United States Patent [19]

Hubble et al.

[11] **3,829,960**

[45] **Aug. 20, 1974**

[54] **METHOD OF MAKING A REMOVABLE BOTTOM FOR A STEELMAKING FURNACE FROM PREFORMED REFRACTORY SHAPES**

[75] Inventors: **David H. Hubble; John A. Lamont,** both of Westmoreland, Pa.

[73] Assignee: **United States Steel Corporation,** Pittsburgh, Pa.

[22] Filed: **June 22, 1973**

[21] Appl. No.: **372,733**

Related U.S. Application Data

[62] Division of Ser. No. 256,689, May 25, 1972, Pat. No. 3,799,526.

[52] **U.S. Cl.** **29/527.1,** 264/30, 264/35, 266/43

[51] **Int. Cl.** **B23p 17/04**

[58] **Field of Search** .... 29/527.1; 266/35, 36 P, 266/41, 43; 264/30, 35

[56] **References Cited**

UNITED STATES PATENTS

51,401	12/1865	Bessemer	266/35
256,607	4/1882	Tucker	264/30 UX
405,392	6/1889	Bertrand	264/30 X
556,539	3/1896	Haws	266/35
1,010,312	11/1911	Planche	264/30
3,070,449	12/1962	Davies et al.	265/30 UX
3,337,206	8/1967	Bouvier	264/30 X
3,673,288	6/1972	Childs	264/30 X

Primary Examiner—Charles W. Lanham
Assistant Examiner—D. C. Reiley, III
Attorney, Agent, or Firm—Ralph D. Dougherty

[57] **ABSTRACT**

A method of making a removable bottom for a steelmaking furnace from preformed basic refractory shapes, said bottom having tuyeres for injecting gas or other material into a bottom blown steelmaking vessel and the product of the method.

8 Claims, 12 Drawing Figures

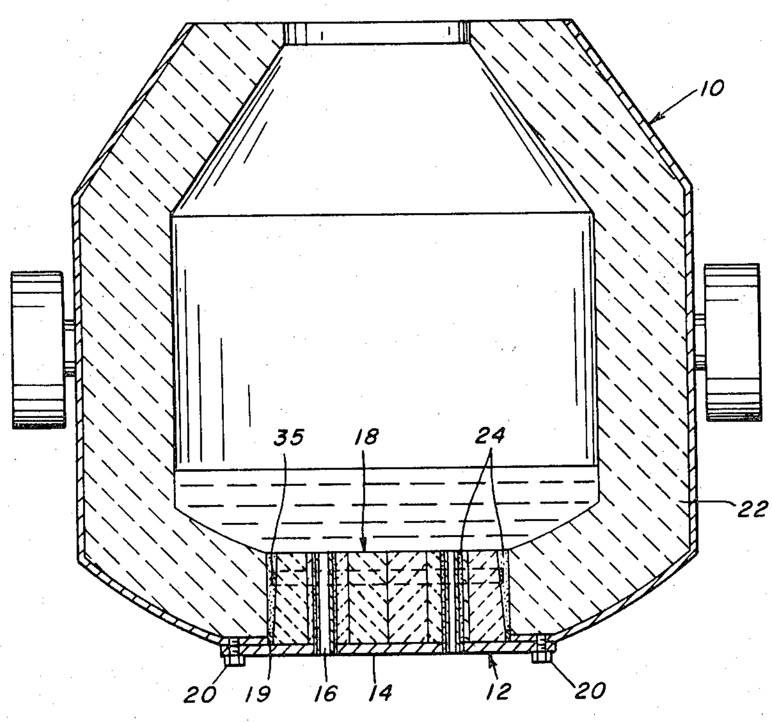


FIG. 1.

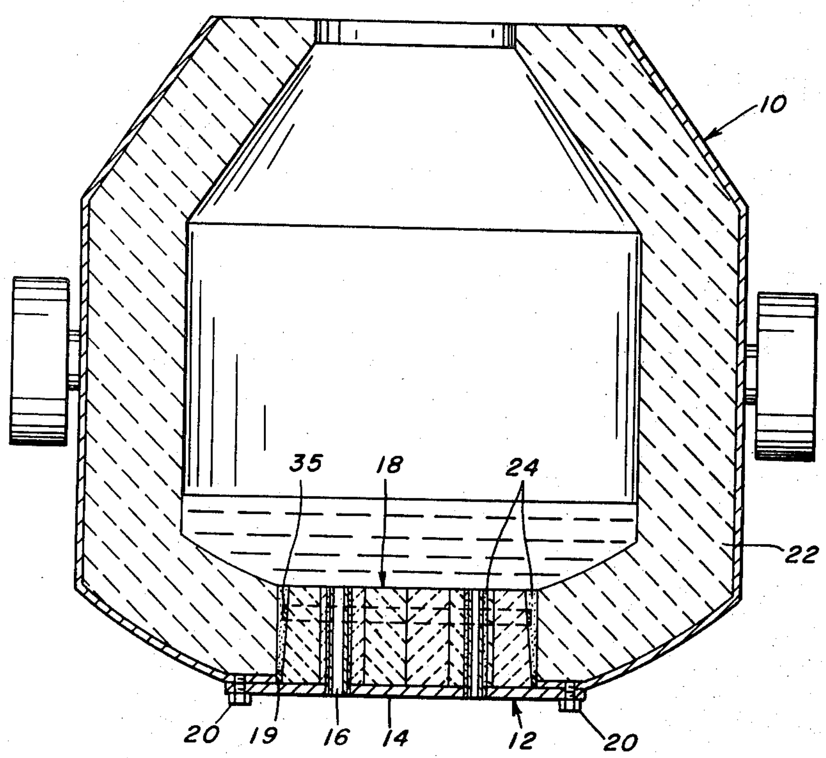
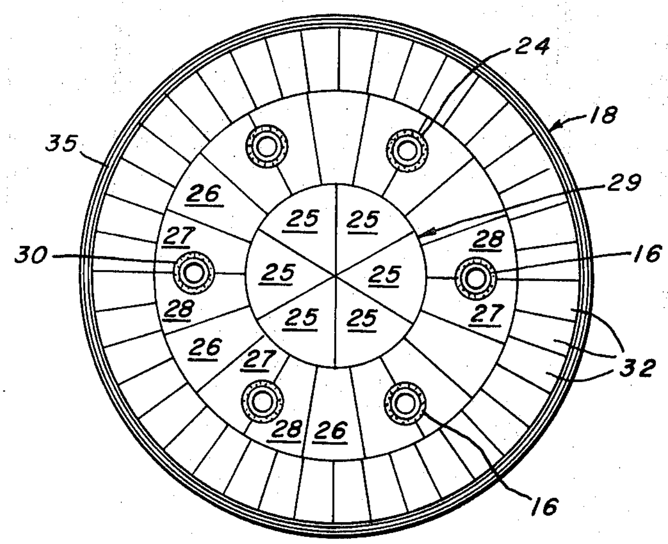

10
35
18
24
22
20
19
16
14
12
20

FIG. 2.


24
18
35
26
29
25
25
27
28
30
25
25
16
28
27
25
25
26
27
32
28
26
16

PATENTED AUG 20 1974 3,829,960

SHEET 2 OF 4

FIG. 5.

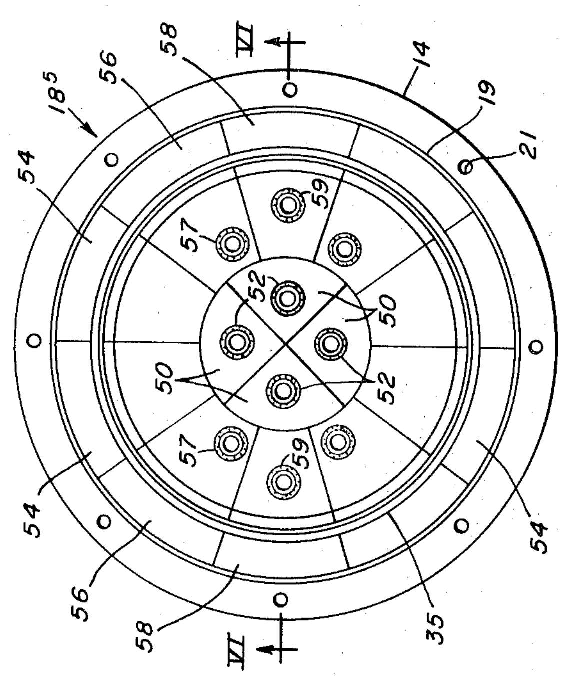


FIG. 6.

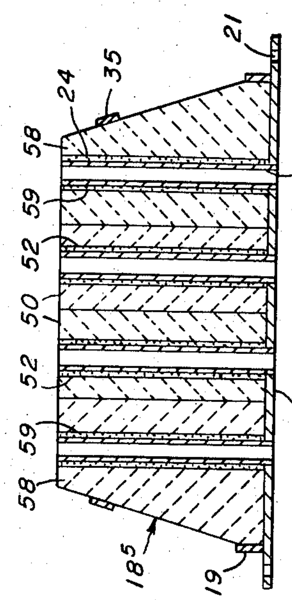


FIG. 3.

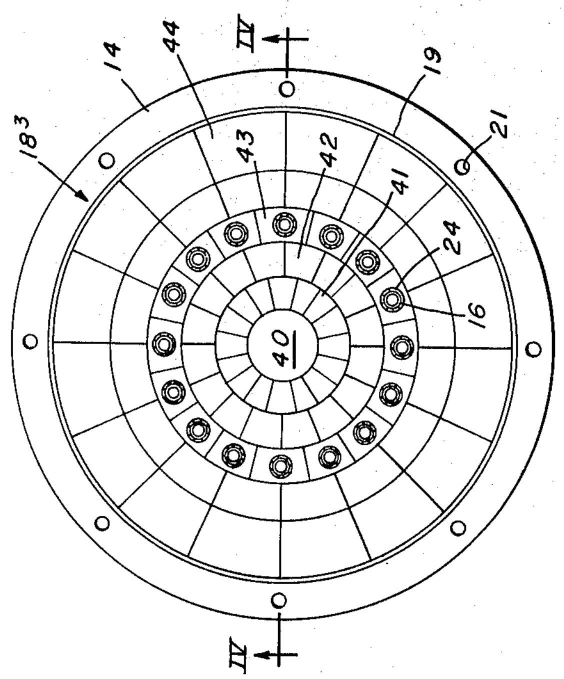
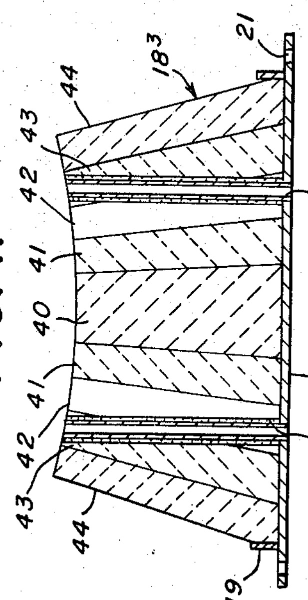


FIG. 4.



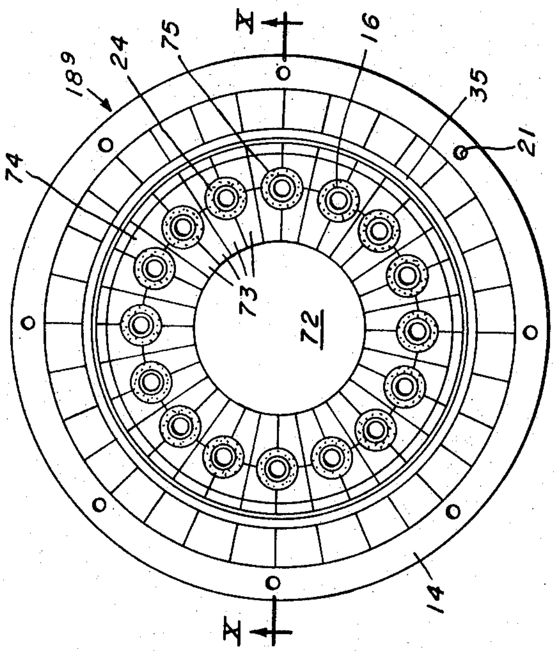


FIG. 9.

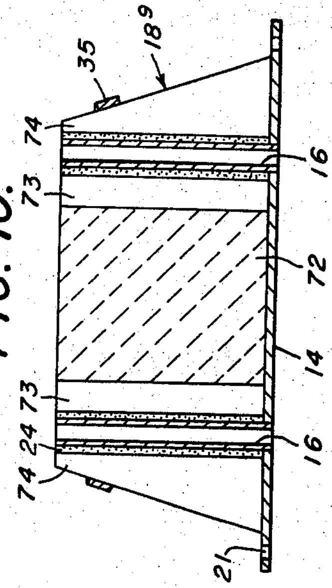


FIG. 10.

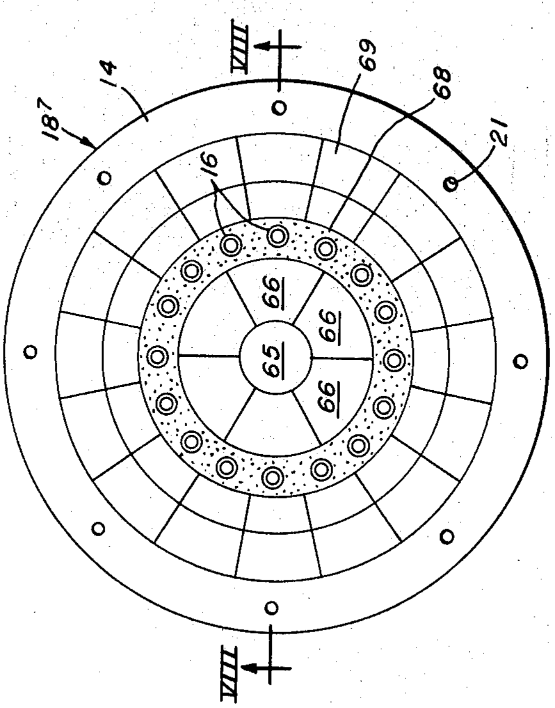


FIG. 7.

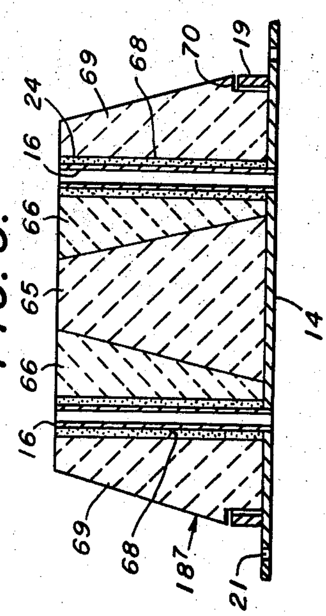


FIG. 8.

FIG. 11.

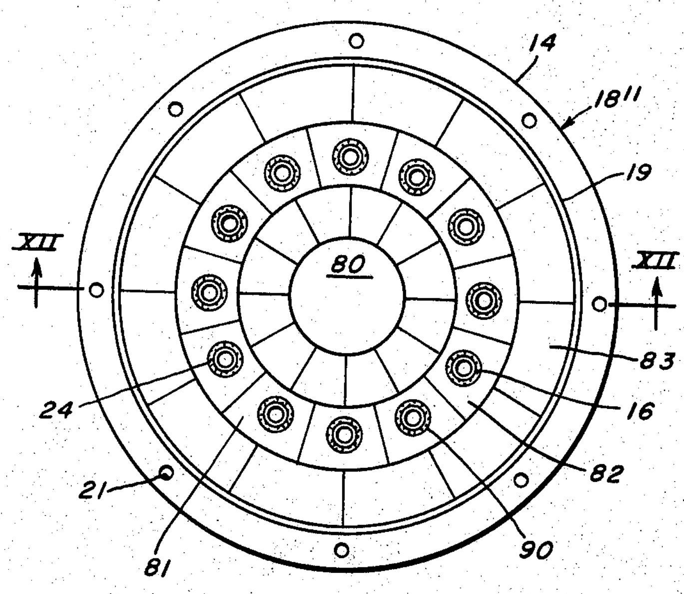
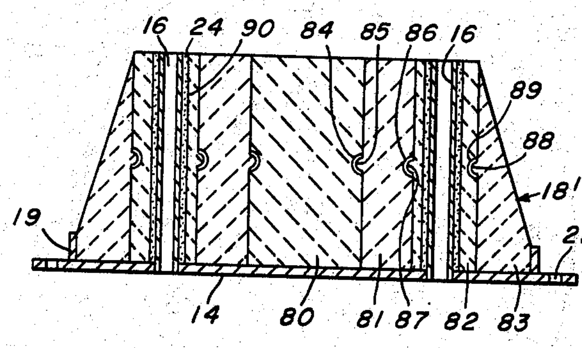

14
18''
19
XII
XII
80
83
16
24
82
21
90
81

FIG. 12.


16
24
90
84
85
86
16
89
88
18''
19
21
14
80
81
87
82
83

METHOD OF MAKING A REMOVABLE BOTTOM FOR A STEELMAKING FURNACE FROM PREFORMED REFRACTORY SHAPES

This is a division of application Ser. No. 256,689, filed May 25, 1972, now U.S. Pat. No. 3,799,526.

In the bottom-blown oxygen steelmaking process as presently practiced, which is known as the "Q-BOP" process, a furnace, or vessel, has a removable bottom which contains one or more tuyeres. Oxygen and other gases or particulate matter, such as lime or other flux, is blown through the tuyeres into the vessel. The tuyeres and the surrounding refractory in the removable bottom wear during the production of steel in the vessel. Periodically, bottoms which are worn or have damaged tuyeres

Heretofore, the usual method of making a removable bottom or plug for a steelmaking vessel has been to cast a mixture of dolomite and tar into a mold on a removable bottom plate. A cast plug is of relatively low density, because pressure cannot be applied during forming. Further, a cast plug cannot be prefired to sufficiently high temperatures, such as in the range of 2,000° to 3,200° F, to obtain the good properties inherent with ceramic bonding that are obtained in conventionally fired ceramic products. This is for two reasons, first the size of the plug is too large to be placed in such a furnace and secondly, the plug as cast ordinarily has metal tuyeres protruding through it which would be damaged by such high temperatures.

We have invented a method of making a removable bottom by using preformed refractory shapes of a predetermined configuration.

It is an object of our invention to provide a method of making removable furnace bottoms requiring no forming or heating equipment at the assembly site.

It is also an object to provide a method of making a furnace bottom having an extremely long operating or useful life.

It is a further object of our invention to provide a method of making a furnace bottom having higher density and greater hot strength than bottoms heretofore available, such as those made by casting of dolomitic material.

It is another object to provide a removable bottom for a bottom-blown steelmaking furnace, which bottom has a high density and high hot strength.

FIG. **1** is a partly diagrammatic vertical sectional view of a bottom-blown oxygen steelmaking furnace in which the bottom is made in accordance with our invention.

FIG. **2** is a plan view of the refractory plug in the bottom shown in FIG. **1.**

FIG. **3** is a plan view of a modified form of bottom in accordance with our invention.

FIG. **4** is a section on line IV—IV of FIG. **3.**

FIG. **5** is a plan view of another modified form of bottom in accordance with our invention.

FIG. **6** is a section on line VI—VI of FIG. **5.**

FIG. **7** is a plan view of still another modified form of bottom.

FIG. **8** is a section on line VIII—VIII of FIG. **7.**

FIG. **9** is a plan view of yet another modified form of bottom.

FIG. **10** is a section on line X—X of FIG. **9.**

FIG. **11** is a plan view of another modified form of bottom.

FIG. **12** is a section on line XII—XII of FIG. **11.**

FIG. **1** shows a bottom-blown oxygen steelmaking vessel **10** which has a removable bottom **12.** The bottom **12** comprises a bottom plate **14,** and one or more generally upstanding tuyeres **16** (FIGS. **1, 2**) which are surrounded by a refractory plug **18** (FIGS. **1, 2**) and a retaining ring **19** (FIG. **1**), which ring **19** is upstanding from plate **14.** The bottom plate **14** is fastened to the furnace **10** by bolts **20** (FIG. **1**) in holes **21** (FIGS. **3, 4**). The sides of the plug **18** do not contact the refractory lining **22** of the vessel, but there is sufficient clearance between the refractories **18** and **22** to permit insertion of a pitch-bearing monolithic material **24** hereinafter described or the like, which material **24** affords a metal- and slag-tight seal.

According to our invention, we form the plug **18** of a plurality of high density, pitch bearing refractory shapes **25, 26, 27,** and **28** (FIG. **2**) having predetermined configurations placed around the tuyeres **16** leaving a minimum of open space around each tuyere **16,** as shown in FIG. **2.** We construct the plug **18** so that the refractory shapes **25, 26, 27** and **28** generally form the plug into the frustum of a cone or pyramid or other substantially pyramidal shape. The embodiment of FIGS. **1** and **2** is a six-tuyere plug **18** with the tuyeres **16** in a circular pattern. The central cylinder **29** (FIG. **2**) is formed of six identical shapes **25.** The shapes **26, 27, 28** (FIG. **2**) surrounding the central cylinder **29** are solid shapes **26,** and shapes **27** and **28** each of which has a hemi-cylindrical trough **30** which trough **30** forms a hole for a tuyere **16** when shapes **27** and **28** are emplaced adjacent each other. The hole is filled around the tuyere **16** with a basic monolithic refractory **24.** The outermost refractory shapes **32** are placed within the retaining ring **19** to form a substantially solid plug **18.** When all the refractory shapes **25, 26, 27, 28** have been installed, one or more bands **35** (FIG. **1**) of steel or other material are placed on the plug **18** to prevent movement of the shapes **25, 26, 27, 28** during subsequent steps and during transportation and installation of the completed plug **18** in the furnace **10.** These bands **35** are left in place permanently. The configuration of each refractory shape **25, 26, 27, 28** must be such that, after installation of the bottom **12** in the furnace **10** and heating the furnace, the refractory shapes cannot move relatively to each other when the furnace is tilted.

The refractory shapes **25, 26, 27, 28** of FIGS. **1** and **2** have vertical surfaces. Although these shapes **25, 26, 27, 28** apparently can move relatively to one another when furnace **10** is tilted, preheating of the furnace lining **22** prior to charging the furnace **10** expands the refractory shapes, whereby frictional force develops between them to hold them firmly in position relatively to one another when the furnace **10** is tilted. If desired, the shapes **25, 26, 27, 28** can be held in position by mortar between each shape. This, of course, is a more expensive method of making the bottom **12.**

The exact configuration of refractory shapes used will depend on the desired arrangement of tuyeres **16** in the bottom **12.** FIGS. **3** through **12** illustrate several possible alternative configurations but are not meant to limit our invention. The common features of each of the specific arrangements shown are (1) special preformed pitch-bearing basic refractory shapes, (2) a monolithic pitch-bearing basic material **24** or the like filling the voids **30** around the tuyeres **16,** (3) provisions in the design to prevent movement of the preformed pitch-bearing basic refractory shapes relative to each other after the plug is installed in a bottom blown furnace, and (4) the composition of the shapes and material for filling voids **30.** The absence of shape movement may be obtained by a variety of means including use of tapered or keyed shapes, interlocking shapes, tongue and groove shapes, etc. After installation of the bottom **12** in the furnace **10,** a basic monolithic material **24** or the like is inserted between the plug **18** and permanent lining **22** to provide tightness as illustrated in FIG. **1.**

FIGS. 3 and 4 illustrate a plug 18^3 formed of inverted arch bricks. The central shape **40** is a frustum of a cone. The surrounding shapes **41, 42, 43, 44** are tapered so the plug 18^3 acts as an arch when the furnace is inverted, preventing shape movement. The shapes **41, 42, 43, 44** can be the same length in which case the top of the plug 18^3 will be flat. Alternatively, the shapes **41, 42, 43, 44** can be longer nearer the periphery as shown in FIG. 4 to form a dished upper surface of the plug 18^3. A dished surface can be formed by emplacing a monolithic refractory material **24** or the like (not shown in FIG. 4) on bottom plate **14** to form the contour desired for the top of the plug 18^3, then installing equal length shapes thereon. Since shapes **41, 42, 43, 44** are positioned at an angle and tuyeres **16** are substantially vertical, hole **46** is formed through shapes **42** and **43.** Monolithic refractory material **24** is inserted in each hole **46** surrounding each tuyere **16** to form a substantially solid plug 18^3.

The embodiment of FIGS. **5** and **6** is a 10-tuyere plug 18^5. Four different special shapes are used around the tuyeres **16** which are in a straight pattern. The four central shapes **50** are quadrants of a cylinder, each having a longitudinal hole **52** which enables the shape **50** to be installed on the tuyere-containing bottom plate **14** with a tuyere **16** in each hole **52.** The ten shapes surrounding the central shapes **50** include four shapes **54** which are solid, four shapes **56** which have offset holes **57** and two shapes **58** which have holes **59** on their centerline. The ten outer shapes **54, 56, 58** engage retaining ring **19.** Basic monolithic material **24** or the like is inserted in each hole **52, 57, 59** surrounding each tuyere **16** to form a substantially solid plug 18^5.

The plug 18^7 of FIGS. **7** and **8** contains a large central solid shape **65** which is the frustum of a cone. A number, for example six, of tapered intermediate shapes **66** form a solid cylinder with shape **65.** Tuyeres **16** are arranged in a circular pattern in void **68** between shapes **66** and tapered outer shape **69** disposed outside the shapes **66.** The tapered outer shapes **69** are notched at **70** to engage retaining ring **19.** Basic monolithic material **24** or the like is placed in the void **68** between shapes **66** and **69** to form a solid plug 18^7.

The plug 18^9 of FIGS. **9** and **10** include a central cylindrical shape **72** surrounded by a number of intermediate shapes **73.** Each of the shapes **73** abuts a tapered shape **74.** A pair of intermediate shapes **73** and their abutting pair of outer shapes **74,** each of which shape has a recessed quarter-cylindrical hole, which holes form a hole **75** for a tuyere **16.** The hole **75** is then filled with a basic monolithic material **24** or the like to form a substantially solid plug 18^9. Band **35** is placed around the plug 18^9 prior to emplacement in furnace **10.**

FIGS. **11** and **12** illustrate a plug 18^{11} formed of interlocking shapes **80, 81, 82, 83.** Central cylinder **80** has a groove **84** (FIG. **12**). Each surrounding intermediate shape **81** has an inward projection **85** which engages groove **84** in cylinder **80** and a groove **86** in its outer surface to receive a similar projection **87** from a shape **82** in the next course. Outer tapered shapes **83** have inward projections **88** (FIG. **12**) which engage a groove **89** in the outer surface of shapes **82.** Tuyeres **16** extend through suitable holes **90** in shapes **82** and the void therebetween is filled with a basic monolithic material **24** or the like in the same manner as FIG. **5.**

Tuyeres may extend through one or more shapes as in FIGS. **5** and **6,** they may be positioned between rows of shapes as in FIGS. **7** and **8,** at the point of communication of four or more shapes as in FIGS. **9** and **10,** at the interface of two bricks as in FIGS. **1** and **2,** or any combination thereof. Tuyeres can be perpendicular to the bottom plate or at an angle thereto. Of course, the assembly of the plug becomes more difficult as the angle of inclination of the tuyere increases from normal.

PLUG MATERIAL

The preformed pitch-bearing basic refractory shapes shown in FIGS. **1–12** may be of the pitch-bonded tempered (baked) or pitch-impregnated types in magnesite or dolomite composition (or combinations thereof). While the refractory composition is not limited, the following table shows the properties of the preferred materials which should be used to insure service performance superior to prior art plugs:

Table

Brick Type	Acceptable Property Levels: Formed Bulk Density, lbs/cu. ft.	2000 F Residual Carbon, %	Modulus of Rupture at 2700 F, psi
Tempered magnesite	>185	>4	—
Tempered dolomite	>175	>4	—
Burned – impregnated magnesite	>180	>2	>1000
Burned – impregnated dolomite	>190	>1.5	>800

Our tempered refractory shapes (FIGS. **1–12**) are made of a mixture of a basic refractory aggregate such as magnesite or dolomite or both, high temperature pitch and fine carbon. Magnesite is defined as magnesium oxide derived from naturally occurring carbonates or hydroxides, or derived synthetically from sea water or brine. Dolomite is defined as a mixture of calcium and magnesium oxides derived from naturally occurring carbonates. Our magnesite has a composition of about 85 to 98% MgO (on the pitch free basis) and preferably about 94 to 96% MgO. Dolomite has a composition of about 38 to 45% MgO, with the balance substantially lime. Both magnesite and dolomite are fired to a temperature of above 3,000° F to drive off gases and to produce a dense stable product. The density of this product is defined by its grain porosity. For our application, the grain porosity (i.e., pore volume) of the magnesite or dolomite must be less than 12% of total volume and preferably less than 8%. The silica content of the refractory aggregate must be no greater than 3.0%. A higher silica content will reduce the melting point of the refractory, increasing the wear rate of the plug. The total R_2O_3 content of the dolomite must be limited to 1% maximum. R_2O_3 can be iron oxide, aluminum oxide, chromic oxide or boric oxide or the like. These oxides act as a flux on the dolomite and will cause a breakdown of the refractory, increasing the wear rate. Higher R_2O_3 contents can be tolerated in magnesite because it has a higher MgO content. The magnesite or dolomite must be sized in a manner to obtain the maximum product density, but must all be –3 mesh.

Fine carbon such as lampblack, fine coke, or fine graphite is mixed with the basic refractory aggregate and preheated to a temperature of 300° to 600° F. The particle size of the fine carbon must be –100 mesh, and preferably should be –325 mesh. About 85 to 95 parts of magnesite are mixed with 0.5 to 4.0 parts of fine carbon, but we prefer 92 to 94 parts of magnesite and 1½ to 2½ parts fine carbon.

Pitch having a ring and ball softening point in the range from 150° to 285° F and preferably in the range of 185° to 230° F is preheated to from 50° to 200° F above its softening point. We mix from 2 to 8 parts of pitch with the previously formed refractory aggregate - carbon mixture to form a moldable mass. Preferably about 2 to 6 parts of pitch are employed in the mixture. The pitch should have a Quinoline Insoluble fraction ranging from 8 to 17%.

The thoroughly mixed moldable mass is maintained at a temperature of from 50° to 200° F above the softening point of the pitch while it is pressed into a mold to form the desired shape. When pressing is completed, the shape is placed in a muffle oven, baked at a temperature of from 350° to 800° F for a period of from 2 to 100 hours. The preferred baking temperature is from 500° to 600° F, and the preferred baking time is from 6 to 60 hours. In a muffle-type furnace, the pitch volatiles, which are driven off, are retained in the region surrounding the plug to form a reducing atmosphere, thus avoiding oxidation by exposure of the bottom to oxidizing gases.

Our burned-impregnated refractory shapes are of a mixture of a basic refractory aggregate such as magnesite or dolomite, or both, and a high temperature pitch which is subsequently injected into the pores or the brick by vacuum impregnation. The magnesite and dolomite for the impregnated brick has the same composition, density, sizing and other restrictions as defined above for the tempered brick. This refractory material is pressed with a temporary chemical binder, then fired to a temperature above 2,800° F for at least 30 minutes to form the desired refractory shape. After firing, the shape is placed in a vacuum impregnation chamber and pitch is forced into the pores of the shape. Pitch having a ring and ball softening point from 120° to 250° F, and preferably in the range of 160° to 220° F is used to impregnate the shape.

MONOLITHIC MATERIAL 24

The pitch-bearing basic monolithic material **24** (FIGS. **1–12**) to be placed in the space between the preformed shapes and tuyeres may be either a water-based pitch-bearing material or a mixture of pitch or tar with sized magnesite and dolomite.

Our water-based, pitch-bearing basic refractory monolithic material is made of a mixture of magnesite, high-temperature pitch, fine carbon and a water-soluble chemical bonding agent. Our magnesite has a composition of from 90 to 98% MgO and preferably about 94 to 96% MgO. The magnesite is fired to a temperature above 3,000° F to drive off gases and to produce a dense stable product. The density of this product is defined by its grain porosity. For our application, the grain porosity (i.e., pore volume) of the magnesite must be less than 12% of its total volume and preferably less than 8%. The silica content of the magnesite must be limited to less than 3%. A higher silica content will reduce the melting point of the monolithic refractory material, increasing the wear rate of the material after installation. The magnesite must be sized in a manner to obtain the maximum product density, but should all be –3 mesh.

We prepare a mixture of:

a. about 85 to 95% and preferably 90 to 93% magnesite;

b. about 1 to 5% and preferably 1½ to 2½% fine carbon, such as lamp black, fine coke, or fine graphite;

c. about 2 to 8% and preferably 3 to 5% ground pitch; and

d. about 1 to 8% and preferably 2 to 5% water soluble chemical bonding agent such as chromic acid, sodium silicate, magnesium chloride, magnesium sulfate, or boric acid.

The particle size of the fine carbon and ground pitch must be –100 mesh, and preferably should be –325 mesh to obtain uniform distribution throughout the product.

Any suitable pitch which has a ring and ball softening point in the range of 210° to 300° F and preferably in the high end of the range may be used, including but not limited to petroleum pitch, coal tar pitch and the like. The water soluble chemical binder can be added in dry powder form or premixed with water. The monolithic material may be cast or rammed into the space around the tuyeres in a manner to obtain the best possible density.

Our alternative monolithic material **24** (FIGS. **1–12**) is a pitch or tar refractory mixture made of a mixture of magnesite and/or dolomite, and pitch having a ring and ball softening point from 60° to 250° F. Optionally, fine carbon may be added to this mixture. The magnesite and dolomite requirements are those described above. The mixture comprises 85 to 98% refractory aggregate, 2 to 15% pitch, and 0 to 5% fine carbon. This mixture may be placed around the tuyeres cold or it may be preheated to liquify the pitch.

The amount of space left around each tuyere shall be the minimum consistent with practical considerations for a particular tuyere arrangement (i.e., from 0 to 3 inches.) Although it is possible for shapes to be so closely fitted around the tuyeres that no monolithic material would be required, size tolerances for the shapes, size of tuyeres, tuyere locations, and other practical considerations make this impossible in nearly all cases. There is no requirement that the tuyere be centered in the space.

As a specific example, we made a plug **18** from burned-impregnated magnesite brick in the general design illustrated in FIGS. **1** and **2.** This impregnated magnesite brick had a composition on a pitch-free basis of 95.2% MgO, 2.8% CaO, 1.3% SiO_2, 0.4% Fe_2O_3, and 0.3% Al_2O_3. The bulk density of the preformed shapes **25, 26, 27, 28** used averaged 185 lbs/cu. ft., the residual carbon content was 2.2%, and the modulus of rupture at 2,700° F was 1,250 psi.

These shapes **25, 26, 27, 28** were installed on a bottom plate **14** around the tuyeres **16** and steel bands **35** were applied. A pitch-bearing monolithic material **24** consisting of a mixture of 92% magnesite and 8% of a 150° F softening point pitch was then rammed into the approximately ½ inch wide space **30** between the tuyeres **16** and surrounding preformed shapes **27, 28.** The assembled plug **18** was installed in the bottom of a 40-ton experimental Q-BOP vessel **10** which was operated intermittently for 46 heats. The plug **18** had a wear rate of about 0.16 inch per heat.

It is readily apparent from the foregoing that we have invented a method of making a removable bottom for a bottom blown steelmaking process which method requires no forming or heating equipment at the assembly site and which resulting bottom has high density, high hot strength and a long operating life.

We claim:

1. A method of making a tuyere-containing removable bottom for a steelmaking furnace comprising:

installing on a metal bottom plate containing a generally upstanding tuyere fixed thereto, a plurality of pitch-bearing refractory shapes having a predetermined configuration to form a substantially solid plug leaving only a minimum of open space around each tuyere, and

filling said space around each tuyere with a pitch-bearing monolithic material.

2. A method according to claim **1** further comprising installing a metal band around said plug above said bottom plate and substantially parallel thereto, whereby movement of any shape relatively to any other shape is prevented.

3. A method according to claim **1** wherein said plug is frusto-conical in shape.

4. A method according to claim **1** wherein said plug is frusto-pyramidal in shape.

5. A method according to claim **1** wherein said shapes consist essentially of tempered magnesite, and have a bulk density greater than 185 lbs/cu. ft. and a residual carbon content greater than 4%.

6. A method according to claim **1** wherein said shapes consist essentially of tempered dolomite, and have a bulk density greater than 175 lbs./cu. ft. and a residual carbon content greater than 4%.

7. A method according to claim **1** wherein said shapes consist essentially of burned-impregnated magnesite, and have a bulk density greater than 180 lbs./cu. ft, a residual carbon content greater than 2% and a modulus of rupture at 2,700° F greater than 1,000 lbs./sq. in.

8. A method according to claim **1** wherein said shapes consist essentially of burned-impregnated dolomite, and have a bulk density greater than 190 lbs./cu. ft., a residual carbon content graater than 1.5% and a modulus of rupture at 2,700° F greater than 800 psi.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,829,960 Dated August 20, 1974

Inventor(s) David H. Hubble et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Correct the attorney of record's name
from "Ralph D. Dougherty"
to -- Ralph H. Dougherty --.

Column 1, line 16, after "tuyeres" insert -- must be removed from the vessel and replaced between heats. --

Column 3, line 50, after "between" insert -- center --

Column 5, line 42, after "pores" change "or" to -- of -- (In application,

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents