. If clay brick are used between the shell and first row of magnesite brick, a ⅛ inch thick corrugated cardboard should be placed between the clay brick and the first row of magnesite to allow for expansion of the brick and thereby prevents spalling from this source. Any openings between the tuyères and brick work should be sealed to prevent air from escaping through the cupola in back of the lining. Either an iron cement or a chromium base air setting cement can be used for this purpose.

The basic lining should be carried up to not less than 45 inches above the tuyères and where the bed height is maintained above 45 inches best results are obtained at the beginning of the heat by running the basic brick lining to the full height of the bed. However, after the first few metal taps the bed will be settled considerably from its initial height and thereafter sulphur reduction in all of the metal will be maintained to a low percentage throughout the heat providing, of course, that the slag volume is sufficiently large enough and of the proper basicity to promote uniform control.

Owing to the high expansion properties of magnesite brick at elevated temperatures, ample space must be left between the brick, during installation of the lining to allow for this expansion to take place. In laying the brick, provision for expansion of the brick is made at the rate of ¼ inch per foot. This is usually taken care of by the normal space left at the brick joints. Approximately 1/32 inch, with an additional ¼ inch open joint at every 17th brick in the course, appears to be sufficient to allow for full expansion of the brick at cupola operating temperatures approaching the softening point of the magnesite brick, above 3500° F. and thus prevents spalling from this source. Laying the brick in the above manner promotes a snug lining after cooling and contraction of the brick, and results in very little cracking at the joints; whereas an allowance of ¼ inch open joints at every fifth brick in the course, as was the early attempted practice, resulted in cracking of the ceramic bonded joints and through the thin sections of the brick during the cooling and contraction cycles.

In installing the lining, one end and one side of each brick is dipped in a thin slurry of the mortar materials. The mortar air sets soon after it is applied to the dry brick's surface, thereby bonding the brick together at the joints with sufficient strength to prevent movement of the brick before firing. After installation of the brick lining is completed, thorough drying of the lining at a temperature of about 250° F. is essential to prevent spalling of the brick. Later the lining should be heated to higher temperature, gradually bringing the temperature up to 2100° F. or higher, and then holding at these temperatures until the brick reaches a uniform temperature throughout.

Heating the brick in the above manner allows the brick to expand, close up the joints and form a ceramic bond between one another. The tight joints resist slag or metal penetration to a high degree and thereby promote a uniform burn out during cupola operations, which will prolong the life of the lining to a considerable extent.

Of the two types of brick used, namely; magnesite and chromium brick, the chromium brick appeared to be more resistant to erosion than the magnesite brick. This was especially pronounced when the brick were installed in alternate courses. However, due to the high chromium pick up by the iron from the chromium brick, the use of chromium brick above the tuyères was discontinued. The chromium brick also gave the best results in the well of the cupola, especially at the breast and at the slag hole. The slag hole was especially troublesome when other types of bricks were used. Shut downs for slag hole repair were occasioned during the heat previous to the use of chromium slag hole brick for this purpose.

The cupola bottom is rammed with molding sand similar in respect to materials used and methods applied in the art. Since it is possible that some slag could contact the bottom layer, the use of basic materials for the bottom is preferable. The cupola spout 16 should be lined by ramming with magnesium or bauxite patching materials. The lining should be dried and heated to redness by means of an oil torch and later given a coating of a suitable wash and again heated to red heat before making the first metal tap.

The lining of a cupola is inert, taking no part in the reactions of the processes but must be made of a material to correspond to the slag produced. The slag is the active agent effecting sulphur removal and purification. Thus, the basic lining permits the highly basic slags to react only with the materials in the charge, whereas when melting in an acid lined cupola there will be a reaction between the basic slag and lining materials since they are of opposite character. These reactions will continue until an approximately neutral slag is reached.

From this description it can readily be seen that the reactions of highly basic slags account for the heavy burn-out sometimes encountered in acid lined cupolas. Because of these reactions basic materials or fluxes that have been charged are converted to acid slags. Slags of this nature do not react with the sulphur in the coke in a manner to prevent sulphur absorption by the metals during melting, whereas in my basic lined cupola where basic slags can be carried in sufficient quantity to react not only with sand and slag forming constituents in the charge but also with the sulphur in the coke and metal charge, desulphurization of the metal in the melt can be accomplished.

Proper control of basicity and viscosity of the slags as well as proper control of cupola operations is essential to desulphurization in my basic lined cupola.

A properly balanced slag seems to be composed of approximately 5%–6% of limestone and 1¼% of fluorspar to the metal charged. The amount of fluxing material, however, may have to be changed according to the condition of the charge and composition of the coke used.

The above mentioned slag ratios produced low viscosity fluid slags that promoted good sulphur removal from the metal charge.

In order to reduce the sulphur in the metal charge to a large degree it becomes necessary to charge a greater amount of limestone than theoretically required. This is because materials rich in iron such as steel, absorb carbon and sulphur very readily at temperatures above the critical range and during the melt down. The trend towards sulphur removal is in direct relation to the amount of flux used and basicity of the slag.

It may thus be seen that silica content and slag volume are controlling factors of sulphur reduction in the cupola.

By using the proper fluxing procedure of the metal charge the melting technique in my basic lining is, of course, completely changed. One has but to examine the cupola itself to realize what damaging influence a basic slag in an acid lined standard cupola has on the mechanical operation of the cupola. With my basic lining there is no sloughing of the brick; that is no bridging; the cupola walls are comparatively free from slag adherence after the heat.

The tuyère remains bright throughout the heat in my basic lined cupola providing, of course, that the slag is maintained at its proper consistency. The reason for this is believed to be due to the thermal conductivity of the magnesite brick and storage of the heat in the first few courses of brick above the tuyères. Therefore, any slag that is descending along the cupola lining is maintained at a sufficiently high temperature to allow it to flow by the tuyères and into the well without chilling.

The average burn out per side in my newly lined basic cupola amounted to 1½ inches on a 25 ton heat. This burn out decreased on the second heat, which was also 25 tons to 1 inch per side.

The third heat melted in this cupola was also a total of 25 tons and the burn out obtained from this third heat was ¾ inch per side. The original diameter of the cupola was 42" and no attempts were made to patch the lining during the melting of the three heats.

From this it would seem to indicate that some economy in lining repair can be obtained by the use of basic brick. The average length of each heat was three and three-quarter hours. Normally one can expect a burn out of 3¾ inches per side operating for each heat for this length of time with an acid lined cupola.

The Figure 6 illustrates a condition where the magnesite brick has been partly burned away as it will do under several heats with the portion which is burned away repatched with dolomite, indicated by the reference character 71. The patching with dolomite to build up the space left vacant by the burn out material may be done in any suitable manner with proper instruments and internal diameter of the dolomite is made to register substantially to the same diameter as the original magnesia base brick. As the patching material wears away, it may again be repatched by the dolomite material, thereby maintaining the cupola in complete operation without removing the brick construction.

There may also be a possibility of reducing the cost of lining repair in the basic cupola by operating until the brick work has burned out to a point where it would be advisable to remove the bricks and replace the burned away bricks with new basic bricks.

In regard to the slag for the basic lining, obviously, one can be assured of complete basicity. One can use such quantities of sulphur bearing slags as the initial sulphur content in the coke or the metal necessitates.

It is important that one obtain a good basic carbide slag, something similar to that obtained in the electric basic steel process, however, such a slag is apt to give trouble in its removal through the slag hole if a silica brick is used for this purpose. It is, therefore, essential that the slag hole be made of a good dense, basic brick and it has been experienced that chromium bricks work out as the best material for this. It is also essential that the basic slag be maintained in a good fluid condition for ready removal from the cupola. A good tight fitting slag spout cover will aid materially in obtaining free slagging, since as soon as the cold air strikes the slag, it freezes over very quickly, a condition which causes trouble in keeping the spout clean, if it is not properly protected from the atmosphere. A 12 inch long slag spout pitched at a 45° angle gave the best results in basic slagging operations.

Highly basic carbide slags frequently disintegrate into a fine grayish-white powder after cooling and exposure to the atmosphere, similar in respect to highly basic slags from the basic electric process.

There is considerable loss in the silicon content when melting in the basic cupola. In the operation of my basic cupolas, the slags are essentially basic. This merely means that the acid-basic ratio is so adjusted that the phase is relatively high as compared with the acid phase. This is termed a basic slag or a slag of high basicity. The effect of a highly basic slag is to tend to reduce (1) the sulphur content of the charge, (2) the silicon content of the charge. This is true because both of those elements of oxidation are acidic elements. Consequently, the more highly basic the slag, the greater the reduction is likely to occur in both sulphur and silicon content of the iron. In basic cupola operation, most interest in the past has been evinced in the degree of the sulphurization and this has paralleled approximately the degree of basicity of the slag. Concomitant with the reduction in sulphur (acid component), a reduction in silicon will also take place. Thus, the higher the degree of desulphurization, the greater the reduction or drop in the silicon content of the molten iron. The desired silicon content is obtained by extra addition of silicon in the charge (ferro-silicon or high silicon pig) to compensate for basic silicon operation or silicon loss.

A marked pick up in the carbon has been noted on all processes and it rather appears that in identifying the properties of the basic melted metal one is going to have to think in terms of total carbon plus silicon ratios rather than in terms of total carbon and silicon as separate entities as in common practice at the present time.

I have obtained total carbons with 100% steel mixes of the order of 3.7% and with all cast iron scrap mixes, I have no difficulty in obtaining total carbons of the order of 3.5%. Sulphur content in these basic charges, where formerly they averaged .15% to .17%, I have no difficulty in obtaining sulphurs of .05% to .07% without any ladle treatments.

In operating my basic cupola, it is of importance not to tap to an acid lined cupola spout, especially where low sulphur irons are desired, since, if the basic slag which has absorbed a considerable amount of sulphur, comes in contact with an acid sand bottom or acid lining in the cupola spout, reverse action will take place and the sulphur will be precipitated from the acid material and absorbed by the iron.

The loss in silicon in the charge in basic cupola operations ranges up to 30%. Silicon losses can be controlled to a considerable extent where the sulphur content in the product is satisfactory at 10% lower than might be expected in the product when melted in the acid cupola. This can be accomplished without loss of silicon any greater than the normal loss when melting in the acid cupola by adjustment of the slag basicity and volume.

Indications are that higher silicon losses that are encountered in the basic cupola are purification reactions in the metal involved. Since the metal in the various processes melted in the basic cupola is usually of .5% lower silicon content than the same calculated silicon irons that are melted in the acid cupola, nevertheless, the basic melted metals showed greater fluidity and remained liquid for a longer period of time than the same types of metals that were melted in the acid lined cupolas.

Carbon pickup is quite marked. There is no difficulty in obtaining carbon contents of the order of 3.50% in all scrap mixture. This can be accomplished regularly with less coke than is necessary when melting in an acid cupola. Carbon can be controlled within reasonable limits on all types of metal without the use of carbon raisers by simple adjustment of coke charges.

The fact that adequate carbon can be secured in all processes without the use of pig iron, presents an opportunity for large savings in metal

mixture costs which will offset the higher initial lining costs in basic cupola operations.

The effect of low carbons in reducing fluidity of iron is well known as is the difficulty of obtaining adequate carbon and control of this element to meet required specifications when melting in the acid cupola.

The simplicity of obtaining adequate carbon and carbon control to meet required specifications, without the use of expensive pig rich mixtures when melting in the basic cupola, is without doubt one of far reaching importance.

While the fluidity of the metal was no doubt due to the high carbon content of these metals indications are that some of the fluidity was due to removal of oxides and sulphur by the high basicity slags that were used in the charge.

As the slag volume and basicity of the slag increases, the loss in manganese decreases. This appears to offer an economy in the use of expensive manganese additions to the charge. However, consideration must be given to the amount of sulphur in the metal charge, the nature of the slag under which the metals are being melted in regard to basicity, viscosity and temperature. Slag to metal contact time is an important factor in manganese control.

The phosphorus in the metal charge was reduced by as much as 50.% on several occasions. The reduction of phosphorus varied widely, but in most cases the reduction was greater than 10.% than the calculated phosphorus in the metal charge. The basicity of the slag or the silicon in the melt did not seem to have any great effect on the extent of dephosphorization.

In operating a basic cupola good tapping practice is important. Tapping to slag except at the cross-overs, should be avoided, the cross-overs being that period in the operation of the cupola where a change is made from melting one type of metal to another type of metal. If basic slags which have absorbed considerable amounts of sulphur come in contact, for example, with an acid sand bottom of the cupola, reverse action will take place and the sulphur will be released from the slag and again be absorbed by the iron involved. As previously pointed out, these reactions can be eliminated by the use of basic bottom materials.

In comparing lining costs to metal melted in acid vs. basic cupola practice, the initial costs of a basic lining are about three times as high as that of the acid lining. This cost is greatly reduced per ton of iron melted because of the small amount of burn-out in the basic lining compared to that of the acid cupola. The smaller amount of burn-out in the basic cupola reduces labor costs for repairs, material handling, and mulling time and wear. A most complete elimination of bridging in the basic cupola reduces chipping costs to a minimum.

The greatest opportunity offered in basic cupola melting is in the vast saving that can be made in metal mixtures in which pig iron is used. Pig iron is usually higher in price than cast iron scrap and since adequate carbon can be secured to meet specifications with all scrap mixtures the cost of the mixture can be reduced according to differential in the price of pig iron versus cast scrap.

The clean low sulphur iron produced in the basic cupola eliminates slag defects and hot tears that are worthy of consideration. The savings that can be obtained from this source are considerable. The use of basic lined ladles in conjunction with the basic lined cupola will insure clean metal delivery to the pouring basins.

Summarizing, it is to be noted that I have invented a cupola for melting cast iron having three principal melting zones, namely; a charging zone, a melting or combustion zone and a well zone. The well zone comprises that portion of the cupola below the tuyères. The melting or combustion zone comprises that portion above the tuyères and including principally the courses **1** to **6** as indicated on the drawing of Figure 2. The charging zone comprises that portion above the melting and combustion zone. The charging zone comprises a refractory inner shell of substantially bauxite mortar. The melting or combustion zone comprises a refractory inner shell of substantially all basic bricks and preferably magnesite bricks. The well zone comprises a refractory inner shell of both basic and neutral bricks and preferably the basic bricks comprising magnesite bricks, and the neutral bricks comprising chromium bricks. As pointed out before the chromium bricks resist erosion of the metal better than magnesite bricks and this is one reason for surrounding the tap hole and slag hole with chromium bricks. Each of the refractory inner shells for the respective zones thus comprises a material having properties of the same general nature as the basic slag of the cupola. The same is true for the tap hole construction and the slag hole construction in that these constructions each comprise a material which is of the same general nature as the slag of the cupola. Likewise, I preferably line the cupola spout **16** and the slag spout **17** with material which has the same properties as the slag of the cupola.

For the purpose of substantiating the importance of this invention to the ferrous foundry industry, some advantages of basic cupola operation may be set forth:

1. Cleaner and hotter iron-needs only one skim in the ladle.
2. Reduction in coke of 10 to 15 lbs. per 1000 metal charge.
3. Use of all scrap mixes with adequate carbon pick-up to meet specification.
4. Sulphur reduction without ladle treatment.
5. Phosphorus reduction as separate treatment.
6. Elimination of bridging.
7. Improved fluidity and longer life of metal in ladle.
8. Tuyères stay open all through the heat which promotes uniform combustion and melting control.
9. Burn out in brick about one-third of what it is in the acid cupola.
10. Total absence of slag wool promotes a healthier atmosphere around the cupola.
11. Improved control in carbon pick-up.
12. Elimination of silicate slimes and hence freedom to "condition" the metal in terms of control of size, form and distribution of the separating graphite.
13. Improved cleanliness of resultant castings with freedom from such surface defects as silico-manganese surface slag imperfections.
14. Elimination of necessity to provide a balanced silicon manganese ratio in the molten cast iron as compared with acid cupola practice.
15. Elimination of the commonly recurring gasification problems attendant on acid cupola practice, particularly when the manganese content of the cast iron is raised beyond the approximate limit of 1.0 to 1.2 percent.
16. The importance of the practicability of pro-

ducing high manganese irons for special engineering purposes in the basic cupola instead of having to resort to electric furnace melting.

While these facts do not cover all the discovered advantages of basic melting they will suffice to indicate the importance of the discovery of the many factors which are inherent in successful basic cupola operation.

Although the invention has been described in some particulars and in its preferred form with respect to construction of the cupola, materials recommended for specific purposes, employment and application of these materials, and physical operation of the basic cupola, it is understood that the present disclosures of the preferred form have been made only by way of example. Numerous changes in details of construction, materials and operation and particularly in the favorable integration of same, may be resorted to without departing from the spirit and scope of the invention as heretofore described.

What is claimed is:

1. In a cupola for melting cast iron, said cupola having a wall defining a collecting well, the provision of an improved construction for said wall and the provision of improved tap and slag holes through said wall, comprising, two vertically disposed courses of clay fire brick disposed one upon the other and forming an outer shell and two vertically disposed courses of magnesite and chrome brick disposed one upon the other and forming an inner shell, said chrome brick making up about 15–50 per cent of the total, a tap hole and a slag hole through said second and third courses respectively, said holes defined by a breast work of the chrome brick on top of and on the sides of said holes and with the magnesite brick composing the balance of the inner shell, said chrome brick employed to provide good erosion resistance, said holes lined with dolomite patching material, said tap hole having a large feed hole portion on the inner side and a small tap hole portion on the outer side.

2. In a cupola for melting cast iron, said cupola having a cylindrical wall, a collecting well defined by the wall, a charging door, and tuyères arranged above said collecting well, the provision of an improved wall construction comprising, a first course of fire brick laid on their broad side at the bottom of the wall in the collecting well, a second and third course on top of the first course and below said tuyères comprising two vertically disposed courses of clay fire brick disposed one upon the other and forming an outer shell, and two vertically disposed courses of magnesite and chrome bricks disposed one upon the other and forming an inner shell, said chrome bricks making up 15–50% of the total of bricks in said second and third courses, a tap hole and a slag hole through said second and third courses respectively, said holes defined by a breastwork of the chrome brick at the top and sides of said holes and with the magnesite brick in the balance of the inner shell, said chrome brick employed to provide good erosion resistance, said holes being lined with dolomite patching material, a first course above said tuyères comprising a double shell of magnesite bricks, the second, third and fourth courses above the tuyères comprising a similar double shell of magnesite bricks having a slightly greater internal diameter than said double shell of said first course above the tuyères, fifth and sixth courses above said fourth courses disposed above the tuyères consisting of a single shell of magnesite bricks backed with refractory fill material to maintain uniform cupola wall thickness, and the balance of the cupola wall above said fifth and sixth courses comprising low quality brick faced with a plaster.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
249,548	Reese	Nov. 15, 1881
689,585	Hartman	Dec. 24, 1901
1,565,084	Frerichs	Dec. 8, 1925
2,101,391	Grotewohl	Dec. 7, 1937
2,472,655	Fairchild	June 7, 1949

FOREIGN PATENTS

Number	Country	Date
908	Great Britain	Sept. 21, 1872
7,050	Austria	Mar. 10, 1902

OTHER REFERENCES

Foundry Trade Journal, vol. 70, June 24, 1943, pages 149–153.

The Foundry, June 1950, pages 82–85, 193 and 196–199.